Responses to Comments on Draft Environmental Impact Report

Volume 2 of 2

For the
San Francisco Public Utilities Commission's

Regional Groundwater Storage and Recovery Project

July 9, 2014

Important Dates:	
Draft EIR Publication Date:	April 10, 2013
Draft EIR Hearing Dates:	May 14, 2013 in San Mateo County
	May 16, 2013 in San Francisco
Draft EIR Public Comment Period:	April 10, 2013 through June 11, 2013
Final EIR Certification Meeting Date:	August 7, 2014

City and County of San Francisco Planning Department
Case No. 2008.1396E
State Clearinghouse No. 2009062096

Regional Groundwater Storage and Recovery Project

Responses to Comments on Draft EIR

Volume 2 of 2

San Francisco Planning Department Case No. 2008.1396E
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Written comments should be sent to:

Sarah Jones, Environmental Review Officer
Regional Groundwater Storage and Recovery Project
San Francisco Planning Department
1650 Mission Street, Suite 400
San Francisco, CA 94103

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Draft EIR Comment Letters and Emails

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Draft EIR Comment Letters and Emails

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			GC-3, Adequacy of the Draft EIR
			GC-4, Discussion/Involvement with the SFPUC
			PD-7, SFPUC Easement at Golden Gate National Cemetery
			OV-1, Cumulative Projects
			LU-1, Construction-period Impacts
			LU-2, Land Use Impacts Due to Operations
			LU-3, Cumulative Land Use Impacts
			LU-6, Land Use Designations
			AE-5, Aesthetic Impacts at Sites 14 and 15
			CR-3, Impacts on Cultural and Historical Resources at the Golden Gate National Cemetery
			AL-1 Additional Alternatives to the Proposed Project
G-San Mateo PW-Chow	Mark Chow	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			PD-2, Required Permits and Approvals
			PD-5, Well Facility Design and Construction
			HY-3, Storm Water Pollution Prevention Plan and Site-specific Discharge Plan
			HY-4, San Mateo County Flood Control District Policy
			HY-5, Operational Well Maintenance Discharges to Storm Drains
G-BAWSCA-Sandkulla	Nicole M. Sandkulla	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			IN-1, Purpose of the WSIP
			PD-3, Project Figures
			PD-8, Treatment for Volatile Organic Compounds
			PD-15, Project Operational Triggers
			PD-19, Maintenance Pumping Rates
			PD-25, Clear Project Description
			HY-15, Well Interference and Mitigation Measure M-HY-6
			HY-44, Amount of Overdraft

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Draft EIR Comment Letters and Emails

Comment Code	Full Name	Comment Type	Topic Code
G-BAWSCA-Sandkulla	Nicole M. Sandkulla	Letter	HY-48, Mitigation of Groundwater Depletion Impacts
G-Daly City-Sweetland	Patrick Sweetland	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			OV-1, Cumulative Projects
			HY-24, Compressibility Values and Subsidence Monitoring
			HY-29, Cumulative Seawater Intrusion Impacts
			HY-33, Hydraulic Connectivity
			HY-41, Potential Water Quality Impacts from the Hillside Disposal Site
			HY-47, Groundwater Depletion Analysis
			HY-49, Cumulative Impacts of Groundwater Depletion
G-San Mateo RS-LoCoco	Joseph A. LoCoco	Email	GC-1, Unrelated to Adequacy of the Draft EIR
			GC-5, Not Related to GSR Project Draft EIR
			PD-2, Required Permits and Approvals
			PD-5, Well Facility Design and Construction
			TR-1, Traffic Control Plan
G-Colma-Laughlin	Michael P. Laughlin	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			GC-3, Adequacy of the Draft EIR
			PD-5, Well Facility Design and Construction
			PP-1, Colma Spanish/Mediterranean Architectural Requirement
			AE-1, Visual Impact of Tree Removal and Replanting at Site 7
			AE-2, Visual Quality at Site 8
			AE-3, Visual Impacts at Site 9
			AE-4, Design of Well Facility Sites in Colma
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			TR-1, Traffic Control Plan
			NO-1, Mitigation Measures M-NO-1 and M-NO-3
			HY-3, Storm Water Pollution Prevention Plan and Site-specific Discharge Plan

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Draft EIR Comment Letters and Emails

Comment Code	Full Name	Comment Type	Topic Code
G-San Bruno-Fabry	Klara A. Fabry	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			PD-6, Facility Classifications
			PD-9, Use of Portable Generators
			PD-10, Pumping at Peak Capacity
			PD-13, Project Operations during Put Periods
			PD-14, Operating Agreement
			PD-16, SFPUC Storage Account
			OV-2, References
			RE-1, Sea Level Elevations
			HY-24, Compressibility Values and Subsidence Monitoring
			HY-34, Nitrate in Irrigation Water
			HY-48, Mitigation of Groundwater Depletion Impacts
O-TRT-Drekmeier	Peter Drekmeier	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			GC-3, Adequacy of the Draft EIR
			HY-50, Diversions from the Tuolumne River
			HY-51, Raker Act
			HY-52, Data After Publication of the WSIP PEIR, including the Kirkwood Agreement
			AL-1, Additional Alternatives to the Proposed Project
O-RHH-Rosekrans	Spreck Rosekrans	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			GC-2, Project Merit
			GC-7, Water Supply Planning
			HY-51, Raker Act
			AL-1, Additional Alternatives to the Proposed Project
O-CGC-Maddow	Robert B. Maddow	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			GC-2, Project Merit
			PD-18, Recharge Test and Scaling Up from Pilot Test to Basin-wide Implementation
			PD-24, Project Implementation Alternatives

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Draft EIR Comment Letters and Emails

Comment Code	Full Name	Comment Type	Topic Code
O-CGC-Maddow	Robert B. Maddow	Letter	HY-9, Groundwater Rights
			HY-15, Well Interference and Mitigation Measure M-HY-6
			HY-34, Nitrate in Irrigation Water
O-CLMP-Quick	Deborah E. Quick	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			GC-3, Adequacy of the Draft EIR
			GC-6, CEQA Process
			PD-4, Facility Site Locations
			PD-11, Using Partner Agency Wells for GSR Pumping
			PD-12, Project Operating Period
			PD-16, SFPUC Storage Account
			PD-17, Groundwater Recharge from Precipitation
			PD-20, Hydrogeology, Well Screening Intervals and Seals
			PD-21, Project Pumping in Prolonged Drought
			PD-22, Emergency Pumping
			PD-23, Project Pumping in WSIP PEIR
			PD-26, Commenter's Description of Project
			OV-1, Cumulative Projects
			OV-3, Modeling Climate Change
			OV-4, Groundwater Modeling
			OV-5, Uncertainty of Model Results
			LU-5, Importance of Irrigation for Cemetery and Golf Course Land Uses
			AE-6, Project's Effects on the Aesthetic Quality of Cypress Lawn Memorial Park and Other Cemeteries
			AE-7, Project's Effects on Water Quality Aesthetics
			CR-2, Historic Value of Resources at Cypress Lawn and Other Cemeteries
			GG-1, Operational Greenhouse Gas Emissions
			GG-2, Electricity Use
			UT-1, Water Supply Sources

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Draft EIR Comment Letters and Emails

Comment Code	Full Name	Comment Type	Topic Code
O-CLMP-Quick	Deborah E. Quick	Letter	UT-2, Wastewater System Capacity
			HY-1, North and South Westside Groundwater Basins
			HY-2, Hydrologic Setting
			HY-6, Duration and Frequency of Monitoring
			HY-7, Pumping Costs
			HY-8, Significance Criterion for Project Impacts to the Aquifer
			HY-9, Groundwater Rights
			HY-10, Well Interference Thresholds
			HY-11, Significance Thresholds for Groundwater Levels Falling below the Well Screen
			HY-12, Well Interference Monitoring
			HY-13, Methods for Determining if Well Interference Impacts are Due to the Project
			HY-14, Reduction of Well Interference Impacts to Less than Significant
			HY-15, Well Interference and Mitigation Measure M-HY-6
			HY-16, Well Interference Mitigation Measure Performance Standards
			HY-17, Participation of Irrigators for Mitigation Measure M-HY-6
			HY-18, Representation of Existing Irrigators
			HY-19, Effects of Climate Change on Irrigation Demand
			HY-20, Operation of Multiple Wells Simultaneously
			HY-21, Cypress Lawn Discharge Capacity
			HY-22, Barrier Boundaries relative to Well Interference Estimates
			HY-23, Subsidence
			HY-25, Significance Thresholds for Subsidence
			HY-26, Inclusion of a Subsidence Map in the Draft EIR
			HY-27, Adequacy of Seawater Intrusion Analysis
			HY-28, Saltwater/Freshwater Interface and Upconing

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Draft EIR Comment Letters and Emails

Comment Code	Full Name	Comment Type	Topic Code
O-CLMP-Quick	Deborah E. Quick	Letter	HY-29, Cumulative Seawater Intrusion Impacts
			HY-30, Use of Averages in the Draft EIR Seawater Intrusion Analysis
			HY-31, Sea Level Rise for Seawater Intrusion
			HY-34, Nitrate in Irrigation Water
			HY-35, Vertical Stratification of Constituents
			HY-36, Contamination Limited to the First 50 Feet
			HY-37, Using Time-averaged Water Levels in the Draft EIR Water Quality Evaluation
			HY-38, Drinking Water Quality
			HY-39, Irrigation Water Quality
			HY-40, Groundwater Contamination in Areas not Near GSR or Partner Agency Wells
			HY-42, Impacts on Safe Yield or Sustainable Yield of the Westside Groundwater Basin
			HY-43, System Losses
			HY-45, Groundwater Budget
			HY-46, Local and Regional Impacts of Pumping
			HY-48, Mitigation of Groundwater Depletion Impacts
			HY-49, Cumulative Impacts of Groundwater Depletion
			HY-53, Need for More Details on Monitoring and Mitigation Measures
			AL-2, Environmentally Superior Alternative
I-King	Christopher King	Letter	PD-3, Project Figures
I-Robert	Robert in San Bruno	Letter	GC-1, Unrelated to Adequacy of the Draft EIR
			GC-2, Project Merit
			PD-1, Project Objectives
			LU-4, Land Use Decisions
I-Lawrence (1)	Steve Lawrence	Email	GC-1, Unrelated to Adequacy of the Draft EIR
			HY-23, Subsidence

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Draft EIR Comment Letters and Emails

Comment Code	Full Name	Comment Type	Topic Code
I-Lawrence (1)	Steve Lawrence	Email	HY-32, Project's Effects on Lake Merced
			HY-44, Amount of Overdraft
			HY-54, Rising Groundwater Levels and Land Use Impacts Therefrom
I-Lawrence (2)	Steve Lawrence	Email	GC-2, Project Merit
			HY-32, Project's Effects on Lake Merced
			AL-1, Additional Alternatives to the Proposed Project

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G-VA-MADDEROM

DEPARTMENT OF VETERANS AFFAIRS
Office of Construction & Facilities Management
Washington DC 20420

May 25, 2013

Greg Bartow
Groundwater Program Manager
San Francisco Public Utilities Commission
525 Golden Gate Ave., 10th floor
San Francisco, CA 94102

RE: VA's Comments to San Francisco Public Utilities Commission's (SFPUC) Draft Environmental Impact Report (EIR) for the Regional Groundwater Storage and Recovery Project

The U.S. Department of Veterans Affairs (VA) has reviewed the EIR for the Regional Groundwater Storage and Recovery Project, San Francisco, CA released for public review on April 10, 2013 by the San Francisco Planning Department.

Thank you for providing VA with the opportunity to comment on the Draft EIS document. Here are VA's review comments. GC-1

A) The Draft EIS fails to recognize the fact that the two wells that are being proposed to be placed on Golden Gate National Cemetery (GGNC) property will adversely and negatively impact the environment, by eliminating VA's future ability to utilize Federally owned groundwater located below the cemetery, for cemetery irrigation needs and purposes. VA is planning to re-establish existing irrigation wells on GGNC property, in order to reduce dependence on SFPUC potable water currently being used for cemetery irrigation purposes, and to support and enhance National Cemetery Administration operations and mission of honoring and providing dignified burial services to Veterans and their families. Establishment of two SFPUC owned wells on VA national cemetery property will have significantly adverse and negative effects upon VA, including environmental impacts impinging on VA's ability to reduce the use of potable water to maintain the national cemetery grounds. OV-1

B) SFPUC's proposed plan to establish two wells on GGNC cemetery grounds would have negative impact to the aesthetic environment and operation of the national cemetery. AE-5 As demonstrated by preliminary plans that have been sent to VA, SFPUC's plan reflects definite adverse impacts to the architectural, historical, and aesthetics of these historic national cemetery grounds. CR-3

C) SFPUC proposed plan to establish two wells on GGNC cemetery grounds would negatively impact the national cemetery operations and security. Proposed installation of SFPUC operational facilities on the GGNC property carries with it a new level of perpetual non-VA access to the facility. This would lead to non-VA personnel, equipment, and potential SFPUC subcontractors needing to enter upon the cemetery grounds, to perform maintenance and repair on the proposed new facilities. LU-2

D) There are substantial environmental benefits that will be obtained thru VA re-establishing irrigation wells to reduce reliance on SFPUC potable water system, in lieu of SFPUC placing two OV-1

G-VA-MADDEROM cont.

wells on GGNC property. It would benefit the environment by reducing the quantity of potable water needed to maintain the national shrine appearance of the cemetery grounds, while at same time increasing the availability of SFPUC potable water to be supplied for other public uses within the SFPUC water distribution district. This benefits SFPUC and the environment, by lessening the GGNC potable water usage impact on their infrastructure, and eliminating the associated energy, chemical, processing, labor, and conveyance costs of providing potable water to GGNC for irrigation purposes. By investing in new irrigation well infrastructure and associated well operational costs, NCA will be able to reduce annual irrigation expenses, so that those cost savings can be used to benefit veterans in other ways. This is a very responsible approach to acquiring resources necessary for operation of the GGNC. It also demonstrates NCA's prudent stewardship of taxpayer dollars, and VA being environmentally responsible, while supporting and enhancing NCA's mission of honoring and providing dignified burial services to Veterans and their families. OV-1 Cont.

Project Description (starting Page 3-102) Comments:

1. The description indicates that the "... well facility would be located on an existing SFPUC easement ..." – the existing easement is only for conveyance of water (i.e. underground piping passing through) – it does not cover installation and operation of water production well (s). PD-7

2. With respect to Proposed Well 14 - the analysis presented in Table 5.2-1 similarly incorrectly notes the easement status – it is noted under the column heading: "On SFPUC Land?" as "Yes, SFPUC Right of Way".

3. With respect to Proposed Well 14 - in this same table – it notes that the construction is "adjacent" to the land use of "Cemetery" – when in fact, it is in the middle of a Veterans National Cemetery. LU-6

4. With respect to Proposed Well 14 – p 5.2-13 repeats this assertion of "existing SGPUC easement".

The Summary of Impacts - Land Use Table 5.2-2 presents several errors in analyses:

5. VA is certainly not in agreement with the analyses of LS for Site 14, which alleges that "Project operations would not result in substantial long-term or permanent impact on the existing character or disrupt or displace land uses." The well pumps will make substantial noise during operation – not in character with a National Cemetery. LU-2 More problematic would be the access to the well house for either "normal" maintenance or "emergency" repairs. It is presumed that "normal" O&M activities, either by in-house personnel and equipment or by SFPUC contractors, would not take into account the operating requirements of a National Cemetery with respect to funeral corteges, committal services, visitors seeking quiet solitude at gravesites, interment operations, ceremonies, etc LU-2

6. Same comment for Site 15. LU-2

7. With respect to Site 14 - one cannot conclude that a "Cumulative Impact" can be "Less than Significant" if there is a Direct Impact (see comment #5 above). LU-3

8. Same comment for Site 15. LU-3

9. The justification provided on p 5.2-32 for (construction) "Impact Conclusion: Less than Significant with Mitigation" regarding Land Use for Site 14 is quite faulty. It "" over 1,100 feet of new pipeline construction, yet the only land use under analyzed regards vehicular traffic internal to the Cemetery. It proposes Mitigation Measure M-LU-1 (Maintain Internal Cemetery Access) LU-1

as the only necessary Mitigation. It speaks nothing of other types of land use impacts such as: dust, visual, vibration, etc. on National Cemetery operations, including funeral corteges, committal services, interment operations, ceremonies, etc. LU-1 Cont.

10. The justification provided on p 5.2-32 for (construction) "Impact Conclusion: Less than Significant with Mitigation" regarding Land Use for Site 14 is quite faulty. Presented in this same section is an analysis of the noise impacts to the adjacent residences – however – it does not present any information, data, or analyses w/r to noise impacts to the National Cemetery operations. LU-1

11. The justification provided on p 5.2-32 for (construction) "Impact Conclusion: Less than Significant with Mitigation" regarding Land Use for Site 14 is quite faulty. In the noise analyses (only for residences) it presents, for the first time, the concept of nighttime drilling for installation of the wells. No VA National Cemetery nation-wide is allowed to be open after dark. If this nighttime drilling concept is actually proposed, there are no analyses thereof – and regardless, VA would not approve. LU-1

12. Section 5.2.3.5 Operation Impact and Mitigation Measures is likewise faulty in its analyses. This section lumps Sites 14 and 15 in with many others as: "Less than Significant with Mitigation." VA disagrees with the statement concluding: "... the cemetery land use would, therefore, not be disrupted or displaced." It talks of daily visitations during periods of groundwater pumping. It says nothing regarding scheduling of such visitations, nor their interaction with National Cemetery operations. LU-2

13. With respect to Site 14 - Table 5.3-4 presents a "Less than Significant" conclusion regarding night-time light during construction – how can this conclusion be correct when p5.2-32 speaks of night-time well drilling? There is minimal lighting in any National Cemetery – primarily honor flag and security lighting only – any night-time construction lighting would stand out tremendously. AE-5

14. Same comment for Site 15.

15. Page 5.3-70 notes that "... relatively few visitors would be affected by the construction activities over the 16-month duration at this location." This conclusion is quite incorrect. GGNC typically performs approximately 500 burials per year and typically receives hundreds of visitors throughout the cemetery grounds on a daily basis for activities such as gravesite visitation, funeral corteges, committal services, and ceremonial activities.

16. Page 5.3-70 also notes that "... less-than-significant level ... and inconspicuous construction area during the entire construction period and for all phases of construction in the GGNC." How does SFPUC plan to construct an 1,100' trenching operation for installation of water and storm water pipelines and an electrical feed "inconspicuously? How does SFPUC intend to require this in their Statement of Work? How does SFPUC intend to enforce said conditions of "inconspicuousness"? VA does not believe inconspicuous construction would be feasible in this scenario. AE-5

17. Similar comments for Site 15 as #15 and #16 above.

18. Page 5.3-94 presents a statement regarding to access to the proposed well pump house during construction, which is in contradiction to that of operation. "The mitigation measure requires that the well facility be located as close to the north GGNC fence ... It also requires the use of plywood temporarily placed on the ground to access the well facility, thereby eliminated the need for permanent grass pavers . . ." M-CR-5a states there will be grass pavers. Which is it? AE-5

G-VA-MADDEROM cont.

19. Page 5.3-94 regarding Mitigation Measure M-CR-5a – this MM fails to recognize and address the fact that the National Cemetery itself is nationally listed as a historic landmark listed, nor presents any discussion with respect to impact of the proposed SFPUC well structures on the National Cemetery itself. CR-3

Under this SFPUC proposal, there would be a great need for SFPUC to satisfactorily address the cultural, historical, and environmental impacts relative to the Golden Gate National Cemetery. In that regard, of considerable concern is that the Draft EIR fails to identify with any specificity impacts to this national shrine as required under Section 106 of the National Historic Preservation Act (NHPA) (16 U.S.C. § 470f). CR-3 As VA maintains burial operations at this facility, these impacts will greatly affect Veterans, Veterans families, visitors and VA personnel. VA believes that the proposed SFPUC wells on the NCA property would have a significant, adverse impact on NCA's operations and mission; preclude NCA from accessing the much needed, Federally-owned groundwater located below the NCA property; have significant environmental and historic preservation impacts; and reflect a true failure of the SFPUC to duly consider and pursue other viable alternatives besides attempting to locate their wells on NCA property. GC-3 Consequently, VA strongly urges SFPUC to select an alternative that does not impact the Golden Gate National Cemetery. AL-1

In closing, VA appreciates SFPUC's efforts in engaging the community, in order to ensure that the most viable solution is selected. VA would like to have further discussions on the issues discussed above, and appreciates the opportunity to work more closely with SFPUC with regard to ensuring full and proper analysis of the potential significant adverse impacts associated with the contemplated SFPUC wells, as well as due consideration of any requisite mitigations and/or alternatives. GC-4

We also thank SFPUC for providing us with the opportunity to comment. Please don't hesitate to contact me at 317-916-3797 or via e-mail at Glenn.Madderom@va.gov, to discuss our comments further.

Thank you in advance for your consideration and attention to this matter. GC-1

Sincerely yours,

G Madderom

Glenn Madderom
Chief, Cemetery Development and Improvement Service
575 N. Pennsylvania St, Room 495
Indianapolis, IN 46204-1581

COUNTY OF SAN MATEO

Department of Public Works

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May 17, 2013

G-San Mateo PW-CHOW

Ms. Sarah B. Jones, Acting Environmental Review Officer
San Francisco Planning Department
1650 Mission Street, Suite 400
San Francisco, CA 94103

Re: Notice of Availability of Public Review of Draft Environmental Impact Report for the Regional Groundwater Storage and Recovery Project, northern San Mateo County

Dear Ms. Jones:

The San Mateo County Department of Public Works, in its capacity as the Administrator of the San Mateo County Flood Control District (District), which includes the Colma Creek Flood Control Zone and the San Bruno Creek Flood Control Zone, hereinafter collectively referred as "Zones," has reviewed the Draft Environmental Impact Report for the subject project and offers the following comments: GC-1

- Our records confirmed that proposed project sites 5 through 14 and alternate sites 17, 18, and 19 are located within the Colma Creek Flood Control Zone and project site 15 is located within the San Bruno Creek Flood Control Zone. The District requires that the discharge rates from the various sites not exceed the existing rates prior to development, and drainage calculations showing existing and future discharge rates must be submitted to the District for review. HY-4

- The San Mateo County Flood Control District should be listed as a Permitting Agency in Table 3-11, on page 3-144, of the DEIR, in order to gain access onto the District's property. For example, the District would need to approve the use of the access road to Site 9. Conditions of approval would need to be met, such as, but not limited to, all gates shall be locked when the contractor is not working at the site, any removed fence sections shall be restored to existing or better condition, and SFPUC shall repair or replace any damage to the access road pavement or fence sections as a result of its operations. PD-2

- The DEIR states on Page 5.16-70, "The building and parking areas at all sites would result in limited amounts of new impervious surfaces. Therefore, project-related increases in stormwater runoff resulting from increases in impervious surfaces would not increase the potential for on- or off-site flooding and the impact would be less than significant." The District's policy described above of requiring that project proponent demonstrate that the post development discharge rate from the site not exceed the existing rate prior to development would still apply. Therefore, drainage calculations showing existing and future discharge rates must be submitted for review. If it is determined that the future discharge rate exceeds the existing rate, an on-site storm water detention system which would release surface runoff at a rate comparable to the existing flow rate of the site must be designed and incorporated into the project. HY-4

- The DEIR, on pages 5.16-71 and 5.16-72, states that Impact HY-5 would be less than significant, therefore requiring no mitigation measures. Discharges as a result of the weekly or monthly exercising of the production wells must still comply with the San Francisco Bay Region Municipal Regional Stormwater NPDES Permit (Order R2-2009-0074, NPDES Permit No. CAS612008). Therefore, the District requests that Impact HY-5 comply with the same conditions to be set by the RWQCB for Impact HY-2, which is discussed on page 5.16-68 of the DEIR. At a minimum, the District would like to be notified at least 14 days in advance of any HY-5

G-San Mateo PW-CHOW cont.

planned discharge. Additionally, no discharges shall occur during storm events. It should also be noted that the Permit Order cited on page 5.16-68 (listed as Order No. 99-059, NPDES Permit No. CAS002992) is not the permit currently in effect and should be corrected. HY-5 Cont.

- The Storm Water Pollution Prevention Plan and/or the Erosion and Sediment Control Plan to be prepared in accordance with Mitigation Measure M-HY-1, on Page 5.16-63, shall be submitted to the District for review. Tracking of dirt/mud will not be allowed onto the access road to Site 9. No trash and debris shall be allowed to be discarded along the access road and flood control channel. HY-3

- Discharge plans prepared in accordance with Mitigation Measure M-HY-2, on Page 5.16-67, shall be submitted to the District for review. Sediment laden and contaminated water shall not be discharged into the District's flood control channels without prior treatment to remove sediment and other contaminants. HY-3

- The District advocates that trash management measures be incorporated into the design elements of the storm drainage system and appurtenances. Please ensure that trash collecting devices are installed at storm drain inlets and maintained by the owner. PD-5

If you have any questions, please contact me at (650) 599-1489. GC-1

Very truly yours,

Mark Chow

Mark Chow, P.E.
Principal Civil Engineer
Utilities-Flood Control-Watershed Protection

MC:EVG:ac
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cc: Ann M. Stillman, P.E., Deputy Director, Engineering and Resource Protection
Joe LoCoco, P.E., Deputy Director, Road Services

BAWSCA
Bay Area Water Supply & Conservation Agency

G-BAWSCA-SANDKULLA

May 24, 2013

Ms. Sarah B. Jones
Acting Environmental Review Officer
Regional Groundwater Storage and Recovery Project Draft EIR Comments
San Francisco Planning Department
1650 Mission Street, Suite 400
San Francisco, CA 94103-2479

Subject: **Case No. 2008.1396E – Regional Groundwater Storage and Recovery Project, Draft Environmental Impact Report, State Clearinghouse No. 2005092026**

Dear Ms. Jones,

Thank you for the opportunity to provide the following comments from the Bay Area Water Supply & Conservation Agency (BAWSCA). BAWSCA represents the interests of 24 cities and water districts, an investor-owned utility, and a university, that purchase water wholesale from the San Francisco Regional Water System. These agencies, in turn, provide water to 1.7 million people, businesses, and community organizations in Alameda, Santa Clara, and San Mateo Counties. BAWSCA member agencies are highly dependent on the SFPUC Regional Water System (RWS) to provide a reliable supply of potable drinking water critical to the health and safety of consumers in the region. GC-1

These comments address the Draft Environmental Impact Report (DEIR) for the Regional Groundwater Storage and Recovery project dated April 10, 2013.

1. **One clear, definitive description of the Groundwater Storage and Recovery Project (Project) should be decided on and used consistently throughout the document.** The Project is described multiple times and in multiple ways. One consistent description should be used that includes the following:
   - Clear description of how the en-lieu recharge will work;
   - Clear description of how the dry-year groundwater pumping from the Westside basin by the Project Partners results in additional water being added to the RWS (i.e., directly through adding groundwater into the RWS and also by reducing surface water use by the Project Partners, which in turn makes that water available to other RWS users); PD-25
   - Which specific entities should expect to receive groundwater pumped from the Westside Basin during drought years or other uses of the Project; and
   - Clarify that the Project can be used in drought years, but also under other circumstances (e.g., emergencies).

G-BAWSCA-SANDKULLA cont.

2. **A robust system of actual water level measurements should be used to ensure that the water is actually being stored at the rate, and in the locations, that it is assumed to be.** The DEIR states multiple times that the volume of water in storage in the Westside Basin will be calculated using metered surface water deliveries (the Put) and metered groundwater extractions (the Take). Given the importance of this supply to regional water supply reliability, the calculated storage should be confirmed using actual field data, and using the groundwater basin model, as appropriate. HY-48

3. **The projected maintenance pumping rates for the Project wells are very different from that of the Project Partner wells.** The document should discuss the difference in assumptions regarding the maintenance of the Project wells and the Project Partner wells. If the Project wells need to be exercised more than the currently projected rates, please address the impact that will have on the Project operations and yield. PD-19

4. **A clear description, perhaps in chart form, that describes the triggers/conditions under which the Project would be operated would be helpful.** For example, if the basin has not reached full storage capacity, will the Project be used in a dry year? The relationship of the Put water to the SFPUC's self-imposed Interim Supply Limitation should also be clarified as part of this description. PD-15

5. **The yield of the Project needs to be clarified given the modeling results cited in the DEIR that suggest that the Westside Bain is in overdraft by about 1,000 AFY.** The proposed mitigation is to add additional Put years to offset the storage losses. Please clarify the how the project yield might, or might not be, decreased as a result of the need to do additional Put years as opposed to Hold or Take Years. The relationship of the Put water to the SFPUC's self-imposed Interim Supply Limitation should also be clarified as part of this description. HY-44

6. **Section 2.1 – Introduction (page 2-4).** The DEIR needs to be revised to correctly reflect the purpose of the WSIP as adopted by the Commission on October 30, 2008. San Francisco has a perpetual obligation to provide 184 mgd to the Wholesale Customers. The obligation is documented in the <u>2009 Water Supply Agreement Between San Francisco and its Wholesale Customers</u>. With the WSIP, the Commission deferred a decision to provide water supply in excess of 184 mgd to the Wholesale Customers (or 265 for the entire water system) until 2018. IN-1

7. **Section 3.4.2 – Production Wells and Associated Facilities (page 3-16).** The last sentence notes that certain additional treatment may be needed at some sites for certain water quality constituents. The text identifies Volatile Organic Compounds (VOCs) as a possible constituent for treatment. Table 3-3 (pages 3-18 through 3-22) indicates which sites are expected to need treatment and what constituents would be addressed. No sites indicate VOC treatment and there is no discussion of any specific treatment process or chemicals associated with VOC PD-8

G-BAWSCA-SANDKULLA cont.

removal in the section on "Well Plus Chemical Treatment" (page 3-29). Page 5.16-136 does suggest blending as a possible way to treat VOCs. The water quality discussion on page 5.16-29 notes that detected VOCs are rare and if detected are at low levels in the groundwater basin. Samples from Sites 1 and 11 detected VOCs in one sampling but only at Site 11 upon additional sampling. If there is a reasonable potential that VOCs may be encountered at one or more sites, the expected treatment scheme should be discussed in this section. PD-8 Cont.

8. **Section 3.4.1 – Groundwater Storage and Recovery, Figure 3-2 (page 3-9).** The volume of surface water deliveries should be added to the Project Conditions portion of Figure 3-2. Also, for Figure 3-2, please clarify what year the demand is representative of (i.e., is it current conditions or 2035 conditions). PD-3

9. **Section 5.16.3.7 – Operation Impacts and Mitigation Measures – Groundwater (page 5.16-93).** The text describes an ongoing monitoring program and analysis of groundwater data to understand project operation impacts on nearby wells. If the groundwater model is to be used for analysis purposes, the periodic recalibration of the model is important for accurate results. Please clarify the expected interval for model recalibration. HY-15

Thank you for the opportunity to provide these comments on the DEIR for the Regional Groundwater Storage and Recovery Project dated April 10, 2013. If you have any questions, please contact me at (650) 349-3000. GC-1

Sincerely,

Nicole M. Sandkulla, P.E.
Water Resources Planning Manager

cc: J. Labonte, SFPUC
T. Roberts, Terry Roberts Consulting
File

G- DALY CITY- SWEETLAND

CITY OF DALY CITY

Department of Water and Wastewater Resources

153 Lake Merced Boulevard
Daly City, CA 94015
(650) 991-8200
Fax (650) 991-8220

Patrick Sweetland, Director

June 10, 2013

Sarah B. Jones
Acting Environmental Review Officer
San Francisco Planning Department
1650 Mission Street, Suite 400
San Francisco, CA 94103

Subject: Regional Groundwater Storage and Recovery Project

Dear Ms. Jones:

The City of Daly City welcomes the opportunity to comment on the Draft Environmental Impact Report (DEIR) for the Regional Groundwater Storage and Recovery Project. Daly City would again acknowledge a well established track record of mutual cooperation with San Francisco aimed at preserving the Westside Groundwater Basin as a potable drinking water supply. Our agencies joint efforts include securing grant funding to install a series of groundwater sentinel wells, activities to construct and distribute recycled water, creating a fully vetted groundwater aquifer model, ongoing semi-annual groundwater monitoring among basin users, and efforts aimed at developing a Lake Management Plan addressing sustainable water levels at Lake Merced. It is from that vantage the City of Daly City offers the following comments. GC-1

HY-7: Project operation would not result in substantial land subsidence due to decreased groundwater levels in the Westside Groundwater Basin where the historical low water levels are exceeded (*Less than Significant*). Daly City concurs. The subsidence analysis provides reasonable results given the tools and data available. However, in "Approach to Analysis," the DEIR states that "laboratory test results of the compressibility of clays in the Westside Groundwater Basin were not available and, therefore, typical soil compressibility values of the Merced Formation (which underlies much of the Westside Groundwater Basin) were used in the estimations of subsidence." The November 19, 2012 memorandum "Response to Comment on Subsidence TM" provides additional explanation on the consideration of sediment age and burial depth in the selection of assumed compressibility values utilized in the calculations.[1] Nevertheless, the issue remains that the compressibility values used in the subsidence calculations are assumed. Furthermore, the proposed project will significantly increase HY-24

[1] Memorandum from Peter Leffler to Greg Bartow, *"Response to Comment on Subsidence TM,"* November 19, 2012.

groundwater extractions from the deepest parts of the aquifer system (the "deep" aquifer), which is beneath the thickest and most extensive continuous clay bed identified in the basin (the "W-clay"). It is prudent to establish baseline land surface elevation information from which future data can be compared to reliably conclude whether or not subsidence occurs. The South Westside Basin Groundwater Management Plan specifies actions to collect evidence of active subsidence should basin water levels decrease below historic levels. HY-24 Cont.

HY-9 and C-HY-5: Project operation could have a substantial, adverse effect on water quality that could affect the beneficial uses of Lake Merced (*Less than Significant with Mitigation*). Daly City concurs. The impacts to Lake Merced are also a concern for the San Francisco Groundwater Project. Modeled lake levels are for the project conditions are lower than the existing condition scenario. Corrective actions are proposed that include adding supplemental water (either SFPUC system water, treated storm-water, or recycled water), if available, and/or altering or redistributing pumping patterns. GC-1 Daly City is working in conjunction with San Francisco on a Lake Merced Management Plan as part of its efforts associated with the Vista Grande Drainage Basin Improvement Project. OV-1

HY-12: Project operation would not cause a violation of water quality standards due to mobilization of contaminants in groundwater from changing groundwater levels in the Westside Groundwater Basin (*Less than Significant*). Daly City concurs with the following caveat. The basis for the *Less than Significant* impact seems to depend in part on the DEIR text describing shallow groundwater zones as being isolated, hydraulically separated, and disconnected hydraulically from the Primary Production Aquifer. The following observations indicate the Primary Production Aquifer is not isolated from land surface and percolating groundwater recharge.

- If the Primary Production Aquifer were isolated/hydraulically separated from groundwater recharge, as purported by the DEIR, then water and dissolved constituents in recharge are not expected to migrate downwards into the Primary Production Aquifer. However, monitoring data from Primary Production and deeper Deep Aquifer wells has detected constituents like nitrate (pg. 5-16.28), and VOCs (pg. 5.16-29), which are associated with land surface activities. These constituents conceivably reached these depths by migrating downwards with recharge. HY-33

- In-lieu recharge depends on a hydraulic connection between groundwater recharge and the Primary Production Aquifer, although the characteristics of that connection are spatially variable. Conjunctive use pilot projects have shown that in-lieu recharge to the shallow aquifer over large basin areas contribute significant volumes of water that can be extracted by wells constructed in the Primary Production and Deep Aquifers (pg. 5-16.20). An in-lieu recharge project would be infeasible if the Primary Production Aquifer was isolated, hydraulically separated or disconnected from groundwater recharge.

However, changes to vertical gradients primarily influence the potential for constituents near land surface to reach the Primary Production Aquifer in groundwater recharge. On average, the project reduces vertical hydraulic gradients relative to existing conditions, and significant groundwater quality changes due to the project are therefore not expected. We request that the importance of vertical gradients be emphasized in the next EIR document by removing phrases like "assuming there is a hydraulic connection," "disconnected hydraulically," and "limited hydraulic connectivity." We believe this can be easily achieved by incorporating the information as was presented in the January 31, 2013 memorandum "Clarification of Task 10.6 Technical Memorandum Aquifer Nomenclature and Physical Processes Affecting Water Quality in the South Westside Groundwater Basin." [2] HY-33 Cont.

Therefore, Daly City concurs that water quality impacts, if any, should be *Less than Significant*. Groundwater monitoring and analyses as part of managing the project under the Operating Agreement as well as water supply monitoring by the Participating Pumpers should identify the presence of constituents of concern, and the extracted groundwater would be treated to ensure all drinking water standards are met.

Additionally, please note that the Hillside Class III Disposal Site located in Colma is closed, but it is a community concern in regards to potential water quality impacts. Daly City is aware of some community members that have identified it as a potential threat to the basin groundwater supply.[3] The disposal site location is shown in Appendix H of the DEIR – Technical Memorandum 10.6 "Groundwater Quality" (Figure B-1, Solid Waste Facility Location in Attachment 10.6-B *Existing Regulated Sites – Geotracker, SWIS, DTSC, and SLIC*), and the DEIR concludes that the Hillside Class III Disposal Site is outside of the Groundwater Protection Zone for the proposed project wells.

HY-41

Information from the Westside Basin Groundwater Monitoring Program indicates that in the vicinity of the Hillside Disposal Site, groundwater flow in the Primary Production Aquifer is away from Daly City wells and south towards Colma and South San Francisco. Although groundwater and dissolved constituents originating at the site are likely moving away from Daly City, they could be moving toward pumping wells located south of Daly City. Daly City wants to express the importance of water quality monitoring in this and all parts of the basin, and notes that should water quality at proposed wells be impacted by groundwater originating at the Hillside Disposal Site, monitoring and analyses required under the Operating Agreement as well as bi-annual water supply monitoring should identify the presence of constituents of concern. Any violation of

[2] Memorandum from Greg Bartow to Tim Johnston, *"Clarification of Task 10.6 Technical Memorandum Aquifer Nomenclature and Physical Processes Affecting Water Quality in the South Westside Groundwater Basin,"* January 31, 2013.

[3] Steve Bond and Associates, Inc., March 14, 2008 letter to Mr. Vic Pal, San Francisco Bay Regional Water Quality Control Board, "March 2008 Tentative Order, Waste Discharge Requirements for Hillside Landfill, Colma, San Mateo County."

drinking water standards would be addressed by treatment, such as blending, to ensure all drinking water standards are maintained. HY-41 Cont.

Lastly, the DEIR correctly notes that rising groundwater levels would not dilute nitrate concentrations. Furthermore, it correctly notes that pumping and in-lieu recharge could result in changes in groundwater flow directions and conceivably transport existing elevated concentrations of dissolved nitrates in groundwater towards Project wells or Partner Agency wells. The DEIR indicates that should this occur, the elevated nitrate concentrations in the water produced by the wells would be addressed through treatment, such as blending, to ensure that all drinking water standards for nitrate are met. GC-1

HY-14: Project operation may have a substantial adverse effect on groundwater depletion in the Westside Groundwater Basin over the very long term (*Less than Significant with Mitigation*). Daly City concurs. The groundwater modeling conducted for the DEIR revealed that the basin leaks stored groundwater, and therefore all the water delivered for storage most likely will not be available for extraction during drought periods. The modeling analysis however assumes that all of the surface water delivered for storage is available for extraction, and as a consequence there is a simulated net reduction in groundwater storage. As modeled, the groundwater projects therefore appear unsustainable. The DEIR concludes that because the depletion volume is small relative to the total volume of groundwater stored in the basin, the impact of this long-term depletion is insignificant. However, the comparison to total groundwater in storage is a misleading metric because a substantial portion of the groundwater volume is not accessible for extraction and use.

HY-47

Under project operations, these concerns are addressed because by the terms of the Operating Agreement future groundwater extraction is limited to the water in the SFPUC Storage Account, and the Operating Agreement specifies that the Storage Account shall account for these water losses. Furthermore, the proposed mitigation allows additional in-lieu recharge to be added when surplus SFPUC system water is available, which will help maximize the Storage Account available for extraction during drought periods.

The hydraulic relationships between recharge, well locations, extraction rates, groundwater level changes, and basin leakage are complex. Additionally, the hydrologic sequence utilized for modeling the effects of these relationships under project operations has less rainfall recharge than occurred historically, and the design drought was inserted late in the simulation period. As a consequence, simulated groundwater storage never fully recovers and additional water deliveries are required to maintain the Storage Account balance. However, the timing and magnitude of these additional deliveries is not intuitive. For example, storage is increased by in-lieu recharge, which occurs at varying rates and magnitudes across the entire basin, but the pumping reductions occur at specific Participating Pumper well locations. The Operating

Agreement will address these concerns because it specifies that future groundwater monitoring and hydrologic analyses are required to adaptively manage the project, determine actual leakage losses, and account for losses in the SFPUC Storage Account. HY-47 Cont.

C-HY-4: <u>Operation of the proposed Project would not have a cumulatively considerable contribution to seawater intrusion. (*Less than Significant*)</u>. Daly City concurs. Sea water intrusion is an issue for the San Francisco Groundwater Project, which is located in the North Westside Basin, and less of an issue for the Regional Groundwater Storage and Recovery Project proposed for the South Westside Basin. The DEIR concludes that the San Francisco Groundwater Project could result in a significant cumulative impact on groundwater quality from seawater intrusion in the North Westside Basin, but the GSR Project would not have a considerable contribution to seawater intrusion in the South Westside Basin. The seawater intrusion analysis could benefit from more thorough spatial analysis of modeled groundwater fluxes. However, the Operating Agreement provides for groundwater monitoring, which presumably includes sentinel wells located near the Pacific Ocean in the North Westside Basin and San Francisco Bay in the South Westside Basin. These sentinel wells are located some distance away from portable production wells, and their purpose is to identify early intrusion should it occur and initiate actions to correct and manage it. For example, the San Francisco Groundwater Project proposes to mitigate seawater intrusion in the North Westside Basin, should it occur, by adjusting the distribution and magnitude of pumping rates at proposed project wells, thereby protecting production wells located in the South Westside Basin. HY-29

C-HY-8: <u>Operation of the proposed Project would have a cumulatively considerable contribution to a cumulative impact related to groundwater depletion effect (*Less than Significant with Mitigation*)</u>. Daly City concurs. Daly City notes that the combined impacts from the Regional Groundwater Storage and Recovery Project and the San Francisco Groundwater Supply Project, when considered cumulatively, provide mutually beneficial impacts in some respects. By itself, the Regional Groundwater Storage and Recovery Project increases groundwater outflow (leakage) to the Pacific Ocean by raising onshore groundwater levels during "PUT" and "HOLD" periods. By capturing a large part of that outflow, the San Francisco Groundwater Supply Project reduces the leakage losses that would otherwise occur and increase the total yield of the San Francisco Groundwater Project and the Regional Groundwater Storage and Recovery Project. Conversely, by elevating groundwater levels in the northern part of the South Westside Groundwater Basin, the Groundwater Storage and Recovery Project reduces the risk of seawater intrusion created by the San Francisco Groundwater Supply Project. The DEIR does not explicitly point out these potentially mutually beneficial impacts. HY-49

Thank you Ms. Jones, for your consideration of our comments. Should you have any questions or require additional information, please do not hesitate to contact me directly. GC-1

Sincerely,

Patrick Sweetland
Director of Water and Wastewater Resources

Cc: Greg Bartow, SFPUC
John Fio, HydroFocus, Inc.
Timothy Johnson, SF Planning (via email)
Kelly Capone, SFPUC (via email)

G - SAN MATEO RS - LOCOCO

From: Joe Lo Coco [mailto:jlococo@smcgov.org]
Sent: Tuesday, June 11, 2013 12:14 PM
To: Jaimes, Daniel
Cc: Diana Shu; Huey, Calvin
Subject: Fwd: SFPUC EIR extension

Daniel,

San Mateo County's comments to the EIR for the SFPUC's Regional Groundwater and Storage Project are as follows: GC-1

1)At the Garden Village Elementary School, we suggest that the SFPUC consider planting a hedge against the fence that surrounds the new facility that is intended to be constructed near the intersection of Park Plaza Drive and 87th Street. We are also concerned that the fencing be adequately secured, in light of its proximity to a local school. PD-5

2)Because of the proximity of this facility to the Park Plaza Drive/87th Street intersection, it'll be important that traffic controls be set up well in advance of the intersection to advise motorists when the work is actively occurring and lane or parking restrictions apply. TR-1

3)At Westborough Boulevard, access points to the 12' x 7' culvert need to be identified. GC-5

4)The County will require that the existing storm drain culvert on Westborough Boulevard immediately adjacent to the SFPUC's new jack and bore operations, be videoed before and after the SFPUC's construction to ensure that the SFPUC project does not result in settlement of the storm culvert or displacement of the storm culvert joints. Any settlement will need to be corrected by the project. GC-5

5)The contractor will be required to pay encroachment permit fees in conjunction with encroachments received to perform work in the County right of way. PD-2

We thank you for the opportunity to comment. GC-1

Joseph A. LoCoco, Deputy Director, Road Services

G-COLMA-LAUGHLIN cont.

TOWN OF COLMA
PLANNING DEPARTMENT
1190 El Camino Real • Colma, California 94014
Phone: (650) 757-8888 • FAX: (650) 757-8890

May 28, 2013

Via Email to: Mr. Tim Johnson, timothy.johnston@sfgov.org

Ms. Sarah Jones
San Francisco Planning Department 1650 Mission Street, Suite 400
San Francisco, CA 94103-2479

Re: Case No. 2008.1396E - SFPUC Regional Groundwater Project EIR Comments – Colma Sites 7, 8 and 17 (Alternative). South San Francisco Site 9

Dear Ms. Jones,

Thank you for the opportunity to comment on the SFPUC Regional Groundwater Storage and Recovery Project EIR. We have also appreciated the outreach and informational meetings provided by SFPUC staff regarding this project. After reviewing the document, we are in agreement with all the mitigation measures that will be applied to the project, and where we have not commented, we concur with the recommended mitigation measure. We would like to make the following comments on the document and regarding several of the mitigation measures: GC-1 GC-3 GC-1

Global Comment for all Colma Sites: Spanish/Mediterranean Architectural Requirement. The Land Use Element (pg. 5.02.13 Commercial Land Use Development Guidelines and pg. 5.02.33, Land Use Policy 5.02.3110), requires that all new buildings visible from public roads should incorporate a Spanish/Mediterranean architectural theme. This is also a policy in the Open Space and Conservation Element. In addition, the Colma Municipal Code has a "DR" zoning overlay for all of the sites that requires Spanish/Mediterranean design. For the structure proposed on Site 8 and possible structures on Sites 7 and Alternate Site 17, the exteriors should incorporate Spanish/Mediterranean elements which include articulated building walls, tile roof elements, trellis' and other features. PP-1 The Town has worked very hard to create a cohesive design style, and we consider any variation for the proposed structures to be a significant impact, requiring mitigation. This must be addressed in the Final EIR with the inclusion of compliance with Town of Colma design requirements. In addition, the general discussion about the Town of Colma in the Aesthetics section should be updated to include this information. AE-4

Site 8, Aesthetics, pg. 5.3-24. The Town is in strong disagreement with the statements regarding the characteristics of Site 8. The site is visible from the Town's highly successful and visually pleasing auto row, behind a successful renovated retail building (Kohl's) and across the street from the historic Town Hall. Visual quality of the AE-2 area is not moderately low – it would be moderate to moderately high. Site 8 also has high (not low) viewer concern, especially from our auto dealer community and the Town. Over the past year, the Town has had numerous meetings with SFPUC staff only to be disappointed with their reluctance to make any substantive changes to the structure proposed on Site 8 that would make it more attractive than a concrete bunker that will serve to substantially degrade the visual character of our auto row. The site is in close proximity to auto dealerships which have invested millions of dollars in facilities and upgrades to existing facilities. The new 28 million dollar Lexus dealership is just northwest of the site. The Final EIR must address compliance with Town of Colma design requirements. Based on the Table 5.3-3, the Town finds that the proposed building on Site 8 would have a significant impact based on moderate to moderately high visual contrast/change and moderate to moderately high visual sensitivity. AE-2 Cont.

Site 9 Overhead Electrical Connection. Figure 3-4 shows that Site 9 requires an electrical connection through a commercial business in the Town of Colma. This electrical connection is proposed to be above ground, which is unacceptable. The line would impact the existing commercial business and visually impact views from the Verano neighborhood. The Town of Colma requires undergrounding of utilities for all new construction, from the pole to the project site pursuant to Municipal Code Section 5.09. In addition, General Plan policy 5.02.361 requires that all new construction projects to place utilities underground. Power for this site should be taken from the South San Francisco side or undergrounded if on the Colma side. PD-5

Site 9 Visual Impacts. Figure 3-23 shows that a chemical treatment and filtration building will be highly visible from the back windows of 4-5 historic residences to the east within Colma, in addition to residences at the Verano neighborhood. The Final EIR must address this visual impact and mitigation. AE-3 This impact should also be addressed in a discussion to Cultural Resources in the Final EIR. The reviewer should view the Historic Resources Element of the Colma General Plan. CR-1

Traffic Control Plan, Mitigation Measure M-TR-1: The Town looks forward to receiving and reviewing the Traffic Control plan, and working with the SFPUC on traffic control measures that will lessen the extent of traffic impacts in Colma. Colma is a regional shopping destination for automobiles (along Serramonte Boulevard) and other retail establishments. From Thanksgiving weekend through New Year's, traffic increases for holiday shopping – especially on weekends. While construction of the project could take place during this timeframe, additional provisions would need to be made to manage the project so as not to impact businesses during this time. TR-1

Noise Control and Expanded Noise Control Plans, Mitigation Measures M-NO-1, M-NO-3: The Town looks forward to receiving and reviewing the Noise Control plans, and working with the SFPUC on noise control measures that will lessen noise impacts to our existing cemeteries and sensitive receptors in close proximity to the sites (especially Cypress Lawn at Alternate Site 17 in Colma). NO-1

TOWN OF COLMA
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Site Maintenance, Mitigation Measure M-AE-1a: We agree that construction will have a temporary visual impact on the visual character of the site or its surroundings. However, we believe that there is also a visual impact at Site 8, which is along one of our primary commercial thoroughfares (Serramonte Boulevard) and should be included as one of the sites requiring mitigation. Once applied (for site 8), there would be a less than significant impact. We agree with the conclusion of this Mitigation Measure as applied to Site 7. AE-2

Tree Removal and Replacement, Mitigation Measure M-AE-1e: The project includes the removal of trees within a tree mass recognized in the General Plan. While the General Plan does not preclude modification of tree masses or tree removal, it is the Town's expectation and desire that replacement trees and landscaping be provided in strategic locations along Colma Boulevard to maintain and even enhance its scenic quality and to visually screen proposed improvements. Specifically, the Town would like to see a slightly bermed planting in the island currently occupied by dirt and weeds directly behind the sidewalk along Colma Boulevard, and in additional locations along and surrounding site, with a majority of the improvements close to Colma Boulevard. With this additional clarification, we concur with the Mitigation Measure as written. AE-1

Landscape Screening, Mitigation Measure M-AE-3a: We concur with this Mitigation Measure as applied to Site 7. We believe that the addition of a building at Site 8 will create a significant visual impact that will require landscape screening and this impact should be discussed in the Final EIR. Over the past year we have had meetings with the SFPUC concerning the aesthetics of the building proposed at Site 8, expressing strong concerns about the visual impact of the proposed structure to our surrounding commercial businesses and our historic Town Hall to the north. During one of the meetings, we concluded that 2-3 trees could be planted to the north of the building to screen views of the building as viewed from Serramonte Boulevard without conflict to the Integrated Vegetation Management Policy. In addition, we have requested planting of approved vegetation on the slope directly adjacent to Serramonte Boulevard to resolve a long-standing property maintenance issue with overgrown weeds. We request that this Mitigation Measure, with the provisions stated above, be applied to Site 8. AE-2

Implementation of a Storm Water Pollution Prevention Plan, Mitigation Measure M-HY-1: The Town welcomes the opportunity to review and comment on the plan to assure that illicit discharges are not made into any Town storm drain facilities. Town and the sewer district approval for any discharges to the storm drain or sanitary sewer system are required. HY-3

G-COLMA-LAUGHLIN
cont.

Please feel free to contact me if you have any questions concerning the Town's comments. GC-1

Sincerely,

Michael P. Laughlin, AICP City Planner

CC (via email):

Mr. Greg Bartow, gbartow@sfwater.org
Ms. Kelley Capone, kcapone@sfwater.org

G-SAN BRUNO-FABRY

CITY OF SAN BRUNO

Klara A. Fabry
Public Services Director

PUBLIC SERVICES DIRECTOR
ADMINISTRATION AND ENGINEERING

June 13, 2013

Sarah Jones, Acting Environmental Review Officer
Regional Groundwater Storage and Recovery Project
San Francisco Planning Department
1650 Mission Street, Suite 400
San Francisco, CA 94103

Subject: City of San Bruno comments on the Draft Environmental Impact Report for the Regional Groundwater Storage and Recovery Project (State Clearinghouse No. 2005092026)

Dear Ms. Jones:

The City of San Bruno provides the following comments on the Draft Environmental Impact Report for the Regional Groundwater Storage and Recovery Project ("DEIR"). GC-1

1. DEIR, pages 3-39, 5.2-17, 5.8-15, 5.8-19, 5.8-29, and 5.8-30. The potential selection of drive-up portable generators should be included in the project description to allow for this potential. The DEIR should also include the analysis and potential impacts associated with the potential use of permanent, on-site generators to allow for this potential and provide flexibility in the project implementation. PD-9

2. DEIR, page 5.15-14. The classification of facilities as "Important" (Class II) with an associated restoration time of 30 days may not be consistent with San Bruno's desire for emergency supplies. The project design should allow for more rapid restoration of service. PD-6

3. DEIR, page 5.16-136. The DEIR does not acknowledge the potential for a project-related rise in groundwater levels to intercept nitrate mass in the vadose zone, resulting in an increase in nitrate concentration in groundwater. The potential for this mechanism should be included in the analysis and monitoring developed to capture any evidence that this may be occurring. HY-39

4. DEIR, page 5.16-152. Given the significant proposed change in the groundwater pumping regime and the lack of understanding of historical subsidence and of the compressibility of subsurface materials, land subsidence monitoring should be performed, including development of a baseline of land surface elevation for future comparison. HY-24

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5. DEIR, page 3-10: The potential impacts of pumping at the peak pumping capacity of 8.3 mgd (Section 3.4.2) should be modeled if such higher rates are being considered for the project as part of normal operations. Impacts of pumping at 8.3 mgd rather than the modeled 7.2 mgd will be more severe near the pumping locations and during the period of pumping. This is true even if the annual volume pumped is the same under both the 8.3 mgd and 7.2 mgd pumping rates. If the 8.3 mgd pumping rate is only intended to be used in the event of unscheduled down time then the document should state that production at 8.3 mgd would only occur as a result of unscheduled down time in order to meet the annual target of 8,100 AFY. Additionally, an estimate of the frequency of pumping at this rate should be made and the corresponding analysis conducted. PD-10

6. DEIR, page 3-141. The statement in Section 3.8.2 that "…when groundwater is pumped to provide a dry year supply, pumping would reduce the balance of water in the SFPUC Storage Account" does not reflect that maintenance and temporary usage of project facilities by SFPUC would also reduce the balance of water in the SFPUC storage account. The text must be updated to reflect all conditions that would reduce the balance of water in the SFPUC Storage Account. PD-16

7. DEIR, page 5.1-12. The citation of San Bruno 2011 in Section 3.8.1 is incorrect. The reference section includes San Bruno 2011 as

   San Bruno, City of. 2011. History*. Website accessed April 15, 2011 at:* *http://sanbruno.ca.gov/city_history.html.*

   which has no reference to the apportionment of groundwater production. OV-2

8. DEIR, page 5.11-3, footnote. Elevations are not correct in the footnote. Mean sea level is 0.52 ft NGVD 29 and 3.23 ft NAVD 88. Information on tidal datums can be found at http://www.ngs.noaa.gov/Tidal_Elevation/diagram.jsp?PID=HT0027&EPOCH=1983-2001. RE-1

9. DEIR, page 3-10. In order to be consistent with the Operating Agreement, the following edits should be made and the environmental analysis conducted consistent with the edits set forth below.

   Change from:

   During dry years, Partner Agency water deliveries from the regional water system would be comprised of reduced surface water deliveries and groundwater pumped from Project wells, as identified in the Operating Agreement. The Partner Agencies' pumping from their existing wells would not exceed the annual average rates consistent with the pumping limits expressed in the Operating Agreement.

   to:

   During dry years, Partner Agency water deliveries from the regional water system would be comprised of reduced surface water deliveries and groundwater pumped from Project wells, as identified in the Operating Agreement. The Partner Agencies' pumping from their existing wells would not exceed rates consistent with the pumping limits expressed in the Operating Agreement.

   PD-14

10. DEIR, page 5.16-146. Measured data may not be sufficient to account for losses, thus the usage of the groundwater model as a tool should be included in the mitigation measure, with guidance from the Operating Committee. Additionally, losses will occur during Put, Take, and Hold conditions, so the accounting and environmental analysis should not be limited to only Put and Hold years.

    Change text from:

    > *The SFPUC Storage Account monitoring program will use data from metered SFPUC in-lieu water deliveries to the Partner Agencies and regularly measured changes in groundwater elevations during a series of Put and Hold Years to determine the volume of stored water while developing rules to account for losses in groundwater storage, based on generally accepted principles of groundwater management.*

    to:

    > *The SFPUC Storage Account monitoring program will use data from metered SFPUC in-lieu water deliveries to the Partner Agencies, regularly measured changes in groundwater elevations, and from the regional groundwater model to determine the volume of stored water while developing rules to account for losses in groundwater storage, based on generally accepted principles of groundwater management.*

HY-48

11. DEIR, page 3-140. The following statement should be changed to reflect operations during Put Periods. The DEIR analysis should be consistent with this change in project description as well.

    Change from:

    > *Neither Project wells nor Partner Agency wells would be pumped in these Put Periods, apart from volumes needed to periodically exercise the wells.*

    to:

    > *Pumping from Project wells and Partner Agency wells during Put Periods would be limited to volumes needed to periodically exercise the wells, emergency usage, and other functions described in the Operating Agreement.*

PD-13

12. DEIR, page 3-141. Change the following text to accurately reflect accounting from:

    > *During these Take Periods, when groundwater is pumped to provide a dry-year supply, pumping would reduce the balance of water in the SFPUC Storage Account.*

    to:

    > *During these Take Periods, when groundwater is pumped from Project wells for Project purposes, such as providing a dry-year supply or performing maintenance, pumping would reduce the balance of water in the SFPUC Storage Account.*

PD-16

G-SAN BRUNO-FABRY
cont.

13. Mitigation Measure M-HY-14: Prevent Groundwater Depletion. This proposed mitigation measure should recognize the Operating Committees role in the development of the accounting for basin losses. Not only will the SFPUC work with the Operating Committee on the development of the accounting methodology, but also the Partner Agency's will be working with the Operating Committee as provided in the Operating Agreement. HY-48

San Bruno appreciates the opportunity to review and provide comments on the DEIR. Please do not hesitate to contact me should you have any questions regarding these comments. GC-1

Sincerely,

Klara A. Fabry
Public Services Director

O-TRT-DREKMEIER

Tuolumne River Trust

CELEBRATING 30 YEARS

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June 5, 2013

Sarah B. Jones, Acting Environmental Review Officer
Regional Groundwater Storage and Recovery Project
San Francisco Planning Department
1650 Mission St., Suite 400
San Francisco, CA 94103

Dear Ms. Jones:

The Tuolumne River Trust (TRT) appreciates the opportunity to comment on Case No: 2008.1396E – the Regional Groundwater Storage and Recovery Project (Project). GC-1

TRT is concerned the Project will increase diversions from the Tuolumne River in normal and wet years, potentially resulting in negative impacts on the stretch of River below O'Shaughnessy Dam. HY-50 The Project EIR simply tiers off the 2008 Water System Improvement Program (WSIP) PEIR, and fails to incorporate new conditions and information that have become available since the WSIP was approved. HY-52

The approved Modified WSIP capped water sales in the SFPUC service territory at 265 mgd until at least 2018. Historically, 85% of SFPUC water has come from the Tuolumne River and 15% from the SFPUC's Bay Area reservoirs.

Conditions related to management of the SFPUC's Bay Area reservoirs have changed since the WSIP was approved. Most notably, the SFPUC will be required to release an additional 7.4 mgd into Alameda and San Mateo Creeks for fish and wildlife upon completion of upgrades to the Calaveras and Crystal Springs Dams. HY-50

Presumably, to make up for this shortfall diversions from the Tuolumne River would need to increase in order to provide supplemental surface water to the agencies that currently pump groundwater. The cumulative impacts of diverting more water from the Tuolumne River must be analyzed in the Project EIR. The Project EIR also should study the potential of augmenting aquifer replenishment with injection wells utilizing local stormwater or recycled water to reduce impacts on the Tuolumne River. AL-1

Another issue that must be addressed regards the Raker Act. The Raker Act prohibits the SFPUC from selling water from the Tuolumne River to private companies. Since Cal Water is one of the utilities that would receive surface water from the SFPUC under the Project, the EIR should address whether this could be accomplished without violating the Raker Act, especially considering that yield from the SFPUC's Bay Area reservoirs will be reduced by 7.4 mgd. HY-51

The Project EIR must consider new information that has become available since the WSIP PEIR was approved. For example, on April 16, 2012, the SFPUC HY-52 released a report titled, "Sensitivity of Upper Tuolumne River Flow to Potential Climate Change Scenarios" (Attachment A). This information must be considered when determining potential impacts on the Tuolumne River of increasing diversions from Hetch Hetchy Reservoir.

After the WSIP was approved, the SFPUC embarked on its Upper Tuolumne River Ecosystem Program (UTREP) that is studying the stretch of the Tuolumne River between O'Shaughnessy Dam and Early Intake. The UTREP is "An ongoing effort to conduct long-term, collaborative, science-based investigations designed to: 1) Characterize historical and current river ecosystem conditions; 2) Assess their relationship to Hetch Hetchy Project operations; and 3) Provide recommendations for improving ecosystem conditions on a long-term, adaptively managed basis." HY-52 Cont.

The UTREP is a legally required program with which the SFPUC must comply to meet its obligations under the Kirkwood Agreement. While completion of the UTREP is behind schedule, the information that is currently available must be incorporated into the environmental review for the Regional Groundwater Storage and Recovery Project.

TRT is concerned that increased diversions from Hetch Hetchy could have negative impacts on Poopenaut Valley and other sensitive ecosystems downstream of O'Shaughnessy Dam, especially in light of likely changes in the timing of runoff in the coming era of climate change. An up-to-date analysis, with current data using current analysis protocol, needs to be part of the Project EIR. HY-50

TRT is concerned that current operations of O'Shaughnessy Dam are in violation of the Kirkwood Agreement. Following is some background information.

On January 31, 1985, the City and U.S. Interior Department entered into a Stipulation (Attachment B) that required a study of the impacts on fish, wildlife, recreational and aesthetic values, as a condition of any modification (including expansion) of the City's Hetch Hetchy System that might affect the flow of the Tuolumne River between O'Shaughnessy Dam and Early Intake. The 1985 Stipulation further provides that the purpose of the study is to determine what change, if any, should be made to the flow release schedule. It reserves the Interior Department's authority to require such change after consideration of any objection. HY-52

On November 4, 1985, the City entered into an Interim Agreement (Attachment C) with the Tuolumne River Trust and other conservation organizations, confirming this obligation with respect to the third generating unit of the Kirkwood Powerhouse. The Interim Agreement also granted the groups standing to enforce the conditions of a subsequent agreement between the City and the Interior Department relating to a fisheries study.

On March 10, 1987, the City and Interior Department entered into a Stipulation (Attachment D) requiring the City, or the U.S. Fish and Wildlife Service (FWS), to undertake a study "…to determine what, if any effect, the Kirkwood Powerhouse and Kirkwood Addition would have or have had on the habitat for and populations of resident fish species, between O'Shaughnessy Dam and Early Intake…" The condition requires the study to be completed by December 1992, subject to extension only if the USFWS determines that the study is inconclusive or inaccurate as a result of climatic or other environmental conditions. The Stipulation specifies adjustments to the minimum flow releases, if the USFWS determines that flow in the Tuolumne River "…should be increased."

USFWS issued a draft report in 1992 (Attachment E) titled "Instream Flow Requirements for Rainbow and Brown Trout in the Tuolumne River Between O'Shaughnessy Dam and Early Intake." This report was never finalized, however, it states, "In 1988, the U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology (IFIM) was applied to the Tuolumne River below Hetch Hetchy Reservoir…An annual fishery allocation of between 59,207 acre-feet and 75,363 acre-feet is recommended, based on the findings of the instream flow study."

The report recommended increasing instream flows from O'Shaughnessy Dam. For example, in the months of December and January, it recommended an increase in flows from a minimum of 35 cfs to 50 cfs in dry years, from a minimum of 40 cfs to 70 cfs in normal years, and from a minimum of 50 cfs to 85 cfs in wet years.

However, Table 5.3.1-2 of the WSIP PEIR (Vol. 3, Section 5.3, pp. 5.3.1-13) shows the "Schedule of Average Daily Minimum Required Releases to Support Fisheries Below O'Shaughnessy Dam" based on a 1985 agreement. Attachment F compares flows listed in the WSIP PEIR with those recommended by the draft USFWS report. HY-52 Cont.

On March 20, 2006 the Tuolumne River Trust, represented by the Natural Heritage Institute, gave notice that the SFPUC was in violation of the "Modification for Kirkwood Powerhouse Unit No. 3 to Stipulation for Amendment of Rights-of-Way for Canyon Power Project Approved by Secretary of the Interior on May 26, 1961 to Fulfill the Conditions Set Forth in Provision 6 of Said Amended Permit." Our letter (Attachment G) asserted that the study required by the Stipulation had not been published and the minimum flow release schedule had not been adjusted.

On February 5, 2008, the SFPUC responded (Attachment H), stating, "The purpose of this letter is to propose a collaborative process to resolve these implementation issues by December 2009." The SFPUC proposed, among other things, "the following measures, schedule and conditions to resolve the outstanding issues from the 1987 Stipulation."

"The SFPUC, the USFWS, Yosemite National Park Service staff, and SFPUC consultants will work together to gather the information necessary to develop physical and biological objectives for an adaptive management plan for O'Shaughnessy Dam flow releases. It is anticipated that these initial studies shall be completed by December 2009."

"The SFPUC and the USFWS, in consultation with the Yosemite National Park, the US Forest Service, the California Department of Fish and Game, SFPUC consultants, and the Trust, will review ongoing study material and work together to develop an adaptive management plan for releases into the affected reach to enhance a wider range of resource values. This plan will include a monitoring program, and may also include annual consultations between the USFWS and the

O-TRT-DREKMEIER cont.

SFPUC regarding water releases into the affected reach. The SFPUC and USFWS agree to make best efforts to complete the adaptive management plan by December 2009." HY-52 Cont.

On May 26, 2009, the Tuolumne River Trust accepted the proposed measures, schedule, and conditions proposed by the SFPUC. To meet the obligations of the agreement, the SFPUC initiated its Upper Tuolumne River Ecosystem Program (UTREP).

We sincerely hope the Final EIR for the Regional Groundwater Storage and Recovery Project will address the issues raised in this letter. The Project EIR must address current conditions and potential violations of the Kirkwood Agreement, and incorporate up-to-date information. GC-3

Thank you for the opportunity to comment on the Draft Project EIR. GC-1

Sincerely,

Peter Drekmeier

Peter Drekmeier
Bay Area Program Director

Attachments included on enclosed CD.

Attachment A

O-TRT-DREKMEIER Cont.

San Francisco Water Sewer
Services of the San Francisco Public Utilities Commission

1155 Market Street, 11th Floor
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April 16, 2012

TO: Commissioner Anson B. Moran, President
Commissioner Art Torres, Vice President
Commissioner Ann Moller Caen
Commissioner Francesca Vietor
Commissioner Vince Courtney

THROUGH: Ed Harrington, General Manager

FROM: David Behar, Climate Program Director, Water Enterprise

RE: Final Report: "Sensitivity of Upper Tuolumne River Flow to Potential Climate Change Scenarios"

Please find enclosed the above named final report. This report was the subject of the summary and oral report provided to the Commission on January 10, 2012, and we promised to forward the full report upon completion. No changes to the conclusions or analysis presented on January 10 were made prior to finalization of the report.

HY-52 cont.

<u>NEXT STEPS</u>

As reported on January 10, this report identified runoff projections utilizing a range of possible changes to temperature and precipitation due to climate change. Two subsequent analyses are in the works now:

1) Estimate the potential effects on water supply these changes in runoff might indicate. This analysis will utilize the Hetch Hetchy Local System Model (HHLSM), our water supply planning model. Timeframe: Completed Summer 2012.

2) Scope and implement a comprehensive climate change assessment utilizing the most advanced climate science available, careful characterization of uncertainty, and the use of decision-making approaches that account for that uncertainty. This assessment will use the results of this report and the newly calibrated hydrologic model for Hetchy. Timeframe: Scope and contract completed mid-2012, assessment completed calendar 2013.

Attachment A

O-TRT-DREKMEIER Cont.

Sensitivity of Upper Tuolumne River Flow to Climate Change Scenarios

Prepared by:

HY-52 cont.

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San Francisco, CA 94103

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JANUARY 2012

O-TRT-
DREKMEIER
Cont.

Sensitivity of Upper Tuolumne River Flow to Climate Change Scenarios

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Sensitivity of Upper Tuolumne River Flow to Climate Change Scenarios

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O-TRT-
DREKMEIER
Cont.

Sensitivity of Upper Tuolumne River Flow to Climate Change Scenarios

Glossary of Terms and Acronyms

Albedo
The fraction of short wave solar radiation reflected by a surface or object, often expressed as a percentage. Snow covered surfaces have a high albedo; the albedo of soils ranges from high to low; vegetation covered surfaces and oceans have a low albedo.

Algorithm (modeling)
Software or a sequence of instructions for functions that model a physical process.

Anthropogenic
Resulting from or produced by human beings.

Aspect (Geography)
The direction that a mountain slope faces. Snow will melt out on south facing slopes while snow remains on north facing slopes.

Calibration (Hydrologic Models)
The adjustment of parameters in hydrologic process algorithms in a hydrologic model so that simulated streamflow and snowpack information more closely matches recorded streamflow and snow course measurements.

HY-52 cont.

CDEC
The California Data Exchange Center collects data with the cooperation of 140 other agencies and provides real-time forecast and historical hydrologic data.

Climate
Climate is the "average weather", or more rigorously, is the statistical description of weather in terms of the mean and variability of relevant quantities (temperature, precipitation, wind) over a period of time ranging from months to tens or hundreds of years.

Climate Model (Global Climate Model or General Circulation Model, GCM)
A numerical representation of the climate system based on the physical, chemical and biological properties of its components and feedback processes. The climate system can be represented by models of varying complexity, with the complexity increasing with the number of spatial dimensions and the physical, chemical or biological processes that are explicitly represented, or the level at which empirical parameterizations are involved. Coupled atmosphere/ocean/sea-ice General Circulation Models (AOGCMs) provide the most comprehensive representation of the climate system.

Climate System
The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere.

Diurnal Temperature Range (DTR)
The difference between the maximum and minimum temperature during a day.

El Niño-Southern Oscillation (ENSO)
El Niño is a warm water current which periodically flows toward the coast of Ecuador and Peru. This is associated with a fluctuation of the inter-tropical surface pressure pattern and circulation in the Indian and Pacific oceans, called the Southern Oscillation. This coupled atmosphere-ocean phenomenon is collectively known as El Niño-Southern Oscillation, or ENSO.

Evapotranspiration
The combined process of evaporation from the Earth's surface and transpiration from vegetation. *Potential* evapotranspiration is the total evapotranspiration that could occur if moisture were continuously available. *Actual* evapotranspiration is the evapotranspiration that occurs given the available moisture supply.

Exceedance Probability
The likelihood that an event or condition will be exceeded expressed as the ratio of the number of actual occurrences of exceedance to the number of possible occurrences of exceedance. Exceedance probability is often used in environmental risk modeling.

GNL, HRS, SLI, PDS, TUN, CHV, HTH, BKM, MCN, MSR, MID HY-52 cont.
Acronyms used by the California Data Exchange Center (CDEC) for hydrometeorological stations in the Tuolumne watershed.

Greenhouse Gas (GHG)
Greenhouse gases trap heat within the surface-troposphere system. They are natural and anthropogenic gases that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the atmosphere.

HFAM
Hydrologic Forecast and Analysis Modeling developed by Hydrocomp, Inc. HFAM version 2.3, completed in 2011, was used for the climate change analysis. HFAM is a continuous simulation model that operates on hourly time steps. The model interface is the computer screens used to operate the model and view results.

Historic Meteorological Database
Historic data refers to observed and extended historic data. Meteorological data were processed to provide hourly timeseries when observed hourly data were not available. Processing included:

- Temperature – estimating hourly values from max-min daily records, correlations with other sites.
- Precipitation – daily to hourly distributions from other sites or from prior events at the same site. Correlations with other sites.
- Solar radiation – top of atmosphere data reduced by atmospheric absorption and cloud cover.

- Potential Evapotranspiration – diurnal patterns and seasonal median values.
- Wind – diurnal patterns and seasonal median values.

(See also Static Meteorological Database)

Hydrologic Model
A numerical representation of processes in the hydrologic cycle (snow accumulation and melt, soil moisture, infiltration, evapotranspiration, runoff and streamflow) based on continuous meteorological timeseries (precipitation, potential evapotranspiration, solar radiation, wind, air temperature). HFAM is a hydrologic model that has been calibrated to represent hydrologic processes in the Tuolumne River.

IPCC
The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization and the United Nations Environmental Program.

Land Segment
A portion of the land surface for which hydrologic processes are modeled. Land segments in HFAM have unique characteristics (elevation, slope, aspect, vegetal cover, soils, etc.). Runoff from land segments enters stream reaches that carry flows through the channel network.

Lapse Rate HY-52 cont.
The decrease in temperature in the atmosphere per unit of elevation. A typical lapse rate for moist air is 3 ˚F per 1000 ft. of elevation but lapse rates are highly variable.

Median
A value in an ordered set of values that separates the higher half of the values from the lower half.

MID
Modesto Irrigation District

NCDC
National Climate Data Center, NOAA, Ashville, NC

Parameterization
In climate and hydrologic models, this is the technique of representing processes that cannot be explicitly resolved at the spatial or temporal resolution of the model (sub-grid scale processes).

PDO
The Pacific (inter) Decadal Oscillation, or PDO, is a long-lived El Niño-like oscillatory pattern of climate variability centered over the Pacific Ocean and North America. The PDO has considerable influence on climate sensitive natural resources in the Pacific and over North America, including the water supplies and snowpack in some selected regions in North America (Mantua N.J. 2002)

Response Time (or Time to Equilibrium)
The response time or adjustment time is the time needed for the climate system or its components to re-equilibrate to a new state, following a forcing resulting from external and internal processes or feedbacks. Atmospheric response times are relatively short (days to weeks). Ocean response times, due to their large heat capacity, are much longer (decades to centuries).

SFPUC
San Francisco Public Utilities Commission

Simulation
The imitation of a real process or processes that entails representing certain key characteristics or behaviors of a selected physical system to gain insight into their functioning. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Hydrologic models and climate models are examples of simulation models. Output from these models may be called 'simulated data'.

SNOWCF
The snow correction factor is a HFAM model parameter which increases precipitation when precipitation falls as snow to compensate for reduced catch at gages.

Soil Moisture
Water stored in or at the land surface and available for evaporation or transpiration.

HY-52 cont.

Solar Radiation
Radiation emitted by the Sun. It is also referred to as short-wave radiation.

Static Meteorological Data Base
Historic data that have been adjusted by removing historic trends. Only air temperature records at Hetch Hetchy Reservoir and Cherry Valley Dam were adjusted. The static meteorological database is used to create weather inputs for 2010 current conditions and future conditions under climate change scenarios. (See also Historic Meteorological Database)

SRES
Special Report on Emissions Scenarios developed by the IPCC.

Surficial Hydrologic Processes
Hydrologic processes (snow accumulation and melt, infiltration, soil moisture storage, evapotranspiration, etc.) that occur at the land surface, or (typically) within a few meters of the land surface.

TID
Turlock Irrigation District

Trend Analysis
Analyzing information or data with the goal of identifying a pattern, or trend, in the data. In climate change studies, trends in meteorological timeseries are evaluated by fitting a straight line

to the data over twenty or more years (least squares fit) to separate climate change effects from the chaotic variability of weather.

XML (Extensible Markup Language)
XML is a general purpose specification for creating custom markup languages. Its purpose is to aid information systems in sharing structured data. It is used by HFAM so that input and output can be shared easily with WORD, EXCEL and other XML conversant software.

HY-52 cont.

O-TRT-
DREKMEIER
Cont.

Sensitivity of Upper Tuolumne River Flow to Climate Change Scenarios

Executive Summary

Climate change is a concern to water managers with facilities within the Tuolumne watershed. The purpose of this study was to determine streamflow sensitivities to possible increases in temperature and change in precipitation due to climate change. For this study, the likelihood of any particular climate future was not assessed, and the report did not seek to comprehensively frame all the changes climate scientists expect from global warming. Nor did the report seek to address potential water supply impacts of climate change. The goal of the study was simply to assess the sensitivity of reservoir inflows to a range of changes in two variables, temperature and precipitation. For that reason, a physically-based conceptual hydrology simulation model was calibrated against past conditions and used to assess potential changes in the timing and volume of runoff that may occur for the years 2040, 2070 and 2100 as compared to the conditions in 2010. A review of the literature and consultation with climate science experts allowed selection of climate scenarios that encompassed a range of temperature and precipitation changes that may be experienced through 2100 so that potential changes in watershed runoff could be simulated and analyzed.

Climate Change Scenarios

HY-52
cont.

Climate change scenarios for this study were selected to represent a range of possible future climate conditions based on the range of predictions by global climate models.

Table ES-1 lists the potential future climate condition in terms of a change in temperature and precipitation from the 2010 conditions for the years 2040, 2070 and 2100 for each climate change scenario. A 34-year stationary meteorological database was developed and the increments shown in Table ES-1 were used to create adjusted temperature and precipitation timeseries that represent potential future conditions for each climate change scenario. This technique allowed the analysis of a 34-year period with consistent climate conditions at three future dates, each of which had six combinations of temperature and precipitation changes.

Hydrologic Simulation Model

The HFAM hydrologic model of the Tuolumne, developed by Hydrocomp over a twelve year period for the Turlock Irrigation District (TID), was used in this study to simulate the watershed's hydrologic response to precipitation, temperature, evaporation, solar radiation and wind. The model calculates the hydrologic response of more than 900 land segments in the watershed above Don Pedro and routes runoff downstream to reservoirs through 75 channel reaches. Each land segment represents the elevation, soil and rock outcrop, vegetation and aspect associated with a portion of the watershed. The model performs detailed mass and energy budget calculations to simulate the hydrologic cycle on each land segment. By combining and routing the flow from each segment, the model provides detailed information on the effects of basin-wide temperature and precipitation changes on runoff, snow, evapotranspiration and soil moistures.

Table ES-1. Constructed climate change scenarios with temperature increases and precipitation changes

Scenario	Description	Mean Annual Temperature (˚F (˚C))[1]			Mean Annual Precipitation (in)[1]		
Current Conditions	2010 conditions	55.1 (12.8)			36.9		
Future Climate Change Scenarios		Change from Base (˚F (˚C))[2]			Change from Base (%)[3]		
		2040	2070	2100	2040	2070	2100
1A	Low temperature increase no precipitation change	+1.1 (0.6)	+2.3 (1.3)	+3.6 (2)	0	0	0
2A	Moderate temperature increase no precipitation change	+1.8 (1)	+4.0 (2.2)	+6.1 (3.4)	0	0	0
2B	Moderate temperature increase precipitation decrease	+1.8 (1)	+4.0 (2.2)	+6.1 (3.4)	-5	-10	-15
2C	Moderate temperature increase Precipitation increase	+1.8 (1)	+4.0 (2.2)	+6.1 (3.4)	+2	+4	+6
3A	High temperature increase no precipitation change	+3.0 (1.65)	+6.3 (3.5)	+9.7 (5.4)	0	0	0
3B	High temperature increase Precipitation decrease	+3.0 (1.65)	+6.3 (3.5)	+9.7 (5.4)	-5	-10	-15

[1] Mean annual temperature and precipitation at HTH station.
[2]Temperature increases are given in degrees F (degrees C) added to the 2010 current conditions static meteorological database.
[3]Precipitation changes are given in percent change to the 2010 current conditions static meteorological database.

HY-52 cont.

Simulated Reservoir Inflows

Climate change in the Tuolumne River affects snow accumulation and melt, soil moisture and forests, reservoir inflows, and the water supplies available for all purposes. Table ES.2 summarizes the modeling results in terms of the change in simulated median annual runoff at O'Shaughnessy and Don Pedro dams for the different future climate conditions (climate change scenario at future climate date).

Simulated changes in median annual runoff do not fully describe how water supplies would be affected. When firm yield from reservoirs is evaluated, low runoff years are critical. Climate change effects are exacerbated in low runoff years. Table ES.3 summarizes the modeling results in terms of the change in simulated 5 (extremely wet), 50, and 95 (critically dry) percent exceedance annual runoff for two climate change scenarios, 2A moderate temperature increases with no precipitation change, and 3B high temperature increases with precipitation decreases.

O-TRT-DREKMEIER Cont.

Table ES.2. Change in median runoff volume for future climate conditions

Climate Change Scenario		O'Shaughnessy Runoff (% change from 2010)			Don Pedro Runoff (%change from 2010)		
		2040	2070	2100	2040	2070	2100
1A	low temperature increase no precipitation change	-0.7%	-1.5%	-2.6%	-1.1%	-2.4%	-3.6%
2A	moderate temperature increase no precipitation change	-1.2%	-2.9%	-5.4%	-1.8%	-4.0%	-6.4%
2B	moderate temperature increase precipitation decrease	-7.6%	-15.8%	-24.7%	-9.5%	-19.1%	-28.7%
2C	moderate temperature increase precipitation increase	1.4%	2.2%	2.4%	1.1%	2.0%	2.8%
3A	high temperature increase no precipitation change	-2.1%	-5.6%	-10.2%	-3.0%	-6.5%	-10.1%
3B	high temperature increase precipitation decrease	-8.6%	-18.6%	-29.4%	-10.7%	-21.6%	-32.3%

Table ES.3. Change in runoff volume for future climate conditions for extremely wet, median, and critically dry years (based on results from 1975-2008)

HY-52 cont.

Climate Change Scenario		Example years	O'Shaughnessy Runoff (% change from 2010)			Don Pedro Runoff (% change from 2010)		
			2040	2070	2100	2040	2070	2100
2A	moderate temperature increase no precipitation change	Extremely wet	-0.6%	-1.4%	-2.4%	-1.1%	-2.6%	-3.7%
2A	moderate temperature increase no precipitation change	Median	-1.2%	-2.9%	-5.4%	-1.8%	-4.0%	-6.4%
2A	moderate temperature increase no precipitation change	Critically dry	-3.4%	-8.8%	-15.1%	-4.2%	-9.8%	-16.1%
3B	high temperature increase precipitation decrease	Extremely wet	-7.1%	-14.3%	-21.8%	-8.7%	-16.7%	-24.3%
3B	high temperature increase precipitation decrease	Median	-8.6%	-18.6%	-29.4%	-10.7%	-21.6%	-32.3%
3B	high temperature increase precipitation decrease	Critically dry	-14.7%	-30.9%	-46.5%	-16.6%	-33.3%	-48.1%

Runoff timing within the water year changes under the future climate conditions. Figure ES-1 shows the average monthly median runoff volume at O'Shaughnessy for the current climate and for the 2040, 2070 and 2100 future climate condition for two climate change scenarios (2A moderate temperature increases with no precipitation change and 2B moderate temperature increases with precipitation decreases). Reservoir operations may need to be revised to manage increased runoff in November through April, and decreased runoff in May for most scenarios, and in June and July for all scenarios.

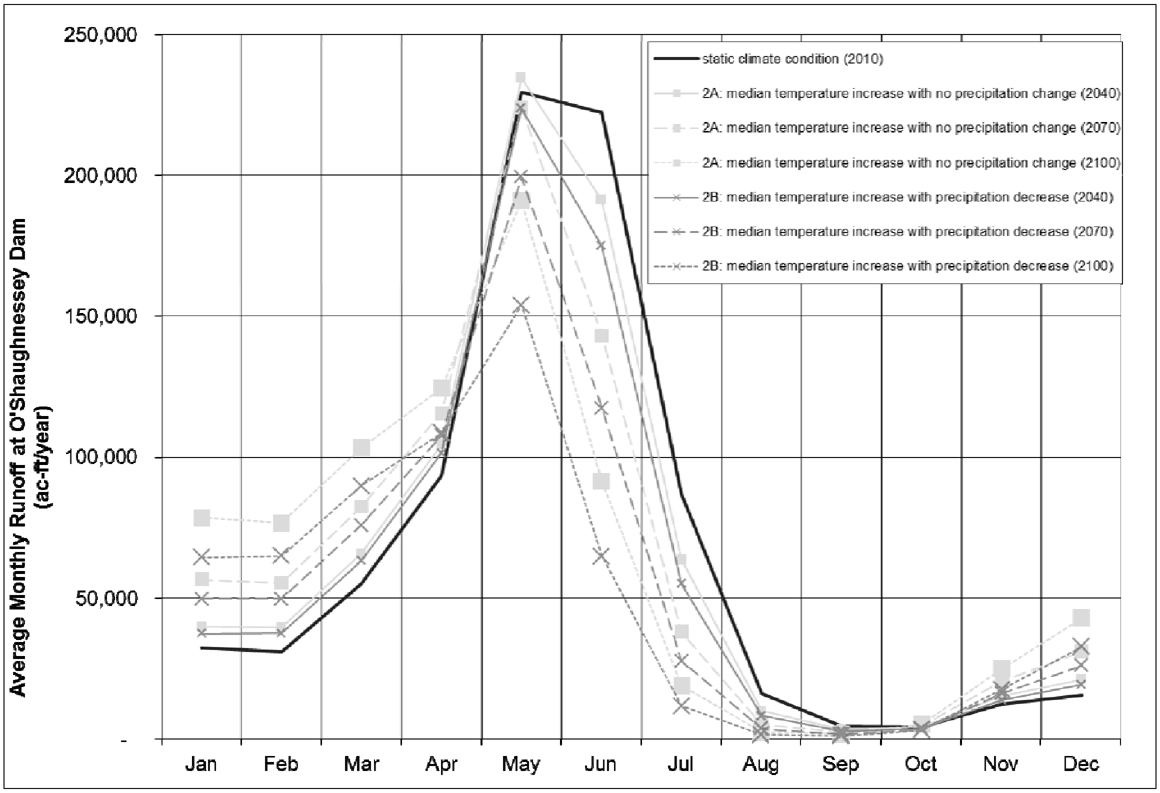

Figure ES-1. Average monthly runoff at O'Shaughnessy Dam for moderate temperature increase and precipitation change scenarios at future climate dates

HY-52
cont.

Conclusions

The simulated change in 2040, 2070 and 2100 hydrologic conditions based on the climate change scenarios results in a progressively altered snow and runoff regime in the watershed. Snow accumulation is reduced and snow melts earlier in the spring. Fall and early winter runoff increases while late spring and summer runoff decreases, and these changes become more significant at the later time periods. Total runoff is projected to decrease under the climate change scenarios evaluated, in some cases marginally and others significantly.

The reliability of projected changes in reservoir inflows for the climate change scenarios is good because the model is physically-based and has been calibrated over a 34-year period to accurately represent hydrologic conditions in the Tuolumne watershed during a range of temperature and precipitation conditions. The temperature and precipitation timeseries used for the climate change scenarios increases are within the range of temperatures experienced in the Tuolumne during the calibration period. For example, a climate change scenario may have higher temperatures than experienced in the same period historically but similar temperatures would have been observed at other times in the calibration period.

This study created daily reservoir inflow data during the 34-year analysis period (water years 1974 to 2008) for all climate change scenarios which can be used for subsequent water resources planning studies by TID and SFPUC.

Reduced snow accumulation and a resulting shift of runoff from the spring to the winter runoff in the Tuolumne were expected due to the temperature increases of the climate change scenarios. In addition, the climate change scenario results showed that:

- Climate change effects are most exacerbated in low runoff years because of increased evapotranspiration results, particularly when expressed as a percent of runoff.
- Soil moisture reductions in summer would be significant by 2070 and 2100. The predicted reduction in summer soil moistures would be expected to change vegetation distribution within the watershed. The potential changes in vegetation would cause a secondary change in the hydrologic response of some land segments but this effect was not modeled in this study.
- The future climate condition in year 2040 of climate change scenario 3B (high temperature increases with precipitation decrease) results in reductions in median runoff of -8.6% at O'Shaughnessy Dam and -10.7% at Don Pedro Dam. Relatively large reductions in runoff may take place in 30 years if both temperature rise and precipitation decrease occurs.
- The future climate condition in year 2040 of climate change scenario 1A (low temperature increase and no precipitation change) results in minimal runoff reductions of 0.7% at O'Shaughnessy Dam and 1.1% at Don Pedro Dam. The 1A results in terms of runoff and timing changes are small compared to the year-to-year variation that is currently experienced.

HY-52
cont.

1. Introduction

The Tuolumne River, located on the western slopes of the Sierra Nevada in California, provides 85 percent of the San Francisco Public Utilities Commission (SFPUC)'s water supply for 2.5 million Bay Area residents and water to 8,000 agricultural customers and over 200,000 electrical customers of the Turlock and Modesto Irrigation Districts (TID/MID).

1.1 Purpose and Objectives

Water managers with facilities within the Tuolumne watershed are concerned about the potential impact that climate change may have on their future water availability. Water resources in the Tuolumne watershed, like any mountainous watershed in the Western United States, depend on snowpack, which accumulates precipitation during winter months and releases melt water to the river during spring and early summer months. Changes to precipitation would affect reservoir inflow through changes in snowpack accumulation. Similarly, changes to temperature would also affect reservoir inflow through watershed evapotranspiration, snow accumulation and snowmelt. The SFPUC and TID are working together to better understand the possible impacts of climate change on Tuolumne River streamflow. HY-52 cont.

The key objective of this study is to assess changes in streamflow and watershed hydrologic response to potential temperature and precipitation changes for the years 2040, 2070 and 2100 as compared to the conditions in 2010. Scenarios of temperature and precipitation changes through 2100 were constructed based on literature review and interviews with climate experts. The scenarios encompass a range of temperature and precipitation changes that may occur in the 21st century as a result of climate change. These climate scenarios, however, are not ranked or characterized in terms of their likelihood, and do not represent a "projection" of climate change in the watershed. To characterize possible future changes to climate more precisely, the use of climate model ensemble output, careful characterization of uncertainties contained in that output, lessons learned from paleoclimate reconstructions, and other climate science assessment techniques are required.

A physically-based conceptual model, Hydrologic Forecast and Analysis Model (HFAM) (Hydrocomp, Inc., 2011, HFAM II Reference and User's Manual), was calibrated and used to simulate hydrologic processes (snow accumulation and melt, infiltration, runoff, channel flow). Simulation results were used to assess changes in the timing and volume of runoff. The analysis compared simulated unimpaired inflows (full natural flow) to Hetch Hetchy, Eleanor, Cherry and Don Pedro reservoirs under the 2010 current climate condition with the constructed potential future climate conditions. Results of the analysis will help water resource planners understand the sensitivity of water supply, irrigation and power generation to potential changes in streamflow resulting from climate change.

This report describes the study area, which consists of the 1,532- square miles drainage area above La Grange Dam; the evidence of climate change; the study approach with assumptions, methods and limitations, and the construction of climate change scenarios. The report also describes model set-up and calibration of the HFAM hydrologic model of the Upper Tuolumne watershed and simulations made with the model to determine the potential effects of temperature and precipitation changes on streamflows.

1.2 Scope

The scope of this study was limited to:

1. Reviewing climate change studies applicable to the Central Sierra Nevada and the Tuolumne watershed and seeking expert advice.
2. Constructing six scenarios of temperature and precipitation changes that represent a range of 18 potential future climate conditions in 2040, 2070 and 2100.
3. Examining the 79-year (1930 to 2008) historical weather observations to identify trends in historical climate and create a 34-year (1975 to 2008) static weather sequence to represent current climate condition (2010).
4. Creating 34-year weather sequences based on 1975 to 2008 but adjusted to represent the future climate condition in 2040, 2070, and 2100 for each of the six climate change scenarios.
5. Improving calibration of the existing HFAM model, particularly at Hetch Hetchy, Cherry and Eleanor reservoirs. HY-52 cont.
6. Simulating unimpaired inflows (full natural flow) to Hetch Hetchy, Eleanor, Cherry and Don Pedro reservoirs using the Tuolumne HFAM model for the current climate condition and for each of the eighteen future climate conditions.
7. Analyzing changes in runoff and hydrologic processes from the current condition for all climate change scenarios at the 2040, 2070 and 2100 time horizons.

1.3 Acknowledgements

This report was jointly prepared by Hydrocomp, SFPUC and TID. Hydrocomp was responsible for watershed model setup, model calibration, simulations of climate change scenarios and interpretation of the model results. Hydrocomp produced sections 4, 5, 6 and 7.

1.4 Study Area

The Tuolumne River, which drains a 1,960-square-mile watershed on the western slope of the Sierra Nevada range (Figure 1-1), is the largest of three major tributaries to the San Joaquin River. The mainstem of the river originates in Yosemite National Park and flows southwest to its confluence with the San Joaquin River, approximately 10 miles west of Modesto. The study area consists of the drainage area above La Grange Dam which encompasses 1,532 square miles. This watershed extends from the crest of the Sierra Nevada near 13,200 feet to the base of the foothills in the Central Valley of California near 800 feet. The sub-study areas are the watersheds of Cherry Lake, Lake Eleanor and Hetch Hetchy (Figure 1-1).

Attachment A

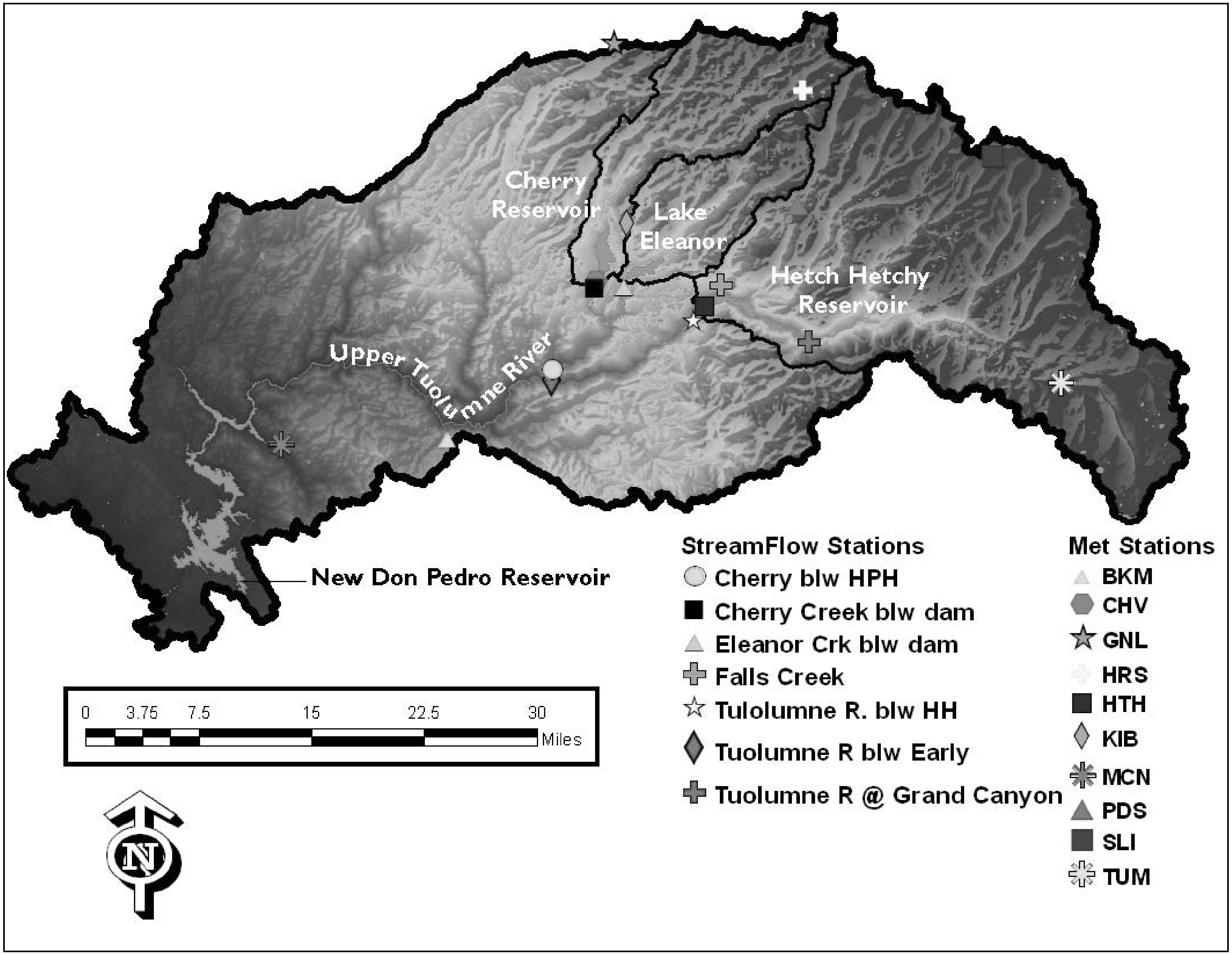

Figure 1-1 Tuolumne River Watershed, stream and meteorological station locations and key reservoirs

O-TRT-DREKMEIER Cont.

HY-52 cont.

The distribution of watershed area for the Tuolumne basin above Don Pedro exhibits a nearly linear trend (Fig 1-2). Nearly 10% of the watershed is contained in each 1,000 ft elevation band up to about 10,000 ft. Only a small fraction of the watershed exists at higher elevations. The SFPUC-managed watersheds show a similar pattern with much of the watershed area lying between 5,000 and 9,000 ft.

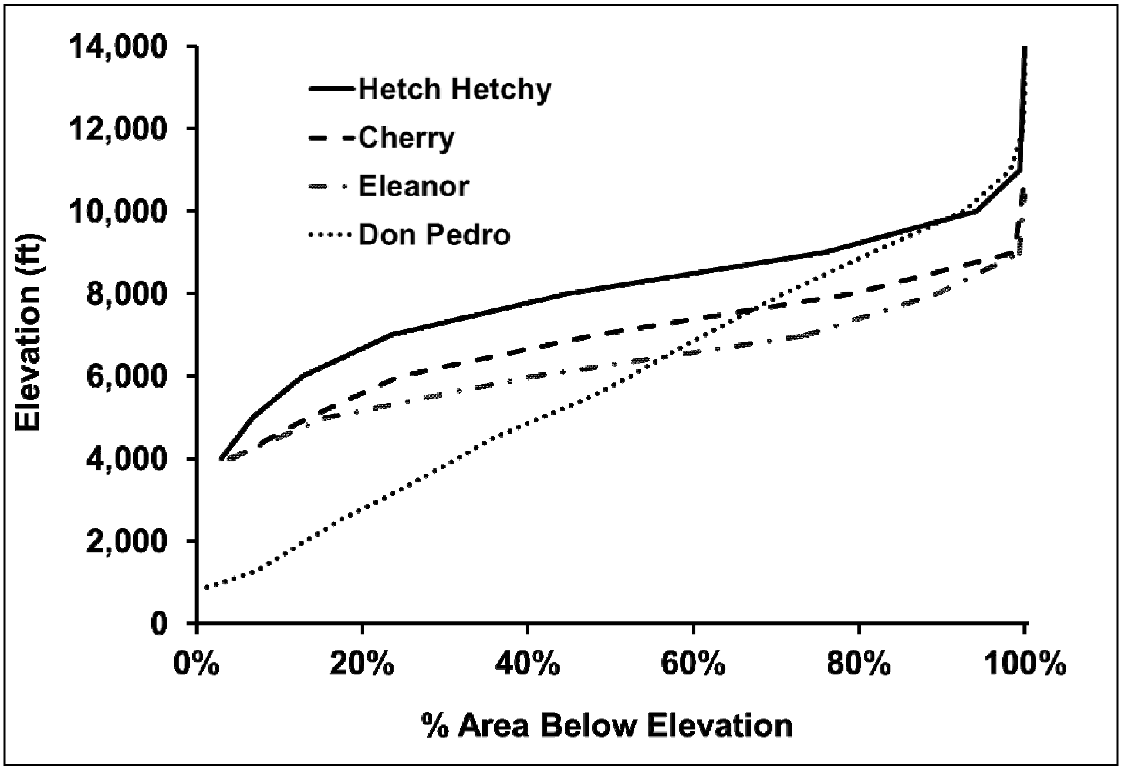

Figure 1-2. Hypsometry for the major Tuolumne River basin reservoirs

HY-52 cont.

Given the great range in elevation, the Tuolumne watershed has vast variation in vegetation, soil structure and morphology. At higher elevations (6,000 -13,200 ft), the watershed is exposed granitic bedrock that was scoured by glaciers during the Tioga and earlier glacial periods, with steep mountains and deep canyons. The mountainous middle elevations (3,500-6,000 ft) are dominated by coniferous forest which begin to transition to oak dominated forests. Lower elevations (800-3,500) are composed of oak forests and oak savannah with a mix of rural land use and townships and grassy hillslopes. These variations in natural vegetation coverage are controlled by the large variation in available moisture due to a strong orographically-driven precipitation pattern.

Mean annual precipitation ranges from 8 inches to above 60 inches in the mountains. The watershed is dominated by a Mediterranean climate with hot, dry summers and cool, wet winter periods (Figure 1-3). The winter storm season may begin as early as October and extend into May. Typically winter snowline is near 5,500 feet but varies from year to year. The snow transition zone is between 4,000 and 5,500 feet, with snow events occurring often in the winter, but the snow accumulation may ablate. Snow events at elevations as low as 2,000 feet are not uncommon and occur nearly every year.

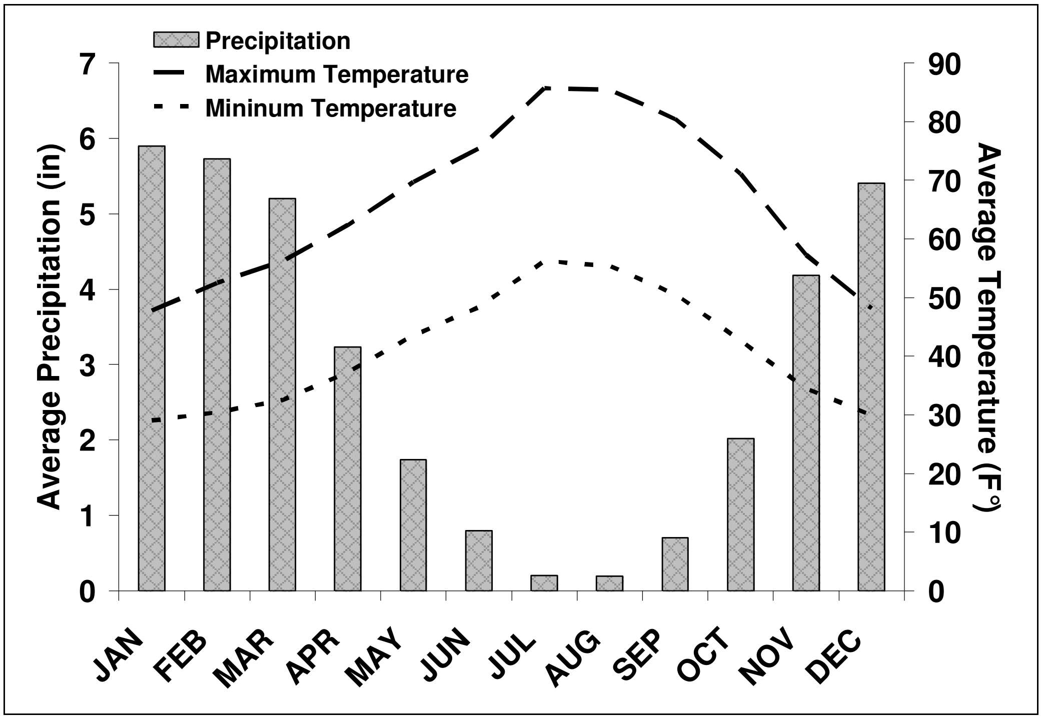

Figure 1-3. Climograph for the Hetch Hetchy meteorological station.

HY-52 cont.

Annual variation in precipitation and hydrologic conditions results in a large disparity of annual inflow – ranging from 20 to 250% of average inflow. This variation is controlled by the snow accumulation during the winter season as typically 75% of the annual runoff occurs during the April thru July snowmelt runoff period. Due to this pattern reservoir management typically focuses on this period.

Table 1-1. Watershed Characteristics at Primary Reservoirs in the Study Area

Reservoir	Drainage Area (sq. mi.)	Elevation range (ft)	Average annual inflow (thousand acre-feet)
Hetch Hetchy	459	3,800-13,200	747
Eleanor	79	4,650-10,400	171
Cherry	117	4,700-10,800	281
New Don Pedro	1,532	800-13,200	1,844

Two main water projects exist on the Tuolumne River. The SFPUC owns and operates the Hetch Hetchy Water and Power Project (Hetch Hetchy Project). This system, located in the upper Tuolumne River watershed, includes dams and flow diversions on the Tuolumne River, Cherry Creek (a tributary to the Tuolumne River), Eleanor Creek (a tributary to Cherry Creek), and Moccasin Creek (tributary to Don Pedro Reservoir). Water from this project is utilized for the Hetch Hetchy Regional Water System which delivers water to the San Francisco Bay area. The second major project is New Don Pedro Reservoir which is owned and operated by Turlock Irrigation District and Modesto Irrigation District. The two irrigation districts utilize watershed runoff and reservoir storage to meet irrigation demands, domestic water supply and power generation needs. Water that is released from Don Pedro Dam can be diverted into two diversion canals (Turlock Canal and Modesto Canal) which serve as the main distribution for each district's operations.

1.5 Evidence of changing climatic conditions

The world's climate has been changing and the vast majority of scientists attribute this change to an increase in the emission of carbon dioxide (CO_2) and other greenhouse gases (Intergovernmental Panel on Climate Change, 2007). The global average surface temperature has risen between 1.08˚F and 1.26˚F (0.6˚C and 0.7˚C) since the start of the 20th century (World Meteorological Organization, 2005). Figure 1-4 presents the trend in annual global average temperature.

HY-52 cont.

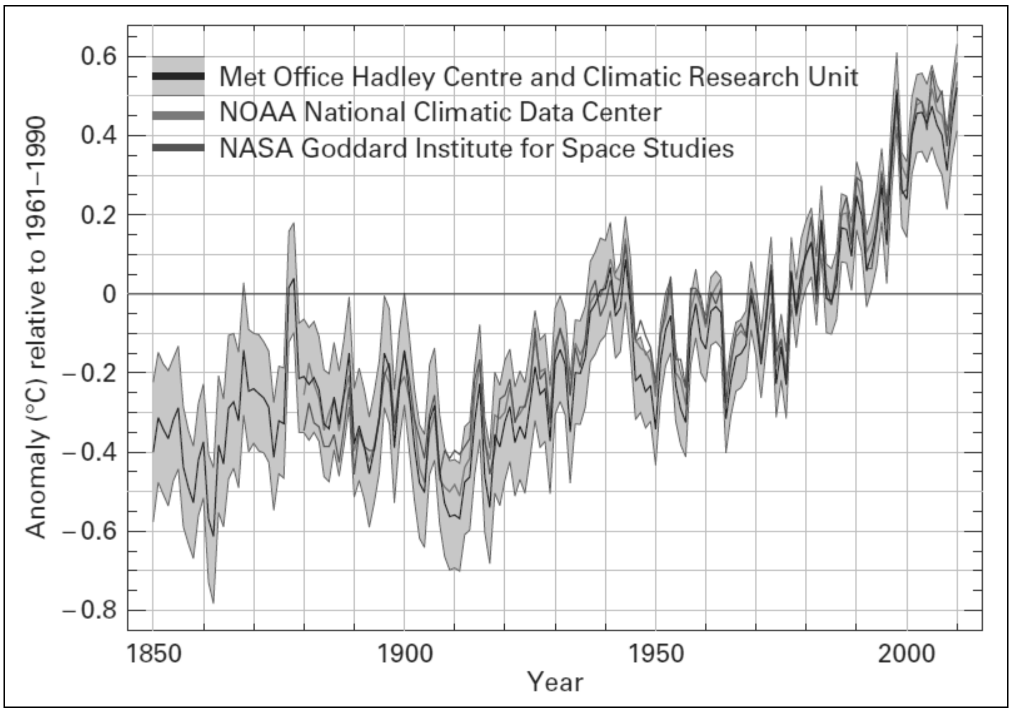

Figure 1-4. Annual global average temperature anomalies (relative to 1961–1990) from 1850 to 2010 from the Hadley Centre/CRU (HadCRUT3) (black line and grey area, representing mean and 95 per cent uncertainty range), the NOAA National Climatic Data Center (red); and the NASA Goddard Institute for Space Studies (blue) (Source: WMO, 2011)

2. Study Approach

This study analyzes the hydrologic response of the Upper Tuolumne watershed to changes in temperature and precipitation. To assess this response, a physically-based conceptual model, HFAM was used. The Hydrocomp Forecast and Analysis Model or HFAM was completed in 2007 and is the most recent edition in the Stanford (Crawford and Linsley 1966), Hydrologic Simulation Program (Hydrocomp, Inc., 1976), Hydrologic Simulation Program-Fortran (HSPF, Bicknell et al. 1997) and Seattle Forecasting Model (SEAFM), (Hydrocomp, Inc., 1993) family of continuous simulation models. An application of HFAM to the Tuolumne (Tuolumne HFAM model) has been developed over the last twelve years by Hydrocomp for TID (Hydrocomp 2000, 2007). It has been used in operations at Don Pedro Reservoir since 1999. The Tuolumne HFAM model simulates hydrologic processes (snow accumulation and melt, infiltration, runoff, channel flow and reservoir operations) using hourly input meteorological data (precipitation, temperature, evaporation, solar radiation and wind speed). The model set-up and calibration are discussed in Section 3.

A historical meteorological database was developed by Hydrocomp for the Tuolumne HFAM model for the period of 1930 to 2008. Historic meteorological records at real-time stations that report to CDEC were extended prior to the period of record by correlations to the long-term stations. This study focuses on the "Historic" 34-year period from 1975 to 2008 to rely more on observed weather data rather than extended data and to use better reservoir inflow records for calibration and validation. In addition, this period covers a reasonable cross-section of wet, dry and average years to represent long-term variability. Using the water year type classification at Hetch Hetchy Reservoir, the study period includes 10 extremely wet years, 3 wet years, 9 normal years, 4 dry years and 8 critically dry years[1]. HY-52 cont.

A warming pattern has been detected in the Sierra Nevada (Barnett et al. 2008, Bonfils et al. 2008), and upward trends in temperature were observed at stations within the study area as well (Section 5.1). Trends over several decades are an integral part of climate and have been observed in the past. However, recent warming trends are significant because they "differ in length and strength from trends expected as a result of natural variability" (Barnett et al. 2008). The anthropogenic influence on the climate system is changing the means and variability of hydrologic variables (IPCC, 2007, Milly et al. 2008). These upward trends in temperature indicate a non-stationary process and so undermine the assumption of stationarity used in water resources engineering.

Stationarity is the property of natural systems to fluctuate within an unchanging envelope of variability. This is a fundamental concept in the practice of water resources engineering. Most hydrologic analyses used in water resources planning assume that hydrologic data are stationary, which means that probabilistic behavior of any variable is time invariant. Weather and streamflow data that includes progressive climate effects may be outside of this unchanging

[1] The classification is based on a runoff indictor representing the cumulative inflow to Hetch Hetchy Reservoir since October 1 of the current water year. Extremely wet, wet, normal, dry and critically dry represent 15%, 20%, 30%, 20%, 15% of the years on record, respectively.

envelope and this creates difficulties for reservoir system yield or reliability analysis. To determine reservoir system yield and reliability, one needs the average yield of the river basin and the variability of the flows over time. The purpose of storage is to even out the variability of flows to give a sustained firm yield over time. Yield/reliability analysis with climate change effects, e.g. without a stationary record to rely upon, is uncharted territory. Traditional analysis is not applicable, and research will be needed to develop analysis methods. For that reason, it was decided that records needed to be adjusted to a hypothetical quasi-steady condition at each of the time horizons of interest. For each of those quasi-steady state conditions, a firm yield can be computed and storage needs assessed.

Because streamflow simulated with the Tuolumne HFAM model may later be used in water resources planning analysis, a "Current Condition" 34-year weather sequence was developed by increasing earlier temperature records to remove upward trends in the "Historic" weather sequence and hence creating a stationary (quasi-steady or static) weather sequence (Figure 2-1 and Section 5.2) that represents the climate in 2010.

HY-52
cont.

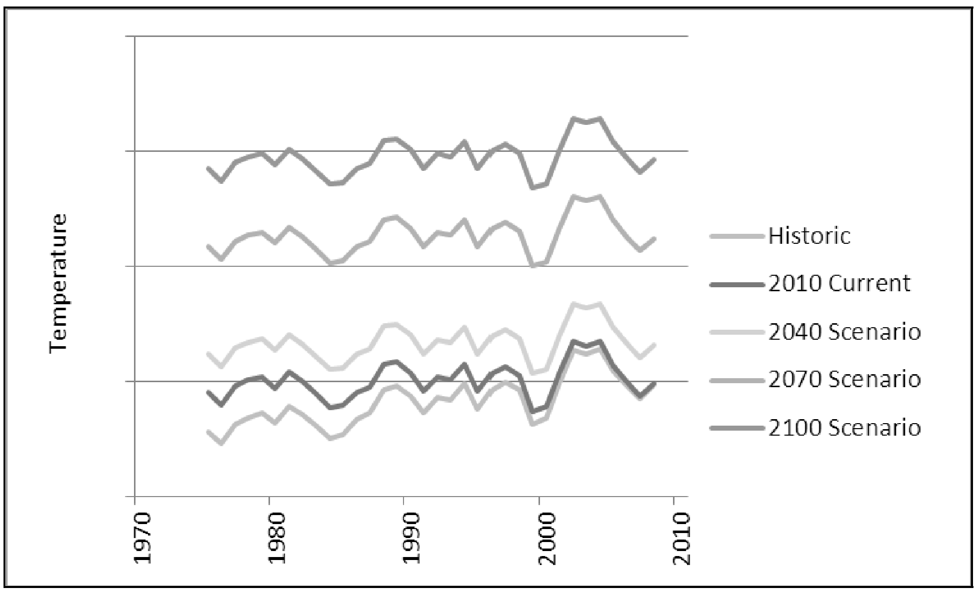

Figure 2-1. Conceptual representation of "Historic" weather sequence, "2010 Current Condition", and potential conditions in 2040, 2070 and 2100 time horizons using delta method

The well-known approach of scenario planning was selected to incorporate potential changes in future climate rather than using climate model outputs. Constructed climate change scenarios were developed through review of climate science, climate modeling, current climate projections and discussion with climate experts. The result of this process is six climate change scenarios of changing temperature and precipitation that represent a plausible range of climate uncertainties (Section 3).

The climate change scenarios consist of changes in mean annual temperature and precipitation over the study area. The "Current Condition" 34-year weather sequence is adjusted using the delta method to include the effects of changing mean annual temperature or mean annual precipitation (Figure 2-1). The delta method is described by Bader et al. (2008) as: "Climate model output is used to determine future change in climate with respect to the model's present-day climate, typically a difference for temperature and a percentage change for precipitation. Then, these changes are applied to observed historical climate data for input to an impacts model”. The application of the delta method is discussed in Section 5.2.

This study approach has some limitations. First, climate projections indicate not only changes in annual precipitation and temperature but also indicates greater climate variability during the 21st century. They indicate both a greater frequency in extreme temperature events and diurnal range, as well as greater frequency of extreme precipitation events – both wet and dry (IPCC, 2007). The change in frequency of events and seasonal shift are not captured by this study approach.

Secondly, the Tuolumne HFAM model parameters are calibrated for current watershed vegetation conditions but studies show that vegetation may change as climate changes. With changes in temperature and precipitation, ecosystem structure (e.g. vegetation patterns, drainage network, soil properties) will change. Panek et al. (2009) modeled vegetation shifts in Yosemite National Park for the next century based on IPCC climate scenarios. Under all scenarios, alpine vegetation disappeared, the spatial extent of subalpine conifer forests decreased and shifted upwards, while montane chaparral and hardwoods expanded and desert vegetation appeared. Evapotranspiration and runoff will change as new vegetation is established. The water balance will also be affected by an increase in forest fires and the death of current vegetation, which will temporarily decrease transpiration and increase storm runoff. The Tuolumne HFAM model setup assumes that the types and spatial extent of vegetation will remain the same as today. Addressing this variable would require adjustments to the calibrated land segment parameters based on expert judgment, a potential task for future model development. HY-52 cont.

3. Defining Climate Change Scenarios

Considering the wide range of climate change projections from different emission scenarios and different climate models, as well as the complexity of using climate model outputs in the Tuolumne HFAM model, it was decided that for a first assessment of streamflow sensitivity to temperature and precipitation changes, a selection of constructed scenarios that represents a plausible range of future climate conditions would be sufficient.

The construction of scenarios was guided by consultations with two experts in the state of climate change science and the current literature for California, Joel B. Smith[2] and Dan Cayan[3]. In addition to their expertise, both have extensive experience working with utilities in understanding vulnerability to climate change. The experts' guidance was based on review of climate science, climate modeling, and climate projections as of 2008-2009.

The six constructed scenarios are described by changes in mean annual temperature and precipitation from 2010 conditions for time horizons 2040, 2070 and 2100 (Table 3-1).

The climate change scenarios have temperature increases from the present-day conditions (2010) to 2100 ranging from 3.6 ˚F (low increase) to 9.72 ˚F (high increase). Mean annual precipitation changes in three of the six scenarios. The dry scenarios have a 15% reduction from the present-day in 2100 whereas the wet scenario has a 6% increase by the end of the 21st century. HY-52 cont.

Following the work done by Cayan et al. (2009) for the 2008 California Climate Change Scenarios Assessment, the changes in temperature and precipitation were based on projections from six GCMs that contributed to the IPCC Fourth Assessment (IPCC 2007) using two Special Report on Emissions Scenarios (SRES) emissions scenarios – a moderately low emissions scenario (B1) and a medium-high emissions scenarios (A2). Models were chosen on the basis of having a climatology which gives reasonable representation of precipitation in California, having a semblance of ENSO, having reasonable spatial resolution, and providing daily output.

[2] Joel B. Smith, Principal at Stratus Consulting (http://www.stratusconsulting.com) and lead author for the Synthesis Report on climate change impact for the Third Assessment Report of the IPCC in 2001.

[3] Dr. Daniel R. Cayan. Researcher meteorologist at the Scripps Institution of Oceanography, University of California San Diego and U. S. Geological Survey. He heads the California Nevada Applications Program and the California Climate Change Center.

Attachment A

O-TRT-DREKMEIER Cont.

Table 3-1. Constructed climate change scenarios

Scenario	Description	Mean Annual Temperature (˚F (˚C))[1]			Mean Annual Precipitation (in)[1]		
Current Conditions	2010 conditions	55.1 (12.8)			36.9		
Future Climate Change Scenarios		**Change from Base (˚F (˚C))[2]**			**Change from Base (%)[3]**		
		2040	**2070**	**2100**	**2040**	**2070**	**2100**
1A	Low temperature increase no precipitation change	+1.1 (0.6)	+2.3 (1.3)	+3.6 (2)	0	0	0
2A	Moderate temperature increase no precipitation change	+1.8 (1)	+4.0 (2.2)	+6.1 (3.4)	0	0	0
2B	Moderate temperature increase precipitation decrease	+1.8 (1)	+4.0 (2.2)	+6.1 (3.4)	-5	-10	-15
2C	Moderate temperature increase Precipitation increase	+1.8 (1)	+4.0 (2.2)	+6.1 (3.4)	+2	+4	+6
3A	High temperature increase no precipitation change	+3.0 (1.65)	+6.3 (3.5)	+9.7 (5.4)	0	0	0
3B	High temperature increase Precipitation decrease	+3.0 (1.65)	+6.3 (3.5)	+9.7 (5.4)	-5	-10	-15

[1] Mean annual temperature and precipitation at HTH station.
[2]Temperature increases are given in degrees F (degrees C) added to the 2010 current conditions static meteorological database.
[3]Precipitation changes are given in percent change to the 2010 current conditions static meteorological database.

HY-52 cont.

Figure 3-1 presents evolution of annual temperature and precipitation for the Sacramento Region based on projections from six GCMs for two emissions scenarios (Cayan et al. 2009).

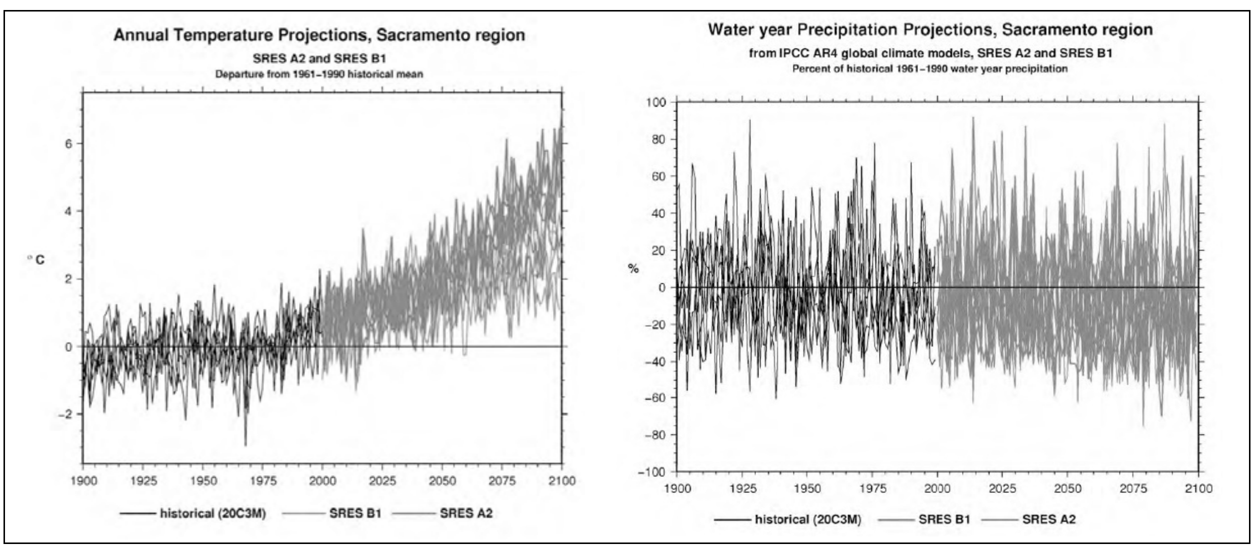

Figure 3-1. Annual temperatures and precipitation near Sacramento, for six for the six GCMs (CNRM CM3.0, GFDL CM2.1 MIROC3.2, MPI ECHAMS, NCAR CCSM3, NCAR PCM1) for the 1901-1999 historical period (black) and for the projected 2000–2100 periods under the A2 (red) and B1 (blue) GHG emissions scenarios. In this case, the values plotted are taken directly from the GCMs from the grid point nearest to Sacramento (Source: Cayan et al. 2009).

O-TRT-DREKMEIER Cont.

Temperatures in California are projected to rise significantly over the 21st century. According to Smith (2008), "there is virtually no doubt that temperatures will continue to rise in California (and over the entire United States), so assuming a rise in temperature is reasonable." It is important to note that the two main sources of uncertainty in the temperature projections are the imperfect physics in modeling the many complex atmospheric processes and the emissions scenarios themselves. Cayan states (pers. comm. June 2008): "The choice of emissions scenario does not make a big difference on the temperature change until after 2050. At 2100, the choice of scenario makes a big difference." Overall, these GCMs project warming in the mid-century from about 1.8˚F to 5.4˚F (1˚C to 3˚C), and rising by the end of the 21st century from about 3.6˚F to 9˚F (2˚C to 5.4˚C).

It is fair to say that there is no conclusive evidence the region will become drier, but there is a reasonable possibility that annual precipitation will decrease. At Sacramento, change in precipitation lacks consensus for the early period, but by mid and late 21st century the models tend toward drier, especially for the SRES A2 scenario (Figure 3-2). Median of results range from just a couple of percent drier to about 8 percent drier for A2 at end-of-Century but some individual models project up to 15 percent drier. Because winter precipitation in Sacramento is well correlated to that in the Sierra Nevada, these precipitation projections are considered at this time to be representative of precipitation variability in the central Sierra Nevada (Cayan et al. 2009).

HY-52 cont.

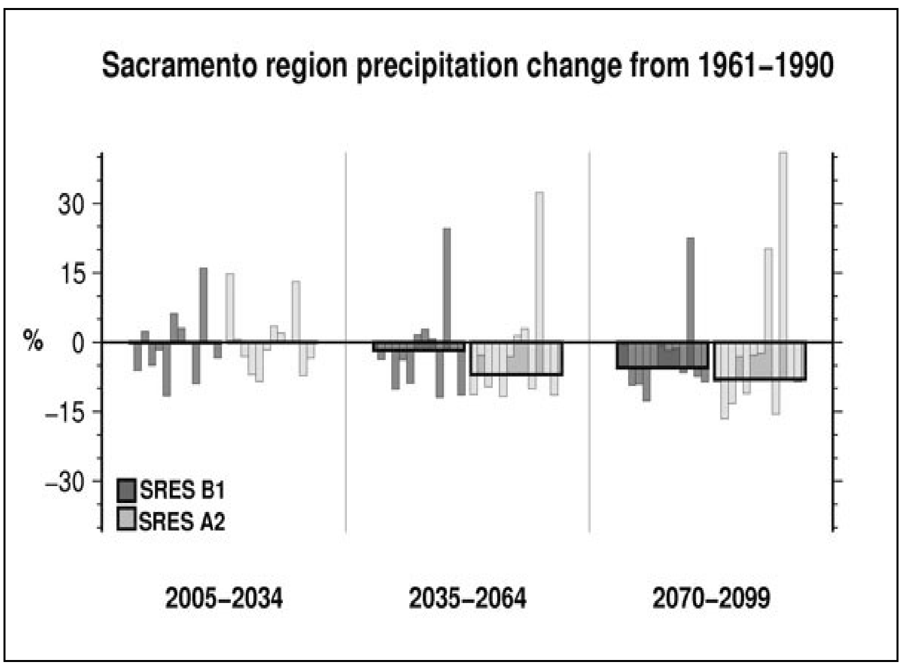

Figure 3-2. Differences in 30-year mean annual precipitation for early, middle and late 21st century relative to 1961-1990 climatology for 12 GCMs for SRES B1 and A2. Light bars are individual model averages and heavy lines are the median of the 12 GCMs. Precipitation is taken directly from the GCMs from the grid point nearest to Sacramento (Cayan, pers. comm., Jan 2009).

4. Tuolumne HFAM Model

4.1 Model Setup

The current Tuolumne HFAM model system includes:

- HFAM program, version 2.3
- watershed input files that describe the physical characteristics of the watershed (topography, soils, vegetation, channel reaches) and the operations of reservoir spillways and outlets, diversions, tunnels and power houses
- a historical meteorological database of precipitation, temperature, evaporation, wind movement and solar radiation
- data management software and spreadsheets

The Tuolumne HFAM model includes the following components:

- land segments: simulate surficial hydrologic processes (snow accumulation and melt, infiltration, evapotranspiration and soil moisture storage, and runoff)
- river reaches: simulate channel processes (flow velocity, stage in channel reaches)
- reservoirs: simulate the storage and release of flow from natural lakes and reservoirs

HY-52 cont.

The current Tuolumne HFAM model set up is described in detail in previous reports (Hydrocomp, Inc., 2000, 2007)

Figure 4-1 shows a schematic of river reaches and reservoirs in the Tuolumne HFAM model. For the analysis of climate and hydrologic changes, reservoirs are simulated as reaches with no storage. This allows calculation of the total unregulated inflow to each reservoir.

The drainage area of each river reach was subdivided into land segments, areas with quasi-homogeneous hydrologic characteristics, such as mean annual precipitation, soils and vegetation cover. Selected physical processes in land segments, e.g. infiltration and interflow outflow, are modeled as frequency distributions. Figure 4-2 shows the land segments within the drainage area of the Dana Fork of the Tuolumne River (reach 3010). The Dana drainage area is 27 square miles and was divided into 14 land segments based on elevation and aspect. Land segments need not be contiguous and some land segments are composed of non-contiguous areas.

The Tuolumne HFAM model calculates the hydrologic response of more than 900 land segments in the watershed above Don Pedro and routes runoff downstream to reservoirs through 75 channel reaches. Each land segment represents the elevation, soil and rock outcrop, vegetation and aspect associated with a portion of the watershed. The model performs detailed mass and energy budget calculations to simulate the hydrologic cycle on each land segment. By combining and routing the flow from each segment, the model provides detailed information on the effects of basin-wide temperature and precipitation changes on runoff, snow, evapotranspiration and soil moistures.

O-TRT-DREKMEIER Cont.

HY-52 cont.

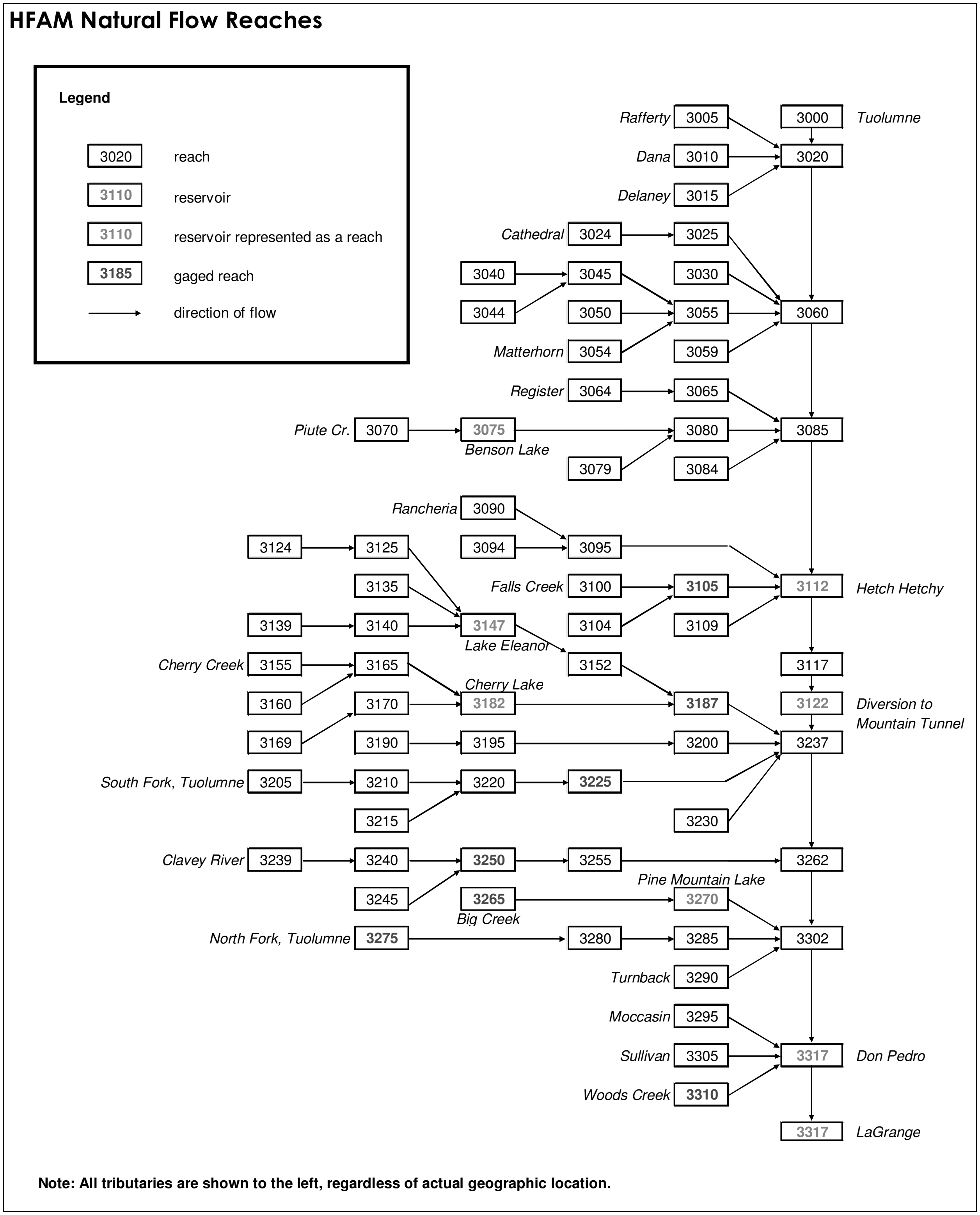

Figure 4-1. Tuolumne HFAM model reaches and reservoirs

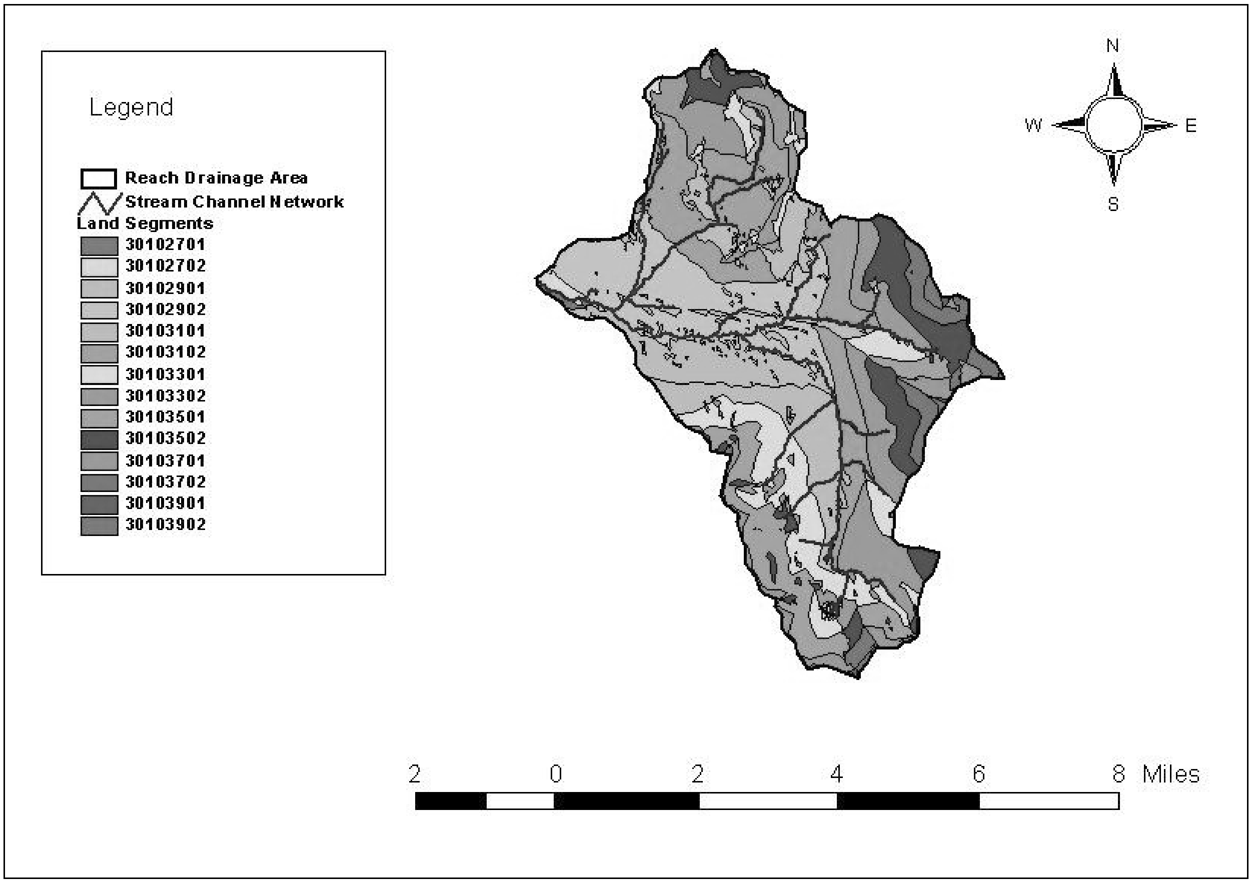

Figure 4-2. Dana Fork Tuolumne River land segments

HY-52
cont.

The model requires continuous hourly meteorological input timeseries and produces comprehensive hourly output timeseries for many variables including soil moisture, snowpack, evapotranspiration, runoff from the land surface, and reservoir inflows. HFAM results can be viewed in the HFAM interface or exported as hourly or daily data files for use in other programs. HFAM creates XML output files readable by Microsoft Word and Excel.

4.2 Meteorological Database

The Tuolumne watershed model includes a historical meteorological database of hourly precipitation, temperature, evaporation, solar radiation and wind speed for period of 10/1/1930 to 9/30/2008. Precipitation and evaporation are used to calculate rainfall and runoff on the land surfaces and in the channel reaches and reservoirs. Temperature, solar radiation and wind speed data are needed for simulation of snowpack heat exchange and melt on the land segments.

Figure 1-1 shows the California Data Exchange Center (CDEC) station identifier and location of each meteorological station used by the Tuolumne HFAM model. Table 4-1 lists the meteorological stations used by the Tuolumne HFAM model and indicates which of the meteorological data types are available at each station (precipitation, temperature, wind, solar radiation, and evaporation).

Table 4-1. Tuolumne meteorological stations

Station ID	Name	Precip	Temp	Evap	Solar	Wind
MID	Modesto Roof	✓				
MOR	Modesto Reservoir	✓				
HTH	Hetch Hetchy Reservoir	✓	✓	✓		
BKM	Buck Meadows	✓	✓		✓	✓
TMM	Tuolumne Meadows	✓	✓			
TUM	Tuolumne Meadows	✓	✓			
PDS	Paradise Meadows		✓			
HRS	Horse Meadow		✓			
SLI	Slide Canyon		✓			
CHV	Cherry Valley Dam	✓	✓			
MCN	Moccasin	✓	✓			
GNL	Gianelli Meadow		✓			

Table 4-2 lists station elevations and the long-term average daily temperature range (daily maximum temperature minus daily minimum temperature) of each of the temperature stations. The daily temperature range at stations in mountainous terrain is affected by upslope movement of warm air during the day and by cold air drainage into valleys at night. The topography at each station determines these air movements. The daily temperature range in the Tuolumne watershed decreases with elevation at all locations except TUM/TMM. TUM/TMM has a large temperature range and is unique due to cool air pooling (Lundquist 2008).

HY-52 cont.

Table 4-2. Tuolumne temperature stations

Station	Elevation (ft.)	Start of Records	Daily Temperature Range (deg F)
BKM	3200	1989	27.5
PDS	7650	1989	25.1
HRS	8400	1987	23.5
GNL	8400	1998	21.1
TUM/TMM[1]	8600	1992	32.3[2]
SLI	9200	1985	24.6
MCN	938	1950	31.4
CHV	4764	1950	26.1
HTH	3858	1930	26.0

Notes:

1. Temperature records at TUM (8600 ft) begin in 1998. These TUM records were extended for the period 1992 to 1998 using records taken at TMM (9200 ft).
2. The TUM station records from 1998 to 2008 have an average daily range of 32.8 deg. F. The TUM station records from 1992 to 1998 have an average daily range of 31.4 deg F.

Data records are not available for the entire historical data period (1930 to 2008) for all the meteorological stations, as shown in Table 4-2. The real-time stations (BKM, TUM/TMM, PDS, HRS, GNL and SLI) that record and transmit data in real-time did not begin recording data until 1985 or later. Hydrocomp extended the records back in time by estimating meteorological conditions prior to the period of real-time records based on the data recorded at nearby stations with long periods of record (historical stations), adjusted according to the difference in long-term average temperature between the real-time station and the historical station. Data sources and extension is discussed in detail in Appendix E.

A maximum/minimum temperature adjustment method was developed to extend real-time temperatures by adjusting data from the historical stations using the difference between long-term minimum daily temperature and long-term maximum daily temperature at the real-time and historical stations (this adjustment method is described further in Appendix E). This adjustment method does not bias the daily temperature range and was used to estimate the revised extended data period at all the real-time stations.

4.3 Modeling System Calibration

Modeling system calibration in the Upper Tuolumne, a large and geographically complex watershed, requires:

- Analysis of watershed topography, soils, vegetation and forest cover to define watershed elements (land segments, reaches).
- Analysis of historic meteorological data including locations of stations, estimating missing and invalid measurement from correlations among stations, and analysis of atmospheric lapse rates.
- Analysis of stream gage and reservoir release records
- Model parameters adjustments at multiple sites to reduce for modeled and recorded streamflow differences, and for improved representation of snow course snowpack water content. HY-52 cont.
- Analysis of model algorithms.

Although differences between model results and watershed measurements are deemed 'model error' and more descriptive term is 'modeling system error' where the modeling system includes the data series employed and the level of detail for watershed elements defined in the model.

The Tuolumne HFAM model was first developed by Hydrocomp in 1998 and has been used to support hydrologic forecasting for TID. Model calibration is an on-going activity, as more data are collected and new data stations are added. The model was re-calibrated in 2007, when the model was upgraded from HFAM 1.1 to HFAM II (Hydrocomp, 2007).

For the modeling of the Tuolumne climate change scenarios, the HFAM model parameter SNOWCF was changed from the value used for TID operational model (1.05 - 1.08) to 1.0 for all land segments so that temperature increases in the climate change scenarios would not change total precipitation depths.[4] The precipitation factor (ratio between precipitation at the gage and at the land surface) for each land segment was increased to compensate for the SNOWCF parameter change to maintain the same total precipitation on each land segment.

In addition, the Tuolumne HFAM model calibration was refined using the previously unavailable Hetch Hetchy estimated inflow records and the USGS gage on the Grand Canyon of the

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[4] Precipitation falling as snow is not captured by gages as effectively as rainfall. The SNOWCF (snow correction factor) increases the precipitation depth for recorded snowfall events.

Tuolumne.[5] Biases between observed and HFAM-simulated streamflow were present prior to the recalibration, particularly for SFPUC reservoirs. The model was recalibrated based on available estimated reservoir inflows and gaged streamflow data for water years 1975 through 2008.

Steps taken to improve modeling system calibration for the Upper Tuolumne are described for watershed elements, the hydrometeorological data base, and for model structure, algorithms and parameters.

4.3.1 Watershed Elements

Upper Tuolumne watershed structural elements are land segments and stream reaches. Hydrologic processes in land segments, e. g. infiltration, evapotranspiration, snow accumulation and melt, provide runoff to streams. Stream reaches collect runoff and route flows downstream.

In the Upper Tuolumne HFAM application areas within land segments have similar elevation, soils or exposed rock, topography, aspect and vegetal cover. Land segments are non-contiguous. Approximately 32,000 GIS defined areas were combined into more than 900 land segments.

Increasing the number of land segments in the Upper Tuolumne application is possible, for example by reducing the elevation interval or by increasing the number of aspect categories used but this would not significantly improve the model calibration for inflows to O'Shaughnessey, Cherry Valley or Don Pedro. The level of watershed element detail that is needed or helpful for improved calibration is linked to basin scale; in a 2 sq. mi. watershed 100 land segments might be helpful, but in a 2000 sq. mi. watershed 100,000 land segments would be cumbersome, delaying calibration model runs without improving model accuracy. Increasing the number of stream reaches can be equally ineffective for improving model calibration. HY-52 cont.

Assignments of meteorological data to land segments in the Upper Tuolumne were changed during calibration based on model results. In mountainous watersheds, the distance from a gage to a land segment and elevation/exposure differences affects these assignments.

4.3.2 Meteorological Data Base

Each land segment requires hourly precipitation, temperature, potential evapotranspiration, wind and solar radiation. These data are rarely observed within a land segment and must be estimated or scaled to account for gage location to land segment differences, particularly for elevation and aspect differences (Appendix E).

Missing and incomplete records at gaged locations in the Tuolumne are filled using both program routines and human judgment. Outliers or erroneous data are located and replaced by human judgment. Data transmitted from real-time sensors at snow course sites are often erroneous and extended periods of missing data are common at these sites. Missing or erroneous data at CHV, HTH and MCN are uncommon.

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[5] USGS Site 11274790, Tuolumne in the Grand Canyon of the Tuolumne above Hetch Hetchy, installed in October 2006.

Hydrometeorological data records at the real-time snow course sites were extended back in time from 1974 to 1985 or later (Appendix E). Data from gaged sites were scaled as necessary to represent conditions at the land segments. Precipitation is scaled using isohyetal mapping. Wind is scaled as a function of elevation. Potential evapotranspiration are assumed constant with elevation.

Air temperatures in land segments are calculated using lapse rates, and affect the temperature dependent snowfall vs. rainfall assignments. Temperatures are important for snowpack heat exchange and snowmelt timing. Analyses attempted to estimate lapse rates continuously throughout the Upper Tuolumne from concurrently available hourly temperature, wind, and precipitation data series. These analyses were inconclusive due to limited concurrent historic data and station to station lapse rates based on long-term daily maximum and minimum temperature records were used (Table E-4, Appendix E).

Temperature is strongly dependent on elevation and often declines with increasing elevation at a 'lapse rate' of -2 to -6 degrees F. per thousand feet. Lapse rates are dynamic, cold air draining from mountain slopes into valleys may create temperature inversions. In the Tuolumne historic hourly temperatures are not available at CHV or HTH. Typical diurnal temperature cycles, with daily minimum temperatures at 4 to 6 a.m. and daily maximum temperatures at 2 to 4 p.m., are used to estimate hourly temperatures from daily maximum and minimum temperatures. These typical diurnal cycles are often not present during storms. Wind and heat releases by condensing water vapor during storms affect lapse rates. HY-52 cont.

Direct calculation of lapse rates from concurrent records at the real-time stations (PDS, HRS, SLI and TUM/TMM) was erratic and unrealistic due to distances between station locations and relatively small elevation differences between stations.

Much of the improvement in the calibration was due to corrections to the meteorological data. In addition, model calibration for the Tuolumne tributaries improved when extended temperature records were revised using the maximum/minimum temperature adjustment method as discussed in Section 4.2.

4.3.3 Model Algorithms and Parameters

The algorithms that calculate snow accumulation and melt and surficial hydrologic processes in the HFAM model were first developed at Stanford and have evolved over many years based on thousands of applications but algorithm updates are made when observed data warrants. One algorithm update was made during this project to attenuate liquid water outflow from snowpacks. Streamflow data showing the diurnal variability of flows during snowmelt were collected in the Upper Tuolumne for Raffery, Parker Pass and Gaylor basins (Lundquist and Dettinger, 2005). These are small basins, 6 to 10 sq. mi. in area, tributary to Tuolumne Reach 3000 (Figure 4-1). The Lundquist and Dettinger data for the time difference between maximum snowmelt rates, usually about 2 p.m., and the peak basin outflow measured during snowmelt indicated that liquid water releases from snowpacks were attenuated more than previously modeled in HFAM. The algorithm update delayed peak liquid water outflow timing by several hours.

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Data collected at the recently installed streamgage at Tuolumne Grand Canyon (USGS 11274790, 301 sq. mi.) supported this algorithm change, although as drainage areas increase snowpack water outflow timing may not be separated from other flow attenuation processes; e. g. flow routing in reaches and flow through ponds and lakes.

The timing of peak flows measured during snowmelt is also dependent on where snow is melting in a watershed. Figure 4-3 shows snow water equivalent in the Tuolumne above the Tuolumne Grand Canyon gage on May 1, 2008. Modeled peak flow timing May 1st was 7:30 p.m. in Reach 3000 and 8 p.m. in Reach 3085 (Tuolumne Grand Canyon). Snowmelt runoff observed at Reach 3085 on May 1st was primarily coming from the northern watershed areas tributary to Puite, Matterhorn and Register Creeks rather than from land tributary to Reach 3000. Peak snowmelt timing would have minimal secondary effects on model results for climate change but the algorithm update does more closely follow snowpack processes.

HY-52
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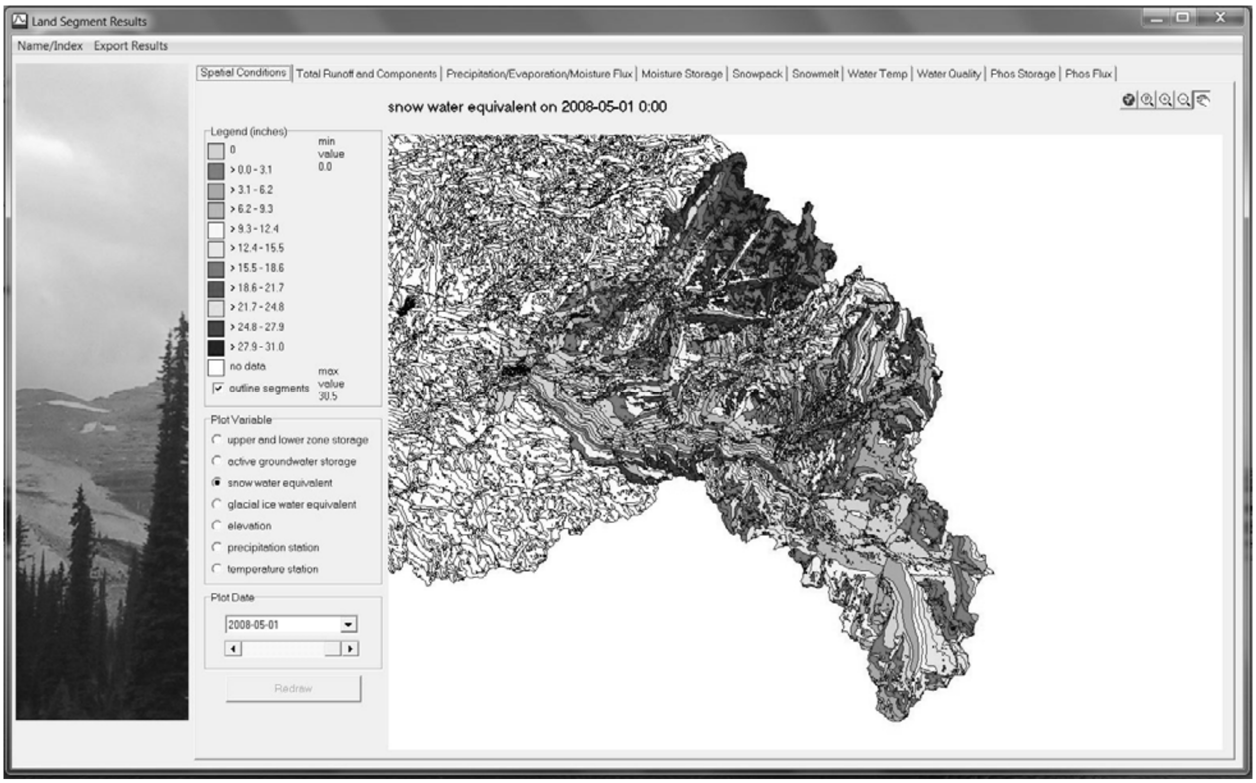


Figure 4-3. Modeled Snowpack Water Equivalent above Tuolumne Grand Canyon, May 1st, 2008

Model parameters represent the diverse characteristics of the Upper Tuolumne. Watershed land at elevations below 6500 ft. is covered by forests, shrubs and grass. Soils are granite derived silt and sand with relatively high infiltration rates and soil moisture holding capacities. Watershed lands above 6500 ft. are exposed granite with near zero infiltration rates and moisture holding capacities or valley meadows with substantial infiltration rates and soil moisture holding capacities. Lakes and ponds are found in high elevation valleys. Lakes, ponds and perched aquifers in meadows in high elevation valleys provide base or groundwater flows for streams even where exposed granite predominates.

Model parameter changes in calibration affected surface runoff, interflow and groundwater flowpath assignments (HFAM parameters INFILT, INTFW, and AGWRC), and snow accumulation, net heat exchange and melt (HFAM parameters TSNOW, NEGHTE, HSHADE and FSHADE). HFAM parameters are defined in the HFAM II Reference and User's Manual (Hydrocomp, 2011).

Model parameter calibration for snow accumulation and melt and for surficial hydrologic processes, especially for inflows to O'Shaughnessey, Eleanor and Cherry Valley reservoirs, was significantly refined because reservoir inflow estimates for these sites were provided for 1974 through 2008 by SFPUC. Appendix B shows simulated reservoir inflows and newly calculated reservoir inflow estimates for O'Shaughnessey and Don Pedro for water years 1974 through 2008.

4.3.4 Calibration Results

Figure 4-4 shows a summary of the calibration results for the Clavey River, the South Fork Tuolumne River and for La Grange, as seen in the HFAM interface. The calibration results summary includes a plot of simulated and observed monthly flows, a bar chart of simulated and observed long-term average monthly flows, the total simulated and observed flow volumes and the percent difference in these volumes over the period of record within water years 1975 to 2008. HY-52 cont.

Figure 4-5 shows simulated inflows to O'Shaughnessey dam in water year 2002 (a sample normal year[6]) compared to calculated natural inflows, as seen in the HFAM interface.

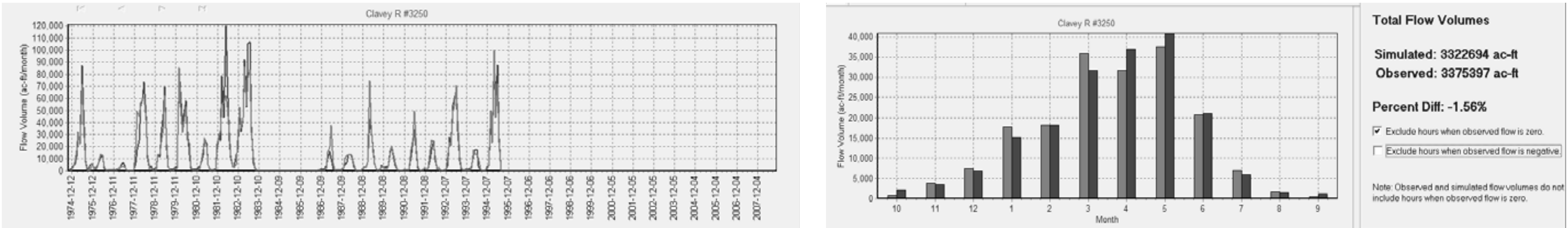
Figure 4-6 shows an example of the calibration results in water year 2002, an average snow year, as seen in the HFAM interface. Observed snow water equivalent at the Horse Meadows (HRS) real-time data observation site at 8400 feet elevation is compared to simulated snow water equivalent on a land segment that represents the Horse Meadows location. The zero observed data point on May 21st is incorrect and is a bad data point.

Annual hydrographs from October 1974 through September 2008 are given in Appendix B.

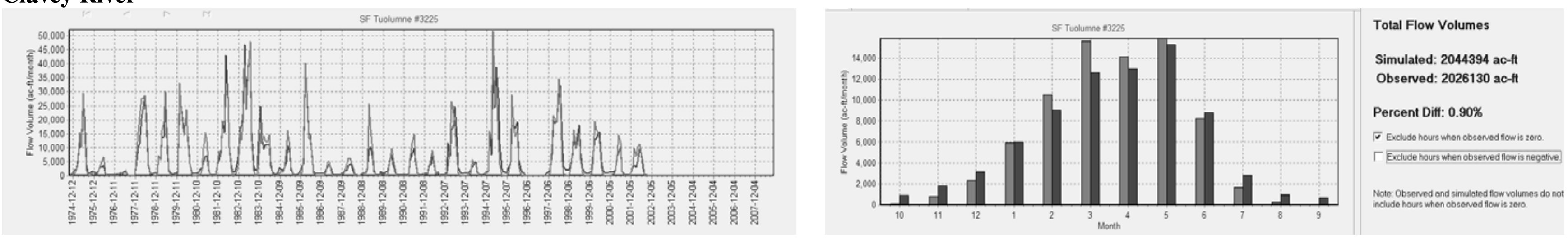
The USGS installed a new streamflow gage on the Tuolumne in the Grand Canyon of the Tuolumne above Hetch Hetchy (11274790) at 3,830 feet with a drainage area of 301 square miles. Data records began 10/21/2006 and will be useful for on-going calibration of the model.

[6] See footnote 2 for description of water year classification system.

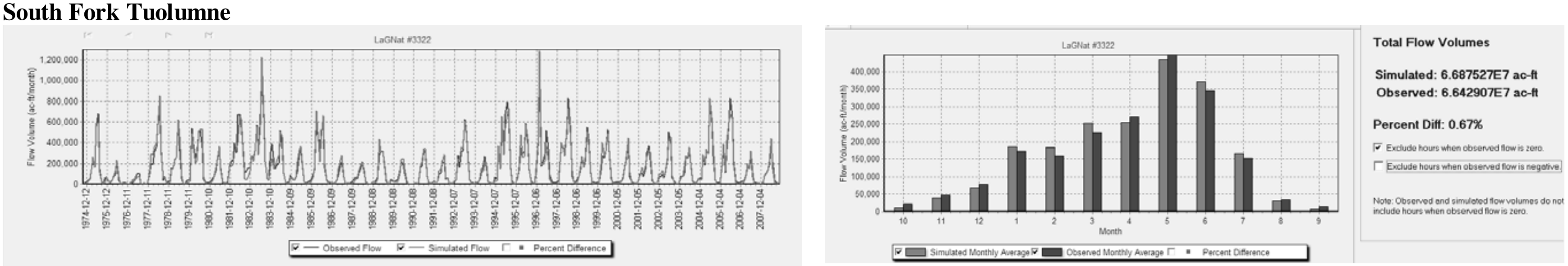
Attachment A



Clavey River



South Fork Tuolumne



La Grange

Figure 4-4. Calibration results for the Clavey River, the South Fork of the Tuolumne River and the Tuolumne River at New Don Pedro Reservoir

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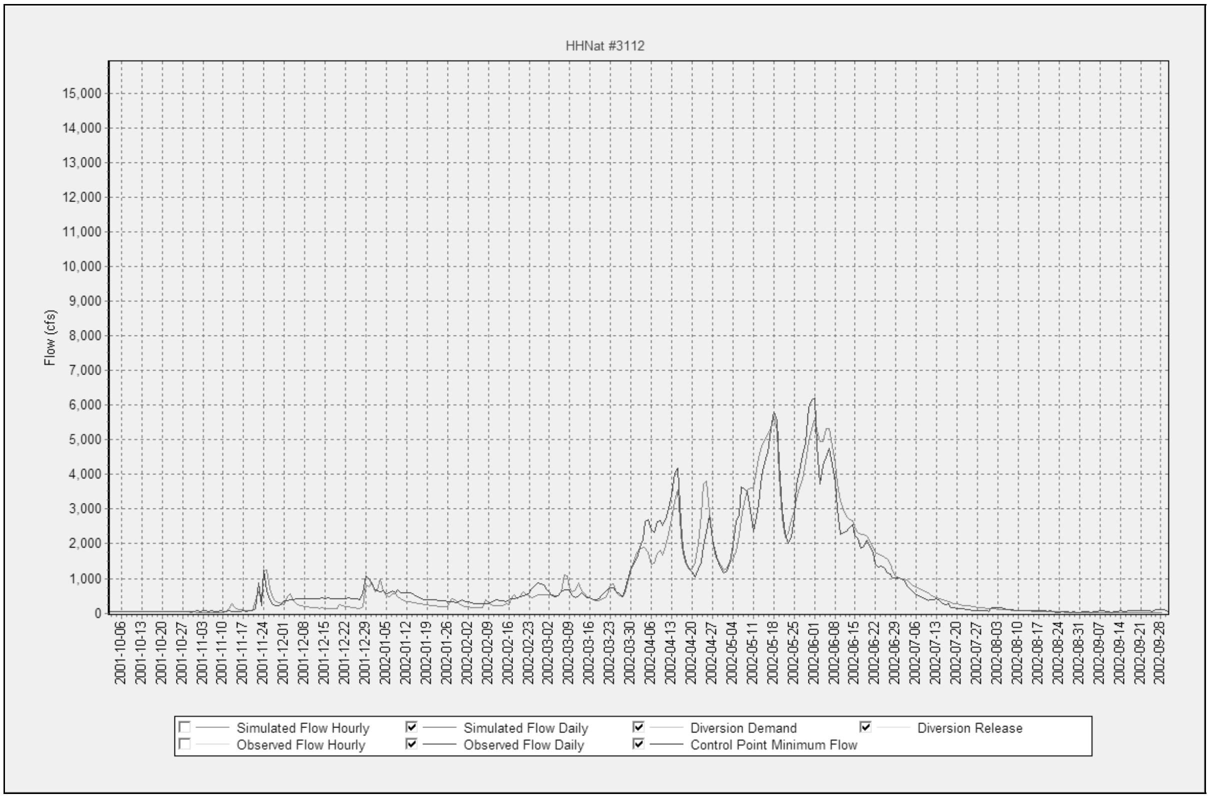

Figure 4-5. O'Shaughnessey simulated and observed natural inflow, 2002 (normal year)

HY-52 cont.

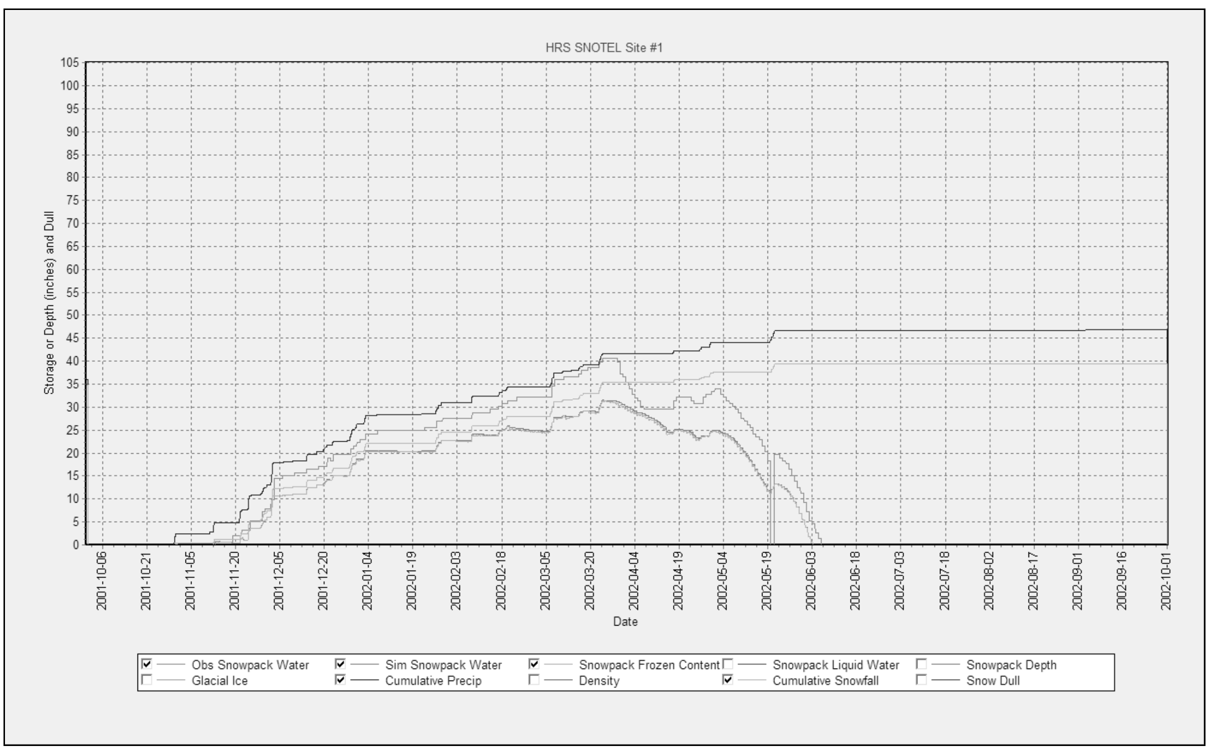

Figure 4-6. Simulated and observed snow water equivalent at 8400 ft., HRS, 2002

5. Constructing Current Conditions and Climate Change Scenarios Weather Inputs

5.1 Historical Trends and Current Climate

Climate is represented in the Tuolumne HFAM model as input timeseries of precipitation, temperature, wind, solar radiation, and evaporation. Climate change scenarios were developed to represent the range of plausible future conditions in the Upper Tuolumne River watershed. The input timeseries for the climate change scenarios were built based on trends and statistics seen in historical meteorological data.

This section summarizes the analysis of historical data. Specific details on the historical data and the analysis are available in Appendix E. Temperature was the only data series found to have consistent historic trends, as in detail in Appendix E and summarized below.

Hourly precipitation, temperature, wind, solar radiation, and evaporation data were compiled for the period of 1930 to 2008 into a 79-year Tuolumne historical meteorological database. These data include records collected at the stations for the period of record and extended records estimated from data recorded at historical stations using the maximum/minimum temperature adjustment method, as discussed in Appendix E. HY-52 cont.

The historical meteorological database for the Tuolumne watershed was found to have long-term temperature trends, but no trends were detected in precipitation, wind, solar radiation or evaporation. A meteorological database was needed for the climate change study that represents the current climate condition without the long-term trends, so that eventually reservoir yield could be computed and storage needs assessed using traditional analysis (see Section 2). A static meteorological database was created from the historical database, with adjustments to the historical temperature from 1960 to 2008 to remove the long-term temperature trends.

Methods used to adjust the historic temperatures to static conditions are in Appendix E. This static meteorological database was used as the current climate condition of 2010 in this analysis.

5.1.1 Precipitation Trends

Figure 5-1 shows the total annual precipitation at Hetch Hetchy (HTH) for the historical data period and the long-term historical annual precipitation trend. The historical annual precipitation trend line is relatively flat and does not indicate any long-term trend in precipitation.

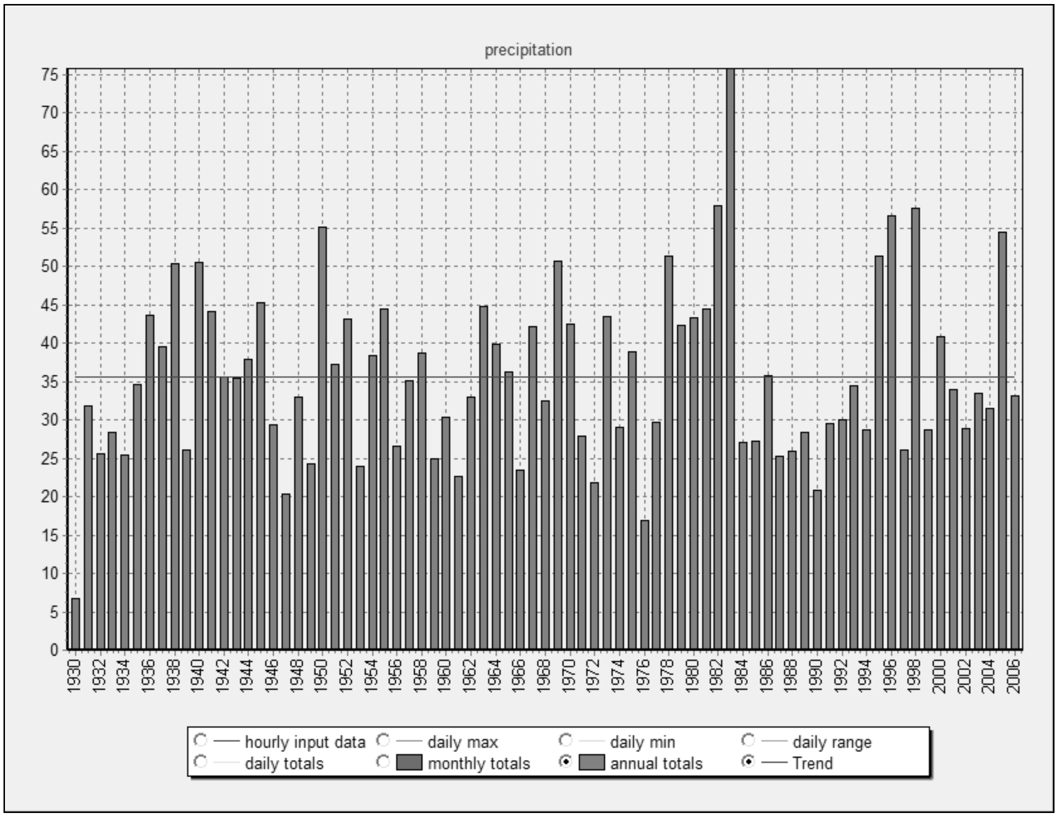

Figure 5-1. HTH historical annual precipitation and trend (plot generated by HFAM)

HY-52 cont.

5.1.2 Temperature Trends

Analysis of historical data from the Tuolumne stations shows overall trends toward increasing temperatures. The details of these trends are complex, but in summary the trends are:

1) Average daily temperatures have increased over the full 79-year period 1930 to 2008, but increases are not consistent over the 79-year period.
2) There are no apparent trends in average daily temperatures from about 1930 to 1960.
3) From about 1960 to the present average daily temperatures at Hetch-Hetchy (HTH) and Cherry Valley (CHV) increase, but the increase is due to an increase in daily minimum temperatures. Daily maximum temperatures show no significant trend.
4) Temperature records at Moccasin at 938 ft. elevation do not show preferential increases in daily minimum temperatures relative to daily average or daily maximum temperatures.

These results correspond to the findings of other climatic studies in the region. Daily minimum temperatures in the Sierras have generally increased since 1900, with most of the increase occurring before 1930 and since 1960 (Behnke, R. 2011). Daily minimum winter temperatures in the Sierras increased over 1.5^{o}C (2.7^{o}F) between 1950 and 1999, while winter average daily maximum temperatures increased over 0.8^{o}C (1.4^{o}F) (Bonfils et al. 2008). Increasing minimum daily temperatures have also been noted at other stations in the Sierra Nevada (John Shaake, pers. comm. December 2009). While temperature has increased in the region overall, there is spatial variability in observed temperatures changes related to elevation and hillslope aspect at individual monitoring stations (Behnke R. 2011, Lundquist and Cayan 2007).

There is a correlation between climate in the Upper Tuolumne River basin and the Pacific Decadal Oscillation that is presented in Appendix E. However, accounting for this correlation has no significant impact on the observed temperature trends and therefore can be ignored in creating the static meteorological database for 2010 current conditions.

The increasing daily minimum temperature trends from 1960 to the present happened when the gage locations and instrumentation at Hetch Hetchy and Cherry Valley were stable (as discussed further in Appendix C.2). Tables of historic temperature trends at Tuolumne river stations are provided in Appendix E.

5.1.3 Solar Radiation Trends

Solar radiation data for the analysis period 1974 to 2008 were calculated from theoretical clear sky solar radiation and percent sunshine estimated from sky cover descriptions at Cherry Valley and Moccasin. The calculated data were compared to short record solar radiation observations at Buck Meadows (BKM) and at high elevation stations in the Tuolumne (TUM, DAN, and TES), (Appendix E). The calculated solar radiation data series show no significant trends.

HY-52 cont.

5.1.4 Wind Speed Trends

Wind speeds for the analysis period 1974 to 2008 were from the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) Reanalysis data set (Kalnay et al. 1996) and from limited observations at Buck Meadows (BKM). These data show no significant trends (Appendix E).

5.1.5 Evaporation Trends

Evaporation data were only recorded at Hetch Hetchy (HTH) for part of the historical data period. Evaporation data before and after the period of data collection are set to the monthly long-term averages with a diurnal pattern. These data have no significant trend.

5.2 Weather Inputs for Climate Change Scenarios

A simple and commonly-used method of developing meteorological timeseries to represent climate change scenarios is the “delta method”. The method was developed in the early days of climate change assessments but is still widely used today. In the delta method, a future timeseries is generated from an historical timeseries representing present-day climate by adding or multiplying it by an adjustment factor equally across all seasons and diurnally to represent future climate. One consequence of this assumption is that the future frequency and magnitude of extreme weather events are the same as they are in present-day climate. Another is that this approach assumes change will occur equally at all times of the year. The method assumes that changes in climates are only relevant at coarse scales, and that relationships between variables are maintained towards the future. While these assumptions might hold true in a number of cases, they could be wrong, particularly in highly heterogeneous landscapes where topographic conditions cause considerable variations over relatively small distances. Nevertheless, the relative simplicity of the delta method approach makes it appropriate for this first sensitivity analysis.

A delta-adjusted future meteorological database was generated from the 2010 current condition static meteorological database to represent each of the future climate conditions listed in Table 3-1. The precipitation for each future climate condition was applied as a multiplication factor to each precipitation record in the static meteorological database. The temperature increase for each future climate condition is stated as average temperature increases instead of increases to minimum and maximum temperatures. Since the historical temperature records in the Tuolumne at Hetch Hetchy and Cherry Valley show that minimum daily temperatures have increased much more than maximum daily temperatures, this tendency is assumed to continue, becoming gradually more moderate. The method of modeling the relative changes in the minimum and maximum temperatures is discussed in Appendix E.

HY-52 cont.

6. Analysis of Hydrologic Response

This section presents the simulated hydrologic response for the period 1975 to 2008 for the climate change scenarios.

Section 6.1 provides results for the 2010 static current condition which uses the de-trended meteorological inputs discussed in Section 5.1. Sections 6.2 to 6.5 compare the 2010 static current condition simulated hydrology to the simulated hydrology for each constructed climate change scenario.

6.1 Effects of Historical Trends

The historical meteorological database was found to have long-term historical trend for minimum and average daily temperature. The observed minimum daily temperature increases over the 1960 to 2008 period at both the Hetch Hetchy (HTH) and Cherry Valley (CHV) gages. A "static meteorological database" was created (as described in Section 5.1) by adjusting the historical temperature data to remove trends using the methods discussed in Appendix E.

HY-52
cont.

Table 6-1 lists the mean daily temperatures at Hetch Hetchy and Cherry Valley calculated from the historical and static meteorological database for the 34-year period, water years 1975 to 2008.

Table 6-1. Mean daily temperature in historical and static meteorological database

Station	Historical Meteorological Database (deg F)	Static Meteorological Database (deg F)	Difference (deg F)
Hetch Hetchy	54.19	55.07	+ 0.88
Cherry Valley	53.36	54.34	+ 0.98

The static meteorological database represents the current climate condition and was used to simulate the current hydrological conditions (year 2010). The higher temperatures in the static meteorological database resulted in increased simulated watershed evapotranspiration and decreased simulated total runoff in the 2010 current condition compared to the historical condition. Table 6-2 lists the percent change in simulated total runoff and total watershed actual evapotranspiration at O'Shaughnessy and Don Pedro dams.

Table 6-2. Change in current hydrological conditions from historical condition

Location	Hydrological Characteristic	Current Climate Condition[1] (% change from historical)
O'Shaughnessy	total runoff	- 0.5 %
O'Shaughnessy	actual evapotranspiration	+ 1.9 %
Don Pedro	total runoff	- 0.9 %
Don Pedro	actual evapotranspiration	+ 1.8 %

[1]The current climate condition (year 2010) was simulated using the static meteorological database.

The adjustments made to historical temperature to remove trends and create a static temperature record are constant from 1930 to 1960, and decrease linearly from 1960 to 2008 (Table E.7). The resulting change in simulated streamflow and actual evapotranspiration are also greater in the early record and become smaller after 1960, disappearing entirely by 2008.

6.2 Runoff Timing and Volume

The future hydrological conditions were simulated with HFAM using the future meteorological database which represents each of the future climate conditions (climate change scenario at a future climate date). The results of these simulations were compared with 2010 current climate simulated hydrologic conditions to analyze the potential hydrological effects of climate change at 2040, 2070 and 2100.

Appendix A provides comparisons of the change in simulated runoff, actual evapotranspiration and snow water equivalent for each future climate condition compared to the current condition.

The effect of temperature increase can be assessed by comparing the results of climate change scenarios 1A (low temperature increase with no precipitation change), 2A (moderate temperature increase with no precipitation change) and 3A (high temperature increase with no precipitation change). The effect of precipitation change can be assessed by comparing the results of climate change scenarios 2A (moderate temperature increase with no precipitation change), 2B (moderate temperature increase with precipitation decrease) and 2C (moderate temperature increase with precipitation increase) or by comparing 3A (high temperature increase with no precipitation change) with 3B (high temperature increase with precipitation decrease). HY-52 cont.

Table 6-3 summarizes the percentage change in median runoff volume at O'Shaughnessy and Don Pedro Dam for each future climate condition. The percentage changes in simulated runoff for each future climate condition are given in comparison with the current climate condition based on the 2010 current conditions meteorological database. Simulated runoff volumes based on the 2010 current conditions meteorological database are approximately one percent lower than the runoff simulated with the historical meteorological database (Table 6-2).

Climate change scenarios cause changes in monthly runoff timing that can be seen in the plots of simulated average monthly runoff for the current and future climate conditions, shown in Section A.1.3. Under climate change scenario 2A in 2100 at O'Shaughnessy, the May through August runoff would decrease by 45% from the current condition (31% of current condition annual runoff), the September through April runoff would increase by 81% (26% of annual runoff), and 5% of the annual runoff would be lost to additional evapotranspiration.

Table 6-3. Change in median runoff volume for future climate conditions

Climate Change Scenario		O'Shaughnessy Runoff (% change from 2010)			Don Pedro Runoff (%change from 2010)		
		2040	2070	2100	2040	2070	2100
1A	low temperature increase no precipitation change	-0.7%	-1.5%	-2.6%	-1.1%	-2.4%	-3.6%
2A	moderate temperature increase no precipitation change	-1.2%	-2.9%	-5.4%	-1.8%	-4.0%	-6.4%
2B	moderate temperature increase precipitation decrease	-7.6%	-15.8%	-24.7%	-9.5%	-19.1%	-28.7%
2C	moderate temperature increase precipitation increase	1.4%	2.2%	2.4%	1.1%	2.0%	2.8%
3A	high temperature increase no precipitation change	-2.1%	-5.6%	-10.2%	-3.0%	-6.5%	-10.1%
3B	high temperature increase precipitation decrease	-8.6%	-18.6%	-29.4%	-10.7%	-21.6%	-32.3%

These results illustrate that runoff is a residual. The long term water balance in the watershed is: HY-52 cont.

Precipitation – Actual Evapotranspiration = Total Runoff (E.6)

The effect of the climate change scenarios on actual ET was greater than initially anticipated. With warming, snow disappears earlier in the spring and so there is a longer snow free season. For that reason, there is an increase in actual ET in a warmer climate. At higher elevation, in 2010 conditions, soil moisture in valleys (e.g. Tuolumne Meadows) allows increased ET in a warmer climate; soil moisture is not completely depleted when snow returns. This explains the reduction in runoff above Hetch Hetchy in scenarios 1A, 2A and 3A.

The potential ET was kept constant in the model due to uncertainty in changes in land cover conditions in the future. A refinement of the model would be to make educated assumptions on land cover conditions and associated change potential ET in a warmer climate.

6.2.1 Actual Evapotranspiration

The watershed water balance equation (E.6) can be restated as:

Actual Evapotranspiration = Precipitation – Total Runoff (E.7)

As climate change increases temperatures, rainfall replaces snow in the fall and winter and reduced snowpacks melt earlier in the spring. Evapotranspiration increases in the fall and winter and begins earlier in the spring. Model algorithms follow a basic hierarchy; at low soil moisture water that reaches the land surface usually infiltrates into the soil profile and is later evaporated or transpired. Algorithms reduce infiltration and allow more runoff as soil moisture storage increases.

Evapotranspiration changes in the climate change scenarios are straightforward in principle but are complex in detail. In the Tuolumne, granite outcrops are common above 6500 ft. These outcrops have very low moisture storage capacity compared to soils at lower elevations. At lower elevations with higher forest density and more grasses, brush and shrubs, evapotranspiration will decrease as soil moistures are depleted in summer.

In climate change scenarios 1A, 2A and 3A, there is an increase in evapotranspiration and a decrease in simulated long-term runoff with no change in precipitation. In climate change scenario 2C, there is an increase in evapotranspiration and in simulated long-term runoff so the runoff increase is less than the increase in precipitation.

Section A.2 of Appendix A shows figures of simulated actual evapotranspiration for the future climate conditions compared to the current condition.

Figure 6-1 shows an example of simulated daily actual evapotranspiration on the watershed above O'Shaughnessy Dam in water year 1994, a sample dry year. The simulated daily actual evapotranspiration for the current climate condition is plotted in red; the simulated daily actual evapotranspiration for the future climate condition in year 2100 of climate scenario 2A (moderate temperature increases with no precipitation change) is plotted in blue. Figure 6-1 shows a consistent increase in evapotranspiration in 2100 from October through May compared to current evapotranspiration.

HY-52
cont.

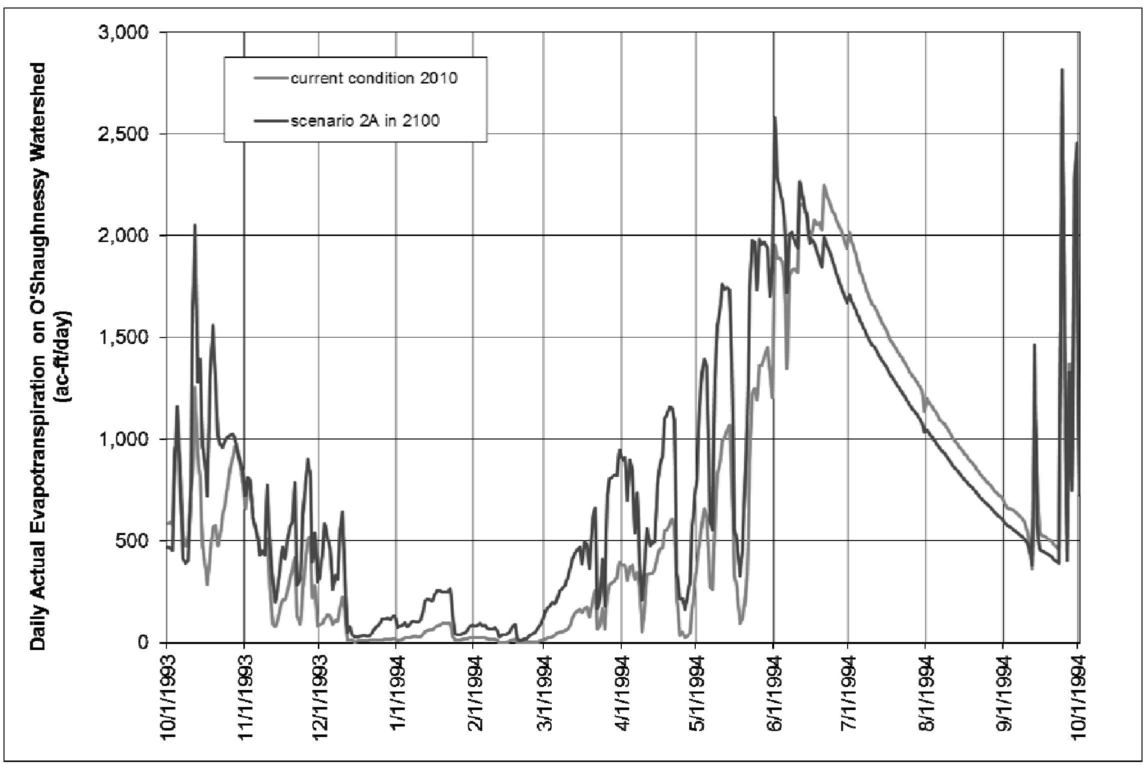

Figure 6-1. Simulated watershed actual evapotranspiration above O'Shaughnessy for current climate condition (red) and scenario 2A in 2100 (blue), water year 1994

O-TRT-DREKMEIER Cont.

Increasing temperatures due to climate change and reduced soil moisture will very likely, over time, alter forest extent and density. Forests may expand at higher elevations and decline at lower elevations. This could change evapotranspiration and require adjustments to the calibrated land segment parameters. Changes in total water yield from Tuolumne due to forest migration may be limited, however, if the total forest extent does not change.

6.2.2 Low and High Runoff Years

The results provided above in are valid for median runoff (exceeded in 50 percent of all water years). Simulated changes in median annual runoff do not fully describe how runoff would be affected during high runoff or drought years. When firm yield from reservoirs is evaluated, low runoff years are critical.

Table 6-4 summarizes the modeling results in terms of the change in simulated 5 (extremely wet), 50 (the median value as shown in Table 6-3) and 95 (extremely dry) percent exceedance annual runoff for two climate change scenarios (2A moderate temperature increases with no precipitation and 3B high temperature increases with precipitation decreases).

Table 6-4. Change in runoff volume for future climate conditions at 5%, 50%, and 95% exceedance level

Climate Change Scenario		Exceed Prob	O'Shaughnessy Runoff (% change from 2010)			Don Pedro Runoff (% change from 2010)		
			2040	2070	2100	2040	2070	2100
2A	moderate temperature increase no precipitation change	5%	-0.6%	-1.4%	-2.4%	-1.1%	-2.6%	-3.7%
2A	moderate temperature increase no precipitation change	50%	-1.2%	-2.9%	-5.4%	-1.8%	-4.0%	-6.4%
2A	moderate temperature increase no precipitation change	95%	-3.4%	-8.8%	-15.1%	-4.2%	-9.8%	-16.1%
3B	high temperature increase precipitation decrease	5%	-7.1%	-14.3%	-21.8%	-8.7%	-16.7%	-24.3%
3B	high temperature increase precipitation decrease	50%	-8.6%	-18.6%	-29.4%	-10.7%	-21.6%	-32.3%
3B	high temperature increase precipitation decrease	95%	-14.7%	-30.9%	-46.5%	-16.6%	-33.3%	-48.1%

HY-52 cont.

Appendix A provides figures showing simulated runoff, actual evapotranspiration and maximum snow accumulation exceeded in 5, 50, and 95 percent of all water years for climate change scenario 2A. Simulated runoff exceeded in 5, 50, and 95 percent of all water years is also provided for climate change scenario 3B, the scenario which results in the greatest reduction in simulated runoff. These figures show the non-linear effects of climate change on runoff in low and high runoff years and illustrate that soil moisture and evapotranspiration have precedence over runoff in droughts.

Runoff in drought years is a relatively small percentage of precipitation and is very sensitive to changes in precipitation. This non-linear sensitivity is found in response to climate change scenarios too: Runoff reductions, as a percentage of current runoff, are greatest in drought years.

The non-linearity of the response to climate change is also reflected in the difference between the mean (average) change in runoff and the median (exceeded in 50 percent of all water years) change. The percent reduction in mean runoff is consistently less than the percent reductions in median runoff. Table 6-5 summarizes these changes for climate change scenarios 2A and 2B.

Table 6-5. Change in median and mean runoff for climate change scenarios 2A and 2B

Climate Change Scenario		Hydrological Characteristic	O'Shaughnessy (% change from 2010)			Don Pedro (% change from 2010)		
			2040	2070	2100	2040	2070	2100
2A	moderate temperature no precipitation change	precipitation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		median runoff	-1.2%	-2.9%	-5.4%	-1.8%	-4.0%	-6.4%
		mean runoff	-1.2%	-2.9%	-5.1%	-1.8%	-3.9%	-5.9%
2B	moderate temperature precipitation decrease	precipitation	-5.0%	-10.0%	-15.0%	-5.0%	-10.0%	-15.0%
		median runoff	-7.6%	-15.8%	-24.7%	-9.5%	-19.1%	-28.7%
		mean runoff	-7.6%	-15.5%	-23.5%	-9.1%	-17.8%	-26.3%

HY-52 cont.

6.3 Snow Accumulation, Areal Extent, and Snowmelt Timing

Simulated total watershed runoff and actual evapotranspiration are dependent on snow accumulation. Table 6-6 summarizes the percentage change in median annual maximum snow water equivalent on the watersheds above O'Shaughnessy and Don Pedro dams for all future climate conditions. Section A.3 of Appendix A shows figures of simulated annual maximum watershed snow water equivalent for each future climate condition compared to the current climate condition (year 2010). Appendix D provides additional details on the change in snow accumulation and snow melt due to the future climate conditions.

Figure 6-2 shows simulated watershed snowpack above O'Shaughnessy Dam in water year 1994. The simulated watershed snowpack for the current climate condition is plotted in red; the simulated watershed snowpack for the future climate condition in year 2100 of climate change scenario 2A (moderate temperature increase with no precipitation change) is plotted in blue. Figure 6-3 shows the simulated natural inflow to O'Shaughnessy Dam over the same period for the same climate conditions. It can be seen the inflows are accelerated. Precipitation events that fell mainly as snow under the 2010 current condition instead trigger rain events under the future climate scenarios which increase wintertime peak inflows. Meanwhile, snowmelt is accelerated due to warmer temperatures and less spatial snow coverage (shallower snowpack melts faster and need less energy to reach isothermal conditions to generate melt and the resulting runoff).

Table 6-6. Change in median annual maximum snow water equivalent for future climate conditions

Climate Change Scenario		O'Shaughnessy Snow (% change from 2010)			Don Pedro Snow (%change from 2010)		
		2040	**2070**	**2100**	**2040**	**2070**	**2100**
1A	low temperature increase no precipitation change	-1.6%	-11.4%	-21.7%	-11.9%	-26.6%	-38.8%
2A	moderate temperature increase no precipitation change	-4.3%	-24.5%	-43.8%	-20.8%	-41.6%	-59.8%
2B	moderate temperature increase precipitation decrease	-10.3%	-33.4%	-54.8%	-25.9%	-49.5%	-67.6%
2C	moderate temperature increase precipitation increase	-2.0%	-20.8%	-38.3%	-18.8%	-38.4%	-56.6%
3A	High temperature increase no precipitation change	-15.5%	-45.8%	-73.5%	-33.6%	-60.8%	-81.4%
3B	High temperature increase precipitation decrease	-20.6%	-53.6%	-79.5%	-38.2%	-66.2%	-85.6%

The simulated snow areal extent is also reduced for the future climate conditions. Figure 6-4 shows a spatial plot of the simulated snow water equivalent in the Tuolumne watershed on April 1, 1992 for the current climate condition displayed in the HFAM interface. April 1st is used as a reference point of peak annual snowpack accumulation. Figure 6-5 shows the same plot of simulated snow water equivalent for the future climate condition in year 2100 of climate change scenario 2A (moderate temperature increases with no precipitation change). Figure 6-6 shows the same plot of simulated snow water equivalent for the future climate condition in year 2100 of climate change scenario 2B (moderate temperature increases with precipitation decrease). Note that the color legend is different in each plot as it corresponds to an increasingly smaller range of snow water equivalent depth. HY-52 cont.

O-TRT-DREKMEIER Cont.

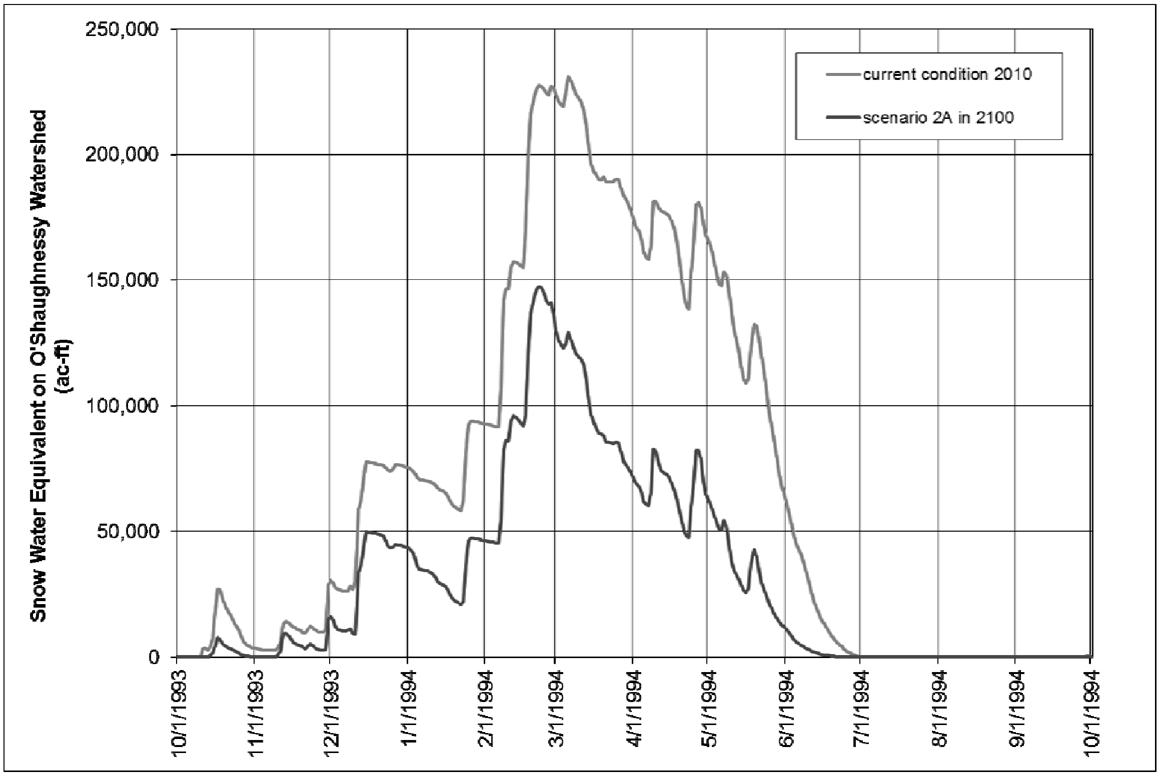

Figure 6-2. Simulated watershed snowpack above O'Shaughnessy Dam for current climate condition (red) and scenario 2A in 2100 (blue), water year 1994.

HY-52 cont.

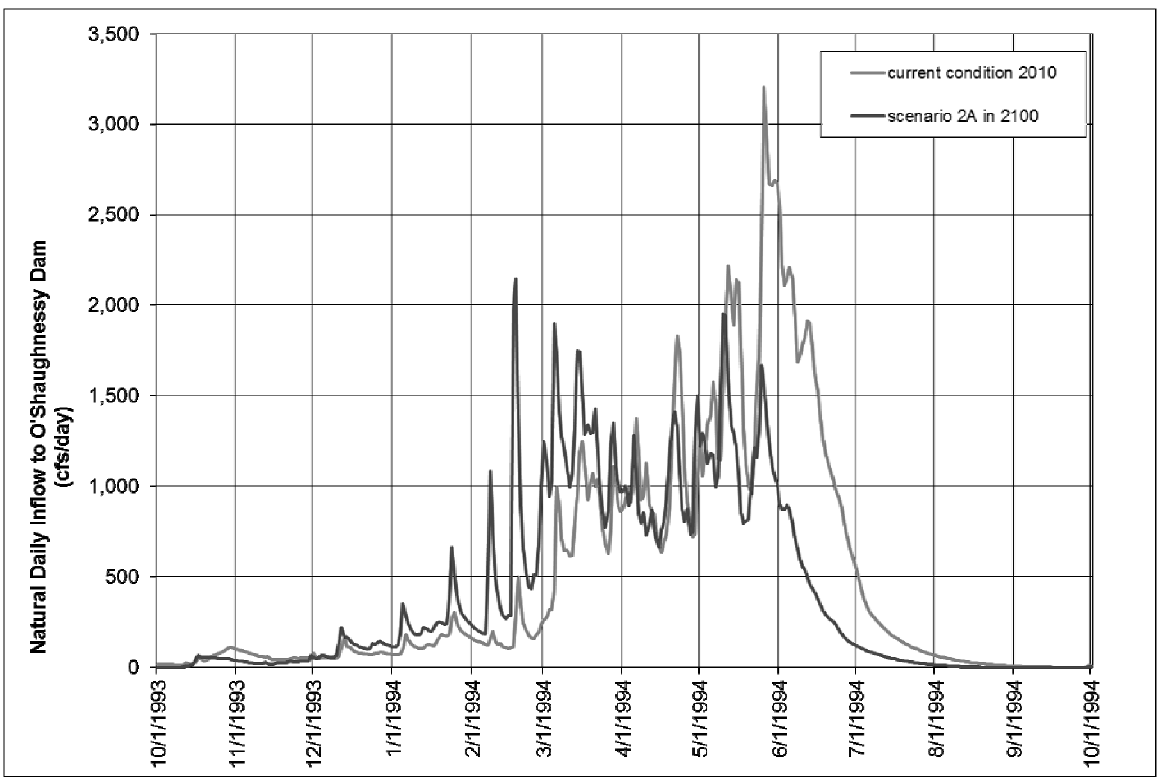

Figure 6-3. Simulated natural inflow to O'Shaughnessy Dam for current climate condition (red) and scenario 2A in 2100 (blue), water year 1994

Attachment A

O-TRT-DREKMEIER Cont.

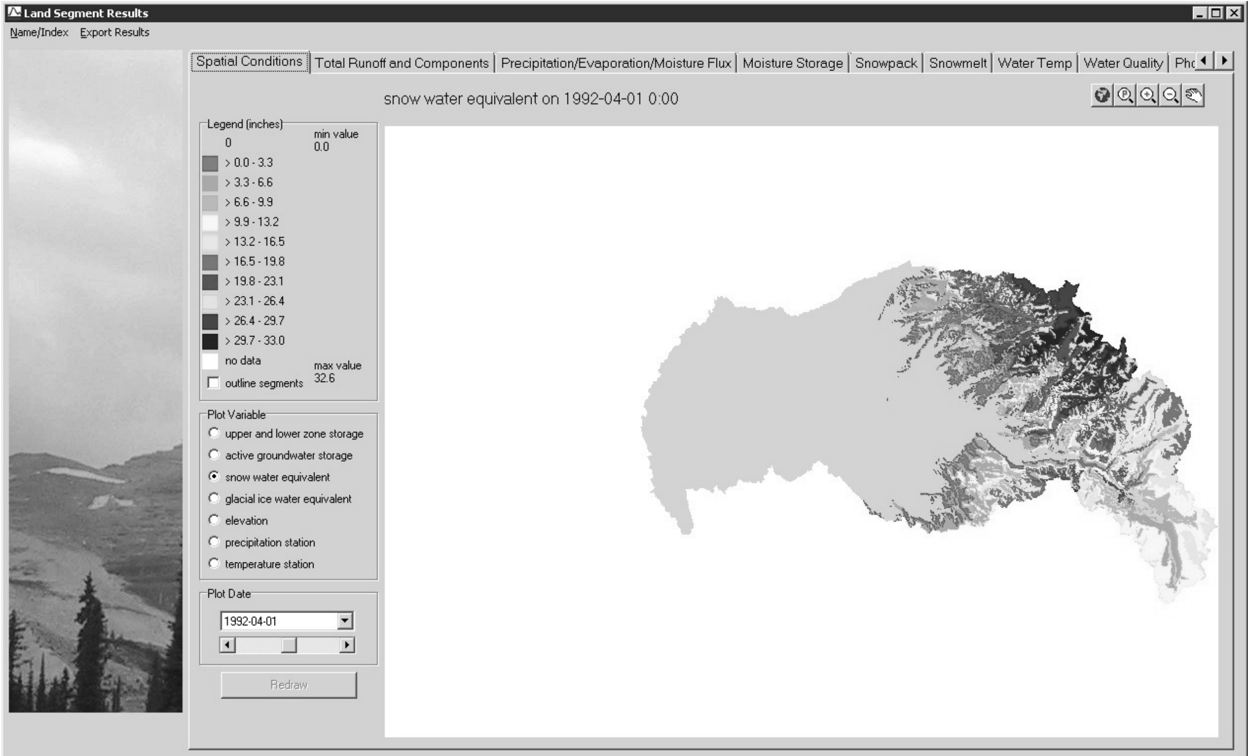

Figure 6-4. Simulated snow water equivalent on 4/1/1992 for current climate condition

HY-52 cont.

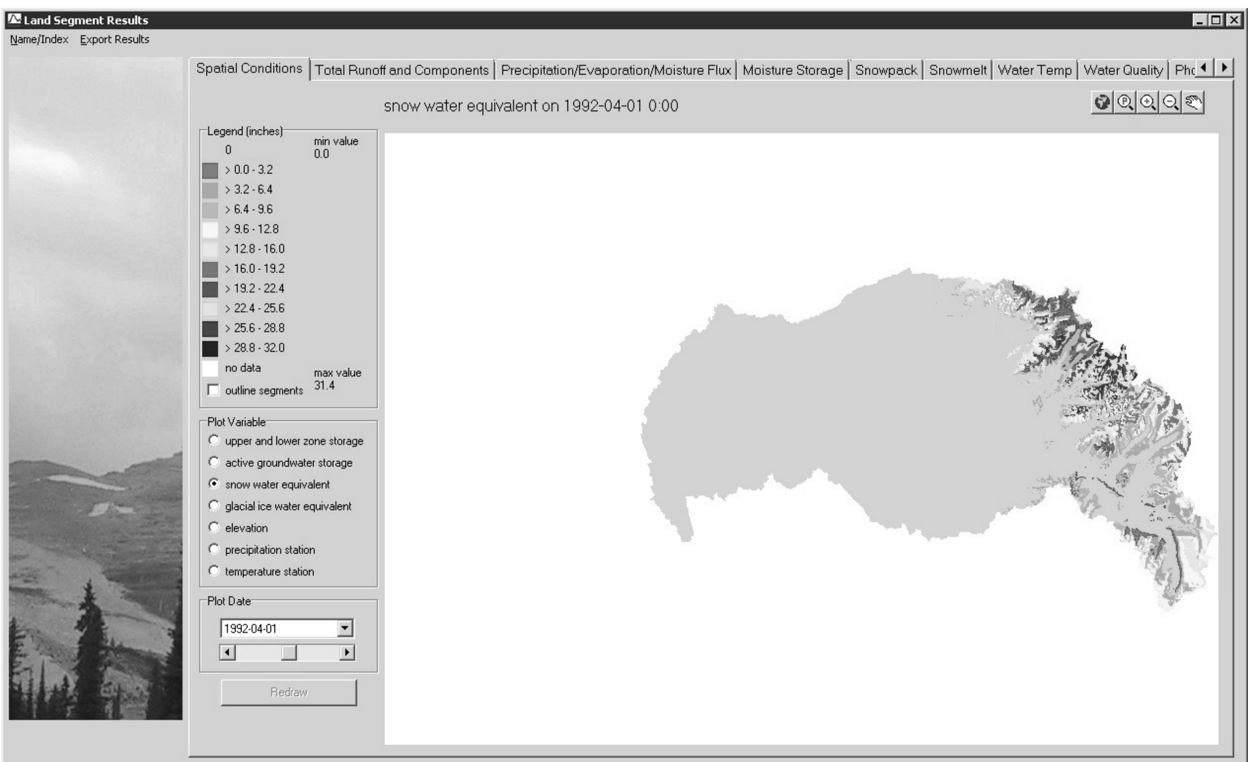

Figure 6-5. Simulated snow water equivalent on 4/1/1992 for scenario 2A in 2100

O-TRT-DREKMEIER Cont.

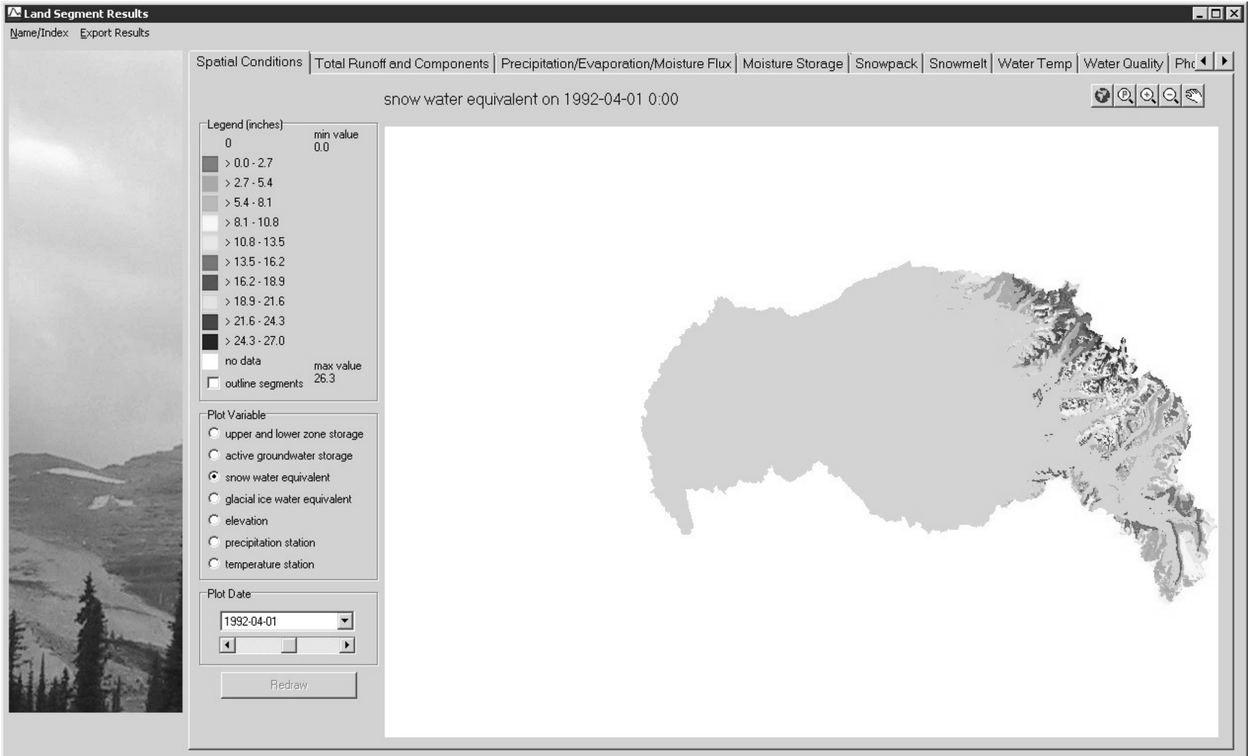

Figure 6-6. Simulated snow water equivalent on 4/1/1992 for scenario 2B in 2100

HY-52 cont.

Figure 6-7 shows the simulated snow water equivalent in the watershed above O'Shaughnessy Dam for water years 1987 to 1995. The simulated snow water equivalent for the current climate condition is plotted in red; the simulated snow water equivalent for the future climate condition in year 2100 of climate change scenario 2A (moderate temperature increases with no precipitation change) is plotted in blue. The reduction in snowpack in the watershed above O'Shaughnessy Dam and the increased actual evapotranspiration that occurs with earlier spring melt result in a 5.6% reduction in simulated flow at O'Shaughnessy Dam over water years 1987 to 1995 compared to the current condition. Simulated flows at Don Pedro Dam are reduced by 6.5% over the same period.

Figure 6-8 shows the simulated snow water equivalent on two land segments with SW aspect at different elevations in the Tuolumne watershed for water year 1992. Snow water equivalent for the land segment at 10,000 feet shown as a solid line; snow water equivalent for the land segment at 7,000 feet is shown as a solid line. The simulated snow water equivalent for the current climate condition is plotted in red; the simulated snow water equivalent for the future climate condition in year 2100 of climate change scenario 2A (moderate temperature increases with no precipitation change) is plotted in blue.

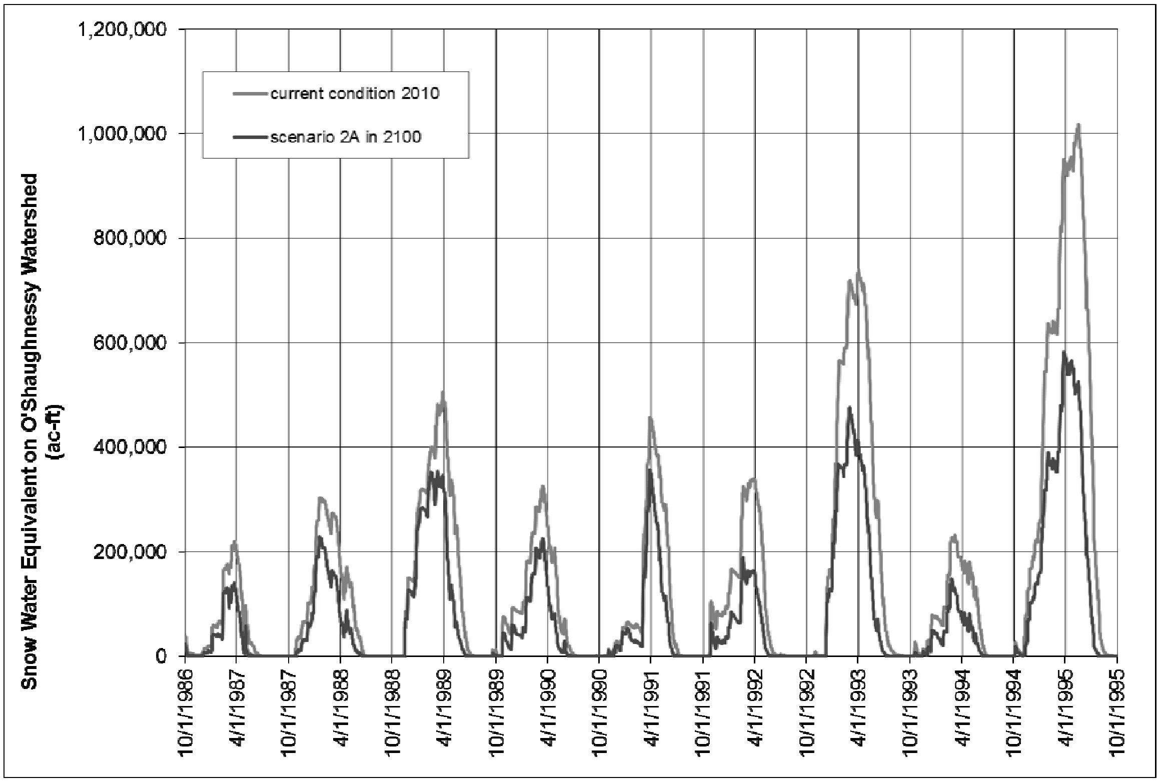

Figure 6-7. Simulated watershed snow water equivalent above O'Shaughnessy Dam for current climate condition (red) and scenario 2A in 2100 (blue), water years 1987 to 1995

HY-52 cont.

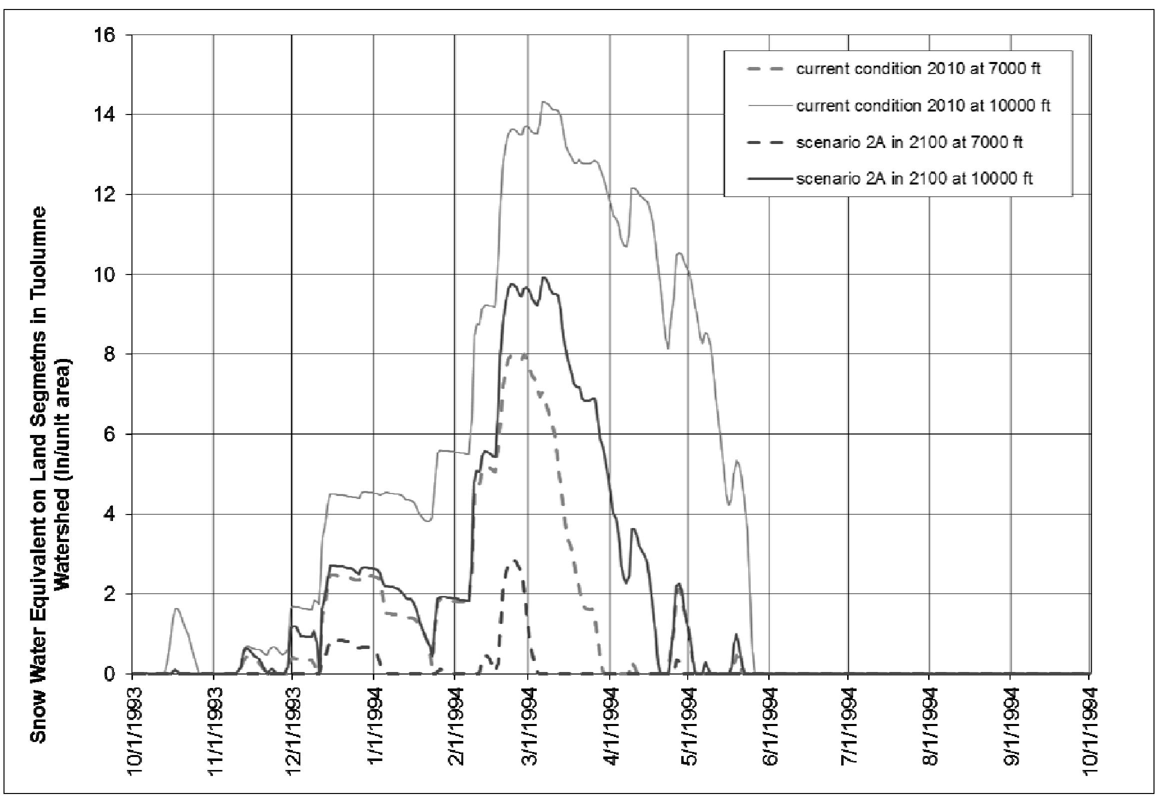

Figure 6-8. Simulated watershed snow water equivalent on land segments at 10000 ft (solid) and 7000 ft (dashed) ft for current climate condition (red) and scenario 2A in 2100 (blue), water year 1992

6.4 Physical Processes, Snowmelt Runoff and Actual Evapotranspiration

Under future climate conditions, winter snow decreases and melts earlier in the spring, resulting in an increase in actual evapotranspiration and a decrease in watershed runoff. Runoff reductions are greater in years with less than normal precipitation. Actual evapotranspiration in all water years is key for runoff reductions.

Actual evapotranspiration (AET) is dependent both on soil moisture, decreasing as soil moisture is depleted, and on snow cover. AET decreases as soil moisture is depleted. In years when there is a large snowpack and in years when cool spring temperatures delay snowmelt, actual evapotranspiration is reduced.

The relative influence of soil moisture and snowpack on actual evapotranspiration losses depends on soil moisture storage and on elevation. The watershed above O'Shaughnessy Dam has more exposed granite and higher elevations, so its actual evapotranspiration is more dependent on snowpack than soil moisture. Lower elevations have less snow and deeper soils so actual evapotranspiration is more dependent on soil moisture.

To illustrate the relationship between actual evapotranspiration, snowpack and soil moisture for the O'Shaughnessy watershed, simulation results are shown for water year 1995, a year with a large snowpack and late spring melt, and for water year 1994, a year with a low snowpack and early spring melt. HY-52 cont.

Figure 6-9 shows simulated cumulative actual evapotranspiration for the O'Shaughnessy watershed for each year of the 34-year meteorological database for the future climate condition in year 2100 of climate change scenario 2A. The red line shows the simulated actual evapotranspiration for water year 1995, a sample wet year. The blue line shows the results for water year 1994, a sample dry year.

The simulated 1995 runoff to O'Shaughnessy Dam for the future climate condition in year 2100 of climate change scenario 2A was 1,378,000 acre-feet. Simulated actual evapotranspiration was 258,000 acre-feet, approximately 19 percent of runoff. In comparison, the simulated 1994 runoff for the same future climate condition was 299,000 acre-feet and simulated actual evapotranspiration was 283,000 acre-feet, approximately 95 percent of runoff.

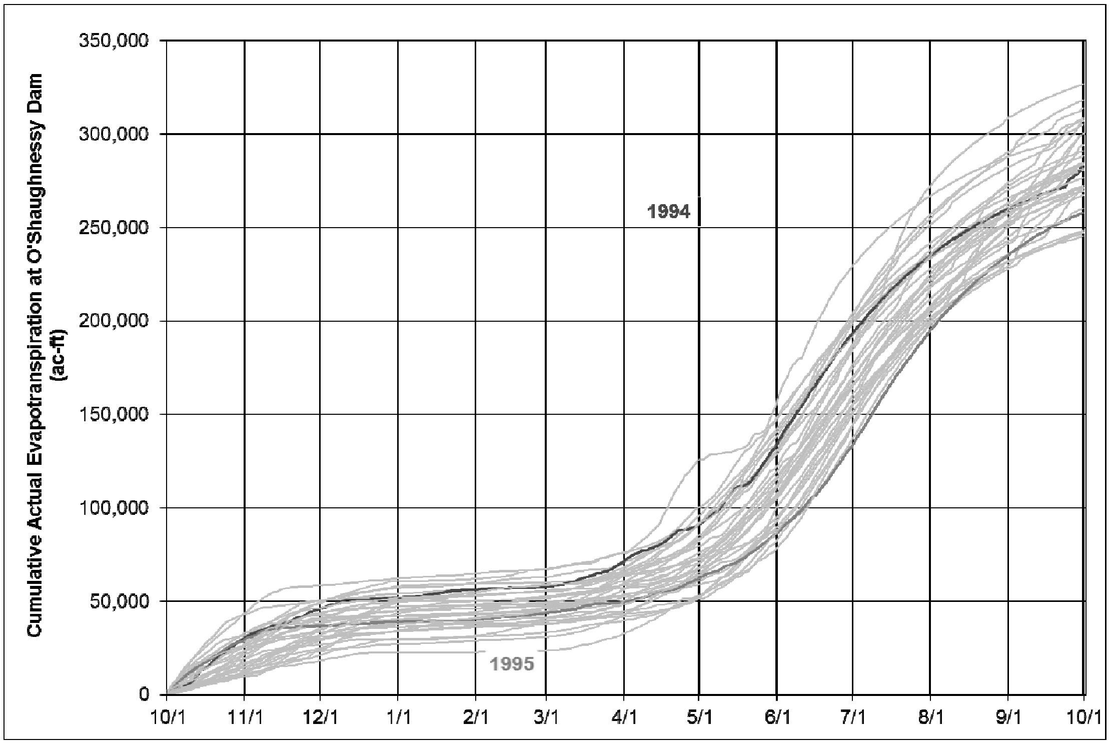

Figure 6-9. Simulated watershed cumulative actual evapotranspiration above O'Shaughnessy Dam for scenario 2A in 2100, water year 1995 in red and water year 1994 in blue.

HY-52 cont.

Figure 6-10 shows the simulated watershed snow water equivalent above O'Shaughnessy Dam for each year of the 34-year meteorological database for the future climate condition in year 2100 of climate change scenario 2A. The red line shows the simulated snow water equivalent for water year 1995. The blue line shows the simulated snow water equivalent for water year 1994.

Figure 6-11 shows the same information for soil moisture. The much larger snowpack in 1995 increases soil moisture in April and May, 1995, compared to April and May, 1994. This increase in soil moisture is not proportional to the difference in snowpack between 1995 and 1994. Soil moisture storage is limited by soil moisture storage capacity.

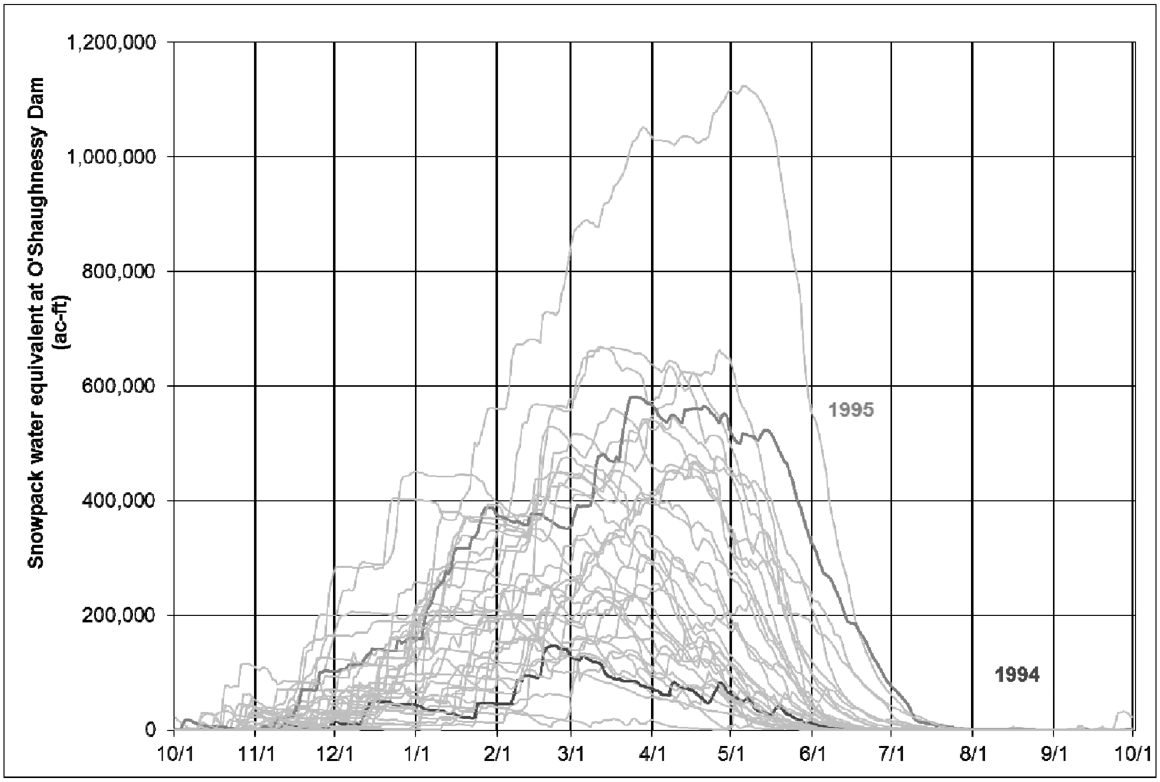

Figure 6-10. Simulated watershed snow water equivalent above O'Shaughnessy Dam for scenario 2A in 2100, water year 1995 in red and water year 1994 in blue.

HY-52 cont.

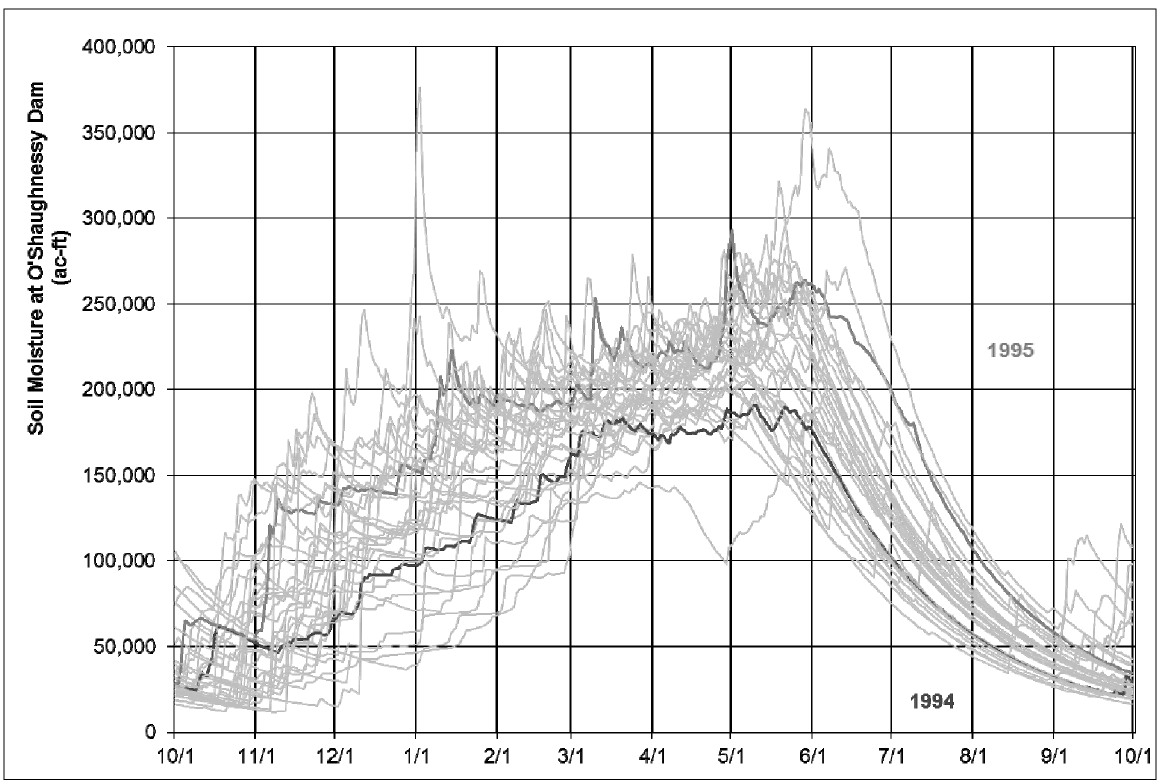

Figure 6-11. Simulated watershed soil moisture above O'Shaughnessy Dam for scenario 2A in 2100, water year 1995 in red and water year 1994 in blue.

O-TRT-DREKMEIER Cont.

6.5 Soil Moisture

HFAM II calculates the hydrologically active moisture storage, the storage that is depleted during the summer and refills in the late spring in most years. Simulated soil moisture storage volumes do not include water in deep alluvium that is not accessible to transpiration or evaporation.

Figure 6-12 shows the simulated watershed soil moisture above O'Shaughnessy Dam for the current climate condition (red) and the future climate condition in year 2100 of climate change scenario 2A (blue) for water year 1995, a year with a large snowpack and late spring melt.

In contrast, Figure 6-13 shows the same results for water year 1994, a year with a low snowpack and early spring melt.

Soil moisture changes under future climate conditions are more noticeable in years with above average precipitation, but reduced soil moistures in summer are found in all years. The amount of change in soil moisture under the future climate condition in year 2100 of climate change scenario 2A would affect all types of vegetation.

HY-52 cont.

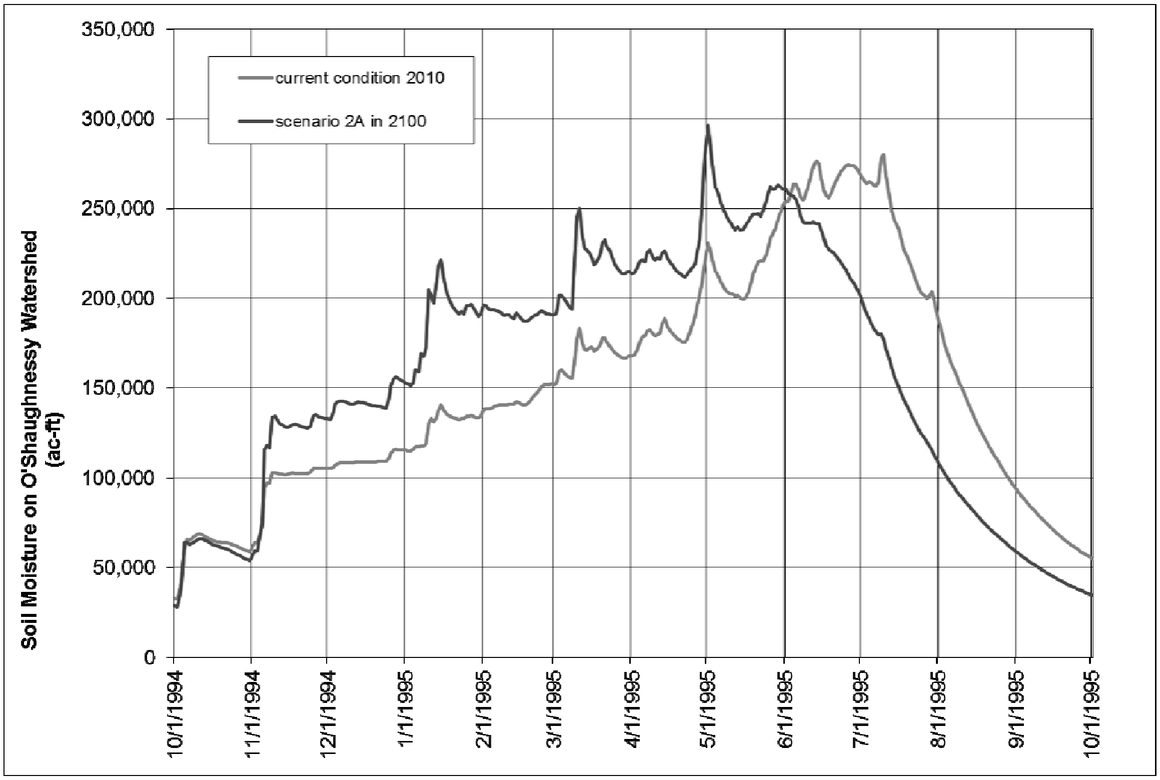

Figure 6-12. Simulated watershed soil moisture above O'Shaughnessy Dam for current climate condition (red) and scenario 2A in 2100 (blue), water year 1995

HY-52 cont.

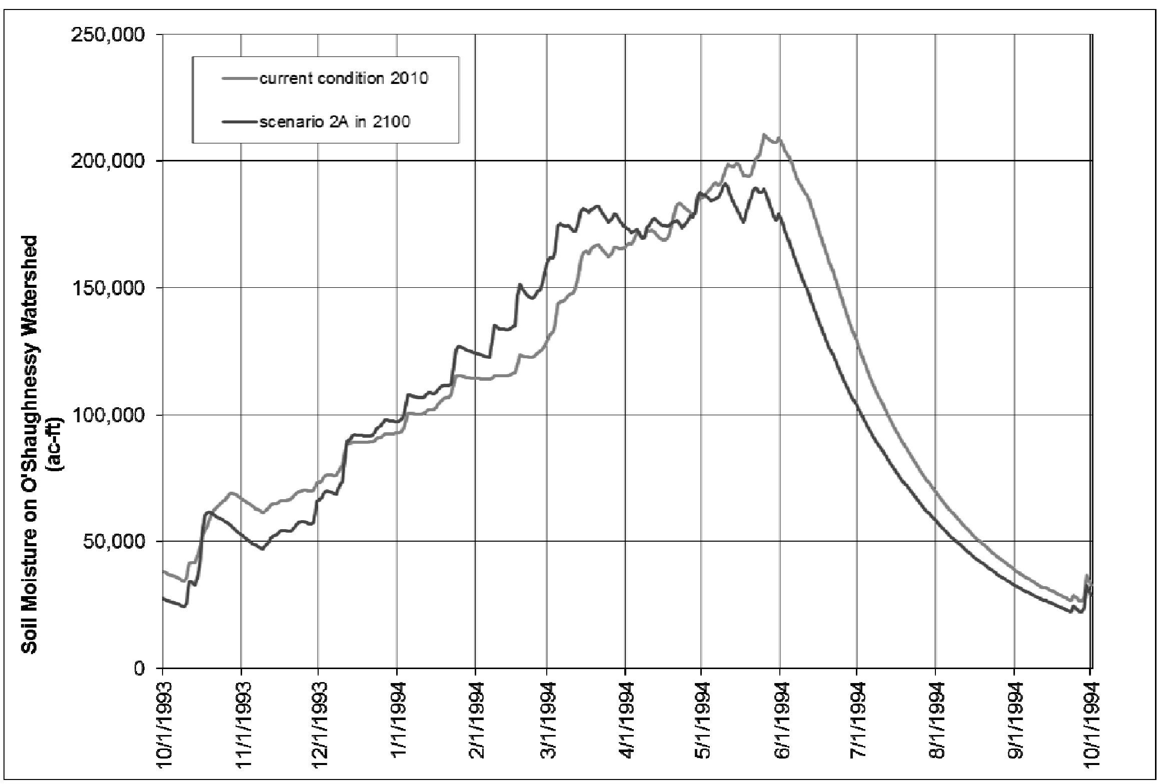

Figure 6-13. Simulated watershed soil moisture above O'Shaughnessy Dam for current climate condition (red) and scenario 2A in 2100 (blue), water year 1994

7. Conclusions

7.1 Tuolumne Climate Change Modeling Methods

Minimum daily temperature increases in the Sierra Nevada are known to be sensitive to climate change but the historical trends of increasing minimum daily temperatures and reduced daily temperature range found at Hetch Hetchy and Cherry Valley from 1960 to the present were unexpected. A method was developed to create the average temperature increases in the climate change scenarios consistent with historical trends in daily minimum temperatures while retaining a reasonable daily range in temperatures.

The modeling results of the climate change scenarios are internally consistent and are generally within the range of conditions found in the historical meteorological records. For example, model runs for the 2A climate change scenario in 2100 have a 46.5 degrees F average temperature at Hetch Hetchy, 6.2 degrees F higher than the average current January temperature (40.3 degrees F), but equal to the average current March temperature at Hetch Hetchy. The HFAM model uses detailed soils, vegetation, and topographic information and these data together with meteorological timeseries to create the model results.

Assumptions and limitations in this study include: HY-52 cont.

- Observed data are not sufficient to document the physical processes responsible for the increasing minimum daily temperatures at Hetch Hetchy and Cherry Valley; water vapor and cloud cover changes may have occurred. Changes in gage locations, instrumentation and shading at Hetch Hetchy as described in Appendix C-2 are likely to have had effects, but similar increasing daily minimum temperatures are present at Cherry Valley without known instrumentation changes, and minimum daily temperature increases begin in 1960 at Hetch Hetchy before instrumentation changes occurred. Increasing daily minimum temperatures have been observed elsewhere in the Sierra Nevada. (John Schaake, pers. Comm., Behnke, R. 2011, Bonfils et al. 2008)

- Existing vegetation distributions were assumed unchanged and calibrated land segment parameters for current conditions were used without adjustments to model the future climate conditions in 2040, 2070, and 2100. This assumption might be refined by further analysis.

- Historical meteorological temperature and precipitation were assumed to retain their current characteristics, e.g., temperatures retain observed seasonal patterns and storms are no more or less frequent in the future climate conditions. Historical solar radiation, potential evapotranspiration and wind speed were assumed unchanged in the future climate conditions.

- The climate change scenarios have broad ranges for projected future temperatures and precipitation.

- The effects of climate change on Tuolumne River flood frequency were not established by this analysis because the frequency and magnitude of large storms in the future climate change scenarios are uncertain.

As additional data are collected in the Tuolumne, and as more detailed GCM results become available, it will be possible to refine the future climate and watershed runoff projections.

7.2 Tuolumne Climate Change Modeling Results

Climate change in the Tuolumne River affects snow accumulation and melt, soil moisture and forests, and reservoir inflows, and potentially the water supplies available for all purposes. Table 7-1 summarizes the modeling results in terms of the change in simulated median annual runoff at O'Shaughnessy and Don Pedro dams for the climate change scenarios at the future climate dates.

HY-52 cont.

Table 7-1. Change in median runoff volume for future climate conditions

Climate Change Scenario		**O'Shaughnessy Runoff (% change from 2010)**			**Don Pedro Runoff (%change from 2010)**		
		2040	**2070**	**2100**	**2040**	**2070**	**2100**
1A	low temperature increase no precipitation change	-0.7%	-1.5%	-2.6%	-1.1%	-2.4%	-3.6%
2A	moderate temperature increase no precipitation change	-1.2%	-2.9%	-5.4%	-1.8%	-4.0%	-6.4%
2B	moderate temperature increase precipitation decrease	-7.6%	-15.8%	-24.7%	-9.5%	-19.1%	-28.7%
2C	moderate temperature increase precipitation increase	1.4%	2.2%	2.4%	1.1%	2.0%	2.8%
3A	high temperature increase no precipitation change	-2.1%	-5.6%	-10.2%	-3.0%	-6.5%	-10.1%
3B	high temperature increase precipitation decrease	-8.6%	-18.6%	-29.4%	-10.7%	-21.6%	-32.3%

Note: The same results are shown in Table 6-3.

O-TRT-DREKMEIER Cont.

Simulated changes in median annual runoff do not fully describe how water supplies would be affected. When firm yield from reservoirs is evaluated, low runoff years are critical. Climate change effects are exacerbated in low runoff years. Table 7-2 summarizes the modeling results in terms of the change in simulated 5 (dry), 50 (the median runoff shown in Table 7-1) and 95% percent exceedance annual runoff for two climate change scenarios (2A moderate temperature increases with no precipitation and 3B high temperature increases with precipitation decreases).

Table 7-2. Change in runoff volume for future climate conditions at 5%, 50%, and 95% exceedance level

Climate Change Scenario		Exceed Prob	O'Shaughnessy Runoff (% change from 2010)			Don Pedro Runoff (% change from 2010)		
			2040	2070	2100	2040	2070	2100
2A	moderate temperature increase no precipitation change	5%	-0.6%	-1.4%	-2.4%	-1.1%	-2.6%	-3.7%
2A	moderate temperature increase no precipitation change	50%	-1.2%	-2.9%	-5.4%	-1.8%	-4.0%	-6.4%
2A	moderate temperature increase no precipitation change	95%	-3.4%	-8.8%	-15.1%	-4.2%	-9.8%	-16.1%
3B	high temperature increase precipitation decrease	5%	-7.1%	-14.3%	-21.8%	-8.7%	-16.7%	-24.3%
3B	high temperature increase precipitation decrease	50%	-8.6%	-18.6%	-29.4%	-10.7%	-21.6%	-32.3%
3B	high temperature increase precipitation decrease	95%	-14.7%	-30.9%	-46.5%	-16.6%	-33.3%	-48.1%

Note: The same results are shown in Table 6-4.

HY-52 cont.

Runoff timing within the water year changes under the future climate conditions. Figure 7-1 shows the average monthly median runoff volume at O'Shaughnessy for the current climate and at the 2040, 2070 and 2100 future climate dates for two climate change scenarios, 2A moderate temperature increases with no precipitation and 2B moderate temperature increases with precipitation decreases. Under climate change scenario 2A in 2100 at O'Shaughnessy, the May through August runoff would decrease by 45% from the current condition (31% of current condition annual runoff), the September through April runoff would increase by 81% (26% of annual runoff), and 5% of the annual runoff would be lost to additional evapotranspiration. Reservoir operations would need to be revised to manage increased runoff in November through April, and decreased runoff in May for most climate change scenarios, and in June and July for all climate change scenarios.

O-TRT-DREKMEIER Cont.

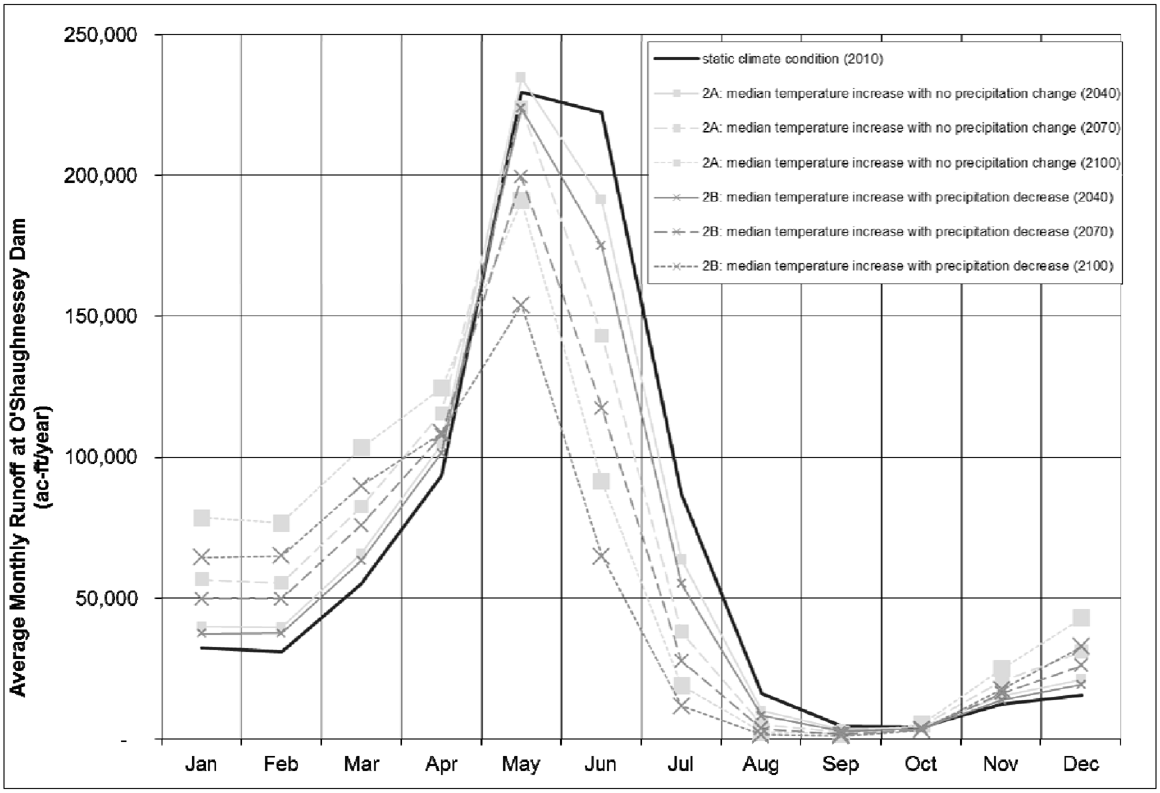

Figure 7-1. Average monthly runoff at O'Shaughnessy Dam for moderate temperature increase and precipitation change scenarios at future climate dates

HY-52 cont.

The simulated change in future hydrologic conditions based on the climate change scenarios results in a significantly altered snow and runoff regime in the watershed. Snow accumulation is reduced and snow melts earlier in the spring. Fall and early winter runoff increases and late spring and summer runoff decreases.

The reliability of projected changes in reservoir inflows for the climate change scenarios is good because the model is physically-based and has been calibrated over a 34-year period to accurately represent hydrologic conditions in the Tuolumne watershed during a range of temperature and precipitation conditions. The temperature and precipitation timeseries used for the climate change scenarios are within the range of temperatures experienced in the Tuolumne during the calibration period. For example, a climate change scenario may have higher temperatures than experienced in the same period historically but similar temperatures would have been observed at other times in the calibration period.

Reduced snow accumulation and a resulting shift of runoff from the spring to the winter runoff in the Tuolumne were expected due to the temperature increases of the climate change scenarios. In addition, the climate change scenario results showed that:

- Climate change effects are most exacerbated in low runoff years because of increased evapotranspiration results, particularly when expressed as a percent of runoff. This result is important for reservoir 'firm yield' analysis. This study created daily reservoir inflow data during the 34-year analysis period (water years 1974 to 2008) for all climate change scenarios which can be used for subsequent operations studies by TID and SFPUC.

- Soil moisture reductions in summer would be very significant by 2070 and 2100. The predicted reduction in summer soil moistures would be expected to change vegetation distribution within the watershed. The potential changes in vegetation might cause a secondary change in the hydrologic response of some land segments but this effect was not modeled in this study.

- The future climate condition in year 2040 of climate change scenario 3B (moderate temperature increases with precipitation decrease) results in reductions in median runoff of -8.6% at O'Shaughnessy Dam and -10.7% at Don Pedro Dam, so relatively large reductions in runoff may take place in 30 years if both temperature rise and precipitation decrease occur.

- The future climate condition in year 2040 of climate change scenario 2A (moderate temperature increase and no precipitation change) results in insignificant runoff reductions of 0.6% at O'Shaughnessy Dam and 1.1% at Don Pedro Dam. The 2A results in terms of runoff and timing changes are small compared to the year-to-year variation that is currently experienced.

HY-52 cont.

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HY-52 cont.

APPENDIX A

HY-52 cont.

Future Climate Condition Simulation Results

O-TRT-
DREKMEIER
Cont.

APPENDIX A

Future Climate Condition Simulation Results

A.1 Changes in Simulated Runoff Timing and Volume

A.1.1 Simulated Annual Runoff Comparisons

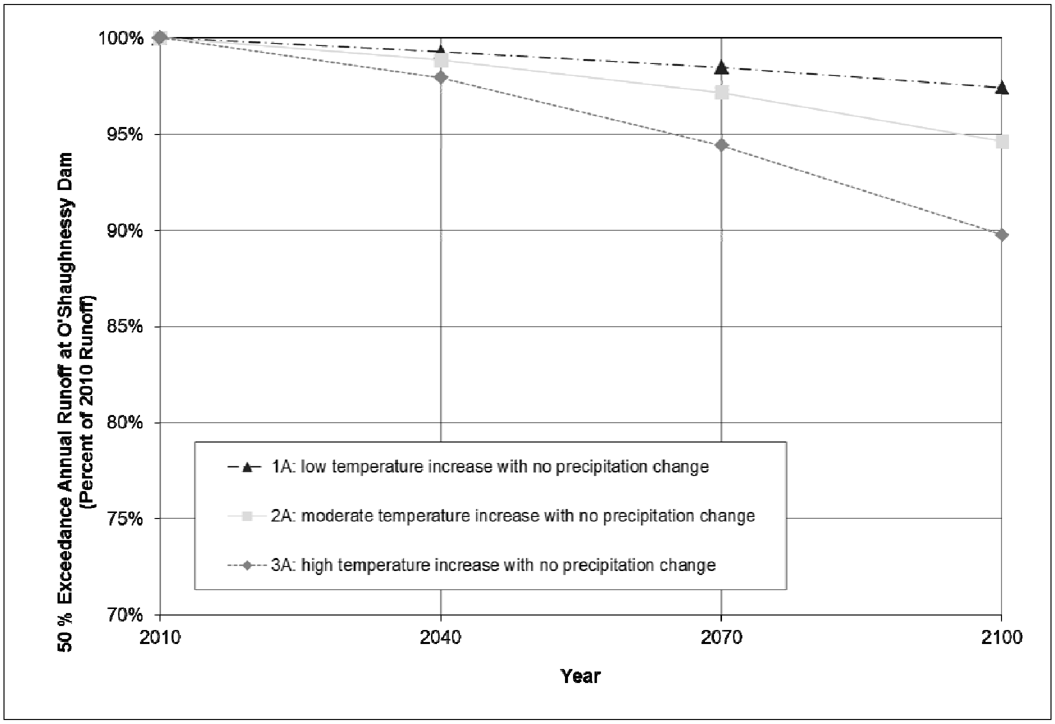


Figure A-1. Annual runoff at O'Shaughnessy Dam for temperature change scenarios

HY-52
cont.

O-TRT-DREKMEIER Cont.

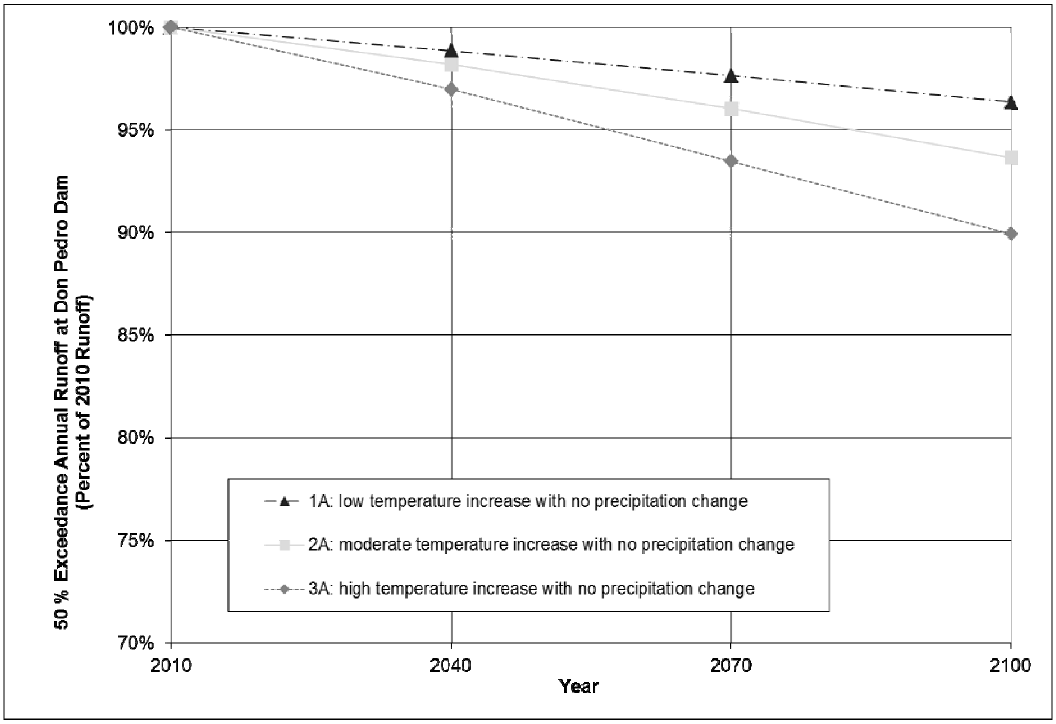


Figure A-2. Annual runoff at Don Pedro Dam for temperature change scenarios

HY-52 cont.

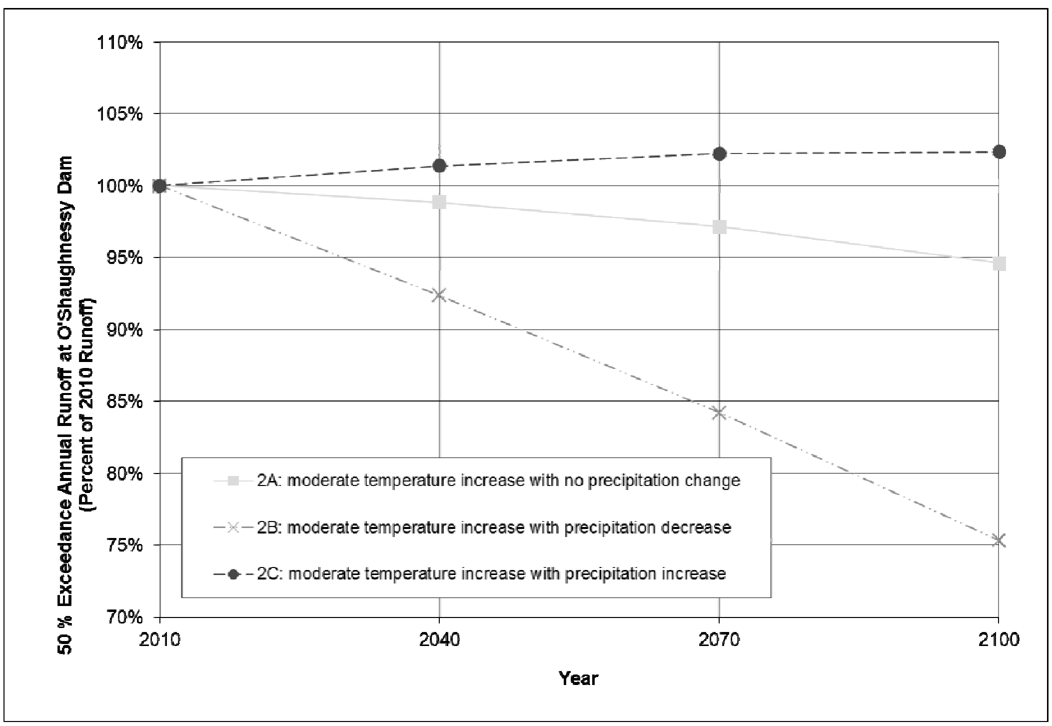


Figure A-3. Annual runoff at O'Shaughnessy Dam for moderate temperature increase and precipitation change scenarios

O-TRT-DREKMEIER Cont.

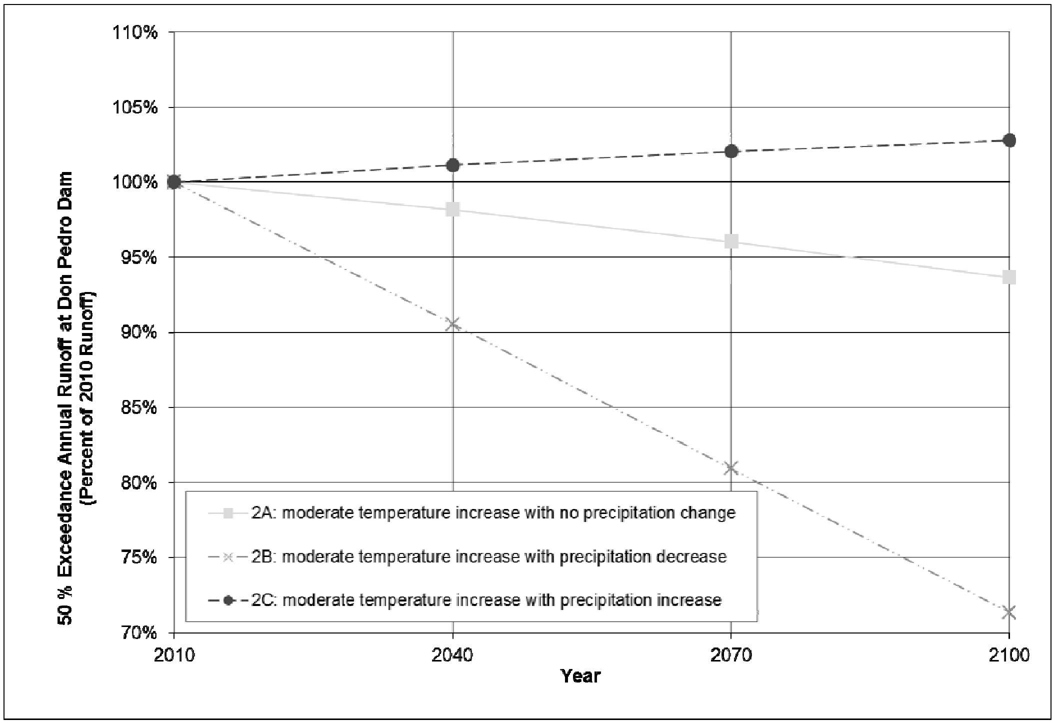


Figure A-4. Annual runoff at Don Pedro Dam for moderate temperature increase and precipitation change scenarios

HY-52 cont.

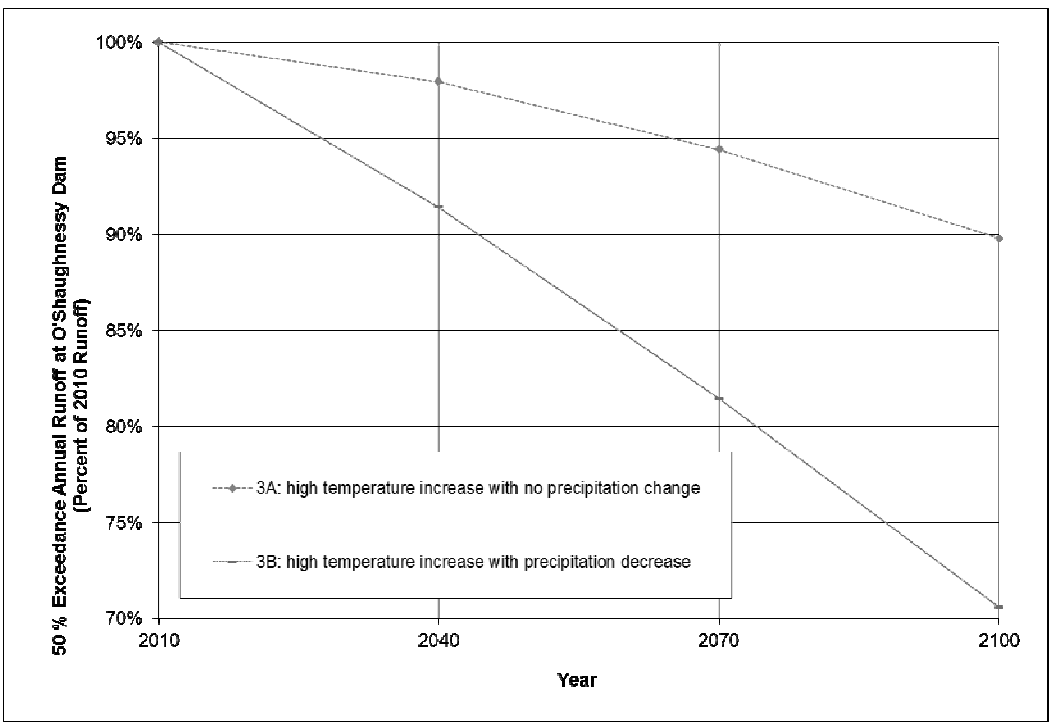


Figure A-5. Annual runoff at O'Shaughnessy Dam for high temperature increase and precipitation change scenarios

O-TRT-DREKMEIER Cont.

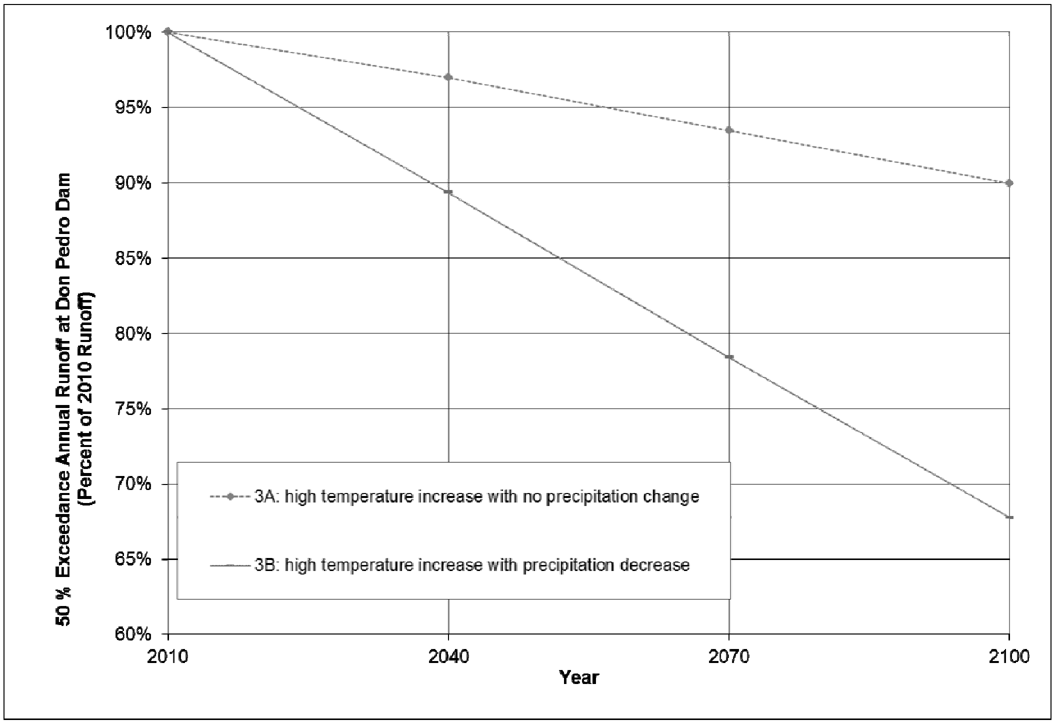


Figure A-6. Annual runoff at Don Pedro Dam for high temperature increase and precipitation change scenarios

HY-52 cont.

O-TRT-
DREKMEIER
Cont.

A.1.2 Simulated Annual Runoff in Low and High Runoff Years

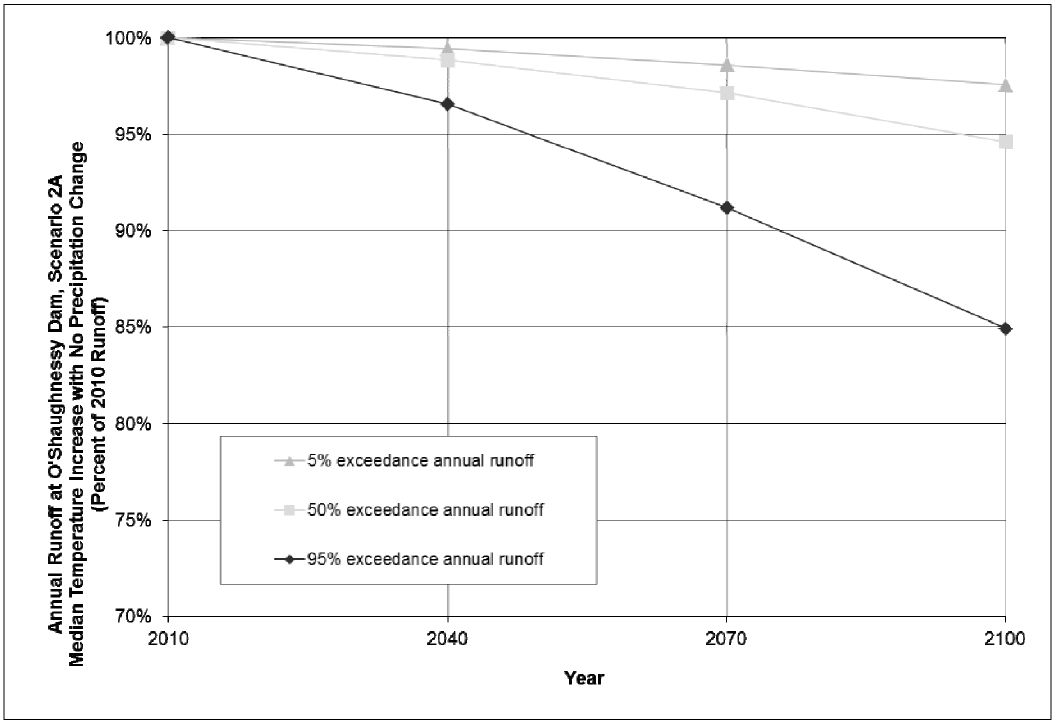


Figure A-7. Annual runoff at O'Shaughnessy Dam for scenario 2A (moderate temperature increase with no precipitation change) for 5%, 50% and 95% exceedance

HY-52
cont.

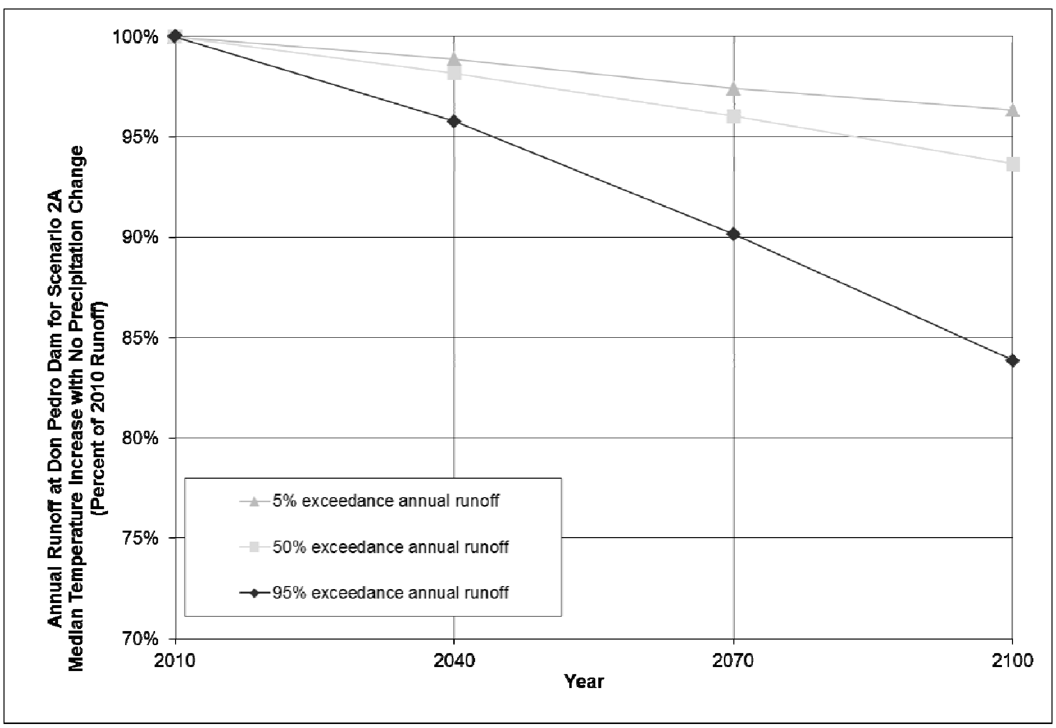


Figure A-8. Annual runoff at Don Pedro Dam for scenario 2A (moderate temperature increase with no precipitation change) for 5%, 50% and 95% exceedance

O-TRT-DREKMEIER Cont.

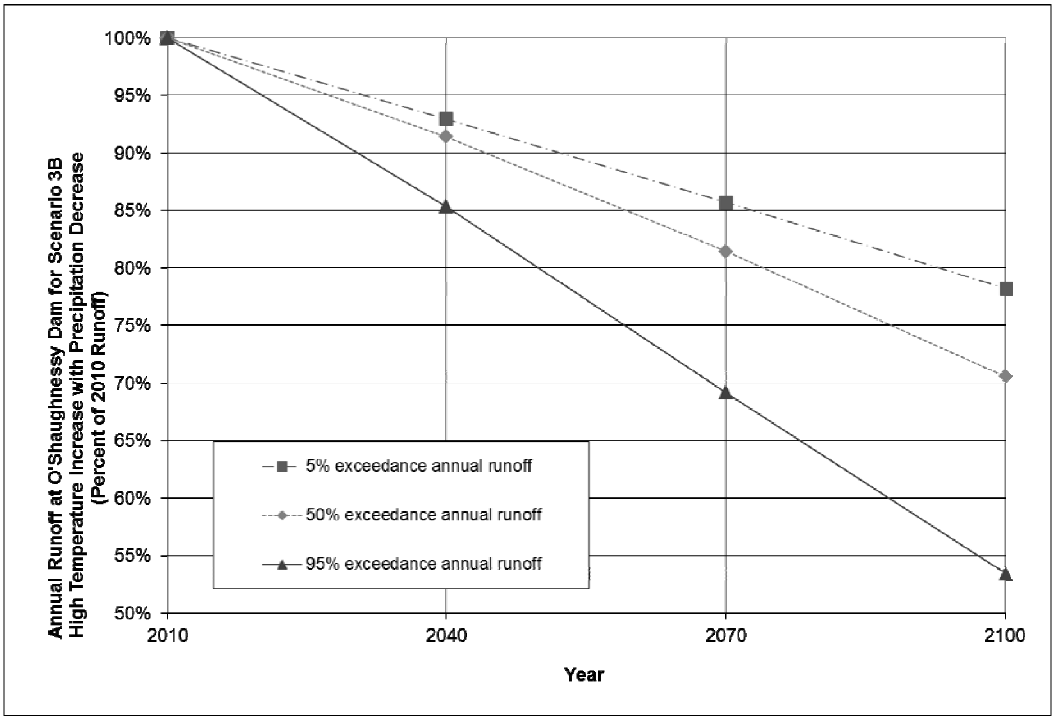


Figure A-9. Annual runoff at O'Shaughnessy Dam for scenario 3B (high temperature increase with precipitation decrease) for 5%, 50% and 95% exceedance

HY-52 cont.

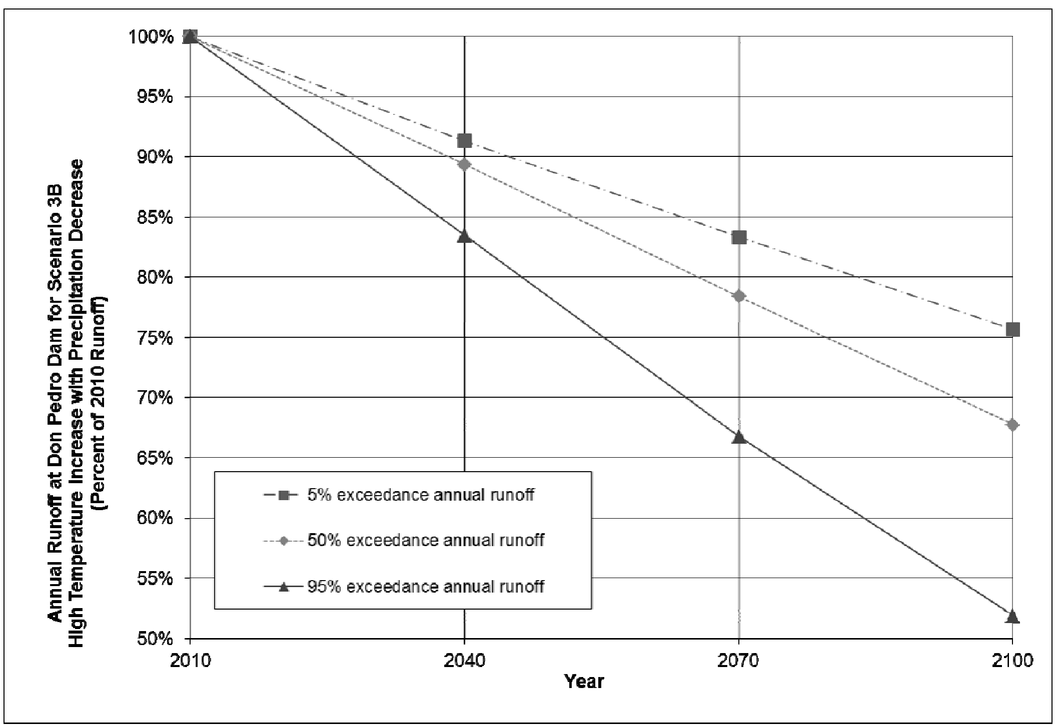


Figure A-10. Annual runoff at Don Pedro Dam for scenario 3B (high temperature increase with precipitation decrease) for 5%, 50% and 95% exceedance

Attachment A

O-TRT-DREKMEIER Cont.

A.1.3 Monthly Runoff Timing Comparisons

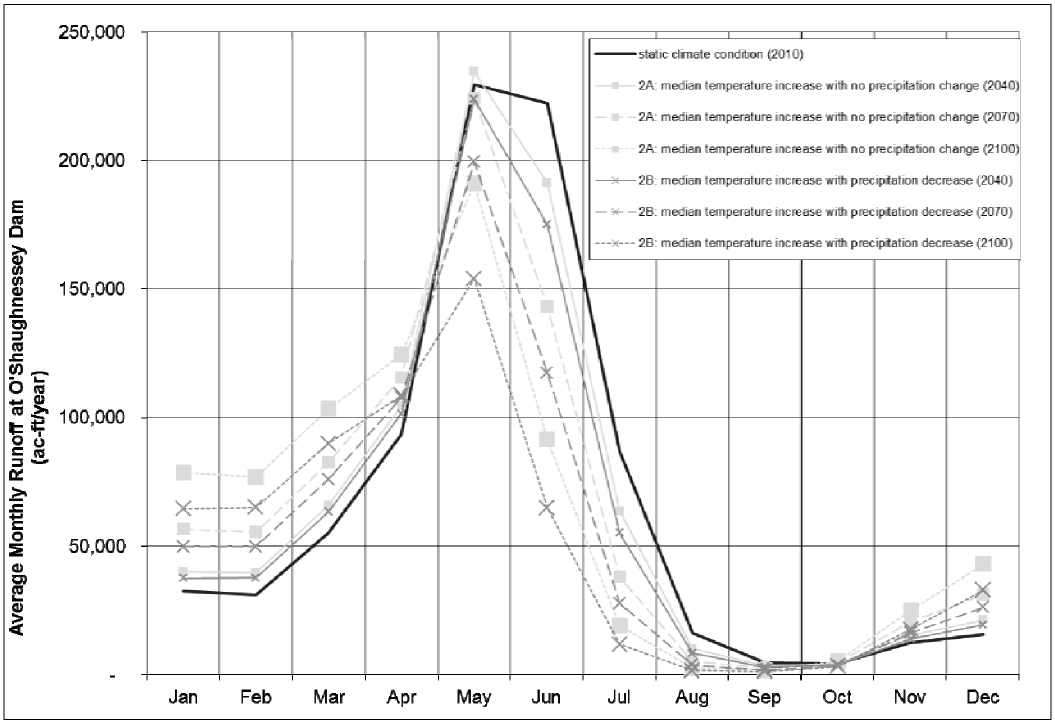


Figure A-11. Average monthly runoff at O'Shaughnessy Dam for moderate temperature increase and precipitation change scenarios at future climate dates

HY-52 cont.

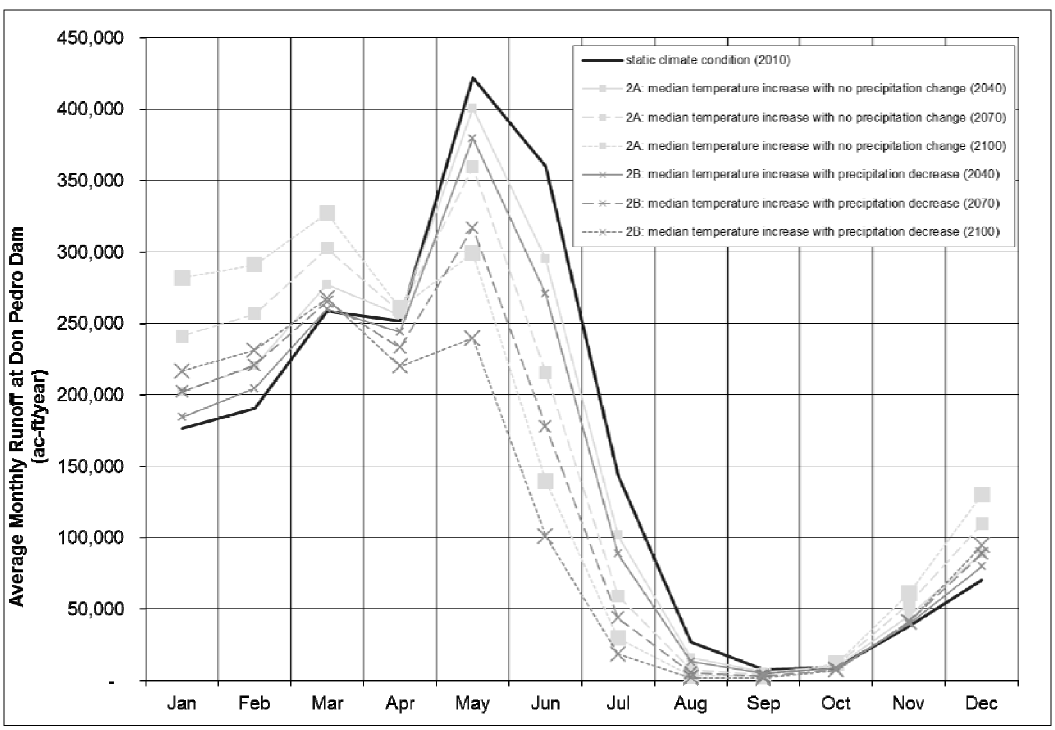


Figure A-12. Average monthly runoff at Don Pedro Dam for moderate temperature increase and precipitation change scenarios at future climate dates

O-TRT-DREKMEIER Cont.

A.1.4 Drought Period Comparison

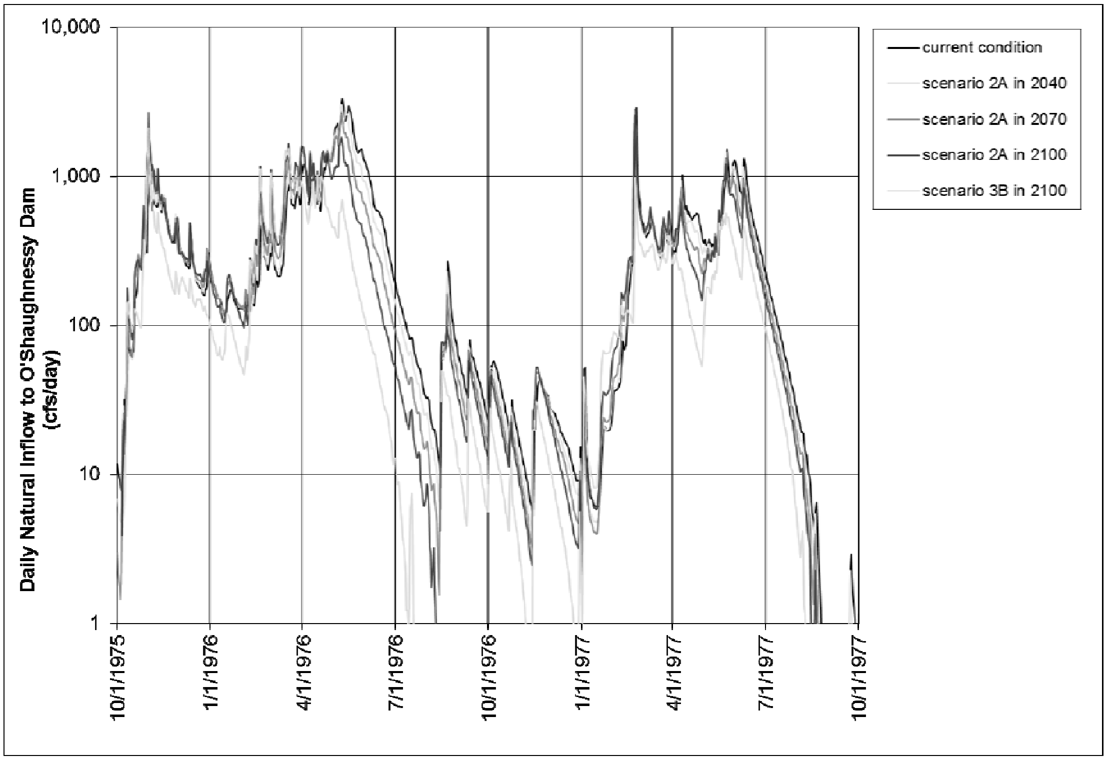


Figure A-13. Daily natural inflow to O'Shaughnessy Dam, water years 1976 and 1977 on log scale

HY-52 cont.

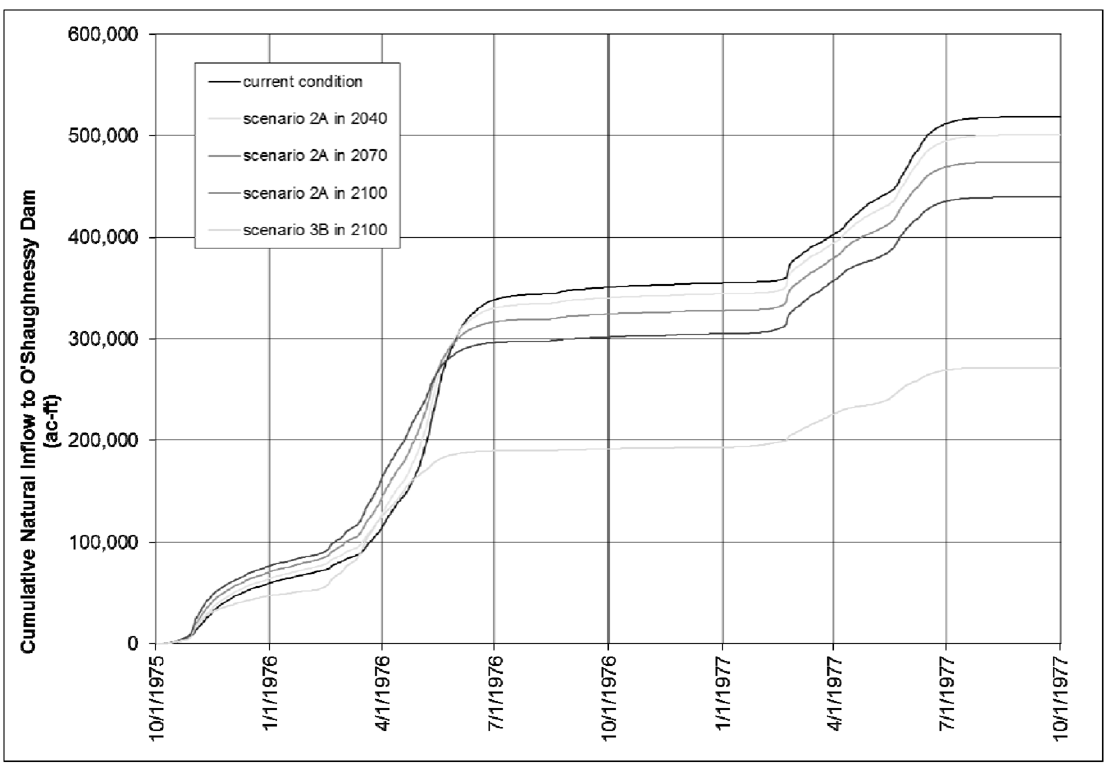
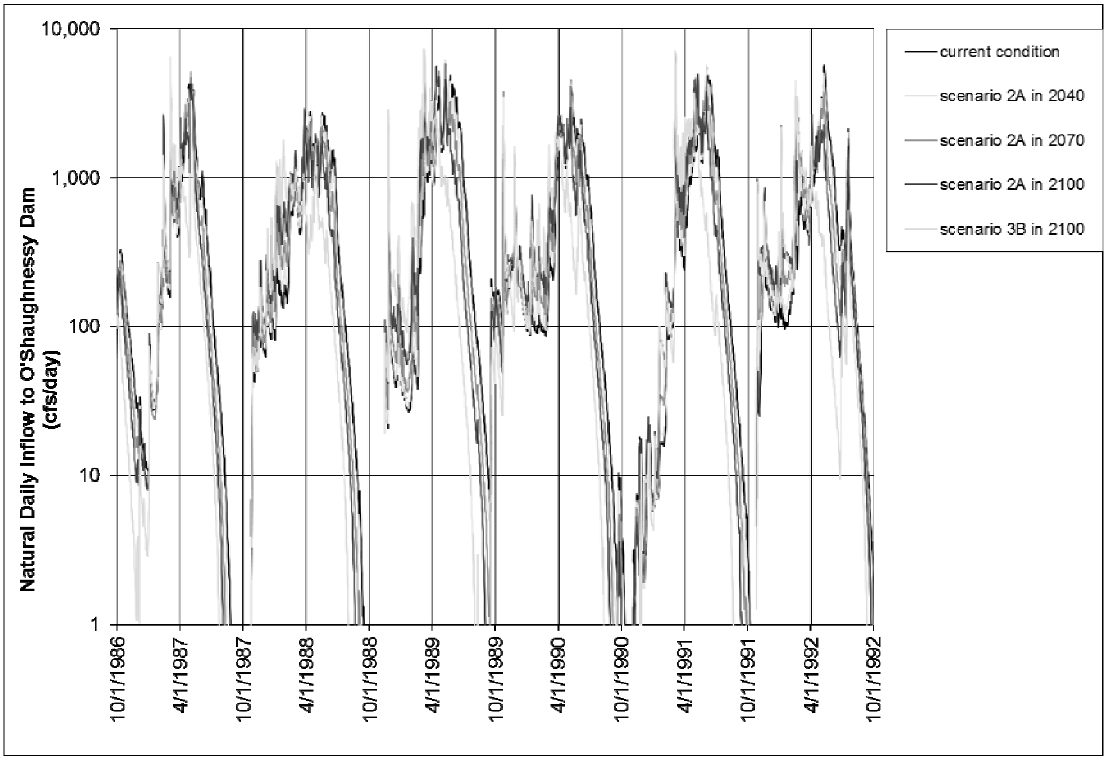


Figure A-14. Cumulative natural inflow to O'Shaughnessy Dam, water years 1976 and 1977



HY-52 cont.

Figure A-15. Daily natural inflow to O'Shaughnessy Dam, water years 1987 to 1992 on log scale

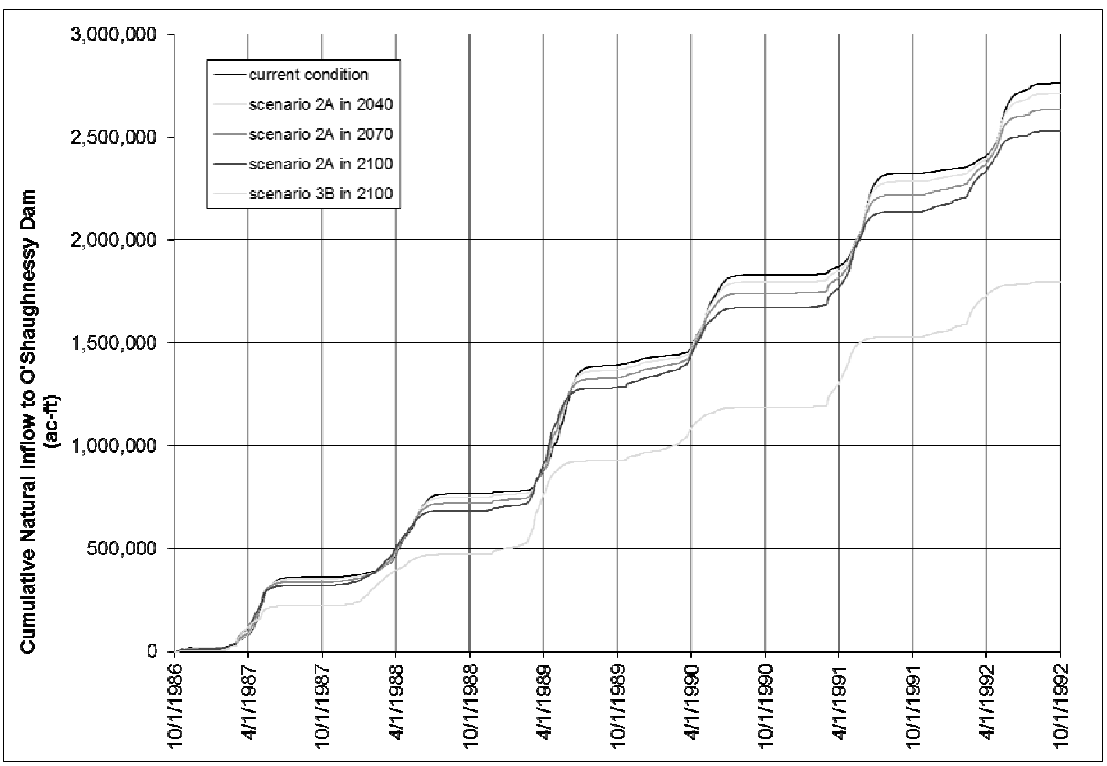


Figure A-16. Cumulative natural inflow to O'Shaughnessy Dam, water years 1987 to 1992

A.2 Changes in Simulated Actual Evapotranspiration

A.2.1 Simulated Annual Actual Evapotranspiration Comparisons

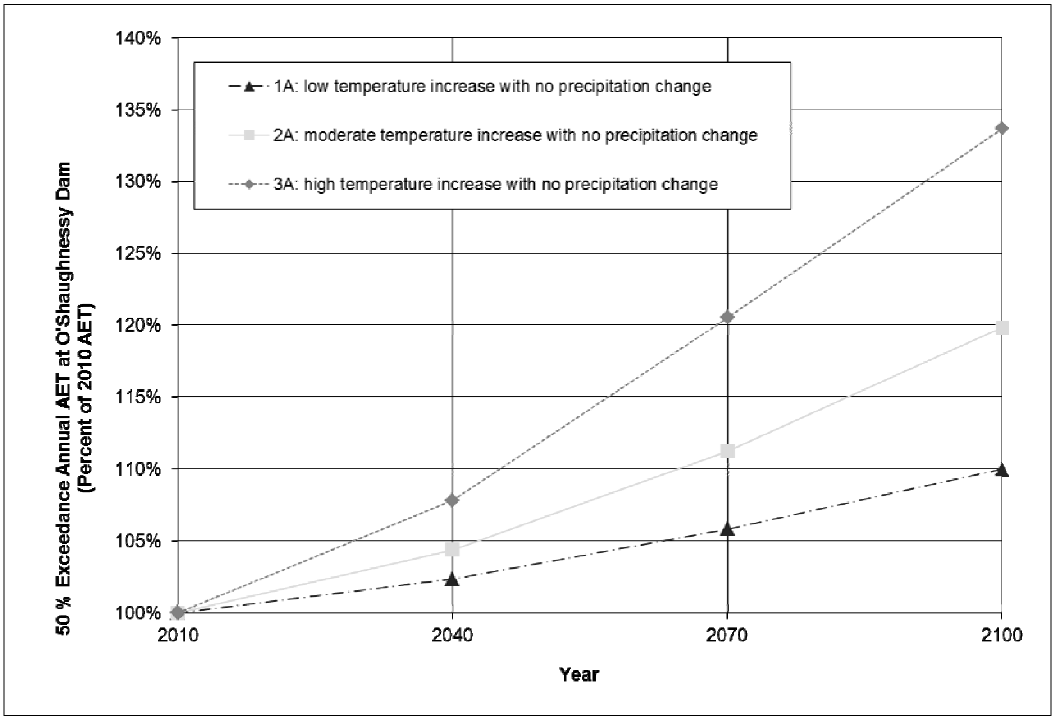


Figure A-17. Annual AET at O'Shaughnessy Dam for temperature change scenarios

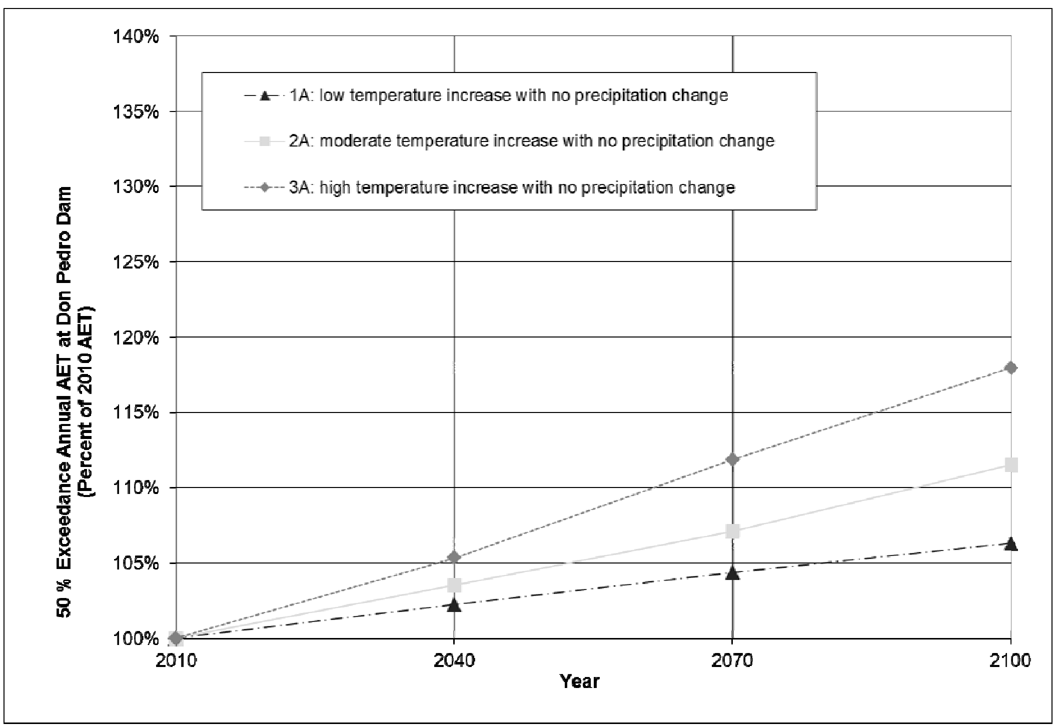


Figure A-18. Annual AET at Don Pedro Dam for temperature change scenarios

HY-52 cont.

O-TRT-DREKMEIER Cont.

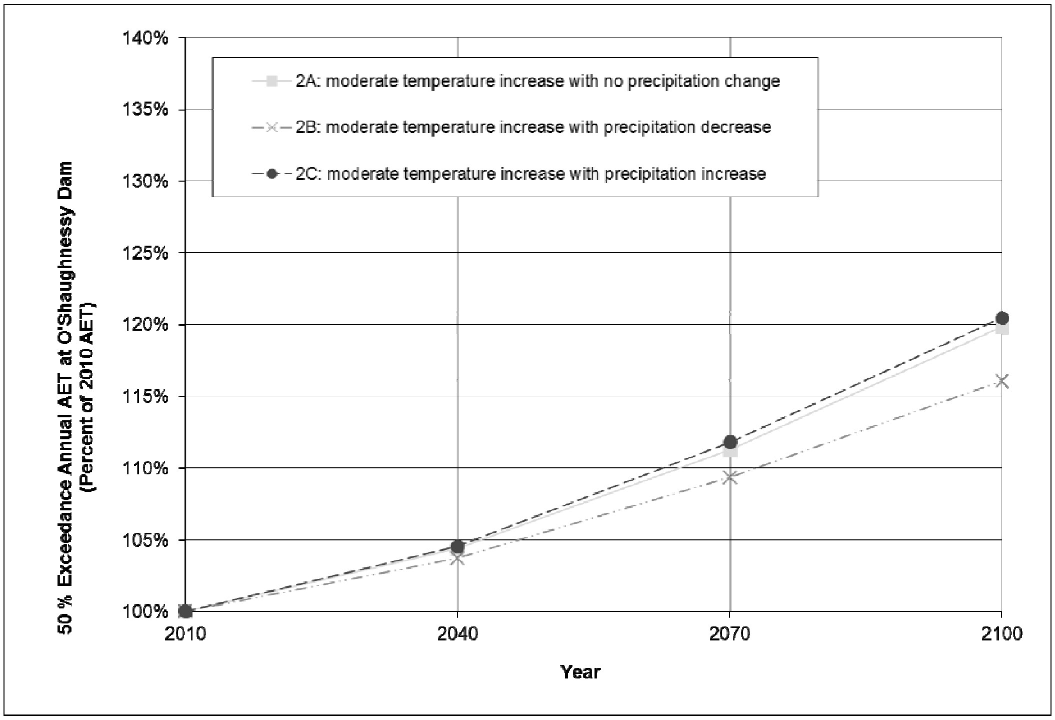


Figure A-19. Annual AET at O'Shaughnessy Dam for moderate temperature increase and precipitation change scenarios

HY-52 cont.

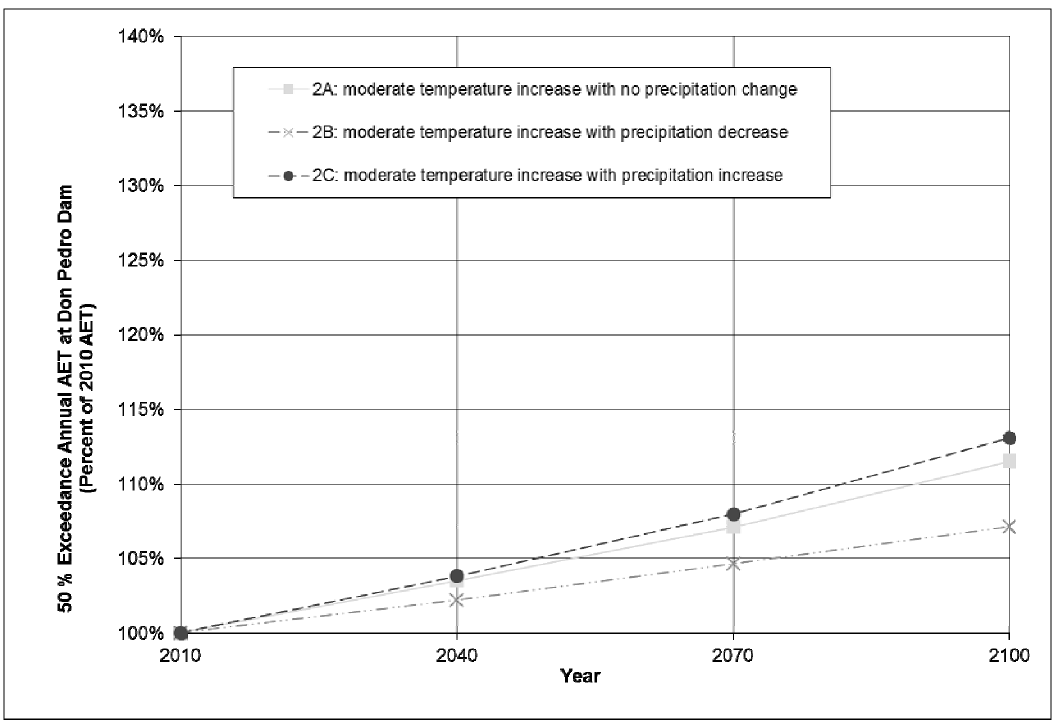


Figure A-20. Annual AET at Don Pedro Dam for moderate temperature increase and precipitation change scenarios

O-TRT-DREKMEIER Cont.

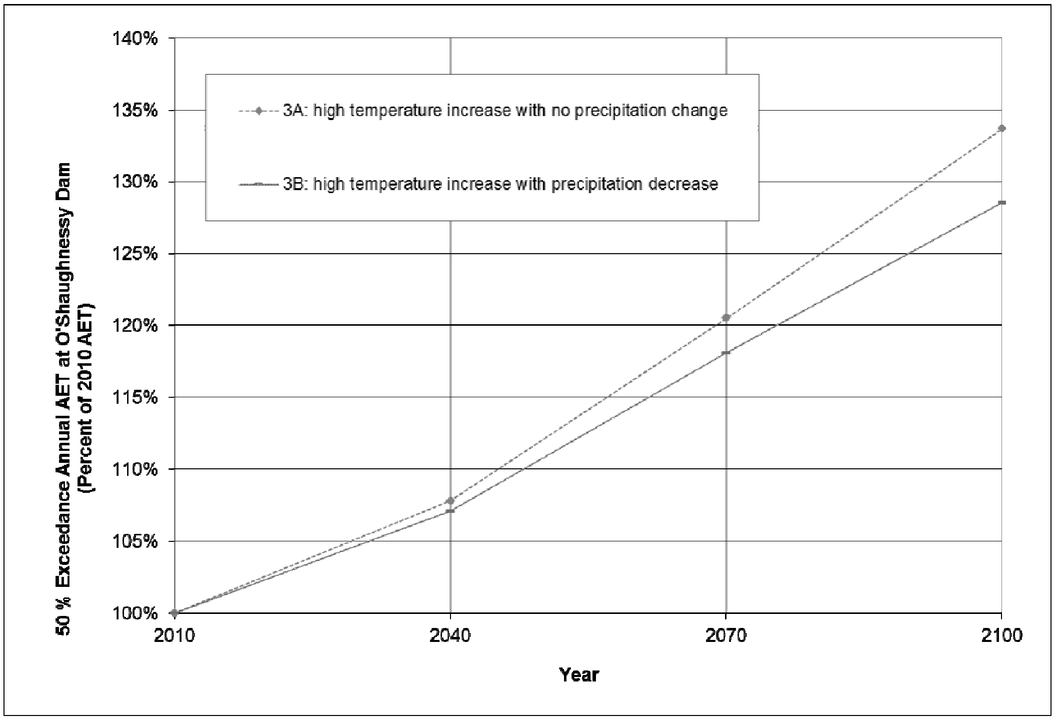
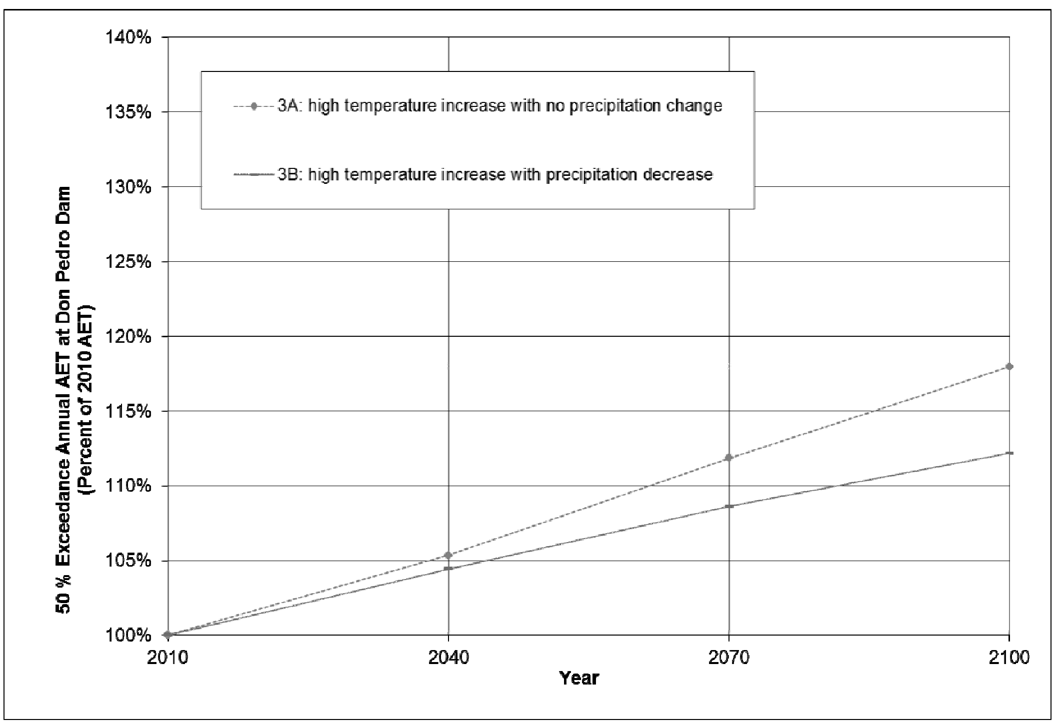


Figure A-21. Annual AET at O'Shaughnessy Dam for high temperature increase and precipitation change scenarios

HY-52 cont.



FigureA-22. Annual AET at Don Pedro Dam for high temperature increase and precipitation change scenarios

A.2.2 Simulated Annual Actual Evapotranspiration in Low and High Runoff Years

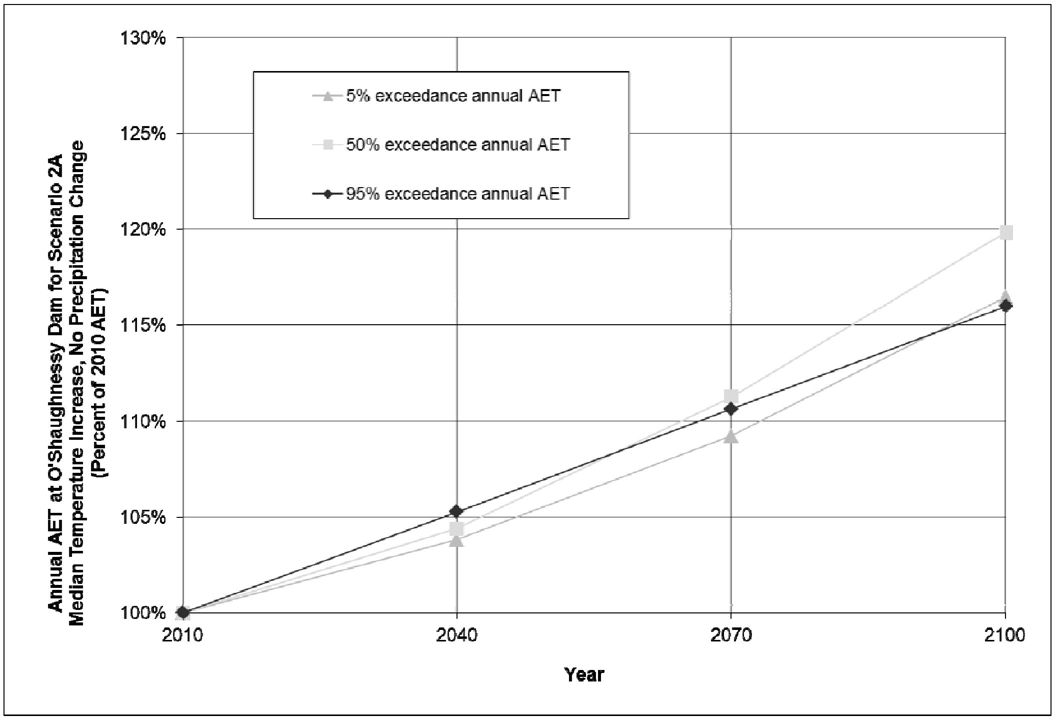


Figure A-23. Annual AET at O'Shaughnessy Dam for scenario 2A (moderate temperature increase with no precipitation change) for 5%, 50% and 95% exceedance

HY-52 cont.

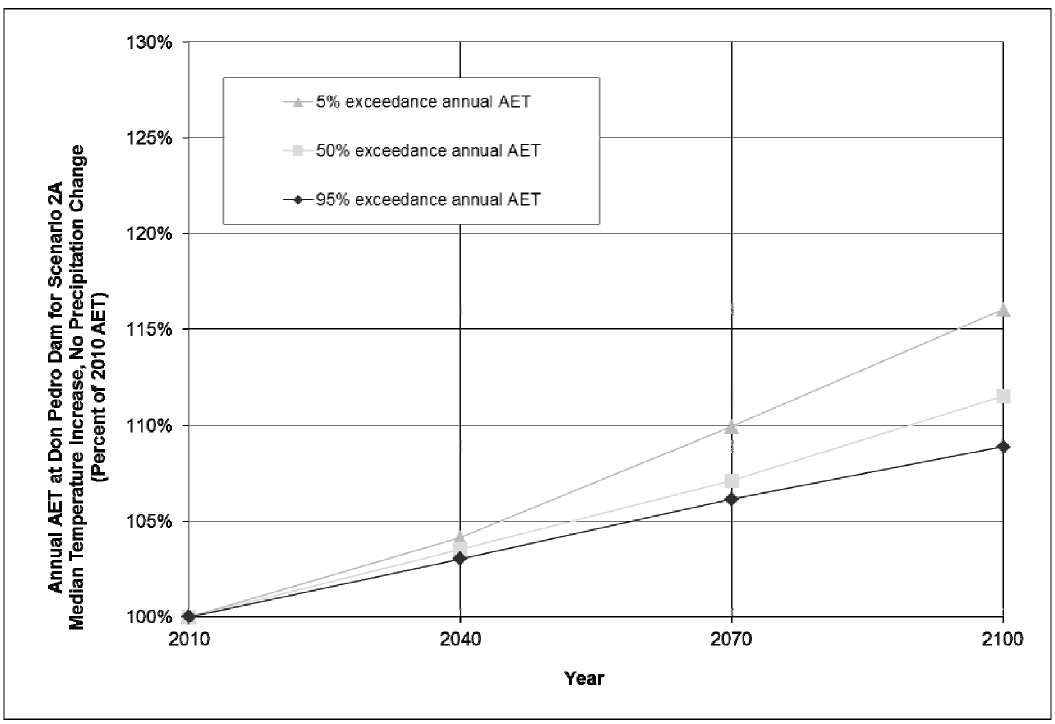


Figure A-24. Annual AET at Don Pedro Dam for scenario 2A (moderate temperature increase with no precipitation change) for 5%, 50% and 95% exceedance

A.3 Changes in Simulated Snow Water Equivalent

A.3.1 Simulated Annual Maximum Snow Water Equivalent Comparisons

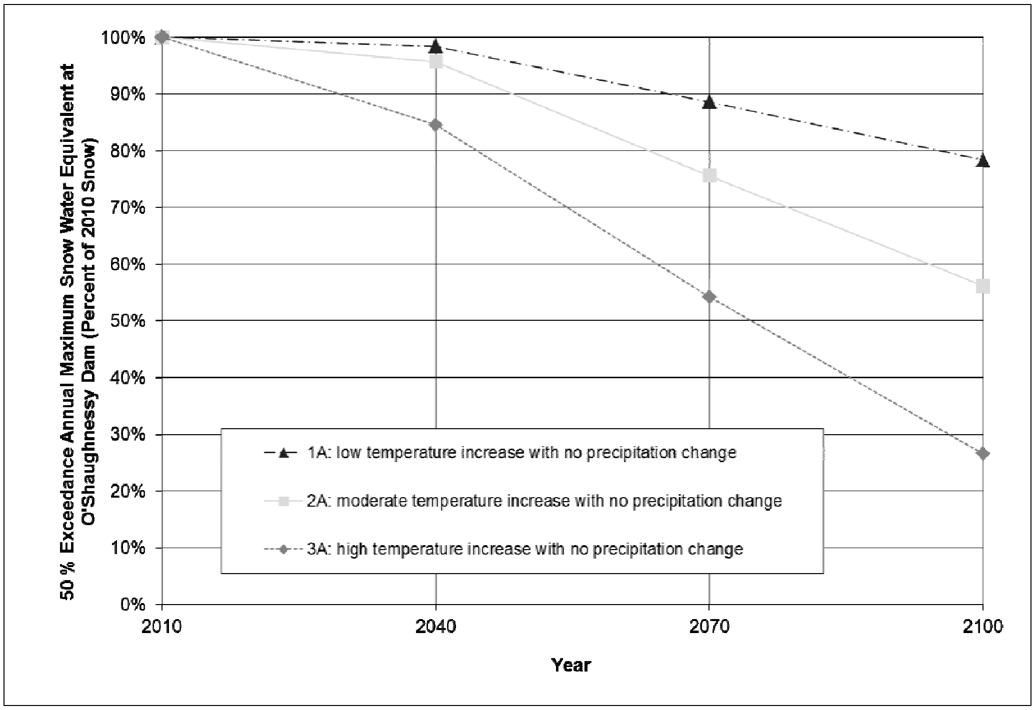


Figure A-25. Annual maximum snow water equivalent at O'Shaughnessy Dam for temperature change scenarios

HY-52 cont.

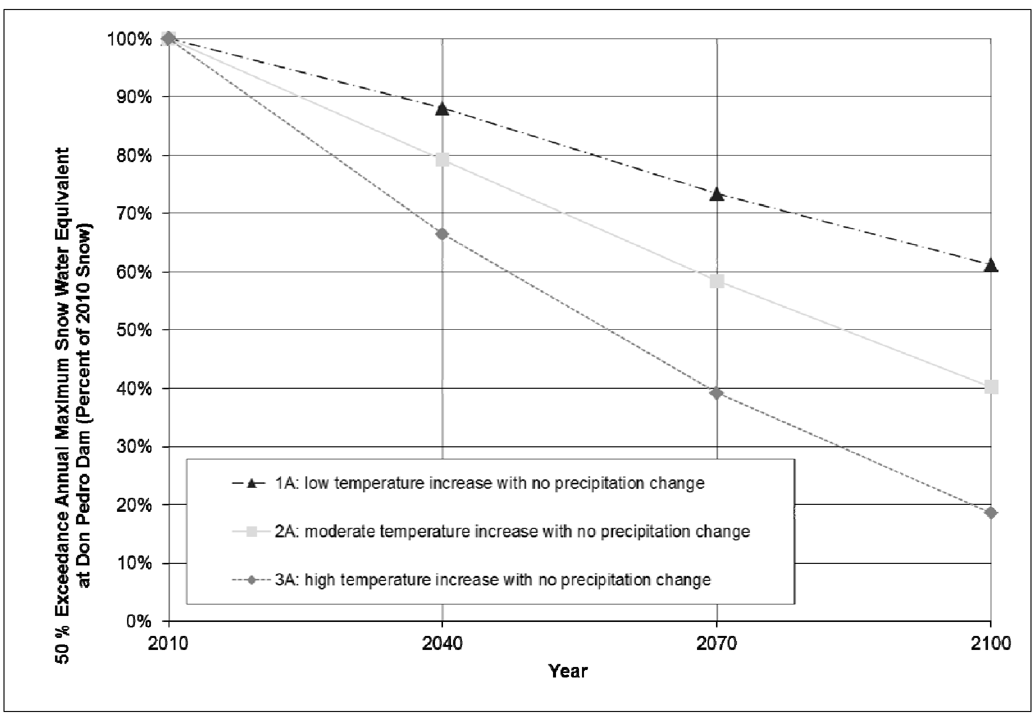


Figure A-26. Annual maximum snow water equivalent at Don Pedro Dam for temperature change scenarios

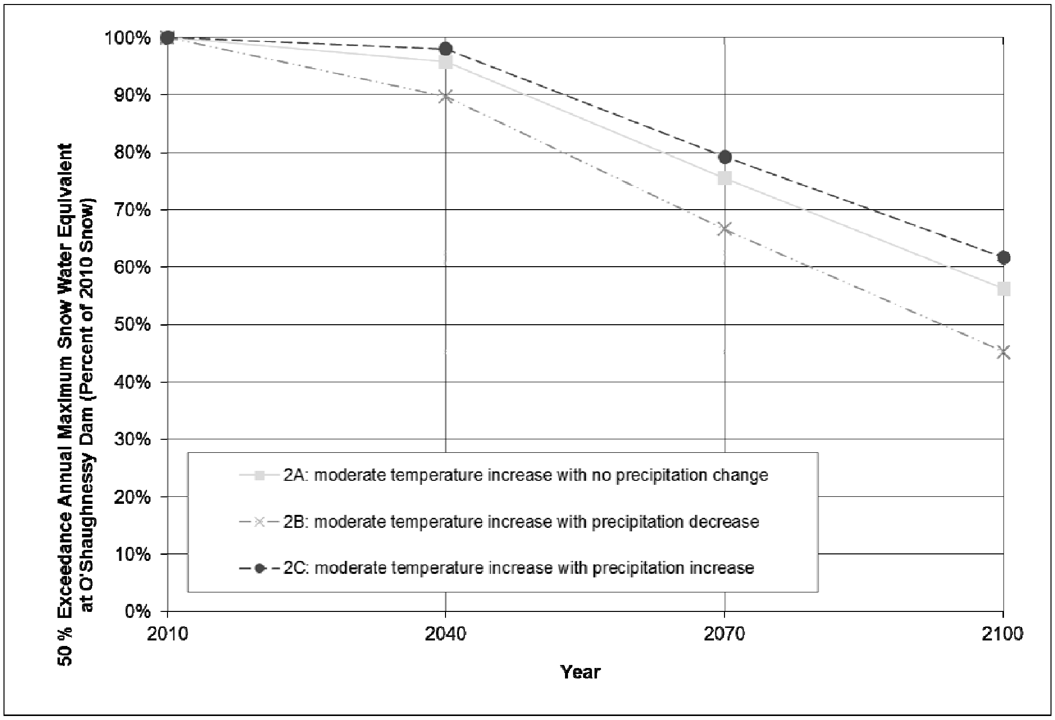


Figure A-27. Annual maximum snow water equivalent at O'Shaughnessy Dam for moderate temperature increase and precipitation change scenarios

HY-52 cont.

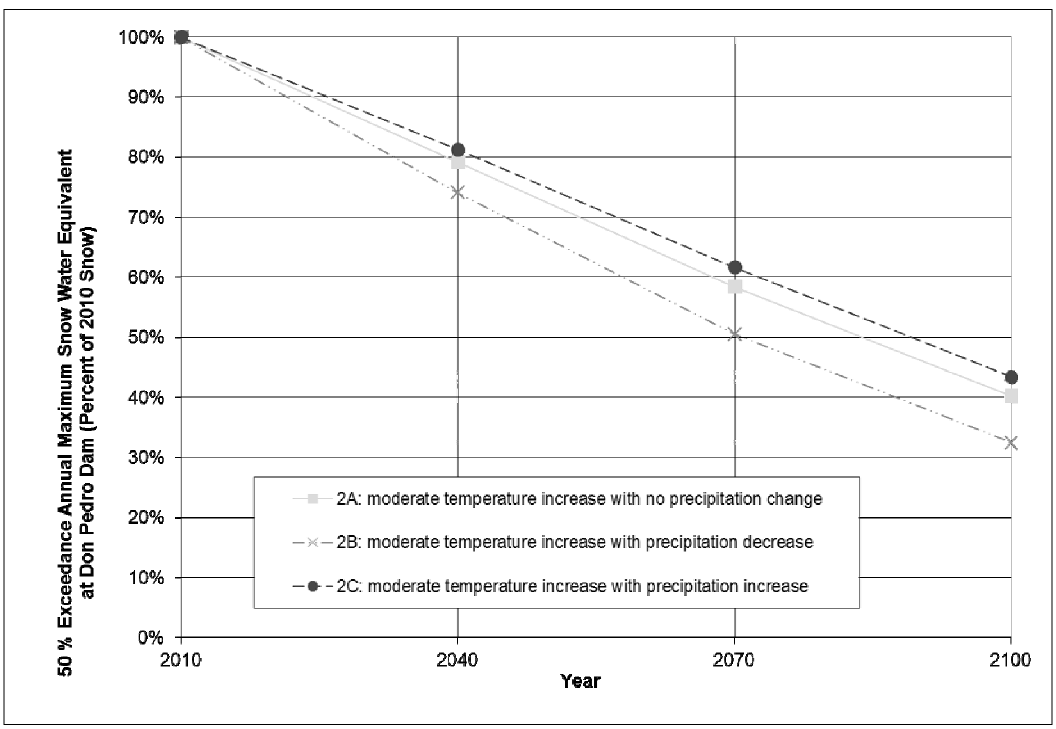


Figure A-28. Annual maximum snow water equivalent at Don Pedro Dam for moderate temperature increase and precipitation change scenarios

O-TRT-DREKMEIER Cont.

A.2.2 Simulated Annual Maximum Snow Water Equivalent in Low and High Runoff Years

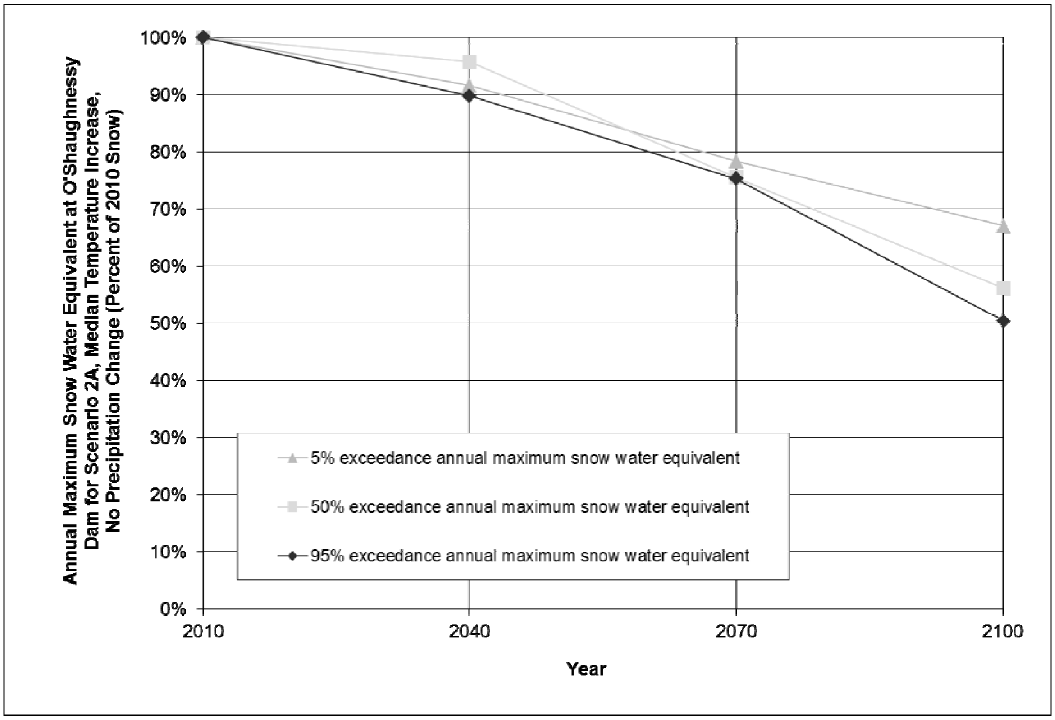


Figure A-29. Annual maximum snow water equivalent at O'Shaughnessy Dam for scenario 2A (moderate temperature increase with no precipitation change) for 5%, 50% and 95% exceedance

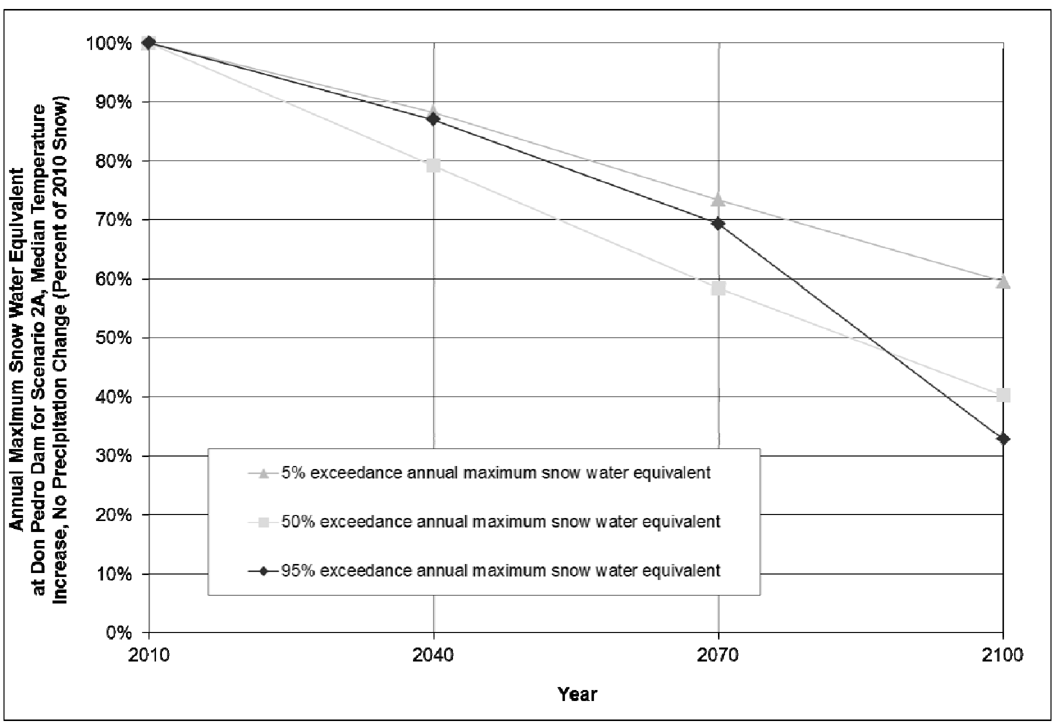


Figure A-30. Annual maximum snow water equivalent at Don Pedro Dam for scenario 2A (moderate temperature increase with no precipitation change) for 5%, 50% and 95% exceedance

HY-52 cont.

O-TRT-DREKMEIER Cont.

APPENDIX B

HY-52 cont.

Calibration Results

O-TRT-DREKMEIER Cont.

APPENDIX B

Calibration Results

This appendix provides daily hydrographs of HFAM simulated and estimated actual natural inflow to Hetch Hetchy and Don Pedro reservoirs for each year in the calibration period, water years 1975 to 2008.

Hetch Hetchy flows are plotted with a maximum Y-axis of 20,000 cfs. Flows higher than 20,000 cfs only occurred during the January 1997 storm; HFAM simulated daily average peak flow during this storm is 44,788 cfs and estimated actual peak flow is 37,685 cfs.

La Grange flows are plotted with a minimum Y-axis of 0 cfs and a maximum Y-axis of 40,000 cfs. Flows higher than 40,000 cfs occurred during the January 1997 storm; HFAM simulated average daily peak flow during this storm is 107,212 and estimated actual peak flow is 117,706 cfs. The estimated natural inflows to Don Pedro reservoir include negative values due to the method of calculation and are needed for correct inflow volumes however negative inflows would not actually occur.

HY-52 cont.

O-TRT-
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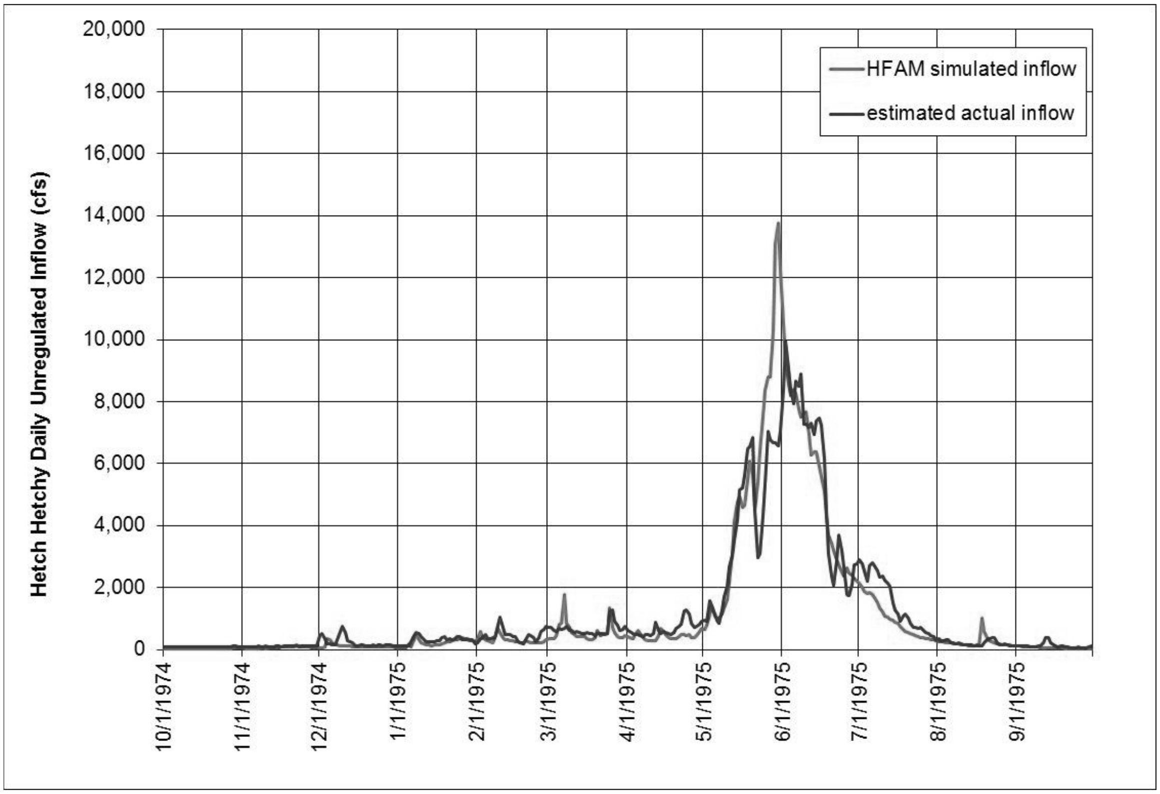

Figure B.1a Hetch Hetchy Daily Unregulated Inflow, water year 1975

HY-52
cont.

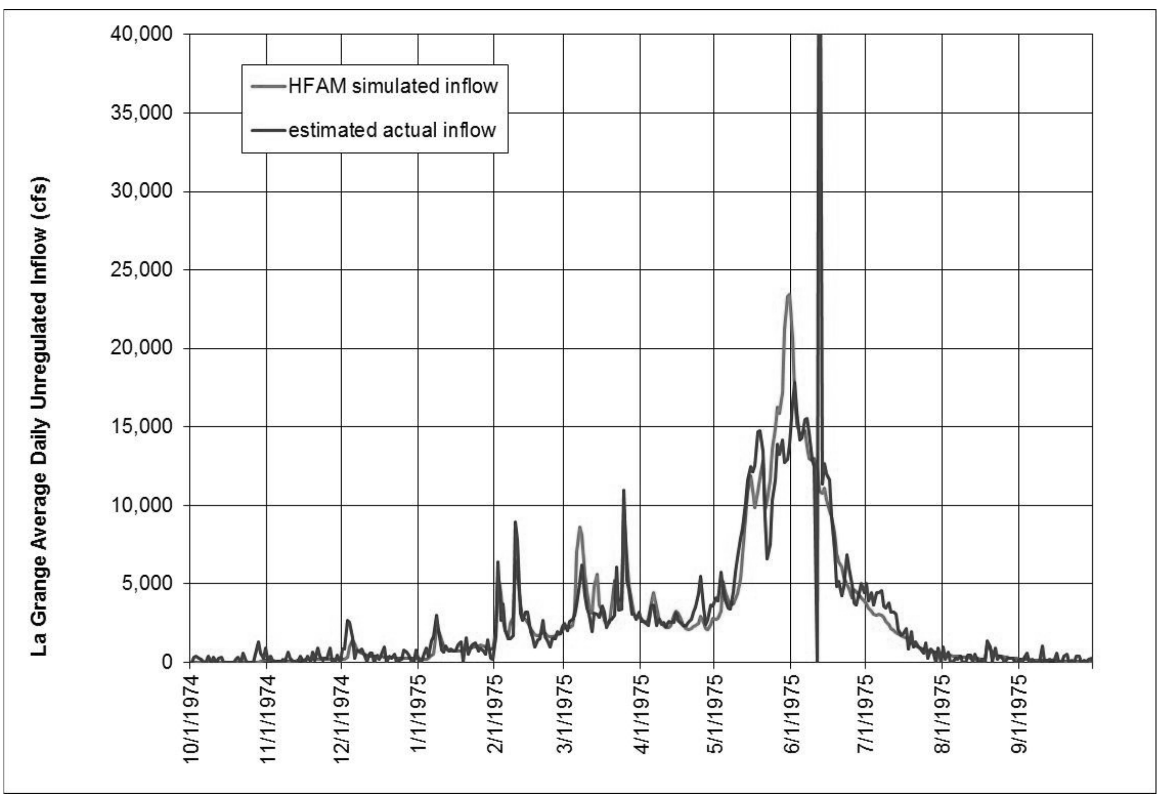

Figure B.1b La Grange Daily Unregulated Inflow, water year 1975

O-TRT-DREKMEIER Cont.

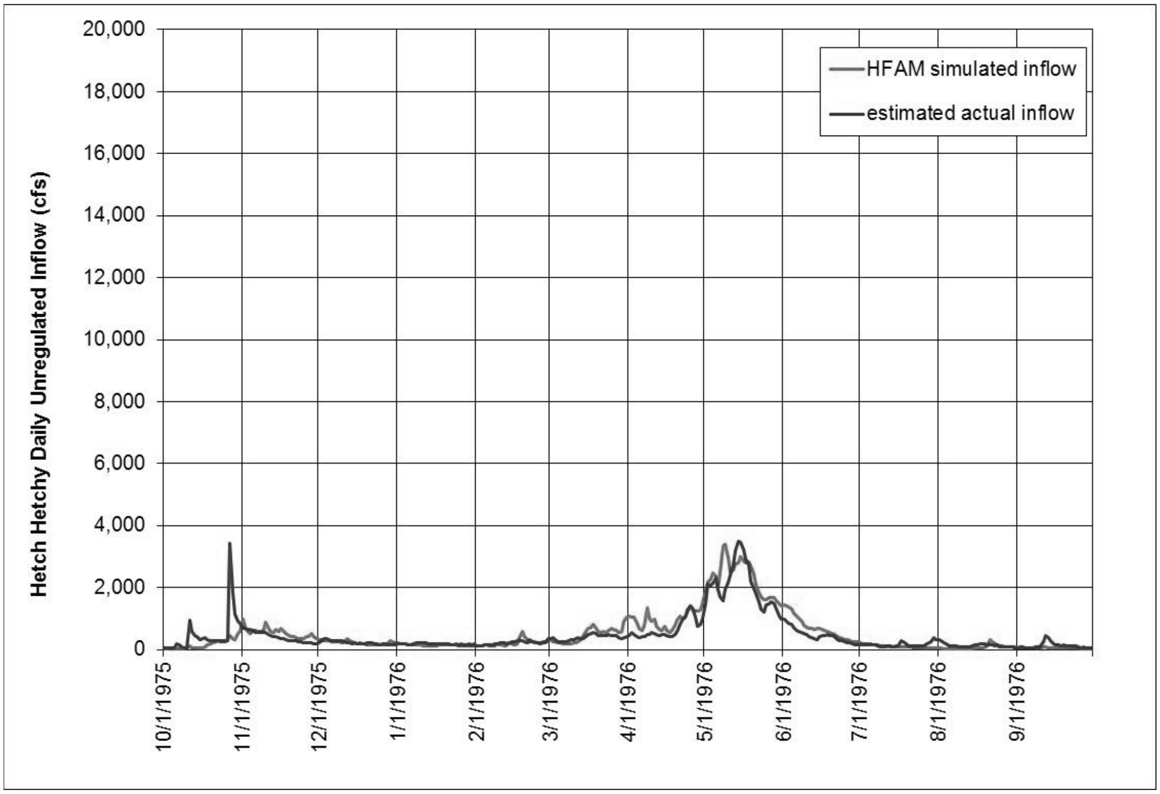

Figure B.2a Hetch Hetchy Daily Unregulated Inflow, water year 1976

HY-52 cont.

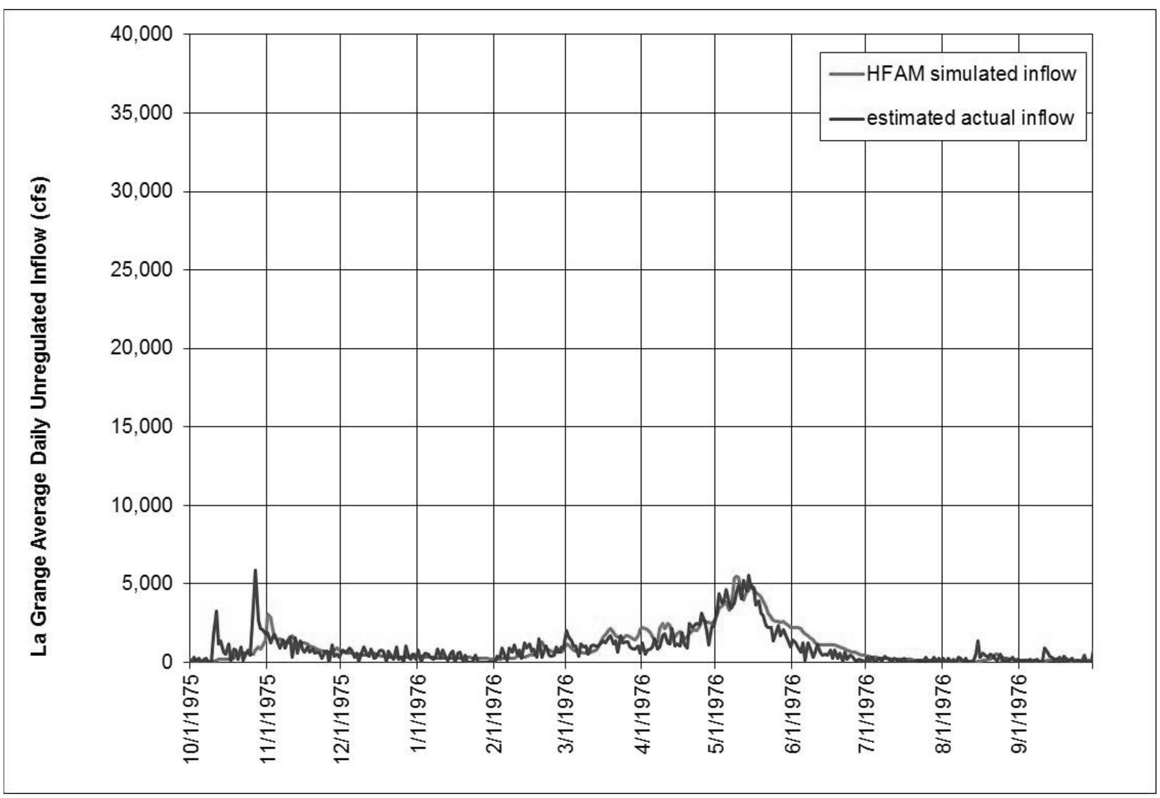

Figure B.2b La Grange Daily Unregulated Inflow, water year 1976

O-TRT-
DREKMEIER
Cont.

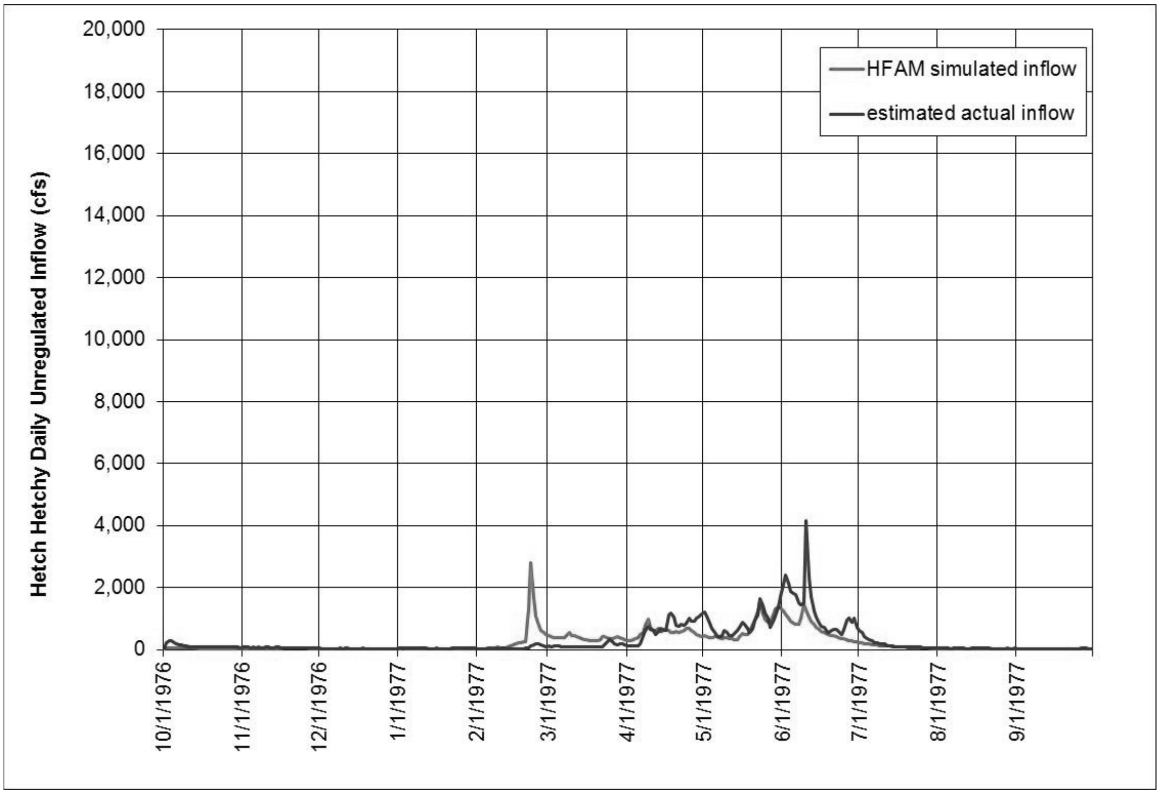

Figure B.3a Hetch Hetchy Daily Unregulated Inflow, water year 1977

HY-52
cont.

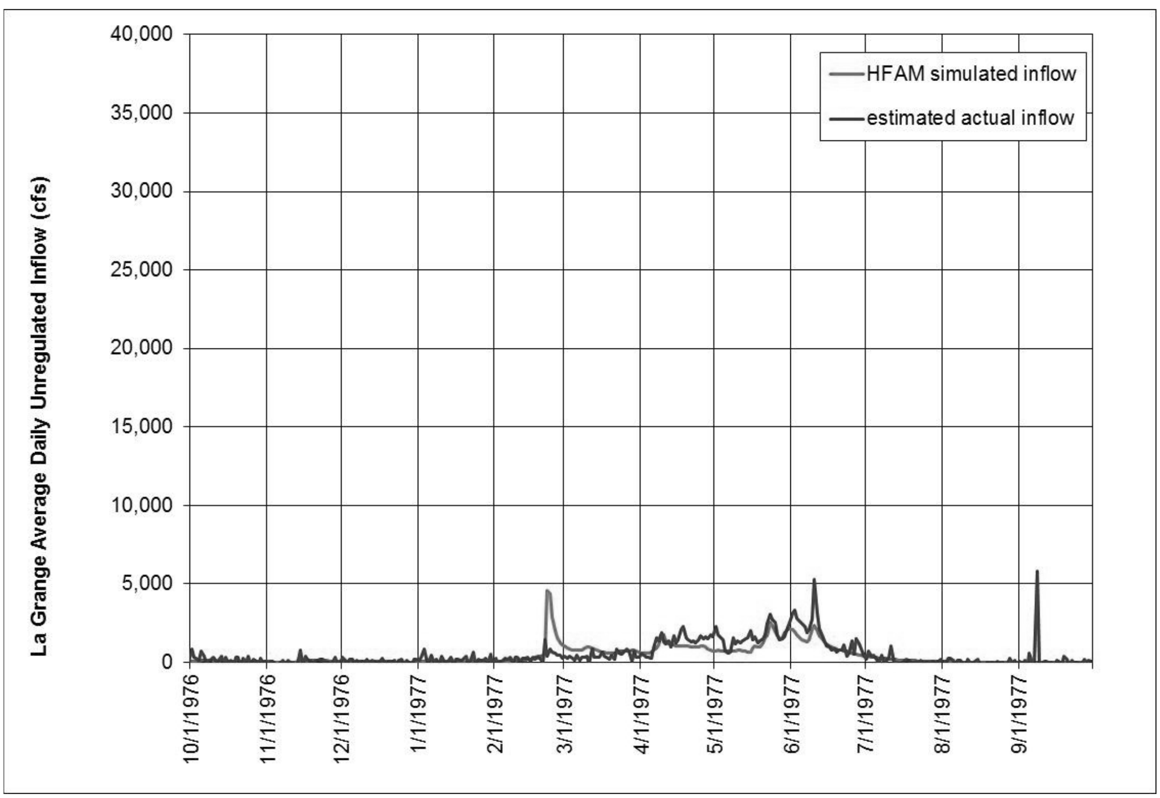

Figure B.3b La Grange Daily Unregulated Inflow, water year 1977

O-TRT-DREKMEIER Cont.

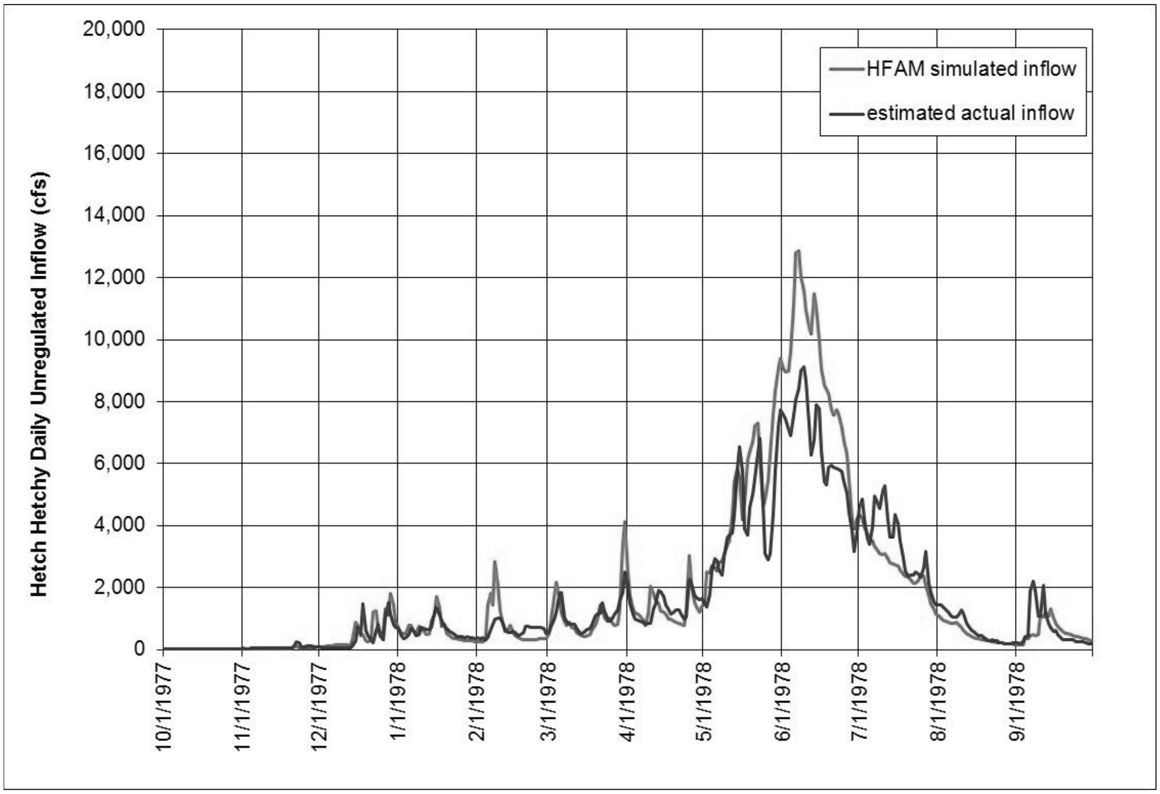

Figure B.4a Hetch Hetchy Daily Unregulated Inflow, water year 1978

HY-52 cont.

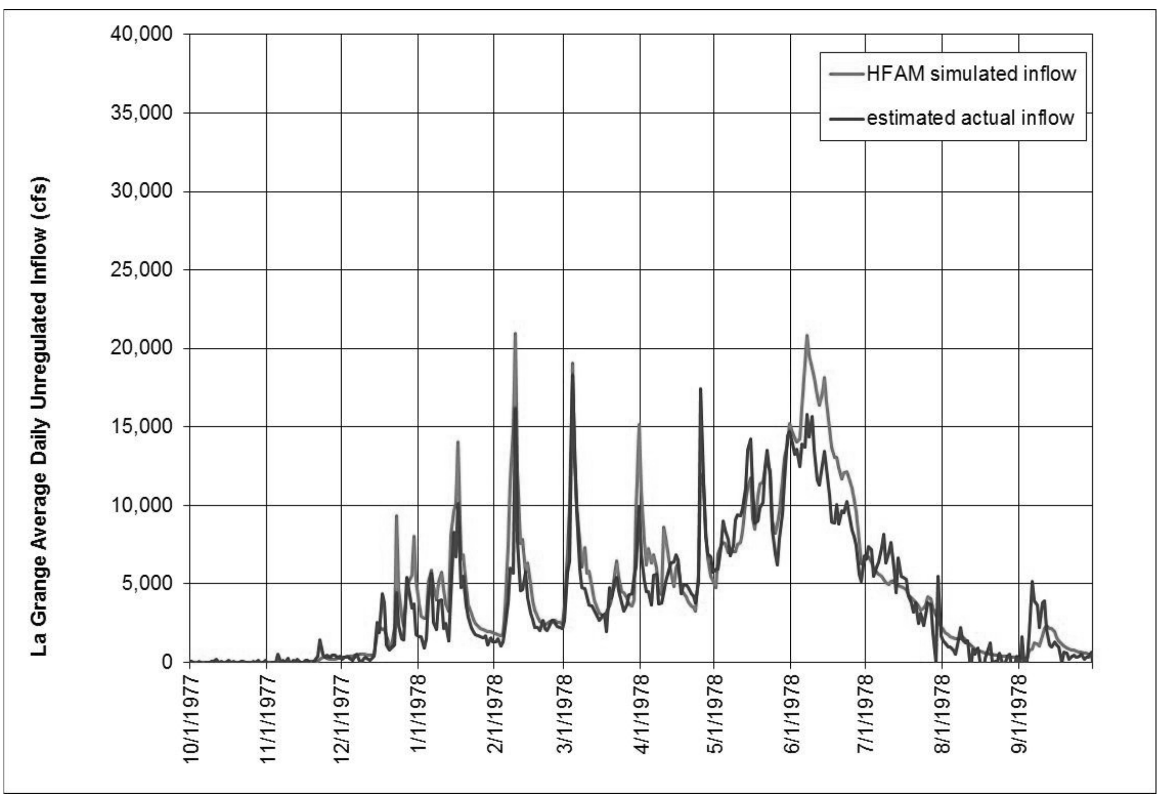

Figure B.4b La Grange Daily Unregulated Inflow, water year 1978

O-TRT-
DREKMEIER
Cont.

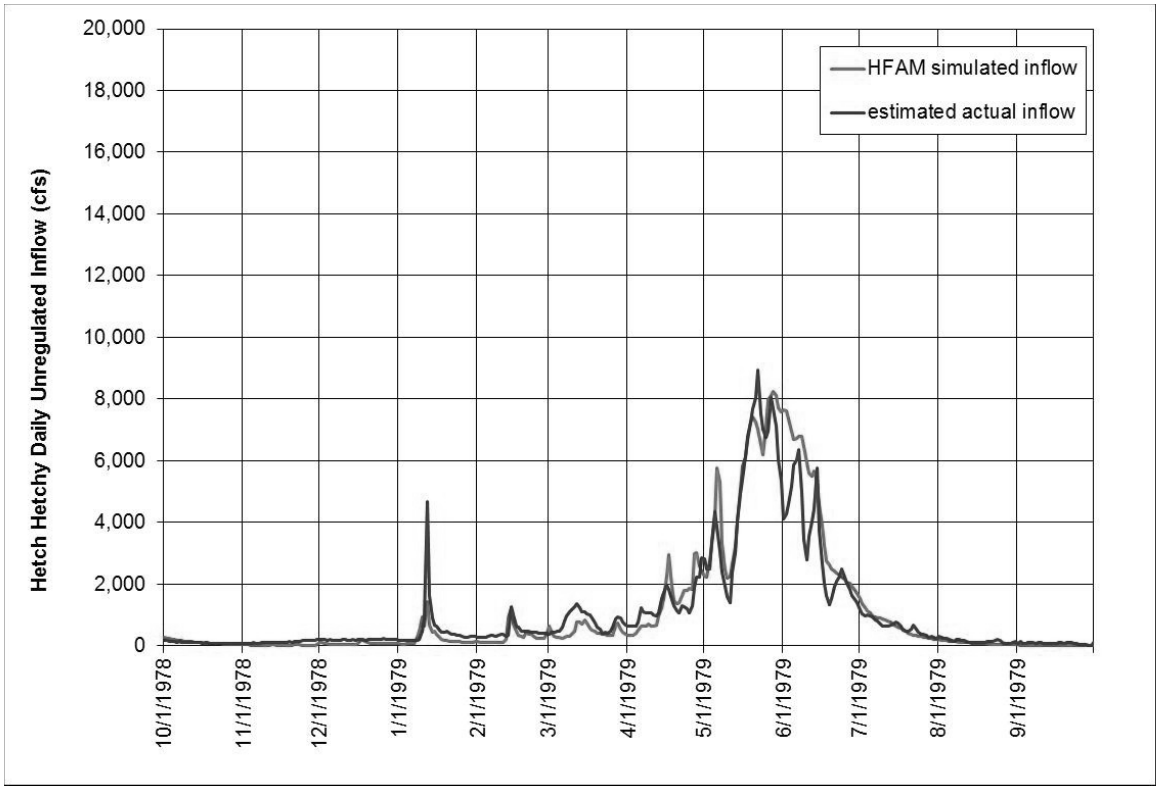

Figure B.5a Hetch Hetchy Daily Unregulated Inflow, water year 1979

HY-52
cont.

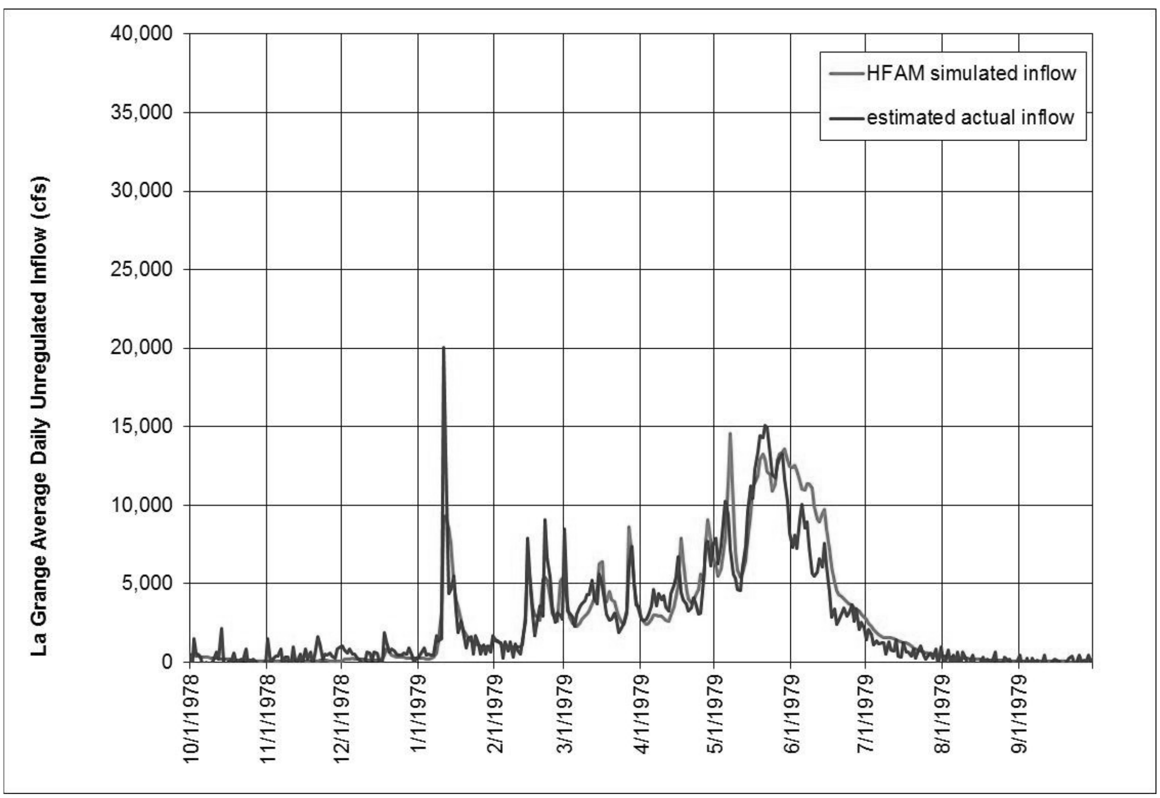

Figure B.5b La Grange Daily Unregulated Inflow, water year 1979

O-TRT-DREKMEIER Cont.

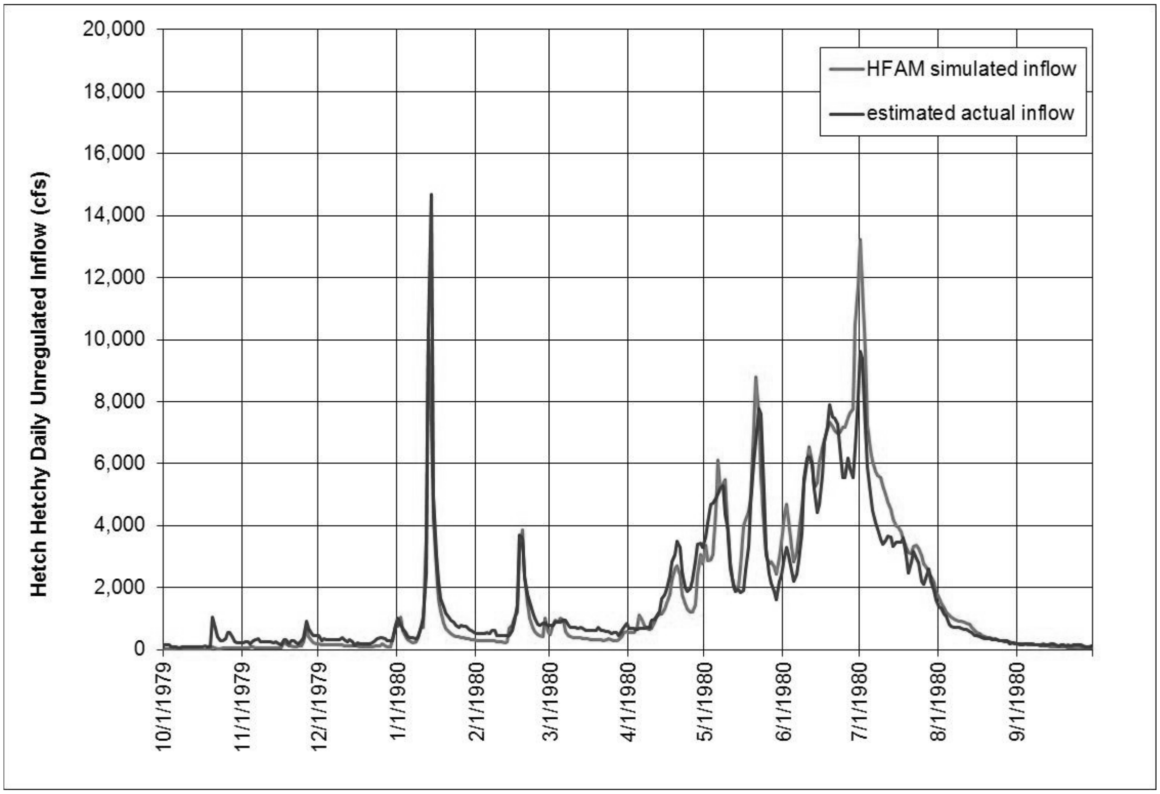

Figure B.6a Hetch Hetchy Daily Unregulated Inflow, water year 1980

HY-52 cont.

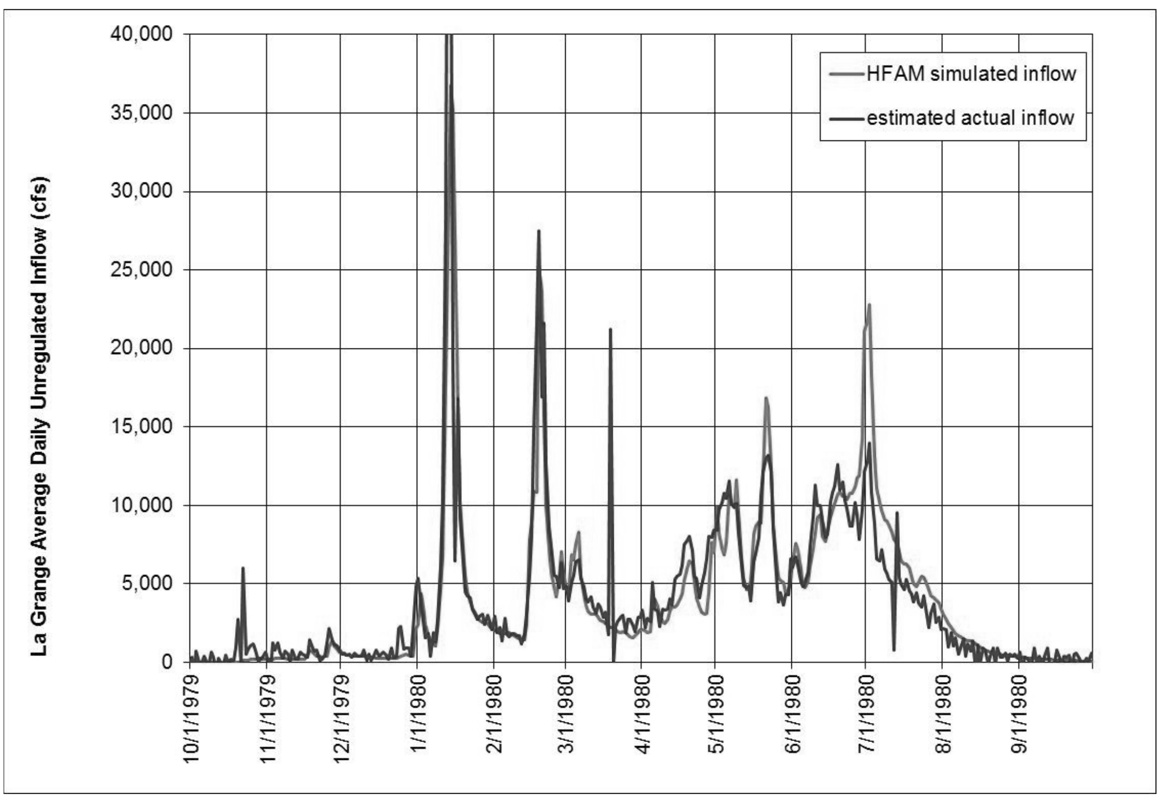

Figure B.6b La Grange Daily Unregulated Inflow, water year 1980

O-TRT-DREKMEIER Cont.

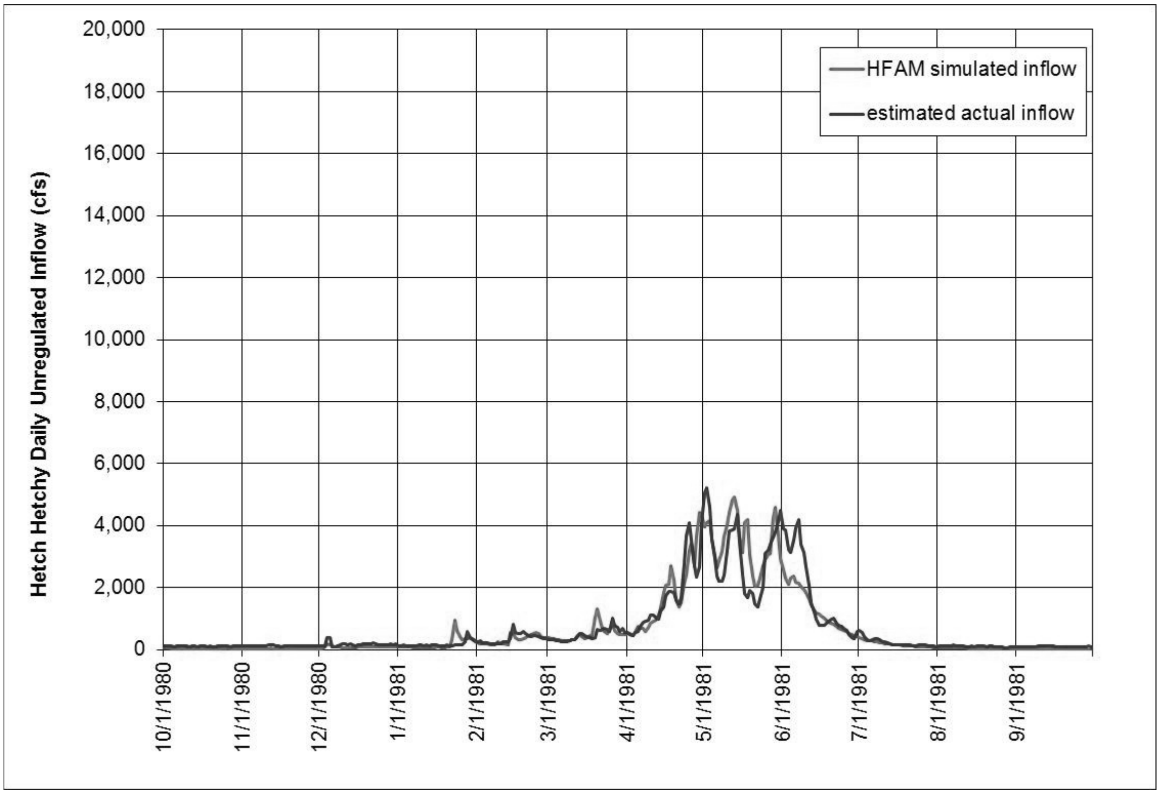

Figure B.7a Hetch Hetchy Daily Unregulated Inflow, water year 1981

HY-52 cont.

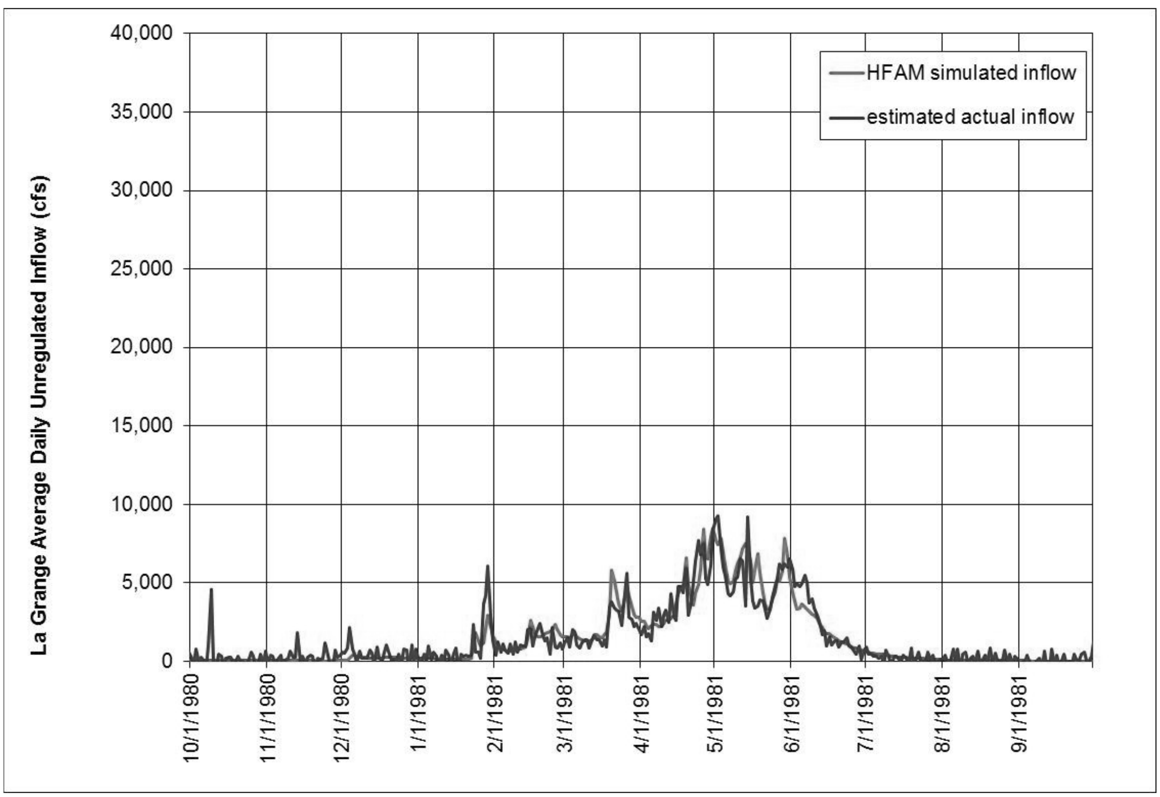

Figure B.7b La Grange Daily Unregulated Inflow, water year 1981

O-TRT-DREKMEIER Cont.

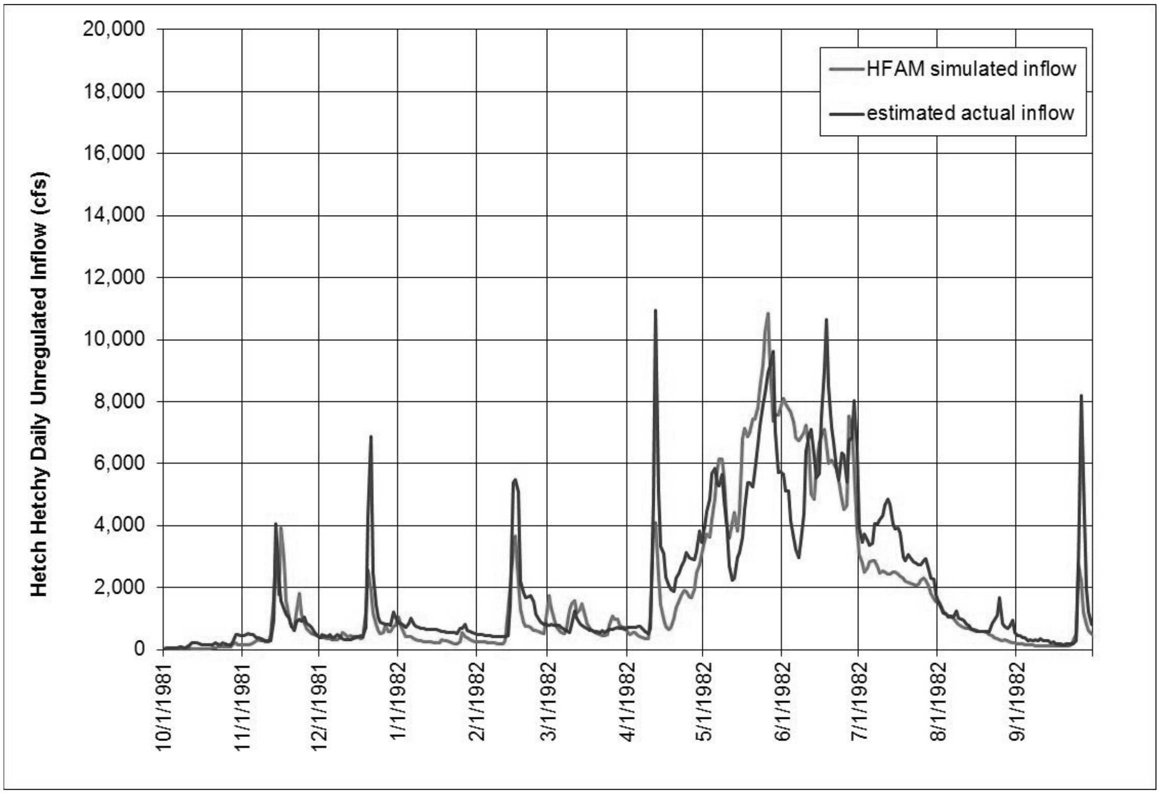

Figure B.8a Hetch Hetchy Daily Unregulated Inflow, water year 1982

HY-52 cont.

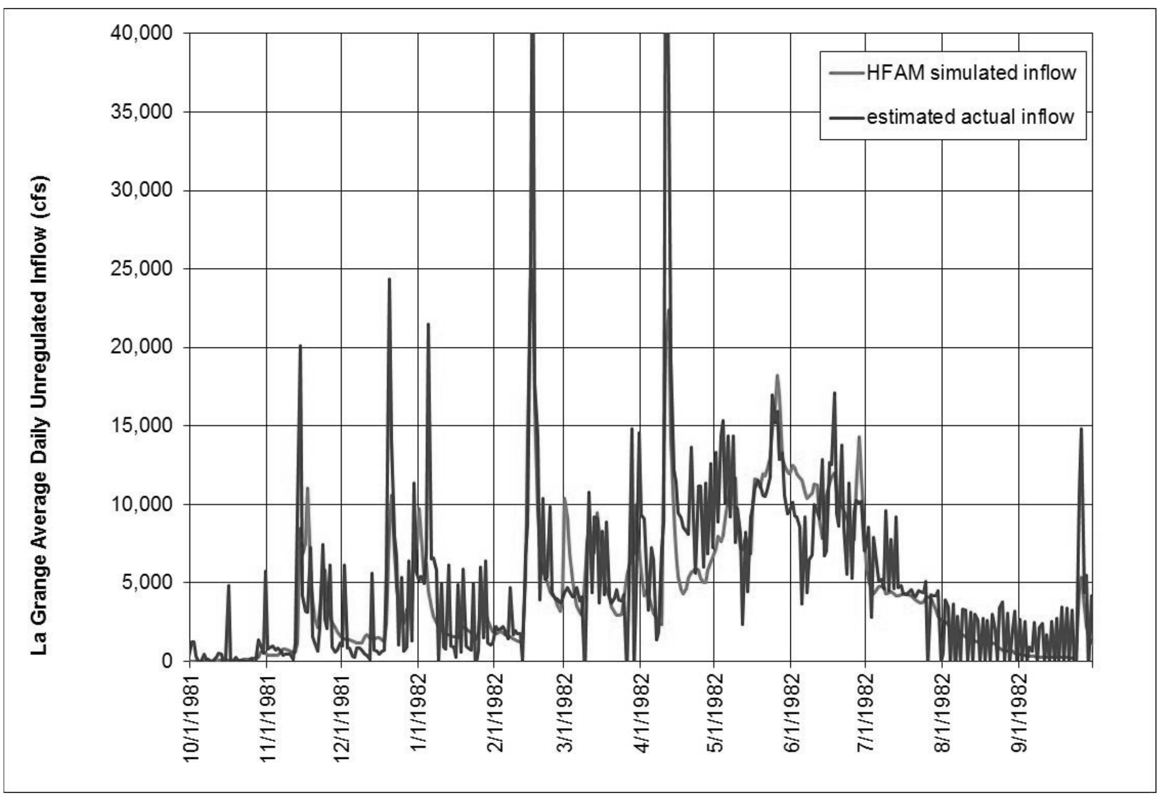

Figure B.8b La Grange Daily Unregulated Inflow, water year 1982

O-TRT-DREKMEIER Cont.

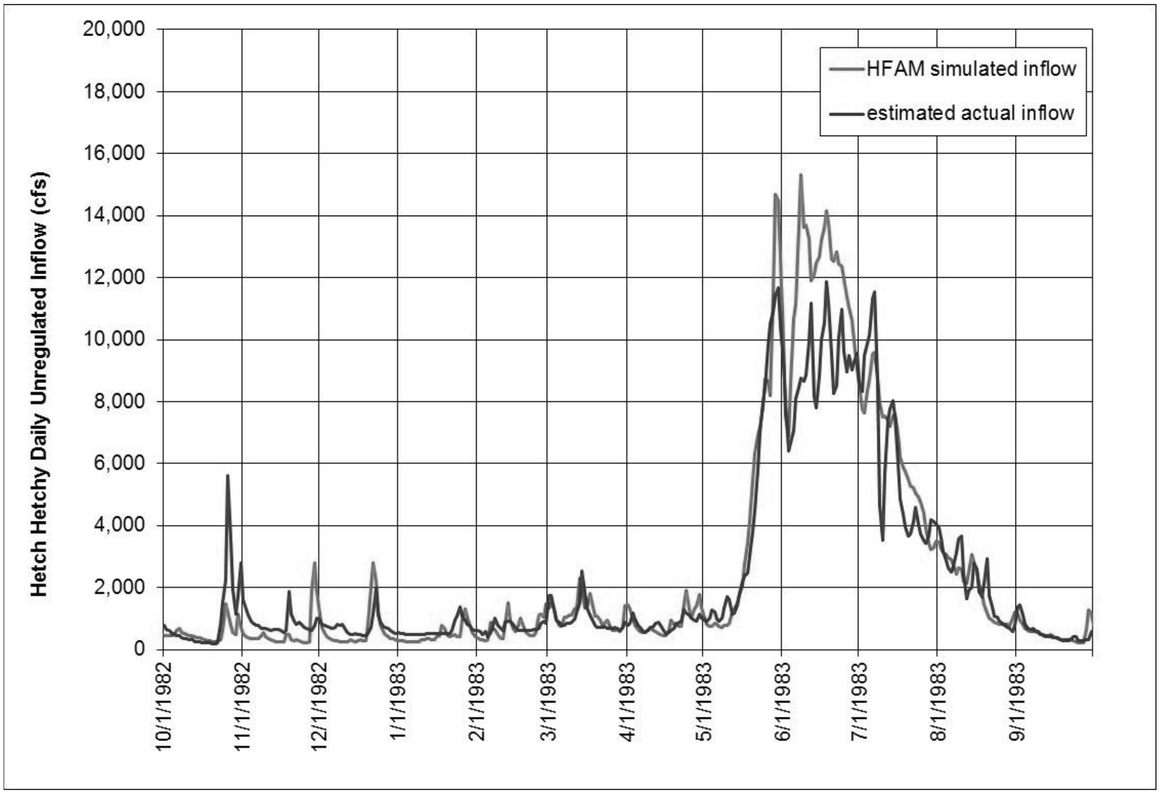

Figure B.9a Hetch Hetchy Daily Unregulated Inflow, water year 1983

HY-52 cont.

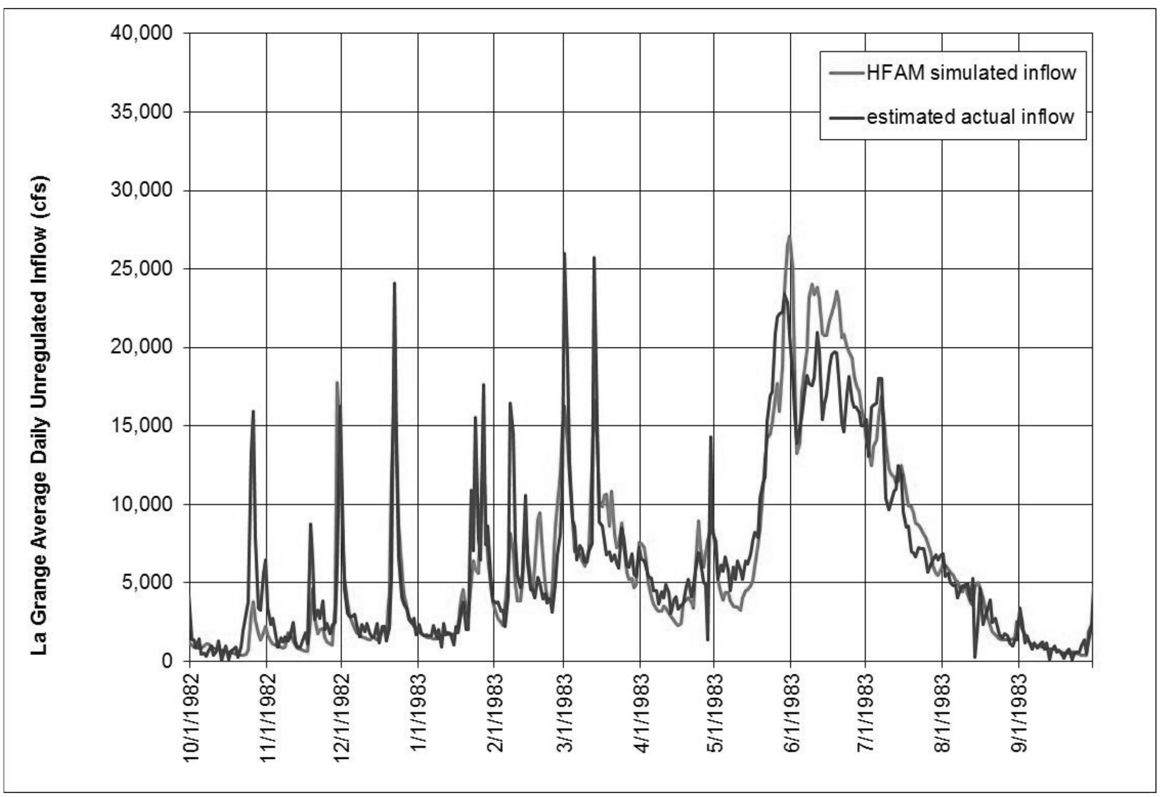

Figure B.9b La Grange Daily Unregulated Inflow, water year 1983

O-TRT-DREKMEIER Cont.

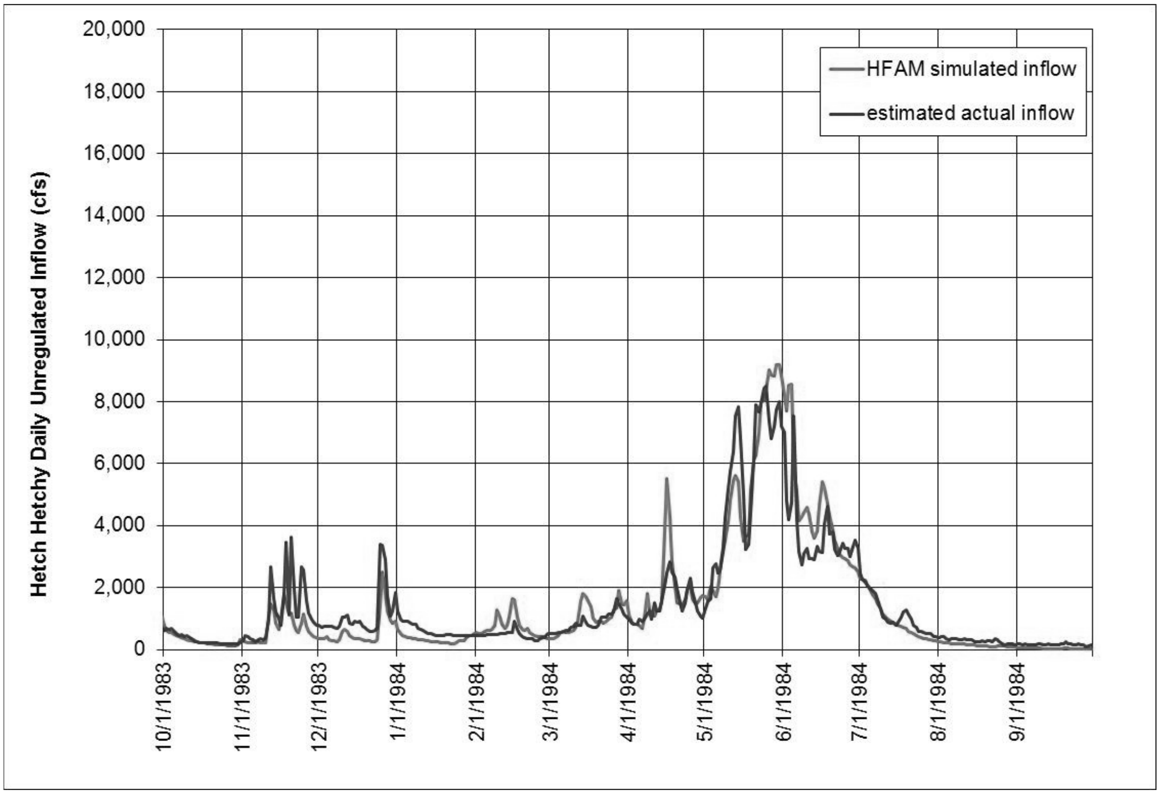

Figure B.10a Hetch Hetchy Daily Unregulated Inflow, water year 1984

HY-52 cont.

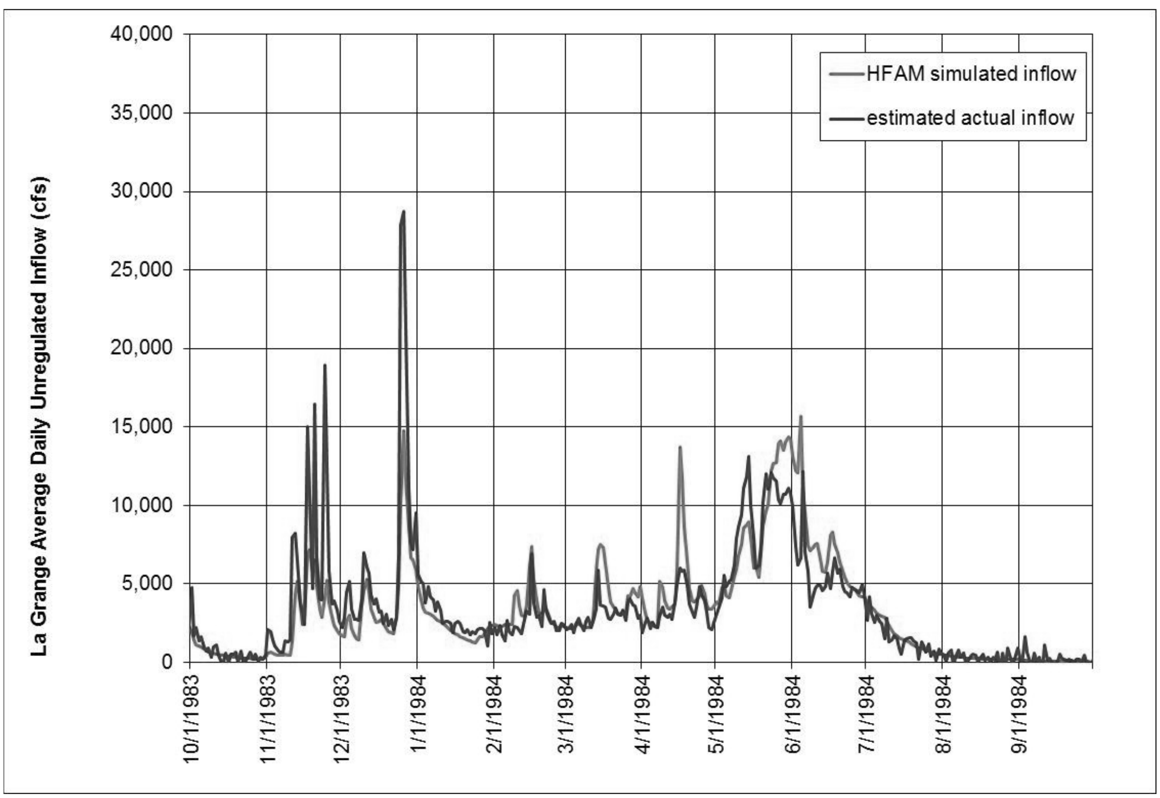

Figure B.10b La Grange Daily Unregulated Inflow, water year 1984

O-TRT-DREKMEIER Cont.

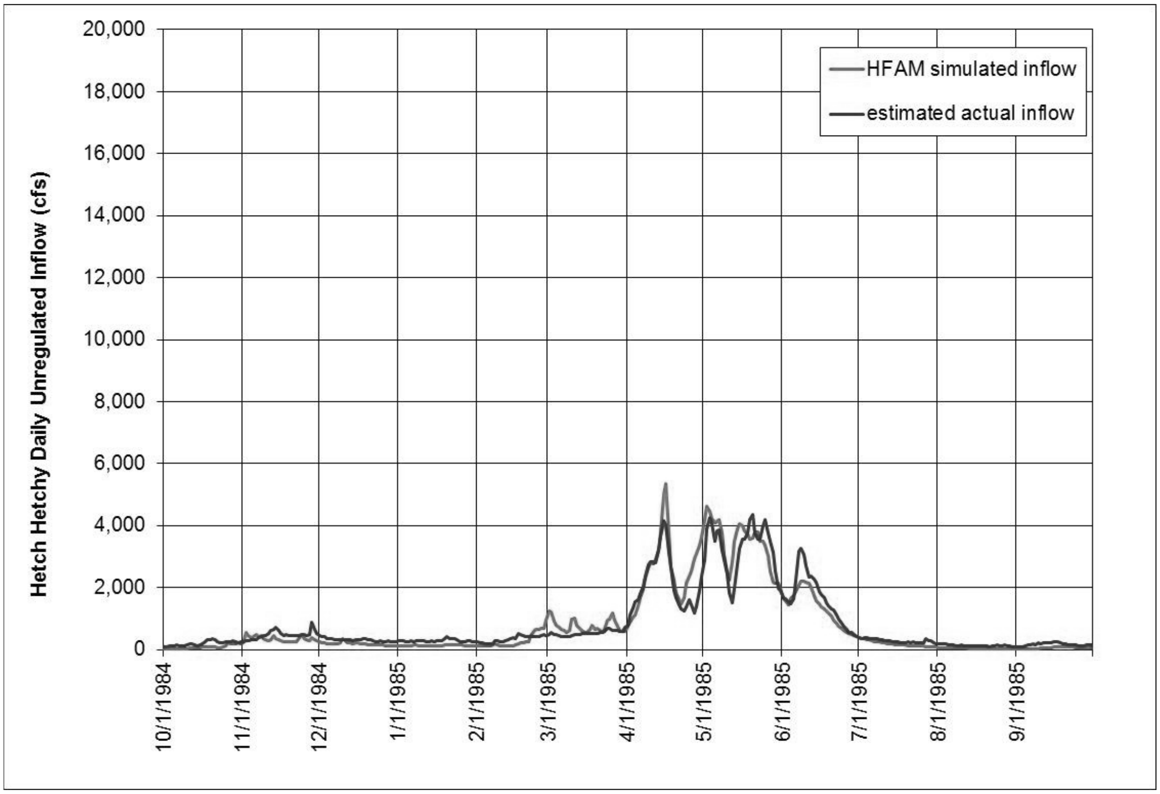

Figure B.11a Hetch Hetchy Daily Unregulated Inflow, water year 1985

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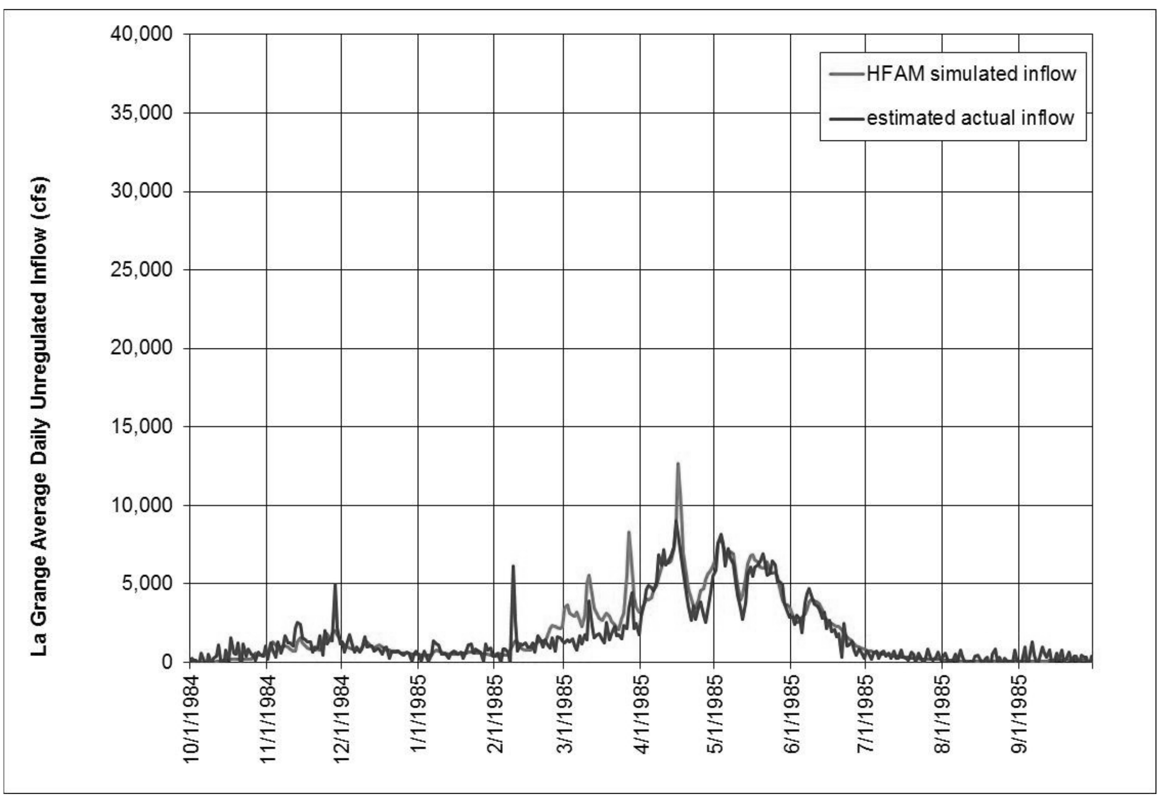

Figure B.11b La Grange Daily Unregulated Inflow, water year 1985

O-TRT-DREKMEIER Cont.

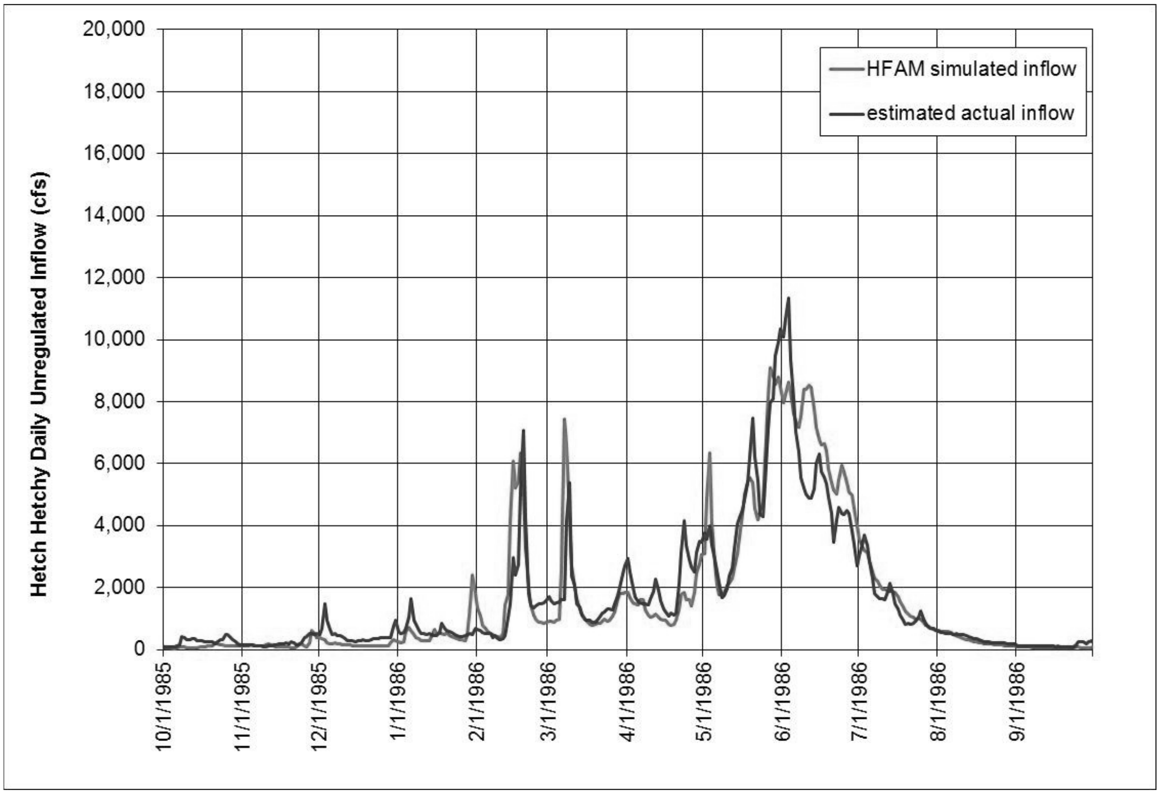

Figure B.12a Hetch Hetchy Daily Unregulated Inflow, water year 1986

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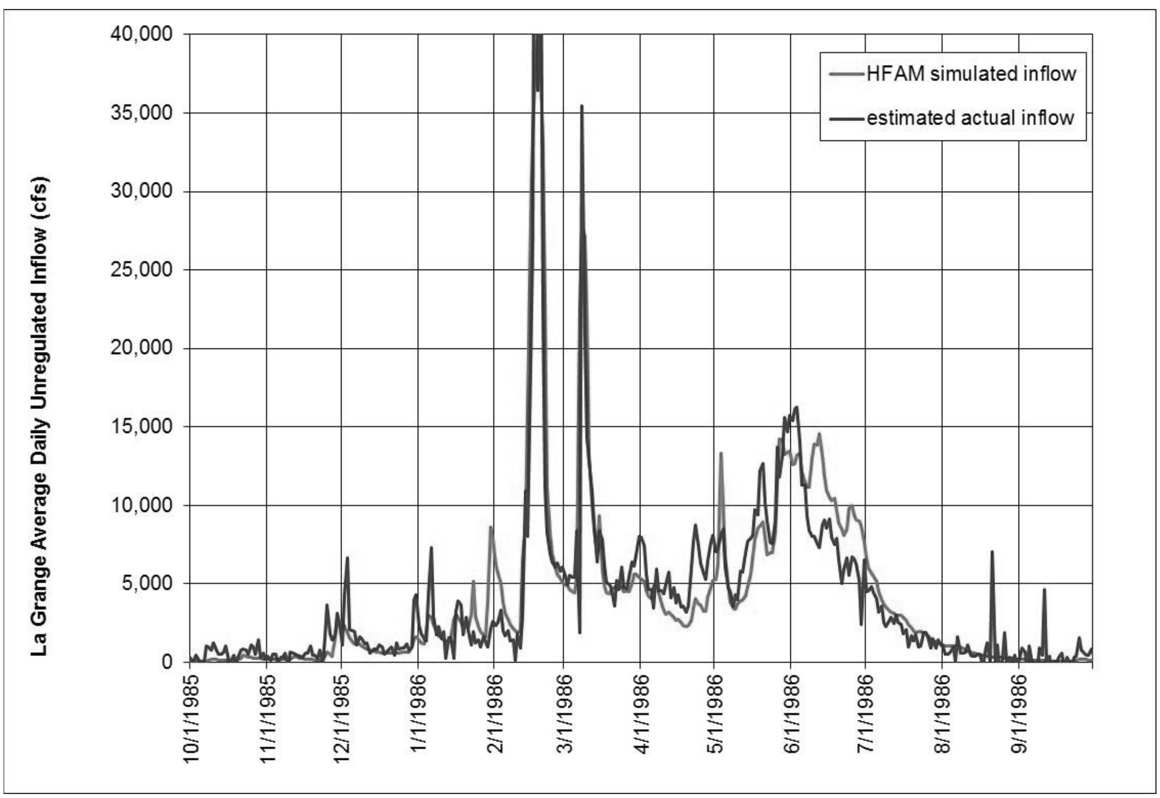

Figure B.12b La Grange Daily Unregulated Inflow, water year 1986

O-TRT-
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Cont.

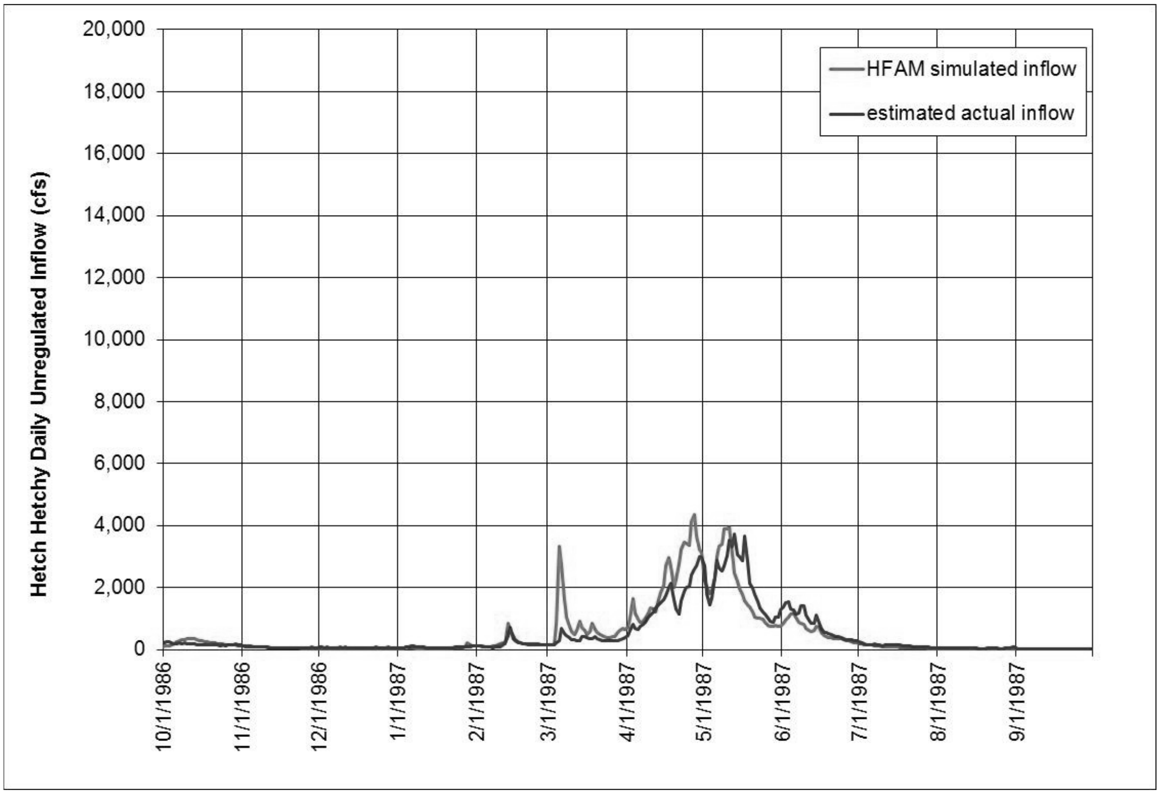

Figure B.13a Hetch Hetchy Daily Unregulated Inflow, water year 1987

HY-52
cont.

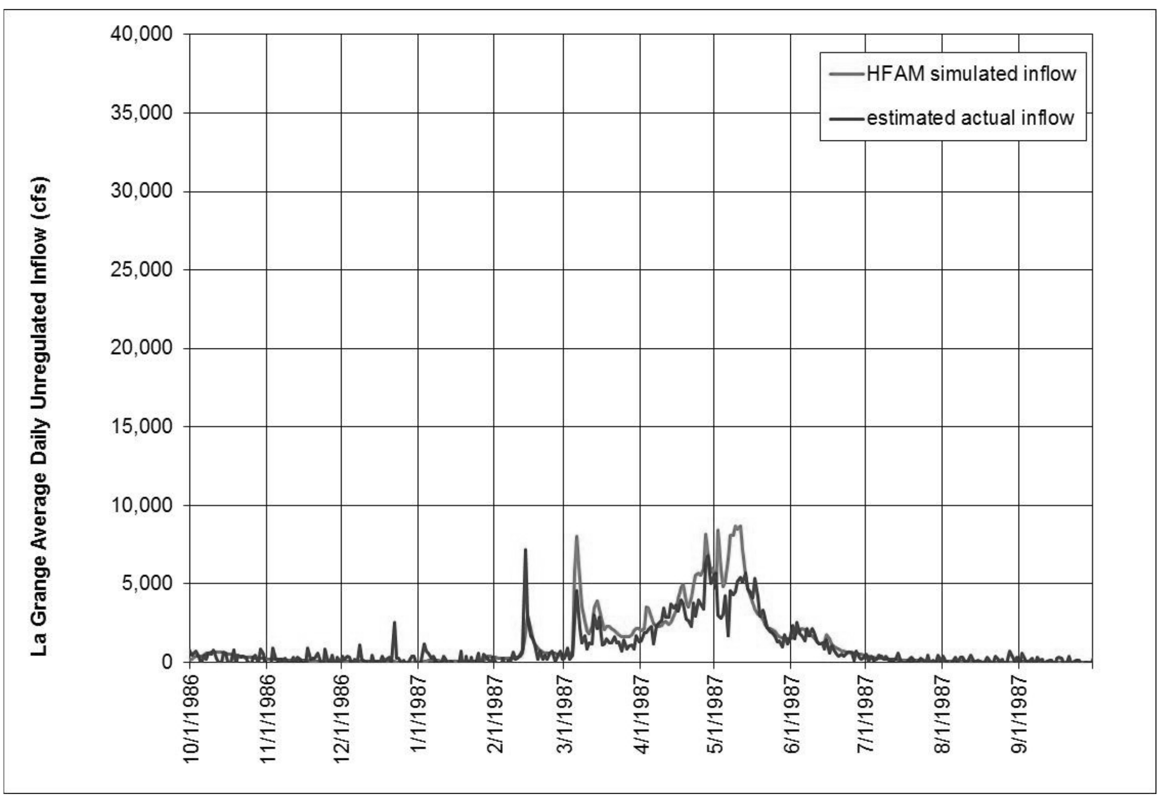

Figure B.13b La Grange Daily Unregulated Inflow, water year 1987

O-TRT-DREKMEIER Cont.

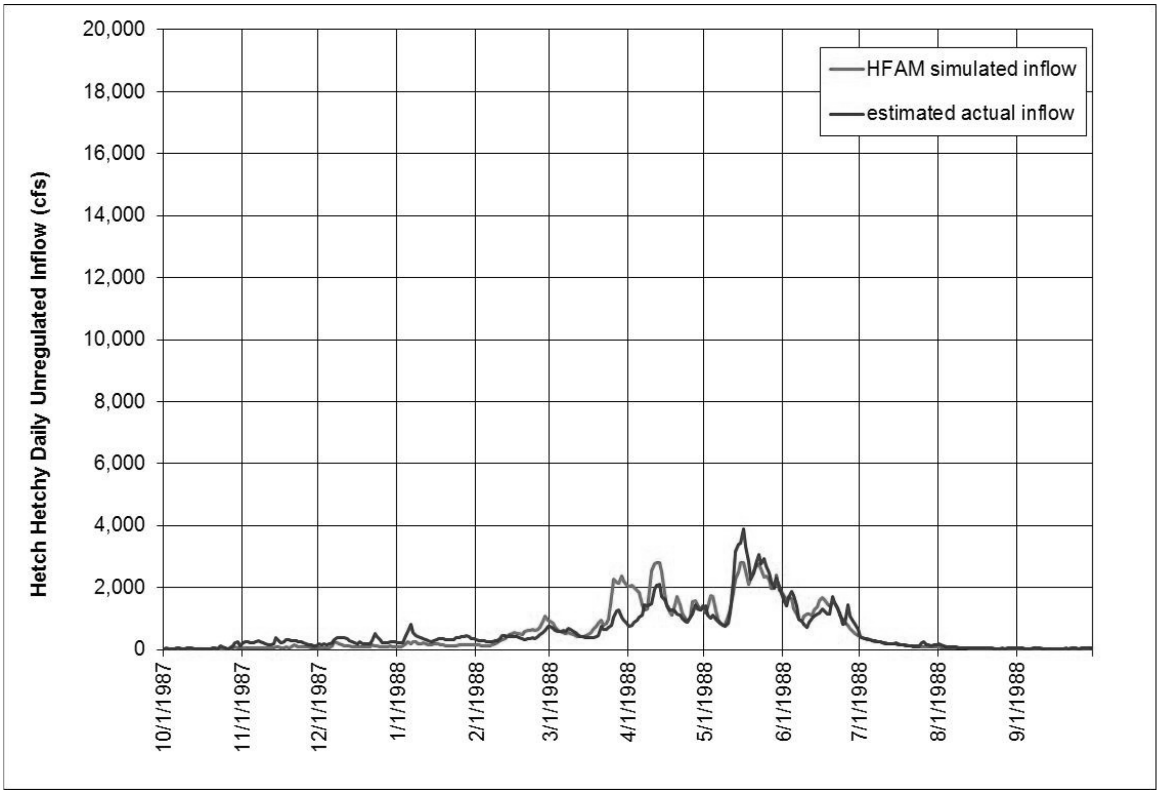

Figure B.14a Hetch Hetchy Daily Unregulated Inflow, water year 1988

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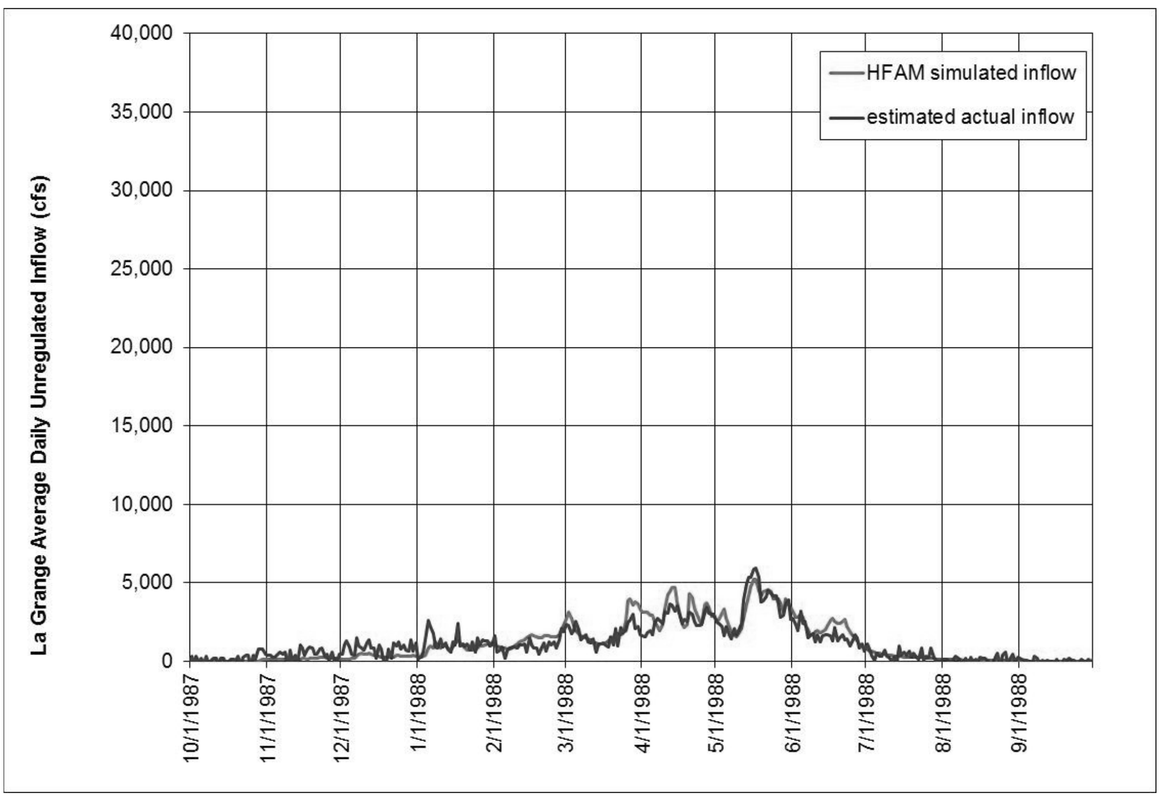

Figure B.14b La Grange Daily Unregulated Inflow, water year 1988

O-TRT-DREKMEIER Cont.

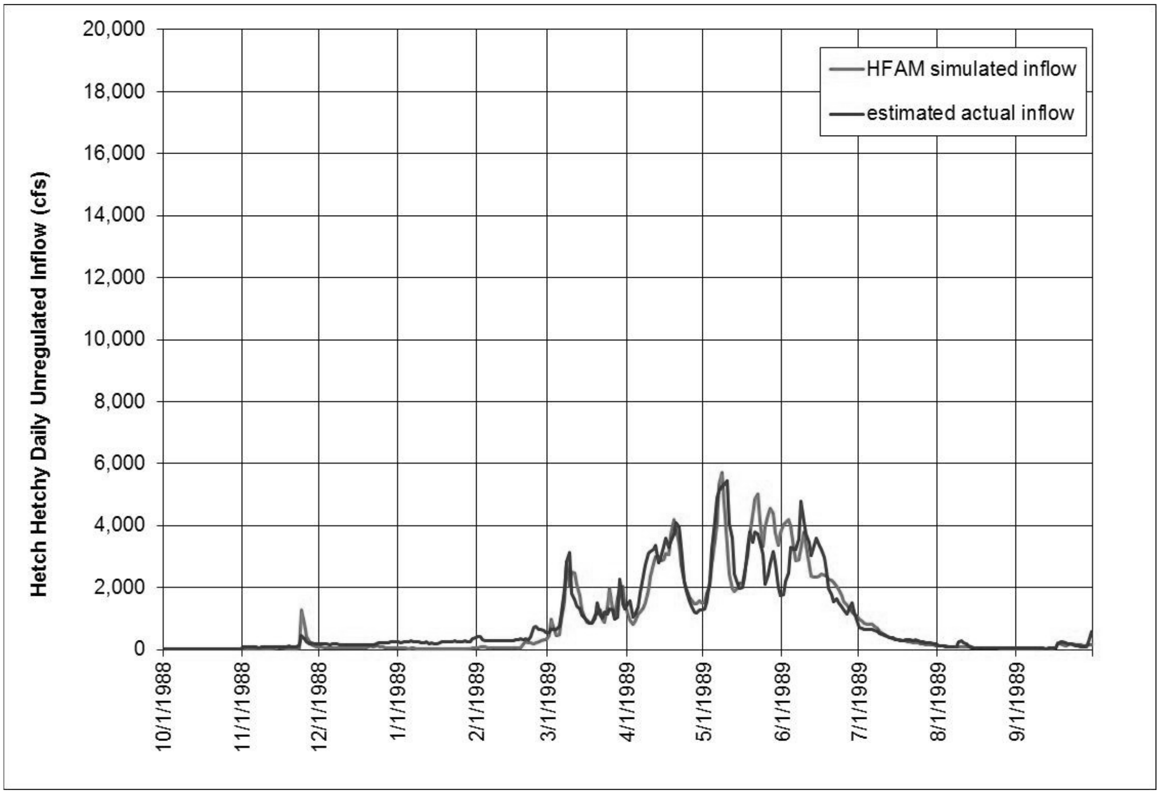

Figure B.15a Hetch Hetchy Daily Unregulated Inflow, water year 1989

HY-52 cont.

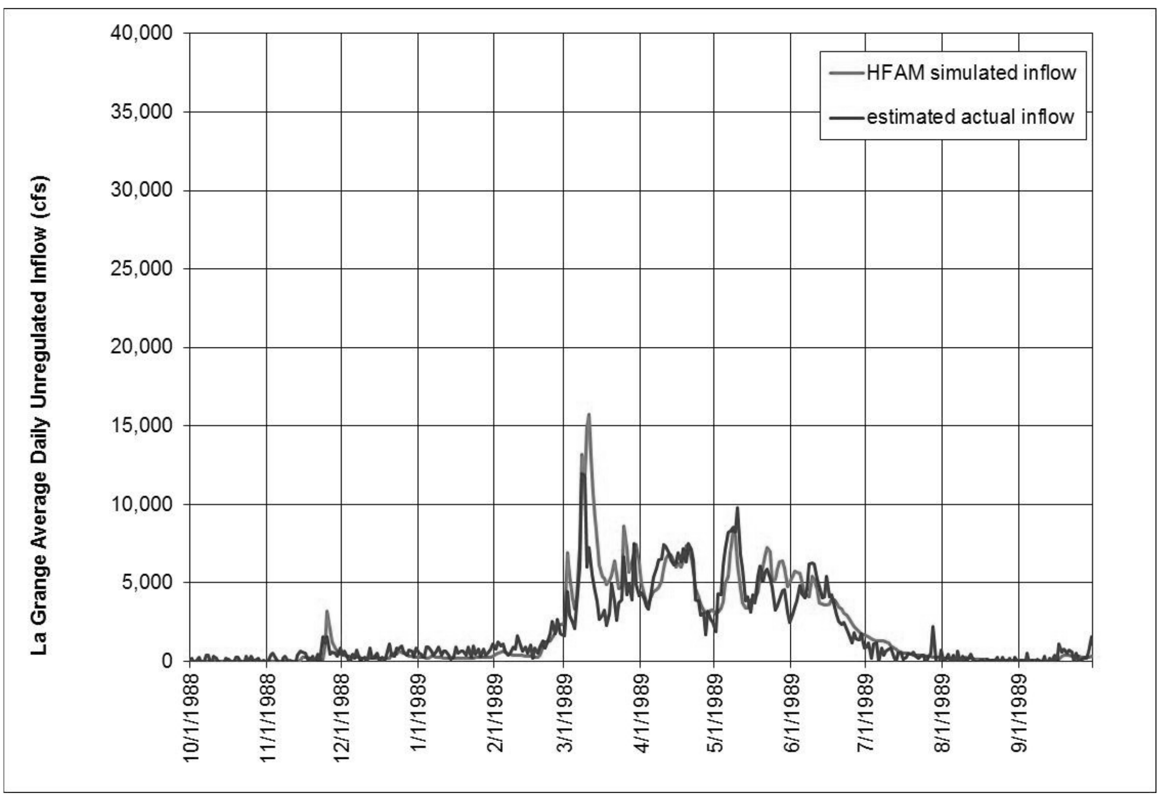

Figure B.15b La Grange Daily Unregulated Inflow, water year 1989

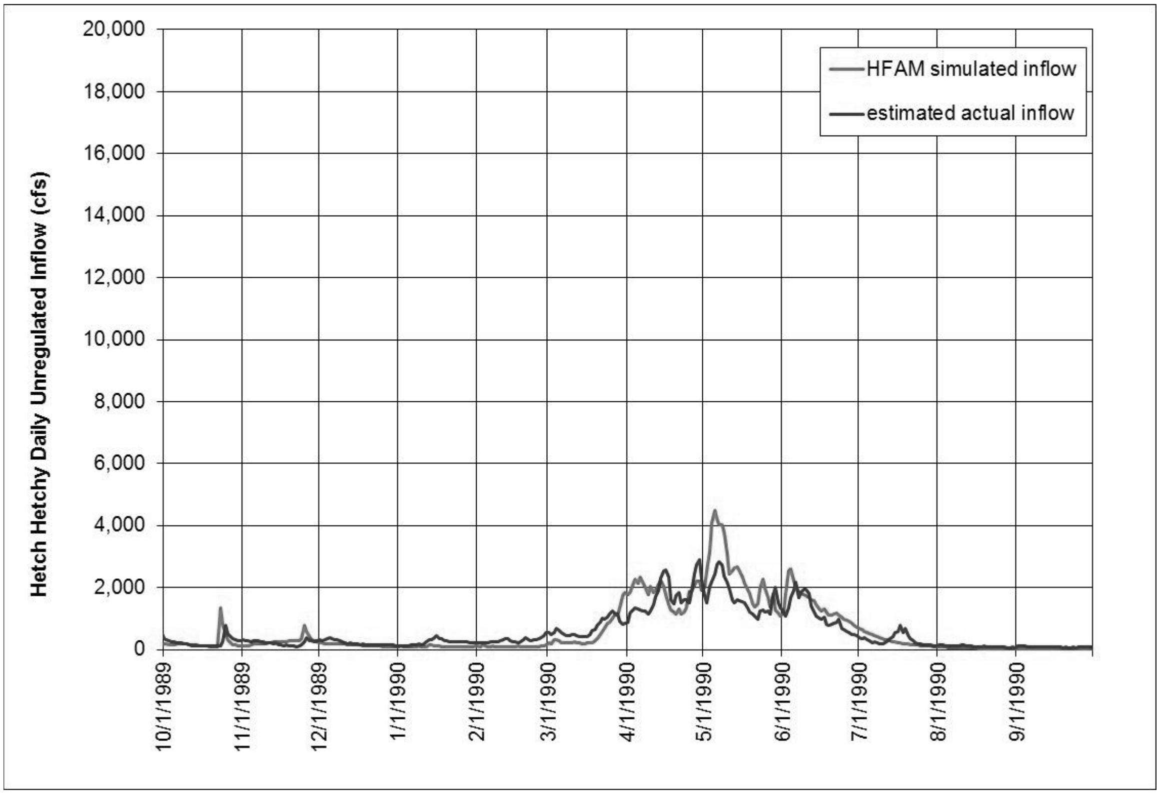

Figure B.16a Hetch Hetchy Daily Unregulated Inflow, water year 1990

HY-52 cont.

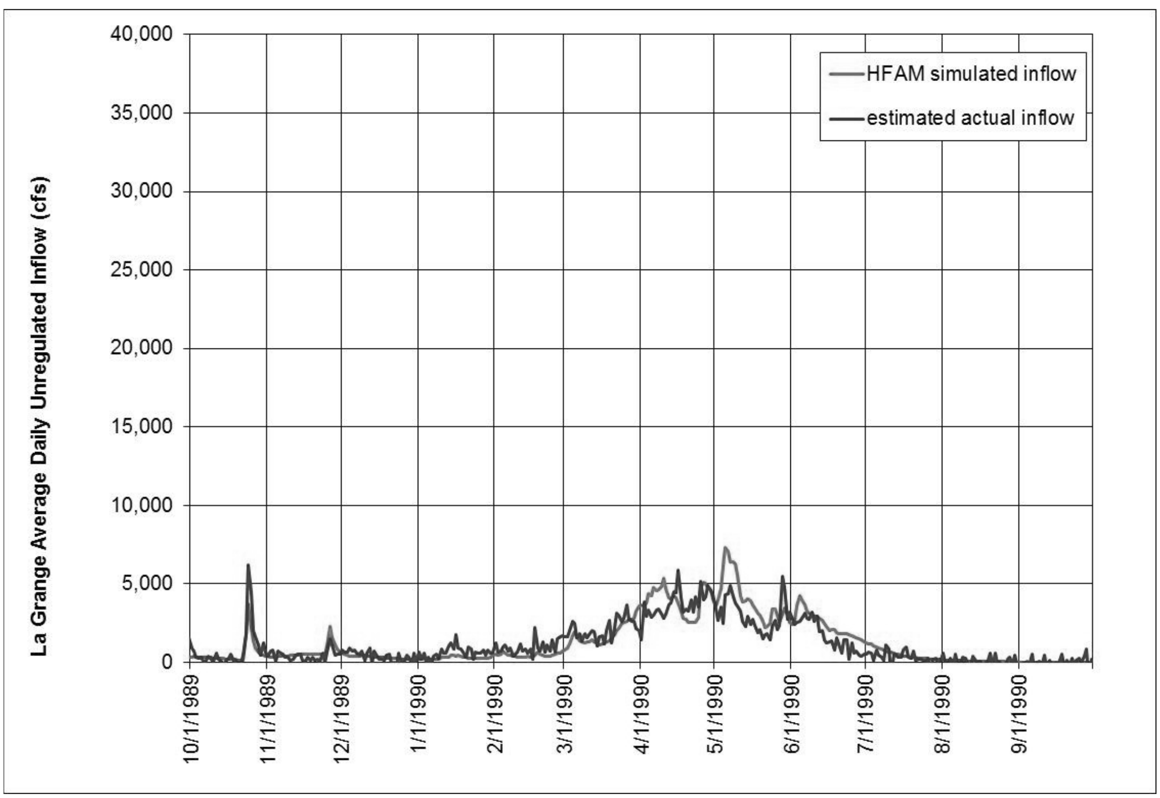

Figure B.16b La Grange Daily Unregulated Inflow, water year 1990

O-TRT-DREKMEIER Cont.

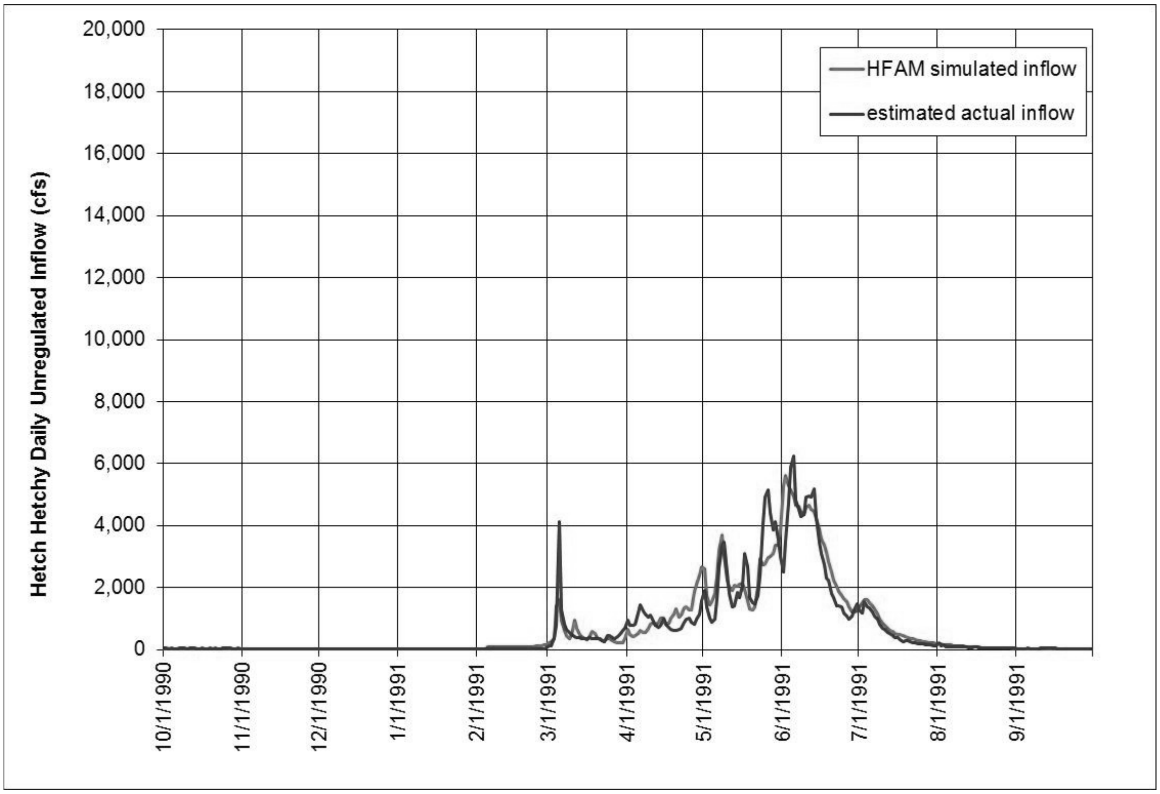

Figure B.17a Hetch Hetchy Daily Unregulated Inflow, water year 1991

HY-52 cont.

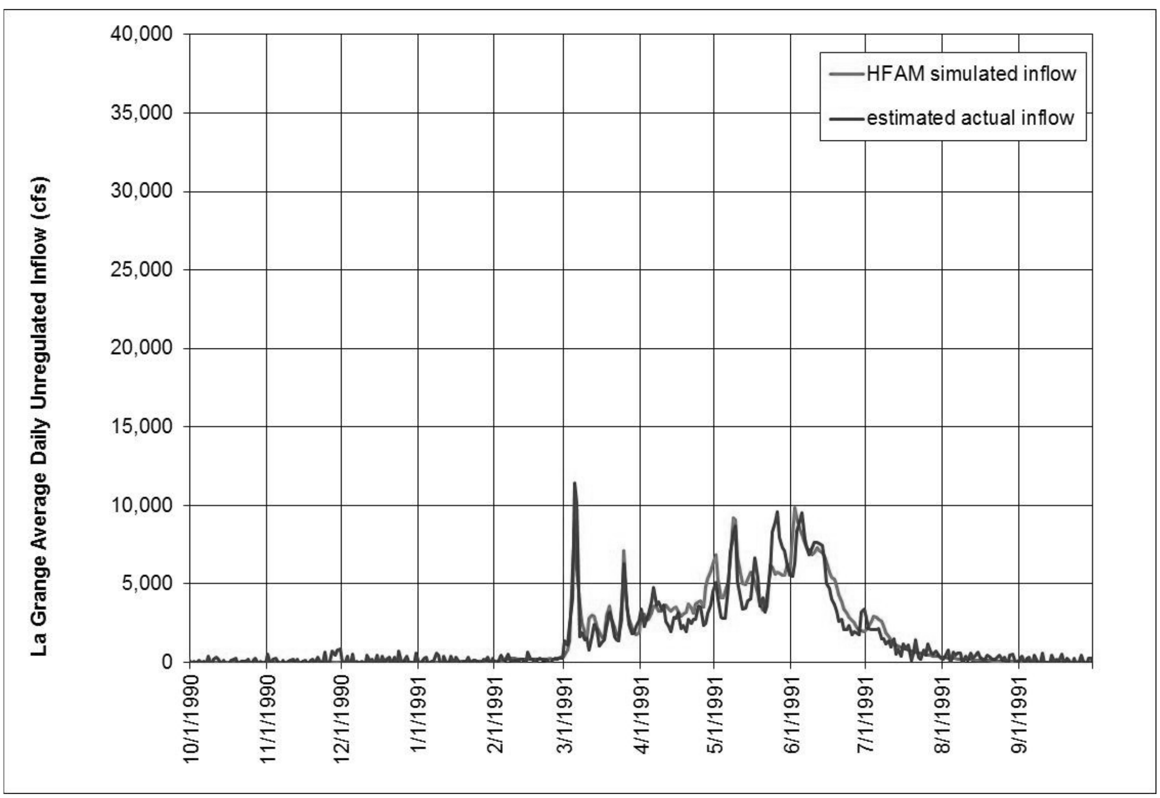

Figure B.17b La Grange Daily Unregulated Inflow, water year 1991

O-TRT-
DREKMEIER
Cont.

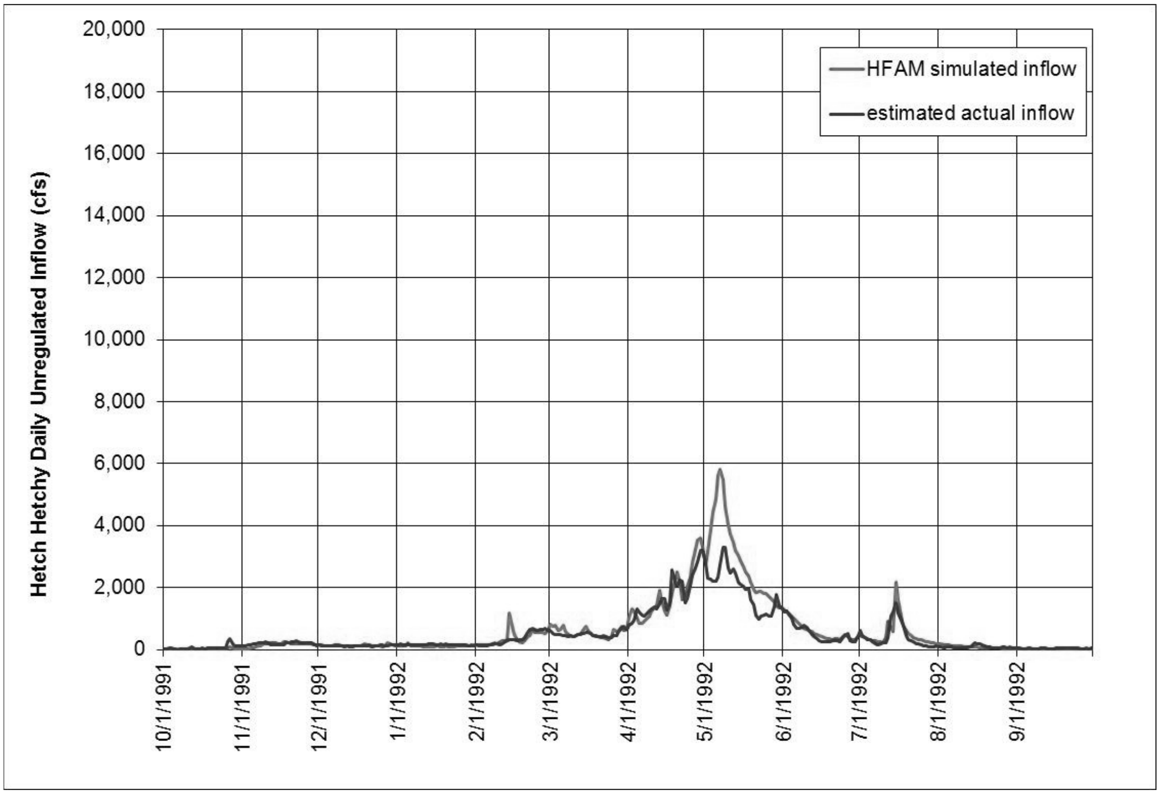

Figure B.18a Hetch Hetchy Daily Unregulated Inflow, water year 1992

HY-52
cont.

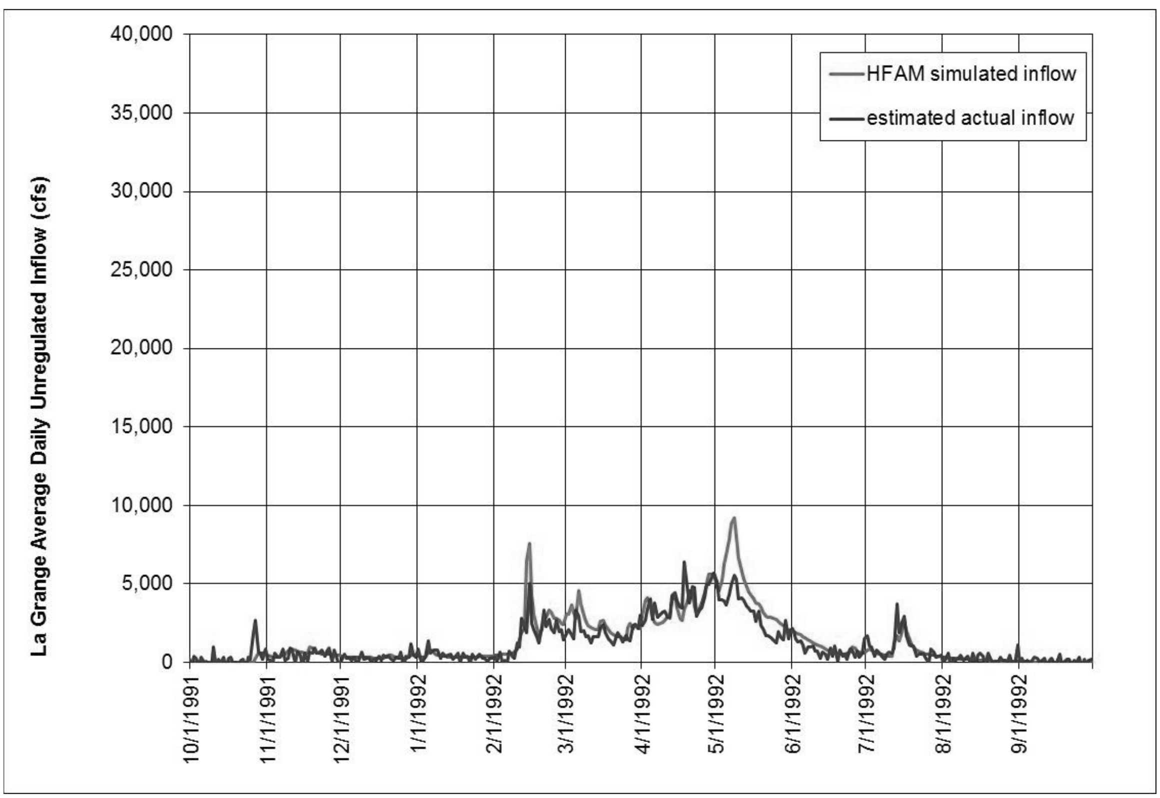

Figure B.18b La Grange Daily Unregulated Inflow, water year 1992

O-TRT-DREKMEIER Cont.

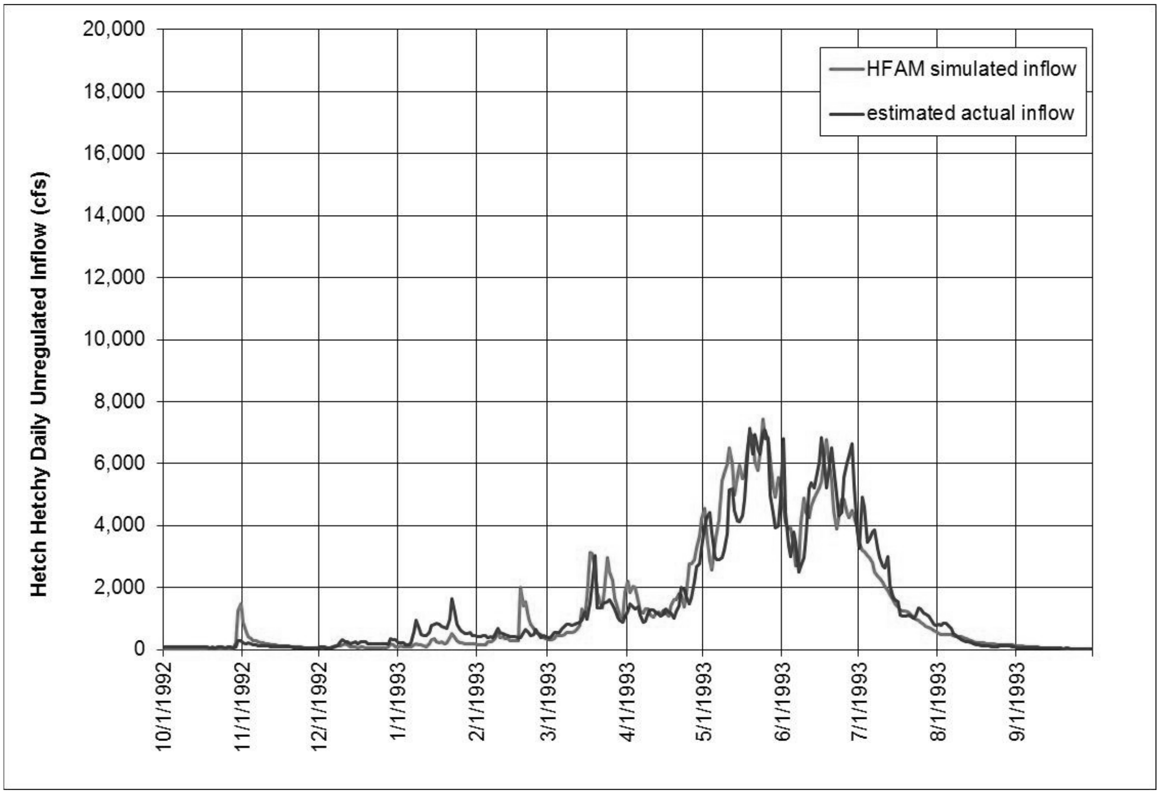

Figure B.19a Hetch Hetchy Daily Unregulated Inflow, water year 1993

HY-52 cont.

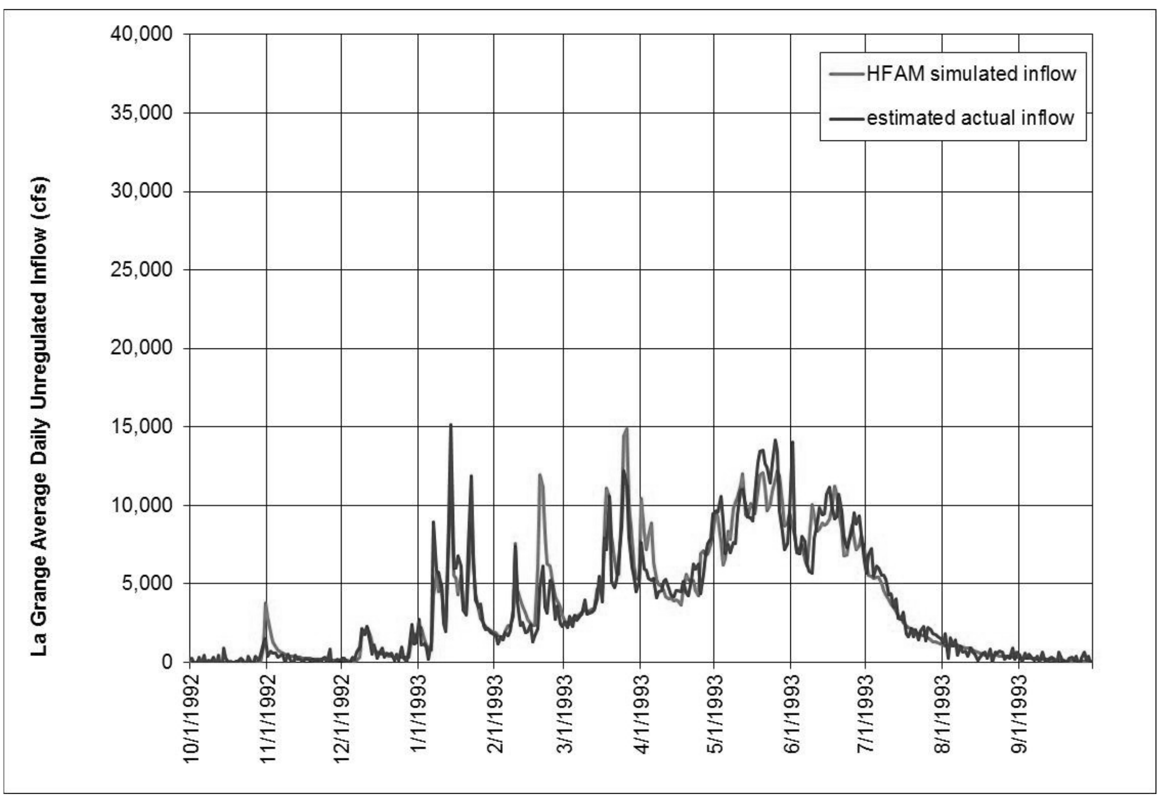

Figure B.19b La Grange Daily Unregulated Inflow, water year 1993

O-TRT-DREKMEIER Cont.

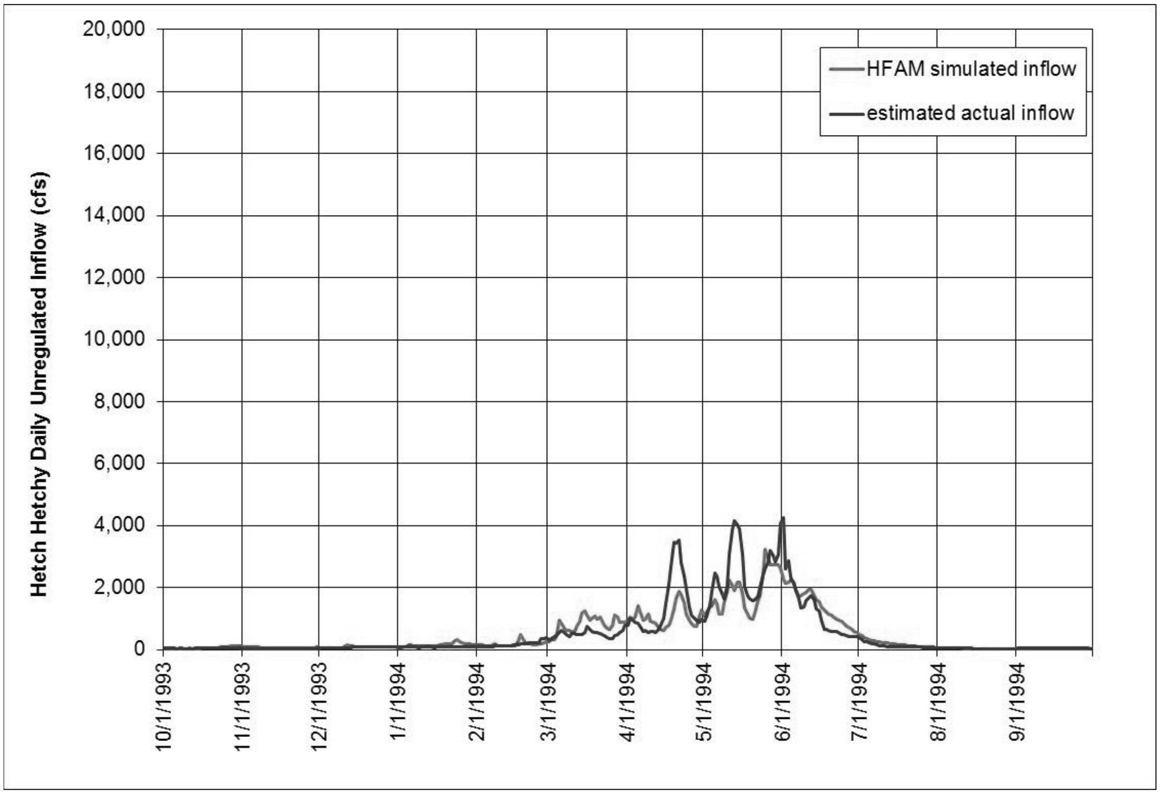

Figure B.20a Hetch Hetchy Daily Unregulated Inflow, water year 1994

HY-52 cont.

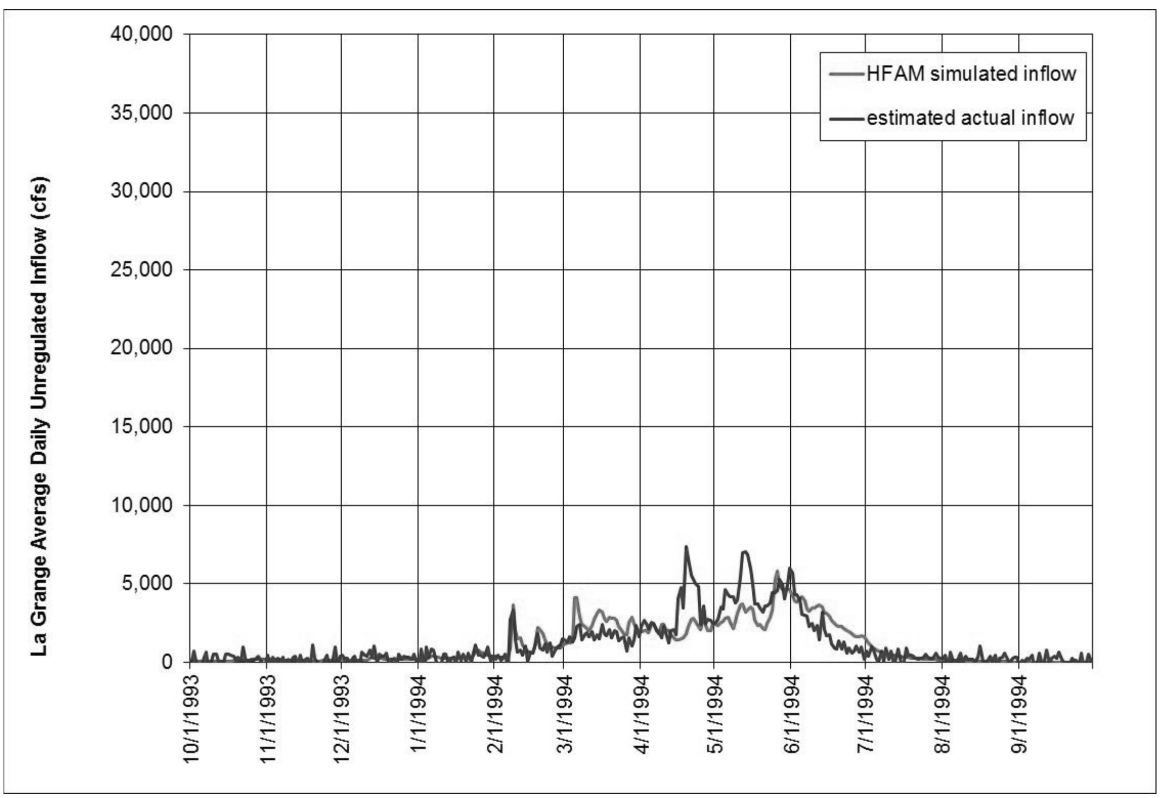

Figure B.20b La Grange Daily Unregulated Inflow, water year 1994

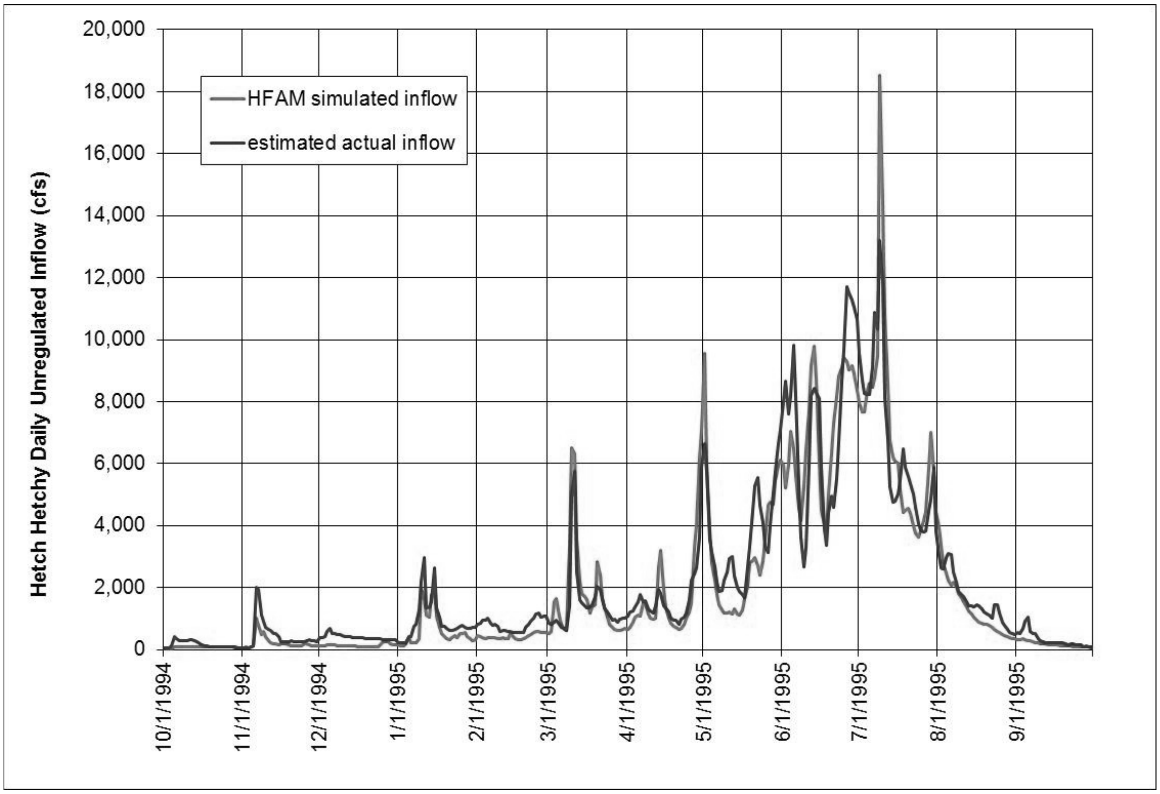

Figure B.21a Hetch Hetchy Daily Unregulated Inflow, water year 1995

HY-52 cont.

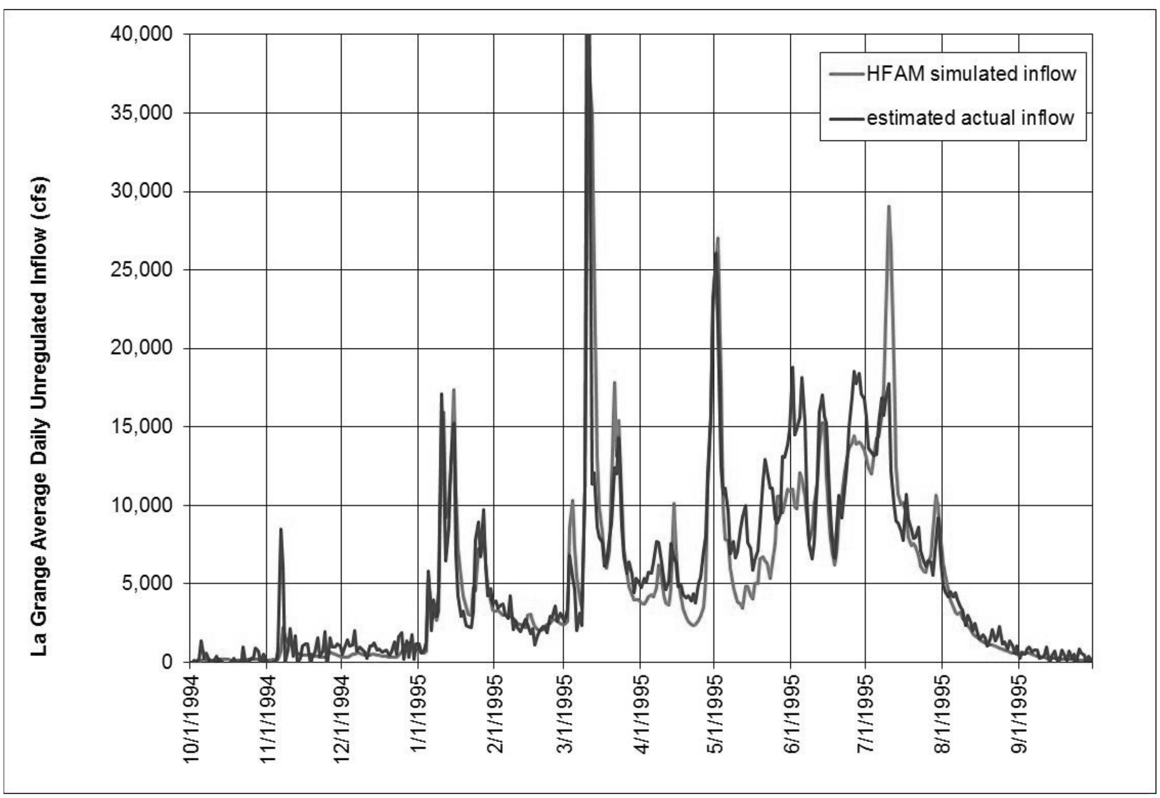

Figure B.21b La Grange Daily Unregulated Inflow, water year 1995

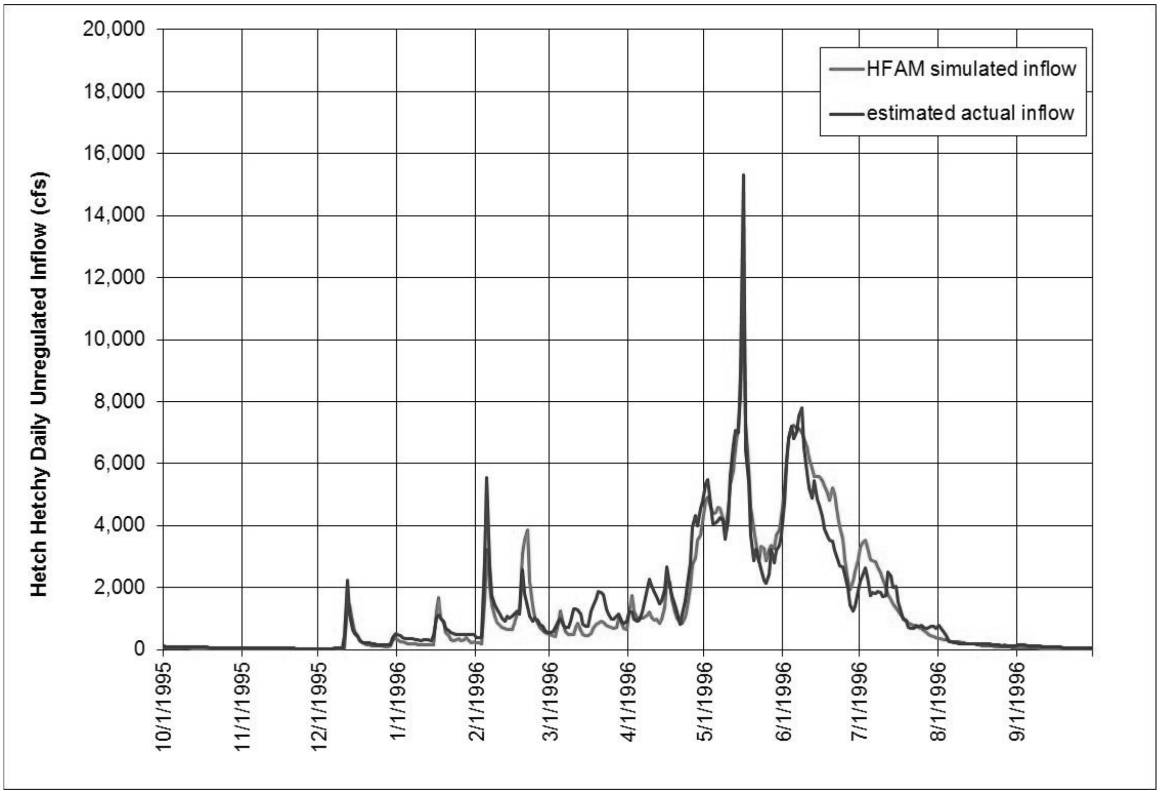

Figure B.22a Hetch Hetchy Daily Unregulated Inflow, water year 1996

HY-52
cont.

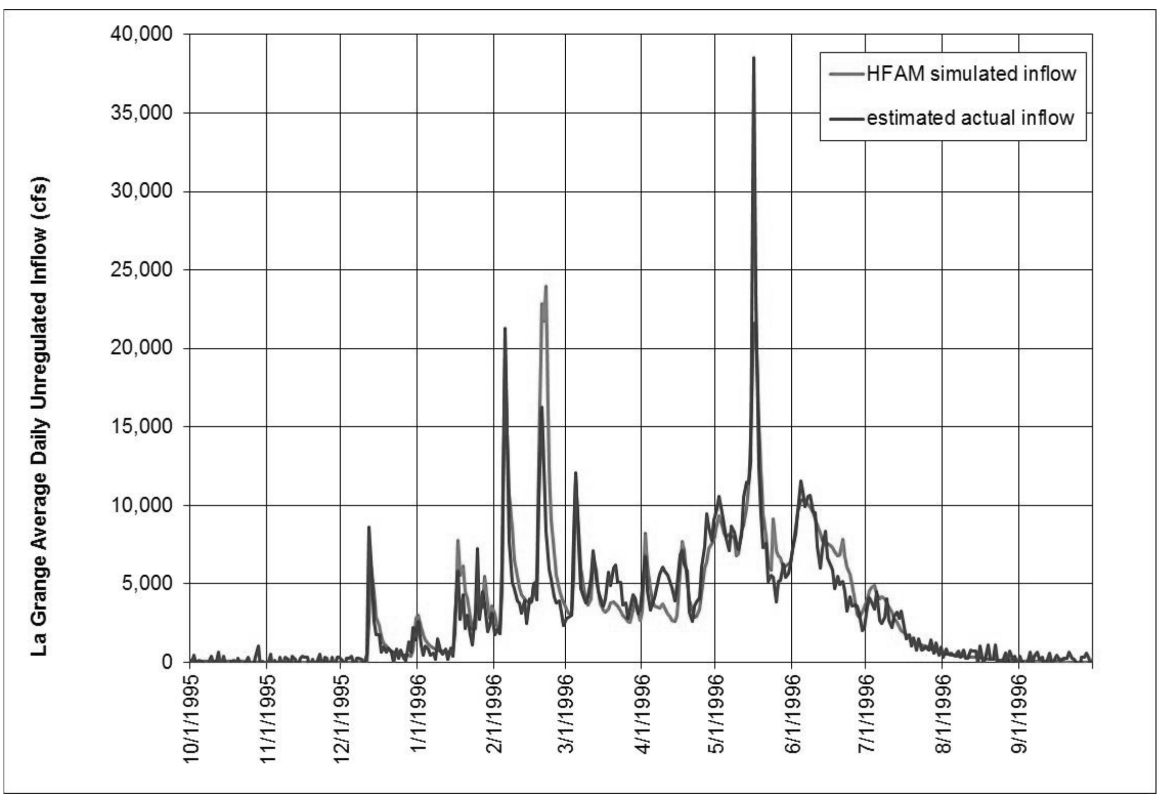

Figure B.22b La Grange Daily Unregulated Inflow, water year 1996

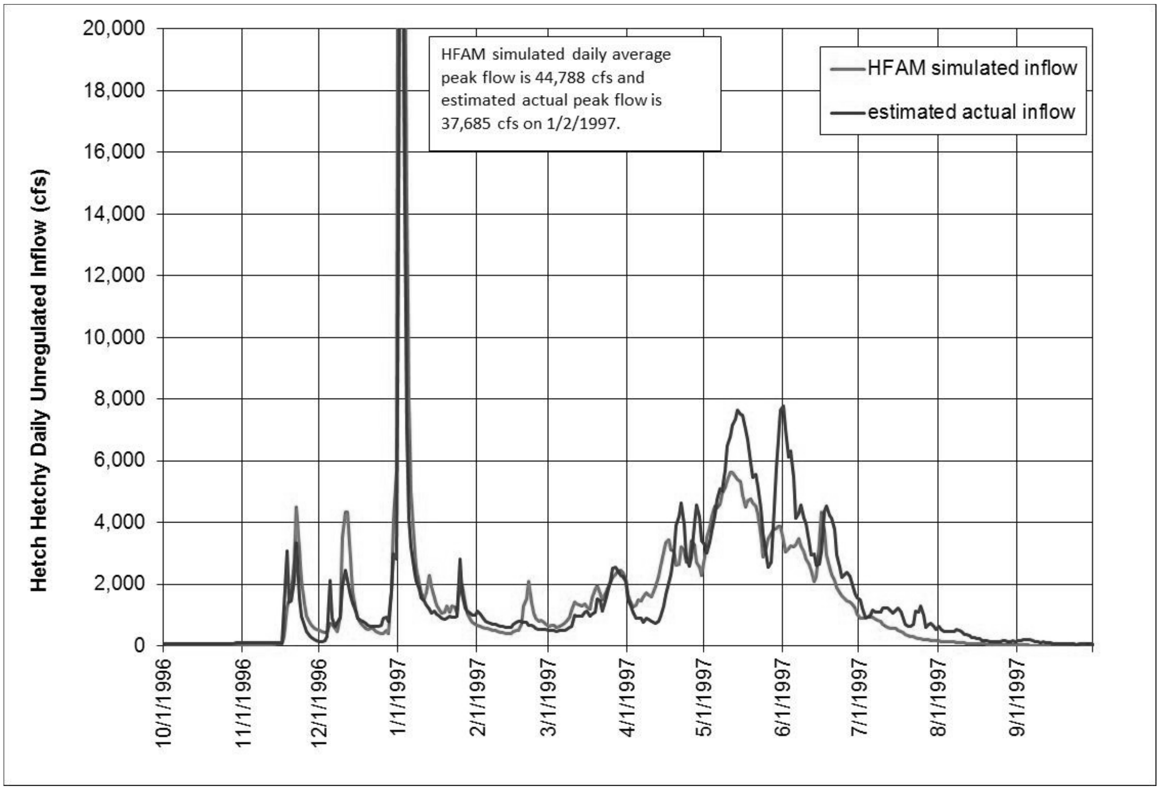

Figure B.23a Hetch Hetchy Daily Unregulated Inflow, water year 1997

HY-52 cont.

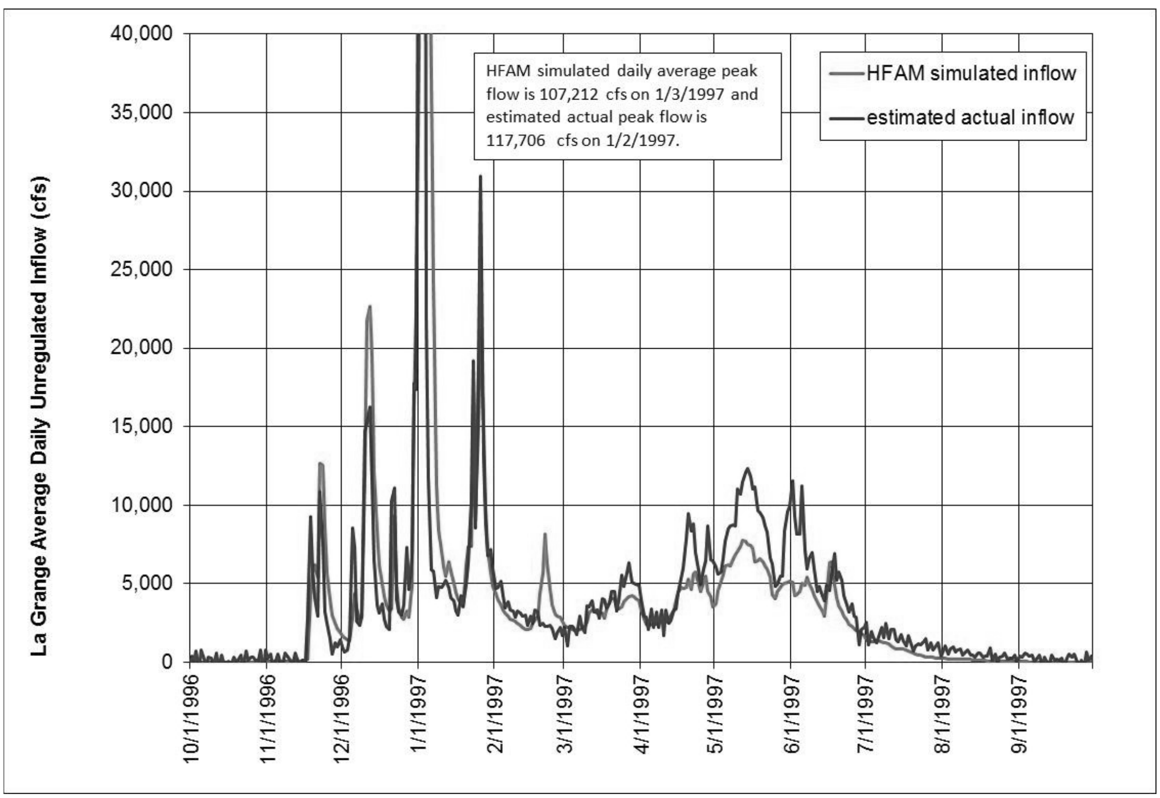

Figure B.23b La Grange Daily Unregulated Inflow, water year 1997

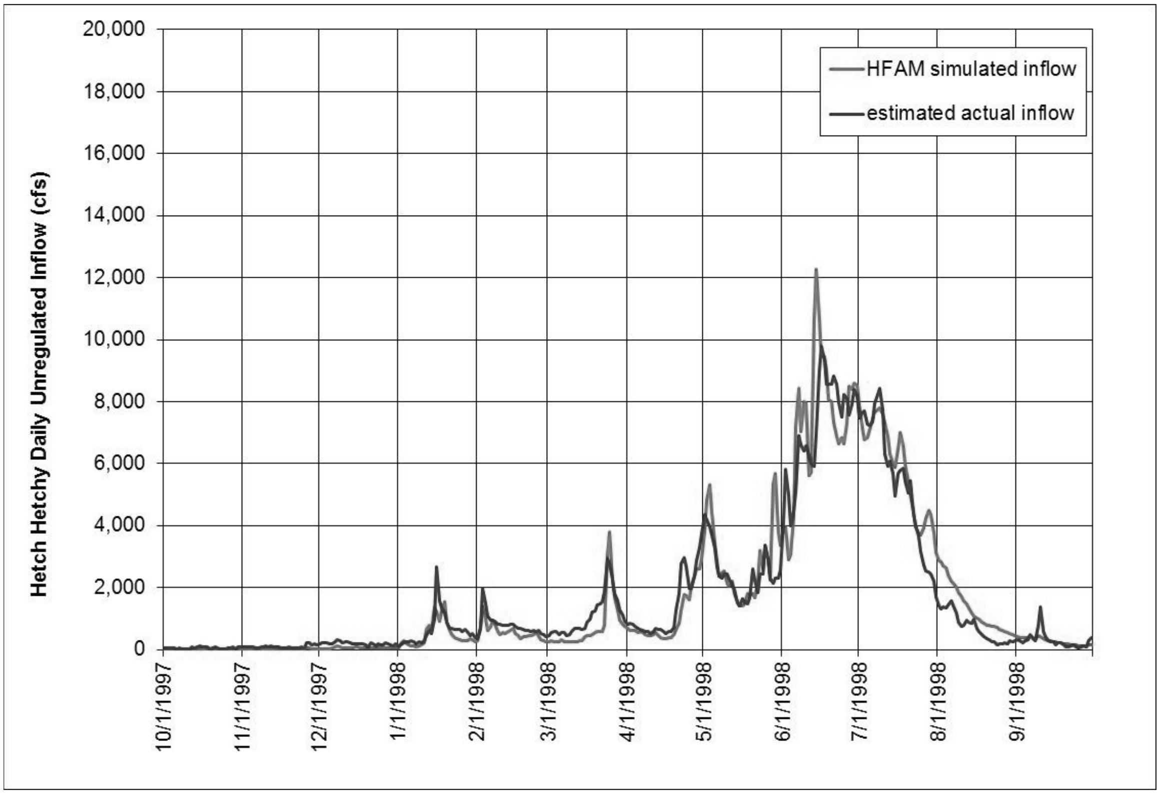

Figure B.24a Hetch Hetchy Daily Unregulated Inflow, water year 1998

HY-52 cont.

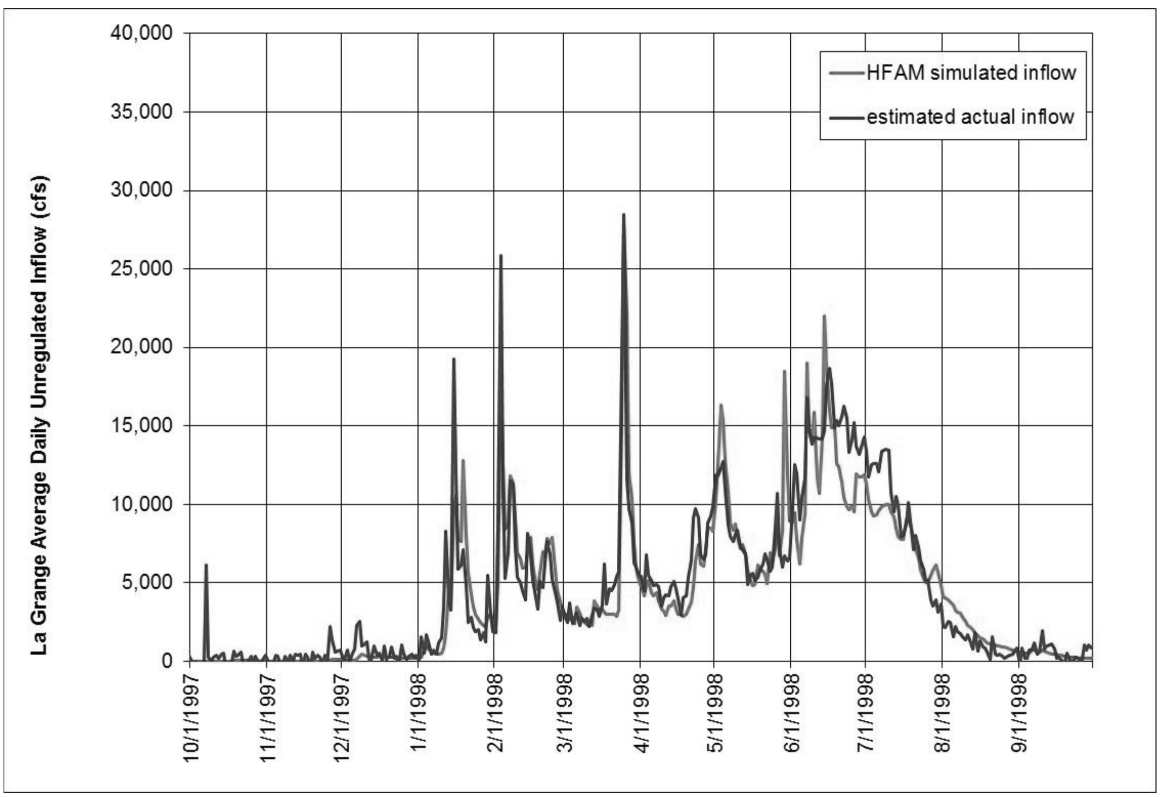

Figure B.24b La Grange Daily Unregulated Inflow, water year 1998

O-TRT-DREKMEIER Cont.

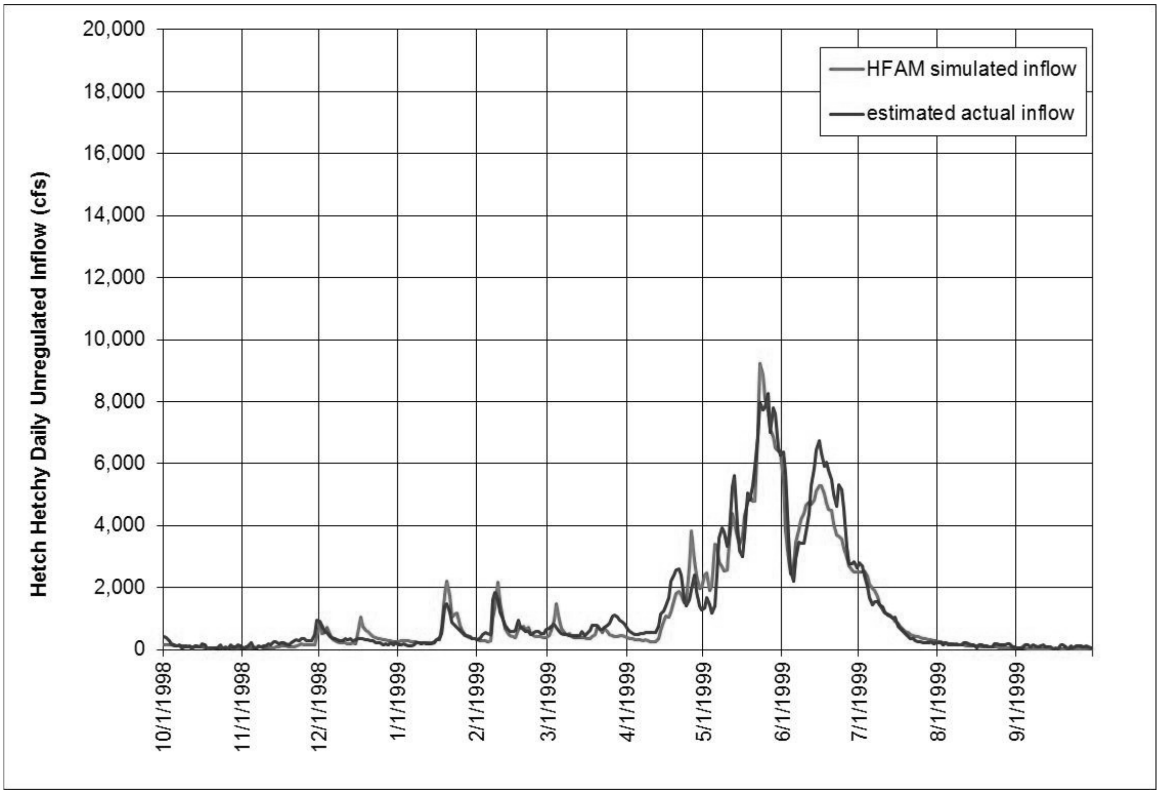

Figure B.25a Hetch Hetchy Daily Unregulated Inflow, water year 1999

HY-52 cont.

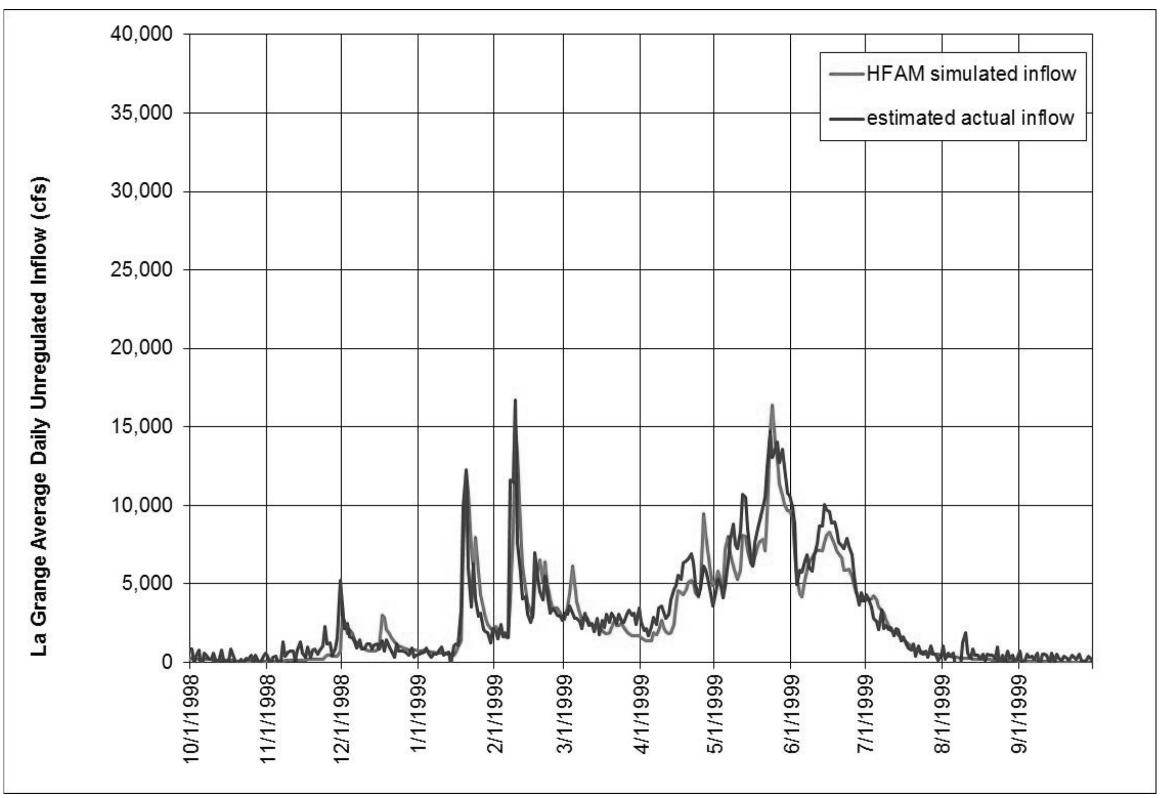

Figure B.25b La Grange Daily Unregulated Inflow, water year 1999

O-TRT-DREKMEIER Cont.

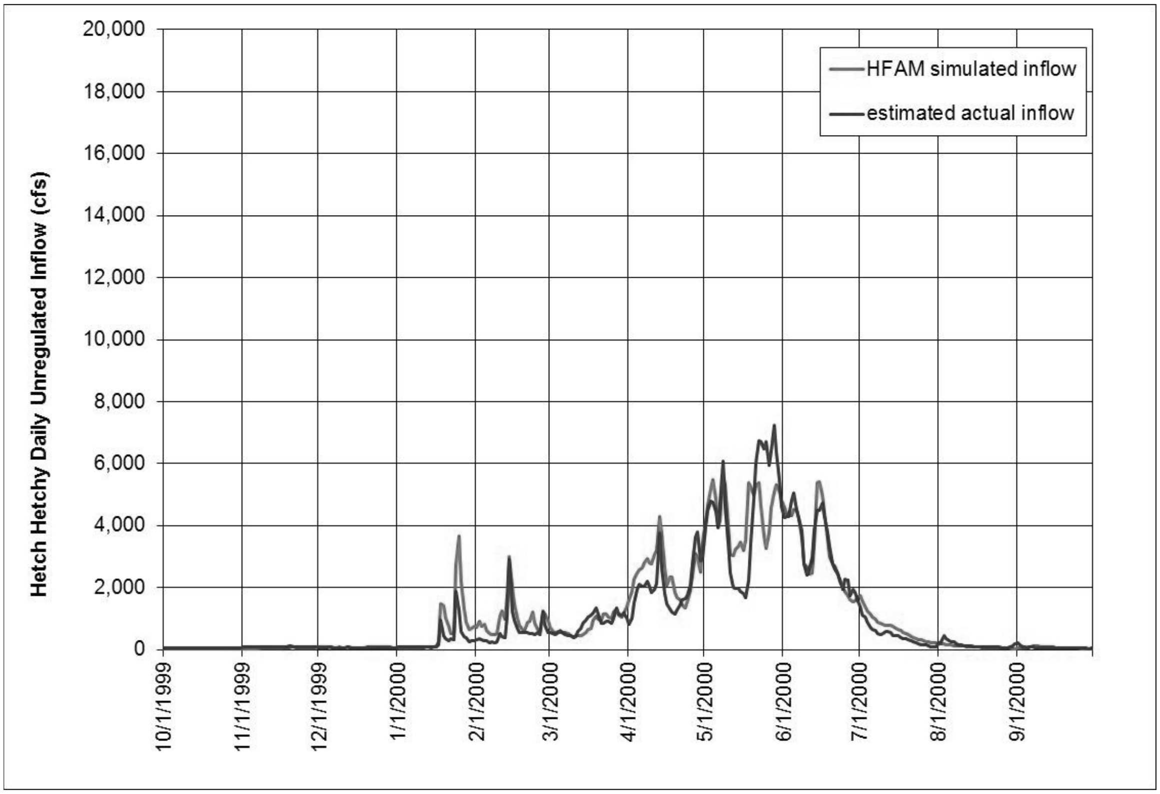

Figure B.26a Hetch Hetchy Daily Unregulated Inflow, water year 2000

HY-52 cont.

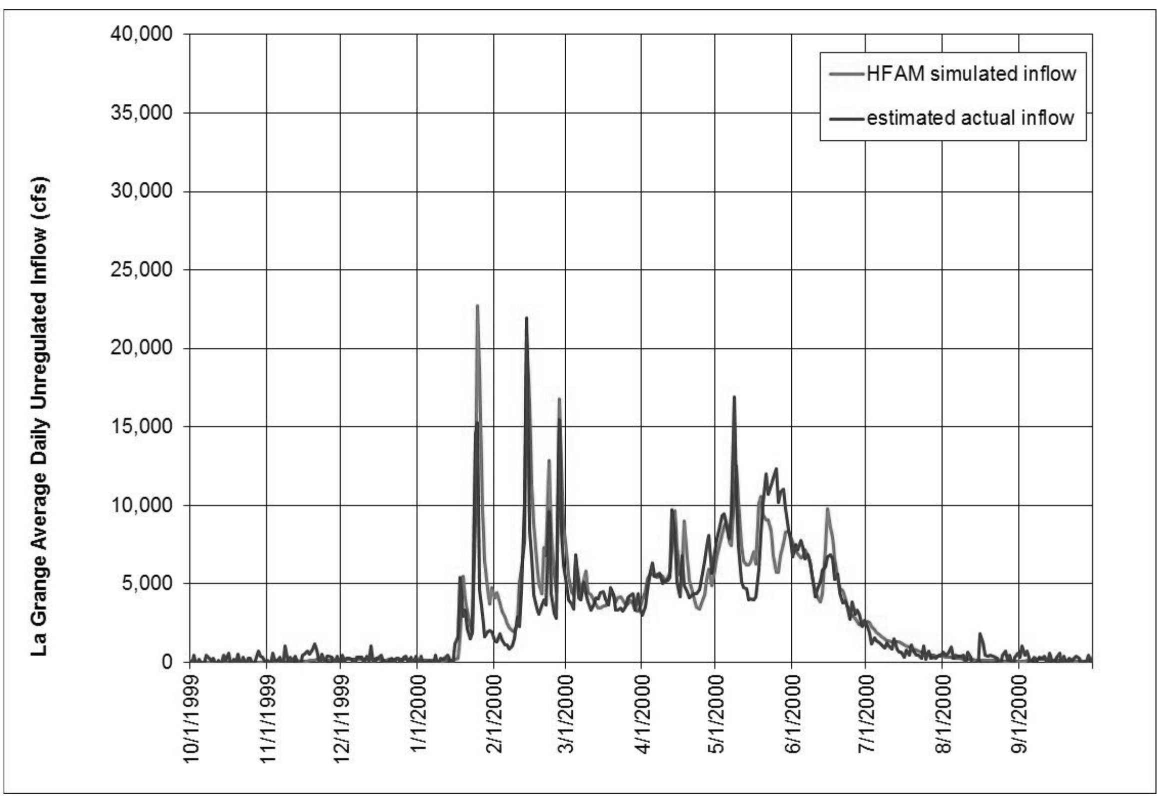

Figure B.26b La Grange Daily Unregulated Inflow, water year 2000

Attachment A

O-TRT-DREKMEIER Cont.

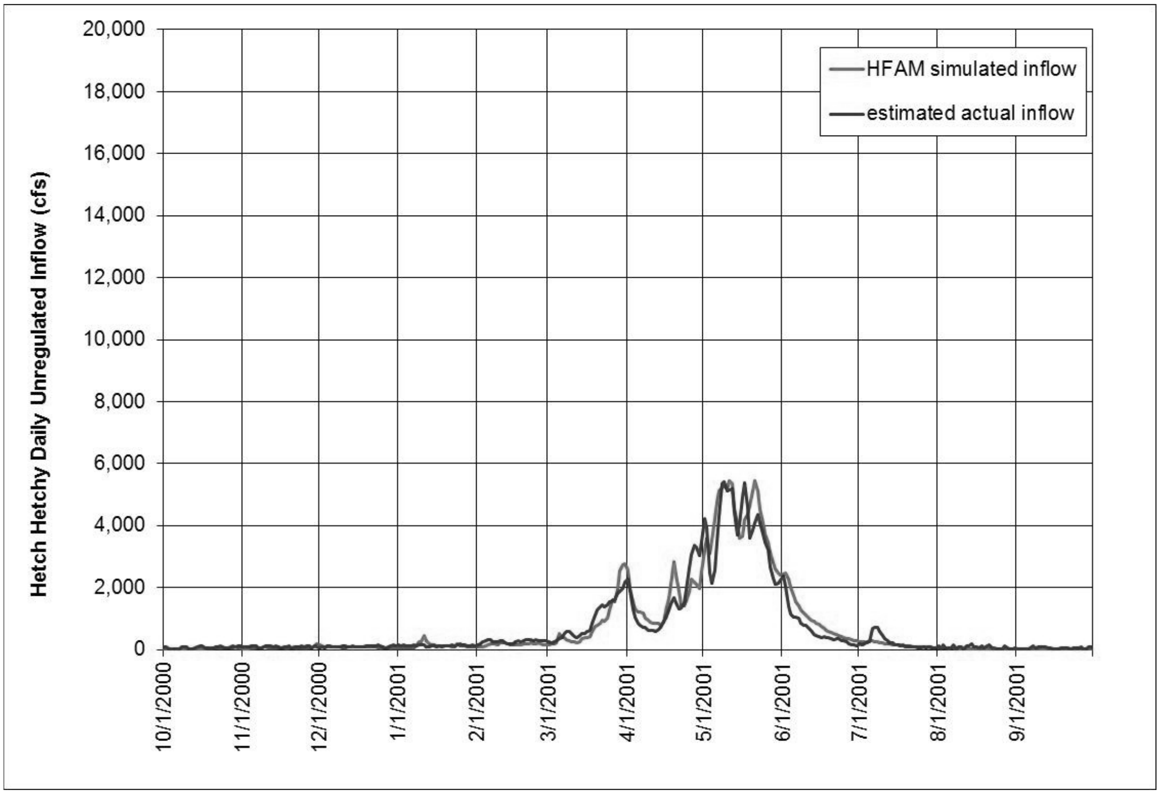

Figure B.27a Hetch Hetchy Daily Unregulated Inflow, water year 2001

HY-52 cont.

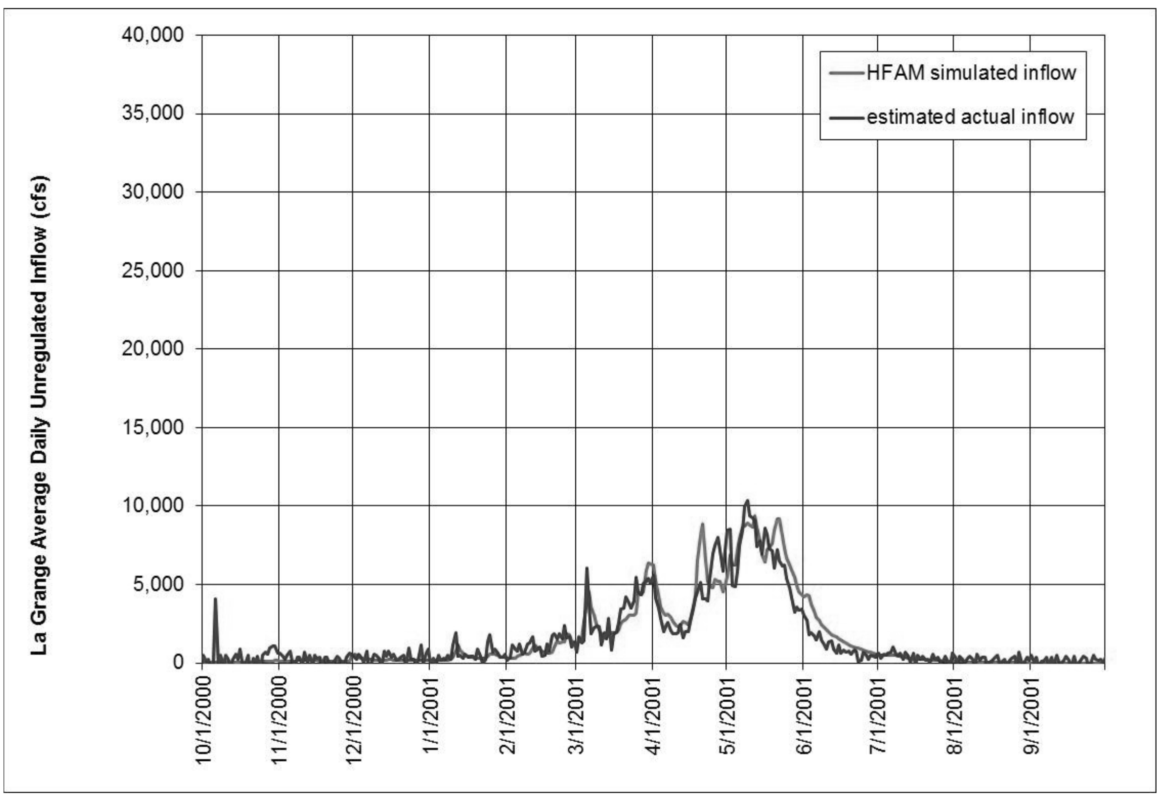

Figure B.27b La Grange Daily Unregulated Inflow, water year 2001

O-TRT-DREKMEIER Cont.

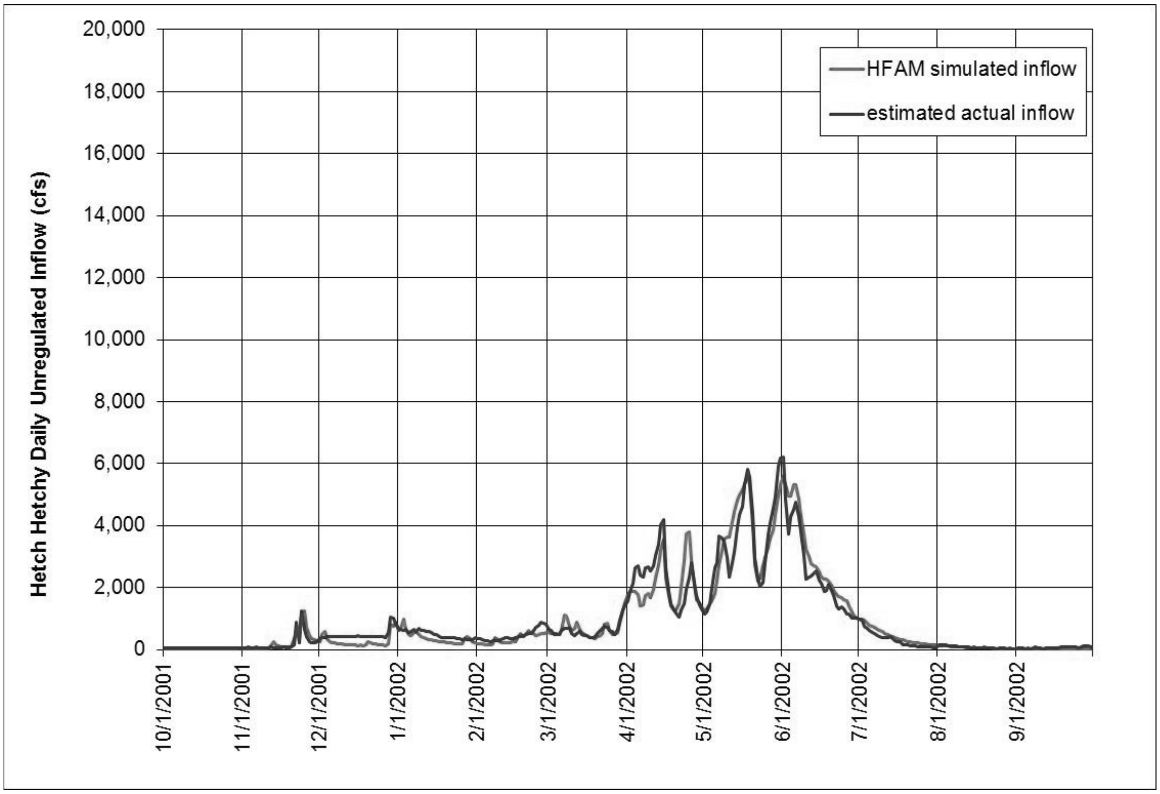

Figure B.28a Hetch Hetchy Daily Unregulated Inflow, water year 2002

HY-52 cont.

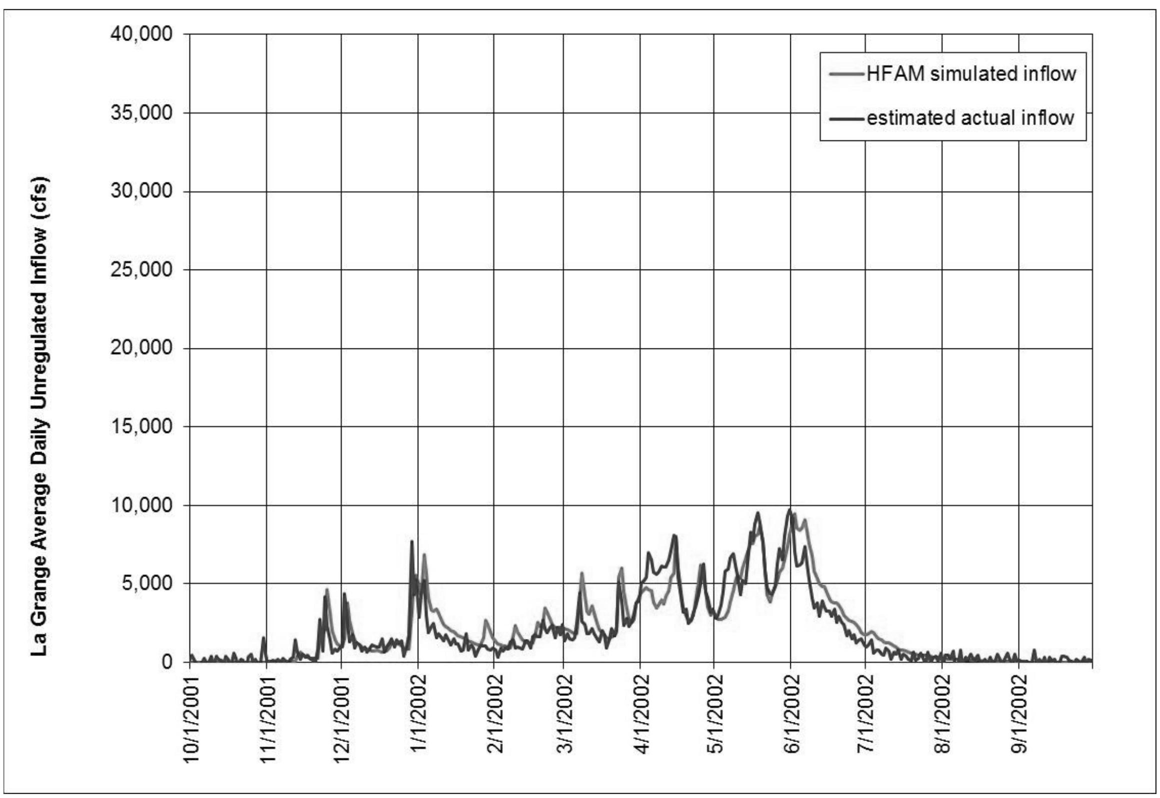

Figure B.28b La Grange Daily Unregulated Inflow, water year 2002

O-TRT-DREKMEIER Cont.

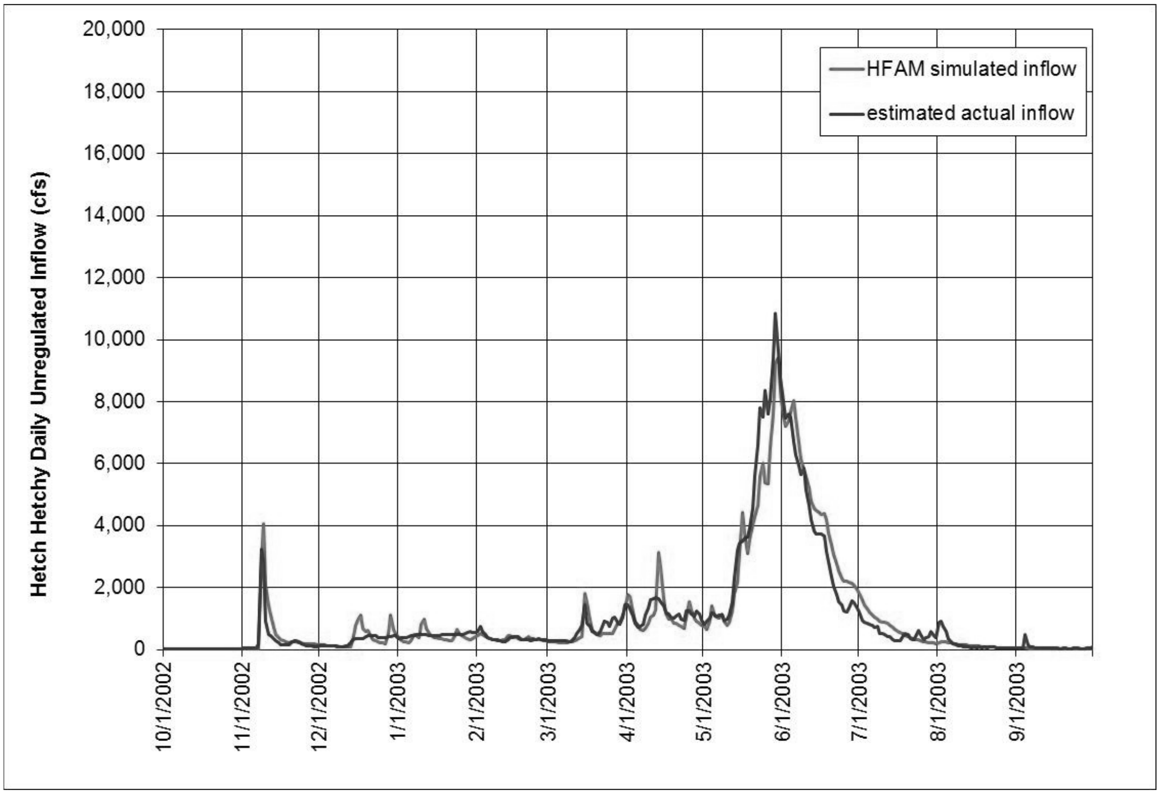

Figure B.29a Hetch Hetchy Daily Unregulated Inflow, water year 2003

HY-52 cont.

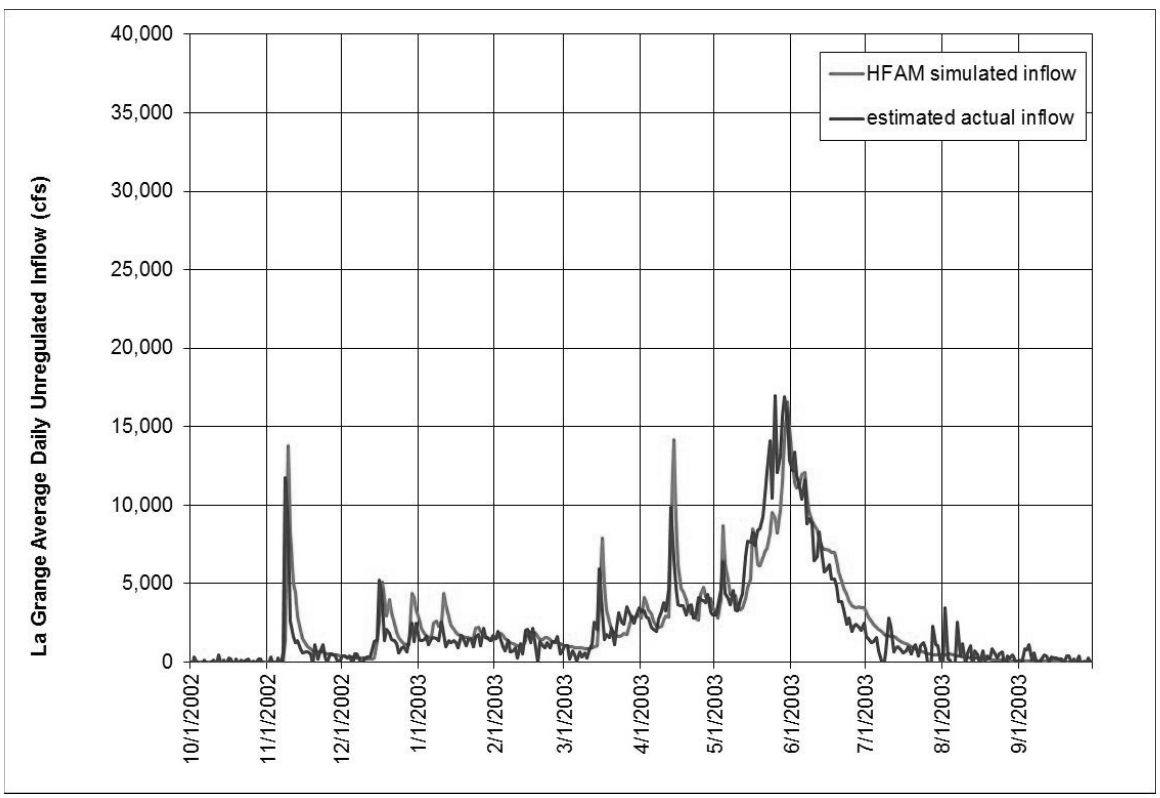

Figure B.29b La Grange Daily Unregulated Inflow, water year 2003

O-TRT-DREKMEIER Cont.

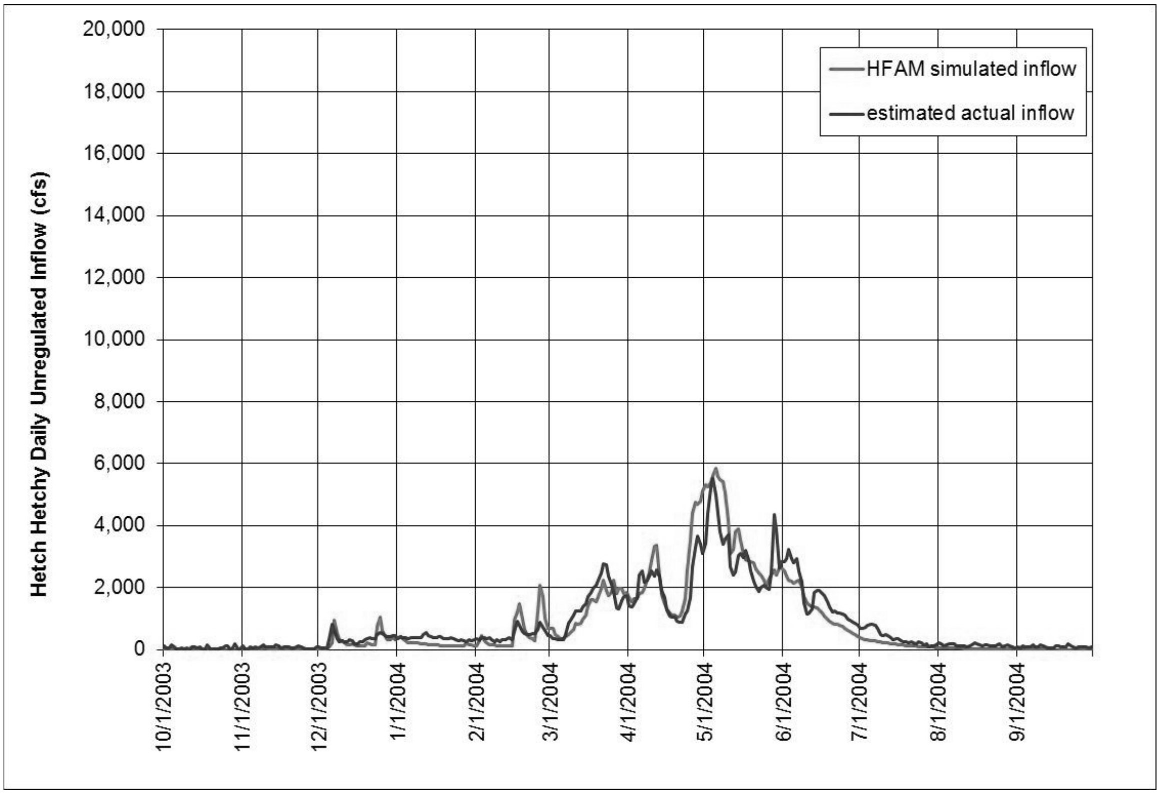

Figure B.30a Hetch Hetchy Daily Unregulated Inflow, water year 2004

HY-52 cont.

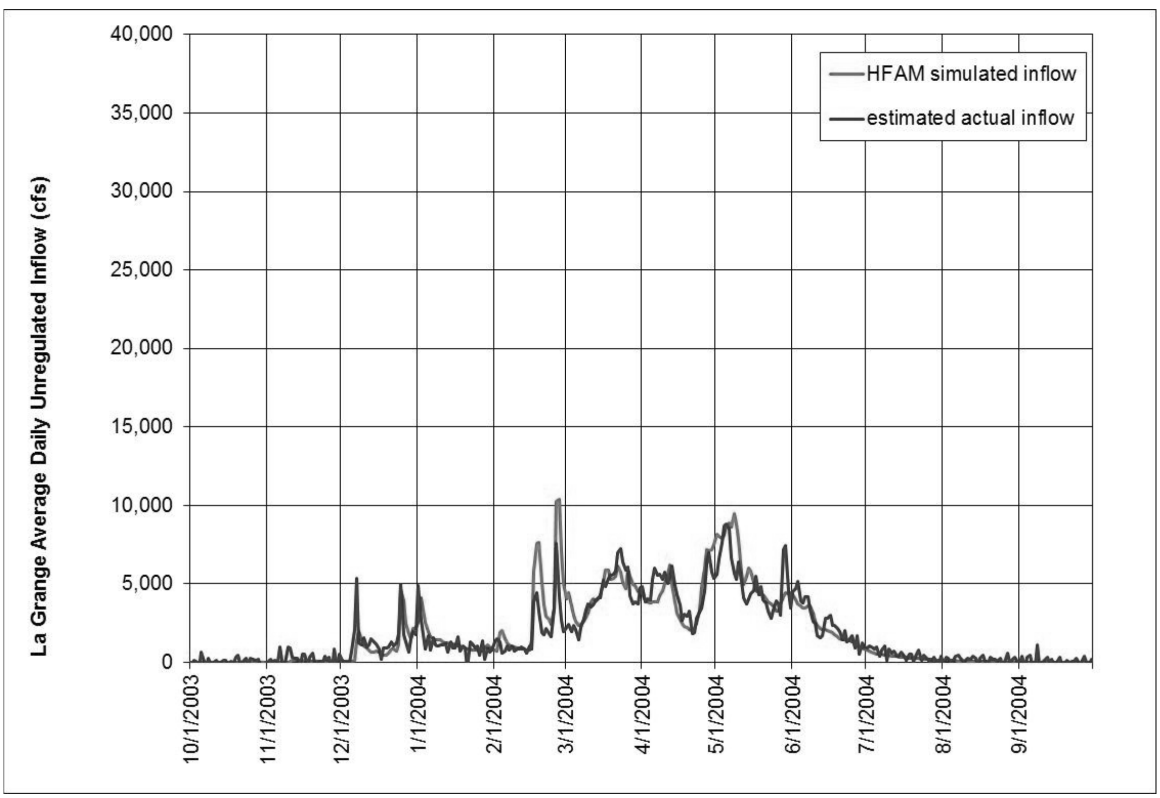

Figure B.30b La Grange Daily Unregulated Inflow, water year 2004

O-TRT-DREKMEIER Cont.

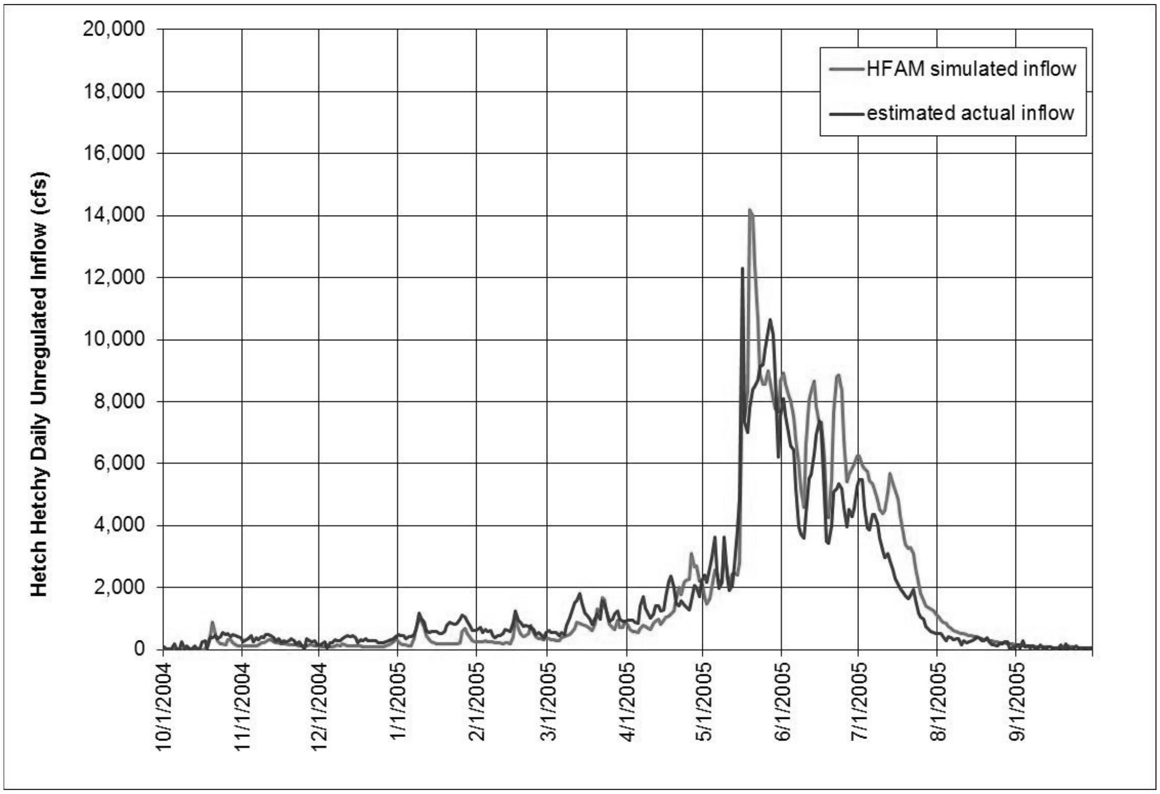

Figure B.31a Hetch Hetchy Daily Unregulated Inflow, water year 2005

HY-52 cont.

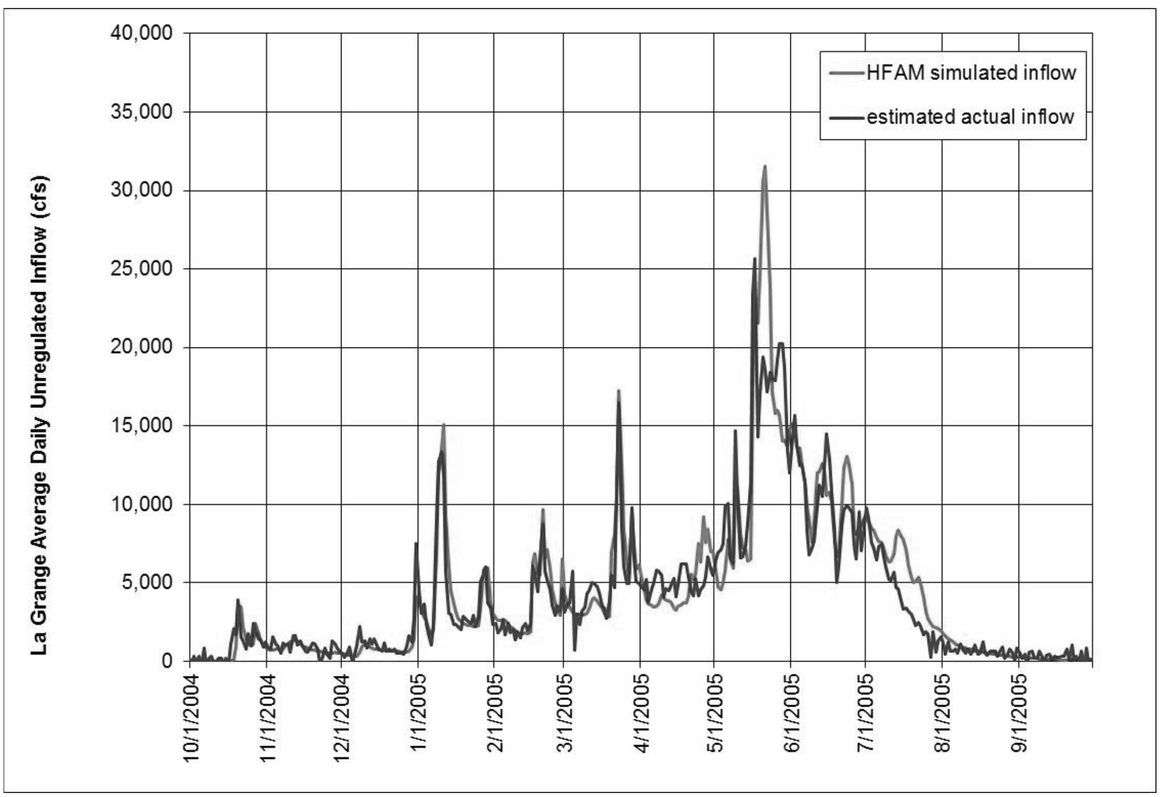

Figure B.31b La Grange Daily Unregulated Inflow, water year 2005

O-TRT-DREKMEIER Cont.

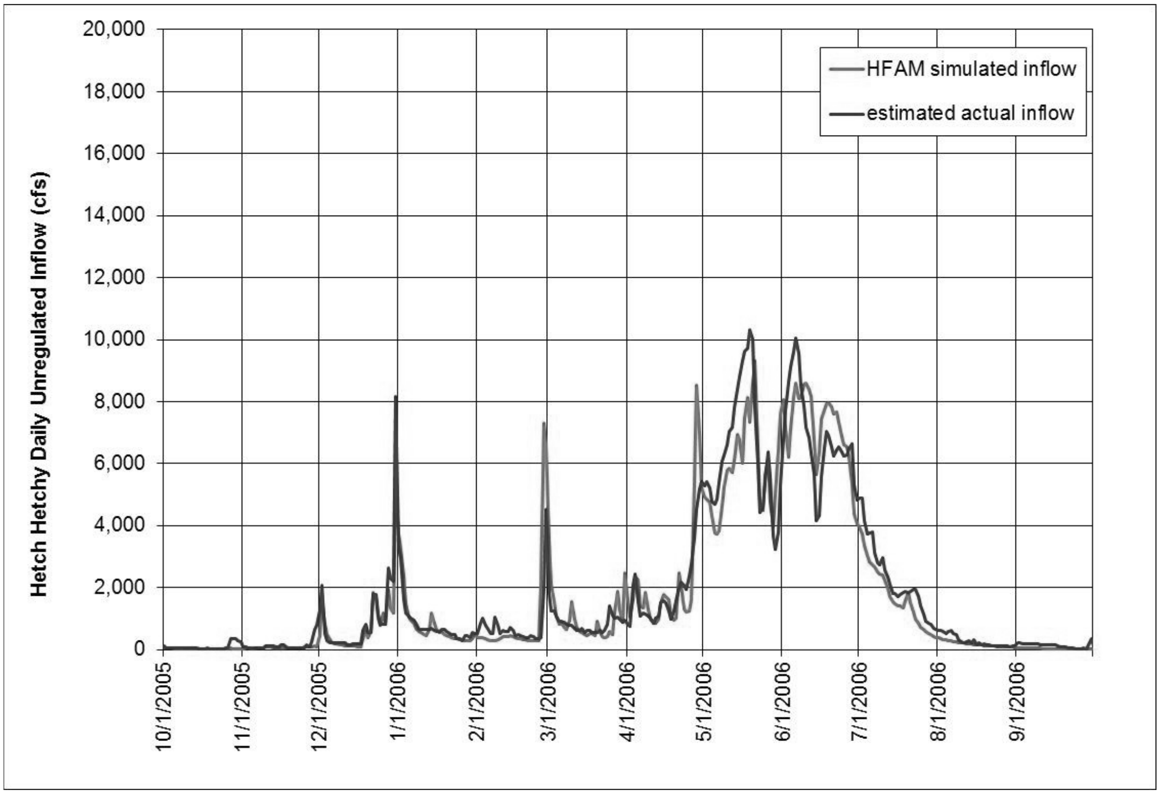

Figure B.32a Hetch Hetchy Daily Unregulated Inflow, water year 2006

HY-52 cont.

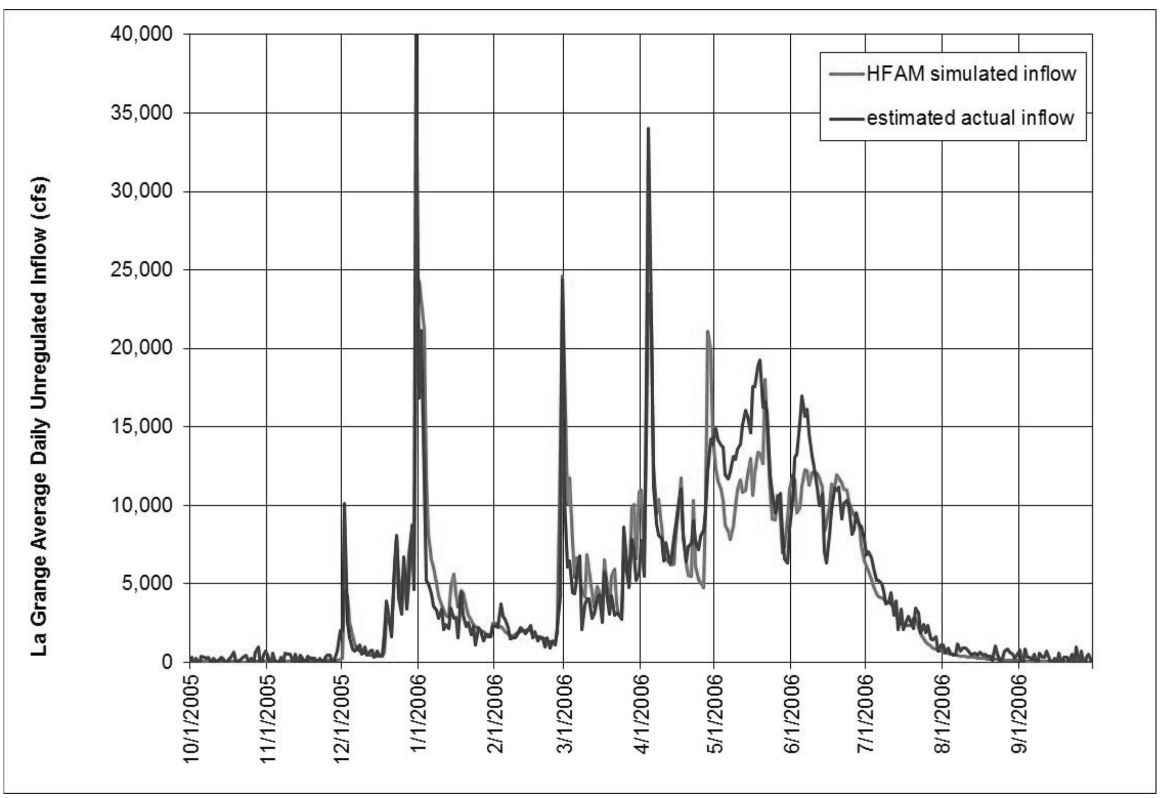

Figure B.32b La Grange Daily Unregulated Inflow, water year 2006

O-TRT-DREKMEIER Cont.

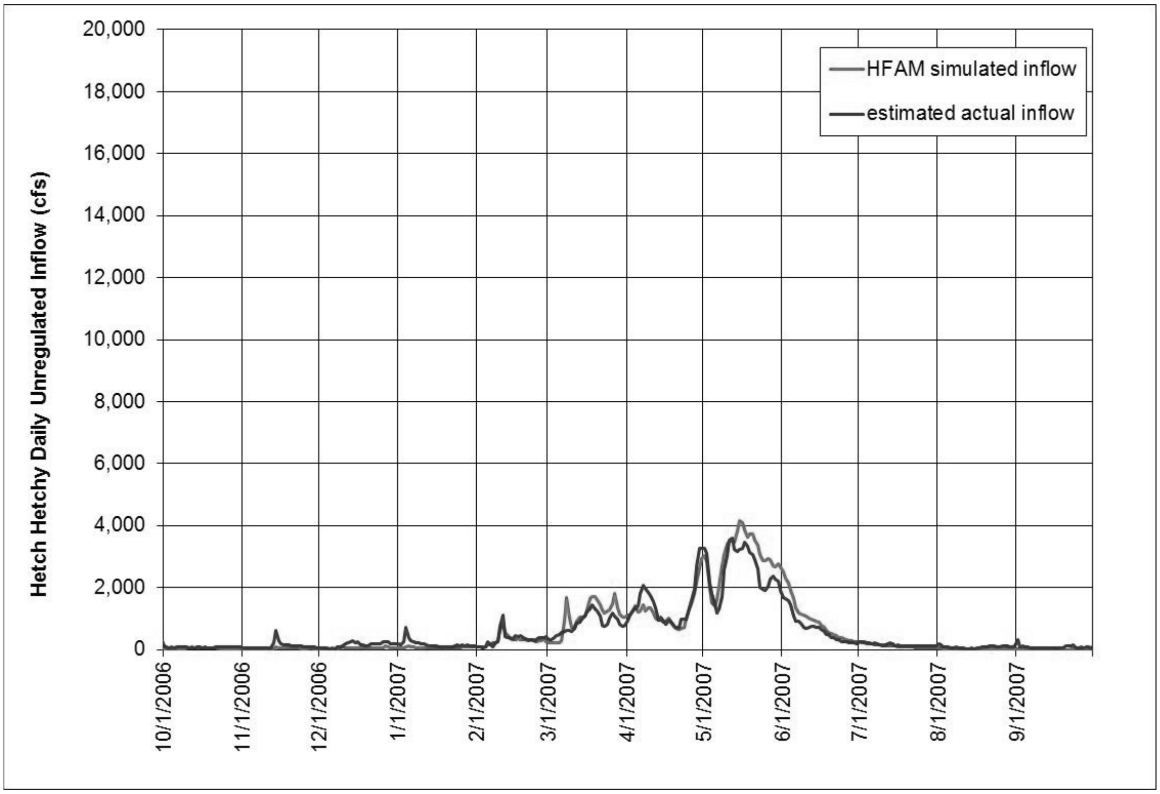

Figure B.33a Hetch Hetchy Daily Unregulated Inflow, water year 2007

HY-52 cont.

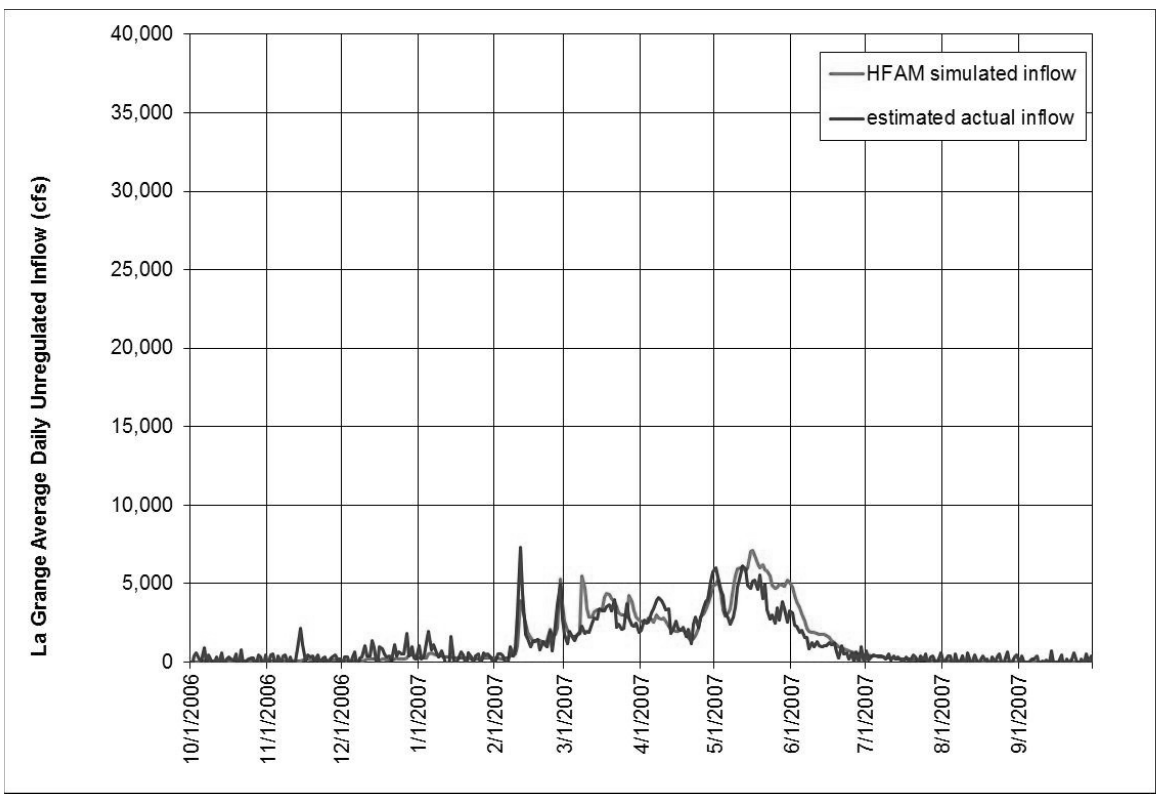

Figure B.33b La Grange Daily Unregulated Inflow, water year 2007

O-TRT-DREKMEIER Cont.

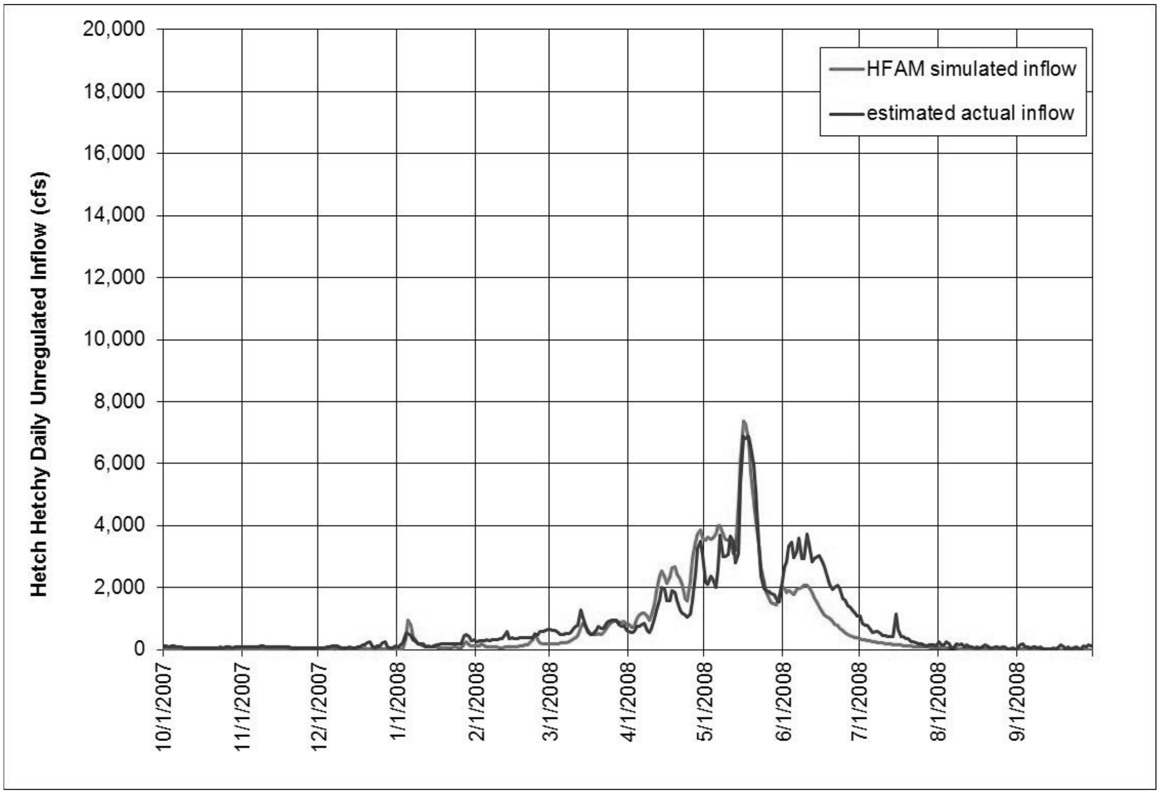

Figure B.34a Hetch Hetchy Daily Unregulated Inflow, water year 2008

HY-52 cont.

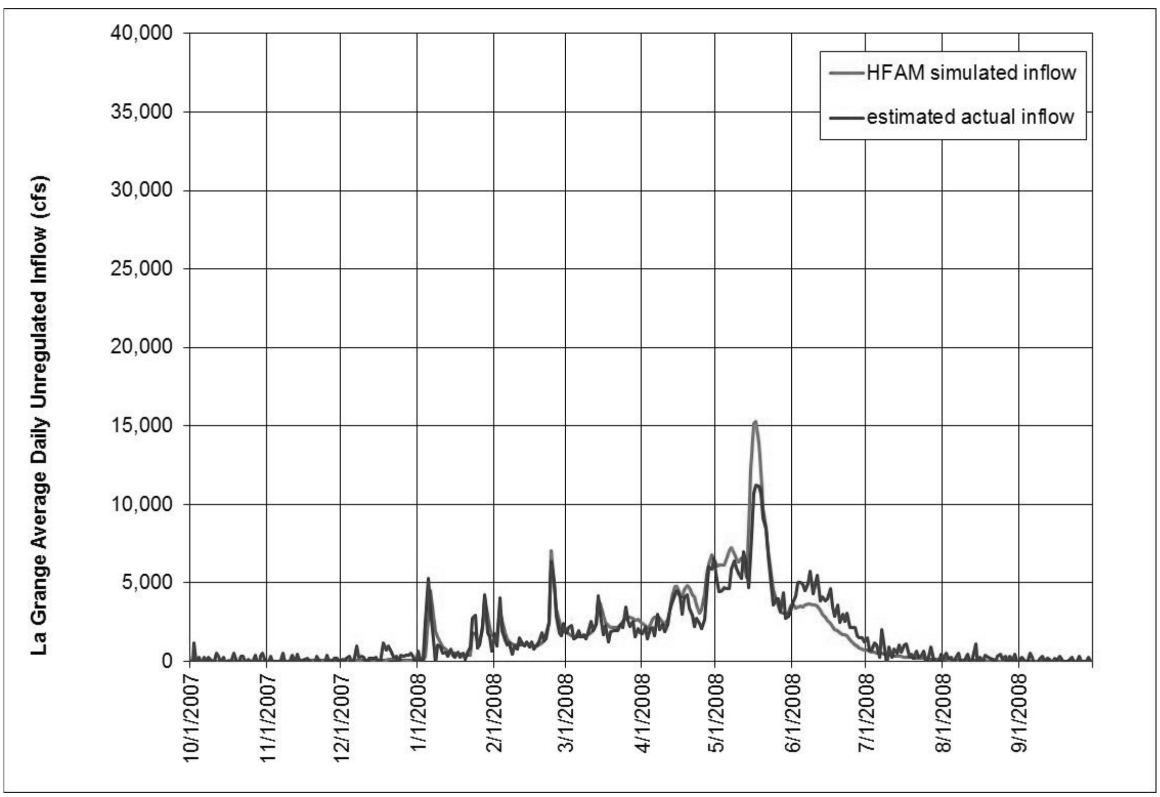

Figure B.34b La Grange Daily Unregulated Inflow, water year 2008

APPENDIX C

HY-52 cont.

Long Term Meteorological Records at Hetch Hetchy and Cherry Valley

APPENDIX C

Long Term Meteorological Records at Hetch Hetchy and Cherry Valley

C.1 NOAA Substation History and Data Base Notes

A NOAA Substation History, published in 1958, shows installation of maximum-minimum temperature gages and a storage rain gage in 1910. No significant changes in location of the gages are listed from 1910 to 1958.The instruments appear to have remained in place to the present, except for the changes noted by Bruce McGurk.

In 1942, a recording rain gage was added at Hetch Hetchy. When the Tuolumne River modeling database was first established in 1998, hourly data were obtained from NCDC for Hetch Hetchy from 1948 to 1996. Overall, the hourly data were only 91 percent complete and the storage rain gage data were more reliable.

When only daily total precipitation data are available, patterns of hourly precipitation distributions for similar daily total precipitation are used. An hourly distribution, randomly selected from a collection of distributions, is used to create hourly data for the day. Hourly distributions are seasonally dependent. HY-52 cont.

The NOAA Substation History in 1958 includes the Cherry Valley station, installed in October 1955, and states that the instruments are “on the ground, well shaded by surrounding trees”.

C.2 Summary of notes and photographs provided by Bruce McGurk, Operations Manager & Hydrologist, Hetch Hetchy Water & Power - Moccasin in May 2009

The Hetch Hetchy station (HTH) has been at the same site since 1930. The glass maximum and minimum thermometers and standard 8 inch NWS manual brass rain gauge were serviced about 8 am, 7 days per week through 9/13/86 by Hetch Hetchy Water and Power (HHWP) watershed keepers. A retired watershed keeper, who spent 6 months at O’Shaughnessy when he joined HHWP in 1975, described the station as it was in 1975 in a recent phone conversation. His description matches what is there now, with one important change. The thermometers were then in the cotton-belt shelter across the road, about 25 ft. from the rain gauge (Photo 1).

O-TRT-DREKMEIER Cont.

Photo 1. Hetch Hetchy rain gauge and road

HY-52 cont.

The temperature shelter now is on the north side of a cluster of live oak trees, and the shelter is now on the north side rather than the south side of a 12 ft. wide blacktop road. The shelter is about 10 ft. from the road and has shading during a lot of the day, as it did prior to 1986; the view east is occluded by a deciduous and a conifer, and the view west is also mostly shaded but might get late afternoon sunshine in summer.

The rain gauge is on the south side of a 6 ft. patch of evergreen shrubs (Photo 2), the road and conifers to the east, and is fairly open to the west and south. The gauge has no windscreen, which is the normal setup for a NOAA gauge.

O-TRT-DREKMEIER Cont.

HY-52 cont.

Photo 2. Hetch Hetchy rain gauge and evergreen shrubs

The manual rain gauge and the cotton belt shelter have not moved, but on 9/13/1986, a Fisher-Porter 8 inch recording gauge was installed next to the manual can and a new temperature system was installed that was far from optimal. NOAA decided at that time to change from glass thermometers (breakage issues, mercury, etc.) to electronic systems through their system, and installed a thermistor network sensor. NOAA also changed to a naturally aspirated sensor shelter and abandoned the cotton-belt shelter at that time. The new temperature shelter was apparently fastened to the railing of the watershed keeper's house for several years – in February 2006 (Photo 3) you can just see the white blob in front of the blue truck on a railing below the porch roof. Last year it was put on a pole 10 ft. away in the yard, and that is a better site. Being next to the building and only about 3 ft. off the ground was not the NOAA standard. However, there is still a lot of shade there, especially afternoon in the summer, but there is an oak that sheds its leaves and probably leaves the shelter exposed to the sun in the winter time.

Photo 3. Hetch Hetchy temperature gauge

HY-52
cont.

The climate station near Cherry Dam (CHV) has had less change. It is behind the bunkhouse that was built in the 1950's when Cherry Dam was built (see Photo 4). I tracked the station back to 1975, and it is still using the same gage and glass thermometers, and has been consistently serviced by watershed keepers. I do not believe it is an official NOAA site, so it never got the automatic rain gauge or the electronic thermistor setup. The shelter and temperature sensors are shown in Photo 5. A paved parking area is closer than optimal and the access road is near as well.

The Hetch Hetchy and Cherry climate stations may have had vegetation and shading changes over this long time period. I have not researched photos of the Hetch Hetchy site back when the road was a train

Photo 4. Cherry Valley climate station

HY-52 cont.

Photo 5. Cherry Valley shelter and temperature sensors

APPENDIX D

HY-52 cont.

Snow Accumulation and Melt with Climate Change

O-TRT-DREKMEIER Cont.

APPENDIX D

Snow Accumulation and Melt with Climate Change

The Tuolumne River watershed's range in elevation and its diverse topography, soils, forests and vegetation is amenable to large-scale snow accumulation and melt process analysis, rather than small-scale analysis that might be done on an experimental watershed. The observed runoff at gages comes from multiple land segments. These land segments are at different elevations, and will have different aspect and shading from solar radiation. Snowpack water yield on a given day may occur only in a limited elevation range.

Real-time stations with snow pillow measurements of snow water equivalent do allow process analysis and comparisons between historic conditions and climate change scenarios. In the following figures, simulated Slide Canyon (SLI) snowpack conditions are compared to historic snow measurements for water year 1992. Slide Canyon is at 9200 feet elevation. Figure D-1 shows Slide Canyon observed and simulated snow water equivalent and liquid water in water year 1992. Figure D-2 shows the same model results for late March, April and May of water year 1992.

HY-52 cont.

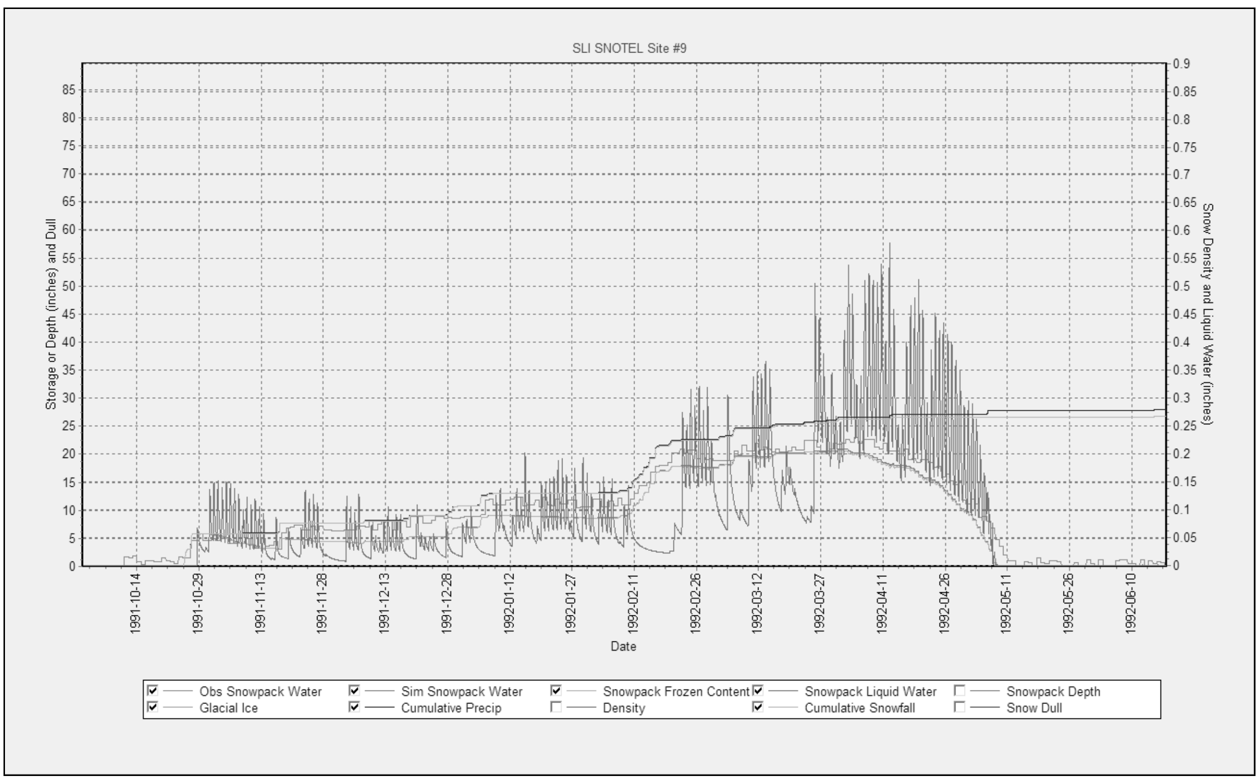

Figure D-1. Slide Canyon observed (pink) and simulated snow water equivalent (red) and liquid water content of the snowpack (blue), water year 1992

O-TRT-DREKMEIER Cont.

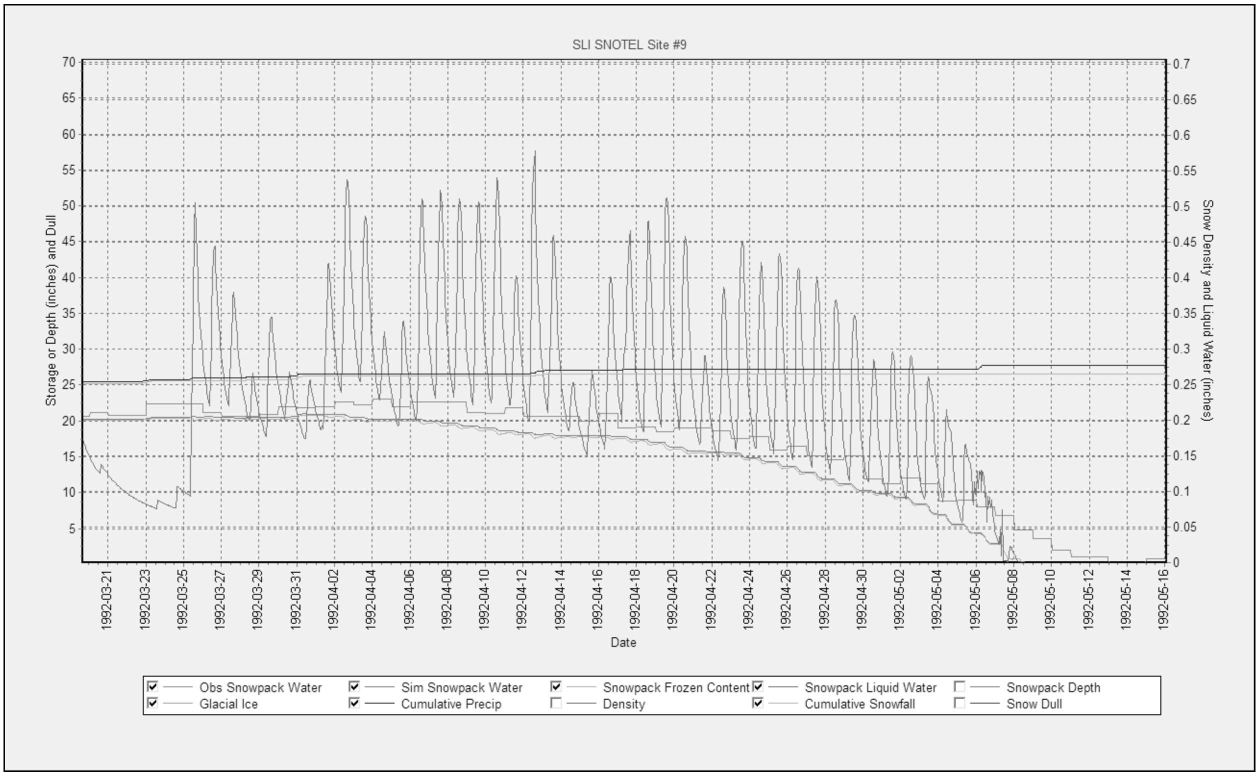

Figure D-2. Slide Canyon observed (pink) and simulated snow water equivalent (red) and liquid water content of the snowpack (blue), March to May, water year 1992.

HY-52 cont.

O-TRT-DREKMEIER Cont.

For each of the climate change scenarios, hourly temperature adjustments were made based on the expected average daily temperature increase and the corresponding change in the maximum and minimum daily temperatures. The simulated snowpack depth is reduced due to these higher temperatures.

Figure D-3 shows Slide Canyon observed historic and simulated climate change scenario 2A in 2100 snow water equivalent and liquid water content in the snowpack. For climate change scenario 2A in 2100 (moderate temperature increase of 3.4 degrees C/6.12 degrees F with no change in precipitation), less snow accumulates than under current conditions because some precipitation that historically fell as snow was simulated as rainfall. Simulated snow depth reaches only 10 inches water equivalent compared to 21 inches water equivalent for historic conditions. The simulated climate change scenario 2A in 2100 results are based on water year 1992 meteorological conditions with the temperature adjustments for climate change scenario 2A in 2100.

HY-52 cont.

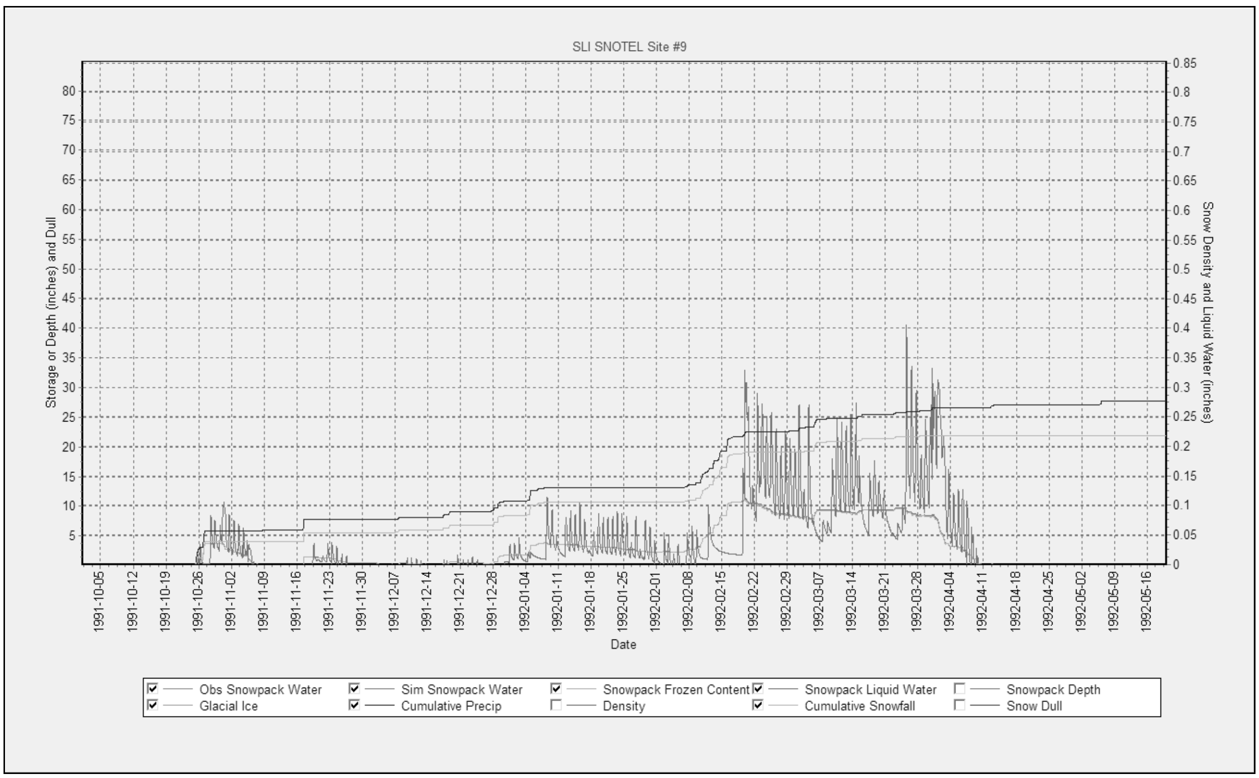

Figure D-3. Slide Canyon observed (pink) and scenario 2A in 2100 snow water equivalent (red) and liquid water content (blue) of the snowpack, water year 1992

Figure D-4 shows details of the snowpack melt out for climate change scenario 2A in 2100. The period of significant melt under the future climate conditions, April 1st to 10th, did not experience significant melt out historically – the historic ‘obs snowpack water’ in Figure D-4 show only minor melt in March and early April.

The snowpack melts out by April 10, 1992 for climate change scenario 2A in 2100, compared to May 8, 1992 for historic conditions.

HY-52 cont.

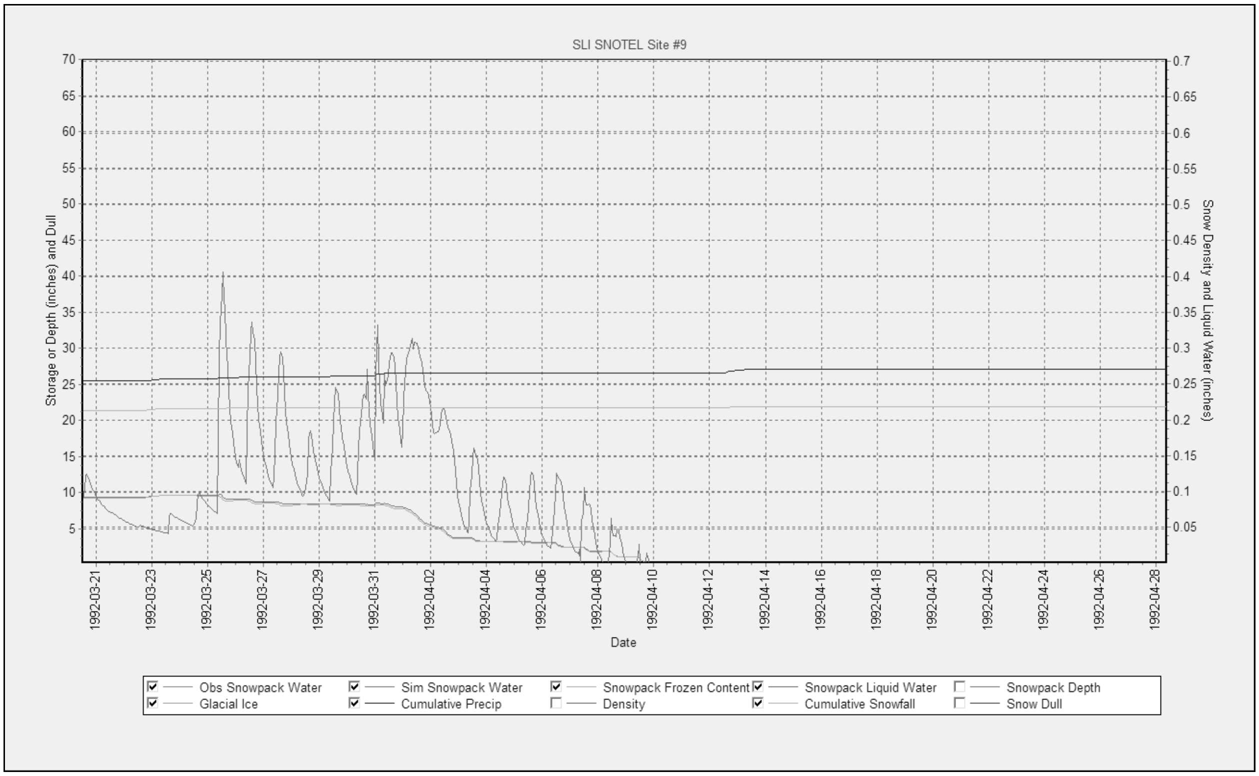

Figure D-4. Details of the Slide Canyon snowpack melt out for scenario 2A in 2100

Attachment A

O-TRT-DREKMEIER Cont.

Figure D-5 shows Slide Canyon simulated historic snowpack albedo, air temperature and solar radiation, solar radiation, negative heat, snow melt and snow yield (water leaving the snowpack) in water year 1992. Figure D-6 shows the same information during only the melt out period of water year 1992.

During the fall and winter with historic conditions, there is little or no water yield from the snowpack. Negative heat builds during the night whenever the snowpack cools below 0 degrees C. The snow must warm to 0 degrees C before melt can occur. Figure D-5 shows that melt does occur in fall and winter, but melt that enters liquid water storage will often re-freeze at night when the net heat exchange between the atmosphere and the snowpack becomes negative and the snowpack cools.

In Figure D-6, it can be seen that warmer night time temperatures reduce or prevent the increase of negative heat during the night time and the snowpack remains at 0 degrees C. The liquid water holding capacity of the snowpack is exceeded, melt occurs, and water leaves the snowpack.

HY-52 cont.

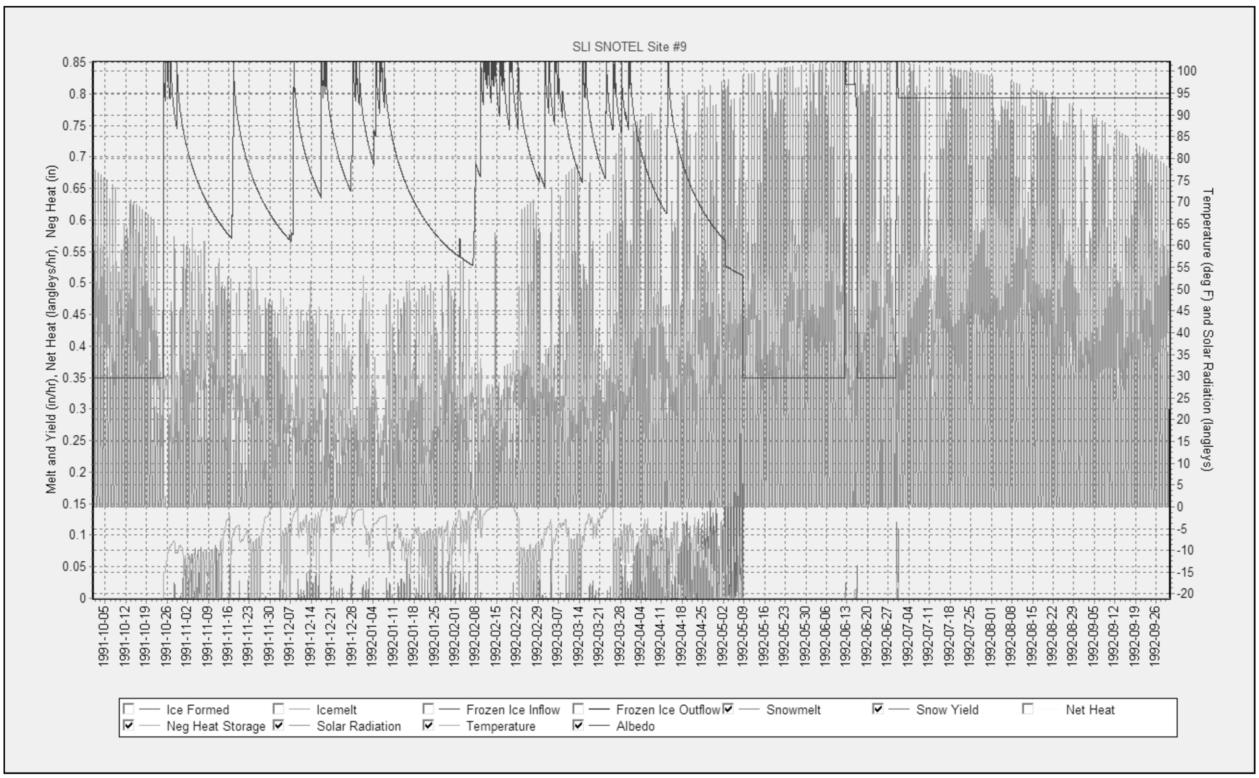

Figure D-5. Slide Canyon simulated historic snowpack albedo, air temperature, solar radiation, negative heat, snow melt and snow yield, water year 1992

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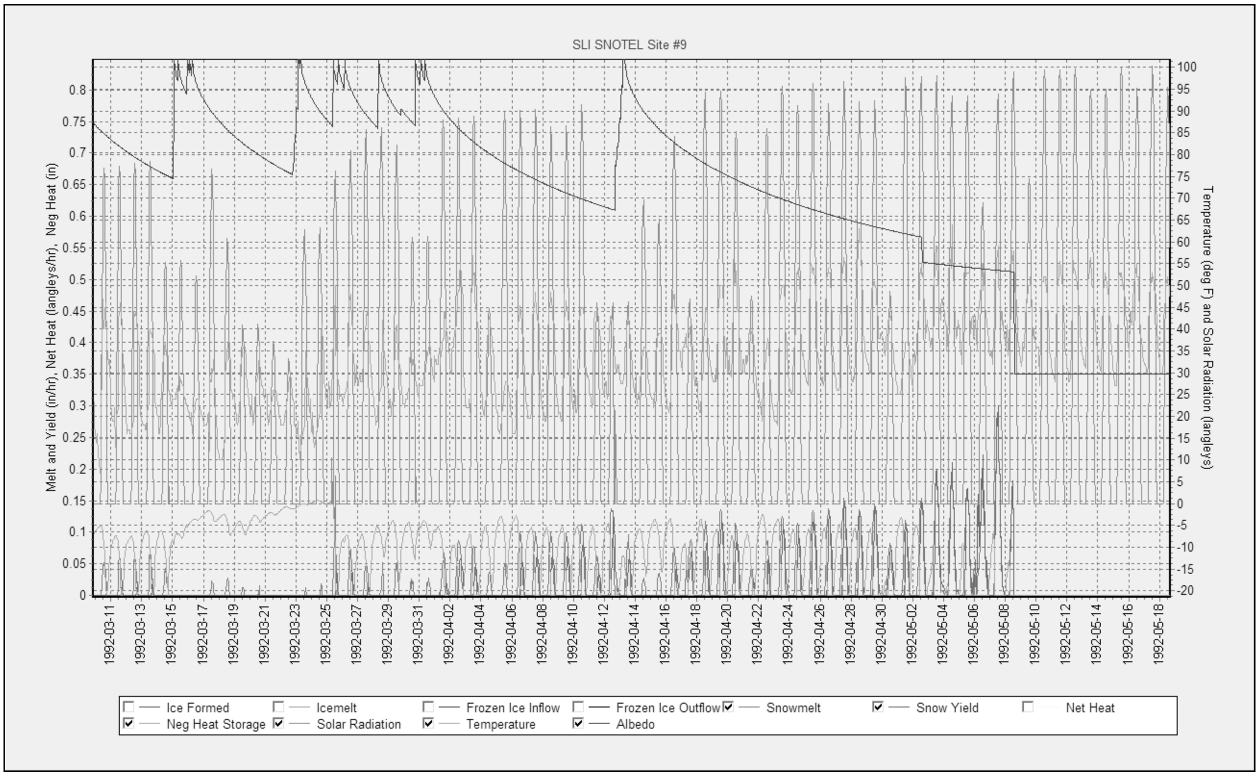
Cont.



HY-52
cont.

Figure D-6. Slide Canyon simulated historic snowpack albedo, air temperature, solar radiation, negative heat, snow melt and snow yield, May and June of water year 1992

Attachment A

O-TRT-DREKMEIER Cont.

Figure D-7 shows Slide Canyon simulated snowpack albedo, air temperature, solar radiation, negative heat, snow melt and snow yield for climate change scenario 2A in 2100 based on adjusted meteorological data from water year 1992. With higher temperatures, snowpack does not build until late December. Negative heat in Figure D-7 is much less consistent than the historical conditions shown in D-5. Figure D-8 shows the melt out of the snowpack. As in Figure D-6, warmer night time temperatures in Figure D-8 tend to reduce or prevent night time negative heat and the snowpack remains at 0 degrees C. The liquid water holding capacity of the snowpack is exceeded and water leaves the snowpack. In Figure D-8 for climate change scenario 2A in 2100, melt out ends by April 10, 1992 compared to May 8, 1992 for the historical conditions shown in Figure D-6.

With climate change and warmer temperatures and earlier spring melt, physical processes appear to cause melt out to be more episodic. Negative heat appears more likely to interrupt melt when the Slide Canyon snowpack begins melting in March.

HY-52 cont.

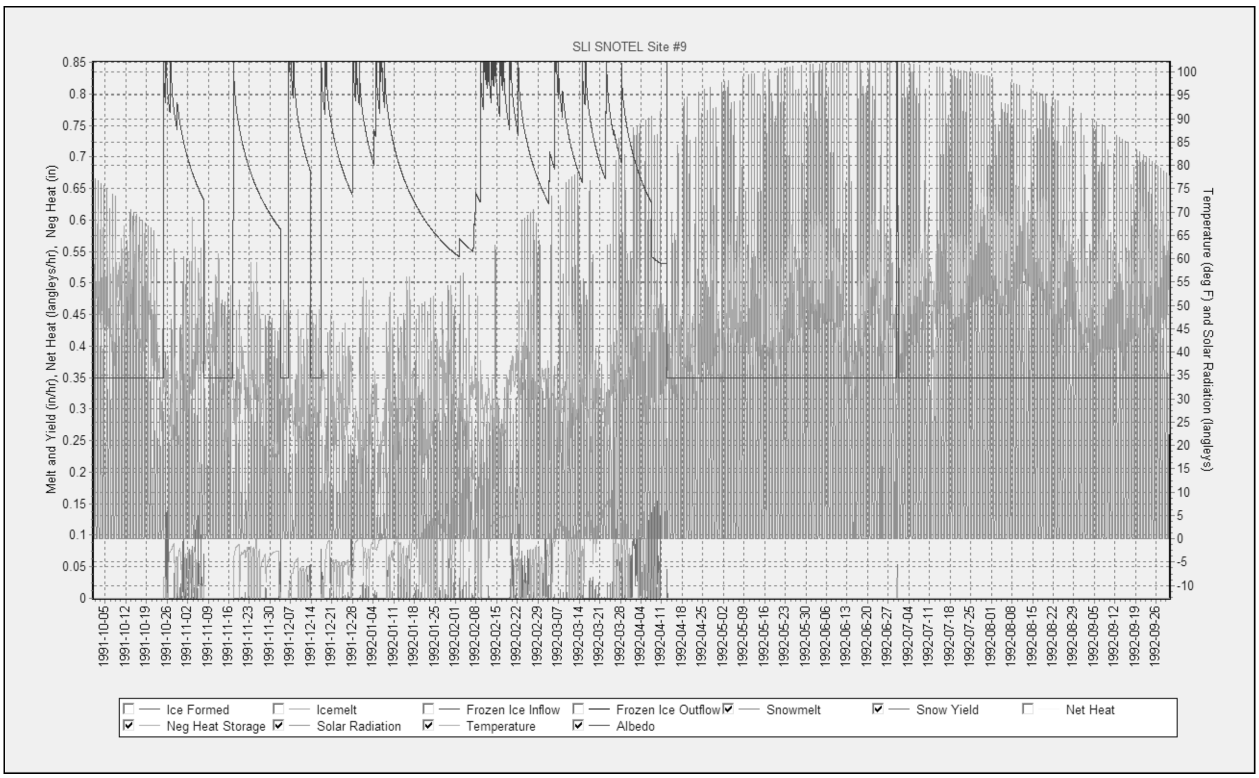
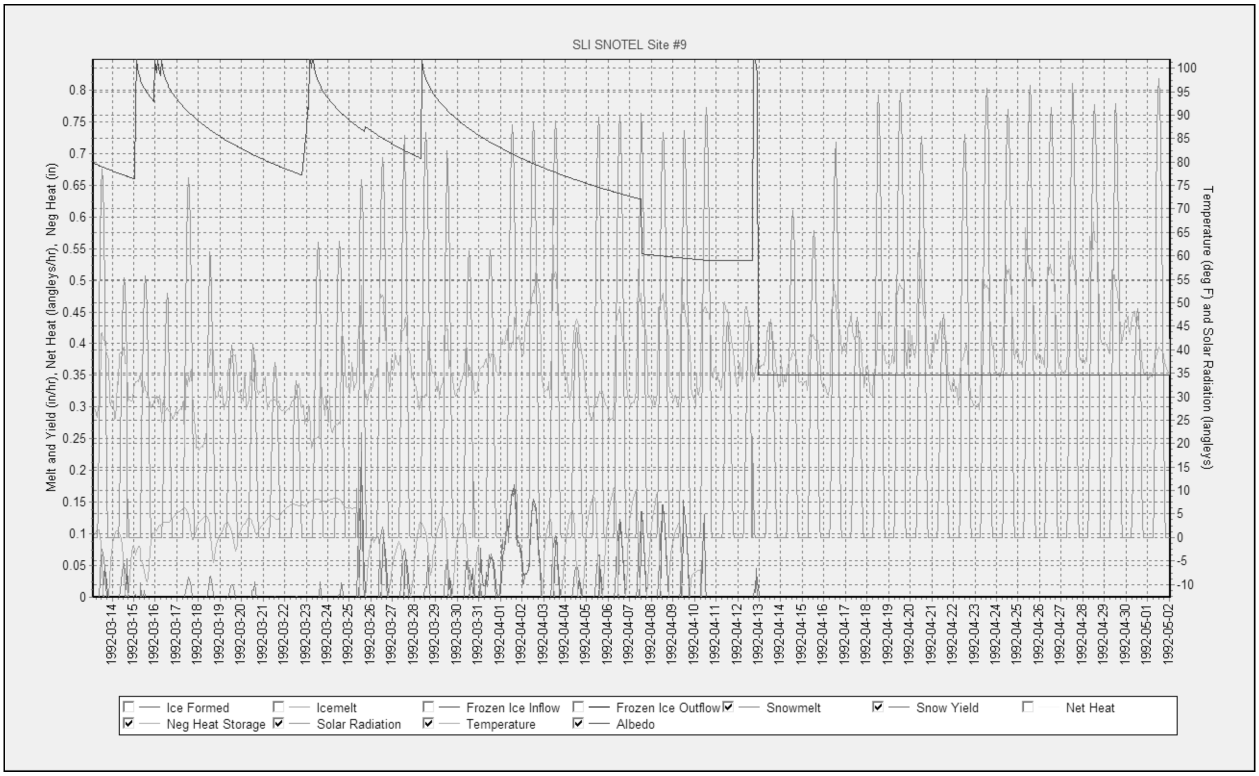


Figure D-7. Slide Canyon simulated snowpack albedo, air temperature, solar radiation, negative heat, snow melt and snow yield for scenario 2A in 2100, water year 1992

O-TRT-DREKMEIER Cont.



HY-52 cont.

Figure D-8. Slide Canyon simulated snowpack albedo, air temperature, solar radiation, negative heat, snow melt and snow yield for scenario 2A in 2100, May and June of water year 1992

APPENDIX E

HY-52 cont.

Tuolumne Meteorological Data

O-TRT-DREKMEIER Cont.

APPENDIX E

Tuolumne Meteorological Data

HFAM requires hourly input data for precipitation, temperature, evaporation, wind speed and solar radiation.

For the current project, the HFAM meteorological database for the Tuolumne watershed was improved by correcting obvious errors in the data and updating the database to Sept 30, 2008. The current database includes data for all stations for water years 1931-2008. Data sources and adjustments are described in detail in section E.1.

In addition to the historic database, a static database was created for water years 1931-2008 which represents the climatic conditions in 2010, as described in section E.2.

Future climate scenarios are developed from the 2010 current conditions static database. The method for addressing the different trends in minimum and maximum temperatures is described in section E.3. HY-52 cont.

It is important to distinguish between climate change and climate variability when predicting future meteorological conditions. A short analysis of historical temperature data and climate variability is presented in section E.4.

E.1 Tuolumne Meteorological Data Sources

E.1.1 Precipitation Data

Table E.1 summarizes the station names and data sources for Tuolumne hourly precipitation data compiled for the HFAM meteorological database.

Table E.1 Precipitation data in HFAM database

HFAM PRECIPITATION DATA						
HFAM Station #	**CODE**	**Station Name**	**Station Elev. (ft)**	**Station for Estimation of Earlier Record**	**Extended Data Starts**	**Extended Data Ends**
218	HTH	Hetch Hetchy	3858	(none)		
220	BKM	Buck Meadows	3200	Groveland 2	1930	June 1999
235	TUM	Tuolumne Meadows	8600	HTH	1930	Sept. 1997
260	CHV	Cherry Valley Dam	4764	HTH	1930	approx. 1955
265	MCN	Moccasin	938	HTH	1930	approx. 1950

O-TRT-DREKMEIER Cont.

E.1.2 Temperature Data

Table E.2 summarizes the station names and data sources for Tuolumne hourly temperature data compiled for the HFAM meteorological database.

Table E.2 Temperature data in HFAM database

HFAM TEMPERATURE DATA							
HFAM Station #	**CODE**	**Station Name**	**Station Elev. (ft)**	**Observation Interval**	**Station for Estimation of Earlier Record**	**Extended Data Starts**	**Extended Data Ends**
218	HTH	Hetch Hetchy	3858	Daily	none		
265	MCN	Moccasin	938	Daily	none		
260	CHV	Cherry Valley Dam	4764	Daily	HTH	Oct. 1930	Dec. 1952
230	PDS	Paradise Meadow	7650	Hourly	CHV	Oct. 1930	Sept. 1991
235	TUM	Tuolumne Meadows	8600	Hourly	HTH	Oct. 1930	Oct. 1992
220	BKM	Buck Meadows	3200	Hourly	CHV	Oct. 1930	Sept. 1991
245	HRS	Horse Meadow	8400	Hourly	CHV	Oct. 1930	April 1988
255	SLI	Slide Canyon	9200	Hourly	CHV	Oct. 1930	Oct. 1990

HY-52 cont.

Estimation of Hourly Temperature Data

Temperature data are recorded and published in two observation intervals, either daily maximum and minimum temperatures or hourly temperatures. Daily stations are Cherry Valley Dam, Hetch Hetchy, and Moccasin. These records are available for a longer period than the hourly records and are more complete.

To disaggregate daily temperatures to hourly values required by HFAM, the daily maximum is assigned to 4 PM and the daily minimum is assigned to 4 AM. Temperatures at other hours are calculated using a symmetrical diurnal variation between maximum and minimum temperatures.

Hourly temperature records acquired from telemetry stations operated by the US Forest Service and the California Dept. of Water Resources are listed in Table E.3.

Table E.3 Real-time stations in the Tuolumne watershed

ID	**Name**	**Latitude**	**Longitude**	**Elevation (ft)**	**Operator**
BKM	BUCK MEADOWS	120.10	37.823	3200	US Forest Service
HRS	HORSE MEADOW	119.66	38.158	8400	CA Dept of Water Resources
PDS	PARADISE MEADOW	119.67	38.047	7650	CA Dept of Water Resources
SLI	SLIDE CANYON	119.43	38.092	9200	CA Dept of Water Resources
TUM	TUOLUMNE MEADOWS	119.35	37.873	8600	CA Dept of Water Resources

Some of these stations were installed in the 1980's but data are less reliable in the early years. Hourly data in the HFAM database begin the month after the end of extended (i.e. estimated from long-term stations) data, as indicated in the last column of Table E.2.

For years prior to the start of hourly telemetry records, data are estimated from nearby stations. HFAM's Horse Meadow, Buck Meadows, Paradise Meadow, and Slide Canyon temperature records are estimated from Cherry Valley Dam temperatures. Tuolumne Meadows temperatures are estimated from Hetch Hetchy. Estimated temperature is a function of lapse rates and the difference between elevations of the stations:

Estimated Temperature = Temperature at Nearby Station + (Lapse Rate * Elevation Difference)

Temperature lapse rates are given in Table E.4. Lapse rates were calculated from concurrent record at the two stations and were re-calculated for the current study. Hence the current HFAM database has been revised for the early (extended) data period.

HY-52
cont.

Table E.4 Lapse Rates for estimation of early records in the HFAM database (deg F/1000ft)

	Record Based on Cherry Valley Data				Record Based on Hetch Hetchy Data
Month	PDS-CHV	SLI-CHV	HRS-CHV	BKM-CHV	TUM -HTH
JAN	4.30	3.68	4.58	1.19	3.55
FEB	4.46	4.01	4.91	0.98	3.88
MAR	4.54	4.18	5.10	1.03	3.94
APR	4.82	4.28	5.14	0.93	3.92
MAY	5.01	4.41	5.38	1.74	3.78
JUN	4.81	4.48	5.18	1.14	3.62
JUL	5.00	4.60	5.19	0.51	3.81
AUG	5.26	4.63	5.35	0.00	3.99
SEP	4.91	4.55	5.16	0.00	4.24
OCT	4.87	3.98	4.95	0.00	3.86
NOV	4.42	3.97	4.70	0.00	3.65
DEC	4.29	3.63	4.48	0.56	3.38
MEAN	**4.72**	**4.20**	**5.01**	**0.67**	**3.80**

E.1.3 Evaporation Data

The evaporation data station is Hetch Hetchy (HFAM station HTH 218). For years when no evaporation data are available, average values are adequate. It was not necessary to revise the evaporation data for the current study.

E.1.4 Wind Data

The wind data in prior versions of the HFAM database were measured at Buck Meadows. In the current database, wind data are based on NCEP-NCAR Reanalysis (Kalnay et al. 1996) 700 millibar wind data for Yosemite (latitude 37.5 N, longitude 120 W).

For the period October 2005 to September 2008, reanalysis wind data were not available. For those years, HFAM's wind data are a function of surface wind measurements at Buck Meadows modified to increase consistency with the reanalysis data.

During the final calibration, selected periods of wind data were modified to improve simulation of spring snowmelt.

The current database retains the station name Buck Meadows. A summary of data sources is shown in Table E.5.

Table E.5 Sources of wind data in the current HFAM database

HFAM Wind Data for Station ID BKM 220	Start Date	End Date
Monthly average for years 1948 to 2008	1/1/1930	12/31/1947
Reanalysis wind data, scaled by 1/7	1/1/1948	9/30/2005
A function of hourly Buck Meadows wind, based on a correlation between reanalysis data and Buck Meadows data	10/1/2005	9/30/2008

Reanalysis Wind Data

HY-52 cont.

The NCEP-NCAR Reanalysis Project provides simulated historical meteorological data, including upper atmosphere wind speeds.[7] The website states that "reanalysis datasets are created by assimilating ("inputting") climate observations using the same climate model throughout the entire reanalysis period in order to reduce the effects of modeling changes on climate statistics. Observations are from many different sources including ships, satellites, ground stations, RAOBS, and radar." Reanalysis wind data were provided to Hydrocomp for the period 1948-2005.

The format of the reanalysis data is a pair of velocities for each day, which are components of velocity on the north-south coordinate and the east-west coordinate. The N-S (or zonal) velocity is called Vwind and the E-W (or meridianal) component is called Uwind.

Zonal Components	Value (+ or -)	Direction
Vwind	+	towards North (southerly wind)
Vwind	-	towards South (northerly wind)

Meridianal Components	Value (+ or -)	Direction
Uwind	+	towards East (westerly wind)
Uwind	-	towards West (easterly wind)

[7] Reanalysis data are provided by the NOAA-ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/

To create a data series for HFAM, the resultant magnitude of the wind speed was calculated from Uwind and Vwind. The wind direction information is not used in HFAM. The units were converted to miles per hour and the time step was converted from daily to hourly assuming the same wind speed for all hours in each day.

HFAM requires data for wind speeds at the land surface. The upper-atmosphere (700 millibar) reanalysis wind speeds were divided by seven to estimate wind speed at the land surface. It is not necessary to define this scaling factor precisely because HFAM parameters are adjusted during model calibration.

Correlation between Buck Meadows Surface Wind and Reanalysis Data

Prior versions of the HFAM database included wind speeds measured at the Buck Meadows weather station. The reanalysis data differ statistically from surface measurements of wind. The surface measurements are much less variable than the reanalysis wind data. To increase the consistency of the HFAM database Buck Meadows wind data for October 2005 – September 2008 was modified:

- For Buck Meadows wind speeds less than 1.5 MPH, the HFAM wind is 0.2 MPH
- For Buck Meadows wind speeds between 1.5 and 3.4, the HFAM wind was computed as: HY-52 cont.
  HFAM wind = $0.8104x^2 - 1.3762x + 0.4681$ (where x is wind speed at Buck Meadows)
- For Buck Meadows wind speeds greater than 3.7, the HFAM wind was computed as
  HFAM wind = $0.6x + 3.7$ (where x is wind speed at Buck Meadows)

These modifications to the wind data improved the simulation of snowmelt for 2005-2008.

Wind Data Modifications for the Final Calibration

Adjustments to wind were made in 1980, 1985, 1988, 1993, 1995, 1997, 2005 and 2008. Adjustments were for periods of two to four weeks during April, May or June and wind velocities were typically scaled by 0.5 to 2 during these periods.

E.1.5 Solar Radiation Data

The solar radiation data in prior versions of the HFAM database are data from the weather station at Buck Meadows. In the current database, solar radiation data for water years 1975-2008 were estimated from theoretical maximum solar radiation at the land surface and sky cover descriptions at Cherry Valley Dam and Moccasin. This method improved the model calibration because it is more consistent from year to year. The solar radiation data prior to 1975 are the original HFAM data scaled by a factor of 1.07 to increase consistency and remove trends.

The current database retains the station name Buck Meadows. A summary of data sources is shown in Table E.6

Table E.6 Sources of solar radiation data in the current HFAM database

HFAM Solar Radiation Data for Station ID BKM 220	Start Date	End Date
Prior HFAM data scaled by 1.07	1/1/1930	9/30/1974
Cherry Valley Dam and Moccasin Sky cover description,	10/1/1974	9/30/2008
and theoretical clear sky solar radiation		

Theoretical Clear Sky Solar Radiation

Maximum (clear sky) solar radiation at the land surface was obtained from an Excel spreadsheet application called ***solrad.xls (version 1.2)*** developed by Greg Pelletier of the Washington State Department of Ecology, Olympia, WA. Solar radiation was calculated for the latitude and longitude coordinates of Buck Meadows and an elevation of 1000 m. The *solrad.xls* spreadsheet provided hourly values of solar radiation for one year. Figure E.1 shows the seasonal variation of solar radiation at noon.

HY-52 cont.

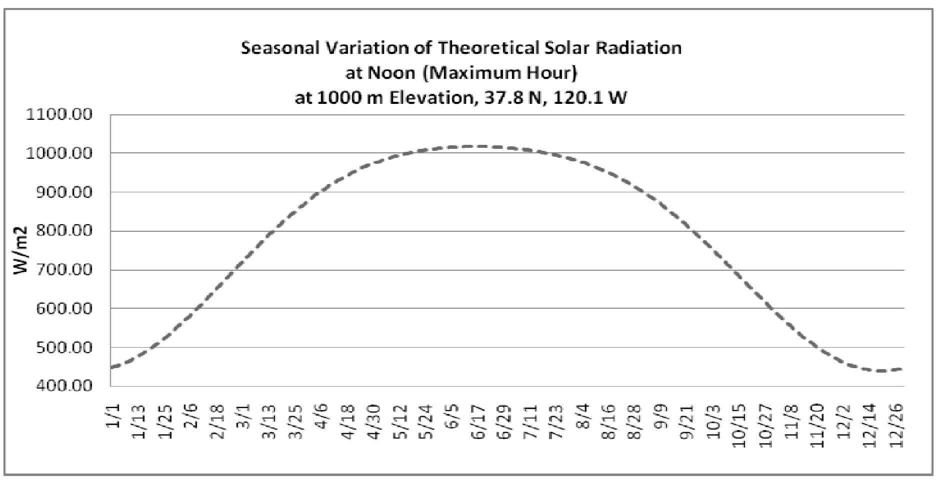


Figure E.1 Seasonal variation of solar radiation at noon

The HFAM data series of solar radiation was estimated by multiplying clear sky solar radiation by percent possible sunshine:

Solar Radiation = Theoretical Clear Sky Solar Radiation (hourly) * % Possible Sunshine (daily)

Percent possible sunshine was estimated from sky cover descriptions. For the study period, water years 1975-2008, the most useful data available are sky cover descriptions at Cherry Valley Dam and Moccasin. By comparing a short record (Oct 2006 to April 2007) of solar radiation measurements at Buck Meadow (BKM), as well as the average of measurements at Tuolumne Meadows (TUM), Dana Meadows (DAN) and Tioga Entrance Station (TES) correlations between sky cover and percent possible sunshine were developed, shown in Table E.7.

Attachment A

O-TRT-DREKMEIER Cont.

Table E.7 Daily sky cover descriptions and corresponding values of percent possible sunshine

Sky Cover Description	% Possible Sunshine
Rain or Snow	40
Cloudy	50
Fog or Smoke	90
Part Cloudy	90
Clear	100

Figure E.2 shows the comparison of percent possible sunshine based on solar radiation measured at weather stations with percent possible sunshine estimated from sky cover descriptions, for October 2006 to January 2007.

HY-52 cont.

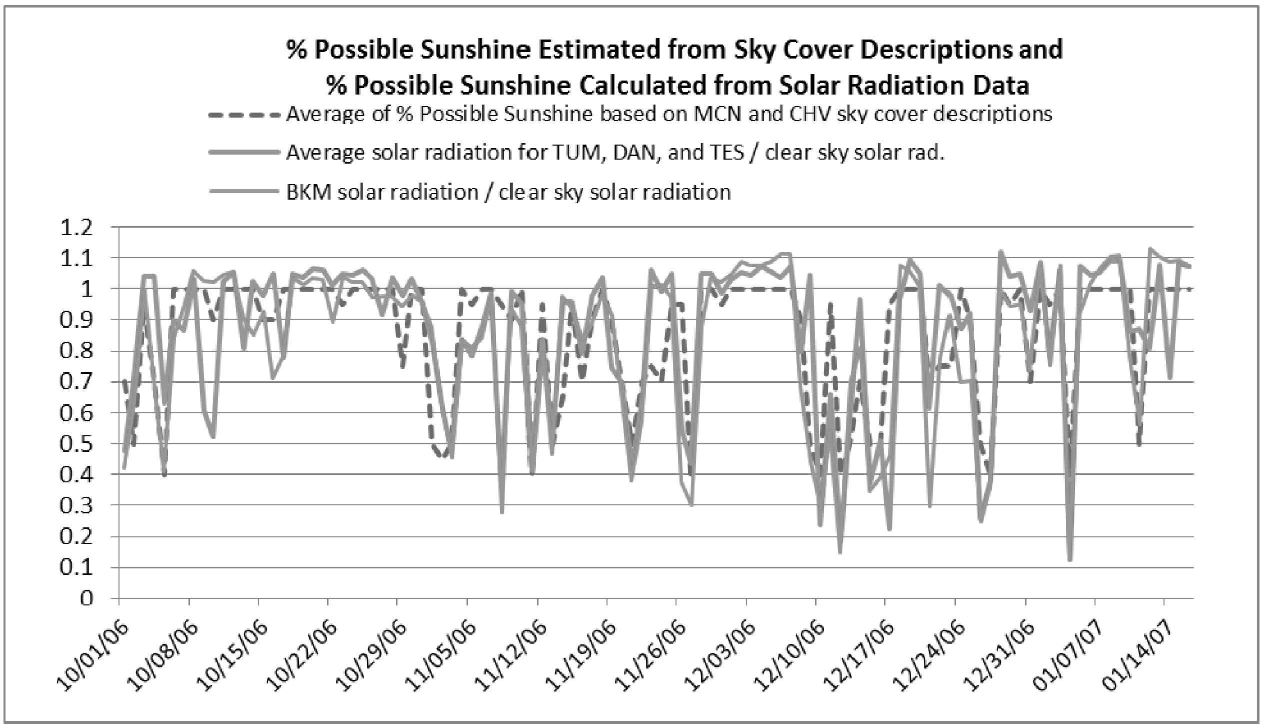


Figure E.2 Percent possible sunshine estimated from solar radiation data

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DREKMEIER
Cont.

E.2 Trends in Historic Meteorological Database and HFAM Static Data

Hydrocomp evaluated trends in historical temperature data using the revised database which includes data added for recent years and corrections made to erroneous temperature data.

Trends in the current solar and wind data were also calculated. As shown in Figures E.3 and E.4, the final wind and solar data do not have significant long-term trends over the water years 1931-2008

HY-52
cont.

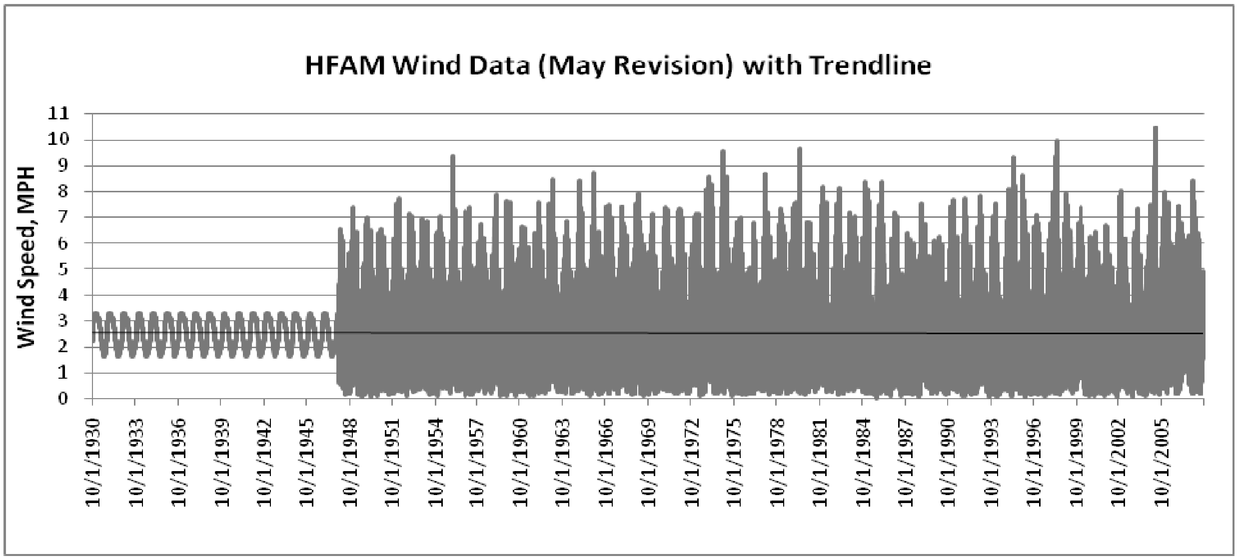


Figure E.3 Trends in wind data for 1931-2008

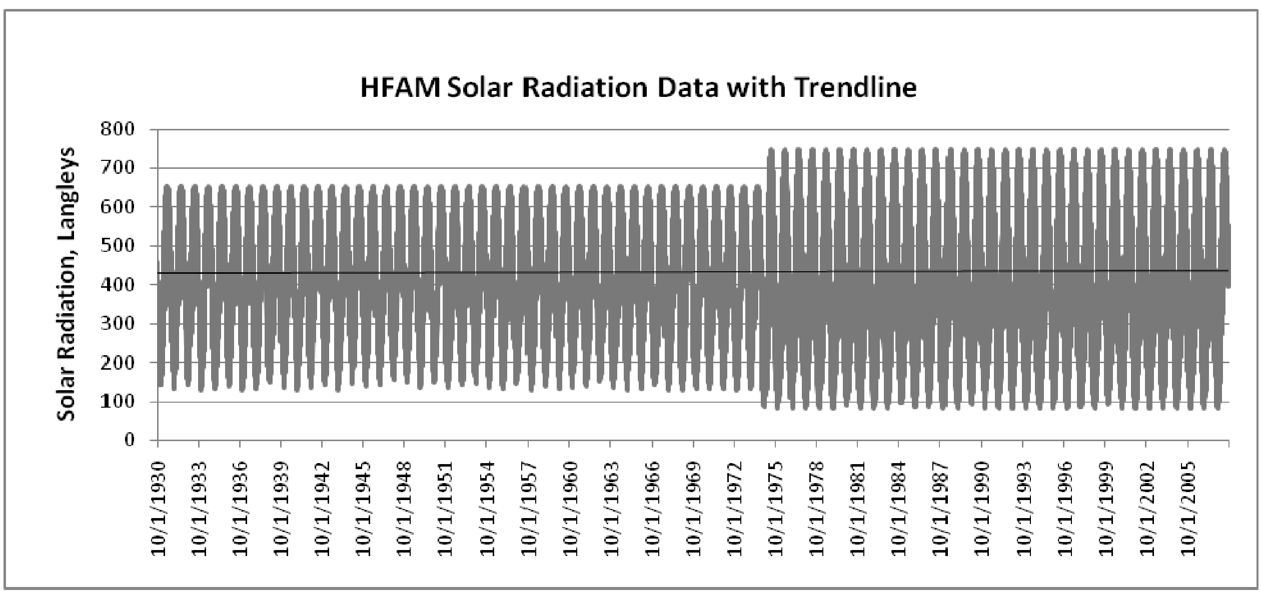


Figure E.4 Trends in solar radiation data for 1931-2008

O-TRT-
DREKMEIER
Cont.

Trends in Temperature Data

Trends in the HFAM temperature data were quantified from linear regression equations calculated by MS Excel. The average annual temperature change for the long-term records for Cherry Valley Dam, Hetch Hetchy and Moccasin are given in Table E.8 for the 34-year climate change study period, water years 1975-2008.

Table E.8 Average annual change in temperature over the 34-year period 1975-2008 (deg F/year)

	CHV	HTH	MCN
Daily Maximums	0.0756	0.0703	0.0926
Daily Minimums	0.1118	0.1285	0.0262

The annual rates in Table E.8 multiplied by 34 give temperature change over the 34-year climate change study period (1975-2008), as shown in Table E.9. Average daily temperature changes in HFAM are equivalent to the average of the change in daily maximum and daily minimum temperature because HFAM uses a constant symmetrical pattern to disaggregate daily maximum and minimum temperatures to hourly temperatures.

HY-52
cont.

Table E.9 Change in temperature based on trend for 1975-2008 (deg F)

	CHV	HTH	MCN
Daily Maximums	2.57	2.39	3.15
Daily Minimums	3.79	4.37	0.89
Average	3.18	3.38	2.02

Trends were also calculated for the 49-year period 1960-2008 because preliminary analysis indicated that 1960 was the beginning of the warming trend. A longer record may give more reliable information. The 49-year trends are shown in Table E.10.

Table E.10 Average annual change in temperature over the 49-year period water year 1960-2008 (deg F/year)

	CHV	HTH	MCN
Daily Maximums	0.0103	0.0175	0.1052
Daily Minimums	0.1138	0.1031	0.0268

Multiplying the annual rates in Table E.10 which were calculated over the 49-year period by 34 gives another estimate of the temperature change over the 34-year climate change study period (1975-2008), shown in Table E.11. Moccasin trends are similar for both 34-year and 49-year calculations. However, Cherry Valley Dam and Hetch Hetchy temperature changes are larger for the 34-year records than the 49-year record, especially for maximum temperatures.

Table E.11 Change in temperature based on trend for 1960-2008 (deg F)

	CHV	HTH	MCN
Daily Maximums	0.35	0.60	3.58
Daily Minimums	3.87	3.51	0.91
Average	2.11	2.05	2.24

Trends were also calculated for the hourly telemetry stations. These shorter records are more subject to short-term weather fluctuations. Table E.12 shows the trends calculated for these stations.

HY-52 cont.

Table E.12 Trends for telemetry stations with hourly temperature data average annual change for analysis period (deg F/year)

Station	Trend Analysis Starts	# of years	Change in Daily Average Temperature	Change in Daily Maximum Temperature	Change in Daily Minimum Temperature
Horse Meadow	Oct 1989	19	0.23 deg F/year	0.23 deg F/year	0.20 deg F/year
Paradise Meadow	OCT. 1991	17	0.16 deg F/year	0.15 deg F/year	0.15 deg F/year
Tuolumne Meadows	Oct. 1993	15	0.19 deg F/year	0.25 deg F/year	0.13 deg F/year
Buck Meadows	Oct. 1991	17	0.07 deg F/year	0.11 deg F/year	0.07 deg F/year
Slide Canyon	Oct. 1990	18	0.12 deg F/year	0.14 deg F/year	0.08 deg F/year

Corrections to Historic Temperature Data to Develop Static Records

The steps followed to develop static temperatures are:

1) Generate static temperature records for the long-term daily maximum and minimum temperatures stations: Cherry Valley Dam, Hetch Hetchy, and Moccasin
2) Confirm that there are no trends in the static data for the period 1930-2008 for Cherry Valley Dam, Hetch Hetchy, and Moccasin
3) Extend the short records for hourly telemetry station by applying lapse rates to the static temperature data.
4) Confirm that there are no trends in the static data for hourly telemetry stations for the period 1930-2008

Attachment A

O-TRT-DREKMEIER Cont.

Static Temperatures Records for the Daily Max-Min Temperatures Stations: Cherry Valley Dam, Hetch Hetchy, and Moccasin

Daily maximum-minimum temperature records are disaggregated to hourly data for the HFAM database using the same hourly pattern each day. Minimum temperatures are assigned to 4 AM and maximums are assigned to 4 PM. Because the diurnal pattern never varies, the historical record's mean, maximum and minimum temperatures can be modified by adding hourly temperature increments.

For example, to create a static temperature record for Moccasin, hourly temperature increments in Figure E.5 were added to the historical Moccasin record. The increment to the daily minimum temperature is 0.91 deg F and the increment to the daily maximum temperature is 3.58 deg F; the average daily increment is 2.4 deg F. These increments were determined by trend analysis for the period 1960-2008 (see Table E.11).

HY-52 cont.

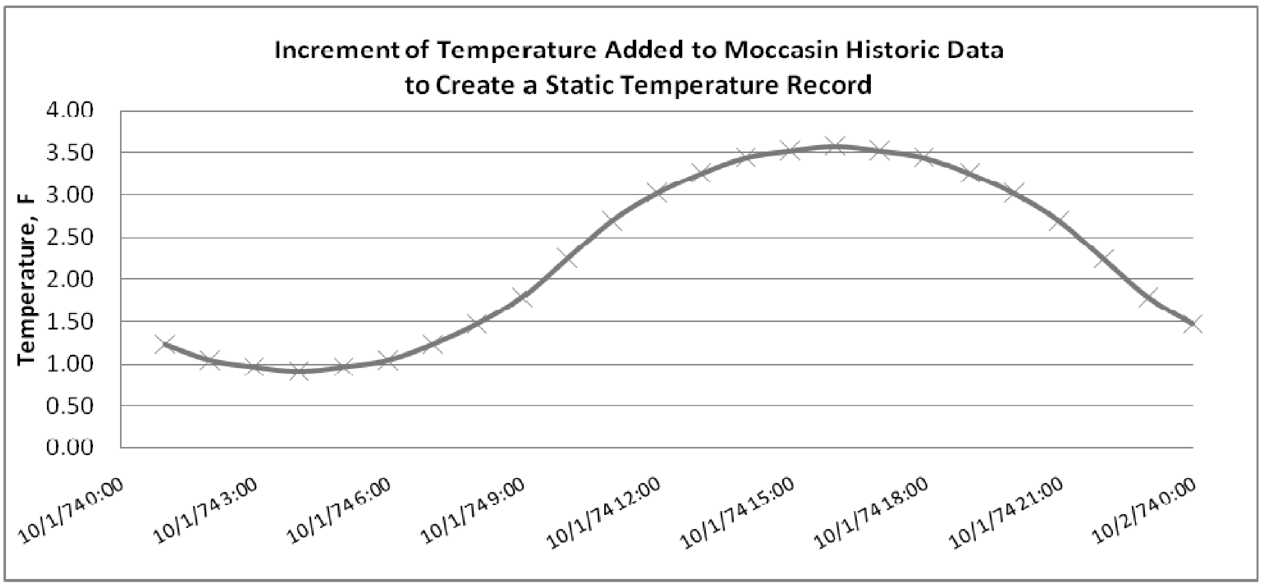


Figure E.5 Increments of temperature added to Moccasin historic data to create a static record

O-TRT-DREKMEIER Cont.

Warming trends for minimum temperatures at Cherry Valley Dam and Hetch Hetchy are greater than the trend in daily maximum temperatures. Only minimum temperatures trends were incorporated in static temperature data. Figure E.6 shows the adjustments used to generate static temperature records for the long-term stations and Table E.13 illustrates the pattern of adjustments for Cherry Valley Dam and Hetch Hetchy.

Table E.13 Cherry Valley Dam, Hetch Hetchy, and Moccasin temperature change applied to the 34 years 1975-2008 to create static record

	CHV	HTH	MCN
Daily Maximums	0	0	3.58
Daily Minimums	3.87	3.51	0.91
Average	1.93	1.76	2.24

HY-52 cont.

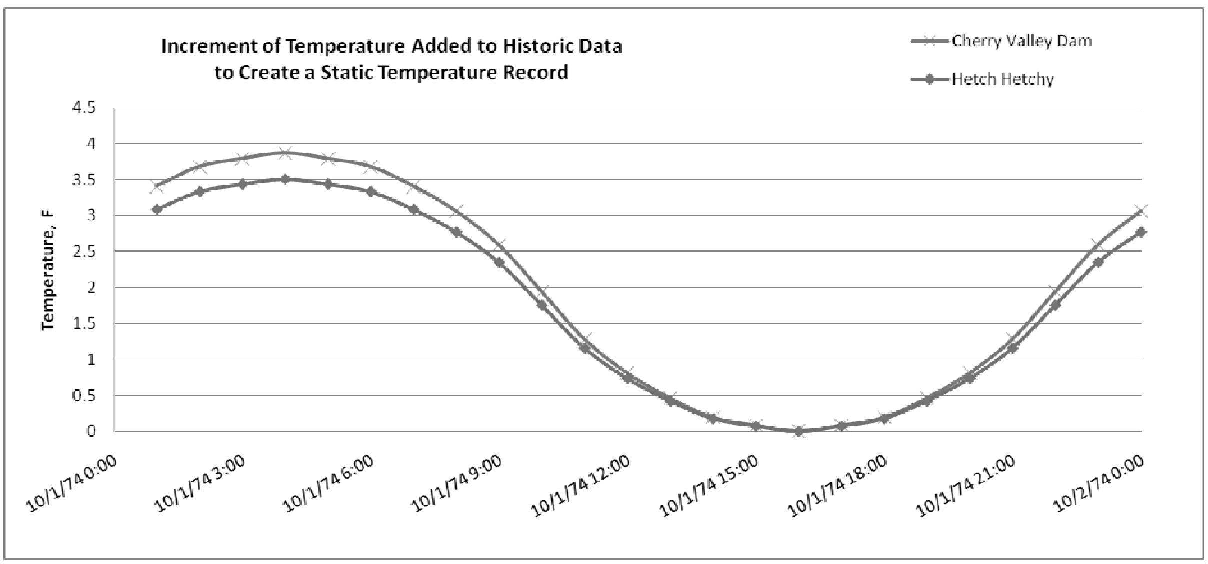
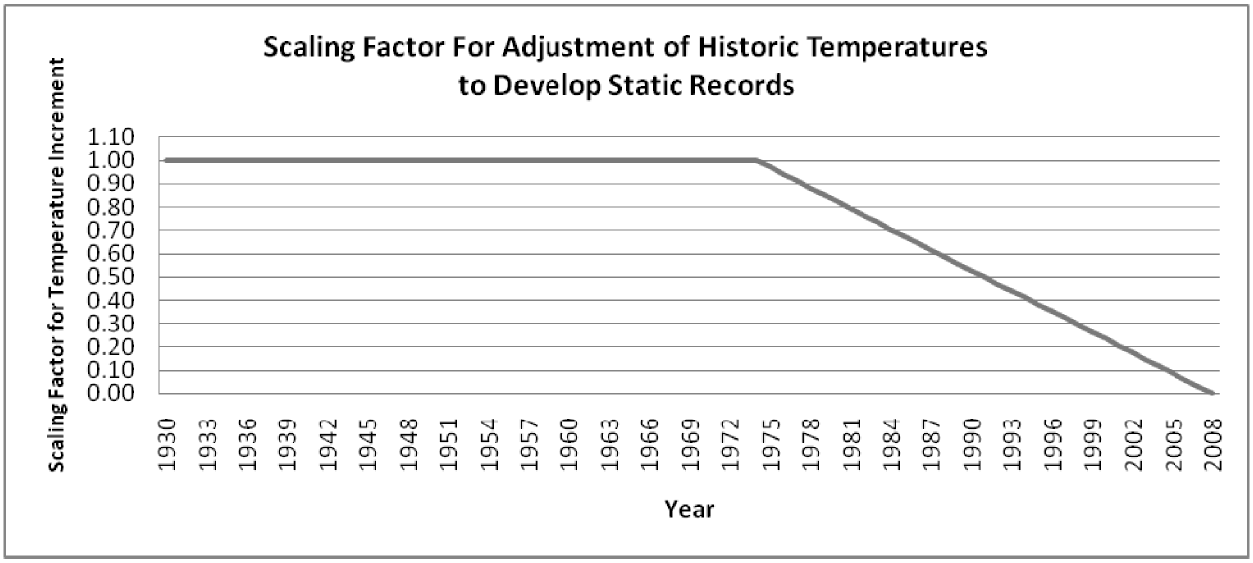


Figure E.6 Increments of temperature added to Cherry Valley and Hetch Hetchy historic data to create a static record

The static adjustments to Moccasin, Hetch Hetchy and Cherry Valley temperatures shown in Figures E.5 and E.6 were decreased linearly for water years 1975-2008. The static temperature is calculated with the following equation using scaling factors illustrated in Figure E.7:

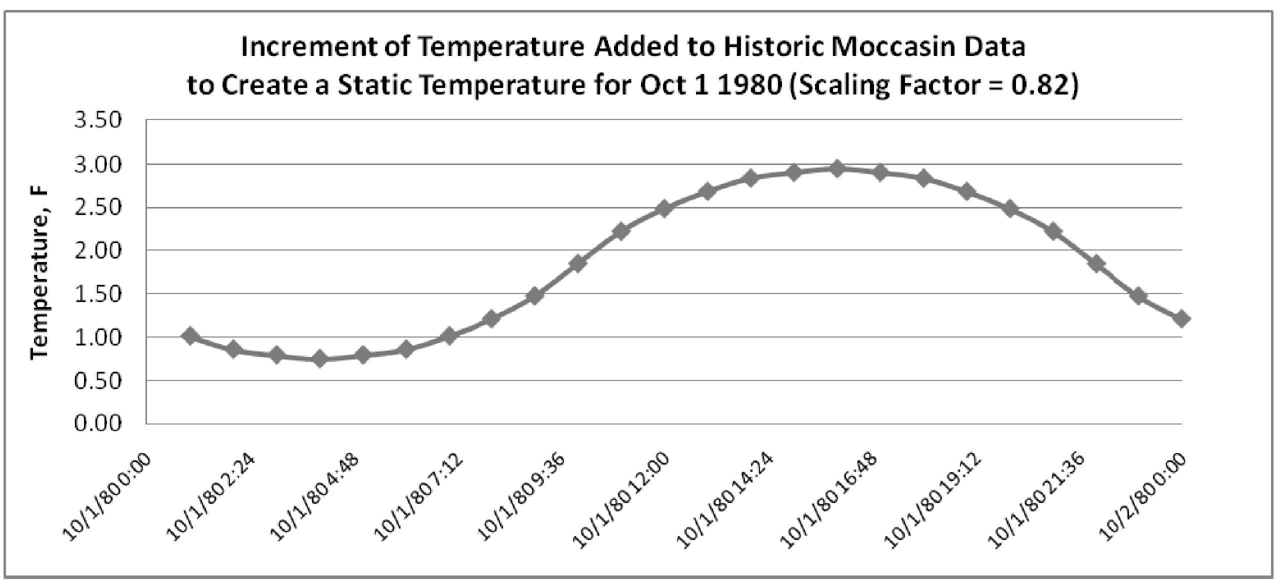
Static Temperature = Historic Temperature + (Static Adjustment * Scaling Factor)



HY-52 cont.

Figure E.7 Scaling factors for static temperature records

Figures E.8 and E.9 are examples of the scaled static temperature increments for Moccasin. The scaling factor for 10/1/1980 is 0.82 and the factor for 10/1/2000 is 0.24.



O-TRT-
DREKMEIER
Cont.

Figure E.8 Scaled static temperature increments for Moccasin, 1980

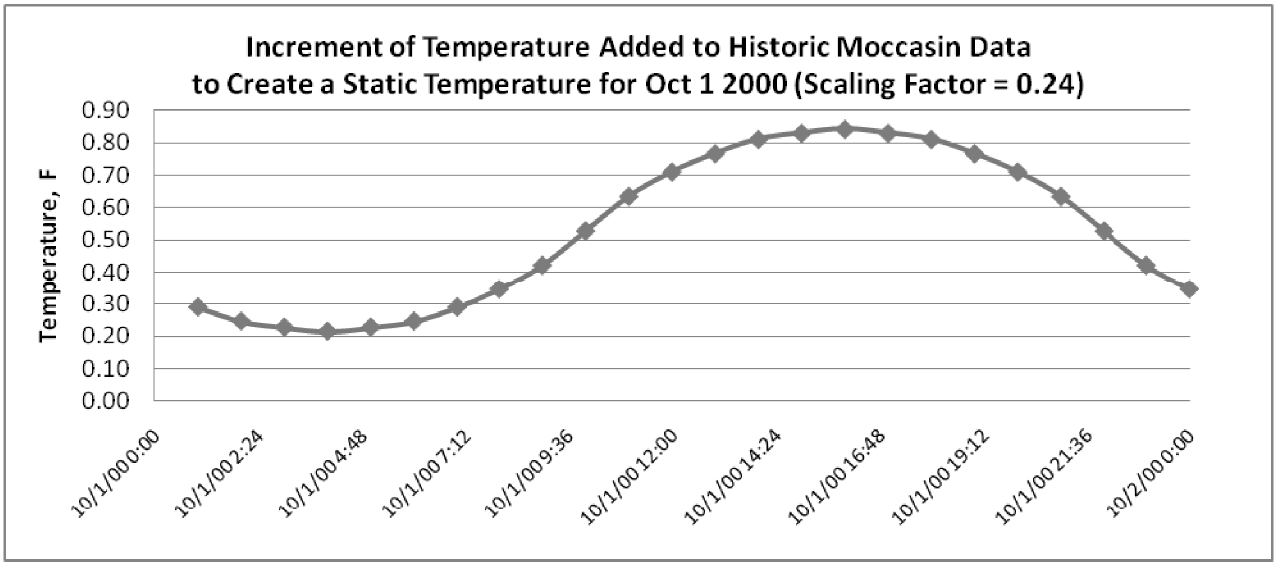


Figure E.9 Scaled static temperature increments for Moccasin, 2000

HY-52
cont.

Static Temperatures Records for the Hourly Telemetry Temperatures Stations:
Horse Meadow, Tuolumne Meadows, Paradise Meadow, Buck Meadows and Slide Canyon

Warming trends were calculated for the hourly temperature stations. However, there is less certainty in trends because the records are shorter.

The HFAM database contains estimated data for years prior to the start of hourly telemetry records. HFAM's Horse Meadow, Buck Meadows, Paradise Meadow, and Slide Canyon temperature records are estimated from Cherry Valley Dam temperatures. The HFAM historical data were estimated by applying lapse rate adjustments from Cherry Valley Dam to the telemetry stations. To create the static HFAM data, the same lapse rate adjustments were applied to the static Cherry Valley temperature record. Trend analysis of the resulting records for the period 1930-2008 is acceptable.

Tuolumne Meadows (TUM) is the only hourly record extended with Hetch Hetchy (HTH) temperature data. Lapse rate adjustment of the static Hetch Hetchy temperature to Tuolumne Meadows did not remove trends in temperature data. A different method was used to create a static record for TUM:

1. Adjust the historic TUM data for November 1, 1992- September 30 2008 by +2.9 degrees F multiplied by scaling factor. The scaling factor decreases linearly from 1.0 to 0.0.
2. Extend the TUM record based on HTH data. Both static adjustments and lapse rate adjustments were made. The lapse rate adjustments are the same as were used for the HFAM historic database. The static temperature adjustments are a diurnal pattern shown in Figure E.10. No scaling factor is used.

O-TRT-DREKMEIER Cont.

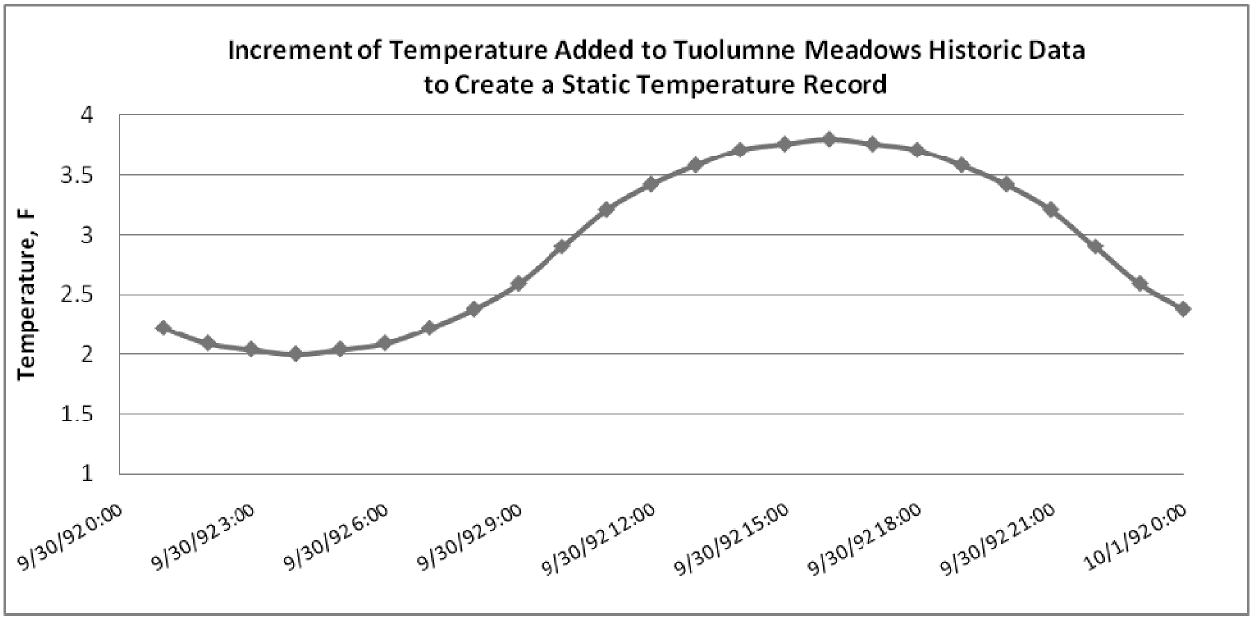


Figure E.10 Static temperature increments for Tuolumne Meadows

HY-52 cont.

Trends in HFAM Static Temperature Data

The HFAM static temperature records were checked to ensure that trends are small. Table E.14 summarizes the trends in daily maximum, minimum and average temperature by the HFAM temperature stations for the 78 years 1930-2008. All changes are less than 2 degrees F. Trends in daily average temperature are all less than 1.1 degrees F over 78 years.

Table E.14 Trends in HFAM Static Temperature Records
Changes in Temperature over 79 years, 1930-2008 (deg F)

Stations With Daily Observations					
	CHV	**HTH**	**MCN**		
Daily Maximums	-1.16	-1.34	0.22		
Daily Minimums	0.07	1.29	-0.21		
Daily Average	**-0.49**	**-0.01**	**0.04**		
Stations With Hourly Observations					
	BKM	**HRS**	**PDS**	**SLI**	**TUM**
Daily Maximums	1.45	-0.19	0.01	0.30	0.39
Daily Minimums	-1.66	-0.84	-0.52	-0.27	0.39
Daily Average	**-1.03**	**-0.99**	**-0.92**	**-1.09**	**-0.13**

E.3 Development of future temperature timeseries

A delta-adjusted future meteorological database was generated from the static meteorological database to represent each of the future climate conditions listed in Table 3-1. The delta method consists of adjusting existing timeseries by a given factor or factors to develop a new set of timeseries (Bader et al. 2008).

Predicted temperature changes are given as average temperature increases in Table 3-1. The historical temperature records in the Tuolumne at Hetch Hetchy and Cherry Valley show that minimum daily temperatures have increased much more than maximum daily temperatures. This tendency is assumed to continue, with the daily temperature cycle becoming gradually more moderate.

Hydrocomp developed a method to calculate the increases to daily minimum and daily maximum temperatures, given a specified increase to daily average temperatures. Figure E.11 shows the relationship used to determine the daily minimum and daily maximum temperature increases from the average daily temperatures increase in degrees F. Use of this relationship when calculating the hourly temperature increase ensures that the daily range in temperature (i.e. the daily maximum minus the daily minimum temperature) remains within reason for all climate change scenarios. HY-52 cont.

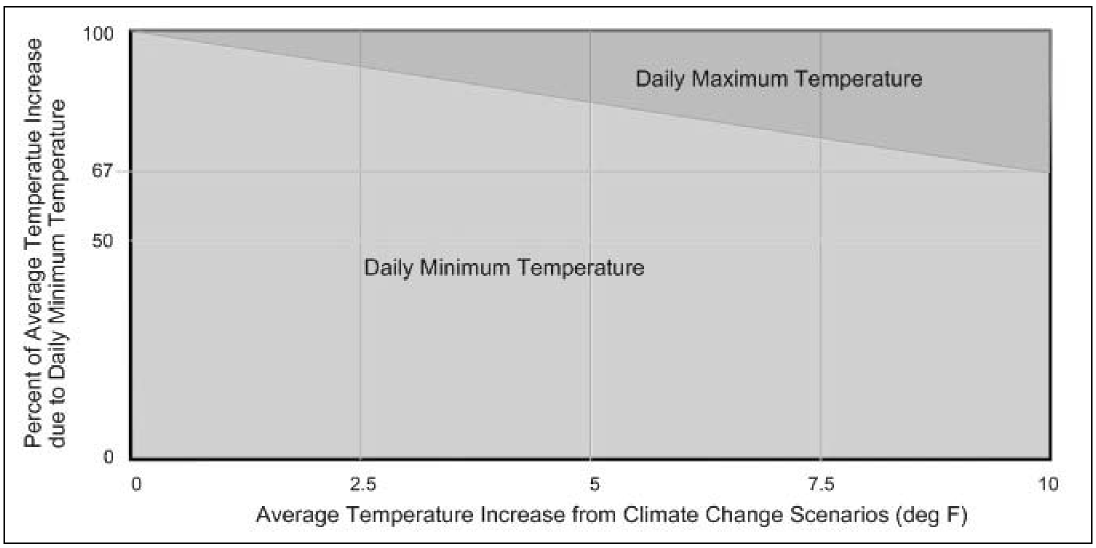


Figure E.11. Percentage of average temperature increase due to daily minimum and daily maximum temperature increases

E.4 Climate variability and trends in temperature data

The potential climate change scenarios were developed based on statistical analysis of historical meteorological data. It is important to distinguish between climate change and climate variability in such an analysis. Weather in the Sierras is driven by climate patterns over the Pacific Ocean, which are affected by El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) (Mantua N. 2002). The overall warming trend in the Western United States between 1950 and 1999 is smaller when the PDO is accounted for (Bonfils et al. 2008).

The impact of the PDO on weather in the Upper Tuolumne Basin was studied by correlating the Pacific Decadal Oscillation Index (PDOI) with the daily minimum and maximum temperatures (T_{min} and T_{max}) at Hetch Hetchy Dam from 1930-2009 and at Cherry Valley Dam from 1953-2010. There is a small correlation between the PDOI and T_{min} that is seen at both sites when data are averaged monthly, seasonally, or annually. There is no consistent relationship between the PDOI and T_{max}). Figure E.12 shows the correlation between the annual average value of T_{min} and the PDOI at Hetch Hetchy.

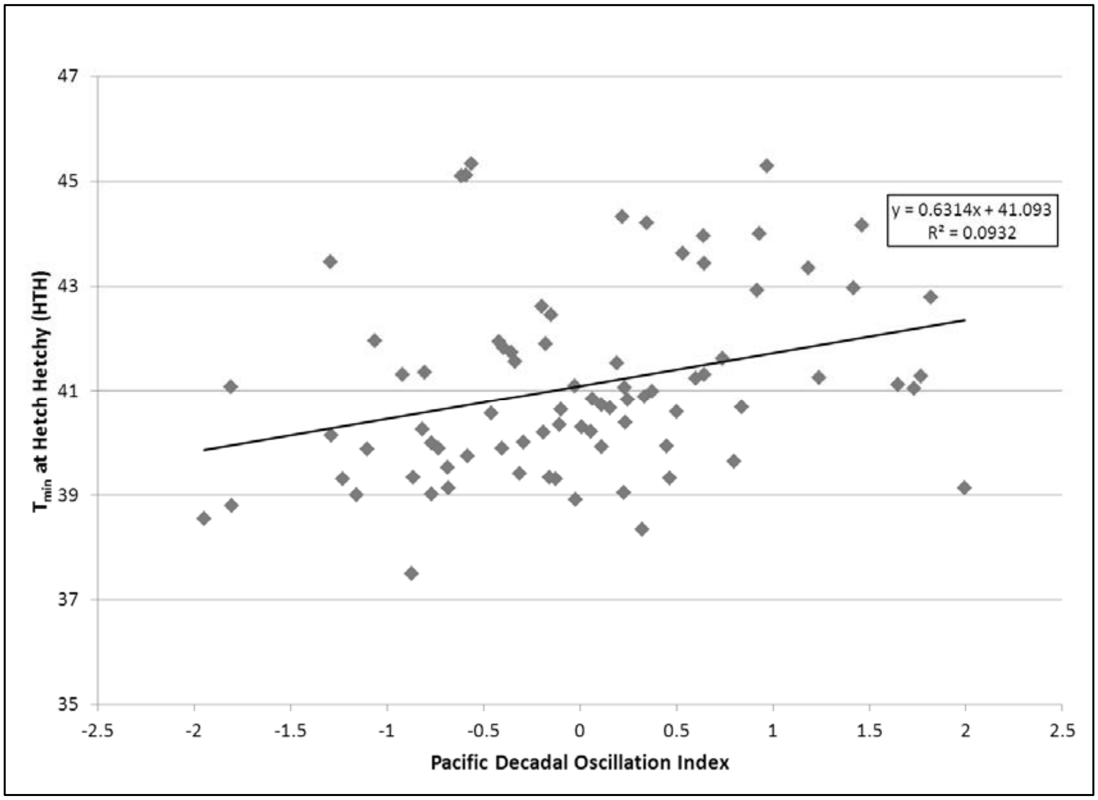


Figure E.12. Correlation between PDOI and annual average Tmin at HTH

HY-52 cont.

The annual average daily minimum temperature at Hetch Hetchy with the PDOI correlation removed is presented in Figure E.13. The timeseries that excludes the PDO is slightly different than the raw timeseries, and the warming trend after 1960 is not significantly altered. The raw timeseries is used to develop inputs for the HFAM model so that the input includes all climate variability.

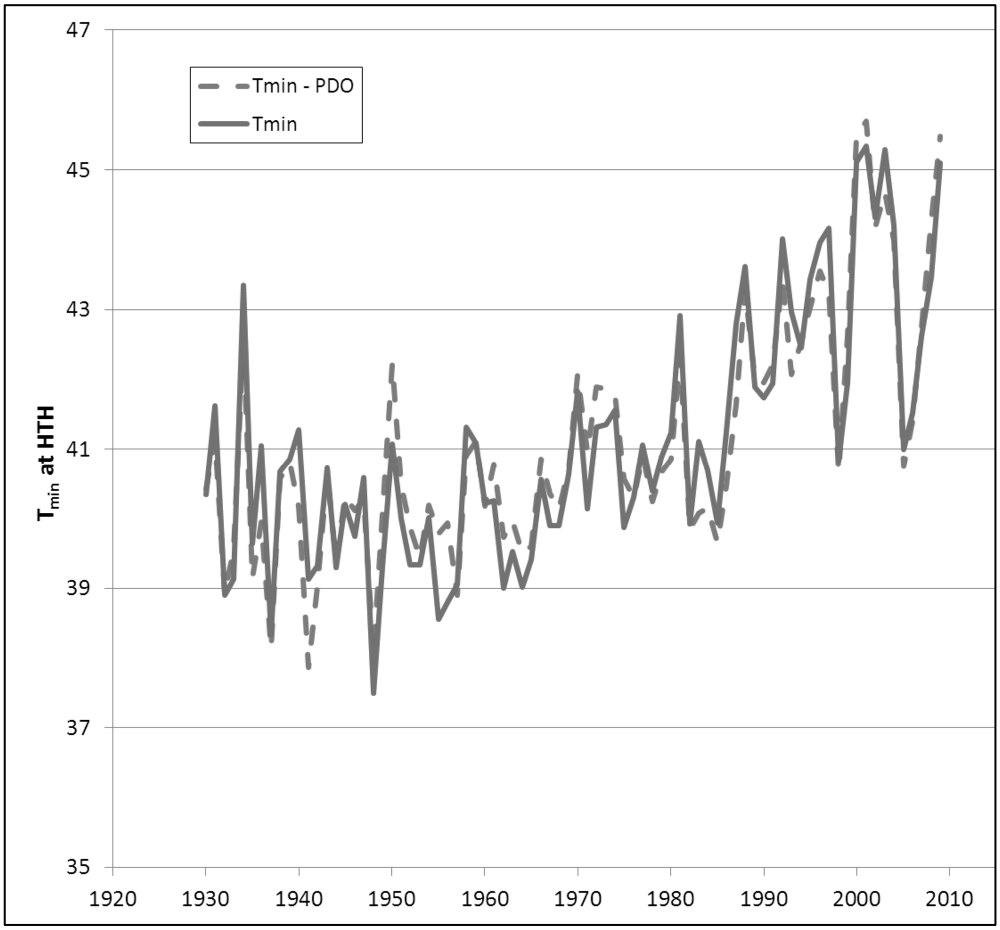


Figure E.13. Annual average Tmin without the PDOI correlation

There was no significant relationship found between Tmin and Tmax and the ENSO index.

HY-52 cont.

Attachment B

O-TRT-DREKMEIER cont.

1985

Stipulation for Amendment of
Rights-of-Way for
Canyon Power Project
Approved by
Secretary of the Interior
on May 26, 1961
to fulfill the conditions
set forth in Provision 6 of
said Amended Permit

Pursuant to the Act of December 19, 1913 (38 Stat. 242), and in consideration of relocation and installation of its facilities and the granting to it by the United States of amended rights-of-way applied for, the City and County of San Francisco, a municipal corporation of the State of California, on May 23, 1961 stipulated and agreed and did bind itself, its successors and assigns to the terms, conditions and obligations set forth in the amended rights-of-way approved May 26, 1961 and amendments or modifications subsequent thereto.

HY-52 cont.

Condition number 6 of said amended rights-of-way provided, among other things, that the interim stream flow releases would be subject to a study for a recommended flow schedule. The study, with recommendations, was completed August 23, 1976. Following the City's objections to certain aspects of the study's recommendations, the City now hereby agrees, amends and/or supplements said rights-of-way and binds itself, its successors and assigns, to each of the following terms, conditions, and obligations, consisting of six provisions, including the water release schedule set forth on Exhibit A:

1. That the minimum amount of water released from Hetch Hetchy Reservoir to the Tuolumne River at O'Shaughnessy Dam be in accordance with the schedule attached hereto as Exhibit A.

2. That the allowable rate of change in the magnitude of water releases from Hetch Hetchy Reservoir to the river at O'Shaughnessy Dam be changed from the present stipulation of "... not more than double nor less than one-half the previous release over a one-hour period ..." to "not more than double nor less than one-half the previous release over a four-hour period except when the previous release is 200 cfs or less, in which case the rate of change shall not exceed 50 cfs over a four-hour period."

3. That, insofar as the storage capacity at Hetch Hetch Reservoir and emergency situations allow, releases to the Tuolumne River shall be managed to prevent sudden or short-term high magnitude releases or spills at O'Shaughnessy Dam. HY-52 cont.

4. That the San Francisco Public Utilities Commission provide the appropriate field offices of the U.S. Forest Service, the National Park Service, the U.S. Fish and Wildlife Service, and the California Department of Fish and Game with periodic reports of releases from Hetch Hetchy Reservoir to the Tuolumne River at O'Shaughnessy Dam. The reports should (1) be furnished on a monthly basis by the 10th workday of the month following that reported on, (2) indicate the magnitude of the release at any given time during the report period, and (3) contain an explanation of any circumstances preventing compliance with the schedule of minimum reservoir releases specified in Recommendation No. 1.

5. That the San Francisco Public Utilities Commission notify the appropriate field office of the U.S. Forest Service, the National Park Service, the U.S. Fish and Wildlife Service, and the California Department of Fish and Game at least 7 days in advance of any anticipated noncompliance with the schedule of minimum reservoir releases specified in Recommendation No. 1.

6. That the foregoing conditions are imposed for the Tuolumne River from O'Shaughnessy Dam to Early Intake with respect to the existing Hetch Hetchy facilities and capacities along the Tuolumne River. San Francisco agrees that any proposed expansion, alteration, or other modification of the water and power supply facilities which could alter flows along that stretch of river will be subject to review by the Department of the Interior for the purpose of determining what change, if any, should be made in the flow release schedule stipulated in Condition 1. San Francisco further agrees that it will provide to the Department of the Interior advance information concerning any such proposed projects and will assist

the Department of the Interior in making its review by undertaking as part of San Francisco's environmental review a study of any such project's impact on fish, wildlife, recreational, and aesthetic values due to changes in river flow. The plan of study will be formulated in coordination with the U.S. Fish and Wildlife Service, National Park Service, U.S. Forest Service and the California Department of Fish and Game, and approved by the Department of the Interior, to insure that all aspects of the proposed projects that could impact river flow are adequately investigated. At the conclusion of the study and based upon such study, the U.S. Fish and Wildlife Service will recommend to the Secretary of the Interior such changes in the flow releases schedule as may be necessary to protect fish, wildlife, recreational, and aesthetic values. Such recommendations, shall become part of these conditions, unless San Francisco, within 30 days from receipt of notice of the recommendations, shall file with the Secretary of the Interior, its objections thereto. In such event, at its request, San Francisco shall be afforded a hearing regarding these objections before a special hearing officer who will render proposed findings of fact. The Secretary, after considering the proposed findings of fact and the record, shall determine what additional flows, if any, shall be required over those specified above.

HY-52 cont.

The City further agrees that said conditions, and release schedule, are hereby made a part of and included in said rights-of-way and its stipulations.

IN WITNESS WHEREOF, the said City and County of San Francisco has caused this instrument to be executed in the City of San Francisco, California, this 13th day of December, 1984.

General Manager of Public Utilities Commission, City and County of San Francisco

HY-52 cont.

Subscribed and sworn to before me this 13th day of December, 1984

FORM APPROVED:

Thomas M. Berliner
City Attorney
City and County of San Francisco

DATE: 12/14/84

Romaine A. Boldridge
Secretary, Public Utilities Com.
City and County of San Francisco

DATE: December 13, 1984

Assistant Secretary for Fish and Wildlife and Parks

DATE: JAN 31 1985

2528p

Attachment B

O-TRT-DREKMEIER cont.

xhibit A

That the minimum amounts of water to be released from Hetch Hetchy Reservoir to the Tuolumne River at O'Shaughnessy Dam shall be in accordance with the following schedules:

	Minimum Release Schedules (cfs)			Cumulative Precip. (inches)/runoff (acre-feet)		
	A	B	C	A Equal to or greater than:	B Less than Col. A but equal to or greater than:	C Less than Col. B:
anuary	50	40	35	8.8	6.1	---
ebruary	60	50	35	14.0	9.5	---
arch	60	50	35	18.6	14.2	---
pril	75	65	35	23.0	18.0	---
ay	100	80	50	26.6	19.5	---
une	125	110	75	28.5	21.3	---
uly	125	110	75	575,000	390,000	---
ugust	125	110	75	640,000	400,000	---
eptember 1-15	100	80	75	---	---	---
eptember 16-30	80	65	50	---	---	---
ctober	60	50	35	---	---	---
ovember	60	50	35	---	---	---
ecember	50	40	35	---	---	---
inimum amount of ater (acre-feet)	59,235	50,019	35,215			
requency (percent)[1/]	60	32	8			

etermination of applicable schedule (A, B or C) is to be made on the first of each month during January through ugust. Determinations for January through June are to be based on cumulative precipitation at Hetch Hetchy ince October 1 of the preceding year. Determinations for July and August are to be made based on calculated umulative runoff into Hetch Hetchy since October 1 of the preceding year. The release schedule which is in ffect on August 1 of each year shall remain in effect until the following January.

1/ The frequency of each schedule is based on precipitation and runoff data which have been collected over the past 50 years at Hetch Hetchy. During the first three months Schedule B is adjusted to be in effect n average of 25% of the time and Schedule C 15% of the time.

HY-52 cont.

OCT-17-2005 16:13 CCSF 415 554 8793

INTERIM AGREEMENT

BETWEEN CITY AND COUNTY OF SAN FRANCISCO, CALIFORNIA TROUT, FRIENDS OF THE RIVER, SIERRA CLUB, AND TUOLUMNE RIVER PRESERVATION TRUST REGARDING FISHERIES STUDIES TO DETERMINE THE EFFECT OF THE KIRKWOOD POWERHOUSE, INCLUDING THE ADDITION TO THE KIRKWOOD POWERHOUSE ON THE FISHERIES RESOURCES OF THE TUOLUMNE RIVER FROM O'SHAUGHNESSY DAM TO EARLY INTAKE.

1. The parties to this agreement are the City and County of San Francisco ("City") acting through its Public Utilities Commission ("Commission"), California Trout, Friends of the River, Sierra Club, and Tuolumne River Preservation Trust (referred to collectively as either "Interested Parties" or "The Trust, Etc."). HY-52 cont.

2. The purpose of this interim agreement, in part, is to provide sufficient time for the Commission and the Department of the Interior ("D.O.I.") to enact a formal agreement concerning additional fisheries studies to be conducted by the Commission as well as implementation of increased flows should they be mandated by the fisheries studies. The parties anticipate that this interim agreement will be superseded to the extent that the terms hereof are substantively included in the agreement to be formulated between the Commission and D.O.I. To the extent that terms and conditions contained herein are not substantively set forth in the agreement between the Commission and D.O.I., said terms and conditions herein shall remain in effect. This

agreement shall remain in full force and effect until such time as it is terminated by mutual consent of the parties hereto.

3. Once the City has received concurrence from the D.O.I. and other state or federal agencies who have not yet completed their review of the project known as Kirkwood Powerhouse Unit Number 3 ("Kirkwood Addition") within a time acceptable to the Commission, the City shall then proceed immediately to arrange for appropriate fisheries studies to make a determination as to what effect, if any, the Kirkwood Powerhouse Project and the Kirkwood Addition would have or have had on fisheries operations between O'Shaughnessy Dam and Early Intake. The studies will include information compiled since 1967. The studies shall be conducted over a four year period; the consequent reports and analyses shall be published by December, 1989. This deadline shall be extended in the event that the consultants conducting said studies have determined that because of climatic or other environmental conditions, the results of said studies would result in inaccurate or inconclusive data.

HY-52 cont.

4. If, as a result of the foregoing fisheries studies, the consultants conducting the studies can preliminarily determine on or after December 31, 1986 that flows in the upper region of the Tuolumne River between O'Shaughnessy Dam and Early Intake should be increased, the City will increase its annual releases as set forth in Exhibit A to the document known as "Stipulation for Amendment of Rights-of-Way for Canyon Power Project Approved by Secretary of the Interior on May 26, 1961 to fulfill the

conditions set forth in Provision 6 of said Amended Permit", dated January 31, 1985, agreed to with the D.O.I.

Under Schedule "A" to include the following:

1. Anytime the draft through the Canyon Tunnel exceeds 920 CFS the fish release at O'Shaughnessy Dam will be increased an additional 64 CFS.

2. On July 1st 15,000 acre-feet will be available to mitigate any deficiency in the existing fish release shown to be required as a result of the fisheries studies, as provided for in paragraph 3, above.

Under Schedule "B" to include the following:

1. Anytime the draft through the Canyon Tunnel exceeds 920 CFS the fish release at O'Shaughnessy Dam will be increased an additional 64 CFS.

2. On July 1st 6,500 acre-feet will be available to mitigate any deficiency in the existing fish releases shown to be required as a result of the fisheries studies, as provided for in paragraph 3, above.

Under Schedule "C" to include the following:

1. On July 1st if the water storage behind O'Shaughnessy Dam is at or above 210,000 acre-feet, (the highest storage reached in 1976) 4.400 acre-feet will be available to mitigate any deficiency in the existing-fish releases shown to be required as a result of the fisheries studies, as provided for in paragraph 3, above.

HY-52 cont.

It is understood and agreed that water releases made by the City at Hetch Hetchy for fisheries purposes shall remain in the Tuolumne River between O'Shaughnessy Dam and New Don Pedro Reservoir, and the timing of these releases will be such as to coincide with the documented causes for the decrease in fisheries in the affected stretch of the river. By way of example, if fish population have declined because of warm water conditions, the releases shall be made during the summer months. The extent of these releases shall be determined by consultation between the City, Commission staff, appropriate state and federal agencies, as well as The Trust, Etc..

5. The four year study(s) to be conducted shall be those requested by the California Department of Fish and Game, the United States Fish and Wildlife Service, and/or the United States Parks Service. It is anticipated that the types of studies the Commission will be responsible for conducting will include fish population, habitat preference and IFIM studies. The studies will be conducted by the California Department of Fish and Game, the United States Fish and Wildlife Service, or private consultants jointly selected by the City, the Commission and the above state and federal agencies, in consultation with The Trust, Etc. The population and preference studies will be conducted over the next four years, or longer if necessary, as provided for in paragraph 3, above. The IFIM study, analysis and report will be concluded by the end of the fourth year, or as extended if necessary, as provided for in paragraph 3, above. The purpose of

HY-52 cont.

delaying the IFIM study toward the end of the fourth year is to allow the techniques associated with the study to reach a more refined level, thereby producing more accurate quantifications. Should the above studies not produce the results anticipated, other necessary studies may be undertaken.

6. In the event that the results and analysis of all studies dictate an increase to the present flow regime, such an increase shall be implemented up to the limits set forth in paragraph 4 above, except that necessary spring spill-flows shall not be subject to these limitations or cause a reduction in the minimum flows found necessary in other seasons.

7. It is specifically understood that the ultimate agreement encompassing the above shall be between the City and the D.O.I.. The Trust, Etc. shall function as interested parties who shall have standing to enforce the terms and conditions of said agreement.

HY-52 cont.

8. Upon execution of this agreement, The Trust, Etc. shall each withdraw their opposition to the Kirkwood Addition and request all other parties with whom it has been in contact urging or proposing opposition to the Kirkwood Powerhouse, to withdraw their opposition also. The Trust, Etc. shall each send written request to all said parties with copies to be forwarded to the City. Further, The Trust, Etc. will each make personal contact with all such parties requesting their withdrawal of opposition to this project. Furthermore, The Trust, Etc. will not seek through direct or indirect means to subvert the purpose of the

SULAN

Kirkwood Addition as both an operational and economic resource for the City, as contemplated by this agreement. Additionally, should a party not to this agreement challenge the Kirkwood Addition, The Trust, Etc. shall not take a position adverse to the City, whether before state or federal agencies, legislative branches, or the judicial system.

IN WITNESS WHEREOF, City and Interested Parties have executed this Agreement in quadruplicate as of November 4, 1985.

HY-52 cont.

CITY AND COUNTY OF SAN FRANCISCO,
a municipal corporation

APPROVED:

RUDOLF NOTHENBERG
General Manager
Public Utilities Commission

Authorized by
PUBLIC UTILITIES COMMISSION

Resolution No. _______

Adopted: _______

Attest: _______

THEODORE CHUNG
Acting General Manager
Hetch Hetchy Water and Power

ROMAINE BOLDRIDGE
Secretary

APPROVED AS TO FORM:

GEORGE AGNOST, City Attorney

By

GEORGE E. KRUEGER
Utilities General Counsel

CALIFORNIA TROUT

FRIENDS OF THE RIVER

TUOLUMNE RIVER PRESERVATION TRUST

SIERRA CLUB

ANTONIO ROSSMANN
Attorney for California Trout, Friends of the River and Tuolumne River Preservation Trust

Kirkwood Addition as both an operational and economic resource for the City, as contemplated by this agreement. Additionally, should a party not to this agreement challenge the Kirkwood Addition, The Trust, Etc. shall not take a position adverse to the City, whether before state or federal agencies, legislative branches, or the judicial system.

IN WITNESS WHEREOF, City and Interested Parties have executed this Agreement in quadruplicate as of November 4, 1985.

HY-52 cont.

CITY AND COUNTY OF SAN FRANCISCO, a municipal corporation

APPROVED:

RUDOLF NOTHENBERG
General Manager
Public Utilities Commission

Authorized by
PUBLIC UTILITIES COMMISSION

Resolution No. ______

Adopted: ______

Attest: ______

THEODORE CHUNG
Acting General Manager
Hetch Hetchy Water and Power

ROMAINE BOLDRIDGE
Secretary

APPROVED AS TO FORM:

GEORGE AGNOST, City Attorney

By
GEORGE E. KRUEGER
Utilities General Counsel

CALIFORNIA TROUT

FRIENDS OF THE RIVER

TUOLUMNE RIVER PRESERVATION TRUST

SIERRA CLUB

ANTONIO ROSSMANN
Attorney for California Trout, Friends of the River and Tuolumne River Preservation Trust

Attachment D

O-TRT-DREKMEIER cont.

United States Department of the Interior

OFFICE OF THE SOLICITOR
WASHINGTON, D.C. 20240

Memorandum

To: Director, National Park Service

From: Assistant Solicitor, Parks and Recreation

Subject: Yosemite National Park-Kirkwood Power House Agreement

Enclosed is a copy of:

MODIFICATION FOR KIRKWOOD POWERHOUSE UNIT NO. 3 TO STIPULATION FOR AMENDMENT OF RIGHTS-OF-WAY FOR CANYON POWER PROJECT APPROVED BY SECRETARY OF THE INTERIOR ON MAY 26, 1961 TO FULFILL THE CONDITIONS SET FORTH IN PROVISION 6 OF SAID AMENDED PERMIT.

HY-52 cont.

Please retain the original (which had previously been sent to Dave Jervis of your office) in your permanent records for the Park and the Hetch-Hetchy Project.

David A. Watts

Attachment

cc:
Western Regional Director, FNP]
Superintendent, Yosemite]
Director, Bureau of Reclamation]
Assistant Secretary, FW]w/attachment
San Francisco Field Solicitor]
Tom Berliner, San Francisco City Attorney

MODIFICATION FOR KIRKWOOD POWERHOUSE UNIT NO. 3
TO STIPULATION FOR AMENDMENT OF RIGHTS-OF-WAY FOR
CANYON POWER PROJECT APPROVED BY SECRETARY OF THE
INTERIOR ON MAY 26, 1961 TO FULFILL THE CONDITIONS
SET FORTH IN PROVISION 6 OF SAID AMENDED PERMIT

Pursuant to the Act of December 19, 1913 (38 Stat. 242), and in consideration of relocation and installation of its facilities and the granting to it by the United States of amended rights-of-way applied for, the City and County of San Francisco ("City"), a municipal corporation of the State of California, on May 23, 1961 stipulated and agreed and did bind itself, its successors and assigns to the terms, conditions and obligations set forth in the amended rights-of-way approved May 26, 1961 and amendments or modifications subsequent thereto.

Condition number 6 of said amended rights-of-way provided, among other things, that the interim stream flow releases would be subject to a study for a recommended flow schedule.

On December 13, 1984, the City, acting through the General Manager of its Public Utilities Commission, executed a further stipulation to fulfill the conditions set forth in condition number 6 and bound itself, its successors and assigns, to the terms, conditions and obligations, consisting of six provisions, including a water release schedule set forth on Exhibit A, contained therein. Condition number 6 of this Stipulation provided, in part, that the City agreed that any proposed expansion, alteration, or other modification of the water and

HY-52
cont.

power supply facilities which could alter flow along the stretch of river in issue would be subject to review by the Department of the Interior ("Department") for the purpose of determining what change, if any, should be made in the agreed upon flow release schedule. This Stipulation was approved by the Department on January 31, 1985. (hereinafter "1985 Stipulation")

By letter of July 3, 1985, the City, acting through the General Manager, San Francisco Water Department, requested the Department's review and concurrence with a proposal to add a third generator to the Kirkwood Powerhouse on the Tuolumne River in accordance with condition number 6 of the 1985 Stipulation.

HY-52 cont.

Following discussions with the Department, the City now hereby agrees to supplement and amend said 1985 Stipulation, to provide for additional protection of fishery resources and to provide variability in the water releases resulting from spring runoff to the extent practicable so as to enhance park resources and visitor enjoyment, and to bind itself, its successors and assigns, to each of the following terms, conditions, and obligations, consisting of 8 provisions, as follows:

1. At the direction of the Department, the U.S. Fish and Wildlife Service, or the City, shall conduct studies to make a determination as to what effect, if any, the Kirkwood Powerhouse Project and the Kirkwood Addition would have or have had on habitat for and populations of resident fish species, between

O'Shaugnessy Dam and Early Intake. The studies will include information compiled since 1967. The studies will be conducted over a four-year period; the consequent reports and analyses shall be published by December, 1992. This deadline shall be extended in the event that the U.S. Fish and Wildlife Service determines that because of climatic or other environmental conditions, the results of said studies would result in inaccurate or inconclusive data.

2. If, as a result of the foregoing studies, the U.S. Fish and Wildlife Service preliminarily determines on or after December 31, 1986, that flows in the upper region of the Tuolumne River between O'Shaugnessy Dam and Early Intake should be increased, the City will adjust its minimum releases as set forth in Exhibit A to the document known as "Stipulation for Amendment of Rights-Of-Way for Canyon Power Project Approved by Secretary of the Interior on May 26, 1961 to Fulfill the Conditions Set Forth in Provision 6 of Said Amended Permit", as dated January 31, 1985, (also referred to herein as the "1985 Stipulation") in the following manner. HY-52 cont.

Under Schedule "A" to include the following:

a. Anytime the draft through the Canyon Tunnel exceeds 920 CFS the flow release schedule at O'Shaughnessy Dam will be increased an additional 64 CFS.

b. At any time after May 1st, 15,000 acre-feet will be available to mitigate any deficiency in the existing flow release schedule shown to be required as a result of the studies, as provided for in paragraph 1, above.

c. Increases to the March through July portion of the flow release schedule in addition to those specified in paragraphs "a" and "b" above necessary to protect habitat for or populations of resident fish species in any year the draft through the Canyon Tunnel exceeds 920 CFS.

HY-52 cont.

Under Schedule "B" to include the following:

a. Anytime the draft through the Canyon Tunnel exceeds 920 CFS the flow release schedule at O'Shaughnessy Dam will be increased an additional 64 CFS.

b. At anytime after May 1st 6,500 acre-feet will be available to mitigate any deficiency in the existing flow release schedule shown to be required as a result of the studies, as provided for in paragraph 1, above.

c. Increases to the March through July portion of the flow release schedule in addition to those specified in paragraphs "a" and "b" above necessary to protect habitat for or population of resident fish species in any year the draft through the Canyon Tunnel exceeds 920 CFS.

Under Schedule "C" to include the following:

a. On July 1st if the water storage behind O'Shaughnessy Dam is at or above 210,000 acre-feet (the highest storage reached in 1976), 4,400 acre-feet will be available to mitigate any deficiency in the existing flow release schedule shown to be required as a result of the studies, as provided for in paragraph 1, above.

b. Additional increases to the March through July portion of the flow releases schedule necessary to protect habitat for or populations of resident fish species in any year the draft through the Canyon Tunnel exceeds 920 CFS.

HY-52 cont.

It is understood and agreed that water releases made by the City at Hetch Hetchy provided herein shall remain in the Tuolumne River between O'Shaughnessy Dam and New Don Pedro Reservoir, and the timing of these releases will be such as to coincide with the documented causes for the decrease in the habitat for or populations of resident fish species in the affected stretch of the river. The extent of these releases shall be determined by the U.S. Fish and Wildlife Service, in consultation with the City, Commission staff, appropriate state and federal agencies, and interested members of the public.

3. The four-year study(s) to be conducted shall be as determined by the U.S. Fish and Wildlife Service, in consultation with the California Department of Fish and Game, the U.S. Forest Service and the National Park Service. It is anticipated that the types of fisheries studies to be conducted will include fish population, habitat preference, and IFIM studies. The studies will be conducted by the U.S. Fish and Wildlife Service; the California Department of Fish and Game; or, a private consultant selected by the U.S. Fish and Wildlife Service in consultation with the City, the Commission, and the above state and federal agencies, and with interested members of the public. The U.S. Fish and Wildlife Service shall have the right to undertake these studies itself should it elect to do so. If so directed, the City shall conduct these studies through a private consultant selected by the U.S. Fish and Wildlife Service in consultation with the City, the Commission and the above state and federal agencies, and with interested members of the public. The population and preference studies will be conducted over the next four years, or longer if necessary, as provided for in paragraph 1, above. The IFIM study, analysis and report will be concluded by the end of the fourth year, or as extended if necessary, as provided for in paragraph 1, above. The purpose of delaying the IFIM study toward the end of the fourth year is to allow the techniques associated with the study to reach a more refined level, thereby producing more accurate quantifications. Should the above studies not produce the results anticipated, other necessary studies may be undertaken. HY-52 cont.

4. In the event that the results and analysis of all studies dictate an increase to the present flow regime as determined by the U.S. Fish and Wildlife Service, such an increase shall be implemented by the City, without right to any appeal, administrative hearing or further review, up to the limits set forth in paragraph 2 above, except that any changes to the spring portion of the flow release schedule specified in paragraph 2, Schedules A and B, subpart "c" and Schedule C, subpart "b" shall be afforded such review as provided for in paragraph 5 of this Modification.

HY-52 cont.

5. Both the City and the Department specifically recognize and agree that the issue of changes in the flow release schedule will be studied by the U.S. Fish and Wildlife Service or its designee consistent with the terms of this Modification. In the event that the U.S. Fish and Wildlife Service shall determine that changes to the March through July portion of the flow release schedule specified in paragraph 2, Schedules A and B, subpart "c" and Schedule C, subpart "b" may be necessary based upon these studies, it will recommend to the Secretary of the Interior such changes in the flow release schedule as may be necessary to protect the habitat for or population of resident fish species during the March through July portion of the flow release schedule. Such recommendations shall become part of these provisions, unless the City, within thirty (30) days from receipt of notice of the recommendations, shall file with the Secretary of the Interior, its objections thereto. In such event, at its

request, the City shall be afforded a hearing regarding these objections before a special hearing officer who will render proposed findings of fact. The Secretary, after considering the proposed findings of fact and the record, shall determine what additional flows, if any, shall be required.

6. The City agrees to fund the studies determined to be appropriate by the U.S. Fish and Wildlife Service under the terms of this Modification at a cost not to exceed $200,000, unless otherwise mutually agreed by the parties hereto.

HY-52 cont.

7. In an attempt to enhance park resources and visitor enjoyment, each year within ten days of the completion of the City's March 1 snow survey, the Superintendent of Yosemite National Park ("Superintendent") and the General Manager of the Hetch Hetchy project ("General Manager") shall meet, together with a representative of the U.S. Fish and Wildlife Service.

At the outset of the meeting, the General Manager shall explain whether the City's operating criteria for the Hetch Hetchy project indicate that the year will be a normal water year (as defined by a "Schedule A" year pursuant to the Flow Release Schedule set forth in the 1985 Stipulation), that is, a year when the snow survey indicates that the reservoir will fill and spill by July 1.

Attachment D

O-TRT-DREKMEIER cont.

If such operating criteria indicate that the year will be a normal water year (Schedule A), the above-named persons shall make best efforts to develop a framework for the timing and quantity of releases from Hetch Hetchy Reservoir that will enhance the variability of flows and consider other measures to simulate to the extent possible the natural conditions of the Tuolumne River, and to the extent that such variability and other measures will not affect the City's operating and water requirements.

HY-52 cont.

If the General Manager, at any time, determines that climatic or other conditions require a departure from said framework or Schedules to meet the City's operating and water requirements, the General Manager will convene another meeting of the above-named persons in order to review whatever adjustments to the framework may be necessary. Provided, however, the City will not exceed 920 CFS through the Canyon Tunnel in a non-normal (Schedule B or C) year.

After ten years of operating pursuant to these procedures, the parties, based upon their experiences during this time period, shall meet and attempt to develop supplemental criteria to be incorporated, as an amendment to this Modification, that will establish variances in the release regime sought by the National Park Service, subject to the limits of the City's operating and water requirements and the fisheries requirements as discussed above. This ten year period may be extended for such additional periods as the parties may deem necessary.

No action shall be taken pursuant to this section which will adversely affect the fishery resource protections set forth elsewhere in this Modification. HY-52 cont.

8. It is further agreed that this Modification is solely concerned with the operations of a third generator at the Kirkwood Powerhouse within the Hetch Hetchy Water and Power System as it is presently configured and that the provisions of other Raker Act Stipulations, including condition 6 of the 1985 Stipulation, remain in effect in accordance with their terms and amendments thereto.

IN WITNESS WHEREOF, the City and County of San Francisco has caused this instrument to be executed in the City of San Francisco, California, this 10 day of March. 1987.

General Manager of Public Utilities Commission, City and County of San Francisco
SUBSCRIBED AND SWORN to before me this 10th day of March, 1987.

Secretary, Public Utilities Commission, City and County of San Francisco

HY-52 cont.

FORM APPROVED:

DATE: March 10, 1987

Utilities General Counsel
City and County of San Francisco

DATE: March 10, 1987

Assistant Secretary for Fish and Wildlife and Parks (Sgd) P. Daniel Smith

DATE: MARCH 11, 1987