Continuous Sharing - SRG

Description and Rationale

Many regulated rivers have resource assessment and allocation systems to share the available water resource amongst water users. Many of these river systems support multiple resource assessment and allocation systems. Typically, each system is unique to a specific valley or water sharing plan.

This section discusses the continuous sharing system which is designed to set up a system of sharing a water resource where the behaviour of one user has as little effect on other users as possible. Each water user is accounted for separately with their own inflows to their share of the system's storage capacity and each separately paying for any storage, transmission, and operational losses. This tracking is performed using water user accounts.

When a continuous sharing system is set up and each water user account is initialised, each is assigned:

- A priority (high or medium)
- A share factor
- A maximum allowable account balance
- A fractional share of the inflows into the system's storages
- An annual resource cap

The fractional share of the inflows determines how much a water user's account will be credited with when there is an inflow to a storage (If two storages are in series then only the net inflow between the two would be shared as inflow. In more complex situations, for example where there is significant irrigation between the storages, the users may have different shares in each reservoir). The sum of all the inflow shares in a system should add up to 1. In some systems a group of users may be given priority access to inflows when the storages are low, in effect making them higher security users.

The maximum allowable account balance establishes how much water an account can accumulate at any one time. The sum of all the maximum allowable account balances must not exceed the total active storage in the system, thus all water users can store their maximum allowable balances at the same time.

Each user is responsible for covering the transmission and operational costs of delivering their water from the storage to the point of use. This cost is determined by the use of a delivery efficiency factor which represents the average efficiency of delivery to the water user's location. And consequently influences the size of their share and the volume of water released when orders are made.

To allow for the management of the total use of water in a system each water user is assigned an annual resource cap which limits the amount of water they can use in any water year regardless of their account balances. The system may permit unused resource cap to be carried over to the following water year. There may be limits on how much resource cap can be carried over for an account and limits on the total amount carried over for a system.

The annual resource cap is a tradable item. A cap adjustment factor would be required to determine the value of an account's share of the cap for temporary trade, but this is not modelled in Source at this stage. Storage gains and losses are calculated from a fixed annual pattern and are shared amongst water user accounts in proportion to their share account volumes (account balances).

As the storage, transmission, and operational gains/losses are calculated using average values the sum of all the account balances in a system will start to diverge from the total active volume. To account for this divergence a reconciliation of account balances is carried out, periodically, to bring them into line with the total active volume. If the sum of the account balances is greater than the active volume, the difference is treated as a loss from the accounts; on the other hand, if the sum of the account balances is less than the active volume of the storage, the differences is treated as an inflow to the accounts.

Scale

The continuous sharing system can encompass parts or all of a regulated river system. Its scale could therefore be considered to be up to river system scale. The volumes allocated to the Continuous Sharing priority accounts, and the water user accounts within these, are updated every model timestep.

Principal developer

The original modelling representation of Continuous Sharing was developed by predecessors to the QLD Department of Science, Information Technology and Innovation. This was achieved using IQQM (developed by predecessors to the NSW Office of Water). Continuous Sharing was enhanced and incorporated into Source by eWater CRC.

Scientific provenance

The functionality described in this section represents the system that has been developed by SunWater in Queensland and has been introduced into the St George (Condamine Balonne) (DERM, 2010) and Macintyre Brook schemes (DNRW, 2008).

Version

Source version 2.16

Availability/conditions

Automatically included with the licensed product (not included in public version).

Dependencies

Continuous Sharing is a sub component of the Resource Assessment system framework. Each account is hosted by a water user and explicitly associated with a volume of water held in storage. It is therefore the type of resource assessment/allocation that is applicable to regulated systems with Water User node/s (with attached Supply Point node/s) and Storage node/s.

Assumptions

The following assumptions should be noted:

- A storage must be assigned as the continuous sharing water resource
- The inactive volume (i.e. dead storage) of each storage resource should be configured by the user
- Accounts are managed separately – one account's behaviour will have little effect on other accounts
- Rainfall, evaporation and seepage are shared based on current balances for accounts
- The ability to model an embedded annual accounting system within a continuous sharing system is not required.
- All users have the same share inflow at all of the reservoirs in a continuous share system.
- Users' water is stored evenly amongst all of the reservoirs in a continuous share system.
- User's are not limited to pumping their own water (i.e. allocation is not considered as a limit to diversions) so shortfalls are only refunded when there is less water in the stream than the order.
- Reconciliation is carried out periodically to ensure modelled account balances are in line with the total active storage volume. Differences are treated as inflows or losses to accounts.

Definitions

The following definitions apply in this section:

account

Entity used to manage a water user's entitlement - i.e. share of the system's inflows, active storage volume, and usage of this share.

active capacity

The volume of water in a storage minus the dead storage volume when the storage is full.

active volume

The volume of water in a storage minus the dead storage volume.

airspace

The remaining storage capacity in an account or reservoir.

annual resource cap

Long term maximum annual volume that a user is allowed to take at the specified location (water year).

cap balance

The amount of water that a user is allowed to take at the specified location during the remainder of the water year.

cap adjustment factor, C

Used to adjust the annual resource cap during trading. Usually it is set to the share factor *S* (eg. in the Macintyre Brook system). However, in some systems such as the St George system, the cap adjustment factors were set to 1.0 to prevent growth in usage resulting from trading from a zone with a low share factor to a zone with a higher share factor.

maximum cap carryover percentage

Maximum amount of annual resource cap that an individual user can carry over into the next water year.

maximum system cap carryover percentage

Maximum amount of annual resource cap that a system can carry over into the next water year.

nominal volume (shares)

Relative value of a water entitlement measured at the water user's location.

reconciliation

Periodic adjustment of the share account volumes (balances) to match the available volume of water in the system storages.

share inflow

Percentage of storage inflow to the system assigned to a share account.

share factor S

Factor used to determine withdrawals from water orders and to determine share account sizes. The share factor is proportional to the average cost of delivering water to a water user (ie. the delivery efficiency).

storage loss

Estimated daily losses from the storages based on average or maximum monthly lake evaporation and seepage used in the daily accounting.

total active volume

Sum of active volumes for a resource allocation system's storages.

total conceptual storage

Sum of the active capacity of all the storages in a resource allocation system.

water order

The order for water sent to a storage by a user at the location of the user.

withdrawal

Volume of water taken out of a share account to meet a water order.

Zone

A geographic location defined by a reach of a watercourse (usually specified in the water plan)

Other definitions can be found in the eWater glossary at www.ewater.com.au/glosssary.

Structure and processes

There are two types of water allocation accounts in a continuous sharing system:

- High Priority Allocation (equivalent to high security of supply); and
- Medium Priority Allocation (equivalent to general security of supply).

The high and medium priority account types are identical except that when the storages in the system fall below a modeller-specified threshold (the medium priority threshold) the high priority accounts share all of the storage inflows, while the medium priority accounts do not receive any inflow. Both types of account have a maximum account balance that is an absolute volume.

By default, each water user in the system has an account of each type (ie. a high priority and medium priority allocation account), although only one account is required to have a maximum account balance greater than zero (that is an absolute volume greater than zero) for the user to be part of the continuous sharing system. The water user will be able to order water to the sum total of the current balance of all their accounts (but within the limit imposed by their annual resource cap).

In a continuous sharing system the sum of all of the maximum account balances must be equal to the total conceptual storage. Accounts are credited when a storage inflow, rainfall event or account reconciliation takes place and debited when losses occur, a water order is placed or an account reconciliation is carried out. Accounts are not debited when water is used during unregulated flow events (as no orders are involved)

The total conceptual storage volume is the combined active capacity of all assigned storages in the system. Usually, for storages with ungated spillways, their contribution to the total is the active storage at full supply level; while for storages with gated spillways, their contribution is the capacity at the maximum water supply storage level based on operating and management decisions such as to maintain airspace for flood mitigation. For example, in the Macintyre Brook system the total conceptual storage is:

Maximum useable volume of Coolmunda Dam (69 000 - 210 ML dead storage) + max useable volume of Whetstone Weir (270 - 3 ML) + max useable volume of Ben Dor Weir (400 - 20 ML) = 69 437 ML (DNRW, 2008).

Annual Resource Cap

An annual resource cap is used to manage the amount of diversion that occurs in a resource allocation system. Its main application is in systems where no growth in diversions is allowed. A concern in these systems is that if a water entitlement ismoved (eg. via a trade) the delivery efficiency may be increased. In these cases, the water user could potentially take advantage of the efficiency gain to divert more water, thereby violating the requirement for no growth in diversions.

The usage limit is a volumetric constraint that is applied in addition to the limit imposed by the balances of a water user's accounts. The annual resource cap operates at both the water user account level and the system level, where the annual resource cap at system level is simply the sum of the annual resource caps of all water user accounts.

The diversion categories that the cap applies to are selected by the modeller. For example, in the Macintyre Brook Scheme the annual resource cap applies only to water diverted under regulated flow conditions but in the St George Scheme it also includes water diverted during unregulated flow periods.

Important differences between the annual resource cap and account based limits are:

- Account based limits apply to water ordered but the annual resource cap applies to water diverted; and
- The annual resource cap represents a higher priority usage limit than the one represented by the balance of the accounts. Once a water user's annual resource cap has been reached, no water can be diverted, regardless of the balances in the user's accounts.

The sequence of events in water use is:

A water user makes an order for water (the size of which is limited by their cap and account balances).

- The water user's accounts are immediately debited the amount of the order after adjusting for average water delivery efficiency.
- Once the water arrives at the water user's location and the water user diverts the water their cap balance is debited.

The following items are used to maintain and keep track of the status of the annual resource cap applied to the resource allocation system and water users:

- Annual resource cap (water user). This forms a constraint on usage that is additional to the ordering constraint imposed by account balances. The water user's cap may be either specified or calculated based on the total shares (nominal volume) allocated to the account. Although it applies to a water user, the cap is set up at account level to enable auto-calculation based on account shares (nominal volumes).
- Cap balance (water user). This total reflects the amount of the water user's annual cap remaining at any time.
- Cap carryover percentage (system and water user). This is the maximum percentage of annual cap that can be carried over from the remaining cap balance of the previous water year. Limits are defined for both water users and the system; the total carryover volume for all water users cannot exceed the volumetric equivalent of the system limit.

At the start of the water year each water user's cap balance is credited with its cap amount, as well as any carryover. At the end of the water year the cap balance is truncated to the water user's cap carryover percentage, and reduced further if necessary to meet the system carryover limit (calculated from the system carryover percentage). Throughout the water year (ie. at each time-step) the cap balance is adjusted as water is diverted for use by the associated water user.

Hence, two sets of "books" are kept for each water user: one which maintains the balances of all high priority and medium priority accounts belonging to the water user and the other is a cap balance which tracks water diverted by the water user during the water year. In the Macintyre Brook system the cap balance is debited only when water is diverted under regulated flow conditions (ie. drawn from high priority and medium priority accounts) but in the Condamine-Balonne it is debited when water is diverted during unregulated flow events as well. If the cap balance is zero then the water user can divert no more water, irrespective of the status of the high priority and medium priority accounts (and in the Condamine-Balonne, even if there is a unregulated flow event).

Sharing Storage Losses

Losses from storages are determined during the order phase by using a fixed table of loss rates. These loss rates are approximations used for resource allocation and are not the same as those used for modelling the physical system; hence, they must be specified separately by the modeller.

The loss rates may be average or maximum rates of evaporation (in mm/model time-step) and may include allowance for seepage; these may vary with time of year. The appropriate loss rate is applied to the surface area of the storage at each time-step to determine its volumetric loss.

The volumetric losses are then distributed to accounts using the ratio of each account balance to the sum total of all account balances.

Estimating Transmission and Operational Losses

Transmission and operational losses are shared to each water user based on the principle that the water user should be levied a cost for delivery that represents the average efficiency of delivery. The average delivery efficiency is also called the share factor.

Usually, the further away from a storage a water user is the lower the average delivery efficiency becomes, but this effect can be counteracted by the presence of intermediate tributaries from which the operator can meet the demand. In practice the delivery efficiency factors could be allocated on a zone by zone basis; for example, the Macintyre Brook scheme has three different delivery efficiency factors.

When a water user places an order their account is immediately debited by an amount which is equal to the volume ordered divided by their average delivery efficiency.

If a water user is unable to divert the water they ordered because of a shortfall in the flow in the river then the water user is refunded the volume that was not delivered (adjusting by the average delivery efficiency to convert the shortfall back into an equivalent account credit).

Defining shares of inflow to storages

The share of inflow to the resource allocation system's active storage capacity for each account is the fraction of the total inflow in any given model time-step that would be allocated to that account, assuming the account has sufficient spare capacity available to accommodate it. The sum of inflow shares for all accounts adds up to 1. Adjustments to shares of inflow during model runs to allow for insufficient spare capacity being available are discussed in the section on Sharing Storage Inflows, below.

The modeller may input a value for a given account's share of inflow or opt to have it calculated instead. When calculating, the share of inflow is set according to the fraction of the resource allocation system's active storage capacity allocated to the account, ie. its maximum balance. Before this can be done, the sum of the share of inflow values for accounts that the modeller has specified must be calculated and subtracted from one. This determines what fraction of the inflow is going to be available to share amongst the accounts without a specified share of inflow. The available fraction of the inflow is then distributed to each of these accounts according to the ratio of their maximum balance to the resource allocation system's active storage capacity. These calculations are undertaken during the model initialisation phase.

Sharing Storage Inflows

Inflows to the storages in the system are shared to the users as a function of their share of inflow. Water users can participate in the sharing of inflows only while their account balances remain below their maximums. Inflows to all the storages in the continuous sharing system are distributed to individual accounts on the basis of the ratio of their share of inflow to the total of all shares of inflows. If an account is full then the share of inflow value for that account is set equal to zero (for that time-step), and the total of all shares of inflows is adjusted accordingly (ie. the total becomes less than one for the current model time-step).

The modeller also provides a storage threshold. When storage is above this level, inflow is assigned to all accounts (including medium priority accounts) according to their share of inflow. Below the threshold, inflow is shared only to high priority accounts.

If a given account is not full and the calculated amount of water to credit to the account exceeds the spare capacity available, then the share of inflow value for the current time-step is reduced so the calculated amount of water to credit is just enough to fill the account, and the total of all shares of inflows is adjusted accordingly. In this situation, all accounts that have already been processed and which still have spare capacity available, are reprocessed.

Reconciliation

As the sharing of storage losses, transmission and operational losses is based on long term averages, or an upper bound for storage losses in some cases, the total balance of accounts deviates from the total usable volume. From time to time the difference between account balances and the total active storage volume has to be reconciled. If the total of account balances is greater than the total active storage volume the shortfall is treated as if it were a storage loss. If the total of account balances is less than this volume then the excess is treated as if it were a storage inflow, except that account priorities (securities of supply) are not taken into account in distributing the excess.

The frequency with which this reconciliation is undertaken is specified as a single value by the modeller, and the default is once each day. In practice, the frequency of this reconciliation may be variable. For example, according to the resource operation plan for the St George system, account reconciliation should take place "prior to an inflow event", "periodically", or "monthly as a maximum". In the resource operation plan for the Macintyre Brook system the reconciliation should take place "at least once every 30 business days", "in response to significant inflows", or in response to "changes in usage activity".

In a river system where orders are delayed, for example because one storage is closer to the user than another, the volume of pending releases is subtracted from the total usable volume before the reconciliation takes place.

Ownership

The continuous sharing resource allocation system owner may be one of a number of owners in the physical system being modelled. The other owners use their own resource allocation systems which could be another continuous sharing system or could be some other system altogether. Resource allocation system calculations must be undertaken for each owner separately. For this reason the modeller must specify the percentage shares of each storage in the physical system belonging to each owner.

For a given continuous sharing resource allocation system owner the total conceptual storage belonging to the owner is required and is calculated by evaluating the share of the active volumetric capacity in each storage belonging to this resource allocation system's owner:

Equation 1	$Active\_Capacity_{system}(s) = Owner\%(s) \bullet (FullSupply(s) - DeadStorage(s))$

where:

Active_Capacitysystem(s) Total active or usable volume in storage s assigned to the resource allocation system/owner, when the storage is at full supply level.

DeadStorage(s) Dead storage volume for storage *s*

FullSupply(s) Full supply volume for storage *s*

Owner%(s) An owner's percentage of the capacity (volume) of storage *s*

Sum the *Active_Capacitysystem(s)* terms to obtain the total conceptual storage volume:

Equation 2	$TotalConceptualStorageVolume = \sum \left(ActiveCapacity_{system}(s) \right)$

Account set up options

A modeller can either specify each water user account's maximum balance, annual resource cap, share of inflows, and initial balance or have these parameters and variables calculated from the number of shares (nominal volume). The following sections detail how model parameters are calculated when the number of shares is specified.

Maximum account balance calculation

When the "shares" (nominal volume) allocation option is specified for an account, the number of shares is specified. The system translates this number to a maximum balance: the maximum storage volume allocated to the account. The calculation can only be done once all accounts have been setup as the absolute volume allocated to other accounts (with "volume" option) and the total number of shares must be known.

The calculations are undertaken during the model initialisation phase and comprise three steps. First, the resource allocation system's total conceptual storage is apportioned between priority (security of supply) levels using a percentage allocation specified by the modeller.

Second, for a given priority level, the maximum balance volumes of accounts specified directly by the modeller are subtracted from the active storage capacity available for this priority level. The remaining active storage capacity is available for distribution between accounts at this priority level for which shares are specified by the modeller.

Third, for a given account the maximum balance is calculated using:

Equation 3	$$MaximumBalance(account) = AvailableCapacity(p) * \frac{\frac{Shares(account)}{ShareFactor(account)}}{\Sigma\left(\frac{Shares(p)}{ShareFactor(p)}\right)}$$

where:

ShareFactor is the average delivery efficiency for account (*account*)

Shares is the number of shares associated with the current account (*account*)

p is the accounts in the resource allocation system with the current priority level

AvailableCapacity is the part of the priority level's active storage capacity left over for sharing between the priority level's accounts with a "shares" option.

The average delivery efficiency (share factor) is included in the calculation because nominal volumes (shares) are defined at the location of the water user rather than at the storage.

To determine the Maximum Balance that should be configured from water user annual cap volumes:

Equation 4	$$MaximumBalance(account) = AvailableCapacity(p) * \frac{\frac{AnnualCap(account)}{ShareFactor(account)}}{\Sigma\left(\frac{AnnualCap(p)}{ShareFactor(p)}\right)}$$

where:

ShareFactor is the average delivery efficiency for account (*account*)

AnnualCap is the annual volume of water allocated to the water user account (*account*)

p is the accounts in the resource allocation system with the current priority level

AvailableCapacity is the part of the priority level's active storage capacity left over for sharing between the priority level's accounts with a "shares" option.

Share of inflow calculation

The modeller may opt to have each account's share of inflow calculated, instead of specifying this value. If this is the case, the share of inflow is set according to the fraction of system's storage capacity allocated to the account, ie. its maximum balance. The sum of shares of inflow for all accounts must add up to 1. The calculation steps are:

- The sum of the share of inflow values that the modeller has specified must be calculated and subtracted from one; the difference is fraction of the inflow available to be shared amongst the accounts without a specified share of inflow.
- For these accounts their share of inflow is then the ratio of their maximum account balance to the total conceptual storage multiplied by the fraction of inflow available to be shared amongst these accounts (from the previous step).

The inflow share (%) allocated to an account is calculated as follows:

Equation 5	$$InflowShare(account) = \left(1 - \sum InflowShares(us)\right) * Allocation(p) * \frac{\frac{Shares(account)}{ShareFactor(account)}}{\sum\left(\frac{Shares(p)}{ShareFactor(p)}\right)}$$

or

Equation 6	$$InflowShare(account) = \left(1 - \sum InflowShares(us)\right) * Allocation(p) * \frac{MaximumBalance(account)}{\sum(MaximumBalance(p))}$$

where:

InflowShare(us) is the user specified inflow shares (%). Note that the $\left(1 - \sum InflowShares(us)\right)$ term will equal 1 if the user has not manually specified any inflow percentages.

Allocation is the percentage of the available storage capacity allocated to the current priority level (*p*)

ShareFactor is the average delivery efficiency for account (*account*)

Shares is the number of shares associated with the current account (*account*)

p is the current priority level

MaximumBalance is the maximum balance associated with an account (*account*).

Annual resource cap calculation

The modeller may choose to either specify an account's annual resource cap or have it calculated. The calculated annual resource cap is the product of the volume of annual resource cap per share in the system, which must be specified by the modeller, and the number of shares allocated to the account.

Initial balance

The modeller may specify an initial balance for an account, which becomes the account balance when the model starts. The initial balance must be less than the maximum balance. If no initial balance is specified, the account balance starts at zero. To ensure all account balances are set correctly at the start of the model run, a reconciliation process is carried out immediately after the initialisation phase.

Initialisation phase

Calculations undertaken in the Initialisation Phase include:

- For each priority level, the total number of shares and the active storage capacity to be shared between accounts with the share option set are evaluated.
- For each account for which the modeller has chosen to specify a number of shares (nominal volume), the maximum account balance is calculated (see Ownership - SRG).
- The continuous sharing resource allocation system owner may be one of a number of owners in the physical system being modelled. The other owners use their own resource allocation systems which could be another continuous sharing system or could be some other system altogether. Resource allocation system calculations must be undertaken for each owner separately. For this reason the modeller must specify the percentage shares of each storage in the physical system belonging to each owner.

For a given continuous sharing resource allocation system owner the total conceptual storage belonging to the owner is required and is calculated by evaluating the share of the active volumetric capacity in each storage belonging to this resource allocation system's owner (Equation 1).

Sum the *Active_Capacitysystem(s)* terms to obtain the total conceptual storage volume (Equation 2).

Account set up options

A modeller can either specify each water user account's maximum balance, annual resource cap, share of inflows, and initial balance or have these parameters and variables calculated from the number of shares (nominal volume). The following sections detail how model parameters are calculated when the number of shares is specified.

- Maximum Account Balance Calculation.
- For each account for which the modeller has chosen not to specify the share of inflows, the share of inflows is calculated (see Share of inflow calculation).
- The annual resource cap for the system is calculated as the sum of the annual resource caps for all accounts.
- The annual resource cap for each water user is calculated as the sum of the annual resource caps for the accounts associated with that water user.
- Outstanding orders for all accounts are initialised to zero.
- Accounts are reconciled - see Structure and Processes section
- A seasonal pattern of estimated storage loss for each associated storage, that is a function of month, is used to forecast the loss or gain from each storage (DERM, 2010; DNRW, 2008). The seasonal pattern is input by the modeller. These forecast losses are summed to get a total forecast loss or gain from all associated storages. This is distributed to water user's account balances in proportion to their balances. No check is made to ensure the total forecast loss is smaller than the available active storage or that any gain is smaller than available airspace - this is taken care of by the reconciliation process. However, a check is made to ensure there is at least one account with a non-zero account balance, otherwise no distribution is possible.
- Reconcile accounts (at specified frequency) below.

> The actual storage losses or gains will vary from the estimates. The differences created in the account balances are corrected during the reconciliation process.

Resource allocation and Water accounting phase

The inflows available to be shared are the system owner's net unallocated inflows to all of the storages associated with the resource assessment system. For headwater storages all of the inflows are unallocated; for re-regulating storages the unallocated inflows represent the flow that is in excess of orders.

The method for sharing inflows to account balances is described in the Structure and Processes section, above. It is implemented using net unallocated inflows during the previous time-step and the storage states at the end of the previous time-step (being the storage states at the start of the current time-step). Net unallocated inflows are the difference between unallocated inflows and unallocated outflows, or zero if unallocated inflows are less than unallocated outflows. The active storage is total storage less dead storage capacity, or zero if the storage has drawn down so that total storage is below dead storage capacity.

Adjust account balances for storage losses/gains (each time-step)

A seasonal pattern of estimated storage loss for each associated storage, that is a function of month, is used to forecast the loss or gain from each storage (DERM, 2010; DNRW, 2008). The seasonal pattern is input by the modeller. These forecast losses are summed to get a total forecast loss or gain from all associated storages. This is distributed to water user's account balances in proportion to their balances. No check is made to ensure the total forecast loss is smaller than the available active storage or that any gain is smaller than available airspace - this is taken care of by the reconciliation process. However, a check is made to ensure there is at least one account with a non-zero account balance, otherwise no distribution is possible.

> **Note:** the actual storage losses or gains will vary from the loss or gain estimates. The differences created in the account balances are corrected during the reconciliation process.

Reconcile accounts (at specified frequency)

Reconciliation is carried out to correct any mismatch between the system's active storage volume and the total of account balances, as described in the Structure and Processes section above. The frequency of reconciliation is specified by the modeller - the default is each day.

Carry over cap balances (at start of water year)

The annual resource cap provides a constraint on the amount of water used by the system each water year (see the Structure and Resources section above). A proportion of the cap balance of each water user can be carried over at the start of the water year. The steps for evaluating the carryover are:

- Initialise the system cap balance by setting it equal to zero;
- For each water user, the cap balance that can be carried over is the lesser of their cap balance and their carry over limit (the product of their annual resource cap and their carryover limit as a fraction);
- The resultant carryover cap balance is added to the system cap balance;
- Once all water user carryover cap balances are calculated, if the total system cap balance is greater than the allowable carryover balance for the system as a whole (being the product of the annual resource cap for the system and the carryover limit for the system expressed as a fraction), then the cap balance for any water user carrying over more than the system limit percentage allows is reduced (see method below); and
- The annual resource cap for each water user is added to their carryover cap balance.

The method for reducing cap balances for carryover in excess of the system limit in the fourth step entails calculating the total excess cap balance by summing excess carryovers for individual water users and then reducing the cap balances for those users having a cap balance above the system limit.

First, the *total excess cap balance* is initialised to zero.

The *total required reduction* is calculated. This is the difference between the system cap balance and the allowable carryover cap balance for the system as a whole, using:

Equation 7	$$RequiredReduction = CapBalance_{system} - AnnualCap_{system} \bullet \frac{Carryover\%_{system}}{100}$$

where:

AnnualCapsystem is the annual cap volume for the system

Carryover%system is the system carryover percentage [specified upper limit value].

The *total excess cap balance* is then calculated by firstly evaluating the carryover limit for each water user as governed by the system's carryover percentage using:

Equation 8	$Carryover\_Limit_{system}(wu) = Annual\_Cap\_Volume(wu) \bullet \frac{Carryover\%_{system}}{100}$

where:

wu is the current water user

Annual_Cap_Volume(wu) is the annual cap volume for the current water user

System_Carryover_% is the system carryover percentage [specified upper limit value].

Then, if this result for *Carryover_Limitsystem(wu)* is less than the carryover cap balance for this water user (*CapBalance(wu)*), the excess is added to the total excess cap balance.

Once calculation of the total excess cap balance is completed, the reduction ratio (*RR*) required for cap balances in excess of the system limit percentage is evaluated as the ratio of the total required reduction to the total excess cap balance.

For each water user, if their carryover cap balance is greater than *Carryover_Limitsystem(wu)* the cap balance is adjusted as follows:

Equation 9	$CapBalance(wu) = \left(CapBalance(wu) - Carryover\_Limit_{system}(wu)\right) \bullet RR + Carryover\_Limit_{system}(wu)$

Ordering phase

During the ordering phase it is necessary to know how much water is available in the accounts for each water user. Recalling that continuous sharing account types (high and medium priority) have their balance debited when orders are placed: the account that is debited first depends on modeller supplied settings at the water user level - usually high priority water is used first.

The amount that can be debited from both types of account is limited by the account balance and cap balance. As the cap balance is not deducted until the water is used, it is necessary to add the volume from orders placed in previous time-steps but not yet delivered to find the "additional usage limit" imposed by the cap balance. The annual resource cap, the average delivery efficiency, and remaining account balances, including the "additional usage limit" adjustment, are taken into consideration when modelling orders placed by a given water user.

Before Orders are placed

The following calculations are performed for each water user to evaluate any constraints required on their orders:

- The water user’s "additional usage limit" limits the amount of water that can be ordered and is evaluated as the cap balance minus outstanding orders (ie. those not yet delivered).
- The maximum volume that a water user can order from any one account they have in the resource allocation system is the product of the account balance and the average delivery efficiency.
- The total order placed by a water user must also be less than or equal to the additional usage limit, otherwise it is reduced so that the additional usage limit is not exceeded (this assumes that the details of an order are known to the level of water user, account, extraction point, and time-step the order was placed).

After orders are placed

After orders are calculated for the current time-step the withdrawal from the resource allocation system’s active conceptual storage for each user is calculated as the order adjusted for the average delivery efficiency. The water user’s account(s) are debited this amount. The unadjusted order is added to the total of outstanding orders for the water user.

Flow phase

In the flow phase, cap balances are debited for water user extractions in the current time-step. The outstanding orders total for each water user is reduced by the amount of orders that are delivered.

Account balances are credited for any shortfall between the water user's final orders (that are expected to be delivered in the current time-step) and the water actually delivered to the water user in this time-step. This is done because the water user's account balance has already been debited for the ordered amount.

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