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208 Hearing

Thursday, July 27, 2017
Town Hall
Grand Lake, CO

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PUBLIC NOTICE

Thursday, July 27, 2017

Community House
Grand Lake, CO
10:00 a.m. – 3:30 p.m.

NWCCOG COUNCIL MEETING

The Northwest Colorado Council of Governments (NWCCOG) will hold a rulemaking hearing to consider a request to amend the Regional Water Quality Management Plan (208 Plan) to recommend designation of Grand Lake as an Outstanding Water, as defined at 5 CCR 1002-31.6(47). The hearing is at 10:00 a.m., July 27, 2017 at the Community House, Town of Grand Lake.

Written comments are encouraged. If any individual or entity would like to make a presentation or has detailed comments on this matter you may request party status. Written comments and requests for party status should be emailed to Lane Wyatt at qqlane@nwccog.org and must be received by 5:00 pm on July 7. Limited public comments will also be taken at the hearing. Additional information is available at www.nwccog-qq.org.

The current 2012 Regional Water Quality Management Plan (208 Plan) can be found on the Northwest Colorado Council of Governments website: http://nwccog.org/programs/watershed-services/.

BEFORE THE NORTHWEST COLORADO COUNCIL OF GOVERNMENTS

RE: Hearing to Consider Proposal to Revise 208 Plan to Recommend Designation of Grand Lake as Outstanding Waters

PREHEARING ORDER July 14, 2017

Northwest Colorado Council of Governments (NWCCOG) received a request from Outstanding Grand Lake to revise the NWCCOG Regional Water Quality Management Plan to recommend designation of Grand Lake as an Outstanding Water.

A hearing has been set for July 27, 2017 at 10:00 A. M., Community House, Grand Lake, Colorado.

Notice has been sent to interested jurisdictions and organizations and published in newspapers in the NWCCOG region.

A. PARTIES TO THE PROCEEDINGS

1. Party Status. Requests for Party Status were received from and **granted** for the following parties:

Outstanding Grand Lake Foundation
Melody Hudson
Town of Grand Lake
Grand County
Three Lakes Watershed Association
Northern Water Conservancy District
Colorado River Water Conservation District

2. Order of Party Presentation and Time Allocation

Outstanding Grand Lake Foundation - 20 min for Request and 5 min for Response to Comments
Melody Hudson – 3 min
Town of Grand Lake - 10 min
Grand County - 10 min
Three Lakes Watershed Association - 5 minutes
Northern Water Conservancy District - 20 minutes
Colorado River Water Conservation District - 5 minutes

B. FINAL HEARING ORDER OF PROCEEDINGS

- Introduction and staff report to NWCCOG Council.
- Presentation from Outstanding Grand Lake Foundation, proponents of the request.
- Questions by NWCCOG Council members.
- Presentations by Parties. (See A.2. Order of Party Presentation and Time Allocation.) NWCCOG Council members may ask questions following the presentation by any Party.
- Public comment.
- Response to party and public comment by Outstanding Grand Lake Foundation.
- Staff response and wrap-up.
- NWCCOG Council deliberation and decision.

No cross-examination is allowed during the hearing, but members of the NWCCOG Council may ask questions of any Party to the proceedings at any time.

Before the Northwest Colorado Council of Governments
Proposal to Amend the 208 Plan
July 27, 2017

STAFF REPORT

TO:	NWCCOG Council
FROM:	Lane Wyatt, Watershed Services Program
FOR:	NWCCOG hearing July 27, 2017
SUBJECT:	Proposal to amend the 208 Plan to recommend designation of Grand Lake as an Outstanding Water
APPLICANT:	Outstanding Grand Lake Foundation Represented by Samantha Bruegger, Grand Lake Chamber of Commerce
PROPOSAL:	Amend the 208 Plan to recommend designation of Grand Lake as an Outstanding Water

BACKGROUND:

The purpose of the July 27, 2017 hearing is to consider a request by the Outstanding Grand Lake Foundation to amend the NWCCOG Water Quality Management Plan, or 208 Plan, to recommend that the Colorado Water Quality Control Commission (WQCC) designate Grand Lake as and Outstanding Water.

The governor of Colorado designated NWCCOG as the Areawide Waste Treatment Management Planning Authority under Section 208, in February 1976. In that capacity, NWCCOG adopted a water quality management plan, known as the "208 Plan." http://nwccog.org/programs/watershed-services/ The 208 Plan was adopted pursuant to Section 208 of the Federal Clean Water Act as implemented through the Colorado Water Quality Control Act. The purpose of Section 208 is to require plans for coordinated regional approaches to water quality management.

The 208 Plan provides recommendations for state water quality standards and classifications, and policies for future water quality management in the region, among other things. The 208 Plan also serves as a type of master plan for water quality that counties and municipalities in the region implement through land use regulations that require consistency with the 208 Plan.

The 208 Plan is developed through the input and recommendations of member jurisdictions of NWCCOG and QQ regarding existing and desired future water quality conditions in each subbasin in the region. The 208 Plan is approved by the NWCCOG Council and presented to the Colorado Water Quality Control Commission (WQCC). When the WQCC receives a request to site wastewater treatment plants, or to change designations or classifications of waters in the state, it refers to the 208 Plan for guidance. The most recent revision to the 208 Plan was in 2012. Revisions to the 208 Plan must be made after a public hearing by the NWCCOG Council.

In regard to Grand Lake, the only specific recommendation in the NWCCOG 208 Plan, under the Policy Plan in Section 1.2, is "a water quality standard for Grand Lake that represents an attainable level of clarity." This recommendation, along with actions by NWCCOG, Grand County, the Town of Grand Lake, the Colorado River Water Conservation District and many others, has precipitated over a decade of activities to improve water clarity in Grand Lake. A critical joint commitment to improving Grand Lake water quality is embodied by the Memorandum of Understanding between NWCCOG, Grand County, the Bureau of Reclamation, Northern Water, and the River District (Clarity MOU) (see Northern Exhibit 5).

Grand Lake. Grand Lake is Colorado's largest natural lake and is located at the west entrance to Rocky Mountain National Park. It also serves as a conduit for water pumped from the Colorado River to the east slope through the federal Colorado – Big Thompson Project (C-BT). Pumping has resulted in observably diminished clarity. The C-BT is owned by the Bureau of Reclamation. Northern Water Conservancy District also pumps water through the C-BT for its end users on the east slope.

Water Quality Standards for Grand Lake. In its most recent action on this matter in May, 2016, the Colorado Water Quality Control Commission (WQCC) adopted the following narrative standard for Grand Lake clarity:

> "the highest level of clarity attainable, consistent with the exercise of established water rights, the protection of aquatic life, and protection of water quality throughout the Three Lakes system."

This narrative standard is the first and only clarity standard in Colorado. The clarity standard will be reconsidered by the WQCC in its regular review of water quality standards and classifications for the Upper Colorado River basin in 2019.

Included with this narrative standard are Goal Qualifiers that the WQCC uses to provide guidance on achieving the narrative standards. Goal Qualifiers for Grand Lake are: an average clarity of 3.8 meters and minimum clarity of 2.5 meters over the period of July 1 through September 11. Goal Qualifiers guide the adaptive management process to improve Grand Lake Clarity described in the Clarity MOU. The adaptive management process, described below, has resulted in regular communication between the MOU parties to make adjustments to C-BT operations and evaluate the relative clarity improvements of those adjustments.

Adaptive Management Process. The MOU stipulates an adaptive management process to implement operational modifications to the C-BT to try to achieve the Grand Lake clarity narrative standard while the Bureau of Reclamation conducts a NEPA process to evaluate structural and operational alternatives to improve clarity in Grand Lake. The adaptive management process outlines a specific approach, committee membership, and timelines. The adaptive management committee is required to:

- Prepare an annual operational plan for the Colorado Big Thompson project with the objective of improving Grand Lake clarity.
- Provide for regular monitoring of water quality indicators in both Grand Lake and Shadow Mountain Reservoir.
- Establish a system of weekly communication to discuss current water quality conditions and potentially make recommendations to the Bureau of Reclamation on changes in operation to benefit Grand Lake clarity.
- Maintain records of weekly discussions and develop an annual summary report which will be provided to the Water Quality Control Commission

Bureau of Reclamation NEPA Process. In response to concerns raised by Grand County, the Town of Grand Lake, Three Lakes Watershed Association, Northern Water, Colorado River Water Conservation District, NWCCOG-QQ and other parties, the Bureau of Reclamation has initiated a NEPA evaluation of both structural and operational alternatives that may improve clarity in Grand Lake. The ongoing adaptive management process will inform the operational component of the alternatives being considered, as well as improve clarity in Grand Lake.

COLORADO WATER BODY CLASSIFICATIONS AND DESIGNATIONS

Outstanding Grand Lake Foundation, (OGLF), the proponent of amending the 208 Plan, ultimately wants the WQCC to revise the water quality designation for Grand Lake to Outstanding Waters. The current water quality designation for Grand Lake is Reviewable Water. Reviewable Waters are subject to the WQCC's antidegradation review process, as explained below.

Outstanding Waters designation is part of a broader regulatory scheme of water quality standards and classifications established by federal and state law. First, all waters must be classified based on the uses that they can support (called "classifications" or "classified uses" in Colorado, 5 CCR 1002-31). Two examples of use classifications are water supply, and cold water fisheries. Second, waters are assigned numeric and/or narrative standards to protect those classified uses. Third, waters are designated, based on their assimilative capacity, to establish whether they can be degraded or whether they must be kept at existing levels to protect the classified uses ("antidegradation designation").

Under the WQCC regulations, there are three levels of antidegradation protection: use-protected, reviewable, and outstanding waters. The level of water quality protection is designated by the Water Quality Control Commission pursuant to a rulemaking process and public hearing.

1. Use-Protected Designation. This minimum level of water quality protection applies to all state waters and requires that all existing classified uses of waters be protected. The Clean Water Act and Colorado regulations require that "existing classified uses and the level of water quality necessary to protect such uses shall be maintained and protected".

Permitted dischargers are in compliance with this requirement if they do not cause an exceedance of the numeric and narrative water quality standards in receiving waters. 5 CCR 1002-31.8 (1)(c).

2. Reviewable Waters. Grand Lake currently falls into this intermediate level of protection that applies to any water that is not use protected or classified as an Outstanding Water. In this intermediate category, waters "must be maintained and protected in their existing quality unless it is determined that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located." Before any new or increased water quality impacts are allowed in these waters from a "regulated activity", such as a point source discharge under Section 402 or 404 of the Clean Water Act, the Water Quality Control Division (WQCD) applies an anti-degradation review. Antidegradation review takes into account whether the degradation is "significant," and if yes, whether the degradation "is necessary to accommodate important economic or social development in the area in which the waters are located." Colorado's antidegradation regulation establishes a process for determining whether the degradation is "significant" and whether the degradation is "necessary." This process limits degradation to 15% of the increment between current water quality and the pertinent water quality standard, for example. 5 CCR 1002-31.8 (3).

3. Outstanding Waters. Outstanding Waters designation requires the highest level of water quality protection. These waters "shall be maintained and protected at their existing quality" without exception. This means that any "regulated activity" cannot cause degradation of the existing water quality except for short-term degradation "for activities that result in long-term ecological or water quality benefit or clear public interest." No permanent increase in pollutants or pollution loads is permissible. 5 CCR 1002-31.8 (1)(a).

Criteria for Outstanding Waters Designation - Any person may propose a water segment to the WQCC for designation as an Outstanding Water, either during the triennial review of water quality standards, or at any time. As part of a public rulemaking process, the WQCC may designate waters as Outstanding Waters only if three criteria are met. These criteria for designating Outstanding Waters are:

1. [E]xisting quality for [12 listed] parameters is equal to or better than that specified in tables I, II, and III for the protection of aquatic life class 1, recreation class P and (for nitrate) domestic water supply uses. Parameters include dissolved oxygen, pH, *E. coli,* chronic ammonia, nitrate, chronic cadmium, chronic copper, chronic lead, chronic manganese, chronic selenium, chronic silver, and chronic zinc. 5 CCR 1002-31.8 (2)(a)(i).

2. The waters constitute an outstanding natural resource, based on the following:

A. The waters are a significant attribute of a State Gold Medal Trout Fishery, a National Park, National Monument, National Wildlife Refuge, or a designated Wilderness Area, or are part of a designated wild river under the Federal Wild and Scenic Rivers Act; or

B. . The Commission determines that the waters have exceptional recreational or ecological significance, and have not been modified by human activities in a manner that substantially detracts from their value as a natural resource. 5 CCR 1002-31.8(2)(a)(ii)(A-B)

3. The water requires protection in addition to that provided by the combination of water quality classifications and standards and the protection afforded reviewable water under section 31.8(3). 5 CCR 1002-31.8(2)(a)(iii).

REQUEST TO DESIGNATE GRAND LAKE, NOTICE, AND HEARING

NWCCOG learned in January 2017 from the WQCD that a group made inquiries about designating Grand Lake as an Outstanding Water. At the March 2, 2017 QQ meeting representatives OGLF provided an overview of the Foundation and proposed that NWCCOG amend its 208 Plan to recommend to the WQCC designation of Grand Lake as an Outstanding Water. A letter was sent by NWCCCOG to OGLF to clarify their intent on March 3, 2017 (Attachment 1). OGLF then followed up with a written request on April 17, 2017 (Attachment 2). In the meantime, the Grand County BOCC held a public workshop on this matter on April 11th. The Town of Grand Lake also heard a proposal by the Grand Lake Chamber of Commerce for OW designation, most recently on June 26, 2017, and supported this request (Attachment 3). There has also been on-going communications between OGLF and NWCCOG on this topic.

A public hearing is required for the NWCCOG Council to amend the 208 Plan. A hearing provides the Council with an opportunity to review the proposal, get the necessary background on the 208 Plan, state stream designations, and other pertinent information. In addition, the hearing will allow NWCCOG to get direct input from stakeholders and the public in order to make a well-informed decision based on a solid record of evidence. Based on that evidence, NWCCOG must determine whether the proposed designation satisfies the designation criteria, and whether amending the 208 Plan to recommend designation of Grand Lake as Outstanding Waters will further regional water quality objectives of the 208 Plan.

Public notice for the July 27 NWCCOG hearing was place in the Middle Park Times and Sky-Hi News the week of June 19, 2017. Notice was also provided directly to the following individuals and entities:

Outstanding Grand Lake Foundation - Samantha Bruegger, Geoff Elliot, Ken Fusik
Grand County - BOCC, Ed Moyer, Lee Staab, Katherine Morris
Town of Grand Lake - Jim White
River District – Jason Turner, Peter Fleming, Mike Eytel
Northern Water - Jeff Drager, Esther Vincent, Jen Stephenson, Peter Nichols

Bureau of Reclamation – Signe Snortland
WQCD - Nicole Rowen, John Hranac, Blake Beyea
Colo Parks and Wildlife - Jon Ewert
GCWIN - Kayli Foulk
Three Lakes Water and Sanitation District
Winter Park WSD - Mike Wageck
Grand County #1 WSD - Bruce Hutchins
Fraser WWTP - Jeff Durbin, Joe Fuqua
Granby Sanitation District – Tammy Granger
Middle Park Water Conservancy District – Stan Cazier

In Response to the Notice, we have received written comments and requests for party status to provide time to make presentations or statements from the following entities (in addition to OGLF, the proponent of the proposal to recommend Outstanding Waters designation for Grand Lake).
:
Outstanding Grand Lake Foundation (Attachment 4)
Grand County (Attachment 5)
Town of Grand Lake (Attachment 3)
Three Lakes Watershed Association (Attachment 6)
The River District (Attachment 7)
Bureau of Reclamation (did not request time for a presentation) (Attachment 8)
Melody Hudson, concerned citizen (Attachment 9)
Northern Water (Attachment 10)

In addition, we anticipate there will be requests to comment from the public. All requests for party status are granted.

STAFF EVALUATION OF EVIDENCE RE: COMPLIANCE WITH STANDARDS FOR DESIGNATION

NWCCOG staff has reviewed the WQCC criteria for Outstanding Waters designation, the information submitted by parties, and have provided findings in *italics* as to whether the OGLF proposal complies. A water body proposed for Outstanding Waters designation must comply with all three criteria:

1. [E]xisting quality for [12 listed] parameters is equal to or better than that specified in tables I, II, and III for the protection of aquatic life class 1, recreation class P and (for nitrate) domestic water supply uses. . . 5 CCR 1002-31.8 (2)(a)(i). Parameters include dissolved oxygen, pH, *E. coli,* chronic ammonia, nitrate, chronic cadmium, chronic copper, chronic lead, chronic manganese, chronic selenium, chronic silver, and chronic zinc.

WQCD. NWCCOG referred this question of existing water quality to comply with the OW criteria to the Water Quality Control Division (WQCD). They provided three files (Attachment 11) that are representative of water quality of Grand Lake. For natural lakes the WQCD indicated it tries to characterize water quality near the deepest part of the lake. Two of their files are from at the top in the center of the lake and one from the bottom. The top ones were sampled by Northern and the USGS. The results show Grand Lake meets the 12 parameter test in the upper portion of the water column. The WQCD assessment of both USGS and Northern data also shows the Arsenic standard and the water supply standard for manganese are exceeded but this is not relevant to OW determination as neither are one of the 12 parameters assessed to determine eligibility for OW designation.

Note that the WQCD analysis at the Grand Lake mid-station uses Northern's data but only considers two years of data. WQCD requires the last five years of data to determine current conditions therefore these results, although useful, are not fully compliant with their own assessment protocol.

Northern analyzed its data at the Mid-station, but included the most recent five year period (2012-2016) and both the upper and lower portions of the lake. In their assessment of this data (see Northern Exhibit 1) Northern found existing water quality was less (worse) than the water quality standard for both manganese and pH near the bottom of the lake. Dissolved oxygen also exceeded the standard at the sample site near the connecting boat channel to Shadow Mountain Reservoir.

OGLF also looked at Northern's data and concluded that existing water quality is better than standards for the 12 parameters required for designating OW, except E.coli. , see Attachment 4

The WQCD, Northern, and OGLF all recognize that there is no data for E. coli, one of the required 12 parameters for OW designation. However, it would be surprising if E. coli was an issue in the center of the lake given no wastewater discharge and limited untreated stormwater that may bring bacteria from pet waste or other sources.

Bureau of Reclamation indicates that temperatures at the surface of Grand Lake often exceed the chronic water quality standard (temperature is not one of the 12 WQCC parameters that must be met of designation as OW). and is concerned that OW designation because it could potentially interfere with Reclamation's ability to meet the primary purposes of C-BT as outlined in Senate Document 80.

Grand County supports OGLF's efforts to protect Grand Lake and prevent further degradation of water quality. Grand County is concerned OW may disrupt the current cooperative efforts and progress to improve Grand Lake as embodied in the Clarity MOU and the NEPA alternatives analysis and may create an additional regulatory burden on some Grand County communities, and so does not "wholly embrace" the proposal for OW designation.

Three Lakes Watershed Association does not support the proposal as there is potential for unintended consequences, particularly in regard to land use and property rights, and the potential derailment of current cooperative progress in improving Grand Lake clarity.

Finding. With regard to the criteria that existing water quality is better than water quality standards for the 12 parameters, these data analysis results submitted are conflicting and a little ambiguous. The difference in results appears to be whether one considers the top of the lake *separately from the bottom, with Northern finding exceedances in the bottom few meters of the lake for pH and manganese. It is not uncommon for deeper lakes to have pH and dissolved manganese problems near the bottom as they are effected by the seasonally reduced dissolved oxygen concentrations when a lake becomes temperature stratified. The conclusion though is that existing water quality at the bottom of the lake does not meet the 12 parameter test where the top does comply.*

2. The waters constitute an outstanding natural resource, based on the following:

   A. The waters are a significant attribute of a State Gold Medal Trout Fishery, a National Park, National Monument, National Wildlife Refuge, or a designated Wilderness Area, or are part of a designated wild river under the Federal Wild and Scenic Rivers Act; or

Northern and the Bureau of Reclamation maintain that this criterion has not been satisfied because Grand Lake does not have federal or state designation as a State Park or wildlife area, Gold Medal fishery, National Park or Monument, or Wilderness Area.

OGLF points out that Grand Lake is a defining attribute of Rocky Mountain National Park.

Finding – Grand Lake is not part of any of these designated areas, as Northern and the Bureau of Reclamation point out. However, it is clearly a significant attribute of Rocky Mountain National Park and also abuts the Arapahoe National Recreation Area. Therefore, it does meet this sub-criteria.

   B. The WQCC determines that the waters have exceptional recreational or ecological significance, and have not been modified by human activities in a manner that substantially detracts from their value as a natural resource.

OGLF describes in some detail Grand Lake's role in providing exceptional recreational experiences to visitors and residents.

Grand County concurs with OGLF that Grand Lake is essential to the thriving business economy which includes recreation, and applauds their efforts to protect Grand Lake.

Northern recognizes Grand Lake's recreational importance although questions whether it is "exceptional". Northern points to their Exhibit 2 to document that the aquatic ecology of Grand Lake has been significantly altered.

Bureau of Reclamation states that fishing and recreational values are protected under the authorizing legislation of the C-BT project, therefore designation of Grand Lake as OW is unnecessary.

Finding – Grand Lake does have exceptional recreational significance. NWCCOG, Grand County and others made this point to the WQCC as part of the rulemaking proceeding for the clarity standard. C-BT features do alter Grand Lake with the Adams tunnel inlet, which is located below the surface in Grand Lake, and the connecting channel to Shadow Mountain Reservoir where pumped water enters Grand Lake. In spite of these features, lake levels are held relatively constant and these C-BT features do not detract from the Grand Lakes value as a natural resource. However, C-BT pumping does noticeably degrade the clarity of Grand Lake and detracts from its aesthetic and recreational experience, as has been pointed out by citizens and the stakeholders working to improve clarity. Other modifications from a natural, undisturbed lake include shore line development and docks that provide access to the lake itself. This development promotes human activities intended to enjoy Grand Lake's recreational and aesthetic value.

Grand Lake's ecological significance lies primarily in its geology as Colorado's largest natural lake and its remarkable location. The aquatic ecosystem has been modified through the introduction of several aquatic species and the surrounding riparian areas are typical of this altitude and have been altered by human activity in the form of development. Some of the modifications promote Grand Lake's value as an exceptional recreational natural resource rather than substantially detract from its value as such. However, Grand Lake could not be considered to have exceptional ecological significance, and it is arguable that the impact of C-BT pumping detracts from its value as having exceptional recreational significance unaltered by human activities, as required by this criteria.

3. The water requires protection in addition to that provided by the combination of water quality classifications and standards and the protection afforded reviewable water under section 31.8(3).

<u>OGLF</u> points out that most designated OW are located in headwater areas, like Grand Lake, and so face few if any threats. Grand Lake has had a blue-green algae bloom requiring a health alert. Pumping also may introduce arsenic. Unlike other OW areas the source of these threats comes from downstream due to pumping.

<u>Grand County and Three Lakes Watershed Association</u> recognize Grand Lake's need for additional protection as the motivation for seeking a clarity standard.

<u>Northern</u> points out the unique level of protections in place through binding agreements (Northern Exhibit s 4 and 5). Northern believes the primary concern in Grand Lake is clarity and these protections are sufficient and that OW designation will complicate these efforts to improve clarity. Another complication for OW designation is depicting the existing condition to protect because annual hydrologic conditions vary significantly and these variations effect both natural water quality in Grand Lake and the operations of C-BT.

Bureau of Reclamation suggests that there is no existing or imminent threat to the water quality and values that can be regulated or protected by OW designation.

Finding – Grand Lake clarity is threatened by the operations of the Colorado-Big Thompson Project. Water from Shadow Mountain Reservoir which is laden with particles from a variety of sources is moved into Grand Lake when pumping occurs. This is the primary water quality issue impacting water clarity. Designation as an Outstanding Water will not trigger an anti-degradation review for the C-BT project, or Windy Gap operations, because the C-BT is not considered by the WQCC to be a point source discharge, and therefore not a "regulated activity", and the Windy Gap project already has been permitted. Therefore designation will not afford any protection from the deleterious impacts of these projects.

There are no point source dischargers into Grand Lake at this time. Wastewater is collected from the Town of Grand Lake and surrounding areas, treated and discharged into a ditch that flows to Willow Creek and eventually the Colorado River below Granby Reservoir.

The Town of Grand Lake has installed a storm water collection and treatment system to help protect the lake from pollution in runoff. Future threats to water quality in Grand Lake are largely limited to those caused by land use disturbances. Grand County and the Town of Grand Lake have regulations that protects against water quality impacts from growth and development. Grand Lake is also currently protected by the fairly rigorous anti-degradation review process afforded by its current designation as a Reviewable Water.

Threats to water quality from activities that may be regulated by OW designation are limited and very minor, and so the additional protections of OW designation does not seem justified

COMPLIANCE WITH 208 PLAN POLICIES:

The pertinent 208 Plan Policy to the issue of designating Grand Lake as an Outstanding Water is Policy 1, Protect and Enhance Water Quality, which states:

> "The surface and ground waters of the region shall be protected to minimize degradation of existing water quality and maintain existing and designated uses of those waters; waters not currently supporting designated uses shall be restored as soon as possible."

Policy 1 implementation measures recommended in 2012 "a water quality standard for Grand Lake that represents an attainable level of clarity", but does not recommend any additional waterbodies to be designated as Outstanding Waters.

The Plan makes clear that NWCCOG should pursue water quality improvement wherever possible and provides a list of impaired water bodies needing attention and specific watershed protection projects NWCCOG supports.

Designation of Grand Lake as an Outstanding Water is not inconsistent with the goals and policies of the 208 Plan, however it is not specifically endorsed. The 208 Plan recommends

NWCCOG consult with designated management agencies in recommending selected revisions to these standards at triennial reviews and rule making hearings scheduled by the Commission. The July 27, 2017 NWCCOG hearing on OGLF' proposal for Grand Lake is in accord with this recommendation.

CONSIDERATIONS

To assist the NWCCOG Council on deliberations on this request to amend the 208 Plan to recommend Outstanding Water designation for Grand Lake the following summarizes some key considerations:

- Within the NWCCOG region there are 15 stream segments designated as Outstanding Waters. A designated stream "segment" may include all tributaries or multiple streams in a geographic area, for example all streams in the Ptarmigan Wilderness area are a single segment. Of these 15 segments 11 are located in wilderness areas. Four additional segments designated Outstanding Waters are not in wilderness area, but located entirely on federal land.

- The Grand Lake clarity standard resulted in years of collaboration, technical assessments, and trust-building to look at ways to improve Grand Lake water quality. These efforts have significantly expanded the understanding of the complexities of the Three Lakes system (see for example Northern Exhibit 7) and involve the primary entities that have the ability to improve Grand Lake water quality. Key to these efforts is the commitment of the Bureau of Reclamation, which has not been subject to any water quality regulations, and Northern, to participate and provide funding. Both the Bureau and Northern are opposed to OW designation because of the uncertainties it brings to meeting their primary missions, but also to the existing efforts to improve Grand Lake clarity.

  Grand County and many other stakeholders invoked the protections afforded to Grand Lake by Senate Document 80, the federal authorization for the C-BT, as the basis for the need to address Grand Lake clarity. These efforts have prompted the Bureau of Reclamation to promise to improve Grand Lake clarity and study alternatives to do so. The NEPA alternatives analysis is well-underway.

  If the lake is designated as an Outstanding Water, the non-degradation standard would apply to any structural alternatives, such as dredging Shadow Mountain Reservoir or a Grand Lake bypass, that are likely to require a Corps of Engineer's 404 permit and a 401 Certification by the WQCD. Before permits could be issued, the Bureau of Reclamation would have to prove that the project would not increase pollutants or loading to Grand Lake for any water quality parameter. Temporary impacts from the project would be allowed for "activities that result in long term ecological or water quality benefit or clear public interest." 5 CCR 1002-31.8 (1)(a). Examples of temporary impacts include elimination of invasive species; construction of fish barriers to prevent the spread of non-native species; construction of bridges at stream crossing to minimize damage to the stream and improve water quality; or construction of aquatic habitat improvement.

- Reclamation and Northern are concerned that this additional layer of potential regulation will raise a host of legal and technical issues that will complicate or stall the entire effort to improve Grand Lake clarity because of the precedent it will set for other federal projects. Reclamation indicated that OW designation could potentially interfere with Reclamation's ability to meet the primary purposes of C-BT as outlined in Senate Document 80

- Any development or construction that involves disturbance of one acre or more requires a WQCD storm water permit for construction activities. The WQCD has indicated that if the lake is designated as an Outstanding Water, no additional runoff from increased impervious areas could leave a development site. Other restrictions like water quality monitoring may be imposed. Both the Town of Grand Lake's comprehensive plan and the Grand County Master Plan encourage redevelopment around Grand Lake. The County designated the area around the three lakes as a growth area (see map on p. 56). The Town desires "quality, controlled and smart growth along the Highway 34 corridor and to avoid 'leapfrog' growth conditions." (page 16). The Town's comprehensive plan also specifically mentions redevelopment and possible annexation opportunities. According to the WQCD development of any property that drains to Grand Lake and requires a stormwater permit for erosion during construction is likely to have more onerous permit requirements if it is designated as OW.

- There is uncertainty regarding the effect on a permitted wastewater facility whose effluent is discharged downstream of Grand Lake, but is pumped back into the lake when the C-BT is operating. The Outstanding Waters prohibition on new pollutants or increase in pollutant loads could limit the facility's ability to expand to accommodate new growth. In conversations with the WQCD, staff describes the current permitting situation as measuring attainment 5 miles downstream. They are uncertain how this situation would change if Grand Lake were designated OW.

STAFF RECOMMENDATION:

Staff recommends that the NWCCOG Council delay action on this proposal until Bureau of Reclamation analysis of alternatives is complete and it is determined whether any of these alternatives will be implemented. The water quality conditions for the 12 parameter test should be re-evaluated then to see if it complies.

Evidence provided demonstrates that compliance with the WQCC's three requirements for designation of Grand Lake as an Outstanding Water is subject to interpretation. Staff concludes that the most significant issue associated with this proposal is how it may interfere, complicate, or disrupt the progress and goodwill developed to improve clarity through operational opportunities (as outlined in the clarity MOU process) and the Bureau's NEPA evaluation of structural and operational alternatives. These initiatives should be complete before the WQCC reconsiders of the current clarity standard and the OGLF will propose OW designation of Grand Lake to the WQCC.

Staff recognizes and applauds OGLF's efforts to protect water quality, implement watershed protection measures and enthusiasm to promote watershed awareness.

Attachment 1

P.O. Box 2308 • Northwest Colorado COUNCIL OF GOVERNMENTS 970-468-0295 • Fax 970-
WATER QUALITY / QUANTITY COMMITTEE

March 3, 2017

Dear Outstanding Grand Lake Coalition,

I understand that the Outstanding Grand Lake Coalition ("Coalition") plans to request that the Water Quality Control Commission (WQCC) designate Grand Lake as Outstanding Natural Resource Waters, often referred to as Outstanding Waters. Northwest Colorado Council of Governments ("NWCCOG") is the designated management agency for Region 12, which includes Grand Lake, and the agency responsible for the regional water quality plan ("208 Plan"). We want to make sure the Coalition understands that at this time, an Outstanding Waters designation for Grand Lake is not consistent with the 208 Plan.

The 208 Plan, adopted pursuant to Section 208 of the federal Clean Water Act, and Section 25-8-203 of the Colorado Water Quality Control Act, functions as a master plan for water quality management in Region 12. It provides demographic information, descriptions of wastewater treatment facilities, summaries of transmountain diversions, recommendations for State water quality standards and classifications, and an overview of the Region's water quality. It also provides policy recommendations for future water quality management in the region. Consistency with the 208 Plan is a primary consideration when the WQCC evaluates proposed changes to water quality classifications, standards, and designations.

The 208 Plan states that "NWCCOG does not currently recommend any additional waterbodies to the list of 'Outstanding Waters' designation."[1] For an Outstanding Waters designation proposal to be consistent with the 208 Plan, NWCCOG would need to amend the 208 Plan. The Coalition may initiate a 208 Plan amendment at any time by sending me a letter. I will then work to schedule a time for a hearing with proper notice before the NWCCOG board.

At this time, I have some question as to the impact a designation would have on local Grand County dischargers, potential additional storm water requirements, and existing agreements regarding improved clarity in Grand Lake. It may be helpful for us to discuss these questions before you request a 208 Plan amendment.

[1] 2012 Upper Colorado River Water Quality Management Plan, C-40, available at http://nwccog.org/wp-content/uploads/2015/04/Upper-Colorado-Watershed-2012-208-Plan.pdf.

Please let me know if this is something the group would like to request, and I am happy to talk with you at any time.

Sincerely,

Lane Wyatt, 208 Administrator

CC:

Grand County BOCC, c/o Ed Moyer
Jim White, Town of Grand Lake
Ken Fucik, Outstanding Grand Lake Coalition member
Samantha Brugger, Grand Lake Chamber of Commerce Executive Director and Outstanding Grand Lake Coalition member
Samantha Miller, Outstanding Grand Lake Coalition member
Geoff Elliot, Grand Environmental and Outstanding Grand Lake Coalition member
Jon Stavney, Executive Director, NWCCOG
Barbara Green, counsel, NWCCOG and QQ
Torie Jarvis, Staff Attorney, NWCCOG/ QQ

Attachment 2

Grand Lake Chamber of Commerce
970.627.3402
www.grandlakechamber.com

Dear Northwest Colorado Council of Governments,

Grand Lake is a unique natural resource that has contributed to Colorado's recreation and tourism industry for over 100 years. Sitting at the western entrance to Rocky Mountain National Park, it contributes to attracting hundreds of thousands of visitors to this area annually. Because of its uniqueness as the largest and deepest natural lake in Colorado, the exceptional recreation and tourism it provides, and its heritage as the headwaters to one of the most important rivers in the western United States, Grand Lake is deserving of designation as an Outstanding Resource Water for Colorado. As such, it is requested that the Northwest Colorado Council of Governments authorize designation of Grand Lake as an Outstanding Water in a revision to the 208 Water Quality Management Plan.

Warmest Regards,

Samantha Bruegger
Grand Lake Chamber of Commerce/ Outstanding Grand Lake Foundation

Attachment 3

TOWN OF
GRAND LAKE

October 11, 2016

Vice Chairman David Baumgarten
Colorado Water Quality Control Commission
Colorado Department of Public Health and Environment
4300 Cherry Creek Drive South, A-5
Denver, CO 80246

RE: Outstanding Grand Lake

Dear Vice Chairman Baumgarten,

The Grand Lake Town Trustees support Grand Lake Chamber of Commerce efforts to secure Outstanding National Resource Water (ONRW) designation for Grand Lake as a marketing effort to recognize and promote our outstanding aesthetic and recreational values worldwide.

Grand Lake is Colorado's largest and deepest natural lake and fed by headwater streams flowing from Rocky Mountain National Park. For over 100 years Grand Lake it has been a magnet for visitors from around the world attracted to its outstanding natural beauty, ecological value, and recreation opportunities. Grand Lake is, in fact, the heart of our local economy with generations of Colorado families drawn to the lake to enjoy its communion of water, blue sky and majestic mountains. As the headwater of the Colorado River, Grand Lake history is interwoven with the American West, contributing to our remarkable state heritage.

We look forward to partnering with our Grand Lake Chamber and the Colorado Water Quality Control Commission to secure this ONRW designation recognizing Grand Lake's inherent beauty and the bountiful recreation to the World."

Thank you,

Jim Peterson, Mayor of Grand Lake

Distribution:

- Samantha Bruegger, Grand Lake Chamber of Commerce
- Jim White, Grand Lake Town Manager

P.O. BOX 99, GRAND LAKE, COLORADO 80447-0099
PH. 970/627-3435
FAX 970/627-9290
E-MAIL town@townofgrandlake.com

Attachment 4

A STATEMENT OF BASIS FOR DESIGNATING GRAND LAKE AS AN OUTSTANDING WATER PURSUANT TO 5 CCR 1002-31.8(2)(a)

Northwest Colorado Council of Governments

Public Hearing: July 27, 2017, 10:00 a.m.

Presented By

Outstanding Grand Lake Foundation

The Outstanding Grand Lake Foundation (OGLF) would like to extend our gratitude for the opportunity to request to amend the Regional Water Quality Management Plan (208 Plan) to recommend designation of Grand Lake as an Outstanding Water by the Colorado Water Quality Control Commission. At this time, OGLF represents the voices of nearly 2,000 supporters, including the Town of Grand Lake, the neighboring Grand Lake community of Columbine Lake, Infinite West, the Colorado Headwaters Land Trust, Shadowcliff, and hundreds of individual citizens.

OGLF is the 501(c)(3) foundation of the Grand Lake Chamber of Commerce, established *"to promote sustainable development through environmental education & eco-tourism, while recognizing that a healthy lake is correlative with a thriving business community."* OGLF is managed by a formal Board of Directors, which include business owners, lakefront home owners, educators and scientists. The foundation requests the amendment to the 208 Plan as an important step in the Outstanding Waters hearing process, as defined by the state.

The requirements to be considered an Outstanding Water are contained in **REGULATION NO. 31 - THE BASIC STANDARDS AND METHODOLOGIES FOR SURFACE WATER** and specifically **5 CCR 1002-31.8(2)(a).** The designation as an Outstanding Water requires compliance with three provisions which in the case of Grand Lake includes (1) meeting certain water quality parameters, (2) having exceptional recreational or ecological significance, and has not been modified by human activities in a manner that substantially detracts from their value as a natural resource, and (3) requiring protection in addition to that provided by the combination of water quality classifications and standards and the protection afforded reviewable water under section 31.8(3). That Grand Lake meets these requirements to be designated an Outstanding Water is clearly demonstrated below.

WATER QUALITY OF GRAND LAKE

Water Quality requirements to meet Outstanding Water designation are defined in 31.8(2)(a)(i):

The existing quality for each of the following parameters is equal to or better than that specified in tables I, II, and III for the protection of aquatic life class 1, recreation class P and (for nitrate) domestic water supply uses:

- *Table I: dissolved oxygen, pH, E. coli*
- *Table II: chronic ammonia, nitrate*
- *Table III: chronic cadmium, chronic copper, chronic lead, chronic manganese, chronic selenium, chronic silver, and chronic zinc.*

Outstanding Grand Lake Foundation reviewed and analyzed the data from 2013 – 2016 collected in Grand Lake, by Northern Colorado Water Conservancy District, (http://www.northernwater.org/DynData/WQDataMain.aspx) covering each of the water quality parameters listed above, except E. coli. In all cases and for all parameters, the collected data met or exceeded the standards set in Tables I, II, and III of Regulation 31. Specifically, the analysis showed that the data met the requirement that *"Existing quality" shall be the 85th percentile of the data for ammonia, nitrate, and dissolved metals, the 50th percentile for total recoverable metals, the 15th percentile for dissolved oxygen, the geometric mean for E. coli, and the range between the 15th and 85th percentiles for pH.*

EXCEPTIONAL RECREATIONAL OR ECOLOGICAL SIGNIFICANCE

The waters of Grand Lake are an outstanding natural resource as both a defining attribute of Rocky Mountain National Park and as a source of exceptional recreational significance. Grand Lake is a prominent ecological feature to the Kawuneeche Valley of Rocky Mountain National Park. Carved out by ancient glaciers, Grand Lake reaches to a depth of 256 feet, ranking it the deepest and largest natural lake in the state. It is surrounded by majestic mountains that draw visitors to the western entrance of the Park from locations as diverse as the Front Range to countries around the world. Visitors to the park choose the destination to also recreate on Colorado's largest natural aquatic asset. Grand Lake is a visible attribute of the park, with views of the lake from multiple park trails.

Grand Lake's role in enhancing the experience of visitors to the Park has long been recognized. This was made most apparent when the Superintendent of Rocky Mountain National Park in 1968 requested the assistance of the Federal Water Pollution Control Administration (now the USEPA) to determine the measures necessary to prevent the pollution of Grand Lake, Lake Granby, and Shadow Mountain (*Water Quality Conditions in Grand Lake, Shadow Mountain Lake, Lake Granby*, Environmental Protection Agency, December 1970).

As a headwater lake, Grand Lake is fed by waters from the Park, which are designated as Outstanding Waters. These waters are the beginning of a national heritage. They are the beginning of the Colorado River which gave rise to the development of the western U.S. One cannot talk about the history of this country without acknowledging the significance of the waters generating from Grand Lake.

For over a century, Grand Lake has been a premiere destination for world class recreation and is home to the highest elevation yacht club in the world. This history of recreation and tourism, including its boating and camping stories is well documented in the annals of the Grand Lake Historical Society. Anyone who walks down by the park on the lake front on a summer day will be hard-pressed to convince anyone that Grand Lake is not providing an outstanding recreational experience. In fact, the Federal Lands Livability Initiative stated that Grand Lake is of great recreational significance in their 2014 Gateway Community Livability Assessment & Recommendations Report. Similarly, In 2009 the WQCC acknowledged the importance of Grand Lake in CCR 1002-33.44(Q): "The Commission determined that it is appropriate to adopt water quality standards for the protection of Grand Lake's clarity because of Grand Lake's **uniqueness** as Colorado's largest natural lake. Grand Lake adjoins and complements Rocky Mountain National Park in the headwaters of the Colorado River and **its social and economic importance is worthy of protection.**"

But it is not just the tourists who have benefitted and continue to enjoy the unique ecological and recreational experiences provided by Grand Lake. The lake has attracted a unique demographic of full-time and second home residents. Early in its history, vacation and permanent homes were established around the lake and in the town by families who have maintained these properties through many generations of their families. Other residents originally came to Grand Lake as children on family vacations and have since returned to settle in Grand Lake as retirees to enjoy what they remember from their past. Then there are the many more that came to visit Grand Lake and never left after experiencing the uniqueness of the lake and all it has to offer. There is a reason that the town's motto is "soul of the Rockies".

NEED FOR ADDITIONAL PROTECTION

Part iii of **5 CCR 1002-31.8(2)(a)**addresses the need for "protection in addition to that provided by the combination of water quality classifications and standards and the protection afforded reviewable water under section 31.8(3)". Most Outstanding Water designations are afforded to water bodies in headwater locations. Grand Lake itself is a headwater lake fed by headwater streams. As such, in a normal situation, it would face few, if any, water quality challenges. However, Grand Lake is in the paradoxical situation of being threatened by downstream sources. Given its outstanding characteristics, the need to insure further protection is evident. In a letter to NWCCOG on June 27, 2017, the Grand County Board of Commissioners pointed out they supported the efforts of NWCCOG in 2008 and 2014 to get a site-specific Grand Lake Clarity Standard "because, like the OGLF, the County believes that Grand Lake deserves protection in addition to that provided by the combination of water quality classifications and standards and the protection afforded reviewable water under section 31.8(3). **(5 CCR 1002-31.8(2)(a)(iii))**". The conditions and trends in 2008 and 2014 remain unchanged, supporting the need for additional protection of the lake.

In addition to the statements by both the WQCC and the Board of County Commissioners, there is more specific justification for the need for additional protection. In 2006 Grand Lake was under a health alert as a result of a blue-green algal bloom. Currently, there are no regulations in place that directly address such occurrences, this can result in a loss of Grand Lake's protected and currently attained uses as Class E Recreation and as a domestic water supply. Another threat can arise from potential arsenic loading from downstream sources. Any loading which deteriorate the lake's current water quality status could result in an impaired status that would affect fish, water and recreation. Such events become more of a threat from downstream sources to which Grand Lake would not normally be exposed because of its headwaters location. The consequences of such threats become significant in light of the state of Colorado's branding and marketing strategies, as identified by NWCCOG's study and report, which stated "*Outdoor recreation activities in the headwaters counties are the iconic images for statewide economic development activity. Keeping these resources strong is a powerful, statewide economic* *development strategy*" (***Water and Its Relationship To the Economies of the Headwaters Counties,*** prepared for NWCCOG by Coley/Forrest, Inc., December 2011).

CONCLUSIONS

OGLF requests that NWCCOG amend the 208 Plan to include a recommendation that Outstanding Water designation be granted to Grand Lake. As demonstrated above, Grand Lake meets the needed criteria to qualify for such designation as outlined in **5 CCR 1002-31.8(2)(a)(i-iii).**

1. Water quality,
2. Exceptional recreational or ecological significance, and,
3. Need for additional protection.

This has also been attested to in various printed statements by the WQCC and the Grand County Board of Commissioners as well as indirectly stated in NWCCOG's study calling for keeping recreational resources in headwaters counties strong. On merit alone, OGLF's request to support Outstanding Water designation deserves the support of NWCCOG.

OGLF understands that others are challenging the foundation's request to designate Grand Lake as an Outstanding Water. However, such challenges are not directed to Grand Lake's merits under **5 CCR 1002-31.8(2)(a)(i-iii)**; rather, they are based on speculative statements with little to no merit. For example, it has been said that there could be onerous new regulations without any evidence or statement of fact of what this would entail. Such undefined speculation underscores fears that do not provide a legitimate basis for denial, especially when the evidence in favor of Outstanding Water designation is so strong.

Concerns have also been expressed that Outstanding Water designation might conflict with the ongoing process related to Grand Lake clarity and result in a lack of agency cooperation. This is completely unfounded given that the two processes are entirely independent of one another and can be pursued on parallel timelines. One is a Federal process with state involvement, while Outstanding Waters is entirely state driven. The ultimate aim of one process is improvement in clarity; the Outstanding Waters process is to preserve existing water quality. These processes are not conflicting or mutually exclusive, nor cause for a public agency to take a position that they are unwilling to cooperate on something that has mutually agreeable goals. If that is indeed a public agency's position then full public disclosure should be provided to all entities participating in Outstanding Waters discussions.

OGLF reiterates that this is only the start of a complex process that extends through 2019. During this time, OGLF will have the responsibility of meeting many procedural requirements before a final decision is given by the WQCC. We are committed to presenting a case to the state that can be judged on its own merits and consistent with criteria. We have met these requirements in our presentation to NWCCOG and we respectfully request that you include the Outstanding Waters process, as pursued by the Outstanding Grand Lake Foundation, in the 208 Plan.

Warmest Regards,

Samantha Bruegger

Samantha Bruegger
Executive Director
Grand Lake Chamber of Commerce/ Outstanding Grand Lake Foundation

Attachment 5

BOARD OF COMMISSIONERS

RICHARD D. CIMINO
District I, Fraser 80442
MERRIT S. LINKE
District II, Granby 80446
KRISTEN MANGUSO
District III, Kremmling 80459

E-Mail: [illegible]1@co.grand.co.us
PHONE: 970/725-3100
Fax: 970/725-0565
LEE A. STAAB
County Manager
ALAN N. HASSLER
County Attorney

June 27, 2017

Northwest Colorado Council of Governments
Attn: Lane Wyatt
PO Box 2308
Silverthorne, CO 80498

Dear Lane,

The Grand County Board of County Commissioners (BOCC) appreciates this opportunity to provide prehearing comments to the Northwest Colorado Council of Governments (NWCCOG) regarding a request to amend the Regional Water Quality Management Plan (208 Plan) to recommend designation of Grand Lake as an Outstanding Water, as defined at 5 CCR 1002-31.6(47). With this letter, Grand County is also requesting party status for the hearing on July 27.

Grand County recognizes and salutes the Outstanding Grand Lake Foundation's (OGLF) drive to protect water quality in Grand Lake and the surrounding region, to promote watershed awareness and ecotourism, and to support the economy in Grand Lake and Grand County as a whole. The BOCC concurs with the OGLF mission "that a healthy lake and surrounding water are essential to our thriving business economy." Grand County also wishes to recognize and commend the citizens involved and the Grand Lake Chamber for courageously and thoughtfully pursuing this initiative through the necessary channels to protect the waters of Grand Lake.

In April of 2017, representatives from the OGLF conducted a workshop with the BOCC which allowed for a healthy exchange of concepts and concerns. The concerns that Grand County expressed have not deviated much from that day, and are detailed in the paragraphs that follow.

P.O. BOX 264 HOT SULPHUR SPRINGS CO 80451

Like the OGLF, Grand County would also like to see no further degradation to Grand Lake water quality. At the same time, however, a National Environmental Policy Act process is currently underway to consider alternatives to improve clarity in Grand Lake. This process may finally realize Senate Document 80's second primary operational purpose for the Colorado-Big Thompson (C-BT) Project: "To preserve the fishing and recreational facilities *and the scenic attractions of Grand Lake*, the Colorado River, and the Rocky Mountain National Park" (emphasis added). It is not clear how an Outstanding Waters designation might affect the constructability of some of the alternatives, and Grand County is concerned about the potential for unintended consequences that the designation may have on any of the alternatives requiring construction of new, or alteration of existing, C-BT facilities. Barring construction projects, Grand County is also concerned about any other potential unforeseen consequences to the Grand Lake Clarity NEPA process.

Grand County, together with NWCCOG, the Colorado River District, Northern Water, and the Bureau of Reclamation, is currently in year two of a five year Memorandum of Understanding to adaptively manage Grand Lake "to implement the Grand Lake Clarity narrative standard" while Reclamation conducts a "planning and NEPA process to evaluate alternatives to improve clarity in Grand Lake as described in the Clarity Supplement." (From the Grand Lake Clarity Stakeholders' Memorandum of Understanding, executed in January and amended in June of 2016.) Grand County is concerned about the potential for negative consequences with respect to current agency cooperation that may result from an Outstanding Waters designation effort proceeding at the same time that other cooperative efforts are taking place between east and west slope Grand Lake Clarity Stakeholders.

Because of the C-BT Project and the use of C-BT facilities granted to the Municipal Subdistrict of Northern Colorado Water Conservancy District for their Windy Gap Project, the watersheds that would be impacted by this proposal include not only the Three Lakes (Grand Lake, Shadow Mountain Reservoir, and Granby Reservoir) basins, but potentially also Willow Creek and the Fraser River basins. An antidegradation rule may mean new regulations on Grand County communities that would be considered onerous by some.

The natural tributaries to Grand Lake are the North and East Inlets, which originate in Rocky Mountain National Park and which, for as long as they are within the Park, are classified Outstanding Waters. These tributaries flow through a narrow section of town before entering Grand Lake. The origins of this native inflow might make it seem an easy choice to also declare Grand Lake an Outstanding Water. However, Grand Lake is also hydraulically connected to the C-BT system, serving as a forebay to the Adams Tunnel.

Waters from Granby Reservoir, Willow Creek Reservoir, Shadow Mountain Reservoir, and Windy Gap Reservoir are introduced into Grand Lake because of this hydraulic connection, and have a detrimental impact on Grand Lake water quality.

As the NWCCOG board is well aware, in 2008, with the support of the Town of Grand Lake and Grand County, NWCCOG proposed a site-specific Grand Lake Clarity Standard to the Water Quality Control Commission, and a revised standard in 2014. Grand County pursued this action because, like the OGLF, Grand County believes that Grand Lake "requires protection in addition to that provided by the combination of water quality classifications and standards and the protection afforded reviewable water under section 31.8(3)." (5 CCR 1002-31.8(2)(a)(iii)) While at first glance the Outstanding Waters designation would appear to be consistent with the protections that Grand County has been seeking for over a decade for Grand Lake, there are a number of uncertainties that impair the county's ability to wholly embrace this proposal, at this time. We appreciate the NWCCOG Board's careful consideration of these matters as it makes the determination of whether or not to designate Grand Lake as an Outstanding Water.

Sincerely,

Kristen Manguso
Commissioner Chair

Merrit Linke
Commissioner

Richard Cimino
Commissioner

Cc: Outstanding Grand Lake
Town of Grand Lake

Attachment 6

July 6, 2017

Northwest Colorado Council of Governments
249 Warren Avenue
Silverthorne, CO 80498

Please consider this letter as an affirmation from the Board of Directors of the Three Lakes Watershed Association of our position relative to the Outstanding Grand Lake initiative for an Outstanding Natural Resource Water(ONRW) designation for Grand Lake.

Our Association has been involved in clean water issues in the Upper Colorado River drainage for decades. Clean water not just in Grand Lake, but in all the waters in the drainage is our primary mission. We have attended and participated in 100's of meetings and calls on Grand Lake Clarity and Three Lakes (Grand Lake, Shadow Mountain Reservoir, Granby Reservoir) Water Quality for decades.

We are a 501(c)(3) and have membership of 250-500 from year to year. In addition to water quality, other examples of our activities are things like purchasing and maintaining the Grand Lake Fire Boat, improving Town boat ramps, supporting GCWIN, leasing the dock for the water quality testing boat, etc.

In the last few years, we have seen some progress with Grand Lake Clarity and Three Lakes Water Quality, which have suffered from the unintended consequences of the Colorado Big Thompson (CBT) Project for far too long.

We were instrumental in establishing the first and only water clarity standard in Colorado for Grand Lake. We were instrumental in the East and West Slope interests (including NWCCOG) execution of a 5 year Grand Lake Clarity MOU for peak tourist summer season clarity goals/standards with triggers for better water quality in Shadow Mountain Reservoir. The Bureau of Reclamation has initiated a formal NEPA process to more thoroughly vet Alternatives to current operations of the CBT Project. These are Alternatives to existing pumping operations of CBT (which reverses the natural flow), while maintaining existing water rights and improving Grand Lake Clarity.

Better water quality and clarity for Grand Lake and all the Three Lakes is an objective we share with the proponents of the ONRW designation. We want the same thing. We share the same goal.

However, we are in the unfortunate position that we cannot support the request for ONRW designation.

We believe there are too many unknowns and potential unintended consequences in the working application of the designation to ascertain essential public support.

Our concerns are specifically in two areas. One concern is in the area of Land Use/Property Rights. In addition, we feel the ONRW designation could dilute the focus or derail the current progress and direction for improving Grand Lake Clarity.

Yours Sincerely,
Three Lakes Watershed Association
Board of Directors

Attachment 7

Colorado River District
Protecting Western Colorado Water Since 1937

Michael Eytel
Sr. Water Resource Specialist
Colorado River District
meytel@crwcd.org

July 7, 2017

Northwest Colorado Council of Governments
Attn: Lane Wyatt
P.O. Box 2308
Silverthorne, CO 80498
qqlane@nwccog.org

Re: Party Status Request for 208 Plan Amendment

Dear Lane:

The Colorado River District would like to request Party Status in the hearing to amend the Regional Water Quality Management Plan (208 Plan) to recommend designation of Grand Lake as an Outstanding Water, as defined at 5 CCR 1102-31.6(47). The River District is still reviewing the proposal and would like to reserve the right to comment on the issue.

Sincerely,

Michael Eytel

Michael Eytel

Mike Eytel | **Senior Water Resource Specialist**
meytel@crwcd.org | www.ColoradoRiverDistrict.org
T: 970.945.8522, ext. 215 C: 970.485.0483

Attachment 8

United States Department of the Interior

BUREAU OF RECLAMATION
Great Plains Region
Eastern Colorado Area Office
11056 West County Road 18E
Loveland, CO 80537-9711

IN REPLY REFER TO:

EC-1000
2.2.4.22 (WTR 7.00)

JUL - 3 2017

Lane Wyatt
Northwest Colorado Council of Governments
PO Box 2308
Silverthorne, CO 80498
qqlane@nwccog.org

Subject: Response to June 22, 2017, Notice of Hearing Concerning "Request to Amend the Regional Water Quality Management Plan (208 Plan) to Recommend Designation of Grand Lake as an Outstanding Water" - General

Dear Mr. Wyatt:

On behalf of the Bureau of Reclamation, I am submitting a response to your request for pre-hearing comments concerning the proposal to recommend the designation of Grand Lake as an "Outstanding Water".

The Colorado-Big Thompson (C-BT) Project was authorized on December 21, 1937, under Senate Document 80, 75th Congress, 1st Session (Senate Document 80). The C-BT Project is federally owned and was designed as a trans-basin water diversion system for moving water from the Western Slope to the Eastern Slope. Grand Lake is an integral part of the C-BT Project infrastructure and has been used for conveyance since the 1940s, transporting water from Shadow Mountain Reservoir and Granby Reservoir through Grand Lake to the Alva B. Adams Tunnel for diversion to the Eastern Slope.

Although Grand Lake was formed through natural geological processes, it has been engineered for conveyance and used as part of the C-BT Project infrastructure since the Project's inception. Since its authorization, the C-BT Project has operated in accordance with Senate Document 80, which details in the "Manner of Operation" section the following primary purposes:

1. To preserve the vested and future rights in irrigation.

2. To preserve the fishing and recreational facilities and the scenic attractions of Grand Lake, the Colorado River, and the Rocky Mountain National Park.

3. To preserve the present surface elevations of the water in Grand Lake and to prevent a variation in these elevations greater than their normal fluctuation.

4. To so conserve and make use of these waters for irrigation, power, industrial development, and other purposes, as to create the greatest benefits.

5. To maintain conditions of river flow for the benefit of domestic and sanitary uses of this water.

Reclamation does not support the designation of Grand Lake as an "Outstanding Water" because this could potentially hinder Reclamation's ability to meet the primary Project purposes outlined in Senate Document 80 by placing unnecessary restrictions on Project operations. Reclamation reserves the right to operate the C-BT Project in accordance with Senate Document 80 and other applicable authorities.

In addition, Grand Lake does not clearly meet the three criteria for designation as an "Outstanding Water" outlined in the Colorado Code Regulation Number 31 (31.8.2).

With regards to Criteria 1, temperature data has been collected by the Northern Colorado Water Conservancy District and U.S. Geological Survey from January 2010 to present, at depths ranging from 0 to 80 meters. This long-term temperature data suggests that from July to September, temperatures from 0-5 meters in Grand Lake often exceed the trout-based summer temperature chronic criteria for sub-lethal exposure (16.6 degrees C).

With regards to Criteria 2, neither the waters nor the immediately adjacent lands are part of a larger system with a special designation, such as a Gold Medal Trout Fishery, a National Park, National Monument, or Wilderness Area. Fishing and recreational values are protected under the authorizing legislation for the C-BT Project; therefore, designation of Grand Lake as an "Outstanding Water" is unnecessary to achieve this goal.

Criteria 3 suggests that for a body of water to be designated as an "Outstanding Water," there must be an existing or imminent threat to the water quality and values, which merits the highest level of protection and regulation of the offensive activity under the Antidegradation Rule.

Reclamation remains committed to the Memorandum of Understanding No. 16-LM-60-2578 (MOU) with Grand Lake clarity stakeholders, including NWCOG, which provides the framework for implementation of an adaptive management process to improve clarity in Grand Lake. As we continue into the second year of the MOU, Reclamation has announced the 2017 operational plan after working collaboratively with stakeholders by inviting them to review scenarios and provide comments on the proposed plan. Weekly adaptive management conference calls are scheduled to begin on July 6, 2017. Meanwhile, Reclamation has initiated an environmental assessment to evaluate a range of alternatives to improve clarity in Grand Lake.

Thank you for the opportunity to comment on this matter.

Sincerely,

J. Signe Snortland
Area Manager
Eastern Colorado Area Office

Attachment 9

June 6, 2017

Northwest Colorado Council of Governments

Dear Mr Wyatt,

As a private citizen and a recent part-time resident of Grand Lake, I am writing to you regarding the request by the Outstanding Grand Lake Foundation to designate Grand Lake as an Outstanding National Resource Water. I am not part of any stakeholder group or organization and am trying to educate myself on the complexities and dynamics of C-TB and the consequential water quality of Grand Lake, Shadow Mountain Lake and Lake Granby.

Based on all my research, it appears that this request is premature, could create division within the 21 cooperating agencies, 8 federal, 3 state, and 10 local governments, and ultimately be a distraction to the NEPA process.

What are the implications of the designation, the funding dynamics associated with maintaining a protected body of water (and could that funding need be met), and lastly does Grand Lake at this time even meet the requirements of the Outstanding National Resource Water designation based on the EPA guidance factors? In the letter to the Colorado Water Quality Control Commission the Outstanding Grand Lake Foundation initiating rulemaking for their designation of Grand Lake an (ONRW), it states "Grand Lake deserves this designation so that it can join its rightful spot beside such other similarly designated natural waters like Lake Tahoe and Lake Yellowstone". As we all know, Lake Yellowstone is within the boundaries of a federal park, pristine in nature and minimally affected by human activities. According to

California Case 2:13-cv-00267-JAM-EFB, "Lake Tahoe has an average depth of 1000 ft. and an area of 191 square miles. This depth, the low ratio of watershed to lake area, and the watershed's geology result in a very low level of nutrients to support algal growth, producing the Lake's clarity." It seems that these two lakes do not have any parallels to Grand Lake.

As we are all stewards of our environment, do we also have a duty to think beyond a specific issue? The issue of clarity seems to be at the forefront of this designation. Do we also need to consider the impact to aquatic life, waterfowl, migratory birds, water demands east of the continental divide as that population is exploding. Where does the east meet the west in this scenario?

With the recent anonymous publication in the Grand Lake's Boardwalk, titled "Elimination of Shadow Mountain Reservoir" (see attached article) residents have tremendous concern regarding the dynamics of this article. It raises so many questions regarding the impact on the local economy, property values, recreational activities, and the impact to fish and fowl environments, etc.

As a private citizen who has the voice of many local residents, it appears that this designation will cause newly created divisions. It also appears that the NEPA process has finally brought all the cooperating agencies, federal, state and local governments together. Shouldn't they now be afforded the opportunity to focus on their adaptive management plan at this time?

Thank you for your time,

Melody Hudson

Mailing address: 8133 East 29th Place, #122

Denver, CO 80238 Mobile 303-918-202

[illegible]

6/23/17 Boardwalk

Eliminat[illegible] Mountain Reservoir?

Outstanding Gra[illegible] to protect the future [illegible] watershed after discussion of [illegible] Shadow Mountain Reservoir.

On July 27th [illegible] Colorado Council of Governments ([illegible]) will be holding a public hearing [illegible] Lake to discuss amending the 208 [illegible] Plan to allow for designation of Grand Lake as an Outstanding Water. This meeting is being held in response to a request of the Outstanding Grand Lake (OGL) Foundation to make the designation. The state of Colorado has authority under the Clean Water Act to set water quality standards for our lakes and rivers. In doing so, the law provides for three levels of protection: Tier 1, Tier 2, and Tier 3. Currently, Grand Lake is classified as a Tier 2 water where its protected uses are described as a cold water aquatic resource, suitable for providing drinking water and are a recreation and aesthetic resource. Outstanding Water designation (Tier 3) provides the highest level of protection with the same protected uses as provided in Tier 2. The difference between these two classifications is that Tier 2 allows for degradation of water quality up to the point that it does not change the protected uses. Tier 3 protects these uses but allows no further water quality degradation from what exists today.

When the Clean Water Act was established [illegible] 1972, it established the process for protecting the [illegible] of the nation's waters as described in the paragraph above. It included not only the Tiered classification above but also anti-degradation standards. This latter was meant to insure that existing water quality standards and uses were not further degraded. So how effectively have these regulations been applied? Studies done in the late 1960's by the then Federal Water Pollution Control Agency (formed into the EPA in 1970) measured clarity of 10 meters (approx. 33 feet) in Grand Lake and Lake Granby and reaching to the bottom in Shadow Mountain. Last summer, Grand Lake clarity went below 2.5 m and could not reach a 3.8 m average in spite of agreements reached in April 2016 with the State of Colorado.

Despite the ongoing objections and pleadings of many in Grand County over the years to fix the problem, a solution has yet to be found. Recently, the Corps of Engineers issued its Record of Decision that will allow another 30,000 acre-feet per year to be pumped through Grand Lake; this is roughly a 20% increase in pumping per year. It is this pumping with its nutrient filled waters that leads to the algal blooms that turn the lake green in summer.

A review of meeting minutes (obtained through a Freedom of Information Act request) between Northern Water and the highest levels of the Department of the Interior should give us cause as to why Outstanding Water protection is needed for Grand Lake. In a meeting held May 21, 2014, the minutes state "...if a structural solution requires pumping from Lake Granby directly into Grand Lake then Shadow Mountain may need to be eliminated." In another meeting on March 17, 2015 between these same parties, the minutes record that "(name withheld) does not want clarity in Grand Lake linked to the preservation of recreation and aesthetic values. ... it is not a good strategic move to have clarity linked to recreation and aesthetic values". In other words, forget protecting the lake and the notion as to why people come to Grand Lake. Grand Lake Area Chamber of Commerce (970) 627-3402 www.grandlakechamber.com

It is important that anyone interested in the future of Grand Lake (the town and the lake) attend the hearing in July and understand the process and importance of Outstanding Water designation. In essence, it becomes the last line of defense that will protect our lake.

For more information on Outstanding Grand Lake: *www.outstandinggrandlake.org*

OUTSTANDING GRAND LAKE

Attachment 10

July 7, 2017

NORTHWEST COLORADO COUNCIL OF GOVERNMENTS

WRITTEN COMMENTS OF NORTHERN COLORADO WATER CONSERVANCY DISTRICT

IN THE MATTER OF AMENDING THE REGIONAL WATER QUALITY MANAGEMENT PLAN (208 PLAN) DESIGNATING GRAND LAKE AS AN OUTSTANDING WATER, AS DEFINED AT 5 CCR 1002-31.6(47)

The Northern Colorado Water Conservancy District ("Northern Water"), by and through its water quality counsel, Berg Hill Greenleaf Ruscitti LLP, hereby submits its written comments in the above-captioned matter. Counsel's contact information on behalf of Northern Water is set forth below.

Respectfully submitted this 7th day of July 2017.

BERG HILL GREENLEAF RUSCITTI LLP

/s/ Katherine A.D. Ryan

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ATTORNEYS FOR NORTHERN COLORADO WATER CONSERVANCY DISTRICT

1. Outstanding Waters and the Clean Water Act

The objective of the federal Clean Water Act is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" – the familiar "fishable and swimmable" goal one often hears. The maintenance objective of the Clean Water Act is accomplished by states through what is known as an anti-degradation policy.

States have adopted anti-degradation policies using a three-tiered approach to maintain and protect various levels of water quality and uses. The first tier provides protection and maintenance of existing uses. The second tier provide provides protection of existing water quality in segments where water quality exceeds level necessary to support propagation of fish, wildlife and recreation. The third tier (Outstanding National Resource Waters) provides special protection for waters for which ordinary use classifications may not suffice. For these waters, water quality must be maintained and protected and only temporary or short-term changes are permitted.

2. Outstanding Waters Definition

Under federal law, "where high quality waters constitute an outstanding National resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected." 40 CFR 131.12(a)(3). Colorado law further requires that in order to be designated outstanding water, the water body must meet each of three tests:

1) The water quality must be better than "fishable, swimmable" based on 12 indicator parameters. These parameters include: dissolved oxygen, pH, E. Coli, chronic ammonia, nitrate, chronic cadmium, chronic copper, chronic lead, chronic manganese, chronic selenium, chronic silver and chronic zinc. Data must be representative of the segment and data for all 12 parameters must be available;
2) Waters must be an outstanding natural resource which is to be judged by whether 1) the waters are either outstanding state fishing waters (State Gold Medal Trout Fishery) or federal lands that have been given special protection status (National Park, National Monument, National Wildlife Refuge, Wilderness Area, Federal Wild & Scenic); or 2) the waters have exceptional recreational or ecological significance and have not been modified by human activities in a manner that substantially detracts from their value as a natural resource; and
3) The waters need protection beyond that provided by water quality classifications and standards for reviewable waters.

Furthermore, outstanding designation cannot be inconsistent with Colorado statute 25-8-104 by causing an injury to exercise of water rights. 5 CCR 1002-31.6 (47).

3. Lack of technical support for the proposal

Northern Water notes that although the burden of proof lies on the proponents, they have provided no information in support of their proposal and to demonstrate that Grand Lake meets the requirements for outstanding water. Due to the lack of information provided by the proponent, the proposal is premature.

4. Grand Lake does not meet the criteria to be eligible for the outstanding water designation

Northern Water has undertaken to review existing information for Grand Lake relevant to the three tests for the designation (EXHIBIT 1).

Grand Lake does not meet all required numeric water quality criteria. Water quality data show that Grand Lake does not meet the pH, dissolved oxygen and manganese standards of the test. E Coli data, required for designation are not available for Grand Lake – Northern Water has not been collecting E Coli Data as part of its routine monitoring. No E Coli data are available from the USGS records, nor from CDPHE, nor from the Grand County Water Information database. Northern Water has no knowledge of any other potential source of E Coli data.

Grand Lake does not have a special State or Federal designation as a National or State park or wildlife refuge.

Northern Water recognizes the importance of Grand Lake's recreation although it is unclear what would qualify Grand Lake as "exceptional" recreationally relative to the rest of the Three Lakes and other lakes and reservoirs in Colorado.

Grand Lake does not have exceptional ecological significance and the proponents have not provided any evidence in support. Waters of ecological significance are waters that are important, unique or sensitive ecologically. For example, Bear Creek, a small stream on the east side of Pikes Peak in the Arkansas drainage is the only stream in Colorado where the federally threatened greenback cutthroat resides, could be considered a resource of ecological significance. In contrast, the Grand Lake fishery is stocked and is also host to Mysis Shrimp that were introduced in the 1969 (EXHIBIT 2) and have significantly altered the aquatic ecosystem of Grand Lake.

Grand Lake has been modified by human activities since it is a feature of the Colorado-Big Thompson Project (EXHIBIT 3).

The Water Quality Control Commission ("Commission" or "WQCC") recognized the significant anthropogenic impact on the Three Lakes (including Grand Lake) in its 1990 Reg 33 Rulemaking Hearing to consider a High Quality 2 designation for the segment that includes the Three Lakes. The Commission concluded that, "Because of significant coliform and nutrient problems in this area, the segment is not of such consistently high quality to justify a "High Quality" classification. There is a high level of human activity including existing point source discharges in this area and it is a changing situation deserving of additional study, in view of continuing land and water resource development." It is notable that the High Quality 2 designation that the Commission found Grand Lake did not meet is a lower designation than Outstanding Water.

Concerns from local stakeholders regarding Grand Lake clarity and impacts related to the operation of the Colorado-Big Thompson project were such that the WQCC was petitioned to adopt a clarity standard for Grand Lake in 2008. Grand Lake clarity, in fact, appears to be the issue that is most relevant to all stakeholders, rather than outstanding waters designation, which has an uncertain regulatory effect in the short-term.

5. Existing protections for Grand Lake are sufficient

Proponents provided no information or lines of evidence to explain why Grand Lake requires protection beyond those already in place through the existing water quality standards. In fact, Proponents ignored several additional protections in place for Grand Lake. These provisions are even more stringent than protection provided by the existing designation of Grand Lake because they are in place through binding agreements (EXHIBITS 4 and 5) involving Grand County, the WQCC, Northern Water and Reclamation – the four organizations with legal authority over the Lake.

In 2008, the WQCC was petitioned to consider the adoption of a clarity standard for Grand Lake, a first in Colorado. In absence of definite answers at the time, the WQCC adopted a narrative standard – the highest level of clarity attainable consistent with the exercise of water rights – plus a 4-meter standard with a delayed effective date, while also directing the stakeholders to work collaboratively to develop an appropriate clarity standard, which would also protect aquatic life and not adversely impact C-BT deliveries to the East Slope. In 2014, although much more information had been collected and compiled, consensus was lacking for a definitive numeric clarity standard, or identification of any permanent and feasible solution to improve clarity. Northern Water along with Grand County and the Northwest Colorado Council of Governments jointly requested an extension in the delayed implementation date. The WQCC granted this delay and directed the parties to also consider impacts to water quality in the Three Lakes in the development of a clarity standard.

By 2015, through concerted efforts between all interested parties and the Bureau of Reclamation, it had become apparent that a single and rigid numeric standard would not work for all intended purposes. Instead, the parties agreed to pursue an adaptive management approach focused on achieving numeric clarity goals (instead of standards). This approach was memorialized in an agreement signed by Northern Water, the Bureau of Reclamation, Grand County, the Northwest Colorado Council of Government and the Colorado River Water Conservation District in January 2016. The parties proposed this approach, which the WQCC adopted in 2016. The clarity goals are a 3.8 meter average and a 2.5 meter minimum for the July through September 11 period. The Clarity MOU lays out the terms of collaboration and consultation between the parties in order to inform C-BT operations although Reclamation retains ultimate decision authority.

Building on the strong technical foundation developed by the Three Lakes Technical Committee, the U.S. Bureau of Reclamation initiated preliminary investigations of possible alternatives to improve clarity in Grand Lake beginning in 2012. In 2013, Northern Water and Reclamation signed Supplement 10 (Clarity Supplement), which is an amendment to the C-BT Repayment contract and commits both Northern and Reclamation to evaluate alternatives to improve clarity in Grand Lake. In 2017, Reclamation formally initiated the National Environmental Policy Act (NEPA) process to evaluate alternatives. Alternatives considered may include operational changes, structural alternatives (such as a pipeline around Grand Lake and/or Shadow Mountain Reservoir), watershed management and non-structural options.

Through the NEPA process that led to the authorization to move forward with the Windy Gap Firming Project and Chimney Hollow Reservoir, numerous mitigation commitments were made. These commitments are requirements, set up as permit conditions, and include extensive and continued water quality monitoring in the Three Lakes, Secchi monitoring in Grand Lake and especially nutrient mitigation which all support efforts to improve clarity in Grand Lake.

6. Development of a baseline for water quality

The adoption of an Outstanding Waters designation for Grand Lake would allow no degradation from the time the designation would be adopted. This means that a "baseline" of water quality for the lake would need to be defined as the reference point against which the no-degradation rule would be applied.

The Proponents have not provided any supporting information to explain how this baseline would be characterized.

Water quality in Grand Lake, clarity in particular, is highly dependent on hydrology and C-BT Operations. EXHIBIT 6 shows a retrospective of clarity in Grand Lake since 2007. Data show a high degree of variability. Characterizing the baseline in this context would be challenging. The baseline could wind up being arbitrary or even non-protective if standards are assessed at an inopportune time.

The baseline would primarily affect point source discharges, although it is not clear that there any existing or expected discharges to regulate.

7. The implications of the designation are not fully understood and could be far reaching:

The WQCC states in its 1993 Statement of Basis and Purpose that "the restriction associated with this designation are extreme, and it is essential that it be applied with discretion so as to not unduly restrict future development in Colorado."

A 1989 management document, *Outstanding National Resource Waters*[1]*: A Resource Management Tool* drafted in by the National Park Service to educate their managers on how to use the ONRW designation to protect NPS interests specifies that "Managers should note that the ONRW designations can affect the ways in which new or expanded construction or developments in a park can be undertaken. In fact, in some circumstances, ONRW designation would prohibit any new construction or substantial modification of existing structures if a point source discharge were substantially modified. And, where fill would be required for the construction or modification not only of buildings but roads and parking lots as well, as in parks like Everglades and Biscayne, ONRW could wholly prohibit the activity. Even where the

[1] http://npshistory.com/publications/water/onrw.pdf

construction would be for visitor' centers or other necessary visitor facilities, ONRW designation can prohibit construction. Because ONWR designation can be such a potent tool, substantially affecting a manager's flexibility, options should be pursued that provide protection without unduly limiting management's ability to meet other NPS mandates."

Implications are clear for point sources as they would be directly regulated under the no degradation "rule." Implications for non-point sources are unclear .

8. **Grand Lake issues are complex and the designation would undermine existing efforts to improve Grand Lake clarity**

The Three Lakes system and C-BT Operations are very complex technically, politically, from a regulatory standpoint. EXHIBIT 7 provides a summary of the water quality dynamics of the Three Lakes system that highlights the complexities and water quality trade-offs that we know about. It has taken over 10 years to assemble enough data to provide a sound knowledge base to support the evaluation of alternatives to improve Grand Lake Clarity. It has taken as long to foster trust and collaboration to get to the agreements that have set the stage for adaptive management and for the NEPA process to evaluate alternatives to improve clarity in Grand Lake.

Adding another regulatory designation with uncertain requirements will only complicate the issues, and potentially create new regulatory hurdles, damage, and undermine the collaborative work in progress, potentially complicate the NEPA process, and distract resources from the existing work to address clarity in Grand Lake.

The outstanding water proposal has already and will further draw resources of Grand County, NWCCOG, River District, Northern and Reclamation away from achieving the highest level of clarity attainable. The proposal is therefore counter-productive with regard to making Grand Lake the best it can be.

WBID	COUCUC12					2017_COUCUC12_Northern_GL-MID-1_Grand Lake Mid Section at 1m (USGS #09013900)
Site Number	GL-MID-1	Datastore Period of Record:	1/29/2013	to	10/7/2014	
Site Name	Grand Lake Mid Section at 1m (USGS #09013900)					
Agency	Northern	Calculation Period of Record:	10/1/2010	to	12/31/2015	
Latitude	40.24332					
Longitude	-105.81362					
Datum					n	<-Output "TVS Table"
AQ Use	Aq Life Cold 1				n	<- Output "Graphs" tab
Rec Use:	Recreation E				n	<- Output "NH3" tab
WS Use Y/N	water supply				n	<- Show "Standards Table"
Temp Tier:	w):CL,C				n	<-- show acute paired calcs. ** will not work with the show calcs tab.
Agriculture	agriculture	**ALL Green Boxes are Required.**				
Date Assessed	6/13/2017					
Assessor	JCH					
Code Version	06/05/2017.a					

		Aquatic Life		Water Supply	Agriculture	Existing	n	Acute	Status	Summary
	"J" Flag	Chronic	Acute*		(TREC)	Quality	C, A	Max		Stat.
Ag-D ug/L	0	0.00	0.10	NS	NS	0	6 , 6	0	No	0.85
Ag-T ug/L	0	NS	NS	100	NS	0	6 , 6	0	XTD	0.5
NH3 mg/L	15	15.29	27.36	NS	NS	0.01	20 , 0	0.12	No	0.85
As-D ug/L	0	150	340	NS	NS	0.20	6 , 6	0.22	No	0.85
As-T ug/L	2	NS	NS	0.02	100	0	6 , NA	0.20	No	0.5
Cd-D ug/L	1	0.11	0.37	NS	NS	0.00	6 , 6	0.01	No	0.85
Cd-T ug/L	1	NS	NS	5	10	0	6 , 0	0	XTD	0.5
Chloride-T mg/L	0	NS	NS	250	NS	0.52	4 , 0	0.76	No	0.5
Cu-D ug/L	4	2.00	2.58	NS	NS	1.03	5 , 5	1.19	No	0.85
Cu-T ug/L	4	NS	NS	1000	200	0.87	5 , NA	0	XTD	0.5
DO-D mg/L	0	NS	7	3	3	7.60	19 , 0	9.30	No	0.15
Fe-D ug/L	0	NS	NS	300	NS	57.41	19 , 0	142	No	0.85
Fe-T ug/L	0	1000	NS	NS	NS	81.85	6 , 0	110	No	0.5
Hardness mg/L	0	NS	NS	NS	NS	17.33	15 , 0	25.82	No	avg
Hg-T ug/L	0	0.01	NS	2	NS	0.00	4 , 4	0.00	No	0.5
Mn-D ug/L	0	920.07	1665.28	50	NS	1.83	19 , 19	31.60	No	0.85
Mn-T ug/L	0	NS	NS	NS	200	1.02	19 , NA	0	XTD	0.5
Ni-D ug/L	0	11.81	106.29	NS	NS	0.23	6 , 6	0.24	No	0.85
Ni-T ug/L	0	NS	NS	100	200	0.18	6 , NA	0	XTD	0.5
NO5-T mg/L	7	NS	NS	10	100	0.02	20 , 20	0.07	No	0.5
Pb-D ug/L	3	0.36	9.18	NS	NS	0.08	6 , 6	0.13	No	0.85
Pb-T ug/L	3	NS	NS	50	100	0.03	6 , 0	0	XTD	0.5
pH min-D ug/L	0	NS	6.50	5	NS	7.07	N/A , 20	7.70	No	0.15
pH max-D ug/L	0	NS	9	9	NS	7.52	N/A , 20	7.70	No	0.85
Se-D ug/L	3	4.60	18.40	NS	NS	0.08	6 , 6	0.09	No	0.85
Se-T ug/L	3	NS	NS	50	20	0.06	6 , NA	0	XTD	0.5
SO4-T mg/L	0	NS	NS	250	NS	2.83	4 , 0	3.34	No	0.85
Temp(s) C	0	N/A	18.30	NS	NS	N/A	N/A , 0		DM exceeded: 12	DMs
Temp(w) C	0	N/A	9	NS	NS	N/A	N/A , 0		See Summer line	DMw
U-D ug/L	0	NS	NS	NS	NS	0.27	4 , 4	0.29	No	0.85
U-T ug/L	0	NS	NS	30	NS	0.21	4 , NA	0	XTD	0.5
Zn-D ug/L	2	24.62	32.50	NS	NS	0.49	2 , 2	0.50	No	0.85
Zn-T ug/L	2	NS	NS	5000	2000	0.45	2 , NA	0	XTD	0.5

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Nutrients	2013	2014	2015	2016	2017	2018	Stds
TN mg/L	10\ 0.2585	9\ 0.219	0	0	0	0	2.01
TP mg/L	10\ 0.0125	10\ 0.011	0	0	0	0	0.17
Chlor a. mg/m2	5\ 5.67	0\ 0	0	0	0	0	150

WBID	COUCUC12					2015_COUCUC12_USGS_USGS-09013900_GRAND LAKE AT GRAND LAKE, CO.
Site Number	USGS-09013900	Datastore Period of Record:	10/29/2008	to	3/25/2014	
Site Name	GRAND LAKE AT GRAND LAKE, CO.					
Agency	USGS	Calculation Period of Record:	10/1/2008	to	12/1/2014	
Latitude	40.2433185					
Longitude	-105.8136222				n	<-Use Site Specific Information
Datum					n	<-Output "TVS Table"
AQ Use	Aq Life Cold 1				n	<- Output "Graphs" tab
Rec Use:	Recreation E				n	<- Output "NH3" tab
WS Use Y/N					n	<- Show "Standards Table"
Temp Tier:	CL,CLL				y	<-- show acute paired calcs. ** will not work with the show calcs tab.
Agriculture	agriculture	**ALL Green Boxes are Required.**				
Date Assessed	6/16/2015					
Assessor	SMW					

	"J" Flag	Aquatic Life Chronic	Acute*	Water Supply	Agriculture (TREC)	Existing Quality	n	Acute Max	Status	Summary Stat.	
Ag-D ug/l	0	0.01	0.16	NS	NS	0	12	0	No	0.85	
Ag-T ug/l	0	NS	NS	NS	NS	0	12	0	XTD	0.5	
NH3 mg/l	0	4.5	22.01	NS	NS	0.2178	48	0.311	No	0.85	
As-D ug/l	0	150	340	NS	NS	0.185	11	0.32	No	0.85	
As-T ug/l	0	NS	NS	0.02	100	0.2	3	0.2	Yes: Chronic WS,	0.5	n=3, M&E
Cd-D ug/l	0	0.14	0.47	NS	NS	0	12	0.013	No	0.85	
Cd-T ug/l	0	NS	NS	NS	10	0	12	0	XTD	0.5	
Chloride-T mg/l	0	NS	NS	250	NS	0.92	9	1.13	No	0.5	
Cu-D ug/l	0	2.53	3.34	NS	NS	1.235	12	2.5	No	0.85	
Cu-T ug/l	0	NS	NS	NS	200	1.04	12	0	XTD	0.5	
DO-D mg/l	0	NS	7	3	3	7.235	50	9.2	No	0.15	
Fe-D ug/l	0	NS	NS	300	NS	39.18	48	60.5	No	0.85	
Fe-T ug/l	0	1000	NS	NS	NS	80.75	12	149	No	0.5	
Hardness mg/l	0	NS	NS	NS	NS	22.83	41	26.8	No	avg	
Hg-T ug/l	0	0.01	NS	NS	NS	0.00125	9	0.0019	No	0.5	
Mn-D ug/l	0	1008.54	1825.41	50	NS	89.03	48	544	Yes: Chronic WS,	0.85	Mn-D; n=48
Mn-T ug/l	0	NS	NS	NS	200	2.865	48	0	XTD	0.5	
Ni-D ug/l	0	14.91	134.2	NS	NS	0.3685	12	0.64	No	0.85	
Ni-T ug/l	0	NS	NS	NS	200	0.235	12	0	XTD	0.5	
NO3-T mg/l	0	NS	NS	10	100	0.1149	48	0.129	No	0.85	
Pb-D ug/l	0	0.49	12.53	NS	NS	0.04245	8	0.156	No	0.85	
Pb-T ug/l	0	NS	NS	NS	100	0.015	8	0	XTD	0.5	
ph min-D ug/l	0	NS	6.5	NS	NS	7	51	9.2	No	0.15	
ph max-D ug/l	0	NS	9	NS	NS	8.45	51	9.2	No	0.85	
Se-D ug/l	0	4.6	18.4	NS	NS	0.08	12	0.08	No	0.85	
Se-T ug/l	0	NS	NS	NS	20	0.07	12	0	XTD	0.5	
SO4-T mg/l	0	NS	NS	250	NS	3.7	9	3.92	No	0.5	
Temp(s) C	0	N/A	0	NS	NS	N/A	.		DM exceeded: 50	DMs	
Temp(w) C	0	N/A	0	NS	NS	N/A	51	18.1	See Summer line	DMw	
Zn-D ug/l	0	31.63	41.76	NS	NS	1.875	12	2.8	No	0.85	
Zn-T ug/l	0	NS	NS	NS	2000	0.65	12	0	XTD	0.5	

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Nutrients	2008	2009	2010	2011	2012	2013	Stds
TN mg/l	0	0	0	0	0	0	2.01
TP mg/l	1\ 0.011	9\ 0.013	9\ 0.013	10\ 0.012	9\ 0.013	9\ 0.014	0.17
Chlor a. mg/m2	0\ 0	0\ 0	0\ 0	0\ 0	0\ 0	0\ 0	150

WBID	COUCUC12					2015_COUCUC12_WQCD_Lakes_GRAND BOTTOM_GRAND01-L
Site Number	GRAND BOTTOM	Datastore Period of Record:	7/30/2010	to	7/30/2010	
Site Name	GRAND01-L					
Agency	WQCD_Lakes	Calculation Period of Record:	10/1/2008	to	12/1/2014	
Latitude	-2146826246					
Longitude	-2146826246				n	<-Use Site Specific Information
Datum					n	<-Output "TVS Table"
AQ Use	Aq Life Cold 1				n	<- Output "Graphs" tab
Rec Use:	Recreation E				n	<- Output "NH3" tab
WS Use Y/N					n	<- Show "Standards Table"
Temp Tier:	CL,CLL				y	<-- show acute paired calcs. ** will not work with the show calcs tab.
Agriculture	agriculture					
Date Assessed	6/11/2015					
Assessor	SMW					

ALL Green Boxes are Required.

		Aquatic Life		Water Supply	Agriculture	Existing	n	Acute	Status	Summary
	"J" Flag	Chronic	Acute*		(TREC)	Quality		Max		Stat.
Ag-D ug/l	0	0	0.09	NS	NS	0	1	0	No	0.85
Ag-T ug/l	0	NS	NS	NS	NS	0	1	0	XTD	0.5
Al-D ug/l	0	NS	NS	NS	NS	0	1	0	No	0.85
Al-T ug/l	0			NS	NS	0	1	0	XTD	0.5
As-D ug/l	0	150	340	NS	NS	0	1	0	No	0.85
As-T ug/l	0	NS	NS	0.02	100	0	1	0	XTD	0.5
Cu-D ug/l	0	1.87	2.39	NS	NS	0	1	0	No	0.85
Cu-T ug/l	0	NS	NS	NS	200	0	1	0	XTD	0.5
Fe-D ug/l	0	NS	NS	300	NS	31	1	31	No	0.85
Fe-T ug/l	0	1000	NS	NS	NS	31	1	0	XTD	0.5
Hardness mg/l	0	NS	NS	NS	NS	16	1	16	No	avg
Mn-D ug/l	0	895.92	1621.57	50	NS	0	1	0	No	0.85
Mn-T ug/l	0	NS	NS	NS	200	0	1	0	XTD	0.5
Pb-D ug/l	0	0.33	8.38	NS	NS	0	1	0	No	0.85
Pb-T ug/l	0	NS	NS	NS	100	0	1	0	XTD	0.5
Se-D ug/l	0	4.6	18.4	NS	NS	0	1	0	No	0.85
Se-T ug/l	0	NS	NS	NS	20	0	1	0	XTD	0.5
Zn-D ug/l	0	22.89	30.22	NS	NS	0	1	0	No	0.85
Zn-T ug/l	0	NS	NS	NS	2000	0	1	0	XTD	0.5

COLORADO
HOUSE OF REPRESENTATIVES
State Capitol
Denver
80203

July 18, 2017

Colorado Water Quality Control Commission
Colorado Department of Public Health and Environment
4300 Cherry Creek Drive South, A-5
Denver, CO 80246

Dear Commissioners:

We, the undersigned, respectfully request that the Colorado Water Quality Commission initiate rulemaking to designate Grand Lake as an Outstanding Water. Outstanding Waters are a formal designation through the Colorado Water Quality Control Commission.

Grand Lake is Colorado's largest and deepest natural lake. It sits at the base of Rocky Mountain National Park where it is fed by headwater streams that are themselves already designated as Outstanding. For over 100, years it has been a magnet for tourists from around the world attracted to its outstanding natural beauty, ecological significance and the recreation opportunities it affords. Generations of families are propelled to return to the lake to enjoy its communion of blue water, blue sky and majestic mountains. As a headwater lake, it has served as the birthplace of the West and contributes to the remarkable history and heritage of the Colorado River. Because of its recreational opportunities, unmatched beauty, water quality that benefits from input from other Outstanding designated sources, and quality of life offerings, it provides the basis for the existence not only for the surrounding town of Grand Lake but also for much of Grand County.

The Outstanding Waters designation will support national and Colorado values that include: enjoyment of a recreational treasure, including small water craft boating and fishing around the nation's highest yacht club; the uniqueness of Colorado's largest and deepest natural lake; and an aesthetic focal point for Rocky Mountain National Park which attracts over 3.5 million visitors from around the world each year. All of these features place Grand Lake as a top quality Outstanding Water. Grand Lake deserves this designation so that it can join its rightful spot beside such other similarly designated natural waters like Lake Tahoe and Lake Yellowstone.

Thank you,

K C Becker

KC Becker
House Majority Leader
House District 13

Summary of Water Quality Test for Outstanding Waters

Northern Water routinely collects data at three sites in Grand Lake:

- SM-CHL/GL-CHL – Site located just east of the connecting channel in Grand Lake
- GL-MID – Site located in the mid-section of Grand Lake
- GL-ATW – Site located near the Adams Tunnel West Portal

Nutrient, metals, and general chemistry samples are collected at a depth 1 meter below the surface and approximately 1 meter above the bottom. Profiles of the physical parameters are taken at one meter increments until a depth of 25 meters, then the increment increases to every 5 meters to the bottom of the water body.

Data collected on Grand Lake for the most recent five-year assessment period, 2012-2016, were compared to the 12 parameters required for the Outstanding Waters Designation to see if the existing water quality was better than or equal to the designated water quality standard. The results are shown in the table below:

	SM-CHL	GL-MID	GL-ATW
Dissolved Oxygen	No	Yes	Yes
pH	Yes	No	Yes
E. coli	No Data	No Data	No Data
Ammonia (chronic)	NA	NA	NA
Nitrate	Yes	Yes	Yes
Dissolved Cadmium (chronic)	Yes	Yes	Yes
Dissolved Copper (chronic)	Yes	Yes	Yes
Dissolved Lead (chronic)	Yes	Yes	Yes
Dissolved Manganese (chronic)	Yes	No	Yes
Dissolved Selenium (chronic)	Yes	Yes	Yes
Dissolved Silver (chronic)	Yes	Yes	Yes
Dissolved Zinc (chronic)	Yes	Yes	Yes

There were three out of the twelve parameters where the water quality was less than the designated standard required for Outstanding Waters:

- Dissolved Oxygen at SM-CHL – The dissolved oxygen standard for cold water aquatic life class 1 is 7 mg/L from mid-October to July (for protection of spawning habitats) and 6 mg/L from August to mid-October. On 7/2/2013 and 7/17/2013, the dissolved oxygen at SM-CHL was less than 7 mg/L; 6.68 and 6.45 respectively.
- pH at GL-MID – The pH standard for cold water aquatic life class 1 is calculated with the average of the values in the upper portion (0.5-2 meters) and the lower portion (1-3 meters above the bottom) of the lake for each profile. The 15th and the 85th percentiles of the sample averages for each portion are compared to the minima (6.5) and maximum (9) pH standard for the determination of attainment. At GL-MID, the minimum pH was exceeded at the bottom depth for the assessment period.
- Dissolved Manganese at GL-MID – The chronic standard for dissolved manganese for cold water aquatic life class 1, is obtained through comparing the 85th percentile against the hardness based equation using mean hardness. At GL-MID at the bottom depth, dissolved manganese was not in attainment of the chronic standard for the assessment period.

FINAL REPORT

EFFECTS OF WATER CLARITY AND OTHER FACTORS ON AQUATIC LIFE OF GRAND LAKE, COLORADO

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Prepared For
Northern Colorado Water Conservancy District

February 28, 2014

EXECUTIVE SUMMARY

This project evaluated the current state of knowledge regarding effects of water clarity and other factors on aquatic life in Grand Lake, Colorado. Existing data and reports were compiled along with a review of scientific literature. Gaps were addressed with field sampling of key components of the reservoir's aquatic life and with laboratory analyses to determine food web structure and evaluate factors limiting for aquatic life at Grand Lake. Data from the present study were combined with existing data on Grand Lake and comparable data from other coldwater reservoirs in Colorado to evaluate the relationship between clarity and other factors on aquatic life of Grand Lake. The food web of Grand Lake is dominated by an extremely abundant Mysis shrimp population that competes with sport fish for zooplankton. Growth and condition of most sport fish in Grand Lake are fair to poor. We believe that the relatively modest changes in water clarity induced by the pumping of water from Shadow Mountain Reservoir have not adversely affected fish populations. Direct effects of turbidity or suspended solids on fish health have not been observed at the levels found in Grand Lake. The data suggest that pumping from Shadow Mountain Reservoir has an enriching effect that should be beneficial to Grand Lake's fish populations. Reducing nutrients and zooplankton pumped into Grand Lake to improve water clarity could result in declines in *Daphnia* and sport fish growth and production.

INTRODUCTION

Clarity of lakes has both aesthetic and ecological aspects. This project focused on ecological aspects. Humans often equate water clarity with water quality and even ecosystem health. Indeed, reduced water clarity can be symptomatic of environmental degradation, for example, cyanobacteria blooms and hypoxia resulting from eutrophication that can be harmful to aquatic life. High turbidity levels can alter plant and algal production, impair vision and foraging of fish (De Robertis et al. 2003), and can even be lethal at extremely high levels. However, health of aquatic life and some beneficial uses of water, such as recreational fishing, may be enhanced by some factors that can reduce water clarity to intermediate levels by providing cover for young fish and increasing productivity of the system (Ney 1996; Stockner et al. 2000; Anders and Ashley 2007).

At Grand Lake, Colorado, water clarity has been affected by Colorado-Big Thompson system operations. Water pumped into Grand Lake from downstream has different physicochemical and biological characteristics than water in Grand Lake (WQP 2013), contributing to a reduction in water clarity, particularly in certain years and seasons (Boyer and Hawley 2012). However, Grand Lake has also experienced dramatic changes resulting from introductions of nonnative species for sport fishery management, some occurring after the completion of CBT. The introduction of Mysis shrimp *Mysis diluviana* has had a strong negative influence on the lake's food web, with consequences for both water clarity and the health of other aquatic life. The purpose of this study is to examine effects of 1) pumping/water clarity and 2) other factors including Mysis shrimp on aquatic life at Grand Lake, with an emphasis on zooplankton and fish.

STUDY SITE

Grand Lake is located at 2,550 m ASL in Grand County, Colorado near the southwest border of Rocky Mountain National Park. Grand Lake is the second largest (208 ha) and deepest (81 m) natural lake in Colorado (Nelson 1988). Colorado River cutthroat trout *Oncorhynchus clarkii pleuriticus* were probably native to the lake but were thought to be hybridized with rainbow trout *Oncorhynchus mykiss* by the early 1900s (Wiltzius 1985). The lake is currently stocked with kokanee *Oncorhynchus nerka* and rainbow trout; brown trout *Salmo trutta* and lake trout *Salvelinus namaycush* are naturally reproducing. Since the 1940s the lake has been part of the Colorado-Big Thompson Project (CBT). The CBT's Alva B. Adams Tunnel was completed on the eastern end of the lake in 1944 and was opened in 1947 (Table 1). The tunnel is used to shuttle water pumped from Granby Reservoir (beginning in 1951) and through Shadow Mountain Reservoir and Grand Lake to northeastern Colorado. Mysis shrimp were introduced into Grand Lake (and many other western U.S. waters) in 1969 with a goal of increasing sport fish growth (Martinez 1991). Unexpectedly, these introductions harmed rather than helped sport fish populations as Mysis shrimp preyed on zooplankton populations but were relatively immune to predation by fishes (Nesler and Bergersen 1991; Chipps and Bennett 2000).

METHODS

We used a combination of field sampling, laboratory analyses and comparative analysis. Data from the present study were combined with existing data on Grand Lake and comparable data from other coldwater reservoirs in Colorado to interpret conditions at Grand Lake and to evaluate the relationship between water clarity and other factors on aquatic life of Grand Lake.

Biological sampling

We sampled zooplankton quantitatively at each of three sites (Figure 1) during June-August 2013 using 153 µ and 500 µ mesh Wisconsin nets (June, August) or Clarke-Bumpus metered plankton sampler (July) towed vertically from 10 m to the surface (Table A1). We also collected zooplankton for stable isotope analysis with both 153 µ and 500 µ mesh nets, by towing the nets horizontally just below the surface. We were unable to capture enough plankton biomass in June for stable isotope analysis.

Mysis shrimp were sampled at night at the time of the New Moon on June 10, 2013 and August 7, 2013 using a net of the same configuration used by Colorado Parks and Wildlife for their standardized Mysis shrimp monitoring statewide (Martinez et al. 2010). This net had a 1.0-m diameter (0.785 m^2) opening and 500 µ mesh. Sampling began about 45 min after sunset and was performed at 8 sites, stratified by depth and quadrant of the lake (Figure 1). Two samples each were collected from within 0-20 m, 20-40 m, 40-60 m, and >60 m depth strata. The net was towed vertically with a windlass at about 1.0 m/s from 1 m above the bottom (or 60 m if depth> 60 m) to the surface. One sample was preserved in 70% ethanol for enumeration and measurements. A second sample was frozen for stable isotope analysis.

Fish were sampled from the catch collected by CPW in July, and supplemented with sampling we conducted during August 7-8, 2013. We also collected samples of fingerling and catchable rainbow trout from CPW hatcheries that provide fish for stocking at Grand Lake. Samples were collected from Finger Rock State Fish Hatchery on August 8, 2013, and from Rifle Falls State Fish Hatchery on September 6, 2013. Fish were measured and weighed and dorsal muscle tissue was collected for stable isotope analysis. We collected otoliths from a subset of salmonids (brown, lake, and rainbow trout) sampled from the lake for age determination. Lake trout abundance was estimated by the Summer Profundal Index Netting (SPIN; Sandstrom and Lester 2009) in July. A total of 36 variable mesh gill nets was set across 10-m depth strata.

Laboratory

Preserved zooplankton were identified to genus or species and life stage. Samples were counted in a Sedgwick-Rafter cell or plankton wheel (Lind 1979). Sample counts were converted to individuals/L based on abundance and the volume of lake water sampled. A subsample of up to 25 individuals from each sampling date and site was measured. Mysis shrimp samples were counted and counts converted to individuals/m^2. A subsample of 25 individuals from each sampling date and site was measured from the tip of the rostrum to the tip of the telson.

Samples for stable isotope analysis were dried at 60°C to constant weight and then pulverized to a fine powder in a mortar and pestle. Samples of this material were sent to the Stable Isotope Laboratory at Cornell University for determination of C:N ratio, $\delta^{13}C$, and $\delta^{15}N$. We normalized isotopic signatures for lipid content using the method of Post et al. (2007). Food web structure was evaluated on the basis of relative carbon and nitrogen isotope signatures of nodes in the web, and expected trophic fractionation when prey are consumed ($\Delta\delta^{15}N \approx 3$, $\Delta\delta^{13}C \approx 0.5$ per trophic level, Vander Zanden et al. 2007; McCuchan et al. 2003).

Otoliths of salmonids were embedded in epoxy resin, sectioned perpendicular to the sulcus and polished to a thickness of 0.8-1.0 mm. Age was determined by microscopic examination of annular marks. Growth was computed by fitting a von Bertalanffy growth function to the sizes-at-age determined from otoliths (Quist et al. 2012). Body condition was estimated by relative weight, W_r, an index of plumpness and well-being in fish (Pope and Kruse 2007).

Comparative analysis

We combined data from the present study on Grand Lake with existing data on water quality and food webs of 15 coldwater lakes and reservoirs in Colorado (Table 2) including Big Creek Lake, Blue Mesa Reservoir, Carter Reservoir, Dillon Reservoir, Eleven Mile Reservoir, Granby Reservoir, Grand Lake, Horsetooth Reservoir, Mc Phee Reservoir, Ruedi Reservoir, Shadow Mountain Reservoir, Taylor Park Reservoir, Turquoise Reservoir, Twin Lakes, and Vallecito Reservoir. Data gathered included surface temperature, Secchi depth, zooplankton (*Daphnia*) density, Mysis shrimp density, and fish growth obtained from our own research and databases of Northern Water, Colorado Parks and Wildlife, USBR and other sources. These data allowed us to put measurements obtained from Grand Lake in the context of findings at other important coldwater systems in Colorado.

Effects of pumping

We assumed that pumping water from Shadow Mountain Reservoir into Grand Lake could reduce water clarity when the source water was higher in dissolved and suspended substances than the water in Grand Lake itself. We differentiated between two clarity-reducing effects: reduced light penetration caused by light attenuating substances in the water such as dissolved and particulate organic matter, and increased light scattering from particulate matter in the water such as algal cells, fine detrital particles, and suspended inorganic material. We reviewed the scientific literature on effects of water clarity on lakes. Our focus was on evaluating potential direct and indirect effects of reduced water clarity on aquatic life, primarily fish. We also considered the effects of other characteristics of pumped water such as nutrients, organic matter and zooplankton, which could have an enriching effect on the Grand Lake food web.

RESULTS AND DISCUSSION

Biological sampling

The density of total zooplankton increased from < 1.00 plankters/L in June to > 200 plankters/L in August (Table 3). All taxa increased over the summer, but cyclopoid copepods were by far the most numerous zooplankton taxon sampled, increasing from 0.7 plankters/L in June to about 190 plankters/L in August. Catch composition was very different between 153 µ and 500 µ nets (Table A2, Figure A1), with the 500 µ net missing virtually all *Bosmina* and most copepods. Density of all *Daphnia* spp, the zooplankton preferred by fish, was very low all summer, and only exceeded 1 plankter/L in August (1.468 plankters/L) when the surface temperature was > 17.0 °C. These results appear to be fairly typical for the lake. The mean *Daphnia* density measured in NCWCD monitoring at Grand Lake during 2005-2013was just 0.6 ± 0.5 *Daphnia*/L. We believe the low *Daphnia* density at Grand Lake is primarily due to the presence of a very large Mysis shrimp population that can access the epilimnion throughout most of the year, and not the result of low system productivity.

The density of Mysis shrimp was very high, at about 800 mysids/m^2 in June and August (Table 4). Mysis shrimp areal and volumetric densities were more variable across sites and depths in June compared to August. In August Mysis shrimp areal density was highest in the 40-60 m depth stratum and was about half that at all other depth strata. On a volumetric basis, Mysis shrimp density was highest in the shallowest stations, and lowest in depths > 60 m where dissolved oxygen on the bottom was lowest. These are the first estimates of Mysis shrimp density measured at Grand Lake, so there are no historical data to which to compare. However, Mysis shrimp density at Grand Lake was higher than all other waters in the comparative analysis (below).

Body condition of sport fish was fair to poor for all species sampled. Relative weight (W_r) was generally below the norm (100) for each species (Figure 2). Mean W_r was 82, 81, 94, and 83 for brown trout, kokanee, lake trout and resident rainbow trout. The range of W_r for lake trout was greatest (W_r = 55-120), with some individuals in good to excellent condition but many others in fair to poor condition. Surprisingly little historic data were available on the fish populations at Grand Lake. The best information available was collected by Jon Ewert (CPW), who conducted periodic surveys at Grand Lake to monitor the status of the fishery beginning in 2005. Relative weights of brown trout and lake trout were similar to 2013 in 2005-2012, with lake trout generally in somewhat better body condition than brown trout (Table 5).

Consistent with differences in body condition, the growth rate of brown trout was poorer than lake trout. Growth of brown trout (Figure 3) was fair and was similar to that measured in Dillon Reservoir, where size and condition of brown trout is unacceptable to many anglers and has required extraordinary management measures by CPW in 2012-2013 to improve growth. Few brown trout in Grand Lake achieve even intermediate size (“preferred”, Hyatt and Hubert 2001). Alternatively, lake trout growth in Grand Lake was fair to good, with some fish achieving “memorable” size within 10 years (Figure 3). No historic data on fish growth at Grand Lake were available. Growth of lake trout in Grand Lake was modest compared to the state’s premier lake trout fishery at Blue Mesa Reservoir. However, an abundance estimate performed by CPW and CSU in July 2013 (Jon Ewert, CPW, unpublished data) suggested that lake trout abundance (N=2,491, CL=2008-2738) and density (12.9 fish/ha) were relatively high in Grand Lake.

We determined carbon and nitrogen isotopic signatures of zooplankton, Mysis shrimp, suckers, hatchery rainbow trout, resident rainbow trout, brown trout, and lake trout. In aggregate, the signatures suggested several patterns. The signatures of Mysis shrimp suggested that zooplankton are not their only prey resource (Figure 4). Because of the extremely low density of preferred zooplankton prey (*Daphnia*) in Grand Lake, it is likely that Mysis shrimp must supplement their diet with detrital material and algae with lower carbon and nitrogen signatures than zooplankton. Kokanee, which are typically the most planktivorous sport fish species, also must have relied on other prey besides zooplankton. Although not sampled, we believe that based on experience in other Colorado waters kokanee are probably consuming chironomid larvae and pupae.

The carbon and nitrogen signatures of brown trout and lake trout increased with fish size (Figure 4). The largest sizes of both species had similar isotopic signatures that strongly suggested that hatchery rainbow trout and kokanee contributed significantly to the diet and growth of these fish. Fingerling kokanee and rainbow trout have been stocked in fairly consistent numbers during 2003-2013 (Figure 5), supporting the notion that hatchery prey are important for some lake trout and brown trout at Grand Lake. Signatures of smaller lake trout suggested that they consumed Mysis shrimp, zooplankton, kokanee, and perhaps chironomid larvae. Smaller brown trout diet was probably composed of invertebrates not sampled, such as chironomid larvae.

Comparative analysis

At 208 surface ha, Grand Lake was the second smallest water body in our dataset (Figure 6). This may explain why the lake was not included in statewide coldwater reservoir surveys conducted by CPW in the 1990s and 2000s (Martinez et al. 2010). Grand Lake is also unusual because water level fluctuations are much less than in the other systems. Although most of the systems in our set are manmade reservoirs, Big Creek Lake and Twin Lakes were originally natural water bodies that were subsequently modified for water supply, as at Grand Lake. Grand Lake’s surface elevation (2,550 m ASL) is similar to the average elevation of waters in the dataset (Figure 6), which ranged 1655-3009 m ASL.

Average (July-September) Secchi depth at Grand Lake (3.35 m) was slightly lower than the average for all waters in the dataset (3.86 m; Figure 6). Generally, waters with the highest Secchi depth were also waters with high summer *Daphnia* densities and lowest Mysis shrimp abundance (Figure 6). However, Twin Lakes had relatively clear water but very low *Daphnia* density, and Shadow Mountain Reservoir had high *Daphnia* density and turbid water, suggesting that both top-down and bottom-up factors control water clarity in Colorado coldwater reservoirs, including Grand Lake. Determining the relative importance of top-down/bottom-up effects on clarity at Grand Lake is difficult with the present observational data because the transport of substances, including inorganic material, from Shadow Mountain Reservoir may mask some food web effects on clarity.

Water temperature at Grand Lake was similar to other reservoirs at similar elevation (Figure 7). Surface temperature reached its annual maximum (~18 °C) in the first week of August (Figure 7). Comparison with surface temperatures measured in 1940-1942, prior to completion of the CBT, suggest that pumping and transfers through the Adams Tunnel have not affected the lake's surface temperature during the growing season (Figure 8). The thermal regime at Grand Lake is favorable for Mysis shrimp. Mysis shrimp have a thermal preference of 6-12°C (Boscarino et al. 2010), and avoid water temperatures > 17 °C (Johnson and Martinez 2012). The temperature of Grand Lake's epilimnion exceeds this threshold for only about one month or less during late July- early August (Figure 8), allowing Mysis shrimp to prey on epilimnetic zooplankton for most of the year.

Density of Mysis shrimp measured in Grand Lake in 2013 was higher than the average Mysis shrimp density measured at 10 other Colorado reservoirs containing the species (Figure 6). The relatively favorable thermal regime and extremely abundant Mysis shrimp population are very likely responsible for the lake's exceptionally low *Daphnia* density (Figure 6). Only Twin Lakes and Dillon Reservoir had lower *Daphnia* density, partially due to their relatively oligotrophic status.

Effects of pumping- clarity

Extensive water quality monitoring by NCWCD and others has documented changes in water clarity of Grand Lake associated with pumping water from Granby Reservoir into Shadow Mountain Reservoir and Grand Lake (WQP 2013). Post-CBT Secchi depths have ranged 1.2 to 5.7 m. Unfortunately, few water clarity (Secchi depth) data exist prior to the 1990s and only a single observation exists from prior to operation of the CBT (9.2 m in 1941; Boyer and Hawley 2012). Nor are there substantive data available on the status of fish populations in Grand Lake before the Adams Tunnel became operational. This lack of "pre-treatment" data makes inference about how pumping has affected aquatic life in Grand Lake more difficult but results of studies in the literature provide insights.

The limnological literature shows that reduced light penetration (and increased scattering) can have wide-ranging effects on aquatic life in lakes (Table 6). Fundamentally, light attenuation limits the depth of the photic zone (~ 3 x Secchi depth; Horne and Goldman 1994), where photosynthesis exceeds respiration. Thus, the maximum depth where rooted macrophytes, benthic algae and phytoplankton can persist is set by water clarity. Reduced clarity can then affect the distribution and production of herbivorous insects and littoral zooplankton. Reduced light penetration may also favor phytoplankton over macrophytes in competition for light. Very low light penetration can even shift the composition of the phytoplankton assemblage toward cyanobacteria (Mur et al. 1977; Huisman et al. 1999), which then can limit production of grazers and other consumers.

Because of the shape and composition of Grand Lake's basin, most of the lake bottom with suitable depths (<10 m) and substrate for rooted macrophytes occurs in the southwest corner of the lake. It is in that area of the lake that changes in water clarity should have the most readily observable effects on the density and distribution of rooted macrophytes. Rooted macrophytes can provide habitat for various fish food organisms so this region of the lake may be an important foraging area for fish that consume certain invertebrates. If turbidity reduces the biomass of macrophytes it could affect production of fish food organisms. However, this area comprises a relatively small fraction of the lake's area, and such indirect effects of fish food production should be small and difficult to demonstrate. There are more direct potential effects of reduced clarity on visual-foraging consumers that would affect the entire lake.

Both light intensity and scattering affect predators by reducing their visual field and increasing energy spent foraging. Many fish species, including salmonids, rely on vision for detecting their predators and prey (Confer et al. 1978; Mazur and Beauchamp 2003). Turbidity reduces their visual range and reaction distance (Vinyard and O'Brien 1976; Vogel and Beauchamp 1999) and thus reduces the ability of predators and prey to detect each other (Ferrari et al. 2010; Chivers et al. 2012). Predators have an easier time detecting prey in clear water, and prey species may change their behavior (e.g., forage less) to avoid predators in clear water. In more turbid water visual predators and prey detect each other at closer distances, making prey easier to capture, but increasing the search time of predators.

Because prey fish feed on smaller prey than piscivores, they detect their prey at relatively shorter distances. Hence, their foraging success is less affected by turbidity than for piscivores (Vinyard and O'Brien 1976). Turbidity ranging 0.95-11 NTU had no effect on weakfish *Cynoscion regalis* consumption of Mysis shrimp (Grecay and Targett 1996). Planktivorous salmon feeding was unaffected by a turbidity range of 0-40 NTU (De Robertis et al. 2003). Other studies have demonstrated that prey fish may actually forage more under moderate turbidity (~10-100 NTU) than they would in clear water, partly because it is not advantageous to reduce foraging when evading predators is unlikely. Abrahams and Kattenfeld (1997) found that planktivorous minnows were more likely to forage in turbid water (11-13 NTU) than in clearer water. Likewise, Gregory and Northcote (1993) found that invertebrate-eating juvenile salmon increased their foraging when turbidity increased to 35 NTU, and was impaired only when turbidity approached 150 NTU. Juvenile steelhead *Oncorhynchus mykiss* showed reduced growth rate at 25-50 NTU (Sigler et al. 1984) but others have found conflicting results (Swenson and Matson 1976). Regardless, the average turbidity measured at Grand Lake during the 2011, 2012 growing seasons (1.99 NTU; range 0.60-3.90 NTU; n = 104) was well below the level that the literature suggests would adversely affect foraging or growth of prey fish such as kokanee and rainbow trout.

Turbidity may affect foraging by piscivores more than by prey fish because piscivores can detect their prey at much longer distances in clear water compared to prey fish so the reduced visual field caused by turbidity is more significant to piscivores. Mazur and Beauchamp (2003) found that reaction distance of lake trout was unaffected by low turbidity (0.08 - 0.55 NTU) but decreased by about 15% when turbidity increased to 1.50 NTU, and by about 30% when turbidity increased to 3.18 NTU, but little more at 7.40 NTU (Vogel and Beauchamp 1999) (Figure 9). Reaction distance of cutthroat and rainbow trout changed little at 0.08 – 1.50 NTU (Barrett et al. 1992; Vogel and Beauchamp 1999). Overall, these studies suggest that lake trout reaction distance may be reduced by turbidity more than for rainbow and cutthroat trout. Whether such changes affect the feeding and growth of piscivores is harder to evaluate because predators can search more to compensate for a reduced visual field, and studies suggest that their capture success may actually increase under more turbid conditions.

Jönsson et al. (2013) found that although encounter rate and duration were reduced by turbidity (3.2-7.5 NTU) capture success of piscivores increased with turbidity. This may help explain why predation by adult cutthroat trout on juvenile salmonids did not differ between clear (0.5 – 2.4 NTU) and turbid (12-87 NTU) treatments (Gregory and Levings 1996). Abrahams and Kattenfeld (1997) found that predation on planktivorous minnows did not decline in turbid (11-13 NTU) water and Chivers et al. (2012) found that minnows were less able to recognize and respond to predators in turbid water (31 NTU, making piscivory more successful.

While turbidity can have indirect effects on fish health by limiting feeding, suspended solids associated with turbidity can have direct effects on fish health via physical injury and physiological stress (Michel et al. 2013). Although turbidity is not always a good surrogate for the quantity and nature of suspended solids that can affect fish health (Davies-Colley and Smith 2001; Bilotta and Brazier 2008), studies often use turbidity as a benchmark. Sigler et al. (1984) found that juvenile steelhead trout died when chronic turbidity ranged 100-300 NTU. In New Zealand, acute exposure at up to 20,000 NTU had no effect on several aquatic insects, crayfish and fish (Rowe et al. 2002). The lethal turbidity levels for two sensitive fish species were 3,050 NTU and 20,235 NTU, and much higher for others. In a review of more than 70 studies, Newcombe and MacDonald (1991) found that salmonids were most sensitive to suspended solid concentrations at the egg-fry life stages. Lethal and sublethal effects were rarely demonstrated below 20 mg/L and most reported effects occurred at orders of magnitude higher TSS. During 2005-2011 TSS averaged about 2 and 3 mg/L and never exceeded 13 mg/L in surface water of Grand Lake and Shadow Mountain, respectively (WQP 2013). The literature suggests that adverse health effects of turbidity inducing substances on fish occur at substantially higher turbidities and TSS than have been observed at Grand Lake.

Effects of pumping- enrichment

Pumping affects more than turbidity at Grand Lake. Monitoring has shown that water that enters Grand Lake from Shadow Mountain Reservoir has higher nutrient and organic matter concentrations (WQP 2013; McCutchan 2013). Phytoplankton and zooplankton are also transported from Shadow Mountain Reservoir to Grand Lake during pumping. Thus, to understand the potential effects of pumped water on the aquatic life of Grand Lake it is also necessary to examine the effects of substances in the water pumped into Grand Lake that can affect system productivity.

Many connote the term eutrophication with degraded water quality, and assume that "cleaner" (clearer) water will be beneficial for all forms of aquatic life (Ney 1996). This perception is inaccurate. Generally speaking and below some threshold, the productivity of fish populations is inversely related to indicators of oligotrophy such as water clarity (Oglesby 1977; Olem and Flock 1990; Figure 10). Thus, lake management goals of clear water and productive fish populations can be conflicting. Increasing nutrient and chlorophyll concentrations decrease clarity but increase fisheries production until the assimilative capacity of the system is exceeded and decomposition of unconsumed primary production results in degraded habitat (e.g., hypoxia) (Stockner et al. 2000). At low to intermediate trophic states, reducing nutrient loading to encourage clearer water deprives the food web of resources that could contribute to higher growth and abundance of fishes.

Colorado's reservoir fisheries are primarily supported by energy produced in the pelagic zone (Johnson and Goettl 1999; Johnson and Martinez 2000). Based on the lake's steep-sided basin morphometry, we would expect pelagic production to be the primary energy source for Grand Lake also. Nutrient inputs can stimulate increased production of phytoplankton, and provided a suitable N:P ratio, the phytoplankton produced can provide more resources for grazing zooplankton including *Daphnia*. Several studies have demonstrated a very strong linkage between *Daphnia* density and the growth of sport fish in Colorado (Martinez and Wiltzius 1995; Johnson and Martinez 2000; Johnson and Martinez 2012). At Grand Lake *Daphnia* density was among the lowest of the reservoirs we examined, and growth and body condition of most sport fish were fair to poor. Mysis shrimp undoubtedly contribute to the reduced *Daphnia* density at Grand Lake but nutrients transported from Shadow Mountain Reservoir could be moderating the effects of Mysis shrimp on *Daphnia* and fish.

In fact, nutrient supplementation has been proposed as a management tool to mitigate effects of Mysis shrimp predation on *Daphnia* and thereby increase sport fish production in other lakes with Mysis shrimp and salmonid sport fisheries (Caldwell and Wilhelm 2011). Not enough is known about the food web to advocate for purposeful nutrient additions at Grand Lake, but we do believe that reducing nutrient loading would be detrimental to fish populations. Surface TP at Grand Lake averaged about 11 µg/L during 2005-2011 (WQP 2013), and was nearly always below the 25 µg/L interim water quality standard for TP in coldwater lakes and reservoirs. During 2008-2011 total nitrogen at the surface averaged about 250 µg/L and rarely exceeded the 426 µg/L interim water quality standard for TN (WQP 2013). These relatively low nutrient concentrations occurred despite that fact that TP and TN loading are approximately five times higher than they would be without pumping from Shadow Mountain Reservoir (Boyer and Hawley 2012). A large number of studies suggest that fish production would decrease with lower nutrient concentrations (Figure 10). For example, Plante and Downing (1993) found that salmonid (including brown trout and kokanee) production increased with TP up to about 100 µg/L, and lake trout growth and size structure increased with nutrient additions to an oligotrophic Arctic lake (Lienesch et al. 2005). Thus, nutrient inputs to Grand Lake from Shadow Mountain Reservoir are probably beneficial to food web production. The specific effects of nutrients on fish production at Grand Lake are difficult to predict because they depend on algal nutrient limitation status, the effects of Mysis shrimp and the conversion efficiency of phytoplankton to fish. Maintaining a relatively high N:P ratio would favor edible algae and a higher conversion efficiency. Reducing nutrient inputs would likely result in declines in *Daphnia* and sport fish growth and production.

Direct transport of *Daphnia* from Shadow Mountain Reservoir is also likely compensating for Mysis shrimp predation, and is probably beneficial to fish production in Grand Lake. Although the system-level impact of this zooplankton subsidy was not quantified, monitoring data show that *Daphnia* density in the water flowing into Grand Lake from Shadow Mountain Reservoir is much higher than that measured in the water column of Grand Lake (Figure 11). Management alternatives aimed at improving water clarity in Grand Lake that reduce or eliminate the enriching effects of Shadow Mountain Reservoir nutrients and zooplankton will likely be detrimental to the growth and production of Grand Lake's fish populations.

CONCLUSIONS

The relatively modest changes in turbidity in Grand Lake caused by pumping may allow prey fish to forage more freely, improving their opportunity for feeding and growth. While piscivores such as lake trout and brown trout may need to devote more energy to searching for prey, they may experience a higher probability of capturing the prey which could offset search costs. Direct effects of turbidity or suspended solids on fish health have not been observed at the levels found in Grand Lake.

The food web of Grand Lake is dominated by an extremely abundant Mysis shrimp population. Predation by Mysis shrimp suppresses zooplankton populations that are essential to productive sport fisheries in Colorado's coldwater lakes and reservoirs. Growth and body condition of most sport fish in Grand Lake are fair to poor and satisfactory body condition of large lake trout and brown trout are probably only sustained by annual stocking of kokanee and rainbow trout. Although no pre-CBT fish data exist, we believe that changes in water clarity induced by the pumping of water from Shadow Mountain Reservoir have not adversely affected fish populations. In fact, the data suggest that pumping from Shadow Mountain Reservoir has an enriching effect that should be beneficial to Grand Lake's fish populations. Reducing nutrients and zooplankton pumped into Grand Lake to improve water clarity could result in declines in *Daphnia* and sport fish growth and production.

RECOMMENDATIONS

Important areas for future research to better understand the influences of pumping on aquatic life in Grand Lake include:

- Investigations to quantify the indirect effects that Mysis shrimp predation upon herbivorous zooplankton have on water clarity.
    - Has the Mysis shrimp population reduced system-wide grazing on phytoplankton, resulting in poorer water clarity than would exist in the absence of Mysis shrimp?
    - Would reductions in Mysis shrimp biomass result in improved water clarity, and if so, how might such reductions be accomplished?
- Importance of zooplankton pumped into Grand Lake from Shadow Mountain Reservoir
    - Does the biomass of *Daphnia* pumped into Grand Lake represent a meaningful food subsidy supporting growth of sport fish?
- Long-term effects of subsidies of nutrients and organic matter from Shadow Mountain Reservoir to Grand Lake.
    - Will continued inputs of organic matter and ungrazed phytoplankton exceed the assimilative capacity of Grand Lake, resulting in increased hypoxia in the hypolimnion?
    - How do water residence time and seasonal timing of pumping influence food web benefits derived from subsidies (e.g., effects on particle settling vs. uptake by food web vs. flushing)?
- Effects of climate on the food web
    - Will a warmer climate increase the epilimnetic thermal refuge for *Daphnia*, reducing predation by Mysis shrimp and contributing to increased grazing and food for planktivorous fish?
    - How will climate change interact with human population growth to alter the timing and quantity of water transfers through Grand Lake?
- Effects of nutrient stoichiometry on phytoplankton, zooplankton and water clarity.
    - How will changes in climate and land use in the watershed affect N:P and nutrient inputs to Three Lakes system, and how will such changes affect water clarity?

- How might changes in N:P ratios in Grand Lake's inflows affect phytoplankton community composition and edibility for primary consumers that are the food of sport fish?
    - Is nutrient management aimed at maintaining an N:P ratio that improves grazing on phytoplankton a means to improve water clarity and fisheries production?
- Effects of increased clarity on aquatic life in Grand Lake
    - Given the overwhelming influence that Mysis shrimp appear to have on the food web, what evidence is there to expect modest changes in water clarity (i.e., 4 m Secchi depth standard) would enhance the health of aquatic life?
    - Would changes to water management aimed at improving water clarity necessitate reductions in the subsidies of nutrients and plankton that support fish growth in Grand Lake and that compensate for the effects of Mysis shrimp?
    - Would the removal of such subsidies actually intensify competition for zooplankton by Mysis shrimp and fish in Grand Lake, and result in further reductions in growth and condition of fishes?

ACKNOWLEDGMENTS

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Table1 Chronology of events related to changes in water clarity and the food web at Grand Lake, Colorado.

Year	Event	Source
1941	9.2 m Secchi depth measured	BOR 2012
1944	Adams Tunnel completed	NCWCD
1945	Shadow Mountain Dam completed	NCWCD
1947	Adams Tunnel opened, water transfers begin	NCWCD
1951	First water pumped from Granby to Shadow Mountain	NCWCD
1951	Kokanee introduced into Granby (first place in State)	Martinez 1991
1953	Maximum Secchi depth 4.6 m	BOR 2012
1957	CBT completed	NCWCD
1961	Lake trout introduced into Granby	Martinez 1991
1969	Mysis introduced into Grand Lake	Douglas Silver
1971	Mysis introduced into Granby	Martinez 1991
1985	Windy Gap Project completed	NCWCD

Table 2. Characteristics of lakes and reservoirs included in the comparative analysis. “Natural lake” includes water bodies that were natural prior to modifications for water supply.

Water body	Code	Natural lake?	Mysis?	Year built/ altered	Elevation (ft)	Area (ac)	Capacity (ac-ft)
Big Creek Lakes	BCL	YES	YES	-	8996	351	-
Blue Mesa Reservoir	BMR	NO	NO	1965	7519	9180	940700
Carter Reservoir	CTR	NO	YES	1952	5759	1443	112230
Dillon Reservoir	DIL	NO	YES	1963	9022	3442	257269
Eleven Mile Reservoir	ELE	NO	NO	1932	7418	3400	97779
Granby Reservoir	GBR	NO	YES	1949	8281	7255	539790
Grand Lake	GDL	YES	YES	1947	8366	515	68600
Horsetooth Reservoir	HST	NO	YES	1949	5430	1900	156735
Mc Phee Reservoir	MCP	NO	NO	1984	6924	4470	381,195
Ruedi Reservoir	RUE	NO	YES	1968	7779	996	102369
Shadow Mountain Reservoir	SHM	NO	YES	1946	8367	1337	17,354
Taylor Park Reservoir	TAY	NO	YES	1937	9327	2009	106200
Turquoise Reservoir	TUR	NO	YES	1968	9873	1788	129432
Twin Lakes	TWN	YES	YES	1984	9199	1834	95988
Vallecito Reservoir	VAL	NO	NO	1941	7665	2720	129700

Table 3. Density (n/L) of *Daphnia* spp (DAP), *Bosmina* spp (BOS), cyclopoid copepods (UCY), and calanoid copepods (UCA) at three sites on Grand Lake sampled in June, July and August 2013.

Date	Site	DAP	BOS	UCY	UCA	Sum
06/10/13	ATW	0.008	0.004	0.426	0.039	
	MID	0.012	0.000	1.192	0.071	
	9A5	0.004	0.000	0.474	0.036	
	MEAN	0.008	0.001	0.697	0.049	0.755
	SD	0.004	0.002	0.429	0.019	
07/18/13	ATW	0.932	0.381	19.807	0.894	
	MID	0.213	15.446	14.659	0.340	
	9A5	0.199	2.692	17.697	1.246	
	MEAN	0.448	6.173	17.388	0.827	24.836
	SD	0.419	8.114	2.588	0.457	
08/07/13	ATW	2.368	3.158	162.229	10.263	
	MID	1.579	1.184	187.490	11.052	
	9A5	7.894	2.763	220.252	27.235	
	MEAN	3.947	2.368	189.990	16.183	212.489
	SD	3.441	1.044	29.092	9.580	
All	MEAN	1.468	2.848	69.358	5.686	79.360
	SD	2.159	3.114	104.803	9.099	

Table 4. Summary of Mysis shrimp sampling performed with a 1.0 m diameter, 500-µm mesh plankton net at Grand Lake, Colorado on June 10, 2013 and August 7, 2013.

						Catch		
Month	Station	Stratum (m)	Depth at station (m)	Time of tow	Sample number	No. per haul	No. per m^2	No. per m^3
June	8	00-20	11	21:58	GDL061013005	81	103.2	10.3
	5	00-20	14	22:35	GDL061013009	992	1263.7	97.2
	7	20-40	24	21:19	GDL061013001	1665	2121.0	96.4
	1	20-40	33	23:32	GDL061013015	138	175.8	5.9
	6	40-60	47	21:36	GDL061013003	918	1169.4	26.0
	2	40-60	56	23:06	GDL061013013	124	158.0	2.9
	4	>60	84	22:13	GDL061013007	762	970.7	16.2
	3	>60	85	22:48	GDL061013011	493	628.0	10.5
					MEAN=	646.6	823.7	33.2
					SD=	550.2	700.8	39.9
					N=	8.0	8.0	8.0
August	8	00-20	16	21:17	GDL080713003	444	565.6	37.7
	5	00-20	13	21:36	GDL080713005	435	554.1	55.4
	7	20-40	28	20:55	GDL080713001	516	657.3	25.3
	1	20-40	31	22:11	GDL080713008	535	681.5	23.5
	6	40-60	48	21:02	GDL080713002	844	1075.2	23.4
	2	40-60	46	21:58	GDL080713007	1045	1331.2	30.3
	4	>60	84	21:26	GDL080713004	478	608.9	10.1
	3	>60	85	21:42	GDL080713006	432	550.3	9.2
					MEAN=	591.1	753.0	26.9
					SD=	227.7	290.0	14.9
					N=	8.0	8.0	8.0

Table 5. Mean total length and body condition (W_r) of lake trout and brown trout sampled in six surveys on Grand Lake, Colorado. Data from 2013 collected by CPW and CSU; previous years data collected by Jon Ewert (CPW).

	2005	2008	2009	2012	2013	
Date of survey	06/22	07/08	07/08	06/25	07/17	08/08
LAKE TROUT (n)	14	11	12	10	87	1
Mean size (in)	12.6	16.5	13.2	13.2	16.5	18
Body condition	102	87	86	80	94	95
BROWN TROUT (n)	35	31	35	28	37	46
Mean size (in)	12.9	12.3	11.3	11.5	326	300.2
Body condition	98	85	83	82	85	81

Table 6. Potential physical and biological effects of pumping from Shadow Mountain Reservoir on the clarity and production of Grand Lake. "High" levels of these factors have not occurred to date.

Level	Reduced light penetration	Increased light scattering	Increased substances in water
Low to moderate	Shallower photic zone	Reduced visual field for predators and prey	Nutrients: subsidy taken up by pelagic food web
	Reduced macrophyte distribution: reduced invertebrate production	Increased foraging time for prey and predators	Organic matter: subsidy to detritivores, increased biomass of macroinvertebrates including Mysis
	Competitive edge to phytoplankton over macrophytes	Reduced success evading predators Increased capture success by predators	Plankton: subsidies of phytoplankton and zooplankton in pumped water to consumers
High	Phytoplankton competition for light: shift in algal community composition toward cyanobacteria, reduced food for zooplankton	Reduced encounter rates with prey, increased activity and reduced growth	Organic matter: Increased biological oxygen demand in hypolimnion Inorganic particles: inhibition of zooplankton grazing, gill abrasion in fish, sedimentation and smothering

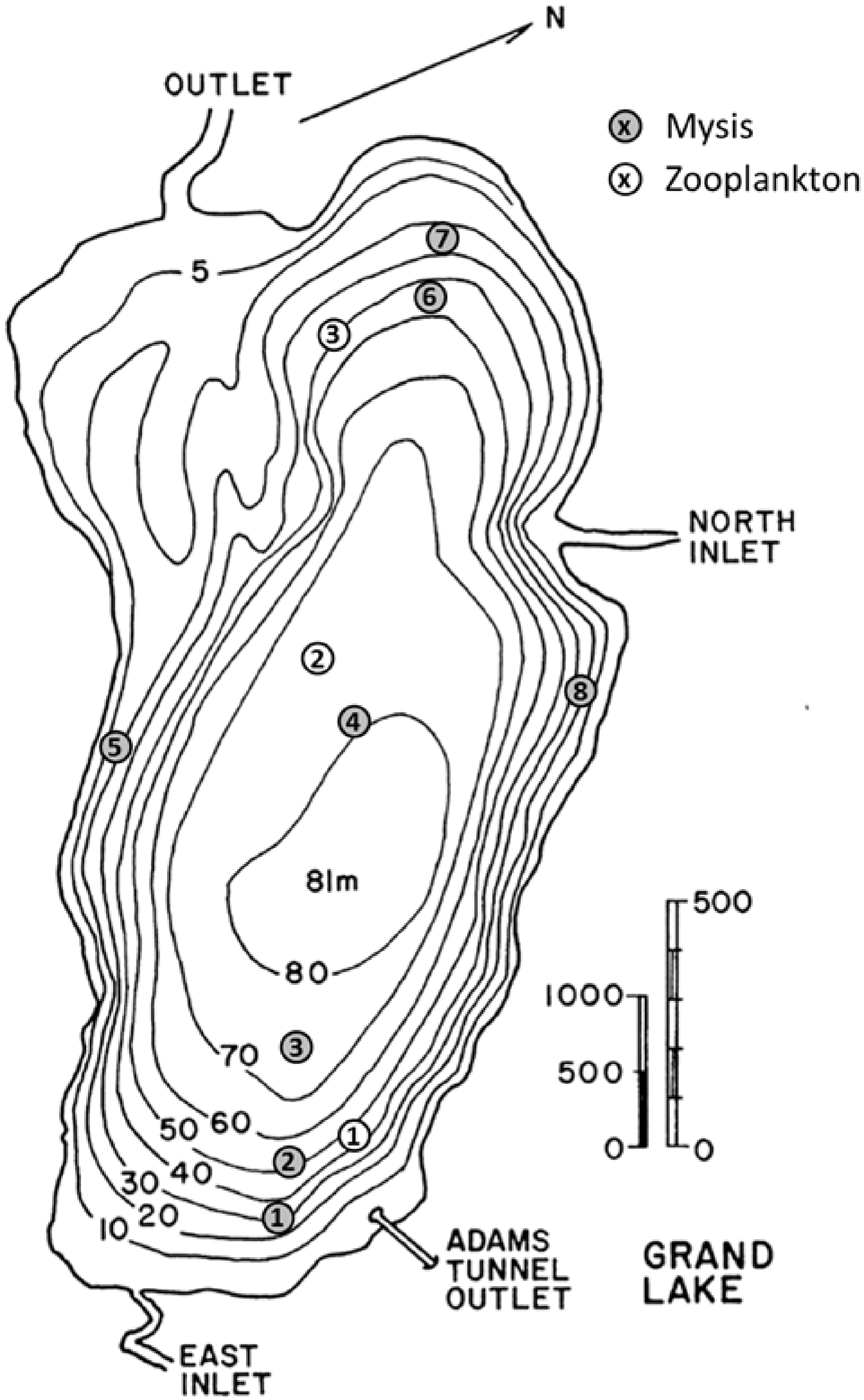


Figure 1. Bathymetric map (meters) of Grand Lake, Colorado (Nelson 1971) showing approximate locations of Mysis shrimp and zooplankton sampling sites used by CSU during summer 2013.

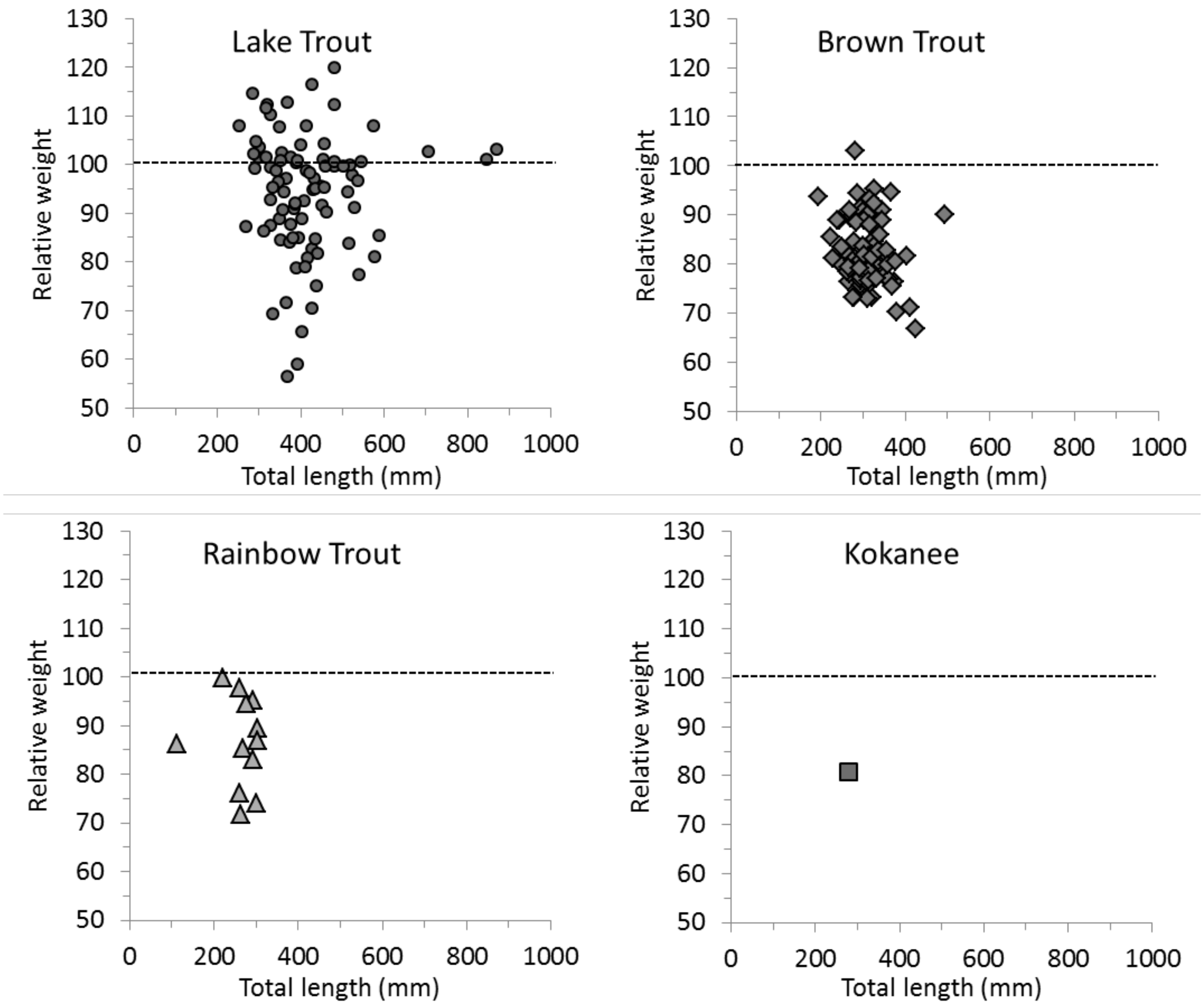
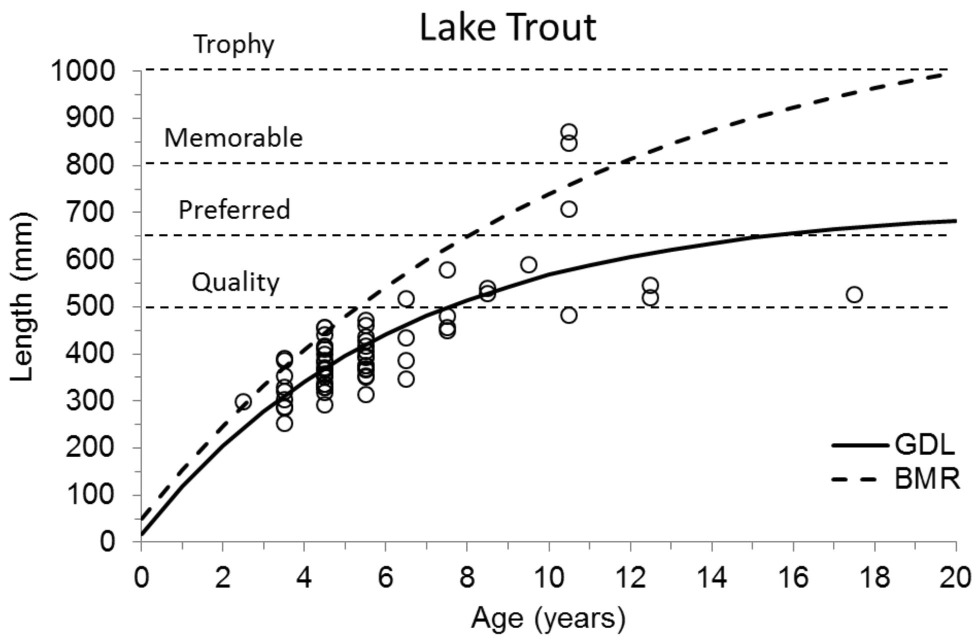


Figure 2. Relative weight, an index of body condition, of lake trout (Piccolo et al. 1996), brown trout (Hyatt and Hubert 2001), rainbow trout (Simpkins and Hubert 1996) and kokanee (Hyatt and Hubert 2000) sampled at Grand Lake during July, August 2013. Relative weight of 100 is considered normal, greater than 100 is better condition, and less than 100 is poorer condition.



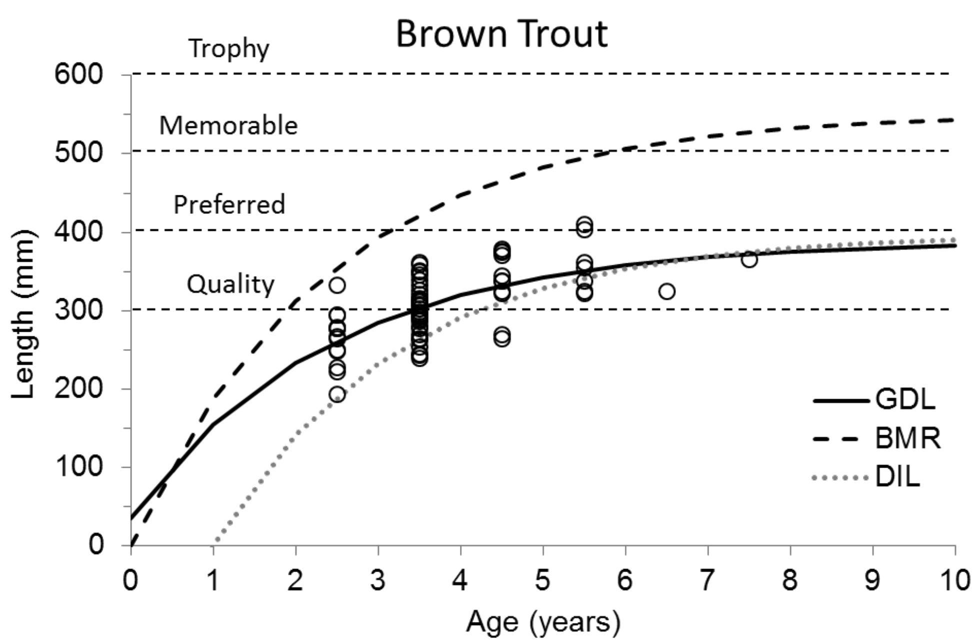


Figure 3. Length at age of lake trout and brown trout from Grand Lake compared to Blue Mesa and Dillon reservoirs. Size categories are from Willis et al. (1993).

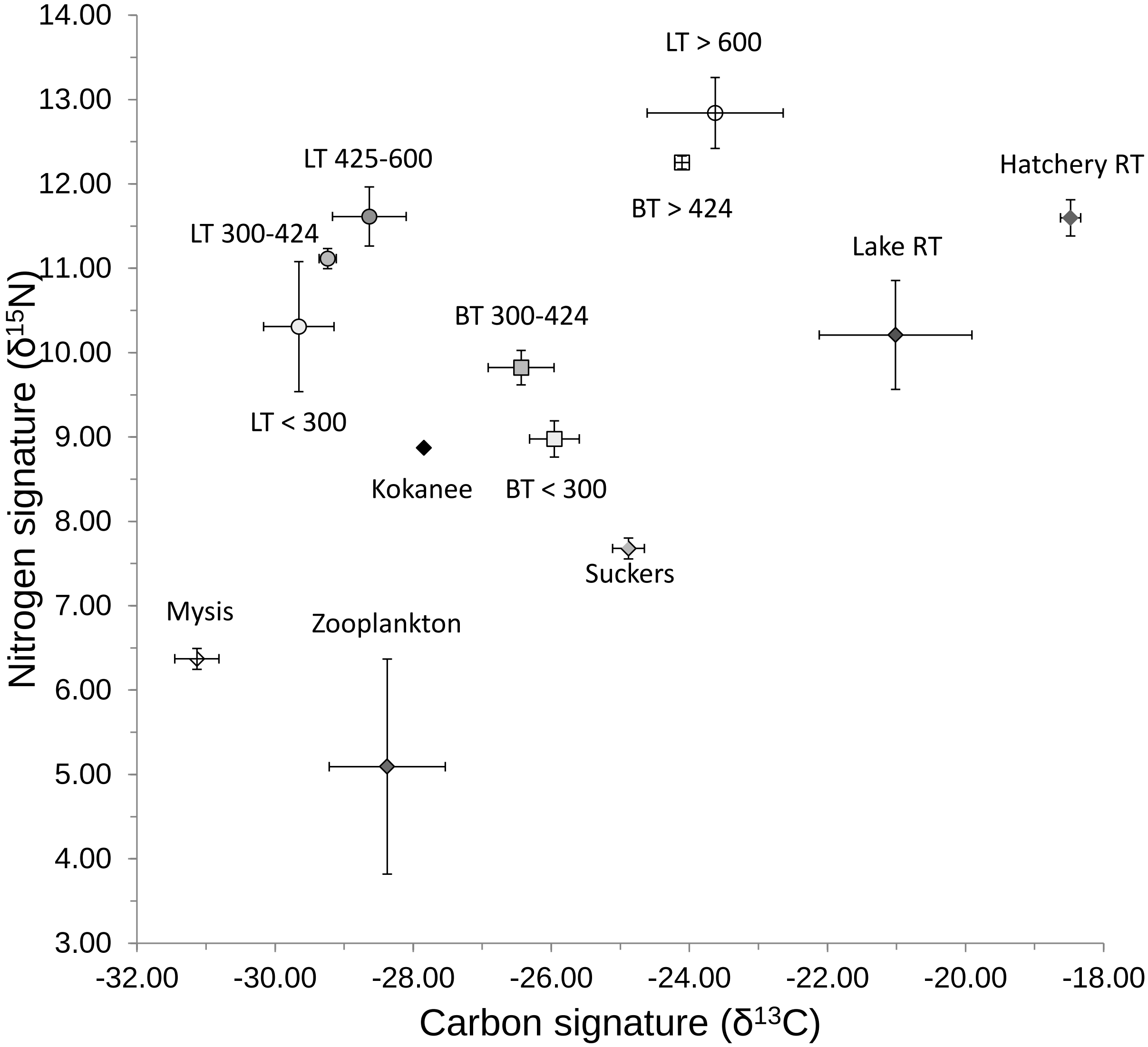


Figure 4. Mean (±2SE) stable carbon and nitrogen isotope signatures of fish and some invertebrates sampled from Grand Lake, Colorado and rainbow trout fingerlings from two Colorado Parks and Wildlife hatcheries during summer 2013.

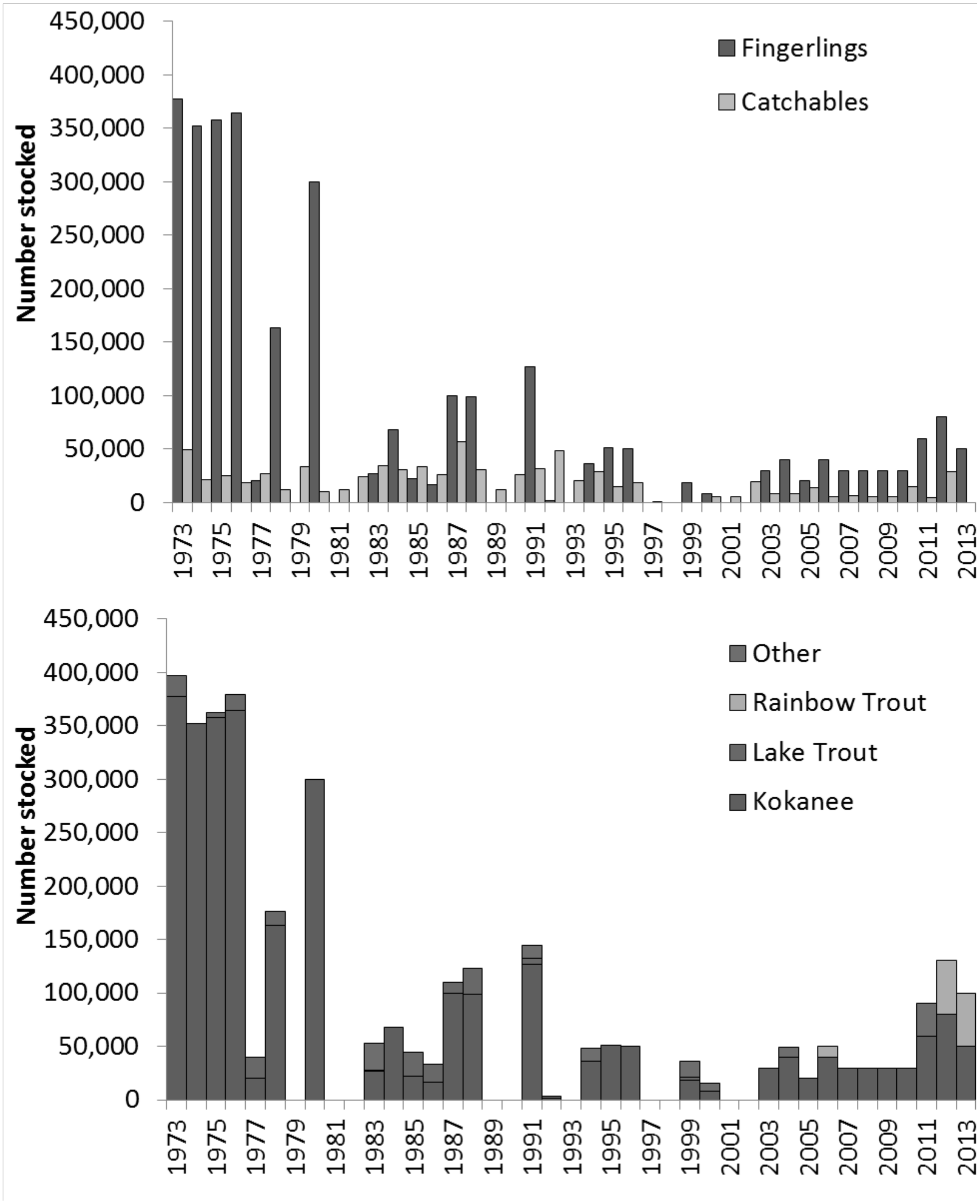


Figure 5. Upper panel: number of fingerlings (mostly kokanee, lake trout, and rainbow trout) and catchables (mostly rainbow trout), and lower panel: all species stocked into Grand Lake by Colorado Parks and Wildlife since 1973.

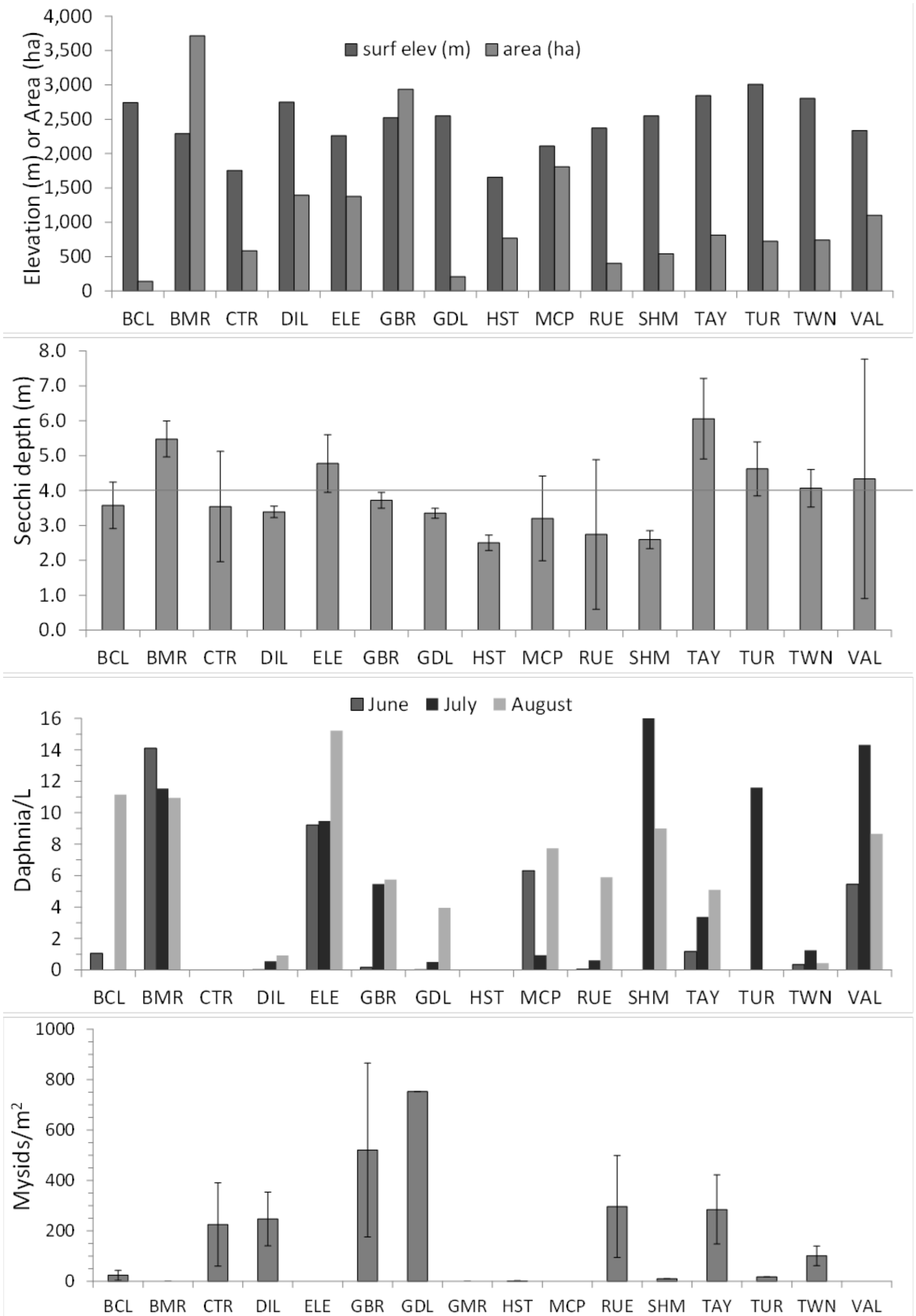


Figure 6. Some characteristics of 15 coldwater lakes and reservoirs in Colorado.

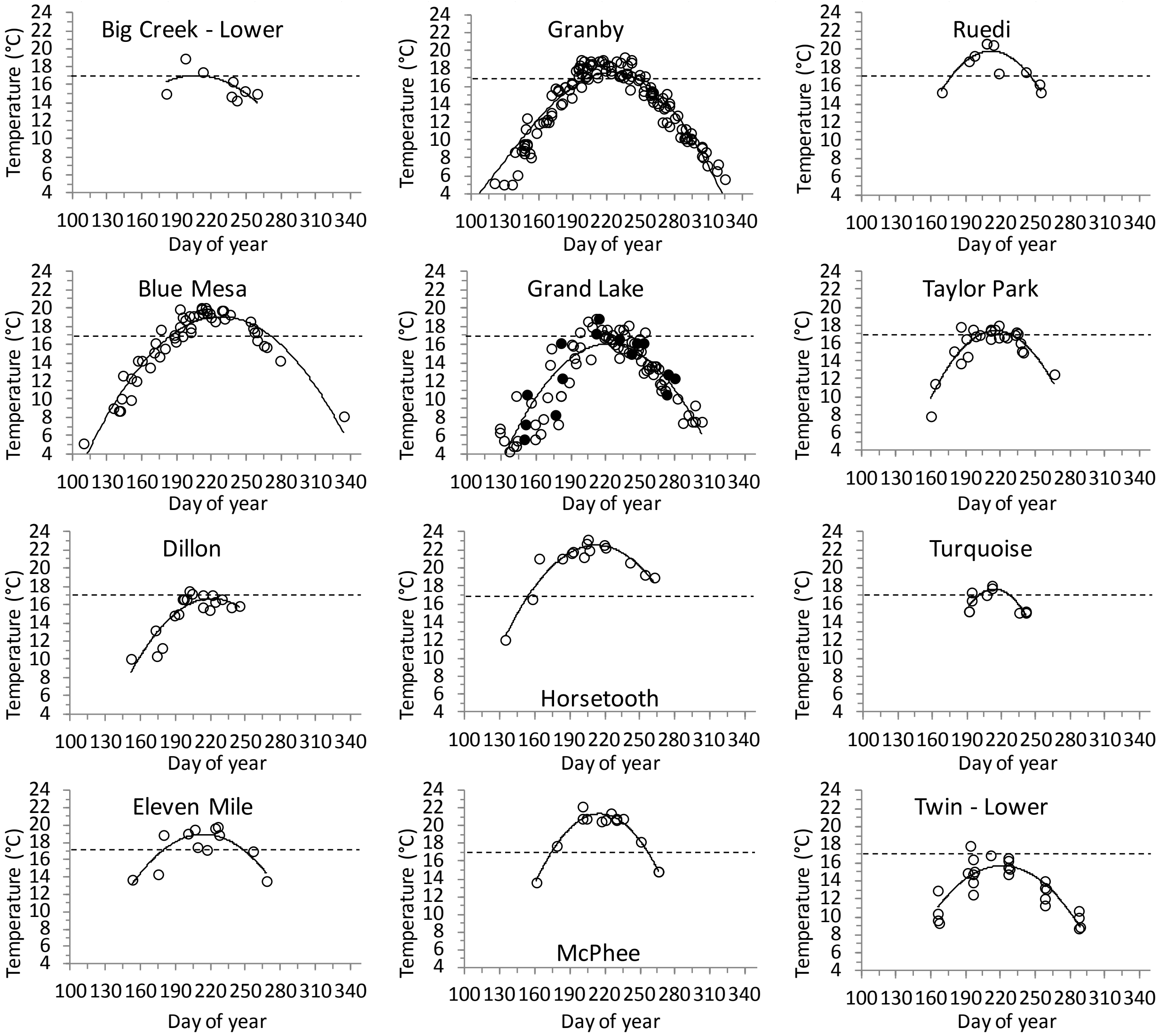


Figure 7. Surface temperature (1-m) of 12 Colorado reservoirs. Parabolas fitted simply to visualize differences among waters. Horizontal dashed lines represent the upper thermal limit of Mysis shrimp.

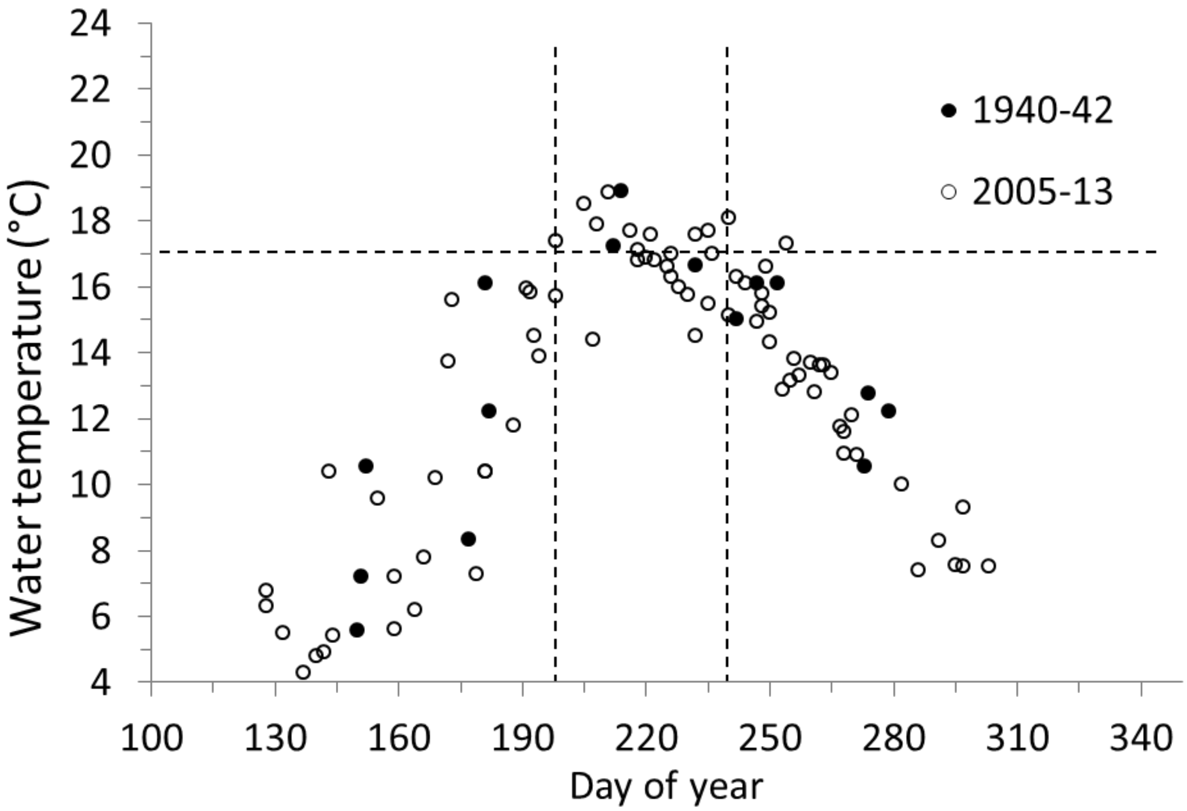


Figure 8. Surface temperature of Grand Lake measured during two time periods, before and after the completion and operation of the Adams Tunnel. Horizontal line represents the upper thermal tolerance of Mysis shrimp; vertical lines represent the approximate time period when surface temperatures are high enough to prevent Mysis shrimp access to the epilimnion.

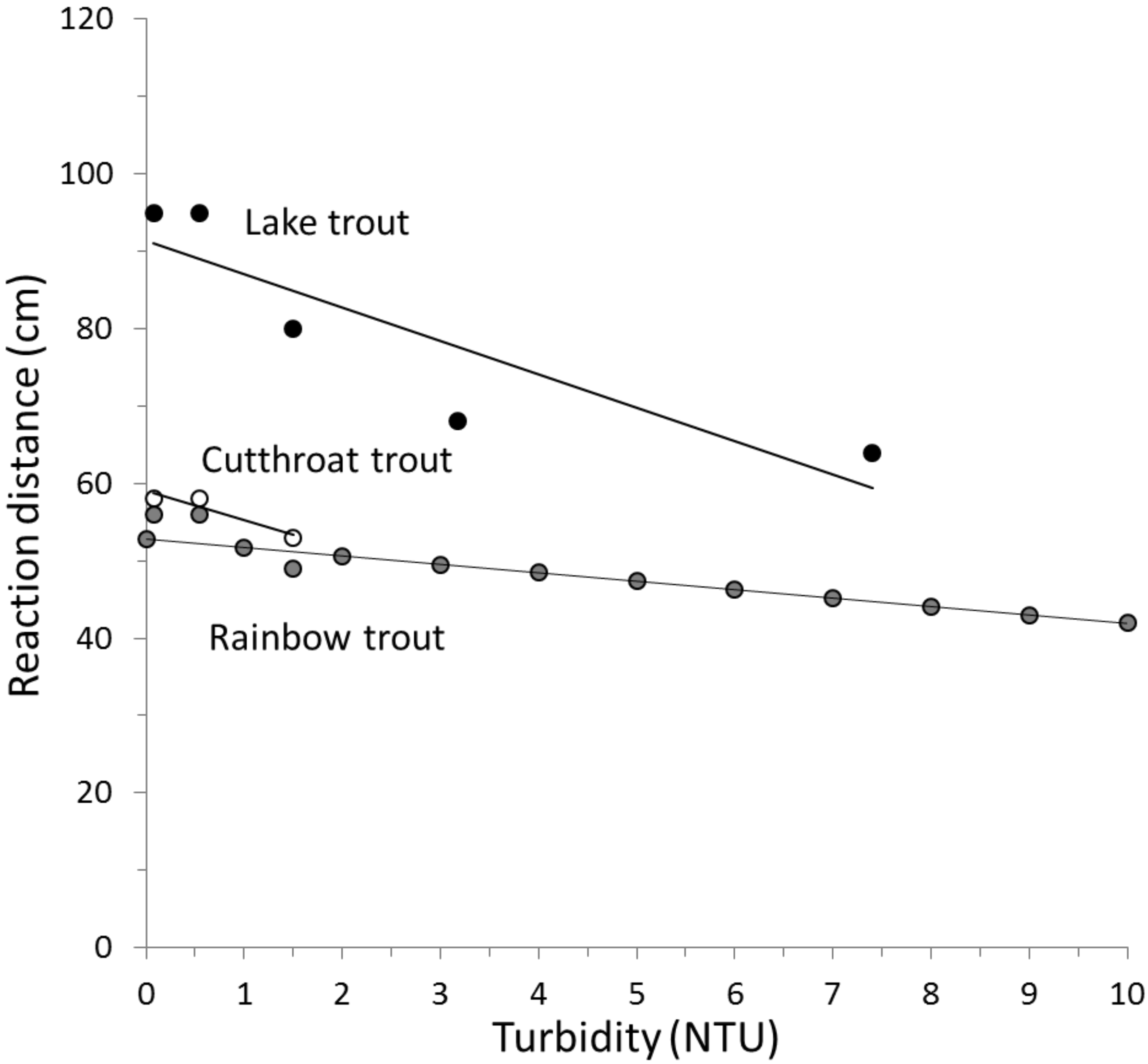
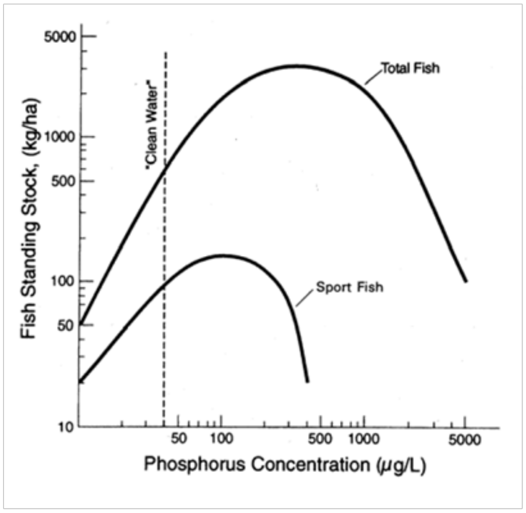
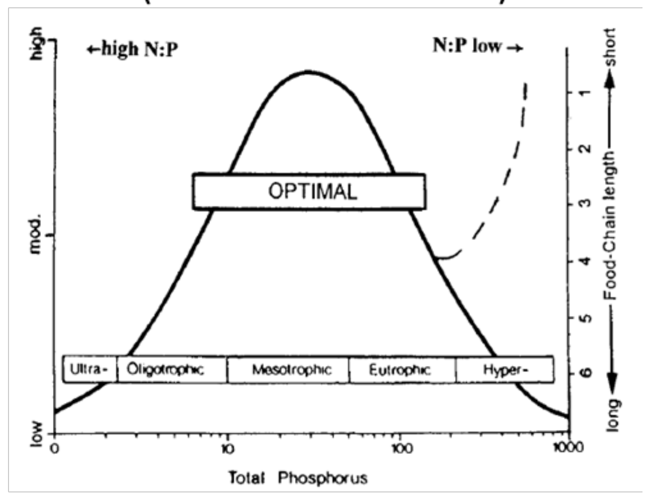


Figure 9. Reaction distance of lake trout (Vogel and Beauchamp 1999; Mazur and Beauchamp 2003), cutthroat trout (Mazur and Beauchamp 2003), and rainbow trout (Barrett et al. 1992, Mazur and Beauchamp 2003) as a function of turbidity.

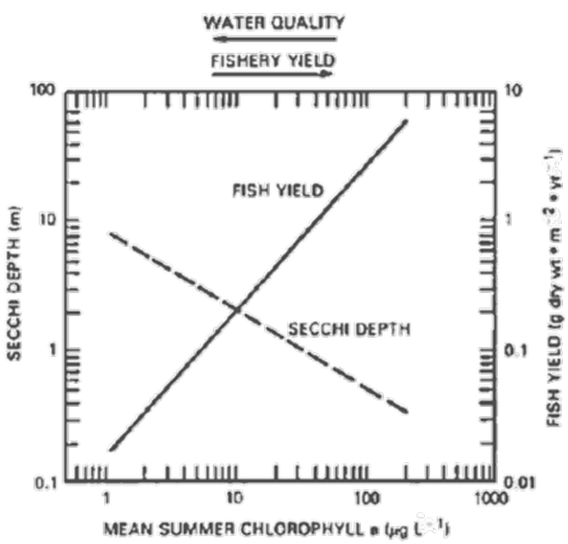
All fish
(Ney 1996)



All fish
(Stockner et al. 2000)



All fish
(Olem and Flock 1990)



Trout and salmon
(Plante and Downing 1993)

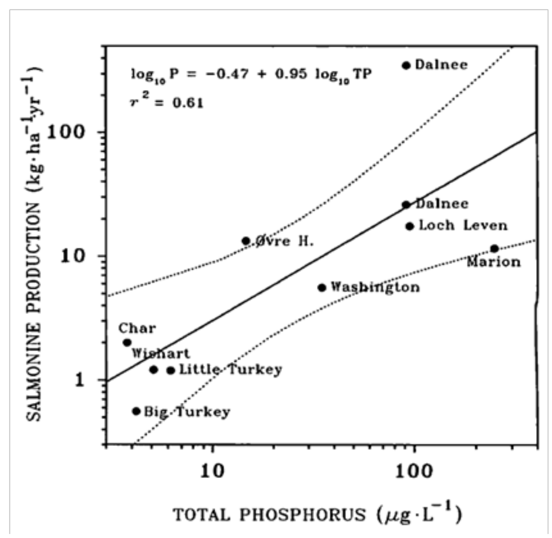


Figure 10. Effects of lake trophic conditions on fish production and yield.

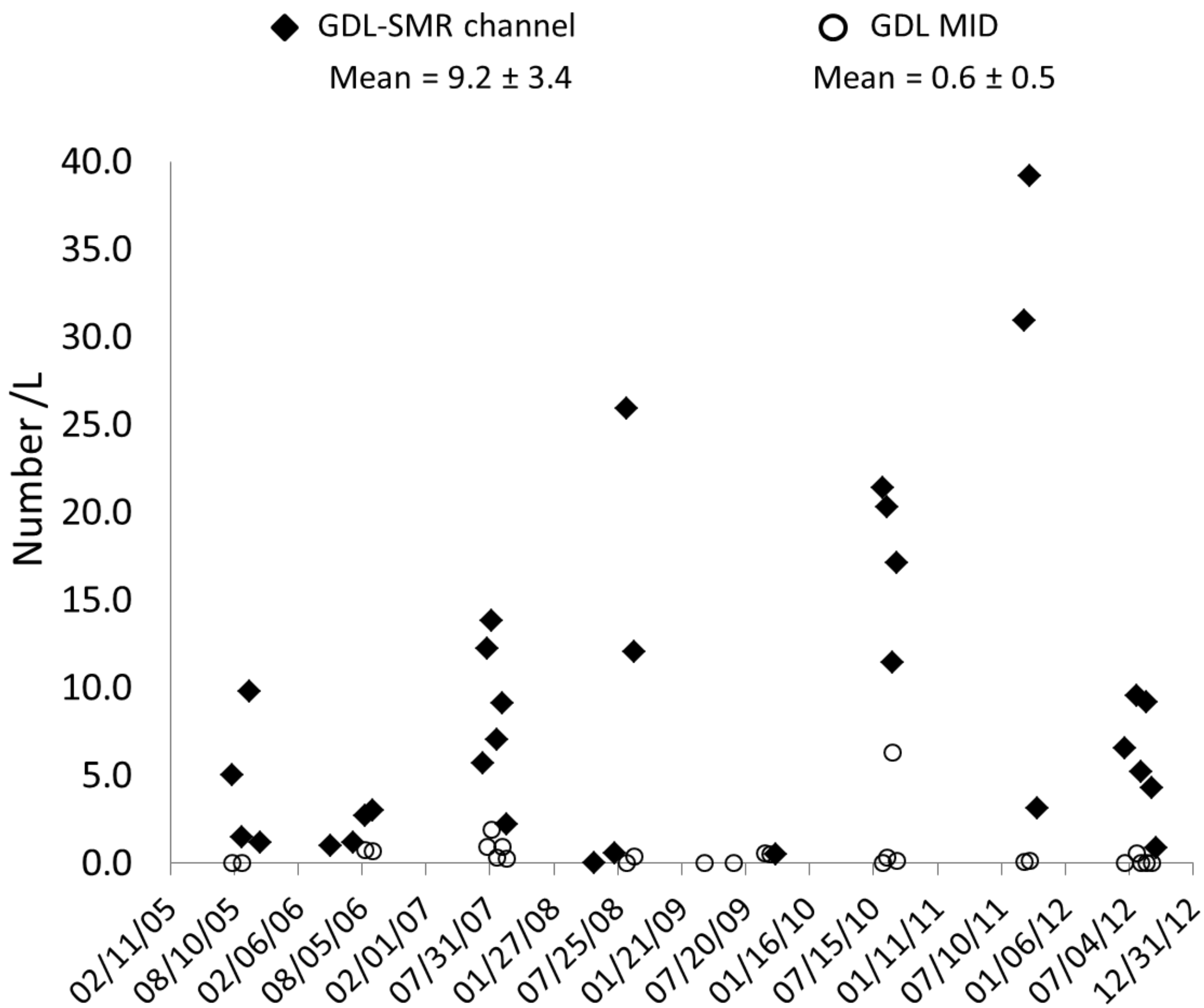


Figure 11. *Daphnia* density in the channel between Grand Lake and Shadow Mountain Reservoir, and at the mid-lake station (5-10 m) on Grand Lake.

APPENDIX

Table A1. Summary of zooplankton sampling performed at three stations and three dates at Grand Lake, Colorado.

Date	Sample number	Sampling gear	Mesh (µ)	Station	Depth sampled (m)	Max depth (m)
06/10/13	GDL061013001	Wisconsin net	153	GL-ATW	00-10	72
06/10/13	GDL061013002	Wisconsin net	153	GL-ATW	00-10	72
06/10/13	GDL061013005	Wisconsin net	153	GL-MID	00-10	83
06/10/13	GDL061013006	Wisconsin net	153	GL-MID	00-10	83
06/10/13	GDL061013008	Wisconsin net	153	GL2009A5	00-10	72
06/10/13	GDL061013009	Wisconsin net	153	GL2009A5	00-10	72
06/10/13	GDL061013004	½ m cone	500	GL-ATW	Surface	83
06/10/13	GDL061013007	½ m cone	500	GL-MID	Surface	83
06/10/13	GDL061013010	½ m cone	500	GL2009A5	Surface	72
07/18/13	GDL071813004	Wisconsin net	153	GL-ATW	Surface	45
07/18/13	GDL071813006	Wisconsin net	153	GL-MID	Surface	82
07/18/13	GDL071813012	Wisconsin net	153	GL2009A5	Surface	74
07/18/13	GDL071813003	Clarke-Bumpus	153	GL-ATW	0-10	45
07/18/13	GDL071813005	Clarke-Bumpus	153	GL-MID	0-10	82
07/18/13	GDL071813011	Clarke-Bumpus	153	GL2009A5	0-10	74
07/18/13	GDL071813001	¼ m cone	500	GL-ATW	Surface	45
07/18/13	GDL071813008	¼ m cone	500	GL-MID	surface	82
07/18/13	GDL071813010	¼ m cone	500	GL2009A5	surface	74
07/18/13	GDL071813002	Clarke-Bumpus	500	GL-ATW	0-10	45
07/18/13	GDL071813007	Clarke-Bumpus	500	GL-MID	0-10	82
07/18/13	GDL071813009	Clarke-Bumpus	500	GL2009A5	0-10	74
08/07/13	GDL080713001	Wisconsin net	153	GL-ATW	00-10	43
08/07/13	GDL080713004	Wisconsin net	153	GL-MID	00-10	85
08/07/13	GDL080713007	Wisconsin net	153	GL-NW	00-10	.
08/07/13	GDL080713002	Wisconsin net	153	GL-ATW	surface	43
08/07/13	GDL080713005	Wisconsin net	153	GL-MID	surface	85
08/07/13	GDL080713008	Wisconsin net	153	GL-NW	surface	.
08/07/13	GDL080713003	Mysis net	500	GL-ATW	surface	43
08/07/13	GDL080713006	Mysis net	500	GL-MID	surface	85
08/07/13	GDL080713009	Mysis net	500	GL-NW	surface	.

Table A2. Length distributions of seven zooplankton taxa sampled on July 18, 2013 with 153 µ and 500 µ mesh Clark-Bumpus metered plankton sampler at three stations in Grand Lake, CO

	Mesh Size: 153 µ								Mesh Size: 500 µ						
	Cladoceran					Copepod			Cladoceran					Copepod	
Length Class in mm	Unidentified *Daphnia* spp.	*Daphnia galeata mendotae*	*Daphnia pulicaria/pulex*	*Daphnia rosea*	*Bosmina longirostris*	Unidentified cyclopoid	Unidentified calanoid	Length Class in mm	Unidentified *Daphnia* spp.	*Daphnia galeata mendotae*	*Daphnia pulicaria/pulex*	*Daphnia rosea*	*Bosmina longirostris*	Unidentified cyclopoid	Unidentified calanoid
0.1					4			0.1							
0.2					36	1		0.2					3	1	
0.3	1				15	8	2	0.3	4	2			5	5	
0.4					11	18	6	0.4	2	1			1	2	
0.5		3		2	4	15	7	0.5						3	
0.6		3		2		16	11	0.6						3	
0.7		1	1	1		11	5	0.7							
0.8						4	6	0.8							
0.9						1	6	0.9						1	
1.0		1		1		1	5	1.0							
1.1				1			12	1.1							
1.2				1			6	1.2							
1.3								1.3			1	1			
1.4		2						1.4		1					
1.5								1.5				2			
Total	1	10	1	8	70	75	66	Total	6	4	1	3	9	15	0
Mean Length	0.3	0.8	0.7	0.8	0.3	0.5	0.8	Mean Length	0.3	0.6	1.3	1.4	0.3	0.4	--

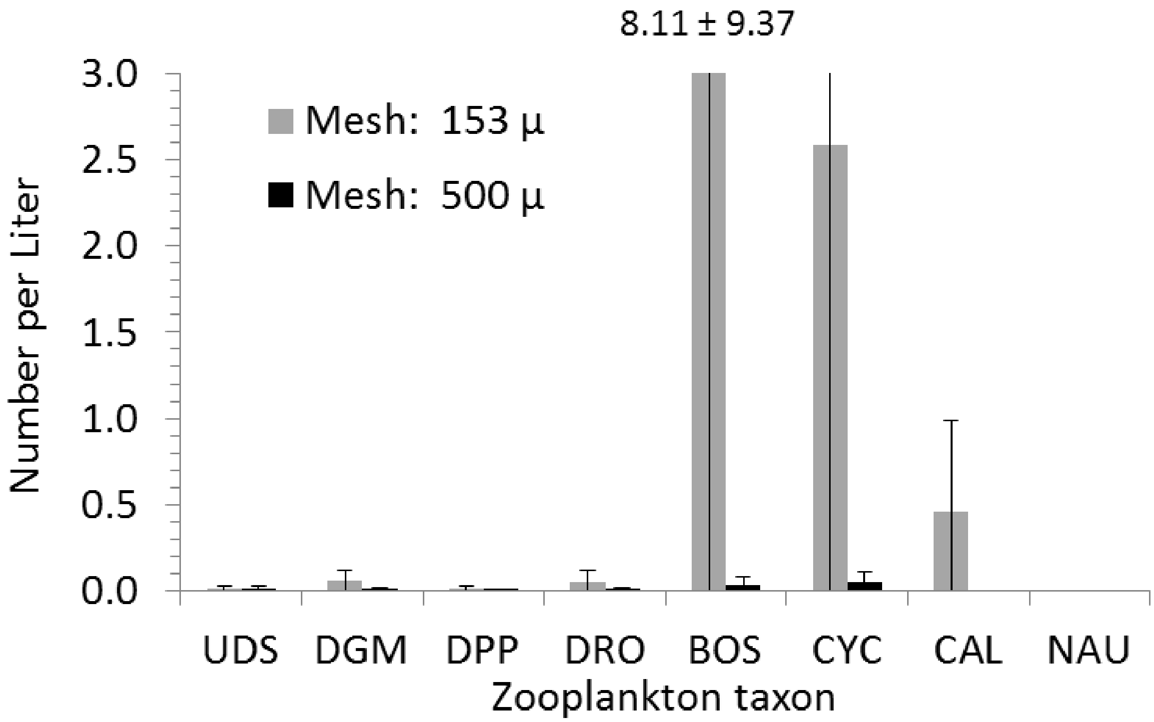


Figure A1. Density (± 2SE) of eight zooplankton taxa sampled on July 18, 2013 with a 153 µ and 500 µ mesh Clarke-Bumpus metered plankton sampler at three stations on Grand Lake, CO. UDS isunidentified *Daphnia* species, DGM is *Daphnia galeata mendotae*, DPP is *Daphnia pulex/pulicaria*, DRO is *Daphnia rosea*, BOS is *Bosmina longirostris*, CYC is cyclopoid copepod, CAL is calanoid copepod, and NAU is copepod nauplius.

Colorado-Big Thompson Project & Windy Gap Project Overview

Northern Water, a political subdivision of the State of Colorado created in 1937, provides water for agricultural, municipal, domestic and industrial uses to an eight-county service area with a population of about 860,000. Northern Water and the U.S. Bureau of Reclamation (USBR) operate the Colorado-Big Thompson (C-BT) Project, which collects water on the West Slope and delivers it to Northeastern Colorado through the 13-mile Adams Tunnel beneath Rocky Mountain National Park (Figure 3).

FIGURE 1 – THREE LAKES SYSTEM

The C-BT Project annually delivers an average of 213,000 acre feet of water to northeastern Colorado. Water is provided to the Cities of Fort Collins, Greeley, Loveland, Longmont, Boulder, Louisville, Lafayette, and Broomfield, many smaller communities, rural and domestic water districts, and local industries. Water is also delivered to approximately 120 ditch, reservoir and irrigation companies serving about 640,000 irrigated acres of farm and ranch land between April and October, the primary growing season.

Runoff from the headwaters of the Colorado River is collected in the Three Lakes System (Granby Reservoir, Shadow Mountain Reservoir and Grand Lake). Granby Reservoir also receives water pumped from Willow Creek Reservoir and Windy Gap

FIGURE 2 – FLOW DIRECTION BETWEEN GRAND LAKE AND SHADOW MOUNTAIN RESERVOIR DURING PUMPING AND DURING RUNOFF

Reservoir in addition to the natural runoff from the Three Lakes watershed. When direct runoff to Grand Lake is sufficient to meet East Slope delivery requirements, the rest of the flow moves naturally from Grand Lake to Shadow Mountain, to the Colorado River and eventually Granby Reservoir. When East Slope delivery requirements are greater than the direct runoff to Grand Lake, Adams Tunnel deliveries are supplemented with water pumped from Granby Reservoir. Water is pumped from Granby Reservoir to Shadow Mountain Reservoir via the Granby Pump Canal, from where it is gravity fed to Grand Lake before reaching the West Portal of the Adams Tunnel.

After exiting the Adams Tunnel, the water travels through a series of tunnels, pipelines and canals to eventually be stored in the East Slope terminal reservoirs (Horsetooth Reservoir, Carter Lake and Boulder Reservoir). It is then distributed to the end-users either directly from the canals, the reservoirs, the Southern Water Supply Project Pipeline, or via deliveries to the South Platte tributaries (Cache La Poudre River, Big Thompson River, Little Thompson River, Saint Vrain Creek, Left Hand Creek and Boulder Creek) that are used as a conveyance system.

The Windy Gap Project is located just west of the town of Granby on Colorado's West Slope. The project consists of a diversion dam on the Colorado River below the confluence with the Fraser River, the 445-acre-foot Windy Gap Reservoir, a pump plant and a six-mile pipeline to Granby Reservoir. The project came online in 1985 to serve municipal and industrial water needs and utilizes C-BT infrastructure to move water to the East Slope. The Windy Gap Project was designed to annually divert and deliver an average of 48,000 acre feet of water, primarily between April and July. During the spring runoff, water from the Fraser and Colorado Rivers is pumped from Windy Gap Reservoir to Granby Reservoir where it is stored for delivery through the C-BT facilities to water users on the Front Range. The Windy Gap Project introduces water from the Fraser River watershed into the Three Lakes system.

Power Generation

C-BT power plants generate an average of 770 million kilowatt hours of renewable energy per year. The C-BT Project's West Slope pump plants annually use 70 million kilowatt hours. The remaining 700 million kilowatt hours are sold to customers in Colorado, Eastern Wyoming and Western Nebraska. Power is generated by water flowing through C-BT Project power plant turbines to produce hydroelectricity. The power sold to customers is enough to supply approximately 68,000 homes for a year. The C-BT Project has six power plants. Water flows beneath Rocky Mountain National Park via the Adams Tunnel to the East Slope and descends the Front Range mountains nearly 2,900 vertical feet through these six power plants and four reservoirs. Five are located on the East Slope between Rocky Mountain National Park and the mouth of the Big Thompson Canyon. The Green Mountain Power Plant is located on the Blue River near Kremmling on the West Slope.

Northern Water's first plant, the Robert V. Trout Hydropower Plant, is located at Carter Lake on the East Slope, and began generating electricity in May 2012. The Poudre Valley REA markets and distributes all of the plant's generated power.

The Trout Power Plant is the first power structure built, owned and operated by Northern Water. The federal government owns and operates the other six C-BT hydropower plants, and the Western Area Power Administration markets and distributes the power from those plants.

When the C-BT Project was planned in the 1930s, the power plants at Lake Estes and Green Mountain Reservoir were designed to provide power to the Willow Creek and Farr (previously Granby) pump plants. This was largely due to insufficient electrical infrastructure and power production on the West Slope when the project was built. The Willow Creek and Farr Pump plants receive electricity from the East Slope power plants via a 69,000-volt transmission line extending through the Adams Tunnel. Today, even with adequate West Slope electrical infrastructure and power production, the Adams Tunnel transmission line still provides the West Slope pump plants with a portion of their electrical needs.

The East Slope hydroelectric plants also supply power for peak demands by using a system of forebays, afterbays and penstocks (large-diameter above-ground pipelines). When peak electrical power is needed, such as early-evening hours, water is moved from a plant's forebay (a small reservoir above a hydroelectric power plant) into a penstock leading to the power plant. The force of the water moving through the penstock and turbine generates electricity. After the water passes through the turbine, it is typically released into the afterbay (a small reservoir located below a hydroelectric power plant).

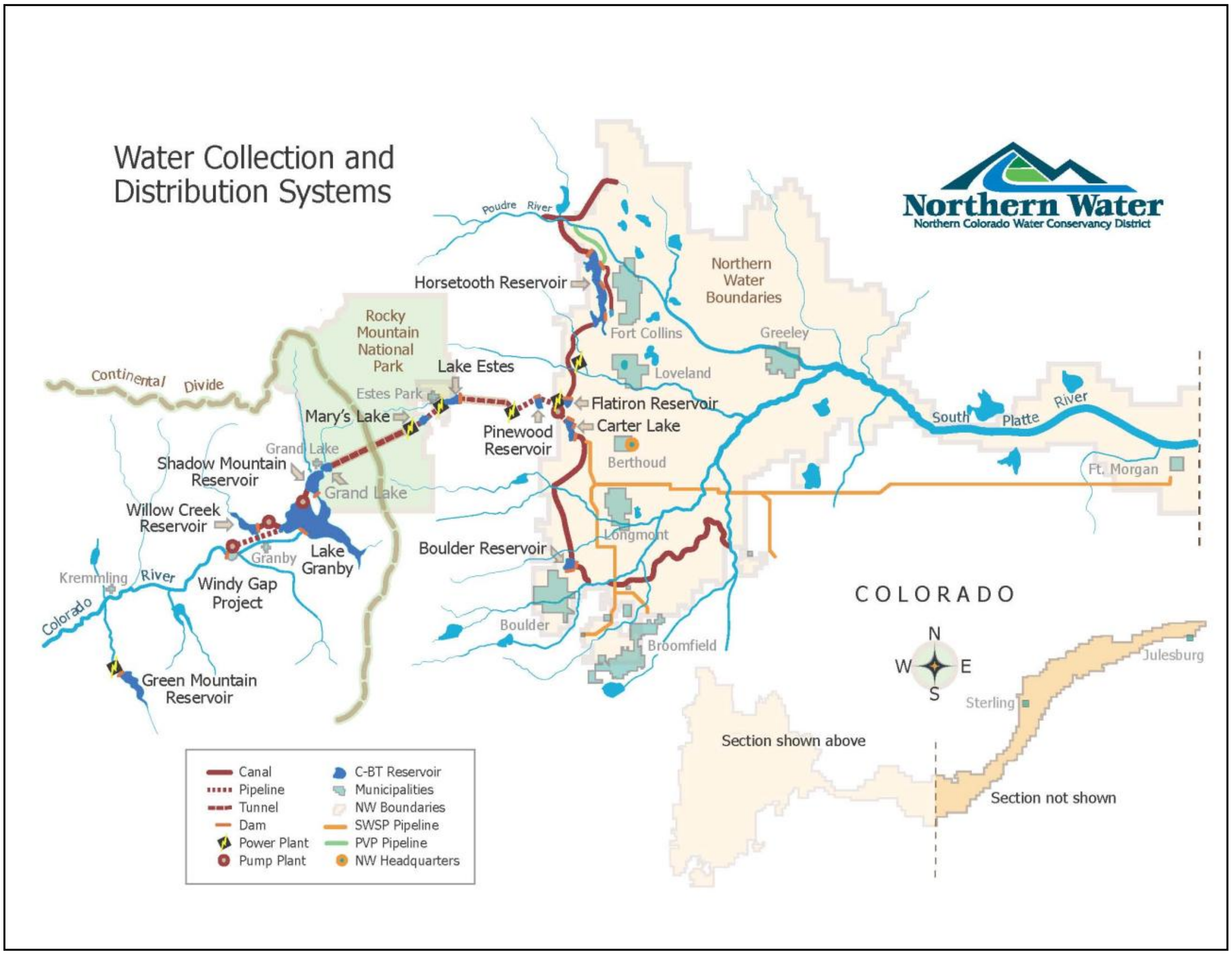


FIGURE 3 - MAP OF C-BT & WINDY GAP PROJECTS

EXHIBIT 4

ORIGINAL

Contract No. 9-07-70-W0020
Supplement No. 10

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Colorado-Big Thompson Project
Colorado

SUPPLEMENT OF CONTRACT BETWEEN THE UNITED STATES OF AMERICA AND THE NORTHERN COLORADO WATER CONSERVANCY DISTRICT FOR ADDRESSING COMMITMENTS ASSOCIATED WITH MEETING THE GRAND LAKE CLARITY STANDARD

THIS SUPPLEMENT, entered into this 23rd day of, Oct 2013, pursuant generally to the Act of June 17, 1902 (32 Stat. 388), and subsequent acts supplementary thereto and amendatory thereof collectively known as the Federal Reclamation laws, particularly, but not limited to, the Act of August 9, 1937 (50 Stat. 595) between the UNITED STATES OF AMERICA, hereinafter called the "United States," acting through the Secretary of the Interior, represented by the "Contracting Officer" executing this Supplement, and NORTHERN COLORADO WATER CONSERVANCY DISTRICT, hereinafter referred to as "Northern Water," a quasi-municipal entity and political subdivision of the State of Colorado, organized and existing under and by virtue of the laws of the State of Colorado, with its principal place of business in Berthoud, Colorado. The United States and Northern Water hereinafter are each sometimes individually called "Party," and sometimes collectively called the "Parties".

WITNESSETH THAT:

The following statements are made in explanation:

EXPLANATORY RECITALS

a. WHEREAS, the United States constructed the Colorado-Big Thompson (C-BT) Project in the State of Colorado, pursuant to Federal Reclamation laws; and

b. WHEREAS, the Parties executed Contract No. 9-07-70-W0020, on July 5, 1938; it has subsequently been amended and supplemented. The original contract along with its amendments and supplements are collectively referred to herein as the "1938 Repayment Contract"; and

c. WHEREAS, the Parties have concerns with the clarity of Grand Lake; and

d. WHEREAS, in 2008, the Colorado Water Quality Control Commission adopted a narrative clarity standard and a numerical clarity standard for Grand Lake; and

e. WHEREAS, the Parties wish to meet the applicable water clarity standard.

NOW THEREFORE, in consideration of the mutual and dependent covenants herein contained, it is hereby mutually agreed as follows:

PURPOSE

1. The purpose of this Supplement is to describe the Parties' commitment to identify and evaluate factors that affect clarity in Grand Lake and to develop a plan in accordance with this Supplement to meet the applicable water clarity standards.

RESPONSIBILITIES

2. a. There may be a relationship between the reduced clarity in Grand Lake and the operation of the C-BT Project as well as other factors. The Parties agree that further study and evaluation would be beneficial to better understand this potential relationship.

b. The Parties will: 1) actively participate in the process of identification, development, and evaluation of factors, causes, and actions that affect clarity in Grand Lake; 2) collaborate with each other and other appropriate parties and groups ("Stakeholders") to identify, develop, and evaluate specific proposed actions to meet applicable water clarity standards in a manner that recognizes the relative contributing factors that affect Grand Lake water clarity, in order to allow for, as appropriate, recommendations by the Parties for specific actions to meet applicable water clarity standards at Grand Lake, including participation in further studies designed to identify specific factors affecting clarity; 3) implement the process and actions defined in Article 4 below as appropriate and within legal limitations and funding constraints, with the goal of preserving and maximizing overall C-BT Project benefits while meeting applicable clarity standards at Grand Lake.

c. The United States will have the final authority to approve both the Stakeholders and the process identified in Article 2.b. above, after consultation with Northern Water, other Federal, state, and local authorities, and other entities as the United States deems appropriate.

PAYMENT RESPONSIBILITY

3. The responsibility for payment of the cost of implementing measures to meet applicable water clarity standards shall be determined in accordance with Reclamation law. The Parties acknowledge that congressional and other authorization may be necessary to implement potential solutions.

IMPLEMENTATION

4. a. Pursuant to the foregoing, if specific actions are identified pursuant to Article 2.b. above, the Parties commit to work cooperatively and collaboratively, with each other and with other Stakeholders; to evaluate any such specific actions under applicable local, state, and/or federally required processes, regulations, policies, and statutes; to cooperate with other Stakeholders to identify sources of funding; and to implement any such specific actions to meet the goal identified in Article 2.b. above within legal limitations and funding constraints and in a manner that recognizes the causes and relative contributing factors that affect Grand Lake water clarity. This Supplement does not affect or modify existing authorities, including those regarding the allocation of costs, for operation and maintenance of or capital improvements related to the C-BT Project.

b. The United States may take actions to meet the applicable clarity standard, and the cost of such actions will be allocated in accordance with Reclamation law. The Parties acknowledge that the exact nature and cost of such actions is unknown until the processes outlined in Article 2 are complete. Until a proposed solution is identified, agreed upon, and appropriate authorizations, if necessary, are obtained, the Parties reserve all rights, arguments, and defenses relative to the proposed solution itself and the allocation of costs therein. In the event the Parties are unable to reach agreement concerning the specific actions that should be taken to meet the goal identified in Article 2.b. above and the United States makes a determination to implement specific action(s), the Parties reserve all rights, arguments, and defenses regarding such determination to implement specific actions, and this Supplement does not modify, waive, limit, or relinquish any right of Northern Water to contest the United States' determination to take specific actions in any judicial, administrative, or legislative forum. The execution of this Supplement shall not be used by either Party in any judicial, administrative, or legislative proceeding as an admission to the contrary.

EFFECT ON THE 1938 REPAYMENT CONTRACT

5. This Supplement is in addition to the 1938 Repayment Contract and, except as expressly provided in Articles 2.b. and 4. above, does not modify or amend the 1938 Repayment Contract. This Supplement shall not be a basis for any direct or indirect interpretation or construction of any provision of the 1938 Repayment Contract for any purpose. Prior drafts of this Supplement are not relevant to the interpretation of this Supplement.

STANDARD CONTRACT ARTICLES

6. The standard contract articles applicable to this Supplement are listed below. The full text of these standard articles is attached as Exhibit A and is hereby made a part of this Supplement.

A. Notices
B. Officials Not to Benefit
C. Changes in Contractor's Organization
D. Assignments Limited - Successors and Assigns Obligated
E. Books, Records, and Reports
F. Rules, Regulations, and Determinations
G. Equal Employment Opportunity (Federally Assisted Construction)
H. Compliance with Civil Rights Laws and Regulations

IN WITNESS WHEREOF, The Parties have executed this Supplement the day and year written above and agree to the terms, provisions, special conditions, and standard provisions expressed or referenced herein.

UNITED STATES OF AMERICA

By_______________________
Michael J. Ryan
Regional Director
Great Plains Region
Bureau of Reclamation

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

By_______________________
Eric W. Wilkinson
General Manager

EXHIBIT A
STANDARD CONTRACT ARTICLES

NOTICES

A. Any notice, demand, or request authorized or required by this Supplement shall be deemed to have been given, on behalf of Northern Water, when mailed, postage prepaid, or delivered to the:

Regional Director
Great Plains Region
Bureau of Reclamation
P.O. Box 36900
Billings, MT 59107

and on behalf of the United States, when mailed, postage prepaid, or delivered to the:

General Manager
Northern Colorado Water
Conservancy District
220 Water Avenue
Berthoud, Colorado 80513

The designation of the addressee or the address may be changed by notice given in the same manner as provided in this Article for other notices.

OFFICIALS NOT TO BENEFIT

B. No Member of or Delegate to the Congress, Resident Commissioner, or official of the Northern Water shall benefit from this Supplement other than as a water user or landowner in the same manner as other water users or landowners.

CHANGES IN CONTRACTOR'S ORGANIZATION

C. While this Supplement is in effect, no change may be made in Northern Water's organization, by inclusion or exclusion of lands or by any other changes which may affect the respective rights, obligations, privileges, and duties of either the United States or Northern Water under this Supplement including, but not limited to, dissolution, consolidation, or merger, except upon the Contracting Officer's written consent.

ASSIGNMENT LIMITED—SUCCESSORS AND ASSIGNS OBLIGATED

D. The provisions of this Supplement shall apply to and bind the successors and assigns of the Parties hereto, but no assignment or transfer of this Supplement or any right or interest therein by either Party shall be valid until approved in writing by the other Party.

BOOKS, RECORDS, AND REPORTS

E. Northern Water shall establish and maintain accounts and other books and records pertaining to administration of the terms and conditions of this Supplement, including Northern Water's financial transactions; water supply data; project operation, maintenance, and replacement logs; project land and rights-of-way use agreements; the water users' land-use (crop census), land-ownership, land-leasing, and water-use data; and other matters that the Contracting Officer may require. Reports shall be furnished to the Contracting Officer in such form and on such date or dates as the Contracting Officer may require. Subject to applicable Federal laws and regulations, each Party to this Supplement shall have the right during office hours to examine and make copies of the other Party's books and records relating to matters covered by this Supplement.

RULES, REGULATIONS, AND DETERMINATIONS

F. 1. The Parties agree that the delivery of water or the use of Federal facilities pursuant to this Supplement is subject to Federal reclamation law, as amended and supplemented, and the rules and regulations promulgated by the Secretary of the Interior under Federal reclamation law.

2. The Contracting Officer shall have the right to make determinations necessary to administer this Supplement that are consistent with its provisions, the laws of the United States and the State of Colorado, and the rules and regulations promulgated by the Secretary of the Interior. Such determinations shall be made in consultation with Northern Water.

EQUAL EMPLOYMENT OPPORTUNITY

G. During the performance of this Supplement, Northern Water agrees as follows:

1. Northern Water will not discriminate against any employee or applicant for employment because of race, color, religion, sex, disability, or national origin. Northern Water will take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, color, religion, sex, disability, or national origin. Such action shall include, but not be limited to the following: employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. Northern Water agrees to post in conspicuous places, available to employees and applicants for employment, notices to be provided by the Contracting Officer setting forth the provisions of this nondiscrimination clause.

2. Northern Water will, in all solicitations or advertisements for employees placed by or on behalf of Northern Water, state that all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, disability, or national origin.

3. Northern Water will send to each labor union or representative of workers with which it has a collective bargaining agreement or other contract or understanding, a notice, to be provided by the Contracting Officer, advising the labor union or workers' representative of Northern Water's commitments under section 202 of Executive Order 11246 of September 24, 1965 (EO 11246), and shall post copies of the notice in conspicuous places available to employees and applicants for employment.

4. Northern Water will comply with all provisions of EO 11246, and of the rules, regulations, and relevant orders of the Secretary of Labor.

5. Northern Water will furnish all information and reports required by EO 11246, and by the rules, regulations, and orders of the Secretary of Labor, or pursuant thereto, and will permit access to his books, records, and accounts by the Contracting Agency and the Secretary of Labor for purposes of investigation to ascertain compliance with such rules, regulations, and orders.

6. In the event of Northern Water's noncompliance with the nondiscrimination clauses of this Supplement or with any of such rules, regulations, or orders, this Supplement may be canceled, terminated or suspended in whole or in part and Northern Water may be declared ineligible for further Government contracts in accordance with procedures authorized in EO 11246, and such other sanctions may be imposed and remedies invoked as provided in EO 11246 or by rule, regulation, or order of the Secretary of Labor, or as otherwise provided by law.

7. Northern Water will include the provisions of paragraphs 1 through 7 in every subcontract or purchase order unless exempted by the rules, regulations, or orders of the Secretary of Labor issued pursuant to section 204 of EO 11246, so that such provisions will be binding upon each subcontractor or vendor. Northern Water will take such action with respect to any subcontract or purchase order as may be directed by the Secretary of Labor as a means of enforcing such provisions, including sanctions for noncompliance: *Provided, however,* that in the event Northern Water becomes involved in, or is threatened with, litigation with a subcontractor or vendor as a result of such direction, Northern Water may request that the United States enter into such litigation to protect the interests of the United States.

COMPLIANCE WITH CIVIL RIGHTS LAWS AND REGULATIONS

H. 1. Northern Water shall comply with Title VI of the Civil Rights Act of 1964 (Pub. L. 88-352; 42 U.S.C. § 2000d), the Rehabilitation Act of 1973 (Pub. L. 93-112, Title V, as amended; 29 U.S.C. § 791, et seq.), the Age Discrimination Act of 1975 (Pub. L. 94-135, Title III; 42 U.S.C. § 6101, et seq.), Title III of the Americans with Disabilities Act of 1990 (Pub. L. 101-336; 42 U.S.C. § 12181, et seq.), and any other applicable civil rights laws, and with the applicable implementing regulations and any guidelines imposed by the U.S. Department of the Interior and/or Bureau of Reclamation.

2. These statutes prohibit any person in the United States from being excluded from participation in, being denied the benefits of, or being otherwise subjected to discrimination under any program or activity receiving financial assistance from the Bureau of Reclamation on the grounds of race, color, national origin, disability, or age. By executing this Supplement, Northern Water agrees to immediately take any measures necessary to implement this obligation, including permitting officials of the United States to inspect premises, programs, and documents.

3. Northern Water makes this agreement in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property discounts, or other Federal financial assistance extended after the date hereof to Northern Water by the Bureau of Reclamation, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. Northern Water recognizes and agrees that such Federal assistance will be extended in reliance on the representations and agreements made in this Article and that the United States reserves the right to seek judicial enforcement thereof.

4. Complaints of discrimination against Northern Water shall be investigated by the Contracting Officer's Office of Civil Rights

United States Department of the Interior

BUREAU OF RECLAMATION
Eastern Colorado Area Office
11056 West County RD 18E
Loveland, Colorado 80537-9711

IN REPLY REFER TO:

EC-1310
WTR-7.00

JAN 28 2016

E. Jane Tollett
Grand County Board of County Commissioners
P.O. Box 264
Hot Sulphur Springs, CO 80451

Subject: Memorandum of Understanding No. 16-LM-60-2578 – Grand Lake Clarity Stakeholders' – Grand Lake – Colorado-Big Thompson Project, Colorado

Dear Ms. Tollett:

Enclosed is a fully executed original copy of Memorandum of Understanding (MOU) between the Northern Colorado Water Conservancy District, Colorado River Water Conservation District, Northwest Colorado Council of Governments, Grand County Board of County Commissioners and the Bureau of Reclamation. The MOU establishes an adaptive management process while Reclamation conducts a planning and National Environmental Policy Act process to evaluate alternatives to improve clarity in Grand Lake as described in the Clarity Supplement.

Thank you for your cooperation and assistance on this matter. Should you have any questions, please contact Laura Harger at (970) 962-4337.

Sincerely,

Jacklynn L. Gould

Jacklynn L. Gould, P.E.
Area Manager

Enclosure

cc: Rod Smith
Department of Interior, Office of the Solicitor
Division of Land and Water Resources
125 South State Street, Suite 6201
Salt Lake City, UT 84138 (w/o encl)

ORIGINAL

GRAND LAKE CLARITY STAKEHOLDERS' MEMORANDUM OF UNDERSTANDING

The Parties to this Memorandum of Understanding (MOU) are the U.S. Department of the Interior Bureau of Reclamation (Reclamation), Northern Colorado Water Conservancy District (Northern Water), Grand County Board of Commissioners (Grand County), Northwest Colorado Council of Governments (NWCCOG), and Colorado River Water Conservation District (River District). For purposes of Sections III, VIII, and X of this MOU, Grand County, NWCCOG and River District collectively constitute the West Slope.

I. EXPLANATORY RECITALS

A. WHEREAS, Grand Lake is Colorado's largest natural lake and part of the headwaters to the Colorado River;

B. WHEREAS, Grand Lake is used as a component of the Colorado-Big Thompson (C-BT) Project authorized by the United States Congress in 1937;

C. WHEREAS, a portion of Senate Document No. 80, entitled "Manner of Operation of Project Facilities and Auxiliary Features," pages 2-5, states that the C-BT Project "must be operated in such a manner as to most nearly effect" the five "primary purposes," (Exhibit A)

D. WHEREAS, the "Manner of Operation of Project Facilities and Auxiliary Features," page 3, states "In order to accomplish these purposes the project should be operated by an unprejudiced agency in a fair and efficient manner, equitable to all parties having interests therein, and in conformity with" twelve "particular stipulations"(Exhibit A);

E. WHEREAS, the Parties recognize Reclamation's operating authority for the C-BT Project. Reclamation will take into account individual input of members of the Adaptive Management Committee (AMC) and consider operational changes to meet the clarity goals.

F. WHEREAS, water clarity in Grand Lake has been measured by Secchi disk visibility and a study dating back to the 1940s has documented a single Secchi disk visibility measurement of 9.2 meters;

G. WHEREAS, Grand County, NWCCOG and the River District believe that the scenic attraction of Grand Lake is diminished due to decreased water clarity;

H. WHEREAS, Reclamation and Northern Water have entered into a "Supplement of Contract Between the United States of America and the Northern Colorado Water Conservancy District for Addressing Commitments Associated with Meeting the Grand Lake Clarity Standard" dated October 23, 2013 (Clarity Supplement), which establishes a long-term commitment to meet the applicable Grand Lake clarity standard (Exhibit B).

I. WHEREAS, the proposed Windy Gap Firming Project, which will transport water from the Colorado River through the west slope features of the C-BT Project for delivery to the front range of Colorado is subject to a permit from Grand County memorialized in Grand County Resolution No.2021PA-12-1 ("2012 Permit"). Condition 7 of the 2012 Permit provides in pertinent part that "the 2012 Permit shall not be effective until the Clarity MOU...[has] been executed;"

J. WHEREAS, for the purposes of this MOU, the Three Lakes System includes Grand Lake, Shadow Mountain Reservoir, Granby Reservoir, and the Colorado River between Shadow Mountain Reservoir and Granby Reservoir.

K. WHEREAS, the Water Quality Control Commission ("Commission") adopted a narrative clarity standard and numeric clarity standard (with a delayed effective date) for Grand Lake in 2008. The Commission amended both standards in 2014.

L. WHEREAS, the Commission's current clarity standard is:

> "The highest level of clarity attainable, consistent with the exercise of established water rights, the protection of aquatic life, and protection of water quality throughout the Three Lakes system."
>
> 5 CCR 1002-33, Numeric Standards Table, at p. 13 (June 30, 2015).

M. WHEREAS, the Commission stated in 2014 that:

> "sufficient effort has not yet been focused on determining an "attainable" level of clarity that is consistent with the constraints identified in the narrative standard", and that "the Commission expects and anticipates a cooperative effort that will focus on identifying an attainable and protective Grand Lake clarity standard".
>
> 5 CCR 1002-33, Numeric Standards Table, at p. 13 (June 30, 2015).

N. WHEREAS, the Parties are engaged in a cooperative effort, as set forth below, in response to the Commission's direction.

O. WHEREAS, Grand County does not accept responsibility for payment of any costs associated with any action alternative(s) selected under Reclamation's National Environmental Policy Act (NEPA) process to improve clarity in Grand Lake as described in the Clarity Supplement (Exhibit B).

II. PURPOSE

The purpose of this MOU is to establish an adaptive management process while Reclamation conducts a planning and NEPA process to evaluate alternatives to improve clarity in Grand Lake as described in the Clarity Supplement (Exhibit B). This MOU formalizes and establishes the terms of an effective, cooperative effort of the Adaptive Management Committee to implement the Grand Lake Clarity narrative standard (see V.A.).

III. TERM

Active participation in adaptive management will commence no later than April 15, 2016, and shall remain in effect until January 1, 2022. This MOU may be extended by mutual agreement of Reclamation, Northern Water and the West Slope until Reclamation issues its decision document upon completion of the NEPA process described above (at II). The MOU implements an interim process while Reclamation and Northern Water complete their efforts as defined in the Clarity Supplement referenced (Exhibit B).

IV. ADAPTIVE MANAGEMENT COMMITTEE

A. **Representation.** Each Party shall be a member of the AMC.

B. **Participation in AMC meetings.** Multiple representatives of each Party may attend and participate in the AMC meetings, as it is expected that the Adaptive Management process will rely on multiple areas of expertise. However, each Party shall reconcile internal differences and present its unified position to the AMC. The Parties' positions may differ.

C. **Stakeholders.** Stakeholders in addition to the Parties must be governmental officials acting in their official capacities and may include, but are not limited to, one representative each from the Western Area Power Administration, U.S. Forest Service, Rocky Mountain National Park, Colorado Parks and Wildlife, Town of Grand Lake, Larimer County and Northern Water's Municipal Subdistrict.

V. IMPLEMENTATION

A. **Narrative Standard.** This MOU is to implement the WQCC's narrative water quality standard:

> "The highest level of clarity attainable, consistent with the exercise of established water rights, the protection of aquatic life, and protection of water quality throughout the Three Lakes system."
>
> 5 CCR 1002-33, Numeric Standards Table, at p. 13 (June 30, 2015).

B. **Clarity Goals.** The annual Clarity Goals for Grand Lake from July 1 through September 11 are an average Secchi depth of 3.8 meters and a minimum Secchi depth of 2.5 meters. The Clarity Goals are intended to guide the adaptive management process established by and implemented through this MOU.

C. **Grand Lake Clarity Operational Planning**

1. **Preparation of Grand Lake Clarity Operational Plan.** On or before June 1 of each year, subject to hydrology, meteorology, and current demands, Reclamation will identify operational scenarios to be modeled and evaluated and will meet with members of the AMC to seek input from individual members on these scenarios.

    a. Reclamation shall present operational scenarios to the members of the AMC along with the results from the corresponding water quality model runs.

    b. The members of the AMC shall review the scenarios and provide individual input and feedback on the operational scenarios at the meeting scheduled on or before June 1.

    c. Reclamation shall consider input provided by members of the AMC, and shall present a Draft Operational Plan and water quality model runs on or before June 15.

    d. The members of the AMC shall review the Draft Operational Plan and members shall individually provide input to Reclamation.

    e. Reclamation shall announce to the members of the AMC its Proposed Final Operational Plan on or before June 21.

2. **Deliveries and yield.** C-BT Project deliveries and yield shall be protected.

3. **Water Quality Conditions**

    a. **Consideration of Water Quality Indicators.** When individual members of the AMC determine on the basis of monitoring, modeling or other analysis that any of the Water Quality Indicators relevant to Grand Lake clarity reach or are expected to reach certain thresholds (as described in i, ii and iii below), such members may provide input to Reclamation. The status of Water Quality Indicators shall be included in the Weekly Summary Forms (as described in Exhibit D).

        i. **Grand Lake Secchi depth.** The moving average Secchi depth of index sites (Jul 1 to date) in Grand Lake is 3.8 meters or less (Exhibit C).

        ii. **Dissolved Oxygen (DO).** DO levels in Shadow Mountain Reservoir are 3 mg/L or less at the bottom or DO saturation near the surface exceeds 100% (Exhibit C).

iii. **pH.** pH in Shadow Mountain Reservoir is greater than 8 S.U. near the surface (Exhibit C).

b. **Consideration of Water Quality Standards.** The AMC members recognize that C-BT Project operations to meet the Clarity Goals may impact the Three Lakes System and may recommend efforts to minimize exceedances of the water quality standards of the Three Lakes System from July 1 through September 11.

c. **Shadow Mountain Monitoring.** Monitoring will be carried out as explained in Exhibit C. Northern Water will make every effort to maintain the monitoring buoys in Shadow Mountain Reservoir but adjustments may be necessary in the event of an equipment failure. In such event, the AMC members shall recommend monitoring protocols to collect necessary data in support of the AMC process. The Parties recognize that Northern Water is not obligated to replace these buoys if they fail.

The AMC members may adjust the thresholds and selected water quality indicators as mutually agreed by the Parties.

4. **Operational Adaptive Management.** AMC members shall meet in person each year on or before June 1 to discuss the anticipated stream flow and hydrologic forecasts, C-BT Project Operations, and the Northern Water and Municipal Subdistrict delivery obligations. AMC members will provide input to Reclamation for consideration in the operational scenarios (see **V.C.1.**). The AMC will schedule weekly conference calls during the period of concern for Grand Lake clarity (July 1 and to September 11), and meet as needed to discuss current and foreseeable operational deviations and water quality. During these calls, members may discuss potential operational changes that could help in meeting Clarity Goals.

   Members of the AMC may provide input to Reclamation to modify the Operational Plan as needed during the weekly conference calls. Adaptive Management may include Reclamation making changes in the C-BT Project operations or other appropriate measures. Reclamation will evaluate any input provided.

5. **Adaptive Management Record.** A Record of the discussions held during the meetings, input, decisions and objections made shall be maintained and compiled by the AMC. The purposes of the Record include, but are not limited to, (1) assisting in the evaluation of C-BT Project operational approaches to meet the Clarity Goals, as well as effects on Water Quality Indicators (see E.2.a.), and (2) providing feedback for Adaptive Management.

a. **Meeting Minutes.** The AMC shall record minutes of the meetings held on or about June 1 and June 15.

b. **Weekly Summary Form.** A Weekly Summary Form shall be prepared by and distributed to the AMC at the weekly meetings. The Weekly Summary Form should include a summary of water quality data, operational parameters of interest, and brief notes on action items and discussion topics from the previous meeting. The information will be presented using a form template such as presented in Exhibit D.

c. **Comments.** Written comments submitted by any Party shall be attached to the Weekly Summary Form for that meeting.

d. **Annual Summary.** The AMC shall annually prepare a summary of what it learned about C-BT Project operational approaches to meet the Clarity Goals, as well as effects on water quality, which it shall provide to the Water Quality Control Commission.

VI. FUNDING

A. The Parties' initial contribution shall be the services of their staff members.

B. If the AMC intends to incur any costs associated with the implementation of this MOU, the Parties shall agree in advance to a funding mechanism for such cost(s), consistent with each Party's applicable legal requirements.

C. This MOU does not assign or allocate responsibility for funding implementation of any measures related to the Adaptive Management process. Without acknowledging or admitting such responsibility, the Parties agree to work together to address implementation of measures in support of the Adaptive Management Process, such as monitoring and reporting costs and securing adequate sources of funding therefor.

1. Any agreement with consultants shall expressly recognize and implement such limitation.
2. The obligations of Grand County, the River District, NWCCOG and Northern Water shall not constitute a general obligation, indebtedness, or multiple fiscal year direct or indirect debt or other financial obligation whatsoever, within the meaning of the Constitution or laws of the State of Colorado.
3. All public funding shall be subject to annual appropriation.

D. Northern Water has a contractual relationship with the United States as defined by its 1938 Repayment Contract and related documents. Nothing herein changes Northern Water's obligations as defined by that contract and related documents, and Northern Water's commitments under this MOU are separate from Northern Water's obligations under that contract and related documents.

VII. WINDY GAP FIRMING PROJECT 1041 PERMIT

Grand County hereby acknowledges and confirms that execution of this MOU by the Parties satisfies the portion of Condition 7 of the 2012 Permit that requires execution of the "Clarity MOU" before the 2012 Permit is effective. This MOU also replaces the Umbrella Agreement referred to on the list of documents attached to the 2012 Permit.

VIII. MODIFICATION

No modification or waiver of this MOU or any covenant condition or provision contained herein shall be valid unless approved in writing by Reclamation, Northern Water and the West Slope.

IX. NO WAIVER

The Parties acknowledge that there are differences of opinion regarding the scope of the obligations to protect water clarity in Grand Lake created by Senate Document 80, the Clarity Supplement, and the Colorado Clarity Standard Process. These issues have not been litigated. The Parties agree that in entering into this MOU and not litigating or otherwise objecting in any form to the legal issues specified above, that this MOU shall never give rise to any claim, defense, or theory of acquiescence, bar, merger, issue or claim preclusion, promissory estoppel, equitable estoppel, waiver, laches, unclean hands or any other similar position or defense concerning any factual and legal position regarding the Parties' respective positions regarding Grand Lake clarity and the Parties' respective interpretations of Senate Document No. 80, the 1938 Repayment Contract, Reclamation Law, or Colorado law. The Parties further agree that they do not intend this MOU to have the effect of precedent or preclusion on any factual or legal issue in any other matter. The Parties expressly reserve their rights to assert any legal or factual position or challenge the legal or factual position taken by any other party on any other matter.

X. BINDING AGREEMENT

This MOU shall be binding upon the Parties, and their respective successors or assigns. The Parties' rights and obligations under this MOU may not be assigned without the express written consent of Reclamation, Northern Water and the West Slope.

XI. ENTIRE UNDERSTANDING

This MOU is the complete integration of all understandings between the Parties. No prior or contemporaneous addition, deletion, or other amendment hereto shall have any force or affect whatsoever, unless embodied herein in writing.

XII. THIRD PARTIES

A. This MOU does not create, and the Parties do not intend to create, in any other individual or entity the status of third-party beneficiary, and this MOU shall not be construed so as to create such status. The rights, duties and obligations documented in this MOU shall operate only between the Parties to this MOU, and shall inure solely to the benefit of the Parties to this MOU.

B. The provisions of this MOU are intended only to assist the Parties in determining or performing their obligations under this MOU.

C. This MOU does not and shall not be deemed to confer upon or grant to any third-party any right enforceable at law or equity arising out of any term, covenant, or condition herein or the breach thereof.

XIII. NO RIGHTS AGAINST THE UNITED STATES

This MOU is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities its officers, employees, or agents, or any other person.

XIV. SEVERABILITY

In case one or more of the provisions contained in this MOU, or any application hereof, shall be invalid, illegal, or unenforceable in any respect the validity, legality and enforceability of the remaining provisions contained in this MOU and the application thereof shall not be in any way affected or impaired thereby.

XV. COMPLIANCE WITH LAWS

At all times during the performance of this MOU, the Parties shall strictly adhere to all applicable federal, state and local laws, rules, and regulations that have been or may hereafter be established.

XVI. SOVEREIGN IMMUNITY

The Parties do not waive their sovereign immunity by entering into this MOU, and each fully retains all immunities and defenses provided by law with respect to any action based on or occurring as a result of this MOU.

XVII. EFFECT ON OTHER AGREEMENTS

Nothing in this MOU affects contracts or other agreements that may exist between any combinations of the Parties.

XVIII. EFFECTIVE DATE

This MOU shall become effective on the date upon which it has been signed by the last Party to sign although a majority of the Parties may agree to implement this MOU if the signature of any other Party(s) is a mere formality~~, provided, however, this MOU shall not become effective unless and until the Water Quality Control Commission amends the existing numeric clarity standard, 5 CCR 1002-33 (June 30, 2015), to an average Secchi depth of 3.8 meters and a minimum Secchi depth of 2.5 meters from July 1 through September 11, with a delayed effective date of January 1, 2022.~~

EWW 6/1/16
EJT 6/14/2016
JG 6-17-16
REK 6-27-16
JSS 6-28-16

XVIII. WEST SLOPE APPROVALS

When West Slope approval or consent is required, the West Slope, shall develop a unified position and Grand County, NWCCOG and the River District agree to execute any required documents consistent with that position.

IN WITNESS WHEREOF, the Parties hereto have signed this MOU effective as of the date and year written above.

BUREAU OF RECLAMATION

By: [signature]
Jacklynn L Gould, Area Manager

Date: 1/28/16

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

By: [signature]
Eric Wilkinson, General Manager

Date: 01/14/2016

COLORADO RIVER WATER CONSERVATION DISTRICT

By: [signature]
Eric Kuhn, General Manager

Date: 1/21/16

NORTHWEST COLORADO COUNCIL OF GOVERNMENTS

By: [signature]
Kam Stegelmeier, NWCCOG Chair

Date: 1-27-16

GRAND COUNTY BOARD OF COUNTY COMMISSIONERS

By: E Jane Tollett
E Jane Tollett, Chairman

Date: 1/26/2016

Attest: Sara L Rosene
Sara L Rosene, Clerk and Recorder
Jane Reed, Deputy Clerk

Date: 1-26-2016

LIST OF EXHIBITS

EXHIBIT A: pdf of SD80
EXHIBIT B: Clarity Supplement
EXHIBIT C: Secchi, DO and pH monitoring/ Secchi Monitoring Protocol Attached
EXHIBIT D: Form Template

75th Congress) 1st Session) | SENATE | (Document (No. 80

COLORADO-BIG THOMPSON PROJECT

SYNOPSIS OF REPORT

ON

COLORADO-BIG THOMPSON PROJECT, PLAN OF DEVELOPMENT AND COST ESTIMATE PREPARED BY THE BUREAU OF RECLAMATION, DEPARTMENT OF THE INTERIOR

PRESENTED BY MR. ADAMS

JUNE 15, 1937--ORDERED TO BE PRINTED WITHOUT ILLUSTRATIONS

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON: 1937

Retyped for clarity January 23, 1997

CONTENTS

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CONTENTS (Continued)

LETTER OF TRANSMITTAL

February 3, 1937

From Senior Engineer Porter J. Preston
To Chief Engineer
Subject: Colorado-Big Thompson project

1. Transmitted herewith is a synopsis of the report of plan of development and cost estimate of the Colorado-Big Thompson project.

2. The plans and designs upon which the estimates are based are shown in the full report to follow this synopsis.

3. The detail estimates have been worked out in the Denver office under the following divisions:

Canals: H. R. McBirney
Reservoirs: K. B. Keener
Power: L. N. McClellan
Hydraulics: E. B. Debler

4. The field work was done under the supervision of M. E. Bunger.

5. The economic study was carried on by R. L. Parshall, senior irrigation engineer, Bureau of Agricultural Engineering, United States Department of Agriculture. This study is later proposed to be issued as a separate document.

PORTER J. PRESTON

Revised synopsis of report submitted June 11, 1937.

LETTERS OF SUBMITTAL

June 11, 1937

Hon. Harold L. Ickes,
Secretary of the Interior

My Dear Mr. Secretary: There is attached hereto the portion of the report on the Colorado-Big Thompson project in Colorado covering the principles and stipulations governing the construction and operation of said project for the protection of the rights and interests dependent on the Colorado River in Colorado.

The provisions contained therein have been considered by the Northern Colorado Water Users' Association, representing the irrigation and other interests on the eastern slope in Colorado, and we respectfully submit that they are satisfactory and meet the approval of said association.

We ask that acknowledgment be made of this communication.

Respectfully yours,

NORTHERN COLORADO WATER USERS' ASSOCIATION,
CHAS. HANSEN, President
MOSES E. SMITH, Vice President
THOMAS A. NIXON, Attorney

June 11, 1937

Hon. Harold L. Ickes,
Secretary of the Interior

My Dear Mr. Secretary: There is attached hereto the portion of the report on the Colorado-Big Thompson project in Colorado covering the principles and stipulations governing the construction and operation of said project for the protection of the rights and interests dependent on the Colorado River in Colorado.

The provisions contained therein have been considered by the Western Slope Protective Association, representing the irrigation and other interests on the western slope in Colorado, and we respectfully submit that they are satisfactory and meet the approval of said association.

We ask that acknowledgment be made of this communication.

Respectfully yours,

THE WESTERN SLOPE PROTECTIVE ASSOCIATION,
SILMON SMITH, Secretary
CLIFFORD H. STONE, Director
A. C. SUDAN, Special Representative of Grand County

SYNOPSIS OF REPORT, COLORADO-BIG THOMPSON PROJECT

Outline of Construction and Operating Conditions

The Colorado-Big Thompson project in Colorado contemplates the diversion of surplus waters from the headwaters of the Colorado River on the Pacific or western slope to lands in northeastern Colorado on the Atlantic or eastern slope greatly in need of supplemental irrigation water.

To accomplish this diversion, the following features are required:

ON COLORADO RIVER

(1) Storage on the Blue River in what is called Green Mountain Reservoir located about 16 miles southeast of Kremmling, Colo., where the Blue enters the Colorado River. This reservoir is to be used to replace water diverted to the eastern slope that would be required by prior rights along the Colorado River.

(2) A hydroelectric plant below the Green Mountain Dam to utilize the flow of the Blue River and water stored in the reservoir for the generation of electrical energy.

(3) A storage reservoir located on the Colorado River about 6 miles northeast of Granby, Colorado, to be known as Granby Reservoir. This reservoir will store the flow of the Colorado at this point as well as water diverted from Willow Creek, a tributary of the Colorado and Strawberry and Meadow Creeks, tributaries of the Fraser River.

(4) A diversion dam located about one-half mile below the junction of the North Fork and Grand Lake outlet and about 3 miles south of the village of Grand Lake. This dam will create a lake known as Shadow Mountain Lake which will have the same elevation as Grand Lake and will aid in supplying the transmountain diversion tunnel with water pumped from Granby Reservoir. This lake together with Grand Lake is to be kept at nearly constant level.

(5) An electrically driven pumping plant on the shore of Granby Reservoir, where water will be pumped into a canal feeding Shadow Mountain and Grand Lakes. The length of the canal is 4½ miles.

(6) An outlet channel at the east end of Grand Lake connecting the lake with the portal of a transmountain diversion tunnel and provided with control features that will regulate the level of Grand Lake within a fluctuating range of 1 foot.

(7) A transmountain diversion tunnel under the Continental Divide 13.1 miles in length extending from Grand Lake to a point in Wind River about 5 miles southwest of Estes Park village.

ON EASTERN SLOPE

(8) A conduit 5.3 miles in length extending from diversion tunnel outlet to penstock of a power plant on the Big Thompson River just below Estes Park village. This conduit will be made up of buried pipe, siphons, tunnels, and open canal. It will be entirely concealed through the area authorized to be taken into Rocky Mountain National Park.

(9) The waste rock from the tunnel is to be terraced and landscaped and all structures connected with the tunnel will be constructed to blend into their natural surroundings.

(10) A power plant known as power plant no. 1 constructed along the Big Thompson River just below the village of Estes Park utilizing the western slope water.

(11) Four additional power plants down the Big Thompson Canyon to utilize all available fall and also all water available for power in the Big Thompson River in addition to the western slope water diverted.

(12) A diversion dam on Big Thompson River about 12 miles west of Loveland to divert the water by means of a canal 9 miles in length to a storage reservoir known as Carter Lake.

(13) Carter Lake Reservoir located 8 miles northwest of Berthoud, Colo., to store water brought over during winter months. Water is released from this reservoir through a 4-mile canal into the Big Thompson River and through a 9-mile canal into the St. Vrain River for irrigation purposes.

(14) A siphon across the Big Thompson River, 9 miles west of Loveland, Colorado, and a canal 10 miles in length to convey water from the fourth power plant to a storage reservoir, located about 5 miles west of Fort Collins, known as Horsetooth Reservoir.

(15) A canal from Horsetooth Reservoir to the Cache la Poudre River and extended north to a pumping plant which lifts water high enough to serve the North Poudre Canal.

(16) A storage reservoir near the mouth of Buckhorn Creek to be known as Arkins Reservoir, supplied from a canal diverting from the Big Thompson River just below the last power plant. It is to be used to aid in balancing the demands for power and irrigation, also storing excess water available in the Big Thompson River. Water will be released from the reservoir for supplemental irrigation in the South Platte area.

(17) Transmission lines connecting the Valmont steam plant of the Public Service Co. with all the hydroelectric plants contemplated, also connecting with the transmountain tunnel portals and the Granby and North Poudre pumping plants. The line connecting power plant no. 1 and Granby pumping plant will run east, and south of the outside boundaries of the Rocky Mountain National Park, crossing the Continental Divide at Buchanan Pass.

In order to carry out the construction, operation, and maintenance of the project as outlined above, it will be necessary to comply with the following requirements as agreed to by representatives of the eastern and western slopes in Colorado and here made as a part of this report.

MANNER OF OPERATION OF PROJECT FACILITIES AND AUXILIARY FEATURES

The construction and operation of this project will change the regimen of the Colorado River below the Granby Reservoir. The project contemplates the maximum conservation and use of the waters of the Colorado River, and involves all of the construction features heretofore listed. In addition thereto, certain supplemental construction will be necessary. This will be for the primary purpose of preserving insofar as possible the rights and interests dependent on this water, which exist on both slopes of the Continental Divide in Colorado. The project, therefore, must be operated in such a manner as to most nearly effect the following primary purposes:

1. To preserve the vested and future rights in irrigation.

2. To preserve the fishing and recreational facilities and the scenic attractions of Grand Lake, the Colorado River, and the Rocky Mountain National Park.

3. To preserve the present surface elevations of the water in Grand Lake and to prevent a variation in these elevations greater than their normal fluctuation.

4. To so conserve and make use of these waters for irrigation, power, industrial development, and other purposes, as to create the greatest benefits.

5. To maintain conditions of river flow for the benefit of domestic and sanitary uses of this water.

In order to accomplish these purposes, the project should be operated by an unprejudiced agency in a fair and efficient manner, equitable to all parties having interests therein, and in conformity with the following particular stipulations:

(a) The Green Mountain Reservoir, or similar facilities, shall be constructed and maintained on the Colorado River above the present site of the diversion dam of the Shoshone power plant, above Glenwood Springs, Colo., with a capacity of 152,000 acre-feet of water, with a reasonable expectancy that it will fill annually. Of said capacity, 52,000 acre-feet of water stored therein shall be available as replacement in western Colorado, of the water which would be usable there if not withheld or diverted by said project; 100,000 acre-feet shall be used for power purposes; and all of said stored waters shall be released under the conditions and limitations hereinafter set forth.

(b) Whenever the flow in the Colorado River at the present site of said Shoshone diversion dam is less than 1,250 cubic feet per second, there shall, upon demand of the authorized irrigation division engineer or other State authority having charge of the distribution of the waters of this stream, be released from said reservoir as a part of said 52,000 acre-feet, the amount necessary with other waters available, to fill the vested appropriations of water up to the amount concurrently being diverted or withheld from such vested appropriations by the project for diversion to the eastern slope.

(c) Said 100,000 acre-feet shall be stored primarily for power purposes, and the water released shall be available, without charge, to supply existing irrigation and domestic appropriations of water, including the Grand Valley reclamation project, to supply all losses chargeable in the delivery of said 52,000 acre-feet of water, and for future use for domestic purposes and in the irrigation of lands thereafter to be brought under cultivation in western Colorado. It shall be released within the period from April 15 to October 15 of each year as required to supply a sufficient quantity to maintain the specified flow of 1,250 cubic feet per second of water at the present site of said Shoshone diversion dam, provided this amount is not supplied from the 52,000 acre-feet heretofore specified. Water not required for the above purposes shall also be available for disposal to agencies for the development of the shale oil or other industries.

(d) The cost of construction and perpetual operation and maintenance of said reservoir or reservoirs shall be a charge against the project and shall be paid from revenues collected from this project as may be provided in contracts between the Secretary of the Interior and the beneficiaries of the project in eastern Colorado, and any other contracting parties.

(e) In the event said reservoir or reservoirs are not maintained with a capacity of 52,000 acre-feet, the Secretary of the Interior should withhold the diversion of water from the western to the eastern slope of Colorado until such storage capacity is made available.

(f) The Secretary of the Interior shall have the option to require the transfer to the United States of any and all rights initiated or acquired by the appropriation or use of water through the works of the project in eastern Colorado, at any time: PROVIDED, HOWEVER, that the title so taken shall be subject to a beneficial use of such water as may be provided in the repayment contract or contracts; and the rights to store water to the extent of said 152,000 acre-feet shall be initiated, acquired, and held by the appropriate authorities for use in western Colorado, for replacement of water diverted to the eastern slope, and for other purposes contemplated for this project.

(g) The Secretary of the Interior shall operate this project in accordance with the following stipulations as to priorities of water use as between the parties claiming or using project water and within the limits of his legal authority. Said 52,000 acre-feet of replacement storage in Green Mountain or other reservoirs shall be considered to have a date of priority for the storage and use of replacement water earlier than that of the priorities for the water diverted or stored for delivery to the eastern slope. The 100,000 acre-feet of storage in said reservoir shall be considered to have the same date of priority of appropriation as that for water diverted or stored for transmountain diversion.

(h) Said Green Mountain Reservoir, or such other replacement reservoirs as provided in paragraph (a) herein, as are planned as a part of the project, shall be constructed at the same time as the other parts of the project and shall be completed before any water is diverted to the eastern slope of the Continental Divide by means of said project.

(i) Inasmuch as the State of Colorado has ratified the Colorado River Compact, and inasmuch as the construction of this project is to be undertaken by the United States, the project, its operation, maintenance, and use must be subject to the provisions of said Colorado River Compact of November 24, 1922 (42 Stat. 171), and of section 13 of the Boulder Canyon Project Act, dated December 21, 1926 (45 Stat. 1057-1064). Notwithstanding the relative priorities specified in paragraph (g) herein, if an obligation is created under said compact to augment the supply of water from the State of Colorado to satisfy the provisions of said compact, the diversion for the benefit of the eastern slope shall be discontinued in advance of any western slope appropriations.

(j) An adequate system, as determined by the Secretary of the Interior, shall be provided for the irrigation of the lands in the vicinity of Kremmling, now irrigated by either natural or artificial means, and the installation made therefor shall be a part of this project. The rights to the use of water for the irrigation of these lands shall be considered to have a date of priority earlier than that of the rights to the use of water to be diverted through the works of this project to the eastern slope. This system shall be designed and built in a manner requiring the least possible continuing annual expense for operation and maintenance but the cost thereof shall not exceed $300,000; and said system shall be provided and in operation before any water is stored for transmountain diversion. In addition, the Secretary shall protect, add to, or improve the source of supply of domestic waters for the municipalities of Kremmling and Hot Sulphur Springs in the manner and to the extent which he may determine to be necessary to provide a source of supply not less than that now available for these municipalities. The cost of these features shall be included in the total project cost.

(k) To compensate Grand County for the loss of taxes through the transfer of property to the United States for the construction of this project, $100,000 shall be paid to said Grand County. This payment shall be made in 10 annual installments of $10,000 each, commencing upon the date when 10 percent of the total property in Grand County required for said project has been removed from taxation.

(l) The project and all of its features shall be operated in a manner determined by the Secretary of the Interior as necessary to provide the water to preserve at all times that section of the Colorado River between the reservoir to be constructed near Granby and the mouth of the Fraser River as a live stream, and also to insure an adequate supply for irrigation, for sanitary purposes, for the preservation of scenic attractions, and for the preservation fish life. The determination of the need for and the amount and times of release of water from Granby Reservoir to accomplish these purposes shall be made by the Secretary of the Interior, whose findings shall be final.

In order to facilitate compliance with the stipulation in paragraphs (j), (k), and (l) hereof a representative may be selected and designated by the interests dependent thereon in Grand County, Colo., and when so designated he will be recognized as the official spokesman of said interests in all matters dealing with project operations affecting Grand County.

The principles and provisions expressed in these stipulations have been approved by the Western Colorado Protective Association, representing interests in western Colorado, and the Northern Colorado Water Users Association as evidenced by the letters hereto attached.

SUMMARY

The Colorado-Big Thompson project comprises 615,000 acres of irrigated lands, out of approximately 800,000 acres lying under the canal systems in the northern and northeastern portions of Colorado.

The water supply for the area is to be derived from a portion of 782 square miles of drainage area above Hot Sulphur Springs lying west of the Continental Divide in Grand County, Colorado, and varying in elevation from 8,050 to 14,000 feet.

HISTORY

The first irrigation in northeastern Colorado occurred about 1860 where the early settlers plowed out small ditches with sufficient grade and length to irrigate a few acres of land in the first bottom--ie. lands not far above the high-water line of the streams and adjacent to them.

The first irrigation of the higher or second bench lands along the Cache la Poudre River was by the Old Union Colony, of Greeley, in 1870. This colony was organized by Horace Greeley, then editor of the New York Tribune, who will be remembered here especially for his advice to eastern young men to "Go west and grow up with the country."

This colony irrigated about 12,000 acres under their first project and it was a success from the start, due in a large measure to the fact that they were people of considerable means and were then able to finance themselves over the period required to bring raw prairie land into profitable cultivation.

This colony was soon followed by others along the Poudre at Fort Collins, on the Big Thompson, at Loveland, and the St. Vrain near Longmont.

The difficulties experienced by these colonists in distributing the water between them led to the creation of Colorado's irrigation laws which have been copied by most of the irrigation States of the West.

This irrigated area of six hundred to eight hundred thousand acres was developed by means of individual initiative and by small scale cooperative enterprises. Today there are 6,400 irrigated farms, served by 124 canals and ditches and 60 storage reservoirs.

IRRIGATION USE

In the early days, irrigation in this area was confined to growing crops to supply local needs, the lack of transportation contributing to high prices for the home-grown production and prohibiting shipping to distant points. The crops grown were mainly the grains and hay for local consumption, with some vegetables. Such irrigation corresponded with the runoff of the streams.

As mining developed in the State, Denver and other towns grew into cities, and after these cities were connected to the East by railroads the markets demanded a more diversified agriculture to supply their needs. Thus a gradual demand developed for later water which the streams could not supply.

This change created a need for storing the flood waters for late irrigation. From 1890 to 1910 was a period of reservoir construction, during which storage was provided for all the available water supply of the streams over and above the direct irrigation requirements for the area here under discussion. Much of this development took place during a decade of more than normal runoff on the eastern slope and also during a period expanding the agricultural area throughout the West.

Attempts to maintain the area under cultivation with the depleted runoffs during the past 10 years have spread the water supply to such an extent that much acreage has had an insufficient water supply to produce full crops or crops producing the higher values. Attempts have been made to supplement the individual farm water supply by the development of the underground sources by pumping from numerous wells throughout the region. This is lowering the water table and already is affecting the water supply of the lower South Platte Valley which receives its irrigation supply largely from return waters.

NEED OF SUPPLEMENTAL WATER

Under such conditions only the older water rights have any assurance of an adequate water supply, and in the dryer years the owners of junior rights are forced to confine their farming to crops that can be matured by the early flood flow or that require a minimum amount of water. In years when the supply is not correctly estimated considerable loss results. Ordinarily the crops raised in this and other irrigated areas do not compete with those grown under rainfall conditions, but a shortage of water always leads to the raising of more of the competing crops. Such crops also cut the income of the irrigation farmer below what he can earn with the higher type, noncompetitive crops.

On fully three-fourths of the 615,000 acres in this area the water supply is inadequate, in spite of every effort to conserve, store flood water, or otherwise add to the water supply that has been within the financial ability of the farmer. This inadequacy is due not only to a development probably too large for the period when runoff of the streams was much higher than at present, but to the fact that the last 10 years have seen a very marked decrease in the stream flow. It must be emphasized that the additional water supply here contemplated is to be used for a supplemental supply and not to create a large new additional irrigated acreage.

There has been expended in this area to date for various types of irrigation works, including nearly $750,000 for pumping plants, most of which have been installed in the last 10 years, about $35,000,000 against which there is an outstanding indebtedness of only $1,510,650. These people, however, have about reached their limit as individuals and mutual irrigation companies to provide for themselves a supplemental water supply so badly needed to make their present water supply secure and are obliged to seek Government aid to bring this about.

It has been conceded by a majority of the irrigation interests in this section of the State that the water supply in 1926 was ample for all their present acreage now irrigated. In order, therefore, to determine the normal shortage in acre-feet over a period of years a comparison of the supply in those years with that of 1926 was made and the difference obtained. These differences are set up in the following table:

Table 1. -- Showing water districts, acreage irrigated, deficiencies 1925 to 1935 with tentative allocation of total supplemental supply

Water district no.	Area irrigated	1926 diversion, acre-feet	Average diversion, 1925-35	Difference, 1926, 11-year average required supple-mentary water in acre-feet	Tentative allocation of supplemental supply: Colorado-Big Thompson project water	Moffat and Jones Pass tunnel water return	Present seepage return acre-feet	Total supple-mental supply, acre-feet
(1)	(2)	(3)	(7)	(15)	(16)	(17)	(18)	(19)
3	213,640	530,000	398,000	132,000	104,000	--	49,500	153,500
4	68,408	235,000	163,000	72,000	44,100	--	21,000	65,100
5	81,806	113,000	94,000	19,000	38,800	--	18,500	57,300
1	92,394	663,000	457,000	206,000	81,400	11,000	83,000	175,400
2	37,899	170,000	154,000	16,000	5,000	4,500	5,100	14,600
64	121,289	513,000	383,000	130,000	36,700	14,500	37,400	88,600
Total	615,436	2,224,000	1,649,000	575,000	310,000	30,000	214,500	554,500

It will be noted from column no. 15 that the total average shortage in this project area which comprises water districts 3, 4, 5, 1, 2, and 64 is 575,000 acre-feet. Column no. 16 is a tentative allocation of the proposed supplemental supply to the various districts. Column no. 18 is the estimated usable return flow that would arise from the addition of 310,000 acre-feet of new water to this area. Column no. 19 is the total usable supplemental supply amounting to 554,520 acre-feet, an amount within 5 percent of the 10-year average shortage. The sale or rental of supplemental water, when available, in the Poudre Valley has averaged $4.50 per acre-foot over a period of years. In extreme cases it has sold as high as $9 per acre-foot.

The deficiency in water supply for the period 1925 to 1934, inclusive, reflected a direct economic loss in crop production of approximately $42,355,000.

The following shows the approximate annual loss in value of crops because of inadequate water supply:

Sugar beets	$1,900,000
Alfalfa	948,000
Small grain	470,000
Beans	302,000
Corn	228,000
Potatoes	425,000
All other crops	444,000
Total	$4,700,000

This average annual direct crop loss is about 19 percent of the $24,800,000 estimated cost of the Colorado-Big Thompson irrigation project.

The crop loss in 1934, due to shortage of water, as compared to 1926, after variation in price and acreage factors had been accounted for, amounted to $12,400,000, or just one-half the cost of the project.

The losses here given are the farm losses and do not include the losses that are due to processing, transporting, or handling of that quantity of production, which would add several million dollars to the loss of the community as a whole.

The effect of such inadequate water supply for the period 1925-35 is shown graphically on drawing no. 1 following.

SUPPLEMENTAL WATER SUPPLY

In 1929 the State engineers of Colorado, in cooperation with the Platte Valley Water Conservation League, and the United States Army engineers, made a comprehensive study of the water resources of the South Platte Basin in northeastern Colorado. This study included the Cache la Poudre River in water district no. 3, the Big Thompson River in water district no. 4, and the St. Vrain River in district no. 5. The investigators determined the excess water available on these streams above present normal demands and also above the normal demands on the South Platte River proper below where these streams enter.

The investigators also determined the location, capacity, and cost of the most feasible reservoir sites for the storage of this excess water.

The results are shown in the following table and have been brought up to date by using the same demands for irrigation as set up in the report and using the water-supply records furnished by the State engineer's office.

Stream	Excess supply available for storage, average, 1918-35	Capacity proposed reservoir by Army engineers	Average annual yields at reservoirs	Total reservoir costs	Cost per acre-foot capacity	Cost per acre-foot yield
	A.F.	A.F.				
Cache la Poudre	30,000	52,000	25,500	$2,747,000	$72	$147
Big Thompson	16,000	32,700	11,300	2,006,000	61	178
St. Vrain	16,000	30,000	14,000	2,186,000	73	156

From the foregoing table it is evident that there is not sufficient excess water available that originates in this area to supply the demands for supplemental water, and the cost of making use of what is available is prohibitive. It will be shown, however, that 16,000 acre-feet of this surplus is available for storage in the Colorado-Big Thompson project reservoirs on the eastern slope with no additional cost.

The water users in northeastern Colorado have now exhausted every possible source of obtaining supplemental water or augmenting their present supply either by storage, transmountain diversion within their individual cooperative means, and by pumping. Fortunately, however, there exists a surplus of water on the headwaters of the Colorado River west of this area and separated from it by the Continental Divide.

In the spring of 1935, $150,000 was allocated to the Bureau of Reclamation to make surveys and prepare plans and cost estimates for bringing water from the headwaters of the Colorado River into the area in northeastern Colorado in need of supplemental water.

In August 1935 the Bureau of Reclamation started surveys for the project and previously there had been started a land classification to determine the irrigated and arable land in the Colorado River Basin in

Colorado in order to arrive at the approximate amount of water now used in the area and how much might be used when full development has been made. Both surveys had been completed, insofar as this project is involved, and the following is the result of the land classification.

LAND CLASSIFICATION--COLORADO RIVER AREA

Since the quantity of water available for diversion from the headwaters of Colorado River might be limited now by the water rights of lands already irrigated, or might in the future limit in turn the development of lands in the Colorado Basin within the State, all the land on Colorado River and its tributaries above the Colorado-Utah line, except the Gunnison River area, has been classified to show the location and extent of irrigated lands and of lands capable of irrigation.

This classification was undertaken in all areas covered by former reports, supplemented by local information as to possible projects and by reconnaissance. For localities with no records of water supply it was assumed to exist unless the contrary was obvious, and doubtful areas were included rather than excluded from the classification. The land was measured by plane-table survey except some small isolated areas which were estimated.

Land that had customarily been irrigated was so classed, no matter how inadequate the supply. Land capable of irrigation was tested according to a set of standards which fairly represent the experience on this area and others as to what constitutes arable land. Where pumping for irrigation was involved land was classified up to 200 feet above the source of supply.

The result of the survey of the irrigated and arable land appears in the following table.

It should be stated, that, as will be shown under the discussion of water supply which follows, the present irrigated area above the Utah state line does not limit the diversion possible at the location chosen. It is also true that the diversion when in opèration, and replacing the summer flow of Colorado River in the manner contemplated by the project plan, will not limit the future development of all the arable land on Colorado River and its tributaries above Gunnison River.

Colorado River drainage--Gunnison excepted--Colorado (land classification according to streams)

Stream name	Irrigated	Arable	Total
Colorado River:	Acres	Acres	Acres
1. To Granby Dam	2,600	1,100	3,700
2. Granby Dam to Hot Sulphur Springs	1,300	350	1,650
3. Hot Sulphur Springs to Kremmling	3,200	1,200	4,400
4. Kremmling to Glenwood Springs	1,100	260	1,360
5. Glenwood Springs to Palisade	7,000	2,500	9,500
6. Palisade to State line	70,600	32,800	103,400
Total	85,800	38,210	124,010
Tributaries:			
Willow Creek	860	120	980
Fraser River	7,100	650	7,750
South Fork Colorado River	610	30	640
Small streams (1)	2,300	4,000	6,300
Williams Fork River	3,600	10,900	14,500
Troublesome Creek	4,200	7,200	11,400
Muddy Creek	4,900	5,100	10,000
Blue River	8,400	3,100	11,500
Small streams (2)	610	570	1,180
Sheephorn Creek	1,200	50	1,250
Piney Creek	790	50	840
Egeria Creek	5,700	9,300	15,000
Cabin Creek area	5,700	2,600	8,300
Catamount Creek	1,000	10	1,010
Sweetwater Creek area	1,100	380	1,480
Eagle River	16,400	5,000	21,400
Small streams (3)	930	60	990
Roaring Fork River	33,100	9,400	42,500
Garfield Creek	2,100	---	2,100
Elk Creek	3,000	130	3,130
Divide and Mam Creeks	13,700	9,100	22,000
Rifle Creek	11,100	3,200	14,300
Parachute Creek	1,700	370	2,070
Roan Creek	5,600	3,300	8,900
Plateau Creek	24,000	7,000	31,600
Small streams (4)	10,200	3,000	13,200
Grand total	256,300	122,830	379,130

(1) Above Hot Sulphur Springs
(2) Between Hot Sulphur Springs and Kremmling
(3) Between Kremmling and Glenwood Springs
(4) Between Glenwood Springs and Palisade

WATER SUPPLY

The stream flow records at the different stations in the Colorado River Basin show the amount of water passing the stations after all present irrigation has taken place above, so there is no need for any further adjustment of stream flow to take care of water consumed in this irrigation.

It is assumed that all arable lands as shown will be irrigated some time in the future, notwithstanding the fact that quite a percentage is so located that it would never be feasible to irrigate. It is also further assumed that reservoirs would be built on the tributaries to conserve a portion of the flood flows to make the irrigation of these arable lands possible.

With the above assumptions it has been found that in a year like 1931, with the run-off only 40 percent of the average for a 31-year period, and the lowest year of record, the Colorado-Big Thompson project would only have to supply approximately 53,000 acre-feet to replace water diverted by the proposed project that could have been used by the Colorado River water users for power and irrigation, provided the project was in operation at that time.

The average run-off of the Colorado for the years of record are: Hot Sulphur, 31 years, 523,000 acre-feet; Glenwood Springs, including Roaring Fork, 3,413,000 acre-feet, Fruita, 6,300,000 acre-feet. These amounts are exclusive of supply consumed in present irrigation of Colorado River Basin lands.

The following is the estimated amount of water available for diversion from the drainage area above the Colorado-Big Thompson collection system at 8,260 feet elevation.

YIELD OF GRANBY RESERVOIR

Stream-flow records available on the Colorado River near the Granby Dam site for the years 1908-11 and 1935-36, and on Willow Creek for the years of 1935 and 1936, were supplemented by estimates based on available stream-flow records on the Colorado River at Hot Sulphur Springs and Glenwood Springs to cover the 37-year period, 1900 to 1936, inclusive.

A capacity of 482,000 acre-feet was selected as the best capacity for the Granby Reservoir, considering cost and use. Of this capacity, 20,000 acre-feet were set aside for dead storage to reduce pumping lifts for waters delivered to Shadow Mountain Reservoir. A further objective is to keep to the lowest practicable area the exposure of reservoir bed when storage is exhausted. This leaves an active capacity of 462,000 acre-feet.

Reservoir operating studies are based on the following conditions:

(a) Recorded (or estimated) past flows of Colorado River at Shadow Mountain and Granby Dams reduced by 27 percent prior to 1906, and 13 percent thereafter, of the flow of the North Fork at Grand Lake to allow for increasing diversions by the Grand River ditch.

(b) Willow Creek diverted to reservoir to the extent of 90 percent of the flow of Willow Creek and other streams intercepted by the diversion canal from May to October, inclusive, of each year.

(c) Strawberry, Meadow, and Walden Hollow Creeks also diverted whenever practicable. The flow of these streams, together with some additional waters capturable from Willow Creek at times, are expected to offset evaporation and seepage losses in excess of present losses from the Granby and Shadow Mountain Reservoir sites.

(d) No releases from Granby Dam for any reason.

(e) Transmountain tunnel to be operated at full capacity from October 1 until March 31 following, with operations thereafter gaged to fit run-off conditions so as to avoid spills and yet concentrate flows in the period of July 15 to September 15, for the purposes of best distribution in power production and to minimize reregulating storage requirements on the eastern slope. The computations assumed infallible forecasts of run-off.

(f) A minimum storage hold-over of 100,000 acre-feet on September 30 of each year to assure dependable power production in winter.

Unit 1,000 acre-feet

Run-off year (October to September)	Inflow to Granby Reservoir		Tunnel diversions	Spills	Shortages
	Colorado River	Willow Creek			
1899-1900	242.8	52.4	320.0	-	-
1900-01	246.9	53.4	320.0	-	-
1901-02	164.9	34.7	255.1	-	64.9
1902-03	222.0	48.8	270.8	-	49.2
1903-04	253.5	51.2	304.7	-	15.3
1904-05	287.9	64.9	310.2	-	9.8
1905-06	292.4	58.7	320.0	-	-
1906-07	381.0	78.3	320.0	-	-
1907-08	190.6	25.6	320.0	-	-
1908-09	323.8	91.5	320.0	-	-
1909-10	200.1	32.5	320.0	-	-
1910-11	268.5	53.6	320.0	-	-
1911-12	350.4	79.3	320.0	-	-
1912-13	215.4	40.3	320.0	-	-
1913-14	371.0	85.1	320.0	-	-
1914-15	223.2	43.8	320.0	-	-
1915-16	249.5	47.8	320.0	-	-
1916-17	348.3	79.7	320.0	-	-
1917-18	322.9	81.2	356.4	18.7	-
1918-19	189.6	36.4	320.0	-	-
1919-20	361.2	78.4	345.6	-	-
1920-21	347.9	90.7	368.6	70.0	-
1921-22	196.8	39.5	320.0	-	-
1922-23	280.3	60.2	320.0	-	-
1923-24	262.2	54.4	320.0	-	-
1924-25	202.6	36.7	320.0	-	-
1925-26	346.4	70.0	320.0	-	-
1926-27	275.0	54.8	320.0	-	-
1927-28	317.5	61.9	338.3	-	-
1928-29	297.1	61.2	358.3	-	-
1929-30	247.4	42.9	320.0	-	-
1930-31	171.5	36.6	320.0	-	-
1931-32	243.9	48.0	320.0	-	-
1932-33	239.6	54.5	320.0	-	-
1933-34	128.9	26.2	320.0	-	-
1934-35	209.2	41.8	252.5	-	67.5
1935-36	279.7	53.8	310.0	-	10.0
Average	263.6	55.4	318.7	2.5	5.5

Operating results cannot be expected to result so favorably. The operating conditions enumerated imply superhuman ability to forecast stream flow. Occasional releases will be required from Granby Reservoir although small in amount. Interruptions in tunnel operation cannot always be arranged so as to lose no water.

In view of these conditions, it is concluded that the firm yield of tunnel water from the Granby and Shadow Mountain Reservoirs should be taken as 300,000 acre-feet annually. Shortages of 5 percent may be expected on an average of once every 5 years and shortages of 25 percent may be expected on an average of once every 20 years. Secondary water may be expected to be available in some years in amounts up to 50,000 acre-feet.

EFFECT OF THE PROPOSED TRANSMOUNTAIN DIVERSION ON FUTURE WESTERN SLOPE DEVELOPMENT

Most of the diverted water is derived from the spring floods, when there is an excess of water over all present and future requirements along the Colorado River in the State. To permit full use of the inflow to the Granby Reservoir, Ranch Creek Reservoir may be constructed near Tabernash to store water locally surplus. The waters there conserved would in part be utilized to replace the waters withheld at Granby Dam, but the greater part of the conserved water would be used to augment irrigation supplies down to Hot Sulphur Springs and to maintain a satisfactory stream flow in this locality for recreational purposes.

With the region above Hot Sulphur Springs taken care of by the Ranch Creek Reservoir, the critical points along the Colorado River, from the standpoint of present and future use of water, are at Glenwood Springs, where the Shoshone power plant of the Public Service Co. uses present stream-flows up to 1,250 second-feet, and near Palisades at the head of the Grand Valley, where the Government highline canal diverts water for irrigation and power purposes. The present irrigated area along the Colorado River between Palisades and the Colorado-Utah state line is 70,600 acres.

The additional arable area in this region, not now irrigated, is as follows:

	Acres
Under constructed canals	13,800
Pumping unit of Grand Valley project, for which canal capacity has been provided	10,000
Lands on Mack Flat, no present provision for water service	9,000
Total	32,800

Maximum irrigation demand at the head of the Grand Valley for the present irrigated area and for the additional area of 23,800 acres for which provision has been made in the constructed canals, is estimated as 1,700 second-feet, and this amount is being demanded in the pending adjudication proceeding.

With maximum irrigation demands there is a full water supply for the Orchard Mesa pumping plant and for the Grand Valley power plant. In the non-irrigation season the controlling requirement is for power with a total demand of 800 second-feet for power and for domestic needs under the higher canals. With the new area of 9,000 acres developed, the future demands are then estimated as 1,800 second-feet in the months of May to August, inclusive, tapering off uniformly to 800 second-feet on April 1 and November 30.

In determination of the effect of the Colorado-Big Thompson transmountain diversion on the western slope, the past stream flows at Glenwood Springs and at the head of the Grand Valley were first depleted to show the resulting stream flows with the following developments:

(a) Full irrigation development of 276,000 acres of irrigated and arable lands along the Colorado River and tributaries above Palisades (the present irrigated area is 186,000 acres).

(b) Full development of Moffat Tunnel diversion from Fraser River and tributaries, Jones Pass diversion from Williams River, and Independence Pass diversion from the Roaring Fork, including replacement storage so that these projects may divert all flows interceptible.

From the reconstructed flows, thus computed, there was subtracted the water estimated to be withheld at the Granby Reservoir site. The reductions in stream flow at Glenwood Springs and at the head of the Grand Valley, during those periods of each year when the resulting stream flows would be less than the future demands above described, then represents the effect of the project on the western slope if no replacement storage were provided. These computations were made for the years 1926 to 1936, inclusive, at Glenwood Springs, and for the entire period of record, 1902 to 1936, inclusive, at the head of the Grand Valley, with the following results:

Year	Shortages at Glenwood Springs (acre-feet)			Shortages at head of Grand Valley (acre-feet)		
	End of flood season, Oct. 31[1]	Nov. 1 to flood season of following year[2]	Total	Before flood season in spring[3]	After flood season to Oct. 31	Total
1902	(4)	(4)	-	6,000	39,000	45,000
1903	(4)	(4)	-	3,000	12,000	15,000
1904	(4)	(4)	-	None	2,000	2,000
1905	(4)	(4)	-	None	14,000	14,000
1906	(4)	(4)	-	None	None	None
1907	(4)	(4)	-	None	None	None
1908	(4)	(4)	-	None	6,000	6,000
1909	(4)	(4)	-	None	None	None
1910	(4)	(4)	-	None	12,000	12,000
1911	(4)	(4)	-	None	1,000	1,000
1912	(4)	(4)	-	None	None	None
1913	(4)	(4)	-	None	7,000	7,000
1914	(4)	(4)	-	None	None	None
1915	(4)	(4)	-	None	9,000	9,000
1916	(4)	(4)	-	None	None	None
1917	(4)	(4)	-	None	None	None
1918	(4)	(4)	-	None	1,000	1,000
1919	(4)	(4)	-	None	7,000	7,000
1920	(4)	(4)	-	2,000	None	2,000
1921	(4)	(4)	-	None	None	None
1922	(4)	(4)	-	None	None	None
1923	(4)	(4)	-	None	None	None
1924	(4)	(4)	-	None	4,000	4,000
1925	(4)	(4)	-	None	None	None
1926	18,000	19,000	37,000	None	2,000	2,000
1927	7,000	32,000	39,000	None	None	None
1928	10,000	18,000	28,000	None	None	None
1929	None	20,000	20,000	None	None	None
1930	12,000	14,000	26,000	None	None	None
1931	37,000	16,000	53,000	1,000	27,000	28,000
1932	14,000	24,000	38,000	None	3,000	3,000
1933	23,000	21,000	44,000	5,000	15,000	20,000
1934	31,000	17,000	48,000	None	28,000	28,000
1935	20,000	15,000	35,000	2,000	11,000	13,000

[1]Encroachment on irrigation supplies.
[2]Encroachment on winter power waters.
[3]These shortages occur in years of late run-off when irrigation requirements rise faster than stream flow. Winter flows are always adequate Nov. 1 to Apr. 1.
(4) Not computed.

DIVERSION PLAN AND STRUCTURES

REPLACEMENT

In order to protect the water users in the Colorado River Basin against any depletion of their water supply by diversions through the Continental Divide tunnel to northeastern Colorado, a storage reservoir is planned on the Blue River about 16 miles southeast of Kremmling, Colo. This reservoir is to be known as the Green Mountain.

The dam site is located in the E½ of sec. 15, T. 2 S., R. 80 W., sixth principal meridian, near the head of a box canyon, between Green and Little Green Mountains, caused by the river cutting through a porphyry sill. The foundation bedrock consists of sedimentary rocks, either Dakota sandstone or Morrison shales, and the intrusive porphyry.

The irrigation outlet capacity is 1,000 cubic feet per second, and the power outlet capacity is 1,500 cubic feet per second. The spillway capacity is 25,000 cubic feet per second.

The reservoir will flood 2,100 acres of land and will have a capacity of 152,000 acre-feet.

From the water-supply studies it was found, assuming that full development had taken place in the Colorado River Basin and that the Big Thompson project had been in operation the last 35 years, that in the year 1931, the lowest year of dependable run-off record, the Colorado Basin users above Glenwood Springs would have been shorted 37,000 acre-feet for irrigation use and the Public Service Co. would have been shorted 16,000 acre-feet at their power plant at Shoshone during the non-irrigation season, or a total shortage of 53,000 acre-feet. Accordingly, 50,000 acre-feet of Green Mountain storage have been allocated to replacement purposes for which the water users in northeastern Colorado will pay $1,500,000. The remaining 100,000 acre-feet are allocated to power and will be paid for out of power revenues.

Since the average shortage for both power and irrigation for the last 10 years, the lowest 10 years of run-off record is 36,000 acre-feet. There would be the 16,000 acre-feet difference, and a portion of the 100,000 acre-feet let out for power that could be used by the Colorado Basin users to supply shortages that might occur in their irrigation use in years of extreme low run-off, these shortages not being caused by the transmountain diversion.

The total estimated cost of the dam and reservoir is $3,776,032, $2,276,032 of which will be paid for from power revenues.

GRANBY RESERVOIR AND STORAGE

The storage of Colorado River waters for the project is to be made in what is known as Granby Reservoir which is located in Tps. 2 and 3 N., Rs. 75 and 76 W., sixth principal meridian, in Grand County, Colorado. The reservoir basin occupies the valleys of Stillwater Creek, the south fork or Arapaho Creek, and the main Colorado River.

The dam site is located about 4 miles northeast of the town of Granby, Colo., in the NE¼ of sec. 11, T. 2 N., R. 76 W., in Grand County, Colo. It is located at the head of a short canyon which the river has cut through pre-Cambrian rocks forming a spur of the main Rocky Mountain mass. At the dam site the canyon at river-bottom level is 200 feet wide, while at elevation 8,275 it is 720 feet in width.

The dam is to be a combination earth and rockfill structure with a maximum height of 223 feet. The outlet capacity is 300 cubic feet per second and the spillway capacity is 12,000 cubic feet per second.

With the high-water line at elevation 8,275 feet the reservoir has a capacity of 482,860 acre-feet, and will flood an area of 6,943 acres.

This reservoir will not only intercept the flow of the Colorado at that point, but the flow of Willow Creek will be intercepted near Dexter, Colo., and brought into the reservoir through a canal of 1,000 cubic feet per second capacity. Willow Creek enters the Colorado about 2 miles below Granby Dam.

It is estimated that Willow Creek will supply an average of about 60,000 acre-feet per year, and that the total estimated cost of this diversion is $733,203.

The storage in Granby Reservoir will also be augmented by the flow of Meadow and Strawberry Creeks, tributaries of Fraser River which enters the Colorado about 5 miles below the dam. The canal intercepting these two creeks will have a capacity of 500 cubic feet per second, and it is estimated they will produce an average of 12,000 acre-feet a year. The total estimated cost of this diversion is $133,600.

If water supply records kept in the future show there is sufficient water supply left in the Fraser River below the City of Denver's diversion, a canal could be taken out of it just below the mouth of St. Louis Creek near the town of Fraser, Colo., and extend from there to Granby Reservoir, intercepting Ranch, Meadow, and Strawberry Creeks on the way. A small regulating reservoir should be built on Ranch Creek above where the Canal intercepts it.

NORTH FORK DIVERSION DAM AND SHADOW MOUNTAIN LAKE

In order to divert the water of the North Fork of the Colorado into Grand Lake and thence to the channel extending from it to the west portal of the Continental Divide tunnel, it is planned to construct a concrete overflow dam 35 feet in height, above streamed, across the North Fork about one-half mile below its junction with the Grand Lake outlet.

The dam site proper is located in the NW¼ of sec. 19, T. 3 N., R. 75 W., and is a glacial moraine cut through by the river.

The water backed up by this dam will form a lake called Shadow Mountain, the name of a nearby mountain, which will have a surface area of 1,356 acres. The elevation of this lake will be the same as Grand Lake and connected with it by means of the present outlet.

NORTH FORK DIVERSION DAM

The dam proper is a concrete gravity overflow spillway section, 90 feet long, with crest elevation at 8,370. This spillway is designed for maximum discharge of 1,800 cubic feet per second. On each side of the overflow section is a concrete gravity section containing three automatic siphon spillways on each side. The total spillway capacity is 9,400 cubic feet per second.

The total estimated cost is $483,928.

GRANBY PUMPING PLANT

As stated before, the water surface elevation of Granby Reservoir is 8,275 and the water surface of Shadow Mountain and Grand Lakes is 8,369. In order to get the water stored in Granby Reservoir into Shadow Mountain lake and available for delivery through the Continental Divide tunnel, a pumping plant is located on the north shore of Granby Reservoir about one-half mile above the junction of the South Fork with the Colorado. A granite spur juts out into the reservoir site at that point making it ideal for the intake tunnels and a shaft for the pump.

The proposed pumping plant will contain three motor-driven vertical-shaft pumping units having a total capacity of 900 cubic feet per second with full reservoir and 550 cubic second-feet at low water. At normal water surface the capacity will be 870 cubic feet per second.

Each pump will be driven by a 6,500-horsepower synchronous motor.

Power will be delivered to the plant from a 69,000-volt transmission line extending from power plant no. 1 just below Estes Park, around the Rocky Mountain National Park, and crossing the Continental Divide at Buchanan Pass about 5 miles south of the park boundary.

The water from the pumps empties into a canal of 900 cubic second-feet capacity and runs by gravity into Shadow Mountain Lake. It is planned to operate this canal all winter when temperatures get as low as 40° below zero. The latent heat in the water and the friction heat absorbed from the pumps will prevent this water from freezing and will keep quite an area open after the water reaches Shadow Mountain Lake.

The total estimated cost of the pumping plant is $1,250,000.

The total estimated cost of the pump canal is $417,553.

CONTINENTAL DIVIDE TUNNEL

The west tunnel portal is connected with Grand Lake by means of a channel constructed 67.5 feet in width and 15 feet in depth. At the lake end of this channel a permanent concrete barrier or weir will be placed with a crest elevation at 8,368 which would be the minimum elevation to which the water in Grand Lake could be drawn. Since the barrier is so constructed that it requires the water to be 1 foot in depth over it to supply the normal capacity of the tunnel, the normal elevation of Grand and Shadow Mountain Lakes would be 8,369 feet.

The present maximum fluctuation of Grand Lake is about 4 feet, or from an elevation of 8,368 in winter to 8,372 feet during the peak run-off from melting snow. The automatic control gates at the North Fork Diversion Dam and at tunnel inlet will so control the elevation of the water surface in Grand Lake that it would never fluctuate more than 1 foot.

The Continental Divide tunnel extends from the easterly end of Grand Lake to Wind River, southwest of Estes Park, with an azimuth of 242° 20' 30", and length of 69,023 feet. It is to be horseshoe shape 9.5 feet in diameter and lined throughout with a 9-inch concrete lining.

It will be located entirely in pre-Cambrian rock consisting of the Longs Peak and related granites and the gneisses and schists of the Idaho Springs formation. The granites are strong massive rocks. Gneisses predominate over schists and only a small proportion have prominent and continuous cleavage planes. The proportion of granite to gneiss and schist is approximately 4 to 1.

From a detailed geological survey of the tunnel and comparing it with conditions actually encountered in the Moffat Railroad tunnel, which was built under the Continental Divide for the Denver & Salt Lake Railroad, and about 25 miles due south of this one, it was estimated there would be only 400 feet of bad ground and 5,200 feet of ground needing support. However, for purposes of estimate, it was figured there would be 6,900 feet of bad ground and 17,500 feet of ground needing support. The total estimated cost is $7,271,371.

POWER CONDUIT NO. 1

Power conduit no. 1 extends from the east portal of the Continental Divide tunnel in Wind River to the penstock of power plant no. 1 on the northeast slope of Prospect Mountain.

Both ends of the Continental Divide tunnel are without the national-park boundaries but the area east of the east portal is authorized by Congress to be taken in, through that area. The water will be taken through a closed conduit consisting of a 10-foot reinforced concrete pipe completely buried. The total length of power conduit is 5.36 miles, of which 1.86 miles is closed conduit, 1.19 miles is concrete lined tunnel, 0.98 mile is siphon, and the remainder is open canal.

The total estimated cost of power conduit no. 1 is $1,101,000.

POWER PLANT NO. 1

Power plant no. 1 will be located on the south bank of the Big Thompson River about one-half mile east of Estes Park. It will contain two 15,000 kilovolt-ampere generating units with auxiliaries. Each unit will consist of a vertical-shaft, single-runner, spiral-casing type hydraulic turbine operating under an effective head of 705 feet direct connected to a 15,000 kilovolt-ampere water-wheel type generator. A complete description with cost estimate will be found in Power and Pumping Summary.

Until there has developed a sufficient market for power to justify the construction of power plants nos. 2 and 3, the water will be turned into the Big Thompson at power plant no. 1 and carried by that stream to a diversion dam located at SE¼ sec. 1, T. 5 N., R. 71 W., about midway between the present diversion dam and power plant for the town of Loveland, Colo.

POWER CANAL NO. 4

From this diversion dam the water will be carried in a canal of 750 cubic second-feet capacity on the south side of the stream a distance of 4.93 miles to a point just above the mouth of the Big Thompson Canyon. At this point a portion of the water will drop direct into the Big Thompson River to supply the supplemental water demands of that stream and a portion will be siphoned across to elevation 5,450 to supply the canal going to the Poudre River, which will be described later. Power plants nos. 4 and 4-A will be constructed at this point to take advantage of a fall of 550 feet into the Thompson and 358 feet to the Poudre Canal when the power market justifies.

CARTER LAKE SUPPLY CANAL

About 3.07 miles below the diversion dam mentioned above, a canal of 300 cubic feet per second takes off toward the south and supplies Carter Lake.

This canal is 8.78 miles in length, of which 7,040 feet is tunnel; 1,878 feet siphon; and the remainder is open canal.

The estimated cost of this supply canal is $710,629.

CARTER LAKE RESERVOIR

This site is located in Ts. 4 and 5 N., R. 70 W., of sixth principal meridian, about 1 mile north and 7 miles west of Berthoud, Colo.

The reservoir will occupy a valley about 2¾ miles long and from one-half to 1 mile wide. The northern portion of the area is a natural basin called Carter Lake. This lake dried up during the last 5 drought years, for the first time within the memory of the white settlers.

The proposed maximum water surface in the reservoir is at elevation 5,760 with a capacity of 111,963 acre-feet. The area of high water line is 1,150 acres. For this water surface three dams will be required. Dam no. 1 is located at the natural outlet of the valley and will contain the outlet works for the reservoir; the other two dams will occupy saddles. These dams are earth and rock fill; the main dam is 243 feet high, and the saddles 43 and 48, respectively.

The capacity of the outlet to St. Vrain supply canal is 300 cubic feet per second, the outlet to the Big Thompson has a capacity of 1,000 cubic feet per second.

The total estimated cost of the reservoir is $1,822,202.

ST. VRAIN FEEDER CANAL

A canal of 300 cubic feet per second capacity will extend from the small outlet of Carter Lake to the St. Vrain, reaching the St. Vrain high enough to supply all ditches.

The length of this canal is 9.76 miles with 3,445 feet in tunnel, 1,575 feet of siphons, and the remainder open canal.

The estimated cost of the St. Vrain feeder is $368,951.

BIG THOMPSON FEEDER

About one-half mile below Carter Lake Dam a canal will be taken out of the draw leading from the dam, and will run into Cottonwood Creek, a tributary of the Big Thompson. This canal will have a capacity of 1,000 cubic feet per second and be 5.37 miles in length.

The cost is estimated at $155,246.

HORSETOOTH SUPPLY CANAL

This canal starts at the end of a siphon across the Big Thompson from power conduit no. 4. This water will pass through power plant no. 4-A when constructed. The canal starts at elevation 5,450 with a capacity of 250 cubic feet per second. The structures, however, are designed for a capacity of 400 cubic feet per second on the theory that some time in the future it might be necessary to increase the capacity of the canal to that amount. The length of this canal is 9.88 miles, of which 12,863 feet is tunnel, 3,296 feet is siphons, and the remainder open canal.

The elevation of 5,450 was chosen because it not only puts the water above all present diversions on the Poudre River, but it afforded the most direct and economical route.

The estimated cost of this feeder is $1,208,391.

HORSETOOTH RESERVOIR

The proposed Horsetooth Reservoir will occupy a valley 6 miles long and from one-quarter to three-quarters of a mile wide, extending in a north-south direction, formed by the erosion of soft red beds of Lykens formation between harder ridges of Lyons on the west and Dakota sandstone on the east. There are three natural outlets to the east through the Dakota hogback, namely, Soldier, Dixon, and Spring Canyons, which are the sites of thee proposed dams of the same names. The fourth proposed dam, Horsetooth, will cross the valley at the north end on a low saddle separating the valley from drainage to the north into the Poudre River. The outlet will be through the Horsetooth Dam saddle. There are no outlets through the other dams. The proposed water surface is at 5,400 feet in elevation which gives a capacity of 96,756. The area flooded will be 1,513 acres. The outlet capacity was designed for 1,200 cubic feet per second with reservoir full. This large capacity is necessary as the irrigation use requires that the entire amount of supplemental water be delivered at a rate that would supply it in 60 days.

The advantages of a reservoir at this point are: It is high enough to supply all users from the main Cache la Poudre River and is located close to it. It takes the place of 6 miles of canal through rough country and allows a canal of 250 cubic second-feet to be constructed from the Big Thompson instead of one for 1,000 cubic feet per second.

The estimated cost of the reservoir is $3,625,021.

POUDRE FEEDER CANAL

From the outlet of Horsetooth Reservoir a canal of 1,000 cubic second-feet capacity will extend north to Lewstone Creek, a tributary of the Poudre. The water will run down this creek to the Poudre above all the diversions except the Poudre Valley.

POUDRE VALLEY FEEDER CANAL

A canal will extend from Lewstone Creek to the Poudre Valley Canal about 1 mile below its headgate, crossing the Poudre River in a siphon. This canal will have a capacity of 400 cubic feet per second to take care of the supplemental demands of the Poudre Valley Canal and also the demands of the North Poudre irrigation district. The total length of the two canals is 5.48 miles.

The cost of the Poudre Feeder and Poudre Valley Canals is estimated at $632,843.46.

NORTH POUDRE FEEDER CANAL

It is planned to enlarge the Poudre Valley Canal for a distance of 3.58 miles from the point the supply canal enters to the location of the pumping plant for the North Poudre district. This will enlarge the canal from a capacity of 500 to 750 cubic feet per second and the estimated cost is $11,436.

NORTH POUDRE PUMPING PLANT

This pumping plant, constructed on the banks of the Poudre Valley Canal, will consist of two 75 cubic second-feet capacity vertical synchronous motor-driven single-stage pumps, operating against an effective head of 187 feet. The estimated cost is $200,000

NORTH POUDRE FEEDER CANAL

This canal of 150 cubic second-feet capacity extends from the pressure outlets of the pumping plant to the North Poudre Canal, a distance of 9.98 miles.

The estimated cost is $128,889.

ARKINS RESERVOIR

This reservoir is located on Buckhorn Creek, a tributary of the Big Thompson, in Tps. 5 and 6 N., R. 70 W., sixth principal meridian, and about 8 miles northwest of Loveland, Colo. The object of this reservoir is to provide storage for Colorado River waters brought over in the wintertime and to be used to supply supplemental water on the lower South Platte in water districts 1, 2, and 64. It will also serve in connection with the use of the 16,000 acre-feet of floodwater now available on the Big Thompson.

The bringing of more of the supplemental water over in the wintertime aids materially in the production of a maximum amount of power out of the waters of the Big Thompson River. For that reason the entire cost of the inlet to Arkins Reservoir and one-half the cost of the reservoir itself is assessed against power and paid for out of power revenues from plant no. 1.

The capacity of Arkins Reservoir is 50,000 acre-feet with a high water line at 5,275 feet elevation and floods 929 acres of land.

The dam site occupies a notch cut through the Dakota sandstone ridge by Buckhorn Creek.

The main dam is an earth- and rock-fill structure 155 feet in height with an outlet capacity of 650 cubic feet per second and a spillway of 10,000 cubic second feet capacity.

There is a saddle dam, in addition to the main dam of earth- and rock-fill construction, 50 feet maximum height, built across a saddle at the southern extremity of the reservoir.

The total estimated cost of the reservoir and dam is $1,740,737.

The estimated cost of the Arkins Reservoir inlet is $351,488.

This inlet diverts from the Big Thompson River just below the dam of the Handy Canal and follows around the north side of the river a distance of 2.33 miles to Arkins Reservoir.

ROCKY MOUNTAIN NATIONAL PARK

Every effort has been made in the survey and design of this project to not disturb the natural beauties of the Rocky Mountain National Park and its surrounding areas. The Continental Divide tunnel was lengthened 1.6 miles in order that its extremities should fall outside the boundaries of the park. The conduit leading from the east portal of the tunnel to power plant no. 1 is to be buried and the surface landscaped through the area authorized by Congress to be added to the park. The waste from the east portal of the tunnel placed in this area is to be terraced and planted with evergreen trees. The waste from the west portal is to be used to fill up some low areas and render the area suitable for the building of summer homes.

The approach to the Western Gateway of the Rocky Mountain National Park will be along the shores of Shadow Mountain Lake with its fluctuation of only 1 foot instead of the swampy area that now breeds mosquitos and exposes mud flats in low water.

The bill authorizing the creation of the Rocky Mountain National Park reserved the right for the Bureau of Reclamation to survey and construct an irrigation project within the boundaries of the park.

OPERATION OF THE SYSTEM

IRRIGATION PROJECT OPERATIONS

The system is planned and it is anticipated that it will be operated in a manner to have the water available in Carter Lake, Horsetooth and Arkins Reservoirs available by July 1, to the full capacity of those reservoirs, 256,000 acre-feet. The usual demand for supplemental water begins July 1 to 15 and extends to September 15 to 30. The outlets of the reservoirs are planned to deliver the water from the reservoirs in 60 to 75 days, including the water that must pass through them for direct delivery that may be in the way of being transferred from the Colorado River Basin to the eastern slope during the period of irrigation application. The balance of the 310,000 acre-feet, or 54,000 acre-feet, will be available for direct irrigation use as brought over during the above period or to some extent may be required prior to July 1.

The run-off of the waters of the Colorado River here contemplated to be used will largely be secured from the melting snows during May, June, and early July and stored in the Granby Reservoir. During the fall of that year, winter and spring of the following year, the water will be transferred from the Granby Reservoir through the Continental Divide tunnel at a uniform rate and restored in the Carter Lake, Horsetooth, and Arkins Reservoirs. This will permit a flow that is well suited to the development of firm power through the five power plants that will eventually be constructed along the Big Thompson as shown on the map of the general layout.

Granby Reservoir will act as a hold-over reservoir to carry the water from years of excessive run-off to years of subnormal flow.

POWER PROJECT OPERATION

Water will be carried through the Continental Divide tunnel at a uniform flow for the generation of power at the several power plants, except that the quantity will be reduced during the summer season when some water from the Big Thompson is available for power purposes in power plants nos. 2, 3, 4, and 4-A. At this period there will be little or no demand for power for pumping at the Granby pumping plant, which will permit the cutting down of the quantity of water to take care of the commercial power load.

It is planned to construct the Granby pumping plant and the Granby pump canal 150 percent of the capacity of the Continental Divide tunnel. This will permit the operation of the pumping plant at full capacity with off-peak power, and reduce the amount of pumping with firm power. The varying discharge of the pump ditch during the 24-hour period will be equalized by the Shadow Mountain and Grand Lakes, so that a uniform discharge will be maintained through the Continental Divide tunnel. The range in height of water surface in Shadow Mountain and Grand Lake to equalize this flow will not exceed two-tenths of a foot, and will be greatest in the winter and early spring months.

There is an average of 16,000 acre-feet of surplus water on the Big Thompson available for storage in the system mainly in May and June. In order to take this water into the reservoirs it will be necessary to reserve capacity in the three reservoirs on the eastern slope until toward the latter part of June. The snowfall, the main source of this water supply, will be known well in advance so that operations of the several parts of the system, including the production of power at the several power plants, can be adjusted to take care of this water and hold back an equal amount in Granby Reservoir.

TENTATIVE PROJECT FINANCIAL SET-UPS

This proposed development consists of two projects: first, the irrigation project; and second, the power project.

It is planned that those features of the development that are used mainly for irrigation are grouped under the irrigation project set-up, while those used entirely, or are made of a greater capacity because of power development, are grouped in whole or in part in the power project set-up.

IRRIGATION PROJECT

The following major features with their appurtenant structures are given with the estimated field costs including 10 percent for engineering and 15 percent for contingencies. The full capacity of Arkins Reservoir is necessary to develop a larger portion of firm power than would otherwise be possible without it. At the same time, a reservoir of half its capacity or additional capacity in Horsetooth or Carter Lake Reservoirs would be necessary to provide capacity to deliver the irrigation water as needed. It is, therefore, deemed equitable to divide the cost of this reservoir equally between the irrigation and power projects.

The Green Mountain Reservoir, with a capacity of 152,000 acre-feet, is larger than is necessary to furnish replacement for a like amount of water diverted by the project above Granby Dam at a time when it would be required for irrigation, present and future, and to furnish the Shoshone power plant 1,250 second-feet or such lesser amount that they would be entitled to receive if the proposed project was not operating. From studies made, it appears that 50,000 acre-feet will be sufficient to replace all the water that the proposed project will take at a time when required for use lower down in the stream within the state. Therefore, 52,000 acre-feet of the Green Mountain Reservoir capacity is allocated for replacement (including evaporation losses) and charged to the irrigation project. The balance of the capacity or 100,000 acre-feet is allocated to the power project and is to be paid for out of power revenues.

The following is a summary of the irrigation project costs:

ESTIMATED COST CHARGEABLE TO IRRIGATION FEATURE

Willow Creek feeder canal		$ 733,203
Granby Reservoir		2,813,703
Granby pumping plant		1,250,000
Granby pump canal		417,553
North Fork diversion dam		483,928
Continental Divide tunnel		7,271,371
Carter Lake supply canal		710,629
Horsetooth supply canal		1,208,391
St. Vrain feeder canal		368,951
Big Thompson feeder canal		155,246
Poudre feeder canal		632,843
Poudre Valley feeder canal		11,436
North Poudre feeder canal		128,889
North Poudre pumping plant		200,000
Horsetooth Reservoir		3,625,021
Arkins Reservoir		1,859,323
Carter Lake Reservoir		1,925,253
Green Mountain Reservoir (52,000 acre-feet replacement) (100,000 acre-feet for power)		3,776,032
Improvement of Colorado River above Kremmling to maintain fishing and to adjust the present irrigation system to the altered conditions		300,000
Less the following items tentatively chargeable to power:		27,871,772
One-half cost of Arkins Reservoir	$ 929,661	
Portion of cost of Green Mountain Reservoir for 100,000 acre-feet	2,276,032	
		3,205,693
Cost of irrigation features		$24,666,079
Say	$24,800,000	

REPAYMENT

Twenty-four million eight hundred thousand dollars upon 310,000 acre-feet at $80 per acre-foot.

Two dollars per acre-foot on 40-year repayment basis.

In the above repayment is predicted upon the contracts to be made upon a basis of 310,000 acre-feet. Besides the 320,000 acre-feet available from the Colorado River drainage there is an average of 16,000 acre-feet available for storage on the Big Thompson, making 336,000 acre-feet in all, leaving 26,000 acre-feet for losses on the eastern slope and for the uncertain, heretofore mentioned in operations on the western slope.

The power costs are shown under the heading "Power and pumping system."

The construction of power plant no. 1 as shown in the power set-up is a necessary development in order to secure power for pumping purposes at the Granby pumping plant.

POWER AND PUMPING SYSTEMS

The ultimate power and pumping system is proposed to consist of the major pumping plant at Granby, power plant no. 1 near the town of Estes Park, power plant no. 2 near Drake post office, power plant no. 3 at Cedar Cove, power plants nos. 4 and 4-A near the mouth of the Big Thompson Canyon, and power plant no. 5 at the Green Mountain Reservoir. If conditions justify, there may also be a pumping plant on the Poudre River near the point where the proposed Poudre supply canal crosses the river. Power plant no. 5, Granby pumping plant, and power plant no. 1, would be interconnected by a single circuit 69,000-volt transmission line. Power plants nos. 1 to 4-A, inclusive, would be interconnected by two 115,000-volt transmission lines and these same lines would extend to one or more load centers where the power could be disposed of commercially.

The buildings for the power and pumping plants would be of reinforced concrete construction of suitable size to house the machinery and provide space for such facilities as would be required for efficient and economical operation. For scenic reasons, special care would be taken in the architectural design of the buildings to make them blend in with the beauties of the surrounding territory so as to be both as inconspicuous as possible and also as artistic as feasible without undue expenditure. An artist's sketch of one of these buildings is included with the report.

Following is a tabulation covering the essential data for each of the power and pumping plants:

POWER PLANTS

Plant designation	Effective head in feet	Turbine capacity in cubic feet per second	Power available in horsepower	Number of units	Size of each unit in horsepower	Installed power in kilowatts
No. 1	704	550	38,800	2	20,000	30,000
No. 2	1,195	550	65,800	2	34,000	50,000
No. 3	388	550	18,000	2	9,000	13,500
No. 4	550	400	22,000	1	22,000	16,000
No. 4-A	381	250	9,500	1	9,500	7,000
No. 5	225	1,500	33,800	2	17,000	26,000
Total installed power in kilowatts						142,500

PUMPING PLANTS

Plant designation	Head in feet	Pump capacity in cubic feet per second	Capacity of each pump in cubic feet per second	Number of pumps	Rating of each motor in horsepower	Power required in kilowatts
Granby	130	870	290	3	6,500	15,000
Poudre	187	150	75	2	2,000	3,000
Total installed pumping, kilowatts						18,000

POWER PLANT NO. 1

Power plant no. 1 will be located on the south bank of the Big Thompson River about one-half mile east of the village of Estes Park and will contain two 15,000 kilovolt-ampere generating units with auxiliaries. Each unit will consist of a vertical-shaft, single-runner, spiral casing type hydraulic turbine operating under an effective head of approximately 705 feet and direct connected to a 15,000 kilovolt-ampere water-wheel type generator with direct connected exciter and pilot exciter. Water would be supplied to each turbine through a steel penstock approximately 5,000 feet long, with synchronous bypasses provided so that the flow through the penstock can be discharged either through the turbines or the bypasses into the Big Thompson River. The bypasses will be mechanically connected to the turbine gate operating mechanism so that rapid governing of the units under varying load conditions can be effected without creating excessive water hammer. Trashracks with shut-off gates for each penstock will be provided in the forebay structure. The headgates will be controlled from the power plant. A spillway will be provided to care for the flow when the headgates are closed and the penstocks inoperative. The plant will be equipped with all necessary auxiliaries, including a traveling crane for handling the large pieces of equipment. A small machine shop will be provided for making minor repairs. An outdoor type substation with self-cooled transformers will be provided for stepping the voltage up to 69,000 for transmission to the Granby pumping plant, and to 115,000 volts for transmission to commercial markets. The substation structure will be of the conventional structural steel type with high voltage oil circuit breakers, lightning arresters and necessary auxiliaries. The control of the oil circuit breakers will be from the main power plant switchboard. Operators' quarters, a warehouse, and a large machine shop for general project repairs will be provided in the vicinity of the power plant.

POWER PLANT NO. 2

Power plant no. 2 will be located about one-half mile northwest of Drake, on the south bank of the north fork of the Thompson River just above its junction with the Big Thompson. The plant will contain two 25,000 kilovolt-ampere generating units of the horizontal shaft type. The net head will be approximately 1,195 feet. Each unit will consist of a double overhung impulse wheel hydraulic turbine with the generator mounted in the center, between the two runners. A direct connected exciter and pilot exciter will be mounted at one end. Water will be delivered to the turbines through two steel penstocks about 4,150 feet long. Each penstock will be provided with two branches to the turbine nozzles and each branch will be provided with a synchronous bypass arranged so that the flow through the penstock can be discharged through either the nozzles of the bypasses to the river. The bypasses will be mechanically connected to the turbine nozzle operating mechanism so that rapid governing can be effected under varying load conditions without excessive water hammer. The headgate structure will be provided with trashracks and sliding gates at the end of the penstocks and a spillway to care for the flow when the gates are closed. The plant will be complete with all necessary auxiliaries for station service requirements and with a crane for handling the machinery. A structural steel outdoor type substation will be provided with self-cooled transformers for stepping the voltage to 115,000 volts, and with outdoor type oil circuit breakers, lightning arresters, and other necessary auxiliaries. The operation of the substation will be handled from the main switchboard of the power plant. Quarters for the operators will be provided adjacent to the power plant.

POWER PLANT NO. 3

Power plant no. 3 will be located about one-half mile east of the Loveland power-diversion dam on the north bank of the Big Thompson River. The plant will contain two 6,500 kilovolt-ampere generating units, each consisting of a vertical hydraulic turbine direct connect to a generator with main exciter and pilot exciter. The effective head will be approximately 328 feet. Water from the headgate structure will be delivered to the turbines through steel penstocks about 650 feet long. Each penstock will be provided with a synchronous bypass arranged so that the flow through the penstock can be discharged either through the turbines or the bypasses to the Big Thompson River, and to allow rapid governing of the units without excessive water-hammer. The headgate structure will be provided with trashracks and sliding gates at the head of the penstocks and a spillway to care for the flow when the gates are closed. The plant will be complete with all necessary auxiliaries for station-service operation, and with a crane for handling equipment. The plant will be provided with a structural-steel outdoor-type substation similar to that proposed for plant no. 2.

POWER PLANTS NOS. 4 AND 4-A

Power plant no. 4 will be located about 2 miles east of Cedar Cove on the south bank of the Big Thompson River, while power plant no. 4-A will be located a short distance upstream from plant no. 4, and at an elevation about 175 feet above the river. The capacity of plant no. 4 will be 16,000 kilovolt-amperes and of plant no. 4-A, 7,000 kilovolt-amperes. One unit only will be provided at each plant and will consist of a vertical-shaft, single-runner, spiral-casing type turbine direct connected to a vertical water wheel generator with direct connected main and pilot exciters. Plant no. 4 will have an effective head of about 550 feet, and plant no. 4-A, 380 feet. Plant no. 4 will receive its water through a single steel penstock about 1,960 feet long, and plant no. 4-A, through a similar pipe about 1,400 feet long. Each plant will be provided with synchronous bypasses similar to those in plants nos. 1 and 3. Plant no. 4 will discharge directly into the Big Thompson River. Plant no. 4-A will be siphoned under the river through a pressure tunnel to the proposed Poudre supply canal, but will have provisions so that if so desired, the water may be discharged directly into the Big Thompson River. The headgate structure will be provided with trashracks, sliding gates, and spillways similar to those in plants nos. 1, 2, and 3. A single outdoor structural steel type switchyard will be provided for the two plants. The equipment in this substation will be similar to that for plants nos. 1, 2, and 3. Plant no. 4-A will be remotely controlled from plant no. 4, so that the two plants can be operated with one set of operators. The plant will be complete with auxiliaries and cranes similar to that in other plants. Quarters for the operators will be provided in the vicinity of the plants.

POWER PLANT NO. 5

Power plant no. 5 will be located about 12½ miles southeast of Kremmling, on the east bank of the Blue River, immediately downstream from the dam forming the proposed Green Mountain Reservoir. The plant will contain two 13,000 kilovolt-ampere generating units of the vertical hydraulic-turbine driven type, with direct connected generator with main and pilot exciters. The plant will have a varying head depending upon reservoir water surface, but it is expected that the average head will be about 225 feet. The trashrack and intake structure will be located immediately upstream from the dam and a single steel penstock installed in the tunnel will conduct the water to the power plant. Each turbine will be provided with a pressure regulator or relief valve to limit the water hammer under sudden change of load conditions. The plant will be complete with necessary auxiliaries for station service, a small machine shop for minor repairs, and a crane for handling equipment. An outdoor structural steel substation will be provided complete with equipment for stepping the voltage up to 69,000 volts for transmission and with oil circuit breakers and other necessary auxiliaries for the control and protection of the lines and equipment. The oil circuit breakers will be controlled from the main switchboard of the power plant. Quarters for operators will be constructed in the vicinity of the power plant.

GRANBY PUMPING PLANT

The Granby pumping plant will be located approximately 6 miles south of the village of Grand Lake on the north shore of the proposed Granby Reservoir. The plant will contain three motor-driven vertical-shaft pumping units having a total capacity of 900 second-feet at full reservoir, and 550 second-feet at low water. The total capacity at the normal water surface will be approximately 870 second-feet. The motors will be of the synchronous type and arranged for semi-magnetic operation. That is, the operator will be required only to close the main switch to the unit in order to place it in operation, and to open the same switch to discontinue operation. The motors will be equipped with direct connected exciters. The water from the Granby Reservoir will be delivered to the pumps through tunnels about 155 feet long. A channel in the reservoir will convey the water to the mouth of the intake tunnels in extreme low water. Water from each pump will be discharged through about 175 feet of tunnel, and 165 feet of steel pipe to the canal at elevation approximately 8,381. This canal, which will be approximately 4 miles in length, will discharge into the proposed Shadow Mountain Lake. The center line of each pump and propeller will be at approximately elevation 8,145, with the base of the motor driving the pump 135 feet above, or at elevation 8,280. Vertical shafts in the rock between the underground pump room and the motor room on the surface will accommodate the shafts connecting the pumps to the motors. Each pump will have a capacity of 290 second-feet when operating under a total dynamic head of 130 feet and will be driven by a 6,500-horsepower synchronous motor.

The entrances to the intake tunnels will be provided with trashrack and stop-log structures, and sliding gates will be installed at the intake and discharge of each pump. The intake gates will be located in the gallery adjoining the pump room and will be hydraulically operated. The discharge gates will be located at the head of the canal and will be of a type which will close automatically in the event power service is interrupted, so as to prevent water in the canal from running back down through the pump.

The pumping plant will be complete with auxiliary pumping units for unwatering the intake and discharge tunnels and the drainage sump. It will also be complete with all other necessary station auxiliaries, including a crane for handling the equipment. A small machine shop will be provided for making minor repairs. Quarters for the operators will be provided in the vicinity of the plant.

Power will be delivered to the plant from a 69,000-volt transmission line, through an outdoor structural steel type substation containing self-cooled transformers, together with all necessary protective apparatus and auxiliaries. The operation of the substation will be handled from the main switchboard of the pumping plant.

POUDRE PUMPING PLANT

The Poudre pumping plant will be located on the Poudre Valley Canal at a point about 3 miles below the crossing of the proposed Poudre supply canal. It is proposed to have a capacity of 150 second-feet, composed of two 75 second-foot vertical synchronous motor-driven single-stage pumps, operating against an effective head of 187 feet. The plant will be complete with all necessary auxiliaries, including a crane for handling the equipment. An outdoor substation will be provided for stepping the voltage down from transmission voltage to motor voltage. Due to the relatively short periods of operation, it is not probable that it will be necessary to construct operator's quarters at this plant.

TRANSMISSION SYSTEM

The transmission system will consist of a single 69,000-volt circuit connecting power plant no. 5 with the Granby pumping plant and power plant no. 1. Power plants nos. 1 to 4-A, inclusive, will be connected by two 115,000-volt lines and two 115,000-volt lines will continue to market. For the purpose of this report only, and to include a sufficient amount in the cost estimates for any probable transmission set-up, this market has been assumed as the Valmont steam plant of the Public Service Co. of Colorado. Power plant no. 4 will be connected with the Poudre pumping plant by one 34,500-volt transmission line. The number of lines and mileage involved in each are as shown in the following tabulation:

From--	To--	Number of lines	Number of miles	Voltage
Power plant no. 5	Ka Rose	1	36	69,000
Granby pumping plant	Grand Lake	1	10	69,000
Do	Power plant no. 1	1	36	69,000
Power plant no. 1	Power plant no. 2	2	12	115,000
Power plant no. 2	Power plant no. 3	2	3	115,000
Power plant no. 3	Power plant no. 4	2	4	115,000
Power plant no. 4	Valmont	2	27	115,000
Do	Poudre pumping plant	1	18	34,500

The line to the Poudre pumping plant would be a wood-pole line with pin-type insulators. All other lines would be of the wood-pole, H-frame type, with suspension insulators, and combining all of the most modern features for continuity of service, ease of maintenance, and long life. The line from power plant no. 1 to the Granby pumping plant will probably require special construction to give added strength in the mountainous region near the Continental Divide.

In order to provide power for construction, it is proposed that one of the first features of the project would be to build one of the permanent 115,000-volt circuits from the Valmont plant to plant no. 1, the permanent 69,000-volt lines from plant no. 1 to Granby pumping plant and from Ka Rose to the Green Mountain dam site, and an extension from the Granby pumping plant to the west portal of the proposed tunnel. Initially this entire line would be operated at 69,000 volts, and under such operation would be adequate for all contemplated construction activities. In connection with supplying construction power it would also be necessary to install a substation at the Valmont steam plant to step voltage up to 69,000 volts for transmission. Preliminary studies indicate that it would be advisable to make this substation of approximately 5,000 kilovolt-ampere capacity.

The estimated cost of installing the facilities to provide construction power are as indicated in the following tabulation:

From--	To--	Miles	Cost	
			Per mile	Total
Valmont	Power plant no. 2	34	$6,750	$229,500
Power plant no. 2	Power plant no. 1	12	4,100	49,200
Power plant no. 1	Granby pumping plant	36	3,600	129,600
Granby pumping plant	Grand Lake	10	3,200	32,000
Ka Rose	Power plant no. 5	36	3,600	129,600
Total Transmission lines		128		$569,900

Substation at Valmont .... $ 61,300
Total to supply power for construction 631,200

The transmission system as provided to furnish construction power would be adequate for transmission of power to markets from power plant no. 1 or power plant no. 5 if either were built individually, but the additional complete system would probably be constructed when two or more plants are constructed. The additional costs of the lines involved in this construction are shown in the following tabulation:

From--	To--	Miles	Cost	
			Per mile	Total
Power plant no. 1	Power plant no. 2	12	$4,100	$ 49,200
Power plant no. 2	Valmont	34	6,750	229,500
Power plant no. 4	Poudre pumping plant	18	1,800	32,400
Total additional cost of permanent transmission system		64		$311,100

In addition to the transmission lines required for the disposal of power, it may be necessary that the government also construct a substation at the point of power disposal. As a market survey has not been conducted to establish the points at which this power can be disposed of, or the quantities involved at each point of disposal, it is assumed for the purpose of this report that the substations will average in cost $10 per kilowatt of capacity. Assuming that provision is made to dispose of a peak capacity of 140,000 kilowatts, this will involve an additional expenditure of $1,400,000.

POWER OUTPUT

Water supply studies indicate that with power plant no. 1 only constructed, there is available, above all requirements for pumping purposes, a constant power output at 100 percent load factor of 120,000,000 kilowatt-hours per year. Since the pumping plant capacity proposed is sufficient to allow pumping to be done in 16 hours of each day it will be possible to handle peak commercial power requirements without undue interference. With this in mind, it has been assumed for the purpose of this report that a market can be found which has a load factor such that 60 percent of this power or 72,000,000 kilowatt-hours per year can be absorbed as firm energy. The balance of this energy, or 48,000,000 kilowatt-hours per year, plus about 40,000,000 kilowatt-hours additional, which is available during various parts of the year, is classed as secondary energy.

Since the Valmont steam plant of the Public Service Co. of Colorado has an installed capacity of 75,000 kilowatts, it appears that the 88,000,000 kilowatt-hours of secondary energy could be absorbed as a fuel saving measure if the price does not exceed fuel costs. Allowing 10 percent for line losses, this is equivalent to an average load of about 9,000 kilowatts.

FINANCIAL OPERATION OF POWER SYSTEM

It is contemplated that the initial power development would consist of the construction of power plant no. 1 only, together with such transmission lines and substations as are required to supply power to the Granby pumping plant and to commercial markets. The estimated construction cost of the strictly power features, as well as items which it is expected that power revenues will repay, is given below.

It is assumed that 5 mills per kilowatt-hour can be secured for firm energy and 1.8 mills per kilowatt-hour for secondary energy with delivery at the market. In each case 10 percent loss is allowed for transmission. The following gives the financial set-up for power plant no. 1, operation costs and returns.

While for the purpose of this report the allocation of construction cost to irrigation and power has been made on the basis set out below, it is understood that this allocation is not thereby fixed, and the same may be changed as further information may warrant until such time as the contract for repayment of the cost of the irrigation features has taken final form.

Power plant no. 1 construction costs

Power plant no. 1 near Estes Park	$ 1,778,000
Conduit from east portal continental divide tunnel to power plant no. 1	1,101,000
Transmission lines connecting power plant no. 1 with Granby pumping plant--with Valmont line to North Poudre pumping plant	440,000
Commercial substation (30,000 kilowatts)	330,000
Headquarters at power plant no. 1 for operation of power system	100,000
Interest during construction, 3 percent	112,000
Total repayable in 50 years with interest	3,831,000
One-half cost of Arkins Reservoir	929,661
Portion of cost Green Mountain Reservoir, for 100,000 acre-feet allocated to power	2,276,032
Payable on 40-year basis without interest	$3,205,693
Total cost power plant no. 1 including other items that are required to be accomplished with the initial development	$7,036,693

Annual revenues from power plant no. 1

From sale of 65,000,000 kilowatt-hours firm power, at $0.005	$325,000
From sale of 79,000,000 kilowatt-hours secondary power, at $0.0018	142,000
From rental of water for power development to privately owned plants	20,000
Gross annual income	$487,000

Annual operation and maintenance plus retirement
of principal

Brought forward	$487,000
3.887 percent, on $3,831,000, interest and retirement of investment on basis of 50 years	148,000
Repayment of $3,205,693 on basis of 40 years without interest	80,000
Operation and maintenance of power plant	36,000
Operation and maintenance Granby pumping plant	27,000
Operation and maintenance of transmission lines	13,800
Operation and maintenance conduit, tunnel, and canals	15,000
Depreciation, 1.5 percent, on $3,831,000	57,000
General expense	18,200
Total annual costs	$395,000
Annual surplus during 40 years repayment period of the non-interest-bearing obligation	$ 92,000

FULL POWER DEVELOPMENT

The results of this study indicate that the initial installation proposed is sufficient from a financial standpoint to return all necessary costs of operation and repayments.

There are five additional plants that can be developed in the future in a manner that will keep pace with the power requirements of the section that may be served and not have a large unearning investment tied up for some years.

The following is an estimate of the cost of the additional power plants that may be constructed in the future, but are not a part of the initial development.

Power plant no. 5	$1,190,000
Green Mountain-Ka Rose transmission line	130,000
Operators' quarters	60,000
Substation (20,000 kilowatts)	200,000
Subtotal	1,580,000
Interest during construction, 3 percent	47,400
	1,627,400

The above plant, together with plant no. 1, will produce: 113,000,000 kilowatt-hours firm power annually; 92,000,000 kilowatt-hours secondary power annually.

The following are the construction costs of developing power plants nos. 2, 3, 4, and 4-A with appurtenant structures:

Power plant no. 2	$2,325,000
Power plant no. 3	665,000
Power plant no. 4	760,000
Power plant no. 4-A	420,000
Power canal no. 2	2,444,000
Power canal no. 3	493,000
Power canal no. 3-A	113,000
Power canal no. 4	1,194,000
Operators' quarters	150,000
Substations (90,000 kilowatt hours)	900,000
Additional transmission lines	311,000
Subtotal	9,775,000
Interest during construction, 3 percent	293,250
Total repayable in 50 years with interest	10,068,250
Arkins Canal feeder, payable in 40 years without interest	351,000
Total power plants nos. 2, 3, 4, and 4-A	10,419,250
Total power plant no. 5	1,627,400
Total second-stage development	12,046,650
Primary development plant no. 1	7,036,693
Cost of full power development	$19,083,243

The total salable output of the full development is estimated as follows, exclusive of that used for pumping:

	Kilowatt-hours
Firm power, annually	360,000,000
Secondary power, annually	(1) 200,000,000

(1) Out of an available production of 387,000,000 kilowatt-hours secondary power.

CONCLUSIONS

(1) There is a large area (615,000 acres) of irrigated land in northeastern Colorado, the major portion of which has an inadequate water supply.

(2) The feasible storage possibilities with the available water supply in the drainage area has been exhausted.

(3) There is at least an available water supply of 310,000 acre-feet on the upper drainage area of the

Colorado River that can be diverted to supplement the present water supply on the eastern slope.

(4) That the diversion of this quantity of water from the Colorado River watershed will not interfere with or encroach upon the present or future irrigation along the Colorado River and tributaries within the state, with the protection provided in the Green Mountain Reservoir.

(5) That the plan for the project here laid out appears entirely feasible from a construction point of view.

(6) That the cost of construction estimated at $2 per acre-foot per annum over the repayment period of 40 years is less than storage water is now commanding and that it will increase the crop values five or more times this annual cost, showing its economic worth.

(7) That the power developments that may be made in the six power plants will produce a large quantity of cheap hydroelectric power that will materially benefit Colorado.

(8) That the revenues from the commercial power generated at power plant no. 1 will pay for the power features as set up under the initial power development, in addition to the power required for pumping at Granby pumping plant, and in lieu of the irrigation features used in power development, the operation of the system to a point where the water leaves the tailrace of the lower power plants can be taken care of by the power development.

(9) That the cost of the irrigation feature of the project is within the ability of the water users to pay.

ORIGINAL

Contract No. 9-07-70-W0020
Supplement No. 10

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Colorado-Big Thompson Project
Colorado

SUPPLEMENT OF CONTRACT BETWEEN THE UNITED STATES OF AMERICA AND THE NORTHERN COLORADO WATER CONSERVANCY DISTRICT FOR ADDRESSING COMMITMENTS ASSOCIATED WITH MEETING THE GRAND LAKE CLARITY STANDARD

THIS SUPPLEMENT, entered into this 23rd day of, Oct 2013, pursuant generally to the Act of June 17, 1902 (32 Stat. 388), and subsequent acts supplementary thereto and amendatory thereof collectively known as the Federal Reclamation laws, particularly, but not limited to, the Act of August 9, 1937 (50 Stat. 595) between the UNITED STATES OF AMERICA, hereinafter called the "United States," acting through the Secretary of the Interior, represented by the "Contracting Officer" executing this Supplement, and NORTHERN COLORADO WATER CONSERVANCY DISTRICT, hereinafter referred to as "Northern Water," a quasi-municipal entity and political subdivision of the State of Colorado, organized and existing under and by virtue of the laws of the State of Colorado, with its principal place of business in Berthoud, Colorado. The United States and Northern Water hereinafter are each sometimes individually called "Party," and sometimes collectively called the "Parties".

WITNESSETH THAT:

The following statements are made in explanation:

EXPLANATORY RECITALS

a. WHEREAS, the United States constructed the Colorado-Big Thompson (C-BT) Project in the State of Colorado, pursuant to Federal Reclamation laws; and

b. WHEREAS, the Parties executed Contract No. 9-07-70-W0020, on July 5, 1938; it has subsequently been amended and supplemented. The original contract along with its amendments and supplements are collectively referred to herein as the "1938 Repayment Contract"; and

c. WHEREAS, the Parties have concerns with the clarity of Grand Lake; and

d. WHEREAS, in 2008, the Colorado Water Quality Control Commission adopted a narrative clarity standard and a numerical clarity standard for Grand Lake; and

e. WHEREAS, the Parties wish to meet the applicable water clarity standard.

NOW THEREFORE, in consideration of the mutual and dependent covenants herein contained, it is hereby mutually agreed as follows:

PURPOSE

1. The purpose of this Supplement is to describe the Parties' commitment to identify and evaluate factors that affect clarity in Grand Lake and to develop a plan in accordance with this Supplement to meet the applicable water clarity standards.

RESPONSIBILITIES

2. a. There may be a relationship between the reduced clarity in Grand Lake and the operation of the C-BT Project as well as other factors. The Parties agree that further study and evaluation would be beneficial to better understand this potential relationship.

b. The Parties will: 1) actively participate in the process of identification, development, and evaluation of factors, causes, and actions that affect clarity in Grand Lake; 2) collaborate with each other and other appropriate parties and groups ("Stakeholders") to identify, develop, and evaluate specific proposed actions to meet applicable water clarity standards in a manner that recognizes the relative contributing factors that affect Grand Lake water clarity, in order to allow for, as appropriate, recommendations by the Parties for specific actions to meet applicable water clarity standards at Grand Lake, including participation in further studies designed to identify specific factors affecting clarity; 3) implement the process and actions defined in Article 4 below as appropriate and within legal limitations and funding constraints, with the goal of preserving and maximizing overall C-BT Project benefits while meeting applicable clarity standards at Grand Lake.

c. The United States will have the final authority to approve both the Stakeholders and the process identified in Article 2.b. above, after consultation with Northern Water, other Federal, state, and local authorities, and other entities as the United States deems appropriate.

PAYMENT RESPONSIBILITY

3. The responsibility for payment of the cost of implementing measures to meet applicable water clarity standards shall be determined in accordance with Reclamation law. The Parties acknowledge that congressional and other authorization may be necessary to implement potential solutions.

IMPLEMENTATION

4. a. Pursuant to the foregoing, if specific actions are identified pursuant to Article 2.b. above, the Parties commit to work cooperatively and collaboratively, with each other and with other Stakeholders; to evaluate any such specific actions under applicable local, state, and/or federally required processes, regulations, policies, and statutes; to cooperate with other Stakeholders to identify sources of funding; and to implement any such specific actions to meet the goal identified in Article 2.b. above within legal limitations and funding constraints and in a manner that recognizes the causes and relative contributing factors that affect Grand Lake water clarity. This Supplement does not affect or modify existing authorities, including those regarding the allocation of costs, for operation and maintenance of or capital improvements related to the C-BT Project.

b. The United States may take actions to meet the applicable clarity standard, and the cost of such actions will be allocated in accordance with Reclamation law. The Parties acknowledge that the exact nature and cost of such actions is unknown until the processes outlined in Article 2 are complete. Until a proposed solution is identified, agreed upon, and appropriate authorizations, if necessary, are obtained, the Parties reserve all rights, arguments, and defenses relative to the proposed solution itself and the allocation of costs therein. In the event the Parties are unable to reach agreement concerning the specific actions that should be taken to meet the goal identified in Article 2.b. above and the United States makes a determination to implement specific action(s), the Parties reserve all rights, arguments, and defenses regarding such determination to implement specific actions, and this Supplement does not modify, waive, limit, or relinquish any right of Northern Water to contest the United States' determination to take specific actions in any judicial, administrative, or legislative forum. The execution of this Supplement shall not be used by either Party in any judicial, administrative, or legislative proceeding as an admission to the contrary.

EFFECT ON THE 1938 REPAYMENT CONTRACT

5. This Supplement is in addition to the 1938 Repayment Contract and, except as expressly provided in Articles 2.b. and 4. above, does not modify or amend the 1938 Repayment Contract. This Supplement shall not be a basis for any direct or indirect interpretation or construction of any provision of the 1938 Repayment Contract for any purpose. Prior drafts of this Supplement are not relevant to the interpretation of this Supplement.

STANDARD CONTRACT ARTICLES

6. The standard contract articles applicable to this Supplement are listed below. The full text of these standard articles is attached as Exhibit A and is hereby made a part of this Supplement.

A. Notices
B. Officials Not to Benefit
C. Changes in Contractor's Organization
D. Assignments Limited - Successors and Assigns Obligated
E. Books, Records, and Reports
F. Rules, Regulations, and Determinations
G. Equal Employment Opportunity (Federally Assisted Construction)
H. Compliance with Civil Rights Laws and Regulations

IN WITNESS WHEREOF, The Parties have executed this Supplement the day and year written above and agree to the terms, provisions, special conditions, and standard provisions expressed or referenced herein.

UNITED STATES OF AMERICA

By ____________________
Michael J. Ryan
Regional Director
Great Plains Region
Bureau of Reclamation

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

By ____________________
Eric W. Wilkinson
General Manager

EXHIBIT A
STANDARD CONTRACT ARTICLES

NOTICES

A. Any notice, demand, or request authorized or required by this Supplement shall be deemed to have been given, on behalf of Northern Water, when mailed, postage prepaid, or delivered to the:

Regional Director
Great Plains Region
Bureau of Reclamation
P.O. Box 36900
Billings, MT 59107

and on behalf of the United States, when mailed, postage prepaid, or delivered to the:

General Manager
Northern Colorado Water
Conservancy District
220 Water Avenue
Berthoud, Colorado 80513

The designation of the addressee or the address may be changed by notice given in the same manner as provided in this Article for other notices.

OFFICIALS NOT TO BENEFIT

B. No Member of or Delegate to the Congress, Resident Commissioner, or official of the Northern Water shall benefit from this Supplement other than as a water user or landowner in the same manner as other water users or landowners.

CHANGES IN CONTRACTOR'S ORGANIZATION

C. While this Supplement is in effect, no change may be made in Northern Water's organization, by inclusion or exclusion of lands or by any other changes which may affect the respective rights, obligations, privileges, and duties of either the United States or Northern Water under this Supplement including, but not limited to, dissolution, consolidation, or merger, except upon the Contracting Officer's written consent.

ASSIGNMENT LIMITED—SUCCESSORS AND ASSIGNS OBLIGATED

D. The provisions of this Supplement shall apply to and bind the successors and assigns of the Parties hereto, but no assignment or transfer of this Supplement or any right or interest therein by either Party shall be valid until approved in writing by the other Party.

BOOKS, RECORDS, AND REPORTS

E. Northern Water shall establish and maintain accounts and other books and records pertaining to administration of the terms and conditions of this Supplement, including Northern Water's financial transactions; water supply data; project operation, maintenance, and replacement logs; project land and rights-of-way use agreements; the water users' land-use (crop census), land-ownership, land-leasing, and water-use data; and other matters that the Contracting Officer may require. Reports shall be furnished to the Contracting Officer in such form and on such date or dates as the Contracting Officer may require. Subject to applicable Federal laws and regulations, each Party to this Supplement shall have the right during office hours to examine and make copies of the other Party's books and records relating to matters covered by this Supplement.

RULES, REGULATIONS, AND DETERMINATIONS

F. 1. The Parties agree that the delivery of water or the use of Federal facilities pursuant to this Supplement is subject to Federal reclamation law, as amended and supplemented, and the rules and regulations promulgated by the Secretary of the Interior under Federal reclamation law.

2. The Contracting Officer shall have the right to make determinations necessary to administer this Supplement that are consistent with its provisions, the laws of the United States and the State of Colorado, and the rules and regulations promulgated by the Secretary of the Interior. Such determinations shall be made in consultation with Northern Water.

EQUAL EMPLOYMENT OPPORTUNITY

G. During the performance of this Supplement, Northern Water agrees as follows:

1. Northern Water will not discriminate against any employee or applicant for employment because of race, color, religion, sex, disability, or national origin. Northern Water will take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, color, religion, sex, disability, or national origin. Such action shall include, but not be limited to the following: employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. Northern Water agrees to post in conspicuous places, available to employees and applicants for employment, notices to be provided by the Contracting Officer setting forth the provisions of this nondiscrimination clause.

2. Northern Water will, in all solicitations or advertisements for employees placed by or on behalf of Northern Water, state that all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, disability, or national origin.

3. Northern Water will send to each labor union or representative of workers with which it has a collective bargaining agreement or other contract or understanding, a notice, to be provided by the Contracting Officer, advising the labor union or workers' representative of Northern Water's commitments under section 202 of Executive Order 11246 of September 24, 1965 (EO 11246), and shall post copies of the notice in conspicuous places available to employees and applicants for employment.

4. Northern Water will comply with all provisions of EO 11246, and of the rules, regulations, and relevant orders of the Secretary of Labor.

5. Northern Water will furnish all information and reports required by EO 11246, and by the rules, regulations, and orders of the Secretary of Labor, or pursuant thereto, and will permit access to his books, records, and accounts by the Contracting Agency and the Secretary of Labor for purposes of investigation to ascertain compliance with such rules, regulations, and orders.

6. In the event of Northern Water's noncompliance with the nondiscrimination clauses of this Supplement or with any of such rules, regulations, or orders, this Supplement may be canceled, terminated or suspended in whole or in part and Northern Water may be declared ineligible for further Government contracts in accordance with procedures authorized in EO 11246, and such other sanctions may be imposed and remedies invoked as provided in EO 11246 or by rule, regulation, or order of the Secretary of Labor, or as otherwise provided by law.

7. Northern Water will include the provisions of paragraphs 1 through 7 in every subcontract or purchase order unless exempted by the rules, regulations, or orders of the Secretary of Labor issued pursuant to section 204 of EO 11246, so that such provisions will be binding upon each subcontractor or vendor. Northern Water will take such action with respect to any subcontract or purchase order as may be directed by the Secretary of Labor as a means of enforcing such provisions, including sanctions for noncompliance: *Provided, however,* that in the event Northern Water becomes involved in, or is threatened with, litigation with a subcontractor or vendor as a result of such direction, Northern Water may request that the United States enter into such litigation to protect the interests of the United States.

COMPLIANCE WITH CIVIL RIGHTS LAWS AND REGULATIONS

H. 1. Northern Water shall comply with Title VI of the Civil Rights Act of 1964 (Pub. L. 88-352; 42 U.S.C. § 2000d), the Rehabilitation Act of 1973 (Pub. L. 93-112, Title V, as amended; 29 U.S.C. § 791, et seq.), the Age Discrimination Act of 1975 (Pub. L. 94-135, Title III; 42 U.S.C. § 6101, et seq.), Title III of the Americans with Disabilities Act of 1990 (Pub. L. 101-336; 42 U.S.C. § 12181, et seq.), and any other applicable civil rights laws, and with the applicable implementing regulations and any guidelines imposed by the U.S. Department of the Interior and/or Bureau of Reclamation.

2. These statutes prohibit any person in the United States from being excluded from participation in, being denied the benefits of, or being otherwise subjected to discrimination under any program or activity receiving financial assistance from the Bureau of Reclamation on the grounds of race, color, national origin, disability, or age. By executing this Supplement, Northern Water agrees to immediately take any measures necessary to implement this obligation, including permitting officials of the United States to inspect premises, programs, and documents.

3. Northern Water makes this agreement in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property discounts, or other Federal financial assistance extended after the date hereof to Northern Water by the Bureau of Reclamation, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. Northern Water recognizes and agrees that such Federal assistance will be extended in reliance on the representations and agreements made in this Article and that the United States reserves the right to seek judicial enforcement thereof.

4. Complaints of discrimination against Northern Water shall be investigated by the Contracting Officer's Office of Civil Rights

EXHIBIT C – WATER QUALITY INDICATORS MONITORING

SECCHI MONITORING

For the purpose of the adaptive management process aiming at reaching Grand Lake Clarity goals as defined in the MOU, Secchi data will be collected as follows:

1. Three Index Sites: GL-WES, GL-MID, GL-ATW (Figure 1)

FIGURE 1 - GRAND LAKE SECCHI MONITORING INDEX SITES

2. Sampling frequency
    a. Once a week starting May 1 (or as soon as ice is off)
    b. Three times a week from July 1 to September 11
    c. If necessary based on operational plans during Jul 1- Sep 11, sampling may be increased to daily (Mon-Fri)
    d. Once a week from Sep 12- October 30
3. During the period of Jul 1 – Sep 11, measurements shall be taken at all three sites[1] on a given day and shall be averaged for the purpose of evaluating:
    a. Jul-to date average against the 3.8 m goal (an example is shown in Figure 2)
    b. Jul-to date minimum against the 2.5 m goal (an example is shown in Figure 3)
4. Secchi measurements will be taken according to the *Secchi Monitoring Protocol for Grand Lake (ATTACHMENT 1)*
5. Secchi measurements will be taken with a viewscope

Figures 2 and 3 are presented as examples of how the water quality information may be compiled.

[1] As described in Attachment 1, two Secchi measurements are taken at each site with a viewscope. These two measurements shall be averaged to produce one value.

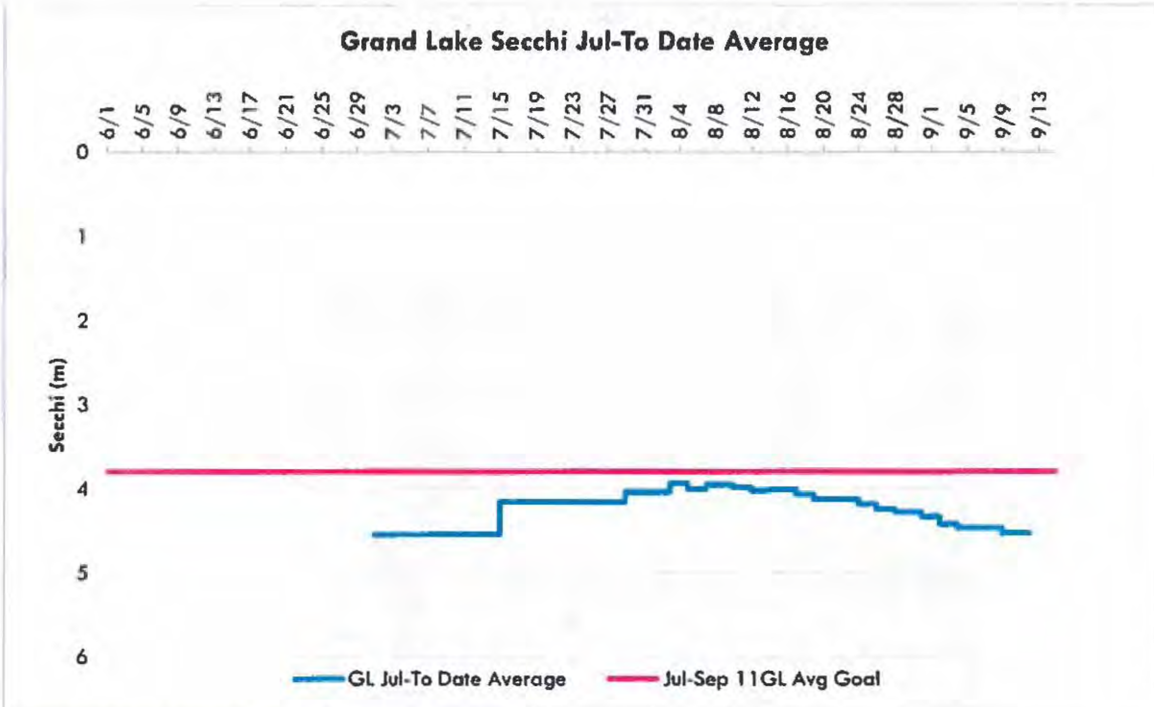


FIGURE 2 - GRAND LAKE SECCHI JUL 1 – TO DATE AVERAGE

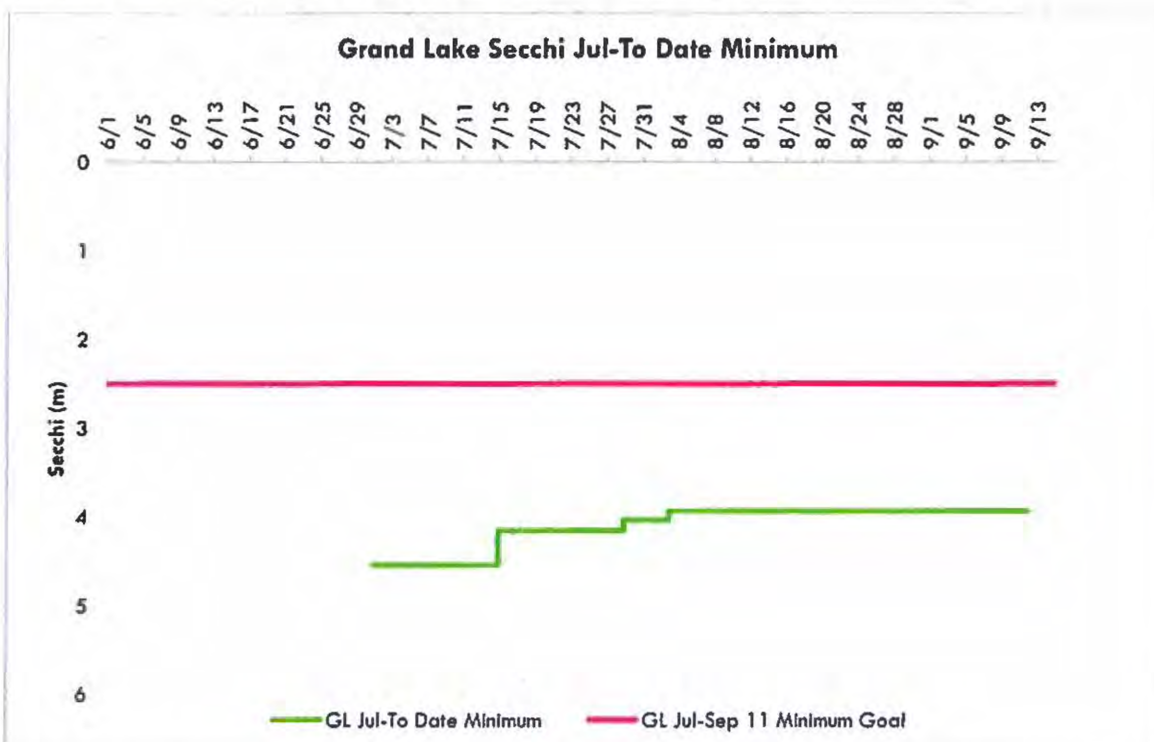


FIGURE 3 - GRAND LAKE SECCHI JUL-TO DATE MINIMUM

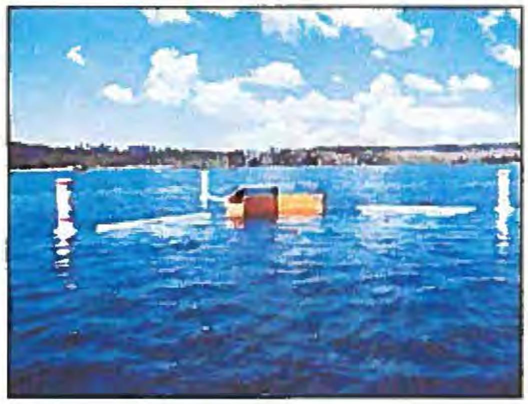
DISSOLVED OXYGEN (DO) AND PH MONITORING

Continuous (every 4 hour) real time monitoring of physical parameters is carried out at two sites in Shadow Mountain Reservoir. The real time monitoring includes DO concentration and percent saturation, temperature, pH, specific conductance and turbidity. Northern Water will make every effort to maintain these systems but adjustments may have to be made in the event of an equipment failure.

MONITORING LOCATIONS

Station	Description	Latitude	Longitude	Depth
SM-DAM	Shadow Mountain Reservoir near Dam	40.2101	-105.8421	7.6 m
SM-MID	Shadow Mountain Reservoir Mid-Section	40.2252	-105.8378	6.7 m

SAMPLING EQUIPMENT AND MAINTENANCE



Buoy monitoring systems are currently located at the Shadow Mountain dam and middle sites (SM-DAM and SM-MID). Each buoy is equipped with a YSI 6820 multi-parameter sonde and is programmed to collect vertical profiles of temperature, D.O., specific conductance, pH and turbidity. The buoy systems are deployed after ice-off in the spring and then taken out in the fall prior to ice cover. When deployed, profiles will be collected every four hours at 0.5-meter increments down through the depth of the water column. Data will be logged and transferred by telemetry on a real-time basis.

FREQUENCY

Profiles will be collected with the buoys at SM-DAM and SM-MID from mid-June until September 11; the sampling period may be longer or shorter depending on when the buoys are deployed and removed for the season.

MAP OF SAMPLING LOCATIONS

A map of the sampling locations overlaid on Shadow Mountain Reservoir bathymetry is shown below.

EVALUATION OF WATER QUALITY INDICATORS

pH and DO will be reviewed using graphical representations such as contour plots and time series graphs presented in Figure 4, Figure 5, Figure 6 and Figure 7. Dissolved Oxygen percent saturation will be reported similarly.

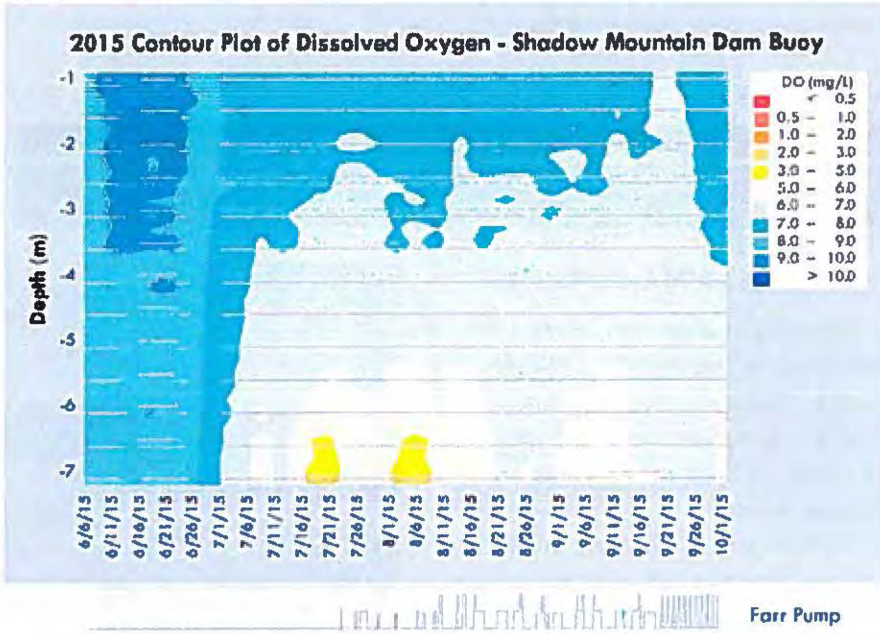


FIGURE 4 - DISSOLVED OXYGEN CONTOUR PLOT AT SHADOW MOUNTAIN DAM (2015)

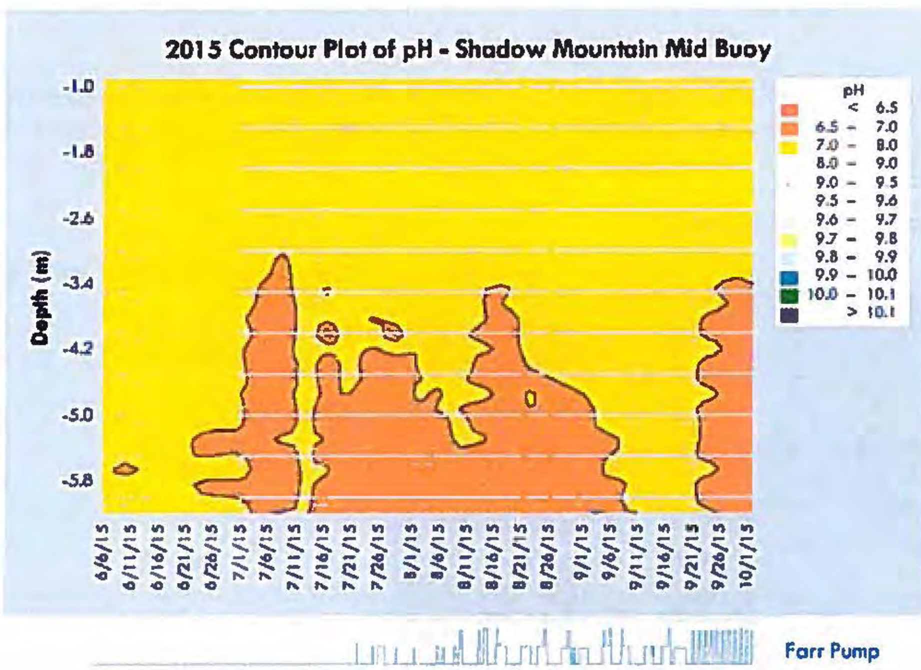


FIGURE 5 - PH CONTOUR PLOT AT SHADOW MOUNTAIN MID (2015)

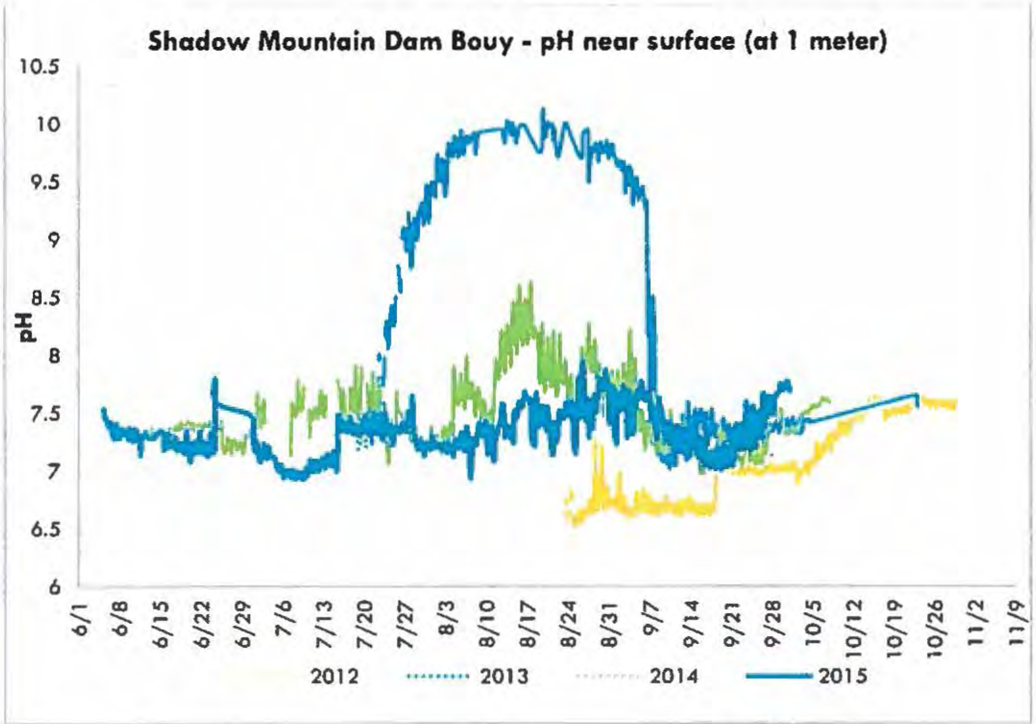


FIGURE 6 - SURFACE PH AT SHADOW MOUNTAIN DAM

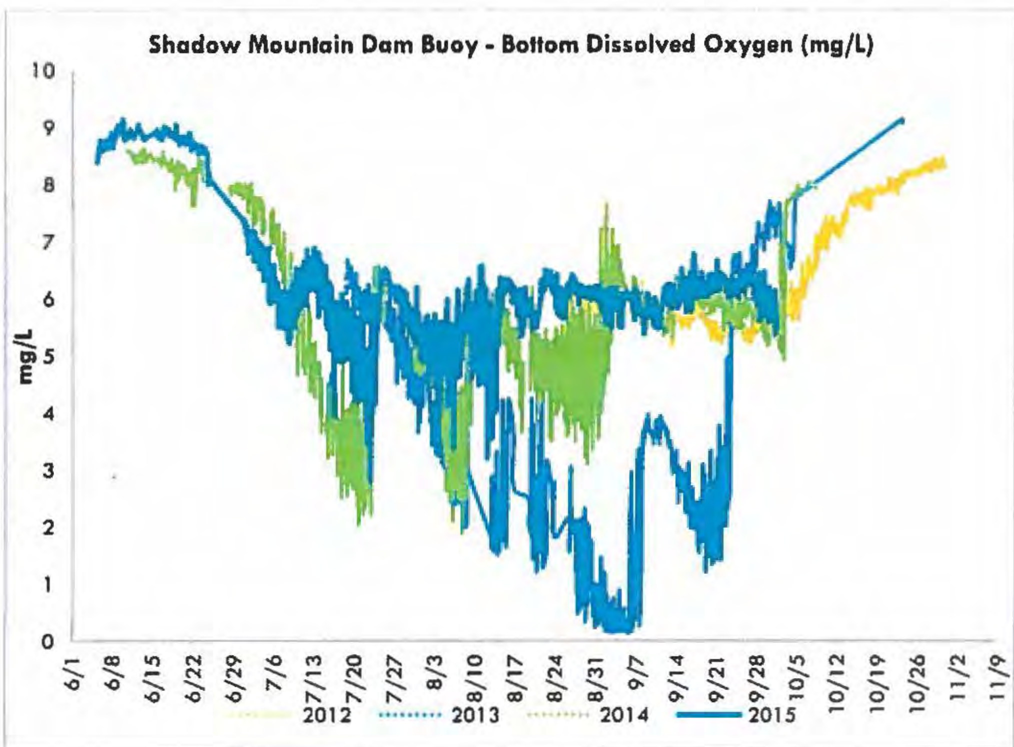


FIGURE 7 - BOTTOM DO AT SHADOW MOUNTAIN DAM

EXHIBIT D - GRAND LAKE ADAPTIVE MANAGEMENT WEEKLY SUMMARY FORM

Meeting Date: XX/XX/2016

Attendees:

	Northern Water	☐		Reclamation	☐		Larimer County	☐
	Northern Water	☐		Reclamation	☐		Town of Grand Lake	☐
	Northern Water	☐		Reclamation	☐		USFS	☐
	Northern Water	☐		Reclamation	☐		RMNP	☐
	Northern Water	☐		USGS	☐			☐
	Northern Water	☐		NWCCOG	☐			☐
	Grand County	☐		CRWCD	☐			☐
	Grand County	☐		WAPA	☐			☐

NOTES

Water Quality Indicators	Current	Yes	No	Comments
GL avg Secchi < 3.8 m ?		☐	☐	
GL min Secchi < 2.5 m ?		☐	☐	
SM Surface pH > 8 ?		☐	☐	
SM Surface DO (%)> 100%?		☐	☐	
SM bottom DO < 3 mg/L ?		☐	☐	

Operational Parameters	Current	Forecast	Comments
Adams Tunnel Deliveries (cfs)		See graph	Source USBR
Big Thompson Deliveries (cfs)		Range	Source NW
Farr Pumping (cfs)		See graph	Source USBR
Shadow Mountain Releases (cfs)		Range	Source USGS Gage/NW
Upper Colorado Native Flow (cfs)		See graph	Source NW
Granby Res. Total Storage (af)		See graph	Source NW
Granby Res. Outflow (cfs)		See graph	Source NW

Climate Forecast (From HUP Report)

5-day Quantitative Precipitation Forecast (QPF): Chance for some light showers today, but overall expect a drying and warming trend through the weekend.

5 day qpf: http://www.wpc.ncep.noaa.gov/qpf/p120i.gif?1445893642

7 day qpf:http://www.wpc.ncep.noaa.gov/qpf/p168i.gif?1445893676

1-5 day minimum temperature anomaly forecast: http://www.wpc.ncep.noaa.gov/medr/95Bwbg.gif

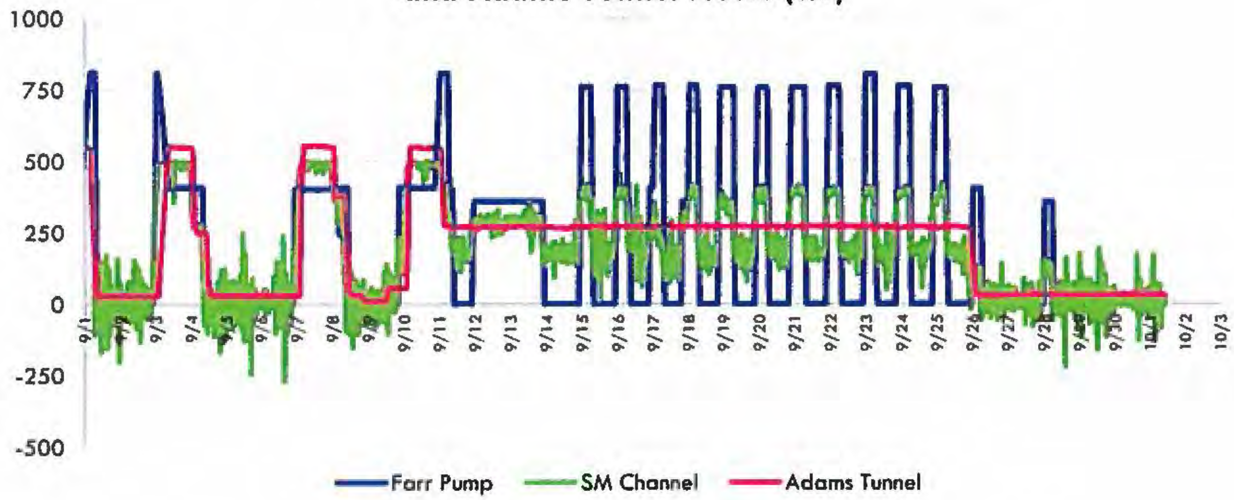
1-5 day maximum temperature forecast: http://www.wpc.ncep.noaa.gov/medr/95Awbg.gif

Precip forecast that goes into the CBRFC forecast. http://www.cbrfc.noaa.gov/rmap/grid/index.php

Action Items Summary:

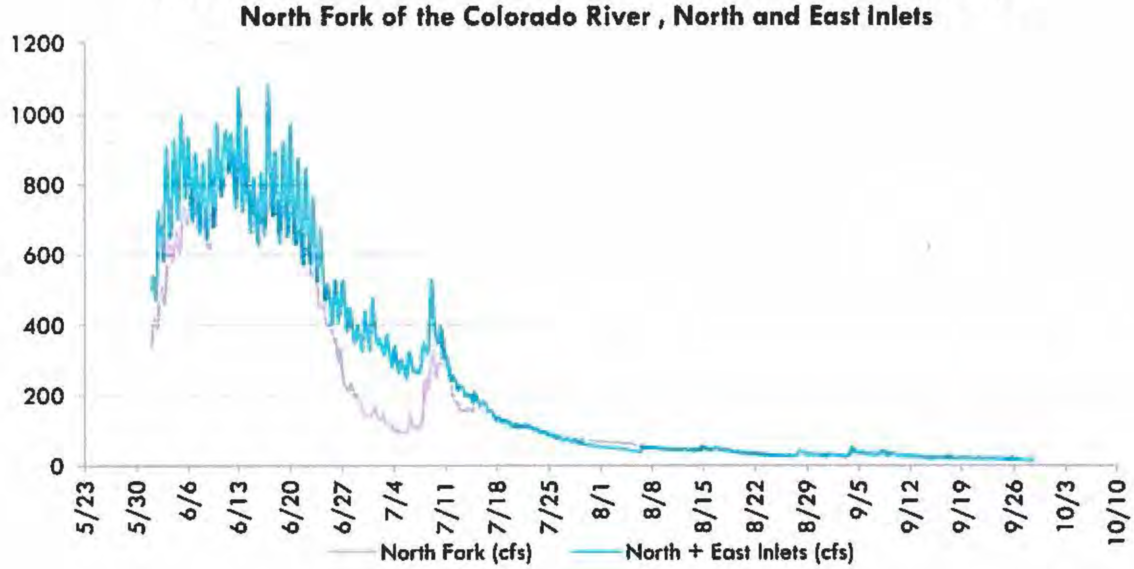
Observed Flows

Observed Farr Pumping, Shadow Mountain Channel and Adams Tunnel Flows (cfs)



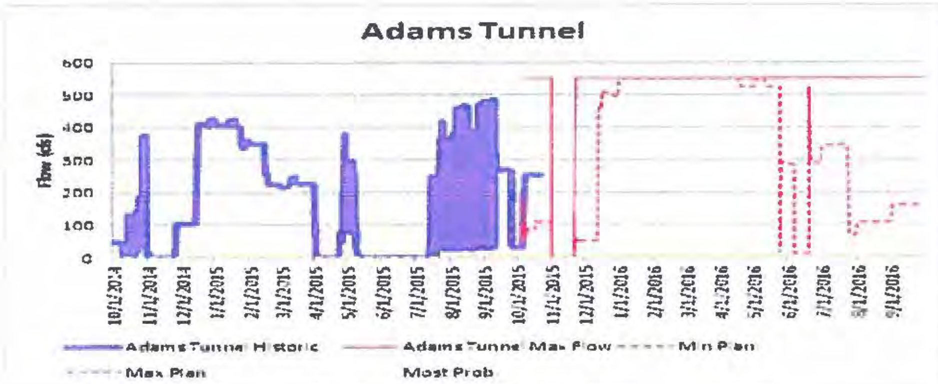
Observed Grand Lake and Shadow Mountain Inflows

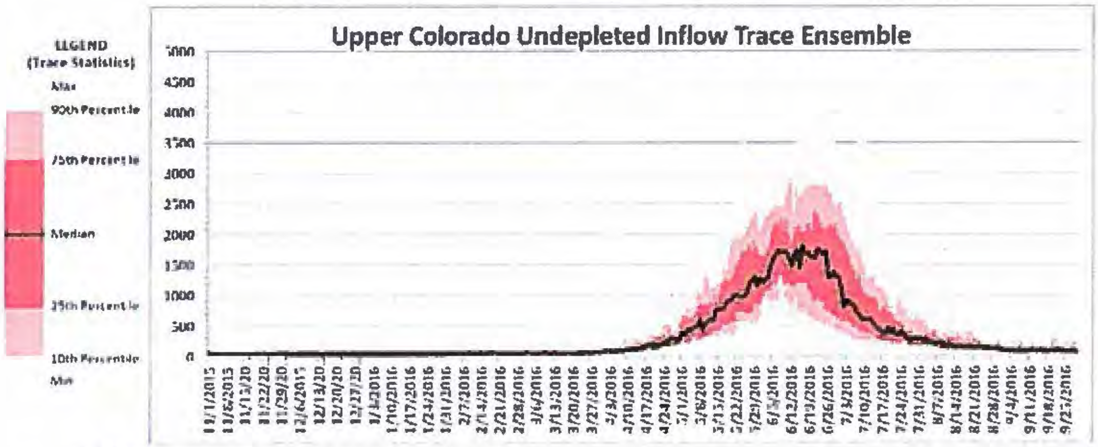
North Fork of the Colorado River , North and East Inlets



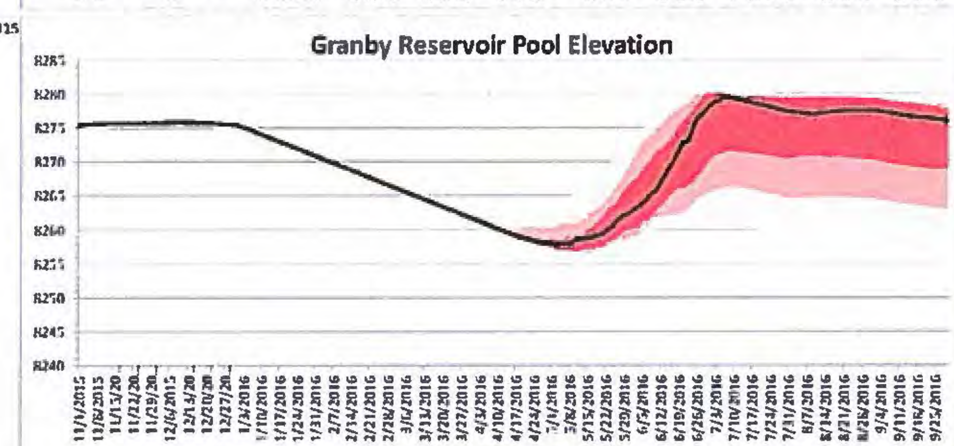
November 12, 2015

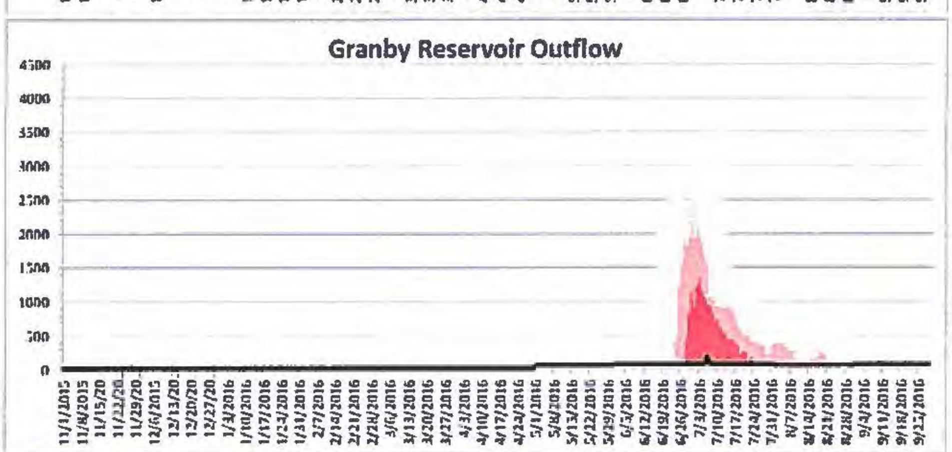
Operational Forecast



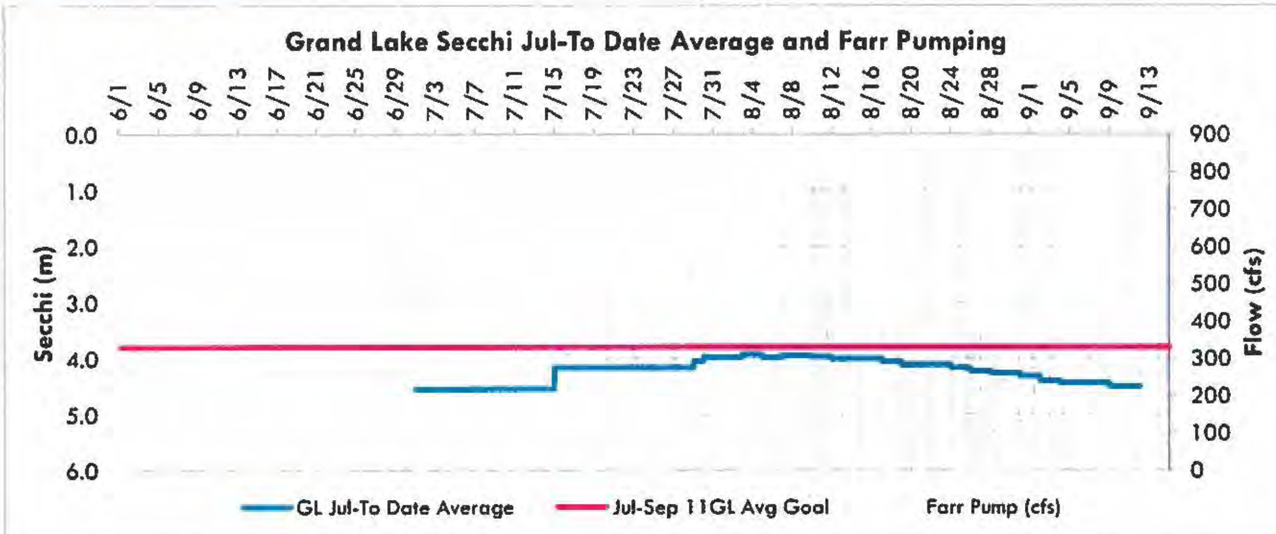


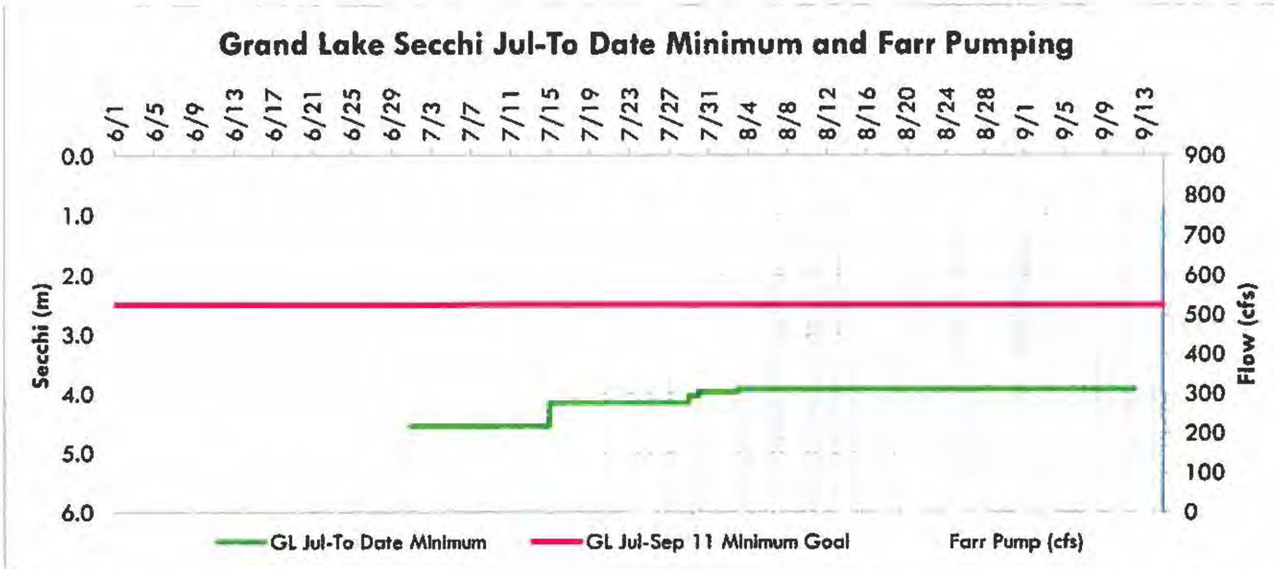
6/1/2015

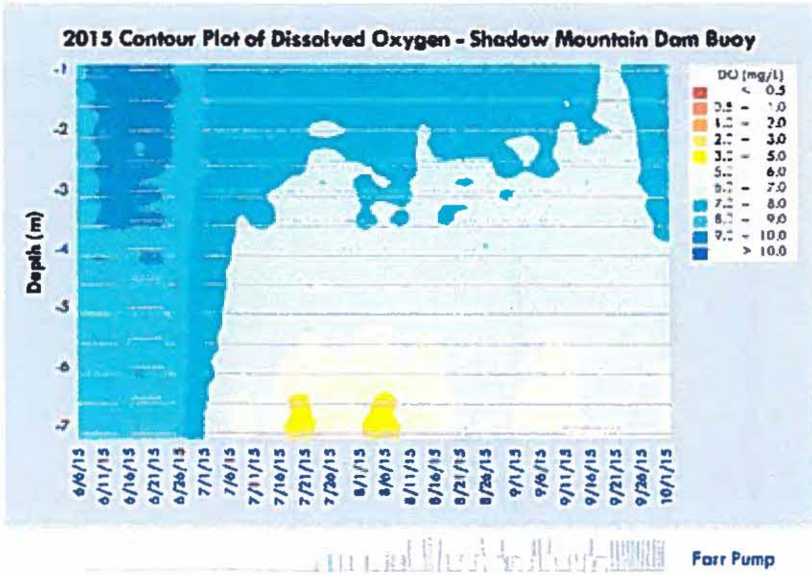


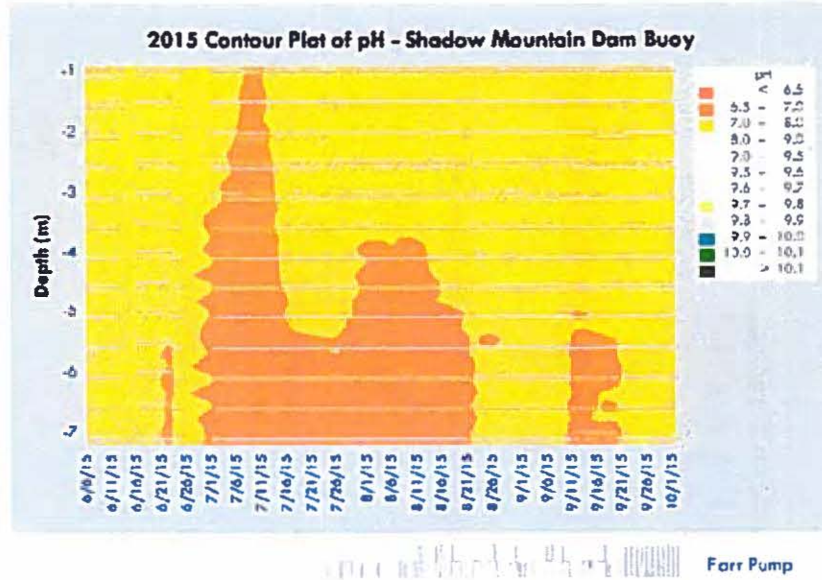


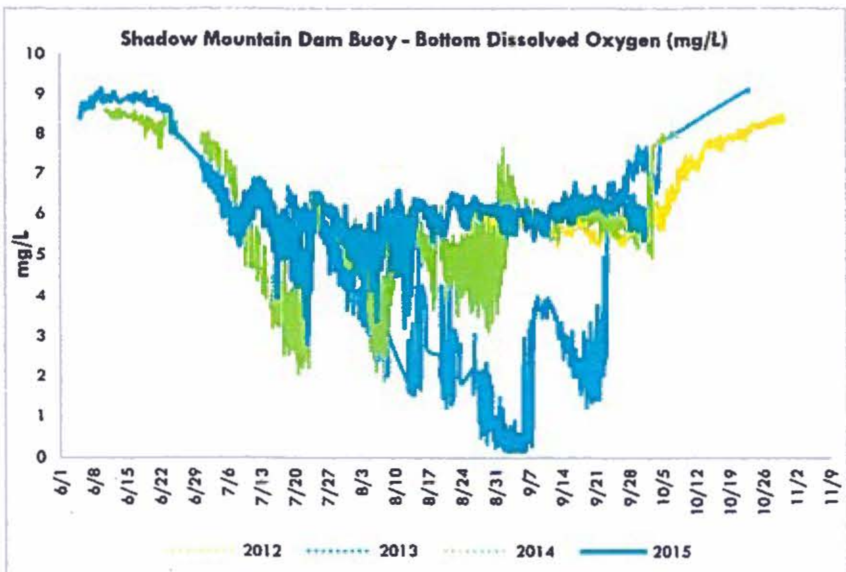
Water Quality Summary

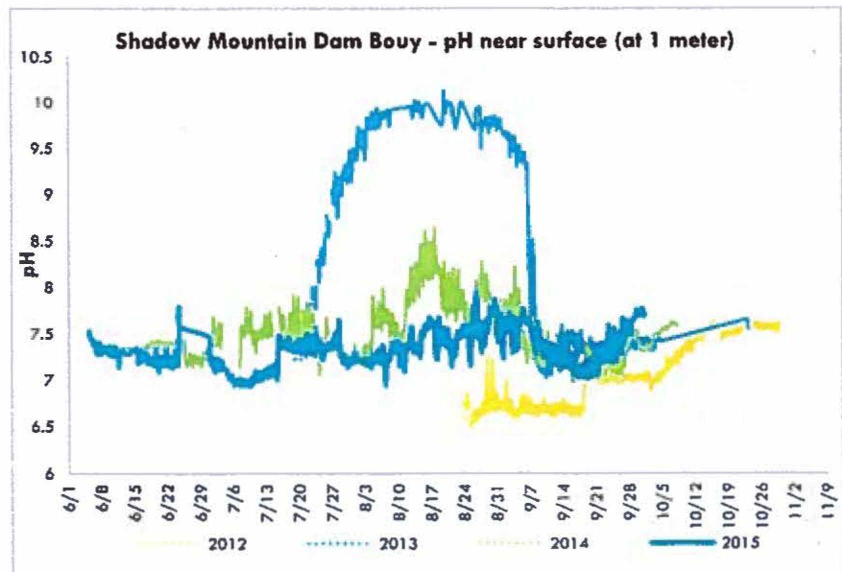


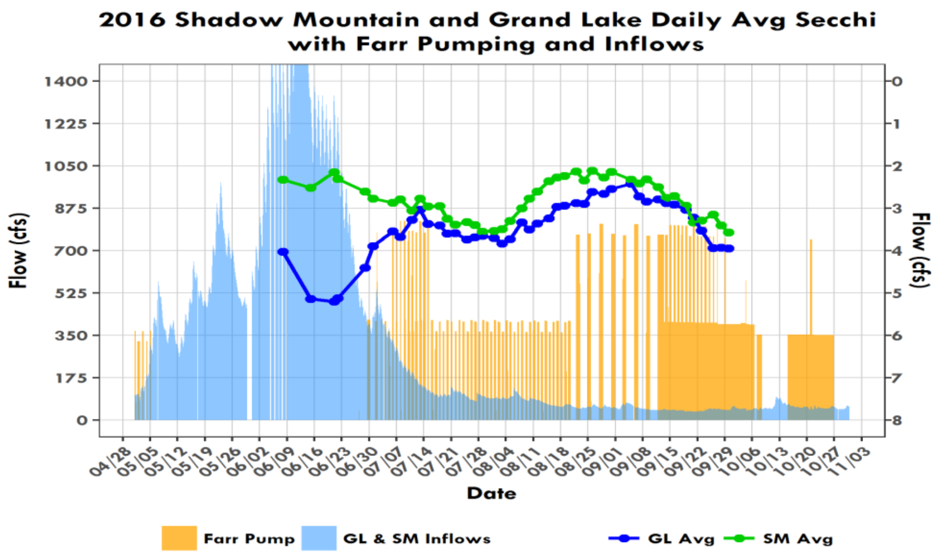


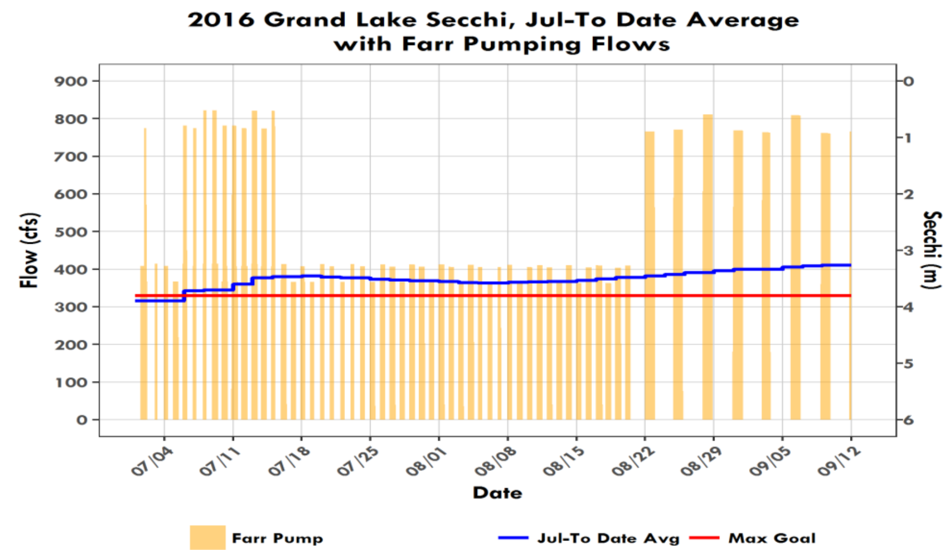

2015 Contour Plot of Dissolved Oxygen - Shadow Mountain Dam Buoy
Depth (m)
DO (mg/L)
Farr Pump

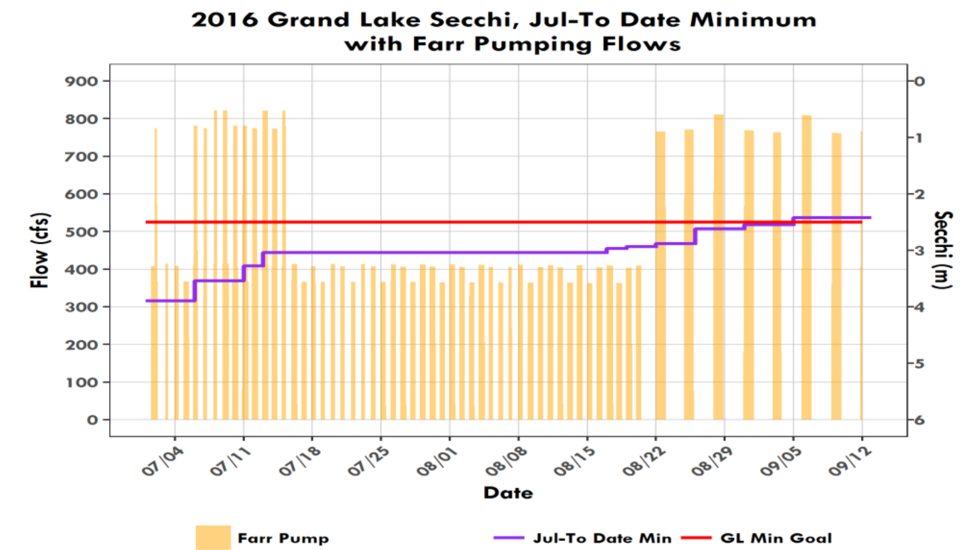

2015 Contour Plot of pH - Shadow Mountain Dam Buoy
Depth (m)
pH
Farr Pump

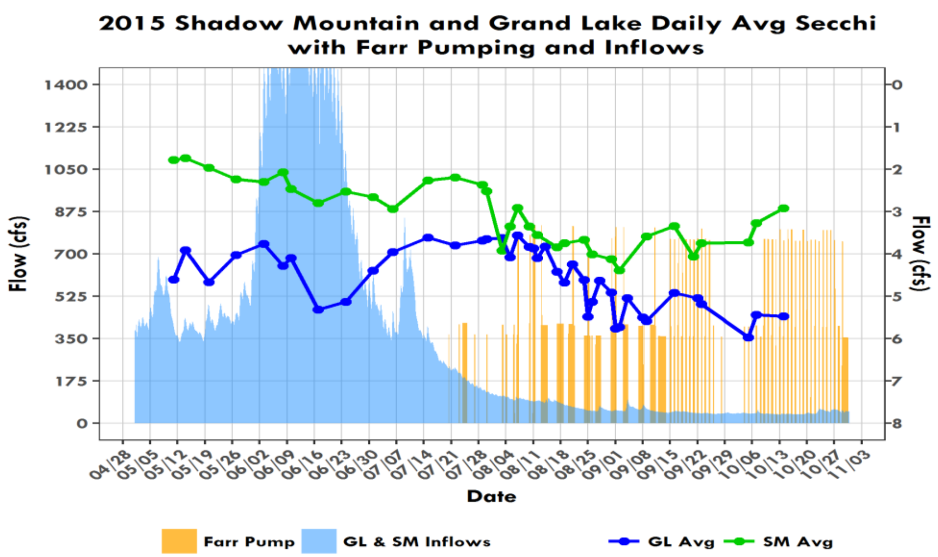

Shadow Mountain Dam Buoy - Bottom Dissolved Oxygen (mg/L)
mg/L
2012
2013
2014
2015


Shadow Mountain Dam Bouy - pH near surface (at 1 meter)
pH
2012
2013
2014
2015


2016 Shadow Mountain and Grand Lake Daily Avg Secchi
with Farr Pumping and Inflows
Flow (cfs)
Date
Farr Pump
GL & SM Inflows
GL Avg
SM Avg


2016 Grand Lake Secchi, Jul-To Date Average
with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Avg
Max Goal


2016 Grand Lake Secchi, Jul-To Date Minimum
with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Min
GL Min Goal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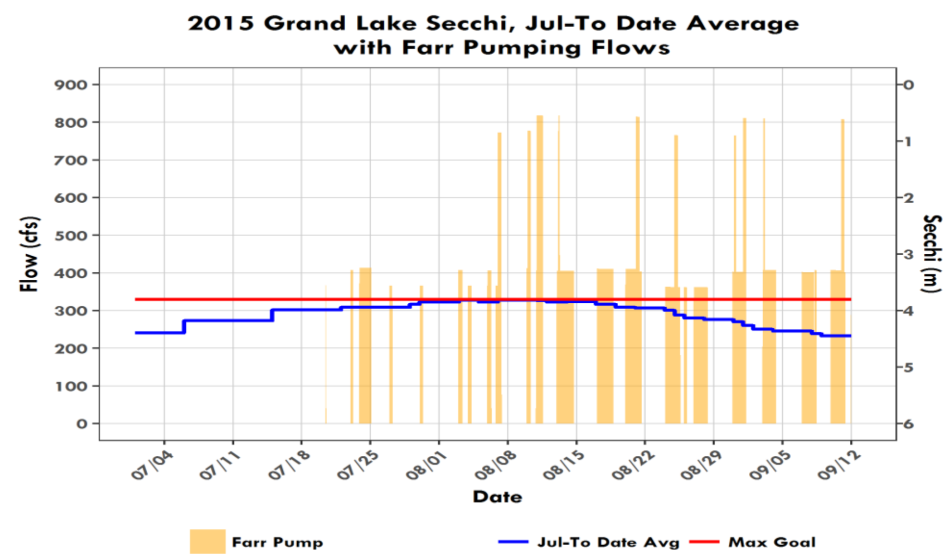
Flow (cfs)
Date
Farr Pump
GL & SM Inflows
GL Avg
SM Avg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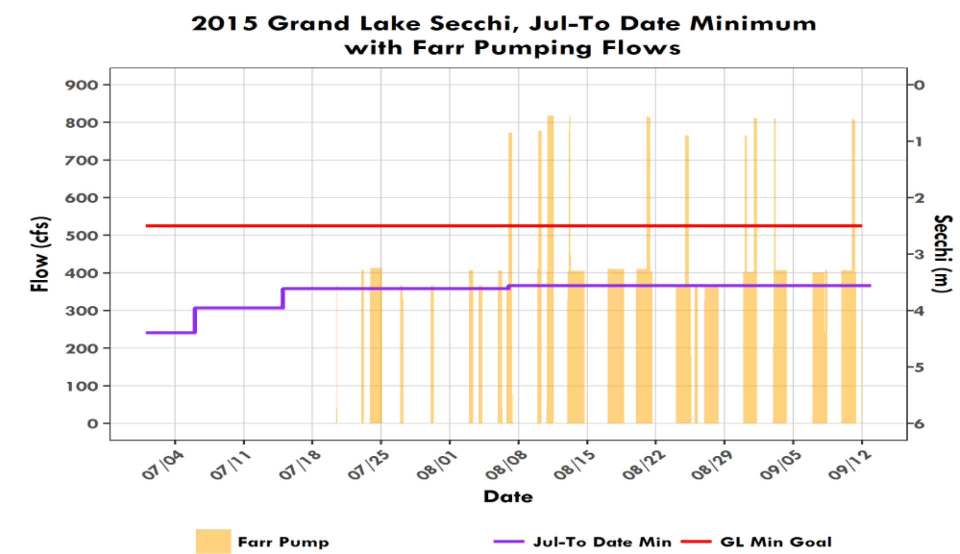
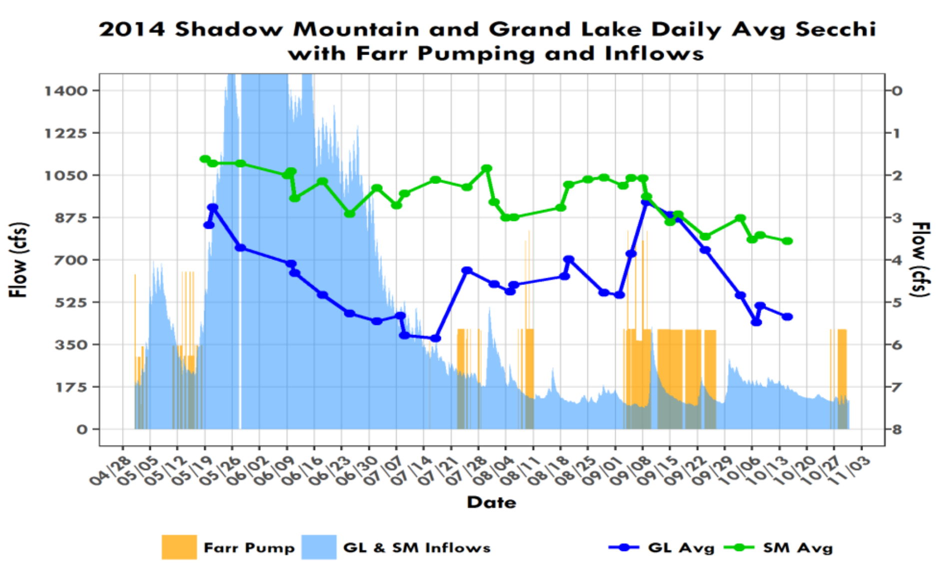
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Avg
Max Goal


2015 Grand Lake Secchi, Jul-To Date Minimum
with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Min
GL Min Goal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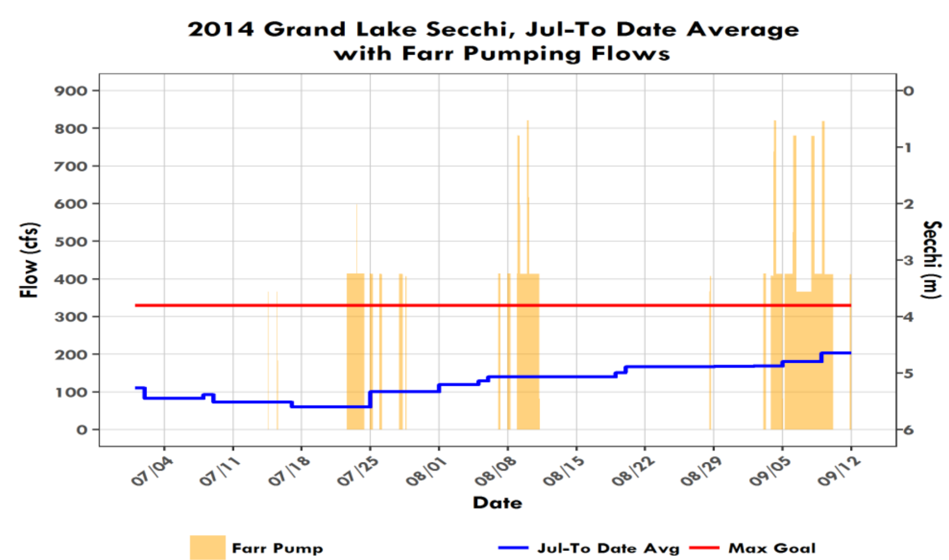
Flow (cfs)
Date
Farr Pump
GL & SM Inflows
GL Avg
SM Avg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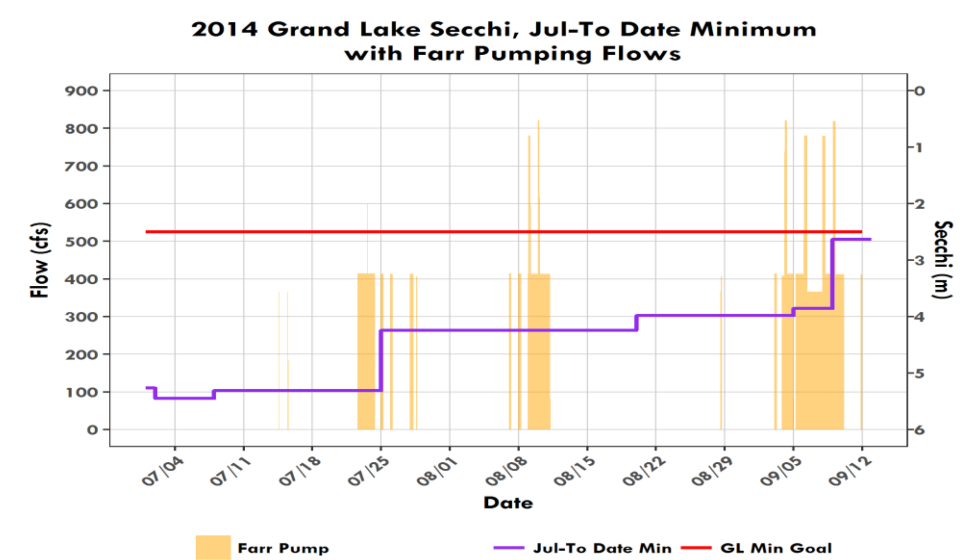
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Avg
Max Goal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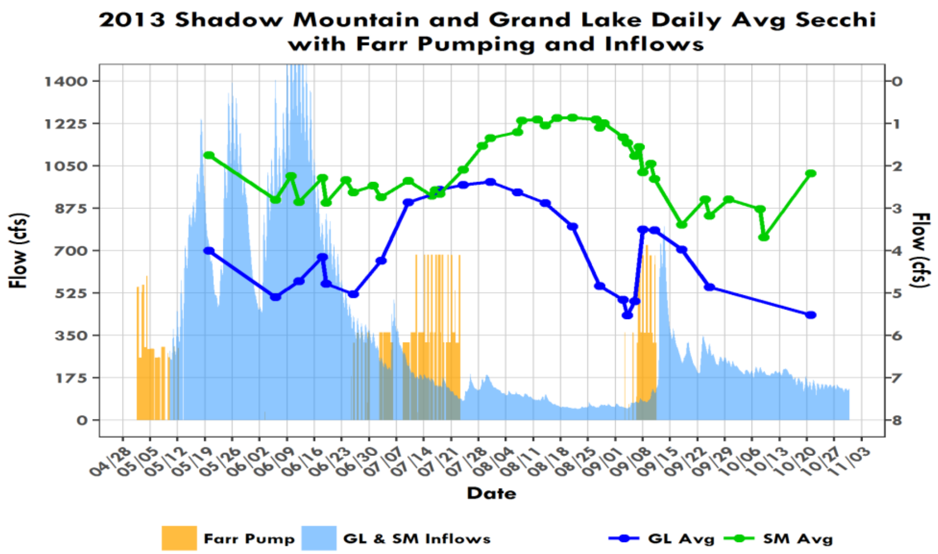
with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Min
GL Min Goal


2013 Shadow Mountain and Grand Lake Daily Avg Secchi
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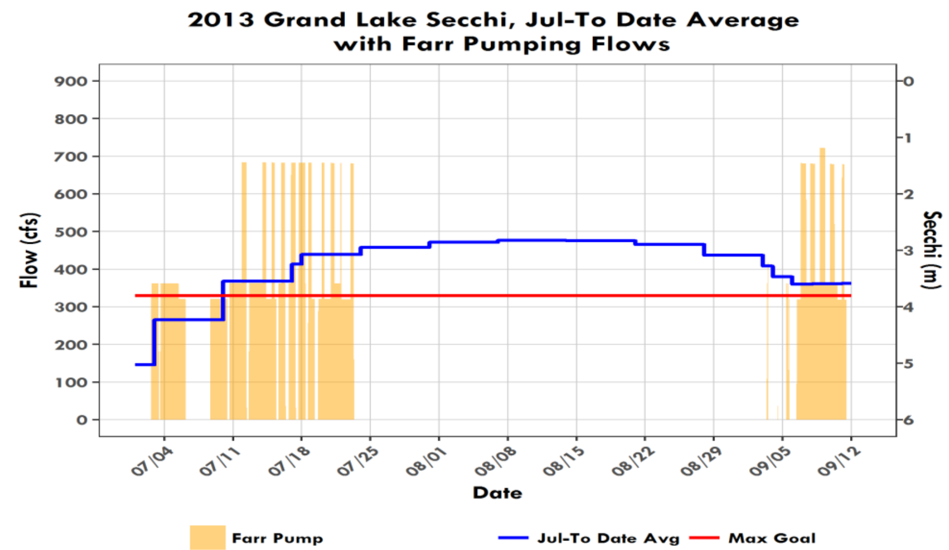
Flow (cfs)
Date
Farr Pump
GL & SM Inflows
GL Avg
SM Avg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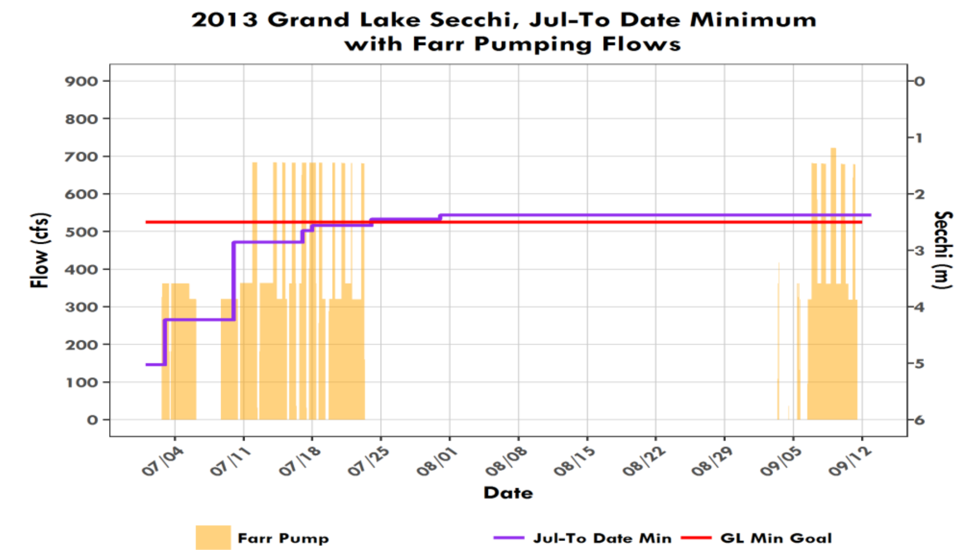
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Avg
Max Goal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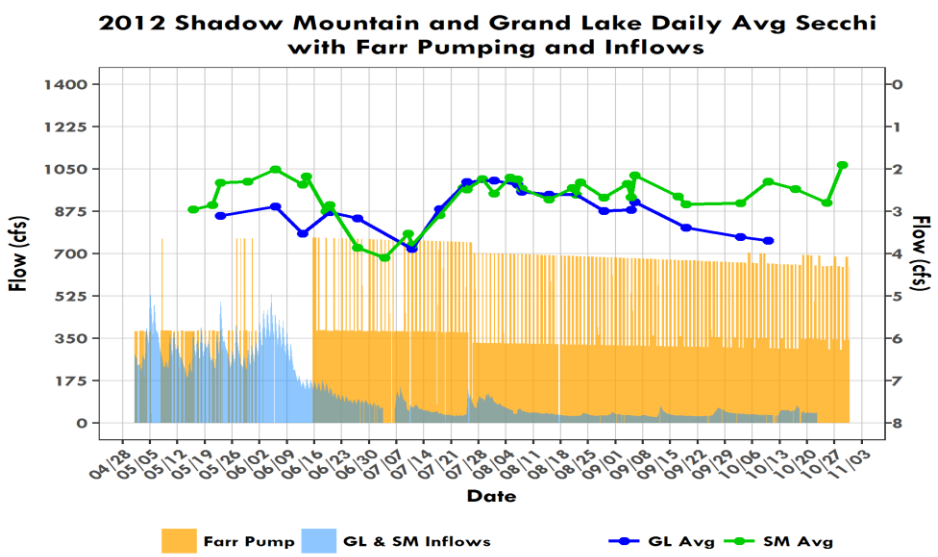
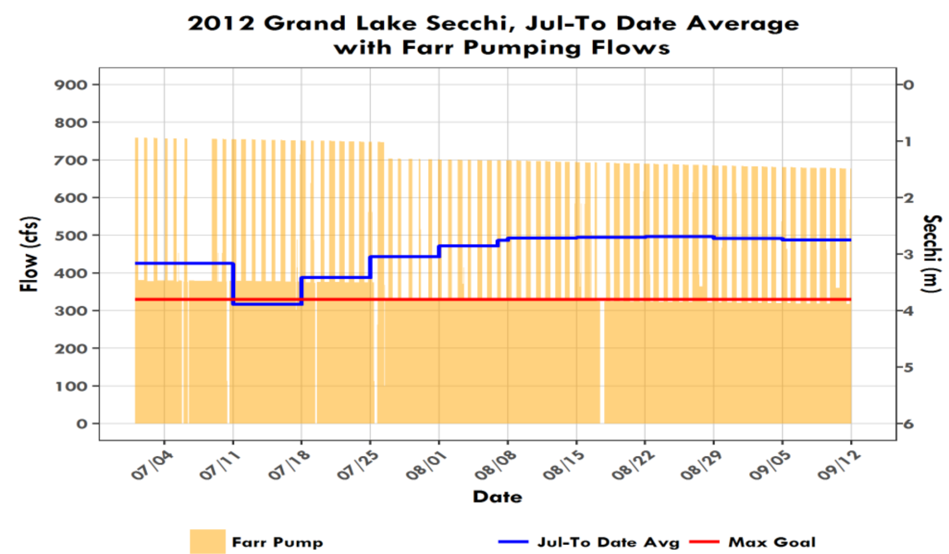
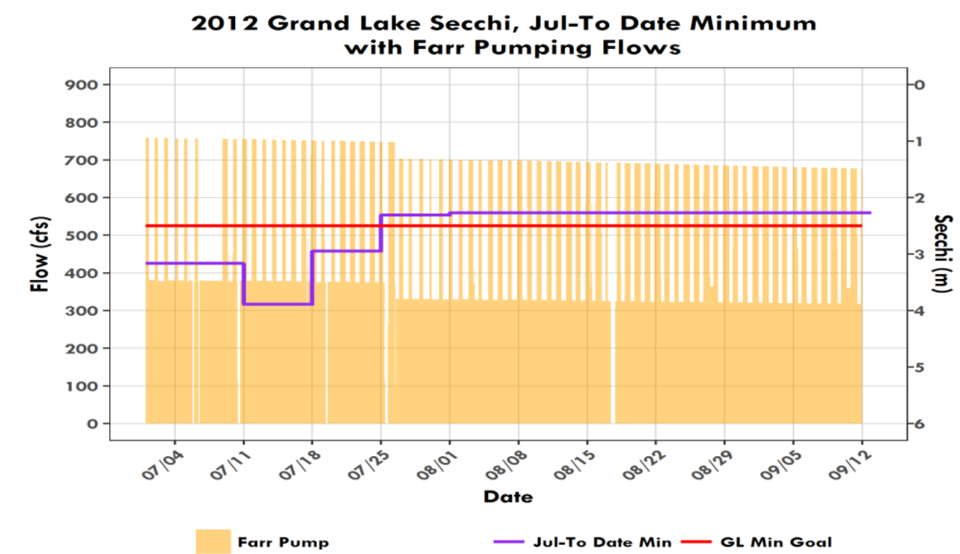
with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Min
GL Min Goal


2012 Shadow Mountain and Grand Lake Daily Avg Secchi
with Farr Pumping and Inflows
Flow (cfs)
Date
Farr Pump
GL & SM Inflows
GL Avg
SM Avg


2012 Grand Lake Secchi, Jul-To Date Average
with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Avg
Max Goal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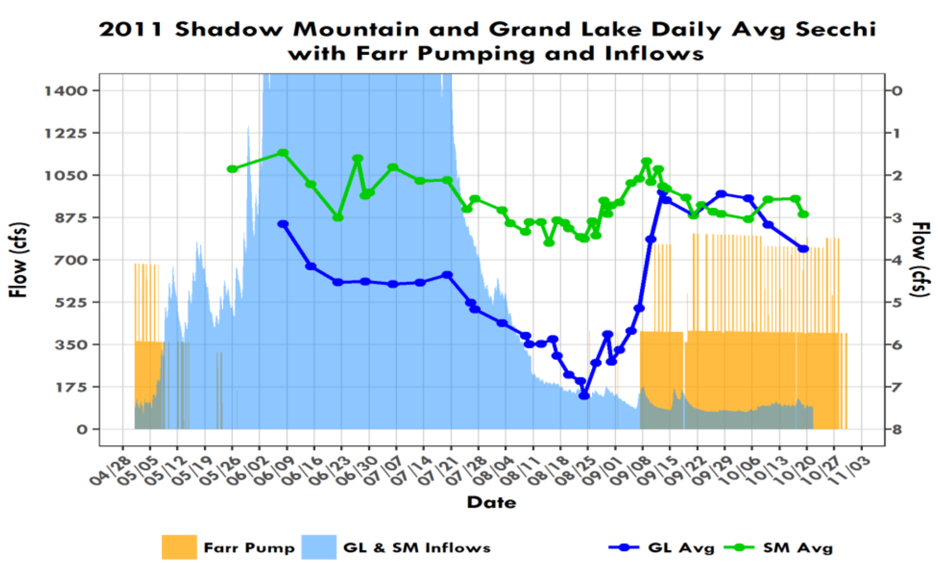
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Min
GL Min Goal


2011 Shadow Mountain and Grand Lake Daily Avg Secchi
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Flow (cfs)
Date
Farr Pump
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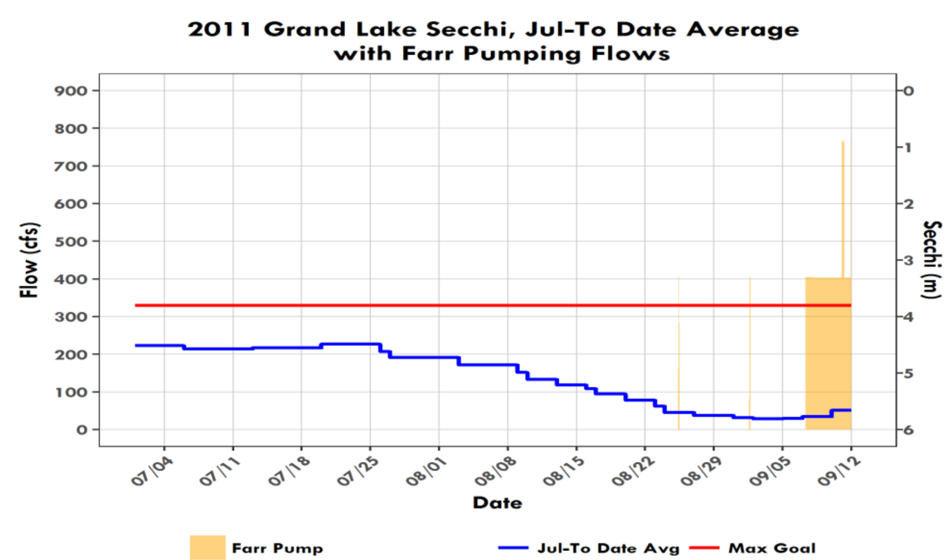
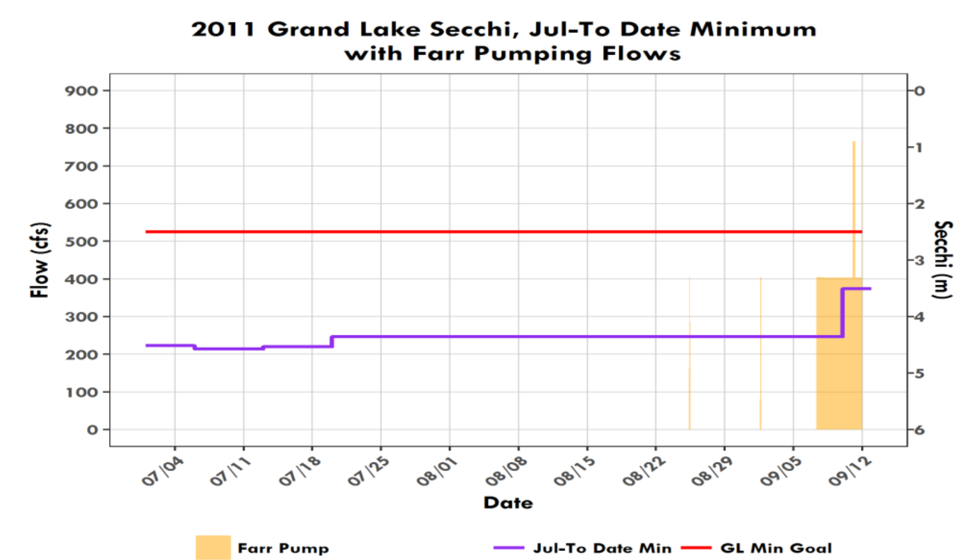
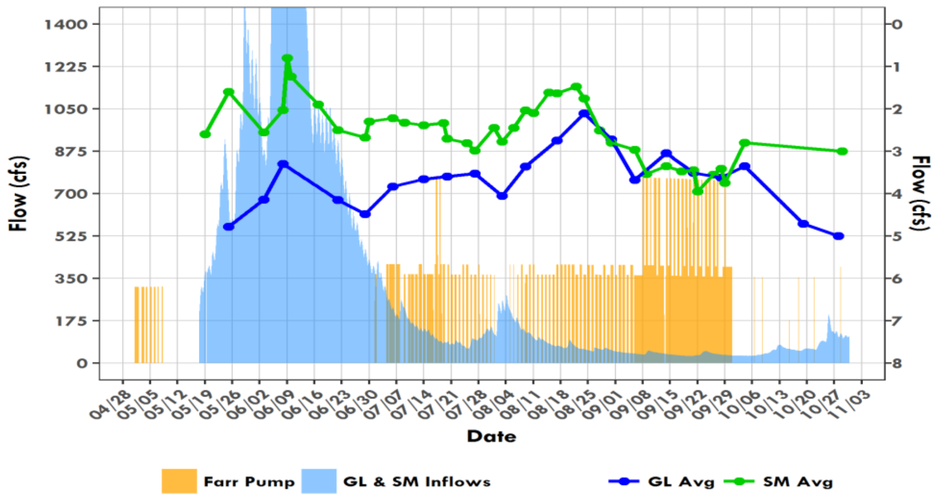
GL Avg
SM Avg

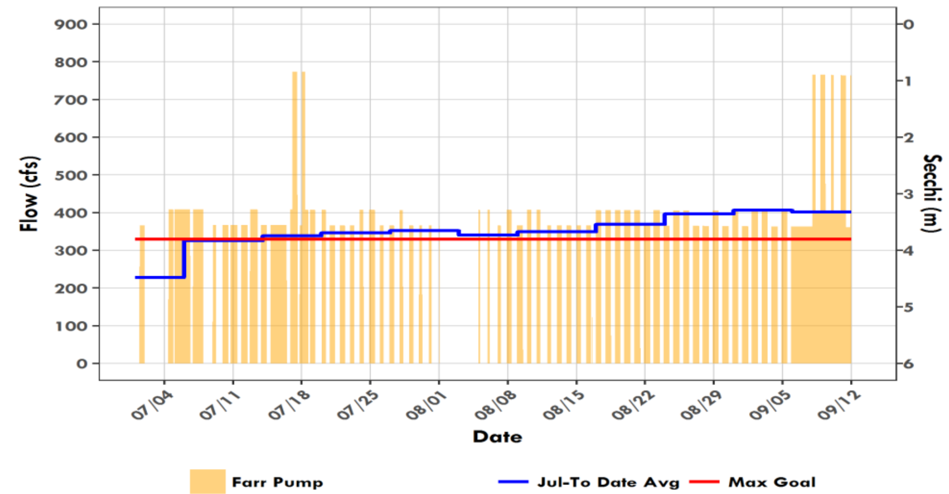

2011 Grand Lake Secchi, Jul-To Date Average
with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Avg
Max Goal


2011 Grand Lake Secchi, Jul-To Date Minimum
with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Min
GL Min Goal

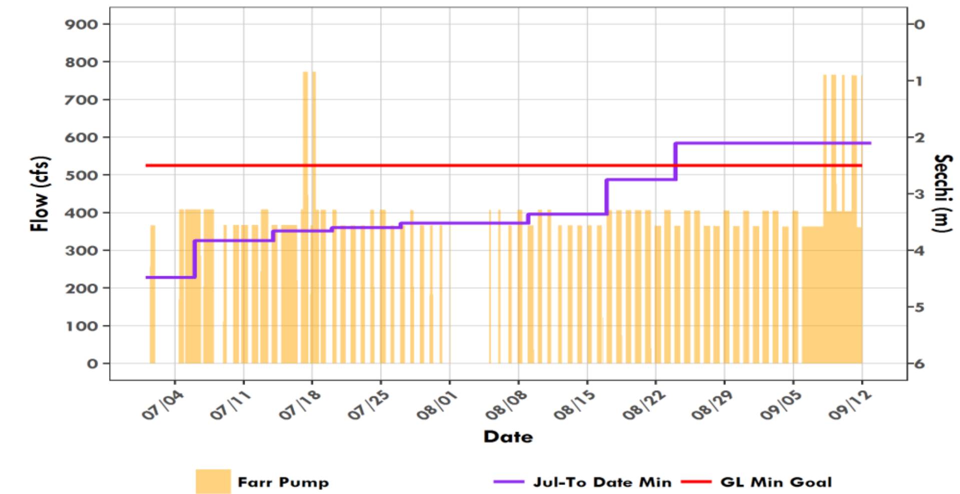
2010 Shadow Mountain and Grand Lake Daily Avg Secchi with Farr Pumping and Inflows



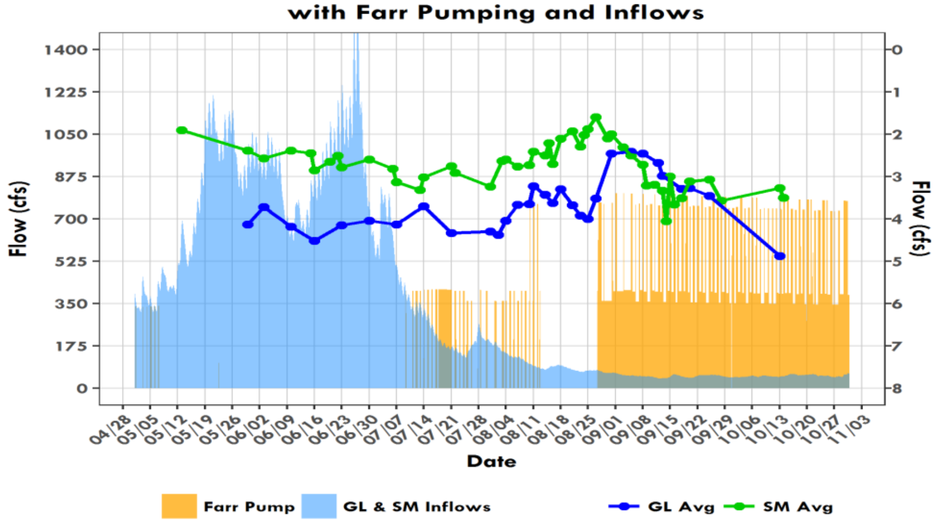
2010 Grand Lake Secchi, Jul-To Date Average with Farr Pumping Flows



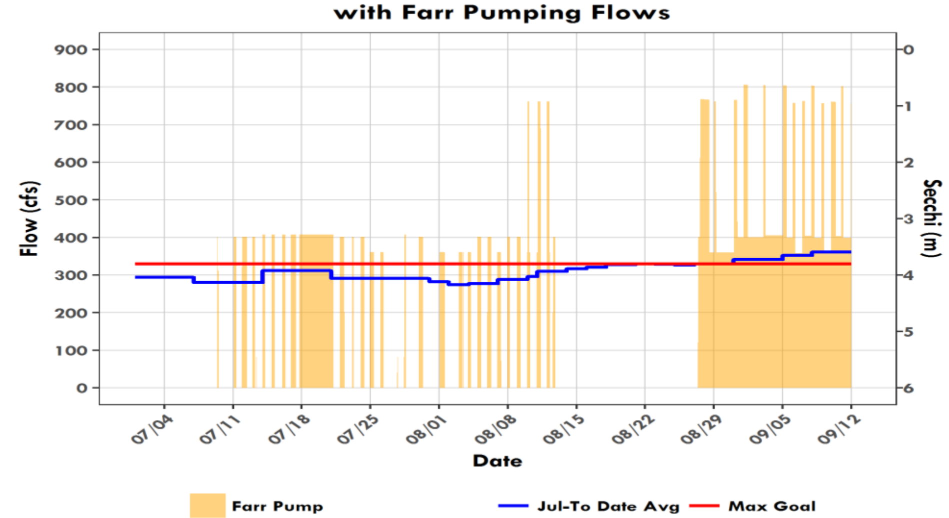
2010 Grand Lake Secchi, Jul-To Date Minimum with Farr Pumping Flows



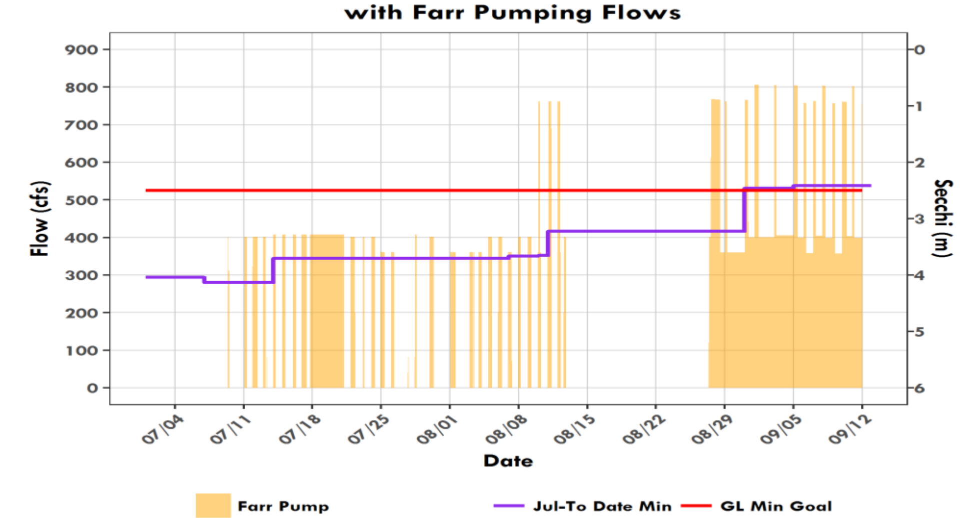
2009 Shadow Mountain and Grand Lake Daily Avg Secchi with Farr Pumping and Inflows



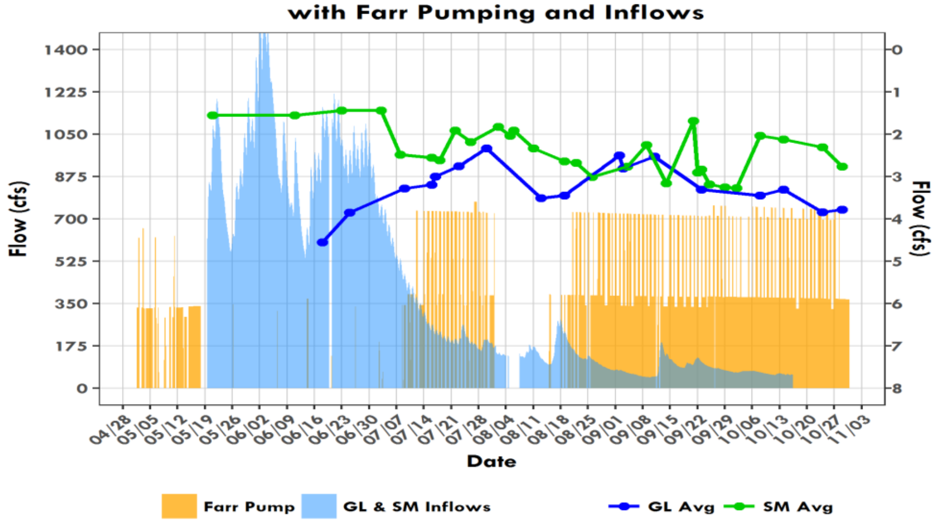
2009 Grand Lake Secchi, Jul-To Date Average with Farr Pumping Flows



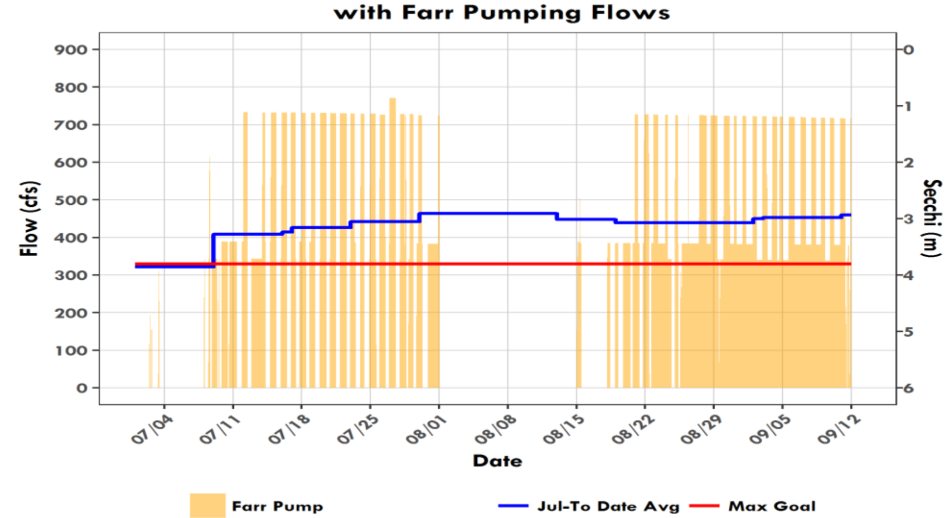
2009 Grand Lake Secchi, Jul-To Date Minimum with Farr Pumping Flows



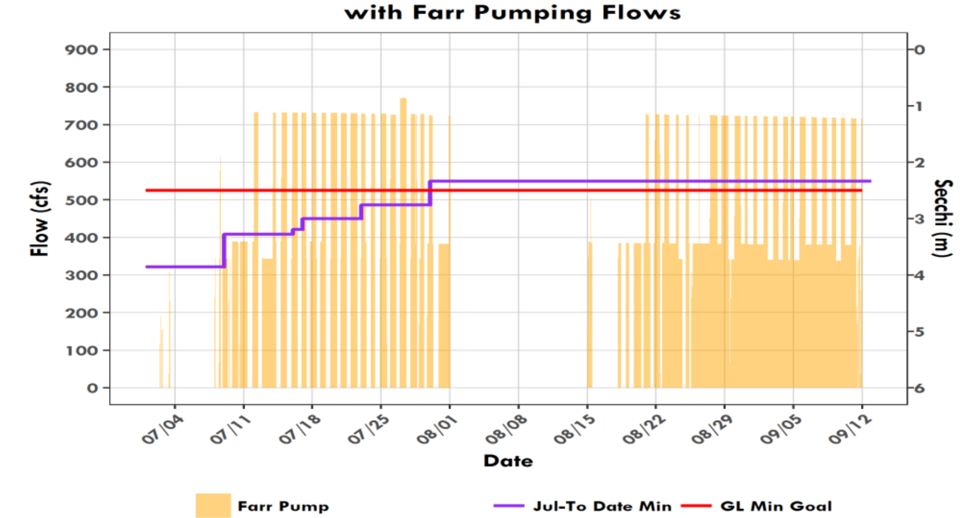
2008 Shadow Mountain and Grand Lake Daily Avg Secchi with Farr Pumping and Inflows

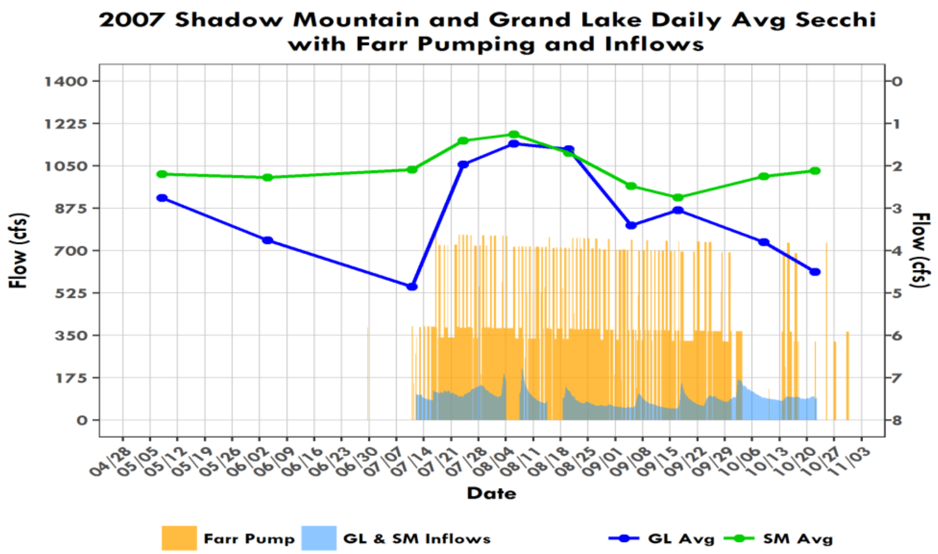


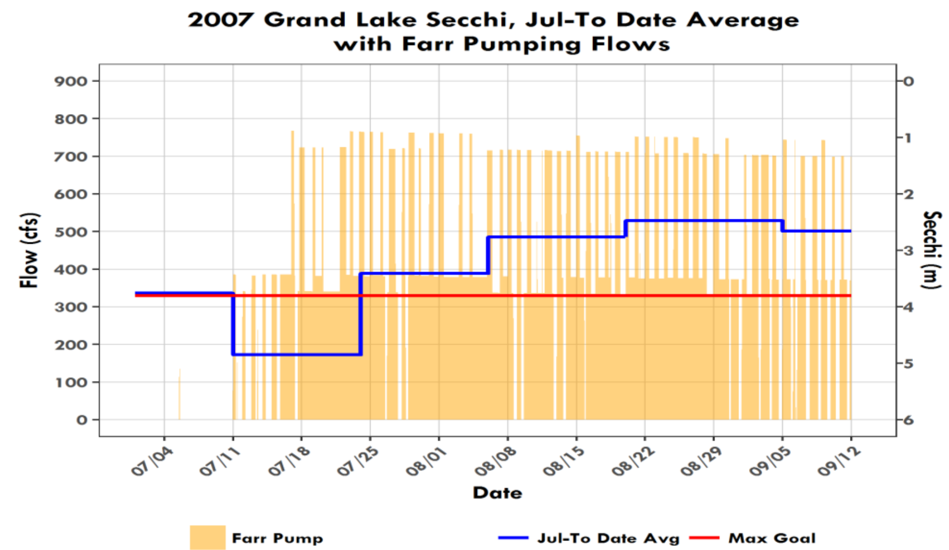
2008 Grand Lake Secchi, Jul-To Date Average with Farr Pumping Flows

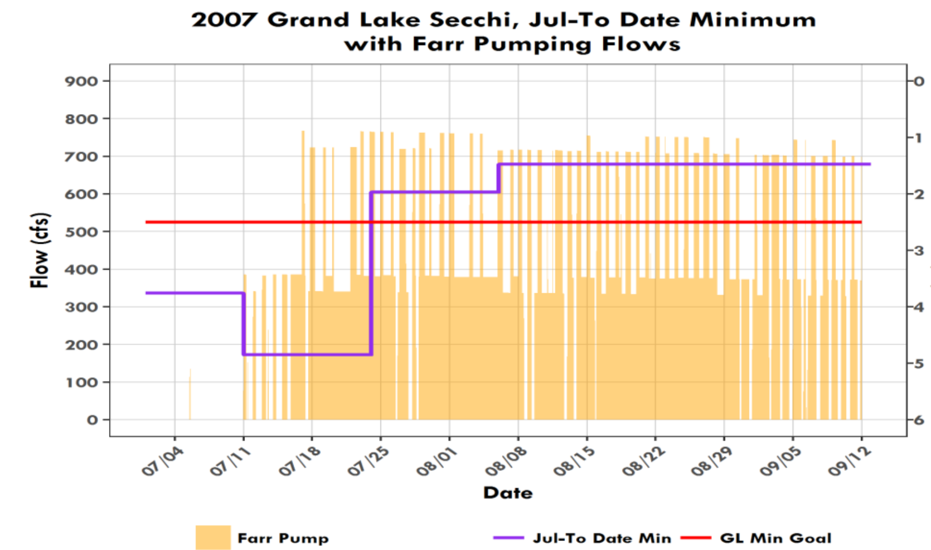


2008 Grand Lake Secchi, Jul-To Date Minimum with Farr Pumping Flows



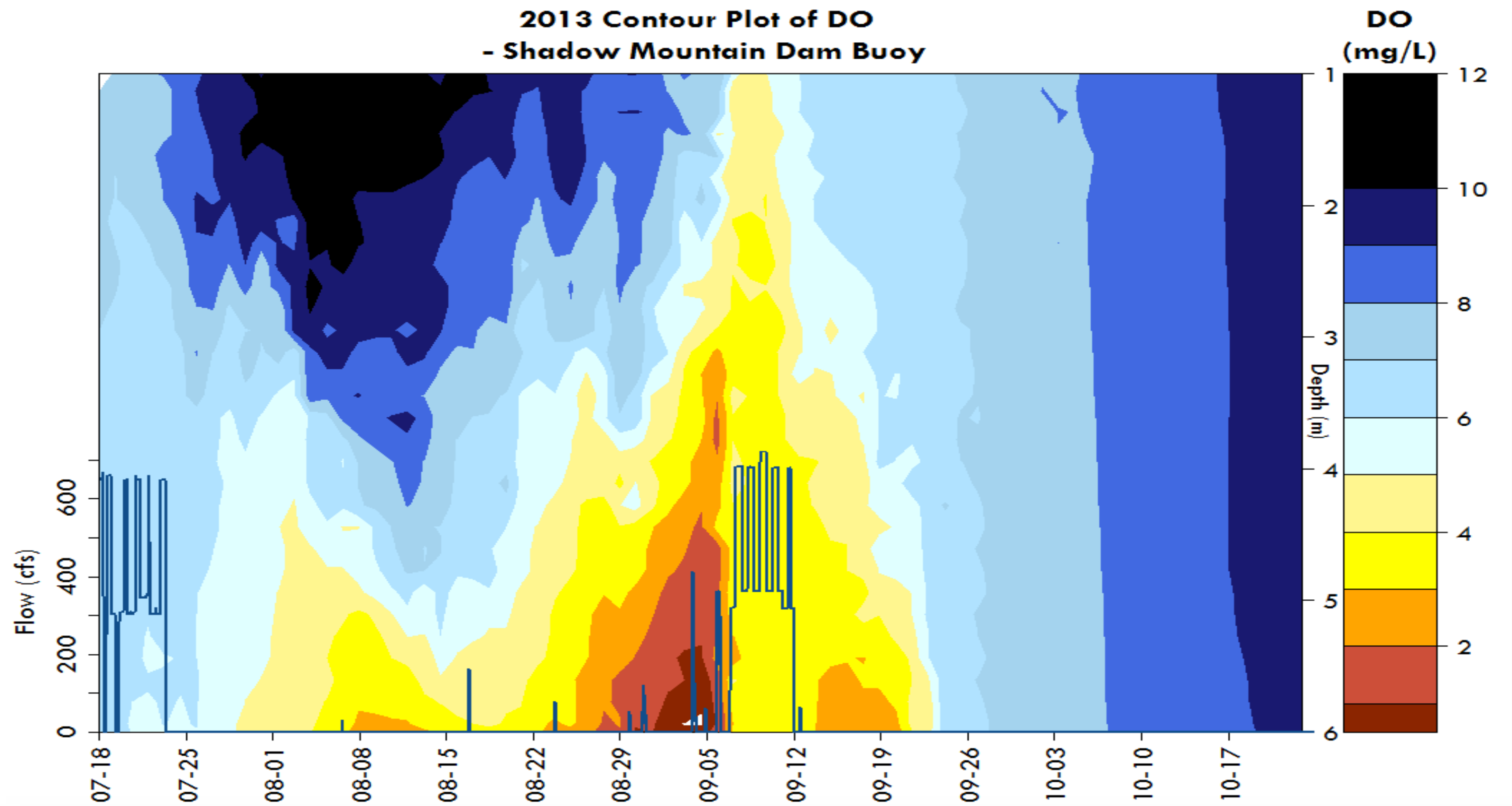

2007 Shadow Mountain and Grand Lake Daily Avg Secchi with Farr Pumping and Inflows
Flow (cfs)
Date
Farr Pump
GL & SM Inflows
GL Avg
SM Avg

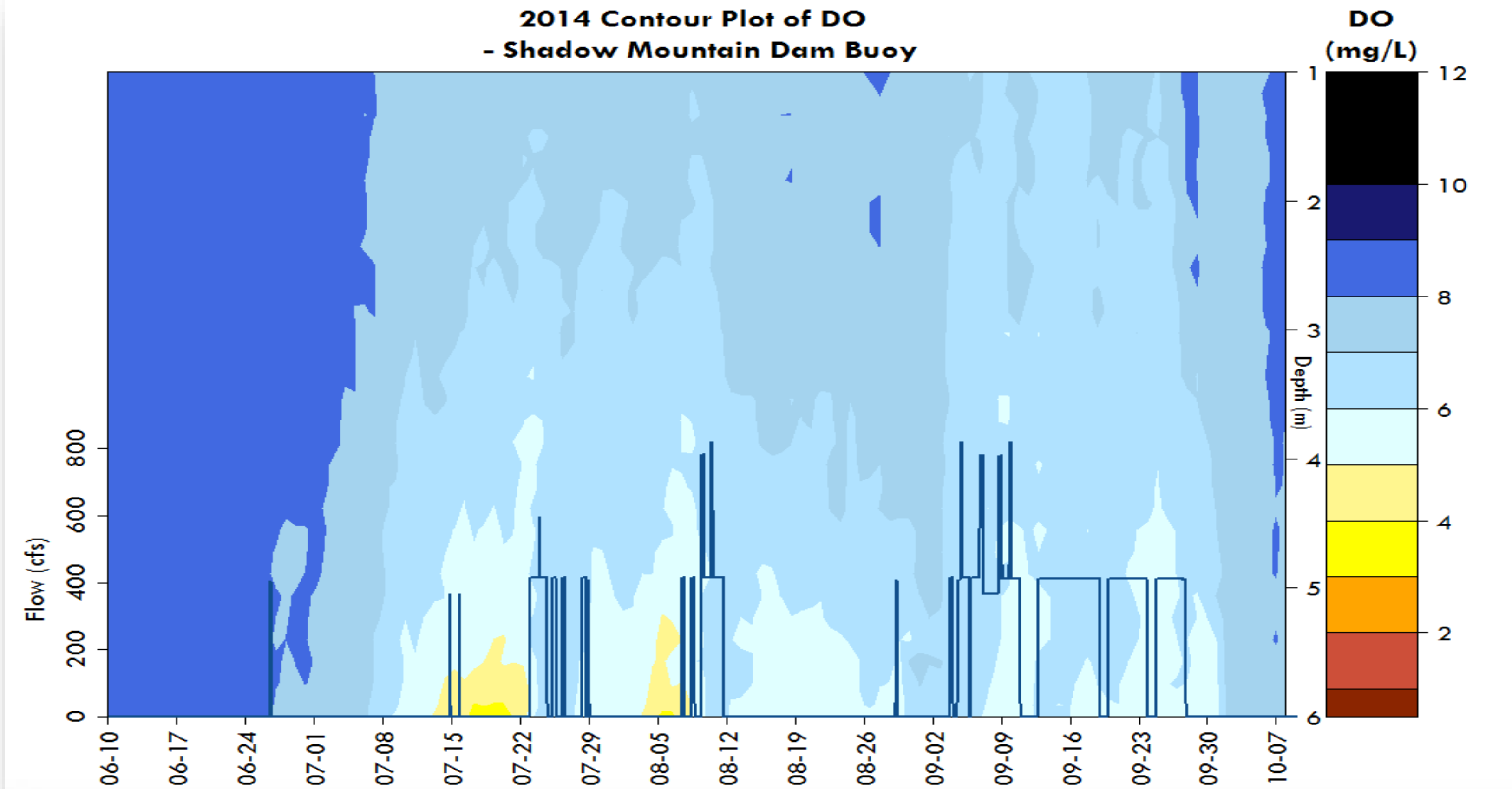

2007 Grand Lake Secchi, Jul-To Date Average with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Avg
Max Goal

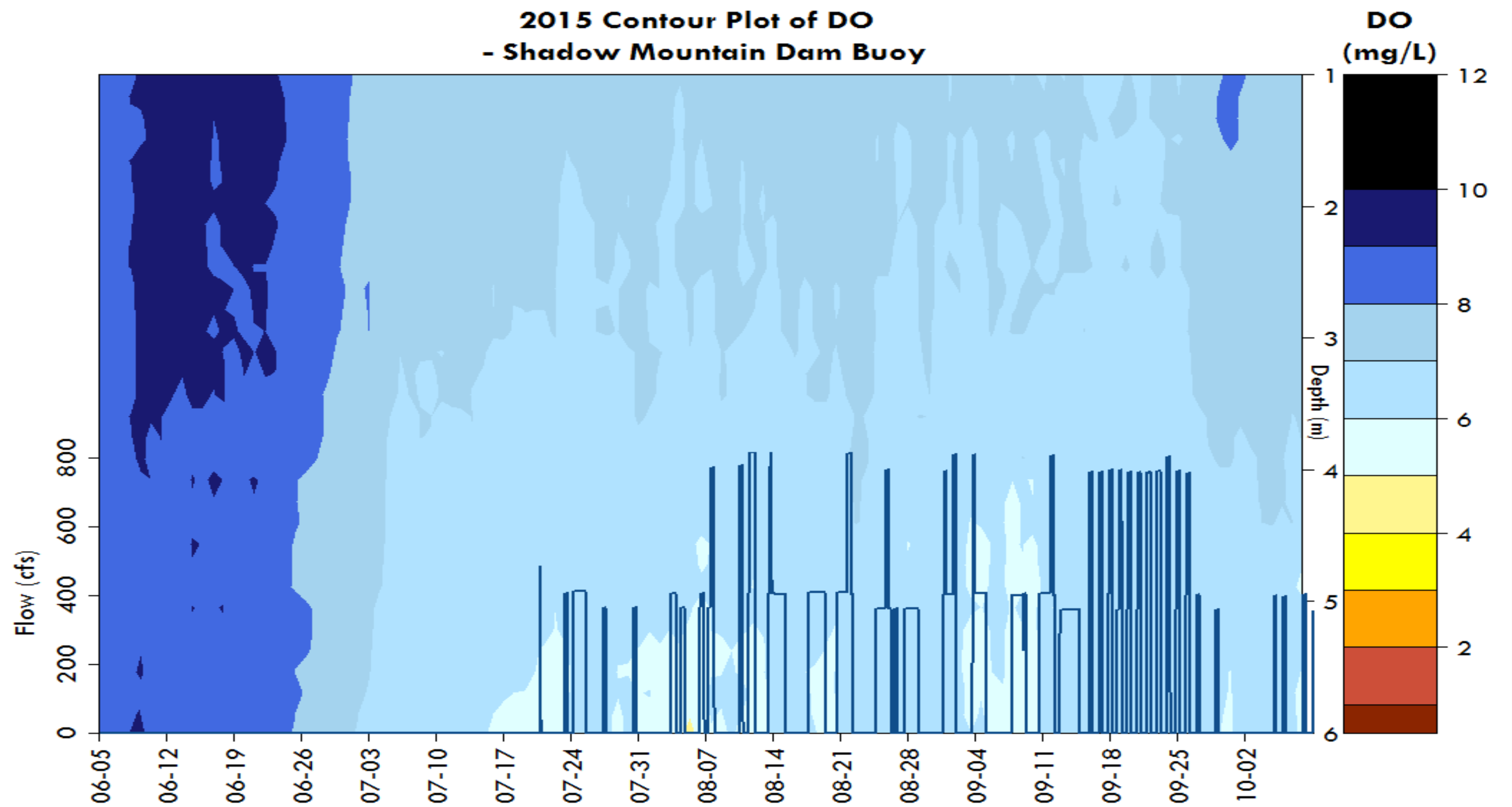

2007 Grand Lake Secchi, Jul-To Date Minimum with Farr Pumping Flows
Flow (cfs)
Secchi (m)
Date
Farr Pump
Jul-To Date Min
GL Min Goal

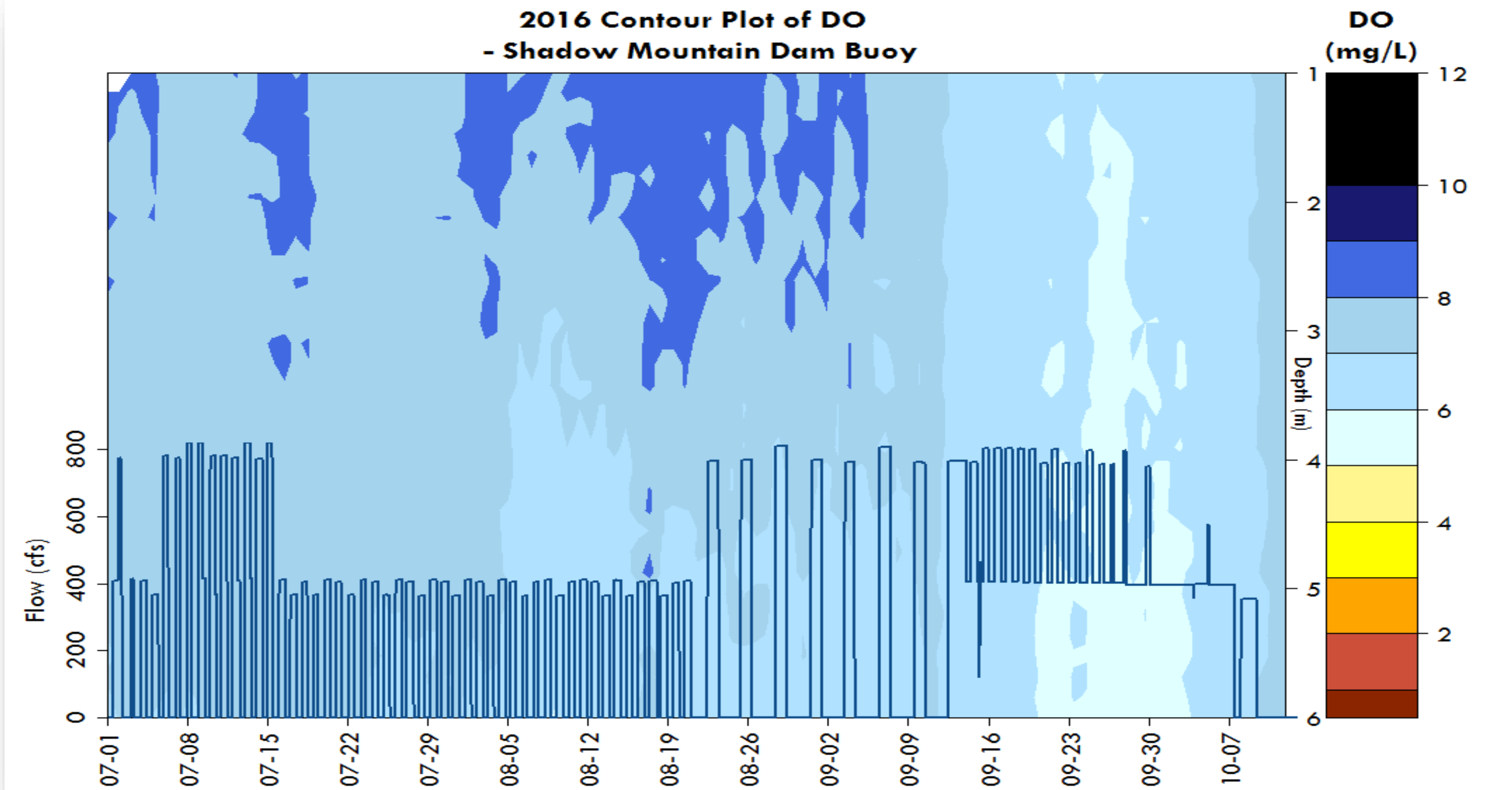
SHADOW MOUNTAIN RESERVOIR DAM

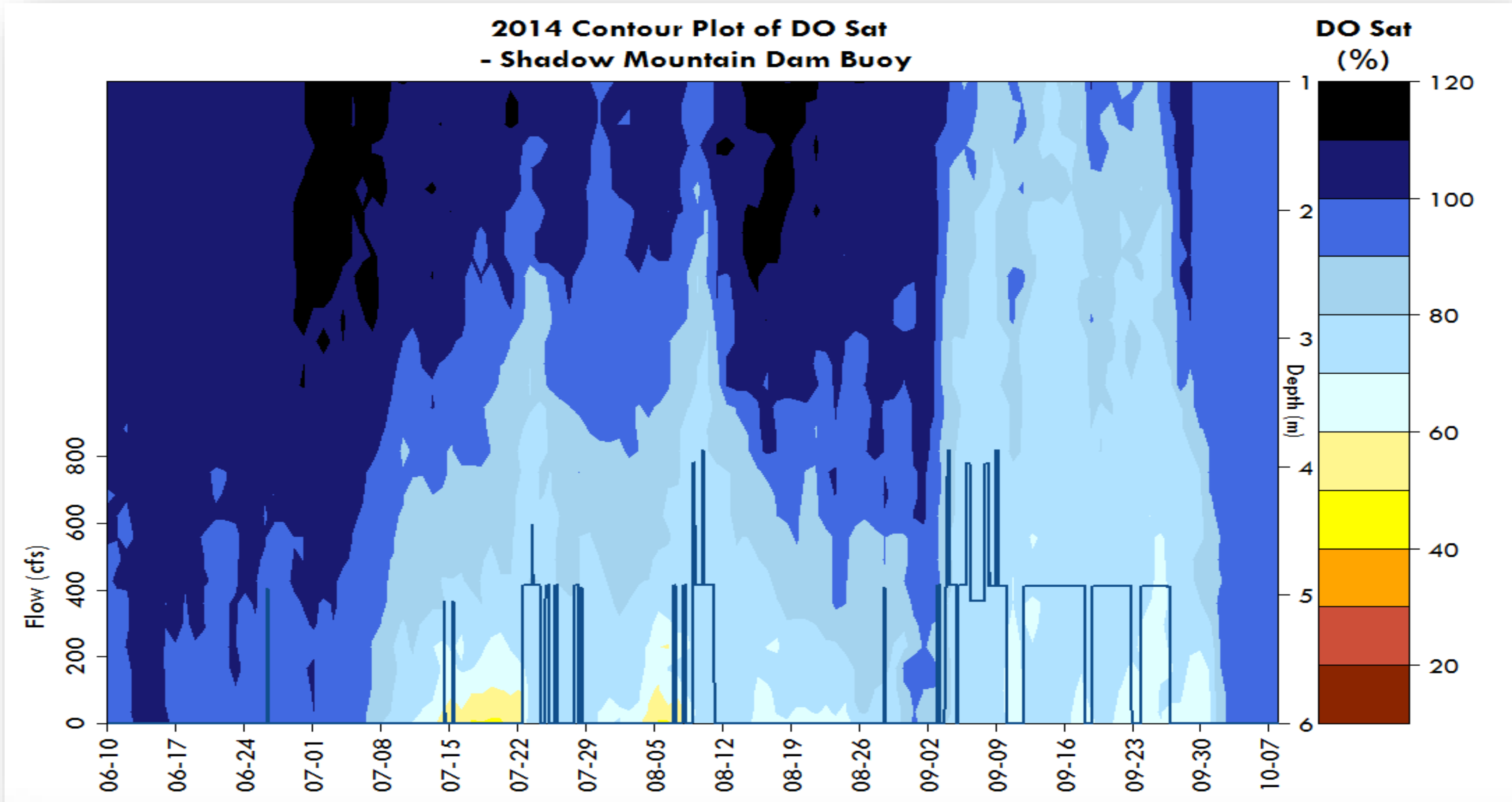
2013-2016 Contour Plots

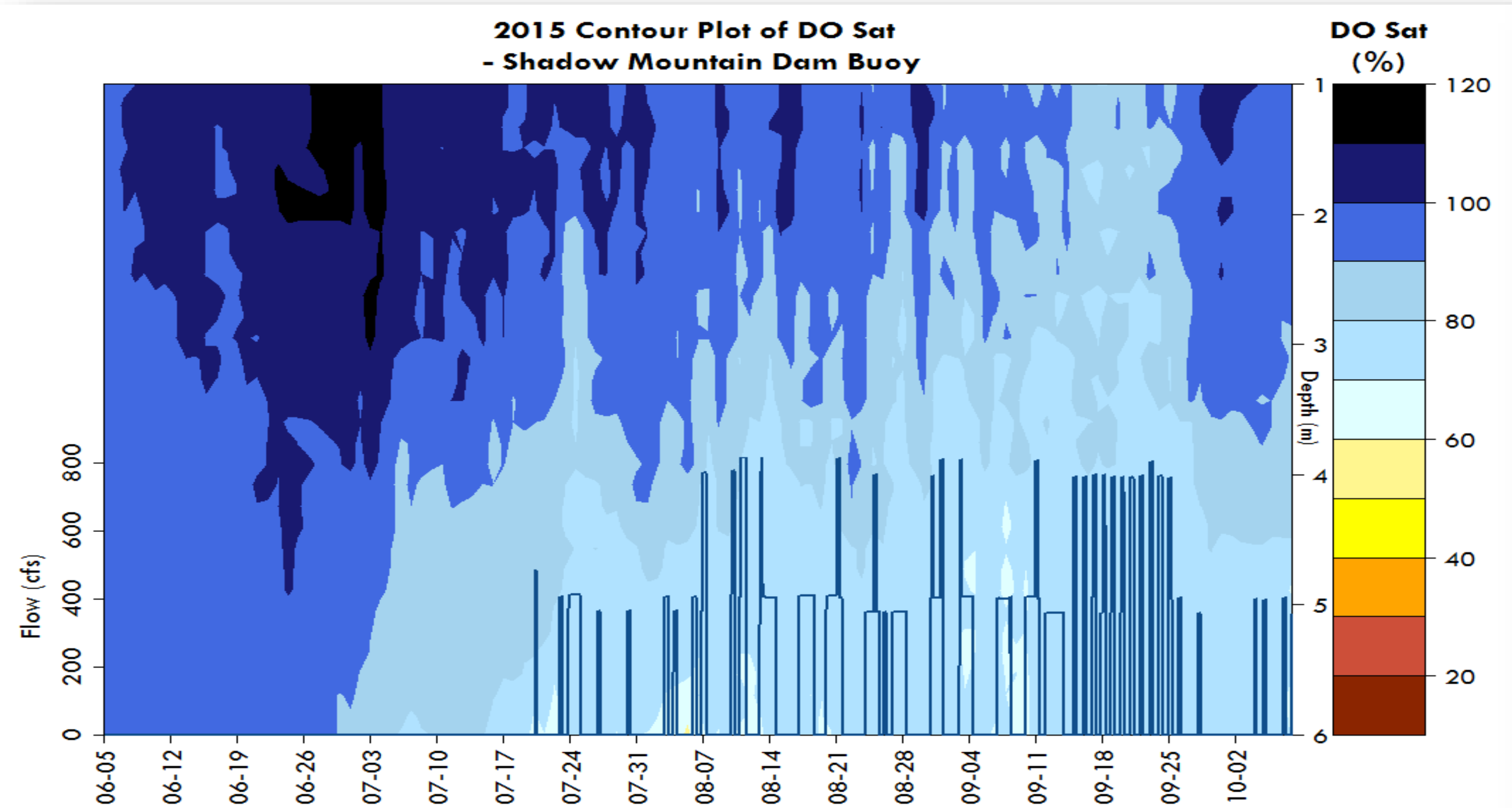

2013 Contour Plot of DO
- Shadow Mountain Dam Buoy
DO
(mg/L)
Flow (cfs)
Depth (m)

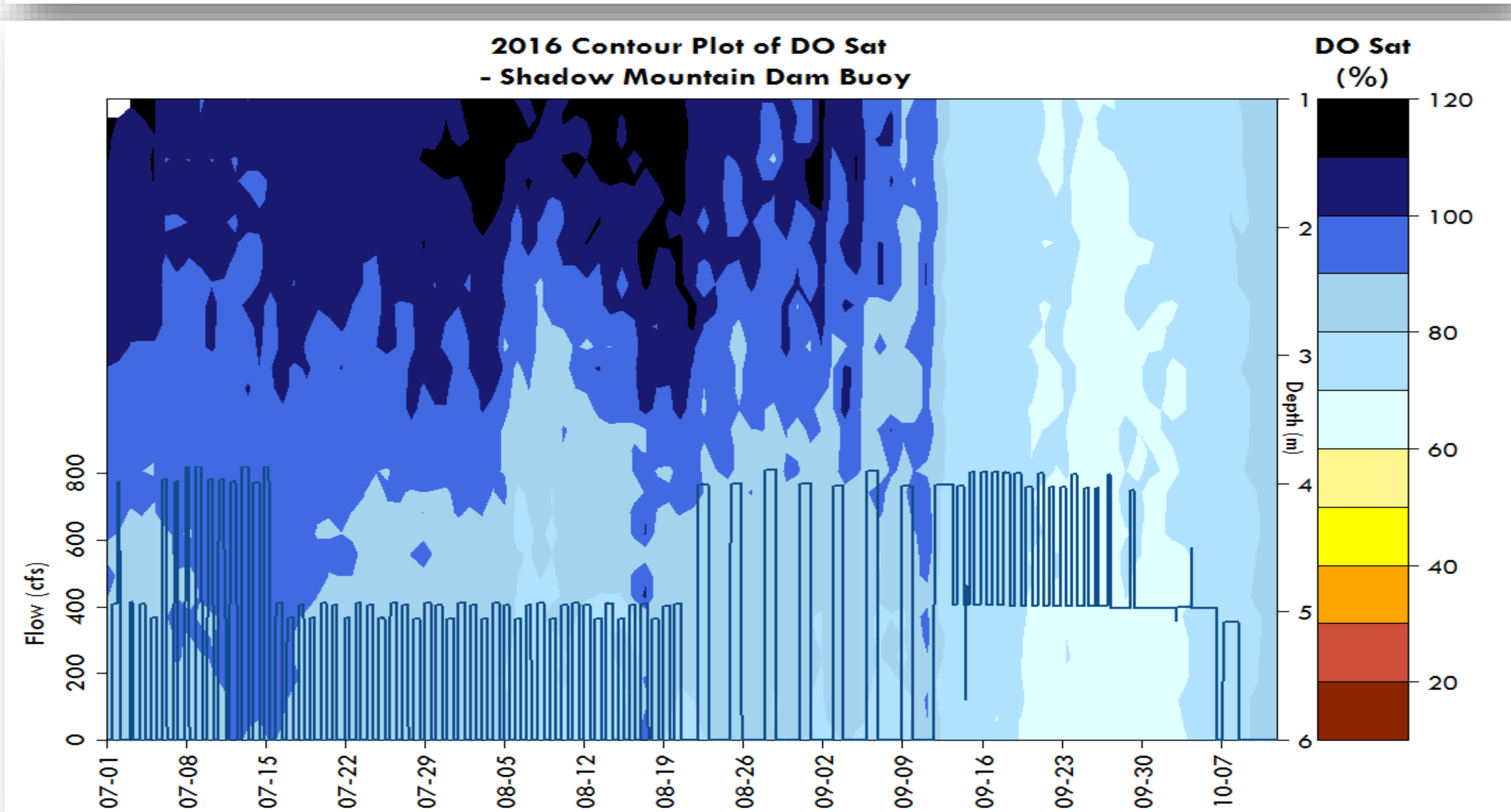

2014 Contour Plot of DO
- Shadow Mountain Dam Buoy
DO
(mg/L)
Flow (cfs)
Depth (m)

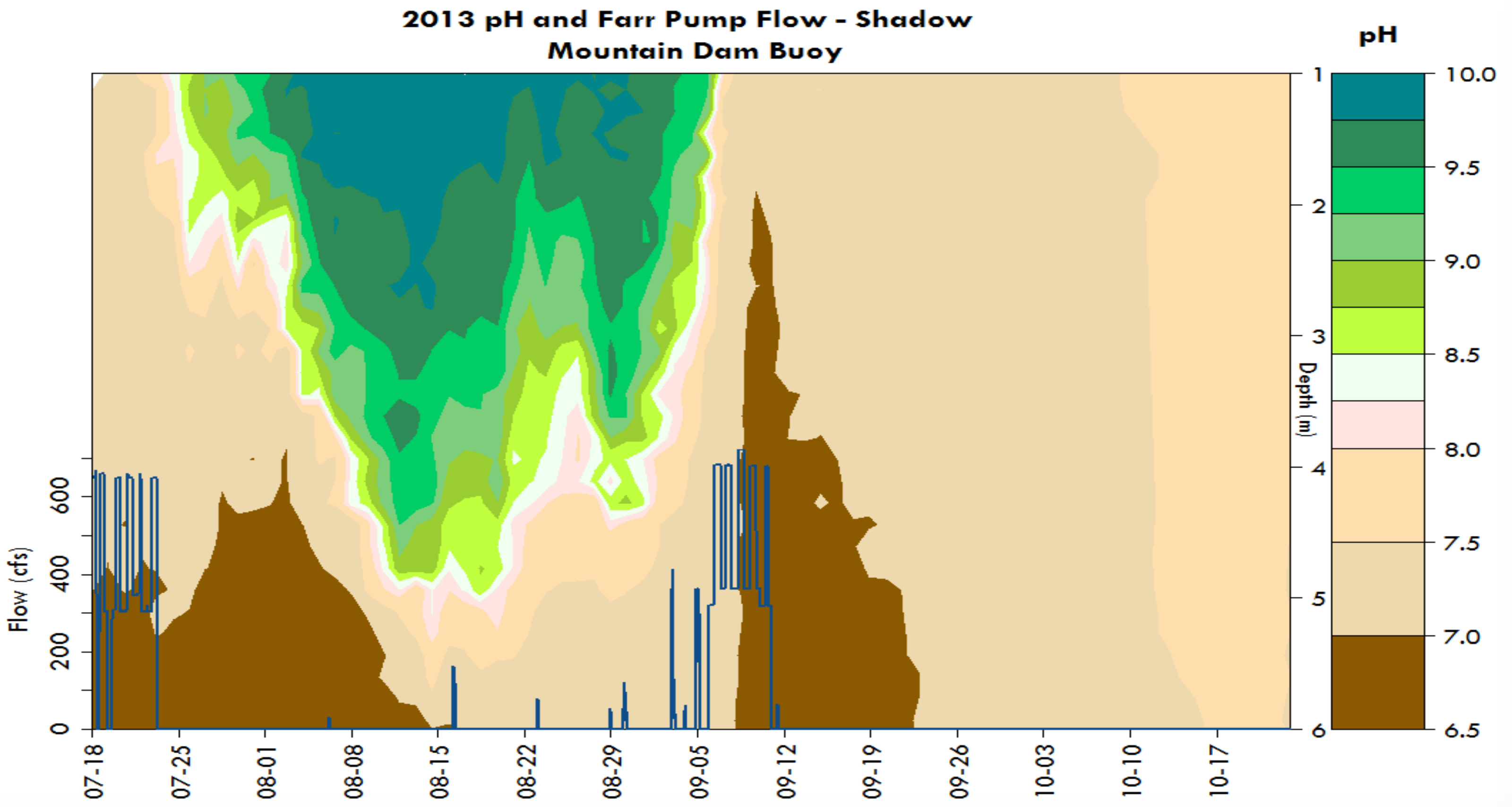

2015 Contour Plot of DO
- Shadow Mountain Dam Buoy
DO
(mg/L)
Flow (cfs)
Depth (m)


2016 Contour Plot of DO
- Shadow Mountain Dam Buoy
DO
(mg/L)
Flow (cfs)
Depth (m)

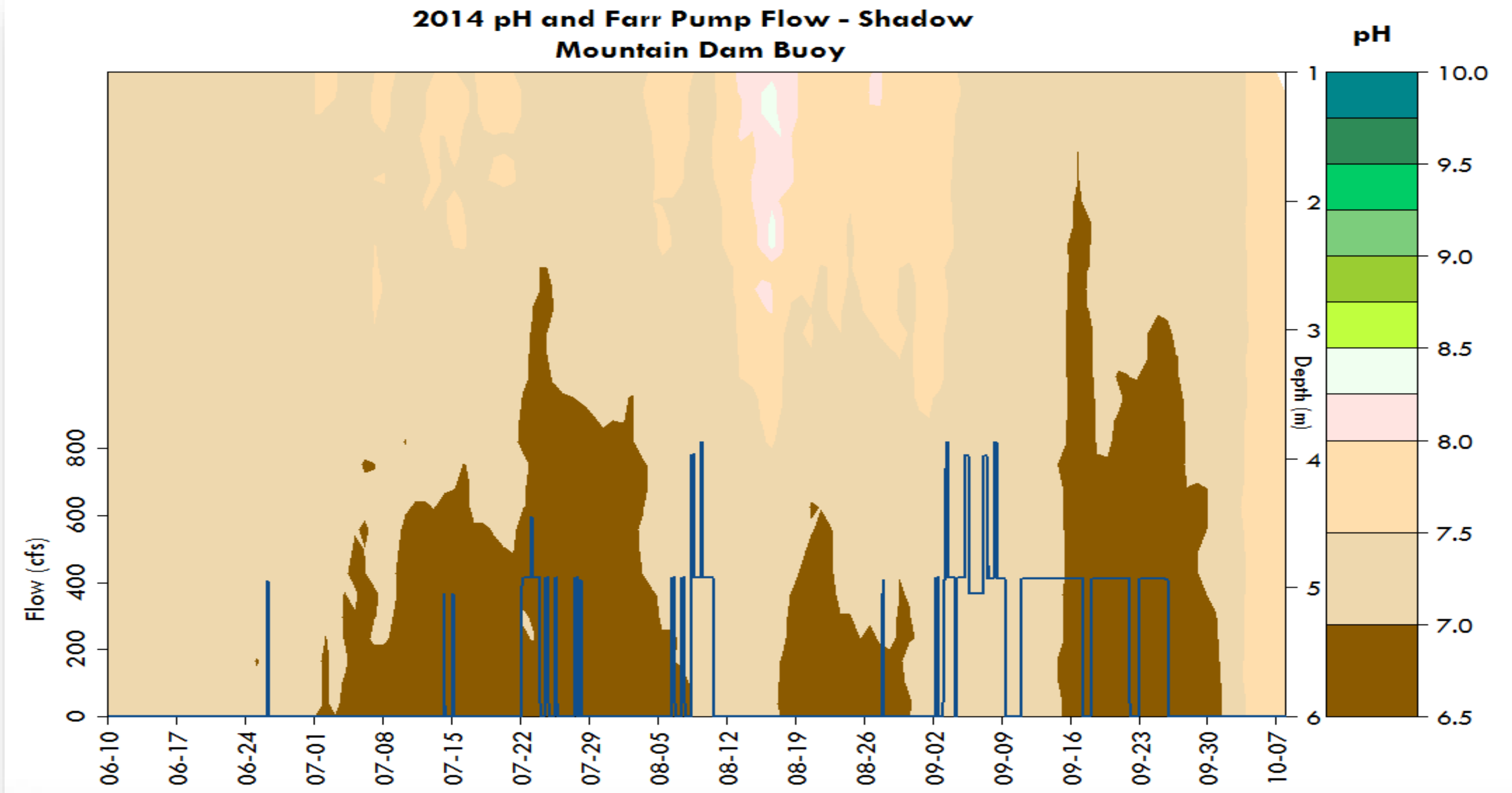

2014 Contour Plot of DO Sat
- Shadow Mountain Dam Buoy
DO Sat
(%)
120
100
80
60
40
20
Flow (cfs)
0
200
400
600
800
Depth (m)
1
2
3
4
5
6
06-10
06-17
06-24
07-01
07-08
07-15
07-22
07-29
08-05
08-12
08-19
08-26
09-02
09-09
09-16
09-23
09-30
10-07


2015 Contour Plot of DO Sat
- Shadow Mountain Dam Buoy
DO Sat
(%)
120
100
80
60
40
20
Flow (cfs)
0
200
400
600
800
Depth (m)
1
2
3
4
5
6
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02

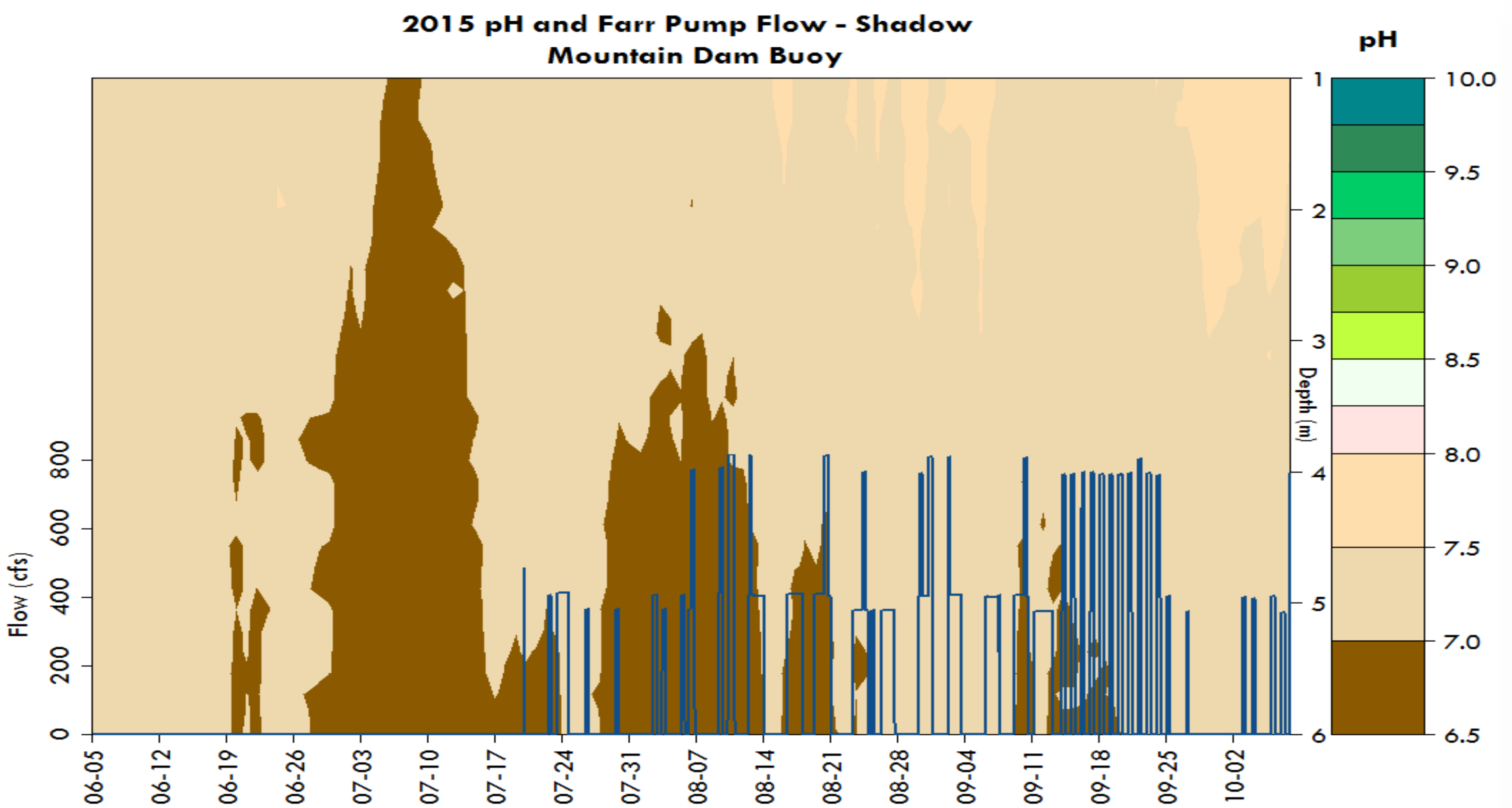

2016 Contour Plot of DO Sat
- Shadow Mountain Dam Buoy
DO Sat
(%)
120
100
80
60
40
20
Flow (cfs)
0
200
400
600
800
Depth (m)
1
2
3
4
5
6
07-01
07-08
07-15
07-22
07-29
08-05
08-12
08-19
08-26
09-02
09-09
09-16
09-23
09-30
10-07



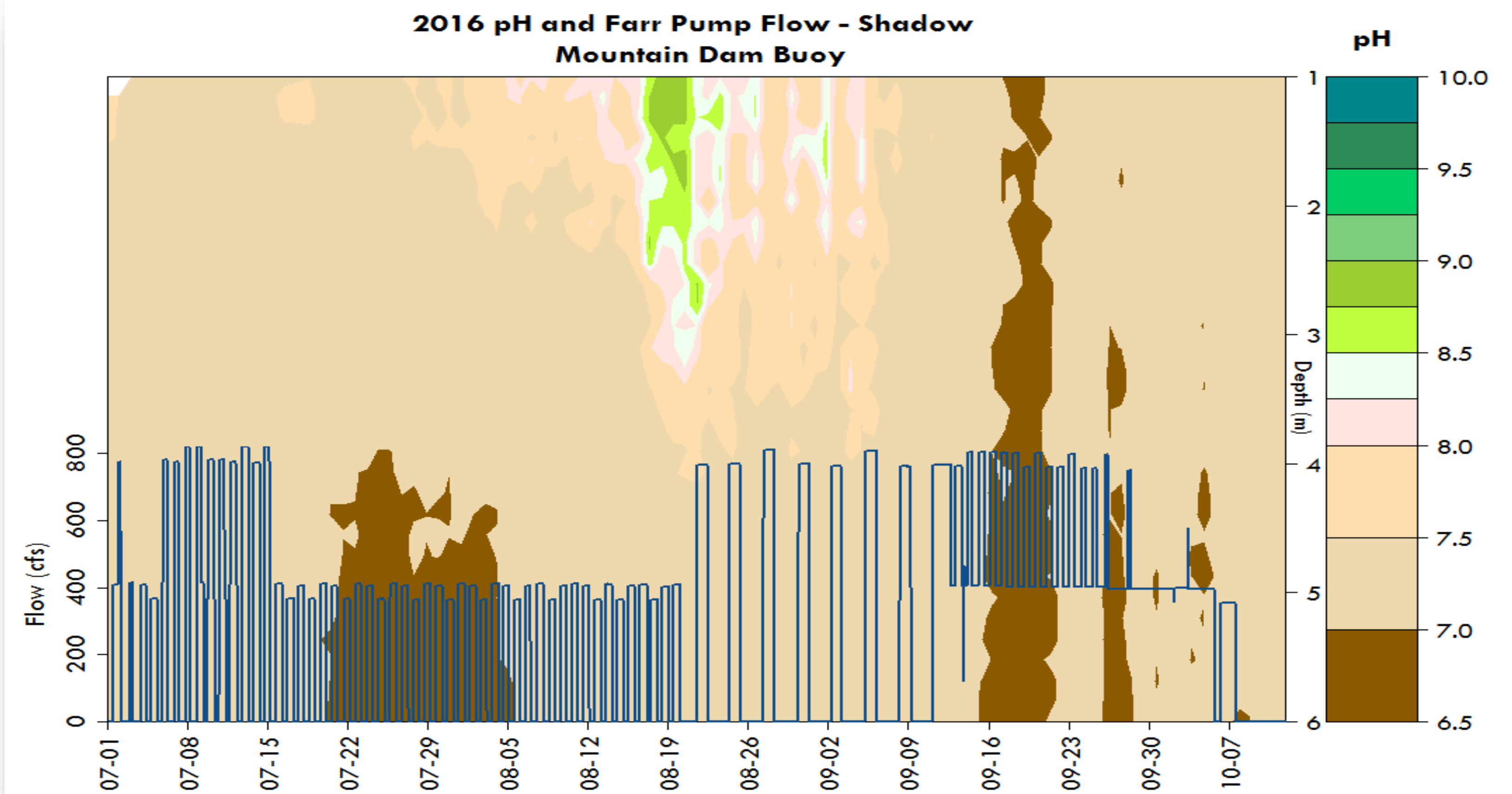
2013 pH and Farr Pump Flow - Shadow Mountain Dam Buoy
pH
Flow (cfs)
Depth (m)



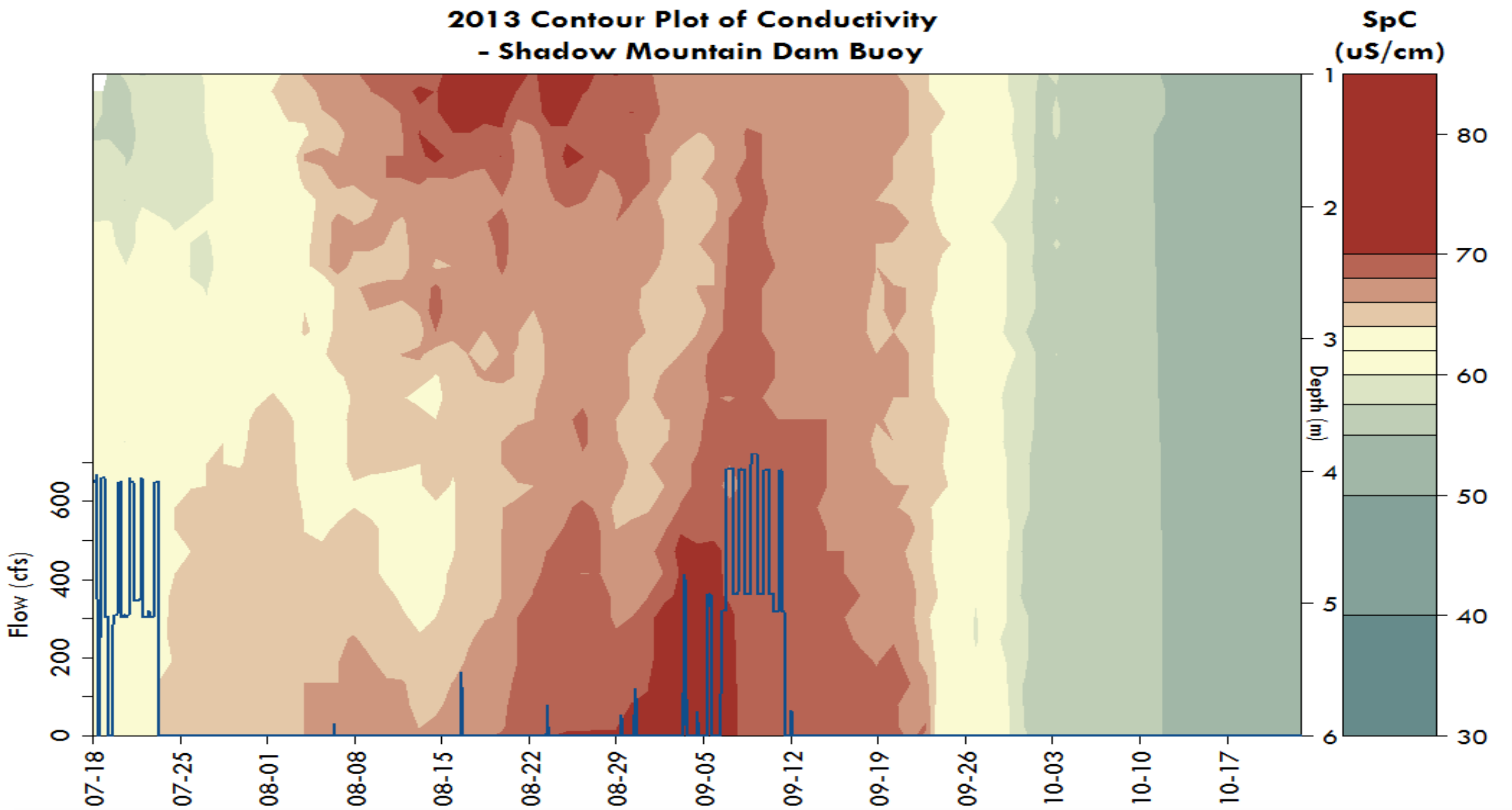
2014 pH and Farr Pump Flow - Shadow Mountain Dam Buoy
pH
Flow (cfs)
Depth (m)

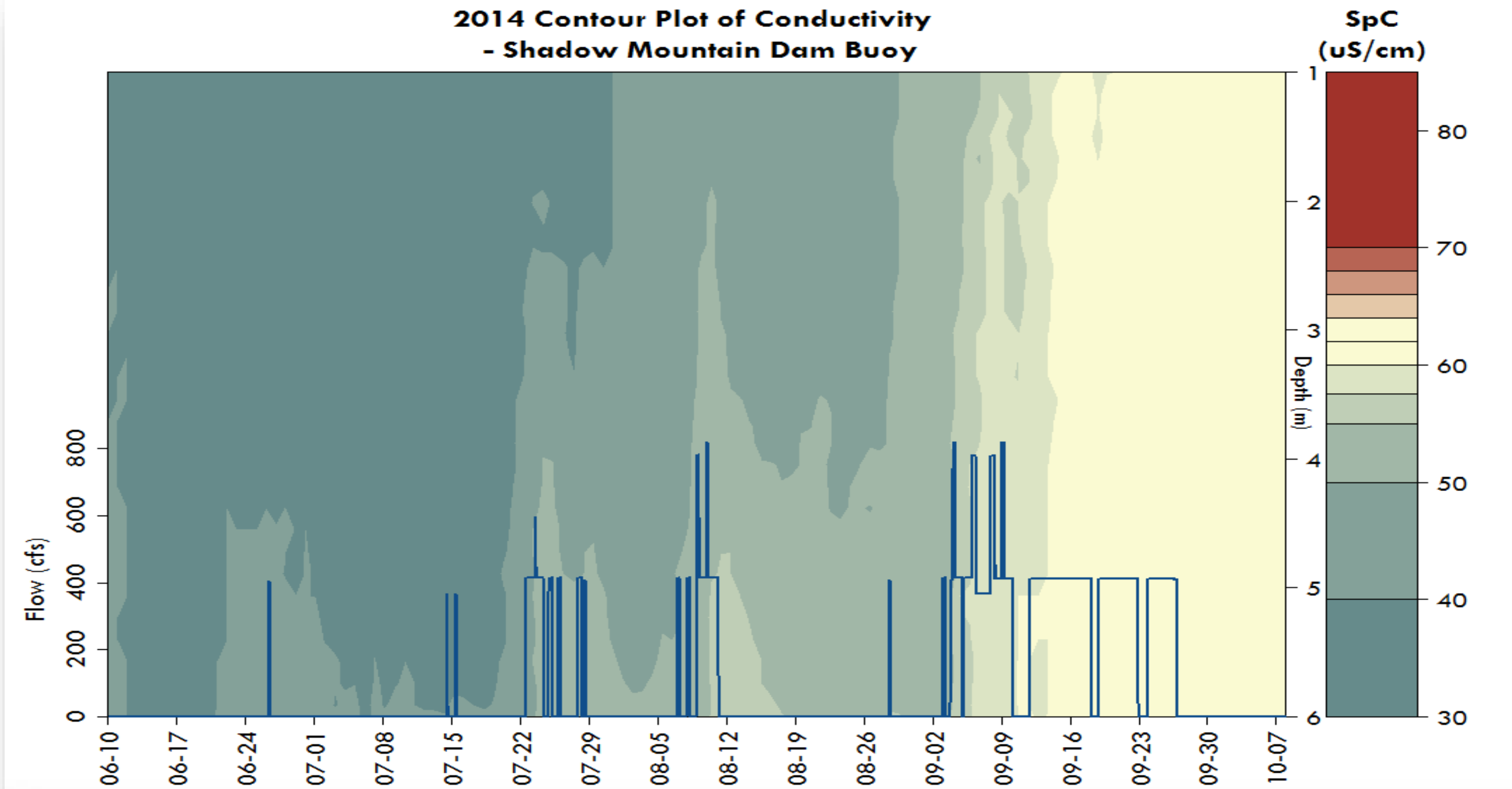


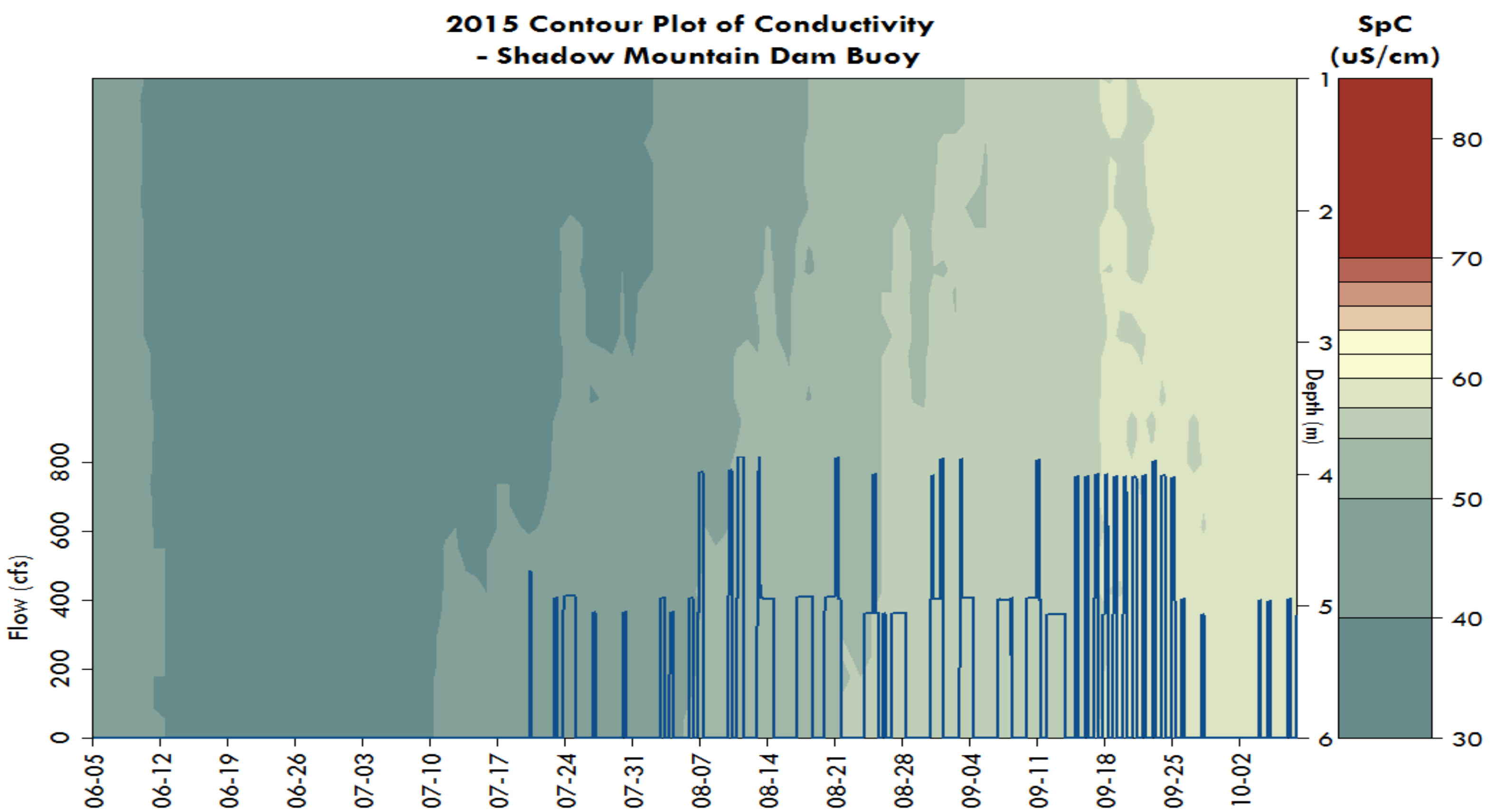
2015 pH and Farr Pump Flow - Shadow Mountain Dam Buoy
pH
Flow (cfs)
Depth (m)

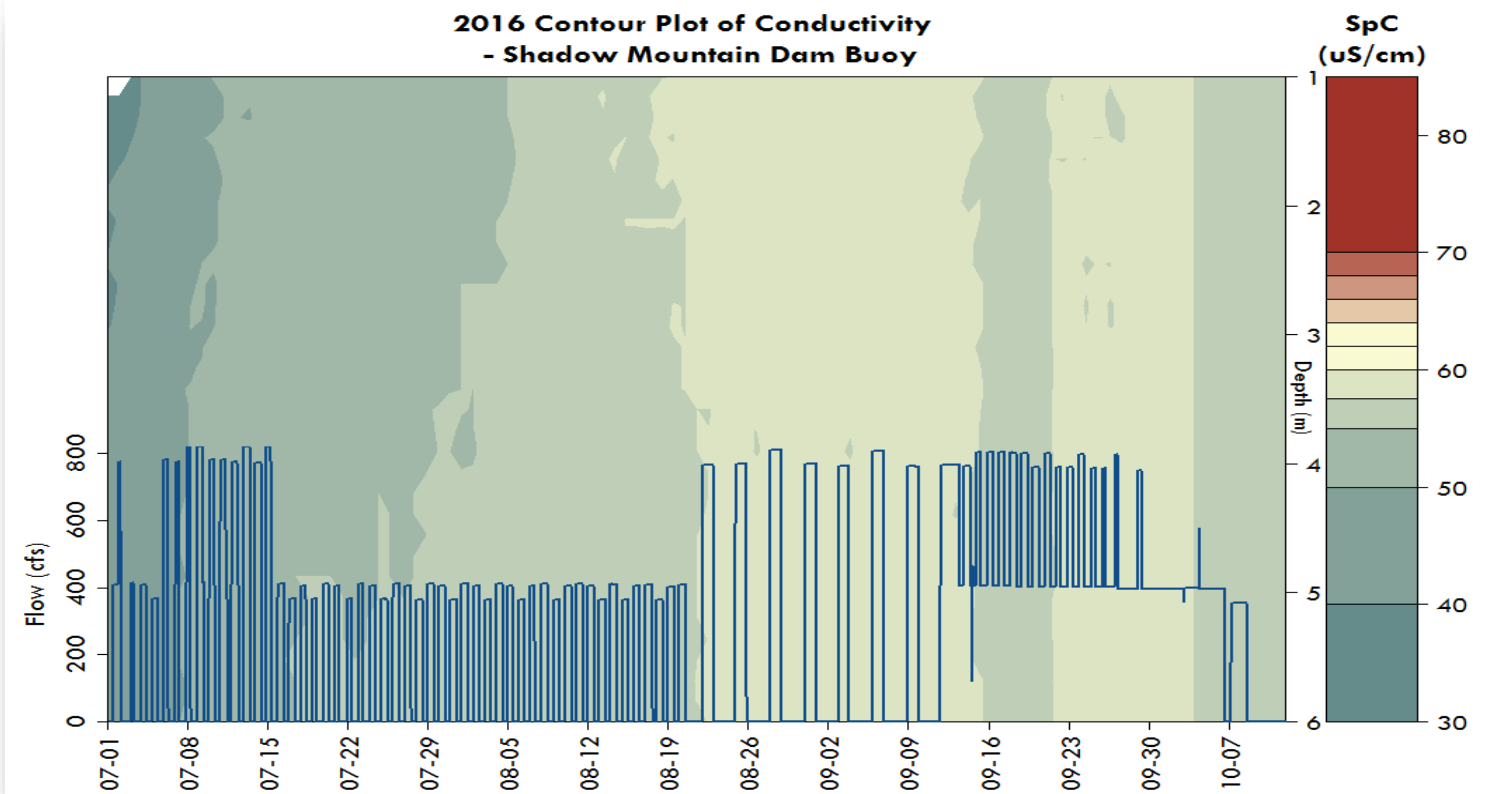


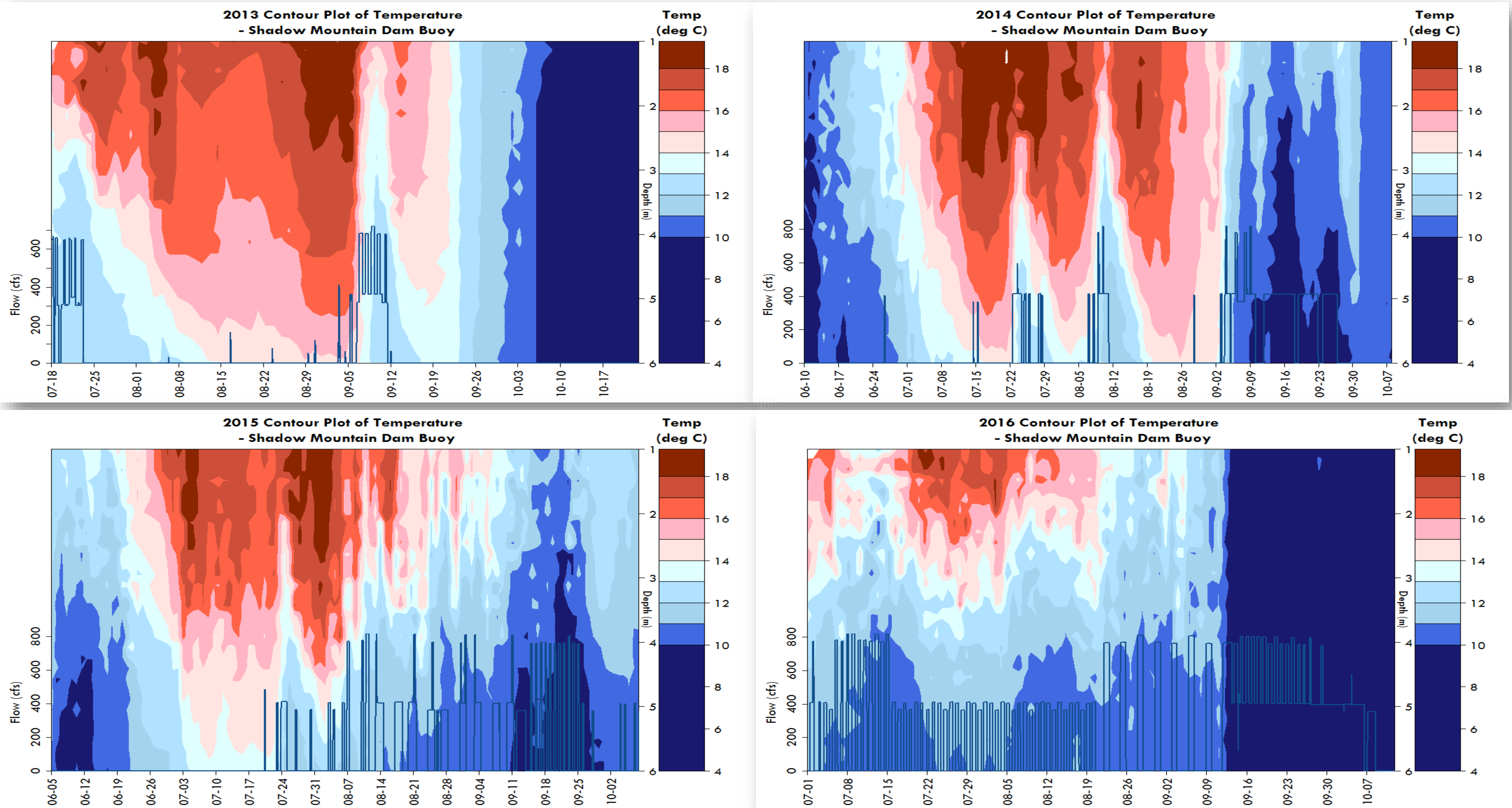
2016 pH and Farr Pump Flow - Shadow Mountain Dam Buoy
pH
Flow (cfs)
Depth (m)

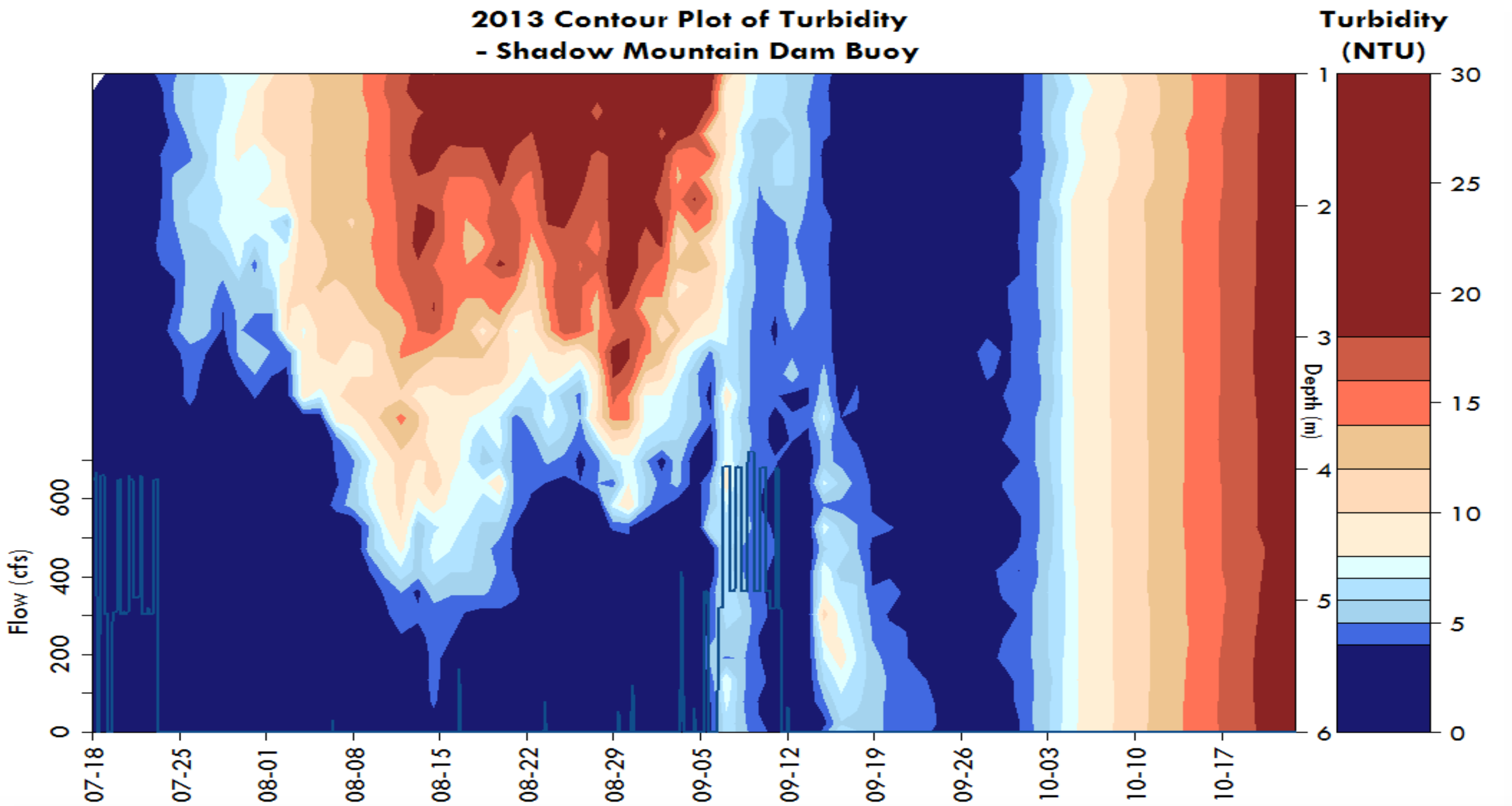

2013 Contour Plot of Conductivity
- Shadow Mountain Dam Buoy
SpC
(uS/cm)
Flow (cfs)
Depth (m)
07-18
07-25
08-01
08-08
08-15
08-22
08-29
09-05
09-12
09-19
09-26
10-03
10-10
10-17

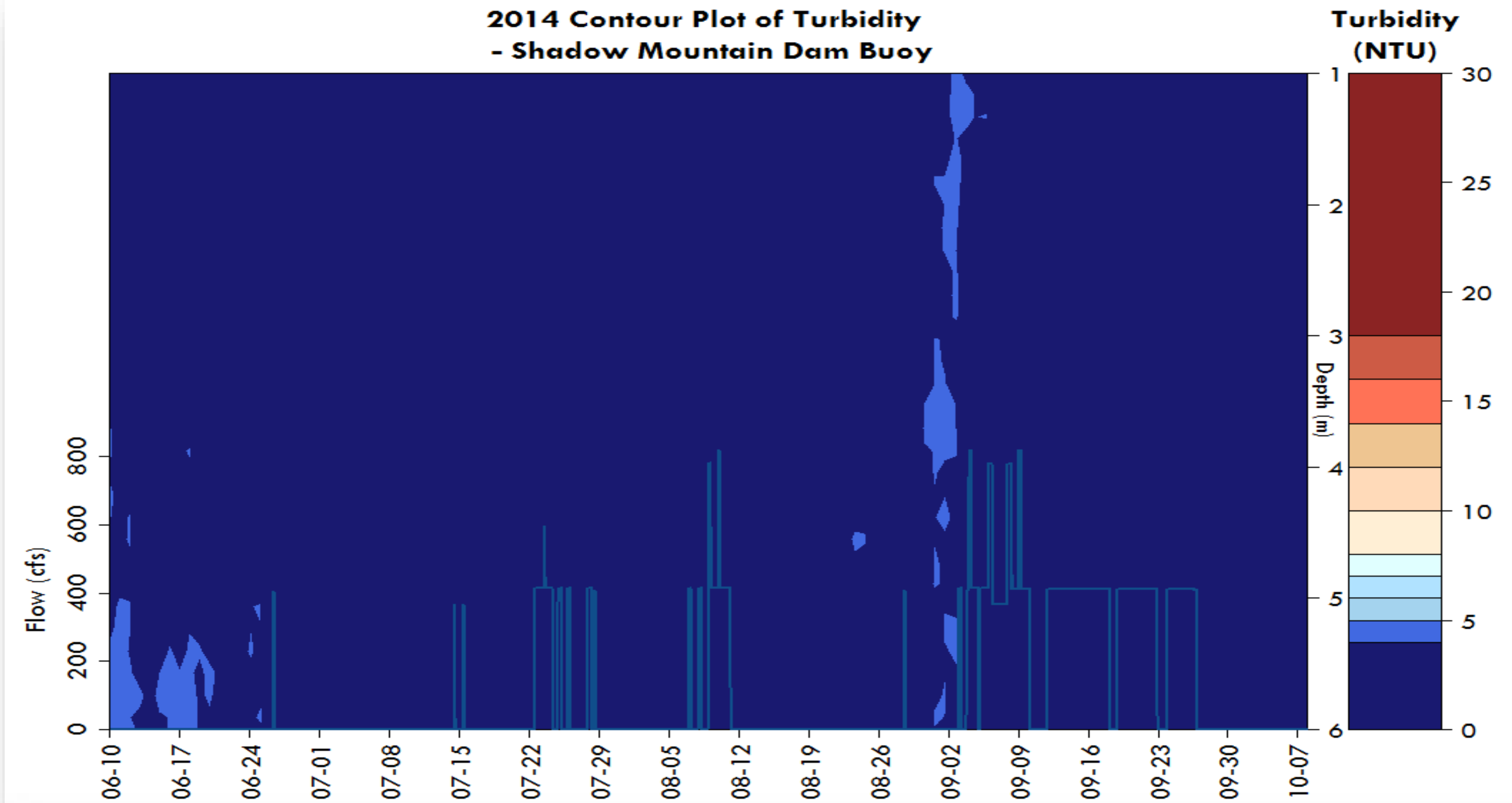

2014 Contour Plot of Conductivity
- Shadow Mountain Dam Buoy
SpC
(uS/cm)
Flow (cfs)
Depth (m)
06-10
06-17
06-24
07-01
07-08
07-15
07-22
07-29
08-05
08-12
08-19
08-26
09-02
09-09
09-16
09-23
09-30
10-07

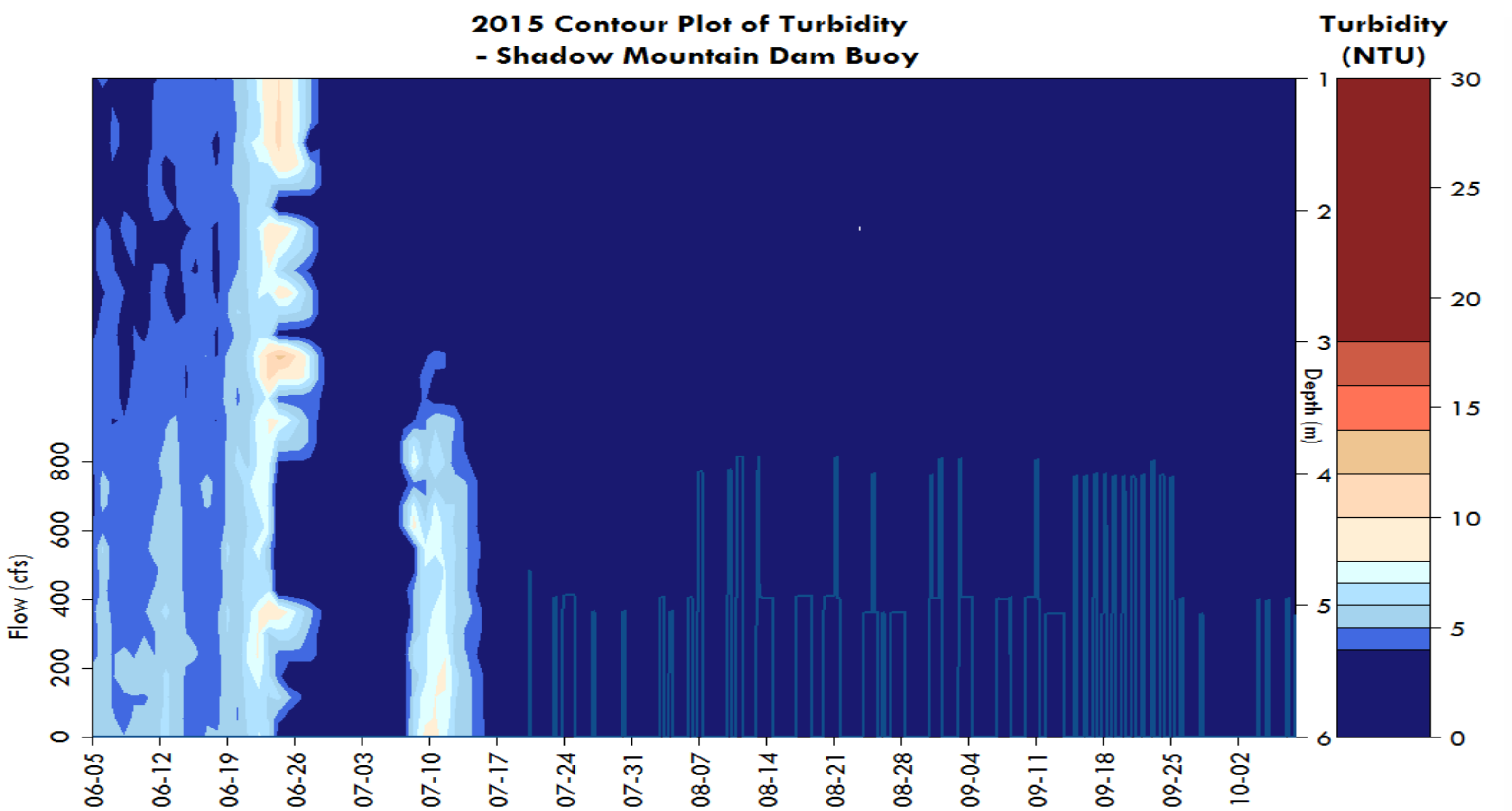

2015 Contour Plot of Conductivity
- Shadow Mountain Dam Buoy
SpC
(uS/cm)
Flow (cfs)
Depth (m)
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02

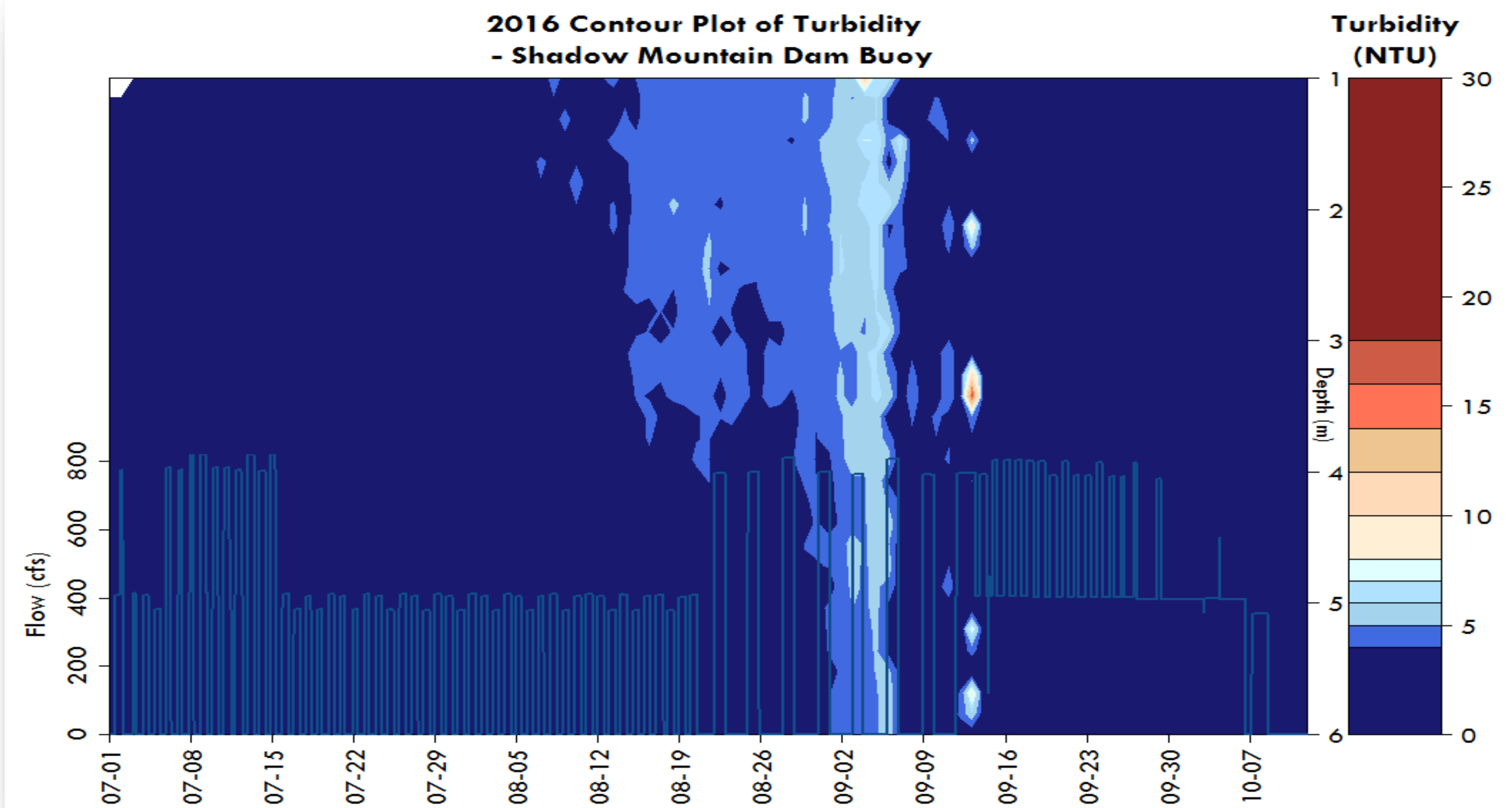

2016 Contour Plot of Conductivity
- Shadow Mountain Dam Buoy
SpC
(uS/cm)
Flow (cfs)
Depth (m)
07-01
07-08
07-15
07-22
07-29
08-05
08-12
08-19
08-26
09-02
09-09
09-16
09-23
09-30
10-07


2013 Contour Plot of Temperature
- Shadow Mountain Dam Buoy
Temp (deg C)
Flow (cfs)
Depth (m)
2014 Contour Plot of Temperature
- Shadow Mountain Dam Buoy
2015 Contour Plot of Temperature
- Shadow Mountain Dam Buoy
2016 Contour Plot of Temperature
- Shadow Mountain Dam Buoy


2013 Contour Plot of Turbidity - Shadow Mountain Dam Buoy
Turbidity (NTU)
Flow (cfs)
Depth (m)
07-18
07-25
08-01
08-08
08-15
08-22
08-29
09-05
09-12
09-19
09-26
10-03
10-10
10-17

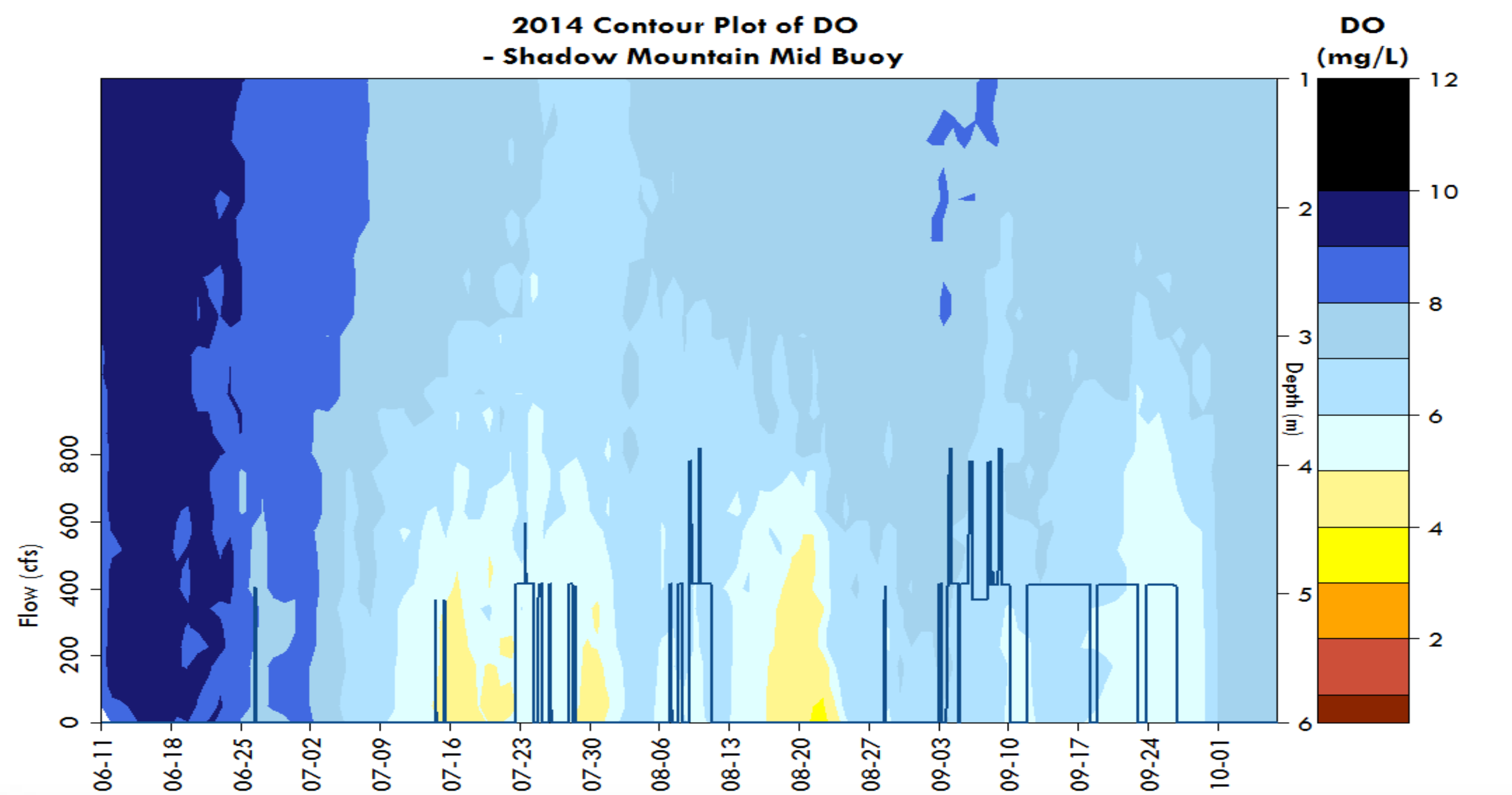

2014 Contour Plot of Turbidity - Shadow Mountain Dam Buoy
Turbidity (NTU)
Flow (cfs)
Depth (m)
06-10
06-17
06-24
07-01
07-08
07-15
07-22
07-29
08-05
08-12
08-19
08-26
09-02
09-09
09-16
09-23
09-30
10-07


2015 Contour Plot of Turbidity - Shadow Mountain Dam Buoy
Turbidity (NTU)
Flow (cfs)
Depth (m)
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02

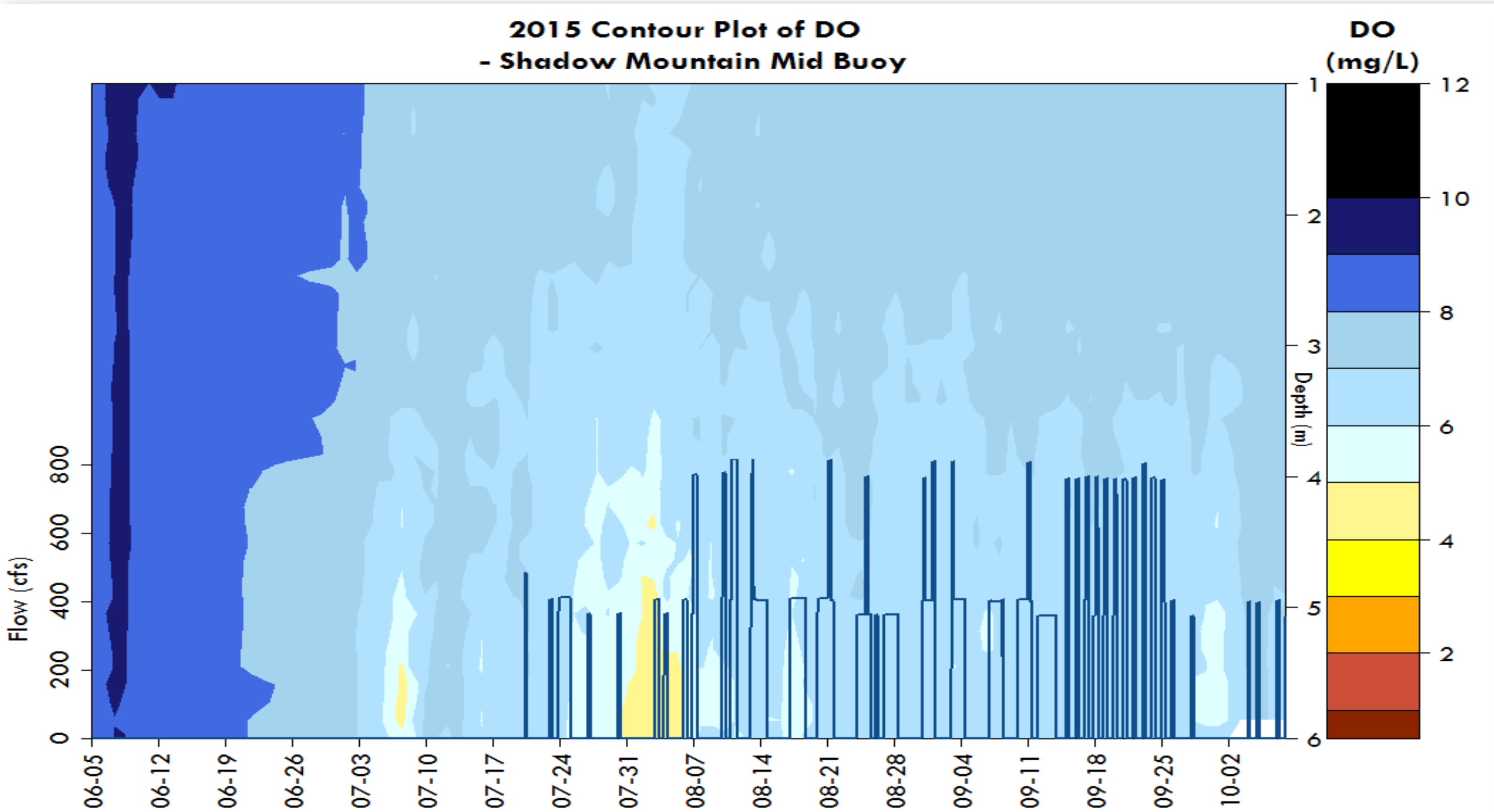

2016 Contour Plot of Turbidity - Shadow Mountain Dam Buoy
Turbidity (NTU)
Flow (cfs)
Depth (m)
07-01
07-08
07-15
07-22
07-29
08-05
08-12
08-19
08-26
09-02
09-09
09-16
09-23
09-30
10-07

SHADOW MOUNTAIN RESERVOIR MID

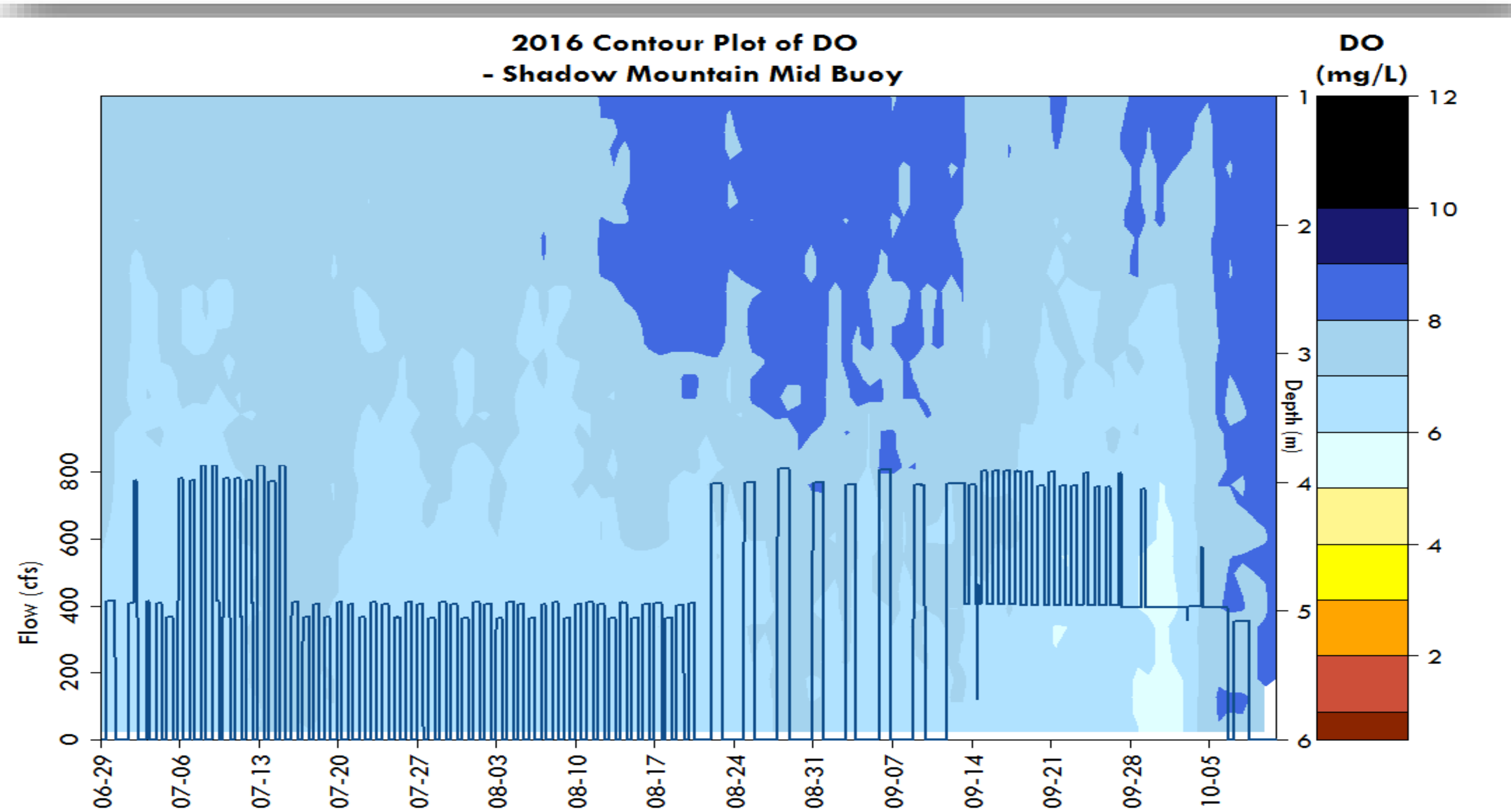
2014-2016 Contour Plots



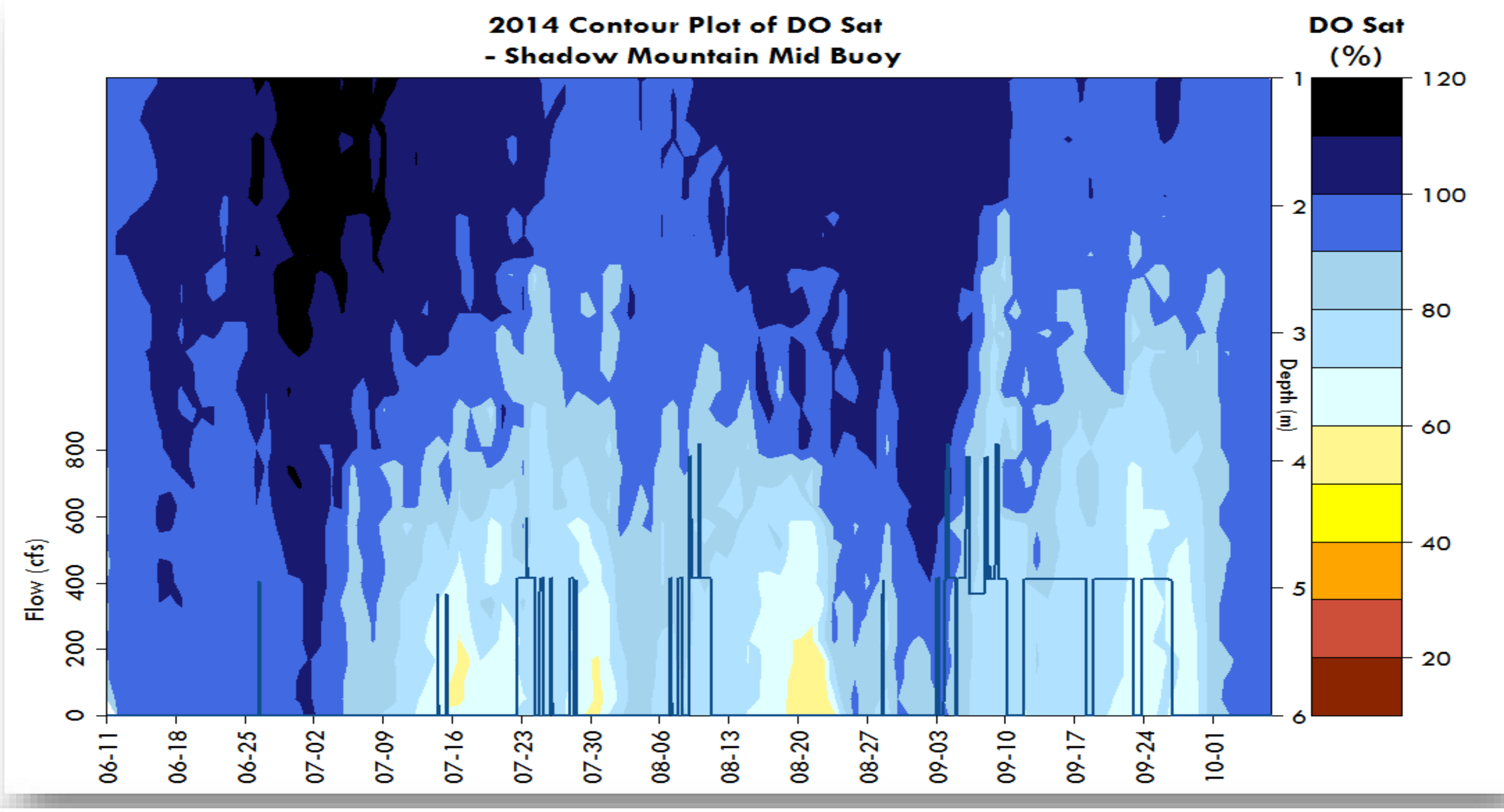
2014 Contour Plot of DO
- Shadow Mountain Mid Buoy
DO (mg/L)
Flow (cfs)
Depth (m)
06-11 06-18 06-25 07-02 07-09 07-16 07-23 07-30 08-06 08-13 08-20 08-27 09-03 09-10 09-17 09-24 10-01

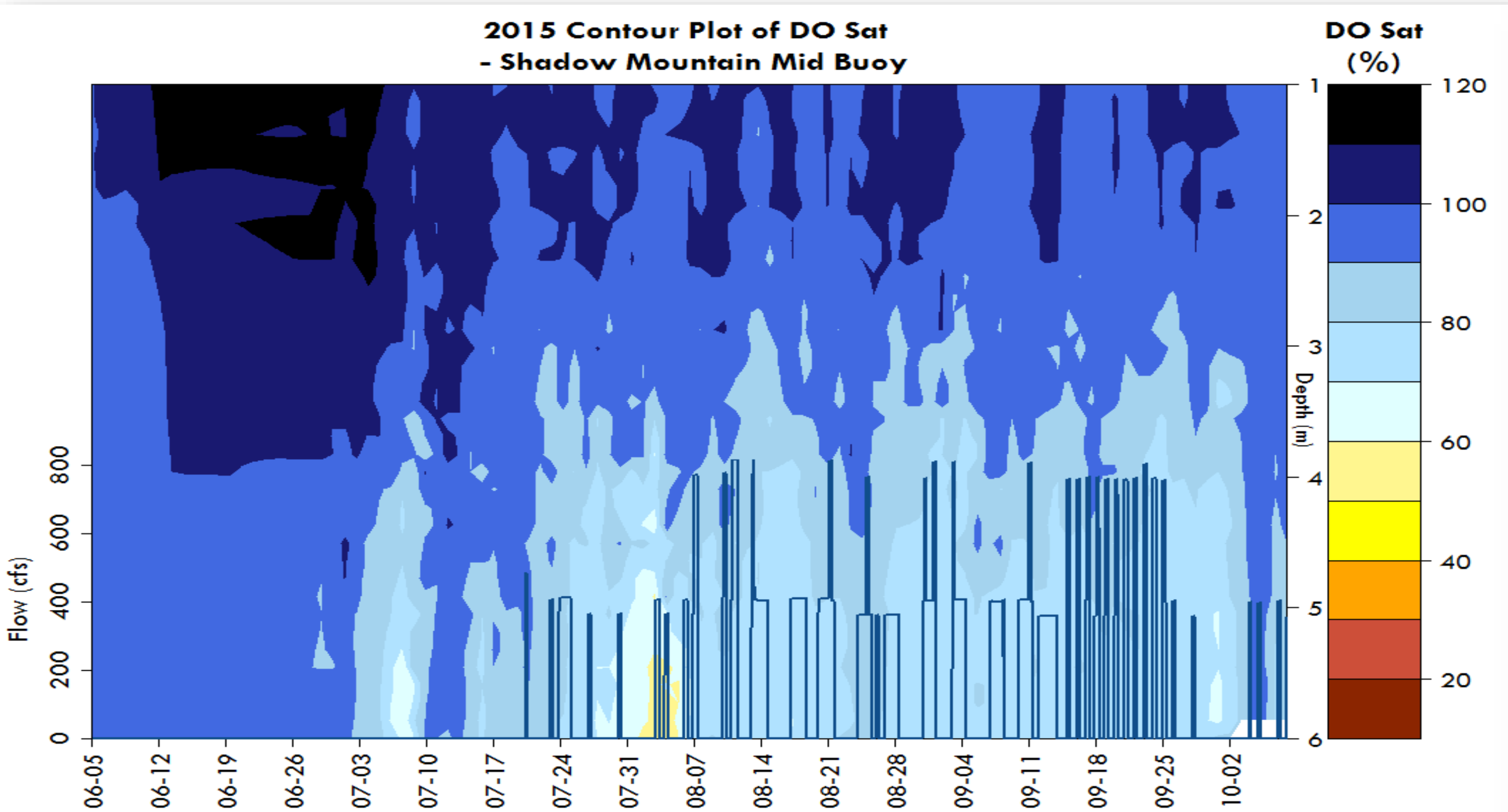


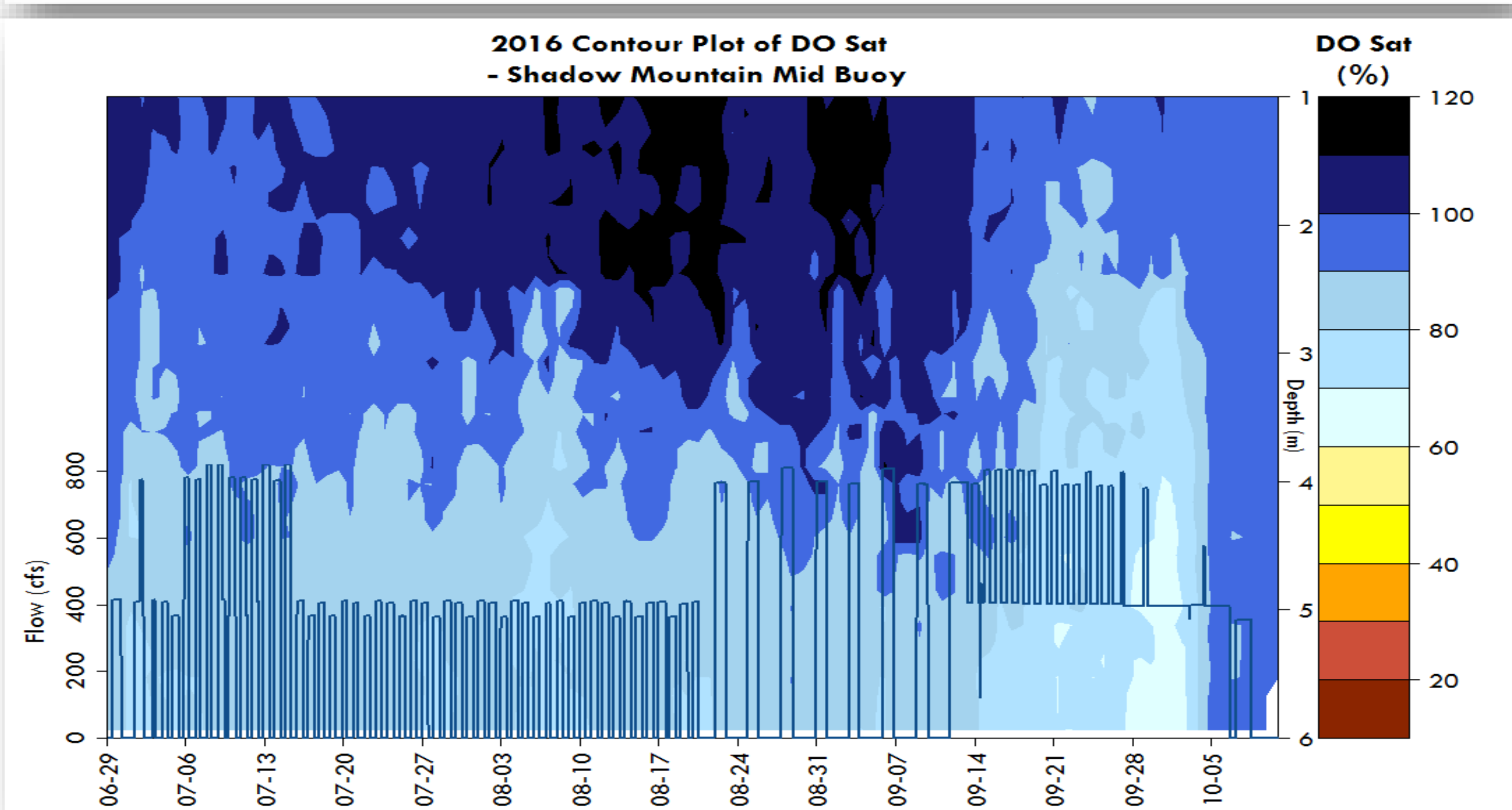
2015 Contour Plot of DO
- Shadow Mountain Mid Buoy
DO (mg/L)
Flow (cfs)
Depth (m)
06-05 06-12 06-19 06-26 07-03 07-10 07-17 07-24 07-31 08-07 08-14 08-21 08-28 09-04 09-11 09-18 09-25 10-02

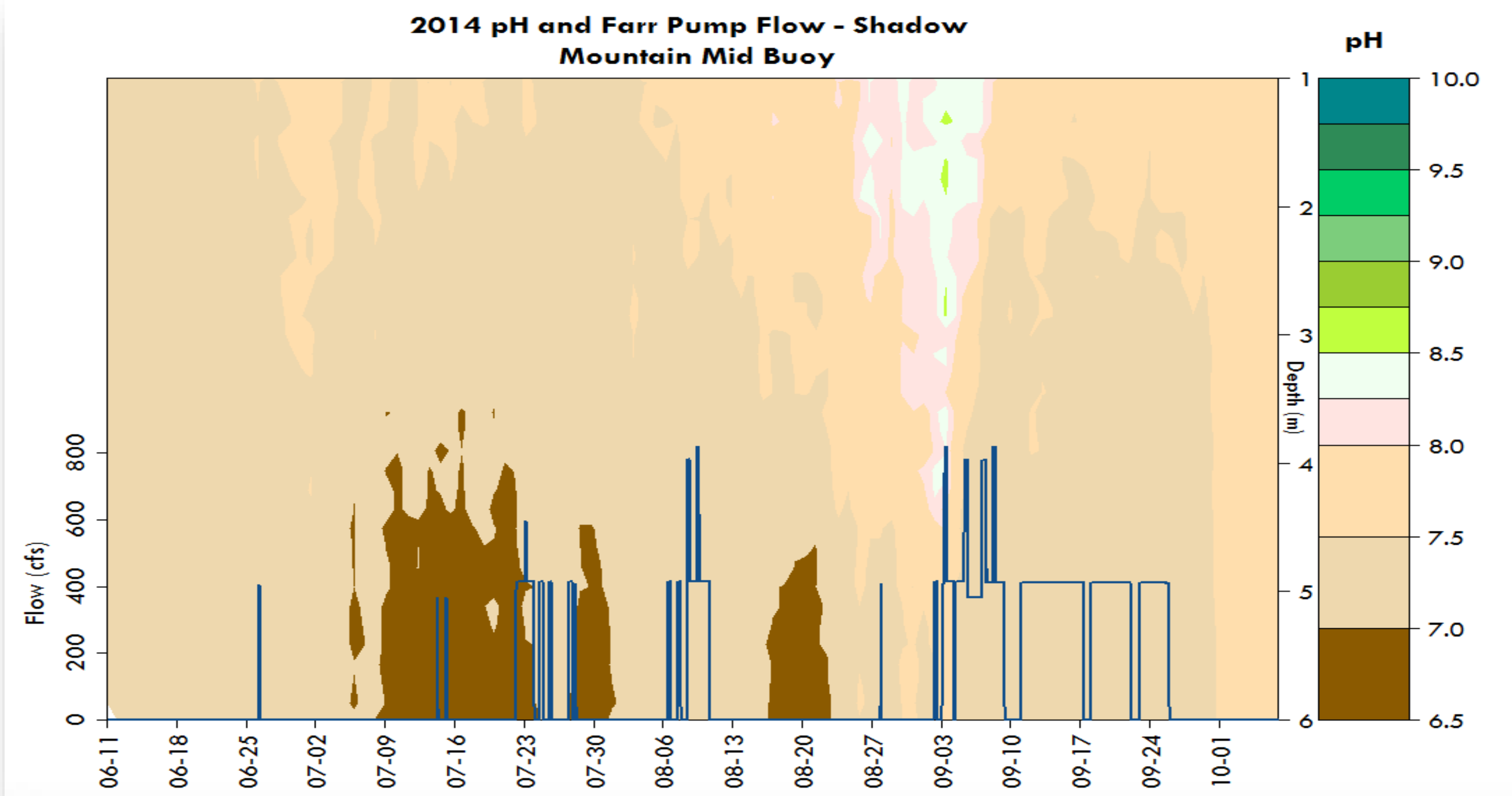


2016 Contour Plot of DO
- Shadow Mountain Mid Buoy
DO (mg/L)
Flow (cfs)
Depth (m)
06-29 07-06 07-13 07-20 07-27 08-03 08-10 08-17 08-24 08-31 09-07 09-14 09-21 09-28 10-05


2014 Contour Plot of DO Sat
- Shadow Mountain Mid Buoy
DO Sat (%)
Flow (cfs)
Depth (m)
06-11
06-18
06-25
07-02
07-09
07-16
07-23
07-30
08-06
08-13
08-20
08-27
09-03
09-10
09-17
09-24
10-01


2015 Contour Plot of DO Sat
- Shadow Mountain Mid Buoy
DO Sat (%)
Flow (cfs)
Depth (m)
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02


2016 Contour Plot of DO Sat
- Shadow Mountain Mid Buoy
DO Sat (%)
Flow (cfs)
Depth (m)
06-29
07-06
07-13
07-20
07-27
08-03
08-10
08-17
08-24
08-31
09-07
09-14
09-21
09-28
10-05



2014 pH and Farr Pump Flow - Shadow Mountain Mid Buoy
pH
Flow (cfs)
Depth (m)
06-11
06-18
06-25
07-02
07-09
07-16
07-23
07-30
08-06
08-13
08-20
08-27
09-03
09-10
09-17
09-24
10-01
10.0
9.5
9.0
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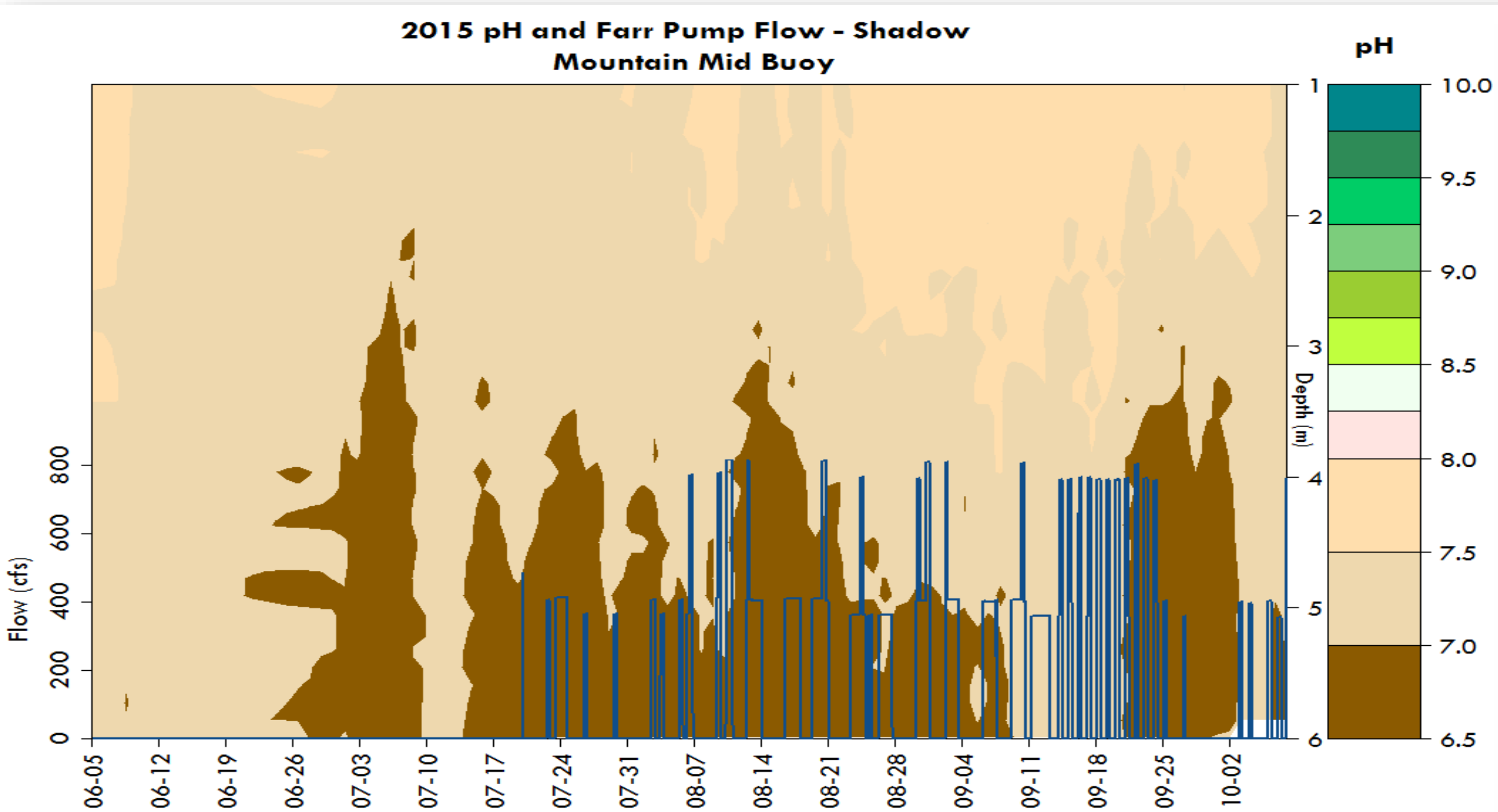
7.5
7.0
6.5



2015 pH and Farr Pump Flow - Shadow Mountain Mid Buoy
pH
Flow (cfs)
Depth (m)
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
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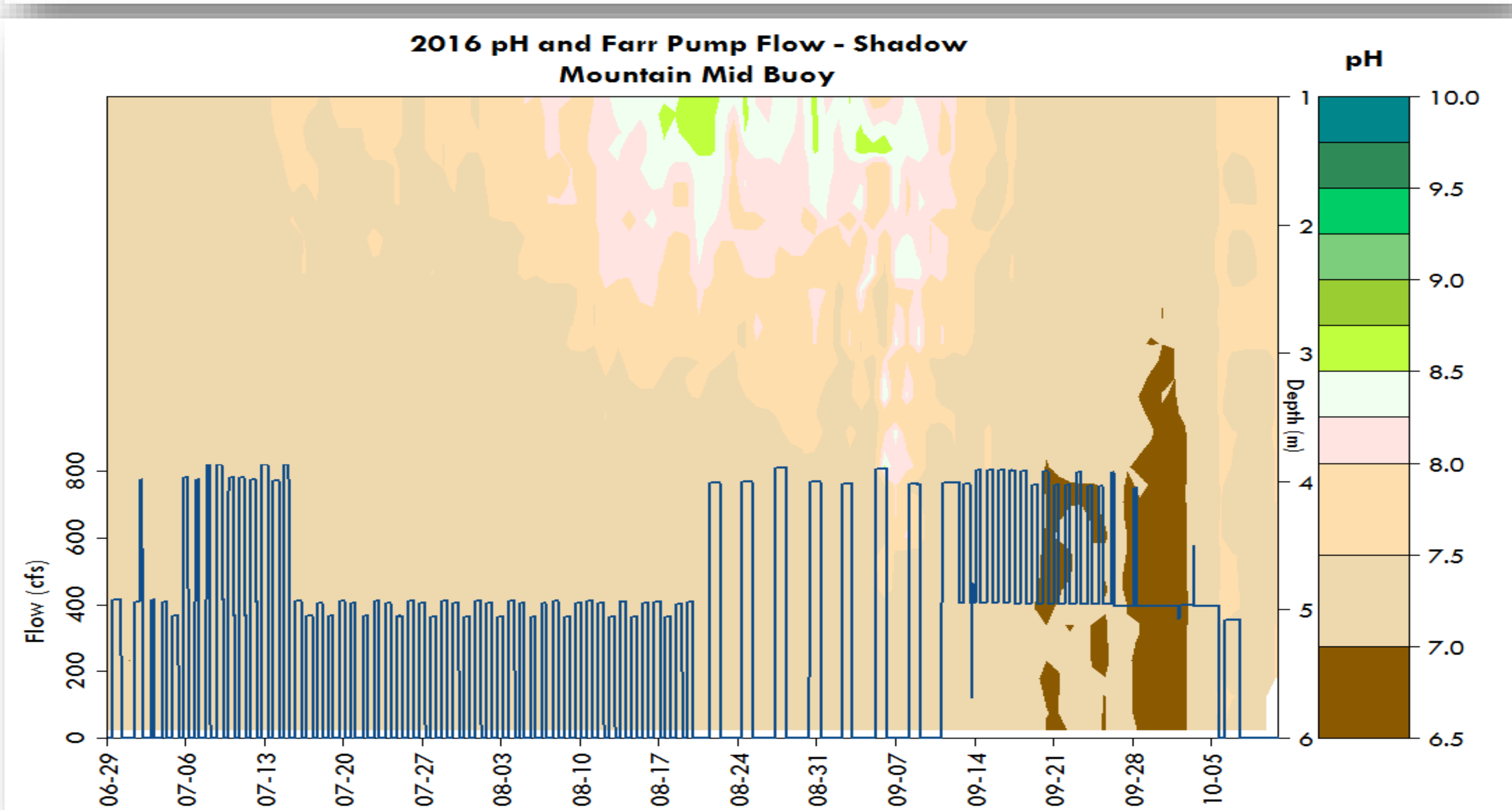
7.5
7.0
6.5



2016 pH and Farr Pump Flow - Shadow Mountain Mid Buoy
pH
Flow (cfs)
Depth (m)
06-29
07-06
07-13
07-20
07-27
08-03
08-10
08-17
08-24
08-31
09-07
09-14
09-21
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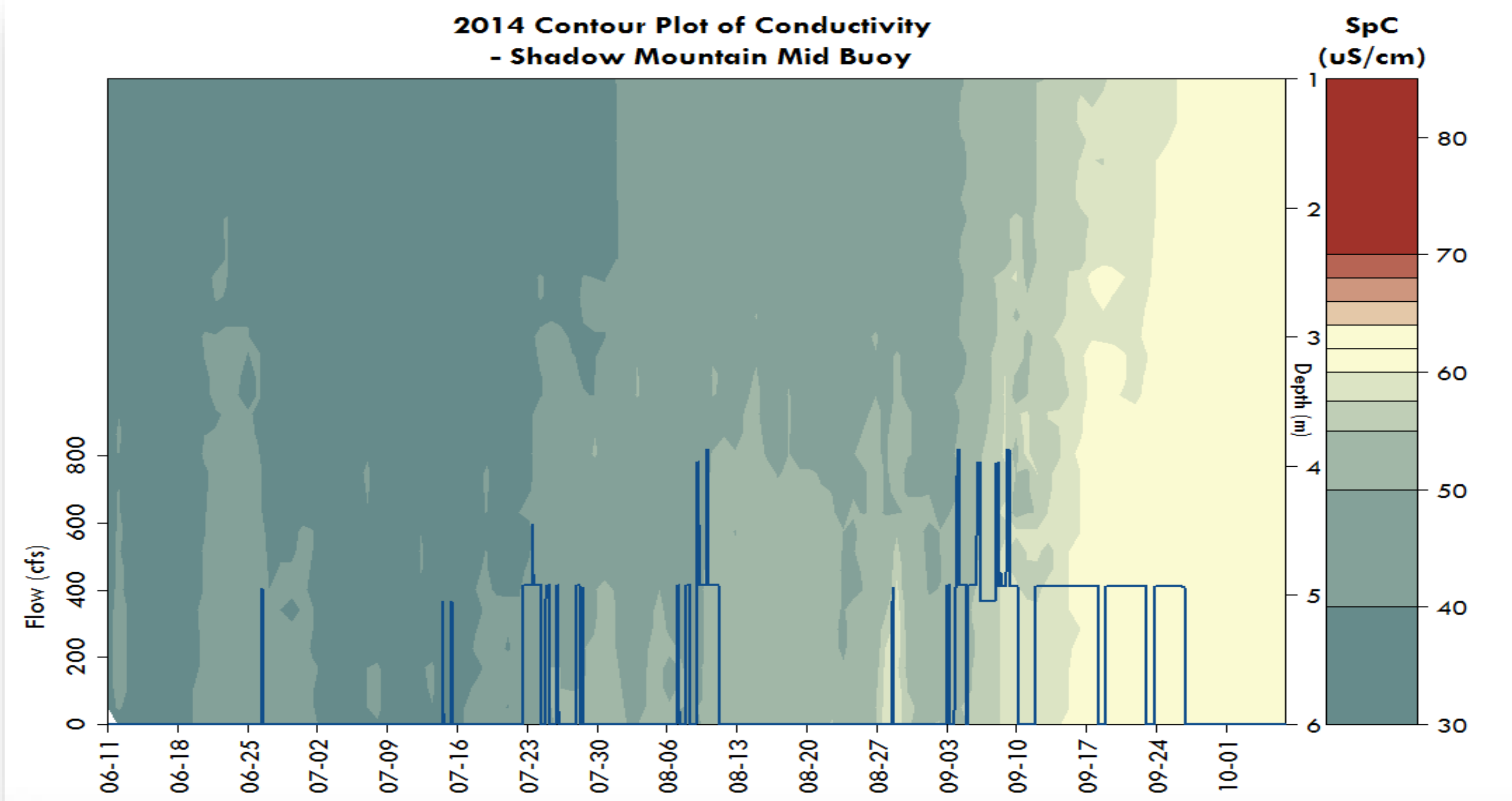
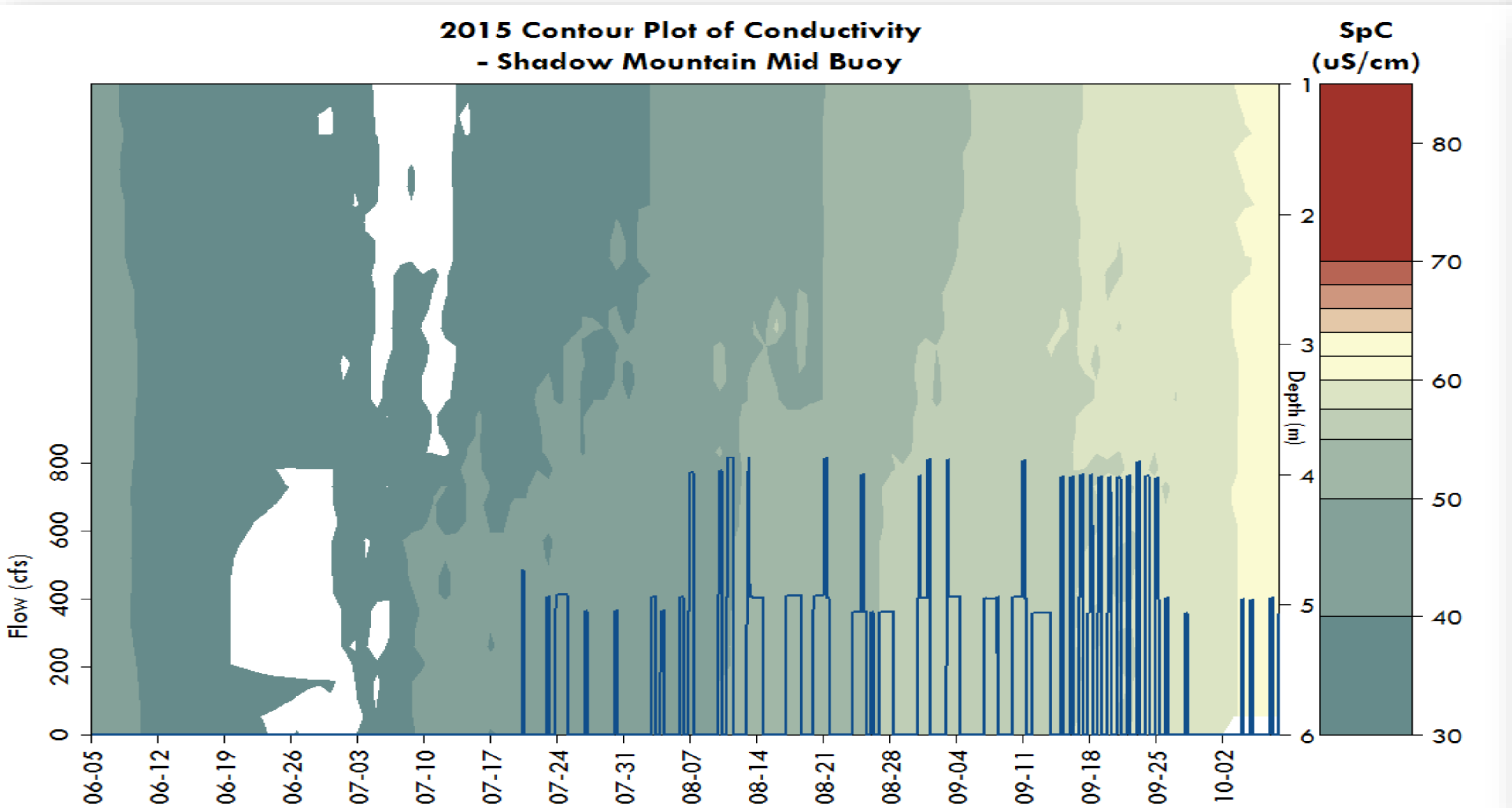
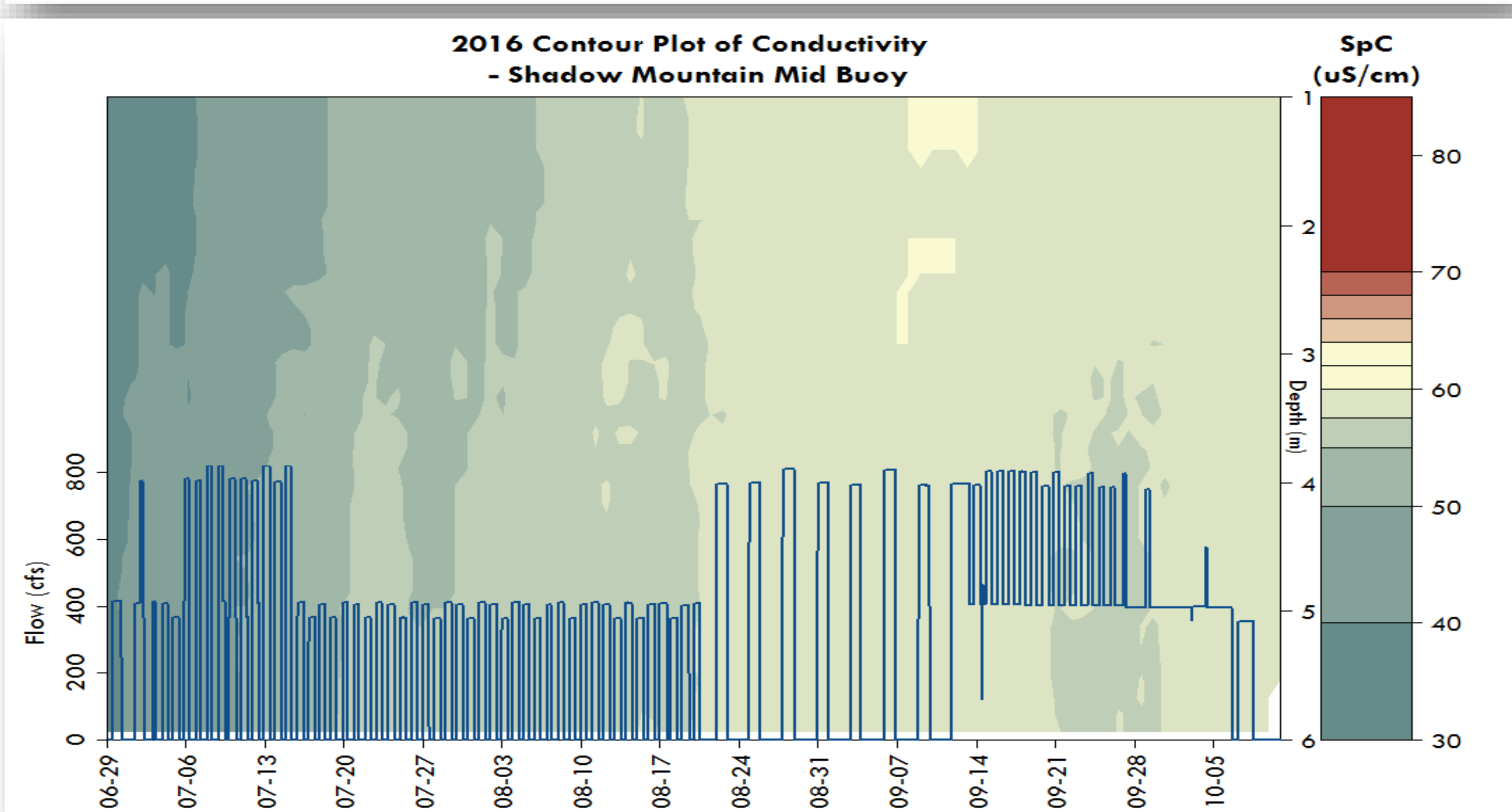
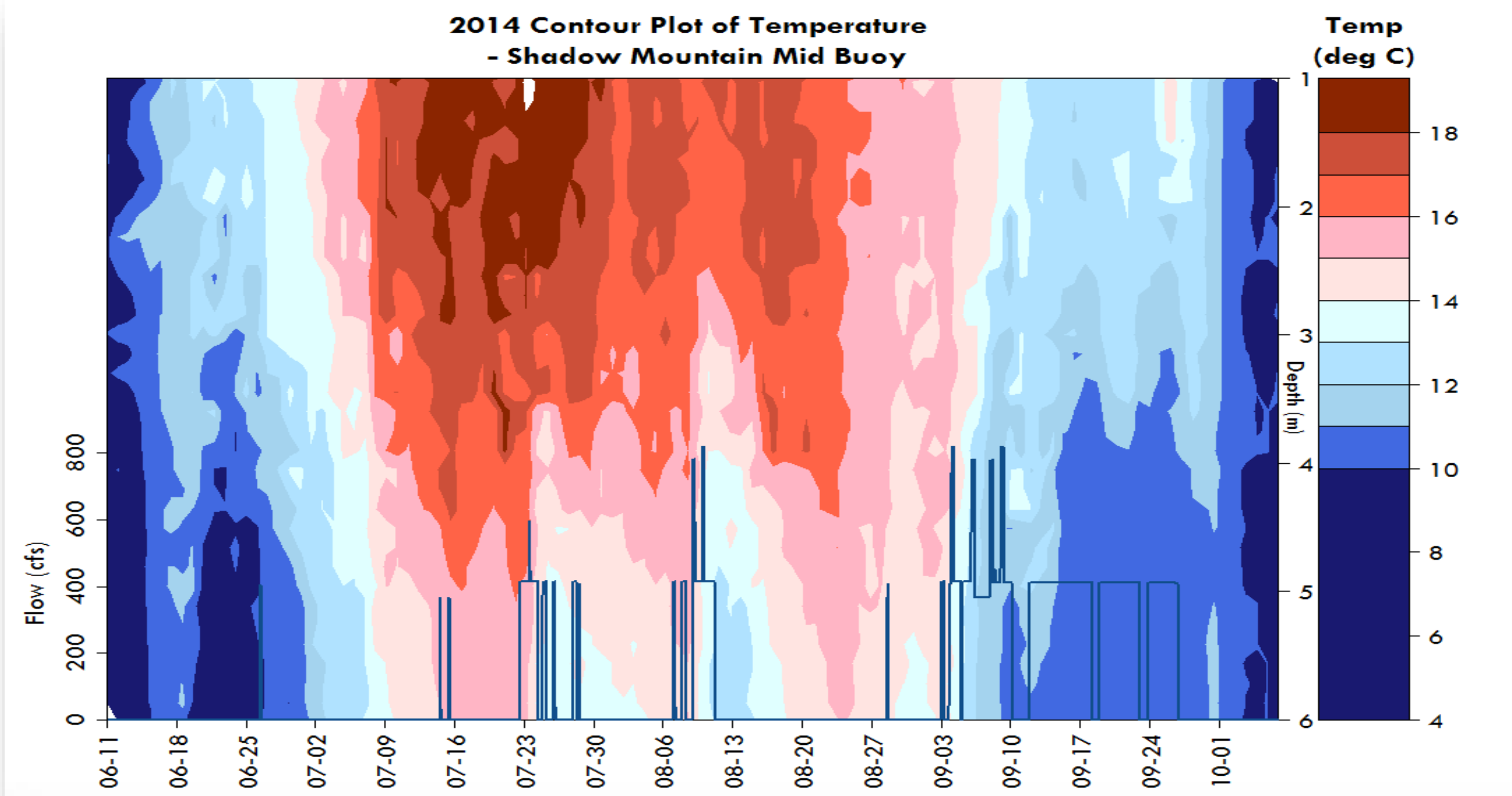
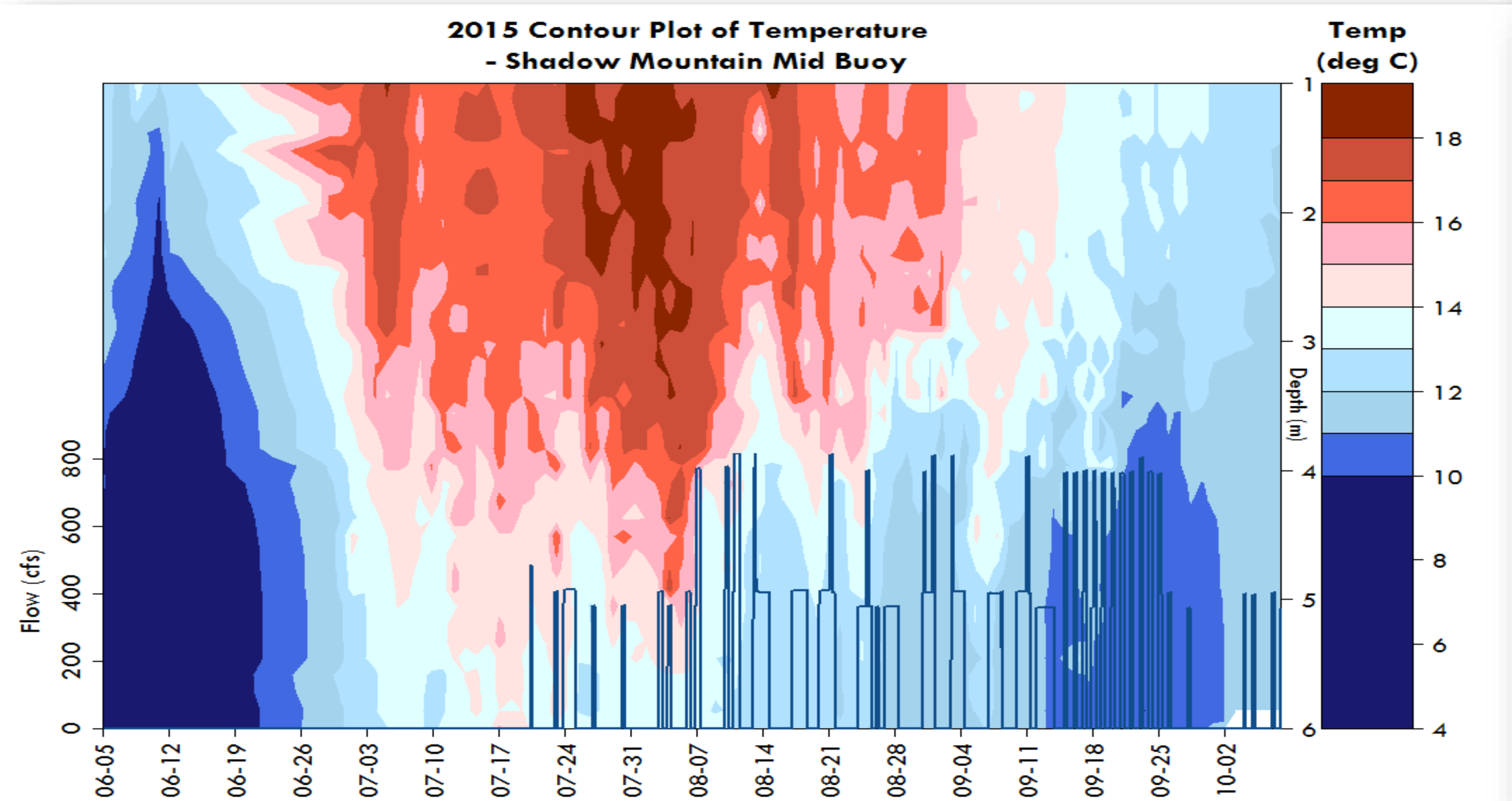
7.5
7.0
6.5

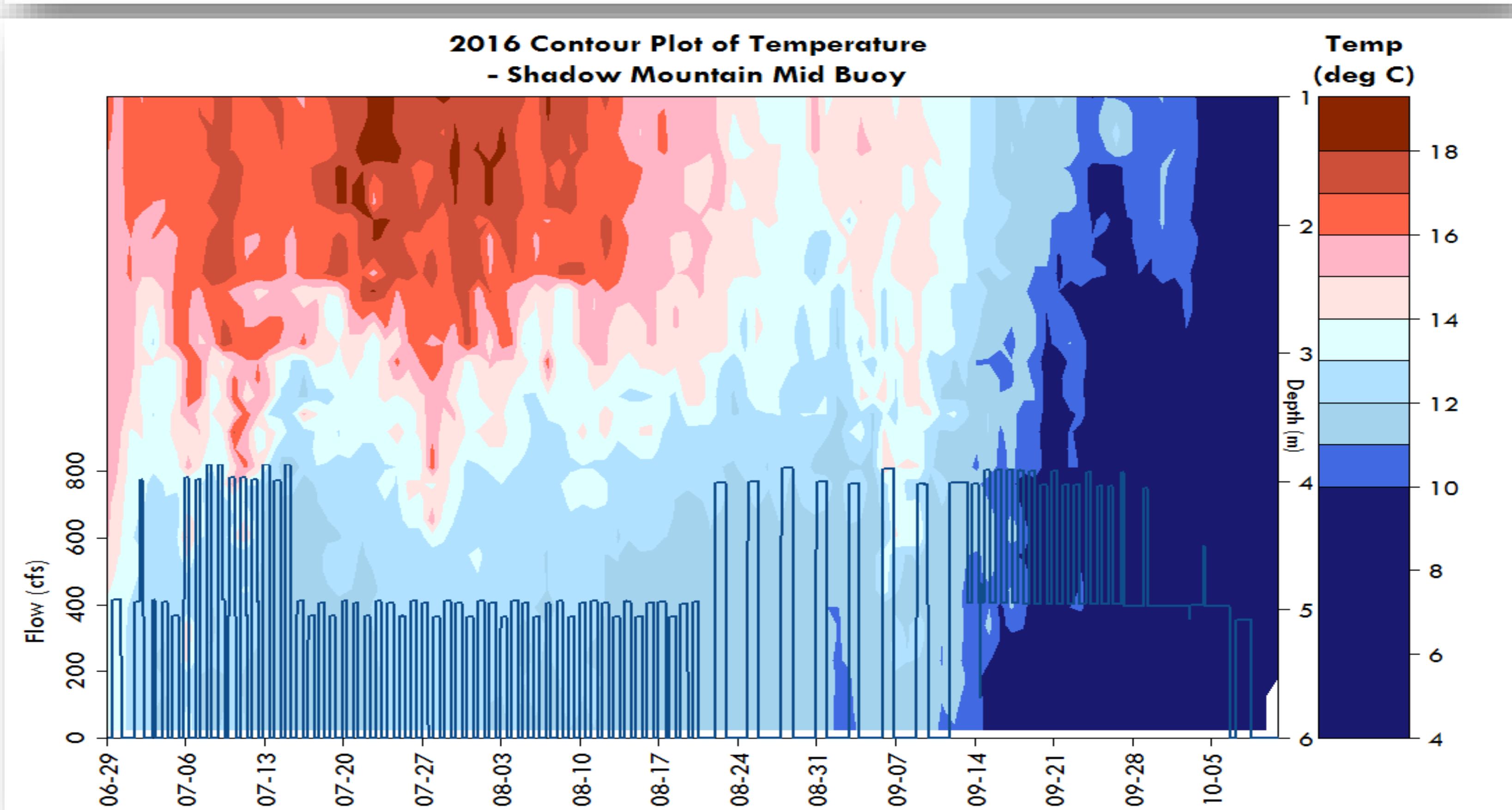

2014 Contour Plot of Conductivity
- Shadow Mountain Mid Buoy
SpC
(uS/cm)
Flow (cfs)
Depth (m)
06-11
06-18
06-25
07-02
07-09
07-16
07-23
07-30
08-06
08-13
08-20
08-27
09-03
09-10
09-17
09-24
10-01

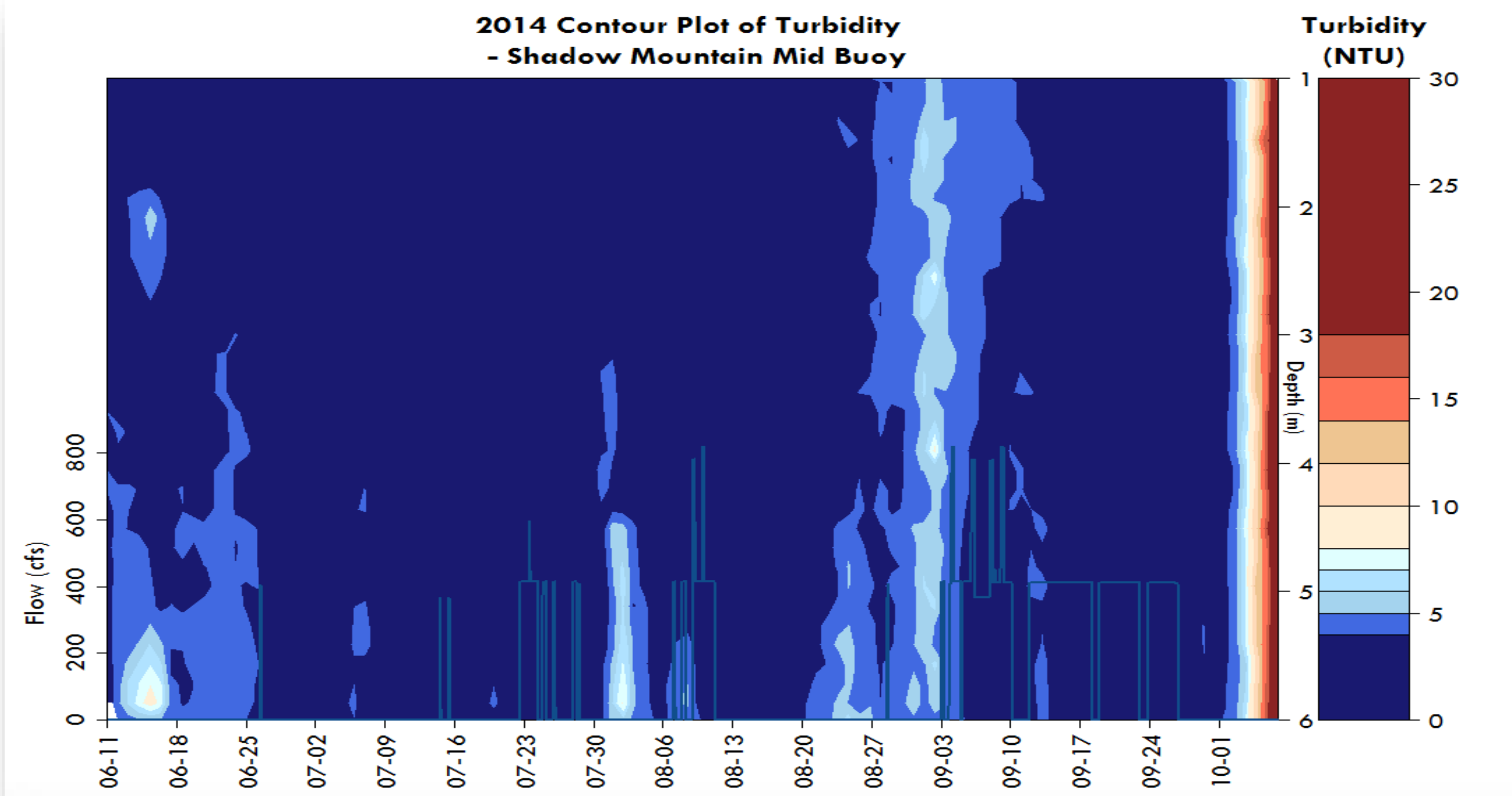

2015 Contour Plot of Conductivity
- Shadow Mountain Mid Buoy
SpC
(uS/cm)
Flow (cfs)
Depth (m)
06-05
06-12
06-19
06-26
07-03
07-10
07-17
07-24
07-31
08-07
08-14
08-21
08-28
09-04
09-11
09-18
09-25
10-02

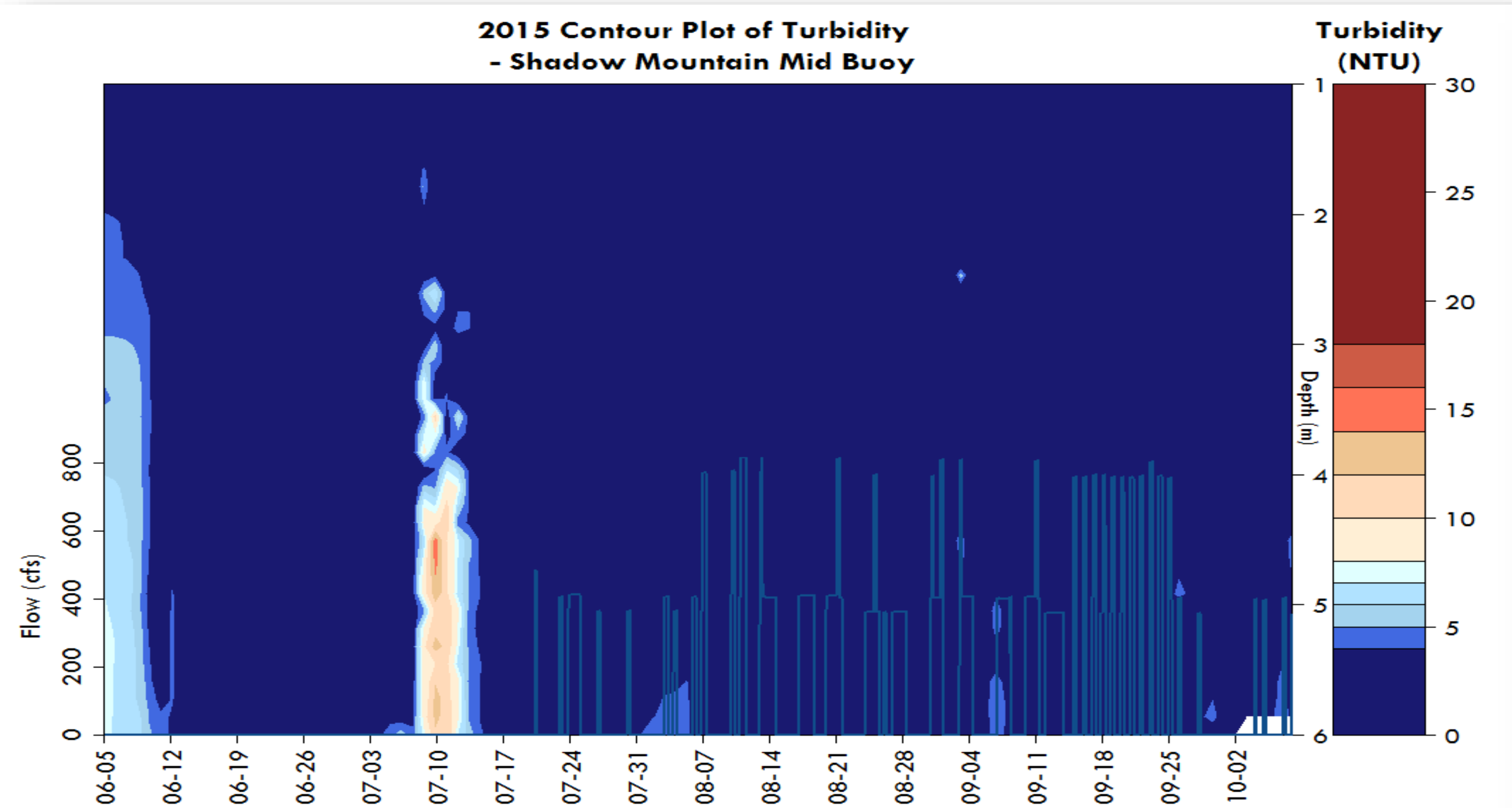

2016 Contour Plot of Conductivity
- Shadow Mountain Mid Buoy
SpC
(uS/cm)
Flow (cfs)
Depth (m)
06-29
07-06
07-13
07-20
07-27
08-03
08-10
08-17
08-24
08-31
09-07
09-14
09-21
09-28
10-05

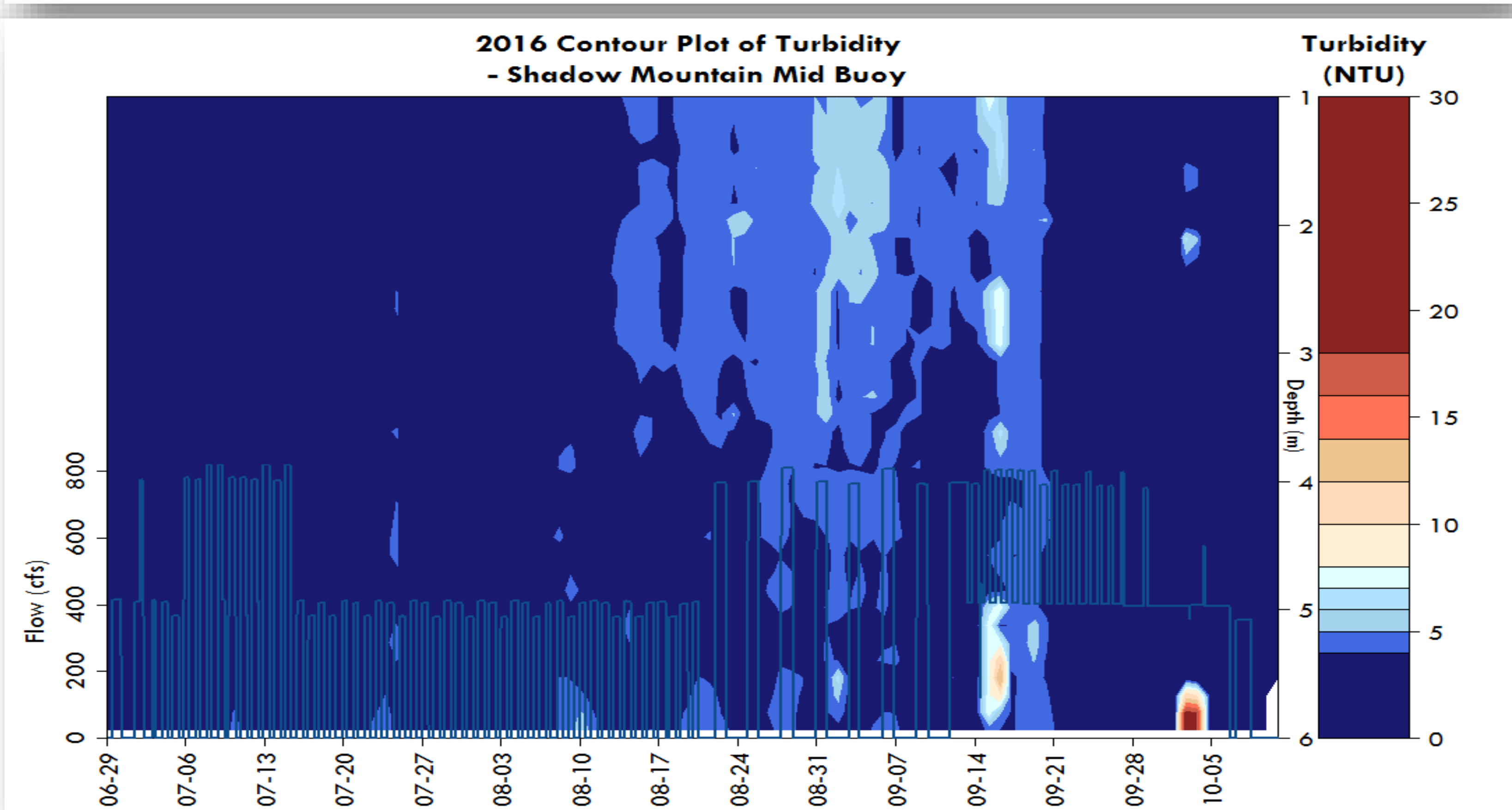

2014 Contour Plot of Temperature
- Shadow Mountain Mid Buoy
Temp
(deg C)
Flow (cfs)
Depth (m)


2015 Contour Plot of Temperature
- Shadow Mountain Mid Buoy
Temp
(deg C)
Flow (cfs)
Depth (m)


2016 Contour Plot of Temperature
- Shadow Mountain Mid Buoy
Temp
(deg C)
Flow (cfs)
Depth (m)


2014 Contour Plot of Turbidity
- Shadow Mountain Mid Buoy
Turbidity
(NTU)
Flow (cfs)
Depth (m)


2015 Contour Plot of Turbidity
- Shadow Mountain Mid Buoy
Turbidity
(NTU)
Flow (cfs)
Depth (m)

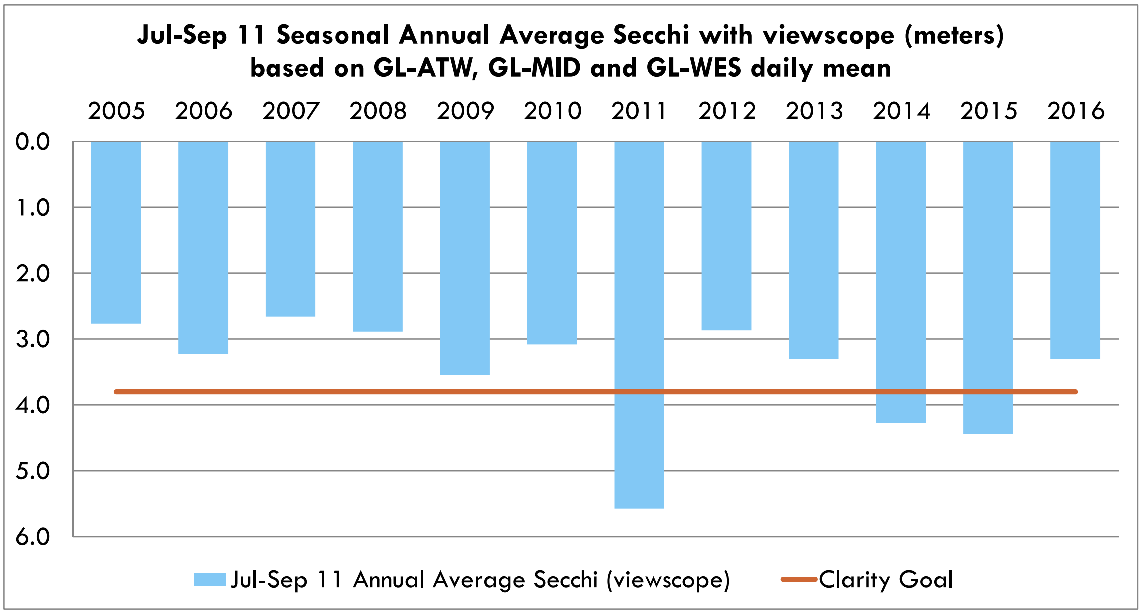

2016 Contour Plot of Turbidity
- Shadow Mountain Mid Buoy
Turbidity
(NTU)
Flow (cfs)
Depth (m)

HISTORICAL SECCHI DATA ASSESSED AGAINST 3.8 m JUL-SEP 11 CLARITY GOAL (AVERAGE)

Year	Jul-Sep 11 Annual Average Secchi (viewscope)	Clarity Goal	Actual minus Goal	Goal Met?
2005	2.8	3.8	-1.03	N
2006	3.2	3.8	-0.57	N
2007	2.7	3.8	-1.14	N
2008	2.9	3.8	-0.91	N
2009	3.5	3.8	-0.26	N
2010	3.1	3.8	-0.72	N
2011	5.6	3.8	1.77	Y
2012	2.9	3.8	-0.93	N
2013	3.3	3.8	-0.50	N
2014	4.3	3.8	0.48	Y
2015	4.4	3.8	0.64	Y
2016	3.3	3.8	-0.50	N

Secchi data with viewscope, averaged daily using GL-WES, GL-MID and GL-ATW. All three sites may not have been sampled on the same day historically. Data were averaged daily regardless of how many of the three sites had been measured

# Years Goal Met	3
Total # of Years	12
% of Years Goal Met	25%
% of Years Goal Met in last 5 years	60%

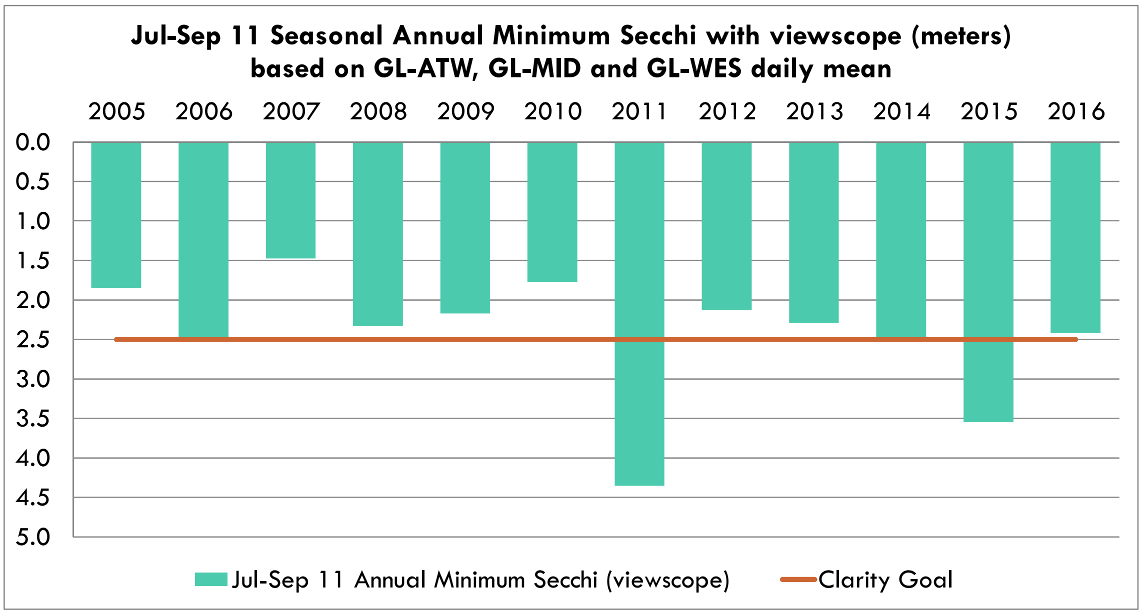


HISTORICAL SECCHI DATA ASSESSED AGAINST 2.5 m JUL-SEP 11 CLARITY GOAL (MINIMUM)

Year	Jul-Sep 11 Annual Minimum Secchi (viewscope)	Clarity Goal	Actual minus Goal	Goal Met?
2005	1.9	2.5	-0.65	N
2006	2.5	2.5	0.00	Y
2007	1.5	2.5	-1.03	N
2008	2.3	2.5	-0.17	N
2009	2.2	2.5	-0.33	N
2010	1.8	2.5	-0.73	N
2011	4.4	2.5	1.85	Y
2012	2.1	2.5	-0.37	N
2013	2.3	2.5	-0.21	N
2014	2.5	2.5	0.00	Y
2015	3.6	2.5	1.05	Y
2016	2.4	2.5	-0.08	N

Secchi data with viewscope, averaged daily using GL-WES, GL-MID and GL-ATW. All three sites may not have been sampled on the same day historically. Data were averaged daily regardless of how many of the three sites had been measured

# Years Goal Met	4
Total # of Years	12
% of Years Goal Met	33%
% of Years Goal Met in last 5 years	60%



CONTENTS

INTRODUCTION

The purpose of this document is to present a common platform of understanding about water quality in the Three Lakes (Grand Lake, Shadow Mountain and Granby Reservoirs) as it relates to clarity issues in Grand Lake. This technical memo does not offer recommendations on a clarity standard for Grand Lake but is intended to serve as a technical foundation to educate and inform the decision making process about a clarity standard for Grand Lake.

This document is an attempt to: synthesize existing knowledge about clarity in Grand Lake, water quality in Shadow Mountain Reservoir, Grand Lake and Granby Reservoir; to characterize possible water quality trade-offs associated with potential clarity alternatives; to identify outstanding information gaps; and to review important elements to consider in the development of a clarity standard.

HYDROLOGY & OPERATIONS

Hydrology and operations have an important impact on water quality because of their direct influence on reservoir water levels, hydraulic residence times, and the sources and volumes of water that enter each water body. The hydrology and operations of the Three Lakes vary from year to year and have been described and assessed in detail ((Boyer & Hawley, 2011), (Boyer & Hawley, 2013), (Boyer & Hawley, 2014) and (Hawley, Boyer, & Adams, 2014a)).

During the snowmelt runoff period, the native tributary inflows to Grand Lake and Shadow Mountain Reservoir are sufficient to meet East Slope delivery requirements through the Adams Tunnel. During this time, water that doesn't flow into the Adams Tunnel flows downstream from Grand Lake into Shadow Mountain Reservoir and then eventually into Granby Reservoir via the Colorado River. When runoff flows taper off and tributary inflows into Grand Lake and Shadow Mountain Reservoir are no longer sufficient to meet East Slope delivery requirements, water is pumped from Granby Reservoir into Shadow Mountain Reservoir via the Farr Pumping Plant and the Granby Pump Canal (Figure 1).

FIGURE 1 – THREE LAKES SYSTEM MAP

FIGURE 2 - FLOW DIRECTION BETWEEN SHADOW MOUNTAIN RESERVOIR AND GRAND LAKE DURING PUMPING AND DURING RUNOFF

The pumped water flows by gravity from Shadow Mountain Reservoir to Grand Lake via the connecting channel and eventually to the west portal of the Adams Tunnel (Figure 1). Water quality in Granby Reservoir, Shadow Mountain Reservoir, and Grand Lake is influenced by the timing and amount of pumping operations as well as by the weather conditions (air temperature, wind, and precipitation events), thermal stratification and turnover, the quality and quantity of the native tributary inflows, and the quality and quantity of pumped flows from Willow Creek Reservoir and Windy Gap Reservoir.

Granby Reservoir is the second largest reservoir in Colorado with a total capacity of 539,758 ac-ft and maximum water depth of 221 feet. Shadow Mountain Reservoir has a total capacity of 17,354 ac-ft and is relatively shallow with a maximum depth of approximately 30 feet near the dam. Grand Lake is the largest (by volume) and deepest natural lake in Colorado. It has a volume at capacity of 68,600 ac-ft and a maximum depth of approximately 265 feet. The water surface elevations in Shadow Mountain Reservoir and Grand Lake are together fixed between 8,366 and 8,367 feet by the design and operation of the C-BT Project.

The geomorphology of these water bodies influences temperature stratification and water quality dynamics. Depending on the stratification (or lack thereof), inflowing and pumped waters may move through the lake and reservoirs as overflows, underflows or interflows and have varying water quality effects (Figure 3). Granby Reservoir and Grand Lake are deep water bodies that display strong stratification during the summer. Both are dimictic (i.e. the waters mix from the surface to bottom twice each year, in the fall and in the spring). Shadow Mountain Reservoir is much shallower and weakly stratifies throughout the summer (Billica, 2013). It does not show a pattern of mixing and stratifying multiple times throughout the summer as is often seen in shallow reservoirs; however stratification of the reservoir can be disrupted by pumping.

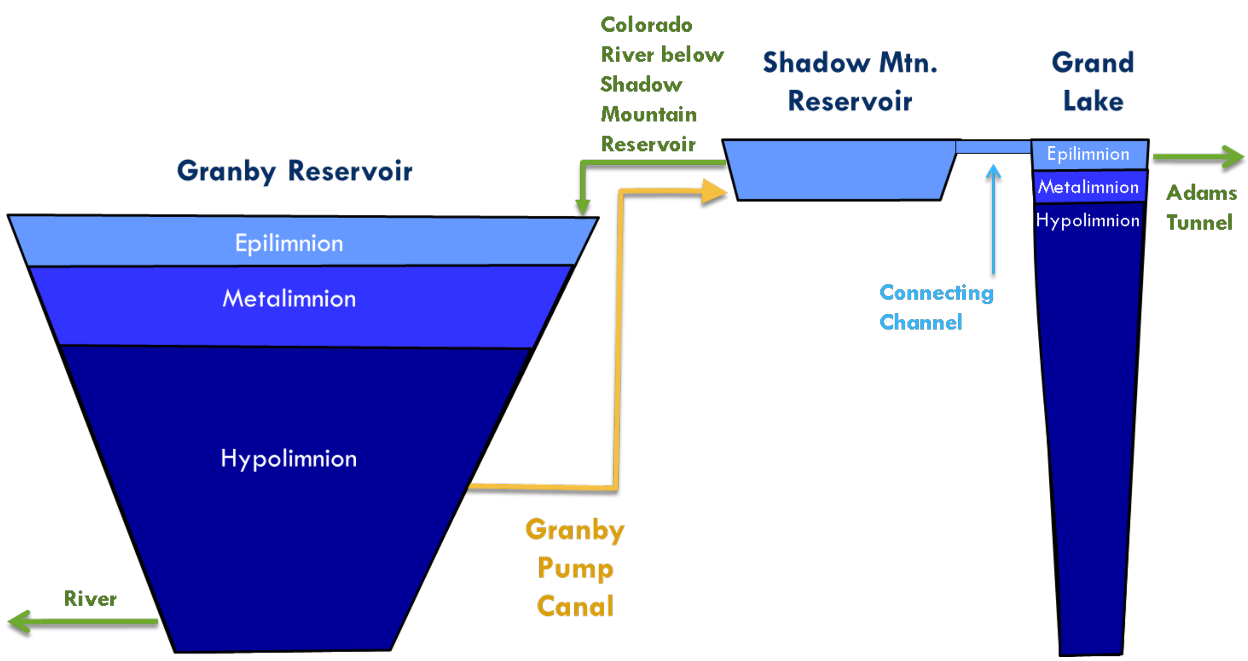


FIGURE 3 - SCHEMATIC OF THREE LAKES OPERATIONS

KEY FACTORS AFFECTING GRAND LAKE CLARITY

This section provides a synopsis of the findings from various reports and studies focused on identifying factors that influence clarity in Grand Lake. Visual water clarity, the distance at which objects can be seen through water, is typically described by Secchi depth measurements. A Secchi disk is a circular plate divided into quarters painted alternatively black and white. The distance at which the disk disappears in the water is the Secchi depth (Figure 5).

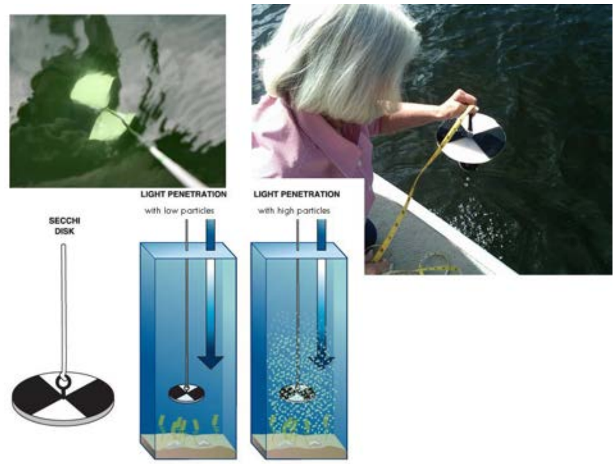


FIGURE 4 - MEASURING CLARITY WITH A SECCHI DISK

RETROSPECTIVE REVIEW OF GRAND LAKE CLARITY

Figure 4 shows average Grand Lake Secchi measurements for the entire period of record available. Clarity in Grand Lake shows seasonal patterns and ranges of clarity that vary with hydrology and operations each year. Historical Secchi depth data are available as early as 1941 for Grand Lake, but only one measurement is available from the period prior to operation of the C-BT System. A Secchi depth value of 9.2 meters was recorded on September 6, 1941 (Pennak, 1955), without the use of a viewscope[1]. As shown in Figure 4, since the C-BT Project became operational, maximum annual Secchi depth readings are consistently 3 to 4+ meters shallower than the 9.2 meter observation in 1941, with one exception in 2011, where the maximum Secchi measurement without the use of a viewscope was 7 meters. Historically high runoff and the extended period of no pumping in 2011 resulted in record post-CBT maximum clarity observations in Grand Lake and in Shadow Mountain Reservoir (Boyer & Hawley, 2013). Post C-BT clarity observations range from 1.2 to 7.0 meters for data without a viewscope. The lowest measurements were observed in 1953 and 2007 and the highest in 2000 and 2011 (Hawley, Boyer, & Adams, 2014a).

FIGURE 5 - GRAND LAKE CLARITY 1941-2014

[1] Secchi measurements can be made with or without a viewscope. A viewscope is a device that can be used while taking a Secchi depth reading to minimize the effects of reflected light, wave action, and surface particles, generally resulting in a more reproducible and slightly greater value (as compared to non viewscope data). (Hawley, Boyer, & Adams, 2013 Operational and Water Quality Summary Report for the Three Lakes, 2014a)

TABLE 1 - SUMMARY STATISTICS FOR SECCHI DEPTH MEASUREMENTS FOR GRAND LAKE (ALL LOCATIONS, VIEWSCOPE DATA), 2007-2013

	Observations	Min (m)	Max (m)	Range (m)	Median (m)	Mean (m)
2007	20	1.4	4.9	3.6	3.0	3.1
2008	183	2.0	4.6	2.7	3.3	3.3
2009	361	2.0	5.0	3.0	3.8	3.7
2010	247	1.6	6.1	4.5	3.5	3.5
2011	468	2.1	7.6	5.4	4.9	4.8
2012	324	2.1	4.4	2.3	3.1	3.1
2013	328	2.1	6.0	3.9	4.1	4.0

Spatial and Seasonal Patterns

Grand Lake Clarity is currently monitored weekly May through October, and 2-3 times a week during times of unusual operation of the C-BT system at 14 sites. Secchi measurements at each of the 14 sites display similar temporal patterns (Hawley & Boyer, Highlights - Current Understanding of Water Quality Related to Grand Lake Clarity Standard, Water Quality Stakeholder Meeting, 2015), although some statistically significant spatial variations (Helsel, 2014) can be observed as shown in Figure 6. Figure 6b shows lower clarity near the Shadow Mountain connecting channel and increasing clarity along the flow path to the Adams Tunnel that corresponds to the direction of flow when Farr pumping is on. These spatial variations do not obscure the overall temporal patterns at each site as illustrated in Figure 6b (2014 data were used for illustrative purposes).

Clarity also varies seasonally ((McCutchan, Jr, 2014) and (Hawley, Boyer, & Adams, 2014a)): snowmelt runoff introduces suspended particulate material each year that degrades clarity in the spring and early summer (duration of effects depends on hydrograph timing and operations); increasing clarity is also common in the fall, even with on-going pumping. Seasonal variations are discussed in more detail later in the document.

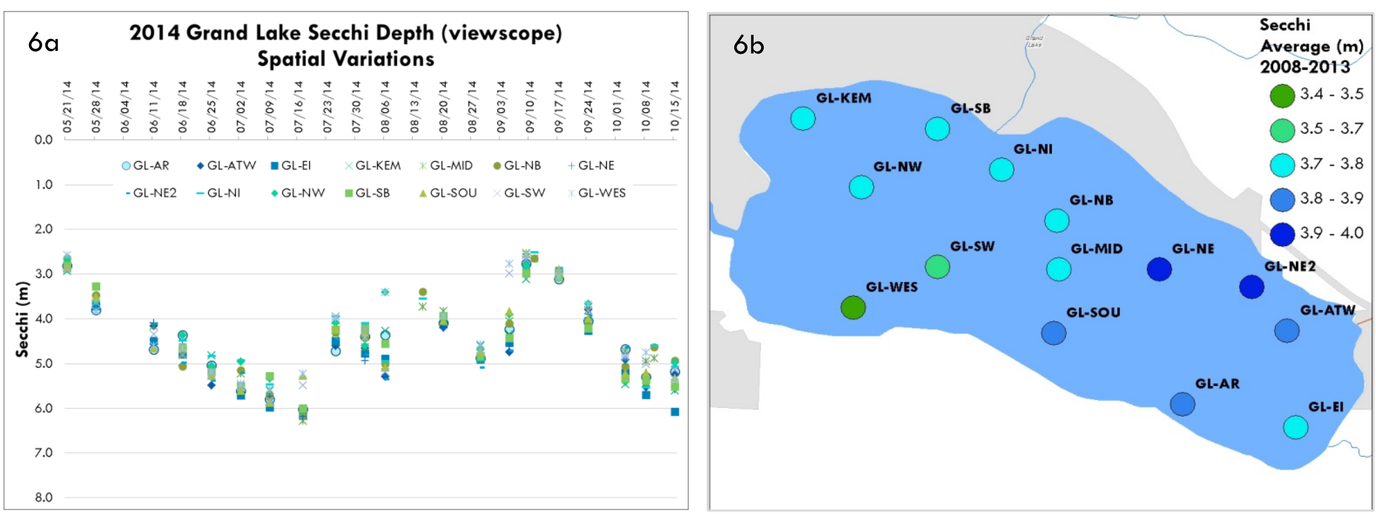


FIGURE 6 - SECCHI MONITORING SITES AND SPATIAL VARIATION

EFFECTS OF PARTICLES ON TRANSPARENCY

Clarity is a function of light transmission through water and is dependent on the optical properties of water which are influenced by the presence of various constituents in the water (dissolved and particulate matter and further breakdown of these as shown in Figure 8). Out of these subcategories, the components of interest and that play a significant role in clarity are: algae, non-algal organic particulates, inorganic particulates and dissolved organic matter (boxes outlined in bold in Figure 7 (Hawley, Boyer, & Adams, 2014a)).

Algae biomass is typically measured as chlorophyll a. Non-algal organic particulates are detritus (i.e. dead algae cells or organisms). Inorganic particulates are of mineral origin and include sand, silt and clay particles. Dissolved organic matter can be a product of decay of leaves or pine needles or result of algal excretion.

FIGURE 7 - BREAKDOWN OF LIGHT ATTENTUATING CONSTITUENTS IN WATER

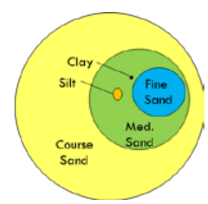


FIGURE 8 - INORGANIC PARTICULATE MATTER

The relationship between Secchi depth and particulate concentrations is an inverse, non-linear relationship and the terms are not additive. Therefore, one needs to look at results on a component by component basis, while considering that the magnitude of clarity improvements computed by removing one of the particulates is dependent upon the concentrations of all particulates, not only the particulate theoretically removed. Simulated Secchi depth (using the Three Lakes Water Quality Model[2]) illustrate the gain in clarity that would occur in the complete absence of one of three types of particulates: chlorophyll a (chl a), inorganic suspended solids (ISS), and non-algal particulate organic carbon (NA POC), (Boyer & Hawley, 2014). Because the magnitude of improvement in clarity achieved by removing one constituent scales inversely (non-linearly) with the concentrations of other constituents, the gain in clarity by removal of one type of particulate is a function of the relative initial concentrations of all particulates. This also means that

[2] The Three Lakes Water Quality model is a dynamic, process based model (Boyer J. M., 2008). It is dynamic in that it simulates results over time and process-based in that the impacts of inflows, outflows, settling, and constituent transformations are described using differential equations based on an understanding of the physical, chemical and biological processes which occur in lakes and reservoirs. It can be used to predict water quality conditions under a variety of situations that are different from what has happened historically. The model was developed to simulate flow and water quality in Grand Lake, Shadow Mountain Reservoir and Granby Reservoir in an integrated fashion.

the relative importance of these constituents may change under different conditions or under various clarity alternatives. Some particles of lesser importance under current conditions could become more important and limiting under a different set of conditions.

In summary: All three types of particles (algae, non-algal organic particles and inorganic particles) are important in how they affect clarity in Grand Lake and their impact on Grand Lake clarity requires a model to simulate outcomes under various conditions.

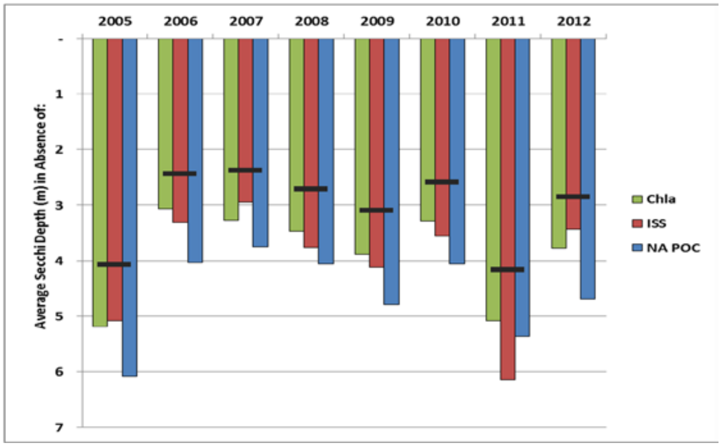


FIGURE 9 - PREDICTED AVERAGE SECCHI DEPTH (JUL-SEP) AS A RESULT OF THE COMPLETE REMOVAL OF ONE TYPE OF PARTICULATE IN GRAND LAKE (2005-2012) *(THE BLACK LINE INDICATES THE AVERAGE WITH ALL PARTICULATES)*

It should be noted that Figure 9 is not intended to provide an estimate of what is attainable in terms of clarity in Grand Lake but is presented to illustrate the role of each particulate type on clarity. It would not be realistic or reasonable to assume that complete removal of any one of the particle-types is feasible.

Major factors affecting Grand Lake Clarity

Particles affecting transparency in Shadow Mountain Reservoir and Grand Lake originate from both native tributaries (North Fork of the Colorado, East Inlet and North Inlet) and the Granby Pump Canal (McCutchan, Jr, 2014). Particles also are produced in situ (phytoplankton, particles derived from aquatic macrophytes) and particles from any of these sources that are deposited in shallow water can be re-suspended. Thus, interpretation of the causes of seasonal and interannual variation in transparency in Shadow Mountain Reservoir and Grand Lake depends on an understanding of the sources of particles affecting transparency (McCutchan, Jr, 2014). Such an understanding also depends on knowledge of processes that remove particles from the surface water of these water bodies (i.e. export and settling).

Farr Pumping/Operations

Farr Pumping directly influences clarity in Grand Lake through delivery of particulate matter from Shadow Mountain Reservoir as shown in Figure 10 ((Hawley & Boyer, 2015), (Boyer & Hawley, 2011)), although the specific source of these particles remains unclear. Modeling results indicate that chlorophyll a, inorganic suspended solids (ISS) and non-algal organic suspended solids can all play an important role in determining clarity in Grand Lake. Relative importance varies with meteorological conditions, operations, time of year and hydrology and the effect of pumping on clarity is highly dependent on these factors (Hawley, Boyer, & Adams, 2014a). In other words, pumping in and of itself, although it is a major driving force, does not explain all changes in clarity in Grand Lake at all times (Figure 11, i.e. Secchi depth in Grand Lake through mid-July during pumping). Some examples are discussed in more detail later in the document (increase in clarity in the fall).

FIGURE 10 - GRAND LAKE CLARITY DURING PUMPING

FIGURE 11 - GRAND LAKE AND SHADOW MOUNTAIN RESERVOIR AVERAGE SECCHI AND FARR PUMPING FLOW, 2012

Below average (2007-2012) clarity was observed in 2012 with near continuous pumping while above average clarity occurred in 2013 when a six-week pumping interruption occurred through the summer (Hawley, Boyer, & Adams, 2014a).

Pumping also significantly influences, and during certain times controls, residence time in Shadow Mountain Reservoir. Residence time is an important factor (McCutchan, Jr, 2014) as it relates to water quality in Shadow Mountain Reservoir, which in turn can impact clarity in Grand Lake. This is discussed in further detail in the next section.

Shadow Mountain Reservoir Clarity Dynamics

Shadow Mountain Reservoir is a shallow (mean depth of 12 feet) water body that is vulnerable to mixing and displays weak stratification during the summer. These morphometric characteristics affect nutrient loading to the surface as the development of low dissolved oxygen levels at the bottom can cause releases of nutrients from the sediment, which can then become available for algal uptake when mixing occurs. The shallowness of the reservoir is also conducive to macrophyte growth.

Shadow Mountain Reservoir receives inflows from the Granby Pump Canal (during pumping), from Grand Lake, during runoff and from the North Fork of the Colorado River. The North Fork is a major source of particulate loading and phosphorous to Shadow Mountain Reservoir evidenced by the 15+ acre delta that has formed over the years since the reservoir was filled. Among the native tributaries, the Colorado River appears to be an important source of particles, especially during snowmelt runoff. The relationship between discharge and particle concentration varies substantially with time of year (McCutchan, Jr, 2014). When snow cover remains at high elevation in the watershed, some important natural source areas of particles may be relatively protected from erosion processes. Later in summer, when the snow cover is gone and precipitation falls directly on bare soil, particle concentrations in the North Fork can increase dramatically. Thus for a given discharge, particle yield tends to be greater in August and September than in May or June (McCutchan, Jr, 2014). However, it is expected that particle loading associated with summer storm events is likely small relative to particle loading during runoff due to the differences in the magnitude of flows, although concentrations during storm events are higher than during runoff. Sufficient data however, are not available to fully characterize summer storm loading and confirm the assumption regarding the lesser importance of storm events relative to runoff. There are on-going studies to better understand these processes.

Water quality in Shadow Mountain Reservoir is highly dependent upon operations and residence time. Near continuous pumping from Granby Reservoir can result in lower peak chlorophyll a in the reservoir. Conversely, long pumping interruptions during the summer can result in much higher peak chlorophyll a concentrations as seen in 2013 (Hawley, Boyer, & Adams, 2014a).

Shadow Mountain Reservoir clarity displays a consistent gradient of decreasing clarity in the direction of flow (i.e. higher clarity at the upstream end of the flow), regardless of direction (whether flow goes from Grand Lake to Shadow Mountain Reservoir or the reverse). This occurs regardless of the water quality of diluting inflows (such as the North Fork). This may be an indication of the re-suspension of materials from the sediment bed of Shadow Mountain Reservoir (Boyer & Hawley, 2011).

There may be an energetic threshold with Farr flow pumping rates causing stronger clarity gradients across Shadow Mountain. There is still significant uncertainty about the mechanisms causing the observed gradient across Shadow Mountain Reservoir, but this patterning could be important and warrants additional study (Boyer & Hawley, 2011). This is included in the outstanding information and gaps section.

Time of Year, Seasonality and Runoff

Time of year and seasonal variations also influence clarity in Grand Lake. Snowmelt runoff introduces suspended particulate material each year that degrades clarity in the spring and early summer (McCutchan, Jr, 2014). The duration of the effect is highly dependent on the timing and magnitude of the hydrograph, the sequencing of hydrology (i.e. wet year following a dry year for example) and operations. This is a natural process and is widely observed (Hawley & Boyer, 2015).

Particle concentrations in the native tributaries increase with discharge, and in many years, the largest flux of particles from the native tributaries to Shadow Mountain Reservoir and Grand Lake occurs during snowmelt runoff. The flux of particles transported by North Inlet and East inlet during the runoff season can be sufficient in some years to reduce Secchi transparency in Grand Lake, even without particles from Shadow Mountain Reservoir or from other sources (McCutchan, Jr, 2014). Settling and flushing gradually remove particles and the seasonal pattern of transparency in Grand Lake probably would be similar to the typical pattern for Dillon Reservoir in the absence of Farr pumping (i.e. minimum transparency in spring or early summer, followed by increasing transparency through summer and fall) (McCutchan, Jr, 2014).

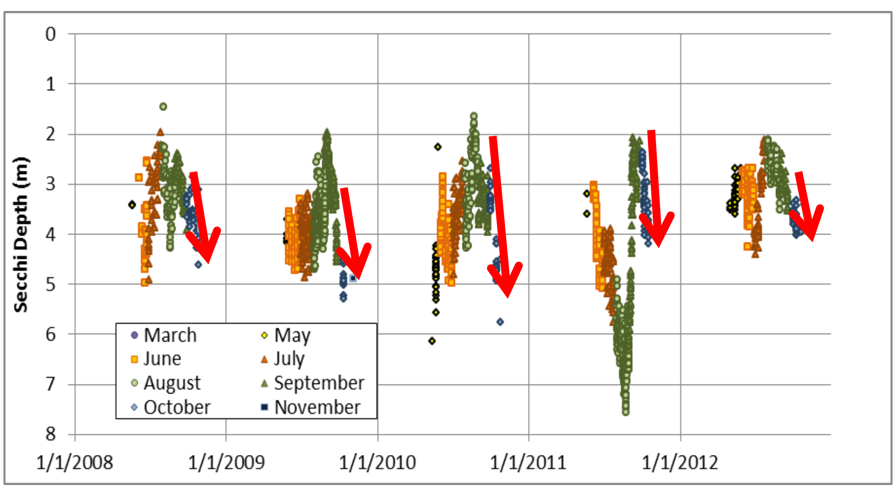


FIGURE 12 - FALL INCREASE IN CLARITY IN GRAND LAKE

Increasing clarity is common in Grand Lake in the fall, even with on-going pumping (Figure 12). Clarity in Grand Lake at this time increases at a greater rate than that observed in Shadow Mountain Reservoir. Seasonal temperature patterns may play a role in this response. Degradation of thermal stratification results in increasing thickness of the epilimnion over this period of time. As a result the mixing volume of water at the top of the reservoir increases, resulting in dilution of inflowing suspended particulate material. At times, water temperature in the connecting channel between Shadow Mountain and Grand Lake extends down to the temperature observed in the metalimnion of Grand Lake, suggesting greater mixing depths and adding to the dilution effect previously mentioned (Hawley, Boyer, & Adams, 2014a).

LESSER FACTORS AFFECTING GRAND LAKE CLARITY

Other factors that may play a lesser role in Grand Lake clarity include wind, algal productivity in Grand Lake itself (as opposed to Shadow Mountain Reservoir), direct runoff from the Grand Lake watershed during storm events, antecedent conditions , air temperature and time of day the measurements are made (Hawley & Boyer, 2015).

OTHER WATER QUALITY CONCERNS AND TRADE-OFFS

This section summarizes other water quality issues of concern in the Three Lakes that may be relevant to consider in the evaluation of potential alternatives to mitigate clarity issues in Grand Lake.

SHADOW MOUNTAIN DISSOLVED OXYGEN

The reservoir is largely divided into north and south areas by a series of islands. Continuous data collected at two buoys located on each side of the islands show significant differences in water quality, circulation patterns, dissolved oxygen dynamics and stratification (Hawley, Boyer, & Adams, 2014a).

Shadow Mountain Reservoir is currently listed as impaired for dissolved oxygen. The dissolved oxygen standard is driven by the need to protect aquatic life and is assessed in the top 0.5-2 meter of the water column. While data show dissolved oxygen levels below the 6 mg/L standard near the dam, dissolved oxygen profiles north of the islands do not show impairment for dissolved oxygen. The dissolved oxygen depletions typically occur late summer (September) and are caused by pumping of poorly oxygenated water from the bottom of Granby Reservoir. The low levels at the bottom of Granby Reservoir are typical of late summer conditions in deeper reservoirs where decomposition and settling of organic matter depletes oxygen. These depletions tend to be exacerbated in years exhibiting lower water levels (Hawley, Boyer, & Adams, 2014a). Once Granby Reservoir turns over in the fall, the water column gets re-aerated and dissolved oxygen levels bounce back in Shadow Mountain Reservoir as well (Hawley & Boyer, 2015).

During periods of no pumping in the summer, a different kind of dissolved oxygen pattern can emerge. Data from 2013 show that under such conditions (six weeks of pumping interruption), Shadow Mountain Reservoir can develop stronger temperature stratification, which leads to dissolved oxygen depletions at the bottom of the reservoir on both sides of the island, but more so near the dam. This can lead to internal loading in the reservoir with releases of nutrients from the bottom sediments (Hawley, Boyer, & Adams, 2014a).

Dissolved oxygen patterns are influenced by air temperature, algal productivity, Farr pumping and conditions in Granby Reservoir.

SHADOW MOUNTAIN CHLOROPHYLL A AND PH

In 2013, the six-week long interruption in pumping (resulting in high residence time) during the summer caused chlorophyll a concentrations across Shadow Mountain Reservoir to reach record levels (52.1 ug/L Figure 13). The algae bloom also caused pH in the top 2-3 meters of the water column to reach levels above the pH standard of 9 during a couple of weeks in August as shown in Figure 14 (Hawley, Boyer, & Adams, 2014a).

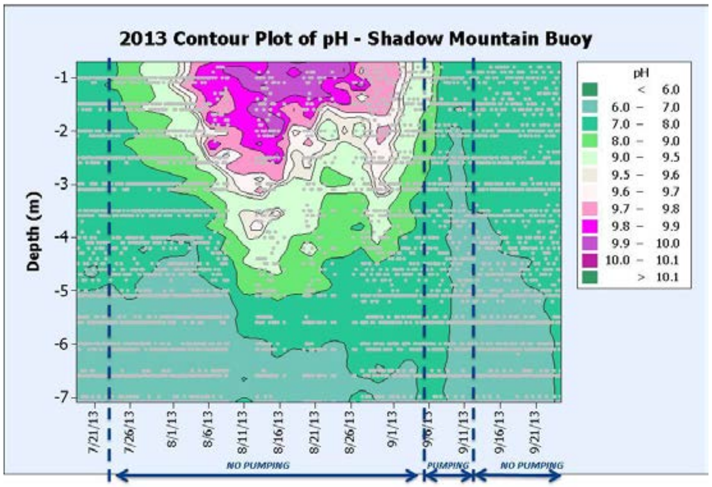


FIGURE 14 - PH CONTOUR PLOT, SHADOW MOUNTAIN DAM, 2013

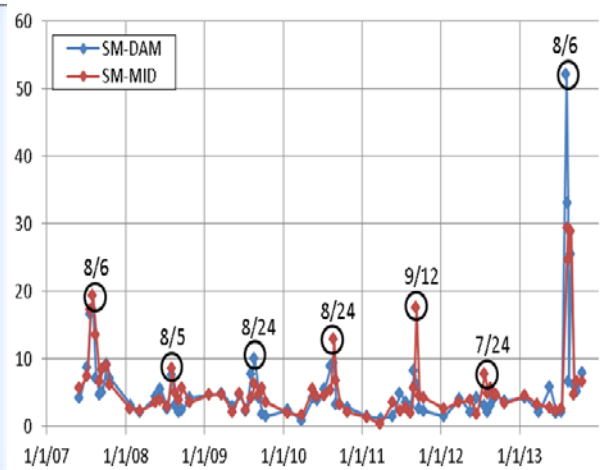


FIGURE 13 - CHLOROPHYLL A PEAKS IN SHADOW MOUNTAIN RESERVOIR, 2007-2013

BOTTOM DISSOLVED OXYGEN & TEMPERATURE EFFECTS IN SHADOW MOUNTAIN RESERVOIR AND IN THE COLORADO RIVER

Under the same set of conditions described in the previous section, bottom dissolved oxygen and water temperature effects should also be considered.

2013 data show that during the six-week pumping interruption, stronger temperature stratification developed (Figure 15). The lack of pumping is expected to be the main reason for the higher water temperature in Shadow Mountain Reservoir (surface water temperature exhibited the highest peak and average values of the recent seven years). Peak water temperature reached 19.9 °C in 2013 (temperature standard in Shadow Mountain Reservoir is 19.3 °C), compared to 18 °C in 2012, which was also a hot year during which pumping was continuous during the summer. Average temperature in Jul-Sep temperature at the top of Shadow Mountain Reservoir was 17.1 °C in 2013 versus 14 °C in 2012 under continuous pumping (Hawley, Boyer, & Adams, 2014a).

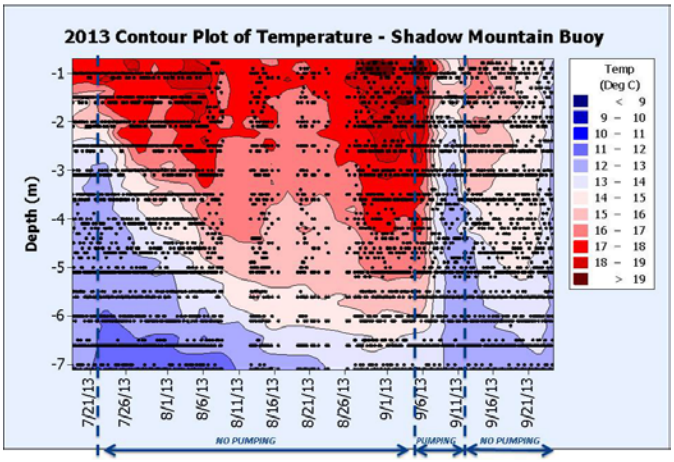


FIGURE 15 - SHADOW MOUNTAIN DAM TEMPERATURE CONTOUR PLOTS, 2013

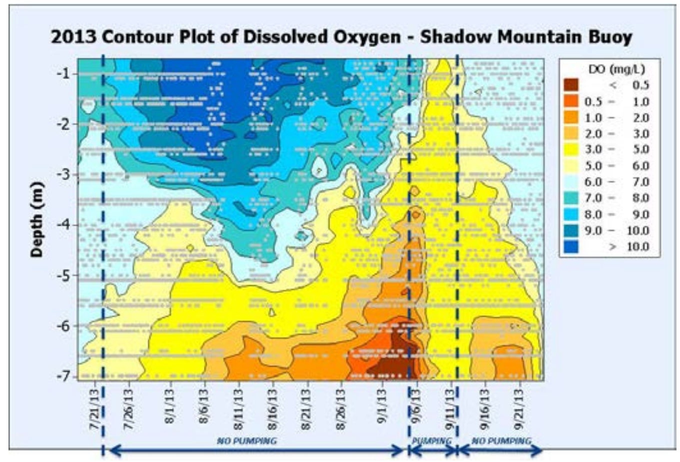


FIGURE 16 - SHADOW MOUNTAIN DAM DISSOLVED OXYGEN CONTOUR PLOTS, 2013

As shown in Figure 16, the lack of mixing induced by Farr pumping through August into early September results in decreasing dissolved oxygen at the bottom to a level of less than 0.5 mg/L (Hawley, Boyer, & Adams, 2014a). The combination of warming surface temperatures and low dissolved oxygen levels at the bottom can create a temperature/dissolved oxygen "squeeze" effect for aquatic life where adequate refuge providing both adequate temperature and dissolved oxygen levels is severely reduced or absent.

Additionally, because releases to the Colorado River from Shadow Mountain Reservoir come from the bottom, there is a potential for low dissolved oxygen levels to occur downstream of the reservoir.

2014 data show a similar pattern of strong stratification during periods of no pumping. Although brief periods of pumping took place in July and August and temporarily disrupted stratification, water temperature in Shadow Mountain Reservoir showed significant warming throughout the water column as early as mid-July (Figure 17). Maximum Weekly Average Temperature (MWAT) data in the Colorado River downstream of the reservoir show exceedances of the temperature standard (17 °C) mid-July, corresponding with the high water temperatures in Shadow Mountain Reservoir (Figure 18). Furthermore, patterns in the temperature downstream of the reservoir mimic those in Shadow Mountain Reservoir, including the drop in temperature corresponding with the short periods of pumping in late July and early August.

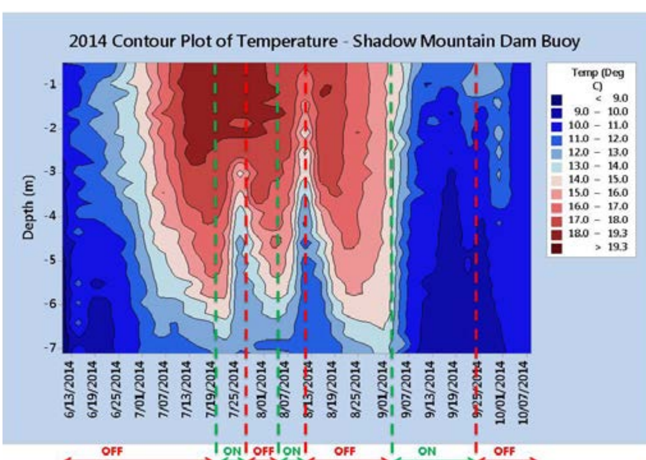


FIGURE 17 - SHADOW MOUNTAIN DAM TEMPERATURE CONTOUR PLOTS, 2014 *(PUMPING SHOWN IN RED AND GREEN)*

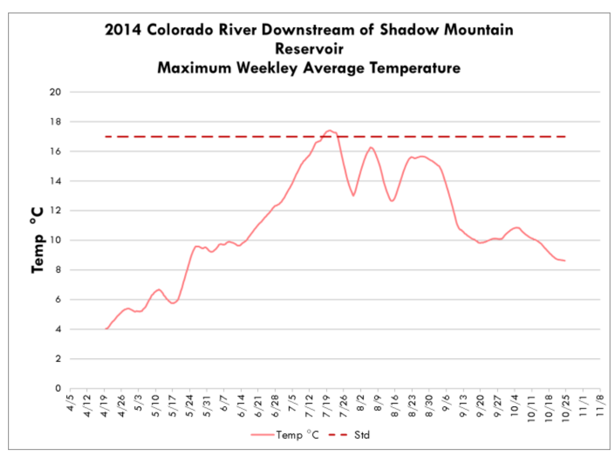


FIGURE 18 - WATER TEMPERATURE IN THE COLORADO RIVER DOWNSTREAM OF SHADOW MOUNTAIN RESERVOIR, 2014

Clarity alternatives that have the potential to increase residence time in Shadow Mountain Reservoir could cause a worsening of water quality in the reservoir with a risk of increased algae blooms, higher chlorophyll a concentrations, occurrences of high pH above the 9.0 standard, greater dissolved oxygen depletions at the bottom, nutrient releases from the sediments and higher water temperatures. It is not certain at this time what minimum flow through the reservoir would prevent these conditions from developing.

The same alternatives could adversely impact dissolved oxygen levels and water temperature in the Colorado River downstream of Shadow Mountain Reservoir.

CHLOROPHYLL A IN SHADOW MOUNTAIN RESERVOIR AND CLARITY IN GRAND LAKE

Data from 2013 show that during the six-week period of no pumping (July 23- September 4), Grand Lake clarity continually improved to reach a Secchi depth of 6 meters. During this time, chlorophyll a levels stayed below 6 ug/L in Grand Lake (Figure 19). Meanwhile, Shadow Mountain Reservoir experienced record high chlorophyll a levels peaking at 52.1 ug/L near the dam, extreme levels of macrophytes and Secchi depth falling below 1 meter (Hawley & Boyer, 2015).

Conversely, data from 2012 during which pumping was continuous for most of the summer (June 15- October) show that chlorophyll a in Shadow Mountain Reservoir remained below 8 ug/L, maximum Secchi depth reached a record high of 4.9 meters (Figure 20). Grand Lake however experienced the lowest maximum summer clarity over recent years (2007-2013) at 4.5 meters and chlorophyll a levels that peaked at over 10 ug/L (Hawley & Boyer, 2015).

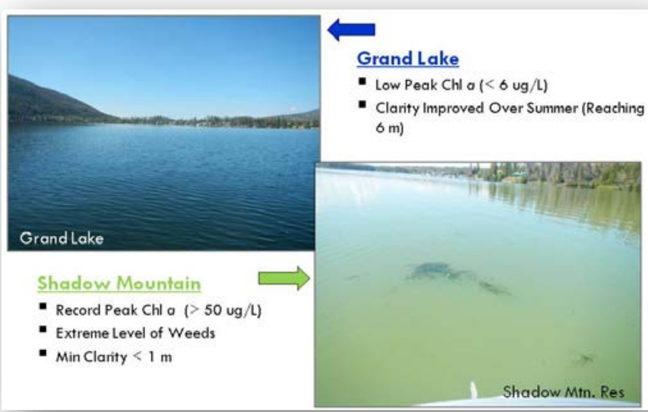


FIGURE 19 - GRAND LAKE AND SHADOW MOUNTAIN WATER QUALITY TRADE OFFS IN 2013, NO PUMPING JUL 23- SEP 4

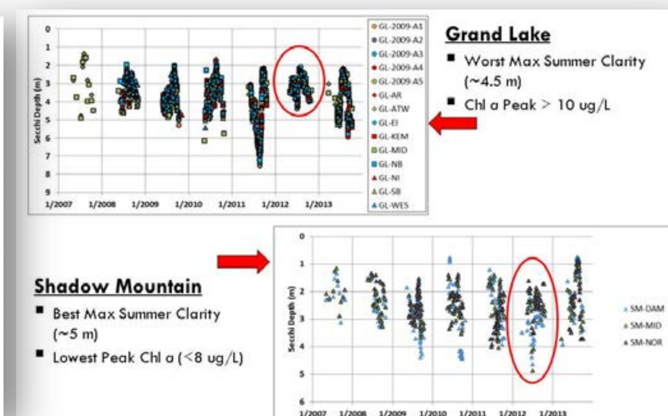


FIGURE 20 - GRAND LAKE AND SHADOW MOUNTAIN RESERVOIR CLARITY TRADE OFFS IN 2012, CONTINUOUS PUMPING JUN 15- OCT 30

Data from 2012 and 2013 illustrates conflicting management objectives for Grand Lake and Shadow Mountain Reservoir from an operational standpoint.

East Slope Water Quality & Direct Use Water Supply Designation (DUWS)

Grand Lake is currently designated as DUWS although a DUWS chlorophyll a standard has not yet been adopted. Under some clarity alternatives, there is a potential for Shadow Mountain Reservoir to also be designated as DUWS.

Under the existing configuration, Grand Lake provides dilution of water from Shadow Mountain Reservoir before it reaches the Adams Tunnel, which has a beneficial effect on water quality delivered to the East Slope (compared to what it would be without dilution). Data show that geosmin (a taste and odor compound) was detected at the East Portal of the Adams Tunnel and contributes to occurrences of geosmin in Horsetooth Reservoir (Billica, Oropeza, & Elmund, 2010).

If algal productivity were to worsen in Shadow Mountain and/or dilution effects from Grand Lake were removed under any of the alternatives, there is a potential for water quality impacts to the East Slope.

Outstanding questions and information gaps

Although knowledge and understanding of water quality in the Three Lakes system has significantly improved in recent years as a result of data collection, modeling and special studies, there remain some areas of uncertainty in understanding certain key aspects that influence Grand Lake clarity.

Shadow Mountain Clarity Gradient

It is unclear what mechanisms cause the observed gradient of decreasing clarity in the direction of flow in Shadow Mountain Reservoir and what flow thresholds trigger re-suspension of particles, or whether they are the same regardless of direction of flow. Data show that there is a source of particles in the northern and shallow portion of Shadow Mountain Reservoir. It is not well understood either whether it is the same area of the reservoir that plays a role regardless of flow direction, or whether different mechanisms are at play. The shallower areas of Shadow Mountain Reservoir have the potential to contribute to re-suspension. The source and composition of particles that cause this gradient is also unclear. The particles could be settled dead algae, settled organic and/or inorganic material from runoff, macrophyte fragments, other bed materials or a combination of these. Re-suspension of this material is expected to occur in this area because the northern portion of the reservoir is much shallower than the southern portion. Gaining a better understanding of this phenomenon is an important goal for future work, since it can directly affect clarity in Grand Lake when Farr pumping is occurring (Boyer & Hawley, 2011).

Role of Macrophytes

The contribution of macrophytes to the particulate matter in Shadow Mountain Reservoir and Grand Lake remains unclear. As macrophytes break down and decompose, they have the potential to contribute to particles. Plants can also trap particles and play a role in resuspension mechanisms, but by providing plant cover on the bottom sediment, they can also minimize the disturbance of these sediments. The net effect of these opposite and confounding processes is unknown.

Little information is available regarding the cycles and growth patterns of macrophytes in Shadow Mountain Reservoir, even though mapping surveys were carried out annually in recent years (2006-2013).

Characterization of Particle Sources

Identification of the sources of particles in the Three Lakes and characterization of particles is a difficult task that is complicated by the combination and agglomeration of particles. Organic particles can attach to inorganic particles and render the characterization of these particles very difficult.

SOURCE OF PARTICLES IN GRANBY PUMP CANAL

The source of particles contributed by the Granby Pump Canal to Shadow Mountain Reservoir is unknown. Data collected at two sites in the canal in recent years does not suggest the canal itself as a source of particles (McCutchan, Jr, 2013). There is some evidence that particles that enter Shadow Mountain Reservoir make their way into Granby Reservoir and could play a role (Boyer & Hawley, 2013) but this possible pathway of particles into Shadow Mountain Reservoir and Grand Lake is not well understood.

RESIDENCE TIME

It is not known at this time what minimum flow through Shadow Mountain Reservoir would keep residence time low enough to prevent adverse conditions (low dissolved oxygen, nutrient releases from sediments, algae growth etc…) from developing.

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Data Sources

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USGS ADVM Site – Shadow Mountain Channel:http://waterdata.usgs.gov/usa/nwis/uv?09014050

GCWIN Wilbur Database:http://wilbur.gcwin.org/

Center for Limnology – CIRES: http://cires.colorado.edu/limnology/monitoring/grand/index.html
login: transparency
password: secchi

Glossary

ac-ft	Acre-Feet
AFDM	Ash Free Dry Mass
C-BT	Colorado Big Thompson
cfs	Cubic Feet per Second
Chl a	Chlorophyll a
DOC	Dissolved Organic Carbon
DOM	Dissolved Organic Matter
DUWS	Direct Use Water Supply
ISS	Inorganic Suspended Solids
MWAT	Maximum Weekly Average Temperature
NA POC	Non Algal Particulate Organic Carbon
TDS	Total Dissolved Solids

TOC	Total Organic Carbon
TSS	Total Suspended Solids
VSS	Volatile Suspended Solids