COLORADO
Colorado Water Conservation Board
Department of Natural Resources

1313 Sherman Street, Room 718
Denver, CO 80203

April 11, 2017

Colorado School of Mines
Attn: Andy Burrow, PhD Canidate, Project Manager
1500 Illinois Street
Golden, CO 80401

RE: Notice to Proceed – WSRF Grant – **POGG1 2017-906** Designing River Basin Storage Along the South Platte River

Dear Andy,

This letter is to inform you that purchase order/contract to assist in the above WSRF grant project has been approved. The original contract documents in the email serve as your copy.

With the executed agreement, you are now able to proceed with the project and invoice the State of Colorado for costs incurred through June 30, 2018. Please provide the project name, contract/PO number, and basin when corresponding with or invoicing for your project along with back-up documentation of cost incurred for the WSRF portion of the grant according to the original scope of work. Upon receipt of your invoice(s), the State of Colorado will provide payment no later than 30 days after review and signed approval of the project manager.

Please refer to the WSRF Criteria & Guidelines for reporting requirements for the six month progress reports and final deliverable requirements in order to avoid a delay in payment. A 30-day advance notice is required in the event you are seeking an amendment to the term of the contract and will require an official letter of request to the CWCB project manager briefly describing the need for the extension, updated insurance certificates and updated schedule.

If you have any questions or concerns regarding this project, please contact Craig Godbout, Project Manager at 303-866-3441 x3210 or at craig.godbout@state.co.us. When submitting invoices and progress reports, send to the PM and cc me at dori.vigil@state.co.us. You can contact me at 303-866-3441 ext. 3250 for additional invoicing and payment disbursement questions.

Thank you.

Sincerely,

//s//

Doriann Vigil
Program Assistant II
O 303-866-3441 ext. 3250
1313 Sherman Street, Rm. 719, Denver, CO 80203
Dori.vigil@state.co.us / cwcb.state.co.com
Attachments

STATE OF COLORADO
Department of Natural Resources

ORDER
Number: POGG1 PDAA 201700000906
Date: 04/11/17
Description:
PDAA WSRF CSM_DESIGN RIV BASIN STUDY
Effective Date: 04/11/17 Expiration Date: 06/30/18

BUYER
Buyer:
Email:

VENDOR
STATE OF COLORADO SCHOOL OF MINES
1500 ILLINOIS ST
GOLDEN, CO 80401-1843

Contact: .
Phone: 3032323915

**** IMPORTANT ****
The order number and line number must appear on all invoices, packing slips, cartons and correspondence

BILL TO
COLORADO WATER BOARD CONSERVATION
1313 SHERMAN STREET, ROOM 718
DENVER, CO 80203

SHIP TO
COLORADO WATER BOARD CONSERVATION
1313 SHERMAN STREET, ROOM 718
DENVER, CO 80203

SHIPPING INSTRUCTIONS
Delivery/Install Date:
F.O.B: FOB Dest, Freight Allowed
VENDOR INSTRUCTIONS:

Line Item	Commodity/Item Code	UOM	QTY	Unit Cost	Total Cost	MSDS Req.
1	G1000		0	0.00	$39,089.00	☐
Description: PDAA WSRF CSM_DESIGN RIV BASIN STUDY						
Service From: 04/11/17 Service To: 06/30/18						
Line Item	**Commodity/Item Code**	**UOM**	**QTY**	**Unit Cost**	**Total Cost**	**MSDS Req.**
2	G1000		0	0.00	$11,841.00	☐
Description: PDAA WSRF CSM_DESIGN RIV BASIN STUDY						
Service From: 04/11/17 Service To: 06/30/18						

TERMS AND CONDITIONS
https://www.colorado.gov/osc/purchase-order-terms-conditions

DOCUMENT TOTAL = $50,930.00

Exhibit A

Statement of Work
Date: 31 October 2016 - revised 4/6/17

WATER ACTIVITY NAME - Designing river basin storage along the lower South Platte using StateMod and optimization

GRANT RECIPIENT – Colorado School of Mines

FUNDING SOURCE – G.I. Bill

INTRODUCTION AND BACKGROUND

Provide a brief description of the project. (Please limit to **no more than 200 words**; this will be used to inform reviewers and the public about your proposal)

The overall purpose of this research is to provide quantitative information to undergird a decision regarding the optimal location, type and size of additional unappropriated water storage along the lower South Platte. In order to identify a location for increased water storage, this research uses flow data produced by StateMod as input for a mixed integer-linear optimization program. This program minimizes the cost to meet all demands and shortages by assigning network flow while adhering to the constraints that force the physical and topographical structures of the river. The program solution contains a location/s and amount of water storage that mitigate the shortages in a given time horizon. Storage methods considered in this research include: (1) expanding existing reservoir capacity by raising the height of dams, as well as dredging, (2) constructing new surface reservoirs and (3) constructing underground storage. Costs used in this study are obtained from estimates associated with like projects in Colorado and California. Feasible locations of underground storage are obtained from the CWCB Underground Water Storage Study. Program solutions are then inserted into StateMod for validation. This process is repeated using subsequent optimization model results until a feasible StateMod outcome is reached.

OBJECTIVES

Overall, we seek to develop a lower South Platte case study that uses a generalized methodology and structure that can be applied to other basins throughout the State of Colorado. The primary objective is to provide quantitative information to undergird a decision regarding the optimal location, type and size of additional unappropriated water storage along the Lower South Platte River. This objective shall be accomplished by producing an optimization model that uses simulated flow, produced by StateMod, as input data. This model shall represent mathematically, and include all necessary information, to correctly constrain the problem based on the physical topography of the basin and the structures contained therein. This objective shall be accomplished using the following tasks:

Executive Summary

Introduction

This executive summary describes a research endeavor by the Colorado School of Mines to use existing tools and applied optimization to identify additional unappropriated water storage along the lower South Platte River between the Kersey Gage and the Nebraska border.

Applied optimization uses a mathematical process to choose the best option, from among many available alternatives, with regard some criterion. Optimization models are especially useful when: (1) there are many unknown values to be determined, (2) the relationships between the unknowns are complex and inextricably linked, (3) the goal has many tradeoffs and (4) a repeatable solution, which can be obtained quickly, is desired. Our optimization model seeks the minimum cost solution of designing additional reservoir storage while using flow data produced by StateMod. We seek to develop a Lower South Platte case study that uses a generalized methodology and structure that can be applied to other basins throughout the State of Colorado.

Section 1: Promotes South Platte Basin Implementation Plan

The main focus of this project is determining additional water storage locations, using existing data and tools, thus advancing the South Platte Basin Implementation Plan (SPBIP) Section 1.9.4. To do so, the Colorado School of Mines (CSM) is developing an optimization model that uses StateMod simulated flow as a data source and finds the minimum cost option to meet both demand and shortages using unappropriated water. Additional storage methods considered in this research include: (1) expanding existing reservoir capacity by raising the height of dams, as well as dredging, (2) constructing new surface reservoirs and (3) constructing underground storage. Costs used in this study are obtained from estimates associated with like projects in Colorado and California. Feasible locations of underground storage are obtained from the CWCB Underground Water Storage Study. Model solutions are inserted into StateMod for validation. This process is repeated using subsequent optimization model results until a feasible StateMod outcome is reached.

By developing quantitative information to undergird a decision regarding the optimal location, type and size of additional unappropriated water storage along the lower South Platte River, this project contributes to funding category 1: develop or advance multi-purpose water supply projects.

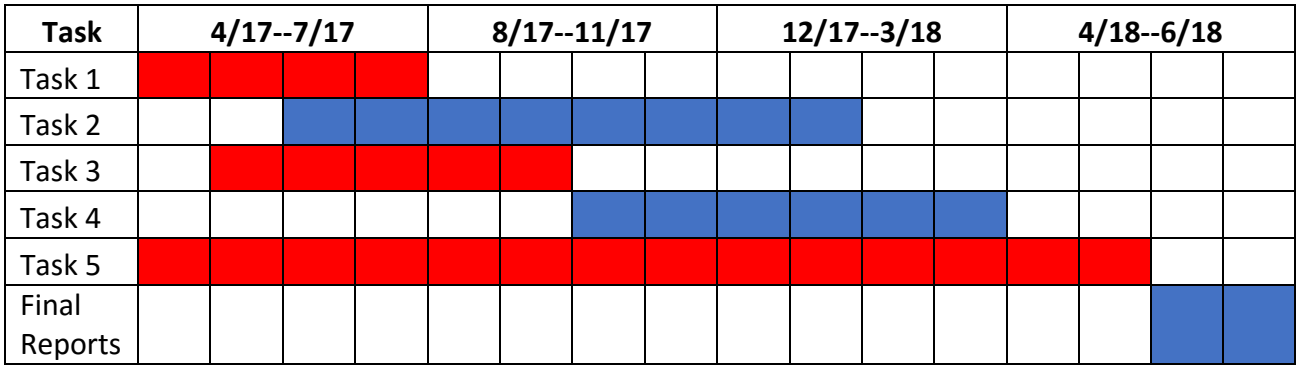
This project also contributes to funding category 2: promoting education and outreach that emphasizes the South Platte BIP priorities. Throughout the course of this project, the work will be mentioned publicly in the following ways: (1) Three separate presentations to Colorado School of Mines (CSM) faculty, (2) technical papers describing the work will be submitted for publication to peer reviewed journals and (3) We will request to present our work at The Institute for Operations Research and the Management Sciences (INFORMS) annual meeting in Houston during October of 2017. INFORMS is the largest society in the world for professionals in the field of operations research, management science and analytics.

Section 2: Project Urgency and Readiness

The matched funding for this project will be exhausted in March of 2017. At that point, if this project receives no further funding, the model will simply exist in an academic environment and will provide only a single solution, not a robust capability to be used in the future for planning purposes in the South Platte Basin. Therefore, it is imperative this project be funded now.

The project's schedule is tied to five different tasks:

1. Cost estimate collection
2. StateMod flow data preparation
3. Feasible underground storage site data collection
4. StateMod—Optimization model interface development
5. Mixed integer-linear optimization model development



Section 3: Matching Funds

The overall project budget is $97,372. Of this total, matching funds from the G.I. Bill amount to $43,283. Thus, the remaining $54,089 is requested via the WSRA grant. Our matching funds represent an 80% match of the total. Of this total WSRA request of $54,089, we are requesting $15,000 from the state fund and $39,089 from the basin fund. Our matching funds exceed the requirement percentage in both cases.

Section 4: Measurable Outcomes

Project success will be measured by a committee consisting of:

(1) Alexandra Newman, PhD, Operations Research at the School of Mines
(2) Tissa Illangasekare, PhD, Civil Engineering at the School of Mines
(3) Andres Guerra, PhD, Civil Engineering at the School of Mines
(4) Dinesh Mehta, PhD, Computer Science at the School of Mines
(5) Reagan Waskom, PhD, Colorado Water Institute

PROPOSED BUDGET CSM Proposal No. 17-0185

April 1, 2017 - June 30, 2018 (15 months)

		Year 1	Year 2	Total
A.	SALARIES AND WAGES		(3 months)	
1.	Alexandra Newman, PI - 3 summer days	$1,933	$0	$1,933
2.	Graduate Research Asst. (Andrew Burrow) @ $1,760/month (no summer)	15,840	5,491	21,331
	Subtotal	$17,773	$5,491	$23,264
B.	FRINGE BENEFITS			
1.	38.8% of A1	$750	$0	$750
2.	GRA tuition and fees (reduced)* Fall 2017 and Spring 2018 and summer 2018 session 1 only	10,810	3,402	14,212
	Subtotal	$11,560	$3,402	$14,962
C.	OTHER DIRECT COSTS			
1.	Travel - domestic	$2,500	$0	$2,500
	Subtotal	$2,500	$0	$2,500
D.	TOTAL DIRECT COSTS	$31,833	$8,893	$40,726
E.	MODIFIED TOTAL DIRECT COSTS @ 50% IDC**	$5,256	$0	$5,256
	MODIFIED TOTAL DIRECT COSTS @ 50.5% IDC	$15,767	$5,491	$21,258
F.	INDIRECT COSTS - 50% of E***	2,628	0	2,628
	INDIRECT COSTS - 50.5% of E	7,962	2,773	10,735
G.	**TOTAL AMOUNT REQUESTED (Lines D + F)**	**$42,423**	**$11,666**	**$54,089**

*student has own health insurance
**Line D not including B2
***Effective July 1, 2017 the IDC rate becomes 50.5%

H.	*COST SHARE - THIRD PARTY (GI BILL)*			
1.	*Tuition*	*$21,670*	*0*	*$21,670*
2.	*Stipend*	*20,488*	*0*	*20,488*
3.	*Supplies*	*1,125*	*0*	*1,125*
	Subtotal	*$43,283*	*$0*	*$43,283*

TASK 1 – Cost estimate collection

Description of Task

The optimization model uses costs associated with reservoir expansion and new reservoir construction. However, site-specific information is not known a priori. For example, our model considers all available locations for new reservoir construction. However, each location may be quite different to consider; one location may have higher permitting fees versus another location that may require more infrastructure. In order to obtain a cost estimate that incorporates this unknown disparity, several cost estimates shall be obtained in order to produce a median value for use in the optimization model.

Method/Procedure

All cost estimates shall come from like projects in Colorado or other similar environments and be gleaned from Environmental Impact Studies produced by the Army Corps of Engineers, Bureau of Reclamation or other like entity.

Deliverable

These costs shall be incorporated into the model mentioned in task 5.

TASK 2 – StateMod flow data preparation

Description of Task

Flow data shall be produced using all available time periods in StateMod.

Method/Procedure

StateMod will be used on all available time periods to simulate flow data. This data will be converted from standard StateMod .xdd file output, into a format compatible with the optimization model.

Deliverable

A correctly formatted data file for use in task 5.

TASK 3 – Feasible underground storage site collection

Description of Task

Underground storage is not possible in all locations because of the underlying geology. So, all possible locations must be determined.

Method/Procedure

All locations for underground storage will be extracted from the CWCB Underground Water Storage Study.

Deliverable

These locations shall be incorporated into the model mentioned in task 5.

TASK 4 – StateMod—Optimization model interface development

Description of Task

In order to ensure the optimal solutions produced by the model mentioned in task 5 are feasible, the solution/s needs to be plugged back in to StateMod for verification.

Method/Procedure

The iterative process of collecting data produced by simulation, running the optimization model, evaluating the solution and plugging the solution back in to StateMod shall be evaluated.

TASK 5 – Mixed integer-linear optimization model development

Description of Task

Develop a mixed integer-linear optimization model that uses flow produced by StateMod to determine the optimal location for additional water storage along the Lower South Platte River, between the Kersey Gage and the Nebraska border. This model shall include as options: (1) expanding existing reservoirs by dredging and dam raising, (2) constructing new surface reservoirs and (3) constructing underground storage. A minimum cost solution may include filling the reservoir naturally or pumping from a downstream location. This model shall be constrained based on physical, topographical and geological information which describes the lower South Platte region.

Method/Procedure

The optimization model will be developed in accordance with accepted standards of practice within the Applied Mathematics, Industrial Engineering and Operations Research communities.

Deliverable

Functional optimization model that produces an optimal solution using flow data produced by StateMod.

REPORTING AND FINAL DELIVERABLE

Reporting: The applicant shall provide the CWCB a progress report every 6 months, beginning from the date of the executed contract. The progress report shall describe the completion or partial completion of the tasks identified in the statement of work including a description of any major issues that have occurred and any corrective action taken to address these issues.

Final Deliverable: At completion of the project, the applicant shall provide the CWCB a final report that summarizes the project and documents how the project was completed. This report may contain photographs, summaries of meetings and engineering reports/designs.

BUDGET

Provide a detailed budget by task including number of hours and rates for labor and unit costs for other direct costs (i.e. mileage, $/unit of material for construction, etc.). A detailed and perfectly balanced budget that shows all costs is required for the State's contracting and purchase order processes. Sample budget tables are provided below. Please note that these budget tables are examples and will need to be adapted to fit each individual application. Tasks should correspond to the tasks described above.

	Total Costs				**Revised Costs**
	Labor	Other Direct/Indirect Costs	Matching Funds	Total Project Costs	Revised total WSRA funds per task
Task 1 - Cost estimate collection	$2,401.40	$6,015.00	$8,656.60	$17,073.00	$7,925.00
Task 2 - StateMod flow data preparation	$2,401.40	$6,015.00	$8,656.60	$17,073.00	$7,925.00
Task 3 - Feasible underground storage site collection	$2,401.40	$6,015.00	$8,656.60	$17,073.00	$7,925.00
Task 4 - Optimization model interface development	$2,401.40	$6,015.00	$8,656.60	$17,073.00	$7,925.00
Task 5 - Mixed integer-linear optimization model development	$14,408.40	$6,015.00	$8,656.60	$29,080.00	$19,230.00
Total Costs:	$24,014.00	$30,075.00	$43,283.00	$97,372.00	$50,930.00

Project Personnel:	PhD Student	Faculty Advisor	Total Costs
Hourly Rate:	$16.985	$80.54	$97.525
All Tasks	1300	24	
Total Hours:	1300	24	
Cost:	$22,081.00	$1,933.00	$24,014.00

* Hourly rates are shown per the sponsor's request. Please be aware that CSM employees are not generally paid on an hourly basis, and invoices for work performed will not show hourly rates.

SCHEDULE

1. Task 5 milestones:
   i. Cost estimate completion, 7/17
   ii. Underground storage site collection completion, 9/17
   iii. StateMod flow data preparation completion, 1/18
   iv. Model completion 5/18

2. Task 4 milestone:
   i. Interface development completion, 3/18

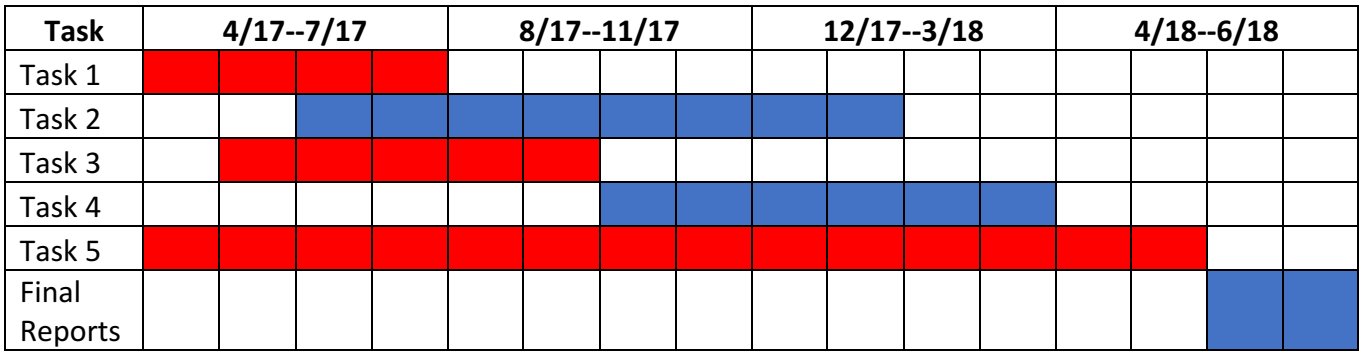


Exhibit B

As a ***proof of concept***, a basic optimization model was developed which used StateMod as a data source for the purposes of designing new water storage along the Lower South Platte River. Our basic model only considered existing reservoir expansion (dam raising only, no dredging) and new reservoir construction as the means for this additional storage.

The flow used in our model was simulated by StateMod at multiple points only the 150-mile reach between Greeley and the Nebraska border (Figure 1).

Figure 1: Points at which StateMod simulates flow

Data was used for August and September of 2011, which produced shortages of 4684 AF and 1854 AF, respectively. Costs used for new reservoir construction and existing reservoir expansion were $3,128/AF and $2,226/AF, respectively. In this case study, it was assumed that all unappropriated water could be used to meet any shortages. The final solution suggests that expanded capacity at either Empire Reservoir or Riverside Reservoir (Figure 2) by 632 AF mitigates shortages during this time period.

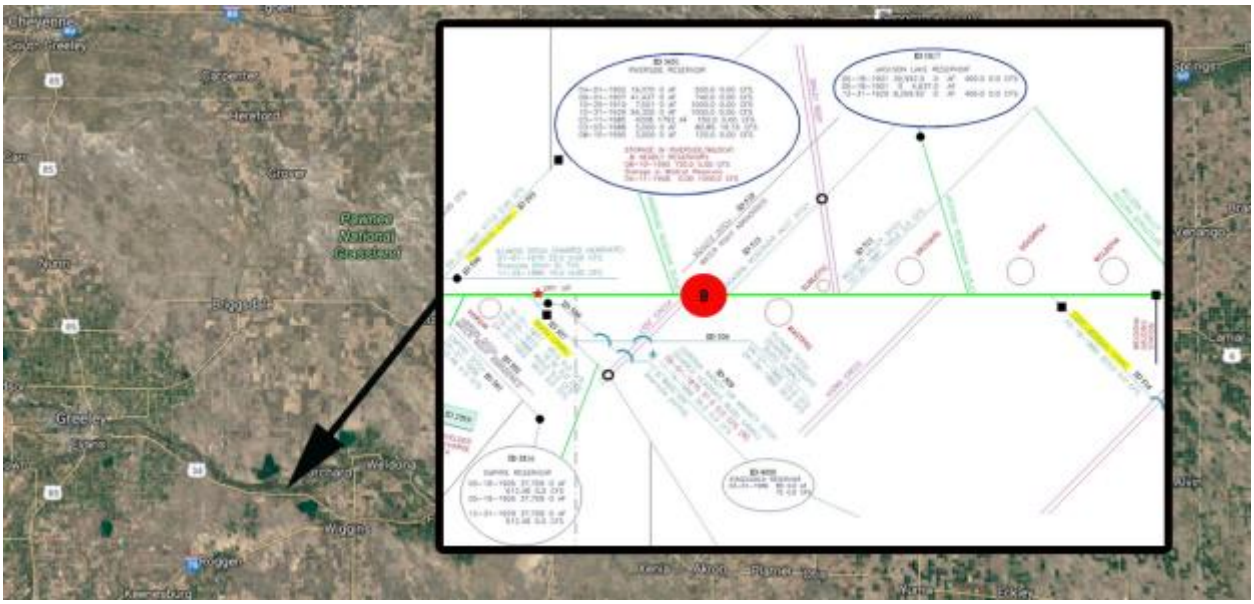


Figure 2: Expanded capacity location along the Lower South Platte