NMFS Internal Memo

TO: Maria Rea

FROM: Craig Anderson

DATE: May 7, 2009

SUBJECT: Analysis of historical Shasta Reservoir storage volumes

Maria,

This technical memo provides a summary of analyses conducted in February 2009 to evaluate historical Shasta Reservoir storage volumes as part of the effort to develop Shasta storage targets for one of NOAA's National Marine Fisheries Service (NMFS) proposed Reasonable and Prudent Alternative (RPA) for the Sacramento River Division as part of the California Central Valley Project (CVP) and State Water Project (SWP) Operations Criteria and Plan (OCAP) Biological Opinion (BO). This summary includes descriptions of and the supporting rationale for the proposed Shasta storage RPAs, the timeline associated with RPA development, an overview of the data records used in the analysis, and statistics specific to individual Shasta carryover storage targets. The analysis is only one component of the comprehensive decision making process. Analyses and modeling simulations conducted by various parties have provided additional, relevant information used by NMFS in developing the ultimate recommendations for Shasta carryover storage targets.

Water temperatures of releases from Shasta Dam are one of the primary controls on the temperature regime of the downstream environment. Because of the thermal dynamics associated with seasonally stratifying reservoirs such as Shasta Reservoir, storage levels are directly linked to cold water pool volume availability. As such, the management of reservoir storage throughout the year has a direct impact on release temperatures and the subsequent thermal dynamics of the mainstem Sacramento River. Establishing minimum storage targets for critical times of the year will allow for the enhanced cold water pool storage availability necessary to provide suitable instream conditions for fisheries below Shasta and Keswick Dams.

Maintaining minimum Shasta Reservoir storage is just one component of a suite of objectives that must be achieved to address the unavoidable adverse effects of Shasta Dam operations. Maintaining suitable Sacramento River temperatures for egg incubation, fry emergence, and juvenile rearing is critically important for the survival of winter-run Chinook salmon. Because this species is blocked from its historic range, suitable temperatures and habitat must be maintained downstream of Shasta Dam through management of the cold water pool behind the dam in the summertime. Furthermore, this winter-run population is the only one in existence, which makes maintaining optimum conditions for this species below Shasta most

crucial until additional populations may be established, either in alternative habitat or to their historic range. Suitable temperatures for spring run Chinook salmon must also be maintained in at all critical points in their life history. Central Valley steelhead are also affected by temperature management actions from Shasta Reservoir, as are the Southern Distinct Population Segment (DPS) of green sturgeon.

The development of the Shasta storage RPA has been an iterative process informed by a suite of analyses and discussions with a variety of agencies and individuals with expertise in and direct knowledge of system operations and biological considerations of the affected species. The analysis of historical Shasta reservoir storage levels summarized in this memorandum came relatively early on in the process as a preliminary step in determining reasonable, appropriate, and relatively attainable storage levels. The data provided herein were directly linked to Shasta storage levels specified in the February 16, 2009 draft of NMFS' RPA document. The results of this and subsequent analyses, modeling simulations, and discussions have led to further refinement of the RPA, which is still in draft form. The rationale and justification for the storage levels ultimately specified can be found in the final BO and RPA documents.

In the February 2009 draft, Action I.2.2 (maintain minimum Shasta Reservoir storage) specifies the following:

> **Description of Action**: Shasta reservoir storage shall be managed to maintain the following levels:
>
> 1. **End of April storage**:
>   - Minimum end of April (EOA) storage for all water year types other than those specified below: 3.8 million acre feet (MAF) (Objective to meet Balls Ferry temperature compliance point (TCP) through management of cold water pool releases).
>   - Minimum EOA storage for wet years: 4.2 MAF (Objective to meet Jellys Ferry TCP through adaptive management of cold water pool releases).
>   - Minimum EOA storage for third (or more) year in a series of dry and/or critically dry years (*i.e.*, a prolonged drought): 3.3 MAF (Objective to meet Clear Creek TCP through management of cold water pool releases).
> 2. **End of September storage and late fall releases:**
>   - Minimum end of September (EOS) storage: 2.2 MAF (Objective to meet 3.8 MAF in EOA the following year).
>   - Minimum EOS storage for second (or more) year in a series of dry and of critically dry years: 1.9 MAF (Objective to meet 3.3 MAF in EOA in the following year).
>   - Fall storage shall not be depleted at a level greater than XX % between September 30 and December 15.

In order to evaluate these proposed Shasta storage levels in the context of storages that have actually been achieved over time, EOA, EOS, December 15th, and end of December (EOD) Shasta storage records (Station ID: SHA) were accessed from the California Department of Water Resources' (DWR) California Data Exchange Center (CDEC) water supply division from 1955-2008. The period of record for December 15th ranged from 1987-2007. These historical

data were then compared to the specified storage targets to generate statistics representing the number of instances in the period of record in which the proposed storage levels were met. The objective and the historical comparison for each objective are listed below.

1. End of April storage

Minimum end of April (EOA) storage for all water year types other than those specified below: 3.8 million acre feet (MAF) (Objective to meet Balls Ferry temperature compliance point (TCP) through management of cold water pool releases).

- For 54 years of data (WY 1955 – 2008), Shasta EOA storage ≥ 3.8 MAF during non-wet WY types and not the third year (or more) of dry/critically dry WY types:
  - 30 years fell within the WY type specifications (**55.7%** of period of record)
  - 22 of 30 years meet the ≥ 3.8 MAF target (**73.3%**)

Minimum EOA storage for wet years: 4.2 MAF (Objective to meet Jellys Ferry TCP through adaptive management of cold water pool releases).

- For 54 years of data (WY 1955 – 2008), Shasta EOA storage ≥ 4.2 MAF during wet WY types:
  - 20 years fell within the WY type specifications (**36.7%** of period of record)
  - 13 of 20 years meet the ≥ 4.2 MAF target (**65.0%**)

Minimum EOA storage for third (or more) year in a series of dry and/or critically dry years (*i.e.*, a prolonged drought): 3.3 MAF (Objective to meet Clear Creek TCP through management of cold water pool releases).

- For 54 years of data (WY 1955 – 2008), Shasta EOA storage ≥ 3.3 MAF during third (or more) year of drought:
  - 4 years fell within the WY type specification (**7.6%** of period of record)
  - 1 of 4 years meets the ≥ 3.3 MAF target (**25%**)

2. End of September storage and late fall releases

Minimum end of September storage: 2.2 MAF (Objective to meet 3.8 MAF in end of April the following year)

- For 54 years of data (WY 1955 – 2008), Shasta EOS storage ≥ 2.2 MAF in all WY types other than second (or more) year of drought:
  - 45 years fell within the WY type specification (**83.3%** of period of record)
  - 39 of 45 years meet ≥ 2.2 MAF EOS target (**86.7 %**)
- Shasta EOS storage ≥ 2.2 MAF in all WY types other than second (or more) year of drought **and** EOA ≥ 3.8 MAF the following year
  - 32 of 39 years of EOS ≥ 2.2 MAF meet EOA ≥ 3.8 MAF target (**82.1%**)

Minimum end of September storage for second (or more) year in a series of dry or critically dry years: 1.9 MAF (Objective to meet 3.3 MAF in end of April in the following year)

- For 54 years of data (WY 1955 – 2008), Shasta EOS storage ≥ 1.9 MAF during second (or more) year of drought:
  - 9 years fell within the WY type specification (**16.7%** of period of record)
  - 3 of 9 years meet 1.9 MAF EOS target (**33.3%**)
- Shasta EOS storage ≥ 1.9 MAF in all during second (or more) year of drought **and** EOA ≥ 3.3 MAF the following year
  - 2 of 3 years of EOS ≥ 2.2 MAF meet EOA ≥ 3.3 MAF target (**66.7%**)

Fall storage shall not be depleted at a level greater than XX% between September 30 and December 15

- For 21 years of data (WY 1987-2007), fall storage changed between September 30 and December *15*:
  - Average: + **4.0%**
  - Maximum increase: + **32.9%** (11 years w/ increased storage)
  - Maximum decrease: - **8.5%** (10 years w/ decreased storage)
- For 53 years of data (WY 1955-2007), fall storage changed between September 30 and December *31*:
  - Average: + **7.0%**
  - Maximum increase: + **85.9%** (25 years w/ increased storage)
  - Maximum decrease: - **14.1%** (28 years w/ decreased storage)
  - For years when EOD storages were less than EOS storages, the following year EOA storages averaged **4.04 MAF**.
  - For years when EOD storages were greater than EOS storages, the following year EOA storages averaged **3.88 MAF**.
  - For the second (or more) year of a drought, EOD storages increased 5 of 9 years. The average EOS to EOD storage change for all of those 9 years was + **19.1%** with average EOA storage the following year of **2.95 MAF**.

Figures 1-5 below provide storage time series, exceedance, and fall storage change plots for graphical/alternative representations of the data and statistics presented above.

As previously stated, this data provided a basic summary of historical Shasta Reservoir storage data for comparison purposes. This analysis was one of many components utilized to establish a basis and supporting rationale for the development of reasonable and appropriate Shasta storage targets for the NMFS OCAP BO. The data used in this analysis, additional graphics, an electronic version of this memo, and a detailed CD catalog are provided on the accompanying CD entitled *Historical Shasta Reservoir Storage Levels*.

Please contact me with further questions and for clarification.

Craig Anderson

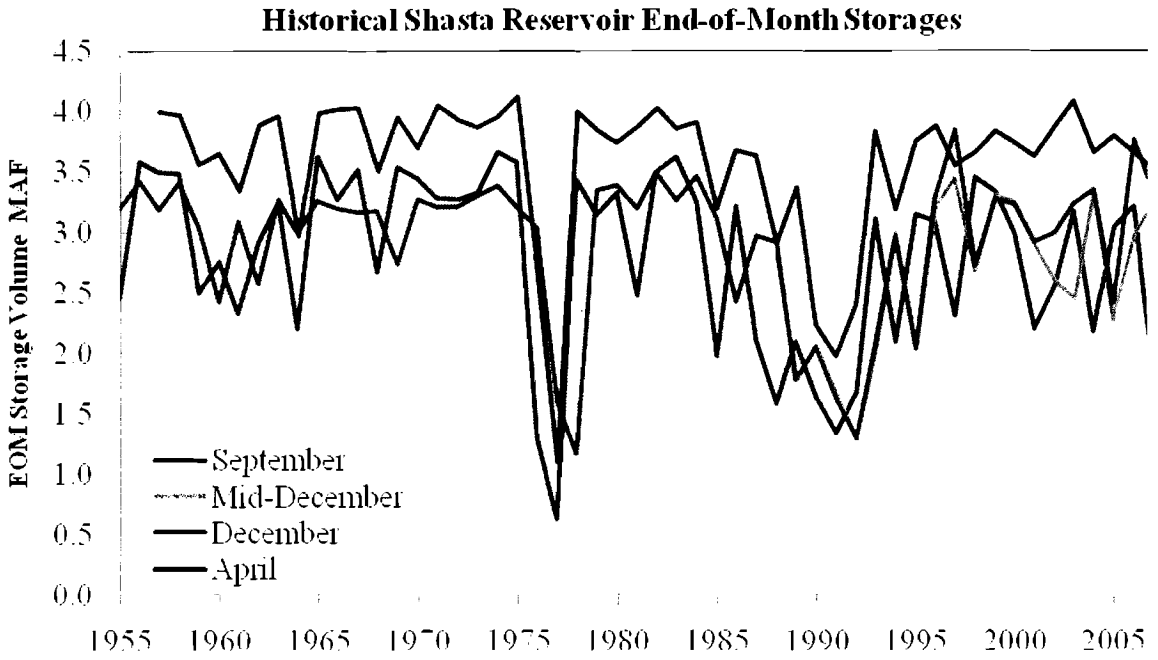


Figure 1. Shasta Reservoir end-of-month storage volumes in million acre-feet from 1955-2007 for September 30, December 15 (Mid-December), December 31, and April 30.

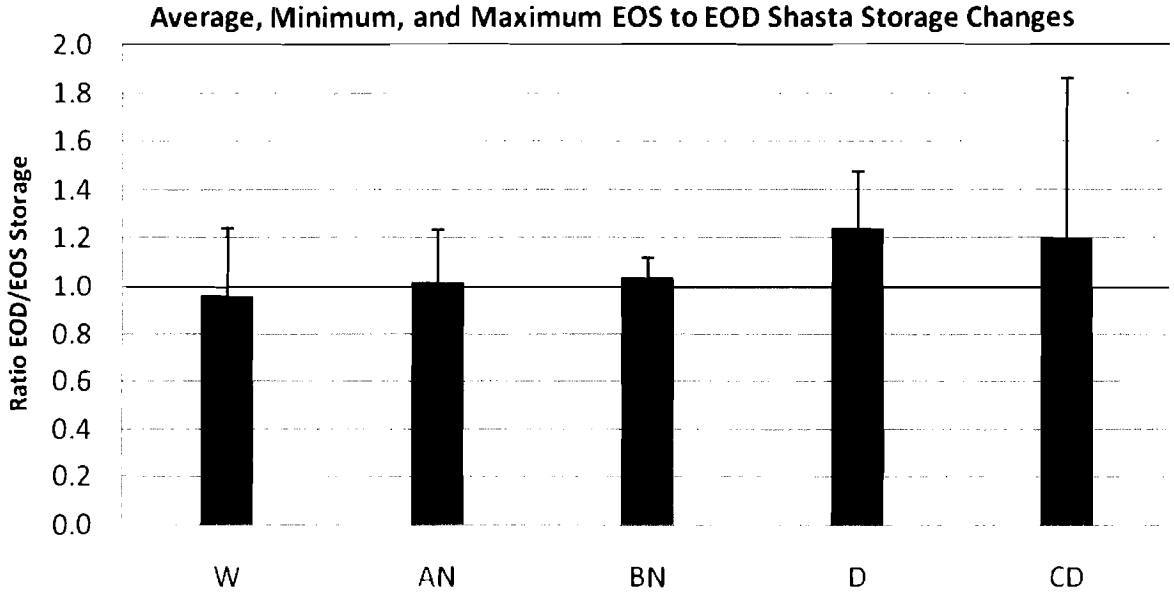
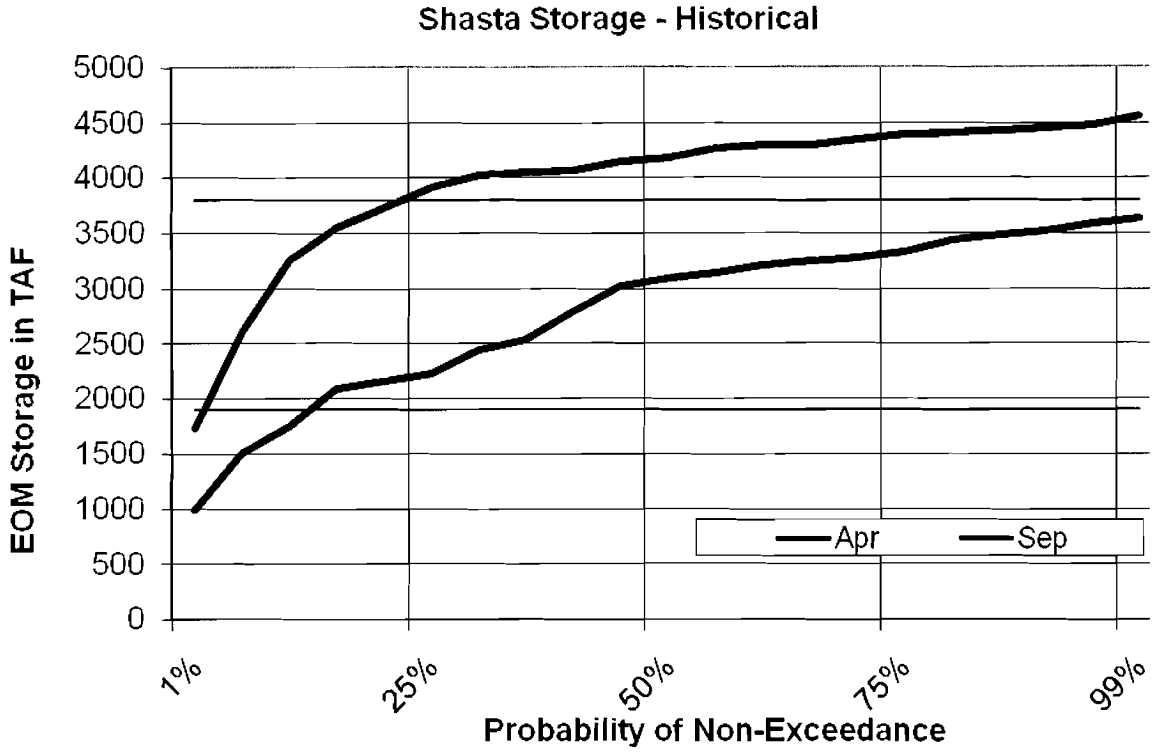
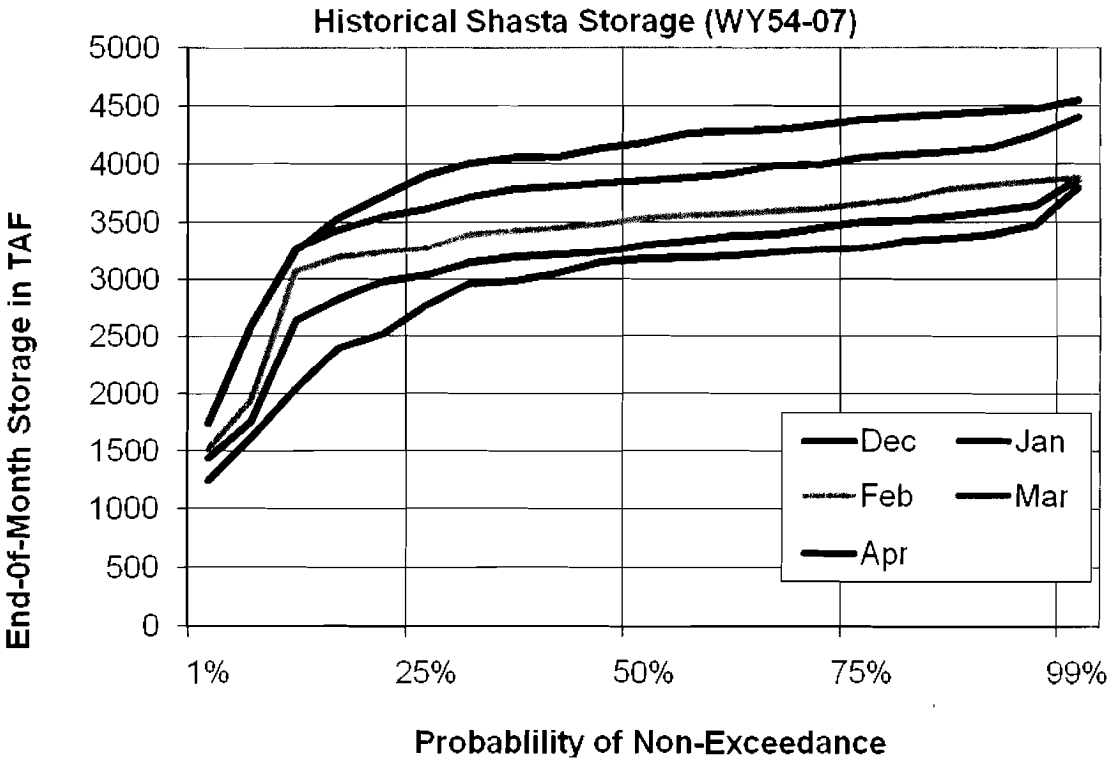
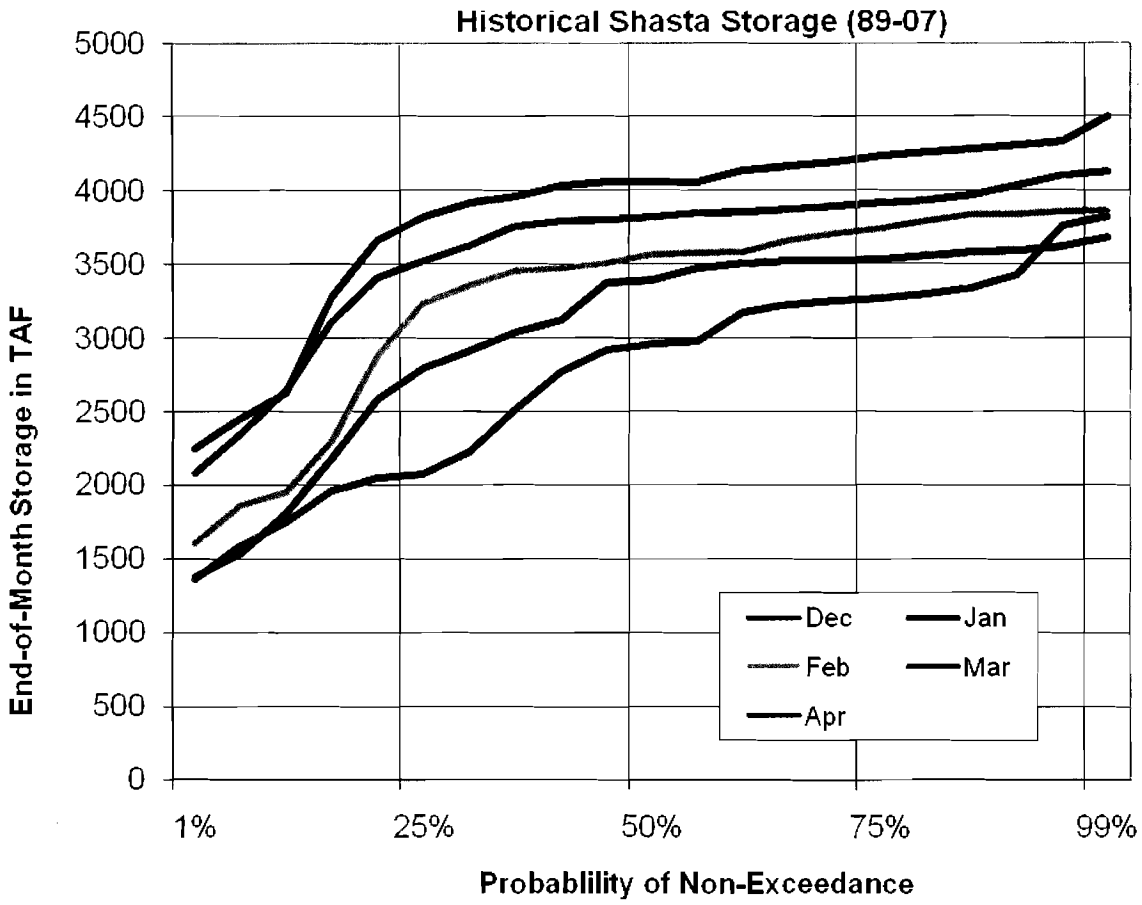


Figure 2. Ratio of December 31 to September 30 Shasta Reservoir storage by water year type from 1955-2007. Solid bars represent the average with whisker bars showing the minimum and maximum and the red line representing 1:1 ratio. Values less than 1 (only wet WY type) reflect a storage depletion between EOS and EOD, and values greater than one (all other WY types) reflect accretions between EOS and EOD.

Figures 3-5. Various EOM Shasta Storage non-exceedance plots






Historical Shasta Storage (89-07)
End-of-Month Storage in TAF
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1%
25%
50%
75%
99%
Probablility of Non-Exceedance
Dec
Jan
Feb
Mar
Apr