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July 18, 2006

Christine Karas
Bureau of Reclamation
6600 Washburn Way
Klamath Falls, Oregon 97603

RE: Review of Bureau of Reclamation's Technical Memorandum Titled "Verification of Modeled Results in the Upper Klamath River Basin to Keno" dated April 2006

Dear Ms. Karas:

As consultants to the Yurok Tribe, we appreciate the opportunity to continue our assessment of the Bureau of Reclamation's (Bureau) study, titled: "Natural Flow of the Upper Klamath River." We submit the following comments regarding the recent updates presented in Technical Memorandum No. 86-68520 – KP 2006-01. The April 2006 Technical Memorandum titled "Verification of Modeled Results in the Upper Klamath River Basin to Keno" was promised by the Bureau following a conference call on January 4, 2006. We understand that this technical memorandum is the final update to the Natural Flow study that is currently under review by the National Academy of Science (NAS) Committee on Hydrology, Ecology, and Fishes of the Klamath River Basin (BEST-K-05-07-A). These comments represent the fourth time that we have submitted comments to the Bureau on behalf of the Yurok Tribe regarding this report.

The NAS Committee is charged with evaluating new scientific information that has become available since the National Research Council issued its 2004 report on Endangered and Threatened Fishes in the Klamath River Basin. The Bureau's Natural Flow study is one of two new reports being evaluated by the NAS. To complete their charge, the NAS Committee has identified the following tasks:

- Review and evaluate the methods and approach used in the Natural Flow Study to create a representative estimate of historical flows and the Hardy Phase II studies, to predict flow needs for coho and other anadromous fishes.
- Review and evaluate the implications of those studies' conclusions within the historical and current hydrology of the upper basin; for the biology of the listed species; and separately for other anadromous fishes.
- Identify gaps in the knowledge and in the available scientific information.

We understand that the NAS Committee will accept new information and data as it becomes available during their review period. In the sections below, we provide an evaluation of the Technical

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Memorandum and offer some analysis of the assumptions in the overall Natural Flow model. We hope that the information in this letter will inform the NAS review.

Executive Summary

Overall, the Technical Memorandum only addresses a subset of the topics which we expected to see covered. Although a full discussion of the historical (1904 to 1918) data was presented, critical steps such as a model verification and development of a sensitivity index were not included in the Tech Memo as requested by the work group. In order to evaluate the Bureau's statistical analysis of the historical data, we conducted a number of supplemental analyses. Our results agree with the Bureau's conclusion that the full 1904 to 1918 data set can be used to generate Link-Keno correlation equations and can be used for model verification. However, there are clear demarcations in the historical data that should be further analyzed to gain a better understanding of how physical changes in the watershed impact flows in the Klamath River.

We compared model output to the full historical data set as a means of model verification. Using a student's t-test, we found that the model output is not of the same population as the historical data. Similar analyses of nearby undeveloped watersheds and climate stations suggest that differences cannot be explained as a result of climate changes. Therefore, there may be flaws in the model assumptions. One such flaw that could easily be changed, is an adjustment of evapotranspiration estimates. We offer a simple means of more adequately representing pre-Project wetland conditions.

Topics We Expected to See in Technical Memorandum No. 86-68520 – KP 2006-01

Development of the Technical Memorandum was proposed by the Bureau during a conference call on January 4, 2006. The intent of the memo was to document the rationale behind a number of assumptions used in the Natural Flow study and to update certain portions of the model based on issues raised by the work group. Because this is the final update to the Natural Flow study for the foreseeable future, we expected that it would address all outstanding concerns.

The work group had requested that the following topics be addressed in the Technical Memorandum:

- **Model verification.** The work group asked the Bureau to compare the modeling results to the historical data as one means of model verification. The Bureau reported during the conference that they had done so and that the modeled results are not of the same statistical population as the historical data. The Bureau promised to document these verification procedures and provide an explanation of the results. This type of model verification was not documented in the Technical Memorandum. We present one possible component of the verification in the section below.
- **History of gages.** Historical data (1904 to 1918) was used by the Bureau to develop equations which describe the relationship between flows in the Link River and flows in the Klamath River at Keno. The Bureau has spent considerable time analyzing the quality of the data collected during the 1904 to 1918 period and making decisions about which data points should be used to develop the Link River to Klamath River at Keno correlation. Gage placement, wind effects, and nearby log jams all affected the quality of the data, particularly at the Link River gage. Construction of the railroad embankment may have affected flows at Keno. Many of the potential influences are documented in early USGS Water Supply papers. The Bureau followed

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through on their promise to present their analysis of historical data in the Technical Memorandum. We present a review of their work below.

- **Spencer Creek.** The Bureau looked at the historical (1904 to 1918) relationship between flows measured in the Link River and flows measured in the Klamath River at Keno to estimate flows at Keno in the Natural Flow study. Because the gage at Keno was moved in December 1913 to a location downstream of the Klamath River confluence with Spencer Creek, the Bureau needed to adjust the Keno record so that it would be consistent over the 1904 to 1918 period of record. Estimates of Spencer Creek flows were subtracted from the Keno record beginning in December 1913. Initially, the Bureau calculated an average of monthly flows from one year of October to December records at Spencer Creek (80 to 100 cfs) and subtracted this from each month of the Keno record when the gage was below Spencer Creek. Because this analysis and the underlying assumptions were not discussed at all in the Natural Flow study, the work group requested that the Bureau document this critical step in the Technical Memorandum. The work group also advised the Bureau that a monthly average from an October to November record is not appropriate to apply to summer months as flows in Spencer Creek would likely be significantly less during the summer. Subtracting 80 to 100 cfs from the summer record can result in over 10 percent difference in flows at Keno. The Bureau updated their Spencer Creek estimates using methods recommended by the OWRD and reported the results of their work in the Technical Memorandum to our satisfaction. However, revised flow estimates at Keno were not reported.
- **Link-Keno Correlation.** The Link-Keno correlation equations were updated based on the historical data analyses and revisions to the Spencer Creek flow estimates. The Bureau promised to discuss the new equations in the Technical Memorandum. New equations were not presented in the Technical Memorandum and it is not clear how the historical data analyses were applied.
- **Sensitivity analysis.** Although a sensitivity analysis feature exists in the current model, it does not allow much flexibility in evaluating many of the initial model assumption or parameters, such as wetland vegetation types and mixtures, etc. Therefore, the Bureau was asked by the team to prepare a sensitivity index specifically for dry months and to create a table that lists the critical elements that change results in the model. A critical step in understanding the results of the model is to understand what factors are the most influential in generating the results. We feel that estimating flows during dry years and dry seasons are the weakest areas of the model, whereas it is these periods that are the most crucial to fish, human residents supported by the river, and most associated ecological influences. No additional sensitivity analyses were conducted as part of the Technical Memorandum.
- **Evapotranspiration.** Work group members expressed concern with the methods and assumptions used by the Bureau to estimate wetland evapotranspiration (ET). Alternatives have been presented (e.g., species mix, inclusion of species specific crop coefficients) to the Bureau but were not incorporated into the model. Although the Bureau recognized the need to evaluate plant distributions and come up with better plant coefficients for wetland communities found in the Klamath Basin, they reported during the January 4, 2006 conference call that they did not and would not have time to modify the ET component of the model prior to NAS submittal. Modifications to the ET data would result in significant changes to the model output. The Bureau noted that changes to ET might be considered during subsequent phases of the modeling effort; however, funding may not be available. We offer suggestions on methods to update ET below.

Additional Information and Analyses

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Summary of Statistical Analysis of Historical Data

The Bureau conducted four different statistical analyses of the 1904 to 1918 historical data set. They used two-tailed student's t-tests to evaluate whether a partial historical record, which reflected the removal of four specific sub-periods believed to be inaccurate within the 1904 to 1918 period of record, was of the same population as the full historic record, which included the potentially inaccurate sub-periods. These analyses were undertaken because the November 2005 version of the Bureau model did not include these "suspect" periods in the regression analysis used to calculate flows at Keno. Reviewers of the model raised concerns that removing the suspect periods of record from the regression may not be statistically valid or warranted.

Several watershed-altering events occurred during the early 1900's, which included the construction of the railroad levee from 1907 to 1908 and the closure of the Klamath Strait for several fall/winter seasons during 1914-1918. Also, changes in the Link River streamflow gage location and operation occurred during October 1909 through December 1911. It was unclear without any statistical testing whether these activities significantly impacted the flow records at the Link and Keno stations. The November 2005 version of the Natural Flow report eliminated measurements from October 1909 through December 1911 due to the assumption that this data was inaccurate based on Water Supply Paper notes. The Tech Memo specifically analyzes the following four suspect time periods to evaluate if their absence results in a flow record that is of the same population as the entire historical record:

- **Test 1** - October 1909-December 1911: problems with Link River gage
- **Test 2** - December 1909 and April-May 1911: high absolute differences between gages
- **Test 3** - October 1917-September 1918 (water year 1918): Klamath Strait gates closed
- **Test 4** - October-January for water years 1915, 1916, and 1918: Klamath Strait gates closed.

The statistical testing conducted by the Bureau and reported in the Tech Memo appears to demonstrate that the partial records without the suspect periods are not significantly different from the full record. It is important to note that the Bureau did not conduct a statistical analysis that evaluated all of the suspect sub-periods in a lumped fashion to understand a collective difference; rather they evaluated each suspect sub-set in isolation. In our initial review of the Tech Memo we noted serious analytical errors in the statistical analysis. For example, the mean values and other variables reported for the "full record" were not consistent in the four tests where this data set was used. For example, the mean of the "full record" is 17.58 cfs in Tests 1 and 2 but only 14.25 in Test 3, yet this mean should be identical. The Bureau provided their data to us and we found that the "full record" used in Test 3 compares favorably with USGS report values. These inconsistencies made it difficult to accept the conclusions of this analysis without a more detailed audit of the data.

Although the Bureau found that the full record was not significantly different than the partial record, they did not modify the regression equation for the model used in the November 2005 report because their comparison of Keno flows using the full versus the partial record showed little difference. However, no formal analysis was conducted beyond a flow exceedence curve to assess this conclusion.

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As reviewers, we felt that it was important to verify the statistical methods conducted and test results obtained by the Bureau and summarized in the Tech Memo. We also wanted to statistically evaluate data sets that the Bureau did not analyze in their Tech Memo. For instance, we felt that it would be relevant to evaluate whether removing all of the suspect data from the historical record (both due to potential gage inaccuracies and watershed-altering events) would result in a statistical difference between the full record and the partial record.

Therefore, we conducted a number of checks on the Tech Memo statistical analyses using the same student's t-test that was employed by the Bureau. A student's t-test is a statistic for measuring the significance of a difference of means between two distributions or, in other words, the likelihood that two different sets of samples are actually drawn from populations with equal true means¹. Confidence limits set upper and lower bounds on an estimate for a given level of significance (ex., the .05 level). We used the same confidence level (0.05) that the Bureau used in the Tech Memo.

We conducted the following statistical tests, which are also summarized in Tables 1 and 2:

- **Test A1** - Flow difference between Link and Keno gages for full historic record compared to the flow difference between Link and Keno gages for a partial record that did not include the months that the Klamath Strait Gates were closed (similar to the Bureau's Test 4 but using actual differences vs. absolute values).
- **Test A2** – Flow difference between Link and Keno gages for full historic record compared to the flow difference between Link and Keno gages for a partial record that did not include the months that the Klamath Strait Gates were closed (winter months of 1915-1917) or the months of unreliable data (October 1909-September 1912).
- **Test A3** – Similar to Test A1, but assessing the **summer** months of July through October.
- **Test A4** – Similar to Test A2, but assessing the **summer** months of July through October.
- **Test B1** – Full historic record of flow at the Keno gage compared to a partial record that did not include the months the Klamath Strait Gates were closed.
- **Test B2** – Similar to Test B1, but assessing the **summer** months of July through October.
- **Test B3** – Full historic record of flow at the Link gage compared to a partial record that did not include the months of unreliable data.
- **Test B4** – Similar to Test B3, but assessing the **summer** months of July through October.

Test A1 was performed to replicate and verify the analysis conducted in the Tech Memo, whereas the other tests were new analyses that were conducted to evaluate a) the effect of removing all suspect periods from the data set, b) if differences are seen on a seasonal basis (Tests A3, A4, B2, and B4), and c)

¹ If the calculated test statistic, T, is greater than the critical T value, then the difference of means is significant and the two distributions may not be from the same population. Confidence limits set upper and lower bounds on an estimate for a given level of significance (ex., the .05 level).

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the effect of using actual Link or Keno gaged flow values instead of a flow difference (Tests B1, B2, B3, and B4).

Our tests verified what the Bureau calculated and summarized in the Tech Memo. We found that the data were from the same populations for all of the statistical tests conducted. No seasonal differences were discerned and removal of the entire suspect time period from the record did not generate a statistically different sample population.

Based on these analyses, we agree that the full 1904 to 1918 data set can be used to generate Link-Keno correlation equations and can be used for model verification.

Using Historical Gage Data to Infer Wetland-River Interactions

As discussed above, statistical tests appear to show that individual physical changes occurring in the Klamath watershed in the early 1900's (e.g. the closure of the Klamath Strait Gates) did not alter flows at the Link or Keno gages in a way that showed a statistical difference when compared to the full historical record. However, it is important to note that the statistical tests performed by the Bureau did not evaluate the effect of the railroad dike construction from 1907 through 1908.

Figure 1 shows flows for both the Link and Keno stations for the full historical record (1904-1918) and includes notes on the key watershed-altering events for context. Although statistical testing shows no differences in the populations when considering partial records that remove specific sub-periods compared to the full record, it is clear from a visual assessment that three distinct periods can be identified from the data. While we are not suggesting that any of these periods be removed from the record for the purpose of model verification or the creation of the Link-Keno regression equation, we feel that certain processes may be better understood from recognizing these periods and how they relate to the physical activities occurring in the watershed.

The periods are grouped by summer/fall low flow relationships between the Link and Keno gages. Summer and fall low flows are roughly equal at the Link and Keno gages during the first period, which starts in 1904 and ends in 1907. During the second period, from 1907 to 1914, summer and fall low flows are higher at the Link gage than at the Keno gage. Finally, flows during the third period, defined as 1914 to 1918, are higher at the Keno gage compared to the Link gage. The period demarcations directly correspond to physical activities in the watershed: a) the construction of the railroad dike from 1907 to 1908 and b) the construction and closure of the Klamath Strait Gates starting in 1914.

The Bureau states in the Tech Memo (p. 5) that “[the] railroad dike has eliminated the spring season overflow of Klamath River through the adjoining marshes into the Lower Klamath Lake.” While this statement is certainly true during the high flow winter and spring months, it fails to address what processes may be affected during the low flow summer and fall months. Visual examination of flows seem to suggest that not only were flows blocked from entering Lower Klamath Lake from Klamath River during the winter/spring, **but flows were blocked from exiting Lower Klamath to Klamath River during the summer/fall months due to the railroad dike.** On numerous occasions we have stressed the importance of Lower Klamath Lake acting as winter/spring storage for water that eventually flows back into the Klamath River during the summer/spring and sustains flows at Keno during the dry season. This idea has never fully been adopted by the Bureau nor incorporated into the model.

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Model Verification

We have asked the Bureau on numerous occasions to conduct a model verification. The most obvious method is to compare modeled flows to the historical data set. A student's t-test could be conducted to analyze whether the modeled results are statistically similar to the historic flow records. Differences could be the result of errors in the model or changes in other factors such as climate. Bureau staff stated in our January 4, 2006 conference call that they have compared modeled results to the historic data set, but they did not report their results or provide any written explanation. The Oregon Water Resources Department has also conducted similar analyses that were presented to the Bureau (J. La Marche, personal communication).

We conducted our own model verification using the flow output data from the Bureau's model and the historical data that they provided to us. The following student's t tests were conducted, which are summarized in Tables 1 and 3:

- **Test C1** – Flow differences between Link and Keno gages for full historic record compared to the flow differences between Link and Keno stations computed from the Bureau model for years 1948-2000.
- **Test C2** – Full historic record of flow at the Keno gage compared to the flow computed for the Keno station from the Bureau model for years 1948-2000.
- **Test C3** - Similar to Test C2, but assessing the **summer** months of July through October.
- **Test C4** - Full historic record of flow at the Link gage compared to the flow computed for the Link station from the Bureau model for years 1948-2000.
- **Test C5** - Similar to Test C4, but assessing the **summer** months of July through October.

The results of our statistical analyses showed that for most of these tests, the output from the Bureau's model for the years 1948 through 2000 was of a different population than the historical record. The only test showing that the data were from similar populations was Test C3, which evaluated Keno flows during the summer months.

To rule out climatic factors that may influence data comparisons using two different time periods, historic (1904-1918) and modeled (1948-2000), we performed statistical analyses on flow data from two nearby rivers; the Rogue River and the Umpqua River and precipitation data from the Klamath SSW station. Specifically, we performed student's t tests to evaluate whether the historic data sets were from the same population as data from the period of 1948 to 2000 for the two rivers and climate station. **Test D1** evaluated the Rogue River and **Test D2** evaluated the Umpqua River; both of which are summarized in Tables 1 and 3. **Test D3** evaluated the Klamath SSW climate station. The statistical analyses for both rivers and the climate station showed that the historic record and the recent record (1948-2000) were from the same population.

Therefore, it is difficult to understand and justify why the modeled results for the Klamath River, at the Link and Keno stations, for the period of 1948 to 2000 is different than the historic record for most of the tests we conducted (Tests C1, C2, C4, and C5). The model is not verified using the historic record.

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Rather, these tests show that the modeled data does not appropriately reflect pre-Project conditions and appear to indicate that there may be fundamental flaws with the model design, with basic assumptions of the model, or both.

Wetland Evapotranspiration

Wetland ET is an important component of the Natural Flow model. In the model spreadsheet, estimates of wetland ET from wetlands surrounding Upper Klamath Lake (UKL) are treated as losses and are subtracted from UKL inflows. Wetland ET estimates are also used by the Bureau to develop flow estimates of the UKL tributaries (Williamson River, Wood River, and Crooked Creek).

With guidance and direct assistance from Dr. Robert Gearheart, Professor Emeritus, Humboldt State University, we have attempted to work with the Bureau to develop a more accurate method of estimating wetland ET than what is currently used by the Bureau. As discussed above, the Bureau has been unable to make changes to their wetland ET estimates given time and budget constraints. However, we feel that many of the modifications we have been proposing are straight forward and could easily be applied.

Figure 2 is a flow chart that Dr. Robert Gearheart developed based on Attachment A of the Natural Flow report. The flow chart outlines the steps that the Bureau used to estimate net ET from wetlands within their XCONSVB modeling platform. We recommend modifying the wetland type, distribution, and acreage to more accurately represent “natural” conditions and therefore, more accurately estimate wetland ET.

- Only three wetland types were considered in the model: salt grass (intermittently flooded marshes), tules and cattails (permanently flooded marshes), and willows (riparian marsh). We feel that this is too simplistic and results in overestimates of wetland ET losses. Wocus communities and isolated areas of open water within the wetland should also be considered. For example, Hank’s Marsh is modeled by the Bureau as consisting of 2,483 acres of tules and cattails, a plant community with moderate to high ET rates (see sheet “UKL_Water-Limiting” of the model spreadsheet). Analysis of color infrared aerial photographs of Hank’s Marsh reveals that there are currently three plant community types (rushes and sedges, tules and cattails, and wocus) and open water within Hank’s Marsh (Forbes, 1996). Using the Hank’s Marsh example, we calculated potential wetland ET for one growing season with the entire 2,483 acres modeled as tules and cattails vs. a more appropriate plant community mix (Table 4). A heterogeneous plant community yields a potential ET that is less than the Bureau estimate. The difference in potential wetland ET is approximately 14 percent. The same plant community distribution likely applies to all 55,517 acres of permanently flooded marshes and can easily be estimated and inferred using color infrared photography.
- The standard XCONSVB database of crop coefficients should be evaluated and modified or replaced. For example, salt grass crop coefficients are probably not appropriate for the wetlands surrounding UKL and are certainly not appropriate for in-lake marginal wetlands. We understand that the salt grass crop coefficients in the XCONSVB database were developed from studies at a Nevada playa where salinity is high. Salt grass typically grows in seasonal wetlands and tends not to evapotranspire in September or October. It does not grow in permanently flooded areas.

On a small scale, considering just Upper Klamath Lake (UKL) wetlands, we wanted to calculate alternative wetland ET estimates for the entire modeling period that could substitute for those given in the

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model spreadsheet. According to Attachment A of the Natural Flow study (page 19), crop consumptive use estimates are not applied to UKL ET estimates, thus potentially simplifying this process. However, we found it too difficult to isolate wetland ET estimates in the Bureau model and had to give up this effort. Documentation of the model spreadsheet is lacking in the Natural Flow study report (see Attachment G) and column headings are often cryptic and appear to refer to spreadsheets, files, or equations and calculations that have not been provided². The following points illustrate our difficulties:

- Wetland areas surrounding UKL were assigned to one of five climate stations. Although total acreage for each climate station is listed in the Natural Flow report, no maps were provided to show where these areas are located or how they were delineated.
- For each climate station, total wetland acreage was divided into three potential wetland types. Permanently flooded marsh areas were modeled using tule and cattail crop coefficients. Intermittently flooded marsh areas were modeled using salt grass crop coefficients. Riparian marsh areas were modeled using willow crop coefficients. The different wetland types were assigned according to elevation; however, no maps were provided to show the delineations.
- We are unable to repeat Bureau ET calculations due to a lack of data. ET calculations were completed using the XCONSVB program which applies the equation given on page 6 of Attachment A. Updated XCONSVB input and output files were not provided. Explanations of earlier input and output files were not provided.
- XCONSVB ET estimates from the tules and cattails wetland type were adjusted based on comparisons with Bidlake and Payne studies (see page 10 of Attachment A). However, the adjustment factor is not provided.
- ET estimates reported in the model spreadsheet have been adjusted for “effective precipitation” (EP), however we are unable to evaluate this adjustment because it was calculated within the XCONSVB program. Summary output tables were not provided. Although the EP equation is provided on page 8 of Attachment A, the value of the normal soil profile depth of depletion coefficient (D) was not provided.

Closing

In conclusion, we feel that Technical Memorandum No. 86-68520 – KP 2006-01 does not adequately address many of the concerns that were raised during the January 4, 2006 conference call and preceding work group meetings. Because we understand this to be the final product related to the Natural Flow study we feel impelled to point out some simple methods that could have been used to assess the model and its assumptions. We also offer a simple means of more accurately estimating ET.

- We had expected that the Technical Memo would document the Bureau’s model verification procedures, provide a flexible sensitivity analysis, and update ET estimates. These concerns have not been addressed.

² For example, column F of the “ukl.lkl_marsh” sheet is labeled as “Fort Klamath 7sw Emergent Lake Marsh - Salt grass at wtr tbl < 1ft 7616 acres” and “serial monthly values from file f7elmuse.sc1”. There is no sheet labeled “fy3lmuse.sc1”.

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- Based on our statistical analyses, we agree that the full 1904 to 1918 data set can be used to generate Link-Keno correlation equations and can be used for model verification.
- A closer examination of the historical flow record in conjunction with large-scale, watershed-altering events should be conducted to better understand interactions between Lower Klamath Lake and Klamath River. Although these processes will ultimately get “lost” in the regression equation and model, it would be beneficial for future model users to be provided with a comprehensive description of how the system operates so that the model can be used most appropriately.
- A statistical comparison of the model results with historical data suggests that the model does not appropriately reflect pre-Project conditions.
- In order to represent pre-Project conditions, wetlands should be modeled as being composed of more than one type of plant community. This would be a simple modification to the modeling assumptions. In one example of adjusting the plant mix in a 2,500-acre wetland from the homogeneous type of the Bureau’s model to a more appropriate heterogeneous plant community, the difference in potential wetland ET was approximately 14 percent for the growing season.
- Important modeling assumptions and components such as ET estimation are conducted outside of the model spreadsheet and are therefore impossible for model users or reviewers to adjust.

Please let us know if you have any questions or concerns regarding these analyses.

A Final Challenge

A useful journey begins with small, affirmative steps. We appreciate the efforts made by the Bureau to complete this Technical Memo, and especially those that respond to specific concerns presented by the work group. We value the documentation provided in this memo, since it lays the foundation for future analysis, as others draw upon and build on the analyses developed by Bureau staff. As the various drafts of the ‘Natural Flow Report’ were released, the Bureau invited technical comment. In addition to our participation in work group meetings, we formally responded four times to their request:

1. Hecht, B., Mallory, B., Porter, S., Gearheart, R.A., 2004, Interim draft review of USBR’s 2003 report of modeling: “Undepleted Natural Flow of the Upper Klamath River: Draft for Review”: Consulting report prepared by Balance Hydrologics for the Yurok Tribe, 46 p. + figures, tables, and appendices.
2. Hecht, B., Mallory, B., Porter, S., Gearheart, R.A., 2005, Comments on USBR’s December 2004 report of modeling: “Undepleted Natural Flow of the Upper Klamath River: Draft for Review”: Consulting report prepared by Balance Hydrologics for the Yurok Tribe, 47 p. + figures, tables, and appendices.
3. Gearheart, R.A., 2005, Review of Attachment A and D – Natural Flow of the Upper Klamath River: Letter report prepared as consultant for Yurok Tribe for John Hicks, Bureau of Reclamation, Klamath Falls Oregon, 12 p.
4. This letter.

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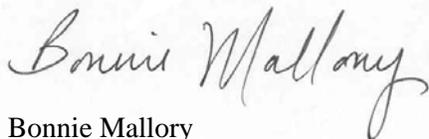
Additionally, Balance staff developed an earlier analysis of monthly flows from the entire Klamath watershed, including the area above Keno, using multiple lines of evidence (Hecht and Kamman, 1996). One chapter of this earlier study included a quantitative analysis of flow persistence, or 'ground-water carryover', the tendency for a wet or dry winter to influence flows two, three, or four summers hence. Because these inter-annual effects can be large at the Keno gage, these equations might have reduced the departures and the variance still remaining in the present Bureau report; they may have freed Bureau staff from the assumptions inherent in the XCONS programs – the descendant of irrigation and drainage models used for years by the Bureau in areas where the annual application of water overwhelms the natural hydrologic processes so dominant in the pre-agricultural Klamath setting.

Together, these documents proffer an important body of information and analysis about a river system whose historical flows are, by all accounts, imperfectly understood. While they were invited by the Bureau, we are not sure that any of these additions or comments were used in its work. The Bureau's most recent Technical Memo does respond to some questions we and other work group members have raised, a suggestion that future analyses may draw upon these contributions.

We will make these documents available, for as long they seem useful, on the Balance Hydrologics website: www.balancehydro.com/reports/Klamath. We will try to answer questions of investigators, whether from the Tribe, Bureau, or the broader public and technical community.

Sincerely,

BALANCE HYDROLOGICS, Inc.



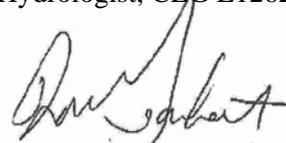
Bonnie Mallory
Geochemist/Water-Quality Specialist



Barry Hecht
Hydrologist, CEG E1262 (OR) and 1245 (CA)



Stacey Porter
Geomorphologist/Hydrologist



Dr. Robert A. Gearheart, Ph.D., P.E.
Professor Emeritus, Humboldt State University



Greg Guensch
Hydrologist/Engineer

Enclosures: References

Table 1: Summary table of descriptive statistics for the datasets used in student's t-test analyses

Table 2: Summary of results for two-sample t-Tests assuming unequal variances: Link River and Klamath River at Keno historical data (1904 to 1918)

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Table 3: Summary of results for two-sample t-Tests assuming unequal variances: 1904 to 1918 historical period vs. 1948 to 2000 modeling period

Table 4: Hanks Marsh potential ET under differing plant community assumptions

Figure 1 Flow chart of evapotranspiration modeling in the XCONSVB platform, Natural Flow of the Upper Klamath River

Figure 2: Historical flows at the Link and Keno stations for 1904-1918

Cc: Dave Hillemeier, Yurok Tribe
Mike Belchik, Yurok Tribe
Suzanne Van Drunick, National Academy of Sciences Klamath Review Committee
(Submitted electronically)

References

Forbes, M., 1996, Master of Science Thesis, Environmental Systems, Humboldt State University.

Hecht, B., and Kamman, G.R., 1996, Initial assessment of pre- and post-Klamath Project hydrology on the Klamath River and impacts of the Project on instream flows and fishery habitat: Balance Hydrologics, Inc. consulting report prepared for the Yurok Tribe, 39 p., + 2 tables, 31 figures, and 2 appendices

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TABLES

Table 1. Summary table of descriptive statistics for the datasets used in student's t-test analyses.

| Dataset | Mean | Median | Skew | Kurtosis | Std Dev | Count |
|--|---------|---------|-------|----------|---------|-------|
| Link Q - Keno Qs for full historic record (1904 - 1918) | 6.47 | 2.37 | 2.08 | 10.220 | 19.97 | 168 |
| Link Qs - Keno Qs for full historic record w/o months gates closed (10/14-1/15, 10/15-1/16, after 10/17) | 8.07 | 5.70 | 1.94 | 9.424 | 20.67 | 148 |
| Link Qs - Keno Qs for full historic record w/o gates closed and unreliable Link data (10/09-8/12) | 2.89 | 0.90 | 0.43 | 0.351 | 15.33 | 113 |
| Link Qs - Keno Qs for historic July - October | 2.74 | 2.52 | -0.28 | 0.485 | 11.46 | 55 |
| Link Qs - Keno Qs for historic July - October w/o gates | 3.50 | 3.50 | -0.44 | 0.517 | 11.84 | 49 |
| Link Qs - Keno Qs for historic July - October w/o gates or 10/09-8/12 | 0.08 | -0.83 | 0.23 | -0.320 | 8.23 | 38 |
| Model-derived Link - Keno Qs (1948 - 2000) | 0.73 | 0.85 | -0.63 | 5.969 | 6.80 | 624 |
| Historic Keno Qs for full record | 125.08 | 119.68 | 0.79 | 0.386 | 54.16 | 168 |
| Historic Keno Qs w/o gates | 128.82 | 121.00 | 0.77 | 0.192 | 55.06 | 148 |
| Historic Keno Qs for summer months | 77.58 | 72.40 | 1.37 | 2.318 | 26.70 | 55 |
| Historic Keno Qs for summer months w/o gates | 80.15 | 73.40 | 1.57 | 2.387 | 26.21 | 49 |
| Historic Link Qs for full record | 131.55 | 118.50 | 0.92 | 0.670 | 58.48 | 168 |
| Historic Link Qs w/o 10/09-8/12 | 126.71 | 114.00 | 0.95 | 0.951 | 58.48 | 133 |
| Historic Link Qs for summer months | 80.31 | 75.00 | 0.92 | 1.337 | 26.04 | 55 |
| Historic Link Qs for summer months w/o 10/09-8/12 | 77.43 | 71.05 | 1.08 | 1.891 | 26.35 | 44 |
| Modeled Q at Keno October 1948 - September 2000 | 115.53 | 105.89 | 0.81 | 0.245 | 52.29 | 624 |
| Modeled Q at Keno summer months 1949 - 2000 | 72.47 | 66.30 | 2.17 | 7.015 | 31.94 | 207 |
| Modeled Q at Link October 1948 - September 2000 | 116.27 | 105.35 | 0.84 | 0.352 | 57.16 | 624 |
| Modeled Q at Link summer months 1949 - 2000 | 71.09 | 65.22 | 1.44 | 2.701 | 31.01 | 207 |
| Rogue River flows for December 1907 - December 1911 (cfs) | 820.54 | 770.96 | 1.08 | 1.018 | 379.63 | 46 |
| Rogue River flows October 1948 - September 2000 (cfs) | 886.68 | 770.96 | 1.34 | 2.135 | 477.15 | 394 |
| Umpqua River flows for September 1905 - September 1918 (cfs) | 7620.97 | 5797.42 | 1.26 | 1.398 | 6796.96 | 157 |
| Umpqua River flows for September 1948 - September 2000 (cfs) | 7789.39 | 5348.39 | 1.72 | 3.828 | 7850.73 | 625 |
| Klamath Falls monthly precipitation for 1905, 1908-1910, 1913, 1915-1918 | 1.00 | 0.69 | 2.23 | 6.154 | 1.08 | 104 |
| Klamath Falls monthly precipitation for September 1948 - December 1997 | 1.17 | 0.82 | 1.94 | 5.534 | 1.18 | 520 |

Table 2. Summary of results for two-sample t-Tests assuming unequal variances: Link River and Klamath River at Keno historical data (1904 to 1918).

| Test | Hypothesis | Pooled Standard Error of Mean ^a | T-Statistic ^b | Degrees of Freedom | Critical T Value ^{c,d} | P(T<=t) ^e | Result |
|------|--|--|--------------------------|--------------------|---------------------------------|----------------------|--------|
| | | $\sigma_{\bar{x}_1 - \bar{x}_2}$ | T | D_f | t | $P(T \leq t)$ | |
| A.1 | Link - Keno flow difference: full historic record = full historic record without the months the Klamath Strait Gates were closed (10/14-1/15, 10/15-1/16, after 10/17). | 2.294 | -0.696 | 314 | 1.972 | 0.487 | accept |
| A.2 | Link - Keno flow difference: full historic record = full historic record without the months the Klamath Strait Gates were closed (10/14-1/15, 10/15-1/16, after 10/17) and the months of unreliable data at the Link Gage (10/09-9/12). | 2.110 | 1.699 | 279 | 1.972 | 0.091 | accept |
| A.3 | Link - Keno flow difference: historic summer months (Jul-Oct) = historic summer months (Jul-Oct) without the months the Klamath Strait Gates were closed (10/14-1/15, 10/15-1/16, after 10/17). | 2.291 | -0.333 | 102 | 1.984 | 0.740 | accept |
| A.4 | Link - Keno flow difference: historic summer months (Jul-Oct) = historic summer months (Jul-Oct) without the months the Klamath Strait Gates were closed (10/14-1/15, 10/15-1/16, after 10/17) and the months of unreliable data at the Link | 2.042 | 1.302 | 91 | 1.987 | 0.196 | accept |
| B.1 | Keno flow: full historic record = full historic record without the months the Klamath Strait Gates were closed (10/14-1/15, 10/15-1/16, after 10/17). | 6.160 | -0.607 | 314 | 1.972 | 0.544 | accept |
| B.2 | Keno flow: historic summer record (July - Oct) = historic summer record without the months the Klamath Strait Gates were closed (10/14-1/15, 10/15-1/16, after 10/17). | 5.195 | -0.496 | 102 | 1.984 | 0.621 | accept |
| B.3 | Link flow: full historic record = full historic record without the months of unreliable data at the Link Gage (10/09-9/12). | 6.881 | 0.704 | 299 | 1.972 | 0.482 | accept |
| B.4 | Link flow: historic summer record (July - Oct) = historic summer record without the months of unreliable data at the Link Gage (10/09-9/12). | 5.302 | 0.545 | 97 | 1.985 | 0.587 | accept |

Notes:

a. Standard error of the mean is computed as.....

$$\sigma_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$$

$$T = \frac{\bar{X}_1 - \bar{X}_2}{\sigma_{\bar{x}_1 - \bar{x}_2}}$$

b. T-statistic is computed as.....

c. Critical T values are approximated from standard reference tables.

d. Tests are evaluated at a 95% confidence level ($\alpha=0.05$).

e. P(t<=T) computed using excel TTEST function for two arrays with two tails and unequal variances.

Table 3. Summary of results for two-sample t-Tests assuming unequal variances: 1904 to 1918 historical period vs. 1948 to 2000 modeling period.

| Test | Hypothesis | Pooled | T- | Degrees | Critical T | P(T<=t) ^e | Result |
|------|---|---|-------------------------------|---------------------|-----------------------------|----------------------|---------------|
| | | Standard Error of Mean ^a $\sigma_{\bar{x}_1 - \bar{x}_2}$ | Statistic ^b T | of Freedom D_f | Value ^{c,d} t | $P(T \leq t)$ | |
| C.1 | Link - Keno flow difference: full historic record = model results | 1.564 | 3.668 | 790 | 1.972 | 0.0003 | reject |
| C.3 | Keno flow: full historic record = model results | 4.674 | 2.042 | 790 | 1.972 | 0.042 | reject |
| C.4 | Keno flow: historic summer record (Jul-Oct) = model summer results | 4.230 | 1.208 | 260 | 1.972 | 0.230 | reject |
| C.5 | Link flow: full historic record = model results | 5.184 | 2.948 | 790 | 1.972 | 0.003 | reject |
| C.6 | Link flow: historic summer record (Jul-Oct) = model summer results | 4.120 | 2.238 | 260 | 1.972 | 0.027 | reject |
| D.1 | Rogue River flow: 1908-1912 record = 1948-2000 record | 60.917 | -1.086 | 438 | 1.972 | 0.282 | accept |
| D.2 | Umpqua River flow: 1904-1918 record = 1948-1998 record | 626.796 | -0.269 | 780 | 1.972 | 0.788 | accept |
| D.3 | Klamath Falls precipitation: 1905-1918 record = 1948-1997 record | 0.118 | -1.465 | 622 | 1.972 | 0.145 | accept |

- Notes:
- a. Standard error of the mean is computed as..... $\sigma_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$
- b. T-statistic is computed as..... $T = \frac{\bar{x}_1 - \bar{x}_2}{\sigma_{\bar{x}_1 - \bar{x}_2}}$
- c. Critical T values are approximated from standard reference tables.
- d. Tests are evaluated at a 95% confidence level ($\alpha=0.05$).
- e. P(t<=T) computed using excel TTEST function for two arrays with two tails and unequal variances.

Table 4. Hanks Marsh potential ET under differing plant community assumptions.

| Month | (kc) | (kc) | (kc) | (P) | (T) | (ET) | (ET) | (ET) | Hargreaves Evap (in/month) | Hanks Marsh Potential ET (in/month) | BOR Hanks Marsh Potential ET (in/month) |
|--------|-------------------------------|--------------------------------|-------------------|--------------------------------------|------------------------------|--------------------------------|--------------------------------|--------------------------------|----------------------------|-------------------------------------|---|
| | Rushes & sedges (salt grass) | Tules & cattails | Wocus | | | 698 ac | 831 ac | 379 ac | | | |
| | kc values (Rushes and sedges) | kc values (Tules and cattails) | kc values (wocus) | Monthly % day-time hours of the year | Mean monthly temperature (F) | ET Blaney - Criddle (in/month) | ET Blaney - Criddle (in/month) | ET Blaney - Criddle (in/month) | | | |
| Apr-99 | 0.61 | 1.13 | 0.6 | 8.8 | 44 | 1.06 | 1.96 | 0.98 | 3.55 | 4777 | 4858 |
| May-99 | 0.94 | 1.48 | 0.7 | 9.71 | 50.9 | 2.63 | 4.14 | 2.07 | 5.65 | 9317 | 10290 |
| Jun-99 | 1.2 | 1.52 | 0.8 | 9.71 | 61.9 | 5.46 | 6.91 | 3.46 | 6.84 | 14801 | 17169 |
| Jul-99 | 1.19 | 1.49 | 0.7 | 9.88 | 65.3 | 6.26 | 7.84 | 3.92 | 7.40 | 16626 | 19470 |
| Aug-99 | 1.1 | 1.39 | 0.7 | 9.34 | 67.7 | 5.96 | 7.53 | 3.77 | 6.25 | 15447 | 18707 |
| Sep-99 | 1.02 | 1.2 | 0.6 | 8.35 | 65.1 | 4.50 | 5.30 | 2.65 | 4.50 | 11138 | 13155 |
| Oct-99 | 0.89 | 0.6 | 0.3 | 7.9 | 52.9 | 2.24 | 1.51 | 0.75 | 2.65 | 4623 | 3743 |

Potential ET Apr - Oct '99 76730 87393

BOR estimate is 14 percent higher. 0.14

Notes:

ET (in/month) = [(T)(P)/100](k)

ET = potential consumptive use (inches/month)

k = (kt)(kc)

kt = 0.173(T)-0.314

T = mean monthly air temperature (Fahrenheit)

P = monthly percentage of annual daylight hours

k = monthly consumptive use coefficients

kt = climatic coefficient

kc - crop coefficient

Plant community acreage estimates from color infrared aerial photo analysis (M. Forbes Master's Thesis).

kc(wocus) = kc(cattail)/2 from Ramey, 2004 (<http://aquat1.ifas.ufl.edu/guide/evaptran.html>). Water lily (a plant similar to wocus) ET is approximately 50% of cattail ET.

Mean monthly temperature from XCONS input file for Klamath Falls (1999 34.2 29.8 35.5 44.0 50.9 61.9 65.3 67.7 65.1 52.9 42.5 31.0).

Hargreaves ET from column E of evap.notes sheet of BOR spreadsheet model "Klamath Falls Hargreaves Evaporation (A. Harrison)" adjusted by (0.75/0.89).

BOR Hanks Marsh potential ET assumes all 2621 acres are tules and cattails.

FIGURES

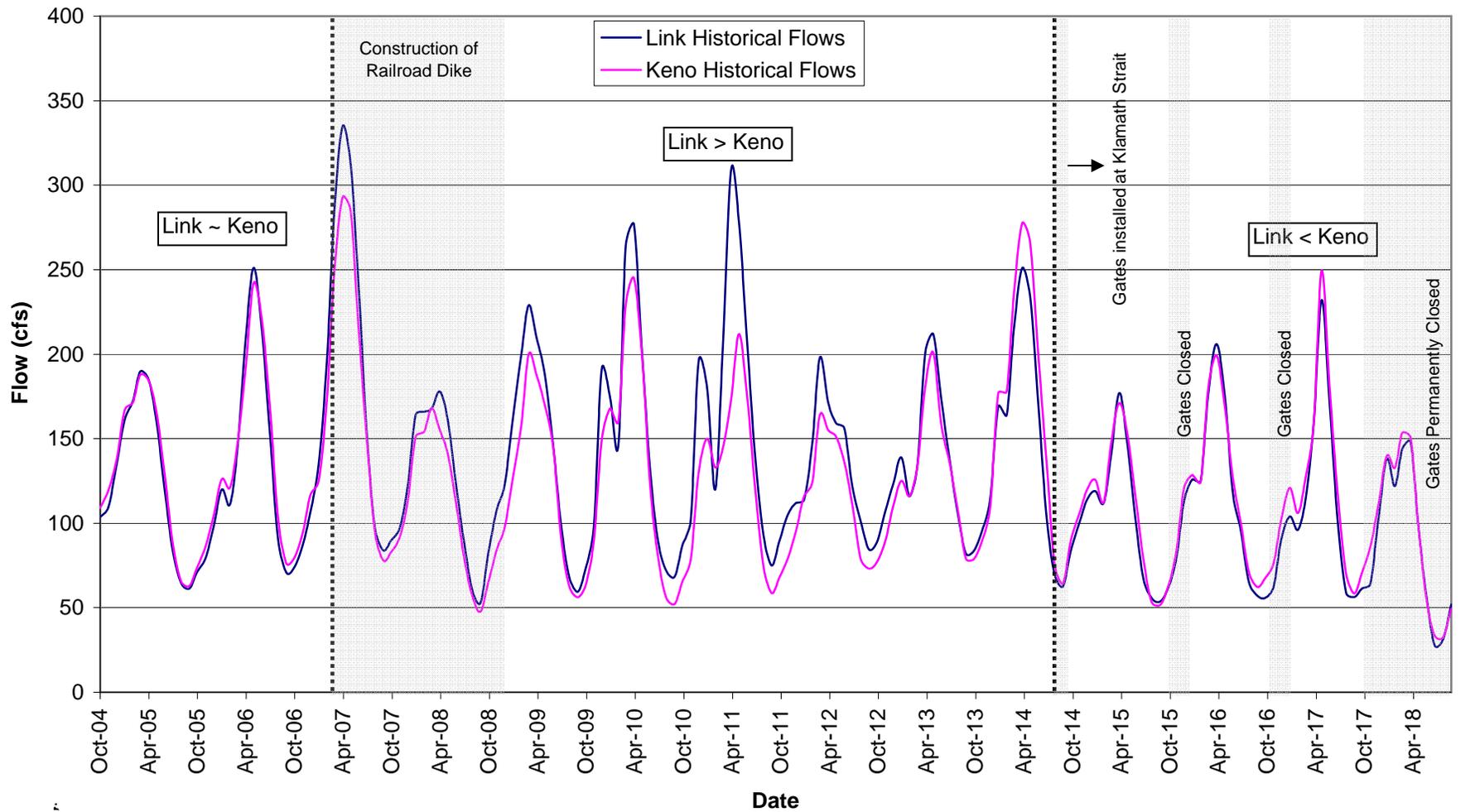


Figure 1. Historical flows at the Link and Keno stations for 1904-1918. Historical flows for the Link and Keno stations are plotted with descriptive notes that identify important time periods when watershed-altering events took place in the early 1900's. Note that three distinct flow patterns can be identified and correspond with physical changes to the watershed.

