GENERAL ADMINISTRATION GUIDELINES FOR RESERVOIRS[1]

Colorado Division of Water Resources

October 2011

[1] This document was originally prepared under the direction of Hal Simpson, former State Engineer, and further revised under the direction of Dick Wolfe, State Engineer. Several staff members of the Colorado Division of Water Resources were instrumental in its development including Claudia Engelmann, Jim Hall, Alan Martellaro, David Nettles, John Sikora and Dick Wolfe with review by many other staff of the Division of Water Resources. We are grateful that Devin Odell from the Attorney General's Office provided critical legal review.

Purpose

These Reservoir Operating Guidelines are a basic practical guide for the staff of the Division of Water Resources ("DWR"), including division engineers, water commissioners and others charged with administering the state's many reservoirs. They reflect the "institutional knowledge" of DWR personnel and the general practice across the state, summarizing DWR's understanding of the statutes, court cases, and administrative rules, policies, and practices related to the storage of water. These Guidelines are intended to provide present and future staff with an understanding of the basic concepts, giving them a common starting point for the many difficult decisions that they must make on a daily basis. We also hope that these Guidelines will be useful to reservoir operators, engineers, attorneys, policy makers and anyone else who seeks a better understanding of general reservoir operations in the State of Colorado.

These Guidelines should not be relied upon for administrative or legal authority, and they are not intended to be or to function as rules or regulations governing the storage of water. Although these guidelines present fundamental examples of reservoir operations, they do not, and could not, cover all of the historic exceptions that exist for specific reservoirs. Given the significant variation in the decrees granting storage rights, in the physical setting and hydrology of the various reservoirs, and in historical administrative practices, nothing in this document should be construed as definitive with regard to any particular reservoir or storage right. Moreover, DWR does not intend for these Guidelines to change the vested rights of any water user. As changes in the law, altered circumstances, and unforeseen situations arise, DWR will periodically update these Guidelines so that they remain as accurate as possible.

Introduction

Storage of water continues to be a critical component of water supply in Colorado. While State Records show needs of agriculture ─ the largest use of water in the state ─ remain fairly constant, water needs for municipal, industrial, environmental and recreational purposes continue to increase. Moreover the administration of interstate compacts, agreements, and treaties, along with the federal government's claims for reserved water rights, are all becoming increasingly important in allocating the remaining waters of Colorado.

The most senior water rights on Colorado streams are direct flow rights, first developed by the earliest settlers in the mid-19th century. Water for direct flow usage was usually plentiful during spring and early summer runoff, but began to diminish in late summer and early fall until it could no longer be diverted. In the most developed areas, such as the South Platte River basin, competition for water led to curtailment of junior rights during the summer and even during the spring in drier years after only several decades of settlement. The seasonal as well as annual fluctuations in water availability, combined with the increasing demand by junior appropriators, led irrigators to capture and store for later use some of the vast quantity of the annual spring runoff from the Rocky Mountain snowmelt. The right to store water was affirmed by the Colorado legislature in 1879 and has become an integral part of the state's water supply.[2]

The task of administering the state's water has been given to the State Engineer, who is appointed by the governor as the Director of DWR, also known as the State

[2] Corbridge, James N. Jr. and Teresa A. Rice. 1999. *Vranesh's Colorado Water Law. Revised Edition.* University Press of Colorado, Niwot, CO. p 53.

Engineer's Office (SEO). The State Engineer appoints division engineers who, in turn, manage local water commissioners, all of whom are charged with administering and distributing the waters of the state, including the determination of the way a water user exercises a storage priority.

General Administration Principles

One Fill Rule

Water may either be stored under a water right under the priority system or in some situations contractually – for instance a user may be able to store reusable water in a reservoir. The one fill rule concerns the storage of water under the priority system. Under Colorado law, a water user may store water whenever the water is physically available, its water right is in-priority, and the decree for the water right has not been filled. Under Colorado Supreme Court decisions, a user is entitled to only one filling of a reservoir water right in any one year unless a user has a water right that provides for a refill and/or additional storage or free river conditions exist (i.e. no downstream shortage of water to meet the demands of all users for their decreed water rights).

In creating this rule, courts did not define a storage year. Given that irrigation reservoirs typically begin filling in the fall, after irrigation has been completed, the SEO, starting with State Engineer M.C. Hinderlider[3] in 1936, adopted a "seasonal year" of November 1 to October 31. The Colorado Supreme Court has recognized this seasonal year for irrigation reservoirs. This is the presumed seasonal year for a majority of reservoirs unless the decree specifies a different date. Subsequently, different

[3] Letter from M.C. Hinderlider, State Engineer, to all Division Engineers and Water Commissioners dated May 11, 1936. Please see Appendix for document.

seasonal years have been adopted by some municipal water suppliers at a set date in the spring, usually April 1 prior to spring runoff when their reservoirs are generally near their lowest point. While this date can vary between municipal suppliers, it cannot be changed once established.

Under the one-fill rule, a reservoir user may only use a storage right to "call" for water during the seasonal year if the decree for the storage right has not yet been filled during that year. (When a user with a decree is short water to meet their decreed demand, the water commissioner will place a "call" or "curtail" users such that no user junior to the "call" in a reach of river may divert in that reach of river.) If the storage right has been filled, the reservoir owner must wait until the beginning of the next seasonal year to place a call for additional water. For example, if a reservoir with a seasonal year beginning November 1 has received the full amount of water it is entitled to under its storage right by June 1, then the user must wait until the next November 1 to begin filling again under that right. In addition, any diversions prior to November 1 will be curtailed if there is a call on the river, whether junior or senior to the storage right.

The reservoir owner could, however, divert water under free river conditions. Alternatively, the reservoir owner could store under a junior priority (either a refill right or separate storage right) or store foreign water. For purposes of this document, the term "foreign water" refers to all water located in a given reservoir except priority storage water associated with the particular reservoir and water stored under free river. Examples of foreign water include: historical consumptive use credits from changed water rights, transbasin water, nontributary water, priority (or free river) water stored by

another structure and relocated to the subject reservoir, recaptured return flows from fully consumable water such as lawn irrigation return flows, etc.

Carryover

Generally, any water remaining in a reservoir at the end of the seasonal year is called "carryover water," and is credited to the next year's fill. This will limit the amount of new water to be put into storage during next year's seasonal year. For example, if a reservoir's decreed and physical capacity is 100,000 acre-feet and at the end of seasonal year 1 it contains 60,000 acre-feet, then the carryover would be 60,000 acre-feet for the next year, seasonal year 2. In this situation, the Division Engineer or Water Commissioner would limit the amount the owner could divert and store in seasonal year 2 to 40,000 acre-feet because the 100,000 acre-foot water right is filled once the 40,000 acre-feet is stored. The 40,000 acre-foot limit would exist even if the owner released water from storage during seasonal year 2 and created additional capacity. In this situation, this additional capacity can only be refilled under free river conditions since no other storage rights exist.

Moving from a reservoir with a single storage right to the next simplest case where a single owner has a senior storage right and a junior enlargement for the same uses, the Division Engineer may account for reservoir storage using the principle of "first in, first out" so long as the decrees do not have contrary provisions. [4] For instance, suppose an irrigation reservoir owner has a senior right for 5,000 acre-feet and a more junior right for 9,000 acre-feet to fill a 14,000 acre-foot reservoir. In year 1, the reservoir

[4] State Engineer's "Written Instruction and Order 2007-02: Instruction and Order Concerning the Administration of Storage Rights by Seniors First" signed May 31, 2007 by Hal D. Simpson (http://water.state.co.us/DWRIPub/Documents/wio2007-02.pdf).

starts empty, is completely filled under the two rights, and releases 7,500 acre-feet during the irrigation season leaving 6,500 acre-feet in the reservoir. Under the “first in, first out” methodology, the reservoir owner may fill 5,000 acre-feet under the senior fill right and the remaining 2,500 acre-feet under the junior right in year 2.

In more complex situations, where multiple owners, types of uses or places of use are involved, the user(s) must keep separate accounts of the various water rights. A basis for keeping separate accounts must first be established by the owner(s) and approved by the Division Engineer. If separate accounts for each water right are tracked then water stored under a junior right would only be carried over into the junior right’s account. In complex situations, all carryover is credited to the most senior storage right in the reservoir at the start of the subsequent year if separate accounts for each priority are not tracked.

Similarly, any foreign water that is stored in a reservoir that is remaining in the reservoir at the end of the season is assumed to be priority water and credited to the most senior storage right unless this water is tracked separately by the reservoir owner. Therefore, detailed accounting of all the different types of priority and foreign water stored in a reservoir is important to avoid limiting the amount of water that can be stored under the most senior storage right.

If the water right for a reservoir allows water stored in priority to be relocated in another structure, the amount of priority water that was relocated to another structure still remaining in that structure at the end of the season counts against the storage right it was originally stored under. This is done to assure that a user does not use a senior right to fill more than one reservoir. For example, assume that municipal reservoir A

has a right for 1,000 acre-feet which is stored in priority during year 1. Also assume during year 1 that 400 acre-feet of the water stored in reservoir A is released and relocated in reservoir B and the remaining 600 acre-feet is released to municipal use. In this case, reservoir A would be entitled to store 600 acre-feet in year 2 not 1,000 acre-feet. The user would only be able to fill the remaining 400 acre-feet in reservoir A in the seasonal fill year subsequent to its release from reservoir B for use. Further, there may also be limits placed on how much the user may store in reservoir B depending on the situation.

Decreed versus Physical Capacity

Given the large investment required for reservoir construction, a potential reservoir owner generally receives a decree for a conditional water right to store an amount of water prior to construction. Upon completion of the reservoir, the actual physical capacity of the reservoir may be different from the decreed capacity. This raises the question of whether the physical capacity or the decreed capacity controls the administration of the amount of water that can be stored. If the physical capacity is less than the decreed capacity, then the allowed amount of fill will be based upon the physical capacity rather than the decreed capacity. For example, when a reservoir is physically full at 50,000 acre-feet and has a decreed capacity of 60,000 acre-feet then the reservoir has reached its one fill and cannot come back in later in the season when space becomes available to fill the additional 10,000 acre-feet. The difference between the decreed capacity and the lower physical capacity is subject to abandonment (or if conditional, to cancellation for failure to prove diligence) unless the reservoir owner

shows intent to make subsequent modifications to enlarge the reservoir to the originally decreed capacity.

When physical capacity is greater than decreed capacity, a fill is based upon the decreed capacity. To use the additional capacity, the reservoir owner must adjudicate a new water right for the difference, use other foreign water legally available for storage in the reservoir, or hope to fill the difference under free river conditions.

Storable Inflow

Storable inflow is the amount of water that is physically and legally available for storage in a reservoir under a particular water right. After the beginning of the seasonal year, all storable inflow must be accounted against the storage right in order to protect other water users, whether or not the reservoir owner actually stores the water. This assures junior water right users that they will be able to divert water in the amount and time that they could have if the senior storage right had filled with all water available to it under its storage priority. For example, if a reservoir operator with a decree to store 20,000 acre-feet of water chooses to bypass 5,000 acre-feet of water that they would otherwise have been able to store in-priority, the Division Engineer considers the bypassed water “storable inflow.” Accordingly, the Division Engineer would credit the bypassed water toward the fill of the reservoir and would consider the storage right to be filled when the reservoir physically contains 15,000 acre-feet of water stored under the storage right.

Storable inflow also includes any out of priority storage by upstream junior storage rights (further discussed in the Out of priority Storage Statute section below). To track the amount of storable water that has not actually been stored, for whatever

reason, the Division Engineer uses what is known as a “paper fill.” A paper fill is an accounting mechanism whereby storable inflow is charged against a storage water right either because the reservoir owner elected not to physically divert or store water under that right or a junior upstream reservoir diverted the storable inflow out of priority. A detailed discussion of paper fill, along with some of the exceptions to the general principle of storable inflow, can be found in the Paper Fill Including Bookover section below.

Generally, a storage right is filled when carryover storage under that water right plus storable inflow, whether actually diverted or only a paper fill, equals the decreed amount of the storage water right or the total physical capacity of the reservoir (which may be restricted due to dam safety or flood control concerns), whichever is less. A reservoir user may continue to physically store water under a fill right even if it has gone out of priority and is called out if it comes back into priority and has not already been filled. In this case, storage is limited to the volume unfilled by the storage right when the reservoir went out of priority. Even if there is capacity to store, the Division Engineer will not allow the reservoir operator to continue to store water beyond that point, unless free river conditions occur, the reservoir has supplemental storage rights that come into priority (such as a refill right or junior storage rights), or the reservoir owner is storing foreign water. Water users may divert beyond the measure of their decrees during free river conditions because this does not infringe upon the rights of other water users.

The water level in a reservoir does not have to be rising or increasing in order for storage to occur and new water can be placed into storage in a reservoir at the same time as previously stored water is being released.

Refill Rights

Some reservoirs operate under decrees that provide for refill rights. A refill right typically has a later priority than the original storage right. However, if the reservoir owner applied for a refill right in the original application, the owner may have been given a right to store under the same priority of the original appropriation after the reservoir achieves its first fill and capacity becomes available. Available capacity for a refill right in a reservoir is created by evaporative and seepage losses in addition to actual storage releases. Storage that is held as the subject reservoir's water right at another location is not included in the available refill capacity of the subject reservoir. While this space cannot be filled under a refill right until the storage held at the other location has been released and put to use, the subject reservoir could be filled under a separate junior storage right for the subject reservoir, under free river conditions or with foreign water.

Paper Fill, Including Bookover

As discussed above, a paper fill is an accounting mechanism whereby storable inflow is charged against a storage water right either because the reservoir owner elected not to physically divert or store water under that right or a junior upstream reservoir diverted the storable inflow out of priority. Some examples of paper fill are described below, followed by a discussion of some of the exceptions to the general rule. These are not meant to be exhaustive on this issue, but should provide an understanding of the most typical situations.

1. A reservoir may have multiple rights. For example, it may have a senior storage right and a junior storage right for additional decreed uses. If water is stored under the junior right before the senior right is filled, then a paper fill for the

amount stored and credited under the junior right will also be charged against the senior storage water right, to the extent that it remains unfilled. Once the senior right is filled (either physically or on paper), the junior right may continue to store under its own priority unless it is (or until it becomes) filled.

2. A paper fill is charged against a water storage right when a reservoir cannot be filled to its decreed capacity because of a flood control limitation on storage (unless flood control is a decreed beneficial use) or because of a State Engineer storage restriction on the dam.
3. A paper fill is charged if sedimentation has occurred limiting the reservoir's physical capacity.
4. A paper fill is charged when actual storage in the reservoir includes foreign water that limits the capacity of the reservoir to fill under a senior priority unless the owner of the senior priority books over the foreign water in the reservoir to the senior right at the rate that the senior right would have filled the space taken up by the foreign water.
5. A paper fill is charged for any exchange on natural flow into the reservoir for foreign water. For example, assume an on-stream reservoir user exchanges 20 cfs of foreign water into the reservoir by making release of a substitute supply downstream at the same time the user is entitled to fill the reservoir in priority. In this example, the reservoir would be paper filled for the 20 cfs or approximately 40 acre-feet each day the exchange occurred.

For on-stream reservoirs, if there is no diversion and storage, a paper fill is charged at the rate of storable inflow to the reservoir. For off-stream reservoirs, the paper fill of the senior right is charged at the rate at which the user could have legally and physically filled under the senior right. For example assume the following:

a. there is 400 cfs stream flow at the headgate of the feeder ditch for off-stream reservoir A
b. reservoir A is empty
c. reservoir A has a fill right for 300 cfs that is in priority
d. the capacity of the ditch to fill reservoir A is 250 cfs
e. the reservoir operator is diverting 200 cfs

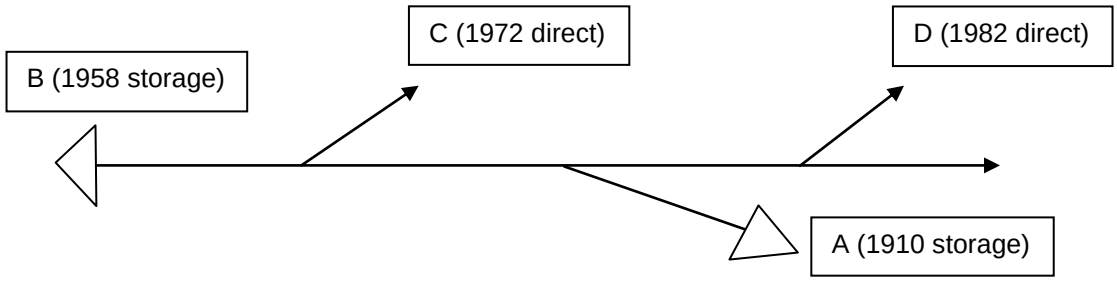
Under these conditions, the reservoir would be paper filled at the rate of 50 cfs per day or approximately 100 acre-feet per day. If an off-stream reservoir is physically full due to storage of foreign water, for example, the rate of paper fill does not occur instantaneously but at a rate that is available at the reservoir from the decreed source of supply. However, if the user does not track the necessary information, then the reservoir is paper filled immediately.

There are times when water will not be counted as storable inflow and used to paper fill a reservoir. When a water user is not able to store water due to safety issues such as repairing and maintaining feeder ditches, winter icing (preventing the reservoir operator from impounding and controlling the inflow) or avoiding poor water quality, then the owner may exclude this water from storable inflow on approval from the Division Engineer. (In addition to the examples above, “paper fill” is also used in applying the out of priority storage statute, as discussed in the following section.)

Out of priority Upstream Storage Statute

As early as 1924, State Engineer Hinderlider allowed upstream reservoirs to fill "as early as possible and depend, to some extent, on the return flow to complete the filling of the reservoirs farther down the river." [5] In 1969, the General Assembly codified this longstanding practice in what is now C.R.S. § 37-80-120. Presently, out of priority upstream storage may only occur against a storage water right on the South Platte in accordance with a plan approved by the Division Engineer. [6] To date, no one has been given approval of such a plan. While other Divisions have not adopted a formal process, some of the considerations that would be taken into account prior to allowing out of priority storage are spelled out in the example below.

Assume structures A and B are reservoirs (owned and operated by different entities) with storage rights and structures C and D are ditches with direct flow rights. All structures are situated on the river as shown below:



In our example, Reservoir A has a decreed and physical capacity of 1,000 acre-feet and has the senior right (1910) on the river, and Reservoir B has a decreed and physical capacity of 200 acre-feet and a 1958 right. Assume that as of March 1, Reservoir A has

[5] Letter from M.C. Hinderlider, State Engineer, to W.B. Gaumer, President, Farmers Reservoir & Irrigation Co. dated November 17, 1924. Please see Appendix for document.

[6] Letters from James R. Hall, Division Engineer, to Division 1 Water Users dated October 6, 2005 and July 27, 2006 regarding South Platte Non-Irrigation Season Administration. Please see Appendix for documents.

diverted 820 acre-feet into storage, and that Reservoir B has been allowed (by approval of the Division Engineer) to divert 200 acre-feet into storage even though its right is junior to Reservoir A's right and Reservoir A has not yet filled (i.e. Reservoir B has stored 200 acre-feet out of priority). If the transit losses to Reservoir A from Reservoir B are 20 acre-feet, then Reservoir A is paper filled to 1,000 acre-feet and no longer able to place a call. At this point, Ditch C would be in priority and thus could divert water and make a call if necessary. Likewise, Ditch D would be entitled to make a call curtailing the diversion of Reservoir A.

Reservoir A would only be allowed to divert additional water to storage under free river conditions. As for Reservoir B, it could continue to divert water under its 1958 water right while at the same time releasing the out of priority water stored and delivering it past Ditch C to Reservoir A even if ditches C or D placed a call. This water then replaces Reservoir A's paper fill with actual water and decreases the risk to Reservoir B that it will be required to release its water to Reservoir A later in the season when it is no longer able to store water under its 1958 priority. In a situation where more than one reservoir is storing out of priority upstream of Reservoir A, all upstream out of priority storage must be aggregated to determine when Reservoir A is paper full.

Administration of the upstream storage statute is further complicated by the requirement to account for any seasonal transit loss changes within the reach from the junior to the senior reservoir and within the feeder ditches of the senior reservoir between the time of out of priority storage and the time the water is released to the senior reservoir. The junior reservoir storing out of priority is responsible for payment of

any increase in transit losses should the senior reservoir not fill assuring the senior reservoir receives the full amount to which they were paper filled.

Due to these complexities required to assure non-injury when storing out of priority, upstream out of priority storage is typically not allowed. In some cases, however, out of priority upstream storage is unavoidable. For example, winter conditions may prevent access to some small high mountain reservoirs for real time operation and may prevent real time measurement of winter inflows due to inaccurate measurements caused by ice cover.

Evaporation

Reservoirs are categorized based on their location from a natural stream as either on-channel or off-channel. When a reservoir is constructed on a natural stream bed (on-channel) it causes an increase in losses to the stream system due to the increase in free water surface area of the stream. When an on-channel reservoir is in-priority and filling, the operator does not have to pay back the stream for this increased loss. However when the reservoir is not filling in priority, the operator is required to release stored water to offset the amount of this increased loss to assure that the total natural flow is passed through the reservoir as if the reservoir did not exist. Usually, the release for this loss is accomplished by lowering the reservoir stage to correspond to the calculated net depletion amount. If daily administration is not practical because of the limited size of a reservoir surface, releases for this loss are often aggregated and made on a monthly rather than daily basis. If more than one water right is in a reservoir or the reservoir contains foreign water, the reservoir owner may specify which type(s) of water to release to account for evaporation.

When predicting the amount of future evaporation to be covered by an on-channel reservoir, the average gross evaporation (free water surface) must be calculated based upon average evaporation atlases in NOAA Technical Report NWS 33[7] and the maximum surface area of the reservoir (unless otherwise decreed). The total gross evaporation estimate from NOAA shall be distributed to all months. The monthly distribution for elevations below 6500 feet msl is: Jan-3.0%, Feb-3.5%, Mar-5.5%, Apr-9.0%, May-12.0%, Jun-14.5%, Jul-15.0%, Aug-13.5%, Sep-10.0%, Oct-7.0%, Nov-4.0%, and Dec-3.0%. The monthly distribution for elevations above 6500 feet msl is: Jan-1.0%, Feb-3.0%, Mar-6.0%, Apr-9.0%, May-12.5%, Jun-15.5%, Jul-16.0%, Aug-13.0%, Sep-11.0%, Oct-7.5%, Nov-4.0%, and Dec-1.5%.[8]

When determining the actual evaporation based on the actual surface area of the reservoir, more site-specific information, if available, may be used or may be required depending upon decree conditions, size of reservoir, impact of reservoir evaporation on other users, and/or availability of data. Any site-specific estimate is subject to evaluation and must be approved by the Division Engineer before use. During times when site-specific instrumentation goes down, NOAA values must be used until the instrumentation is operating again. NOAA values must also be used if site-specific instrumentation is inaccurate, has not been approved by the Division Engineer, or does not exist.

For months during which the surface is completely covered with ice during the entire month, the gross evaporation may be calculated as zero for that month, without

[7] Farnsworth, Richard K., Edwin S. Thompson, and Eugene L. Peck. 1982. *Evaporation Atlas for the Contiguous 48 United States.* NOAA Technical Release NWS 33. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service.

[8] State Engineer's "Policy 2003-2: Implementation of Section 37-92-308, C.R.S. (2003) Regarding Substitute Water Supply Plans" signed August 12, 2003 by Hal D. Simpson http://water.state.co.us/DWRIPub/Documents/policy2003-2.pdf

redistributing that month's percentage into the remaining months of the year. The applicant may prorate the estimated evaporation for months during which the surface is covered with ice over a portion of the surface and/or during a portion of the month. The user must provide evidence of ice cover for that month. For projection purposes only, the ice cover period may be estimated as that period during which the mean air temperature is below 32 degrees Fahrenheit. The Division Engineer, however, will assess actual losses based on actual conditions.

The gross amount of evaporation can be offset for on-stream reservoirs by any evaporation from previously existing free water surfaces, effective precipitation that would have been consumed by any native vegetation, and/or groundwater consumption due to any native phreatophytes. Essentially, statute allows on-stream reservoir owners the right to reduce their required evaporation releases for any natural depletion to the stream that would have occurred if the reservoir were not in existence (37-84-117 (5) C.R.S.). An analysis of the pre-existing conditions must be performed to determine what reduction to the gross amount of evaporation will be allowed. In addition, a user may be required to keep track of actual site-specific precipitation in determining the reduction to the gross amount of evaporation for large reservoirs. Typically, the SEO has assumed for a native site (without phreatophytes) with a deep ground water table that 70% of the total precipitation is either consumed or goes to soil moisture storage.[9]

Seepage

As soon as water stored in a reservoir or in the process of being delivered by a ditch seeps through the bottom or sides of the structure, it is considered waters of the

[9] Wolfe, Dick and Richard L. Stenzel. 1995. "Evaporation." *Evapotranspiration and Irrigation Efficiency.* Proceedings of the 1995 Seminar held in Arvada, CO on October 10-11, 1995. Please see Appendix for document.

state subject to the prior appropriation doctrine. This applies to water that cannot be "re-used" as well as fully-consumable water that is no longer under the dominion and control of the user. A reservoir owner may not recapture seepage water from a reservoir as part of the original storage right unless specifically allowed by decree and may not recapture fully consumable water without dominion and control accounting approved by the division engineer. An appropriator of seepage water cannot require or demand that the seepage continue as the reservoir or ditch owner is generally allowed to make improvements that may eliminate or reduce the seepage.

Absent a specific decreed appropriation to the contrary, water flowing from the toe drain of a dam associated with a reservoir is considered "seepage". Toe drain outlets must drain freely without restriction to protect the dam and must be discharged without use and separate from the measured release from the reservoir. Structures oriented such that the toe drain flow cannot be separated from the measured reservoir release must quantify the toe drain flow in a manner approved by the division engineer and must subtract the toe drain flow from the measured, comingled release. Toe drain flow from on-stream reservoir dams may be counted as an "accretion to the stream flow resulting from the existence of a reservoir" that is used to offset evaporative losses in accordance with §37-84-117 (5), C.R.S. provided the user relinquishes all dominion and control over the released toe drain flow.

Volumetric versus Gage Height Decrees

The amount of storage water could be defined in a decree as a specific volume or up to a specific gage height in the reservoir. A "volumetric" decree is filled once the total volume of water as measured into the reservoir (plus any carryover and paper fill

volume) reaches the decreed amount or physical amount, whichever is less. A “gage height” decree is filled once the level in the reservoir (plus any paper fill amount) reaches the decreed gage height. The difference between gage height and volumetric decrees is that while filling under these two types of rights, evaporation and seepage does not count against the gage height decree but does count against the volumetric decree. (Seepage may or may not count against an on-stream volumetric decree depending on how the inflow is determined.) Once a gage height decree is filled, however, it is then treated just like storage under a volumetric decree for an off-channel reservoir where the storage in the reservoir suffers evaporative and seepage losses. Absent a refill right, foreign water or free river conditions the additional space created by these losses cannot be replaced.

It is important to have a good stage-capacity curve even for reservoirs with gage height decrees. If the reservoir is curtailed due to a call prior to being filled, the stage-capacity curve can be used to determine how much water the reservoir still has under its water right should it come back into priority. If the gage-height decree comes back into priority, it can continue to fill up to the volume associated with the difference between the gage height when it was curtailed and the completely full gage height.

The following is an example of a gage-height decree for Julesburg Reservoir decreed in civil action no. 944:

> It is therefore Adjudged and Decreed, that the said Julesburg reservoir be allowed to have stored in it from the South Platte river by means of the Harmony ditch No. 1, as enlarged and extended as a feeder to said reservoir, and for the benefit of the party or parties aforesaid under and by virtue of said appropriation by construction No. 1, so much water as is necessary to fill said reservoir to a depth of forty-seven (47) feet above the bottom of the lower discharge conduit from said reservoir, being an estimated capacity of one billion two hundred and twenty-seven million

> four hundred and forty-five thousand cubic feet, which appropriation of water for said storage purposes and other beneficial uses took effect on and dates from the 12th day of February, 1904.

The gage height of 47 feet above the bottom of the lower discharge conduit dictates when this reservoir has reached its one fill under this right despite the decree giving an estimated volume associated with this gage height.

Transit (Conveyance) Losses

Transit losses are losses to the stream due to seepage, stream evaporation, or plant consumption. The General Assembly requires the State Engineer to determine and charge transit losses (also referred to as “conveyance losses”) for the delivery of water released from storage or taken into storage. Transit losses vary depending upon channel size, elevation, stream gradient, vegetation, bank storage, time of year, location, distance, and other factors.

Exchanges

In an exchange, water is generally provided at one point on a stream so that it may be diverted out of priority at another point upstream. Reservoirs may be part of exchanges. Some examples of possible exchanges that involve reservoirs include:

- release from a downstream reservoir in exchange for diversion into an upstream reservoir
- release of reusable effluent from a downstream treatment plant in exchange for diversion into an upstream reservoir.
- release from a downstream reservoir in exchange for diversions into an upstream ditch

- consumptive use credits from a downstream changed direct right are left in the stream to replace water diverted in an upstream reservoir

As with all exchanges, the exchange must be approved by the Water Commissioner or Division Engineer and the release downstream timed so that the flow will be the same as if the upstream diversion had not taken place. Further, when a water right holder releases water allowing an upstream diversion by exchange, the diverted water takes on the "character" of the released water. For example, the water stored in a reservoir in exchange for the release of reusable water from a treatment plant would "take on the character" of the reusable effluent and the water released from the treatment plant becomes the same character as the water that was physically stored in the reservoir (either natural stream or delivery water).

Temporary Detention (72-Hour Rule)

Direct water rights may be temporarily detained for up to 72 hours in order to allow more efficient or effective beneficial use of the water. Examples of such detention would be ponds used to receive delivery of a direct flow irrigation water right that is then applied by a sprinkler or temporarily detained and slugged out through a ditch (operational, head stabilization, equalization or flow regulating ponds), or the use of forebays or regulating structures associated with municipal operations. A specific storage right generally will not be required as long as the water is held for less than 72 hours and the detention is for purposes of allowing for more efficient or effective beneficial use of the direct water right. Absent a storage right or free river conditions, all water, including storm water, must be released within 72 hours. Ponds that intercept ground water are subject to additional limitations and all dams associated with the

construction of ponds must comply with all requirements of the State of Colorado's Dam Safety Rules and Regulations.

If storm water is not diverted or captured in priority, by exchange or under a substitute water supply plan or decreed plan for augmentation, Colorado Water Law requires it to be released. The State Engineer's current policy requires that all detained water be released to the stream system within a maximum of 72 hours after detainment.

Surcharge Storage

Surcharge storage means the volume of water that may be impounded but not retained within a reservoir between the normal spillway and the crest of the dam. This surcharge is not considered part of the reservoir fill under the water right. The reason for this is that the reservoir operator does not control water in surcharge and by definition in CRS 37-92-103(10.8) storage is the impoundment, possession, and control of water by means of a dam. Unless free river conditions exist or an exchange is made to "recolor" (or change the character of) this water, surcharge storage must be released within 72 hours. Operation of the reservoir outlet works may be required in order to release the surcharge within 72 hours.

Adequate Measurements

In cases where the reservoir right is limited to gage height, it is important that a staff gage that is easily readable be installed in the reservoir. A stage-capacity table (a table that reflects the capacity or volume of storage in the reservoir based on the stage or elevation of the water in the reservoir) has also usually been developed in conjunction with obtaining an absolute right for the reservoir. As long as the decree for the reservoir covers complete filling of the reservoir and no other water is stored in the

reservoir when the reservoir reaches the full level as measured on the elevation/staff gage, then the reservoir is considered full under that right. While the reservoir is filling, any losses due to evaporation or seepage can be made up. However, once the reservoir has reached its decreed gage height, it cannot be refilled to make up for losses due to evaporation or seepage under this right unless the decree specifically allows this.

Measuring inflow with a decree specifying a staff gage height is more difficult when releases are being made at the same time that water is being stored. In this situation, a reservoir operator may be required to measure via gages all inflow to and outflow from the reservoir to determine the storage under the right. Alternatively, the Division Engineer or Water Commissioner may allow the use of a "computed inflow." In computing inflow, reservoir operators measure the outflow and the change in storage (as measured by the staff gage) over the same period of time and account for net surface water evaporative losses. This method accounts for all inflow, including underflow, unmeasured tributaries, and precipitation on the reservoir's surface.

In cases where the amount of storage allowed is limited to a volume and not a specific gage height (volumetric decrees), an accurate measure of all inflow is generally necessary. This is done by use of a flume or a weir with a continuous recorder. For volumetric decrees, losses due to evaporation or seepage from the reservoir cannot be made up under the storage right.

Recording is often midnight to midnight, but historical and pragmatic practice may allow recording to be 8am to 8am or another 24-hour period. Reservoir operators

must report this recorded information as required by the Division Engineer. Reporting requirements may vary depending on the time of year.

Accounting Principles

Accounting requirements differ depending on the administrative requirements of a reservoir. In simple situations, no independent accounting from the user would be required when the reservoir can be administered without such accounting. The reservoir is simply considered full when it reaches its decreed limit after accounting for carryover (as described separately in this document). In these cases, the only record is often the Water Commissioner's record of diversions and storage contents.

Accounting does become necessary when a reservoir goes into and out of priority prior to being filled or the user is releasing water prior to being filled. As described earlier, accounting is also required if there is more than one storage decree associated with a reservoir (especially if the decrees are for different purposes) or foreign water is stored in a reservoir. In the case of more than one storage decree for different uses or places of use, the user may keep track of each type of water in the reservoir independently. If the user does not provide accounting, all carryover is charged to the senior most right as discussed earlier (except when the first-in first-out principal is applied) and takes on the character of the senior right.

In some cases, a reservoir has been designated as an alternate place of storage for another storage right. In this case, the user must keep track of the different types of water in the reservoir. If a particular right is stored in more than one reservoir (either as an alternate place of storage or relocated to other reservoirs), then the user must

account for storage under this right in all reservoirs so as to document compliance with the decree(s).

Administrative Accounts (Owe-The-River Account)

It is sometimes necessary to use water balance type accounting when it is difficult to directly measure all of the inflow into an on-stream reservoir. With water balance accounting, the inflow is determined by measuring outflow (including releases and evaporation) and change in storage during the day. The determination of inflow is a day in arrears because of the dependence on change in storage information. An administrative account is used to keep track of “errors” in release amounts because of not knowing the inflow until a day late. For example, assume the following:

a. Reservoir A is on stream and cannot store because it is out of priority.
b. The users are releasing 10 cfs (approximately 20 acre-feet/day) from storage in the reservoir for use.
c. The Division Engineer or Water Commissioner is releasing an additional 5 cfs (approximately10 acre-feet/day) as that is the assumed natural inflow to the reservoir.
d. The net evaporation from reservoir A is 1 cfs (approximately 2 acre-feet/day).
e. The reservoir declines approximately 20 acre-feet between day 1 and day

On day 2, the Division Engineer/Water Commissioner and/or user will use water balance accounting to determine that the actual inflow between day 1 and day 2 was approximately 12 acre-feet (Inflow = Releases (30) + Evaporation (2) + Change In Storage (-20)) or 6 cfs rather than the estimated 5 cfs. In this case, an administrative

account or “owe the river account” would be approximately 2 acre-feet. The Division Engineer/Water Commissioner would adjust the release on day 2 to attempt to continue to release natural inflow plus release the 2 acre-feet in the “owe-the-river” account. The same steps would be taken each day to adjust for either too high or too low an estimate of the actual inflow each day and to keep the administrative account as near to zero over time as possible.

Enforcement Principles

Installation of Measurement Device or Reporting Orders

Generally, the Division Engineer or Water Commissioner verbally directs reservoir users concerning the measurement devices and reporting necessary to administer reservoir rights. In accordance with 37-92-502 (5) (a), C.R.S., the State Engineer and the Division Engineers also have formal authority to order any owner or user of a water right to install and maintain at such owner's or user's expense necessary meters, gauges, or other measuring devices and to report at reasonable times to the appropriate Division Engineer the readings of such meters, gauges, or other measuring devices. Users are subject to liability for impacts to other users from improper storage and subject to paying legal fees and costs of the State in enforcement efforts associated with measuring devices and reporting.

Storage Release Orders

In most situations, the Water Commissioner or Division Engineer informally directs a user to release water stored improperly or directs the user to provide information on why they should be able to retain water when it appears they have stored

out of priority. However, if necessary, the Division Engineer can formally order the release of any water that the Division Engineer finds to have been illegally or improperly stored in accordance with 37-92-502 (3), C.R.S. The Division Engineer is directed to deliver this water to users who are entitled to the same and to insure that the release will not cause damage. Users are subject to liability for impacts to other users from improper storage and subject to paying legal fees and costs of the State in such circumstances. In addition to other orders discussed in these guidelines, the Division Engineer may order removal of any obstruction in a river if it impacts water rights.

ADDITIONAL INFORMATION

Dam Safety Restriction and Breach Orders

The State Engineer's staff inspects reservoirs within the state to determine their safe storage level. When necessary, the State Engineer will issue a restriction order to limit the user from storing above this safe storage level (see Rule 4.2.29 of the Dam Safety Rules). The Division Engineer will order the release of water in the reservoir if it exceeds the restricted level.

A breach order is an order issued by the State Engineer, or his designee, to remove all or part of a dam to the level of the natural ground, so it is incapable of impounding water and creating a hazard (see Rule 4.2.3 of the Dam Safety Rules).

Dead/Active Storage

Active storage is that volume of water capable of being released from the reservoir by means of gravity through an outlet of the reservoir. Dead storage is that amount of water that cannot be released without pumping because of the location and elevation of the lowest outlet from the reservoir. A user may be required to pump dead storage water out of a reservoir into the stream to replace evaporation losses or out of priority inflows into the reservoir. The SEO may oppose the use of small ponds with dead storage as an augmentation source in an augmentation plan due to the unreliability and inadequacy of these structures.

Underground Storage

Placing water into underground storage has a number of advantages that achieve the legislature's objective to maximize the beneficial use of all of the State's waters. For example, water stored underground is not lost to evaporation; the water can be used as an emergency supply in the event of disruption to surface water systems; storing water in an aquifer raises the water table and can reduce energy demand and energy costs otherwise needed for well pumping; and storing water underground helps to reduce committing additional surface land to additional large reservoirs, conveyance systems, and stream modifications.

Underground reservoirs are not reservoirs within the meaning of C.R.S. 37-87-101(2) except to the extent such reservoirs are filled by other than natural means with water to which the person filling such aquifer has a conditional or decreed right. Recharge water rights are not considered storage. Underground reservoirs also include porosity storage reservoirs which are defined as underground storage vessels in an alluvial deposit over an aquiclude that is formed by separating a volume of that alluvial deposit by surrounding it by a man-made substantially impermeable barrier so that the volume is hydrologically separate from the original surrounding deposit.

Subgrade Storage

Subgrade storage includes any water stored below the natural land surface elevation such that it must be accessed by means other than gravity drainage. This includes rock quarries in low permeability material, but generally is associated with placing a very low permeability lining around a mined-out gravel pit or other excavation

into high permeability material. The purpose of the very low permeability liner is to isolate the water placed into the excavation from the surrounding ground water, thus impounding, possessing, and controlling the water, rather than letting it flow away with the surrounding ground water and become unavailable for future use.

The very low permeability liner must be approved in accordance with the August 1999 State Engineer Guidelines for Lining Criteria for Gravel Pits (please see Appendix for document). The Liner Guidelines contain a procedure for testing the constructed liner, two allowable liner leakage standards, a mass balance accounting procedure for lined excavations, and provisions to address a liner failure that may occur during operation of the reservoir.

The testing procedure set forth in the Liner Guidelines requires that the liner be demonstrated to meet leakage standards. Typically this is done by holding the lined excavation essentially dry; measuring the volume of water removed from the lined excavation; and calculating the volume of any precipitation entering the lined excavation based on the surface area and a simple on-site rain gage correlated to official weather stations in the area. If the lined excavation is not held essentially dry during the test, the volume of evaporation from the free water surface must also be calculated based on the surface area over the course of the test and data from official weather stations in the area. The differences between the known inflows and the known outflows plus any changes in storage are assumed to be ground water leakage by the liner. If this volume does not meet the leakage standards in the Liner Guidelines then the excavation is determined to be a well and water storage is not allowed.

It should be noted that the Liner Guidelines contain a similar testing procedure as discussed above for locations of high permeability material where a slurry wall has been installed to isolate an area from the local ground water but where no excavation has yet occurred. The procedure here requires piezometers located inside and outside of the slurry wall to monitor water levels on both sides of the wall. Water is then pumped from inside the wall to establish a steady-state head gradient across the wall for the 90 day test. The minimum acceptable head gradient prior to starting the test is ten (10) vertical feet or to bedrock if bedrock is located less than ten feet below the local water table. The same leakage standards used for an excavated area are also used in this instance.

The mass balance accounting procedure set forth in the Liner Guidelines is straightforward and requires any out of priority inflow from any source, including ground water, to be returned to the stream or fully augmented. The Liner Guidelines provision to address a liner failure that may occur during operation of the reservoir requires that if, in two consecutive months, the accounting shows the unregulated ground water inflows exceed the Guideline Standards, the reservoir operator and the State Engineer's Office will consult on the probable cause(s) and possible solution(s) to the excessive inflows. Specific operational requirements and time lines for agreement and repair are also set forth in the Liner Guidelines. The ultimate result of a previously approved liner failing to meet the Guideline Standards during actual operation is a prohibition of storage in the reservoir with a requirement that all out of priority inflows be pumped to the stream or fully augmented pursuant to an augmentation plan or a substitute water supply plan.

Rock quarries in low permeability material that seek to store water are tested in accordance with the Liner Guidelines discussed above as applied to lined excavations

into high permeability material where the excavation intercepts ground water. They are also subject to the same two tiered accounting approach discussed above.

Types of Dams

Colorado laws governing dams and reservoirs were enacted for the protection of lives and property due to potential hazards associated with the storage of water in the reservoir behind a dam. The owner of the dam is responsible for the safe storage of water impounded in the reservoir. There are specific construction and administration requirements depending on the category of a dam. The categories are as follows: jurisdictional size dams, non-jurisdictional size dams, livestock water tanks (LSWT), erosion control dams (ECD) and exempt structures such as mill tailing impoundments (see complete list of these structures in Section 37-87-114(5) C.R.S.). Laws that are contained in the Colorado Revised Statutes establish specific requirements for each type of dam. Jurisdictional and non-jurisdictional size dams, exempt structures, and ECDs are governed by Sections 37-87-101 thru 125, C.R.S. and the Rules and Regulations for Dam Safety and Dam Construction. LSWTs are regulated by Sections 35-49-101 thru 116, C.R.S. The owner of a dam and/or irrigation ditch has responsibilities, and the Division Engineer in charge of each Water Division has additional related authorities, under the following statutes: C.R.S 37-84 inclusive and 37-92 inclusive.

Constructing a dam to create a reservoir does not assure the owner the right to store water. Likewise, having a water right does not constitute an approval to construct the dam. A water right must be obtained through the Water Court. Approval for construction of a dam must be obtained from the State Engineer.

Jurisdictional versus Non-jurisdictional

A jurisdictional dam is one that has a statutory height of greater than 10 feet in height to the spillway crest from the lowest point in the natural stream channel or natural ground surface, or creates a reservoir with more than 100 acre-feet of water, or covers a surface area of more than 20 acres at the high waterline. Plans and specifications for jurisdictional dams must be approved by the State Engineer before construction. The "Rules and Regulations for Dam Safety and Dam Construction" can be accessed from the following website link: http://water.state.co.us/DWRIPub/Documents/ds_rules07.pdf. Additionally, you can obtain a publication from this office free of charge titled, "Guide to Construction and Administration of Dams in Colorado" (or you can download it at the following link: http://water.state.co.us/DWRIPub/Documents/damguide.pdf), which is helpful in providing general information regarding dams, livestock water tanks, and erosion control dams.

A flood control dam is a special purpose dam which is normally dry and has an un-gated outlet structure which will drain the water impounded during the flood. The jurisdictional size and classification of the dam are determined assuming the reservoir is full to the emergency spillway (see Rule 4.2.5.7 of the Dam Safety Rules).

Non-Jurisdictional size dams are smaller in size than jurisdictional size dams. Plans and specifications are not required for construction, however, filing of a Notice of Intent to Construct a Non-Jurisdictional Water Impoundment Structure is required. The form may be obtained from the Office of the State Engineer in Denver, from any Water Division office, or from the DWR website http://www.water.state.co.us/DWRDocs/Forms/Pages/DamForms.aspx, and must be

filed 45 days prior to construction. No fee is required to file the Notice of Intent form. The Division Engineer may require an outlet pipe with a regulating gate to be installed in the bottom of the dam to allow releases to prevent injury to existing water rights. Because any dam, regardless of size, has the potential to cause damage downstream if it should fail, the owner is advised to consult a person familiar with dam construction to ensure the dam is constructed properly. The Notice of Intent form shall be submitted to the Division Engineer of the Water Division in which the dam is to be located. Addresses of the seven division offices are available online at http://www.water.state.co.us/org/contacts.asp.

Livestock Water Tanks

Livestock water tanks are covered under the "Livestock Water Tank Act of Colorado" Sections 35-49-101 to 35-49-116, C.R.S. (Also see Rule 17.4 of the Dam Safety Rules.) A LSWT requires a permit from the State Engineer. A LSWT is a dam constructed to capture run-off water on rangeland to provide water for livestock. They may only be constructed on normally dry water courses, and may also be used for recreation, but not for irrigation. A normally dry water course or stream is considered dry 80% of the time during a calendar year. The structure must not have a ditch or other structure delivering water to or from it.

Height of the dam cannot be greater than 15 feet from the bottom of the stream channel to the spillway crest. Impoundment volume of the reservoir cannot exceed 10 acre-feet. If the LSWT is five feet or less in height to the spillway, and two acre-feet capacity or less, no application is necessary, but an application may be filed to obtain a priority between LSWT's. It is important to note that this is not a water right, but only

provides a priority between LSWT's. The LSWT does not require a water right for its use but may be subject to curtailment from downstream senior users depending on the specific circumstances.

An outlet pipe with a regulation gate is required unless specifically waived by the Division Engineer during review of the application. Standard specifications and application forms are available from any Water Division office or the DWR website http://www.water.state.co.us/DWRDocs/Forms/Pages/DamForms.aspx. The application and fee should be submitted to the division office that the LSWT is to be located in. Construction of the LSWT may begin upon approval of the application by the Division Engineer. The State Engineer may then inspect the LSWT and within 10 days after receiving notice of completion or within 10 days after inspection he must then approve or disapprove of the structure. The U.S. Natural Resources Conservation Service may assist owners in preparing an application, or owners may wish to hire a licensed professional engineer experienced in dam design for assistance.

Erosion Control Dams

In Colorado, many farms and ranches need ways to control erosion. In recognition of this need, the Colorado legislature instituted statutes governing the development and use of these types of structures. Erosion control dams are governed under Section 37-87-122, C.R.S. (Also see Rule 17.5 of the Dam Safety Rules.)

An ECD requires a permit from the Office of the State Engineer. These dams may only be constructed on normally dry watercourses and are only for the purpose of controlling soil erosion caused by floods. The vertical height of the dam cannot exceed 15 feet from the bottom of the channel to the bottom of the spillway. The height is

measured at the toe of the upstream slope where the dam contacts the ground surface. The spillway must have a minimum freeboard of four feet to the dam crest. Impoundment volume of the reservoir cannot exceed 10 acre-feet at the emergency spillway level. An ECD with more than two acre-feet capacity must have an un-gated outlet conduit large enough to pass stored water in excess of two acre-feet within a 36-hour period, but no less than a 12-inch diameter. The vertical location of the outlet must be at or below the two acre-feet storage volume level. In certain circumstances, an outlet structure may be required for an ECD with less than two acre-feet capacity to address water administration issues.

A water right is not required for an ECD but a number is assigned, similar to a LSWT. An ECD is also subject to curtailment from downstream water rights depending upon the circumstances. Since an ECD is not intended to store water, a priority is not assigned. Standard specifications and application forms are available from any Water Division office or the DWR website http://www.water.state.co.us/DWRDocs/Forms/Pages/DamForms.aspx. The application, along with a fee, must be submitted to the Water Division office. Construction may begin upon approval of the application by the Division Engineer. The U.S. Natural Resources Conservation Service may assist owners in preparing an application, or owners may wish to hire a licensed professional engineer for assistance.

Other Regulatory Requirements

Other state and federal agencies regulate runoff from storm water in construction activities, industrial activities and concentrated animal feeding operations. These facilities may involve temporary or permanent detention, retention, or sediment ponds or

basins. These structures are designed to capture, settle, store and/or release water. These structures can be constructed by excavation and/or by placing an earthen embankment across a low area or drainage swale. They can be designed to maintain a permanent pool or to drain completely dry.

The two agencies that regulate these activities are the Colorado Department of Public Health and Environment, Water Quality Control Division http://www.cdphe.state.co.us/wq/PermitsUnit/ and the Environmental Protection Agency http://www.epa.gov/region8/water/stormwater/. Even though these structures are permitted and regulated by these other agencies they must still comply with all State water rights laws regarding diversion and depletion of surface water.

Compensatory Storage Doctrine (Transbasin Storage Agreements)

The cost of constructing and operating large projects precluded all but the largest municipalities. To provide a means to finance, acquire water rights and land surface rights, and for operations, the Colorado legislature created special statutory entities called water conservancy districts. The first of these districts was the Northern Colorado Water Conservancy District, created in 1937 to develop the Colorado-Big Thompson Project. Recognition of compensatory storage as an integral part of transmountain diversions by way of water conservancy districts came in 1943 when the Colorado legislature amended the original Water Conservancy Districts Act to require facilities to be constructed so as not to impair nor increase costs to existing or prospective water users within the natural basin of the Colorado River. Three reservoirs

have been built in the Colorado River drainage as a result of this act. The Colorado-Big Thompson Project built Green Mountain Reservoir with a capacity of 152,000 acre feet in return for the right to divert an expected 320,000 acre feet to the South Platte drainage. Of the 152,000 acre feet, 100,000 acre feet is in the compensatory pool for the benefit of in-basin users. These beneficiaries receive replacement releases either by the language of the authorizing legislation of the project or by contract. This authorizing legislation for the CBT, Senate Document 80, became the model for compensatory storage. The Fry-Ark Project built Ruedi Reservoir with a capacity of 102,000 acre feet in return for the right to divert an expected 69,200 acre feet to the Arkansas River drainage. An individual beneficiary of this compensatory pool obtains release of stored water by contract. The Windy Gap project provided $10M for the construction of compensatory storage, which ultimately helped build Wolford Mountain Reservoir, and the first 3,000 acre feet of Windy Gap water pumped to Granby Reservoir. Municipalities, irrigation companies, and other corporations that construct transmountain diversion projects are not required to provide compensatory storage because they are not incorporated or created under the statute requiring such storage.

Dick Wolfe, P.E.
State Engineer, Director
Colorado Division of Water Resources
October 31, 2011

Appendix

May 11, 1936

TO ALL DIVISION ENGINEERS AND WATER COMMISSIONERS:

Under the construction placed upon the statute providing for the storage of water in reservoirs in this state, the water officials have in the past considered that a decree for direct use of water was superior to one for storage purposes, which interpretation was upheld in a former decision of the Supreme Court. The recent opinion of the Supreme Court in the case of the Park Reservoir Company v. M. C. Hinderlider, State Engineer, et al, reversed its former decision. Therefore, in the future, you are to administer all decrees, whether for direct use or for storage purposes, strictly in their relative orders of priority.

In this connection, the Supreme Court has heretofore ruled that a reservoir is entitled to only one filling in any one year, as against a junior right which may be demanding the water. (Windsor R. & C. Co. v. Lake S. D. Co., 44 Colorado, P. 214.) One filling of the reservoir does not necessarily mean that the reservoir must be actually filled to decreed capacity, but does mean that the sum total of the quantities of water, stored from time to time therein during any one year, is equivalent to the total quantity of water decreed to that particular reservoir.

The aforementioned decision does not define the word "year." In the absence of such definition, it might reasonably be assumed to mean a "calendar" year. For the purpose of greater convenience and efficiency, however, the Legislature has established a "fiscal" year, and this Department for years has used a "seasonal" year in the tabulation of stream flow records, and for other purposes.

As a result of climatic, crop, and other conditions affecting the supply and use of water in the state, it is considered desirable to adopt what might be termed a "seasonal" year, which it is thought will permit of a more practicable and efficient administration of the aforementioned ruling of the Court limiting a reservoir to one filling in any one year. The arbitrary

establishment of a "seasonal" year will not conflict with a former decision of the Court, that there is no such thing as an irrigation season, nor will it affect the right of a ditch or reservoir to call for water at any time, since such calls will be recognized only in order of priority. Until further notice, it will, therefore, be assumed that the "seasonal" year will cover the period from November 1st to October 31st.

While the recent ruling of the Supreme Court may seem to greatly increase difficulties of administration, many of the perplexities will disappear if a reservoir is considered to be a ditch. The only distinction to be kept in mind is the fact that the Court limits a reservoir to one filling a year until all junior rights have been filled, which filling is usually measured in cubic or acre feet, while the right of a ditch to divert water is not limited in quantity, measured in cubic or acre feet or in time during the year, but is limited by the "rate" of diversion mentioned in its decree.

A proper administration of a reservoir will, therefore, require the maintenance of a correct record of the reading of the gage rod in the reservoir on November 1st, and of the beginning and ending of each period of storage during the seasonal year, and of the beginning and ending of releases from the reservoir during the seasonal year, together with the dates of all such gage rod readings. In other words, it is necessary that a debit and credit account on each reservoir be maintained at all times, which account would charge the reservoir with storage therein, and credit the reservoir with releases therefrom. Water carried over in reservoirs after October 31st shall be charged to the new seasonal year's filling privileges, which will have the effect of decreasing the effective storage capacity of the reservoir during the new seasonal year.

For keeping such records, we suggest the use of a "Reservoir Ledger Book" substantially in conformity with the attached form.

Very truly yours,

M. C. Hinderlider / State Engineer.

RECORD OF STORAGE IN AND RELEASES OF WATER FROM .... RESERVOIR

IRRIGATION DIVISION NO..........., WATER DISTRICT NO...........

Decreed Capacity.................................cubic or acre feet as of.................................

" " .... " " " " " " ....

" " .... " " " " " " ....

Date Start Storage	Gage Reading	Date End Storage	Gage Reading	Quan. Stored	Date Start Release	Gage Reading	Date End Release	Gage Reading	Quantity Released

November 14, 1924.

1065

Mr. M. C. Hinderlider,
State Engineer,
Capitol Building,
Denver, Colorado

Dear Sir:

It very frequently happens that about this time of year or a little later the reservoirs in the vicinity of Ft. Morgan begin to ask for all the water in the Platte River to go past our headgates and be used to fill the reservoirs in that vicinity. I have heard that a good bit of water has been permitted to go past the headgates of the Empire and Riverside intake canals and that as a result Jackson Lake will probably within less than thirty days be full and after that time all return water, amounting to 125 second feet or more, which comes into the river below the Riverside headgate will be wasted on down the river.

It is to the interest of everyone to save all possible water and I am writing to call your attention to this situation and to say that if these reservoirs have wastefully managed the storing of water in that part of the river, they should not be permitted to call water past our headgates to make up for any deficiencies they may have because of not using the water to the best advantage that has been available to them.

I do not know that any demand will be made to have water go past our headgates and I sincerely hope that no such demand will be made, but if it is made we will feel that it is unjustly and unnecessarily made, at least to the extent that this fall water has been permitted to go past the headgate of the Riverside intake canal. I understand work is being done on the Empire intake canal and that might possibly be an excuse why they should not take available water, but, on the other hand, it would seem to me that this work could be done at a time of year when they could not reasonably expect to have water available for them and not at a time of year when the failure to take available water might result in unnecessary hardship upon other irrigation enterprises.

DEFENDANT'S EXHIBIT
10
Case# 820W23

It is probably unnecessary for me to call your attention to these matters, as you are doubtless aware of them already, but this question of so handling the river that all possible water is saved in the upper reservoirs is so important to us and all water users along the Platte River that it does not seem to me to be out of place to be quite diligent in calling it to the attention of yourself and all parties interested in irrigation matters.

Yours respectfully,

THE FARMERS RESERVOIR AND IRRIGATION COMPANY

President

WBG*MF
CC - Chas. F. Tew

M. C. HINDERLIDER
STATE ENGINEER
C. C. HAZLEHURST
DEPUTY
J. HAROLD BAILY
CHIEF HYDROGRAPHER

STATE OF COLORADO
ENGINEERING DEPARTMENT
DENVER

November 17th, 1924.

Mr. W.B.Gaumer, Pres.,
Farmers Res.& Irr. Co.,
Ideal Bldg.,
Denver, Colo.

1035

Dear Sir:- Re: Storage Conditions on So. Platte River.

We acknowledge receipt of yours of the 14th inst. with respect to the storage conditions on the South Platte River below the head of your intake.

We are heartily inaccord with your idea of filling the upper river reservoirs as early as possible and depend, to some extent, on the return flow to complete the filling of the reservoirs farther down the river.

We have taken this matter up heretofore with Mr. Cogswell and he assures us that no water was being allowed to pass the head of the O'Brian Canal last week.

We have discussed this matter very fully with Mr. Cogswell, but in the event that orders are made upon your company to pass water which, in your judgment, does not seem proper, we would be pleased to have statement from you to that effect, and we will then issue instructions looking to a more thorough conservation of the water supply.

Very truly yours,

M. C. Hinderlider
State Engineer.

MCH/bo

STATE OF COLORADO

WATER DIVISION ONE
OFFICE OF THE STATE ENGINEER
Division of Water Resources
Department of Natural Resources

810 9th Street, Suite 200
Greeley, Colorado 80631
Phone (970) 352-8712
Fax (970) 392-1816

http://www.water.state.co.us/

October 6, 2005

Re: South Platte Non-Irrigation Season Administration

Dear Water User or Interested Party:

The administration of the waters of the South Platte River remains under pressure from the effects of the recent drought, court decisions and increased competition for the limited resource. As a result, the cooperative administrative approaches that have existed for over thirty years are changing. As you are probably aware, prior to 2001, the State Engineer believed he had authority to approve substitute water supply plans to allow wells to operate when they were out-of-priority. However, the Supreme Court ruled in the *Empire Lodge* case that the General Assembly had not granted such authority to the State Engineer.

In response to this 2001 Supreme Court ruling, the State Engineer proposed new Rules in 2002 to allow for operation of Substitute Water Supply Plans (SWSPs) for tributary wells in the South Platte. Many parties challenged these rules, and the Division 1 Water Court ruled that the State Engineer could not approve Substitute Water Supply Plans under the proposed 2002 Rules. The Colorado Supreme Court confirmed the Water Court's decision in April 2003. Meanwhile, legislation enacted in 2002 and 2003 provided a new statute for some users to employ to obtain the State Engineer's approval of temporary SWSPs under certain conditions. Under some circumstances, the temporary SWSPs are intended to allow wells to operate out-of-priority while the users apply for water court approval of an augmentation plan. Many augmentation plans are now winding their way through the court process with interim SWSP's allowing continued operation of some wells. On June 3, 2005, the Water Judge approved the largest of these plans for the Central Colorado Water Conservancy District.

Changes as a result of Supreme Court rulings, legislation, drought and increased competition for water have created significant hardship on a large segment of users and may continue to create hardship on some users. Not surprisingly, recent events have raised several issues

associated with administration in the South Platte, and our office is considering potential changes to its administrative practices. Prior to making any such administrative changes, we are seeking your input. We foresee continuing administration as it presently exists for this winter, but anticipate changes for the storage season of 2006-2007.

Two of the most significant issues include 1) administration of out-of-priority reservoirs on the South Platte, and 2) winter replacement requirements for out-of-priority well depletions. With the cooperation that has existed on the South Platte, the Division has allowed the out-of-priority storage of water in irrigation reservoirs that divert from the South Platte from the Denver Metro area northeast to the state line when it is apparent that senior downstream reservoirs will fill. This administrative scheme has existed for several decades and has allowed for the maximum utilization of our water resources. However, the statute that guides out-of-priority storage specifically states that out-of-priority storage may only be allowed if the "water so stored can promptly be made available to downstream senior storage appropriators in case they are unable to completely store their entire appropriative right due to insufficient water supply." 37-80-120 C.R.S.

We believe some of the reservoirs that have historically had out-of-priority storage probably cannot return water back to the river promptly, as required by the statute. Thus, even though this practice was allowed through the cooperation of users, the Division needs to review whether it can continue the practice of allowing such out-of-priority storage <u>even</u> when the Division is confident that the water will not be needed downstream for a senior storage right. We are seeking public input on this past practice and whether it should continue in the absence of any statutory changes.

In the past, our office has not kept track of calls based on what would have happened if there was no out-of-priority storage, as occurs in other Divisions, because it has not had a need for this type of accounting. In the future, our office is looking at the possibility of keeping track of the call as if there were no out-of-priority storage. Thus, in a simple example, our office would change the call from the senior date of a downstream reservoir to the junior date of the up-stream reservoir once the out-of-priority storage by the junior plus the storage by the senior would have filled the senior's reservoir. The Division Engineer is also considering extending this concept to the situation of out-of-priority storage for reservoirs that cannot return water and to well users that are required to make replacements for depletions. Our office desires public input on such practices and whether they may occur without authorization from the Water Court or the General Assembly.

On a related topic, some water users may believe that well owners should replace any time there is a shortage in the amount a reservoir can divert whether we have set a call for the reservoir or not. In accordance with statute, our office only sets calls for water rights if there is a viable need for the water for a decreed purpose. For example, in the case of Julesburg reservoir, we will generally place a "bypass call" to assure the fill of the reservoir. A bypass call allows some juniors to divert upstream while passing a portion of the water downstream.

We have adopted this administrative approach because we believe it is consistent with the statutory provision that requires that the Division Engineer "shall also order the total or partial discontinuance of any diversion in his division *to the extent that* the water being diverted is required by persons entitled to use water under water rights having senior priorities." § 37-92-502(2)(a), C.R.S. (emphasis added). We believe it would be inconsistent with this statutory directive if we caused curtailment in excess of what was required by the senior priority to fill its reservoir. Further, we are concerned that changing this administrative practice would waste water by causing water to flow out of the State resulting in the unnecessary loss of water to all users in Colorado.

Other reservoirs upstream from Julesburg Reservoir whose diversions are from the South Platte have generally filled in recent times except for 2004 and a small amount in 2003. Although these reservoirs have historically filled, we have some concern that they may not fill in the future due to changing circumstances. First, it appears reservoirs will continue to be used more extensively than they have in the past because of some users' inability to use ground water supplies as extensively or at all. This will require more water to refill these reservoirs each non-irrigation season. Some reservoir supplies also will be increasingly used for augmentation purposes in the future, once again requiring more water to refill these reservoirs. More importantly, there will likely be less flow in the future available for storage due to reuse of consumable sources, installation of sprinklers reducing return flows, and the use of direct flow rights earlier in the year because of some users' inability to use ground water supplies as extensively or at all. Some might argue that these effects will be at least partially offset by the several hundred wells that can no longer operate. We expect that we will be able to better predict the global impacts of all these changes upon completion of the South Platte Decision Support System modeling. Because of our concern that South Platte reservoirs will not fill without a call, our office presently foresees the need of placing a senior reservoir call in November in all but the best years.

Concerning winter time replacement of depletions by well user groups, the Division has taken the position in the past that, if the user has resources to make aggregated replacement, then that replacement only need be made if the senior right does not fill or the lack of replacement will impact water rights junior to the senior calling right, but senior to the priority of the wells being augmented. Others with rights junior to the wells have argued that replacement must be made any time that the senior is short water. Under the latter approach, these junior water rights may come into priority more quickly if the senior reservoirs fill more quickly. The Division has resisted this argument in the past. However, upon further review, the Division has decided to reconsider, after public input, whether wells should augment any time there is a shortage, regardless of the fact that this may only benefit water rights with priorities junior to the wells and may cause loss of water to all Colorado users in certain circumstances.

It should be noted that recent augmentation plans approved by the court upon stipulation by the parties already require real time winter replacement unless the court approves agreements between the Augmenting Party and one or more reservoir owners to allow delayed aggregated

replacement, if necessary. We will, of course, follow the direction of the legislature if it provides general guidance and the decrees of the Water Court. Even if wells are required to augment any time there is a shortage, our office contemplates that it will still allow limited aggregation within a particular month during the non-irrigation season for efficiency of replacement purposes.

In conclusion, we foresee possible changes in administration having a significant impact on some users, and thus we are seeking your input before implementing any changes. Please provide us with any comments you have by November 30, 2005. **To allow water users the opportunity to adjust to any administrative changes, we anticipate implementing any changes for the 2006-2007 storage season**.

Sincerely,

James R. Hall, P.E.
Division Engineer

Cc: Hal Simpson, State Engineer
Paul Benington, Assistant Attorney General

STATE OF COLORADO

WATER DIVISION ONE
OFFICE OF THE STATE ENGINEER
Division of Water Resources
Department of Natural Resources

810 9th Street, Suite 200
Greeley, Colorado 80631
Phone (970) 352-8712
Fax (970) 392-1816

http://water.state.co.us/

July 27, 2006

Re: South Platte Non-Irrigation Season Administration

Dear Water User or Interested Party:

I am writing this letter as a follow up to my May 3, 2006 letter and the public meeting concerning non-irrigation season administration held June 19, 2006. At the public meeting, I presented a PowerPoint presentation which discussed the preliminary decisions and open questions on non-irrigation season administration. I am very appreciative of the active, insightful participation we received at this meeting. Based on this and previous input, we have made the following administrative decisions effective for water year 2006-2007. The decisions set forth below are based upon the unique circumstances presented in Water Division 1 and unless or until the State Engineer decides otherwise are applicable only to Water Division 1.

Out of Priority Storage Under 37-80-120 C.R.S.

37-80-120 C.R.S. states "In every case in which the state engineer finds that water can be stored out of priority under circumstances such that the water so stored can be promptly made available to downstream senior storage appropriators in case they are unable to completely store their entire appropriative right due to insufficient water supply, the state engineer may permit such upstream storage out of priority, but such storage water shall be promptly released on demand of a downstream senior whenever needed by such senior for actual use".

Prior to allowing any out of priority storage against any reservoir on the South Platte mainstem including Julesburg reservoir, our office will require that users submit a plan to our office at least 45 days prior to storing out of priority. We will post this plan on our Internet site http://www.water.state.co.us/. We will accept comments on the plan from water users if they believe they will be impacted. Any such comments must be received within 30 days of our posting of the proposed plan.

At minimum, it appears a plan proposed by a user must take into account the following issues:

- the commitment and capability to release out of priority water if directed by our office
- recognition of potential additional replacement requirements associated with transit loss changes between the time the storage occurs and the release (for instance, transit loss on the South Platte may differ between November when the water is stored out of priority in the reservoir and April when it is released)
- appropriate accounting (in Excel format) to keep track of the amount stored out of priority against each senior reservoir
- requirements associated with the out of priority storage to assure that the senior reservoirs stored against have water available for "actual use" as required by 37-80-120 C.R.S. (for instance, releases of 50 cfs for North Sterling would not be of use to North Sterling Irrigation District once the District was out of priority since diversions of 50 cfs at the North Sterling headgate would not reach the reservoir)
- documentation that the user has forwarded their proposed plan to the senior users who they wish to store out of priority against. While not required by statute, we believe users who wish to take advantage of 37-80-120 C.R.S. should attempt to reach agreement with those senior users. We hope

> this will help us avoid the potential disputes that may occur as a result of "paper filling" a reservoir, as discussed in the example attached as Appendix A. Note: While our office believes 37-80-120 C.R.S. does not have much practical effect without the concept of "paper filling" and that "paper filling" will not injure the senior reservoir user as it will guarantee the senior its water, we wish to promote agreement amongst water users to the extent possible.

Our office will provide a written response to the proponent of the plan, to parties who comment on the proposed plan, and to users who the proponent would store out of priority against. Our response will also be posted on the Internet. If our office approves the proposal, we will include conditions of approval if necessary.

In determining which reservoir must release water stored out of priority, our office will require the most junior right that stored water out of priority to release the full amount so stored prior to the next most junior right which stored out of priority releasing any out of priority storage.

The use of such plans is experimental. We will revisit the decision to use such plans and the listed requirements, including posting the plan and our response on the Internet, to determine the efficacy and helpfulness of such. As such we may choose not to follow such procedure in the future. The decision by the Division Engineer's Office for Division 1 to utilize the procedure outlined herein is entirely discretionary to the Office and does not guarantee that the Division Engineer's Office will follow this process in the future.

Other Out of Priority Storage

37-80-120 C.R.S. does not allow out of priority storage in reservoirs if the user cannot promptly release water. Nevertheless, as my October 6, 2005 letter states, users have been allowed to store water out of priority without this ability. While historically this has been allowed under the "gentleman's agreement", there is no clear statutory basis for allowing this practice to continue. Most respondents to our letter commented that they did not believe we should continue this practice. Without renewed basin wide cooperation, we agree with these respondents that we cannot allow this practice in the future as the cooperation under which it occurred appears to no longer exist.

Some users, who may not be able to meet the requirements of 37-80-120 C.R.S., proposed the use of an alternative supply to provide replacement of out of priority diversions if necessary. For instance, a user may propose that they would replace out of priority diversions from a lined gravel pit if storage users senior to the out of priority storage did not receive their full entitlement. We appreciate the argument that this should be allowed because it helps assure the maximization of use. It also assures that junior storage rights fill prior to the diversion by more junior priority diverters downstream. On the other side, it is not clear we have the authority to approve this absent specific court or legislative direction. Thus, we will not approve out of priority storage based on replacement of diversions with an alternative supply unless directed by the court.

Aggregation of Well Depletion Replacement

In our October 6, 2005 letter, we stated:

> Concerning winter time replacement of depletions by well user groups, the Division has taken the position in the past that, if the user has resources to make aggregated replacement, then that replacement only need be made if the senior right does not fill or the lack of replacement will impact water rights junior to the senior calling right, but senior to the priority of the wells being augmented. Others with rights junior to the wells have argued that replacement must be made any time that the senior is short water. Under the latter approach, these junior water rights may come into priority more quickly if the senior reservoirs fill more quickly. The Division has resisted this argument in the past. However, upon further review, the Division has decided to reconsider, after public input, whether wells should augment any time there is a shortage, regardless of the fact that this may only benefit water rights with priorities junior to the wells and may cause loss of water to all Colorado users in certain circumstances.
>
> It should be noted that recent augmentation plans approved by the court upon stipulation by the parties already require real time winter replacement unless the court approves agreements between the augmenting party and one or more of the reservoir owners to allow delayed aggregated replacement, if necessary.

This continues to be a point of contention. We believe objectors to delayed aggregated replacement should have their day in court on this issue. Thus, for the time being, we will no longer allow delayed aggregated replacement to occur if there is a reservoir call unless it is specifically confirmed by statute or the court.

As stated in previous letters, we will continue to allow limited aggregation to occur in a month during the non irrigation season if no injury will occur for efficiency of replacement purposes. The Water Court has long recognized the practice of limited aggregation of replacement if there is not injury. Unless directed otherwise by the courts we will also allow aggregated prepaid replacement of depletions in the winter to reservoirs if there is no injury.

Sincerely,

James R Hall

James R. Hall, P.E.
Division Engineer

c: Hal Simpson, State Engineer
Ken Knox
Jack Byers
Dick Wolfe
Water Commissioners
Alex Davis
Paul Benington

Appendix A

Example

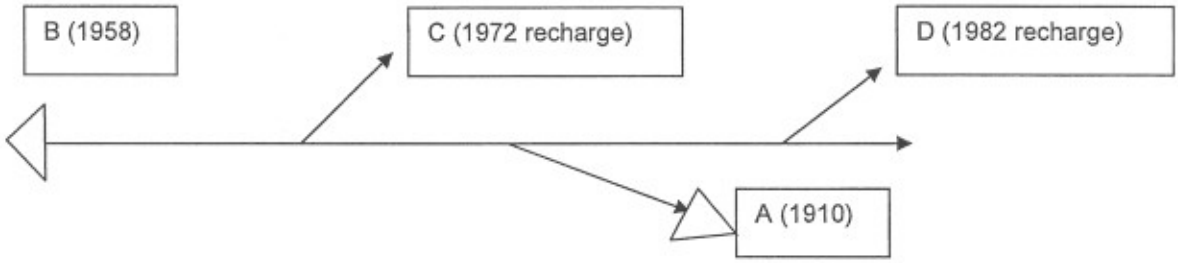
Paper Fill Accounting for Out of Priority Storage under 37-80-120 C.R.S.

Without out of priority storage, a senior reservoir would have filled sooner. Since out of priority storage is not a decreed right, it has no priority. Thus, out of priority storage should not impact other decreed rights whether junior or senior to the decreed right. To meet the requirements of the out of priority statute and at the same time protect decreed water rights, the Division Engineer's Office should paper fill senior reservoirs as if out of priority storage had not occurred.

For example, assume structure A and B are reservoirs and structure C and D are direct flow recharge rights. In our example, assume reservoir A has a decreed and physical capacity of 1000 acre-feet. Also assume reservoir A has 820 acre-feet stored in priority as of March 1, 2006, transit losses to A from B are 20 acre-feet and reservoir B has 200 acre-feet stored out of priority as of March 1. At this point, we would remove Reservoir A's call and Reservoir A would be paper filled to 1000 acre-feet. Recharge C would be in priority and could take water. Reservoir A could continue to divert any water left in the river under free river unless Recharge D was short and placed a call.

Of note, once Reservoir A has paper filled, Reservoir B could continue to divert water under its 1958 water right and release the out of priority water stored delivering it past C to A even if C or D placed a call.

If there were more than one user storing out of priority, then we aggregate all out of priority storage in determining when reservoir A is paper full.



EVAPOTRANSPIRATION
AND
IRRIGATION EFFICIENCY

Proceedings of the 1995 Seminar
Sponsored by
American Consulting Engineers Council of Colorado
and
Colorado Division of Water Resources

ARVADA, COLORADO
OCTOBER 10-11, 1995

Corporate Sponsors
City of Aurora-Water Resources
Southeastern Colorado Water Conservancy District
Denver Water Department
Boyle Engineering
Tuttle Applegate, Inc.
Leonard Rice Consulting Water Engineers, Inc.
McLaughlin Water Engineers, Ltd.
Northern Colorado Water Conservancy District
Colorado Division of Water Resources
GEI Consultants
Bishop-Brogden Associates
Blatchley Associates, Inc.
W. W. Wheeler and Associates, Inc.
Gronning Engineering Co.

Co-Sponsors
Colorado Department of Natural Resources
Colorado Water Conservation Board
American Society of Agricultural Engineers - Rocky Mountain Chapter
American Society of Civil Engineers - Colorado Section, Water Resources Technical Group
U. S. Committee on Irrigation and Drainage
Colorado Water Resources Research Institute
Colorado State University, College of Engineering

Seminar Planning Committee
Ronald K. Blatchley, General Chairman
Ivan A. Walter, Program Chairman
Ralph Toren, Publicity & Sponsors Chairman
Richard L. Stenzel, Discussion Editor
Sondra S. Donnel, Administration & Facilities

EVAPORATION

Dick Wolfe[1], P.E. and Richard L. Stenzel[2], P.E.

Abstract

In Colorado, evaporation from lake and pond surfaces is an important factor when determining stream depletions as well as water rights administration by the Office of the State Engineer. This paper will present and discuss procedures used by the Office of the State Engineer in determining evaporation from lakes, ponds and gravel pit lakes. Additionally, information will be presented describing the procedures used to determine legal and physical availability of historic consumptive use credit from native vegetation to offset gross evaporation for gravel pits. Issues to be addressed in this paper include methods used to estimate evaporation, factors influencing evaporation, historic consumptive use of native vegetation including phreatophytes, statutes and policies regarding evaporation, and recommended guidelines and procedures of the Office of the State Engineer for determining evaporation when evaluating gravel pit substitute supply plans.

Introduction

It is the responsibility of the state engineer acting through seven division engineers and their respective water commissioners responsible for individual stream systems to administer the water rights within the priority system. Evaporation from on stream ponds, reservoirs and gravel pit lakes is of direct concern in reservoir administration and is frequently involved in augmentation plans and substitute water supply plans. In 1989 the Colorado legislature passed Senate Bill 120 which affects gravel pits in operation after December 31, 1980. §37-90-137(1)(a)(II), C.R.S. requires any gravel pit that exposed ground water to the atmosphere after December 31, 1980 to replace all out-of-priority depletions of ground water.

Methods Used to Estimate Evaporation

The major factor affecting evaporation from a water surface is the difference in vapor pressure between the water surface and the air. Evaporation is also

---

[1]Colorado Division of Water Resources

[2]Colorado Division of Water Resources

influenced by factors including solar radiation, elevation, latitude, air temperature, relative humidity, wind travel, and orography (Farnsworth 1993 and 1994). Wind travel is directly related to the amount of exposure (fetch). Another factor is the microclimate that exists at the reservoir site (Doesken 1993).

The most common methods for estimating evaporation include: 1) energy budget; 2) mass-transfer; 3) water balance; 4) evaporation pan; 5) atmometer; and 6) combination of energy and mass-transfer. These methods vary considerably in cost, complexity and accuracy. The most accurate method of estimating evaporation is by the energy-budget method, the mass-transfer method, or a combination of the two (e.g., Penman). However, instrumentation and maintenance of continuing observations are expensive for these methods and their use may not be economically feasible for some time. However, one may justify their application temporarily to calibrate a less costly method.

Theoretical equations have been developed such as the Penman-Monteith equation (Maidment 1993). Evaporation is calculated from meteorological variables and local aerodynamic characteristics. This method is not as widely used as some of the empirically based methods since it requires measurement of several meteorological parameters. Estimates of free water surface evaporation can be based on actual measurements using a water balance method. This requires the measurement of all inflows and outflows from a water body. There can be many difficulties measuring inflows and outflows especially subsurface seepage. Therefore, the water balance method is inadequate to estimate evaporation unless the seepage rate is determined independently, is known to be constant, or is known to be zero.

The atmometer is a device that has not been used widely to measure evaporation. It has been primarily used to estimate evapotranspiration. The Northern Colorado Water Conservancy District (NCWCD) is one agency who has actively used atmometers as part of their Irrigation Management Service (IMS). Atmometers are inexpensive (less than $100), simple to use, and simple to maintain. However, there is insufficient data showing the correlation between free-water surface evaporation, or pan evaporation, to that measured by an atmometer.

The most widely used method to estimate potential evaporation is based on empirical techniques. Because of its inherent simplicity, the evaporation pan is the most widely used instrument to estimate potential evaporation. There are many different designs of evaporation pans but the most commonly used pan is the

U.S. Weather Bureau Class A pan. Detailed procedures have been developed by the National Weather Service (National Weather Service 1989) to properly construct, locate and monitor pan evaporation. The operation of the evaporation pan station is relatively inexpensive and should provide reasonably good estimates of annual evaporation. However, monthly estimates of evaporation can vary considerably from season to season due to heat storage in the large reservoirs as compared to that in an evaporation pan, and effects of advected energy due to large inflows and outflows. Energy storage effects can be corrected, but the correction requires some of the expensive data that are used in the energy-budget method. Evaporation is determined by measuring the difference in observed levels in the evaporation pan, corrected for any precipitation measured in an adjacent or nearby standard rain gage. The estimated rate of evaporation from the reservoir is computed by converting the observed value by a pan coefficient.

Empirical pan coefficients have been developed to correlate the evaporation from the pan to a surrounding lake. The pan coefficient was developed to correct for heat transfer through the sides of the pan that do not exist for the water body (Farnsworth, Thompson and Peck 1982). The bulk of the energy transfer is at the water surface and not through the sides of the reservoir. Whereas the effects of energy advected through the sides and bottom of the pan can be computed from meteorological data, the effects of energy advected in or out of a reservoir, or stored by the reservoir from season to season, must be determined from field measurements of water volume and temperature. The energy advected through the sides and bottom of a Class A pan is accounted for by the pan coefficient. Reported studies show average annual pan coefficients range from 0.6 to 0.8. Other studies have shown month to month pan coefficients vary from 0.29 to 1.05 (Spahr and Ruddy 1983). Typically, a value of 0.7 has been used for all time interval measurements with an overall margin of error of less than 15 percent (Linsley, Kohler and Paulhus 1982).

One difficulty is measuring wintertime evaporation with any method. It is recommended that evaporation pans be drained when freezing conditions persist. Therefore, reservoir evaporation must be estimated by other methods during these periods (National Weather Service 1989).

The size of the reservoir has an influence on the rate and timing of evaporation. Shallow ponds and lakes will warm faster than deep lakes and deep lakes will freeze later than shallow lakes due to the latent heat transfer of the quantity of water in the lake. Latent heat is released during freezing of water and absorbed when thawing the ice (Farnsworth 1993 and 1994).

Historic Consumptive Use of Native Vegetation

Historic consumptive use credit for native vegetation including phreatophytes began with on stream reservoirs (§37-84-117(5), C.R.S). The state engineer computes the surface evaporation from the reservoir deducting any natural depletions to the stream flow which occurred prior to the reservoir being constructed. In 1989 Senate Bill 89-120 was passed pertaining to evaporation from ground water exposed to the atmosphere in connection with the extraction of sand and gravel by open mining. According to §37-80-120, C.R.S., there shall be no requirement to replace the amount of historic natural depletion to the waters of the state, if any, caused by the preexisting natural vegetation cover on the surface of the area which will be, or which has been, permanently replaced by an open water surface.

The consumptive use analysis of vegetative growth including phreatophytes shall be based upon published engineering studies acceptable to the state engineer and engineering analysis of site specific information for the type of growth, ground water depth, and soil information. Historic consumptive use of native vegetation is attributable to either precipitation or ground water resulting from a high ground water table or a combination. The amount of consumptive use credit from precipitation and ground water during the growing season can not exceed the total potential consumptive use of the native vegetation replaced by the water surface of the mined area. Typically, the Office of the State Engineer has assumed for a native site (without phreatophytes) with a deep ground water table that 70% of the total precipitation is either consumed or goes to soil moisture storage. This is based on the average normal precipitation efficiency observed when using the Soil Conservation Service methodology for calculating effective precipitation (Soil Conservation Service 1970). A method frequently used to estimate consumptive use of native site with phreatophytes is the Rantz method (Rantz 1968). Rantz developed coefficients for various phreatophytes to be used in the Blaney-Criddle equation. The coefficients are dependent on the depth to ground water.

Recommended Procedures of the State Engineer for Determining Reservoir Evaporation of On Stream Reservoirs and for Gravel Pits

Several reservoir sites in Colorado have established pan evaporation stations for site specific estimates of reservoir evaporation. By statute (§37-84-117(5),

C.R.S.) the state engineer must order on stream reservoirs to make releases of water as, in the determination of the state engineer, are necessary to prevent evaporation from the surface of such reservoir from depleting the natural flow of the stream running through such reservoir which would otherwise be available for use by downstream vested senior water rights. The state engineer may reduce these evaporation releases due to evaporation by giving credit for natural depletions or preexisting depletions associated with native vegetation including phreatophytes that were located under the reservoir. Any credit for historic depletions from native vegetation is based upon the type of vegetation, density of the vegetation, and the depth to the ground water table. Off stream reservoirs do not require any monitoring by the water commissioner of evaporative losses because any evaporation losses from off stream reservoirs would not affect other water users.

Where pan evaporation data are not available for gravel pits or storage reservoirs, the state engineer recommends the use of the NOAA free water surface atlas for shallow lakes (Farnsworth, Thompson and Peck 1982). A copy of Map 3 of 4 for the area covering Colorado is shown in Figure 1. Gross evaporation from the free water surface shall be calculated based upon this map. The annual values are derived from recorded pan evaporation data and computations from meteorological data for months when pan data were not available. The contours on the map are representative of the general area and may not accurately depict sites with unusual site conditions. Table 1 summarizes the gross evaporation for several sites in Colorado. The conversion of pan data to seasonal free water surface evaporation can be done using the pan coefficients on Map 4 of 4 (Farnsworth, Thompson and Peck 1982).

The net replacement of depletions shall be determined as gross evaporation less any historic consumptive use credit available from native vegetation for the area replaced by the free water surface. The total gross evaporation estimate shall be distributed to all months. Monthly estimates of evaporation were estimated using the distribution of pan evaporation data (Farnsworth and Thompson 1982) with graphical solution techniques. The monthly distribution used by the Office of the State Engineer for elevations below 6500 feet msl is; Jan-3.0%, Feb-3.5%, Mar-5.5%, Apr-9.0%, May-12.0%, Jun-14.5%, Jul-15.0%, Aug-13.5%, Sep-10.0%, Oct-7.0%, Nov-4.0%, and Dec-3.0%. The monthly distribution for elevations above 6500 feet msl is; Jan-1.0%, Feb-3.0%, Mar-6.0%, Apr-9.0%, May-12.5%, Jun-15.5%, Jul-16.0%, Aug-13.0%, Sep-11.0%, Oct-7.5%, Nov-4.0%, and Dec-1.5%. The percent distribution of evaporation will still apply for periods when ice-cover occurs.

The period on non-ice cover generally corresponds to the period when the mean daily air temperature is above 32°F.

The ice-cover period also generally corresponds to the period of snow cover. Doesken (Doesken 1993) estimates that the general period of ice cover for shallow lakes is about ten weeks around December through January in northeastern Colorado and essentially none in southeastern Colorado. The snow cover that exists over an ice surface will absorb infrared (long wave) energy from warm clouds creating heat storage in the snow pack causing ponding on the ice due to the thawing and freezing of the snow pack. The existence of warm clouds causes snow to melt during the time of cloud cover which can be 24 hours a day. During this condition, negligible evaporation or sublimation occurs from the lake surface but snow melt can occur. During periods of no cloud cover, the snow cover reflects solar radiation (short wave) thus delaying the time when lake evaporation will occur. The amount of historic depletion during the non-growing season months results from any evaporation or sublimation of precipitation or ground water.

Estimates of free water surface evaporation for some mountain areas within Colorado, other than those reported in the NOAA atlas, that are based on site specific data should be within 10% of the NOAA atlas. The reliance on adjacent stations with pan evaporation data should be allowed considering existing conditions such as exposure, temperature, relative humidity, etc. For example, the estimate of evaporation for a specific site should be adjusted accordingly if the non-ice cover period differs from the NOAA atlas for a given area.

The amount of historic consumptive use credit that can be taken to offset gross evaporation for an area irrigated prior to reservoir or gravel pit construction is equal to the amount of historic consumption associated with effective precipitation and ground water for the crops historically grown. All credits for effective precipitation and ground water must take into account for any contribution given to these two sources for the irrigation water right that historically provided supplemental water to meet the evapotranspiration needs of the crop. In many cases, the consumptive use credit associated with the irrigation water right is used to meet the additional augmentation needs of a gravel pit site that can not be met by the historic consumptive use of precipitation and ground water.

Summary

Evaporation from gravel pits and reservoirs can be estimated in many ways. Several methods have been discussed identifying advantages and disadvantages of each. However, the state engineer has found that using the NOAA atlas based upon the pan evaporation method to estimate evaporation and subsequent stream depletion provides adequate results for water rights administration. Guidelines and procedures for estimating evaporation from gravel pit lake surfaces are presented as well as guidelines and methods used to estimate historic consumptive use credit of native vegetation.

References

Doesken, Nolan (1993). Colorado Climate Center. Personal communication.

Farnsworth, Richard K., Edwin S. Thompson, and Eugene L. Peck (1982). Evaporation Atlas for the Contiguous 48 United States. NOAA Technical Release NWS 33. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service.

Farnsworth, Richard K. and Edwin S. Thompson (1982). Mean Monthly, Seasonal, and Annual Pan Evaporation for the United States. NOAA Technical Release NWS 34. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service.

Farnsworth, Richard K.(1993 and 1994). National Weather Service. Personal communication.

Linsley, Jr., Ray K., Max A. Kohler, and Joseph L.H. Paulhus (1982). Hydrology for Engineers. McGraw-Hill, Inc., New York, N.Y. pp. 134-174.

Maidment, David R. (1993). Handbook of Hydrology. McGraw-Hill, Inc., New York, N.Y. pp. 4.1-4.53.

National Weather Service (1989). Cooperative Station Observations. National Weather Service Observing Handbook No. 2. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. pp. 46-59.

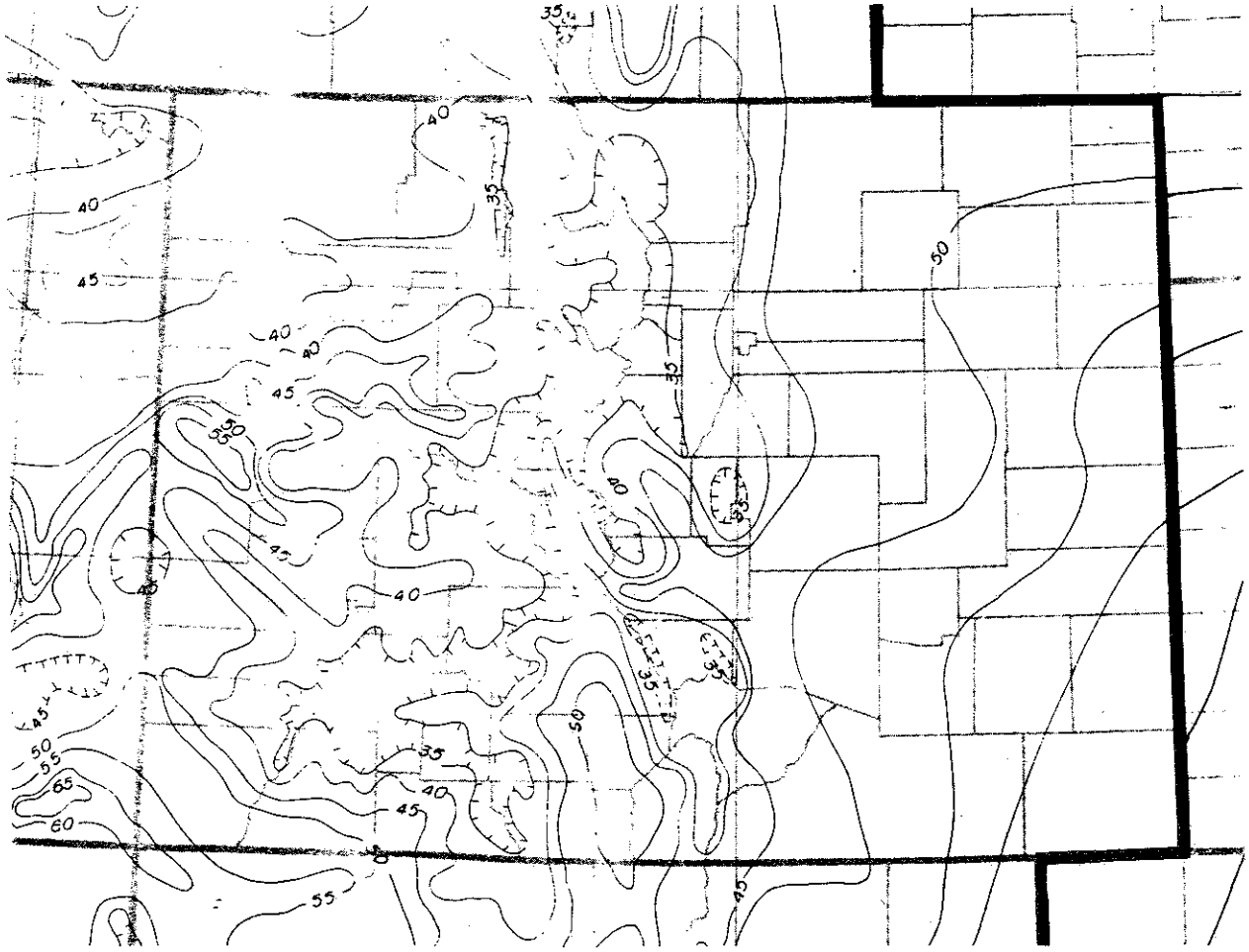
Rantz, S.E. (1968). A Suggested Method for Estimating Evapotranspiration by Native Phreatophytes. U.S. Geological Survey Professional Paper 600-D, pages D-10-D12.

Soil Conservation Service (1970). Irrigation Water Requirements. Technical Release No. 21. U.S. Department of Agriculture.

Spahr, Norman E. and Barbara C. Ruddy (1983). Reservoir Evaporation in Central Colorado. U.S. Geological Survey Water Resources Investigations Report 83-4103.

FIGURE 1

ANNUAL FREE WATER SURFACE EVAPORATION IN COLORADO



Source: Farnsworth, Thompson and Peck 1982 (Map 3 of 4)

Wolfe and Stenzel, 1995 ET & Irr. Eff. Seminar

TABLE 1[1]

APPROXIMATE GROSS EVAPORATION FOR SELECTED SITES IN COLORADO

Site	Gross Evaporation (in)
Northeast	
Denver	43
Greeley	45
Fort Morgan	49
Sterling	49
Limon	48
Boulder	38
Fort Collins	39
Burlington	57
Southeast	
Colorado Springs	45
Pueblo	50
Canon City	45
La Junta	55
Lamar	60
Trinidad	49
Westcliffe	36
Northwest	
Grandby	35
Steamboat Springs	38
Leadville	35
Glenwood Springs	45
Grand Junction	55
Fairplay	40
Rangely	41
Southwest	
Salida	40
Alamosa	50
Durango	43
Cortez	53
Montrose	43
Gunnison	38
Ouray	35

[1] Farnsworth June 1982, Map 3 of 4

Note: Gross evaporation is for the specific site listed. Please use Map 3 of 4 for actual values at desired location because evaporation values can vary considerably over short distances.

STATE ENGINEER GUIDELINES FOR LINING CRITERIA FOR GRAVEL PITS AUGUST 1999

1.0 Design Standard

The intent of the reservoir lining design is to achieve ground water inflow (leakage rate) into the reservoir that is not greater than 0.03 $ft^3/day/ft^2$ (1x 10^{-5} $cm^3/cm^2/sec$) multiplied by the length of the perimeter wall in feet multiplied by the average vertical depth of the perimeter wall as measured from the ground surface to the pit bottom along the toe of the pit side slope, plus 0.0015 $ft^3/day/ft^2$ (5x 10^{-7} $cm^3/cm^2/sec$) multiplied by the area of the bottom of the liner system or natural bedrock bounded by the perimeter wall. Appropriate geotechnical evaluations and analyses should be performed to indicate that the Design Standard could be achieved with the proposed design to a reasonable probability. It is recommended that the applicant submit design and construction plans for review to the State Engineer.

2.0 Construction Standards

The applicant must demonstrate that the constructed liner meets the requirements of the design by performing appropriate quality control observations and tests. The applicant shall provide written documentation of the work performed and results of quality control field and laboratory tests. Tests performed shall meet or exceed the standards established by the American Petroleum Institute (API) and/or the American Society of Testing and Materials (ASTM) as applicable.

3.0 Performance Standards

The Performance Standard shall be three times the Design Standard as described above. The Performance Standard shall be applied to an initial test of competency of the liner, as well as to the ongoing operation of the reservoir.

3.1 Initial Liner Test

For mined pits: The unregulated ground water inflow to the reservoir will be tested by evacuating the contents of the reservoir and observing the inflow of water over a period of ninety days. The start of the test will be under essentially dry conditions.

For unmined pits: The unregulated ground water inflow to the reservoir will be evaluated by constructing a dewatering sump at the lowest portion of the pit and then dewatering until a steady-state condition is achieved. Once a steady-state condition exists, the amount of the unregulated ground water inflow will be determined. This process will generally require the installation of piezometers to be located on the inside and outside of the lined pit in the unmined area in order to determine whether a steady-state condition has been achieved.

A water balance must be done to demonstrate that the balance of the inflows (e.g., precipitation and ground water) and outflows (e.g., evaporation) equals the change in storage volume by a minimum of a 90-day test. Ongoing monitoring of the water balance may also be required as determined by the Division Engineer. The frequency of accounting and monitoring as well as the type and accuracy of the monitoring devices shall be determined after consultation with the Division Engineer.

The applicant shall demonstrate that during a 90-day test period the unregulated ground water inflow to the pit does not exceed the Performance Standard. Demonstration of inflows less than the Performance Standard shall be sufficient cause for a determination that the applicant has constructed a lined reservoir and is entitled to store water. If the unregulated ground water inflow to the reservoir exceeds the Performance Standard, the State Engineer shall require the reservoir to be dewatered until satisfactory changes have been made to the liner to conduct another initial liner test.

4.0 Water Budget Accounting

Monthly accounting shall be required as long as the liner continues to meet the Design Standard. Weekly accounting (or more frequent if required by the Division Engineer) shall be required for liners which do not meet the Design Standard but continue to meet the Performance Standard. Evidence of compliance with the standards shall be established through a mass balance analysis accounting for inflows, outflows, and change in storage.

If the State or Division Engineer determines that the ground water inflow (leakage rate) into the reservoir is greater than the Performance Standard, the applicant shall be required to calculate the inflow to or outflow from the reservoir by means of a mass-balance analysis on a 48-hour basis, and return to the stream system such inflows to the pit within 48 hours, without such water being used by applicant in any manner. This 48-hour accounting shall only be for the entire period specified under the Liner Failure During Operation Section (see below) and shall not be done permanently.

5.0 Liner Failure During Operation

In the event that the average daily unregulated ground water inflow to the reservoir exceeds the Performance Standard for two consecutive months, as evidenced by accounting (see above), the applicant or their successor and the State Engineer's Office shall begin to consult regarding the probable cause of the unregulated ground water inflow, and the appropriate actions to be taken in response thereto. If the State or Division Engineer and the applicant cannot reach an agreement on the appropriate actions to reduce the unregulated ground water inflow to less than the Performance Standard within nine months of the beginning of the consultations, the State or Division Engineer shall provide written notice to the applicant of their determination to correct this problem. The 48-hour accounting shall begin following the two consecutive months that the Performance Standard is exceeded and shall continue until the applicant has demonstrated that the Performance Standard has been met. Applicant shall have two (2) years from the date of such written notice of liner failure to repair the liner to an inflow less than the Performance Standard. If satisfactory repairs are not completed within the two year period, no new water shall be stored in the reservoir until either: 1) the repair is made; 2) the issue is decided by the Water Court under retained jurisdiction, or; 3) the State Engineer's Office otherwise grants permission for storage to continue. The State or Division Engineer may declare the reservoir a well requiring a well permit.

6.0 Legal Storage of Water

Water shall not be impounded in the reservoir except pursuant to lawful diversions allowed by statute or decree. At all other times, all inflow of water into the reservoir from any source, including precipitation and ground water inflows shall be removed by the applicant. The water can be removed by draining, pumping, or other means, and released to the stream system, without use by the applicant in any manner. The applicant shall install the necessary measuring devices, including but not limited to, staff gauges in the reservoir and account on a monthly basis (or more frequently if required) for inflow and outflow, evaporation, precipitation, change in storage and any seepage. Prior to making any storage right absolute, the applicant shall develop and submit to the Division Engineer graphs showing height-storage relationships. Under no circumstance may the applicant withdraw more water from the reservoir than the measured inflow with appropriate evaporation and seepage losses being deducted.

7.0 Retained Jurisdiction

The Water Court shall retain jurisdiction to address injury to water rights caused by failure of the liner that results in ground water inflow exceeding the Performance Standard. Upon a prima facie showing by the State or Division Engineer or the party invoking the retained jurisdiction that such exceedence of the Performance Standard is occurring, and that reasonable efforts to correct the problem have been unsuccessful, and that injury to water rights is being caused thereby, the Water Court will proceed to hear evidence regarding the additional terms and conditions, or limitations and restrictions, that should be imposed upon the operation of the pit.