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Tuolumne Watershed Diversions without Hetch Hetchy Reservoir: Comparison of Interties to Cherry and Don Pedro Reservoirs

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Abstract

Without storing water in Hetch Hetchy Valley, additional conveyance facilities could allow the San Francisco Public Utilities Commission to divert supplies from storage in other Tuolumne River watershed reservoirs. The most obvious potential locations for additional conveyance are at Don Pedro Reservoir or at Holm Powerplant below Cherry Reservoir. Computer modeling, using a 73 year hydrologic record, indicates that either a Don Pedro Intertie or a Cherry Intertie would allow the SFPUC to deliver more than 95 percent of customer demand without diminishing system reliability. Some additional supplies would be needed in dry years to replace the loss of Hetch Hetchy Reservoir.

Overview

Hetch Hetchy Reservoir is the best-known component of the San Francisco Public Utilities Commission's system that provides water to 2.4 million people in San Francisco and other Bay Area communities. Hetch Hetchy Reservoir holds up to 360,000 acre-feet of water, 23 percent of the SFPUC's system total and less than 13 percent of the total in the storage-rich Tuolumne watershed. Under the SFPUC's current system configuration, 85 percent of the water delivered to San Francisco and other Bay Area customers is diverted from Hetch Hetchy Reservoir. Under a water system alternative that allows for restoration of Hetch Hetchy Valley, the SFPUC could construct facilities to divert supplies from other reservoirs in the Tuolumne watershed. Releases from other reservoirs could replace the releases from storage at Hetch Hetchy Reservoir that are currently necessary during summer and fall months when the river's natural flow is insufficient for diversion.

Paradise Regained: Solutions for Restoring Yosemite's Hetch Hetchy Valley (Environmental Defense, September 2004)[1], includes analysis of the potential use of a Don Pedro Intertie, physically linking the SFPUC system to Don Pedro Reservoir. That analysis, produced by Environmental Defense's TREWSSIM[2] model, shows the frequency with which the SFPUC could meet either current or projected future water supply objectives with a combination of its local reservoirs, run-of-river diversions[3], and diversions from San Francisco's Water Bank in Don Pedro Reservoir. TREWSSIM model results show that full system deliveries could be met in most years while retaining significant carryover storage. Under critically dry conditions, which occur in approximately 1 out of 5 years,

additional supplies would be needed.[4] With a Don Pedro Intertie, on average, 96 percent of system deliveries could be met.

Construction and use of a Don Pedro Intertie is institutionally complex. Don Pedro Reservoir is owned and operated by the Turlock and Modesto Irrigation Districts (Districts). While the SFPUC paid for one-half the cost of building the reservoir and approximately one third of its storage is dedicated to holding water that accrues to the SFPUC under its junior water rights[5], the projects' participants are not comfortable identifying the stored water as belonging to the SFPUC. Presently, the storage functions as a "water bank" for the SFPUC, and is used as an accounting device that allows the SFPUC to divert supplies upstream that would otherwise belong to the Districts. The bank is a supply that is often described as water that the SFPUC has "pre-delivered" to the Districts.

A Don Pedro Intertie, providing direct physical access to its Don Pedro Water Bank, would offer the SFPUC the greatest flexibility in accessing Tuolumne River supplies, assuming arrangements could be negotiated with the Districts that would assure that their interests in the reservoir would be protected. A Cherry Intertie, located at Holm Powerplant outfall below Cherry and Eleanor Reservoirs, could provide nearly the same water supplies and also some additional hydropower benefits. In addition, a Cherry Intertie might avoid some of the institutional controversy with the Districts that surrounds a Don Pedro Intertie.

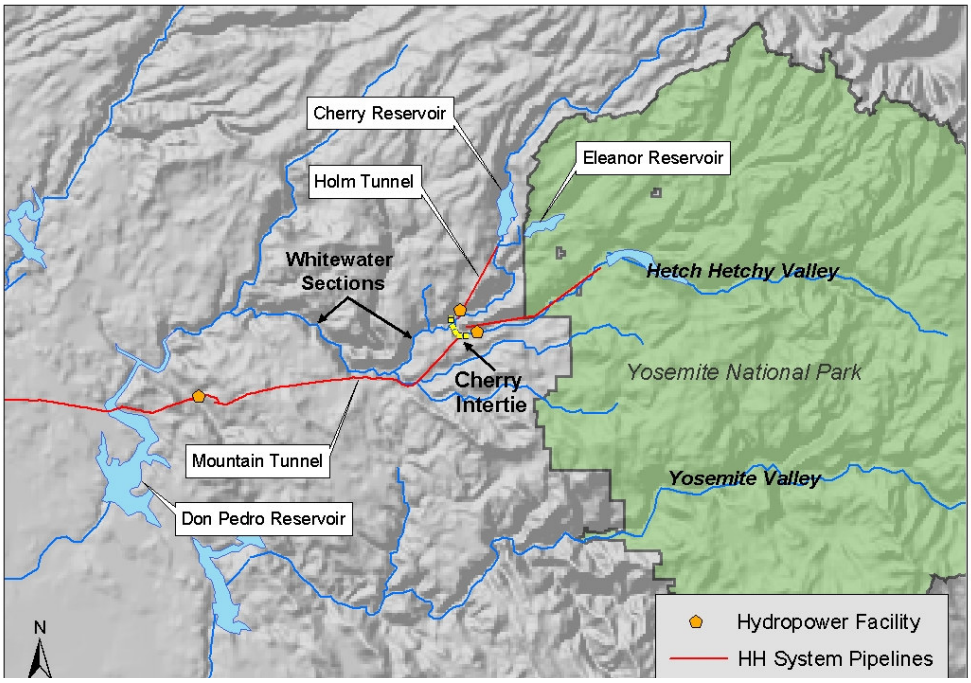
The analysis presented below describes the potential use of a Cherry Intertie, and compares it to a Don Pedro Intertie as presented in *Paradise Regained*. From a water supply perspective there are three possible scenarios that might make a Cherry Intertie less reliable than a Don Pedro Intertie:

- Cherry and Eleanor Reservoirs have a limited supply and could be fully drained, even at a time when there is ample supply in the SFPUC's Don Pedro Water Bank;
- Reoperation of the system with reduced flexibility could cause increased "spills" from Don Pedro Reservoir, even at a time when storage space is available at Cherry and Eleanor Reservoirs;
- Reoperation of the system with reduced flexibility could cause increased "spills" from the SFPUC's Don Pedro Water Bank, reducing its own storage account and providing additional water supply to the Districts.

The Cherry Intertie: Connecting Holm Powerhouse to Mountain Tunnel

The idea of conveying water from Cherry and Eleanor Reservoirs to the San Francisco Bay Area is not new. In the early 20th century, City Engineer Carl Ewald Grunsky investigated the concept when it appeared that it might not be permissible to submerge Hetch Hetchy Valley. Connecting Holm Powerplant to Mountain Tunnel was subsequently proposed as part of a broader plan to increase power generation in *Hetch Hetchy Water and*

Figure 1
Cherry Intertie Location



Power: Systemwide Power Study, Sverdrup & Parcel and Associates, et al., 1981.

The Sverdrup proposal includes a pumping plant at Holm Powerhouse outfall, a pipeline to a site near Early Intake Reservoir, a second Mountain Tunnel to Moccasin, and an additional Moccasin Powerhouse. If Hetch Hetchy Valley is to be restored and a Cherry Intertie built for water supply conveyance, it is assumed that only the pumping plant and pipeline would be built, as a redundant Mountain Tunnel and Moccasin Powerplant would be of limited use. During winter and spring, run-of-river diversions along the Tuolumne River would be diverted into the Mountain Tunnel. During summer and fall, storage releases from the Cherry-Eleanor system would be diverted to the Mountain Tunnel to supplement run-of-river diversions.

Sverdrup estimates the cost, in 1988 dollars, to be $23.2 million for the pumping plant and pipeline. Escalating the cost to 2004 dollars, and incorporating estimates for engineering, legal and administrative costs, and a standard range for the uncertainty of construction costs indicates that the total cost would range from $29.2 million to $64.1 million[6]. This cost is slightly higher than the estimated cost of a Don Pedro Intertie, which ranges from $25 million to $53.5 million.

Modeling Methodology

The TREWSSIM model was modified to include an intertie from Holm Powerhouse to the Mountain Tunnel (see Figure 1). Simulations using this modified version of TREWSSIM indicate that, even with additional provisions to protect and enhance flows for whitewater recreation on the

Tuolumne River, an intertie at Holm Powerhouse would provide nearly all of the water provided by an intertie to Don Pedro Reservoir and would slightly increase hydropower production.

Combined, Cherry and Eleanor Reservoirs can store up to 300,000 acre-feet of water and have an average annual inflow of 433,000 acre-feet. The two reservoirs are connected by a tunnel that is generally used to move water from Eleanor, which has significantly less storage capacity, to Cherry. The inflow and storage of the two reservoirs is less than that of Hetch Hetchy Reservoir but, of course, river flows that pass through the Hetch Hetchy Valley would still be available for diversion.

With a Cherry Intertie, water supplies diverted directly from Tuolumne River flows at Early Intake could be supplemented by diversions from storage at Cherry and Eleanor Reservoirs.[7] Because this storage is a subset of the SFPUC's total Tuolumne supply that includes its Don Pedro Water Bank, a conservative approach was taken with respect to TREWSSIM's ability to capture run-of-river flows at Early Intake[8]. It is important that supplies in Cherry and Eleanor Reservoirs be sufficient under all hydrologic conditions to allow diversion of stored water to the San Francisco Bay Area.

As with a Don Pedro Intertie, diversions using a Cherry Intertie would occur mostly in summer and fall, when run-of-river diversions are not possible. Through the intertie at Holm Powerplant, water would be pumped a short distance – less than 1 mile – to Early Intake Reservoir, where it would enter the existing SFPUC conveyance system at the Mountain Tunnel.[9] These diversions would produce power at both Holm and Moccasin Powerhouses. Some energy would be required, however, to pump the water from Holm to Early Intake. Also, using Cherry and Eleanor Reservoirs for water delivery would diminish the flexibility to schedule releases through Holm Powerhouse to maximize power benefits.

Under the current system, in addition to generating hydropower, summertime releases from Cherry Reservoir extend the season for whitewater recreation on two celebrated reaches of the Tuolumne River upstream of Don Pedro Reservoir. Any diversions through a Cherry Intertie for water supply could not also be used for recreation. TREWSSIM modeling of a Cherry Intertie used flow targets of 1200 cubic feet per second (CFS) for 6 hours per day, 7 days per week, in simulations with a Cherry Intertie. This amount of flow, slightly higher in both rate and duration than currently provided, is incorporated to ensure that diverting from Cherry and Eleanor Reservoirs for water supply would not preclude maintaining or even enhancing the world-class whitewater resources on the middle section of the Tuolumne River. Current releases for whitewater recreation during late summer are generally limited to about 1060 CFS, reflecting the sum of the capacity of the Holm Power Tunnel plus instream flow requirements below Cherry, Eleanor and Hetch Hetchy Reservoirs. Releasing water from Cherry Reservoir to meet a total flow of 1200 CFS would slightly increase the amount of reservoir releases

that would not be available for hydropower generation.

Modeling Results

TREWSSIM analysis indicates that water deliveries with a Cherry Intertie are only about 1 percent less than with a Don Pedro Intertie, under both current and projected future demands. Hydropower production at Moccasin Powerplant would be greater than with a Don Pedro Intertie, though system hydropower production would still be significantly lower than it is under the current configuration with Hetch Hetchy Reservoir. The two interties would accomplish the same general purpose, though each would offer slight advantages under certain circumstances. Depending on further analysis and a final restoration plan, it might ultimately be optimal to construct both interties for increased operational flexibility.

Water Supply

Water supply reliability is determined by how well a system can weather drought. For the SFPUC system, the worst historical conditions occurred during the 6-year drought from 1987-1992.[10] Under scenarios modeled without Hetch Hetchy Reservoir, water deliveries are reduced in all critically dry years so that total SFPUC system storage at the end of the 1987-1992 drought is higher than under scenarios with Hetch Hetchy Reservoir. The magnitude of these reduced deliveries represents the additional water supplies that would be needed to replace the loss of Hetch Hetchy Reservoir.

As reported in *Paradise Regained*, without Hetch Hetchy Reservoir and using an intertie to Don Pedro would allow the SFPUC to make full deliveries of 291,000 acre-feet at the current level of demand in most years. In critically dry years, an average of 19 percent of system demand would be needed to make up for the loss of Hetch Hetchy Reservoir. With a Cherry Intertie, the current system could meet full demands in most years but in critically dry years an additional 22 percent of annual supply would be needed to make up for the loss of Hetch Hetchy Reservoir.

The decrease in reliability is not that water is spilled from the network of reservoirs into the lower Tuolumne River, but that additional spills from San Francisco's Don Pedro Water Bank would occur, providing additional supply to the Turlock and Modesto Irrigation Districts. For example, TREWSSIM modeling shows these increased spills occurring during the summer of 1986, when the Don Pedro Water Bank was full just prior to the six-year drought.

Similarly, under potential future conditions, with demand increased to 339,000 acre-feet and an expanded Calaveras Reservoir, TREWSSIM shows full deliveries would be met with an intertie, either to Don Pedro Reservoir or Cherry Reservoir in most years. In critically dry years, an additional 14 percent of total supply would be needed with a Don Pedro Intertie and an additional 17 percent of new supply would be needed with a Cherry Intertie. As in the scenario under the current level of demand, projected additional spills from the SFPUC's Don Pedro Water Bank with a Cherry Intertie are the cause of the decreased reliability.

Overall, without Hetch Hetchy Reservoir, using a Cherry Intertie would allow 95-96 percent of supplies to be delivered, compared to 96-97 percent using a Don Pedro Intertie. Tables 1 and 2 summarize the results of these simulations from a water supply perspective.

Table 1
SFPUC Delivery Capability without Replacement Supplies
Current Delivery Objective

	Annual Average (1922-1994)		Critically Dry Year Average		Drought Period (1987-1992)
Water Supply Alternative	SFPUC Deliveries (TAF)	Reduction from Base	SFPUC Deliveries (TAF)	Reduction from Base	SFPUC Storage (TAF)
With Hetch Hetchy Reservoir	288	---------	275	---------	559
Don Pedro Intertie	276	4%	222	19%	556
Cherry Intertie	274	5%	214	22%	558

Table 2
SFPUC Delivery Capability without Replacement Supplies
Future Delivery Objective

	Annual Average (1922-1994)		Critically Dry Year Average		Drought Period (1987-1992)
Water Supply Alternative	SFPUC Deliveries (TAF)	Reduction from Base	SFPUC Storage (TAF)	Reduction from Base	SFPUC Storage (TAF)
With Hetch Hetchy Reservoir	339	---------	339	---------	331
Don Pedro Intertie	329	3%	292	14%	380
Cherry Intertie	327	4%	283	17%	377

Hydropower

With a Cherry Intertie, overall hydropower production would be slightly increased compared to that with a Don Pedro Intertie. Operating Cherry and Eleanor as water supply reservoirs, as well as making additional dedicated releases for whitewater, would diminish generation slightly at Holm Powerplant. Supplies would also need to be pumped from Holm to Mountain Tunnel, requiring energy. Increased generation at Moccasin would more than offset these losses, however, making a Cherry Intertie slightly preferable to a Don Pedro Intertie from an energy perspective.

With either a Don Pedro or a Cherry Intertie, operating the SFPUC system without water storage in Hetch Hetchy Reservoir would result in a reduction of between 19 percent and 40 percent of the total current production from its three major power plants. If the Canyon Tunnel were modified to accommodate run-of-river diversions to the Kirkwood Powerplant, power production would be reduced by only 19-20 percent. If no generation at Kirkwood Powerplant were possible, power production would be reduced by 39-40 percent. At $55/MWh, replacing hydropower losses would cost between $18 million and $38 million annually.

Table 3
Average Annual Hydropower Generation under Current Delivery Objective

	Kirkwood	Moccasin	Holm	Holm Pumping	SFPUC Total		
Water Supply Alternative	GWH	GWH	GWH	GWH	GWH	Min. Loss	Max. Loss
With Hetch Hetchy Reservoir	549	427	732	0	1708		
Don Pedro Intertie	352	286	732	0	1369	338	690
Cherry Intertie	352	402	658	-30	1381	326	678

Table 4
Average Annual Hydropower Generation under Future Delivery Objective

	Kirkwood	Moccasin	Holm	Holm Pumping	SFPUC Total		
	GWH	GWH	GWH	GWH	GWH	Min. Loss	Max. Loss
With Hetch Hetchy Reservoir	555	427	731	0	1713		
Don Pedro Intertie	352	286	731	0	1369	345	696
Cherry Intertie	352	422	653	-35	1392	322	673

Minimum Loss assumes run-of-river diversions to Kirkwood Powerhouse

Maximum Loss assumes no generation at Kirkwood Powerhouse

Whitewater Recreation

Under the assumptions incorporated in TREWSSIM, whitewater recreation for both commercial and private rafters, as well as for kayakers, would be improved. Figure 2 shows the frequency of average daily flows on the Tuolumne River just below its confluence with Cherry Creek[11], sorted from highest to lowest, for August and May during the 73-year hydrologic record. During summer months, the average monthly flows do not reflect the daily fluctuations that typically occur, where releases are made for a few hours each day to provide flows for whitewater recreation. Under the

Figure 2
Flows for Whitewater Recreation in August and May

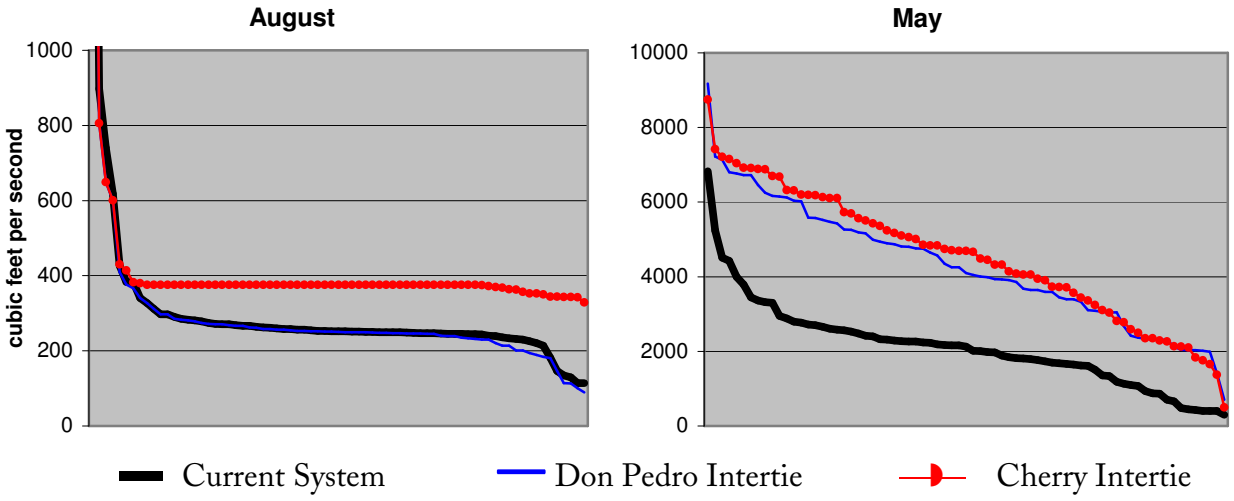


Table 5
Don Pedro Water Bank Spills
(All values in TAF)

	With Hetch Hetchy Reservoir	Don Pedro Intertie	Cherry Intertie (additional whitewater releases)	Cherry Intertie (existing whitewater releases)
June-86	224	222	224	224
July-86	41	43	43	42
August-86	60	44	66	58
September-86	49	25	45	36
October-86	14	25	37	37
Total	**388**	**359**	**414**	**396**

Cherry Intertie scenario, for example, releases of 1200 CFS for 6 hours of the day and much lower stream flows for the rest of the day result in average daily flows of about 375 CFS under most conditions in August.

Figure 2 also shows the cumulative frequency of average daily flows for May during the 73-year hydrologic record. In most years, May is the peak snowmelt month and has the highest flows. These average daily flows have few fluctuations and would be the result of uncontrolled flows passing through Hetch Hetchy Valley. The flows would reach 4000 CFS or more about half of the time during May, providing thrills to those who run the river at that time but also encouraging many would-be boaters to stay home and wait for flows to subside to safer levels.

As mentioned above, some of the projected spills from the Don Pedro Water Bank would be a result of dedicated releases for whitewater. This extra water supply would be held by the Districts in Don Pedro Reservoir, assuming the reservoir itself does not spill. For example, modeling indicates that the hydrology experienced in 1986, immediately prior to the 1987-1992 drought, is one of those times. Of the total increase of 55,000 acre-feet in spills from the Don Pedro Water Bank as a result of using a Cherry Intertie, the increased whitewater flows account for 18,000 acre-feet (see Table 5).

Conclusion

An intertie from either Cherry or Don Pedro Reservoir to the SFPUC conveyance system could allow the SFPUC to meet almost all its water delivery needs. Replacement supplies of between 14 and 22 percent of total system demand would be needed in critically dry years. Opportunities to use transfers, groundwater exchange or expanded local storage to meet these dry year needs are explored in *Paradise Regained*. Other opportunities, including conservation, reclamation and desalination could be pursued as well.

With either intertie, power system impacts would remain significant – between 20 and 40 percent of the system total. *Paradise Regained* describes the cost of replacing the forgone hydropower in ways that would not contribute to increased emissions.

Further analysis is needed to determine which intertie is preferable, or whether both might be constructed, as water and power alternatives are developed that would allow Hetch Hetchy Valley in Yosemite National Park to be restored. That analysis should take place in a public forum that includes all communities that rely on the Tuolumne River for water and power.

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[1] *Paradise Regained* is available online at www.discoverhetchhetchy.org. For a printed copy, call Environmental Defense at (510) 658-8008.

[2] TREWSSIM - Tuolumne River Equivalent Water Supply Simulation – was created by Environmental Defense to investigate alternatives to Hetch Hetchy Reservoir.

[3] Run-of-river diversions would take place either at the current head of the Canyon Tunnel or at Early Intake. The principal difference would be that diverting into the Canyon Tunnel would require a diversion structure within Hetch Hetchy Valley and retrofit of the tunnel, but would still allow much of the current generation of hydropower at Kirkwood to take place.

[4] Critically dry years are determined by the San Joaquin 60-20-20 index, calculated by the California Department of Water Resources.

[5] The Turlock and Modesto Irrigation Districts are, by contrast, 'senior" water rights holders, and are entitled to the majority of the Tuolumne River's flow.

[6] Escalation based on "Civil Works Construction Cost Index System (CWCCIS)", September 2004. Total cost assumes a 20 percent premium for engineering legal and administrative costs and a range of –30 percent to +50 percent for the uncertainty of construction costs.

[7] An intertie to Don Pedro would provide more flexibility. With a Don Pedro intertie, water supplies that could not be diverted as run-of-river at Early Intake could simply be diverted further downstream. With an intertie at Holm, these supplementary supplies would be limited to that water that physically flows through Cherry and Eleanor – a lesser amount.

[8] Analysis of pre-dam daily Tuolumne River flows at Hetch Hetchy (1911-1922) suggests that a monthly model may overpredict the run-of-river supply that can be diverted at Early Intake. With a Don Pedro Intertie, these uncaptured flows could simply be diverted downstream at Don Pedro. With a Cherry Intertie, however, the water would flow into the SFPUC's Don Pedro Water Bank, but not be actually usable. An adjustment was made to TREWSSIM that slightly reduces the amount of "run-of-river" flow that can be diverted.

[9] TREWSSIM uses the value of 660 CFS for the capacity of the Mountain Tunnel as stipulated by the SFPUC, though some sources suggest that the capacity of the Mountain Tunnel is 730 CFS or more. The capacity of the Cherry Intertie is also assumed to be 660 CFS.

[10] TREWSSIM modeling uses historic hydrologic conditions from 1922-1994, but simulations are constrained to include significant carryover storage in case future droughts, caused by global warming or other factors, are worse than historical droughts. This method is slightly different from the SFPUC's methodology, which uses a drought scenario worse than has occurred historically, but assumes that reservoirs will be fully drained by the end of the period.

[11] Other tributaries, including the North, South and Middle Forks of the Tuolumne, and the Clavey River, provide additional flow at various locations along the two whitewater stretches. Theses additional flows can be significant in spring but are quite low by late summer.