Considerations for Modeling a Water Bank at the Aspinall Unit with Current Environmental Flows

Blue Mesa Reservoir and Dam

Draft Report

Prepared for the Colorado River Program of The Nature Conservancy
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August 4, 2011
(Last Update: November 14, 2011)

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1.0 Executive Summary

The Colorado River is in the midst of a decade-long drought. As total basin storage has dropped, water agencies have looked at water banking as a possible approach for ensuring critical junior water users are able to continue in operation if a compact call became imminent. Reclamation's Aspinall Unit (Blue Mesa, Morrow Point, and Crystal Reservoirs) on the Gunnison River is one likely location for a water bank in Colorado. Planners and policy-makers evaluating different water banking options will rely on computer models to better understand the impacts of hydrology, water rights, environmental constraints, and other operating criteria.

In this report, several computer models of the Gunnison River were evaluated to assess their ability to simulate a potential water bank in the basin using the Aspinall Unit reservoirs and the effect on reservoir operations, including environmental flows. Our working assumption is that the bank would first use space at the Aspinall reservoirs to store and build up consumptive credits from fallowing irrigation prior to any compact call and that the space available for such banking would need to account for currently committed environmental flows and all other current operations. We also assume that a clear accounting of current environmental flows and operations at Aspinall will not only inform such an initial water banking concept, but will provide a foundation for examining progressively more complex or markedly different water banking concepts at Aspinall before and during a compact call. Our findings on modeling frameworks should be revisited upon formulation of further water banking concepts for Aspinall.

Accordingly our analysis of modeling tools developed by the State of Colorado (StateMod), Reclamation's Colorado River Simulation System (CRSS) and a model developed for the Aspinall EIS (EIS model) has focused on the ability of each model to simulate the Black Canyon water right, the new EIS/PBO requirements at the Whitewater gage and a water-banking option at Aspinall. The key model functionality required to achieve these objectives includes: the ability to create and track storage accounts at Aspinall in order to simulate one or more water bank accounts; simulate priority administration of water rights and operational policy; track supplies of environmental water and delivery to specific target locations; and to simulate all of these with different hydrology, compact, and demand assumptions.

The Aspinall Unit consists of three reservoirs on the mainstem of the Gunnison River. The uppermost and largest is Blue Mesa (940,700 AF), downstream of Blue Mesa is Morrow Point (117,190 AF), and downstream of Morrow Point is Crystal (25,240 AF). There are hydropower plants at all three dams each having large direct flow water rights for hydropower generation. Morrow Point and Crystal reservoirs are generally kept near full capacity and are used primarily for power peaking and re-regulation of flows upstream of the Black Canyon of the Gunnison National Park. Historical operation of the Aspinall Unit has significantly changed the natural hydrograph downstream by reducing peak flows during the spring runoff and releasing throughout the winter at higher rates than the natural inflow to the reservoirs.

1.1. Environmental Flows

There are three environmental flow target locations below the Aspinall Unit that impact Aspinall operations: the Black Canyon Decree, with a measuring point immediately below the Gunnison Tunnel, a few miles downstream of Crystal Reservoir, the EIS/PBO targets at the Whitewater gage below the inflows from the North Fork and Uncompahgre rivers, and the targets for fish screening, passage and migration at the Redlands dam about 6 miles below the Whitewater gage. The environmental flow targets at the two upstream locations depend on the projected total inflow to the Aspinall Unit, with higher targets set in wetter years, and lower target flows set in drier years. In addition, there are drought recovery provisions whereby flow targets may be reduced under certain circumstances. The flow targets for the Black Canyon include a 300 cubic feet per second (cfs) year-round baseflow runoff, "shoulder" flows of up to 1,000 cfs from May through July, and a 24-hour peak flow during that period that can potentially exceed 15,000 cfs. The peak flow component of the targets at Whitewater for endangered fish species call for a specific number of days at half-bankfull flow (8,070 cfs), and in wetter years for a specific number of days at bankfull flow (14,350 cfs). In all years, in addition to the half-bankfull and bankfull flows, a one-day peak flow is targeted. The baseflow component for the endangered fish specifies at least 1,050 cfs at the Whitewater gage in all months except in dry and moderately dry years. In those years, the baseflow target is reduced but still includes the flows needed to operate the fish screen (40 cfs) or the fish screen and fish ladder (140 cfs) at the Redlands Dam diversion. The target baseflow target at Whitewater is also large enough to provide at least 300 cfs of fish migration flow below the Redlands dam except in drier years.

1.2. Computer Models of the Gunnison River

The focus of this report is to assess the current configuration of the following three models and evaluate their ability to be used to simulate an initial concept for water banking at Aspinall with the Black Canyon Decree and the flow targets for the endangered fish.

1. StateMod Gunnison River Model
2. RiverWare Model of the Gunnison River developed for the PBO and EIS
3. CRSS RiverWare Model of the entire Colorado River basin

The Gunnison River StateMod model is the State of Colorado's water allocation model developed as part of the larger Colorado Decision Support System. There are other StateMod models for the Yampa, White, Colorado and San Juan/Dolores basins in Colorado, but the models are not linked to each other. A daily RiverWare model was developed for the PBO/EIS analyses and is intended to assess incremental impacts of operational changes to the Aspinall Unit as proposed within the EIS alternatives. The CRSS RiverWare model is a long-term multi-decadal planning model of the entire Colorado River basin, including the Gunnison River. There is also a 24 month CRSS model that is used for mid-term planning for anticipated demands, reservoir operations and forecasting of reservoir elevations.

As currently configured, CRSS does not include capabilities to simulate allocation of water by priority administration of water rights, nor does it provide any significant capacity to account for different water "ownership". Hence representation of exchanges, shepherding of releases to specific target locations, and water bank accounting are not possible. While CRSS in its present form is not capable of simulating

the water rights components that are likely needed for water banking alternatives, it may still be useful in providing information about compact deliveries and/or shortfalls from basin-wide simulations, and could be used to identify boundary conditions for simulations by StateMod within the Gunnison basin.

The Aspinall EIS model was designed specifically to evaluate incremental impacts of operational changes proposed within the EIS process, and not as a tool to evaluate water rights administration and accounting. Significant simplifying assumptions are made in the model with respect to hydrology, water rights administration and accounting, water user diversions and consumptive use, and tributary diversions and inflows. In addition, the Black Canyon decree is not fully represented in the model rules, and its impacts are only evaluated via a post-processing of the model outputs.

StateMod for the Gunnison basin is a water allocation model that in its current configuration is designed to simulate water allocation based on current operations in the Gunnison basin using historical precipitation and runoff (naturalized flow). The model has the ability to simulate the water right administration for a water bank and other operational commitments, the ability to track the supply of environmental water and its delivery to specific target locations; and the ability to simulate different input hydrology and demand scenarios. The model as currently configured includes the Black Canyon Decree as able to use only stored Aspinall water and has the direct flow portion deactivated. The Whitewater gage targets are not incorporated into the current model.

Evaluation of these tools in the context of modeling requirements for use in water banking studies leads us to conclude that the StateMod model of the Gunnison is the model best suited for addressing water banking scenarios. There are, however, additional model refinements that would be necessary and assumptions that will need to be clarified.

1.3. Potential StateMod Modifications

Several modifications would be necessary to the current configuration of StateMod to simulate water banking scenarios and the environmental flows. In addition, there is ambiguity in the current configuration of StateMod as to certain aspects of how water right administration of the river system would impact reservoir and water right operations. These ambiguities exist in actual administration of the river (as evidenced through the Division Engineer's accounting spreadsheet and the State's draft reservoir administration guidelines) due in large part to normally abundant supply of water in the Gunnison basin. These ambiguities should be clarified on a conceptual level and then incorporated into StateMod for water bank simulations. Key potential modifications to the Gunnison StateMod model for a water banking scenario include:

- Simulation of environmental flows
    - Activate direct flow portion of Black Canyon Decree
    - Add Whitewater targets
    - Configure the source of environmental targets flows such that they are met either
        - first by any flows in the stream (whether allocated to the Black Canyon direct flow right or not) and then through supplemental storage if not satisfied
        - first by releases of storage from Aspinall to meet the environmental target

    - Incorporate daily flow targets either in the daily version of StateMod , or incorporate daily flow targets into a monthly flow target volume

- Reservoir accounting enhancements
    - Adherence to the one-annual fill rule at reservoirs involved in water bank
        - likely elimination of free water rights at reservoirs
        - assignment of annual fill date to reservoirs
    - Accounting of hydropower direct flow rights and storage rights
        - allow bypasses of storage rights to the direct flow rights without paper-filling the storage rights
        - addition of hydropower direct flow water rights to the model
    - Revise bookover and 2nd fill accounting at Taylor Park to more closely match the Taylor Park Exchange Agreement accounting

1.4. Conclusion and Recommendations for Next Steps

Our review of the currently available models indicates that StateMod is the best option for implementation and detailed testing of water banking options within the Gunnison basin. The next steps we recommend are:

1) Develop concepts of how administration of the Gunnison River water rights would affect several key basin operations including Aspinall hydropower, one-annual fill administration, the Taylor Park exchange accounting, storage accounting given hydropower and rule-curve releases at Aspinall reservoirs and how this administration could work with a water bank in place in Aspinall.

2) Develop a simple StateMod network to better understand the details of the one-annual-fill accounting and use accounting of direct and storage rights when reservoir releases make 'free water' available. This would provide some valuable insight into the steps required to reasonably simulate water bank accounting with StateMod.

3) Consult with the Water Banking Technical Group and Basin Roundtables regarding our analysis and observations.

2.0 Background

The Gunnison River is a major tributary to the Colorado River with its headwaters in central Colorado and with its confluence with the Colorado River at Grand Junction, Colorado. The Gunnison River has undergone significant water development over the past century, including the Gunnison Tunnel/Uncompahgre Project and the Aspinall Unit along with significant private water resources development for irrigation, municipal supply and hydropower. The Uncompahgre Project was one of the first Bureau of Reclamation (Reclamation) projects. Completed in 1909, water from the Gunnison River is diverted to the Uncompahgre River Basin through the Gunnison Tunnel just upstream of the Black Canyon of the Gunnison and delivered to water users through many miles of canals. The Aspinall Unit is a series of three reservoirs (Blue Mesa, Morrow Point and Crystal) operated by Reclamation for multiple and broad purposes under Section 1 of the Colorado River Storage Project Act and are located upstream of Black Canyon of the Gunnison National Park.

2.1 Aspinall Unit

Construction of the three Aspinall Unit reservoirs was completed 1976, though Blue Mesa Reservoir, the largest of the three, was completed in 1965. The reservoirs have single-fill storage rights (Blue Mesa: 940,755 AF; Morrow Point: 119,053 AF; and Crystal: 30,000 AF) with an appropriation date of 11/13/1957 and a re-fill decree that transfers 122,702 AF of the originally decreed storage capacity at Crystal to a second fill at Blue Mesa (also with an appropriation date 11/13/1957). In addition to the storage water rights, the power plants at each of the Aspinall Unit dams have large direct flow hydropower water rights (2,500 cubic feet per second (cfs) at Blue Mesa, 2,500 cfs at Morrow Point, and 3,000 cfs at Crystal) with the same 11/13/1957 appropriation date, and an additional hydropower right of 2,950 cfs at Morrow Point with an appropriation date of 2/2/1959. These water rights were made absolute by decree in Case No. 80CW156 on December 11, 1980. See Section 5.0.

Blue Mesa Reservoir operations are based largely on a storage guidance curve developed by Reclamation. Blue Mesa has total conservation storage capacity of 940,700 AF, with active storage of 748,430 AF, inactive storage of 81,070 AF for minimum power pools, and dead storage of 111,200 AF (EIS page 1-4). The active and inactive storage constitute a live storage capacity of 829,500 AF (at an elevation of 7519.4 feet; http://www.usbr.gov/uc/wcao/water/rsvrs/ds/blue.html). To create space for flood control, generate hydropower, and avoid icing problems in the river upstream of Blue Mesa, the reservoir is currently lowered during the winter and then refilled (to the extent there is available water) by the end of July. During the spring snowmelt-runoff period, Blue Mesa refills, and releases are increased within the constraints imposed by downstream flood control. Reclamation generally tries to just fill Blue Mesa by the time the snowmelt-runoff has peaked to avoid spills and to maximize water supply for power generation during the remainder of the year.

Morrow Point Reservoir (117,190 AF) is operated as a peaking power reservoir, and Crystal Reservoir (25,240 AF) acts as re-regulation reservoir for the upstream hydropower releases, generally maintaining near-full conditions and releasing inflows to avoid severe hourly or daily flow fluctuations through the Black Canyon. Inflows may be passed through the Aspinall reservoirs to meet senior water right demands and are tracked in the Division 4 Engineer's accounting spreadsheet obtained by Hydros (e.g.

direct flow rights of the Gunnison Tunnel and/or releases of water stored in Aspinall to Gunnison Tunnel water users), although from an operational standpoint such bypasses have not been distinguished to date from releases to meet the storage curve. The Division 4 Engineer (Bob Hurford) has indicated that the fill accounting for the Aspinall reservoirs would be administered on an irrigation water year (November 1 to October 31).[1] The Aspinall decrees do not specify any date. Under strict water administration, it may be appropriate to use a different filling year that would approximate minimum storage contents at Aspinall to most efficiently use the single fill and one refill decree. The one fill rule over any year for the Aspinall storage rights is not currently tracked in the Division 4 Engineer's accounting spreadsheet.[2] The State Engineer's Draft Administration Guidelines for Reservoirs (Colorado Division of Water Resources 2010) are unclear as to water rights accounting in instances where co-owned, and equal priority storage and direct flow hydropower exist at the same reservoir. Intentional bypasses of storable flows to the direct-flow water right may or may not be considered as a paper-fill of the storage decree (thereby potentially limiting legal storage capacity at a later date). StateMod can be configured to account for these water rights in either manner as described in Section 3.1. A review of HydroBase records (Colorado Division of Water Resources and Colorado Water Conservation Board 2011) for the Aspinall Unit power plants indicate that all flows through the power plants use storage water as their source of water.[3] This indicates that water routed through the Aspinall power plants is considered a release of stored water rather than a diversion under a direct flow water right for hydropower.

Operation of the Aspinall Unit has a significant impact on flows far downstream of the reservoirs themselves. The impact is on the timing of flows more so than the total amount of the flow. Figure 1 shows the historical flows at the Whitewater gage (USGS gage number 09152500, also known as Gunnison River near Grand Junction, CO) and the gage just below the Gunnison Tunnel, which in turn is just below the Aspinall Unit (USGS gage number 09128000 Gunnison River Below Gunnison Tunnel, CO). The figure demonstrates the difference in flow timing that operation of the Aspinall Unit has had on the

[1] March 29, 2011 phone interview.

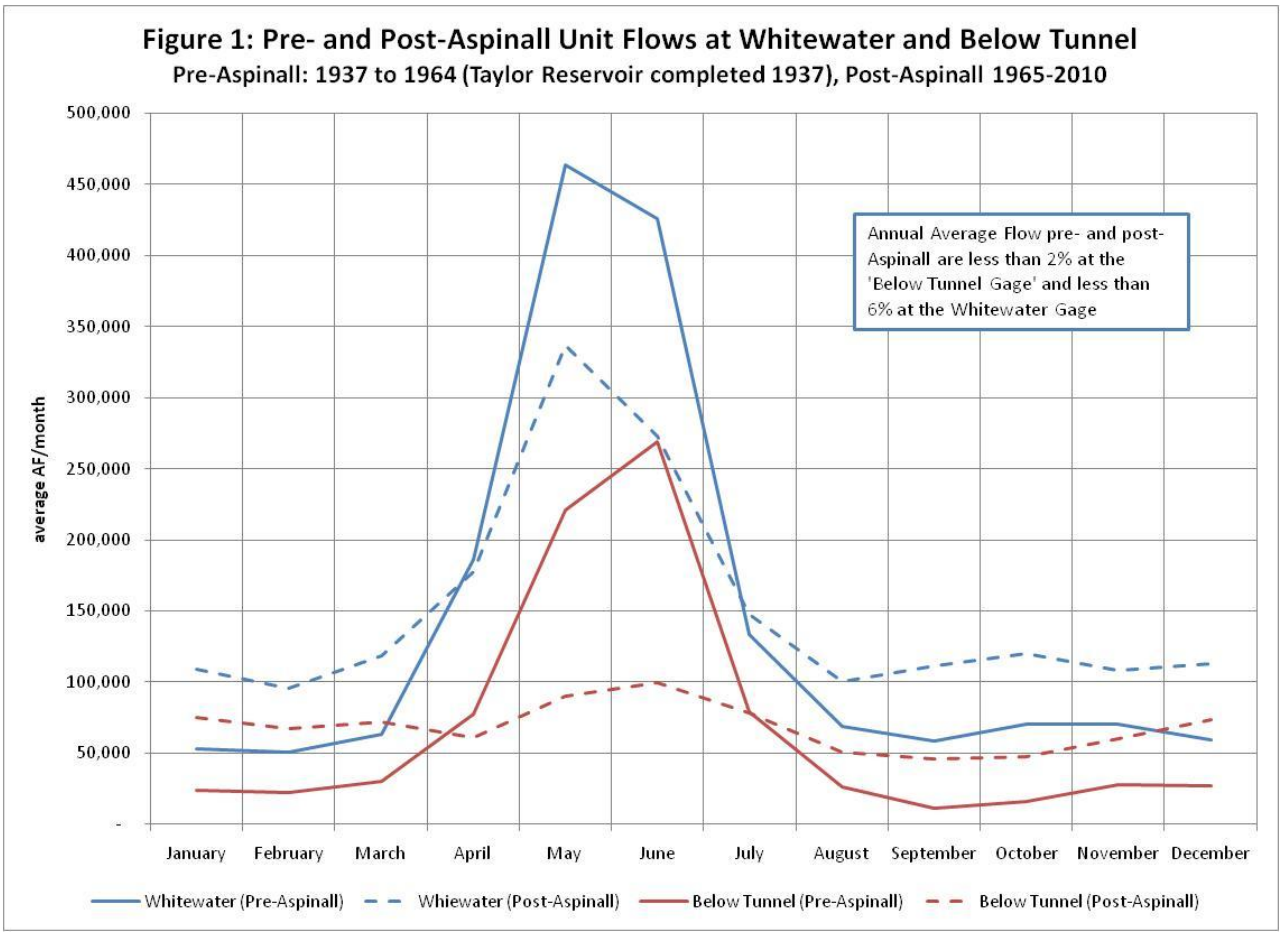
[2] The Division 4 Engineer's accounting spreadsheet accounts for deliveries to the Gunnison Tunnel direct flow right first from inflows into Taylor Park and Aspinall, (excluding Taylor Park releases). Deliveries to the direct flow right can also be accounted as the release of water stored out of priority at Silverjack Reservoir and being made from river flows due to releases from the 2nd fill account of Taylor Park. If the sum of those supplies is insufficient to meet the direct-flow right, releases of UVWUA's 1st fill Taylor Park water stored in Blue Mesa are accounted as being delivered to the Gunnison Tunnel. If still unsatisfied, any water from a release to meet the rule curve at the Aspinall Unit may be used to satisfy the demand at the Gunnison Tunnel. This differs from current StateMod accounting where deliveries to the Gunnison Tunnel direct flow right are not accounted as being made from Silverjack out of priority storage or from the river flows resulting from the release of the 2nd fill of Taylor Park water. These differences may result in higher simulated deliveries of Taylor Park water to UVWUA through the Gunnison Tunnel in StateMod than is shown in the Division 4 Engineer's accounting spreadsheet. Because both the Division 4 spreadsheet and current StateMod set the supplemental storage releases without adjusting for the rule curve releases from Aspinall, however, both may over estimate the release of UVWUA water stored in Blue Mesa, as discussed in Section 3.1 below.

[3] HydroBase structure IDs 6200533, 6200692 and 6200578 total diversions are equal to diversion with coding S:2 F: U:P T: G: (source is storage) for irrigation years 1996 through 2010. The Hydrobase records that include some accounting of both diversions to storage at Aspinall and direct flow diversions to generate hydropower do not appear to be reconciled with the Division 4 Engineer's accounting spreadsheet or the one annual fill rule.

flows in the Gunnison River. Aspinall operations have reduced spring runoff peak flows and increased flows in late summer and winter months. The annual average flow below the Gunnison Tunnel is 831,000 acre-feet per year (AFY) for the 1937 to 1964 (pre-Aspinall) timeframe and is 820,000 AFY for the 1965-2010 (post-Aspinall) timeframe. The average annual flow at the Whitewater gage is 1,704,000 AFY for the 1937-1964 timeframe and is 1,810,000 AFY for the 1965-2010 timeframe. These annual totals are quite similar in the two timeframes, varying less than 2% for the Below Tunnel gage, and less than 6% for the Whitewater gage. The relatively small differences in average annual flow can be attributed to differences in hydrology in the two periods and relatively small changes in upstream depletions and also indicate that the activation of the Aspinall Unit has not resulted in large increases in basin depletions.

The reservoirs are operated by Reclamation and are subject to various agreements. The Taylor Park Reservoir exchange agreement allows the Uncompahgre Valley Water Users Association (UVWUA) to access their stored water in Taylor Park Reservoir via a downstream "exchange" in which water released from the first filling account in Taylor Park is re-regulated in a separate storage account in Blue Mesa (that is not charged against the fill of the Blue Mesa storage rights) for the benefit of the UVWUA and released out of Blue Mesa Reservoir to the Gunnison Tunnel. Under certain circumstances, the United States can acquire an exchange account in Taylor Park Reservoir. This agreement allows for maintenance of relatively stable target environmental flows on the Taylor River between Taylor Park Reservoir and Blue Mesa Reservoir. The UVWUA utilizes its Taylor Park water based on the 'Good Neighbor' policy. The Good Neighbor policy limits the times that UVWUA users call out other Uncompahgre River native water users by instead using their Taylor Park water. This decision is based on time of year and amount of Taylor Park water in storage.

According to the PBO (page 12), the Upper Gunnison Subordination Agreement (decreed in Case No. 03CW263) allows junior water users in the upper Gunnison River to develop up to 60,000 AFY of depletions without interference from the Aspinall Unit, but to date only 8,600 AFY of this amount has been developed and an additional 22,000 AFY is the amount expected to be developed within the reasonably foreseeable future. Reclamation has also entered into numerous, small contracts for Project water. As of December 2009 these contracts for deliveries total 1,000 AF annually of Aspinall Project water (EIS page 1-12).



2.2 Environmental Flows

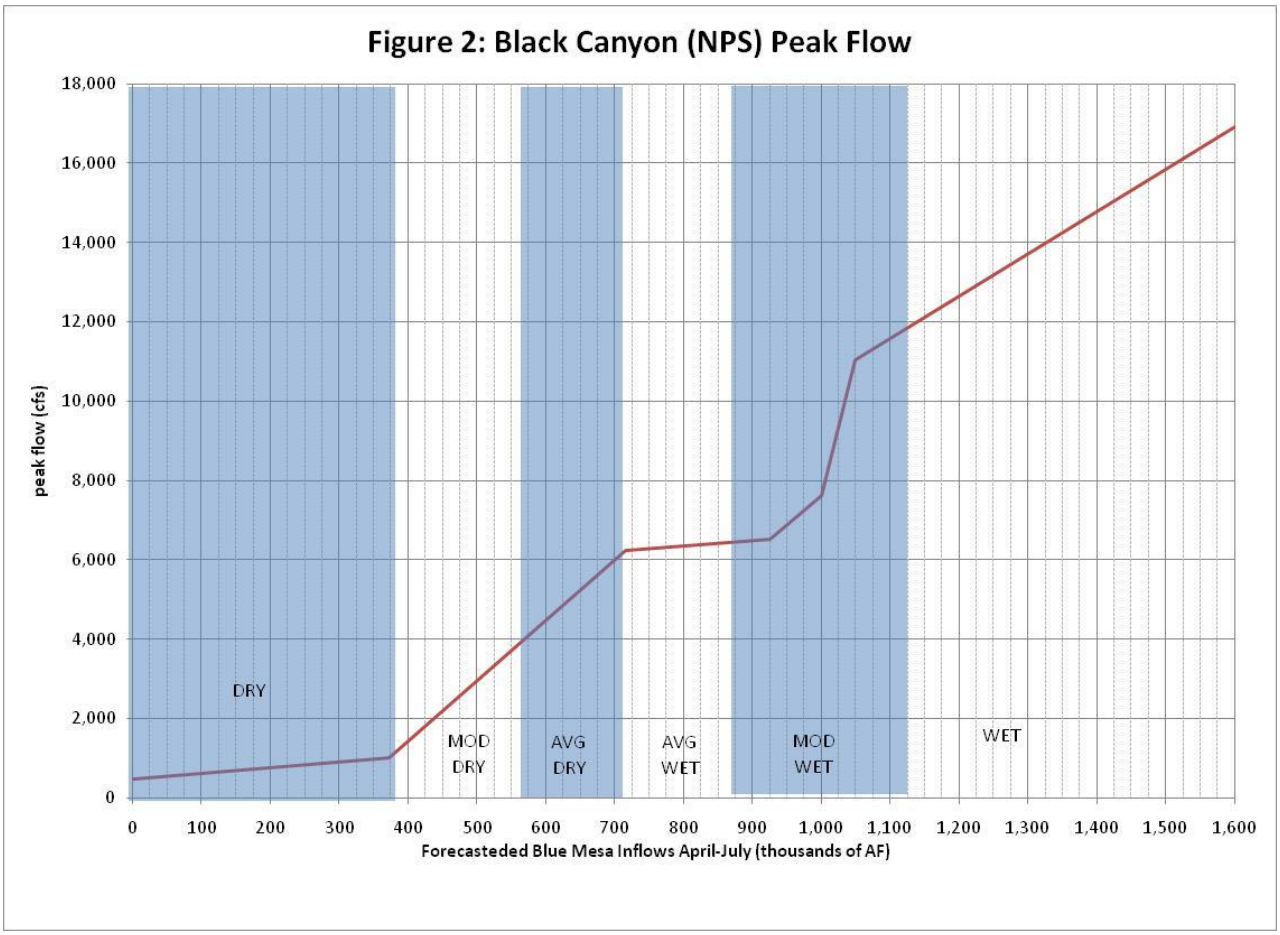
Environmental flow considerations also play a significant role in Aspinall Unit operations. There are two primary environmental flow measurement locations on the Gunnison below Aspinall; the National Park Service Black Canyon instream flow right and the target flows at the Whitewater Gage near Grand Junction, Colorado. The National Park Service holds an in-stream flow water right on the Gunnison River in the Black Canyon of the Gunnison National Park below the Gunnison Tunnel diversion dam. The EIS analyzed several operational alternatives to meet environmental flow targets at the Whitewater gage for endangered fish recovery. The environmental flow targets at Whitewater resulted from several years of work through the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin outside the San Juan River sub-basin (Recovery Program).

Black Canyon of the Gunnison National Park Service In-Stream Flow

In 2009 the National Park Service was awarded a decree for an in-stream flow water right (Colorado water court case number 01CW05; hereafter the Decree). The Decree was based on the Federal Reserved Water Rights doctrine, and the water right was given a priority date of March 2, 1933, the date that Black Canyon of the Gunnison National Monument was established. This priority date is senior to the Aspinall water rights, but has been subordinated to all water rights with adjudicated priorities senior to the Aspinall water rights (Decree, paragraph 32.5.1). It has also been subordinated to the same

60,000 AFY of in-basin depletions as have the Aspinall Unit rights (Decree, paragraph 32.5.3). The Black Canyon water right includes a minimum flow of 300 cfs throughout the year. Between May 1 and July 25, depending on projected inflows to Blue Mesa Reservoir, the in-stream flow right increases up to 1,000 cfs (Decree, paragraph 31.5.3). The decree also calls for a one-day (24 hour) peak release that ranges from 483 cfs to potentially more than 15,000 cfs (Decree, paragraph 31.5.2). The magnitude of the 1-day peak release is based on the May 1 forecast of spring inflows to Blue Mesa as shown on Figure 2. The timing of the 1-day peak is specified to occur between May 1 and June 30 (Decree, paragraph 31.5.2) and to the extent practicable, will be "coordinated with releases made pursuant to the Record of Decision" from the EIS to produce a single peak flow (Decree, paragraph 32.4.4). The Decree further implies that timing of such a release would normally be synchronized with the peak flow of the North Fork of the Gunnison unless downstream flood control considerations would prevent synchronization (Decree paragraph 32.4.4). Since the in-stream flow right is senior to the Aspinall Unit water rights, water may be bypassed without storage in the Aspinall reservoirs to meet the in-stream flow right. Moreover, the decree finds that Reclamation is authorized to operate the Aspinall Unit to meet this water right – including use of its storage and release capacity -- "to efficiently allow the contemplated stream flow patterns" (Decree, paragraph 25).

The ability of Reclamation to meet the Black Canyon peak flow targets as well as those required under the Recovery Program (see below) are constrained by multiple factors, including the timing of tributary runoff into Crystal, Morrow Point, and Blue Mesa Reservoirs, the timing and magnitude of North Fork Gunnison flows, the timing and occurrence of Blue Mesa filling, and river conditions and flood control capacities near Delta, Colorado. These considerations and operational constraints are discussed in detail in the EIS, pages 3-30 through 3-38.



Target Flows at Whitewater and Redlands Dam

Target flows have been quantified by the Recovery Program for the Gunnison River at Whitewater gage, located several miles downstream of the Black Canyon and below the confluences of the North Fork of the Gunnison and the Uncompahgre River. The Recovery Program has a long history of reports and implementation phases. The original document was produced by the USFWS in 1987 and was followed by a Section 7 Consultation Agreement (Fish and Wildlife Service 2000, revised from 1993) and Recovery Implementation Program Recovery Action Plan (RIPRAP), which is frequently updated. Reoperation of the Aspinall Unit to alter releases to meet environmental target flows is one of the more important remaining actions under RIPRAP. More recently the PBO concluded that reoperation of the Aspinall Unit to meet the target environmental flows was found to not adversely affect the endangered fish or their habitat and is expected to "result in overall beneficial effects to the species and critical habitat in the Gunnison and Colorado Rivers downstream from the Aspinall Unit and induce a positive species response due to a more natural hydrologic regime...". The PBO target flows were based on a 2003 report for the USFWS "Flow Recommendations to Benefit Endangered Fishes in the Colorado and Gunnison Rivers" (McAda, 2003; hereafter Flow Recommendations). However, the peak flow targets in the EIS are generally at the lower end of McAda's recommendations, and also uses the lower end of McAda's recommendations for baseflow duration and magnitude in all but dry and moderately dry year types. According to the Flow Recommendations, nearly half of the flow at the Gunnison River at

Whitewater gage and nearly 20 percent of the flow in the Colorado River near the Colorado-Utah State Line gage is produced from flows that are released from or bypassed by the Aspinall Unit (Flow Recommendations Figure 2.1, page 2-2). The EIS analyzed various alternatives to operate Aspinall to meet combined target flows for endangered fish recovery.

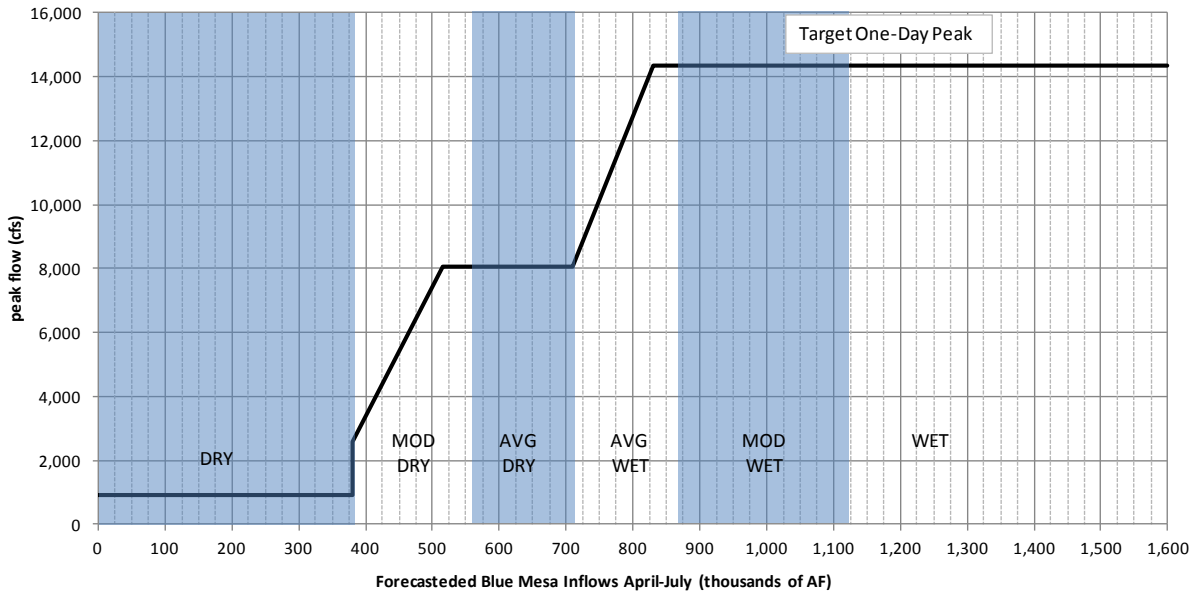
The Whitewater target flows consist of two components: base and peak flow targets. Base flow targets now provide for year-round, monthly minimum flow rates. The base flow minimums are often exceeded during the runoff months. Peak flow targets include a one-day peak flow target and longer duration high flow targets as shown in Figure 3 taken from the EIS (Figure 2.3-1 page 2-8 and Table 2.3 2, page 2-9) and the PBO (Figure 1, page 8 and Table 1, page 9).

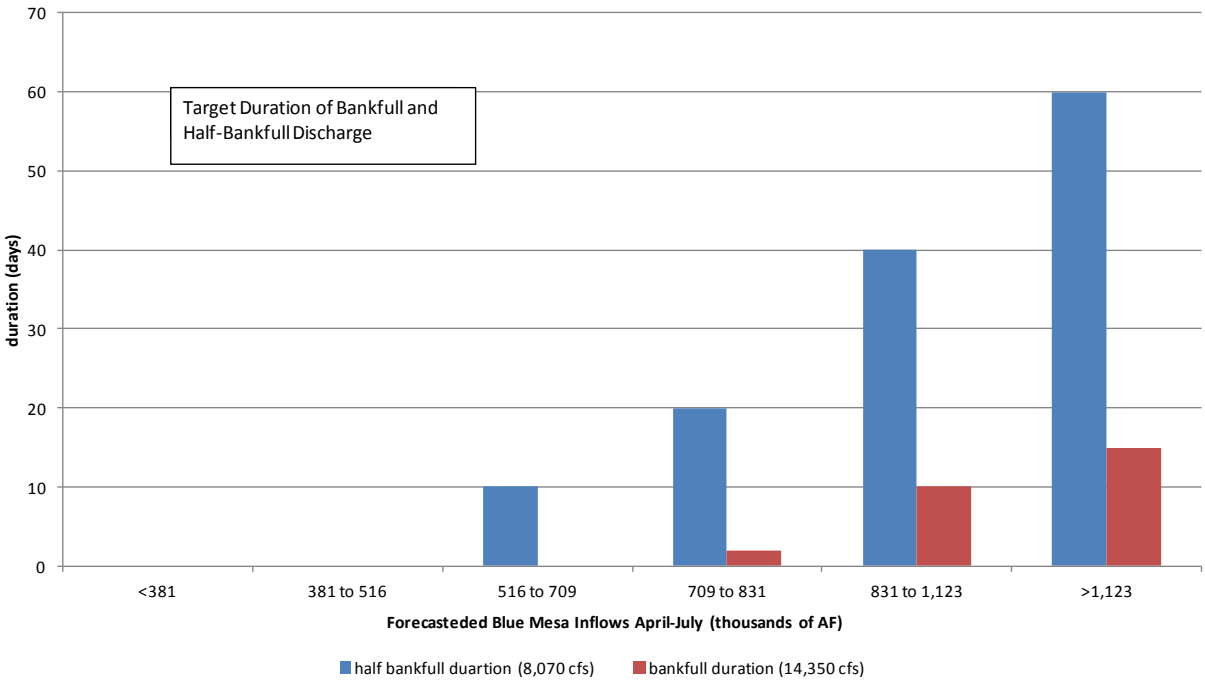
Six hydrologic categories were defined by the Flow Recommendations in terms of the May 1 forecasted inflow to Blue Mesa for the period April to July (Flow Recommendations page 4-8). This hydrologic categorization from the Flow Recommendations is applied for the base flow targets in the EIS (EIS page 1-15) and some provisions of the Black Canyon Decree (paragraph 30.2). However, peak flow targets for both the EIS and the Decree are computed based on different ranges of Blue Mesa inflows than are used for the base flow hydrologic year categorization and the ranges for the peak flow targets are different between the EIS and Decree. The differences in the ranges can be seen in Figures 2 and 3 (base flow categories showed as alternating shaded and un-shaded regions; peak flow ranges shown by break-points in the peak-flow plot). Peak flow target computation for the Decree and the Whitewater peak target from the EIS are determined independently, as shown by the overlay of the two curves in Figure 4, but Aspinall operations are to be synchronized as much as possible given downstream flooding constraints.

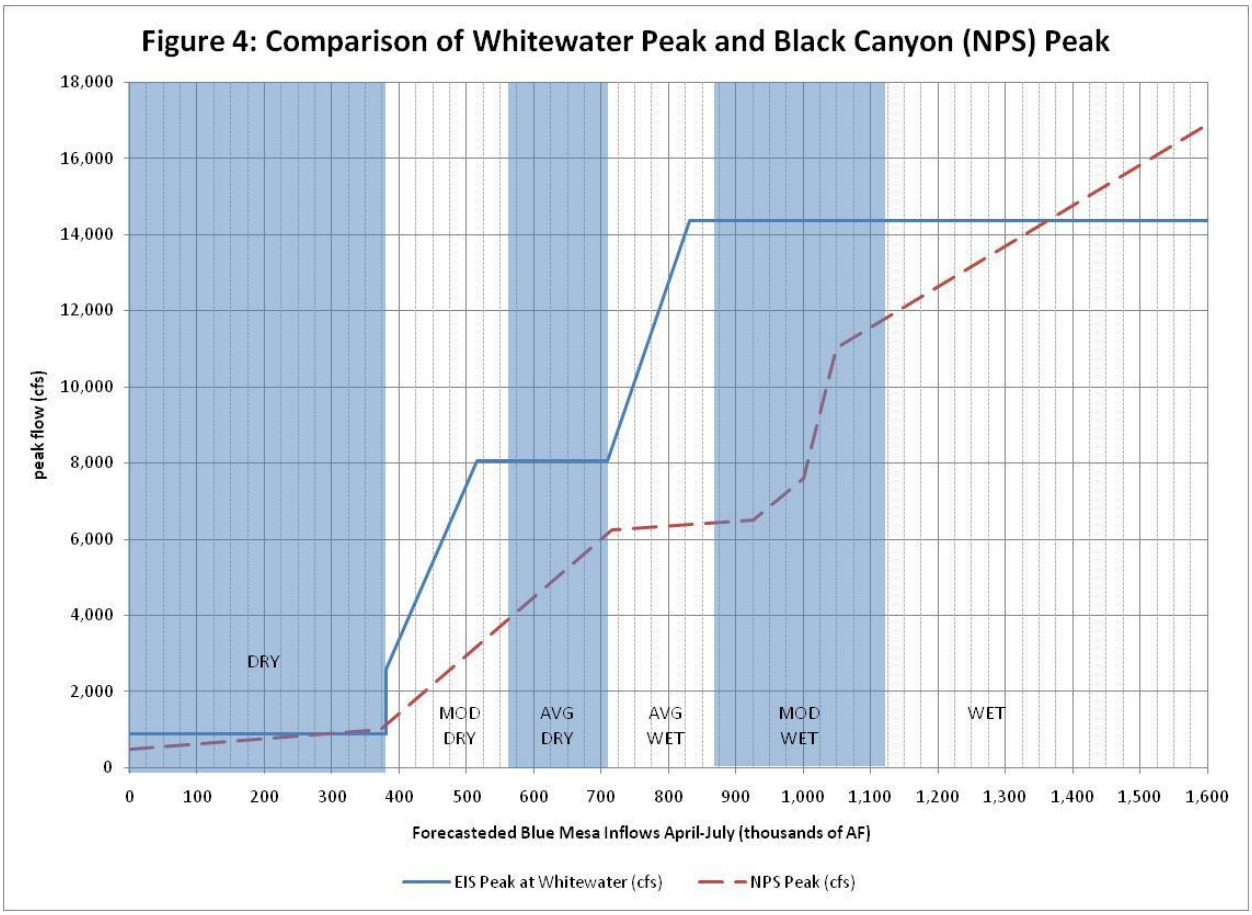
Target Flows at Whitewater: Peak Flows

The Flow Recommendations for peak flows consist of one-day spring peak flow magnitudes and the duration (number of days) of half bankfull (8,070 cfs) and bankfull (14,350 cfs) flow. The target peak flows at Whitewater gage are based on hydrologic category, and are summarized in Table 1 which also compares the full range of the recommendations from the Flow Recommendations with the operational targets proposed in the PBO and EIS. Releases from Aspinall for the one-day peak flow will be made with the intention of matching the peak from the North Fork, subject to flooding considerations at Delta (EIS page 2-8). The Flow Recommendations include two durations for both half and bankfull discharges; a shorter duration is recommended for maintenance of river habitat conditions and a longer duration for improvement of conditions. However, the PBO and EIS only address the lower end of the recommended range of the durations for half bankfull and bankfull flows and therefore only provide for the maintenance of river habitat conditions. The PB0 and EIS also mostly address the lower end of the

Figure 3: Target Whitewater Peak Flows







recommended range for one-day peak flows. The EIS states that releases for half bankfull and bankfull discharge may be made in the April to July timeframe (EIS page 2-8) but does not specifically limit such releases to this time frame.

As indicated by Table 1, in dry and moderately dry years, the PBO and EIS peak flow targets specify the one-day peak flow and do not specify any half bank flow days, though in moderately dry years with Blue Mesa inflows greater than 516 kAF, the one-day peak is equal to half bank flow. For average dry years, the peak flow target is the half bank flow for a duration of 10 days. For average wet years, the duration of the half bank flow is extended to 20 days, the one-day peak range is from half bank flow (8,070 cfs) to bankfull flow (14,350 cfs) scaled linearly based on Blue Mesa inflows. If projected inflows to Aspinall are sufficient to target bankfull flows in average wet years (per Figure 3), they are to be maintained for two days (see note 3 on Table 1). For moderately wet years, the duration of the half bank flow is extended to 40 days, bankfull flows are to be maintained for a period of 10 days. For wet years, the duration of half bank flows is extended to 60 days and bankfull flows are to be maintained for a duration of 15 days. The EIS is not entirely clear, however, that the peak flow targets are intended to be combined in just this way.

In addition, the PBO and EIS specify flow ramping rates for releases out of Aspinall (PBO page 9 and EIS page 2-6). The daily maximum increase is specified as the greater of 500 cfs or 25 percent of the previous day's Black Canyon flow, and the maximum daily decrease is 400 cfs or 15 percent of the

previous day's Black Canyon flow. Ramping is specified to begin 5 days prior to the estimated peak flow date on the North Fork of the Gunnison.

Finally under the Preferred Alternative in the EIS, Reclamation will not bypass the powerplant at Crystal Dam from April 1st to May 10th (except during wet year types to manage flood risks), which makes more storage water available for peak releases and may also improve the chances of filling Blue Mesa Reservoir with only a slight risk of increasing the flood frequency at Delta (EIS, page 2-8). It is not clear, however, if this hold back of storage is modeled for the EIS.

Target Flows at Whitewater: Base Flows

Base flow targets now provide for minimum stream flow rates that vary by season rather than a range of base flow rates. The base flow targets from the PBO and EIS are shown in Table 2 and are compared to the range of base flow targets from the Flow Recommendations. In dry and moderately dry years, the base flow targets in the PBO and EIS generally align with the Flow Recommendations. In average dry and average wet years, the PBO and EIS base flow targets align with the lower range of the Flow Recommendations, but provide for 1,500 cfs in June and July, which is in the middle of the recommended range. In moderately wet and wet years, the PBO and EIS base flow targets are below the recommended target except in June, July and August when the target base flow of 1,500 cfs is the minimum of the recommended range. The PBO and EIS flow targets also address the combined targets for the fish screen and ladder at the Redlands Dam and for fish migration flows below the dam, and factor in the operations and water rights for hydropower and irrigation diversions at the dam. As a result, the base flow targets are generally 1,050 cfs at the Whitewater gage during the fall and winter months, and increase to 1,500 cfs in the summer months. However, the targets are reduced in moderately dry and dry years, such that the senior water rights at the Redlands Dam are satisfied up to 750 cfs and base flows are sufficient to operate the fish screen only in a few months or both the fish screen and fish ladder at the Redlands Dam in other months, as summarized in Table 3, taken from the EIS (Table 2.3 1, page 2-7) and PBO (Table 2, page 10).

The Redlands Dam diverts water for hydropower year round and for seasonal irrigation use from the Gunnison River downstream of the Whitewater gage. The diversion serves a hydropower plant and approximately 3,000 irrigated acres with an average consumptive demand of approximately 8,400 AF. Annual average diversions are approximately 27,000 AF of water for irrigation use and 461,000 AF for hydropower use with return flows from both uses accruing to the Colorado River (CWCB 2004). Water rights at the dam include an irrigation direct flow right of 60 cfs and hydropower right of 610 cfs with priority date 1/4/1911 (junior to Gunnison Tunnel, senior to Aspinall) and an irrigation direct flow right of 80 cfs with priority date 3/27/1944 (junior to Gunnison Tunnel, senior to Aspinall). In addition, there is a hydropower right of 100 cfs with a 10/1/1994 priority date (junior to the Gunnison Tunnel and Aspinall). The Redlands Dam water rights senior to Aspinall and the Black Canyon Decree total 750 cfs (HydroBase, 2011). In the current StateMod configuration, Redlands Dam also has a 'free water' right. This 'right' allows for simulation of diversions in excess of the decreed water rights in the event of 'free river' (i.e. large flow events resulting in unallocated water) provided there is demand for such water and there is physical capacity to divert the water.

Table 1 – Peak Flow Targets at Whitewater

		McAda 2003 Table 4.9 (Flow Recommendations)			EIS Table 2.3 2 PBO Table 1		
Hydrologic Category (McAda)	EIS and PBO Peak Flow Target Blue Mesa April-July Inflow Range (1,000 AF)[1]	Half Bankfull (8,070 cfs) Duration (days)[2]	Bankfull Discharge (14,350 cfs) Duration (days)[2]	One-Day Peak (cfs)	Half Bankfull (8,070 cfs) Duration (days)	Bankfull Discharge (14,350 cfs) Duration (days)	One or Multi-Day Peak Magnitude (cfs)
Dry	<381	0-0	0-0	900-4,000	0	0	900
Moderately Dry	381 to 516	0-10	0-0	>=2,600	0	0	2,600-8,070
Average Dry	516 to 709	10-15	0-0	>=8,070	10	0	8,070
Average Wet	709 to 831	20-25	2-3	>=14,350	20	2	8,070-14,350[3]
Moderately Wet	831 to 1,123	40-60	10-20	14,350-16,000	40	10	14,350
Wet	>1,123	60-100	15-25	15,000-23,000	60	15	14,350[4]

Notes:

1. McAda hydrologic typing was initially based on exceedance intervals at Whitewater and was then defined in terms of forecasted inflows to Blue Mesa (Flow Recommendations, page 4-8). Additionally, the Blue Mesa inflow categories for peak flow targets differ from the hydrologic categorization used for base flows (see Table 2)
2. McAda provides two duration targets: the shorter duration recommendation is for maintenance, and the longer duration recommendation is for improvement
3. The lower range of the one-day peak is below McAda's recommended flows. In addition, the lower range is less than the bankfull discharge but targets include two days at bankfull discharge.
4. In wet years, the EIS one-day peak target is lower than McAda's lower range for a one-day peak

Table 2 – Base Flow Targets at Whitewater

		McAda 2003 Table 4.9 (Flow Recommendations)		EIS Table 2.3 1 PBO Table 2	
Hydrologic Category (McAda)[1]	EIS Hydrologic Typing - Aspinall Inflows April-July (1000 AF) [2]	Base Flow (cfs)	Timing	Base Flow (cfs)	Timing
Dry	<381	750 to 1,050	Maintain 1,050 cfs June to July	750 to 1,050	Maintain 1,050 cfs June to July, 750 cfs August to May, plus fish ladder and/or fish screen March to November[2]
Moderately Dry	381 to 561	750 to 1,050	Maintain 1,050 cfs June to August	750 to 1,050	Maintain 1,050 cfs June to August, 750 cfs August to May, plus fish ladder and/or fish screen March to November[3]
Average Dry	561 to 709	1,050 to 2,000	Gradual decline from peak runoff to target base flow by August	1,050 to 1,500	Maintain 1,500 cfs June to July, 1,050 cfs August to May
Average Wet	709 to 871				
Moderately Wet	871 to 1,123	1,500 to 2,500	Gradual decline from peak runoff to target base flow by September	1,050 to 1,500	Maintain 1,500 cfs June to August, 1,050 cfs September to May [4]
Wet	>1,123				

Notes:

1. McAda hydrologic typing was initially based on exceedance intervals at Whitewater and was then defined in terms of forecasted inflows to Blue Mesa (Flow Recommendations, page 4-8)
2. Hydrologic typing in the EIS for base flow targets conforms to the Flow Recommendations, while this typing has been adjusted for the peak flow targets in the EIS (compare to Table 1)
3. Fish screen requires 40 cfs in addition to Redlands Dam diversion (March through November); Fish ladder requires 100 cfs in addition to Redlands Dam diversion and fish screen flow (April through September)
4. EIS and PBO targets for Moderately Wet and Wet years are below the minimum Flow Recommendation Targets for September through May

The fish screen at the Redlands Dam is designed to reduce the entrainment of fish into the diversion ditch. The fish ladder is designed to provide fish passage at the diversion dam. At least 40 cfs of flow in excess of the Redlands diversion is required to operate the fish screen, and at least 100 cfs of flow in excess of the Redlands diversion and fish screen flow (if any) is required to operate the fish ladder. In dry and moderately dry years, this means that the fish screen and fish ladder flows are added to the base flows targets at Whitewater from March through November, except in July in dry years and except from June to August in moderately dry years. In those excepted months, the 1,050 cfs target at Whitewater enables operation of the fish screen and ladder, all as shown in Table 3.

Following completion of the fish ladder at the Redlands Dam in 1995, Aspinall operations provided 300 cfs of flow below the dam from July to October as formalized by a contract between Reclamation, USFWS, and CWCB. This contract was renewed in 2000, but expired in 2005. Since 2005 Reclamation has informally provided flows for fish migration below the Redlands Dam (EIS page 1-10). The Redlands Dam diversion is limited by its FERC license to 750 cfs whenever 300 cfs migration flow cannot be maintained below the dam (EIS page 2-6). At the same time, the migration flow target of 300 cfs is designed into the base flow targets at Whitewater for most hydrologic categories (a 1,050 cfs base flow target is equal to 750 cfs to Redlands Dam diversion and 300 cfs migration flow below the diversion dam). In dry and moderately dry years, the target flows at Whitewater drop such that flows below the Redlands Dam fall to levels sufficient to operate only the fish screen (40 cfs) or both the fish screen and ladder (140 cfs) as applicable (Table 3) and the migration flows are reduced from 300 cfs, depending on the month (Table 4).

The extent to which the target base flows at Whitewater will provide 300 cfs in migration flows below the Redlands Dam (variable by hydrologic category) is summarized in Table 4. Table 4 was derived by subtracting the anticipated diversion of 750 cfs at the Redlands Dam from the base flow targets at Whitewater (Table 3). In dry and moderately dry years, meeting the base flow targets at Whitewater will not provide 300 cfs of migration flow except in June and July unless Redlands Dam diversions are less than 750 cfs. In all other year types, base flow targets in June and July (also August in moderately wet and wet years) would provide for more than a 300 cfs migration flow.

Table 3 –Base Flow Targets at Whitewater under the Action Alternatives (cfs)

	Dec-Feb	Mar	Apr-May	Jun-Jul	Aug	Sep	Oct-Nov
Wet	1050	1050	1050	1500	1500	1050	1050
Mod. Wet	1050	1050	1050	1500	1500	1050	1050
Avg Wet	1050	1050	1050	1500	1050	1050	1050
Avg Dry	1050	1050	1050	1500	1050	1050	1050
Mod Dry	750	750/790*	750/890*	1050	1050	750/890*	750/790*
Dry	750	750/790*	750/890*	1050	750/890*	750/890*	750/790*

*Indicates months in which additional releases from Aspinall may be made to meet fish screen (40 cfs) and fish ladder (100 cfs) flows in excess of the Redlands Dam diversion.

Table 4 – Resultant Migration Flows below the Redlands Dam (cfs) Derived from Table 3 and Assumed Redlands Dam Diversion

	Dec-Feb	Mar	Apr-May	Jun-Jul	Aug	Sep	Oct-Nov
Wet	300	300	300	650-750^{+}	650-750^{+}	300	300
Mod. Wet	300	300	300	650-750^{+}	650-750^{+}	300	300
Avg Wet	300	300	300	650-750^{+}	300	300	300
Avg Dry	300	300	300	650-750^{+}	300	300	300
Mod Dry	0	40*	140*	300	300	140*	40*
Dry	0	40*	140*	300	140*	140*	40*

*****Indicates months in which additional releases from Aspinall may be made to meet fish screen (40 cfs) and fish ladder (100 cfs) flows in excess of the Redlands diversion. $^{+}$ Indicates months in which the Redlands Dam may divert more than 750 cfs provided at least 300 cfs is bypassed. The sum of water rights at the Redlands Dam is 850 cfs

Environmental Flows Drought Exceptions

The Black Canyon Decree specifies flow modification to the one-day peak flow under certain drought conditions as described in Table 5 (Decree, Paragraph 32.3). The PBO and EIS specify drought exceptions to the peak and base flow targets for the endangered fish flows (EIS page 2-13, PBO pages 10-11) and are summarized in Table 6. Like the peak flow targets, these exceptions for the endangered fish flow targets appear to be determined independently from the drought exceptions provided for in the Black Canyon Decree.

Table 5 – Drought Exceptions Specified in BC Decree (Paragraph 32.3)

Category This Year	Category Previous Years	Blue Mesa Contents (AF)	Peak Flow Change
Moderately Dry **OR** Average Dry	Dry last year **OR** Dry and/or Moderately Dry previous two years	<550,000 on previous Dec 31	Blue Mesa can store "until later released" the difference between the regularly calculated peak flow and the peak flow calculated with a Blue Mesa inflow value proportionally reduced by the ratio of previous year and current year actual inflows to the maximum inflows of the previous and current years' inflow category

Table 6 – Drought Exceptions Specified in the EIS and PBO (EIS page 2-13, PBO pages 10 and 11)

Category This Year	Category Last Year	Blue Mesa Contents	Whitewater Target Change
Moderately Dry	Dry **OR** Moderately Dry	<400,000 AF on Mar 31 **OR** Apr 30	peak flow to 5,000 cfs
Dry **OR** Moderately Dry	n/a	<600,000 AF	base flow to 900 cfs until BM Contents > 600,000 AF
Wet, Moderately Wet **OR** Average Wet	Dry	<522,000* AF on previous Dec 31 **AND** <400,000 AF on Mar 31	reduce number of half-bankfull discharge days to next lower category

*PBO specifies these storage criteria at 522,300 AF; EIS specifies as shown

Environmental Flows at the Colorado-Utah State Line

The endangered fish Flow Recommendations include targets for the Colorado River at the Colorado-Utah State Line, which is downstream of the confluence with the Gunnison River. The PBO recognizes that meeting the flow recommendations on the Gunnison River will provide some benefit to the Colorado River at the Colorado-Utah State Line targets as well since they are downstream (pages 74-75). The PBO also recognizes that due to differing operations on the two rivers, it would difficult to match peak flows at the State Line from both systems and so only requires the resulting flows at the stateline be tracked without additional Aspinall reoperations to meet those flow targets (page 86) . The targets for the Colorado River at the stateline were developed in a similar manner to the Gunnison River at Whitewater targets, containing the same type of hydrologically categorized spring peak, half bankfull and bankfull discharge durations, and summer, fall and winter base flow targets.

3.0 Modeling Alternatives

For this memo, three software models of the Gunnison River Basin were reviewed and compared: (1) State of Colorado's StateMod Gunnison River Basin Water Resources Planning Model, (2) the Gunnison River Riverware model developed for the PBO/DEIS, and 3) Reclamation's Colorado River Simulation System model Each model was developed for different purposes and simulates water rights, demands, reservoir operations, environmental targets and other river operations differently and at varying degrees of spatial and temporal resolution. This section describes the current configuration of the models, as well as presents recommendations for modification or enhancement to assist in analysis of environmental flows and potential water banking scenarios where water right yields and accounting would be necessary.

3.1 StateMod

Background

The State of Colorado over nearly the last two decades has developed a decision support system that includes an extensive data collection and data organizational effort, a large statewide hydrologic database (HydroBase), and the development of generic consumptive use and surface water allocation models that can be applied to any river basin. The consumptive use model is called StateCU and is able

to calculate crop consumptive needs based on irrigated acreage, climate, elevation, crop type, irrigation type and soil type using a variety of methods (e.g. Blaney-Criddle, Penmon-Monteith). The water allocation model is called StateMod and is able to simulate the prior appropriation system of water rights administration used in Colorado and several other western states, operating rules and historical practice to analyze water availability to various projects or users. StateMod uses StateCU model results for agricultural consumptive demands.[4] The variable efficiency function in StateMod allows for more efficient agricultural use of water in water short situations and more inefficient use when water is plentiful (e.g. lower efficiency during peak runoff, and then higher efficiency during late summer). In StateMod, efficiency is defined as the ratio of consumptive use to diverted water.

The State has developed StateMod models for the entire west slope of Colorado, including the Gunnison River Basin. The Gunnison StateMod model has undergone several refinements over the past decade. The latest version is the 2009 release that was made available on the CDSS website on 1/18/2010 (http://cdss.state.co.us/DNN). The model should be run with StateMod version 12.29.30 (not currently available on the website – obtained from Erin Wilson of Leonard Rice Engineers via email on 12/16/2010). The Gunnison StateMod model is available in both a monthly and daily model. Much of the model input was developed for the monthly model and modified as necessary for the daily model. The daily model uses monthly model inputs (e.g. demands, reservoir end-of-month contents, naturalized flow) and disaggregates to daily input based on simple linear interpolation or by using pattern stream gages to emulate the natural daily variability historically observed in the basin. The daily model currently handles instream flow targets by using monthly or annual average values, but has the ability to simulate single-day peaks as specified by the modeler. Potential improvements to the daily simulation of environmental flows are discussed below.

StateMod simulates flows in the river and diversions to water users by starting with a naturalized flow dataset. The StateMod solver then evaluates each water right in the basin to determine its diversion, consumptive use and return flow pattern. StateMod begins with the most senior water right (regardless of location) in the model and determines its diversion as the minimum of the physical flow at the point of diversion, the available flow at the point of diversion, the available flow at downstream diversions, the legal limit (i.e. water right amount), and the physical diversion capacity and demand at that point of diversion. The solver reduces the available flow at downstream diversions by the diversion amount less any immediate return flows. The solver then moves to the next most senior water right and determines its diversion in a similar manner. The solver recognizes if 'new' water is made available upstream of a water right that has already been evaluated. For example, 'new' water can result from reservoir operations that release water to a storage curve (e.g. hydropower releases from Blue Mesa Reservoir) or from agricultural return flows that accrue to a neighboring tributary (e.g. Gunnison Tunnel diversions of Gunnison River water into the Uncompahgre River basin, which are assumed to be available to water rights in the Uncompahgre River basin in the order of priority). When new water is introduced to the system, the solver re-evaluates water rights beginning with the most senior right to ensure that senior

[4] There is still small bug in StateCU that only occurs under very limited circumstances. It does not correctly compute consumptive use (CU) when 1) an option to report CU by senior and junior water rights is active (not typical), 2) the junior right is called out by a downstream senior and 3) daily CU is being computed. Total ditch CU is still correctly computed. Apparently it is in the process of being corrected by the State's contractor, Leonard Rice Engineers.

users can use the maximum amount of water that would be available to them considering all reservoir and return flow operations.

StateMod can also simulate more complex operations such as reservoir operations for multiple users, exchanges and other agreements between water users. Such operations, however, are simulated in the order specified by the model user. StateMod does not optimize a solution for all such operations; it simulates operations in the order prescribed by the model user.

StateMod is able to reasonably quantify the yield of water rights, exchange potential for such water rights to the water bank reservoir, and the amount of flow that would be available to a new junior water right(s). Careful consideration must be given to the model configuration and the prescribed order of model operations to reasonably simulate the yields, flows and accounting that would be necessary under a water banking scenario. The Gunnison StateMod model is currently independent of the Colorado River StateMod model and also independent of larger interstate Colorado River basin operations, such as compact compliance actions that could affect Gunnison River administration. StateMod could be used, however, to examine hypothetical compact compliance independently of interstate operations by turning off some or all post-1922 water rights.

Aspinall Unit Representation in StateMod

The Aspinall unit is represented in the Gunnison StateMod as three reservoirs (Blue Mesa, Crystal and Morrow Point Reservoirs). Morrow Point and Crystal Reservoirs do not store water more than necessary for short-term re-regulation of hydropower releases, and are not considered in much detail for the purposes of this memo. Blue Mesa Reservoir is simulated in StateMod using three storage accounts as shown in Table 7. The 'USA' account in StateMod represents all federal operations of Blue Mesa including storage releases for hydropower. The Aspinall hydropower direct flow water rights are not simulated explicitly in the current configuration of StateMod. StateMod also includes a storage account for the UVWUA Taylor Park Reservoir exchange, which shares the same physical space as the 'USA' account. Under the current configuration of StateMod, the single fill rule is not activated for Blue Mesa Reservoir. When activated, the single-fill rule would allow the USA account in Blue Mesa to store up to its decreed volume only once every irrigation year (November through October), with the end of year contents being carried over and charged to the next year's filling (excluding any water remaining in the UVWUA account). Once the first fill is reached for each account, the reservoir would not be allowed to store more water under that account and all inflows would be bypassed unless there is a free river and no water rights are being administered.[5] The second fill decree for Blue Mesa (122,702 AF, priority date 11/13/1957) should allow for additional storage even when water rights are being in administered, but StateMod does not currently include this re-fill right in the Blue Mesa configuration. Table 7 also compares the StateMod storage values with information from the EIS (Colorado Water Conservation Board 2009, hereafter Gunnison StateMod documentation, page 5-38; and EIS page 1-4).

[5] In a March 29, 2011 phone conservation, the Division 4 Engineer (Bob Hurford) indicated that Blue Mesa often stores under a free river condition. In the StateMod model, the one annual fill rule is only activated for Morrow Point, Crystal and Cerro Reservoirs, but these reservoirs are also assigned 'free river rights' that are approximately equal to the capacity of the reservoirs, effectively allowing these reservoirs two annual fills. Reservoirs store under the 'free river rights' only if the model shows available water and available storage capacity in the reservoirs.

Blue Mesa Operations in StateMod

Prior to the construction of Blue Mesa, the Gunnison Tunnel direct flow water rights controlled much of the flow of the Gunnison River, calling out junior water users in the upper basin. UVWUA holds an absolute direct flow water right at the Gunnison Tunnel for 1,175 cfs (approximate tunnel capacity) with priority date of June 1, 1905. After Blue Mesa was constructed, UVWUA was able to store their Taylor Park Reservoir water in Blue Mesa via the Taylor Park Exchange. The Aspinall water rights are subordinated to in- basin junior users up to 60,000 AFY, which prevents Aspinall from calling out in-basin junior water users. In addition, the large rule curve releases from Aspinall introduce large amounts of 'free water' just above the Gunnison Tunnel that under current administration reduce the potential of a call from downstream senior water rights (e.g. Gunnison Tunnel, Redlands Dam, Austin area; Gunnison River Basin Information, CWCB 2004).

Table 7 – Blue Mesa Storage Accounts (AF)

	StateMod	EIS Table 1.2. 1
Dead and Inactive Storage	192,270	192,270[1]
'USA' Account	748,520	748,430
UVWUA Account	106,200	n/a
Sum of Accounts	1,046,990[2]	940,700
Total Storage	940,790	940,700

1 – Sum of Dead Storage and Inactive Storage from EIS Table

2 – Sum of accounts exceeds physical capacity – UVWUA and USA account share physical space, UVWUA not subject to single-fill rule at Blue Mesa, when activated, and USA account would not be paper filled by storage in UVWUA account. Does not include the refill right.

The UVWUA practices a 'Good Neighbor' policy whereby UVWUA users will at times utilize their Taylor Park Reservoir water prior to calling out other Uncompahgre native rights. This policy is simulated in StateMod by deactivating UVWUA users' senior Uncompahgre native water rights junior to administration number 13917 (priority date Feb. 6, 1888). This priority date was determined through model calibration to achieve a similar level of diversions through the Gunnison Tunnel as seen historically. StateMod simulates the UVWUA ditches individually, requesting Gunnison Tunnel direct flow right water and Taylor Park water out of Blue Mesa Reservoir and using the Gunnison Tunnel as a carrier structure. Therefore, StateMod simulation does not report any demand or shortage at the Tunnel per se, but rather at the ditches that have access to UVWUA water. The combined demand from UVWUA users is met through diversions at the Gunnison Tunnel (direct flow and storage water) and can call out junior upstream Gunnison River water rights to satisfy the direct flow water right. However, rule curve releases of water from Aspinall may protect upstream users from such a call.

Blue Mesa operations simulated in StateMod include hydropower releases, the Taylor Park Reservoir exchange and associated storage releases to the Gunnison Tunnel, releases to the Black Canyon in-stream flow water right, and evaporation. The current configuration of StateMod simulates hydropower releases by releasing storage water from Blue Mesa according to a storage rule curve; no additional releases for hydropower are made after the rule curve is met. Water released from Blue Mesa according to the storage curve becomes available for general allocation just downstream of Blue Mesa and can be

used to satisfy downstream senior water rights, but does not change supplemental storage amounts computed prior to this release. Blue Mesa and the other two Aspinall dams have large direct flow water rights for hydropower in addition to the storage water rights. The direct flow hydropower rights are not explicitly simulated in the current configuration of StateMod since Reclamation operations of hydropower are more readily simulated using the storage curve. However, the Upper Gunnison River Water Conservancy District (UGRWCD) has raised concerns with the State of Colorado that available water in the upper basin is grossly over-predicted without simulation of the direct-flow hydropower rights.[6] Addition of the direct flow hydropower rights in the StateMod model would control the inflows to Blue Mesa Reservoir and significantly reduce the amount of water available for future development in the upper basin, but would likely not affect simulated river flows dramatically. The UGRWCD did not address the subordination of up to 60,000 AF of in-basin use above Crystal Dam in their comments. The current StateMod model has placeholder nodes for the subordination, but demands at these nodes are set to zero. Reclamation has estimated that reasonably foreseeable development above Crystal Dam would not exceed 30,800 AF (EIS, Appendix A, page 8)

The Taylor Park Reservoir exchange is simulated by transferring water from the Blue Mesa 'USA' account to the UVWUA account whenever releases are made from the UVWUA account in Taylor Park Reservoir. Releases are made out of Taylor Park Reservoir to meet in-stream flow targets on the Taylor River as set out in the decree adjudicating the Taylor Park Reservoir exchange agreement (Colorado Water Court case number 86CW203) and allow UVWUA water users to call for this water out of Blue Mesa. The model performs a book-over exchange by crediting water in UVWUA's account in Blue Mesa for any releases out of their Taylor Park Reservoir account that are released to meet the in-stream flow targets. UVWUA can then call their water out of Blue Mesa when needed for supplemental irrigation.

Currently in StateMod, after UVWUA has met its first-fill total under its Taylor Park Reservoir water right by a combination of the previous year's carry-over water in Taylor Park Reservoir[7] and water stored in priority at Taylor Park in the current water year, the UGRWCD can begin to store under its second-fill decree at Taylor Park Reservoir. Also currently in StateMod, releases from Taylor Reservoir's UVWUA account are credited to the UVWUA account in Blue Mesa Reservoir, but these releases are not shepherded to Blue Mesa and can be diverted and consumed by other upper Gunnison (Gunnison River mainstem) users. This modeling simplification is consistent with actual practice since there has always been at least as much water flowing into Blue Mesa as was released from Taylor Park.[8] However, releases of UVWUA water from Taylor Park are not part of the legal water supply for those upper basin water rights, and in practice, this water would not provide protection against calls from downstream rights such as the Gunnison Tunnel or Redlands. Under the 86CW203 accounting conditions, after the first fill water has been released from Taylor Park, the next water released from Taylor Park is charged

[6] July 10, 2010 Letter from the Upper Gunnison Water Conservancy District to the Colorado Water Conservation Board.

[7] At the end of the water year, the sum of UVWUA water stored in Blue Mesa and in Taylor Park is to be charged against the one-annual fill of Taylor Park in the following year (86W203 accounting conditions, paragraph 3). In StateMod, only the portion of water in UVWUA's account in Taylor Park at the end of the water year is charged against the Taylor Park 1st fill for the following water year; StateMod currently omits the UVWUA water in Blue Mesa from this accounting.

[8] February 7, 2011 phone conversation with Division 4 Engineer (Bob Hurford).

to the second fill account. Then except for 19,200 AF that is available for irrigation use, second fill releases are to be shepherded to Blue Mesa, at which point the water becomes part of the supply available to Blue Mesa and downstream water rights. Modeling simplifications in StateMod do not capture all details of the Taylor Park Agreement, but reasonably simulate stream flows under current operation of the Agreement.[9]

In the current configuration of the Gunnison StateMod model, output indicates that releases of supplemental storage water to Gunnison Tunnel are not reset if 'new' water is made available upstream by the release of water to meet the storage rule curve at Blue Mesa Reservoir. This effectively sets deliveries of supplemental storage water and does not allow the Gunnison Tunnel water users to reduce their use of storage water if additional 'new' water is later made available that could have been diverted under the Gunnison Tunnel direct flow water right. This order of simulation may over-estimate the amount of water that UVWUA would need from its storage account, but may more reasonably predict actual orders of supplemental storage water from UVWUA water users. StateMod has the flexibility to change this order of simulation such that the unallocated water from the storage curve releases can be made available prior to computation of storage allocation. However, changing this order may reduce Blue Mesa storage below the storage guidance curve in certain circumstances, but primarily affects accounting of the UVWUA direct flow and storage water rights.

In the current configuration of StateMod, the 1,175 cfs of direct flow water right at the Gunnison Tunnel could call water past the Aspinall Unit and other rights junior to the Gunnison Tunnel. The Gunnison Tunnel direct flow water right cannot call for storage water out of Aspinall. This point may be important from a water allocation standpoint, but is often lost when examining Aspinall historical operations because any bypasses for the Gunnison Tunnel direct flow rights are computed into a total outflow from Aspinall, even though a portion of the total outflow is not coming out of Aspinall storage. StateMod output provides Aspinall outflows by type of water, including differentiation of bypassed water volumes and storage releases by reservoir account. Post-processing of model output and accounting can be performed to determine the amount of water that would have been available to the Gunnison Tunnel direct flow right if maximizing the water available from storage rule curve releases from Aspinall.

There are several senior water rights downstream of Aspinall that could call water past Aspinall. The most significant of these rights is the Gunnison Tunnel, the Black Canyon (National Park Service) in-stream flow right, and the Redlands Dam. In practice, rule curve (hydropower) releases from Aspinall in combination with downstream tributary inflow often provide sufficient water to satisfy these rights without calling out Aspinall or any other upstream rights. However, in dry years, these rights would be able to call water from all upstream juniors (subject to the subordination of the Black Canyon water right to 60,000 AF of in-basin depletions and all decreed rights senior to Aspinall) and there would be no

[9] In the current configuration of StateMod the one-annual-fill rule is not simulated at Taylor Park, but book-over accounting at the end of the water year moves water from the 2nd fill to the 1st fill right. Also currently in StateMod, the 2nd fill at Taylor Park never gets any water because the 'free river water right' effectively doubles the size of the 1st fill. Since water is not delivered to specific users out of the 2nd fill, the stream flows are not affected, but StateMod accounting at Taylor Park does not appear to match up with the Taylor Park Agreement or the Division 4 Engineer's accounting spreadsheet.

requirement for Aspinall to release water from storage (previously stored in priority) to satisfy these demands (except for the Black Canyon right as authorized in the Decree).[10] In 2002, flows at the Redlands Dam were low enough to force a call, but the Colorado River Water Conservation District paid Redlands for lost hydropower generation revenues to prevent such a call, thereby protecting basin users from water curtailment and probable crop failure.

In StateMod, native inflows in the entire basin are first allocated to senior water users (such as the Gunnison Tunnel direct flow water right and Redlands Dam, and the direct flow aspect of the Black Canyon water right, although it is not currently activated in the model) and the required flow would be bypassed by Aspinall and other junior rights to meet these downstream demands. A variety of water users have access to storage water in various reservoirs to use as a supplemental supply. Generally, if the water user demand is not satisfied by the direct flow rights, StateMod immediately attempts to meet this demand using by allocating its supplemental storage supply. StateMod also simulates reservoir releases to the storage rule curve which can produce large amounts of unallocated water below the Aspinall Unit. When rule curve releases results in unallocated water below Aspinall, StateMod re-evaluates all senior water rights so they can potentially benefit from this additional water. The re-evaluation does not consider or alter other reservoir operations computed previously and reservoir releases are held constant through this iterative process because the rule curve releases are the last reservoir operation to be executed. The amount of water initially computed to be bypassed by Aspinall and other junior water rights to meet downstream senior demands is adjusted after the re-evaluation so that the senior rights can utilize the unallocated water, potentially making water available for juniors who had to bypass flows in the initial computation. This re-evaluation occurs within a single model time step (daily or monthly time step) so that output from the model only shows the final allocation of water to direct flow rights and storage allocations. In the current allocation model configuration, the Black Canyon water right is set to only take water from storage in Blue Mesa. The initial amount of bypass water allocated for downstream users is not shown in model output. The result of this iterative process within a single model time step effectively simulates Blue Mesa Reservoir operations in the following order:

1) Book-over of Taylor Park Reservoir releases into the UVWUA account
2) Release of stored UVWUA water to the Gunnison Tunnel for supplemental irrigation supply
3) Release of stored 'USA' water to the Black Canyon decree (shepherded past the Gunnison Tunnel by StateMod)
4) Release of water to meet storage curve[11]

[10] The Decree states that releases from storage that allow this water right to be met efficiently are within the scope of the authorized purposes for Aspinall and its water rights (Decree, paragraph 25)

[11] By not reducing the UVWUA storage releases after re-evaluation of the yield of the direct flow rights due to rule curve releases, StateMod may allocate more of the UVWUA storage releases to the Tunnel than would be needed to meet the UVWUA demand given the direct supply from the rule curve releases. The Division 4 Engineer's accounting spreadsheet accounts for deliveries to the Gunnison Tunnel in a similar, but not identical manner. However, adjusting the UVWUA releases after re-evaluation due to rule curve releases may result in more rule curve releases from the USA account to achieve the same pool elevation. Comparative StateMod runs are probably needed to track the impact of not adjusting the UVWUA storage account after rule curve releases are made.

The storage curve in StateMod is set at a minimum of 692,300 AF at the end of December, and increases linearly to 940,700 AF at the end of June and remains at 940,700 AF until the end of July. It then decreases linearly back to the December target. If storage ever falls below the target, StateMod adjusts the rate of increase (December to June) or decrease (August to December) to a constant rate. Water released to meet the storage curve is used for hydropower generation and to reduce winter icing problems and create reservoir capacity for flood control. Comments on the Colorado River Water Availability Study (CRWAS; CWCB, 2010) received from the Upper Gunnison Water Conservancy District state that a different storage curve should be developed to more accurately portray current operations by Reclamation at Blue Mesa Reservoir, but details of this curve were not included with their comments.[12] Table 8 shows the StateMod storage targets (total Blue Mesa storage including inactive and dead pools of 192,270 AF) and compares them to the storage curve used in CRSS. There are minor differences in the storage capacities for the rule curve in CRSS from those given in the EIS (page 1-4). The PBO/EIS model appears to operate on just the storage targets from the CRSS rule curve for December, March, and July. The differences in the rule curves between the models may not be significant because all have the same general pattern of drawdown by the end of December to avoid icing, drawdown by the end of March to avoid spills and flooding, and re-filling by the end of July. These and other differences in the models make it difficult to compare their outputs directly, however.

Table 8 – Blue Mesa Storage Targets (AF)

	Blue Mesa Target Maximum Storage (AF)	
Month	**StateMod**	**CRSS[1]**
January	733,700[2]	681,200
February	775,100[2]	671,200
March	816,500[2]	661,200
April	857,900[2]	761,200
May	899,300[2]	811,200
June	940,700	911,200
July	940,700	940,200
August	891,020[2]	911,200
September	841,340[2]	856,200
October	791,660[2]	801,200
November	741,980[2]	746,200
December	692,300	692,200

1) CRSS live storage curve (see Section 3.2 below) plus dead pool storage of 111,200 AF

2) Values adjusted to linear increase or decrease if actual end of December or July contents are less than target

Black Canyon and Whitewater Targets in Current StateMod Configuration

StateMod includes model nodes for both the National Park Service in-stream flow right through the Black Canyon of the Gunnison and the target flows at the Whitewater gage. The direct-flow component

[12] July 10, 2010 Letter from the Upper Gunnison Water Conservancy District to the Colorado Water Conservation Board.

of the Black Canyon in-stream water right is deactivated in the current configuration of the StateMod model, and the water right is met from shepherded releases of storage water from Blue Mesa prior to releases to meet the storage curve. In practice, the releases from Blue Mesa to meet the storage curve may provide sufficient water to meet the in-stream flow right and so meeting this right may not require any additional release from storage. Since the Decree is subordinate to all adjudicated rights senior to Aspinall and up to 60,000 AF of in-basin depletions, simulating the right as a direct flow right (with priority date just senior to Aspinall) or keeping the current configuration of only meeting the right with storage releases from Aspinall would make little difference in stream flows or in Blue Mesa contents, but would result in different accounting of the Blue Mesa storage rights (i.e. water either bypasses Aspinall to the Black Canyon direct flow right and is not stored, or is stored and then released via the storage curve and at least partially meets the Black Canyon right, with supplemental releases to satisfy the right if the storage curve releases are not sufficient). Simulation with the Decree activated as a direct flow right and access to Aspinall supplemental storage allocation only after the rule curve release, would allow for a more direct computation of the volume of Aspinall releases from storage needed to fully satisfy the right when water available to a direct flow water right (including use of direct-flow water available from a rule curve release) is insufficient.

The flow targets at Whitewater are deactivated in the current model, but could be activated relatively easily by adding demand at the location and an operating rule to call for water out of Blue Mesa when flows do not satisfy the flow target in a similar manner as the Black Canyon Decree. Such targets could be incorporated into StateMod using Aspinall inflows to categorize hydrologic types and existing model output to estimate flows from other basin tributaries that would contribute to the flow in the Gunnison River at Whitewater. Targets could be developed on a daily basis using model inputs and baseline model results for the North Fork flows for timing and duration of peak flows. However, due to StateMod logic limitations, some of the drought provisions outlined in Tables 5 and 6 (above) could not readily be incorporated in a dynamic modeling manner, but could be simulated using an iterative modeling approach

As noted above the PBO recognizes that due to differing operations on the two rivers, it would be difficult to match peak flows at the State Line from both systems and so only requires the resulting flows at the State Line be tracked without additional Aspinall reoperations to meet those flow targets (PBO page 86). However, in conjunction with the Colorado River StateMod model, it would be possible to add new model nodes to the Gunnison model or perform an external analysis to determine the amount of additional flows (if any) that would be needed from upstream sources (including Aspinall and Colorado mainstem reservoirs) to meet the target flows at the State Line gage. Then scenarios could be constructed to assess the ability of a combination of projects on both rivers to meet target flows at the State Line.

The daily model implementation of the Gunnison StateMod model uses a fairly coarse disaggregation method for demands and reservoir targets. In addition, the daily environmental flow targets for both the Black Canyon in-stream flow right and Whitewater target flows use monthly average values from the monthly demand set and therefore do not include finer resolution of the peak day, bankfull and half bank flow target durations or ramping of flows. A new daily instream flow demand set could be

developed to better capture the peak flows and ramping targets rather than using the constant monthly average value.

Results of the calibration and baseline model runs presented in the Gunnison StateMod documentation show that the reservoir operating curve actually used at Blue Mesa plays a significant role in the flows below the Aspinall Unit, including flows at Whitewater. The documentation indicates that that after discussing with Reclamation, a different operating curve was used prior to 1989. When implemented in the model, the calibration results for the earlier period improved.

Potential StateMod Modifications for Environmental Flow Simulation

Through evaluation of the current configuration of the Gunnison StateMod model, there are several different modifications or enhancements that would aid in quantification of water rights yields, operations and accounting for analysis of environmental flows and potential water banking scenarios.

The Black Canyon in-stream flow right could be modified to operate first as a direct-flow water right senior to the Aspinall unit. The Black Canyon in-stream flow right could be then modified in StateMod to call for supplemental storage water from Aspinall after the releases to storage curve (i.e. hydropower release) have been made. StateMod would then operate Blue Mesa Reservoir in the same manner as previously described, allocating any flows downstream of Aspinall to senior direct flow rights, in particular the Gunnison Tunnel and the Black Canyon right, in the following order.

1) Book-over of Taylor Park Reservoir releases into the UVWUA account
2) Bypass of flows allocated to downstream seniors (e.g. Gunnison Tunnel direct-flow right, Redlands Dam, and the Black Canyon in-stream flow right)
3) Release of stored UVWUA water to the Gunnison Tunnel for supplemental irrigation supply
4) Release of water to meet storage curve
5) Re-evaluation of direct-flow water rights resulting from the release of storage from Aspinall to meet the rule curve; may make water available to other water rights throughout the basin (including the Black Canyon right)[13]
6) Release of additional stored 'USA' water from Blue Mesa to the Black Canyon right if needed (shepherded past the Gunnison Tunnel by StateMod)

This configuration differs from the current StateMod configuration in its treatment of the Black Canyon decree. In the current StateMod configuration, the Black Canyon right is only satisfied by water released from storage. In the proposed configuration, the Black Canyon decree can be satisfied by direct flow water made available from a storage curve release from Aspinall or by any flows that bypass Aspinall to meet seniors downstream of the Gunnison Tunnel (e.g. Redlands Dam). An additional release of Aspinall water to meet the Black Canyon decree would only be necessary if these flows are not sufficient.

This configuration of the Black Canyon right would allow for a simpler quantification of the amount of water required to meet the right in addition to normal Aspinall operations. This modification could also

[13] A post hoc analysis or comparative model run would probably be needed to determine how much less UVWUA storage water could be released to the Tunnel after re-evaluating for rule curve releases, and to assess if such releases may be offset by greater rule curve releases and entail trade-offs between the UVWUA and USA storage accounts as discussed in footnote 11.

be used to test whether this configuration results in a more efficient use of storage water to satisfy this right or leads to significantly different flows or Aspinall storage than the current configuration.

The daily model could be modified to include the one-day peak target for the Black Canyon in-stream flow right. For the monthly model, the daily peak could be incorporated into the total monthly volume target. The increased resolution of the Black Canyon right would be useful if also incorporating the daily flow targets at Whitewater.

Targets at Whitewater could be computed based on the EIS and incorporated into StateMod. The targets would call for supplemental releases from Aspinall after rule curve releases. To develop the targets, some assumptions on the timing of the bankfull and half-bankfull flows would be necessary (e.g. must all days be consecutive). Such a daily data set could also be cast in terms of monthly volumes for the monthly model. In addition, the targets at the Redlands Dam for the fish screen, ladder and migration flows could be added to the StateMod model.

Operations at the Redlands Dam should be examined with the free water right deactivated to assess the impact of shepherding storage releases to meet each of the targets at Redlands (screen, ladder, and migration).

Reservoir accounting should be analyzed closer and modified if necessary to include reasonable representation of the one-annual-fill rules and any decreed refill rights at all Aspinall reservoirs. Accounting of the Taylor Park exchange should also be included in this analysis. The analysis should either provide confirmation of current StateMod reservoir accounting methods or provide recommendations for modification to the model. The distinction between use of direct-flow rights, storage water and remaining storage capacity at any point in time may be important to potential future water banking scenario modeling, particularly with the accounting of the Aspinall hydropower direct flow rights. If annual fill and re-fill limits are modeled for the Aspinall storage water rights, inflows could be first charged to the hydropower rights to provide greater flexibility in the modeling of the storage rights, avoid paper filling the storage rights with the bypasses to hydropower, and allow a better accounting of the water supplies that remain available upstream given such accounting of the direct flow hydropower rights.

Operations of larger interstate Colorado River Basin operations could be incorporated into the StateMod model to varying degrees of detail. Since the Gunnison River is a tributary to the Colorado River, a range of options of coordination with the Colorado River StateMod model could be developed to estimate the impact on the Gunnison River if reconnaissance level scenarios of water banking for compact compliance support the detailed examination of candidate irrigation systems and storage facilities.

StateMod is not a river routing model and its daily simulation mode does not have the ability to temporally lag flows to a downstream location, meaning StateMod releases from Aspinall arrive at Whitewater on the same day. In practice, there is a lag time between Aspinall and Whitewater that can introduce some uncertainty in predicting exact timing of peak flows and coordination with North Fork flows. Although the ability to route stream flow would be a desirable attribute of a short-term

operational model, the error introduced is likely not a major factor for evaluating results from planning model such as StateMod.

3.2 Aspinall PBO/EIS Model

The Aspinall EIS model was developed in RiverWare, and is a daily timestep model that simulates reservoir operations and water diversions of the mainstem Gunnison River from Blue Mesa Reservoir to the Redlands power canal diversion. It does not include an explicit rule curve for monthly drawdowns at Aspinall but operates so as to hit storage targets at end of December (to limit upstream river icing), and at the end of April to maximize storage space for spring runoff. The operational objective for spring and early summer is to fill the reservoir around the time of peak runoff, while limiting downstream flooding at Delta. It is intended to simulate the changes in reservoir operation at the Aspinall Unit that would occur under the various alternatives considered for adoption in order to assist in the recovery of, and avoid jeopardy to, endangered fish species in the Gunnison River.

The model is used to estimate the changes resulting from proposed management alternatives to a set of indicator variables (primarily Gunnison River flows, reservoir storage and hydropower production). These changes are measured against the same variables as simulated in the model using a baseline or "no action" management option. The model uses historical forecasts and actual snowmelt runoff records to determine year types and set targets for downstream flows for the endangered fish recovery program. The policies simulated includes operational objectives for peaking flows, shoulder flows (bankfull and half-bankfull), and base flows at Whitewater and minimum flows at the Redlands diversion dam. The EIS model attempts to meet the Whitewater shoulder and peak targets as part of its operational ruleset. However, the model does not explicitly represent the Black Canyon decree and its associated shoulder and peak flow targets. The baseline model does include a 300 cfs minimum flow target through Black Canyon, as that operation was active prior to the Black Canyon decree. There is an extensive discussion of these operational issues in section 3.3.1.2c of the EIS.

Based on comments received for the draft version of the Final EIS for Aspinall, Reclamation staff (Erik Knight, Grand Junction Area Office) performed additional analyses of the baseline (no-action) and preferred alternative results derived from this model. The original baseline model included a minimum flow of 300 cfs through the Black Canyon, but it did not include the shoulder and peak flows that are part of the decree. The recent analysis evaluated in more detail the expected changes in water operations at Aspinall if the terms of the Black Canyon decree were implemented and included in both scenarios. That analysis showed that when including the Black Canyon decree in the baseline, as part of baseline Aspinall operations to meet downstream water right demands, the amount of additional flows from Aspinall required to meet the endangered fish flow targets was reduced. This result is consistent with our understanding of the Black Canyon decree and the endangered fish flow targets, and reflects the fact that these two different water management objectives have some commonality in the magnitude and timing of their flow requirements.

It is important to understand that the Aspinall EIS model was designed specifically to evaluate incremental impacts of operational changes proposed within the EIS process, and not as a tool to evaluate water rights administration and accounting. Significant simplifying assumptions are made in

the model with respect to hydrology, water rights administration and accounting, water user diversions and consumptive use, and tributary diversions and inflows. In addition, the Black Canyon decree is not fully represented in the model ruleset, and its impacts are only evaluated via a post-processing of the model alternative's outputs.

3.3 CRSS

CRSS is Reclamation's long-term planning and policy model for the Colorado River Basin. Originally developed by Reclamation in the early 1970s as a Fortran-based modeling system, CRSS was implemented in the RiverWare modeling framework in the mid-1990s with the same spatial and temporal resolution, basic input data, and physical process algorithms as the original CRSS. A set of operational rules was also developed to mimic the policies contained in the original model. Since then, CRSS has undergone constant development and enhancements to reflect current operational policy as well as investigating and improving, where necessary, the physical process methodologies being simulated.

CRSS is used to project possible future river and reservoir system conditions, on a monthly time-step, multiple decades into the future. The basis of the simulation is a mass balance (or water budget) approach that accounts for water entering the system, e.g., natural inflows, water leaving the system, e.g., consumptive use and evaporation, and water moving through the system, i.e. either stored in reservoirs or flowing in river reaches.

Input data required for model simulation include physical process parameters, inflow hydrology, and future diversion and depletion schedules for entities in the United States and Mexico. In addition, assumptions regarding mainstream reservoir operations, particularly for Lake Powell and Lake Mead, are also provided as input to describe how water is released and delivered under various hydrologic conditions. Although these data are generally the best available, there are several sources of uncertainty associated with model input, especially when simulating system conditions over several decades. Data uncertainty limits the absolute accuracy of the model; consequently, CRSS is not used to predict future system conditions, but rather to project possible outcomes over a range of hydrologic conditions.

As currently configured, CRSS does not include capabilities to simulate allocation of water by priority administration of water rights, nor does it provide any significant capacity to account for different water "ownership". Hence representation of exchanges, shepherding of releases to specific target locations, and water bank accounting are not possible. While CRSS in its present form is not capable of simulating the water rights components that are likely needed for water banking alternatives, it may still be useful in providing information about compact deliveries and/or shortfalls from basin-wide simulations which could form the boundary conditions for simulations by StateMod within the Gunnison basin.

24-Month model and Mid-Term Operations Model

The 24-month study is also a monthly RiverWare model of the Colorado River Basin. It simulates a 24-30 month horizon from the present and is used to look at mid-term planning for anticipated demands, reservoir operations such as generator outages and power generation, and forecasting of reservoir elevations. It could not address the water rights accounting issues that may be posed by a second level

examination of water banking, but is important to mention because Reclamation rules for the new Aspinall unit operations are likely to be implemented in this model once the ROD for the Aspinall EIS is released.

Aspinall Unit Representation

All of the current monthly RiverWare models represent Aspinall operations via storage curves that specify end-of-month storage targets for Blue Mesa (Table; live storage shown in table does not include 111,200 AF of dead storage). This curve represents the desired maximum active storage in Blue Mesa at the end of each month (does not include flood pool or dead storage). Ability of Reclamation (and the models) to meet these guide curves are constrained by hydrologic conditions and flood control limitations.

Blue Mesa Reservoir - Base Rule Curve	
Month	Target Maximum Storage (AF)
January	570,000
February	560,000
March	550,000
April	650,000
May	700,000
June	800,000
July	829,000
August	800,000
September	745,000
October	690,000
November	635,000
December	581,000

3.4 Conclusions and Recommendations

Our analysis of these modeling tools has focused on the ability of each model platform to simulate a water-banking option at Aspinall and to simulate Aspinall operations with the new EIS/PBO requirements and Black Canyon water right in place. The key model functionality required to achieve these objectives includes: the ability to identify the storage space available at Aspinall for creating and administering water bank account(s) given all other water rights and operational commitments; the ability to track the supply of environmental water and its delivery to specific target locations; and the ability to simulate all of these with different input hydrology and demand scenarios. Our review of the models currently available indicates that StateMod is the best option for implementing and testing various banking options within the Gunnison basin if reconnaissance level scenarios of water banking for compact compliance support the detailed examination of candidate irrigation systems and storage facilities.

We recommend the following next steps:

1) Lay out how strict administration of the Gunnison River water rights would look (including Aspinall hydropower, one-annual fill administration, and the Taylor Park exchange accounting within the model) and how this administration could work with a water bank in place in Aspinall.

2) Develop a simple StateMod network to understand the details of the one-annual-fill accounting and use accounting of direct and storage rights when reservoir releases make 'free water' available. This would provide some valuable insight into the steps required to reasonably simulate water bank accounting with StateMod.

3) Consult with the Water Banking Technical Group and Basin Roundtables regarding our analysis and observations.

4.0 References

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5.0 Water Project Decrees

Project		Water Right Case No.	
Gunnison Tunnel/Uncompahgre Project			
	Gunnison Tunnel	C.A. 1745; 07CW193 (last diligence decree)	
	Taylor Park Reservoir – First Fill	C.A. 2021 ; 84CW188 (cancellation of hydropower right)	
	Taylor Park Reservoir – Second Fill	86CW203	
	Blue Mesa/Taylor Park Exchange	90CW164 (pending)	
UVWUA Uncompahgre River Native Water Rights		Various	
Aspinall Unit		Water District 59	Water District 62
	Blue Mesa Reservoir	CA5782	CA6981
	Blue Mesa Reservoir refill	CA5782	CA10045
	Blue Mesa Power Plant	CA5590, 84CW93; 84CW266; CA5782; 84CW267 (Cancellation of hydropower right)	CA6981; CA10045
	Morrow Point Reservoir	CA5782	CA6981; CA10045
	Morrow Point Power Plant	CA5782	CA6981; CA10045
	Crystal Reservoir	CA5782	CA6981; CA10045
	Crystal Power Plant	CA5782	CA10045
	Transfer between reservoirs	CA 10045	
	Combined final absolute decrees	W-61, 80CW156	
Upper Gunnison Subordination Agreement – UGRWCD		03CW263	
Redlands Power Canal		CA1927, CA8303; 94CW228; 04CW15	
Silverjack Reservoir		CA6981, W2514 (abandoned)	
NPS Black Canyon Reserved Right		01CW5	