California State Water Resources Control Board (SWRCB)

Expert Report

Public Hearing: Water Right Applications 31487 and 31488 filed by the United States Bureau of Reclamation and Petitions to Change License 3723 (Application 5169) of Washoe County Water Conservation District, License 4196 (Application 9247) of Truckee Meadows Water Authority, and Permit 11605 (Application 15673) and License 10180 (Application 18006) of the United States Bureau of Reclamation Truckee River Watershed

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Corrected July 9, 2010

Expert Report of
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Introduction

This expert report describes the review and evaluation of the Truckee River Operating Agreement (TROA) model used in preparing the TROA Draft & Final Environmental Impact Statement/Environmental Impact Reports(EIS/EIR). On behalf of the Truckee-Carson Irrigation District, Churchill County and the City of Fallon, Principia hereby submits its expert report regarding the TROA model upon which the EIS/EIR rests.

TROA Model Overview

A review of the mathematical model upon which the TROA Draft & Final EIS/EIR centrally rests was conducted by Principia. This review was originally conducted in 2004 based upon the draft TROA EIS/EIR (1998), with comments submitted in December 2004. Responses by the U.S. Bureau of Reclamation (BOR) to address these comments in the Final TROA EIS/EIR (2008; SWRCB-7) failed to adequately address the original concerns raised in 2004. Thus, comments and concerns originally stated in December of 2004 remain valid. The review revealed three major facts that call into serious question the fundamental underpinning of the EIS/EIR. These three facts are presented as follows.

(1) The model upon which the EIS/EIR rests so heavily is unreliable in critical respects. In any unbiased scientific review by qualified peers, this model would be rejected for the very uses that are reported in the Draft & Final EIS/EIR.

(2) The model's unreliability is caused by significant, serious and, in some instances, fatal flaws. Such flaws prevent the model from being applied properly to evaluate "what-if" scenarios intended to establish suitable alternatives to or adjustments of planned water allocations.

(3) Employing a fatally flawed model to plan water allocations and to make decisions that would continue well into the future, when other well-tested and reliable stream flow models are readily available for use, introduces scientific unreliability into the TROA process. It leads inevitably to unsupportable management decisions that may be adopted as a regulation and thereby create unintended and seriously flawed consequences.

These facts lead Principia to urge that the model, in its present form, be rejected for use as the foundation for the EIS/EIR. The flaws identified by Principia are summarized below. This summary and associated opinions provide some indication that such assumptions and rules as embedded in the TROA are seriously flawed.

Crippling Flaws in the Model

The specific flaws in the model revealed by Principia's review are identified below. This identification should be viewed as illustrative examples of numerous such flaws that exist and not a comprehensive list of such flaws.

Opinion 1: It is virtually impossible for any independent and unbiased reviewer to follow the steps the model program does take, evaluate values embedded as facts into it, and test the logic to evaluate whether the program computations are indeed being performed as intended, and as reported.

The computer program embodying the TROA model consists of more than 72,000 lines of convoluted FORTRAN language contained in 173 subroutines. The sparse comments contained among these lines do not illuminate, amongst other facts, the innumerable quantities that are assigned unexplained values. Such values furthermore are inexplicably altered as the program instruction courses through the many subroutines of the program. This is very poor and antiquated programming practice that could not be further away from current accepted scientific methodology. What makes this practice untenable in this instance is that not even a rudimentary documentation seems available for the program. Similar efforts by Robertson Software, Inc. and Bill Sikonia of the U.S. Geological Survey (USGS) to document and rationalize the model arrived at these very same conclusions. In a letter dated November 12, 1996, from David Robertson to Mr. Bill Bettenberg (TCID-159), Robertson states the following: "The model is hopelessly complex for anyone to understand. This stems from multiple causes: It is accretionary in that code has been added and added with no attempt to root out obsolete portions or consolidate similar functions. This, coupled with the lack of a crisp overall strategy, antique coding practices, and dubious shortcuts, makes it impossible to defend...." In a similar fashion, Bill Sikonia makes the following statement in a memorandum dated July 26, 1996 ~~(TCID 152)~~ (TCID 151): "For a model of this size, one would have to exert considerable control over coding modifications so that the code remained manageable and understandable. However, the model development did not adhere to good coding practices that would ensure this outcome. (MODFLOW, under the influence of Arlan Harbaugh, is a good example of how to do this right)." Kenn Cartier, who worked with David Robertson came to a similar conclusion in his November 12, 1996 memorandum to Mr. William Bettenberg (TCID-159): "Based on my experience, the TROA model is such a patchwork of assumptions, physical and political simplifications, and convoluted code that it is difficult to say what the output results might represent or whether they approach a realistic representation of the water system."

Opinion 2: The computer program embodying the TROA model has not been provided with adequate output generating features to fully understand its calculations.

The flaw discussed in Opinion 1 is compounded further by the fact that the computer program embodying the TROA model has not been provided with adequate output generating features. Such features would at least allow an independent reviewer to evaluate details of water volumes and flow quantities that the program purports to allocate. For instance, the program claims to track water flow quantities throughout the TROA system, but can produce computed output only for a few selected flows at selected locations. These selections of course were made by the program author and do not reflect the quantities and locations that remain of deep interest to the affected public. In order to evaluate just what the program computes in these matters of interest, an independent reviewer is forced to modify the program code in order to obtain output that is clearly contained in the program but is otherwise unattainable. This tedious and cumbersome task is made unnecessarily difficult by the absence of program documentation.

Opinion 3: The accounting of relevant flow quantities is seriously inadequate in the program.

In this program, flow quantities associated with different sources are lumped together, but thereafter the program is not equipped to track each flow quantity according to its source. It is not possible to evaluate whether, or not, this poor programming practice was intentionally adopted. However, it denies any independent reviewer the basic tools needed to understand just why certain results are predicted by this program. This is a serious programming deficiency which makes it impossible to establish just which specific planned action leads to what computed outcome; just the types of basic information essential to manage the TROA system. It is for this very reason that other well-tested and reliable programs such as **Riverware**® are intentionally equipped to keep rigorous track of flow quantities by their "accounts". The 1990 USGS review reached a similar conclusion when they stated, "They do not account for travel time through the system or account for evapotranspiration and ground-water/surface-water interactions in other than a gross statistical manner." (TCID-137)

Opinion 4: The computer program embodying the TROA model employs antiquated FORTRAN-programming practices and modeling techniques.

The ready availability of modern computer models for river systems makes the continued use of the TROA model suspect. The serious consequences stemming from using an outdated model can neither be easily detected nor readily rectified. Consider an example specific to TROA: each planned action taken on the water system is coded within a program subroutine that is found to have complex, undocumented, and sometimes unexpected interactions with different parts of the program that represent other segments of the flow system. It is thus made impossible for any independent reviewer to evaluate whether, or not these interactions were intentional, and if so why, or merely accidental stemming from the manner in which the program has evolved during the past two decades. In direct contrast, modern modeling programs such as **Riverware**® are designed to isolate actions specific to certain "objects," enabling a user to keep track of intended actions. Further, such programs employ component flow models with relevant physical realism and accounting procedures that keep rigorous track of flow quantities propagating through the system. In reliable programs, complex management decisions may indeed be specified by prescribing "rules"; however, the programming of these rules leaves no room for unintended and thus hidden side effects. Furthermore, the use of generic "objects" in reliable programs simplifies the tasks of program validation and documentation, and makes them transparent. In an August 5, 1996 memorandum from Bill Greer (U.S. BOR), Mr. Greer arrived at very similar conclusions (TCID-154): "In many places the code is extremely convoluted, making it difficult to tell where or how or under what conditions a particular calculation is made; many calculated quantities are constrained by a number of upper and/or lower limits, some of which appear either superfluous or irrelevant; some switches, which prescribe the path the computer follows through the code, are undefined or incompletely defined, so that the conditions under which a particular path is followed are unclear; some portions of the code are apparently never used, but nevertheless remain in place; many temporary variables are assigned names which have no connection with what they represent; in many cases, the same temporary variable name is used over and over within a subroutine to represent different quantities; and in a number of subroutines, hydrologic quantities are calculated using coefficients or factors which, apparently, are not explained or justified anywhere." In David Robertson's November 12, 1996 letter to Bill Bettenberg (TCID-159), he supports this conclusion when he states, "I do think it is perfectly OK to bemoan the

'60s style of the program, its lack of comments, and general inpenetratability."

Flaws in Demonstrating the Model's Validity

Opinion 5: The TROA model has not been calibrated to known conditions in the flow system.

For a mathematical model to be considered valid for application to any physical setting, it is essential to demonstrate that the parameters representing physical properties in it are appropriate to this very setting. For surface water models, such parameters include rates of evaporation, seepage from stream segments and other losses, transit times and return flow delays, among others. The validity and appropriateness of model calibration is typically demonstrated by comparison of quantities predicted by the model against observations as its parameter values are adjusted. In the present instance, it is claimed that some values prescribed as input data to the model, such as the Farad to Derby Dam net change, are based upon some previous (and undocumented) modeling effort. It is further claimed that individual terms such as evaporative losses from reservoirs are based upon observations, that are also unidentified. However, no attempt has apparently been made to check that when all of these estimated quantities are combined in this model, model predictions indeed match physical observations of any recorded stream flow values or similar recorded quantities. A 1990 USGS review of the Bureau of Reclamation model and the Negotiation model made the following conclusion: "Because the models are uncalibrated and lack documentation, conclusions drawn from model simulations contain an unknown degree of uncertainty." (TCID-137). Further in the report, the authors state, "Because of the lack of documentation and the lack of calibration of the models, it is impossible to assess the accuracy of the models." (TCID-137).

Opinion 6: It is a significant flaw that the TROA model is entirely based upon the central premise that available water resources and stream flows will, in future, remain at precisely their historically recorded values.

No attempt seems to have been made to estimate, through appropriate stochastic simulations, the future variations in such quantities which will have significant quantitative consequences upon water planning and allocations. No such variations, which accepted scientific methodology would indicate as real possibilities, were apparently tested for purposes of such planning and allocations which this TROA model was apparently designed to quantify. This flaw is exacerbated by the reliance on long term averages to evaluate the effect of various alternatives, instead of a more detailed evaluation of impacts at a time scale that are relevant to water users.

Opinion 7: The calculation sequences embedded into the TROA model have not been demonstrated to be valid.

When a model program is constructed in support of just one project, it is necessary to demonstrate that the model program operates correctly as intended. This is achieved by running the model with a set of input data for which the output results are known, such as from an analytical solution to even a theoretical stream flow problem. This step is usually referred to as model or program validation. In the present instance, while it is claimed that a mass balance was performed on some reservoirs to "ensure that input minus output equals change in storage," even such a basic calculation has not been undertaken for the TROA system as a whole. This flaw

thus makes it possible for water to be either lost or created in the system simply due to artifacts of mis-programmed complex calculations, because no checks were performed to ensure that the model maintains a valid overall mass balance. In David Robertson's November 12, 1996 letter to Bill Bettenberg (TCID-159), he concludes, "Apparently very minor differences in calculation order give very slight differences in results, which then propagate to major differences in other parts of the run."

Opinion 8: The TROA model has not been verified following its calibration.

In generally accepted modeling practice, it is customary to retain some data not used in making calibration adjustments to evaluate just how well the model predictions compare with such data. This step is frequently achieved by calibrating a model using data collected during some selected time period, and then verifying it with data available to represent a different time period. This is a step that tests the robustness of physical representations embedded in the model in their ability to predict values that have been observed for this period, and which have not been consumed during model calibrations. The serious flaw in the TROA model is that no such verification was even attempted.

Opinion 9: Sensitivity runs have not been conducted with the TROA model to establish just how its predicted results vary when unknown parameter values are adjusted each within its reasonable bounds of variability.

It is reasonable to hypothesize that future water availability and stream flow conditions will vary if the past millennia of recorded history of natural phenomena are any guide. It is thus important to test the variability of the model predictions to reasonable variations in physical parameter values. Well known and accepted scientific methodology requires that such sensitivity analyses be undertaken in any modeling effort. This step becomes particularly important when predicted impacts of implementing water allocation plans are anticipated to be small, in order to determine if predicted changes are significant. In the present instance, numerous examples exist wherein conducting such sensitivity analysis would be appropriate. For example, when it is assumed that future changes in water use would occur, it is appropriate to test the sensitivity of the model to different amounts of such changes in order to evaluate the sensitivity of the model predictions to that parameter value, all other conditions being held the same. The serious flaw in the TROA model is that no such sensitivity analysis was performed. David Robertson alluded to this issue in his November 12, 1996 letter to Mr. Bill Bettenberg (TCID-159) when he stated the following: "Our work showed various sensitivity problems where tiny differences caused substantial differences in paths through the code."

Opinion 10: Given the complexity of this model, the absence of a user's manual or guide which explains the syntax, meaning and function of input data sets supplied to the model makes it virtually impossible for any independent reviewer to evaluate the model's uses and thereby verify its validity.

Not even a basic User's Manual or Program User's Guide has been prepared for the TROA model. Such a lack of basic documentation is unprecedented and represents a serious flaw. Under present circumstances it is difficult to establish just how a valid scientific methodology can be followed to allow a proper peer review of the model can be performed. Robertson Software, Inc. and Bill Sikonia of the USGS were contracted in 1994 to provide just such documentation and quality assurance regarding the model in question (TCID-138). Following

some two plus years of effort to complete this task, both Robertson Software, Inc. and Bill Sikonia concluded that this was an impossible task. In a letter from David Robertson to Mr. Bill Bettenberg dated November 12, 1996 (TCID-159), Robertson makes the following statement: "Kenn Cartier and I spent a couple of years in a vain attempt to document and rationalize the model. It was one of the more frustrating endeavors of my long software career."

Flaws in Model Applications

Opinion 11: This model is unreasonably sensitive to the computer architecture and FORTRAN compiler used to convert the source code to an executable form.

In order for members of the affected public to apply the TROA model for any valid purpose, the computer program embodying it has to be installed in a computer prior to running it. Principia's test runs demonstrated that this model is unreasonably sensitive to the computer architecture and the specific FORTRAN compiler used to convert the source code to an executable form. In other words, when used on different types of computers or with different FORTRAN compilers, the TROA model predicts quantitatively different results. This is also unprecedented and represents a serious flaw in the TROA model. Such differences indicate either the use of dangerously poor programming practices or the inherently chaotic behavior of the flow system as modeled, or some combinations of both. The differences in results predicted by the model for identical input data sets are particularly significant and troubling since no model sensitivity runs were performed. Discussions held by Principia with authors of this model reveal that the authors themselves had not studied this behavior but were not even surprised by such differences in results. In this TROA flow system as modeled even one extra drop of water can trigger a sequence of program "decisions" which drastically alter how the system is predicted to operate. This serious flaw in applying the model is dramatically demonstrated by the significant changes in model predicted results for some months, even when using identical data sets, simply by running the program on two different computer systems.

Opinion 12: Results predicted by the TROA model cannot be checked or verified as valid real-life possibilities.

One of the reasons cited by authors of this model for not having undertaken model calibrations is that the model is known not to predict any flow quantities that can actually be compared to observed values. This is also unprecedented especially for a model intended to reflect water allocation plans that will affect so many and for so long into the future if adopted. For example, the flow system may historically have been operated according to "rules" that differ from their present form. When used to simulate such historical conditions, the TROA model would cause this flow system to operate not according to such historical rules but differently when applied to the same time period. This failure violates the most basic principles of science that are recognized and widely accepted as valid methodology. It is essential to demonstrate that it is not only possible to undertake such comparisons but that important model results indeed compare favorably with actual observations, even just for selected periods. Without the basic ability to subject the TROA model to valid controlled scientific experiments and to compare the resulting model predictions with observed data, the affected public is forced to accept this model as an article of faith based only upon representations by its authors, and without any opportunity to review its basis in science which is the normal practice. Bill Sikonia encountered similar problems when trying to provide documentation and quality assurance regarding the model. In a

July 26, 1996 memorandum ~~(TCID 152)~~ (TCID 151), Mr. Sikonia arrived at the following conclusion: "It is extremely difficult to separate whether operations are simply personal estimates (usually with little justification) on processes and constants, or whether the choices are actually based or rational analysis or dictated by court cases. The model has almost no internal documentation, describing the model's operation, the reasoning behind choices, the flow of logic, or anything else."

Opinion 13: The TROA model makes predictions that are driven by the results expected by parties to water allocation plans.

This model has been so constructed that it fails to consider changes to gains and losses in the flow system as a result of planned changes in operations. Specifically, the TROA as implemented in the model is aimed at finding unappropriated water, storing that water, and then releasing the water when it is deemed beneficial. What the model as constructed fails to account for is the real possibility that at the time of water releases, water may not reach the lower end of the system as a result of increased losses. Therefore, the increased benefit of such releases may not materialize, may be diminished or even cause additional impact to downstream users who may be "charged" the additional transit losses. Consequently, the model will always predict a benefit from the TROA operations whereas in reality the real benefit would be much smaller and the impact on other water users much greater than predicted. This is also a serious flaw of the TROA model and greatly diminishes its validity as a tool for evaluating real changes in water allocations. Bill Sikonia of the USGS came to a similar conclusion near the end of his review work. In a November 14, 1996 memorandum (TCID-160), Mr Sikonia makes the following statement: "On yet another matter, what the Negotiation Model represents, I think, is a political document, not a scientific one. It's telling the principles, namely the Feds, Sierra Pacific, and the Pyramid Lake Paiute Tribe what they want to hear. Any time this was not true, the model was examined to see if the "problem" could be "fixed." No more clear example of this phenomenon occurred than a couple of months ago when the model said, during Environmental Impact Statement runs, that the cui-ui were better off without the Truckee River Operating Agreement (TROA) than with it. Rod Hall went into the model and found the "problem" and – surprise – now the cui-ui do better under TROA. I suspect this happened a lot. Any time the results were not favorable, they would look hard for a problem, or change a process or parameter to give the politically acceptable "more reasonable" result. By contrast, however, I suspect that if the model were telling them what they wanted to hear, errors would go undetected."

Summary Findings

The review of the TROA model illustrates that it is seriously flawed in several significant respects. Some of these flaws prevent a valid model review from being conducted using accepted scientific methodology, given the short time frame allocated for such reviews. Other flaws are more serious and cripple the model from being used in support of the Draft & Final EIS/EIR. Several of the TROA model flaws identified during Principia's review are fatal and prevent it from being used to evaluate the consequences of water allocation plans for the TROA system and its future operations.

It is Principia's scientific view based upon this review, and the experiences of its scientists from modeling reviews conducted during the past two decades, that model flaws which have serious

consequences must be revealed and then evaluated through a process of wide and unhindered scrutiny by scientific peers. Thereafter, each flaw must be rectified through rational means and then rigorously tested before a model is finalized and used for predictive purposes. The ultimate goal of a scientific computer model is to create confidence in the user that the model will actually predict an outcome that can be relied upon. It is by documenting such efforts in an open and thorough manner that the affected public will be persuaded that such confidence is indeed merited. Principia's opinion of the TROA model is that it provides little, if any, confidence in the data it is evaluating and no confidence that the output created by this TROA is either reliable or usable for purposes of decision making. Bill Sikonia arrived at these very same conclusions and stated so in his July 26, 1996 memorandum ~~(TCID-152)~~ (TCID 151): "I think the model is in such a state that it is essentially impossible to go through with understanding. Furthermore, I could not and would not defend it in court." Later, in the same memorandum, Mr. Sikonia concludes, "Because of the lack of a clear understanding of the model's operation, I do not think one can assure the model results are valid. (In fact, I have examples of coding errors that definitely change model results)."

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