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January 8, 2014

TO: Commissioner Vince Courtney, President
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THROUGH: Harlan L. Kelly, Jr., General Manager

FROM: Steven R. Ritchie, Assistant General Manager, Water

RE: The Rim Fire – Hetch Hetchy Watershed Effects Report

The Rim Fire – Hetch Hetchy Watershed Effects Report was prepared in response to widespread concerns about impacts to Hetch Hetchy Reservoir water quality following the 2013 Rim Fire. An interdisciplinary team of SFPUC scientists, water system operators, and planners from the Hetch Hetchy Water and Power, Water Quality, and Natural Resources and Lands Management Divisions of the Water Enterprise completed this comprehensive study following field observations during and after the Rim Fire incident. This report is a summary of those scientific efforts, and provides a detailed overview of Rim Fire impacts, both current and anticipated, as well as a comparative study of other fires within the Hetch Hetchy watershed.

Though the 2013 Rim Fire was a significant wildland fire, the 3rd largest in California, ultimately, its impacts within the Hetch Hetchy watershed are expected to be negligible with no impact to water quality. Only 1.8% of the watershed draining to Hetch Hetchy Reservoir fell within the Rim Fire perimeter. Of that acreage within in the fire perimeter, only 8% received moderate to high soil burn severity and 23% received low burn severity. Field evidence indicates that though there is some increase in erosional processes associated with fire affected soil conditions, the net increase in watershed erosion is negligible. The historical record of water quality for the watershed also supports negligible expected impact to water quality.

Though the Rim Fire has had, and will continue to have, impacts on the Hetch Hetchy watershed, the Hetch Hetchy Regional Water System retains the ability deliver high quality drinking water to its wholesale and retail customers. This report will now add to the historical record and assist us in continuing to monitor the impacts of wildland fires on watershed lands.

Attachment

Rim Fire – Hetch Hetchy Watershed Effects

Photo taken September 26, 2013

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1 Executive Summary

The Rim Fire is the 3rd largest wildland fire in California's history at 257,314 acres and the largest in Yosemite National Park's history. Wildland fires are a natural part of the Sierra Nevada landscape and occur nearly every year within the Hetch Hetchy drainage. Approximately 5,080 (7.93 sq. mi) acres of the Hetch Hetchy watershed, or approximately 2% of the Hetch Hetchy drainage, falls within the Rim Fire perimeter. A majority of the affected watershed has been classified with a burn severity of low to no burn. An evaluation by the National Park Service Burn Area Emergency Response team indicates that there will be no significant impacts to water quality and quantity at Hetch Hetchy Reservoir due to the relatively small area within the watershed affected by the fire. A group of field

experts from the SFPUC reviewed historic fire patterns and further evaluated the fire effects, reservoir water quality conditions, and potential increases in erosion due to the Rim Fire. The area within the Hetch Hetchy watershed affected by the Rim Fire falls within the magnitude and footprint of historical fires conditions. Limnological and water chemistry monitoring during the fire found no effect on water quality conditions. Field surveys of soil conditions indicate a decrease in infiltration rates and an increase in hydrophobicity, however the measured conditions fall within the typical range for local soil types. An increase in erosional processes associated with fire affected soil conditions was found, however due to the limited area affected the net increase in watershed erosion is negligible. There are few historical events of impaired water quality at Hetch Hetchy and they are associated with major storm events and have no correlation to changes in the landscape. The study results indicate that the effects of the Rim Fire are expected to be negligible and there will be no impact on water quality.

2 Introduction

On August 17, 2013 an escaped campfire ignited what became known as the Rim Fire. The fire started in the Clavey River drainage along Jawbone Ridge, approximately 2.5 miles upstream of the confluence of the Tuolumne River. The fire perimeter ultimately encompassed 257,314 acres (402 sq. mi) including areas within the Hetch Hetchy, Cherry and Eleanor watersheds (Figure 1.). The Rim Fire is the third-largest in California history and is nearly equivalent in size to the Hetch Hetchy watershed. The fire expanded greatly in size between August 21st and August 30th – from 16,204 acres to 201,795 acres. Within this time period the fire doubled in size on August 22nd (53,829 to 105,622 acres). The rapid expansion was due to remote, steep terrain, extremely dry fuels, and windy conditions which led to difficult firefighting conditions. Expansion of the fire slowed as it met the fire retardant barriers and large fire breaks on the north and south flanks. Progression eastward (in the vicinity of Hetch Hetchy, Cherry Reservoir and Lake Eleanor) also slowed as the fire encroached on areas with lower canopy densities, less available fuels and increased exposed granite bedrock. The fire lines began to hold the north and south flanks near August 31st, while a majority of the east flank was allowed to reach natural granite fire breaks. Weather conditions in mid-September and a rain event on September 21st slowed the growth of the fire towards the natural eastside fire breaks which led to continual postponement of the forecasted containment date. The fire was considered contained on October 24th and as of October 25th over $127 million was spent on firefighting costs.

2.1 Post Fire Response

The U.S. Forest Service (USFS) and the National Park Service (NPS) convened a Burn Area Emergency Response (BAER) Team to assess post-fire conditions and address emergency stabilization issues prior to the onset of the winter season (see Appendix 1). Due to differences in land management objectives, a BAER team was established for each agency. The two teams worked together performing field and modeling evaluations but developed their own recommendations for each of their administration areas and specific values at risk. The USFS team produced a series of Specialist Reports (Appendix 1a-1h) which identify values at risk due to fire related impacts. The focus of BAER recommendations are on protection of life and property, including roads, buildings, water quality, trails, campgrounds, and private properties. The team developed recommended treatments to mitigate the impacts. These recommendations were forwarded to the Regional and National level agency offices for approval and funding. Among the projects funded as a result of the Rim Fire are HAZMAT cleanup, hazard tree clearing, trail closures, preparation of roads for winter (culvert replacement and removal, floatable clearing, energy dissipaters, ditch pulling, re-grading, rolling dips, and re-signing roads), repair of fire lines, and erosion control measures. The USFS BAER team has proposed two interim funding requests totaling over $9 million.

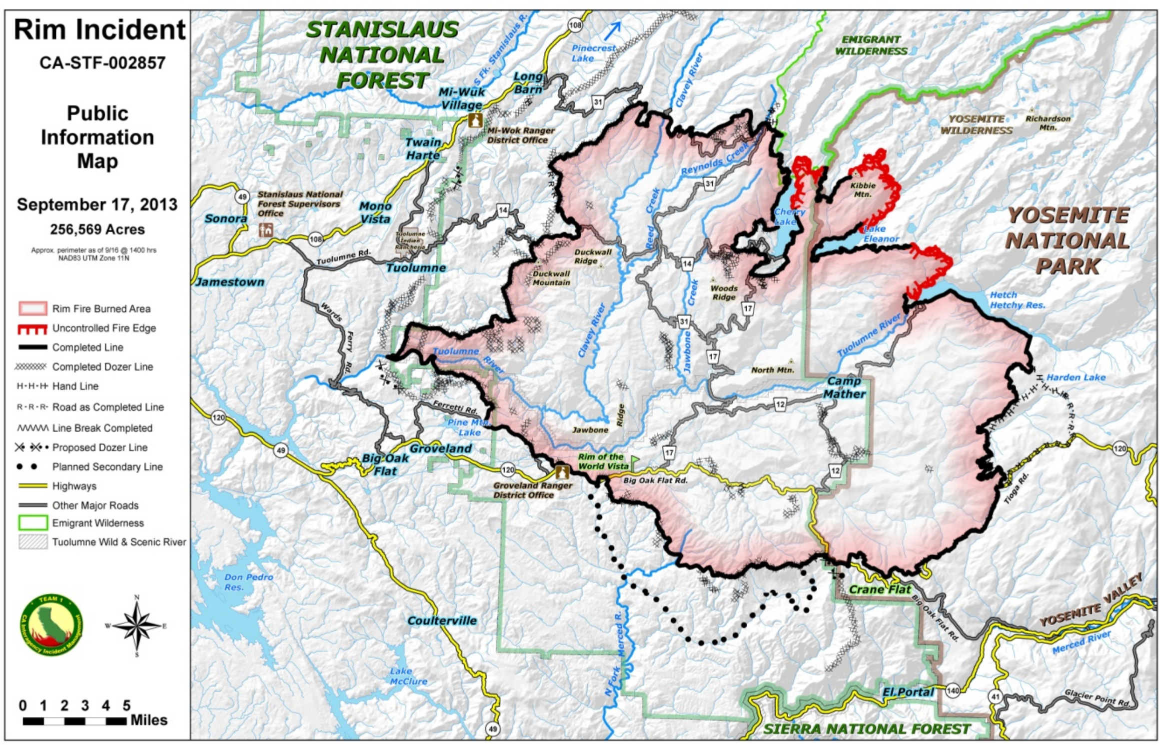

Figure 1: Public Information Map provided by the Rim Fire ICS.

The NPS BAER Team report (see Appendix 1i) addresses issues within Yosemite National Park. During the initial phase of the NPS BAER Team efforts identified critical values at risk included water quality at Hetch Hetchy Reservoir, housing in the Hetch Hetchy compound, and Mather Camp. The identified values at risk were then evaluated to assess the potential risk based on field surveys. The NPS BAER team relied primarily on field experts with little emphasis on modeling results generated by the joint BAER team, due to concerns about model calibration. While numerous resources of interest are discussed in the report, the main interest to the SFPUC is the water quality and hydrology impacts at Hetch Hetchy Reservoir. The NPS BAER team report summary emphasized little to no risk of fire effects to water quality at Hetch Hetchy Reservoir:

"Only 1.8% of the watershed draining to Hetch Hetchy Reservoir falls within the Rim Fire perimeter. Eight percent of this area (0.14% of the watershed) received moderate to high soil burn severity, and 23% (0.41% of the watershed) received low soil burn severity. The remaining area within the fire perimeter was either unburned or received very low soil burn severity. Given the highly dispersed nature of the burn within the watershed and very small amounts of moderate and high soil burn severity, risk to Hetch Hetchy Reservoir from increased post-fire watershed response and erosion is negligible to low."

Wildfires present a number of risks to water quality (Appendix 2). A supplemental evaluation of fire conditions and impacts on the Hetch Hetchy watershed was of interest to the SFPUC. An SFPUC inter-division group of specialists was established to:

- Observe and report on the fire activity in the Hetch Hetchy watershed
- Evaluate on the ground post-fire conditions
- Measure and monitor water quality conditions in the reservoir and monitor for fire related impacts
- Assess potential increases in erosion and sediment transport
- Review Hetch Hetchy watershed fire history

This document summarizes the findings of the specialist team; the individual specialists' reports are included as appendices.

3 Field Observations

3.1 Rim Fire within the Hetch Hetchy Watershed

Approximately 5,080 acres of the Hetch Hetchy watershed lies within the Rim Fire perimeter (Figure 2). Burn severity was classified by the BAER team using analysis of satellite data validated by field observations (for further review see

Appendix 3). A majority of this area is classified as unburned/very low severity (3,560 acres), with smaller areas classified as low burn severity (1,160 acres), moderate burn severity (300 acres), and high burn severity (60 acres). Only 0.5% of the total Hetch Hetchy watershed has low or greater burn severity.

On the ground observations were made during the fire and post-fire to evaluate the severity, extent and potential impact of the burn. Observations included visual evaluation, hydrologic field measurements, limnology profiling, chemistry evaluation of water samples, and field validation of burn severity mapping.

3.2 Fire Observations

The SFPUC team made five trips to Hetch Hetchy Reservoir to observe fire conditions, extent, and severity (August 30, September 5, September 11, September 25 and September 26). These site visits are described in detail in Appendices 4, 5, 6 and 7. Active fire conditions were observed during the initial site visits on August 30 and September 5th. The fires were described as spotty and active mainly in the understory, burning ground duff and dead, downed debris. As the fire progressed, understory burn became more widespread especially in areas on the south shore east of Kolana Rock. The overstory canopy was not greatly affected along the south shore area (Figure 3).

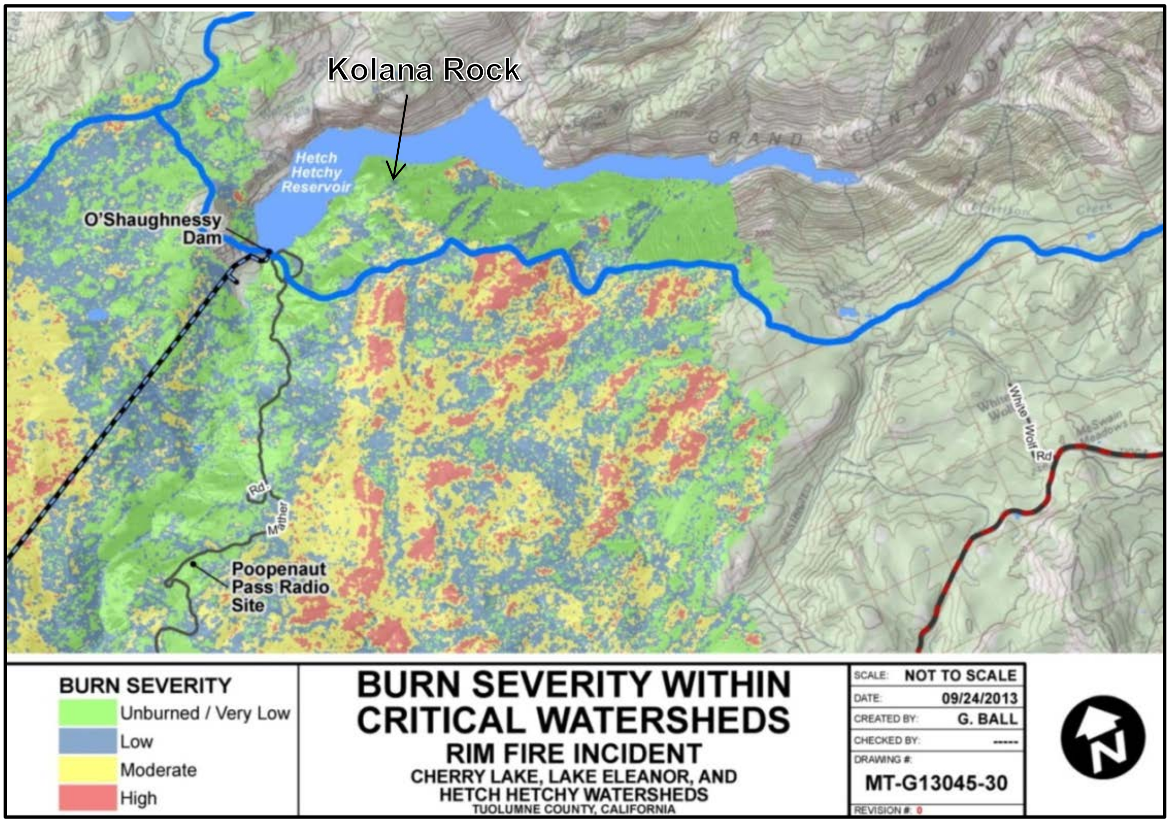

Figure 2: Burn severity map (full version)

Figure 3: Understory burn along the south shore of the reservoir (September 17, 2013).

Active fire conditions also existed on the north side of the lake along the Beehive/Vernon Lake trail during the August 30 and September 5 surveys. This area was affected by mainly low intensity understory burn. There is a subsection of this area classified by the BAER team as having high burn severity (Figure 2). Overstory and understory of this area were both affected by the fire (Figure 4). This area is well above the reservoir and the toe of the slope terminates at a granite outcrop, which will keep potential impacts isolated from the reservoir.

The BAER burn severity map describes the area within the Hetch Hetchy watershed as a total of 5,080 acres, with 70% within the unburned/very low, 23% low, 6% moderate, and 1% high. Misclassification is not uncommon in the BAER burn severity mapping due to the infeasibility in field validating remotely sensed data at all locations. Field observations suggest that the overall burn severity was lower than that identified in the BAER team analyses.

Figure 4: Isolated high burn intensity slope on the north side of Hetch Hetchy Reservoir

3.3 Post Rain Event Observations

September 21st brought the first rain event to the area since the spring. Precipitation totaled 0.77 inches in the Hetch Hetchy Reservoir area. The precipitation fell over a 6 hour period and had a peak 15 minute intensity of 0.6 inches per hour. Storms of this size, intensity and duration are common in the fall and spring at Hetch Hetchy Reservoir. Observations by field staff during and following the event noted no streamflow generation in the small channels adjacent to the reservoir. Due to the lack of streamflow generation there was little possibility of stream borne ash and sediment transport to the reservoir during this event.

On September 25th (south shore, Appendix 7) and 26th (north shore), additional field observations of the post-fire conditions were made. Isolated surface rilling

(Figure 5) was noted on slopes on both aspects due to the September 21st rain event. The rills were initiated at the toe of exposed granite outcrops which contributed surface flow to the upper portion of the soil covered slopes. The flow contribution rate from the granite outcrop exceeded the soil infiltration rates, likely exacerbated by fire induced decreases in soil infiltration rates and increased soil hydrophobicity. The rills did not appear to accumulate additional water downslope as indicated by the lack of rill expansion. The rills were incised 4 to 6 inches and the majority of the material was pushed laterally rather than down slope. The resulting sediment deposits were 5 to 10 cubic feet of material at the base of the hillslope. The lack of observed historical rill scars indicates that the fire conditions may have contributed to the rill formations. The areas around the reservoir with the potential to have rilling is minimal due to the unique topographic features and position necessary to generate concentrated surface runoff to fire affected hillslopes.

Figure 5: Rill formation (left) on the North side of Hetch Hetchy and subsequent sediment deposit (right) on the Beehive/Vernon Lake trail.

3.4 Hydrologic Field Measurements

Wildland fire can affect the hydrologic qualities of burned soils. The significant soil characteristics which can be affected by fire are the infiltration rate (the speed that soil allows water to enter the soil profile) and hydrophobicity (the impediment of water to enter the soil). Infiltration rates can be reduced after a fire due to pore clogging by ash and other debris. Increased hydrophobicity results from chemical changes in soils due to high intensity heat and flame exposure. In addition the removal of vegetation results in less water being lost to evapotranspiration and thus increases overall soil moisture during precipitation events, resulting in increased runoff. Since a majority of the overstory vegetation was unaffected by the fire, there is no indication that there will be a drastic change in evapotranspiration. However, reduction in the infiltration and increases in hydrophobicity can result in increased overland flow and surface erosion.

Field measurements of infiltration and hydrophobicity were made within the fire perimeter at Hetch Hetchy Reservoir as well as other locations to evaluate the potential changes in hillslope hydrology (Appendix 8). The infiltration and hydrophobicity measurement sample set is small, making it difficult to generalize overall conditions, however measurements (Table 1) show that infiltration rates appear to be relatively lower in burned areas when compared to unburned areas. The rates measured in the burned and unburned areas do however fall within the range typically seen for soil types present within the Hetch Hetchy watershed. In addition, the burned area infiltration rates measured (3.0 to 19.3 inches per hour) are higher than typical rainfall intensities (0 to 1 inches per hour), suggesting that burned soils will have ample capacity to absorb most rainfall events, reducing the likelihood of damaging erosion.

Table 1: Infiltration and hydrophobicity measurements.

Location	Burn Intensity	Infiltration Rate	Hydrophobicity	Soil Texture	Soil Structure
South Shore	Light	7.6 in/hr	Extreme	Loamy Sand	No Soil Structure
North Shore (1)	High	7.7 in/hr	Extreme	Sandy Loam	No Soil Structure
North Shore (2)	High	3.0 in/hr	Extreme	Sandy Loam	No Soil Structure
No Burn (1)	None	19.3 in/hr	High/Extreme	Sandy Loam	Fine Granular
No Burn (2)	None	12.1 in/hr	High/Extreme	Sandy Loam	Fine Granular

Hydrophobicity tests were also performed at each of the sampling sites. The test method is the application of water droplets onto the soil surface and timing the period for the resulting water beads to be absorbed into the soil. Observations at the unburned locations displayed high to extreme hydrophobicity, indicating that soils are naturally hydrophobic. The natural hydrophobicity can be due to dryness of the soil or the accumulation of surface organic material. The areas affected by fire showed near the same level of hydrophobicity as the unaffected areas. Fire can increase hydrophobicity by breaking down organic matter which can fill empty soil pore spaces. In the field observations there is only a slight change in hydrophobicity as compared to pre-fire conditions.

The hydrologic soil properties are expected to recover to pre-existing conditions over time (1 to 5 years). Wetting and drying cycles, vegetation growth, flushing via precipitation and other processes will reduce hydrophobicity and increase the infiltration rates to pre-fire conditions. This will hold true in the Hetch Hetchy watershed since the soil structure and the soils’ ability to support vegetation has not been affected.

3.5 Water Quality Monitoring

Water quality throughout the regional water delivery system was monitored during the Rim Fire via the SCADA system, field observations, continued routine sampling, and supplemental sampling to verify that water quality remained unaffected. During the initial periods of the fire, the SCADA system provided real-time observations across the regional system from O'Shaughnessy Diversion Tunnel to Alameda East. However, due to loss of power and communications, the SCADA system partially failed on August 22nd disrupting real-time observations at O'Shaughnessy Diversion Tunnel and Early Intake. Normal SCADA monitoring continued at Priest Reservoir and all downstream locations. Routine grab samples and supplemental reservoir sampling provided direct operational knowledge of water quality conditions. Supplemental sampling efforts included additional limnology and water chemistry sampling trips on Hetch Hetchy Reservoir.

3.5.1 SCADA System

Water quality parameters are monitored in real-time through the SCADA network (Table 2). Turbidity is a first line indicator of water quality and is measured at locations throughout the SFPUC water delivery network. While real-time turbidity monitoring at O'Shaughnessy Dam was interrupted by the fire, throughout the event and through October 2013, aqueduct turbidity remained in the normal operating range of 0.2 to 0.5 NTU range at all downstream monitoring sites. There were no observed shifts or abrupt changes in any of the other parameters monitored by the SCADA network attributed to the Rim Fire.

Table 2: Parameters monitored within the SCADA network

Location	Turbidity	pH	Temp.	Conductivity	UV 254[1]	Chlorine	Fluoride
HH Headwater[5]	x						
OSH Diversion Tunnel	x				x[2]		
Kirkwood	x				x[2]		
Priest Mtn Tunnel	x						
Priest Gate Tower	x						
West Portal	x	x					
Moccasin Gate	x				x		
Oakdale Portal Valve House	x	x	x				
Albers Road Valve House	x	x	x				
San Joaquin Valve House	x	x	x				
Tesla UV Valve House	x	x	x	x			
Tesla Treatment Facility Compliance	x	x	x	x			
Tesla Treatment Facility Pre-UV					x		
Tesla Treatment Facility Coast Range Tunnel	x	x	x	x		x	x
Thomas Shaft[3]	x	x	x		x	x	
Alameda East	x	x	x	x[4]		x	x

Notes:

1. UV254 for OSH, Early Intake, and Moccasin is measured on the small water system supplies. However, OSH and Early Intake were not accessible.
2. OSH and Kirkwood data unavailable until access was restored (11/21/2013 and 10/22/2013, respectively).
3. Thomas Shaft unavailable until sample pump is repaired.
4. Unreliable.
5. Headwaters are monitored by USGS instruments at waterdata.usgs.gov/ca/nwis/uv/?site_no=11274790

3.5.2 Routine Sampling

Routine weekly and biweekly sampling continued from Priest Reservoir and all downstream locations throughout the event to ensure the system remained within normal operating parameters (Table 3). All routine analyses remained normal.

Table 3: Routine Grab Samples analyzed by Moccasin and Millbrae SFPUC labs

Location [LIMS ID]	**Parameter**	**Frequency**
O'Shaughnessy Diversion Tunnel	Total and fecal coliform density by MTF	Mondays
[OSH_DIV_TUNNEL]	Total and E. coli coliform density by Quanti-Tray	Mondays and Thursdays
Kirkwood Powerhouse Raw	Total and fecal coliform density by MTF	Mondays
[KIRKWOOD_PH_RAW]	Total and E. coli coliform density by Quanti-Tray	Mondays and Thursdays
Mountain Tunnel [MT_PRIEST_FA]	Total and fecal coliform density by MTF	Mondays
Priest Gate	Total and fecal coliform density by MTF	Daily, except holidays
[PRIEST_R_FA]	Total and E. coli by QuantiTray	Daily, except holidays
West Portal [WEST_P_FA]	Total and fecal coliform density by MTF	Mondays
Moccasin Gate	Total and fecal coliform density by MTF	Daily
[MOC_TOWER_FA]	Total and E. coli by QuantiTray	Daily
	Total and fecal coliform density by MTF	Daily, except holidays
	Lab turbidity	Daily
Tesla Portal	Field temperature	Daily
[TESLA_PORTAL_FA]	Metals: Ca, SiO2, Fe, K, Mn, Al, Cu, Zn	Weekly
	Chemistry: alkalinity, chloride, conductivity, hardness [Ca and total], pH, and TOC	Weekly
	Crypto and Giardia	Biweekly

3.5.3 Supplemental Monitoring

Media coverage of the Rim Fire emphasized potential threats to the Hetch Hetchy water supply and since the Rim Fire had disrupted SCADA communications there was no real-time monitoring of turbidity at O'Shaughnessy Dam. A supplemental monitoring plan was implemented to definitively address concerns regarding possible water quality impacts from the Rim Fire, including ash deposition on the reservoir. The supplemental monitoring consisted of field inspections, comprehensive chemistry sampling, and limnology profiles.

Background data on reservoir conditions are available from the August 16th routine limnology. Supplemental monitoring (Table 4) was performed to verify water quality within the reservoir. This included comprehensive chemistry analysis at Mountain Tunnel (approximately 12 hours downstream of the reservoir) on August 28th in lieu of direct reservoir samples.

Staff was able to access the reservoir beginning August 30th (Appendix 9). Supplemental reservoir monitoring occurred on September 5th, September 11th and September 25th. The monitoring locations are shown in Figure 6.

Table 4: Supplemental monitoring summary. River Mile indicates the distance along the Tuolumne River from its confluence with the San Joaquin River.

Date	Locations	Sampling
8/16	Hetch Hetchy	Routine limnology
8/28	Mountain Tunnel at Priest	Chemistry
8/30	Hetch Hetchy Reservoir at the dam at River Mile (RM) 117.5: surface, 30', 180', and 285' depths.	Chemistry at the dam. Limnology at the dam and by river mile.
9/5 & 9/11	Mountain Tunnel at Priest; Hetch Hetchy Reservoir at 30' depth at RM117.5, RM120, RM122, and RM124.	Limnology at the dam and by river mile. Chemistry at Mountain Tunnel and at Hetch Hetchy by river mile.
9/25	Hetch Hetchy Reservoir at 30' depth at RM117.5, RM120, RM122, and RM124.	Routine limnology as well as Sonde profiles

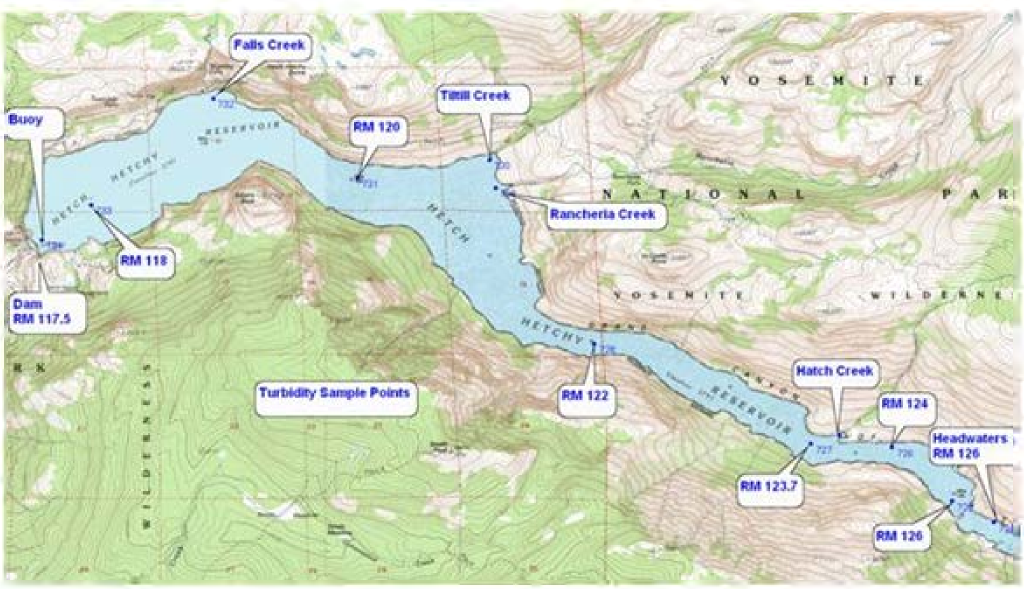

Figure 6: Sampling locations

3.5.3.1 Water Chemistry

A wide range of analytes were evaluated in the comprehensive chemistry sampling (Table 5). These include general chemistry, nutrients, organics, polynuclear aromatic hydrocarbons (PAHs), metals, and radionuclides were collected. Additionally, flavor profile analyses (FPAs) were performed near the O'Shaughnessy Dam (at the surface, at 30 feet, 180 feet and 285 feet), at Alameda East, and at Irvington Portal to assess flavor of treated water upon delivery to the Bay Area on August 30th, September 5th and 12th, 2013. Additional FPAs were conducted at Irvington Portal on September 19th, September 30th, and October 3rd.

All monitored parameters were normal (see results in Appendix 10). There were no measureable changes over the sampling period detected by the comprehensive chemistry sampling. The results, by type of parameter, are summarized below.

- *General chemistry:* All general chemistry parameters (e.g., alkalinity, pH, hardness) were near historic levels with no significant change over the sampling period.
- *Nutrients:* All nutrients (nitrogen compounds, orthophosphate, and sulfate) were non-detect or near detection levels with no significant change over the sampling period.
- *Organics:* Organic measurements of total organic carbon (TOC) and dissolved organic carbon (DOC) were near historic levels with no significant change over the sampling period.
- *Polynuclear Aromatic Hydrocarbons (PAHs):* With one exception, there were no detections of PAHs. The one trace detection of naphthalene at 0.25 μg/L at River Mile 120 on 9/11 was likely due to sampling or laboratory sources.
- *Metals:* All metals were near historic levels with no significant change over the sampling period.
- *Radionuclides:* All gross alpha measurements were non-detect (<3 pCi/L).
- *Flavor Profile Analyses (FPAs):* FPAs were conducted near O'Shaughnessy Dam, Alameda East, and Irvington Portal. A medium intensity (2 on a scale of 0 to 5) fishy odor was detected near O'Shaughnessy Dam on 8/30 at the 285' depth. This is frequently an anoxic location and odor detection was not unexpected. No odors of any intensity have been detected at Alameda East (8/30) or Irvington Portal (9/5 to 10/3).

Table 5: Constituents for analysis

Parameter	Bottle Type	Sample Hold Time
Chemistry:		
Conductivity, pH[1], Alkalinity, Total Hardness, Ca Hardness	1 L Plastic	14 days except pH ASAP and conductivity 24 hrs
Temperature	Field	ASAP
Dissolved Oxygen[2]	Field	ASAP
TDS	1 L Plastic	7 days
TSS	1 L Plastic	7 days
Particle Size Distribution	(2) 1 L Plastic bottles	7 days
Color	500 ml Plastic	24 hrs
Flavor Profile Analysis[2]	1 L Amber Glass	ASAP
Metals[3]:		
Al, Fe, Cd, Cu, Pb, Mn, Ni, Zn, Hg, Se, As, K, Ca, Si	1 L Plastic	6 months except Hg is 28 days
Nutrients:		
NO3, NO2	250 mL Plastic	48 hrs
NH3	250 mL Plastic	24 hrs
TKN	250 mL Plastic, H_2SO_4 Preserved	28 days
Phosphate, Orthophosphate, Sulfate	250 mL Plastic	48 hrs except sulfate is 28 days
Organics:		
TOC	(2) 40 mL VOA Amber, H_2So_4 Preserved	28 days
DOC	(2) 40 mL VOA Amber, Unpreserved	28 days
PAHs	(2) 1 L Amber Glass	7 days
Radionuclides:		
Gross Alpha particle activity	500 mL HDPE plastic and 125 mL HDPE (125 mL is HNO_3 preserved)	6 months

Table Notes:

1. pH is measured in the field and in the lab. Dissolved oxygen is specific to the limnology profile.
2. FPA done typically at Irvington Portal and periodically at Hetch Hetchy Reservoir.
3. EPA 200.7 and 200.8 for metals plus cold vapor method for Hg.

3.5.3.2 Limnology Observations

Limnology profile observations (Appendix 11) include depth profiles using an YSI sonde which measures water temperature, pH, specific conductivity, total dissolved solids, dissolved oxygen, and oxidation reduction potential. Grab samples to measure turbidity were also made at the surface, in the epilimnion, in the hypolimnion and near the bottom of the reservoir. Of the data collected of specific interest is the turbidity, as an indication of any change due to ash or sediment deposition in the lake (Figure 7). The pH measurement is an indication of increased ash (Hetch Hetchy water has very low alkalinity and ash leachate would increase pH) (Figure 8).

Limnological profiles were completed near the Dam and River Miles 120, 122 and 124. Observations of conditions prior to the fire indicated seasonally increasing anoxic conditions at depth in the reservoir so this condition is not attributed to the Rim Fire. The measurements prior to and during the fire, indicate no change in the water quality conditions of the reservoir. Turbidity at Priest Reservoir monitored by SCADA throughout the event remained unaffected and in the normal operating range.

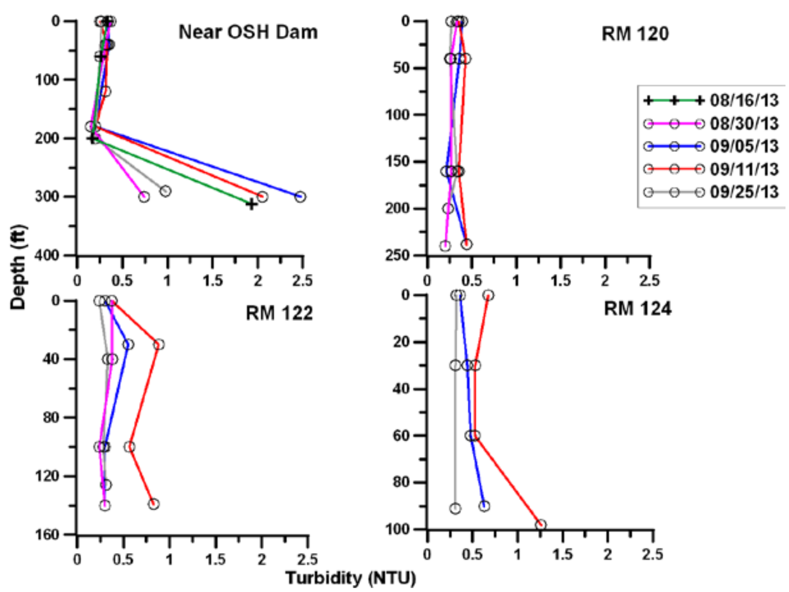

Figure 7: Turbidity profiles in Hetch Hetchy Reservoir prior to and during the Rim Fire.

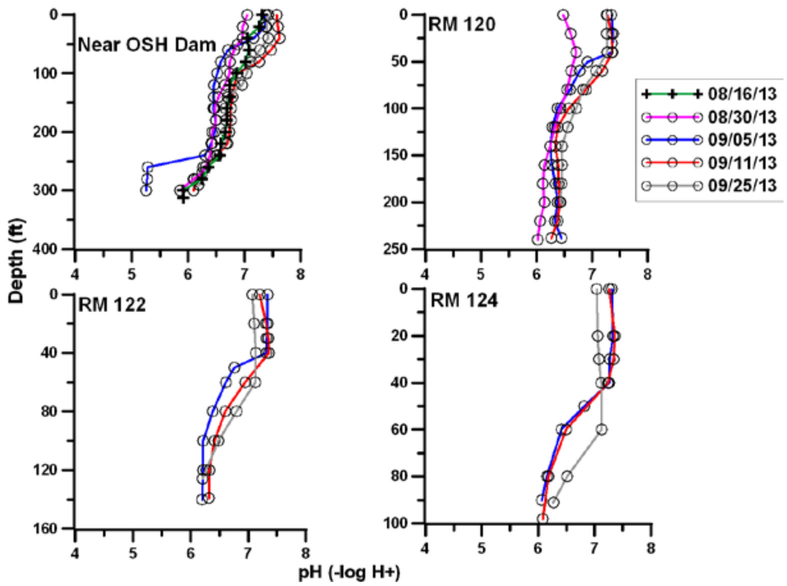

Figure 8: pH profiles in Hetch Hetchy Reservoir prior to and during the Rim Fire.

4 Sediment/Erosion Modeling

4.1 Sediment Delivery Rates

Wildfires impact sediment delivery by increasing both erosion rates and the potential for debris flows. Debris flows, a type of landslides, are large-scale events in which a thick layer of sediment detaches from a hillside and moves a significant distance downhill. The BAER team found no increased risk of debris flow in the Hetch Hetchy watershed due to the Rim Fire.

Hillslope erosion is the process of breakdown and removal of sediment from the land surface; it is a localized series of processes such as surface water detaching and transporting material, rill development and expansion, among others. Eroded sediment tends to travel a short distance and deposit in small depressions or where the hillside becomes less steep. Erosion that occurs directly uphill from Hetch Hetchy Reservoir has the potential to increase sediment delivery to the reservoir. The following section describes erosion rate modeling for hillslopes adjacent to the reservoir.

4.2 ERMiT Modeling

Increased sediment delivery to Hetch Hetchy Reservoir was modeled using the online Erosion Risk Management Tool (ERMiT) (Appendix 12), which was used by the BAER team. ERMiT allows users to predict the probability of a given amount of sediment delivery to the base of a hillslope following wildfire due to erosion. Model inputs include climate data, soil texture, rock outcrops, vegetation type, hillslope length and gradient and soil burn severity class. Ten sites along the

Hetch Hetchy shoreline were modeled, assuming high, moderate, and low burn severity. For the high burn severity scenarios, the model predicted an average 4.3 times increase in sediment erosion. Under the moderate and low severity scenarios, the model predicted an average 3.5 times and 2.6 times increase, respectively (Table 6).

The BAER team assigned 62 acres in the Hetch Hetchy drainage as high burn severity, 300 as moderate burn severity, and 1162 acres as low severity. This leaves 286,476 acres, or 99.5% of the watershed as unburned, which would expect no increase in sediment transport. If each burn classification is weighted by area (Equation 1) there is a 1% increase in total (450 mi^2) potential sediment erosion over the Hetch Hetchy drainage basin, which would have negligible impact on water quality.

Table 6: BAER burn classified areas and predicted percent increase in sediment erosion (relative to pre-burn conditions).

BAER Burn Classification	Predicted Sediment Transport	Area (acres)
No Burn	100%	286476
Low Burn	263%	1162
Moderate Burn	357%	300
High Burn	429%	62

Equation 1: Equation for area weighted increase in sediment delivery

$$\Delta_{HHSed} = \frac{\left(\Delta_{noburn} A_{noburn} + \Delta_{lowburn} A_{lowburn} + \Delta_{medburn} A_{medburn} + \Delta_{highburn} A_{highburn}\right)}{A_{HH}}$$

5 Hetch Hetchy Watershed and Fire History

Wildland fire has an active history in the Hetch Hetchy watershed, with typically at least one fire occurring every year in or on the periphery of the watershed. Historical fires vary vastly in size from isolated ignition of down debris or trees due to lightning to the largest recorded fire of 12,116 acres – the 1948 Rancheria Fire (which was human caused). Recent fire history was reviewed by the Water Quality Division in 2010 (Appendix 13) and updated by the Watershed Forester (Appendix 4). Table 7 below summarizes the fires in the watershed greater than 1,000 acres. The recorded fire history since 1931 identifies 32 fires with areas greater than 100 acres and 28 fires between 10 and 100 acres. Annual total area affected by fire is typically low, compared to the 287,000 acres of the Hetch Hetchy drainage (Figure 9).

Table 7: Fires greater than 1,000 acres within the Hetch Hetchy Watershed, ranked by size on the left and ranked by year on the right.

Acres	Year	Name	Year	Name	Acres
12116	1948	Rancheria Mt	1948	Rancheria Mt	12116
8861	1999	LeConte	1960	Mt. Gibson	1472
5087	2013	Rim Fire	1978	N/A	1553
3755	1988	East LeConte	1985	Pate Valley	1762
3634	1996	Ackerson	1988	East LeConte	3755
1937	2004	Hetchy	1991	Frog	1582
1762	1985	Pate Valley	1996	Ackerson	3634
1582	1991	Frog	1999	LeConte	8861
1553	1978	N/A	2004	Hetchy	1937
1530	2010	Slope	2006	Frog	1098
1472	1960	Mt. Gibson	2009	Wildcat	1293
1293	2009	Wildcat	2010	Slope	1530
1098	2006	Frog	2013	Rim Fire	5087

A significant portion of the historical fire perimeters have overlapping areas (Figure 10). The majority of the larger fires are isolated to the lower elevations, staying in the vicinity of the reservoir. The historical fire record shows at least 418 fires of less than 1 acre, generally confined to higher elevations. The lack of large fires spreading across the landscape and the numerous small fires which do not spread exemplifies the watershed's fire limiting characteristics. Higher elevation areas have sparse forest canopy densities and large areas of exposed granite. These two factors result in a discontinuity of forest vegetation which reduces the ability for fires to spread quickly and become widespread. This has resulted in only about 15% of the entire watershed area being affected by fire activity in the past 82 years of recorded fire history.

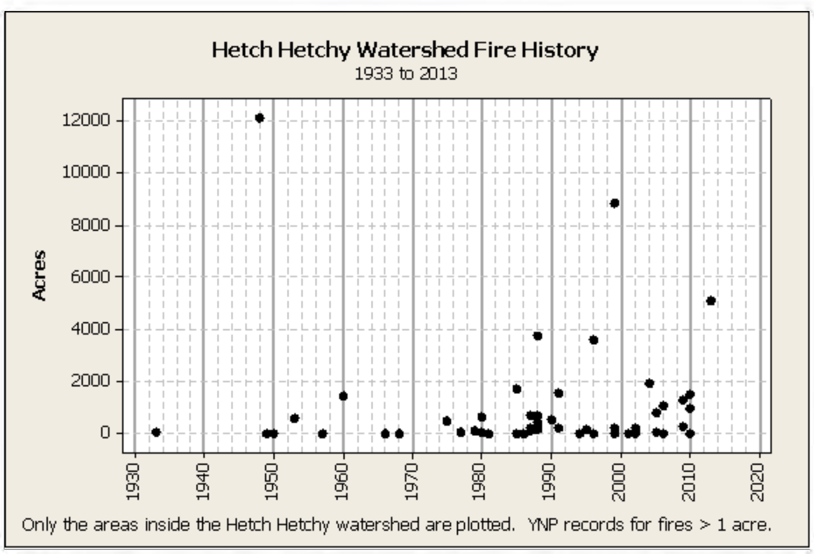

Figure 9: Recorded fires greater than 1 acre Hetch Hetchy Watershed.

The two most recent significant fires in the watershed are the 2010 Slope Fire and the 1996 Ackerson Fire (Appendix 13). The Ackerson and the Rim Fire have overlapping fire perimeters. Both fires extend along the south shore of the reservoir and resulted in understory burn. Effects on water quality due to the Ackerson Fire are discussed in the 1996 Annual Update Report for Hetch Hetchy Watershed Events and Activities (Sebastiani et. al, 1996). The authors summarize the impacts – "long-term effects to water resources at Hetch Hetchy, Lake Eleanor, and Cherry Lake are not expected". They also note that "The Hetch Hetchy Reservoir watershed is largely bedrock controlled and sediment erosion limited". This is the key limiting factor for fire or other natural occurrences to impact water quality in the Hetch Hetchy basin.

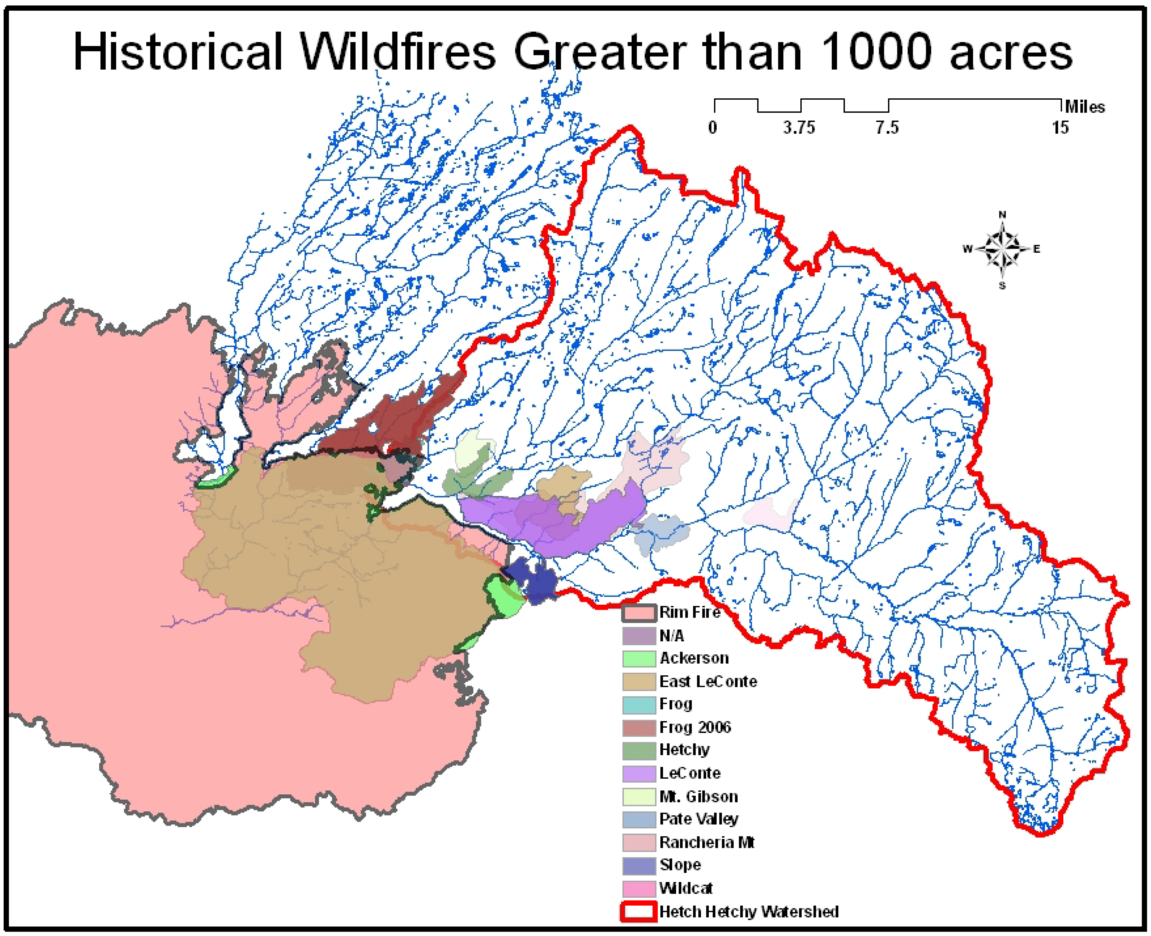

Figure 10: The fire history in the Hetch Hetchy watershed

6 Historical Water Quality

Water quality impairment in Hetch Hetchy Reservoir is uncommon in the historic record. The high water quality and clarity of runoff in the Hetch Hetchy watershed (and in the reservoir) is due to limited sediment sources, preventive watershed management, lack of pollutants, and the overall wilderness aspect of the watershed. These characteristics result in an ideal source for water supply.

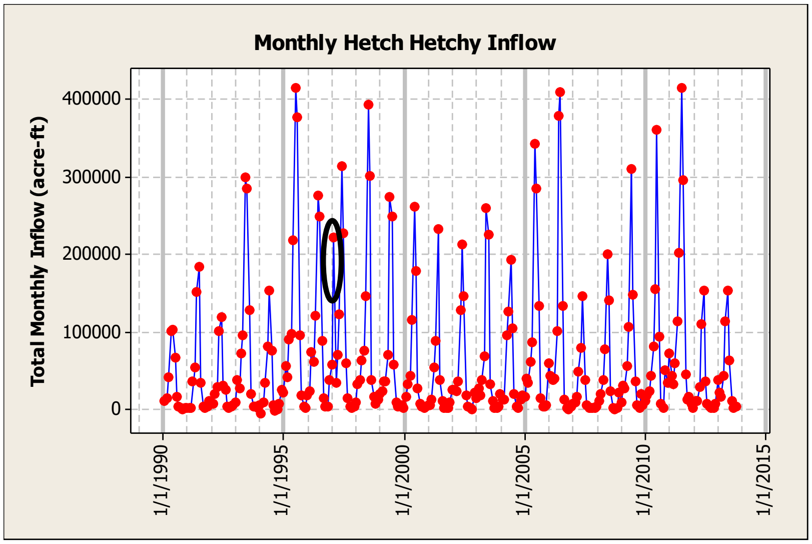

Figure 11: Time series of inflows into the Hetch Hetchy Watershed. Note: circle shows the January 1997 storm.

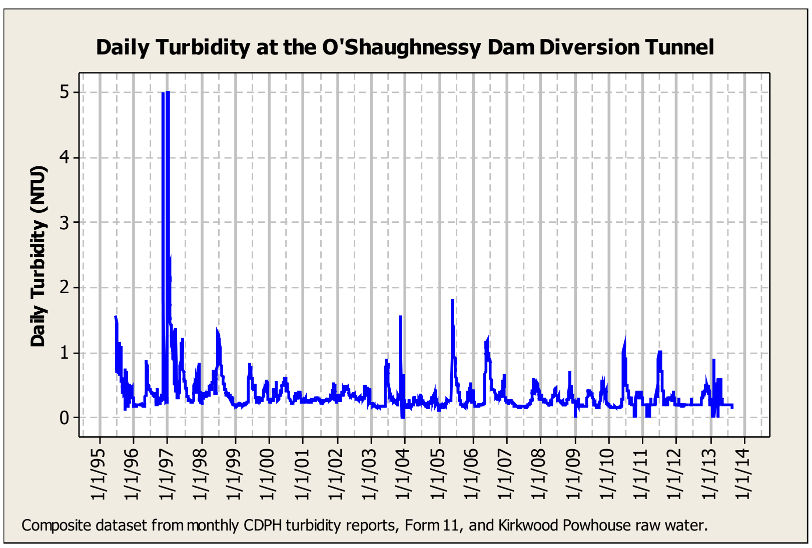

Figure 12: Time series of daily average turbidity, as measured at the O'Shaughnessy diversion tunnel.

The water turbidity at the O'Shaughnessy Diversion Tunnel is typically measured in the range of 0.15 to 0.5 NTU. The turbidity varies seasonally based on limnological conditions (such as anoxic conditions and seasonal reservoir turnover) and runoff and storm effects (Figure 11 and Figure 12). During higher snowmelt runoff periods, turbidity may increase but has not exceeded 1.6 NTU (Table 8). Fall and winter storm events with significant flows can generate increases in turbidity.

Table 8: Elevated turbidity events in Hetch Hetchy Reservoir.

Time	*Comment*	*Peak Turbidity*
Summer 1995	High snowmelt year	1.57 NTU on 7/1/95
Nov-96	Fall Storm	> 5 NTU on 11/22-11/23/96
		> 1 NTU on 11/22-11/24/96
Jan-97	100-year event	> 5 NTU on 1/3-1/10/97
		> 2 NTU on 1/2-1/28/97
Spring 1998	High snowmelt year	1.31 NTU on 6/30/98
Late Nov 2003	Winter storm	1.57 NTU on 11/24/03
Spring 2005	High snowmelt year	1.40 NTU on 6/1/05
Spring 2006	High snowmelt year	1.01 NTU on 6/26/06
Spring 2010	High snowmelt year	1.10 NTU on 6/23/10
Spring 2011	High snowmelt year	1.00 NTU on 6/26-7/16/11

Hydrodynamic pathways through the reservoir were conceptualized by monitoring reservoir conditions during the 2010, 2011 and 2012 snowmelt runoff seasons. Turbidity and temperature profiles were measured longitudinally in the reservoir along the historic river thalweg to identify plunge points, insertion elevations, and mixing of inflow water with the ambient reservoir water. Extensive mixing of the two sources occurs, inherently diluting the signal of inflow water quality. During each snowmelt runoff season, inflow turbidities were above the ambient reservoir level and reached 6 to 20 NTU as measured by grab samples and the USGS headwaters gaging station. As the water traveled through the reservoir, the turbidity signal dampened, which resulted in 1.6 NTU (2010) and 1.0 NTU (2011) peak turbidity measured at the dam.

Two events in the historical turbidity record (archives available since July, 1995) have interrupted the delivery of Hetch Hetchy water to the water supply system (Figure 12). The first was two fall storms over an 8 day period (9.35 inches of precipitation) in November 1996 which resulted in a brief, but significant, increase in turbidity as measured at the O'Shaughnessy Diversion Tunnel. The reported peak turbidity was near 20 NTU. Turbidity conditions quickly decreased and turbidity exceeded 2 NTU for only two days.

The second event was a large rain-on-snow event driven by an "Atmospheric River" (or Pineapple Express) on December 30, 1996 thru January 6, 1997 (9.59 inches of precipitation in a 5 day period) which resulted in a 100 year flow event at Hetch Hetchy Reservoir. This high flow event resulted in turbidities in the reservoir exceeding 5 NTU and the delivery of Hetch Hetchy water was interrupted for a sustained period. The turbidity was above 5 NTU from January 3rd through January 10th. Turbidity remained above 2 NTU until January 29th and fell below 1 NTU on March 7th.

The 1996 Ackerson Fire (Figure 10, Table 7) burned within the watershed on the south side of the reservoir which has limited contributing area and no major tributaries. The affected area is also within the perimeter of the Rim Fire. While the November 1996 and January 1997 turbidity events followed the Ackerson Fire, they corresponded with large storm and runoff events, which muddles the connection due to the wildfire. Wildfires of similar magnitude to the Ackerson Fire have occurred in recent history (in 1999, 2004, and 2010) and did not result in reservoir turbidity events. The two events occurring in a short period and lack of subsequent events indicate a low probability of water quality impairment within the reservoir in any year. Even in the 100 year return period storm, water quality recovered to the filtration avoidance requirement of less than 5 NTU standards within a relatively short period of time (7 days).

7 Summary and Conclusions

The Rim Fire is the third largest wildfire within the Hetch Hetchy watershed. The fire had similar behavior characteristics as previous wildfires and resulted in a mosaic low burn severity pattern. The wildfire history shows overlapping historical fire perimeters with limited extent, illustrating the natural resilience of the watershed to widespread fire. Field observations, water quality monitoring and modeling show:

- Less than 2% of the watershed falls within the fire perimeter.
- Most of the burned area was low intensity.
- Reservoir water quality conditions remain unchanged during and following the fire.
- Water chemistry analyses show no changes in metals, nutrients, radionuclides, organics, polyaromatic hydrocarbons or flavor profiles.
- Hydrology measurements show that changes in infiltration rates and hydrophobicity are not sufficient to significantly increase erosion or change the hydrology.
- Sediment and erosion modeling suggest a 1% increase of total potential watershed erosion.

- Water quality and hydrology in the watershed will not likely be impacted due to the limited areas affected by the fire.

8 Acknowledgements

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Hetch Hetchy Water and Power Division

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- Andrzej Wilczak and Greg Olsen for data compilation.

9 Appendices

The appendices can be downloaded from the SFPUC Hummingbird system:

https://infrastructure.sfwater.org/fds/fds.aspx?lib=HHWP&doc=202929&data=63110919

If you have difficulties or are unable to access the files using this link, please contact:

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