QUALITY CONTROL PLAN

UPPER RIO GRANDE WATER OPERATIONS MODEL

1. Introduction.

Name of Project: Upper Rio Grande Water Operations Model (URGWOM)

Location: Upper Rio Grande basin, from the headwaters of the Rio Grande downstream to Fort Quitman, TX.

Cooperators:
Bureau of Reclamation, Albuquerque Area Office;
U.S. Fish and Wildlife Service, New Mexico Ecological Field Office, Albuquerque;
U.S. Geological Survey, New Mexico District Office, Albuquerque;
Bureau of Indian Affairs, Albuquerque Area Office;
International Boundary and Water Commission (U.S. Section) El Paso, TX;
U.S. Army Corps of Engineers, Albuquerque District Office;
City of Albuquerque, New Mexico;
City of Santa Fe, New Mexico;
Rio Grande Restoration, Taos, New Mexico;
Sandia National Laboratory, Albuquerque, New Mexico;
Los Alamos National Laboratories, Los Alamos, New Mexico;
Paso del Norte Watershed Council, El Paso, TX;
Desert Research Institute, Las Vegas, NV;
El Paso Water Utilities – Public Service Board, El Paso, TX;
SAHRA – Integrated Modeling Team, Tucson, AZ;
NM Interstate Stream Commission, Santa Fe, NM.

Project Description: URGWOM is a daily time-step water operations model for the Upper Rio Grande basin utilizing a numerical computer modeling software (RiverWare) capable of simulating the hydrology, water storage and delivery operations in the Rio Grande from its headwaters in Colorado to Elephant Butte Reservoir in New Mexico and for flood control modeling and planning from Elephant Butte Dam to Fort Quitman, TX. The model is used for water operations, water accounting and in Endangered Species Act Biological Opinion compliance monitoring by state and federal agencies in the basin above Elephant Butte Reservoir. The model is also used in the evaluation of water operation alternatives, such as in the Upper Rio Grande Basin Water Operations Review draft Environmental Impact Statement. An URGWOM database has also been developed to store the vast amount of data necessary to develop and maintain the model.

Project Authorization: The plan to develop a unified water operations model for the Upper Rio Grande basin originated in the fall of 1995 when the Federal agencies initiated discussions regarding the need for a water operations model. In late 1995 and early 1996, the federal agencies met with stakeholders in the basin to discuss the program. As a result

of these discussions, the six federal agencies signed the *Memorandum of Understanding for the Development of an Upper Rio Grande Water Operations Model for Enhanced System Management* (MOU). Five of the federal agencies signed the MOU in January 1996; the International Boundary and Water Commission signed an amendment to the MOU in May 1996. Additional cooperators sign the MOU through a second amendment.

2. Quality Control Plan Objective

   The objective of this Plan is to ensure that URGWOM is capable of reliably simulating the hydrology of the Rio Grande stream system, the operation of reservoirs and the accounting of water using existing data. The development and implementation of a reliable computer model will provide for more efficient and effective management of water in the Upper Rio Grande basin.

3. Roster of URGWOM Steering Committee Members

   The Steering Committee is responsible for overall project management and is composed of one official representative from each of the six federal agencies.
   Steering Committee responsibilities include attending regular meetings of the Committee, approving plans of study, supporting funding and allocating resources to assure completion of component tasks, tracking task accomplishment and expenditure of funds, preparing progress reports, interagency coordination, and public information.

   The current members of the Steering Committee and the agencies they represent are:

   Steven Bowser, Bureau of Reclamation,
   D. Michael Roark, U. S. Geological Survey (also member of Technical Team),
   Cynthia Abeyta, U. S. Fish and Wildlife Service,
   John Cawley or Charles Braden, Bureau of Indian Affairs,
   April Sanders, U. S. Army Corps of Engineers,
   Rong Kuo, International Boundary and Water Commission, (U. S. Section).

4. Roster of URGWOM Technical Team Members and their Relevant Experience

   The Steering Committee supports a core modeling team to develop the model. Members of this team have expertise in computer hardware and software, knowledge of water operations and accounting within the upper Rio Grande basin, knowledge of the data collected on the river, or proficiency in surface water and surface water/ groundwater interaction analysis.

   The past and present members of the Technical Team, and their relevant experience, are as follows:

   Michael Gabora, New Mexico Interstate Stream Commission; B.S. in Earth Science and Masters in Water Resources. Registered Professional Geologist and Professional

Hydrologist with eight years experience in areas of groundwater hydrology, groundwater-surface water interactions, water resources planning and numerical modeling.

Ed Kandl, Bureau of Reclamation; B. S. and M. S. in Geology, with eighteen years of experience in hydrology.

Mike Roark, U. S. Geological Survey; B. S. in Geology and graduate studies in geology and hydrology. Twenty years of experience in the areas of surface and groundwater modeling and groundwater-surface water interaction. Technical Team leader and Steering Committee member.

Garret Ross, Bureau of Reclamation; B.S. in Geological Engineering, M.S. in Mineral Engineering, Registered Professional Engineer with seven years of experience in water distribution, river and reservoir operations, and water accounting, and seven years of experience in the energy and minerals industry.

April Sanders, U. S. Army Corps of Engineers; B. S. in Agricultural Engineering and M. S. in Water Resources with sixteen years of experience in surface water hydrology, hydraulics and reservoir operations. Steering Committee member and former Technical Team leader.

Nabil Shafike; NM Interstate Stream Commission. B.S. and M.S. in Civil Engineering, PhD. in Hydrology and Water Resources. Twenty-Two years experience in water resources planning, numerical modeling and groundwater and surface water hydrology.

Zhuping Sheng, Texas A&M University; Ph.D. in Hydrogeology, Registered Professional Engineer and Professional Hydrogeologist with sixteen years experience in the areas of groundwater and surface water modeling, regional water resources planning and management, well design, well field operations, and aquifer storage and recovery.

Marc Sidlow, U. S. Army Corps of Engineers; B. S. in Civil Engineering. Registered Professional Engineer with twenty-three years of experience in the areas of surface water hydrology, hydraulics and modeling and river and reservoir operations and accounting.

Carole Thomas, U. S. Geological Survey (retired); B. A. in Mathematics and M. A. in Marine Science. Registered Professional Engineer and Registered Professional Hydrologist with thirty-one years of experience in the areas of surface and groundwater modeling, water use investigations and applied hydrology.

Dave Wilkins, consultant; B. S. in Agricultural Economics and M. S. in Civil Engineering, with thirty years of experience with the U. S. Geological Survey in the areas of applied surface water and groundwater hydrology.

Mark Yuska, U.S. Army Corps of Engineers; B. S. in Mechanical Engineering. Registered Professional Engineer with twenty years of experience in the areas of design

and construction of water resource facilities and river and reservoir accounting and operations. Former Technical Team leader.

In addition to the core Technical Team members, other individuals provide specialized support to the Technical Team and their efforts. These individuals and their relevant experience are as follows:

Roberta Ball, U. S. Army Corps of Engineers; B. S. in Civil Engineering and M. S. in Computer Information Systems, with twenty-one years of experience in river and reservoir operations and accounting, construction and computer modeling.

Brad Vickers, Wave Engineering, Inc. B.S. in Agricultural and Irrigation Engineering registered Professional Engineer. Twenty-six years experience in river and reservoir operations, accounting and computer modeling.

5. Roster of URGWOM Technical Review Committee and Their Relevant Experience

The Steering Committee has established an independent Technical Review Committee. This group is composed of representatives of about 15 governmental entities and other basin interests and groups that have pertinent interest in the development of the model, associated activities (such as data collection, companion model development, etc.), or model applications. The Technical Review Committee conducts periodic independent technical reviews of the modeling program to provide objective feedback during the process to assure that program objectives are being met.

The Technical Review Committee also serves to review the development and management of an URGWOM database and model testing program. A Database and Model Testing Quality Assurance/Quality Control Plan was adopted by the Steering Committee in August 2005. That Plan describes a two-stage model testing program that was completed in March, 2006.

Current and former participants in the Technical Review Committee and their relevant experience are as follows:

Brian Ahrens, Colorado Division of Water Resources; B. S. in Civil Engineering. Registered Professional Engineer with twenty-four years of experience in water resource engineering and groundwater modeling.

Charles Braden, Bureau of Indian Affairs; B. S. in Civil Engineering and M. S. in Environmental Engineering. Registered Professional Engineer with twenty-one years of experience in the areas of water rights administration, water quality investigations and surface water and groundwater modeling.

Bobby J. Creel, New Mexico Water Resources Research Institute; Ph.D. in Resource Economics with thirty-six years of experience in the areas of water resources planning and development.

John D'Antonio, State Engineer, New Mexico Office of the State Engineer; B. S. in Civil Engineering. Registered Professional Engineer with twenty-three years of experience in the areas of water resource engineering design, planning and administration.

Rhea Graham, Pueblo of Sandia; A. B. in Geology and M. A. and M. S. in Oceanography. Registered Geologist and Engineering Geologist with twenty-nine years of experience in various aspects of water and natural resource investigations.

Brian Hanson, U. S. Fish and Wildlife Service; B. S. in Wildlife Biology with thirty-one years of experience in the areas of monitoring and evaluating federal water resources development projects.

Steve Harris, Rio Grande Restoration; private guide and outfitter with thirty-one years of experience in river conservation and protection activities.

Walter Hines, CH2M Hill (consultant to the City of Albuquerque); B. S. and M. S. in Civil Engineering. Registered Professional Engineer with thirty-six years of experience in water resource and environmental engineering, hydrology and surface water investigations.

Amy Lewis, Consultant; B. S. in Geology, M. S. in Hydrology, with twenty-three years of experience in the areas of groundwater hydrology and hydrologic modeling.

Dan Murray, USDA Natural Resources Conservation Service; B. S. in Agricultural Engineering. Registered Professional Engineer with eighteen years of experience in hydrology, hydraulics and snowmelt runoff forecasting.

Ed Polasko, National Weather Service; B. S. in Meteorology, with thirty-three years of experience in the areas of hydrology and meteorology.

Herman Settemeyer, Consultant to the Texas Natural Resource Conservation Commission; B. S. and M. S. in Agricultural Engineering. Registered Professional Engineer with thirty-one years experience in water resource engineering.

Paul Tashjian, U. S. Fish and Wildlife Service; M. S. in Geology and two years of post-graduate studies in geology with fourteen years of experience in the areas of climatology and surface water investigations.

John Whipple, New Mexico Interstate Stream Commission; B. S. in Civil Engineering and M. S. in Water Resource Engineering with twenty-one years of experience in water resource investigations, surface water and groundwater modeling.

Steve Vandiver, Rio Grande Water Conservation District (Colorado); B. S. in Civil Engineering. Registered Professional Engineer with thirty-three years of experience in the areas of water resources planning, development and administration.
Jack Veenhuis, U. S. Geological Survey; B. S. in Hydrology and M. S. in Water Resources, with thirty years experience in the areas of surface and groundwater hydrology and hydrologic modeling.

Edie Zagona, Director, University of Colorado Center for Advanced Decision Support for Water and Environmental Systems and Principal Investigator of RiverWare R&D. BS, MS and Ph.D. in Civil Engineering, Registered Professional Engineer with 25 years experience in water resources engineering, with an emphasis on modeling.

Timothy James Ward, University of New Mexico; B. S. and M. S. in Geological Engineering, Ph.D. in Civil Engineering. Registered Professional Engineer with thirty-one years of experience in the areas of hydrology, hydraulics, water resources engineering and education.

In addition to the individuals and the entities they represent listed above, representatives of the Rio Grande basin Pueblos have been regular observers in attendance at meetings of the Technical Review Committee.

6. Quality Control Procedures

Hydrologic Modeling Quality Assurance. Eleven reservoir and river simulation models were evaluated based on general criteria for their use as the URGWOM simulation model. Based on the results of the technical evaluation and the goals and needs defined in the MOU, the Steering Committee unanimously agreed that RiverWare (then known as PRYSM, Power and Reservoir System Model) had the greatest likelihood of successfully being developed for the Upper Rio Grande Water Operation Model.

The physical features of the river and reservoirs in the Rio Chama basin, including operation and accounting, were the subject of a test case to determine if RiverWare was capable of adequately representing the physical, accounting and operational complexities that exist on the Rio Chama, which served as a prototype for the Rio Grande basin. Testing was completed in April 1998, and based on the recommendation of the Technical Team that RiverWare was capable and suitable for modeling the Rio Grande basin, the Steering Committee acted to adopt the recommendation of the Technical Team to apply RiverWare for modeling the remainder of the Rio Grande basin.

RiverWare is supported, maintained and continually enhanced by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado at Boulder. CADSWES ensures that professional software standards are applied to maintain a reliable, robust, version-controlled software product. CADSWES also

provides technical support, training and documentation to members of the Technical Team and the Technical Review Committee. The CADSWES effort is funded in part by the Bureau of Reclamation and URGWOM provides some direct funding for specific development and support needs.

Technical Review Procedures

Technical Team products. Individual Technical Team products will be developed using consistent methods and documented in standardized formats and will be the subject of Peer Review before the product is released for review by the Technical Review Committee.

Peer Review. Each Technical Team work product, including a check on the data as well as the method and procedures, will be accomplished by competent engineers under contract with one of the federal agencies prior to documentation and submittal for review by the Technical Review Committee. Peer review is provided by Conrad G. Keyes Jr. and William J. Miller.

Conrad G. Keyes Jr., consulting engineer and Past President of ASCE Environmental and Water Resources Institute and Past Chair of the Paso del Norte Watershed Council; B. S., M. S. and Sc. D in Civil Engineering. Registered Professional Engineer with forty-seven years of experience in the areas of water resource planning, design, administration and education.

William J. Miller, consulting engineer; Bachelor of Civil Engineering and M. S. in Civil Engineering. Registered Professional Engineer with thirty years experience in the areas of water resource engineering, planning, development and administration.

Technical Review Committee. Documentation of model data, methods and results is prepared and made available to members of the Technical Review Team at least one month prior to a meeting of the Committee. Committee meetings are scheduled on an as-needed basis. At meetings of the Technical Review Committee, the results of the URGWOM efforts to date described in the documentation are presented and discussed; questions are addressed to the extent that time allows.

Written comments from Technical Review Committee members on the URGWOM modeling efforts to date are submitted within one-month after the Technical Review Committee meeting. Memoranda summarizing the comments and the responses to the comments are prepared to ensure that the document and/or model are properly modified or clarified to address the comments.

Model and Data Management

a. Model and Ruleset Versioning

The water operations model and ruleset released to the public at the Phase II Testing Training in August 2005 will be assigned as Version 3.0, along with all the other models

and rulesets (i.e., Account, Forecast and Planning) that were in use at that time. The rulesets that work with the given models will be assigned the same version number with a further extension, in case rules are modified more frequently than models.

The models and rulesets will both be placed in a directory that has the version number. Underscores will be used as separators of model type, version number, descriptors, etc. The first part of the model filename will contain which type of model it is, e.g., WaterOps for a water operations type model. The second part will be the version number of the model, e.g., 3.1. The third through *x* parts will be further descriptors of the model that may contain run periods, alternatives, Annual Operating Plan (AOP) or real-time, etc. The rulesets will follow the same protocol with an extended version number, and with limited descriptors. Extensions .mdl for model and .rls for ruleset will be used.

Example directory, model, and ruleset filenames are listed below:

Account:
- Directory: ../Account/Development/3.1
- Model: ../Account_ 3.1_2006.mdl
- Ruleset: N/A

Forecast:
- Directory: ../Forecast/Development/3.1
- Model: ../Forecast_3.1_2005Apr_50%.mdl
- Ruleset: ../Forecast_3.1.0_2005.rls

Water Operations:
- Directory: ../WaterOps/Development/3.1
- Model: ../WaterOps_3.1_Feb2006_AOP.mdl
- Ruleset: ../WaterOps_3.1.0.rls

Planning:
- Directory: ../Planning/Development/3.1
- Model: ../Planning_3.1_2005-2014_Alt1.mdl
- Ruleset: ../Planning_3.1.0.rls

When a new model and/or ruleset are deemed as a new version, a new directory (or folder) will be created with the new version number, and new model and ruleset filenames will be created in said directories. There will always be a ruleset associated with a model. The same protocol will apply to production and/or public models. Computer date stamps will track the creation and modification dates of directories and filenames.

Readme.txt files will be placed in the directory to describe what modifications have been made to the model or ruleset since the last version.

b. Data and Database Management

Model Input Data files consisting of data collected from appropriate government agencies and metadata files maintained by the URGWOM Technical Team are maintained in database storage system (DSS) files at the Corps of Engineers Albuquerque District Office. These data are for use in model development (including calibration and verification), and public model execution. Data needed for input to publicly released models (and metadata) are available on the URGWOM website.

Provisional data are often required for use in daily water operations model runs, including development of AOPs. The process of appraisal and correction of provisional data used in these models are performed by and based on the judgment of the expert using the data. As such, use of these data is solely the user's responsibility, and explicitly is not the responsibility of the URGWOM agencies. After these data are used in models to make strategic operating decisions, these data may not be vetted until finalized by the collecting agency.

c. Model Accuracy

Model accuracy is subject to river flow and reservoir content data accuracy, input hydrology chosen (modeler judgment), correct policy implementation and physical system representation. The URGWOM users have control only of the input hydrology, policy implementation and physical system representation.

Each model (forecast, planning, daily water operations and accounting) has been constructed to accurately reflect the physical conditions of the natural system and the legal constraints within which the river system is operated. Constraints and discretion (where available) are explicitly implemented as either policy (rules) or accounts, or both, within each model, as appropriate to the particular model.

Model accuracy is defined [for the four models] as: model output conditions (final reservoir and individual account content) equivalent to the actual system state at end of equivalent model run time (date) for historic data-based model runs [accounting model]; model output (reservoir and individual account content) reliably predicting the future condition of reservoir and accounts content (within 10% of the true values), given the input hydrology supplied and any modifications made to the physical system or policy [forecast and planning models]; or successfully guiding delivery of contracted supplies and meeting middle Rio Grande Biological Opinion flow targets with available supply within 10% of the stream gage measurement accuracy on a daily basis [daily water operations].

Model verification (the process of accuracy determination) and validation (the process of physical representation and policy implementation checking) will be based on data such as historic streamflow, with published accuracy limitations. Details of methods and assumptions used in the verification and validation process will be documented and maintained in the URGWOM Repository.

The URGWOM model testing program is designed to identify any mistakes or errors in the model configuration. Model development also provides the opportunity to identify and correct model errors.

d. Models, Ruleset, Data and Document Repository

Public release models and rulesets are maintained at the Corps of Engineers Albuquerque District Office (forecast, planning and daily water operations models). The U.S. Bureau of Reclamation Albuquerque Area Office maintains the accounting model at its offices for internal use. Model data and documents are maintained at the Corps' District Office and are available to the Public on the District's web page. The facilities at the Albuquerque District Office will serve as the URGWOM Repository.

7. Review Documents and Schedule

The following URGWOM Documents prepared by the Technical Team were or will be the subject of peer review and Technical Review Committee review.

Document	Date of Technical Review Committee Review
Conceptualization of the Test Case Reach of the Upper Rio Grande Water Operations Model, Part I – Physical Model	December 11, 1997
Conceptualization of the Test Case Reach of the Upper Rio Grande Water Operations Model, Part I I–Water Accounting and Ownership	January 22, 1998
Technical Review – Physical Calibration	April 29, 1999
Physical Model Documentation – First Technical Review Committee Draft	February 22, 2000
Physical Model Documentation – Second Technical Review Committee Draft	April 26, 2001
Water Accounting Documentation – Technical Review Committee 1st Draft	April 26, 2001
Technical Review Meeting 3rd Draft – Physical Model Documentation	August 22, 2002
Technical Review - Development of Planning Model	November 13, 2003
Technical review of San Acacia to San Marcial groundwater/surface water interaction simulation.	October 14, 2004
Technical review of surface water/groundwater interaction enhancements in Middle Valley and of conceptual model of surface water/groundwater interaction for Mesilla and Rincon Valleys.	September, 2007 *(proposed)*

8. Discussion of Proposed Deviation from Approved Quality Control Plan.

   Any deviation from this approved quality control plan would be subject to the review and approval of the Steering Committee, and in the case of significant deviations, subject to approval of some or all of the agencies represented on the Steering Committee. Deviations from this approved quality management plan must be consistent with the purpose of the MOU for the Development of an Upper Rio Grande Water Operations Model for Enhanced System Management.

Submitted by: _____ Date: _____
William J. Miller

Reviewed by: _____ Date: _____
April Sanders
U. S. Army Corps of Engineers

_____ Date: _____
Steven Bowser
Bureau of Reclamation

_____ Date: _____
Cynthia Abeyta
U. S. Fish and Wildlife Service

_____ Date: _____
D. Michael Roark
U. S. Geological Survey

_____ Date: _____
John Cawley/ Charles Braden
Bureau of Indian Affairs

_____ Date: _____
Rong Kuo
International Boundary and Water
Commission (U. S. Section)