MEMORANDUM

To: **Arne Wick, RWRCC Program Manager**
From: **Stan Jones, Staff Hydrologist**
Date: **May 30, 2014**
Subject: **RWRCC Staff Review of Hydross Model**

You asked me to provide an approximate timeline and a narrative description of RWRCC staff history with the CSKT Hydross model. Bill Greiman, Bob Levitan (retired), Sonja Hoeglund, and I worked cooperatively on the technical review, each focusing on our area of expertise. Following is an approximate timeline of the process. I have also added some of my personal views about the Hydross model and about models in general:

1. In approximately 2004, the CSKT provided a report that describes the basic structure of the model (flowcharts, nodes, decision points, outputs, etc.). It also provides information about how flow estimates were developed for each node (many based on measured data, some based on other models, some estimated). This was reviewed carefully and it looked to be reasonable way to describe the current hydrologic framework. However when CSKT asked us at the time to agree that it <u>should</u> be used as the basis for future negotiations, we were unwilling to do so without first seeing the rest of the model and knowing the assumptions and procedures and what kind of questions the model would be used to answer. All we could do was offer a tentative "maybe", and "so far so good". We explained that in our view, models such as Hydross are a helpful way to describe current understanding of the interaction of hydrologic variables, and can be used to evaluate the effects of alternative management practices, but are typically unsuitable for defining unknowns or for forecasting the future.
2. In 2006 the CSKT gave us limited access to the Hydross model by setting up a computer in a small room in the basement of the Indian Law Center in Helena. Use of the computer was governed by a HYDROSS computer use agreement. RWRCC staff, Bob Levitan (retired), Bill Greiman, and Stan Jones. visited the ILC several times and attempted to gain an understanding of the program. We found it very difficult to use or test the program in any meaningful way partly because the program (as installed) did not allow access to internal components and tables. Furthermore, we were not permitted to download outputs to Excel for later examination on our own computers. Terms were not adequately defined and there was little or no description of where many of the estimates came from or how they were derived.
3. In July 2008 Jay Weiner sent a letter to CSKT requesting that Hydross be installed on our office computers instead of ILC. He pointed out the difficulty of the current arrangement: unable to pop up internal files for review, need for dual monitors, unable to download hydross outputs for later review in our office, inadequate definition of terms and explanations of how estimates were derived. His request was denied.
4. During the 2009 irrigation season, the RWRCC initiated (i.e. the study has been completed but final report has not yet been finalized) an intensive canal seepage study on several canals within

the FIIP. During the following months, calculations of seepage losses were made, along with estimates of uncertainty. Seepage losses were found to be extremely variable, but the results enabled HKM to improve estimates of seepage losses within the Hydross model.

5. In May of 2010 HKM put on an informative two-day demonstration in Billings that explained the model assumptions and procedures, and showed example outputs of baseline and alternative management scenarios. Terms were explained and procedures and estimates were described in a general way. Outputs were presented primarily in graphs and tables. There was discussion on the kinds of future model runs that should be made and how they should be displayed.
6. After the Billings meeting the RWRCC staff agreed among ourselves that the explanations, assumptions, and baseline outputs presented by HKM appeared to be reasonable, and we decided that digging into the internal workings of the model would be extremely time consuming, unlikely to produce much fruit, and might even become a distraction from more important work. Besides, it was still unclear exactly what questions the Hydross model would be asked to answer. So we decided our review of the model should be a broader view to check for comfort level and "reasonableness".
7. Throughout this time, Bill Greiman built extensive spreadsheet models that allowed him to independently evaluate water supply and water use on the FIIP. This gave him intimate knowledge with the workings of the irrigation systems. It also gave us a comfort level that the Hydross model was functioning reasonably well.
8. In about 2010 I was pulled off the CSKT work and directed to prioritize work on other ongoing negotiations in eastern Montana. I continued to interact with Bill on the CSKT work, only at a reduced level.
9. Later in 2010 HKM began periodically sending reports of various model runs along with technical documents in binders. Those reports were reviewed and discussed.
10. In approximately 2010, the Tribes released much of the historic flow data they had collected on streams and canals on the Reservation. This proved to be extremely helpful. Bill was able to see that the river diversion numbers in the Hydross model are based upon solid and reliable data. He was also able to download the data into spreadsheets where he could experiment with other methods to mathematically describe water use and water distribution ("representational hydrographs", etc.).
11. In early 2014, I was reassigned to help with the CSKT related technical work.

My personal opinions (shared by the staff) about models in general and about the Hydross model in particular:

1. Like most irrigation system models, the Hydross model has a very large number of variables, some based on measured data, but much based on estimates or calculations from other models. In fact, give the extremely complex nature of the Flathead Indian Irrigation Project (FIIP), the CSKT Hydross model is necessarily more complex than most. At almost every node there are estimates of flow, of seepage losses, of crop consumptive use, and of amount and location of return flow. In mass balance models such as Hydross, many of the estimates are derived

through an iterative process. For example, efficiency losses are balanced with other estimates such as return flows and return locations until the results appear to be reasonable and consistent with other data. In the end, nobody knows for sure if the estimates are totally correct, all we can hope for is a comfort level that the numbers appear to be reasonable. Uncertainty is fairly high and, unfortunately, the uncertainty of estimates is propagated and multiplied downstream. But that is the inherent nature of such models. It would be difficult or impossible to "prove" such a model right or wrong. Furthermore, the current GUI version of Hydross, unlike previous numeric versions, does not permit the user to easily examine the internal decisions that the model makes. Each time a new run is made, line numbers are automatically reassigned, making it difficult to track and compare 'before' and 'after' conditions. In other words, the model functions somewhat as a "black box" where all you can see are the inputs and outputs but little in between. Again, the best that can hoped for is to develop a comfort level as to the "reasonableness" of the baseline and its sensitivity to changes in the variables. As far as we were concerned, the driving assumption is that the main utility of models such as Hydross is to evaluate alternative management scenarios. While the model could be used to predict hard numbers or flows, the numbers should be used with caution until verified and the model validated with on-the-ground flow measurements. See comments on "adaptive management" below.

2. While it is true that CSKT didn't let us "inside" the model (e.g. they didn't give us the keys to the car), the outputs from the model give good clues as to what is inside, and the outputs are not unreasonable or unexpected. I am comforted by the fact that the upstream end of the model is, in a sense, "locked in" both by the many reliable flow measurements made by the Tribes, and by the outputs from other models (e.g. basin characteristics models of small streams that flow into the system). Likewise, at the downstream end of the FIIP, the model is "locked in" by independent estimates of aggregate water use at the farm turnouts. (see item 3 below). Furthermore, internal to the model, some estimates are validated with miscellaneous flow records made within the system, as well as from the results of the RWRCC canal seepage study.
3. The unfortunate lack of reliable flow measurements at most farm turnouts makes it necessary to estimate farm deliveries, however, the modeled estimates do not appear to be unreasonable when taken as an <u>aggregate</u>, based on results of the Metric model, limited farm turnout measurements, etc. I believe the evidence suggests that, if cropping patterns and water use practices remain similar to past practice, there should be enough water to meet historic on-farm practice. On any given year, some individual headgates will require more water while others will require less, but as long as flexibility is built into the system, the project should be able to deliver water in amounts similar to past on-farm demand.
4. Bill Greiman's work, where he independently modeled the same system using spreadsheets and a wealth of flow data, convinces me that the Hydross model is performing very well -- as well as any monthly-time-step mass-balance model possibly could in such a complex situation.
5. I believe the 2009 model runs provide a reasonably good estimate of current conditions and form a basis to which alternative management practices can be compared. The operational improvement runs show how much water savings HKM and the Tribe believe could be achieved with relatively inexpensive changes in management. This is where I believe we should focus

some more attention. Rather than spending much more time worrying about what is inside the Hydross model or trying to calculate error-ratings (an exercise in futility in my opinion), I think it would be best to focus on the assumptions that drove the operational alternative, and evaluate whether the corresponding outputs describe an achievable goal. Furthermore, we need to be realistic about the kinds investments that would be required to effectively implement the operational improvements, and make sure those investments are made. Having become somewhat familiar with FIIP practices during my work on the canal seepage study, I am convinced that there is ample opportunity to save a considerable amount of water if the project operators are given adequate support and tools to do the job.

6. The fact that HKM used Hydross to produce ‘hard’ numbers that were used as a basis for the CSKT water rights claims was a bit of a stretch for me at first (for reasons previously stated). However, my concerns are mostly abated by “Adaptive Management” provision of the proposed Water Use Agreement. “Adaptive Management” provides a mechanism for the numbers to be adjusted later based on actual water measurement if actual water use differs from the initial FTA numbers. This provision should also provide comfort to the irrigators that they will continue to receive water deliveries at or near historic levels. “Adaptive Management” also allows the FIIP flexibility to make necessary adjustments and refinements as they go along. This provision should be clearly defined in the new water use agreement.
7. Conclusions: Hydross is a useful model in that it increases understanding of a complex and difficult irrigation project. It documents current understanding of the interaction of the many hydrologic variables that drive the FIIP. The model is useful for illustrating the potential effects of alternative management scenarios. But like any model, Hydross is not an end in itself, its limitations should always be recognized. It will need to be validated in the future by water measurement. The “Adaptive Management” provision will help to provide that validation.