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.

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: Jacklynn J. Gould
Jacklynn L Gould, Area Manager

Date: 01/28/16

NORTHERN COLORADO WATER CONSERVANCY DISTRICT

By: Eric D. Wilkinson
Eric Wilkinson, General Manager

Date: 01/14/2016

COLORADO RIVER WATER CONSERVATION DISTRICT

By: Eric Kuhn
Eric Kuhn, General Manager

Date: 1/21/16

NORTHWEST COLORADO COUNCIL OF GOVERNMENTS

By: Karn Stegelmeier
Karn Stegelmeier, NWCCOG Chair

Date: 1·27·16

GRAND COUNTY BOARD OF COUNTY COMMISSIONERS

By: E Jane Tollett
E Jane Tollett, Chairman

Date: 1/20/2016

Attest: Sara L. Rosene
Sara L. Rosene, Clerk and Recorder
By 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

EXHIBIT A - SENATE DOCUMENT 80

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

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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 supplementary 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 supplemental 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 operation, 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.

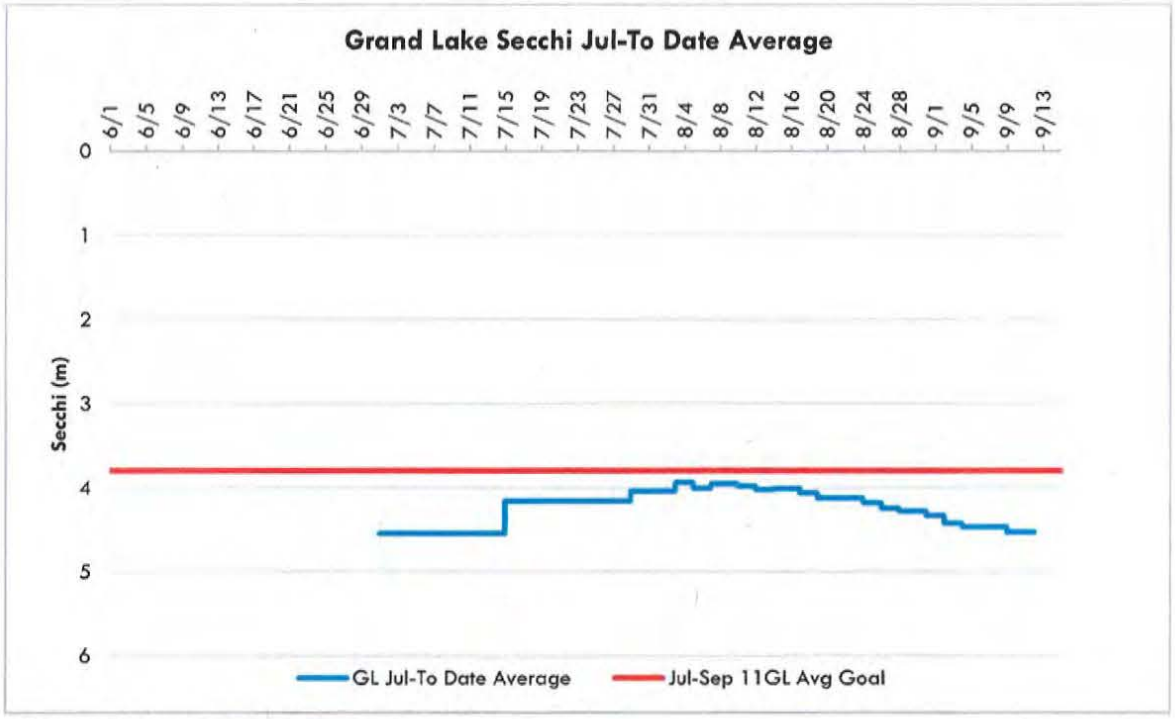


FIGURE 2 - GRAND LAKE SECCHI JUL 1 – TO DATE AVERAGE

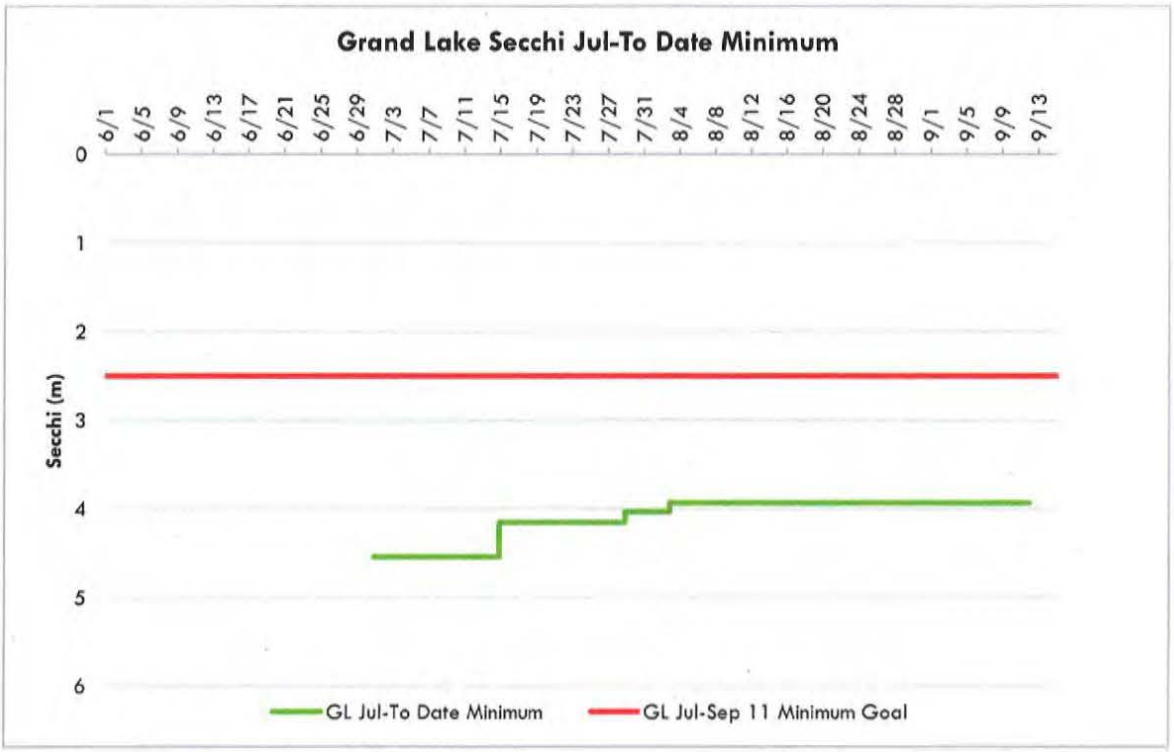


FIGURE 3 - GRAND LAKE SECCHI JUL-TO DATE MINIMUM

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.

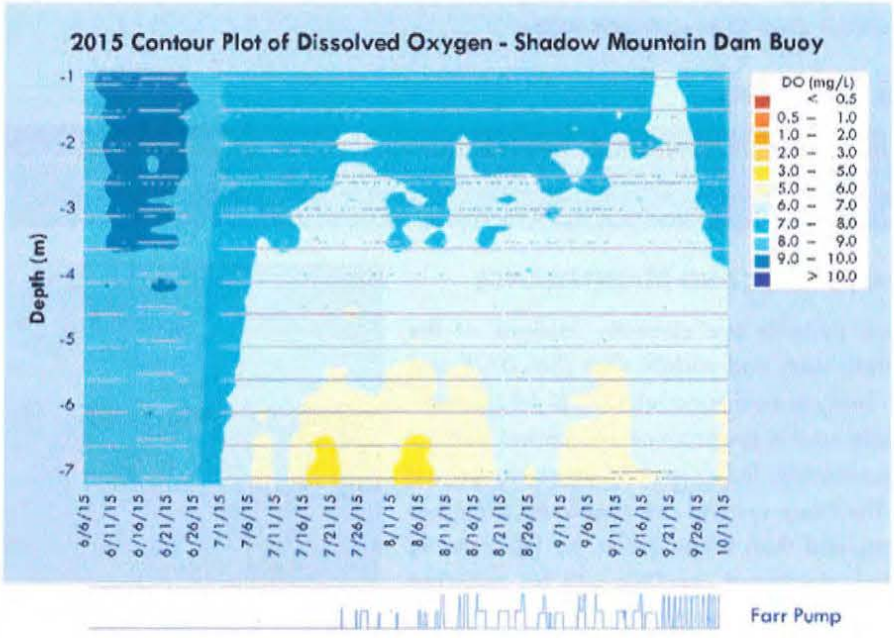


FIGURE 4 - DISSOLVED OXYGEN CONTOUR PLOT AT SHADOW MOUNTAIN DAM (2015)

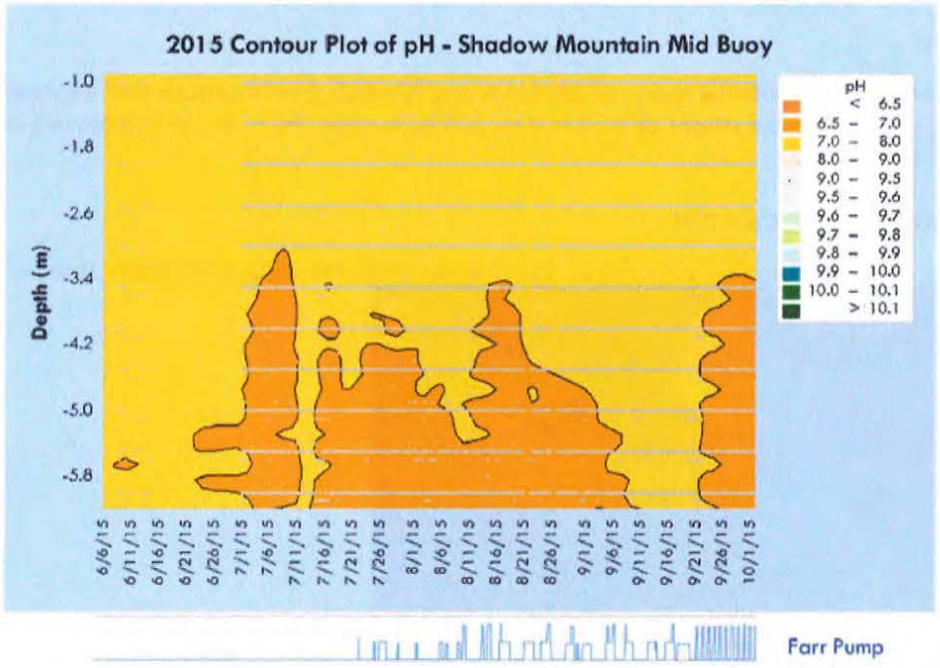


FIGURE 5 - PH CONTOUR PLOT AT SHADOW MOUNTAIN MID (2015)

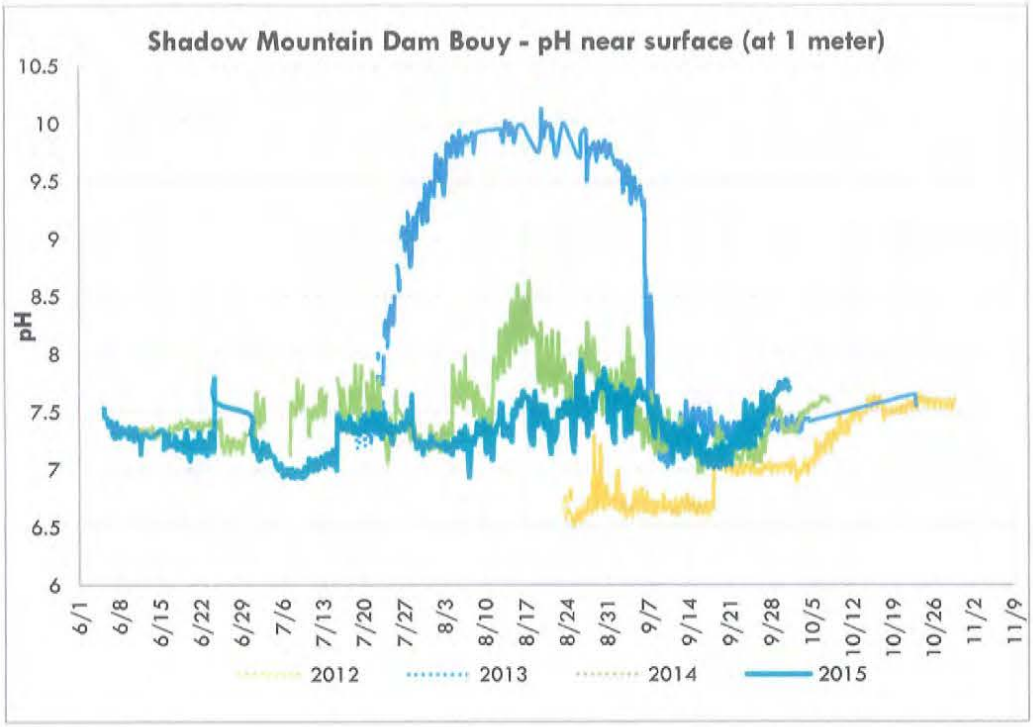


FIGURE 6 - SURFACE PH AT SHADOW MOUNTAIN DAM

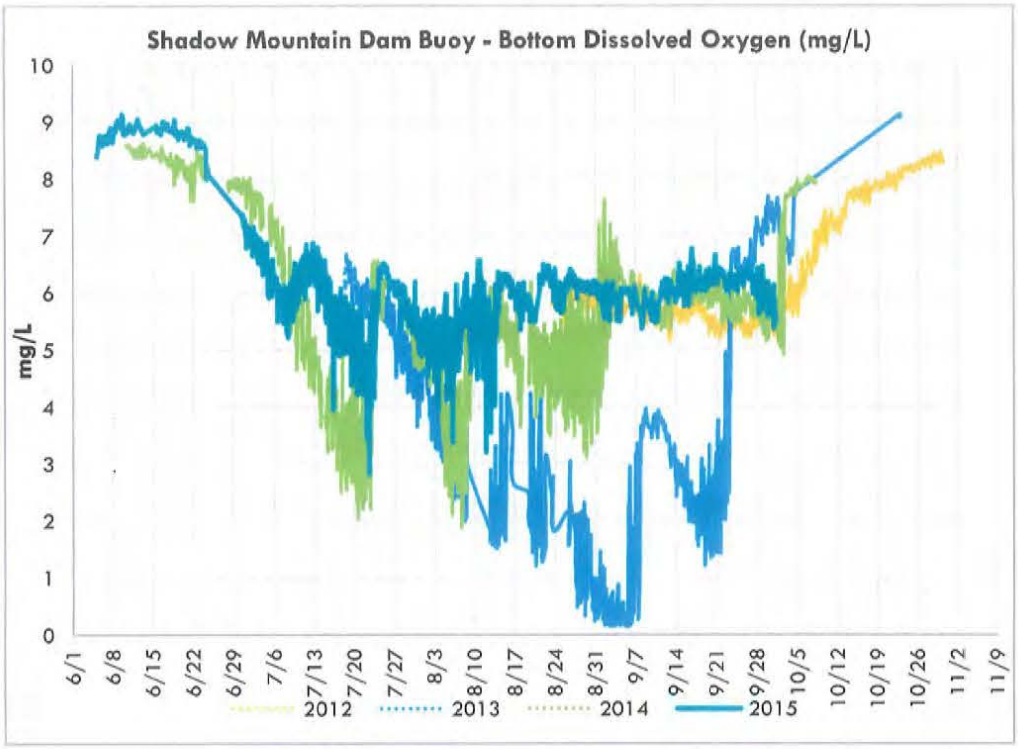


FIGURE 7 - BOTTOM DO AT SHADOW MOUNTAIN DAM

November 12, 2015

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

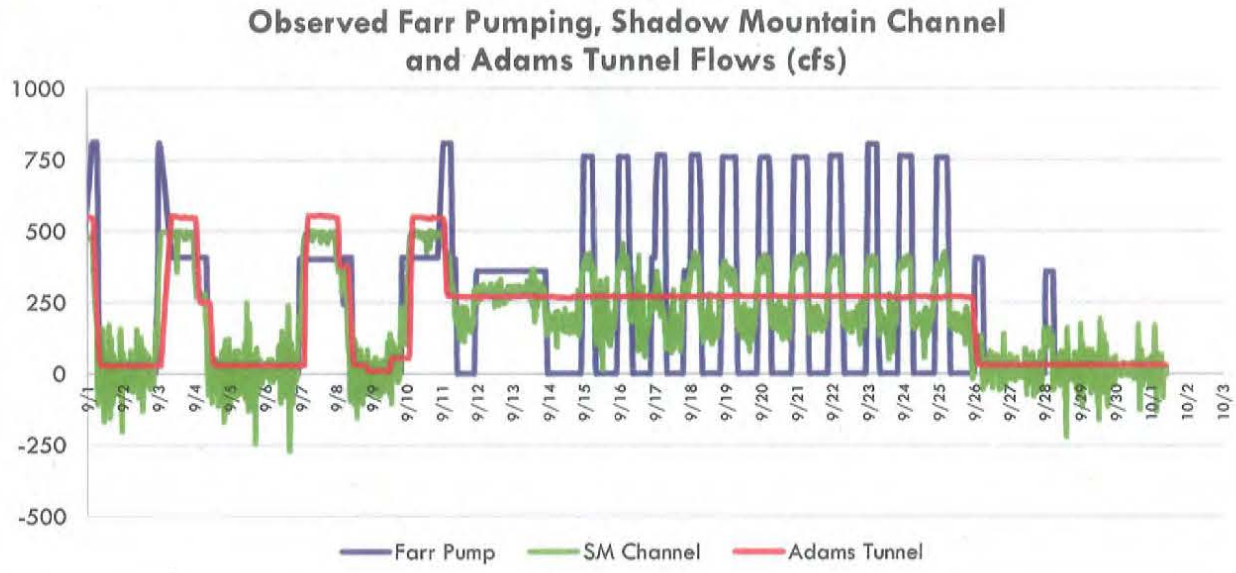
1-5 day minimum temperature anomaly forecast: http://www.wpc.ncep.noaa.gov/medr/95Bwbg.gif

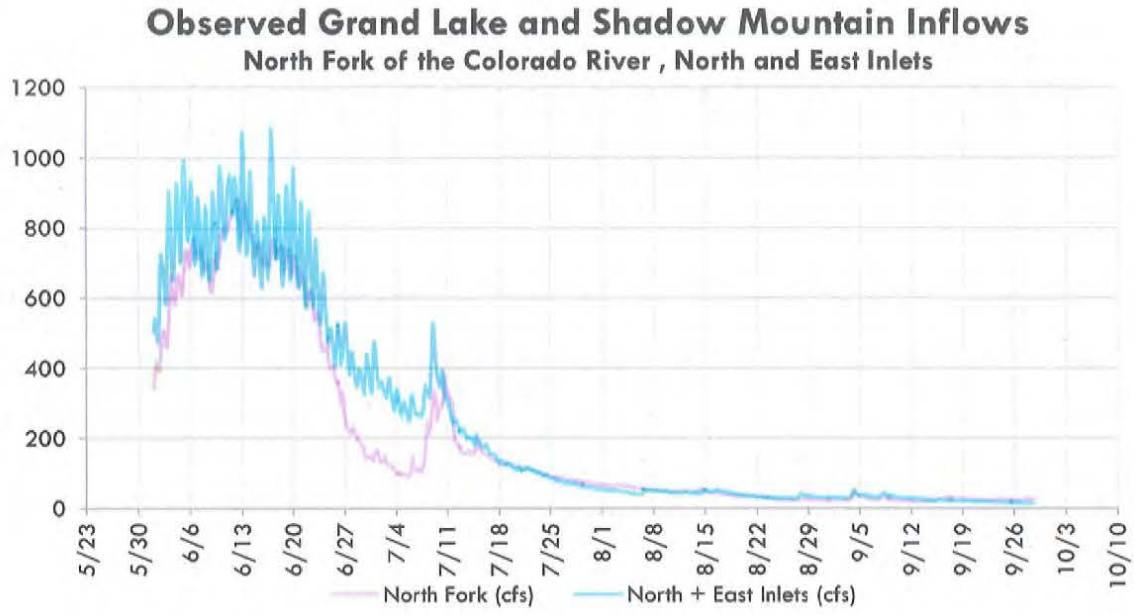
1-5 day maximum temperature forecast: http://www.wpc.ncep.noaa.gov/medr/95Awbg.gif

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

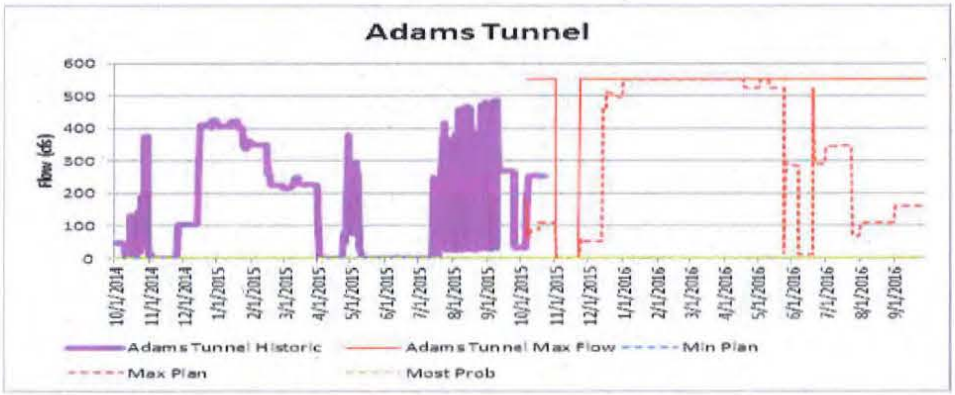
Action Items Summary:

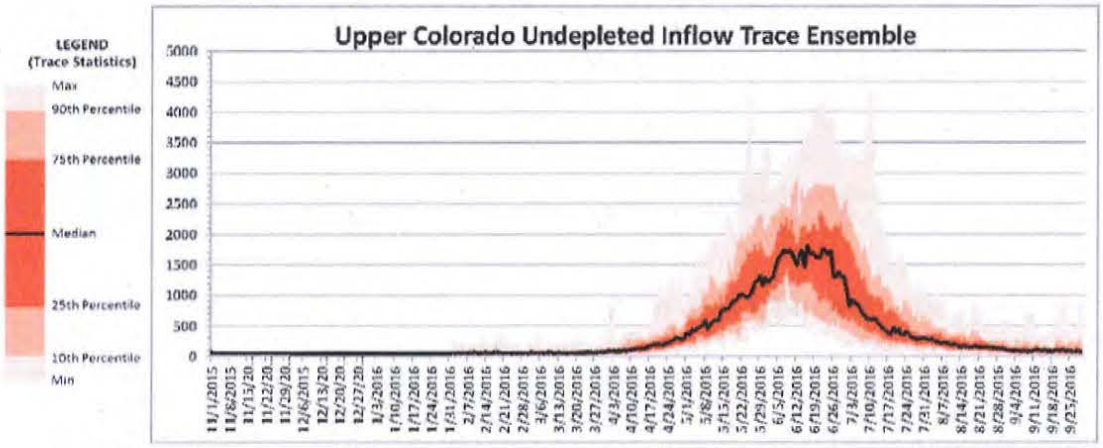
Observed Flows



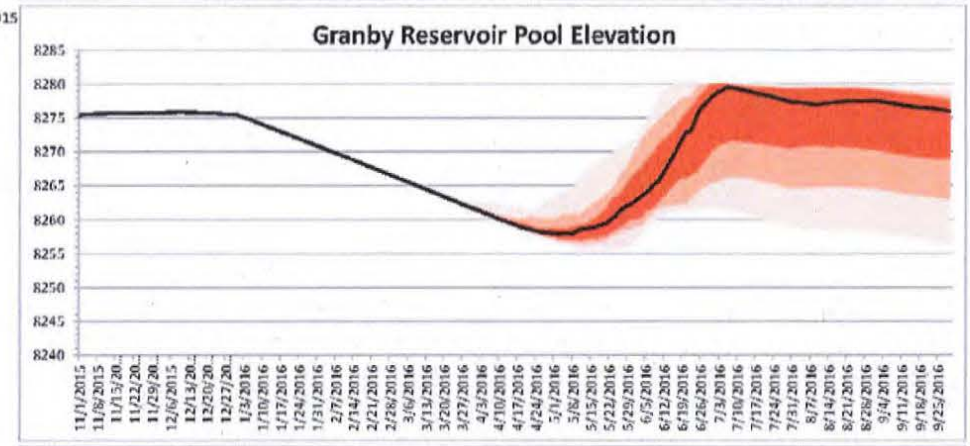


Operational Forecast

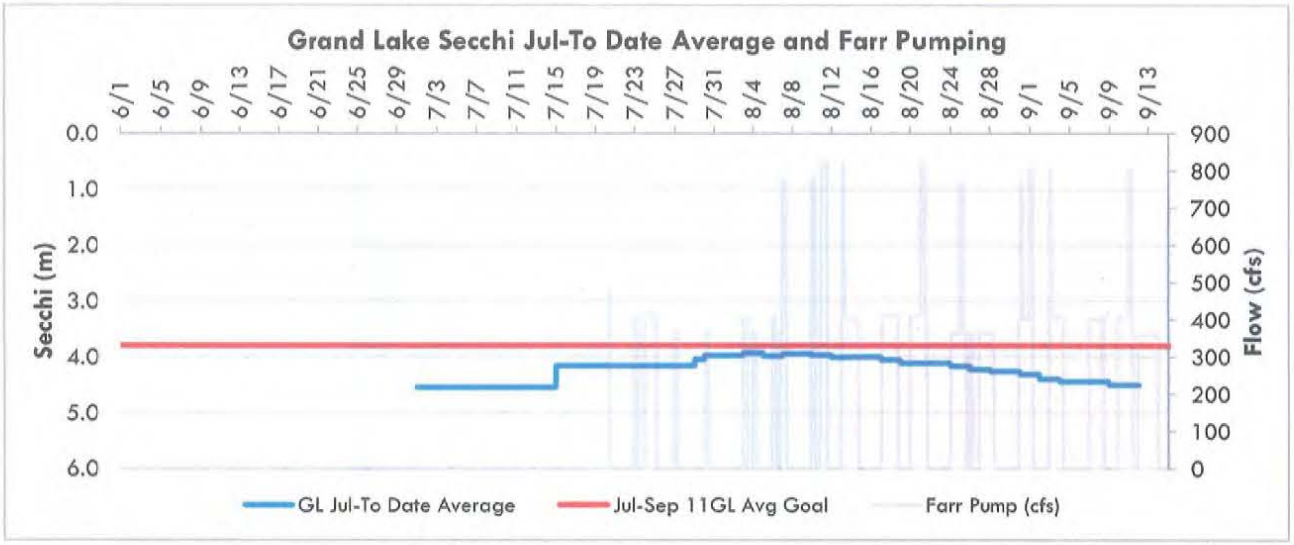


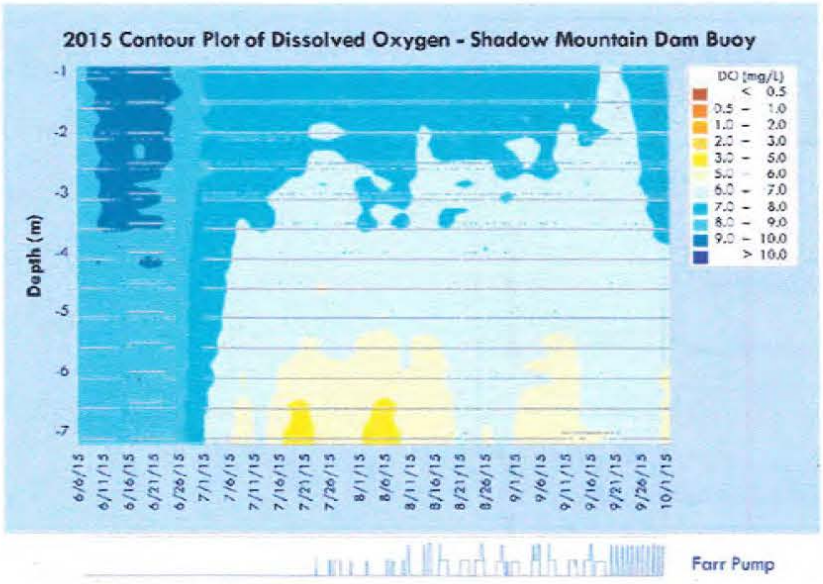


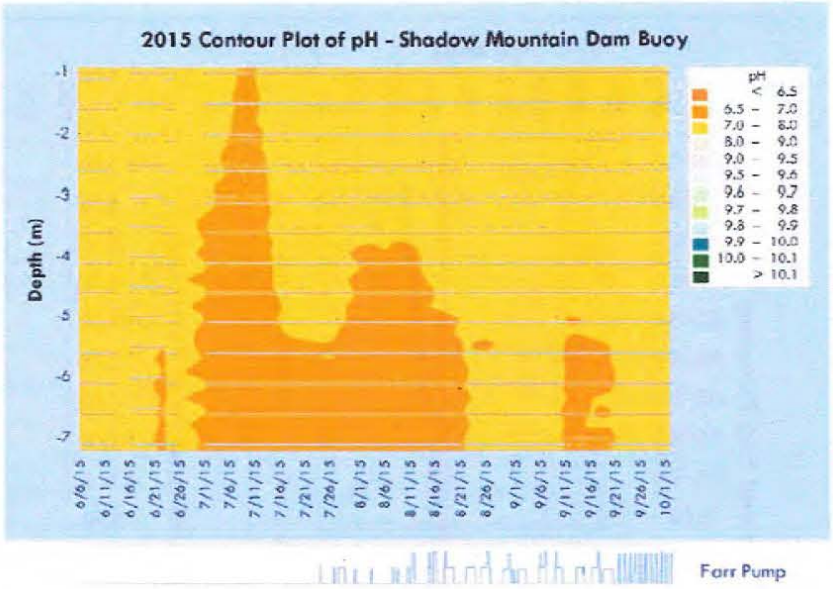
6/1/2015

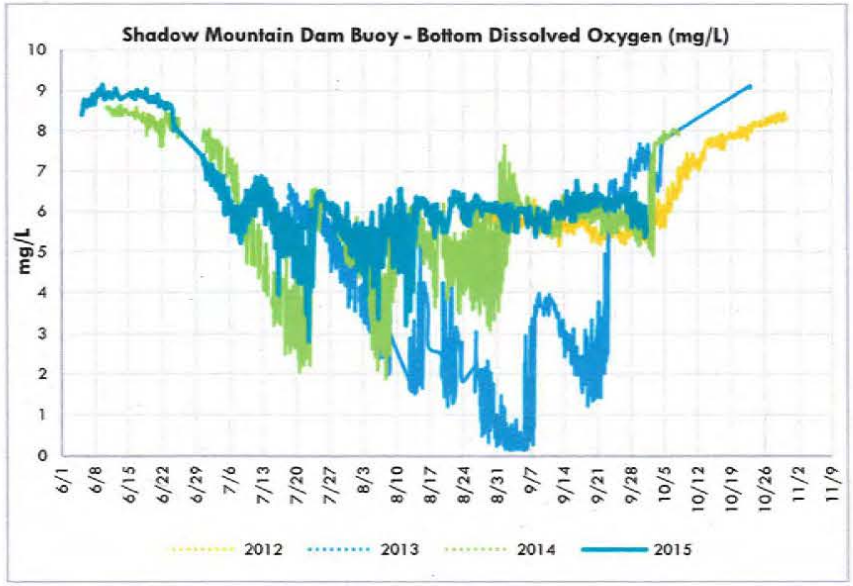


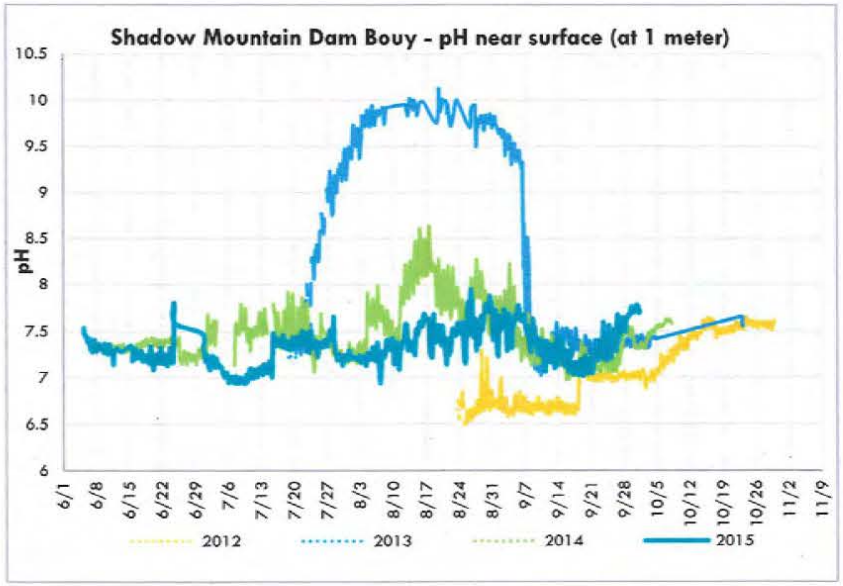
Water Quality Summary




2015 Contour Plot of Dissolved Oxygen - Shadow Mountain Dam Buoy
Depth (m)
DO (mg/L)
< 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 3.0
3.0 - 5.0
5.0 - 6.0
6.0 - 7.0
7.0 - 8.0
8.0 - 9.0
9.0 - 10.0
> 10.0
Farr Pump


2015 Contour Plot of pH - Shadow Mountain Dam Buoy
Depth (m)
pH
< 6.5
6.5 - 7.0
7.0 - 8.0
8.0 - 9.0
9.0 - 9.5
9.5 - 9.6
9.6 - 9.7
9.7 - 9.8
9.8 - 9.9
9.9 - 10.0
10.0 - 10.1
> 10.1
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