Figure 1. Aerial View of the Shasta Temperature Control Device [2,3]

Key Issues:
5- Water Quality
1-Biological Diversity

Climate Zone:
Cs: Temperate

Subjects:
- River Temperature Modification
- Salmon Habitat Restoration
- Hydropower Production Optimization

Effects:
- Improved habitat for salmon spawning and juvenile rearing
- Additional Hydropower Generation
- Role Model for other dams and power plants

Project Name: Shasta Dam Temperature Control Device
Country: Shasta County, California, United States of America

Implementing Party & Period
- Project: U.S. Bureau of Reclamation
1938-1945 (original construction)& 1995-1996 (modified)
- Good Practice: U.S. Bureau of Reclamation
1996 - Present

Key Words:
Temperature Control Device, Hydropower Optimization, Endangered Species, Water Quality, Habitat Restoration, Selective Withdrawal, and Reservoir Stratification

Abstract:
This Good Practice illustrates a successful case study of habitat restoration and hydropower optimization. During the period of late 1980s to the mid-1990s, the Bureau of Reclamation spilled cold water through Shasta Dam's low-level river outlets to provide proper water temperatures for salmon downstream, instead of passing water through the hydro turbines. A Temperature Control Device (TCD), with a unique selective withdrawal system that routes water through Shasta Powerhouse, has provided the answer to maintaining the required water temperature for fish and at the same time, generating clean inexpensive electricity. An aerial view of the TCD, Shasta Dam and power plant is shown in Figure 1.

1. Outline of the Project

The Central Valley Project (CVP) in California, USA, developed, constructed and managed by the U.S. Department of the Interior's Bureau of Reclamation (Reclamation), is one of the Nation's major water resources developments and one of the largest water storage and conveyance systems in the world. The

CVP stores and distributes about 20 percent of California's water (7 million acre-feet (8.6 million cubic meters), and generates more than 5 million MWh of electricity during years of normal rainfall. The Secretary of the United States Department of the Interior authorized the project and the President thereafter approved it on December 2, 1935. Congress re-authorized the Project in the Rivers and Harbors Act of 1937. The Shasta Division of the CVP was authorized by Public Law 386, 84th Congress, 1st Session, on August 12, 1955.

The Sacramento River and Shasta Dam in Shasta/Trinity River Division, Shasta County, California are major components of the Central Valley Project. In addition to generating electricity, Shasta also serves to control floodwaters and store surplus winter runoff for irrigation in the Sacramento and San Joaquin Valleys. It also maintains navigation flows, and provides flows for the conservation of fish in the Sacramento River. Shasta stores about Sixty-four (64) percent of the CVP water supply, with a capacity to store 4.5 million acre-feet (555,000 hectare-meters) and generates 42 percent of CVP hydroelectric production. Other components of the Central Valley Project are shown in table 2.

Table 1. Shasta Dam Specifications

Item	Specification	
River System	Sacramento River	
Catchment Area	17262,35 km^2	
Power Station	Name	Shasta Powerplant
	Max Output	629 MW
	Max. Discharge	538 m^3/sec
	Effective Head	100 m
Dam	Type	Curved Concrete Gravity
	Height	183 m
	Crest Length	1055 m
	ConcreteVolume	4.79 x10^6 m^3
	Design Flood Capacity	8000 m^3/sec
Reservoir	Gross Storage Capacity	5.62 x10^9 m^3
	Effective Storage Capacity	5.52 x10^9 m^3
	Available Depth	145 m
	Maximum Water Surface Elevation	328 m
Temperature Control Device	Number of Gates	5 gates at 3 elevations and 2 low-level side gates
	Elevation of Gates Upper Level Middle Level Pressure Relief Side Gates	311.7 m 281.2 m 249.0 m 219.5 m
	Size of Gates	
	Upper and Middle Pressure Relief Side Gates	13.7 m wide x 14.0 m high 13.7 m wide x 8.2 m high 6.4 m wide x 42.6 m high

Table 2. Central Valley Project Components

Plant	State Location	River	Initial Date in Service	Number of Units	Installed Capacity (KW)	Gross Generation (KWh)
Judge F. Carr	California	Tunnel Lewiston	5-63	2	154,400	329,639,000
Folsom	California	American	6-55	3	196,720	412,143,000
Keswick	California	Sacramento	10-49	3	117,000	406,519,000
New Melones	California	Stanislaus	6-79	2	300,000	377,722,000
Nimbus	California	American	5-55	2	13,500	52,225,000
O'Neil	California	San Luis Creek	11-67	6	25,200	6,665,800
San Luis	California	San Luis Creek	3-68	8	202,000	158,689,300.
Spring Creek	California	Tunnel, Clear Creek	1-64	2	180,000	383,260,000
Trinity	California	Trinity	2-64	2	140,000	383,782,000
Lewiston	California	Trinity	2-64	1	350	2,260,882

Completed in 1945, Shasta Dam is a 602-feet (183 meters) tall curved concrete gravity structure having a gated overflow spillway with a crest elevation of 1037.0-feet (316 meters) above mean sea level (Figure 2). The Shasta Dam impounds water from the Pit, McCloud, and upper Sacramento Rivers to form Shasta Lake, the largest reservoir in California. The dam includes an extensive river outlet works structure with intakes at elevations 942.0-feet (287 meters), 842.0-feet (257 meters), and 742.0-feet (226 meters) respectively above sea level. The five power penstock intakes are located near the right abutment with a centerline elevation of 815.0-feet (248 meters), approximately 240-feet (73 meters) above the old river channel, but only 25-feet (7.6 meters) from the reservoir bottom in front of the intakes. Shasta Powerplant, located directly below the dam includes five turbine-generators with a combined rated capacity of 539 MW. Discharge capacity of the power plant is 17,600 ft3/sec (500m3/sec), the units are being upgraded which will increase the rated capacity to 629 MW and discharge capacity to 19,500 ft3/sec (538 m3/sec). The power plant is operated as a peaking plant with releases varying hourly, daily, seasonally as a function of power and water demand. At approximately 156-feet (48 meters) tall—as tall as 15-story building –Shasta Power plant is one of the largest hydropower plants in California.

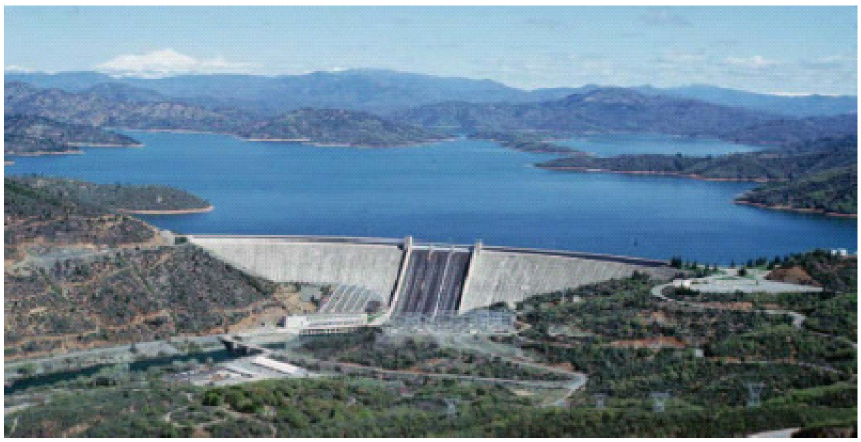

Figure 2. Shasta Dam with penstocks, power plant, and spillway in the foreground, and Shasta Lake in the background.[2,3]

In the1970s, controversy grew around anadromous fish species, primarily Chinook salmon and steelhead trout, and how the presence of dams on the Shasta Division were causing a decline in their populations. The winter-run Chinook salmon enters the River in the winter and optimum spawning takes place during the months of July/August, approximately at a location where the river reach stretches between the 107 MW Keswick Dam and Reservoir and the Red Bluff Diversion Dam (RBDD) downstream of the River. During this time of the year water temperature is high at this location for effective spawning and the optimum spawning of the winter-run Chinook salmon are affected because of egg and fry mortality associated with the elevated water temperatures, thus declining their populations (optimum temperature for salmon spawning is 56^{o}F). Because of that, elevated downstream River Water temperature was determined to be one of the most important factors for the Chinook salmon population decline. Other factors affecting the anadromous fish population decline are: water quantity especially during a dry year, dissolved oxygen, turbidity, and total dissolved gas. Since 1987, water temperature in the upper Sacramento River has been controlled by releasing deeper, colder water from Shasta lake through the low-level outlet works to protect endangered salmon species. However, since these releases were not passed through the Shasta Powerplant hydroelectric generation was significantly reduced. In 1992, as part of the Central Valley Project Improvement Act (CVPIA, Title 34 of Public Law 102-575) Reclamation was authorized to install a Temperature Control Device (TCD) at the upstream face of the Shasta Dam which would control water temperatures in the upper Sacramento River to minimize salmon mortality without the loss of hydropower generation.

The TCD is a specially designed piece of equipment with a unique selective withdrawal system that allows power plant operators to use water from different depths in the reservoir to operate hydropower turbines. The TCD design allows operators to better manage and control water temperatures at the outlet to the powerhouse.

The TCD, designed by the Reclamation engineers is a steel shutter device, weighs more than 8,500 tons ($7.7*10^6$ kg) and is supported vertically by rigid steel frames anchored by more than 325 concrete anchor bolts near the upstream face of Shasta Dam (Figure.1). Divers attached the device to the dam.

The 250-feet-wide by 300-feet-high (76.2 meters-wide, and 91.4 meters-high) shutter structure in TCD is composed of five separate units that are attached to the dam around each penstock intake. These units extend about 50-feet (15.2 meters) upstream from the face of the dam, and are open between units to permit cross flow through the shutter structure. Three sets of hoist-operated gates and trash racks on the front of each shutter unit allow water withdrawal at upper, middle, and low reservoir levels for all five penstocks.

A low-level intake structure (Figure.3) which is 125-feet-wide by 170-feet-high (38.1- meters-wide and 51.8-meters-high) is hydraulically attached to the left of the shutter structure directly above the cold water pool. This structure also extends 50-feet (15.2 meters) upstream from the face of the dam and acts as a conduit to access the deeper, colder water near the center of the dam. The intake structure is made of three intake units that are individually assembled and attached to the dam and have openings at elevation 722-feet (220 meters). Two slide gates mounted on the side of the shutter structure, control the flow from the low -level intake structure to the shutter structure.

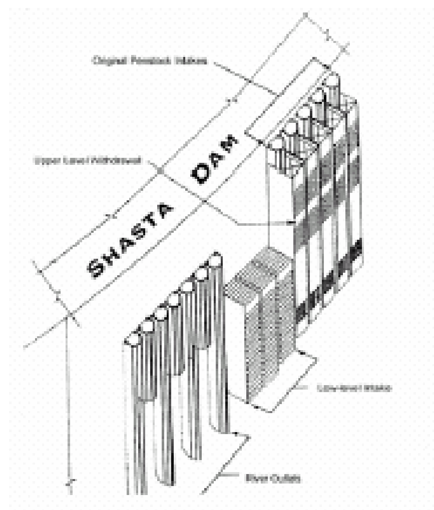

Figure 3. Scematic of the TCD, low-level intake, and river outlet structure on the face of Shasta Dam

The design flow for the TCD is 19,423 ft3/sec (550 m3/sec). A density-stratified hydraulic model was used to predict the hydraulic characteristics of the TCD. The hydraulic model was also used to determine the lowest water elevation that could be accessed by the low level intakes. Withdrawal layer limits are a function of discharge and stratification of the reservoir.

The TCD design also includes (i) impact of leakages that would significantly increase the temperature of under draw discharges or significantly reduce the TCD's ability to conserve the cold water resource (ii) the impact of design basis earthquake, so there are no structural damage and (iii) the effects of large floating debris around the TCD to keep floating debris from becoming entangled in the gate hoist ropes and to protect the exterior coated surfaces of the TCD. In addition, the TCD design considered water temperature equipment which are used to provide the reservoir temperature profile outside of the TCD, and the water temperature at specific gate locations within the TCD structure. Additional water temperature equipments are located in the power plant directly upstream of each turbine. Such water temperature equipments assist the plant operator in selecting TCD gates that should be opened (or closed) to provide discharge temperatures that will best benefit fish downstream in the Sacramento River. All materials of construction meets the requirements of American Society of Testing and Materials

(ASTM), Federal and USBR standards, specifications, and testing procedures as mandated. The TCD is also being monitored for corrosion, cracking, blistering and peeling of the applied coatings and retrofitted for cathodic protection, if necessary. To ensure electrical continuity throughout the steel framework of the shutter and low-level intakes, an electrical continuity bolt was detailed at each end of each structural member.

The selective withdrawal structure at Shasta costs $80,000,000 to design and construct. Shasta TCD costs were allocated as: (i) 37.5% Water and Power Users, (ii) 25% State of California, (iii) 37.5% Non-reimbursable.

2. Features of the Project Area

The Central Valley Project extends (Figure 4) from the Cascade Range on the north to the semiarid but fertile plains along the Kern River on the south. Shasta Dam and Power plant are located on the Sacramento River in Shasta County, California, about 15 miles (24 killo-meters) northwest of Redding, California. The primary area influenced by the Shasta releases is the river reach between Keswick Dam and the Red Bluff Diversion Dam, a distance of about 60 river miles(95 killo-meters). Shasta Lake provides a popular, diverse sport fishery with both cold and warm-water species including Chinook salmon, rainbow trout and other habitats.

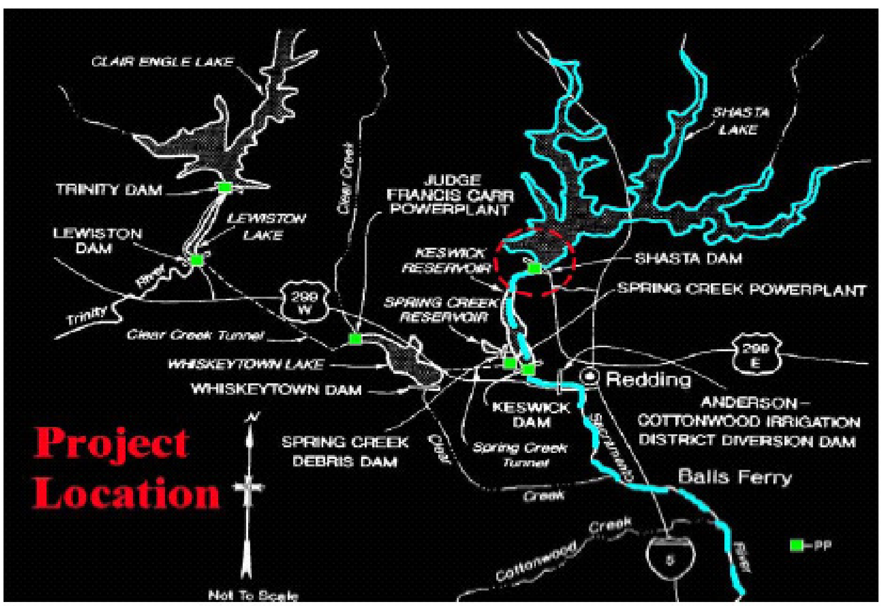

*Figure 4 does not include Red Bluff Diversion Dam

Figure 4. Project Location* [2]

3. Major Impacts

Protection of Fisheries is an important consideration in the project area. Both Shasta and Keswick Dams block a large number of streams tributary to the Sacramento River that are used for spawning by the migratory fish. Shasta dam not only blocks migration upstream, but also blocks the flow of cool water downstream, keeping water temperature above the maximum fifty-six degrees Fahrenheit necessary for salmon spawning. As a result, all runs of Chinook salmon have suffered declines in population growth because of fry mortality associated with elevated water temperature in the Upper Sacramento River.

In 1989, because of the continued population decline of the winter- run Chinook salmon, the Chinook salmon in the Sacramento River was listed as an endangered species under the state and federal Endangered Species Acts (ESA). The Biological Opinion (BO), for the operation of the Federal Central Valley Project and the California State Water Project was issued on February 12, 1993 from the National Marine Fisheries Service (NMFS) for the Winter-Run Chinook salmon. The conclusion was “Based on an assessment of the impacts, NMFS concludes, the proposed long-term operation of the CVP by the Bureau is likely to jeopardize the continued existence of the Sacramento River Winter-Run Chinook salmon.” The BO contains conservation recommendations which included the requirements to continue implementation of the TCD. Hence, Section 3406(b)(6) of CVPIA, which was signed on October 30,1992, authorized Reclamation to install and operate a structural Temperature Control Device (TCD) at Shasta and to develop and implement modifications in CVP operations as needed to assist in the Secretary’s efforts to control water temperatures in the Sacramento River.

Between 1987 and 1996 CVP operators regulated downstream water temperatures by releasing water through the Shasta Dam lower outlet works. Although the water temperature was temporarily improved, hydroelectric generation was greatly reduced, since such releases bypassed the power plant. During this period, releasing water through the outlet works instead of through the turbines has resulted in approximately $65.0M (2,709 GWh) in total replacement power cost. Replacement power was purchased by the Western Area Power Administration (WAPA) from alternate sources due to contractual commitments.

4. Mitigation Measures

In order to mitigate the Chinook population growth decline Reclamation worked closely with all resource agencies and stakeholders to solve the Sacramento River temperature problems. Coordinated efforts with the U.S Fish and Wildlife Service (FWS) and the California Department of Fish and Game (DFG) resulted in an effective solution to meet temperature standards in the upper Sacramento River. In the summer of 1988 DFG and Reclamation developed a strategy to minimize temperature-related mortality to the extent controllable by changing project operations.

In 1988, 1989, and 1990 Reclamation conducted public meetings on the scope of the Shasta outflow Temperature Control Environmental Impact Statement. DFG and FWS staff provided Reclamation with available information on the spatial and temporal distribution of migration and spawning of the four runs of Chinook salmon in the Sacramento River and on the biological effects of temperature on salmon reproductive growth and survival. Reclamation used this data in the evaluation of temperature control options.

California Department of Fish and Game negotiated terms and conditions with Reclamation and developed guidelines for determining what temperature controls are available. After assessing several alternatives, Reclamation Engineers decided that a shutter type Temperature Control Device (TCD) would be the best temperature control alternative from design, construction, operation and maintenance standpoints. In October, 1992 as part of the Central Valley Project Improvement Act, Reclamation was authorized to construct and operate such device with selective withdrawal structure and install it at Shasta Dam, that would control water temperature to improve salmon spawning and rearing habitat. In November of 1994, a contract was awarded for the construction of TCD and the construction was completed in February 7, 1997. The implementation of this “fish-friendly” device provides flexibility to manage Shasta Dam Operations for both salmon protection and recovery and hydroelectric power production revenue. The TCD allows the selective withdrawal of water from the reservoir’s surface during the winter and spring when the water is suitably cool, or from deep in the reservoir during summer when the surface water is too warm The selective withdrawal system drew water from the deepest levels of Shasta Lake through powerhouse turbines , maximizing power generation, while at the same time providing life-producing cold water for threatened Chinook salmon spawning downstream in the Sacramento River. Use of the TCD also improves oxygen and sediment levels in the river water and allows Reclamation to fulfill contractual obligations for both water quality, and delivery as well as power generation.

As a mitigation measure, while under operation, any temperature anomalies of the TCD must be reported promptly to the proper authorities. The reporting is accompanied by data from the TCD and reservoir water temperature probes, unit discharge flows and temperatures, and TCD gate positions. From the physical and mathematical model studies, the greatest TCD benefit appears to be the conservation of cold water within the reservoir until the colder water releases are desired later in the summer. It was recommended that beginning with the first year of service, the TCD should be inspected on an annual basis. Annual inspection is scheduled to take advantage of the seasonal low water mark. Besides annual inspection there are seven-, fifteen-, and twenty-five- year inspection programs. On the seventh, fifteenth, and twenty-fifth year of service the annual inspection will be supplemented by a diver-assisted inspection program. The inspection items should include: debris accumulation inside the TCD, Dam connections, Visual inspection of steel members. Findings of the 7-, 15-, and 25-year inspection programs should be documented.

5. Results of the Mitigation Measures

Results of the mitigation measures have been dramatic. Compared to an estimated total cost of $65M (2,709 GWh) in replacement power (between 1987-1996), TCD operations have increased power generation by 74 percent ($48.1M) and 105 percent ($68.3M) for 1997 and 1998, respectively. The TCD releases also met the river temperature goals almost all the time, whereas before the TCD, the release temperatures were too high on 30 to 45-days during the late summer and early fall-a critical time for salmon reproduction.

The selective withdrawal performance was evaluated on the ability of CVP operators to meet temperature standards at various compliance points along the upper Sacramento River while meeting water delivery and power generation obligations. TCD operations began February 1997. During the months of April through October, average daily river water temperatures between Keswick Dam and Red Bluff Diversion Dam are required to be less than 56 ^{o}F(13.3 ^{o}C). In 1996 this temperature target was exceeded 32 times, and with the TCD operating in 1997 that target was exceeded 17 times. This represents a 47 percent reduction in temperature target violations.

A comparison of temperature profiles collected in1996 (pre-TCD) and 1997 (post-TCD) (Figure 5) indicated that TCD operations modified the reservoir stratification. The isotherm plots in figure 5 show that a larger volume of cold water 44.6 ^{o}F(7 ^{o}C) was stored in Shasta Lake in 1997 and that the cold-water pool was maintained into June. The isotherm plots also illustrate how TCD operations generated a stronger thermo cline (temperature gradient), but the TCD did not appreciably increase the surface water temperatures.

Reclamation engineers have analyzed the multilevel intake structure's performance for three years, (1996-1998) concluding that the structure is performing as desired. In 1997, the first year of operation, project operators met river temperature standards during the summer, with minimal water bypass the powerplant. However, in mid September 1997, the structure developed warm water leakage around the middle gates, which required the withdrawal of cooler, deeper water through the low-level bypass.

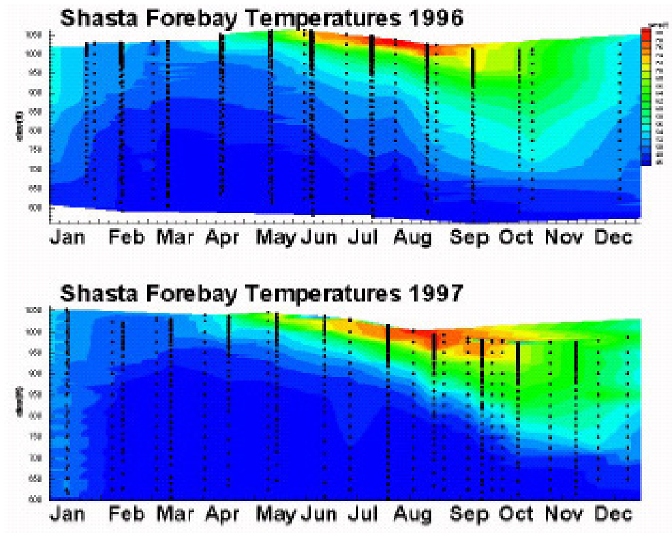

Figure 5. A comparison of Shasta Dam forebay isotherms for pre-TCD (1996) and post-TCD (1997) reservoir operations. [5]

In January 1998, seals were installed stopping the leaks. Despite the leakage problem, reduced bypass in 1997 allowed Shasta Powerplant to generate an additional 300,000 MWh ($45.1M) of hydropower.

During 1998, because of El Nino related weather disturbances, tributaries downstream of Keswick Dam flowed higher and warmer than normal. Consequently, cooler water had to be released from Shasta Dam earlier than usual. However, even with the early releases of cool water, use of the TCD allowed project operators to meet water deliveries and temperature requirements throughout 1998 without using the low-level bypass. This full utilization of the Shasta Powerplant resulted in an additional 1,100,000 MWh ($18.7M) of hydropower generation. Likewise in 1999, 2000, and 2001, Reclamation's Central Valley Operations Office along with the Sacramento River Temperature Task Group has operated the TCD to achieve the Sacramento River temperature goals without having to bypass the Powerplant. Monitoring of the structure's performance continues with the goal of improving the TCD's operational efficiency.

As an example of effective TCD performance Figure 6 shows a thermocline from the data collected in 2001 (post-TCD).

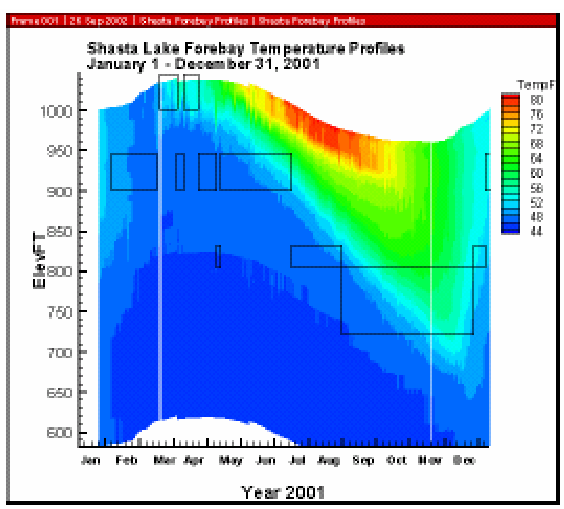

Figure 6. Shasta Lake Temperature Profiles, 2001 [6]

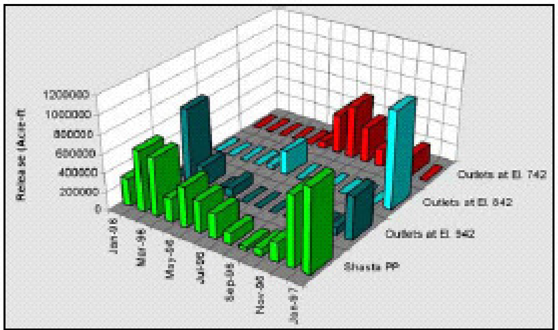

Figure 7. Shasta Dam releases for 1996 and January 1997: pre-TCD release patterns.[6]

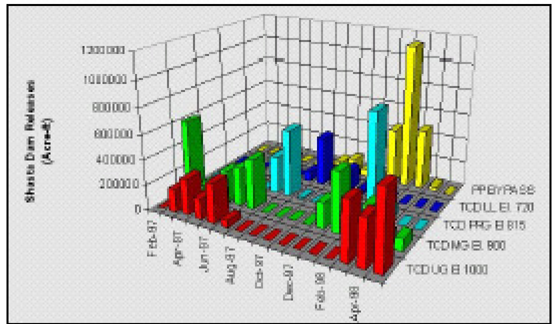

Figure 8. Shasta Dam releases for 1997: post-TCD operations [6]

Reservoir operations for 1996 (Figure.7) and 1997 (Figure.8) are used to compare pre- and post-TCD operations, respectively. The year 1996 was an above normal water year where the reservoir filled to El.1066-feet (325 meters) on May 28, 1996. December 1996 and January 1997 were extremely wet months. These flood flows brought large volumes of cold water into Shasta Lake. In fact, the large inflow and flood control releases in January 1997 represent nearly one-half of Shasta Lake's storage capacity of 4.5 million acre-ft (555,000 hectare-meters) Since Shasta is used for flood control, the majority of the January 1997 flood inflows were released to maintain storage capacity for spring runoff. However, spring runoff flows were below normal and the reservoir elevation topped out at El. 1045-feet (319 meters) on May 9, 1997. As a result, 1997 was a below normal water year and the reservoir was drawn down 72.8-feet (22.2 meters) to meet contractual deliveries.

In 1996, temperature control bypass operations began in May and continued through November (Figure.7), whereas the plot of 1997 operations show that low-level bypasses were not needed until September and even so they were only 16 percent of the total release. In contrast, low-level bypass flows in September 1996 were 91 percent of the total release. In terms of lost power generation, 672,000 MWh ($11.4M) were lost because of low-level bypasses in 1996. In 1997, 65,800 MWh ($1.1M) were lost to low-level bypasses; however, if the TCD had not been operational an estimated 365,300 MWh ($6.2M) would have been lost.

In terms of salmon spawning, Figure 9 shows the estimated number of winter-run Chinook salmon returning to spawn in the upstream of Keswick Dam from 1987 through 1998. The enhancement of this anadromous fish population from 1997 (TCD installed and operated) to 1998 (Figure 9) is an example of how temperature control using the TCD resulted in such population growth.

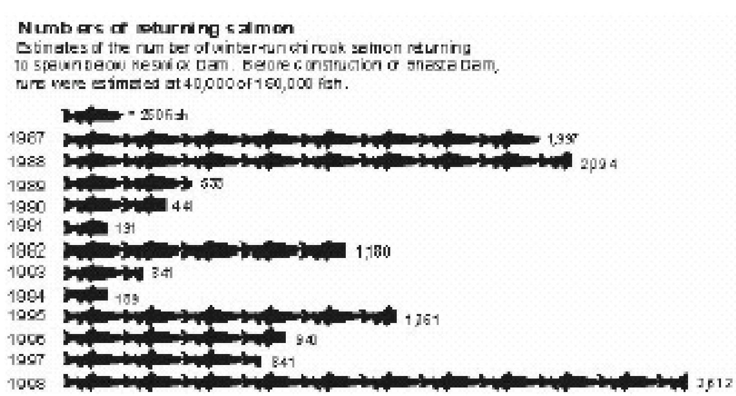

Figure 9. Numbers of Returning Salmon from 1987 through 1998 [7]

More recent data on monitoring of the winter-run Chinook salmon at upstream of the Red Bluff Diversion Dam (RBDD) (Figure 10) confirms the effective performance of the TCD.

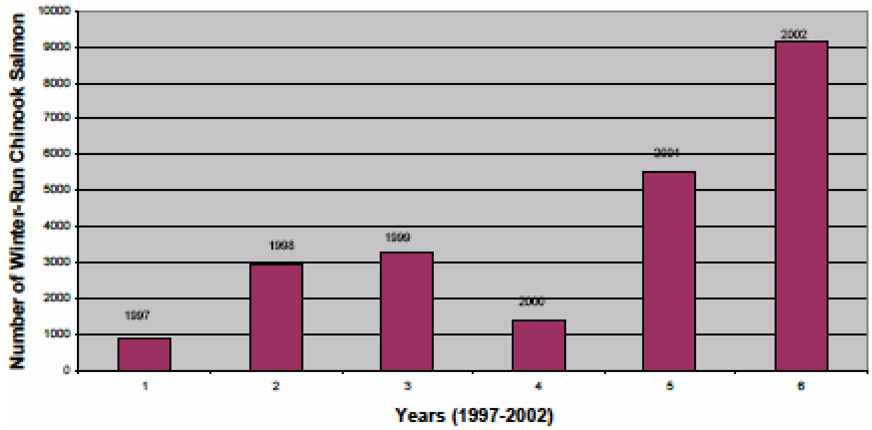

Figure 10. Winter-Run Chinook Salmon at RBDD [8]

Figure 10 shows an increase in population of the winter run Chinook salmon over the years from 1997 through 2002 with the exception of the year 2000.

In addition, operation of the temperature control device improved the control of river turbidity, and dissolved oxygen while significantly benefiting the winter, fall, and spring Chinook salmon runs. This has been done concurrent with meeting existing water and power contractual obligations.

It is also believed that the TCD and modifications in Central Valley Project (CVP) operations would establish sufficient control over water temperatures in the upper Sacramento River to minimize any further loss of salmon.

The National Hydropower Association (NHA) presented Reclamation with a 2002 Hydro Achievement Award in the category of Technical solutions for its state-of-the-art Shasta Temperature Control Device (TCD).

6. Reasons for Success

The following may be cited as reasons for success:

1) **Hydropower Optimization**: At Shasta Dam Cool water bypass releases from 1987 through 1996 resulted in an estimated replacement power of 2,709 GWh ($65M). In contrast, TCD operations have increased power generation by 74 percent ($48.1M) and 105 percent ($68.3M) for 1997 and 1998 respectively.
2) **Temperature Control**: The TCD releases met the river temperature goals 56 ^{o}F (13.3 ^{o}C) almost all the time, whereas before the TCD, the release temperatures were too high on 30 to 45-days during the late summer and early fall—a critical time for salmon reproduction.
3) **Habitat Restoration**: Use of TCD resulted in an increase in the population of anadroumas fish in the Sacramento River. This is in compliance with the P.L. 102-275, state and Federal Endangered Species Act (ESA, P.L. 100-478) and the Central Valley Project Improvement Act (CVPIA), which elevated fish and wildlife protections and restorations to a level of equal importance with flood control, irrigation, navigation, and power production.

7. Outside Comments

1) In speaking about the Shasta Temperature Control Device, Interior Secretary Bruce Babbitt commented, "This device symbolizes our commitment to preserving the salmon of the west through the best science in the world. It also shows that solutions can be found which can accommodate other interests."(Association of California Water Agencies, ACWA News, June 23, 1997)
2) "The cooperation between all the government agencies, including the environmental concerns, people came together from all perspectives," said Redding author and Simpson College instructor Al Rocca. "What Babbitt suggests is this could serve as a model for future projects." (Redding Record Searchlight, May 30th, 1997)
3) "If we didn't go to all this effort we would lose a population of fish that is important to a whole region of state, especially the economies of ocean and river communities," said Harry Rectenwald, a biologist with the California Fish and Game Department. (The New York Times, July 6, 1996)
4) WAPA Administrator J.M. Shafer said "Western acknowledges the high quality of the work performed by the Bureau of Reclamation in designing the TCD and managing the project," (Closed Circuit, WAPA Newsletter)
5) John Merz, manager of the Sacramento River Preservation Trust, said the device would provide the Bureau with the "flexibility" it needs to access cold water when it's needed most without losing power sales. "I appreciate the fact that people call this a fish friendly device but the reality is it's for power," said Merz of Chico, California. (Redding Enterprise-Record, May 30th, 1997.
6) Roger A. Fontes, Assistant General Manager, Northern California Power Agency said "The Temperature Control Device is of vital importance to the operations at Shasta Dam. Cold water protection for spawning Chinook salmon downstream will no longer require that valuable, clean and renewable hydroelectric power be bypassed and lost forever. The TCD will go further; it will allow maximum protection for all Sacramento River salmon runs while concurrently producing Shasta Dam's full hydroelectric potential."
7) "We are very pleased to be recognized for this special achievement," said Kirk Rodgers, regional Director, Mid-Pacific region, Bureau of Reclamation. " The Shasta TCD represents a wining collaboration of technology, biology, and economics working to meet the needs of our customers and the environment." After Reclamation was presented with the 2002 Hydropower Achievement Award by the National Hydropower Association (NHA).

8. Further Information

8.1 References

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