STATE OF TEXAS

TWDB Contract No. 1800012243

COUNTY OF TRAVIS

General Revenue
Research Triangle Institute

This Contract, (hereinafter "CONTRACT"), between the Texas Water Development Board (hereinafter "TWDB") and Research Triangle Institute (hereinafter "CONTRACTOR"), is composed of two parts, SECTION I. SPECIFIC CONDITIONS AND EXCEPTIONS TO THE STANDARD AGREEMENT and SECTION II. STANDARD AGREEMENT. The terms and conditions set forth in SECTION I will take precedence over terms and conditions in SECTION II.

SECTION I. SPECIFIC CONDITIONS AND EXCEPTIONS TO STANDARD AGREEMENT

ARTICLE I. DEFINITIONS

For the purposes of this CONTRACT, the following terms or phrases shall have the meaning ascribed therewith:

1. TWDB – The Texas Water Development Board, or its designated representative
2. CONTRACTOR – Research Triangle Institute
3. EXECUTIVE ADMINISTRATOR – The Executive Administrator of the TWDB or a designated representative
4. PARTICIPANT(S) – Research Triangle Institute
5. REQUIRED INTERLOCAL AGREEMENT(S) – n/a
6. RESEARCH PROJECT – National Weather Service Hydrologic Model Calibration
7. TWDB APPROVAL DATE – n/a
8. DEADLINE FOR CONTRACT EXECUTION – July 13, 2018
9. CONTRACT INITIATION DATE – April 16, 2018
10. STUDY COMPLETION DATE – July 31, 2019
11. CONTRACT EXPIRATION DATE – August 31, 2019

12. TOTAL STUDY COSTS – $200,000.00

13. TWDB SHARE OF THE TOTAL STUDY COSTS – the lesser of $200,000.00 or 100 percent of the total study costs or individual payment submission

14. LOCAL SHARE OF THE TOTAL STUDY COSTS – 0 in cash or 0 percent of the total study costs or individual payment submission

15. PAYMENT SUBMISSION SCHEDULE – Quarterly

16. OTHER SPECIAL CONDITIONS AND EXCEPTIONS TO STANDARD AGREEMENT OF THIS CONTRACT – n/a

SECTION II. STANDARD AGREEMENT

ARTICLE I. RECITALS

Whereas, on April 9, 2018, TWDB staff determined that the CONTRACTOR was the top ranked submission in response to RFQ 580-18-0061;

Whereas, the CONTRACTOR is the entity who will act as administrator of the TWDB's research grant and will be responsible for the execution of this contract;

Now, therefore, the TWDB and the CONTRACTOR, agree as follows:

ARTICLE II. PROJECT DESCRIPTION AND SERVICES TO BE PERFORMED

1. The TWDB enters into this CONTRACT under the authority Texas Water Code §§ 16.316 and 16.3161 and Exhibit A, the original grant application, which is incorporated herein and made a permanent part of this CONTRACT; and this CONTRACT.

2. The CONTRACTOR will conduct a RESEARCH PROJECT, as delineated and described in Exhibit A, according to the Scope of Work contained in Exhibit B.

3. A progress report, including results to date, will be provided to the EXECUTIVE ADMINISTRATOR quarterly, throughout the project. Special interim reports on special topics and/or results will be provided as appropriate. Instructions for the progress report are shown in Exhibit E, TWDB Guidelines for a Progress Report.

4. Within the first 60 days of the commencement of this CONTRACT, CONTRACTOR will consult with TWDB staff to prepare a list of entities that potentially may be affected by the results of this RESEARCH PROJECT. On the STUDY COMPLETION DATE, this list will be reviewed and updated by the CONTRACTOR and submitted to the TWDB with the draft final report.

ARTICLE III. CONTRACT TERM, SCHEDULE, REPORTS, AND OTHER PRODUCTS

1. The CONTRACTOR has until the DEADLINE FOR CONTRACT EXECUTION to execute this CONTRACT and to provide acceptable evidence of any REQUIRED INTERLOCAL AGREEMENT(S) and the Contractors' ability to provide the LOCAL SHARE OF THE TOTAL STUDY COSTS, if applicable, to the EXECUTIVE ADMINISTRATOR for approval or the TWDB's SHARE OF THE TOTAL STUDY COSTS will be rescinded.

2. The term of this CONTRACT shall begin and the CONTRACTOR shall begin performing its obligations hereunder on the CONTRACT INITIATION DATE and shall expire on the CONTRACT EXPIRATION DATE. Delivery of an acceptable final

report prior to the CONTRACT EXPIRATION DATE shall constitute completion of the terms of this CONTRACT.

3. The CONTRACTOR will complete the Scope of Work and will deliver four (4) double- sided copies of a draft final report to the EXECUTIVE ADMINISTRATOR no later than the STUDY COMPLETION DATE. The draft final report will include the scope of work; a description of the research performed; the methodology and materials used; any diagrams or graphics used to explain the procedures related to the study; any data collected; an electronic copy of any computer programs, maps, or models along with an operations manual and any sample data set(s) developed under the terms of this CONTRACT; analysis of the research results; conclusions and recommendations; a list of references, a Table of Contents, List of Figures, List of Tables, an Executive Summary, and any other pertinent information. All final reports should be prepared according to Exhibit D, Guidelines for Authors Submitting Contract Reports to the Texas Water Development Board. After a 30-day review period, the EXECUTIVE ADMINISTRATOR will return review comments to the CONTRACTOR.

4. The CONTRACTOR will consider incorporating comments from the EXECUTIVE ADMINISTRATOR and other commentors on the draft final report into a final report. The CONTRACTOR will include a copy of the EXECUTIVE ADMINISTRATOR's comments in the final report. The CONTRACTOR will submit one (1) electronic copy of the entire final report in Portable Document Format (PDF) and five (5) bound double- sided copies of the final report to the EXECUTIVE ADMINISTRATOR no later than the sixty days (60) after the STUDY COMPLETION DATE.

5. The CONTRACTOR will submit one (1) electronic copy of any computer programs or models and an operations manual developed under the terms of this CONTRACT. In compliance with Texas Administrative Code Chapters 206 and 213 (related to Accessibility and Usability of State Web Sites), the digital copy of the final report will comply with the requirements and standards specified in statute. After a 30-day review period, the EXECUTIVE ADMINISTRATOR will either accept or reject the final report. If the final report is rejected, the rejection letter sent to the CONTRACTOR shall state the reasons for rejection and the steps the CONTRACTOR need to take to have the final report accepted and the retainage released.

6. The CONTRACTOR will submit the most recent progress report with submittal of payments according to the PAYMENT SUBMISSION SCHEDULE. Progress reports shall be in written form and shall include a brief statement of the overall progress made since the last status report; a brief description of any problems that have been encountered during the previous reporting period that will affect the study, delay the timely completion of any portion of this CONTRACT, inhibit the completion of or cause a change in any of the study's products or objectives; and a

description of any action the CONTRACTOR plans to take to correct any problems that have been encountered.

7. The EXECUTIVE ADMINISTRATOR can extend the STUDY COMPLETION DATE and the CONTRACT EXPIRATION DATE upon written approval. The CONTRACTOR should notify the EXECUTIVE ADMINISTRATOR in writing within ten (10) working days prior to the STUDY COMPLETION DATE or thirty (30) days prior to the CONTRACT EXPIRATION DATE that the CONTRACTOR is requesting an extension to the respective dates.

ARTICLE IV. COMPENSATION AND REIMBURSEMENT

1. The TWDB agrees to compensate and reimburse the CONTRACTOR in a total amount not to exceed the TWDB's SHARE OF THE TOTAL STUDY COSTS for costs incurred and paid by the CONTRACTOR pursuant to performance of this CONTRACT. The CONTRACTOR will contribute local matching funds, if applicable, in sources and amounts defined as the LOCAL SHARE OF THE TOTAL STUDY COSTS. The TWDB shall reimburse the CONTRACTOR for one hundred percent (100%) of the TWDB's share of each invoice pending the CONTRACTOR's performance up to ninety percent (90%) of the total funding costs. Upon completion of a Final Report, and written acceptance of said Final Report by the EXECUTIVE ADMINISTRATOR, the TWDB shall pay the remaining ten percent (10%) to the CONTRACTOR upon submission of a final invoice.

2. The CONTRACTOR shall submit payments and documentation for reimbursement billing according to the PAYMENT SUBMISSION SCHEDULE and in accordance with the approved task and expense budgets contained in Exhibit C to this CONTRACT. The CONTRACTOR has budget flexibility within task and expense budget categories to the extent that the resulting change in amount in any one task or expense category does not exceed 35% of the total authorized amount by this CONTRACT for the task or category. Larger deviations shall require approval by EXECUTIVE ADMINISTRATOR or designee which will be documented through an Approved Budget Memorandum to the TWDB contract file. The CONTRACTOR will be required to provide written explanation for the overage and reallocation of the task and expense amount.

   For all reimbursement billings including any subcontractor's expenses, the EXECUTIVE ADMINISTRATOR must have determined that the REQUIRED INTERLOCAL AGREEMENT(S) and contracts or agreements between the CONTRACTOR and the subcontractor are consistent with the terms of this CONTRACT. The CONTRACTOR is fully responsible for paying all charges by subcontractors prior to reimbursement by the TWDB.

3. The CONTRACTOR and its subcontractors shall maintain satisfactory financial accounting documents and records, including copies of invoices and receipts, and shall make them available for examination and audit by the EXECUTIVE

ADMINISTRATOR. Accounting by the CONTRACTOR and its subcontractors shall be in a manner consistent with Generally Accepted Accounting Principles.

4. By executing this CONTRACT, the CONTRACTOR accepts the authority of the State Auditor's Office, under direction of the legislative audit committee, to conduct audits and investigations in connection with any and all state funds received pursuant to this contract. The CONTRACTOR shall comply with and cooperate in any such investigation or audit. The CONTRACTOR agrees to provide the State Auditor with access to any information the State Auditor considers relevant to the investigation or audit. The CONTRACTOR also agrees to include a provision in any subcontract related to this CONTRACT that requires the subcontractor to submit to audits and investigation by the State Auditor's Office in connection with any and all state funds received pursuant to the subcontract.

5. The CONTRACTOR shall submit a signed and completed payment request using the current spreadsheet located at: : http://www.twdb.texas.gov/about/contract_admin/index.asp or you can contact Contracts@twdb.texas.gov for a personalized payment request spreadsheet and along with a progress report as described in Article II, Item 3.

   In addition, the following documentation which documents the TOTAL STUDY COSTS for the reporting period even if the TOTAL STUDY COSTS are zero for reimbursement by the TWDB to the CONTRACTOR for the TWDB's SHARE OF THE TOTAL STUDY COSTS shall be submitted by the CONTRACTOR to the EXECUTIVE ADMINISTRATOR for reimbursement billing:

   A. A completed "Current Reimbursement Worksheet" Payment Request Checklist tab, or an invoice which includes the following information:
      (1) TWDB Contract Number;
      (2) Billing period; beginning (date) to ending (date);
      (3) Total Expenses for this period;
      (4) Total In-kind services, if applicable;
      (5) Less Local Share of the total study costs for the billing period, if applicable;
      (6) Total TWDB's share of the total study costs for the billing period;
      (7) Total costs to be reimbursed by the TWDB for the billing period; and
      (8) Certification, signed by the CONTRACTOR authorized representative, that the expenses submitted for the billing period are a true and correct representation of amounts paid for work performed directly related to this CONTRACT.

   B. Using the "Current Reimbursement" Worksheet, post all expenses for the period on the Invoice Ledger tab and Task Ledger tab for direct expenses incurred by the CONTRACTOR.
      (1) Salaries and Wages, Fringe, Overhead, and Profit.

(2) Other Expenses: Copies of detailed, itemized invoices/receipts for other expenses (credit card summary receipts or statements are not acceptable).

(3) Travel Expenses: Names, dates, work locations, time periods at work locations, itemization of subsistence expenses of each employee, limited, however, to travel expenses authorized for state employees by the General Appropriations Act, Tex. Leg. Regular Session, 2017, Article IX, Part 5, as amended or superceded. Receipts required for lodging; as well as copies of invoices or tickets for transportation costs or, if not available, names, dates, and points of travel of individuals.

C. Using the "Current Reimbursement" Worksheet, post all expenses for the period on the Invoice Ledger tab and Task Ledger tab for direct expenses incurred by all subcontractors.

(1) Salaries and Wages, Fringe, Overhead, and Profit.

(2) Other Expenses: Copies of detailed, itemized invoices/receipts for other expenses (credit card summary receipts or statements are not acceptable).

(3) Travel Expenses: Names, dates, work locations, time periods at work locations, itemization of subsistence expenses of each employee, limited, however, to travel expenses authorized for state employees by the General Appropriations Act, Tex. Leg. Regular Session, 2017, Article IX, Part 5, as amended or superceded. Receipts required for lodging; as well as copies of invoices or tickets for transportation costs or, if not available, names, dates, and points of travel of individuals.

6. Reimbursement Requests that lack required documentation will be denied or short paid if deficiencies are not resolved within ten (10) business days. Denied Reimbursement Requests or eligible expenses that were short paid must be resubmitted by the CONTRACTOR with the required documentation to be reconsidered for reimbursement.

7. If for some reason the reimbursement request cannot be processed due to the need for an amendment to the CONTRACT, the CONTRACTOR will be required to resubmit the Payment Request Checklist dated after the execution of the amendment.

8. The CONTRACTOR is responsible for any food or entertainment expenses incurred by its own organization or that of its subcontractors, outside that of the travel expenses authorized and approved by the State of Texas under this CONTRACT.

9 The CONTRACTOR is responsible for submitting any final payment request and documentation for reimbursement, along with a request to release any retained funds, no later than 120 days following the EXPIRATION DATE. Failure to submit a timely final payment request may result in the release of the retained funds to the

CONTRACTOR and a lapse and closure of any other remaining funding under this CONTRACT.

ARTICLE V. INTELLECTUAL PROPERTY: OWNERSHIP, PUBLICATION, AND ACKNOWLEDGMENT

1. "Use" of a work product, whether a CONTRACTOR Works, a Subcontractor Works or otherwise, shall mean and include, without limitation hereby, any lawful use, copying or dissemination of the work product, or any lawful development, use, copying or dissemination of derivative works of the work product, in any media or forms, whether now known or later existing.

2. "No Compensation Obligation" shall mean there is no obligation on the part of one co- owner or licensee of a work, whether a CONTRACTOR Works, a Subcontractor Works or otherwise, to compensate other co-owners, licensees or licensors of the work for any use of the work by the using co-owner or licensee, including but not limited to compensation for or in the form of: royalties; co-owner or licensee accounting; sharing of revenues or profits among co-owners, licensees or licensors; or any other form of compensation to the other co-owners, licensees or licensors on account of any use of the work.

3. "Dissemination" shall include, without limitation hereby, any and all manner of: physical distribution; publication; broadcast; electronic transmission; internet streaming; posting on the Internet or world wide web; or any other form of communication, transmission, distribution, sending or providing, in any forms or formats, and in or using any media, whether now known or later existing.

4. The TWDB shall have an unlimited, unrestricted, perpetual, irrevocable, non-exclusive royalty-free right to access and receive in usable form and format, and to use all technical or other data or information developed by CONTRACTOR and Subcontractor in, or otherwise resulting from, the performance of services under this CONTRACT.

5. For purposes of this Article, "CONTRACTOR Works" are work products developed by CONTRACTOR and Subcontractor using funds provided under this CONTRACT or otherwise rendered in or related to the performance in whole or part of this CONTRACT, including but not limited to reports, drafts of reports, or other material, data, drawings, studies, analyses, notes, plans, computer programs and codes, or other work products, whether final or intermediate.

    a. It is agreed that all CONTRACTOR Works shall be the joint property of the TWDB and CONTRACTOR.

    b. The parties hereby agree that, if recognized as such by applicable law, the CONTRACTOR Works are intended to and shall be works-made-for-

hire with joint ownership between the TWDB and CONTRACTOR as such works are created in whole or part.

c. If the CONTRACTOR Works do not qualify as works-made-for-hire under applicable law, CONTRACTOR hereby conveys co-ownership of such works to the TWDB as they are created in whole or part. If present conveyance is ineffective under applicable law, CONTRACTOR agree to convey a co-ownership interest of the CONTRACTOR Works to the TWDB after creation in whole or part of such works, and to provide written documentation of such conveyance upon request by the TWDB.

d. The TWDB and CONTRACTOR acknowledge that the copyright in and to a copyrightable CONTRACTOR Work subsists upon creation of the CONTRACTOR Work and its fixing in any tangible medium. CONTRACTOR or the TWDB may register the copyrights to such Works jointly in the names of the CONTRACTOR and the TWDB.

e. The TWDB and CONTRACTOR each shall have full and unrestricted rights to use a CONTRACTOR Work with No Compensation Obligation.

6. For purposes of this Article, "Subcontractor Works" include all work product developed in whole or part by or on behalf of Subcontractors engaged by CONTRACTOR to perform work for or on behalf of any CONTRACTOR under this CONTRACT (or by the Subcontractors' Subcontractors hereunder, and so on). CONTRACTOR shall secure in writing from any Subcontractors so engaged:

a. unlimited, unrestricted, perpetual, irrevocable, royalty-free rights of the TWDB (and, if desired, of CONTRACTOR) to access and receive, and to use, any and all technical or other data or information developed in or resulting from the performance of services under such engagement, with No Compensation Obligation; and either

b. assignment by the Subcontractor to the TWDB (and, if desired by them, jointly to the CONTRACTOR) of ownership (or joint ownership with the Subcontractor) of all Subcontractor Works, with No Compensation Obligation; or

c. grant by Subcontractor of a non-exclusive, unrestricted, unlimited, perpetual, irrevocable, world-wide, royalty-free license to the TWDB (and, if desired by them, the CONTRACTOR) to use any and all Subcontractor Works, including the right to sublicense use to third parties, with No Compensation Obligation.

7. No unauthorized patents. CONTRACTOR Works and Subcontractor Works or other work product developed or created in the performance of this CONTRACT

or otherwise using funds provided hereunder shall not be patented by CONTRACTOR or their Subcontractor unless the EXECUTIVE ADMINISTRATOR consents in writing to submission of an application for patent on such works; and provided that, unless otherwise agreed in writing, any application made for patent shall include and name the TWDB (and, as applicable and desired by them, CONTRACTOR) as co-owners of the patented work:

a. no patent granted shall in any way limit, or be used by CONTRACTOR or Subcontractor to limit or bar the TWDB's rights hereunder to access and receive in useable form and format, and right to use, any and all technical or other data or information developed in or resulting from performance pursuant to this CONTRACT or the use of funds provided hereunder; and

b. the TWDB (and, if applicable, the CONTRACTOR) shall have No Compensation Obligation to any other co-owners or licensees of any such patented work, unless otherwise expressly agreed in writing.

8. CONTRACTOR shall include terms and conditions in all contracts or other engagement agreements with any Subcontractors as are necessary to secure these rights and protections for the TWDB; and shall require that their Subcontractors include similar such terms and conditions in any contracts or other engagements with their Subcontractors. For the purposes of this section, "Subcontractors" includes independent contractors (including consultants) and also employees working outside the course and scope of employment.

9. Any work products subject to a TWDB copyright or joint copyright and produced or developed by the CONTRACTOR or their Subcontractor pursuant to this CONTRACT or using any funding provided by the TWDB may be reproduced in any media, forms or formats by the TWDB or CONTRACTOR at their own cost, and be disseminated in any medium, format or form by any party at its sole cost and in its sole discretion. CONTRACTOR may utilize such work products as they may deem appropriate, including Dissemination of such work products or parts thereof under their own name, provided that any TWDB copyright is noted on the materials.

10. The CONTRACTOR agrees to acknowledge the TWDB in any news releases or other publications relating to the work performed under this CONTRACT.

ARTICLE VI. AMENDMENT, TERMINATION, AND STOP ORDERS

1. This CONTRACT may be altered or amended by mutual written consent or terminated by the EXECUTIVE ADMINISTRATOR at any time by written notice to the CONTRACTOR. Upon receipt of such termination notice, the CONTRACTOR shall, unless the notice directs otherwise, immediately discontinue all work in connection with the performance of this CONTRACT and shall proceed to cancel promptly all existing orders insofar as such orders are chargeable to this

CONTRACT. The CONTRACTOR shall submit a statement showing in detail the work performed under this CONTRACT to the date of termination. The TWDB shall then pay the CONTRACTOR promptly that proportion of the prescribed fee, which applies to the work, actually performed under this CONTRACT, less all payments that have been previously made. Thereupon, copies of all work accomplished under this CONTRACT shall be delivered to the TWDB.

2. The EXECUTIVE ADMINISTRATOR may issue a Stop Work Order to the CONTRACTOR at any time. Upon receipt of such order, the CONTRACTOR shall discontinue all work under this CONTRACT and cancel all orders pursuant to this CONTRACT, unless the order directs otherwise. If the EXECUTIVE ADMINISTRATOR does not issue a Restart Order within 60 days after receipt by the CONTRACTOR of the Stop Work Order, the CONTRACTOR shall regard this CONTRACT terminated in accordance with the foregoing provisions.

ARTICLE VII. SUBCONTRACTS

Each Subcontract entered into to perform required work under this CONTRACT shall contain the following provisions:

a. a detailed budget estimate with specific cost details for each task or specific item of work to be performed by the Subcontractor and for each category of reimbursable expenses;

b. a clause stating that the Subcontract is subject to audit by the Texas State Auditor's Office and requiring the Subcontractor to cooperate with any request for information from the Texas State Auditor, as further described in Article X, Section 1, Paragraph D hereof;

c. a clause stating that payments under the Subcontract are contingent upon the appropriation of funds by the Texas Legislature, as further described in Article X, Section 1, Paragraph A hereof;

d. a clause stating that ownership of data, materials and work papers, in any media, that is gathered, compiled, adapted for use, or generated by the Subcontractor or the CONTRACTOR shall become data, materials and work owned by the TWDB and that Subcontractor shall have no proprietary rights in such data, materials and work papers, except as further described in Article V hereof;

e. a clause stating that Subcontractor shall keep timely and accurate books and records of accounts according to generally acceptable accounting principles as further described in Article X, Section 2, Paragraph G;

f. a clause stating that Subcontractor is solely responsible for securing all required licenses and permits from local, state and federal governmental entities and that Subcontractor is solely responsible for obtaining sufficient insurance in

accordance with the general standards and practices of the industry or governmental entity; and

g. a clause stating that Subcontractor is an independent contractor and that the TWDB shall have no liability resulting from any failure of Subcontractor that results in breach of CONTRACT, property damage, personal injury or death.

ARTICLE VIII. LICENSES, PERMIT, AND INSURANCE

1. For the purpose of this CONTRACT, the CONTRACTOR will be considered an independent contractor and therefore solely responsible for liability resulting from negligent acts or omissions. The CONTRACTOR shall obtain all necessary insurance, in the judgment of the CONTRACTOR, to protect themselves, the TWDB, and employees and officials of the TWDB from liability arising out of this CONTRACT.

2. The CONTRACTOR shall be solely and entirely responsible for procuring all appropriate licenses and permits, which may be required by any competent authority for the CONTRACTOR to perform the subject work.

3. Indemnification. The CONTRACTOR shall indemnify and hold the TWDB and the State of Texas harmless, to the extent the CONTRACTOR may do so in accordance with state law, from any and all losses, damages, liability, or claims therefore, on account of personal injury, death, or property damage of any nature whatsoever caused by the CONTRACTOR, arising out of the activities and work conducted pursuant to this CONTRACT. The CONTRACTOR is solely responsible for liability arising out of its negligent acts or omissions during the performance of this CONTRACT.

ARTICLE IX. SEVERANCE PROVISIONS

Should any one or more provisions of this CONTRACT be held to be null, void, voidable, or for any reason whatsoever, of no force and effect, such provision(s) shall be construed as severable from the remainder of this CONTRACT and shall not affect the validity of all other provisions of this CONTRACT which shall remain of full force and effect.

ARTICLE X. GENERAL TERMS AND CONDITIONS

1. GENERAL TERMS.

   a. No Debt Against the State. This CONTRACT does not create any debt by or on behalf of the State of Texas and the TWDB. The TWDB's obligations under this CONTRACT are contingent upon the availability of appropriated funds and the continued legal authority of the TWDB to enter into this CONTRACT.

b. Independent Contractor. Both parties hereto, in the performance of this contract, shall act in an individual capacity and not as agents, employees, partners, joint ventures or associates of one another. The employees or agents of one party shall not be deemed or construed to be the employees or agents of the other party for any purposes whatsoever.

c. Procurement Laws. The CONTRACTOR shall comply with applicable State of Texas procurement laws, rules and policies, including but not limited to competitive bidding and the Professional Services Procurement Act, Government Code, Chapter 2254, relating to contracting with persons whose services are within the scope of practice of: accountants, architects, landscape architects, land surveyors, medical doctors, optometrists, professional engineers, real estate appraisers, professional nurses, and certified public accountants.

d. Right to Audit. The CONTRACTOR and its Subcontractors shall maintain all financial accounting documents and records, including copies of all invoices and receipts for expenditures, relating to the work under this CONTRACT. CONTRACTOR shall make such documents and records available for examination and audit by the EXECUTIVE ADMINISTRATOR or any other authorized entity of the State of Texas. CONTRACTOR'S financial accounting documents and records shall be kept and maintained in accordance with generally accepted accounting principles. By executing this CONTRACT, the CONTRACTOR accepts the authority of the Texas State Auditor's Office to conduct audits and investigations in connection with all state funds received pursuant to this CONTRACT. The CONTRACTOR shall comply with directives from the Texas State Auditor and shall cooperate in any such investigation or audit. The CONTRACTOR agrees to provide the Texas State Auditor with access to any information the Texas State Auditor considers relevant to the investigation or audit. The CONTRACTOR also agrees to include a provision in any Subcontract related to this CONTRACT that requires the Subcontractor to submit to audits and investigation by the State Auditor's Office in connection with all state funds received pursuant to the Subcontract.

e. Force Majeure. Unless otherwise provided, neither CONTRACTOR nor the TWDB nor any agency of the State of Texas, shall be liable to the other for any delay in, or failure of performance, of a requirement contained in this CONTRACT caused by force majeure. The existence of such causes of delay or failure shall extend the period of performance until after the causes of delay or failure have been removed provided the non-performing party exercises all reasonable due diligence to perform. Force majeure is defined as acts of God, war, strike, fires, explosions, or other causes that are beyond the reasonable control of either party and that by exercise of due foresight such party could not reasonably have been expected to avoid, and which, by the exercise of all reasonable due

diligence, such party is unable to overcome. Each party must inform the other in writing with proof of receipt within two (2) business days of the existence of such force majeure or otherwise waive this right as a defense.

2. STANDARDS OF PERFORMANCE.

a. Personnel. CONTRACTOR shall assign only qualified personnel to perform the services required under this CONTRACT. CONTRACTOR shall be responsible for ensuring that any Subcontractor utilized shall also assign only qualified personnel. Qualified personnel are persons who are properly licensed to perform the work and who have sufficient knowledge, skills and ability to perform the tasks and services required herein according to the standards of performance and care for their trade or profession.

b. Professional Standards. CONTRACTOR shall provide the services and deliverables in accordance with applicable professional standards. CONTRACTOR represents and warrants that he is authorized to acquire Subcontractors with the requisite qualifications, experience, personnel and other resources to perform in the manner required by this CONTRACT.

c. Antitrust. CONTRACTOR represents and warrants that neither CONTRACTOR nor any firm, corporation, partnership, or institution represented by CONTRACTOR, or anyone acting for such firm, corporation, partnership, or institution has (1) violated the antitrust laws of the State of Texas under the Texas Business & Commerce Code, Chapter 15, of the federal antitrust laws; or (2) communicated directly or indirectly the proposal resulting in this CONTRACT to any competitor or other person engaged in such line of business during the procurement process for this CONTRACT.

d. Conflict of Interest. CONTRACTOR represents and warrants that CONTRACTOR has no actual or potential conflicts of interest in providing the deliverables required by this CONTRACT to the State of Texas and the TWDB. CONTRACTOR represents that the provision of services under this CONTRACT will not create an appearance of impropriety. CONTRACTOR also represents and warrants that, during the term of this CONTRACT, CONTRACTOR will immediately notify the TWDB, in writing, of any potential conflict of interest that could adversely affect the TWDB by creating the appearance of a conflict of interest.
CONTRACTOR represents and warrants that neither CONTRACTOR nor any person or entity that will participate financially in this CONTRACT has received compensation from the TWDB or any agency of the State of Texas for participation in the preparation of specifications for this CONTRACT. CONTRACTOR represents and warrants that he has not given, offered to

give, and does not intend to give at any time hereafter, any economic opportunity, future employment, gift, loan, gratuity, special discount, trip, favor or service to any public servant in connection with this CONTRACT.

e. Interested Parties. All non-governmental CONTRACTORS are required to submit a Certificate of Interested Parties at the time the signed contract is submitted to the TWDB. The Certificate of Interested Parties (Form 1295) is a sworn statement by the contracting business entity and must be submitted even if there is no interested party in the transaction. The Form 1295 and instructions for completing and submitting the form are available at: https://www.ethics.state.tx.us/tec/1295-Info.htm. The TWDB is prohibited from executing a contract unless the contracting business entity submits a completed Form 1295.

f. Proprietary and Confidential Information. CONTRACTOR warrants and represents that any information that is proprietary or confidential, and is received by CONTRACTOR from the TWDB or any governmental entity, shall not be disclosed to third parties without the written consent of the TWDB or applicable governmental entity, whose consent shall not be unreasonably withheld.

g. Public Information Act. CONTRACTOR acknowledges and agrees that all documents, in any media, generated in the performance of work conducted under this CONTRACT are subject to public disclosure under the Public Information Act, Government Code, Chapter 552. CONTRACTOR shall produce all documents upon request of the TWDB within two (2) business days when the documents are required to comply with a request for information under the Public Information Act.

h. Accurate and Timely Record Keeping. CONTRACTOR warrants and represents that he will keep timely, accurate and honest books and records relating to the work performed and the payments received under this CONTRACT according to generally accepted accounting standards. Further, CONTRACTOR agrees that he will create such books and records at or about the time the transaction reflected in the books and records occurs.

i. Dispute Resolution. The CONTRACTOR and the TWDB agree to make a good faith effort to resolve any dispute relating to the work required under this CONTRACT through negotiation and mediation as provided by Government Code, Chapter 2260 relating to resolution of certain contract claims against the state. The CONTRACTOR and the TWDB further agree that they shall attempt to use any method of alternative dispute resolution

mutually agreed upon to resolve any dispute arising under this CONTRACT if this CONTRACT is not subject to Chapter 2260.

j. Contract Administration. The TWDB shall designate a project manager for this CONTRACT. The project manager will serve as the point of contact between the TWDB and CONTRACTOR. The TWDB's project manager shall supervise the TWDB's review of CONTRACTOR's technical work, deliverables, draft reports, the final report, payment requests, schedules, financial and budget administration, and similar matters. The project manager does not have any express or implied authority to vary the terms of the CONTRACT, amend the CONTRACT in any way or waive strict performance of the terms or conditions of the CONTRACT.

k. The TWDB is federally mandated to adhere to the directions provided in the President's Executive Order (EO) 13224, Executive Order on Terrorist Financing – Blocking Property and Prohibiting Transactions with Persons Who Commit, Threaten to Commit, or Support Terrorism, effective 9/24/2001 and any subsequent changes made to it via cross-referencing Respondents/Contractors with the Federal General Services Administration's Excluded Parties List System (EPLS, http://www.sam.gov), which is inclusive of the United States Treasury's Office of Foreign Assets Control (OFAC) Specially Designated National (SDN) list.

l. TWDB is prohibited from entering into a contract with a company for goods or services unless the contract contains a written verification from the company that it does not boycott Israel and will not boycott Israel during the term of this CONTRACT.

ARTICLE XI. CORRESPONDENCE

All correspondence between the parties shall be made to the following addresses:

For the **TWDB**:

Contract Issues:
Texas Water Development Board
Attention: Contract Administration P.O.
P.O. Box 13231
Austin, Texas 78711-3231
Email: contracts@twdb.texas.gov

For the **CONTRACTOR:**

Contract Issues:
Alicia Brown
Research Triangle Institute
3040 East Cornwallis Rd.
Research Triangle Park, NC 27709
Email: aliciab@rti.org

For the **TWDB**:
Payment Request Submission: Texas Water Development Board Attention: Accounts Payable
P.O. Box 13231
Austin, Texas 78711-3231
Email: invoice@twdb.texas.gov

Physical Address:
Stephen F. Austin State Office Building
1700 N. Congress Avenue
Austin, Texas 78701

For the **CONTRACTOR:**
Payment Request Submission:
Cheryl Thacker
Research Triangle Institute
3040 East Cornwallis Rd
Research Triangle Park, NC 27709

Physical Address:
Research Triangle Institute
3040 East Cornwallis Rd
Research Triangle Park, NC 27709

IN WITNESS WHEREOF, the parties have caused this CONTRACT to be duly executed in multiple originals.

TEXAS WATER DEVELOPMENT BOARD

Jeff Walker
Executive Administrator

Date: 7.13.18

Research Triangle Institute

~~Katie Hayes~~ Alicia D. Brown
Contracting Officer

Date: 7/11/2018

EXHIBIT A

ORIGINAL GRANT APPLICATION

Statement of Qualifications

RTI Proposal No. 0281800.760
RESPONSE TO RFQ NO. 580-18-RFQ0061

February 15, 2018

National Weather Service Hydrologic Model Calibration

Submitted To
Texas Water Development Board
1700 N. Congress Avenue
6th Floor Reception Desk
Austin, TX 78701

Submitted By
RTI International
P.O. Box 12194
Research Triangle Park, NC
27709-2194
http://www.rti.org/

RTI Administrative Point of Contact
Kaitlin Hayes
Office of Proposal, Project and Procurement Services
Telephone: (919) 541-7482
Fax: (919) 316-3911
E-mail: kehayes@rti.org

RTI International
Proposal No. 0281800.760

This proposal in its entirety is proprietary to RTI and shall not be used or disclosed, except for evaluation purposes. If a contract is awarded to RTI as a result of this proposal, the funding organization shall have the right to use or disclose the data to the extent provided in the contract.

RTI International is a registered trademark and a trade name of Research Triangle Institute.

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Use or disclosure of any information on this page is subject to the restriction in the proprietary statement of this proposal.

TRANSMITTAL LETTER

February 15, 2018

Texas Water Development Board
1700 N. Congress Ave., 6th Floor Reception Desk
Austin, Texas 78701

Dear Texas Water Development Board:

RTI International's Water Resources Management Division is pleased to submit this proposal in response to Request for Qualifications # 580-18-RFQ0061 *National Weather Service Hydrologic Model Calibration*. RTI's technical capabilities have recently been augmented through the January 2017 acquisition of the Consulting Division of Riverside Technology, inc. (Riverside), now RTI's Water Resources Management Division (WRMD). The water resource management experts at Riverside, including all the principals and all technical experts, are now part of RTI's global integrated water resources management practice.

Having grown up in Texas, I fully appreciate the complexities associated with the State's climate and water concerns. Our organization brings to the TWDB more than 17 years of experience with Texas hydrology and meteorology through our work with NWS's Arkansas-Red Basin and West Gulf River Forecast Centers. We've calibrated more than 1,000 basins in the United States, including over 150 basins in Texas. In 2017, working with the WGRFC, we completed a model calibration project for the TWDB for basins in Central Texas. In addition, we've worked on projects for the Lower Colorado River Authority and the Trinity River Authority and developed the calibration data for the Rio Grande Water Allocation Model for the Texas Natural Resources Conservation Commission. On a personal note, two of the engineers on our proposed project team obtained their undergraduate degrees from Texas A&M University, and our proposed project manager also hails from Texas, having grown up in the Houston area, and recently helped with on-the-ground recovery efforts after Hurricane Harvey.

Our organization has more than 25 years of experience and continuous collaboration with and support for the NWS Hydrology Program. Several members of our staff provided development and implementation support for the Advanced Hydrologic Prediction Service, including the original coding implementation support and maintenance of several of the referenced NWS software tools in the RFQ, namely OPT3, UNIT-HG, STAT-QME, LAG/K, and CHANLOSS.

We appreciate the opportunity to continue our work with TWDB. If we are selected, I pledge my personal attention to this project to ensure our results exceed the expectations of the TWDB and WGRFC, and we will provide the best value to the State of Texas. Please feel free to contact me directly with any questions or notifications at (970) 498-1800 or lbrazil@rti.org.

Sincerely,

Larry E. Brazil
Division Vice President

Kaitlin Hayes

Senior Contracting Officer

Enclosed: Attachment 1, Received and Signed

Content Item 1: Execution of Statement of Qualifications

Texas Water Development Board
REQUEST FOR RFQ NO. 580-18-RFQ0061
NATIONAL WEATHER SERVICE HYDROLOGIC MODEL CALIBRATION

CONTENT ITEM 1

EXECUTION OF THE STATEMENT OF QUALIFICATIONS

Company Name: Research Triangle Institute

Address: 3040 E. Cornwallis Road

Research Triangle Park, NC 27709

Phone Number: 919-541-7482

E-Mail: kehayes@rti.org

I, Katie Hayes, am the above-referenced company's representative and I am authorized to submit this response and sign future contract documents. By signing below, the representative certifies that if a Texas address is shown as the address, the respondent qualifies as a Texas Bidder as defined in 34 TAC Rule 20.32(68).

Katie Hayes

Authorized Signature

2/5/18

Date

Senior Contracting Officer

Title:

Content Item 2: Company Profile Summary and History

Content Item 2: Company Profile Summary and History

RTI International is one of the world's leading research institutes, dedicated to improving the human condition by turning knowledge into practice. Our staff of more than 3,700 provides research and technical services to governments and businesses in more than 75 countries in the areas of health and pharmaceuticals, education and training, surveys and statistics, advanced technology, international development, economic and social policy, energy and the environment, and laboratory testing and chemical analysis. Our company information is as follows:

- Research Triangle Institute, 3040 E. Cornwallis Road, PO Box 12194, Research Triangle Park, NC 27709-2194
- Phone: 919-541-6000
- Legal status: 501c3 nonprofit corporation

Kaitlyn Hayes, Senior Contracting Officer, is submitting this proposal and has authority to bind the company. For any questions on this Statement of Qualifications, please contact Kaitlyn Hayes, 919-541-7482, kehayes@rti.org.

Specializing in decision support systems (DSS) for water management, RTI's Water Resources Management Division (WRMD) delivers solutions based on many data sources' observations of global natural resources. Data are collected with a wide variety of sensors, ranging from satellite sounders and imagers to stream gages in local rivers. RTI's technical team consists of hydrologists, GIS and remote sensing analysts, software engineers and developers, and system integrators who have the skill and technical expertise to develop, maintain, and operate DSSs that are built on a range of applications, programming languages, and architectures. The output from RTI's systems, tools, and methods helps managers and stakeholders make informed decisions about water use, risk planning and mitigation, reservoir storage and releases, conservation, climate change, policies and regulations, operations, and development.

RTI staff have worked throughout the West, including Texas, on hydromet monitoring, modeling and real-time forecasting, irrigation water management, integrated river basin management, and reservoir operations. Our diverse client base includes local, state, federal, and international government agencies; water and agriculture companies; and private sector organizations. We support a range of federal agencies in implementing progressive systems, including the U.S. Department of Agriculture (USDA), the U.S. Army Corps of Engineers (USACE), the National Weather Service (NWS), U.S. Geological Survey (USGS), the U.S. Bureau of Reclamation (USBR), and the International Boundary Water Commission (IBWC).

RTI's WRMD also supports international development with water resources, technical and management expertise, and training and technology transfer. Clients include the World Bank, the U.S. Agency for International Development (USAID), the U.S. Trade and Development Agency (USTDA), the International Activities Office (IAO) of NOAA, and host-country government agencies such as the Panama Canal Authority, the Moroccan Ministry of Water, and Mexico's Comisión Nacional Del Agua. RTI WRMD staff have successfully completed projects in more than 30 countries, including countries in Africa and the Middle East, Eastern Europe, the Caucasus, Asia, and Latin and South America.

RTI's WRMD core business includes calibrating and implementing operational river forecast systems throughout the United States and around the world. The NWS River Forecast Centers (RFCs) require accurate, robust, and computationally efficient hydrologic and hydraulic models to issue river forecasts for their areas of service. RTI staff

have provided hydrologic and hydraulic modeling support for the RFCs for more than 15 years, including model calibration for more than 1,000 basins and more than 50 reservoirs. **Figure 1** shows the geographic extent of the areas where we have performed model calibration. This work—especially in Texas and other parts of the service area of the WGRFC—has endowed RTI staff with a specialized depth of understanding and capacity to recognize and address the unique characteristics of individual basins and regions. In addition, we continuously improve our processes and procedures to most efficiently support model calibration activities including data quality control, unit hydrograph development, and potential evapotranspiration estimation, as well as manual, semiautomatic, and automatic calibration tools and techniques. We are constantly reviewing these processes and procedures, allowing us to consistently provide high-value calibration products to the RFCs and to all users of our systems. Several members of the proposed project team have many years of experience working on or leading calibration efforts for numerous RFCs. These task managers' roles have included providing technical expertise, detailed insights into unique characteristics of each RFC, senior review of work products, and training of junior staff.

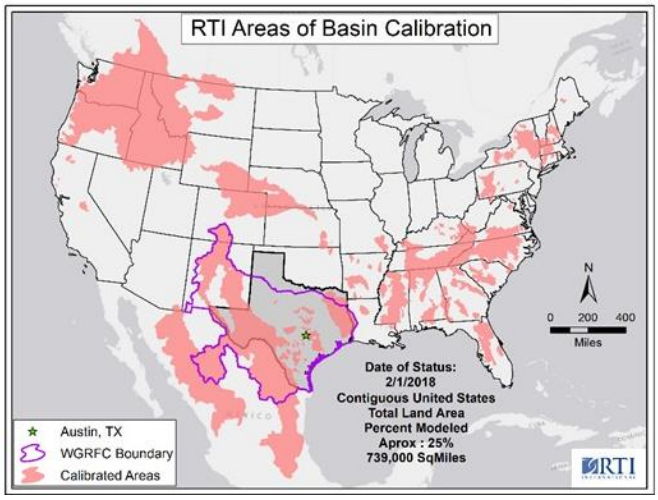

Figure 1. Decades of Experience*. Since 2003, RTI staff have calibrated more than 1,000 basins using the SAC-SMA rainfall-runoff model within the contiguous U.S. for either the NWS or other clients utilizing real-time river forecast systems. This includes more than 300 basins within the WGRFC and 130 basins in Texas.*

RTI's personnel have specialized experience in areas with direct relevance to this project. Our investment in creating efficiencies and improving upon methodologies will be of great benefit in the performance of this model calibration task. Our proposed project team has more than 170 years of combined relevant experience, most of which includes performing model calibrations in support of NWS RFCs. Additionally, RTI has recent experience working with the TWDB and the WGRFC on a model calibration project in Central Texas. RTI also brings value to our calibration efforts through our broader experience with a full spectrum of technologies and activities associated with river forecasting, including design and implementation of data collection networks, implementation of real-time data management systems, and the development and implementation of real-time river forecast systems throughout the world.

RTI's engineers and scientists have experience implementing NWS River Forecast System (RFS), the Community Hydrologic Prediction System (CHPS), the Corps Water Management System (CWMS) from the USACE, MIKE Customized from DHI, and a variety of other forecasting systems. RTI understands the issues unique to model calibration for operational forecasting, particularly:

- the importance of reasonable and physically sensible model parameters for reliable forecasts of extreme events;
- the importance of an unbiased model calibration in long-range ensemble forecasting;
- the need for simple yet effective RES-J, RES-SNGL, and ResSim rule sets for efficient real-time forecasting where reservoirs are present;
- the challenges of calibrating with historical data inputs that may be inconsistent with or from a different source than real-time inputs; and

- the general modeling objectives and preferred methods of the WGRFC, based on our recent model calibration project in Central Texas.

RTI has extensive experience directly applicable to water resources in Texas:

- For the TWDB and the WGRFC, RTI led a model calibration effort of portions of the Colorado, Guadalupe, and San Antonio River basins in 2017.
- Working with the USACE's Risk Management Center and the Fort Worth District, RTI is leading an analysis of extreme storm events in the Trinity River basin.
- RTI is currently working with the USACE Fort Worth District to update the Neches Basin RiverWare model to reflect operational conditions with a permanent salt water barrier in place. In addition, WRMD is using the RiverWare model for multi-objective optimization of operating rules for Sam Rayburn Reservoir.
- RTI performed a detailed water rights analysis of the Lower Colorado River Basin in Texas using the Water Rights Analysis Package (WRAP) model. We developed models to demonstrate potential impacts of a proposed water rights application, and the results were used as a part of expert witness testimony to support litigation efforts to protect existing water rights interests.
- For the Lower Colorado River Authority, we developed a water management plan for grading drought detection methods. Our work was used as part of the greater Water Management Plan for operations for Travis and Buchanan reservoirs in Central Texas.
- RTI developed a natural flow model for the Upper Rio Grande River Basin in the State of New Mexico down to the Rio Grande at El Paso. The calibrated hydrologic models are used by the WGRFC to provide short-term deterministic and long-term probabilistic flow forecasts to the USACE Albuquerque District for input to their Upper Rio Grande Water Operations Model (URGWOM).
- For the Trinity River Authority of Texas, we developed and tested a computerized real-time flood management system for the Trinity River and provided preliminary operational recommendations.
- In collaboration with the NWS IAO and Mexico's National Water Commission (CONAGUA), RTI established multiple river forecast centers in Mexico, including a forecast center for the Rio Grande/Rio Bravo. As part of this work, RTI facilitated the automated sharing of data between CONAGUA and WGRFC, establishing critical data-sharing protocols for precipitation, streamflow, and reservoir operations information in Mexico necessary for forecasting the Rio Grande.
- RTI assisted in the design and implementation of a precipitation and streamflow monitoring network in the Rio Conchos. RTI was ultimately able to develop and provide WGRFC with model calibrations and forecast system configurations for major contributing areas in Mexico. This work, together with the data feeds required as input to the models, permitted integrated forecasting of Rio Grande tributaries and the mainstem on both sides of the international border.
- In collaboration with R.J. Brandes and associates, RTI had primary responsibility for developing natural flow estimates for the Mexican portion of the Rio Grande Water Allocation Model for the Texas Natural Resources Conservation Commission (TNRCC).

RTI has invested decades of experience in learning the critical issues related to successfully and efficiently calibrating NWS hydrologic and hydraulic models. It is at the core of what we do as an organization, as it is for the individuals proposed for this project. We look forward to delivering model calibrations to TWDB and exceeding TWDB's expectations for the NWS Hydrologic Model Calibration project.

Content Item 3: Resumes of Individuals

Content Item 3: Resumes of Individuals

Please find attached complete resumes for the following proposed key personnel:

- Michael Kane, PE, CFM – Project Director
- J. Philip Burkhalter, PhD, PE, PMP – Project Manager; Model Calibration Lead
- Gerald N. "Jay" Day, PhD, PE – Quality Assurance Manager
- Mark Woodbury – Senior Advisor
- John Park, PhD – Senior Water Resources Engineer; CHPS Configuration Lead
- Ian S. Maycumber, PE – Water Resources Engineer; Model Calibrator; CHPS Support
- Noah Friesen, PE – Water Resources Engineer; Model Calibrator
- Eleeja Shrestha – Water Resources Engineer; Data Analysis Lead; Model Calibrator
- Jeremy Carlston – Water Resources Engineer; Data Analysis Support; Model Calibrator; CHPS Support

A summary of the model calibration experience and capabilities of the proposed project team is given in **Table 1**.

Table 1. RTI's Deep Bench. Our proposed project team has more than 170 years of combined relevant experience, the majority of which includes performing calibrations in support of NWS RFCs.

Proposed Project Personnel	Total Yrs. Exp.	RFC Calibration Experience	CHPS Experience	Historical Precip Data Collection	Data Analysis	Diversion Modeling	Hydraulic Modeling	SAC-SMA	MAP/MAT	Routing Model Calibration
Michael D. Kane, PE, CFM	33	√	√	√	√	√	√	√	√	√
J. Philip Burkhalter, PhD, PE, PMP	24	√	√	√	√	√	√	√	√	√
Gerald N. "Jay" Day, PhD, PE	41	√	√	√	√	√	√	√	√	√
Mark S. Woodbury	31	√	√	√	√	√	√	√	√	√
John Park, PhD	22	√	√	√	√	√	√	√	√	√
Ian S. Maycumber, PE	7	√	√	√	√	√	√	√	√	√
Noah Friesen, PE	9	√		√	√	√	√	√	√	√
Eleeja Shrestha	6	√		√	√	√	√	√	√	√
Jeremy Carlston	3	√	√	√	√	√	√	√		√

MICHAEL KANE, PE, CFM

PROPOSED ROLE: Project Director

EDUCATION

MS (Civil Engineering/Water Resources), University of Maryland, 1988
BS (Civil Engineering/Hydrology), University of Maryland, 1983

CERTIFICATIONS AND AFFILIATIONS

- Registered Professional Engineer (CO)
- Certified Floodplain Manager (CO)
- American Geophysical Union
- American Society of Civil Engineers
- American Society of Floodplain Managers
- Chi Epsilon Civil Engineering Honor Society

SELECTED PUBLICATIONS AND PRESENTATIONS

Kane, M. D. (2002). Current technology for management of water resources. Presented at *Panama Canal Administration's World Water Day*, Panama City, Panama.

Kane, M. D. (2001). ESP: Long term forecasting for water management. Presented at *Conference on NOAA/NWS International Hydrologic Assistance Programs*, Silver Spring, MD.

Kane, M. D., Day, G. N., Jubach, R., & Echevers, M. (2000). A Streamflow Forecasting System for the Operation of the Panama Canal. In *Proceedings, EWRI Watershed Management & Operations Management 2000 Conference*, Fort Collins, CO.

Smith, J. A., Day, G. N., & Kane, M. D. (1992). A nonparametric framework for long-range streamflow forecasting. *ASCE Journal of Water Resources Planning and Management*, *118*(1), 82-92.

PERSONAL CAPABILITIES STATEMENT

Michael Kane is the director of Fort Collins Operations at RTI International. As a senior water resources engineer, Mr. Kane specializes in the development and implementation of real-time river forecasting and decision support for water resources systems. He has managed projects involving these systems throughout the United States, including at the TVA and BPA, and abroad in countries such as India, Panama, El Salvador, South Africa, Viet Nam, and Uzbekistan. As director of Fort Collins Operations, Mr. Kane is responsible for the overall operation and performance of the technical staff within the Fort Collins office. Mr. Kane's experience includes conceptualization, design, and implementation of river forecasting systems; design and implementation of water resources decision support systems; development and application of hydrologic models; use of hydrologic computer models (HEC, WSP2, National Weather Service River Forecast System, CHPS, RiverWare®, StateMod (State of Colorado Stream Simulation Model); flood insurance study development; stochastic hydrologic modeling; flood inundation mapping; and training in all aspects of water resources engineering.

RELEVANT WORK EXPERIENCE

National Weather Service Contracts (Science and Engineering Technical Assistance [SETA] and HydroScience IDIQ)

Program manager responsible for the overall management of the $80 million program (SETA) and the follow-on $10 million program (HydroScience IDIQ), including proposal development, client interaction, performance management, budget tracking, billing, and reporting. Through these contract vehicles over the last 13 years, supported NWS forecast system implementation and hydrologic model calibration as well as hydrologic and hydraulic research to improve the forecast products the NWS provides.

Idaho Power Corporation—Snake River Forecasting System, Boise, Idaho

Senior engineer and project manager for the development and implementation of the NWSRFS for the upper Snake River Basin in the Northwestern United States. The forecast system consists of more than 150 subbasins draining to the Hell's Canyon Dam Complex on the Snake River in Idaho.

MICHAEL KANE, PE, CFM

The project involved collecting and analyzing hydrometeorologic data; calibrating hydrologic, routing, and reservoir models; initializing and implementing the system; and providing training and daily support to Idaho Power engineers. The project also involved the development of an enhanced RES-J reservoir model to simulate reservoir release decisions based on seasonal water supply forecasts.

Bonneville Power Administration—Streamflow Model Development, Portland, Oregon
Assisted in initializing, implementing, and testing the operational hydrologic forecast system for the Columbia River Basin. The system uses NWSRFS software and has been tailored to meet Bonneville Power Administration requirements for daily and seasonal streamflow forecasts. Served as project manager for a maintenance and support contract for Bonneville Power Administration's use of the NWSRFS. The project included managing software, hardware, and documentation updates, as well as providing daily support to the Bonneville Power Administration for hydrologic forecasting and system management.

National Weather Service—Panama Canal Forecasting System, Panama
Project manager and senior engineer for the development and implementation of the NWSRFS for the Panama Canal. The project involved collecting and analyzing hydrometeorologic data; calibrating hydrologic and routing models, including a new multi-reservoir operation model developed by Riverside Technology; and training Panama Canal engineers. The system now is used to forecast inflows to the Panama Canal watershed and optimize water use for lock transports, hydropower, municipal use, and flood control.

National Weather Service—Río Lempa River Forecasting System, San Salvador, El Salvador
Project manager and senior engineer for the development and implementation of the National Weather Service River Forecast System (NWSRFS) for the Río Lempa River Basin, which includes portions of El Salvador, Guatemala, and Honduras. The project involved design of a hydrometeorologic network for the basin, implementation of the NWSRFS models at 14 forecast points including 4 reservoirs, installation of equipment, computers, a local area network, and database in the Río Lempa River Forecast Center, and development of forecast products and procedures for disseminating them via the Internet. The project also involved training of local personnel in operation of the system, holding workshops in El Salvador to inform local agencies and people about the project, and design and development of a Spanish language GUI to facilitate the use of the forecasting system.

J. PHILIP BURKHALTER, PHD, PE, PMP

PROPOSED ROLE: Project Manager; Model Calibration Lead

EDUCATION

PhD (Water Resources Planning & Management), Colorado State University, 2005
MS (Water Resources Planning & Management), Colorado State University, 2000
BS (Civil Engineering), Texas A&M University, 1992

CERTIFICATIONS AND AFFILIATIONS

- Registered Professional Engineer (Colorado)
- Certified Project Management Professional (PMP)
- American Society of Civil Engineers
- American Geophysical Union
- American Water Resources Association
- Project Management Institute

SELECTED PUBLICATIONS AND PRESENTATIONS

Burkhalter, J. P., Volckens, A. M., Carney, S. K., & Bratlie, S. L. (2011, November). Implementation of the Corps Water Management System (CWMS) to support real-time water resources decision-making. Presented at *2011 AWRA Annual Water Resources Conference*, Albuquerque, NM.

Burkhalter, J. P., Martin, T. C., Allen, R. G., Kjaersgaard, J., Wilson, E., Alvarado, R. & Polly, J. S. (2013). Estimating crop water use via remote sensing techniques vs. conventional methods in the South Platte River Basin, Colorado. *Journal of the American Water Resources Association*, *49*(3), 498-517.

Martin, T.C., Allen, R. G., Brazil, L. E., Burkhalter, J. P., & Polly, J. S. (2013). Evapotranspiration estimates from remote sensing for irrigation water management. (2013). In J. Qu, A. Powell, & M. V. K. Sivakumar (Eds.), *Satellite-based Applications on Climate Change* (pp. 195-216). Springer.

PERSONAL CAPABILITIES STATEMENT

Dr. Phil Burkhalter has more than 20 years of experience in the civil engineering industry, including consulting and academic research projects. His skills include project management, water resources decision support, and computer modeling with an emphasis on hydrologic and hydraulic modeling, groundwater flow and contaminant transport, system optimization, remote sensing/GIS analysis, water allocation/rights, and consumptive use modeling. Dr. Burkhalter has published papers and made several presentations detailing his research efforts and project work. He is currently the senior water resources group leader of RTI's Water Resources Management Division (WRMD) and actively serves as a project manager. Dr. Burkhalter's experience includes project management, hydraulic and hydrologic modeling and analysis, real-time flood forecasting, data management and evaluation, and decision support system design and development.

RELEVANT WORK EXPERIENCE

Texas Water Development Board (TWDB)—Hydrologic Model Development for the West Gulf River Forecast Center (WGRFC)

Serves as project manager and senior hydrologic modeler for a project to develop and calibrate hydrologic models in Central Texas to support the National Weather Service's (NWS's) WGRFC. Funded by the Texas Water Development Board, the project includes developing hydrologic and routing models within NWS's Community Hydrologic Prediction System. The study area includes sites in the Colorado and Guadalupe River basins near the cities of Austin and San Antonio. The primary purpose of the modeling is to improve the WGRFC's capacity to provide timely and accurate flood forecasts.

National Weather Service—Advanced Hydrologic Prediction Services (AHPS) Implementation at the West Gulf River Forecast Center (WGRFC)

Performed detailed calibration of NWS-RFS models within a number of basins in the WGRFC

J. PHILIP BURKHALTER, PHD, PE, PMP

region. Specifically, derived sets of Sacramento Soil Moisture Accounting (SAC-SMA) model parameters to improve overall predictive performance of existing systems, and developed and calibrated the RES-J model to simulate reservoir operations at numerous sites. Derived unit hydrograph models for selected basins using manual and automated GIS techniques. Also performed detailed calibration of the LAG/K routing model. Project locations included the Sabine, Neches, Lavaca-Navidad, Brazos, and Colorado River basins in Texas.

National Weather Service—Advanced Hydrologic Prediction Services (AHPS) Implementation at the Southeast River Forecast Center (SERFC)

Performed detailed calibration of NWS-RFS models within a number of basins in the SERFC region. Specifically, derived sets of SAC-SMA model parameters to improve overall predictive performance of existing systems. Developed potential evapotranspiration estimates and unit hydrograph models for use with calibrated models. Quality controlled historic precipitation data and developed mean areal precipitation (MAP) estimates for numerous modeled basins. **National Weather Service—Advanced Hydrologic Prediction Services (AHPS) Implementation at the Lower Mississippi River Forecast Center (LMRFC)**

Performed detailed calibration of NWS-RFS models within a number of basins in the LMRFC region. Specifically, derived sets of SAC-SMA model parameters to improve overall predictive performance of existing systems, and developed and calibrated the RES-J model to simulate reservoir operations. Also performed detailed calibration of the LAG/K routing model. Project locations included Tennessee, North Carolina, Mississippi, Arkansas, and, Louisiana.

Tennessee Valley Authority—River Forecast Center Modernization

Served as senior hydrologic modeler; coordinated and performed detailed model calibration of NWS-River Forecast System (RFS) models within the Authority's service area. Specifically, derived sets of SAC-SMA model parameters to improve overall predictive performance of existing systems and developed model configurations to account for reservoir water surface evaporation and direct precipitation effects. Also performed detailed calibration of the LAG/K routing model.

U.S. Army Corps of Engineers' Modeling, Mapping, and Consequences (MMC) Production Center—Corps Water Management System (CWMS) Development

As project manager, oversaw multiple projects in support of the MMC Production Center's efforts to deploy the Hydrologic Engineering Center's (HEC's) CWMS across the country. Activities included developing and deploying a complete CWMS implementation for the Rogue River watershed in Oregon, developing a 2-D river analysis system (RAS) model for the Boise River CWMS in Idaho, and developing a hydrological modeling system (HMS) model for the Willow Creek CWMS in Idaho.

U.S. Army Corps of Engineers—Risk Management Center (RMC) and Hydrologic Hazards Team (HHT)

Currently serves as project manager on a project in the Trinity River Basin in Texas to analyze historical extreme precipitation events. This analysis will support the RMC and HHT's goal of developing a portfolio of hydrologic hazard curves for high-risk dams in the Trinity system.

GERALD N. DAY, PHD, PE

PROPOSED ROLE: Quality Assurance Manager

EDUCATION

PhD (Geography and Environmental Engineering/Systems), Johns Hopkins University, 1990
MS (Civil Engineering/Water Resources), Georgia Institute of Technology, 1976
BS, (Civil Engineering/Water Resources), University of Maryland, 1975

CERTIFICATIONS AND AFFILIATIONS

- Registered Professional Engineer (Maryland)
- American Society of Civil Engineers
- American Water Resources Association
- American Geophysical Union
- American Meteorological Society

SELECTED PUBLICATIONS AND PRESENTATIONS

Quebbeman, J., Micheletty, P., Park, G., Day, G., & Carney, S. (2016, December). *Utilization of expert knowledge in a multi-objective hydrologic model automatic calibration process*. Presented at 2016 AGU Fall Meeting, General Surface Hydrology II, San Francisco, CA.

Day, G. N., Schaake, J., Thiemann, M., Draijer, S., & Miller, G. (2014, November). *Ensemble forecasting in support of dynamic reservoir operations*. Presented at 2014 AWRA Annual Water Resources Conference, Tysons Corner, VA.

Day, G. N. (1990). *A methodology for updating a conceptual snow model with snow measurements*. Technical Report, National Weather Service 43, National Oceanic and Atmospheric Association, Silver Spring, MD.

Day, G. N. (1985). Extended streamflow prediction using National Weather Service River Forecast System. *ASCE Journal of Water Resources Planning and Management*, *111*(2). Available at: https://doi.org/10.1061/(ASCE)0733-9496(1985)111:2(157).

PERSONAL CAPABILITIES STATEMENT

Jay Day is a senior director at RTI International. He specializes in watershed modeling and streamflow forecasting. Dr. Day has extensive experience in implementing river forecasting technology in the United States and around the world. During his career, he has demonstrated his expertise in watershed modeling to support the development of decision support systems (DSS) for improved water management. He spent 13 years at the National Weather Service (NWS) Hydrologic Research Laboratory, where he served as the Water Resources Forecasting Project area leader. In that role, he was responsible for development and operational support of the NWS Ensemble Streamflow Prediction system, which provides probabilistic forecasts of streamflow at time scales ranging from 1 week to several seasons. These forecasts help water managers make complex decisions involving competing objectives of water resource systems. Dr. Day has 40 years of experience and has published more than 20 papers in his areas of expertise.

RELEVANT WORK EXPERIENCE

Tennessee Valley Authority (TVA)—Modernization of TVA's River Forecasting System
Served as project director for the modernization of TVA's river forecasting system. Activities included hydrologic model calibration, implementation of the Community Hydrologic Prediction System (CHPS) Flood Early Warning System (FEWS)-based forecast system, evaluation of algorithms for operational data assimilation, and plans for integrating TVA's RiverWare reservoir modeling system with the CHPS framework.

National Weather Service West Gulf River Forecast Center (WGRFC)—Advanced Hydrologic Prediction System Implementation
Served as project director to provide support to WGRFC in its implementation of the Advanced

GERALD N. DAY, PHD, PE

Hydrologic Prediction System (AHPS) in the Rio Grande, Pecos, and Neuces River basins. Work included precipitation and temperature processing; estimation of natural flows; diversion/consumptive use modeling; hydrologic, hydraulic, and reservoir model calibration.

U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC)—Accelerated CWMS Deployment

Served as program manager for a project to support HEC in accelerating the deployment of the Corps Water Management System (CWMS) throughout the country. The project involved deployment of CWMS in Seattle, Norfolk, Nashville, Louisville, Baltimore, Albuquerque Districts, and the Great Lakes and Ohio River Division. The CWMS deployments included development of HEC-HMS, HEC-RAS, ResSim, and HEC-FIA models.

NASA—Advancing Water Supply Forecasts in the Colorado River Basin for Improved Decision Making

Serves as principal investigator of a project to work with the Colorado Basin River Forecast Center, Utah State, and Colorado State to develop and deploy distributed hydrologic models, advanced data assimilation techniques, and ensemble forecasting to produce forecasts that are more accurate along with estimates of forecast uncertainty. The project has used a genetic algorithm multi-objective optimization technique to speed calibration of the hydrologic models. The project team is working with Denver Water and the Dolores Water Conservancy District to explore ways to utilize the forecasts to improve water management decision making.

NWS Lower Mississippi River Forecast Center (LMRFC)—Advanced Hydrologic Prediction System (AHPS) Implementation, Louisiana

Served as project director for this project to support LMRFC in its implementation of the AHPS in the Lower Mississippi River basin. Assisted LMRFC in data analysis, rainfall-runoff model calibration, routing model calibration, and reservoir model calibration in the Upper Tennessee, Yocoma, Yalobusha, Yazoo, Big Black, and Pearl River basins.

NWS Southeast River Forecast Center (SERFC)—AHPS Implementation, Georgia

Served as project director to provide support to SERFC in its implementation of the AHPS in parts of Virginia, North Carolina, South Carolina, Georgia, Florida, and Alabama. Assisted SERFC in data analysis, rainfall-runoff model calibration, routing model calibration, and reservoir model calibration in the Tar, Neuse, Cape Fear, Roanoke, Pee Dee, Chowan, Santee, Savannah, Altamaha, and Apalachicola River basins.

USACE Albuquerque District—Hydrologic Modeling System (HMS) Model Development

Served as project director to develop an HMS model for the Upper Rio Grande River Basin. The work included precipitation and temperature data analysis and calibration of the snow accumulation/ablation and the deficit loss methods. The HMS model was integrated with the Upper Rio Grande Water Operations Model RiverWare® model within CWMS.

MARK WOODBURY

PROPOSED ROLE: Senior Advisor

EDUCATION

MS (Civil and Environmental Engineering), Utah State University, 1996
BS (Civil Engineering, Magna cum Laude), Texas A&M University, 1988

CERTIFICATIONS AND AFFILIATIONS

- American Society of Civil Engineers
- Chi Epsilon Civil Engineering Honor Society

SELECTED PUBLICATIONS AND PRESENTATIONS

Brazil, L. E., Woodbury, M. S., & Carney, S. K. (2008). Hydrologic forecasting for hydropower. In *Proceedings, Hydrovision 2008,* Sacramento, CA.

Woodbury, M., Brazil, L., & Doyon, S. (2002). A hydrologic forecast and reservoir operations model for the Winnipesaukee River, N.H. In *Proceedings, Second Federal Interagency Hydrologic Modeling Conference*, Las Vegas, NV.

Woodbury, M. S., Godinez, A. A., Day, G. N., & Paulson, R. W. (2000). Establishing an operational river forecasting environment in Mexico. *Proceedings, EWRI Watershed Management & Operations Management 2000 Conference*, Fort Collins, CO.

PERSONAL CAPABILITIES STATEMENT

Mark Woodbury is a director, Environmental Sciences and Engineering, at RTI International. His primary role is conceptualizing, developing, and directing the implementation of projects involving water resource management. These projects address hydrologic simulation and forecasting, climate change impacts, river hydraulics, hydrometeorologic data collection and management, reservoir operations simulation, and water resource management and allocation. His expertise includes project management, training program development and delivery, and technical development and review in data collection and analysis, model calibration, and system implementation. Mr. Woodbury has experience in system development, surface water hydrology and hydraulics, risk analysis, and dam safety. He also has a strong background in mapping and applying computer aided design and GIS technology to hydrologic and hydraulic analyses.

RELEVANT WORK EXPERIENCE

U.S. Bureau of Reclamation, E. CO Area Office—Big Thompson River Streamflow Forecast System Implementation and Data Management Tool Development. Project manager overseeing the implementation of an automated streamflow forecast system using NWS CHPS for the Big Thompson River in Colorado that is used to manage USBR reservoirs, diversions, and hydropower power facilities. Directed the development of tools to assist in automated acquisition, processing and display of precipitation, streamflow, and reservoir data for both forecast system operation and system management. Oversaw operations support and training in the use and application of the system and tools.

National Weather Service—Advanced Hydrologic Prediction Services (AHPS) Implementation at the West Gulf River Forecast Center (WGRFC). Acted in a senior review capacity for detailed calibration of NWSRFS models for a number of basins in the WGRFC region. Reviewed the work of teams that derived sets of SAC-SMA model parameters to improve overall predictive performance of existing systems, and developed and calibrated the RES-J model to simulate reservoir operations. The project also derived unit hydrograph models for selected basins using manual and automated GIS techniques and performed detailed calibration of the LAG/K routing model. Project locations included the Sabine, Neches, Lavaca-Navidad, Brazos, Colorado, and Trinity River basins.

National Weather Service, Missouri Basin River Forecast Center—Streamflow Regulation

MARK WOODBURY

Modeling. Managed an ongoing study of the modeling of streamflow regulation in a river forecasting system framework. The study included a discovery and investigation phase to identify and characterize streamflow regulation challenges, approaches, and tools at NWSRFCs and to propose a general modeling approach and enhancements to existing tools. This phase was followed by a pilot implementation phase in which extensive regulation in the South Platte River Basin was characterized and modeled to demonstrate the modeling approach and assess its effectiveness using probabilistic verification.

National Weather Service, Office of Hydrologic Development—Community Hydrologic Prediction System, Maryland. Participated as the hydrologic focal point on a multidisciplinary development team to identify and document usage scenarios for a conceptual Community Hydrologic Prediction System (CHPS) based on a service-oriented architecture (SOA). Prepared usage scenarios describing broad categories of user interaction with the conceptual system both as a preliminary guide for development and to enhance understanding of the system among the potential user community.

Comisión Nacional del Agua/National Weather Service—National Forecast System Planning and Development, Mexico City, Mexico. Managed a project for planning and developing hydrometeorologic data management and forecast system technologies at the national level in Mexico. Activities included conceptual data processing and database system design, development of plans for decentralizing forecasting and water management activities, technical support and enhancement for current forecasting activities, ongoing forecast system operations training and staff development programs, and calibration and implementation of additional river basins in the forecast system.

Comisión Nacional del Agua/National Weather Service—Streamflow Forecast System, Río Bravo, Mexico. Directed the development and implementation of a river forecast system for the Río Bravo (Río Grande) basin extending from El Paso, Texas/Ciudad Juarez, Mexico to Anzalduas Dam, including the Río Conchos and other tributaries. Oversaw hydrometeorologic data collection and analysis and subsequent model calibration. Implemented a real-time forecast system based on NWSRFS. Facilitated coordination between the Comisión Nacional del Agua and the WGRFC in system design, implementation, and future planning.

Texas Commission on Environmental Quality—Rio Grande Water Allocation Model Development, Texas. Managed participation on a team to develop a water allocation model for the Río Grande in Texas. Worked with partners in Mexico to research historical data and prepare estimates of naturalized flows for multiple control points on the Mexican tributaries to the Río Grande. Estimated historical diversions, water use, and reservoir operations based on historical records and patterns of agricultural use. Used regression analysis to estimate missing periods.

Lowe Foundation—Central City Project Hydraulic and Hydraulic Mitigation Analysis, Fort Worth, Texas. Led a technical review of USACE hydraulic mitigation designs for the Fort Worth, Texas Central City project. Used HEC hydrologic and hydraulic models to analyze multiple storage mitigation alternatives and characterize associated impacts on peak flows and stages for design events.

GI-HYEON (JOHN) PARK, PHD

PROPOSED ROLE: Senior Water Resources Engineer; CHPS Configuration Lead

EDUCATION

PhD (Civil Engineering/Water Resources), University of California, 2006
MS (Hydrology and Water Resources), University of Arizona, 2000
MS (Geological Sciences), Seoul National University, South Korea, 1993
BS (Geological Sciences), Seoul National University, South Korea, 1991

CERTIFICATIONS AND AFFILIATIONS

- Certification, Engineer in Training (EIT), 2012
- American Society of Civil Engineers
- American Geophysical Union
- Korean (native) and English (fluent)

SELECTED PUBLICATIONS AND PRESENTATIONS

Quebbeman, J., Park, G.-H., Carney, S., & Day, G. (2016, December 12–16). *Utilization of expert knowledge in a multi-objective hydrologic model automatic calibration process.* Presented at the American Geophysical Union's Fall Meeting, San Francisco, CA.

Micheletty, P., Day, G., Quebbeman, J., Carney, S., & Park, G.-H. (2016, December 12–16). *Assimilation of ground and satellite snow observations in a distributed hydrologic model to improve water supply forecasts in the Upper Colorado River Basin.* Presented at the American Geophysical Union's Fall Meeting, San Francisco, CA.

Park, G.-H., Day, G., & Carney, S. (2015, November 16–19). *A framework for improved water supply forecasts in the Colorado River Basin.* Presented at the American Water Resources Association's Annual Water Resources Conference, Denver, CO.

Boushaki, F. I., Hsu, K-L., Sorooshian, S., Park, G.-H., Mahani, S., & Wei S. (2009). Bias adjustment of satellite precipitation estimation using ground-based measurement: A case study evaluation over the Southwestern United States. *Journal of Hydrometeorology, 10*(5), 1231–1242.

Park, G.-H., Gao, X., & Sorooshian, S. (2008). Estimation of surface longwave radiation components from ground-based historical net radiation and weather data. *Journal of Geophysical Research, 113*(D4). doi:10.1029/2007JD008903

PERSONAL CAPABILITIES STATEMENT

Gi-Hyeon (John) Park, a senior water resources engineer at RTI International, has experience in computer modeling, data analysis, remote sensing, image processing, GIS, spatial statistics and analysis, and report writing. Dr. Park has used programs such as the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) and River Analysis System (HEC-RAS), ERDAS, tclSadie, ArcGIS/ArcInfo, and Microsoft Office Suite to conduct his work. Dr. Park is proficient with using FORTRAN, C/C++, and many scripting languages (e.g., Python, Perl, bash, C shell). His hydrological modeling experience includes using the National Weather Service River Forecast System (NWSRFS), the Variable Infiltration Capacity (VIC) model, the Common Land Model (CLM), the Soil and Water Assessment Tool (SWAT), and the Kinematic Runoff and Erosion (KINEROS) hydrologic model. Dr. Park also has experience with using the Delft-Flood Early Warning System (FEWS)/Community Hydrologic Prediction System (CHPS) forecasting system and with ensemble streamflow predictions (ESP) forecasts (i.e., Hirsch, eHirsch, ESP, and the Meteorological Ensemble Forecast Processor (MEFP). He has experience with StateMod modeling, groundwater modeling (MODFLOW), snow surveys, and MIKE Customized implementation of the forecast system for the New York State Canal Corporation. His work has included model calibration and optimization (Shuffled Complex Evolution–University of Arizona [SCE-UA], Multi-objective Complex [MOCOM], Multi-objective Complex Evolution Metropolis–University of Arizona [MOSCEM], Non-dominated Sorting Genetic Algorithm [NSGA-II], and

GI-HYEON (JOHN) PARK, PHD

particle filter). Dr. Park's work has included ArcGIS tool development (i.e., ArcGIS extension for Wyoming consumptive water use estimation), lumped and distributed FEWS/CHPS implementation (standalone and live system), remote sensing (satellite precipitation [Precipitation Estimation from Remotely Sensing Information Using the Artificial Neural Network (PERSIANN)]), and remote sensing evapotranspiration (ET; Mapping Evapotranspiration at High Resolution with Internalized Calibration [METRIC], Leaf Area Index, land use and land cover classification.

RELEVANT WORK EXPERIENCE

Advancing Water Supply Forecasts in the Colorado River Basin for Improved Decision Making. As senior engineer for this National Aeronautics and Space Administration (NASA) Research Opportunities in Space and Earth Sciences (ROSES) project, leads the Research Distributed Hydrological Model (RDHM) implementation and calibration and the FEWS/CHPS implementation.

Development and Implementation of the Panama Canal Forecasting System. The purpose of this project, conducted for the Panama Canal Commission (PCC), was to develop and implement the standalone and live CHPS-FEWS for the Panama Canal. This project involved collecting and analyzing hydrometeorological data and calibrating NWSRFS models, including a new multi-reservoir operation model developed by Riverside Technology. This project also involved initializing and implementing the system and training PCC hydrologists on how to use the CHPS-FEWS for the Panama Canal. In 2014, a Live CHPS-FEWS was implemented and delivered to PCC.

Development and Implementation of the New York Forecast System. The purpose of this project was to develop and implement the hydrologic modeling components into the MIKE Customized system for the New York State Canal Corporation. As senior engineer, collected and analyzed hydrometeorological data, calibrated NWSRFS models, and implemented the NWRFS into the MIKE customized platform.

IAN S. MAYCUMBER, PE

PROPOSED ROLE: Water Resources Engineer; Model Calibrator; CHPS Support

EDUCATION

MS (Civil Engineering–Hydraulics/Water Resources), Colorado State University, 2009
BS (Civil Engineering), Colorado State University, 2004

CERTIFICATIONS AND AFFILIATIONS

- Registered Professional Engineer (Colorado)
- American Society of Civil Engineers
- Engineers Without Borders

PERSONAL CAPABILITIES STATEMENT

Ian Maycumber, a water resources engineer at RTI International, specializes in hydraulic and hydrologic model development, flood forecasting systems, and hydro-meteorological network design for both domestic and international clients. As a water resources group leader, his primary responsibilities include providing support and oversight for technical staff, and actively serving as a project manager. Mr. Maycumber's experience includes project management, forecast system development; hydro-meteorological network design; hydrologic model development and calibration, hydraulic model development and calibration, data analysis and quality control, and GIS analysis.

SELECTED PUBLICATIONS AND PRESENTATIONS

Maycumber, I., Woodbury, M., Seid, A., & Alarabawy, M. (2016) Needs assessment and design of a regional hydro-meteorological monitoring system in the Nile Basin. *World Environmental and Water Resources Congress 2016* (pp. 134-143). doi: 10.1061/9780784479841.015

Maycumber, I. (2009). *Strategies for implementing biosand water filter projects: Case studies from the Philippines*. Peace Corps Master's International Anthology of Theses and Reports 2006-2010.

RELEVANT WORK EXPERIENCE

U.S. National Weather Service—Advanced Hydrologic Prediction System (AHPS) Implementation

- Project engineer for the implementation of the AHPS of nine different projects for the Northwest, Southeast, Lower Mississippi, and West Gulf River Forecast Centers. Tasks included collecting, analyzing, and performing quality control on precipitation and temperature data; developing historical mean areal precipitation (MAP) and mean areal temperature (MAT) time series; estimating monthly potential evapotranspiration rates; conducting a water balance analysis; and calibrating the unit hydrograph, routing, soil moisture accounting, and snow accumulation and ablation models to historical flows.
- Lead technical engineer for the development of historical Mean Areal Precipitation (MAP) time series for the entire Southeast River Forecast Center, which includes 433 basins. This work involved the quality control and analysis of 1,304 daily and 477 hourly precipitation stations for a 60-year period.
- Project engineer involved with the hindcast analysis and verification of inflows to Folsom Reservoir for the California Nevada River Forecast Center (CNRFC). Responsibilities included comparing ensemble traces from the NWS EnsPost ensemble postprocessor versus raw MEFP (Meteorological Ensemble Forecast Processor) ensemble traces utilizing the EVS (Ensemble Verification System) tool. Conducted training on ENSPost Parameter Estimation and EVS at CNRFC offices.

U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC)—Upper Rio Grande Model Calibration Project, New Mexico

Project engineer involved with the development of a natural flow model for the Upper Rio Grande River Basin in the State of New Mexico down to the Rio Grande at El Paso. The calibrated

IAN S. MAYCUMBER, PE
hydrologic models will be used by the West Gulf River Forecast Center to provide short-term deterministic and long-term probabilistic flow forecasts to the Albuquerque District for input to their Upper Rio Grande Water Operations Model (URGWOM). Tasks included precipitation and temperature station data collection, analysis, and quality control; estimating monthly potential evapotranspiration rates; developing synthetic unit hydrographs; conducting a water balance analysis; and calibrating the routing, snow accumulation and ablation, and soil moisture accounting models to reproduce historical natural flows, with a focus on seasonal water supply volumes. **Northern Colorado Water Conservancy District (NCWCD)—Hydrologic Forecast System Enhancements, Colorado** Project manager for the development of enhancing the hydrologic models for the NCWCD streamflow forecasting system. Tasks included the analysis and quality control of precipitation and temperature data, extension of the mean areal precipitation (MAP) and mean areal temperature (MAT) time series for ensemble streamflow prediction (ESP), and calibration of soil moisture accounting (SAC-SMA) and snow accumulation and ablation model (SNOW-17). **Interstate Commission on the Potomac River Basin (ICPRB), Rockville, MD —Low Flow Forecast System (LFFS)** Project engineer responsible for the development of an LFFS for real-time monitoring and forecasting of flows within the Potomac River Basin. The LFFS utilizes the Deltares FEWS software integrated with the HSPF-based Chesapeake Bay Watershed Phase 5.2 Model. Primary tasks included developing python scripts to retrieve observed (grid and point) and forecasted datasets for multiple parameters; processing these data within FEWS for visualization and quality control; calculating and processing time series to be utilized by the HSPF model; running and retrieving results of model simulations; and automating the aforementioned processes within a FEWS Live System environment. The LFFS will aid in decision support for how best to manage water resources within the Potomac River Basin during low flow conditions. **Istanbul Disaster Management Office (AKOM)—Establishing a Flood Early Warning System (FEWS) in the Vicinity of Istanbul, Turkey** Project engineer involved with the development of a FEWS encompassing five watersheds in the greater Istanbul area. Tasks included data analysis of historical precipitation and streamflow data, hydrologic model calibration of SAC-SMA for reference basins, forecast basin delineation, synthetic unit hydrograph development, and hydrologic module development and testing within the FEWS forecasting system.

NOAH FRIESEN, PE

PROPOSED ROLE: Water Resources Engineer; Model Calibrator

EDUCATION

MS (Civil Engineering, Hydraulics & River Mechanics), Colorado State University, 2007
BS (Civil Engineering), Colorado State University, 2005

CERTIFICATIONS AND AFFILIATIONS

- Registered Professional Engineer (Colorado)
- American Society of Civil Engineers
- Center for Advanced Decision Support for Water and Environmental Systems, RiverWare®
- Intro to Simulation Modeling (2009); RiverWare®: Rulebased Simulation Modeling (2010)

SELECTED PUBLICATIONS AND PRESENTATIONS

Friesen, N. I., Carney, S. K, & Neel, T. C. (2011). *Multi-reservoir operational model for the Cumberland River*. Presented at HydroVision International 2011, Sacramento, CA.

Friesen, N. I. (2007). *Amplification of supercritical surface waves in steep open channels near Las Vegas, Nevada*, M.S. Thesis, Colorado State University, Fort Collins, CO.

Friesen, N. I. (2007). *Celerity and attenuation/amplification of supercritical flow waves*. Presented at the World Environmental and Water Resources Congress, Tampa, FL.

Friesen, N. I., Duan, J. G., & Julien, P. Y. (2007). *Celerity and attenuation/amplification of supercritical flow waves*. Presented at American Geophysical Union Hydrology Days Conference, Fort Collins, CO.

PERSONAL CAPABILITIES STATEMENT

Noah Friesen is a research environmental engineer at RTI International specializing in reservoir and hydrologic model development and calibration. He has developed models for many different reservoirs around the United States in several different modeling tools, including HEC-ResSim and RiverWare. He has modeled consumptive use in areas with significant irrigation and streamflow regulation. Mr. Friesen also has experience with data analysis and quality control, including correction of time series to ensure consistent periods of record. His research experience is in the following areas:

- Wave propagation in high-velocity flow
- Development and calibration of single and multiple reservoir models
- Calibration of snow and soil moisture models
- Calibration of consumptive use models
- Data analysis, modification, and verification using spreadsheets and other tools
- Data processing and model parameter development using GIS tools
- Script development using Python

RELEVANT WORK EXPERIENCE

National Weather Service—Missouri Basin River Forecast Center (MBRFC), Missouri
Project manager for calibration of hydrologic and consumptive use models in Montana. Project engineer for calibration of reservoir, hydrologic, and consumptive use NWSRFS models for basins on the South Platte, North Platte, Platte, Republican, Solomon, and Missouri rivers in Colorado, Wyoming, Nebraska, Kansas, and Montana. Set up and calibrated HEC-ResSim model for seven jointly operating reservoirs in the Kansas River Basin. Participated in meetings with clients to discuss work performed and suggest further refinement. Located data sources and compiled and digitized data for reservoirs and other relevant locations in the North Platte.

National Weather Service—Northeast River Forecast Center (NERFC), Massachusetts
Project manager for calibration of hydrologic and routing models in Connecticut. Team leader for hydrologic calibration portion of a model development project covering basins in Connecticut,

NOAH FRIESEN, PE
Rhode Island, Massachusetts, New York, and Maine. Project engineer for calibration of hydrologic and reservoir NWSRFS models for basins in and around the Connecticut River Basin. Involved in data compilation, verification, and analysis. **National Weather Service—West Gulf River Forecast Center (WGRFC), Texas** Project engineer for calibration of multi-reservoir system using NWSRFS models in the Brazos River Basin in Texas. Constructed a detailed storage balancing framework incorporating reservoirs in series and parallel, as well as release constraints and downstream control points. **National Weather Service—Lower Mississippi River Forecast Center (LMRFC), Louisiana/Arkansas** Project engineer for calibration of hydrologic models using NWSRFS models in several river basins in Louisiana, Mississippi, and Arkansas. Calibrated RES-J models for two reservoirs on the Ouachita River in Arkansas. Performed review and quality checks on work of peers. **National Weather Service—Arkansas-Red Basin River Forecast Center (ABRFC), Oklahoma** Project engineer for calibration of the NWSRFS models for reservoirs in the Verdigris River in southeastern Kansas. Tasks performed included data processing and analysis, model calibration, and review of reservoir operational information. **National Weather Service—Southeast River Forecast Center (SERFC), Georgia** Project engineer for dam break study for several dams in Georgia and South Carolina. Used the Simplified Dam Break model (SMPDBK) to study potential flooding impacts. Developed reasonable model parameters based on reservoir parametric information and judgment. Performed basic sensitivity analysis on model input parameters. **National Weather Service—Northwest River Forecast Center (NWRFC), Washington** Calibrated snow and soil moisture models for river basins in western Washington, including Mount Rainier and the Olympic Peninsula. Dealt with multiple elevation zones including glacier zones. **New York State Canal Corporation—Hydrologic Model Development, New York** Calibration of hydrologic models for a number of basins in the Mohawk and Upper Hudson River basins. Models include snow accumulation and melt, soil moisture accounting, and streamflow routing. Performed data analysis and management tasks. Reviewed work of other engineers. Calculated inflows for Indian Lake and Great Sacandaga Lake. **Tennessee Valley Authority—Hydrologic Model Calibration, Tennessee** Project engineer for calibration of National Weather Service hydrologic models in the Tennessee Valley. Determined model parameters for use in streamflow forecasting system. Quality controlled model input data.

ELEEJA SHRESTHA, PE

PROPOSED ROLE: Water Resources Engineer; Data Analysis Lead; Model Calibrator

EDUCATION

MS (Civil and Environmental Engineering), University of Nevada, 2010
BS (Civil Engineering), Tribhuvan University, Nepal, 2006

CERTIFICATIONS AND AFFILIATIONS

- Registered Professional Engineer (Colorado)
- American Society of Civil Engineers
- Golden Key International Honor Society
- Tau Beta Pi Engineering Honor Society
- The Honor Society of Phi Kappa Phi

SELECTED PUBLICATIONS AND PRESENTATIONS

Shrestha, E., & Halgren, J. (2013, March). Developing demonstration GSSHA model for Northeast US, *AGU Hydrology Days 2013,* Colorado State University, Fort Collins, CO.

Shrestha, E., Ahmad, S., Johnson, W., & Batista, J. R. (2012). The carbon footprint of water management policy options. *Energy Policy*, *42*(0), 201-212.

Shrestha, E., Ahmad, S., Johnson, W., Shrestha, P., & Batista, J. R. (2011). Carbon footprint of water conveyance versus desalination as alternatives to expand water supply. *Desalination, 280*(1-3), 33-43.

Shrestha, E., Ahmad, S., Johnson, W., & Batista, J. R. (2011). The carbon footprint associated with water management policy options in the Las Vegas Valley, Nevada. *Journal of the Nevada Water Resources Association, 6*(1), 2-9.

PERSONAL CAPABILITIES STATEMENT

Eleeja Shrestha is a water resources engineer at RTI specializing in hydrologic and hydraulic model development and calibration, including GSSHA, HEC-RAS, and HEC-HMS. She also has experience in system dynamics modeling. Ms. Shrestha has worked as a research assistant for the University of Nevada Las Vegas, and her experience includes system dynamics modeling to study carbon footprint of existing and future water supply alternatives for the Las Vegas Valley, and design and cost analysis of RO seawater treatment facility.

RELEVANT WORK EXPERIENCE

Texas Water Development Board (TWDB)—Hydrologic Model Development for the West Gulf River Forecast Center (WGRFC)

Project engineer responsible for developing and calibrating hydrologic models in Central Texas to support the National Weather Service's (NWS's) WGRFC. Tasks included estimating monthly potential evapotranspiration rates, conducting water balance analysis, and calibrating unit hydrograph, routing, and soil moisture accounting models to historical flows.

Panama Canal Authority—Operational Enhancements and Support for the Hydrologic Forecast System

Project engineer responsible for operational enhancements and support for the NWSRFS. Responsibilities included analyzing and quality controlling hydrometeorological data, and performing MAP analysis and water balance analysis.

Morocco NOVEC and MASEN—Climate Change Modeling

Staff engineer responsible for climate change modeling. Responsibilities included quality controlling multiple DSS files, creating an inventory of period of record and cross referencing with the ArcGIS files, analyzing temperature data, estimating monthly potential evapotranspiration (PET) rates, developing 15 HMS models for the Souss-Massa-Draa region in Morocco to model the hydrologic impact of climate change, estimating lag and time of concentrations for the basins, computing

ELEEJA SHRESTHA, PE
percent change in precipitation and temperature difference between historical and forecasted data for six climate models, applying changes to HMS models, and analyzing and comparing climate change scenarios. **Morocco NOVEC—Hydrologic Modeling System (HMS) Modeling** Staff engineer responsible for HMS modeling. Responsibilities included quality controlling multiple DSS files, creating an inventory of period of record and cross referencing with the ArcGIS files, estimating curve number using land use and soil information for use in HMS model, creating precipitation and discharge gage file for use in HMS model, and calibrating HMS subbasins. **Tennessee Valley Authority (TVA)—River Forecast Center Planning** Responsible for assisting with river forecast center planning. Responsibilities included developing unit hydrograph (UH) to use in the Sacramento Soil Moisture Accounting (SAC-SMA) runoff modeling operation for 12 subbasins, calibrating and peer reviewing soil moisture accounting models to historical flows, quality controlling inflow hydrographs for flood inundation mapping, and creating total depth map using probable maximum flood (PMF) inflow series. **National Weather Service—Advanced Hydrologic Prediction System, Missouri Basin River Forecast Center** Staff engineer assisting with the enhancement of river forecast center planning. Responsibilities included verifying and calibrating existing TATUM routing models for 18 reaches required to model total stream flow for 22 subbasins, performing mean areal precipitation (MAP) analysis and quality control for 44 subbasins, preparing calibration assistance program (CAP) parameters for use in SAC-SMA model, and calibrating snow and soil moisture accounting models to historical flows. **National Weather Service—Advanced Hydrologic Prediction System, Southeast River Forecast Center** Staff engineer assisting with the enhancement of river forecast center planning. Responsibilities included estimating monthly PET rates to use in the SAC-SMA runoff modeling operation for seven subbasins, and collecting and analyzing wind and temperature data. **Integrated Water Resources Science and Services—Advanced Hydrologic Prediction System** Staff engineer responsible for GSSHA modeling for the Advanced Hydrologic Prediction Systems (AHPS) Integrated Water Resources Science and Services (IWRSS) project. Responsibilities included developing coarse (1 km), medium (30 m), and high (10 m) resolution GSSHA models for the Upper Susquehanna watershed, Little Choconut Creek watershed near Binghamton, NY, and Johnson City in the downstream part of the Little Choconut Creek watershed, respectively, to examine the technical readiness of GSSHA for deployment at the National Water Center.

JEREMY S. CARLSTON

PROPOSED ROLE: Water Resources Engineer; Data Analysis Support; Model Calibrator

EDUCATION

MS (Civil Engineering), Colorado State University, 2015
BS (Civil Engineering), Colorado State University, 2013

CERTIFICATIONS AND AFFILIATIONS

- Passed the Fundamentals of Engineering (FE) Exam to become an Engineer in Training (EIT), October 2012

SELECTED PUBLICATIONS AND PRESENTATIONS

Carlston, J. S., & Venayagamoorthy, S. K. (2015). Impact of modified inlets on residence times in baffled tanks. *Journal of the American Water Works Association*, *107*(6), E292–E300. http://dx.doi.org/10.5942/jawwa.2015.107.0078

Taylor, Z. H., Carlston, J. S., & Venayagamoorthy, S. K. (2015). Hydraulic design of baffles in disinfection control tanks. *Journal of Hydraulic Research*, *53*(3), 400–407. http://dx.doi.org/10.1080/00221686.2015.1040086

PERSONAL CAPABILITIES STATEMENT

Jeremy Carlston is a water resources engineer at RTI International. During his graduate studies, he gained insight into hydraulic modeling techniques while researching mixing efficiencies of water disinfection systems using computational fluid dynamics. In his current role as a water resources engineer, Mr. Carlston provides support for a variety of projects involving water resources. Roles in typical projects include hydrologic model calibration, hydraulic modeling, building and augmentation of decision support and flood warning systems, and various other duties at a junior engineer level.

RELEVANT WORK EXPERIENCE

TWDB and WGRFC—Hydrologic Model Calibration for the West Gulf River Forecast Center

Assisted in various roles throughout the calibration process of 23 NWS basins. Prepared precipitation, streamflow, and other hydrological data for calibration of various models. Investigated and documented water balance issues to enhance calibration accuracy. Derived unit hydrographs using both GIS-based and historical analysis methods. Performed initial calibrations of LAG/K, SAC-SMA, UNIT-HG, and CHANLOSS models. Summarized results and assisted in creation of final deliverables and report.

AES Panamá—Reservoir Inflow Forecasting for Bayano Reservoir

Built operational forecast system for inflow prediction to Bayano Reservoir in a FEWS software environment. Assimilated open-access precipitation forecast data and processed it for input to SAC-SMA model for 58 basins. Incorporated calibrated SAC-SMA model and unit hydrographs into operational system for live forecasting using this precipitation data. Runs semiweekly forecasts for AES using this system.

Content Item 4: Historically Underutilized Businesses Subcontracting Plan

Content Item 4: Historically Underutilized Businesses Subcontracting Plan

The required sections from this form are provided below.

➤ **If you will not be subcontracting any portion of the contract and will be fulfilling the entire contract with your own resources (i.e., employees, supplies, materials and/or equipment), complete:**

- ☒ Section 1 - Respondent and Requisition Information
- ☒ Section 2 a. - No, I will not be subcontracting any portion of the contract, and I will be fulfilling the entire contract with my own resources.
- ☒ Section 3 - Self Performing Justification
- ☒ Section 4 - Affirmation

SECTION 1: RESPONDENT AND REQUISITION INFORMATION

a. Respondent (Company) Name: Research Triangle Institute — State of Texas VID #: 56-0686338

Point of Contact: Kaitlin Hayes — Phone #: 919-541-7482

E-mail Address: kehayes@rti.org — Fax #: 919-316-3911

b. Is your company a State of Texas certified HUB? ☐ - Yes ☑ - No

c. Requisition #: 580-18-RFQ0061 — Bid Open Date: 02/15/2018 (mm/dd/yyyy)

Enter your company's name here: Research Triangle Institute — Requisition #: 580-18-RFQ0061

SECTION 2: RESPONDENT's SUBCONTRACTING INTENTIONS

After dividing the contract work into reasonable lots or portions to the extent consistent with prudent industry practices, and taking into consideration the scope of work to be performed under the proposed contract, including all potential subcontracting opportunities, the respondent must determine what portions of work, **including contracted staffing, goods and services will be subcontracted**. Note: In accordance with 34 TAC §20.282, a "Subcontractor" means a person who contracts with a prime contractor to work, to supply commodities, or to contribute toward completing work for a governmental entity.

a. Check the appropriate box (Yes or No) that identifies your subcontracting intentions:

☐ - ***Yes***, I will be subcontracting portions of the contract. (If ***Yes***, complete Item b of this SECTION and continue to Item c of this SECTION.)

☑ - ***No***, I will not be subcontracting <u>any</u> portion of the contract, and I will be fulfilling the entire contract with my own resources, including employees, goods and services. (If ***No***, continue to SECTION 3 and SECTION 4.)

Enter your company's name here: Research Triangle Institute — Requisition #: 580-18-RFQ0061

SECTION 3: SELF PERFORMING JUSTIFICATION

(If you responded "No" to SECTION 2, Item a, you must complete this SECTION and continue to SECTION 4.) If you responded "No" to SECTION 2, Item a, in the space provided below **explain how** your company will perform the entire contract with its own employees, supplies, materials and/or equipment.

RTI International specializes in all aspects of this proposed project and has all of the expertise needed to complete the project. RTI is staffed with personnel who have experience and specializations in areas that have direct relevance to the work required. Our proposed project team has more than 170 years of combined relevant experience, the majority of which include performing model calibration efforts through our broader experience in a full spectrum of technologies and activities associated with flood forecasting, including design and implementation of data collection networks, implementation of real-time data management systems, and the development and implementation of real-time flood forecast systems throughout the world. RTI has a few current projects nearing completion which allows our proposed project team availability to fulfill all of the objectives of the defined scope. RTI has delivered again and again on time and to specifications with projects for other clients with similar technical and decision support requirements.

SECTION 4: AFFIRMATION

As evidenced by my signature below, I affirm that I am an authorized representative of the respondent listed in SECTION 1, and that the information and supporting documentation submitted with the HSP is true and correct. Respondent understands and agrees that, if awarded any portion of the requisition:

- The respondent will provide notice as soon as practical to all the subcontractors (HUBs and Non-HUBs) of their selection as a subcontractor for the awarded contract. The notice must specify at a minimum the contracting agency's name and its point of contact for the contract, the contract award number, the subcontracting opportunity they (the subcontractor) will perform, the approximate dollar value of the subcontracting opportunity and the expected percentage of the total contract that the subcontracting opportunity represents. A copy of the notice required by this section must also be provided to the contracting agency's point of contact for the contract no later than ten (10) working days after the contract is awarded.
- The respondent must submit monthly compliance reports (Prime Contractor Progress Assessment Report – PAR) to the contracting agency, verifying its compliance with the HSP, including the use of and expenditures made to its subcontractors (HUBs and Non-HUBs). (The PAR is available at https://www.comptroller.texas.gov/purchasing/docs/hub-forms/ProgressAssessmentReportForm.xls).
- The respondent must seek approval from the contracting agency prior to making any modifications to its HSP, including the hiring of additional or different subcontractors and the termination of a subcontractor the respondent identified in its HSP. If the HSP is modified without the contracting agency's prior approval, respondent may be subject to any and all enforcement remedies available under the contract or otherwise available by law, up to and including debarment from all state contracting.
- The respondent must, upon request, allow the contracting agency to perform on-site reviews of the company's headquarters and/or work-site where services are being performed and must provide documentation regarding staffing and other resources.

Signature	Printed Name	Title	Date (mm/dd/yyyy)
Katlin Hayes	Kaitlin Hayes	Senior Contracting Officer	2/12/18

Content Item 5: Ownership of Business Entity

Content Item 5: Ownership of Business Entity

As a nonprofit organization, RTI is governed by a Board of Governors and does not have company owners. Content Item 5 is therefore not applicable.

Content Item 6: Technical Approach

Content Item 6: Technical Approach

6.1 Demonstration of Requirements

A. Experience providing model calibration data to the NWS in the past 7 years. Within the last 7 years, RTI staff have provided support to WGRFC, Lower Mississippi River Forecast Center (LMRFC), Missouri Basin River Forecast Center (MBRFC), Northeast River Forecast Center (NERFC), Southeast River Forecast Center (SERFC), and Northwest River Forecast Center (NWRFC). This support has included data collection (i.e., precipitation, temperature, streamflow, diversion, and reservoir data), data quality control, computation of MAP and MAT time series, estimation of historical natural flows, estimation of unit hydrographs, calibration of the SNOW-17 and SAC-SMA models, calibration of the RES-J and RES-Sim models, calibration of variable LAG/K, TATUM, and SARROUTE routing models, regulation modeling (i.e., modeling diversions and consumptive use). RTI staff have delivered quality-controlled observed data (e.g., precipitation, temperature, streamflow), processed data (e.g., MAP and MAT time series, natural flows), and calibrated model parameters along with detailed calibration reports.

B. Proven familiarity and knowledge of the climate, meteorology, and hydrology of Texas. Since 2004, RTI staff have provided WGRFC with SAC-SMA, UNIT-HG, and LAG/K model calibrations for more than 120 subbasins. This work has provided RTI with a familiarity and knowledge of the major watersheds in Texas, including those near the project area, such as the Brazos, Trinity, Neches, and Sabine. In 2017, RTI worked with the WGRFC to improve flood forecasting capabilities in the Colorado, Guadalupe, and San Antonio River basins. RTI is also currently involved in projects with the USACE Fort Worth District and Risk Management Center, evaluating extreme precipitation events in the Trinity River Basin and modeling reservoir operations in the Neches Basin. RTI staff also performed data collection and analysis, hydrologic model calibration, and forecast system implementation on the Rio Conchos and the Rio Bravo (i.e., Rio Grande) for the National Water Commission (CONAGUA) in Mexico. With this unique experience, RTI staff are aware of the challenges associated with hydrologic simulations in Southeast Texas, including modeling the effects of the extensive flood control system within the metro-Houston area.

C. Experience with CHPS and/or other software packages used by the National Weather Service River Forecast Centers. RTI staff experience with software packages used by the RFCs extends back to the 1980s, when three current RTI staff were employees of the NWS Office of Hydrology, whose primary responsibility was enhancing and supporting the River Forecast System used daily by the RFCs. These staff helped develop algorithms, tools, and programs used in the forecasting process, including computing mean areal temperature and precipitation, optimization of the SAC-SMA model parameters, and data management in long-range forecasting.

RTI staff has been working with RFC software packages since 1995, with NWSRFS implementations for the Bonneville Power Administration, Panama Canal, and government of Mexico. Following those projects, RTI staff began providing data analysis and calibration services to RFCs and other users in the United States and around the world under multiple IDIQ contracts. Thus, RTI staff became recognized experts in the use of RFC software packages including:

- PXPP – for quality control and analysis of precipitation stations;
- IDMA – for double mass analysis of precipitation and temperature data and MAP and MAT values;
- MAP – for computing mean areal precipitation time series from station data;
- MAT3 – for computing mean areal temperature data from station data;
- MCP3 – for manual calibration of RFC models using historical data;
- ICP – for interactive calibration of RFC models through a graphical user interface; and
- OPT3 – for single objective optimization of RFC models.

As the NWS migrated its forecasting platform from NWSRFS to CHPS, RTI staff began converting clients using the NWSRFS paradigm to the new CHPS systems. We converted systems in Panama, Mexico, El Salvador, Honduras, and Nicaragua. RTI recently supported Idaho Power in its transition from NWSRFS to CHPS.

RTI staff also began developing new CHPS implementations for U.S. agencies such as the Interstate Commission on the Potomac River Basin, the Bureau of Reclamation in Colorado, and the Tennessee Valley Authority (TVA). For TVA, we developed a CHPS system that:

- is fully integrated with HEC-RAS models for river routing;
- is coupled with RiverWare for operation of TVA reservoirs;
- incorporates hydrothermal modeling to couple river and water temperature forecasts;
- takes advantage of the Delft-Flood Early Warning System (FEWS) Archive process (the second application of this tool in the world); and
- includes displays for real-time status and data reporting including the FEWS Status Schematic Displays (SSDs).

D. Experience calibrating rainfall-runoff and hydraulic routing models. Since 1995, RTI staff have calibrated more than 1,000 basins using the SAC-SMA rainfall-runoff model within the contiguous United States for either the NWS or other clients utilizing real-time river forecast systems. Many of the local basin calibrations included calibration of hydrologic routing models (e.g., LAG/K and Tatum). RTI staff also have extensive experience calibrating hydraulic routing models (e.g., FLDWAV and HEC-RAS) for NWS, USACE, and TVA. These models support operational forecasting, Probable Maximum Flood analysis, and Dam Failure analysis.

RTI's model calibration project reports become reference documents that allow RFC staff the ability to easily review basin characteristics, model parameters, and calibration statistics.

E. Ability to clearly communicate results of analyses in graphical, written, oral formats. One of RTI WRMD's strengths is communicating complex and specialized information to our clients and their stakeholders in ways that meet their needs. We have delivered simple reports that focus on the use or application of the technologies we develop, as well as more detailed reports expanding on the processes and intermediate results of our work. Sometimes our audience is the general public or public officials with need for contextual information and explanations of technical issues that aid in decision making. RTI communicates with each of these audiences in the appropriate format and style.

RFC staff have commented on the ongoing value of our past calibrations because our reports have provided key information that they can reference in the course of operational forecasting, including background information about basins, unique characteristics of available data for specific subbasins, and specific features of the calibrations that help them interpret real-time model outputs.

F. Ability to meet project completion deadlines since there will be no contract extensions. RTI is confident in our ability to meet the deadlines for this important project. RTI's WRMD has a deep bench of qualified hydrologists and engineers with experience performing this type of work. The professional team proposed for this project is available to start preliminary data analysis upon contract execution. The WRMD includes a Project Management Office (PMO) that oversees staff allocation to ensure that all projects have the resources required to achieve objectives and produce high-quality deliverables on schedule and within budget. In short, RTI has the experience, the team, and the tools to produce high-quality results within the project budget and schedule.

G. Demonstration of financial capability. Please see **Appendix A**, which demonstrates RTI's financial ability to fulfill all contract requirements.

H. References. Please see **Appendix B** for vendor references.

Appendix A. Demonstration of Financial Capability

Redacted/Abbreviated Version

Research Triangle Institute

Consolidated Financial Statements as of and
for the Years Ended September 30, 2017 and 2016,
and Independent Auditors' Report

RESEARCH TRIANGLE INSTITUTE

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INDEPENDENT AUDITORS' REPORT

To the Board of Governors
Research Triangle Institute:

We have audited the accompanying consolidated financial statements of Research Triangle Institute and its subsidiaries (the "Institute"), which comprise the consolidated balance sheets as of September 30, 2017 and 2016, and the related consolidated statements of revenue, costs, and changes in Institute net assets and of cash flows for the years then ended, and the related notes to the consolidated financial statements.

Management's Responsibility for the Consolidated Financial Statements

Management is responsible for the preparation and fair presentation of these consolidated financial statements in accordance with accounting principles generally accepted in the United States of America; this includes the design, implementation, and maintenance of internal control relevant to the preparation and fair presentation of consolidated financial statements that are free from material misstatement, whether due to fraud or error.

Auditors' Responsibility

Our responsibility is to express an opinion on these consolidated financial statements based on our audits. We conducted our audits in accordance with auditing standards generally accepted in the United States of America. Those standards require that we plan and perform the audits to obtain reasonable assurance about whether the consolidated financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the consolidated financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the consolidated financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the Institute's preparation and fair presentation of the consolidated financial statements in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Institute's internal control. Accordingly, we express no such opinion. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of significant accounting estimates made by management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Opinion

In our opinion, the consolidated financial statements referred to above present fairly, in all material respects, the consolidated financial position of the Institute as of September 30, 2017 and 2016, and the changes in its net assets and its cash flows for the years then ended in accordance with accounting principles generally accepted in the United States of America.

Deloitte & Touche LLP

December 7, 2017

RESEARCH TRIANGLE INSTITUTE

CONSOLIDATED BALANCE SHEETS
AS OF SEPTEMBER 30, 2017 AND 2016
(In thousands of dollars)

	2017	2016
ASSETS		
CURRENT ASSETS:		
Cash and cash equivalents	$ 29,008	$ 31,818
Restricted cash	6,211	6,754
Short-term investments	170,712	176,532
Accounts receivable—net of allowance for doubtful accounts of $500 in 2017 and 2016	74,573	63,051
Unbilled costs and fees	131,615	113,666
Prepaid expenses and other current assets	24,942	20,371
Total current assets	437,061	412,192
PROPERTY AND EQUIPMENT—Net	159,999	121,978
INVESTMENTS	58,186	52,907
GOODWILL	15,932	5,880
OTHER NONCURRENT ASSETS	23,511	14,987
TOTAL ASSETS	$694,689	$607,944
LIABILITIES AND INSTITUTE NET ASSETS		
CURRENT LIABILITIES:		
Accounts payable	$ 67,369	$ 44,693
Current portion of long-term debt	33,305	34,295
Accrued compensated absences	28,702	27,171
Deferred revenue	41,817	40,901
Other accrued expenses	38,016	29,075
Total current liabilities	209,209	176,135
LONG-TERM LIABILITIES:		
Long-term debt—less current portion	46,432	14,921
Other long-term liabilities	22,629	23,511
Total liabilities	278,270	214,567
COMMITMENTS AND CONTINGENCIES (Note 13)		
INSTITUTE NET ASSETS:		
Unrestricted contributed net assets	5,061	5,061
Unrestricted accumulated net assets	409,065	386,161
Total unrestricted Institute net assets	414,126	391,222
Temporarily restricted net assets	542	492
Permanently restricted net assets	1,751	1,663
Total Institute net assets	416,419	393,377
TOTAL LIABILITIES AND INSTITUTE NET ASSETS	$694,689	$607,944

See notes to consolidated financial statements.

RESEARCH TRIANGLE INSTITUTE

CONSOLIDATED STATEMENTS OF REVENUE, COSTS, AND CHANGES IN INSTITUTE NET ASSETS
FOR THE YEARS ENDED SEPTEMBER 30, 2017 AND 2016
(In thousands of dollars)

	2017	2016
UNRESTRICTED REVENUE	$972,277	$884,679
DIRECT COSTS:		
Salaries and employee benefits	255,384	231,983
Other direct costs	405,257	364,540
Total direct costs	660,641	596,523
INDIRECT COSTS	306,574	272,923
Total direct and indirect costs	967,215	869,446
EXCESS OF REVENUE OVER DIRECT AND INDIRECT COSTS	5,062	15,233
INVESTMENT INCOME—Net	18,232	10,195
OTHER (EXPENSE) INCOME—Net	(1,435)	265
INTEREST INCOME (EXPENSE)—Net	3,401	(3,108)
IMPAIRMENT LOSS	(3,232)	(5,346)
OPERATING INCOME BEFORE INCOME TAX EXPENSE	22,028	17,239
INCOME TAX EXPENSE	(515)	(849)
NET OPERATING INCOME	21,513	16,390
POSTRETIREMENT CHANGES OTHER THAN NET PERIODIC BENEFIT COST	1,429	(489)
CURRENCY TRANSLATION ADJUSTMENT	(38)	(14)
INCREASE IN UNRESTRICTED INSTITUTE NET ASSETS	22,904	15,887
PERMANENTLY RESTRICTED—Unrealized gain on permanently restricted assets	88	48
TEMPORARILY RESTRICTED:		
Interest income—net	50	276
Research and development costs	-	(222)
Net change in temporarily restricted	50	54
INCREASE IN INSTITUTE NET ASSETS	23,042	15,989
INSTITUTE NET ASSETS:		
Beginning of year	393,377	377,388
End of year	$416,419	$393,377

See notes to consolidated financial statements.

RESEARCH TRIANGLE INSTITUTE

CONSOLIDATED STATEMENTS OF CASH FLOWS
FOR THE YEARS ENDED SEPTEMBER 30, 2017 AND 2016
(In thousands of dollars)

	2017	2016
CASH FLOWS FROM OPERATING ACTIVITIES:		
Increase in Institute net assets	$ 23,042	$ 15,989
Adjustments to reconcile increase in Institute net assets to cash provided by operating activities:		
Depreciation and amortization	14,264	14,254
Dividends reinvested	(5,207)	(4,657)
Realized and unrealized gain on investments	(12,947)	(5,364)
Unrealized (gain) loss on derivatives	(5,169)	1,291
Postretirement changes other than net periodic pension cost	(1,429)	489
Impairment on property and equipment	-	5,346
Impairment of goodwill	3,232	-
Other loss—net	881	155
Changes in other operating assets and liabilities:		
Accounts receivable and unbilled costs and fees	(19,645)	(11,024)
Other operating assets	(6,648)	545
Accounts payable	9,115	4,984
Deferred revenue	916	(8,832)
Other operating liabilities	13,988	6,518
Net cash provided by operating activities	14,393	19,694
CASH FLOWS FROM INVESTING ACTIVITIES:		
Proceeds from sale of investments	68,439	53,830
Purchases of investments	(49,780)	(97,306)
Acquisition of property and equipment	(39,592)	(12,902)
Proceeds from sale of property and equipment	-	12
Proceeds from divestiture of Microsystem Integration & Packaging Group	500	-
Proceeds from sale of unconsolidated affiliate	-	11,579
Acquisitions—net of cash acquired	(27,970)	(6,595)
Change in restricted cash	543	(2,050)
Net cash used in investing activities	(47,860)	(53,432)

(Continued)

RESEARCH TRIANGLE INSTITUTE

CONSOLIDATED STATEMENTS OF CASH FLOWS
FOR THE YEARS ENDED SEPTEMBER 30, 2017 AND 2016
(In thousands of dollars)

	2017	2016
CASH FLOWS FROM FINANCING ACTIVITIES:		
Borrowings on line of credit	$ 171,311	$ -
Payments on line of credit	(171,311)	-
Borrowings on nonrevolving master loan	33,160	-
Payments on bonds payable	(2,490)	(2,395)
Principal payments on other financial obligations	(2)	(10)
Net cash provided by (used in) financing activities	30,668	(2,405)
NET DECREASE IN CASH AND CASH EQUIVALENTS	(2,799)	(36,143)
EFFECT OF EXCHANGE RATE CHANGES ON CASH	(11)	-
CASH AND CASH EQUIVALENTS:		
Beginning of year	31,818	67,961
End of year	$ 29,008	$ 31,818
SUPPLEMENTAL DISCLOSURES OF CASH FLOW INFORMATION—Cash paid during the year for:		
Income taxes	$ 290	$ 1,638
Interest	$ 2,101	$ 1,944
SUPPLEMENTAL DISCLOSURE OF CASH FLOW INFORMATION—Noncash		
Construction in process accruals	$ 11,953	$ -

See notes to consolidated financial statements. (Concluded)

Pages 7 - 35 have been abbreviated.

Appendix B. References

Appendix B. References

Project	Brief Description of Work, Relevance, and Challenges
TITLE: River Forecast Center Modernization – Hydrologic Model Calibration **Client:** Tennessee Valley Authority **Dollar Amount:** $227,059 **Period of Performance:** 8/2012 – 10/2014 (Three different task orders: 8/8/2012 – 9/30/2012; 10/1/2013 – 9/30/2014; 3/6/2014 – 10/31/2014) **Point of Contact:** Curt Jawdy, cmjawdy@tva.gov	**Description:** Performed hydrologic model calibration for basins within the Tennessee Valley watershed. The project involved data collection and formatting, estimation of reservoir evaporation, and calibration of the Sacramento Soil Moisture Accounting model, unit hydrographs, and variable Lag/K routing models. The resulting hydrologic models were incorporated into the operational forecasting system at TVA. **Relevance to the SOW:** The nature of the work is very similar to the proposed scope. The modeling suite (NWSRFS) and framework (FEWS/CHPS) used for the TVA forecast system is the same as what is used at the WGRFC. **Challenges:** The size (140+ sub-basins) and complexity of the TVA system provided numerous challenges. In addition, the TVA is very concerned with maintaining an accurate water balance; therefore, detailed reservoir evaporation modeling was incorporated. of note
Title: National Weather Service Model Calibration within the Lower Mississippi River Forecast Center Service Area **Client:** NOAA **Dollar Amount:** $475,000 **Period of Performance:** 9/2004 – 8/2012 **Point of Contact:** Gina Tillis-Nash, gina.tillis.nash@noaa.gov	**Description:** Performed hydrologic model calibration for basins throughout the LMRFC service area as part of the AHPS program. Projects included data collection, data analysis, calibration of the Sacramento Soil Moisture Accounting model, unit hydrographs, and variable Lag/K routing models. In addition, multiple projects included the development of reservoir (RES-J) models. During the performance period, RTI staff completed model calibration for 145 sub-basins and developed RES-J models for 20 reservoirs. The resulting hydrologic models were incorporated into the operational forecasting system at the LMRFC. **Relevance to the SOW:** The nature of the work is very similar to the proposed scope. The modeling suite (NWSRFS) used for the LMRFC forecast system is the same as what is used at the WGRFC. **Challenges:** The LMRFC service area includes a wide variety of hydrologic conditions that require unique parameter sets to accurately simulate streamflow. In addition, the service area includes man-made flood diversions near the Mississippi River and significant losses due to karst geology in the Ozarks which had to be accounted for in model development.

Use or disclosure of any information on this page is subject to the restriction in the proprietary statement of this proposal.

Exhibit B

Scope of Work

TASK 1. Historical Precipitation Data Collection.

RTI recognizes that high-quality historical datasets are vital to the model calibration process. Ensuring that precipitation inputs are accurate and consistent over time is critical to the development of models that will perform well in the operational forecast system. Understanding the observed streamflow data and the water balance of the modeled area helps identify where to account for gains or losses so that storm runoff can be isolated and modeled appropriately. The WGRFC will provide XMRG datasets as inputs to the hydrologic models. If these data are not available for any areas, RTI will develop historical precipitation inputs from the available station data, which RTI will quality control as described below.

- ***Evaluating dataset for outliers and adjust/remove if necessary.*** RTI uses quality-control spreadsheets, Python scripts, and the time-series processing application TSTool to check raw precipitation data for outliers, repeated values, and inconsistencies; to compare extreme values with surrounding stations; and to generate monthly statistics. Using these tools, RTI has automated the flagging of potentially erroneous values based on user-defined quality control criteria. This allows us to efficiently perform evaluation of a large number of historical time series.
- ***Checking for changes in the station location, station site conditions, or sensor type over time.*** RTI will perform consistency checks on station rainfall using an RTI-developed spreadsheet version of the Interactive Double Mass Analysis (IDMA) program. Where inconsistencies in the historical data are detected, RTI will adjust the data so the earlier parts of the record are made consistent with the more recent parts. This will help ensure consistency of model inputs over the model calibration period.
- ***Developing Mean Areal Precipitation (MAP) estimates based on XMRGs provided by the WGRFC.*** RTI will derive historical MAP time series for input during model calibration using spatial averaging techniques. To evaluate the general quality of these inputs, RTI will perform a comparison of the data over the calibration period with the Oregon State Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Data set. Large differences between the long-term historical averages of the developed MAP time series and the averages derived from the PRISM dataset will be investigated further and resolved in consultation with the WGRFC.

TASK 2. Data Preparation and Analysis.

- ***Reviewing data provided by the WGRFC and performing basic quality control.*** RTI recognizes the importance of quality control and review of input data prior to beginning model development and calibration. Biased, inconsistent, or otherwise flawed input data can lead to unrealistic parameter sets that may underperform in real-time forecasting, especially in long-range forecasting. RTI will use data analysis procedures developed and successfully applied during previous NWSRFS model calibration projects. These procedures include using the time-series processing application TSTool and internally

developed Data Quality Control spreadsheets to graph and generate statistics on streamflow and precipitation data.

- ***Historical streamflow development.*** RTI will use scripts, spreadsheet tools, and statistical outputs to fill missing streamflow data and estimate average annual basin runoff covering the appropriate period of record. RTI will fill streamflow values on a monthly basis using nearby and relevant gages with good observed records for a water balance analysis, described further under the Hydrologic Model Calibration task. Filled streamflow data will not be used to evaluate performance during calibration.
- ***MAP and MAPX time series.*** For the computed MAP and MAPX time series, RTI will perform a quality and consistency review of the datasets, including computing annual estimates by sub-basin, checking for outliers, and comparing with PRISM datasets. RTI will consult with the WGRFC and recommend solutions for time series with quality issues or for any sub-basins where there are large discrepancies with PRISM.
- **Potential evapotranspiration (PET) estimates.** RTI will use an existing internally developed spreadsheet to estimate an initial average monthly PET curve for each modeled basin. This spreadsheet uses the Penman-Montieth method described in the FAO Irrigation and Drainage Paper No. 56 to calculate reference PET rates based on historical average monthly temperatures in the basin, mean basin elevation, average wind speed, and physiographic setting. These initial PET estimates will be adjusted during the calibration process based on the observed monthly streamflow volumes over the calibration period. Based on these adjustments, RTI will derive adjustment factors by comparing the calibrated monthly average PET values to averages calculated from the MAPE time series that the WGRFC uses operationally. RTI will also use the derived PET estimates in the water balance analysis.

TASK 3. Hydrologic Model Calibration.

- ***Calibrating SAC-SMA and UNIT-HG model parameters.*** Using manual techniques, RTI will calibrate the SAC-SMA and UNIT-HG models for the sites listed in **Attachment 1** of the RFQ. RTI may also use automated parameter estimation tools, such as OPT3, to refine the parameter sets.
- ***CHPS integration.*** Calibrated model parameter sets will be stored in a local database, which will be accessed by existing Python scripts (developed in-house) that create CHPS-ready XML files. In consultation with the WGRFC, manual edits may also be made to the CHPS configuration files to account for updates to basin topology or overall system workflow, as well as incorporating any additional model operations such as CHANLOSS. RTI will perform quality control checks to ensure that the CHPS configuration files as well as the overall CHPS system are functioning correctly. More specifically, RTI will ensure that the standalone system can run warm-state simulations of the entire calibrated system from headwaters to the most downstream point, including routing sub-basins, adding simulated local contributions to overall flow, adjusting modeled flows to observed flows, and computing stages.
- ***Reducing bias with physically realistic and regionally consistent parameters.*** RTI will calibrate the models to achieve the multiple goals of low monthly and annual biases, physically sensible and regionally consistent parameter sets, and simulated hydrographs

that consistently match observed hydrographs in baseflows, hydrograph rise and recession, and peak flows.

- ***Peer and senior review process.*** Each model calibration will undergo peer and senior review processes prior to parameter finalization. In addition, RTI will use multiple webinars over the course of the model calibration process to present detailed reviews of calibration progress and results with the WGRFC. These webinars will ensure that the WGRFC staff are informed of any modeling issues or challenges and have opportunities to provide feedback.
- ***Water balance analysis.*** Prior to beginning parameter estimation, RTI will compute and review the water balance, checking consistency between sub-basins. We will compute runoff coefficients as the ratio of the depth of runoff to MAP, and RTI will compute actual evapotranspiration as the difference between precipitation and runoff, expressed as depths. If RTI observes major discrepancies, RTI will inspect the corresponding data and identify and/or resolve the source of the discrepancies. In addition to serving as another quality-control check on the input data, RTI uses the water balance analysis to provide insight into which sub-basins are thought to be hydrologically similar, how model parameters may vary among the sub-basins, and where there may be withdrawal/gains to the river that are not represented in the data.
- ***Sacramento soil moisture accounting model calibration.*** Prior to model calibration, RTI will meet with the TWDB and the WGRFC to discuss the typical ranges of model parameter values for the modeled region and the modeling objectives, and to review the modeling approach. As part of the model calibration process, RTI will perform a final review of all basin-model parameters within the same geographic region (including previously calibrated models) to check for consistency of model parameters. In addition, RTI will determine if any adjustments to the MAPX time series are needed and provide the WGRFC with recommended adjustment factors.
- ***Unit hydrograph verification.*** RTI will verify the initial UNIT-HG model parameters (provided by the WGRFC) prior to beginning model calibration. During the calibration process, RTI will adjust UNIT-HG ordinates to more accurately represent the observed shape of the basin response as exhibited in the instantaneous observed discharge data. To make these adjustments, RTI will consider the visual hydrograph match and statistical output from the STAT-QME operation and STAT-Q utility. For sub-basins without existing initial UNIT-HG models, RTI will derive 1-hour UNIT-HG models using manual historical event hydrograph analysis or GIS-based analysis.

TASK 4. Withdrawal/Gain Model Development and Calibration.

- ***Improving the total flow simulation at the downstream outlet of the sub-basin.*** For any sub-basin with withdrawals or gains, RTI will develop a modeling approach using techniques similar to those developed by RTI staff in previous model calibration tasks for the WGRFC for regulated basins in the Rio Grande River Basin and for areas in Central Texas where there are significant losses/gains due to flood control, agricultural diversions, or karst geology. The primary objective of this modeling will be to improve the simulation of total flows.
- ***Developing sufficiently complex, but operationally manageable models.*** RTI's goal is to develop models that improve hydrologic forecasts without unduly burdening the WGRFC

forecasters or computing resources. RTI will work to ensure that withdrawal/gain models are calibrated without adverse effects on the operations of the WGRFC, and that they fully meet the center's modeling needs.

- ***Coordinating with the WGRFC to determine appropriate modeling approach.*** RTI will evaluate the gains and losses in each basin and will ensure developed models are sufficiently complex to improve short-term deterministic forecast capabilities, but remain manageable for daily forecasting operations. RTI will work with the WGRFC to determine where regulation models are required and will investigate ways to take advantage of the time-series transformation modules within CHPS to streamline the modeling approach. In the simplest cases (e.g., reservoir seepage gains), RTI will model the loss/gain using a single CHANLOSS operation. RTI will model more complex situations with multiple CHANLOSS operations (e.g., one to account for flood diversions, one to account for irrigation impacts). For more complex scenarios, RTI may apply CONS_USE models of varying complexity, which account for irrigation demands and return flows.
- ***Evaluating existing withdrawal/gain models.*** RTI will review and test any withdrawal/gain models in the existing WGRFC forecast system. Based on the results of the existing model testing, RTI will recommend and implement improvements, if needed, in consultation with the WGRFC.
- ***Identifying additional diversions.*** RTI will perform a detailed investigation of potential withdrawals/gains based on results of the water balance analysis. RTI will work with the WGRFC to collect any additional required diversion data. RTI is also willing to communicate directly with the USACE, San Jacinto River Authority, and HCFCD when needed to ensure that our understanding of the local water control system is accurate.

TASK 5. Routing Model Calibration.

- ***Development of calibrated variable LAG/K and TATUM models.*** RTI will determine, in consultation with WGRFC, whether to use LAG/K or TATUM models. RTI has found that variable LAG/K and layered TATUM routing models generally perform better across a wide range of flows than the constant LAG/K or single coefficient layer TATUM models.
- ***Using existing WGRFC routing models for initial parameterization.*** The starting point for RTI's routing model calibration will be the current parameterization (if one exists) from the WGRFC segment definitions.
- ***Calibrating LAG/K and TATUM model parameters.*** RTI will calibrate model parameters by comparing simulated flow to the downstream observed instantaneous discharge. RTI will use both visual hydrograph analysis and statistical output during our manual calibration process. RTI also has an in-house routing model optimizer that will be used to refine the final parameter values.
- ***Using hydrograph analysis and statistical output for routing model calibration.*** RTI will use visual comparison of hydrograph plots to determine if the timing of the peak and attenuation of the hydrograph are adequately represented. Along with analysis of instantaneous discharge hydrographs, RTI will review statistical output from the STAT-QME module and the STAT-Q utility to evaluate the performance of derived routing model parameter sets.

- ***Using ADJUST-Q when instantaneous data are unavailable.*** If instantaneous data are unavailable, RTI will use mean daily flow data in the routing model evaluation, understanding the limitations of using daily data in identifying parameters for a 1-hour time-step model. RTI will use the ADJUST-Q operation in the upstream sub-basins to adjust the 1-hour simulated flows to the observed daily volumes and route the adjusted time series downstream.
- ***Evaluating parameters further during local area basin model calibration.*** As local area SAC-SMA and UNIT-HG models are being calibrated, RTI will further evaluate the routing model parameters by comparing observed and simulated total flow hydrographs at the basin outlet.
- ***Using constant LAG/K or single layer TATUM models.*** Although they are not the default model configuration, constant value LAG/K models or single layer TATUM models will be used as appropriate depending on data quality, flow conditions, and discussions with the WGRFC.

TASK 6. Task Management Requirements.

- ***Performing management, tracking, reporting functions.*** RTI understands that effective task management is vital to successfully achieving project objectives. Accordingly, RTI will perform management, tracking, and reporting functions in accordance with the guidelines defined in the RTI *WRMD Project Management Manual*. The task manager will develop a Project Management Plan, which will include a communication plan to ensure that TWDB and WGRFC remain well informed of project progress.
- ***Reporting project status.*** RTI will prepare and deliver formal monthly task-order status reports that summarize the activities accomplished in the previous month, problems encountered with impacts, anticipated outcomes from recommended solutions, deliverable status, and schedule tracking. RTI will also maintain regular contact with NWS personnel by telephone and email and will participate in teleconference status meetings as needed. RTI staff will schedule regular communication with TWDB staff throughout the task execution.
- ***Delivering a final task report.*** At the completion of the task, RTI will develop and deliver to the TWDB a final task report summarizing the work performed. RTI understands that it is important for WGRFC forecasters to have documentation of our methodology, final model parameters and calibration statistics, and important basin information. Accordingly, the final task report will include detailed descriptions of all data analysis and calibration work performed. Reported results will include statistical summaries and hydrograph displays of both local and total flow at each forecast point to demonstrate the performance of the final calibrated models. RTI will provide the final report in draft format, which RTI will finalize after evaluation by the TWDB and WGRFC.
- ***Delivering final model files.*** RTI will deliver all input files (time series and model parameters) and CHPS configurations for each calibrated sub-basin. RTI will collaborate with WGRFC to establish a base standalone FEWS system(s) to which data can be directly assimilated. As part of a final check on model bias, RTI will run a top-to-bottom simulation using historical input data and no adjustments to observed streamflow. Analysis of these results provides insight on how a forecast group of basins could perform in real time. This

analysis will be done only for calibrated basins connected along a river reach. RTI will provide the results to the TWDB and WGRFC in the final report.

EXHIBIT C

TASK AND EXPENSE BUDGETS

TASK BUDGET

TASK	DESCRIPTION	TWDB AMOUNT
TASK 1	Historical Precipitation Data Collection	$6,700.00
TASK 2	Data Preparation and Analysis	19,400.00
TASK 3	Hydrologic Model Calibration	130,700.00
TASK 4	Withdrawal/Gain Model Development and Calibration	9,800.00
TASK 5	Routing Model Calibration	12,400.00
TASK 6	Task Management Requirements	21,000.00
Total		**$200,000.00**

EXPENSE BUDGET

CATEGORY	TWDB AMOUNT
Salaries and Wages[1]	$71,601.02
Fringe[2]	27,924.40
Travel[3]	2,008.48
Other Expenses[4]	0.00
Subcontract Expenses	0.00
Overhead[5]	80,311.47
Profit	18,154.63
TOTAL	**$200,000.00**

[1] Salaries and Wages is defined as the cost of salaries of engineers, draftsmen, stenographers, surveymen, clerks, laborers, etc., for time directly chargeable to this CONTRACT.

[2] Fringe is defined as the cost of social security contributions, unemployment, excise, and payroll taxes, workers' compensation insurance, retirement benefits, medical and insurance benefits, sick leave, vacation, and holiday pay applicable thereto.

[3] Travel is limited to the maximum amounts authorized for state employees by the General Appropriations Act, Tex. Leg. Regular Session, 2017, Article IX, Part 5, as amended or superseded

[4] Other Expenses is defined to include expendable supplies, communications, reproduction, postage, and costs of public meetings directly chargeable to this CONTRACT.

[5] Overhead is defined as the costs incurred in maintaining a place of business and performing professional services similar to those specified in this CONTRACT.

EXHIBIT D

GUIDELINES FOR AUTHORS SUBMITTING CONTRACT REPORTS TO THE TEXAS WATER DEVELOPMENT BOARD

1.0 Introduction

The purpose of this document is to describe the required format of contract reports submitted to the Texas Water Development Board (TWDB). Our reason for standardizing the format of contract reports is to provide our customers a consistent, and therefore familiar, format for contract reports (which we post online for public access). Another reason for standardizing the format is so that we can more easily turn a contract report into a TWDB numbered report if we so choose. Remember that your report will not only be seen by TWDB staff, but also by any person interested in the results of your study. A professional and high quality report will reflect well on you, your employer, and the TWDB.

Available upon request, we will provide a Microsoft Word template (used to write these instructions) that gives the fonts, spacing, and other specifications for the headings and text of the report. Please follow this template as closely as possible.

2.0 Formatting your report

The TWDB format is designed for simplicity. For example, we use Times New Roman for all text. We use 12 point, single-spaced text, left justification for paragraph text, 18 point bold for first-level headings, and 14 point bold for second-level headings. Page numbers are centered at the bottom of the page. Other than page numbers, please refrain from adding content to the document header or footer. Page setup should use one-inch margins on all four sides.

2.1 Text

The best way to format your document is to use the styles described and embedded in the template document (Authors_Template.dot) that is available on request from the TWDB. To use the Authors_Template.dot file, open it in Word (make sure *.dot is listed under Files of type) and save it as a .doc file. Advanced users can add the .dot file to their computers as a template. Make sure the formatting bar is on the desktop (to open, go to View→Toolbars→Formatting) or, to view all of the formatting at once, go to Format→Styles and Formatting and select Available Styles from the dropdown box at the bottom of the window. The formatting in the template document provides styles (such as font type, spacing, and indents) for each piece of your report. Each style is named to describe what it should be used for (for example, style names include Chapter Title, Body Text, Heading 1, References, and Figure or Table Caption). As you add to your report, use the dropdown list on the Formatting Toolbar or the list in the Styles and Formatting window to adjust the text to the correct style. The Authors_Template.dot file shows and lists the specifications for each style.

2.1.1 Title

Give your report a title that gives the reader an idea of the topic of your report but is not terribly long. In addition to the general subject (for example, “Droughts”), you may include a few additional words to describe a place, methodology, or other detail focused on throughout the

paper (for example, "Droughts in the High Plains of Texas" or "Evaluating the effects of drought using groundwater flow modeling"). Please capitalize only the first letter of each word except 'minor' words such as 'and' and 'of'. Never use all caps.
Use headings to help the reader follow you through the main sections of your report and to make it easier for readers to skim through your report to find sections that might be the most interesting or useful to them. The text of the report should include an executive summary and sections outlined in 4.4 of Attachment 1. Headings for up to five levels of subdivision are provided in the template; however, we suggest not using more than three or four levels of subdivision except where absolutely necessary. Please avoid stacked headings (for example, a Heading 1 followed immediately by a Heading 2), and capitalize only the first letter of headings or words where appropriate—never use all caps.

2.2 Figures and photographs

To publish professional-looking graphics, **we need all originals to be saved at 300 dots-per-inch** (dpi) and in grayscale, if possible, or in the CMYK color format if color is necessary. Excessive use of color, especially color graphics that do not also work in grayscale, will prevent us from publishing your report as a TWDB numbered report (color reproduction costs can be prohibitive). Preferred file formats for your original graphics are Adobe Illustrator (.ai), Photoshop (.psd), EPS with .tiff preview, .jpg, .png, or .tiff files. Refrain from using low resolution .jpg or .gif files. Internet images at 72 dpi are unacceptable for use in reports.
All graphics shall be submitted in two forms:

1. Inserted into the Microsoft Word document before you submit your report. Ideally, inserted graphics should be centered on the page. Format the picture to downsize to 6 inches wide if necessary. Please do not upsize a graphic in Word.
2. Saved in one of the formats listed above.

2.2.1 Other graphics specifications

It is easiest to design your figures separately and add them in after the text of your report is more or less complete. Graphics should remain within the 1-inch page margins of the template (6.5 inches maximum graphic width). Be sure that the graphics (as well as tables) are numbered in the same order that they are mentioned in the text. Figures should appear embedded in the report after being called out in the text. Also, remember to include a caption for each graphic in Word, not as part of the graphic. We are not able to edit or format figure captions that are part of the figure. For figures and photographs, the caption should appear below the graphic. For tables, the caption should appear above.

2.2.2 Creating publication-quality graphics

When designing a graphic, make sure that the graphic (1) emphasizes the important information and does not show unnecessary data, lines, or labels; (2) includes the needed support material for the reader to understand what you are showing; and (3) is readable (see Figures 1 and 2 for examples). Edward R. Tufte's books on presenting information (Tufte, 1983; 1990; 1997) are great references on good graphic design. Figures 1 through 3 are examples of properly formatted, easy to understand graphics. Do not include fonts that are less than 6 points.

For good-looking graphics, the resolution needs to be high enough to provide a clear image at the size you make them within the report. In general, 300 dpi will make a clear image—200 dpi is a

minimum. Try to create your figures at the same size they will be in the report, as resizing them in Word greatly reduces image quality. Photographs taken with at least a two-megapixel camera (if using digital) and with good contrast will make the best images. Save the original, and then adjust color levels and size in a renamed image copy. Print a draft copy of your report to double-check that your figures and photographs have clear lines and show all the features that you want them to have.

Figures and photographs should be in grayscale. Color greatly adds to the cost of printing, so we are trying to keep it to a minimum. Also remember that your report may be photocopied, scanned, or downloaded and printed in black and white. For this reason, you should use symbols or patterns, or make sure that colors print as different shades in black and white. All interval or ratio data (data measuring continuous phenomena, with each color representing an equal interval) need to be displayed in a graded scale of a single color (Figure 3). This way your figures will be useful even as a photocopy.

If you need help with your graphics or have questions, please contact the TWDB graphics department at (512) 936-0129.

2.2.3 Using other people's graphics

Figures and photographs (and tables) need to be your own unless you have written permission from the publisher that allows us to reprint them (we will need a copy of this permission for our records). Avoid using any figures or photographs taken off the Internet or from newspapers or magazines—these sources are difficult to cite, and it is often time-consuming and expensive to gain permission to reproduce them.

2.3 Tables

Tables should be created in Microsoft Word (see Table 1). Tables should include a minimal amount of outlining or bold font to emphasize headings, totals, or other important points. Tables should be numbered separately from figures, and captions should appear above the text of the table.

Table 1: A sample table. Note caption above table.

Table text heading*

Table text	1940	1950	1960	1970	1980	1990	2000	%GW
Table text	15	441	340	926	196	522	83	97.4
Table text	64	944	626	173	356	171	516	99.9
Total	79	1385	966	1099	552	693	599	

* A footnote should look like this using 10 point Times New Roman.
%GW = percent groundwater
Be sure to describe any abbreviations or symbols, and, unlike in this table, be sure to note the units!

3.0 Units

Measurements should be in English units. Metric units may be included in parentheses after the English units.

All units of geologic time should conform to the most recent geologic timescale (Gradstein and others, 2004). A summary of this timescale is available from the International Commission on Stratigraphy's website at http://stratigraphy.org/chus.pdf.

4.0 Citations and references

It is important to give credit where credit is due. Therefore, be sure to use the appropriate citations and include references in your paper.

4.1 In-text citations

Each piece of information you use in your report that comes from an outside source must be cited within the text using the author's last name and the year of publication. If there are two authors, list the last name of each followed by the year, and if there are more than two authors, list the last name of the first author followed by "and others" and the year. For example: the end of the Jurassic Period occurred approximately 145.5 million years ago (Gradstein and others, 2004).

4.2 References

All sources that are cited within the report should be listed at the end of the paper under the heading References. The references should follow the guidelines in "Suggestions to Authors of the Reports of the United States Geological Survey" (Hansen, 1991). These are available online at http://www.nwrc.usgs.gov/lib/lib_sta.html (a link to the chapter "Preparing references for Survey reports," p. 234-241, is found here). Several examples of complete reference citations are listed at the end of these guidelines. Be sure that any citations that appear in tables or figures are included in the reference list. Also, before submitting the report, please check that all the citations in the report are included in the reference list and all references in the reference list are cited in the report. If at all possible, avoid web-based citations. These materials are often transient and therefore useless to future readers.

5.0 Submitting your report

Before you submit your report, proofread it. Look for spelling and grammatical errors. Also, check to see that you have structured the headings, paragraphs, and sentences in your paper so that it is easy to follow and understand (imagine you are a reader who does not already know the information you are presenting!).

6.0 Conclusions

Following the instructions above and providing accurate and readable text, tables, figures, and citations will help to make your report useful to readers. Scientists may read your report, as well as water planners, utility providers, and interested citizens. If your report successfully conveys accurate scientific information and explanations to these readers, we can help to create more informed decisions about the use, development, and management of water in the state.

7.0 Acknowledgments

Be sure to acknowledge the people and entities that assisted you in your study and report. For example:

We would like to thank the Keck Geology Consortium, the American Society of Civil Engineers, and the Texas Bar CLE for providing examples to use in developing these guidelines. In addition, we appreciate Mike Parcher for providing information on how to create publication-quality graphics,

Shirley Wade for creating the data used in sample Figure 1, and Ian Jones for providing sample Figure 3.

8.0 References

Gradstein, F.M., J.G. Ogg, and A.G. Smith, eds., 2005, A geologic time scale 2004: Cambridge, Cambridge University Press, 610 p.

Hansen, W.R., ed., 1991, Suggestions to authors of the reports of the United States Geological Survey (7th ed.): Washington, D.C., U.S. Government Printing Office, 289 p.

Tufte, E. R., 1983, The visual display of quantitative information: Cheshire, C.T., Graphics Press, 197 p.

Tufte, E. R., 1990, Envisioning information: Cheshire, C.T., Graphics Press, 126 p.

Tufte, E. R., 1997, Visual explanations: Cheshire, C.T., Graphics Press, 156 p.

9.0 Examples of references

Arroyo, J. A., and Mullican, III, W. F., 2004, Desalination: *in* Mace, R. E., Angle, E. S., and Mullican, W. F., III, editors, Aquifers of the Edwards Plateau: Texas Water Development Board Report 360, p. 293-302.

Bates, R. L., and Jackson, J. A., 1984, Dictionary of geological terms: Anchor Press/Doubleday, Garden City, New York, 571 p.

Blandford, T. N., Blazer, D. J., Calhoun, K. C., Dutton, A. R., Naing, T., Reedy, R. C., and Scanlon, B. R., 2003, Groundwater availability of the southern Ogallala aquifer in Texas and New Mexico–Numerical simulations through 2050: contract report by Daniel B. Stephens and Associates, Inc., and the Bureau of Economic Geology, The University of Texas at Austin to the Texas Water Development Board, variably paginated.

Fenneman, N. M., 1931, Physiography of Western United States (1st edition): New York, McGraw-Hill, 534 p.

Hubert, M., 1999, Senate Bill 1–The first big bold step toward meeting Texas's future water needs: Texas Tech Law Review, v. 30, no. 1, p. 53-70.

Kunianski, E. L., 1989, Precipitation, streamflow, and baseflow in West-Central Texas, December 1974 through March 1977: U. S. Geological Survey Water-Resources Investigations Report 89-4208, 2 sheets.

Mace, R. E., Chowdhury, A. H., Anaya, R., and Way, S.-C., 2000, A numerical groundwater flow model of the Upper and Middle Trinity aquifer, Hill Country area: Texas Water Development Board Open File Report 00-02, 62 p.

Maclay, R. W., and Land, L. F., 1988, Simulation of flow in the Edwards aquifer, San Antonio Region, Texas, and refinements of storage and flow concepts: U. S. Geological Survey Water-Supply Paper 2336, 48 p.

For more examples of references, see p. 239-241 of "Suggestions to Authors of the Reports of the United States Geological Survey" at http://www.nwrc.usgs.gov/lib/lib_sta.html.

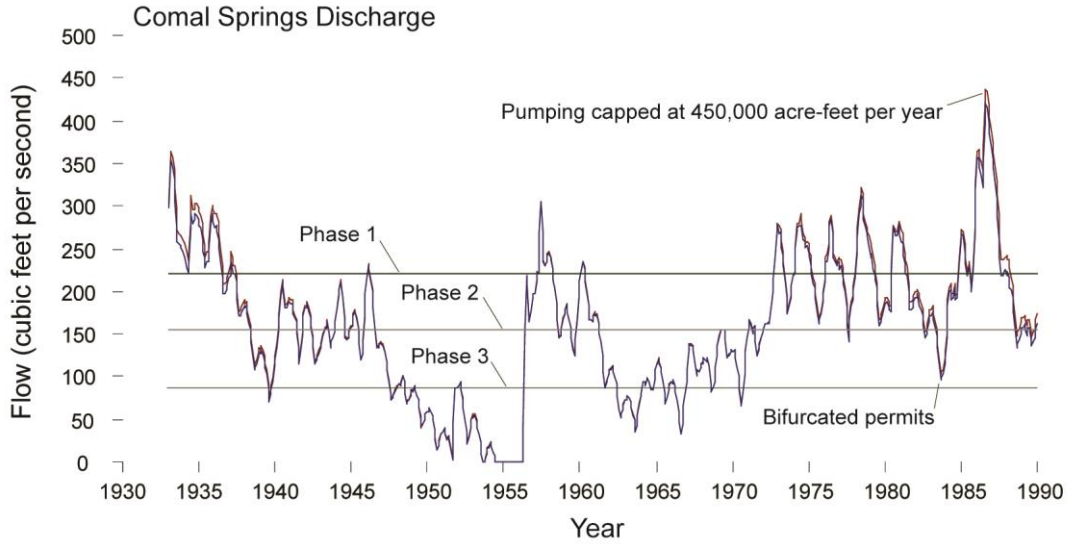

Figure 1. A sample figure showing only the information needed to help the reader understand the data. Font size for figure callouts or labels should never be less than 6 point.

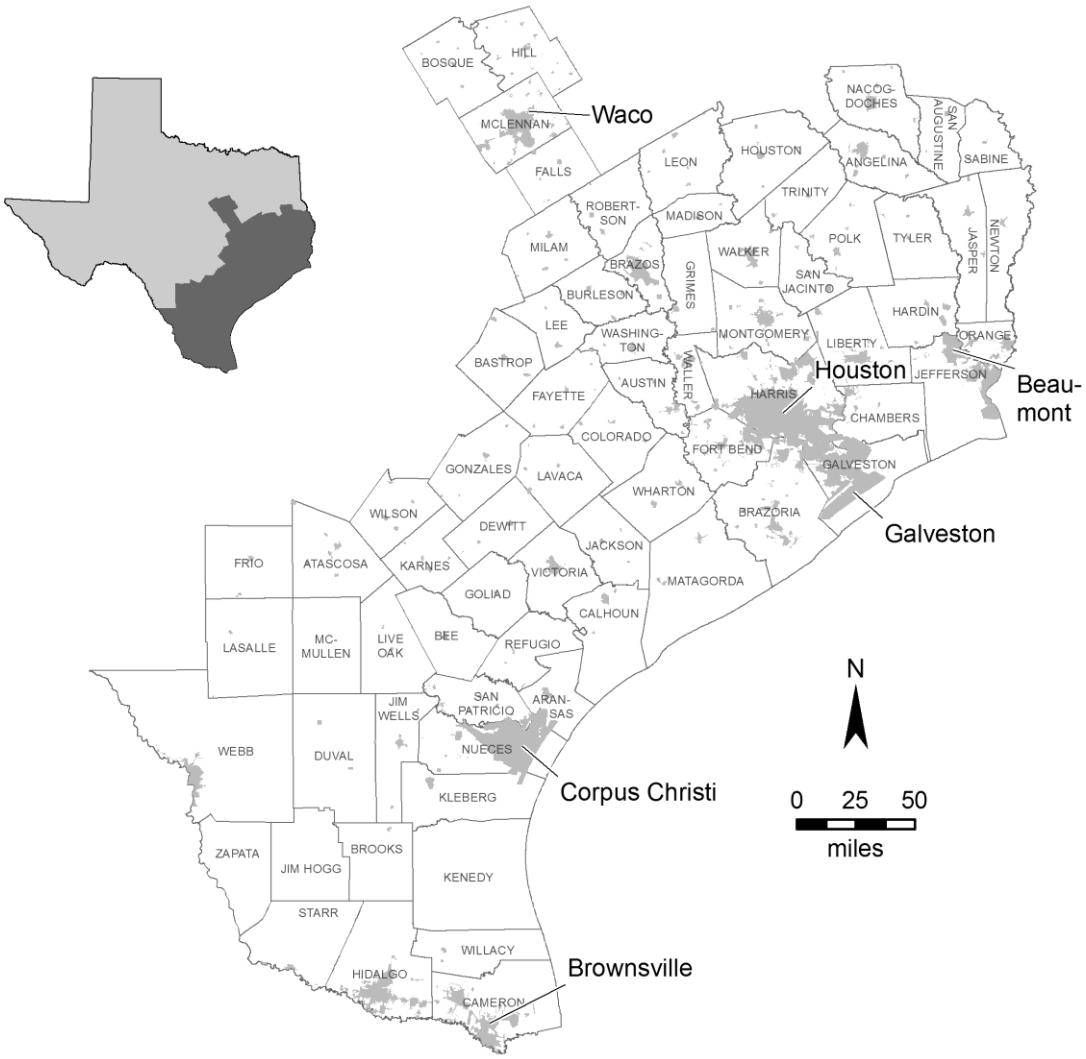

Figure 2. A sample subject area map, giving the reader enough information to understand the location being discussed in this conference. For map figures, be sure to include a north arrow to orient the reader, a scale, and, if needed, a submap that places the figure in greater geographic context. Be sure that text is readable and that any citations listed on the figure or in the figure captions are included in the reference list. Font size should never be less than 6 pt.

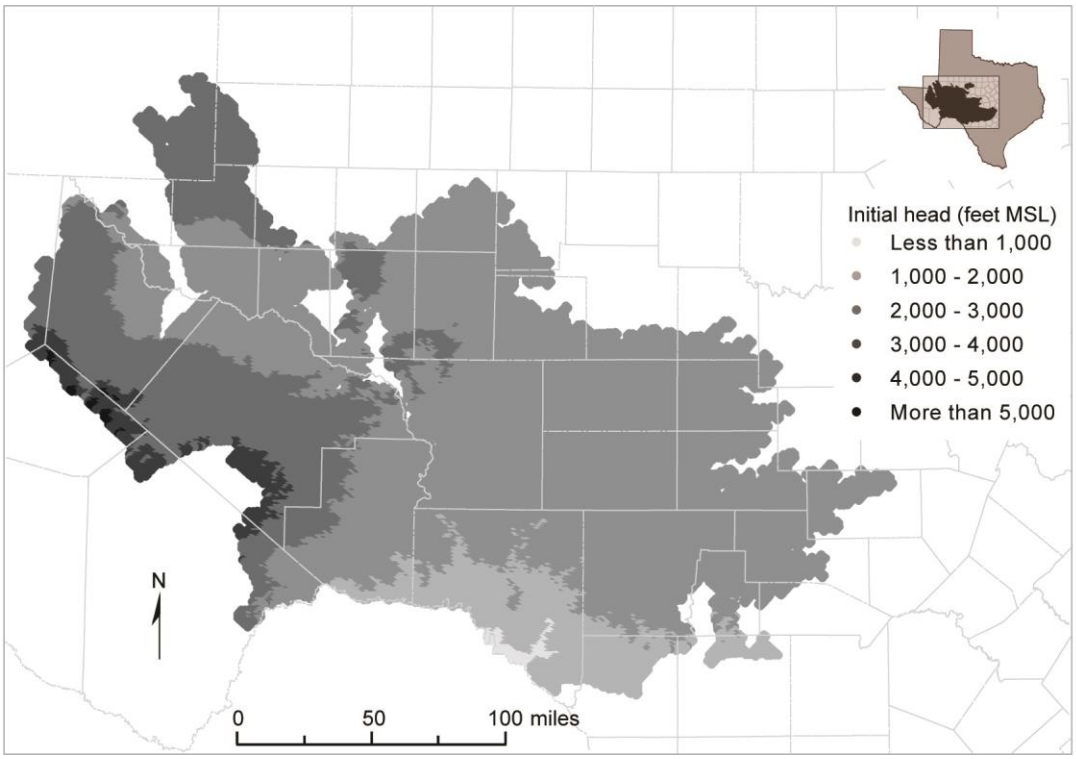

Figure 3. Initial hydraulic heads used in model simulations for layer 1. Note the use of grayscale shading to show differences.

EXHIBIT E
TWDB Guidelines for a Progress Report

Texas Water Development Board Contractors are required by their contracts to provide Progress Reports usually with the submission of an invoice/payment request.

The progress report should contain the following standard elements:

- Date: Date the memo is sent
- To: Name and position of the reader
- From: Name and position of the writer

Subject:TWDB Contract Number and a clear phrase that focuses the reader's attention on the subject of the memo

Work Completed: *(The next section of a progress report explains what work has been done during the reporting period. Specify the dates of the reporting period and use active voice verbs to give the impression that you or you and your team have been busy) For Example:*

Task 1: Completed 3 draft chapters and all appendices. Met with sub consultants on their chapters.
Task 2: Completed sample collection throughout river reach.
Task 3: No work completed in reporting period.

Problems:
If the reader is likely to be interested in the glitches you have encountered along the way, mention the problems you have encountered and explain how you have solved them. If there are problems you have not yet been able to solve, explain your strategy for solving them and give tell the reader when you think you will have them solved.

EXHIBIT F

HUB SUBCONRACTING PLAN PROGRESS ASSESSMENT REPORT

Use current form located at:
http://www.window.state.tx.us/procurement/prog/hub/hub-forms/