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To: Rodney J. Witler
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From: Merlynn D. Bender *[signature]* AUG 20 2012
Bureau of Reclamation, Technical Service Center, 86-68220

Subject: Trinity Reservoir Carryover Storage Cold Water Pool Sensitivity Analysis - Technical Service Center (TSC) Technical Memorandum No. 86-68220-12-06

The attached Technical Memorandum No. 86-68220-12-06 summarizes information relating to the Trinity Reservoir end-of-September carryover storage for cold water fish. This Technical Memorandum is part of a reconnaissance-level sensitivity analysis. Information on the sensitivity of Trinity River temperatures to storage levels in Trinity Reservoir was reviewed; an assessment was made on the effects of system operations on low and high pool elevations through a multi-year drought. Cursory results and suggestions for further investigation are presented.

This cursory sensitivity analysis indicated that end-of-September Trinity Reservoir carryover storage less than 750,000 acre-feet (AF) is potentially thermally problematic for cold water fish in the Trinity River; under current and future operating criteria, the system does show storage significantly below this storage level for the 1987 through 1992 drought. A more severe multi-year drought could depress storage levels further. A more fine-tuned study is required to investigate selective withdrawal or potential operational changes during a multi-year drought at low pool elevations.

If you have any questions or concerns, please contact Merlynn D. Bender at mbender@usbr.gov or call 303-445-2460.

Attachment

cc: 86-68200 (Reading Copy), 86-68220 (Bender/Holdren/File), NC-312 (Zedonis)

Trinity Reservoir Carryover Storage Cold Water Pool Sensitivity Analysis
Technical Service Center Technical Memorandum No. 86-68220-12-06

Introduction

A multi-year drought, such as that which occurred during the period from 1987 through 1992, can decrease Trinity Reservoir storage and result in warmer water released from Trinity Reservoir. Historical data and model results for Trinity Reservoir storage have been examined to illustrate the potential for releases that exceed temperature thresholds.

Historical records of Trinity Reservoir storage and Trinity River flows reflect the historical trace of Central Valley Project (CVP) operations criteria, which have changed over time. Trinity Reservoir is part of a complex water delivery system and the current reservoir operations are different than historical conditions. Regulation changes affecting operations include the 2000 Trinity River Environmental Impact Statement Record of Decision (ROD), implementation of CVP Improvement Act 3406(b)(2) actions, and the Reasonable and Prudent Alternatives (RPA's) from the National Marine Fisheries Service and Fish and Wildlife Service Biological Opinions on the 2008 Operational Criteria and Plan (OCAP). Even if some of these operations criteria do not have direct components in the Trinity basin, their effects on water supplies for the CVP do impact the use of Trinity Reservoir conservation storage. Current regulatory assumptions, constraints, and criteria are reflected in the Central Valley Project/State Water Project (CVP/SWP) planning model, CalSim, which uses an input hydrology time series spanning water years 1922-2003, and allows comparisons of proposed operations to baseline conditions, given a fixed set of operating criteria. For this analysis, the results of two CalSim baseline studies were used, reflecting a 2005 level-of-land-development (LOD) condition (CalSim Existing) and a 2020 LOD condition (CalSim Future). CalSim modeling assumptions are summarized in "CalSim-II Assumptions for Reclamation January 2012 Baselines" (Bureau of Reclamation, 2012).

Although CalSim results are not intended to be used in a predictive sense, results from the two CalSim baseline studies were used to represent reservoir storages under existing regulatory conditions and were compared to historical reservoir storages. This comparison for years 1962-2003 is shown graphically in Figure 1 in units of thousand acre-feet (TAF). The historical operation (green line) of the Trinity Reservoir storage, which did not include ROD flows or more aggressive water supply exports to the Sacramento River basin, allowed higher water surface elevations and storage than the full implementation of current regulatory criteria at existing or future demand levels (blue line and red line). For a multi-year drought period such as 1987 through 1992, current CVP operations strategies would likely result in storage conditions falling to 617,000 AF by the end-of-September of the 5th year. Comparatively, historical operations allowed Trinity Reservoir end-of-September storage to fall to 670,000 AF in the 5th year (1991) of the drought and then recovered in the 6th year (1992). The end-of-September storage is often not the overall low point in storage for a year; however the end-of-water year storage serves as a consistent comparison point.

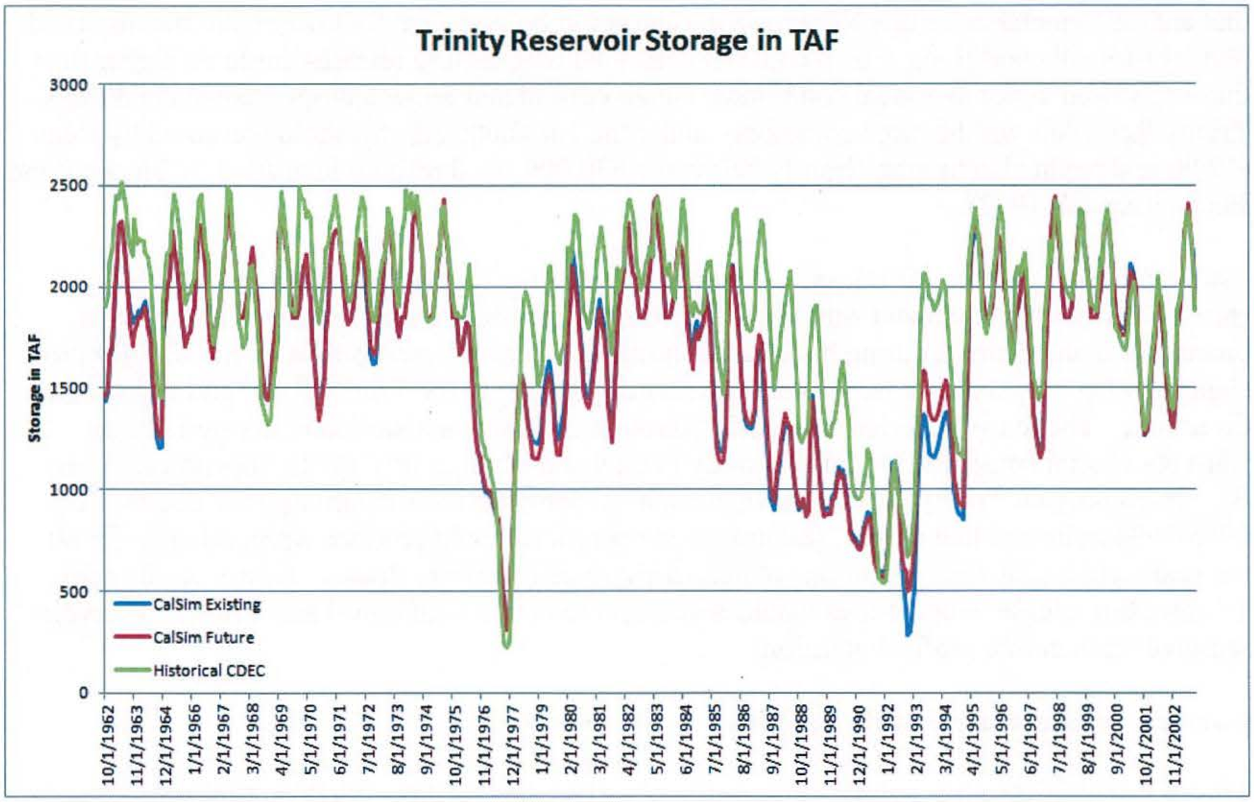

Figure 1. Trinity Reservoir end-of-month storage October 1962 - September 2003.

Previous studies of the relationship between Trinity Reservoir storage and temperature were reviewed to extract information relating Trinity Reservoir storage to the temperature of the water released from Trinity Reservoir. A two-dimension temperature model, such as CE-QUAL-W2 (Cole and Wells, 2006 and Loginetics, 2007), of Trinity Reservoir with multiple branches does not exist and adequate geometry for such a two-dimensional (2-D) appraisal-level analysis is currently not available.

To improve conditions for cold water fish while generating hydropower, maintaining higher Trinity Reservoir water surface elevations and end-of-September carryover storage of 1,000,000 AF has been recommended by Deas (1998) for a single year of drought when selective withdrawal is not used. That reconnaissance-level modeling study was based on one-dimensional (1-D) modeling and was performed based on pre-ROD reservoir operations assumptions.

Finnerty and Hecht (June 26, 1992) testimony indicated that, "Water year 1991 is considered by Trinity County personnel to represent a year in which instream water temperature requirements for salmon fisheries in the Trinity River could just barely be met." The total end-of-September 1991 Trinity Reservoir volume was 670,000 AF.

The CalSim simulations of current operations criteria indicate that, during a drought, the use of conservation storage in Trinity Reservoir would be exercised to a greater extent than was seen historically. An examination of the relatively dry ten-year period from 1985 through 1994 shows that end-of-September Trinity Reservoir storage could be significantly lower than that observed under historical conditions, which could indicate that temperature releases could be higher than those observed under historical conditions. Under current and projected operational conditions, Trinity Reservoir will be more commonly under the 1,000,000 AF threshold identified by Deas (1998) and could also be significantly below the 670,000 AF threshold identified by Finnerty and Hecht (June 26, 1992).

Estimated Trinity Reservoir release temperatures based on Trinity Reservoir water surface elevations from historical and simulated operations indicated warmer releases under current operations than occurred during historical conditions. Trinity Reservoir water surface elevation changes reflect dry and wet periods and associated releases to the Trinity River and transbasin diversions. The ten year period from 1985 through 1994 was a historically dry period that warrants special consideration for this study (Vogel and Marine, July 1991, Appendices A and B). Based only on Trinity water surface elevations, comparatively examining the decade from 1985-1994 indicated that current and projected operations could produce warm releases for all ten years while historical conditions indicated six years of warm releases. However, the actual Trinity Dam release temperatures would depend on selective withdrawal and Trinity Reservoir seasonal temperature profile conditions.

Cursory Temperature Profile Analysis

Trinity Reservoir forebay temperature profile observed data (Smith, 1991) on September 24, 1991 were assessed. The water surface elevation of Trinity Reservoir was 2220.07 ft, corresponding to 720,000 AF of storage. The cursory assessment indicated a classical deep lake thermal structure as shown in Figure 2. The centerline of the main intake release level was about 106 feet below the water surface on September 24, 1991; the corresponding recorded water temperature at 105 feet below the water surface was 11.3 °C (52.3 °F) indicating that cold water was only available below the main outlet level; and the volume of cold water near the bottom of Trinity Reservoir is relatively small.

Without a calibrated hydrodynamic Trinity Reservoir model that incorporates interflows and mixing, further temperature assessment would be uncertain in this relatively long reservoir with a large embayment arm. As pool level drops during a drought or drawdown, it is difficult to predict changes in Trinity Reservoir temperature profiles due to interflows and mixing.

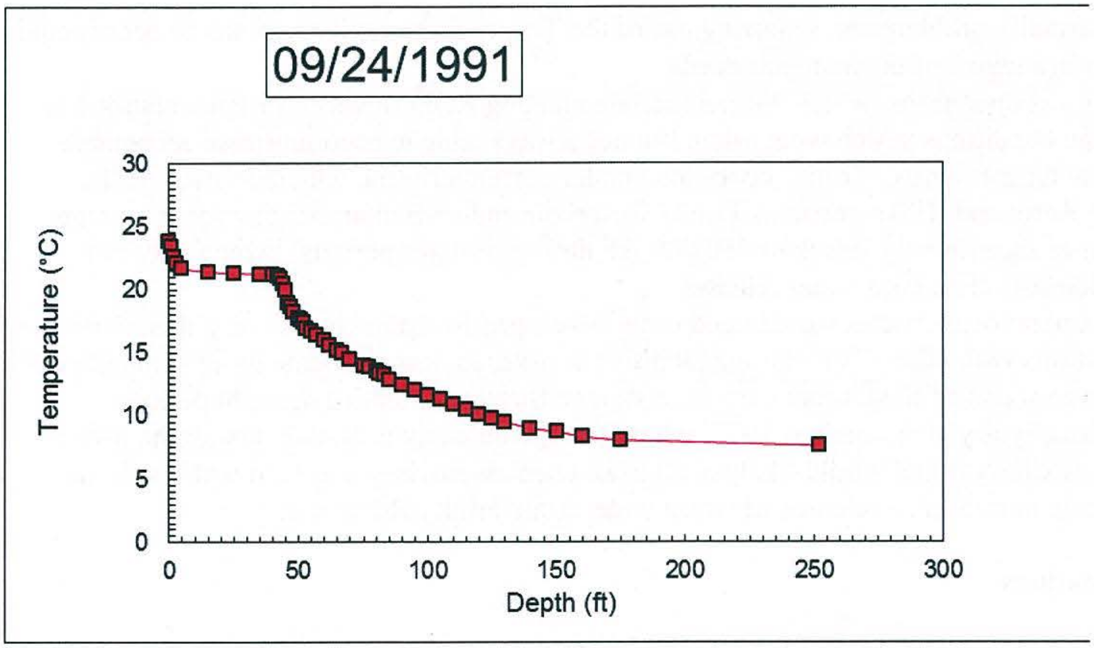

Figure 2. Trinity Reservoir forebay observed end-of-September drought pool temperature profile during September 24, 1991 (observed water surface elevation 2220.07 feet).

Deas (1998) completed an abbreviated selective withdrawal analysis to determine the impact of using the auxiliary intake elevation (centerline at 1999 feet) in place of the power/main intake (centerline at 2114 feet). The volume between the two outlets is 195,000 AF. That preliminary analysis indicated that there is potential for temperature control at Trinity Reservoir by using the deeper auxiliary outlet and foregoing power production. Selective withdrawal provided sufficient operational flexibility at 750,000 AF of end-of-September carryover storage without any temperature concerns. Deas (1998) indicated that care should be used when interpreting those results, as the study did not investigate carryover storage volumes lower than 750,000 AF, it analyzed only a single year of drought, and it used operations before implementation of the ROD. A multi-year drought would likely result in operational rule changes in succeeding years. Additionally, Deas (1998) points out, "Trinity Reservoir is sensitive to inflow water temperature. Just having a cold winter isn't enough to cool the entire lake, the lake needs to be filled with cold water." Therefore, Trinity Dam releases during multi-year droughts will be warmer than a single-year analysis indicates. During extreme droughts, such as that seen in 1977, there is minimal volume of cool water below the level of the main outlet. Also, during June 29, 1977, the five observed water temperature data points between the main outlet centerline and the auxiliary outlet centerline averaged 10.4 °C (50.7 °F), which is relatively warm.

To ensure that Trinity Reservoir end-of-September carryover storage does not decrease below 750,000 AF during drought conditions, additional actions would need to be taken. Those actions need to be identified and studied.

Conclusions

1) A satisfactory relationship can be drawn between Trinity Reservoir storage conditions and Trinity River temperatures. End-of-September carryover of 750,000 AF or less could

be thermally problematic, requiring use of the Trinity Dam auxiliary outlet to access cold water in support of downstream needs.

2) Historical operations, which did not include meeting ROD flows and RPAs, resulted in storage conditions which were often, but not always, able to accommodate acceptable release temperatures. Trinity operations under current criteria, which do include the ROD flows and RPAs, result in Trinity Reservoir end-of-September carryover storage volumes significantly less than 750,000 AF during drought periods, which may not provide sufficient cold water releases.
3) New operational criteria would need to be developed for balancing Trinity Reservoir operations with other CVP storage facilities in order to accommodate more desirable cold water pool end-of September carryover storage through extended drought periods.
4) In critically dry years such as 1977, where storage capacity is already taxed, the lower level auxiliary outlet would likely need to be used extensively and cold water volume depleted to minimize releases of warm water from Trinity Reservoir.

Recommendations

1) Test system-wide operational changes over a range of Trinity Reservoir carryover storage during a severe multi-year drought by using modified CalSim assumptions.
2) Continue to refine understanding of the relationship between Trinity Reservoir water surface elevation, releases for flows and exports, and temperature of Trinity River flows downstream of Lewiston Dam.

Future Work

The TSC suggests the following activities to reduce the uncertainty of this end-of-September carryover pool sensitivity analysis.

1) Collect and process survey-grade Trinity Reservoir geometry (bathymetry) under high pool conditions.
2) Process existing flown above water surface data (from Light Detection and Ranging (LiDAR) data and topographic maps) collected at low pool conditions.
3) Merge the bathymetric and upper reservoir geometric data sets into one data set with a common vertical datum.
4) Based on the cursory "Trinity Reservoir Carryover Analysis" report recommendation (Deas, 1998), expand the examination of selective withdrawal for temperature control at Trinity Reservoir using a calibrated Trinity Reservoir Water Temperature Simulation Model to optimize release temperature given a release temperature target for multiple intakes (power/main intake at centerline elevation 2114 and auxiliary outlet centerline elevation 1999 feet).

Acknowledgments

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This technical memorandum should be referenced as follows:
U.S. Bureau of Reclamation, August 20, 2012, "Trinity Reservoir Carryover Storage Cold Water Pool Sensitivity Analysis," Technical Service Center Technical Memorandum No. 86-68220-12-06 from Merlynn D. Bender, Environmental Applications and Research Group (86-68220) to Rodney J. Witler, NC-156.