
Authors

John R. Hollenbeck, P.E.¹, is the Nacimiento Project Manager within the Public Works Department of San Luis Obispo County, California. He is the full-time manager of the project through the design, bidding and construction phases. Mr. Hollenbeck has been engaged in the evaluation, design, and construction management for hydraulic structures since graduating from Kansas State University with a B.S. and a M.S. degree in Civil Engineering in 1984 and 1986, respectively.

Paul R. Kneitz, P.E.², is an Associate Vice President and Senior Project Manager with Black & Veatch Corporation in Walnut Creek, California. He specializes in managing large water resources projects principally involving raw water and treated water conveyance and water treatment. For the Nacimiento Water Project, he is serving as Deputy Project Manager and Chief Engineer during the design, bidding and construction phases. Mr. Kneitz graduated from the University of California, Berkeley with a B.S. degree in Civil Engineering and an M.S. degree in Structural Engineering in 1976 and 1977, respectively.

Steve N. Foellmi, P.E.³, is a Vice President of the consulting firm of Black & Veatch Corporation and is the Project Manager of the Consulting Engineering Team for the Nacimiento Water Project. Steve has 36 years of engineering experience and has directed preliminary and final design and construction support for conveyance pipelines ranging in diameter from 108 inches to 12 inches and ranging in length from 3,000 feet up to 45 miles. He received a B.S. in Civil Engineering from the University of Wisconsin in 1972 and an M.S. in Civil Engineering from the University of Missouri in 1981 .

Andrew E. Romer, P.E.⁴, is an employee of Bolye Engineering, presently incorporated into the firm of AECOM. He is the Senior Pipeline Design Manager responsible for the design of the pipeline portion of the Nacimiento Project. He is a member of the ASCE Risk Management Committee, and AWWA Standards Committees for Steel and Concrete Pressure Pipe, and is the chair of the AWWA Corrosion Committee. Mr. Romer has published many papers, including two books for the Water Research Foundation. A 1974 and 1979 graduate of the University of Arizona, Mr. Romer is responsible for the design of over \$1 billion in pipeline construction.

¹ in Kansas and California

² in California

³ in California, Arizona, Wisconsin, Michigan, Nevada

⁴ in California, Arizona, Nevada, Utah, Alaska, Ohio, Maryland, North Dakota, South Dakota, & Florida

NACIMIENTO WATER PROJECT – DESIGN AND HYDRAULICS

John R. Hollenbeck, P.E.¹, M. ASCE, Paul R. Kneitz, P.E.², M. ASCE,
Steve N. Foellmi, P.E.³, M. ASCE, and Andrew E. Romer, P.E.⁴, M. ASCE

ABSTRACT

The Board of Supervisors of the San Luis Obispo County Flood Control and Water Conservation District (District) adopted the Final Environmental Impact Report (EIR) for the Nacimiento Water Project (Project) in January 2004, thus providing direction to District staff to begin the design of the raw water conveyance for 15,750 acre-feet per year from Lake Nacimiento located in San Luis Obispo County, California. The District had secured this water right in 1959, and over four decades thereafter, feasibility studies indicated the economical source of water supply for communities within the County was from groundwater; however, the time came when the next economical supply of supplemental water was the surface waters stored behind Nacimiento Dam, and the Project born. The Project consists of 45-miles of pipeline ranging from 36- to 12-inches, three pump stations, and three water storage tanks. The Project's Participants (customers) currently include Paso Robles, Templeton, Atascadero, and San Luis Obispo (Initial Participants) and later were joined by San Luis Obispo County Service Area 10- Zone A.

The design phase of the Project began in 2004, and continued through the successful bidding of the Project in the fall of 2007. An "army of consultants" was hired by the District to perform several professional services including design engineering, environmental permitting, right-of-way, and financing.

This paper describes the hydraulic design of the Project and related engineering elements of the Project design.

¹San Luis Obispo County Flood Control and Water Conservation District, County Government Center-Room 207, San Luis Obispo, CA 93408,
jhollenbeck@co.slo.ca.us

² Black & Veatch Corporation, 2999 Oak Road, Suite 490, Walnut Creek, CA 94597,
KneitzPR@bv.com

³ Black & Veatch Corporation, 15615 Alton Parkway, Suite 300, Irvine, CA 92618,
FoellmiSN@bv.com

⁴ Boyle-AECOM, 1501 Quail Street, Newport Beach, CA 92660,
Andy.Romer@AECOM.com

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SUMMARY OF PROJECT FACILITIES

The Project, illustrated in Figure 1, consists of 45-miles of pipeline ranging from 36- to 12-inches, three pumping stations (Intake, Santa Ysabel, and Rocky Canyon), three water storage tanks (2-850,000 gallons, and 1-300,000 gallons), and a supervisory control and data acquisition (SCADA) system to facilitate the control. Four turnouts are also constructed to regulate the delivery of water to the participants of the City of Paso Robles, Templeton Community Services District, Atascadero Mutual Water Company, and the City of San Luis Obispo. The Project budget is \$176-million, which includes environmental permitting, right-of-way, design, construction, construction management, and District management.

HYDRAULIC DESIGN

The Project's hydraulic design played an important role in the engineering effort. It established key Project features that significantly affected the Project construction and long-term operating costs. Design elements evaluated and/or established include: phased water deliveries, hydraulic loss coefficients, optimization between pipe diameters and pump station capacities, transient control systems, and a potential energy recovery system.

Phased Water Deliveries

Although the ultimate Project capacity was set at 15,750 acre-feet per year (AFY), the water deliveries allocated to the original Project participants were 9,630 AFY. Recognizing that it would take several years to market the unallocated entitlement (Reserve Capacity), the feasibility of the Project design was evaluated assuming system operation using both Phase 1 flows (for 9,630 AFY) and ultimate flows (for 15,750 AFY). In the end, the Project staff sized the facilities to deliver the ultimate capacity, while acknowledging that throughout the first ten years of operation, the actual operating flow rates would be less.

Hydraulic Design Parameters

The design team calculated the Project hydraulics adopted for final design (Black & Veatch, 2006) for both the Phase 1 and Ultimate flow rates. In each case, minor losses that were assumed during the preliminary design to be 10-percent of the total losses, were calculated in detail for the final design computations.

The hydraulic design utilized the following criteria in the analyses:

- All pipelines have a Manning's "n" roughness factor = 0.011

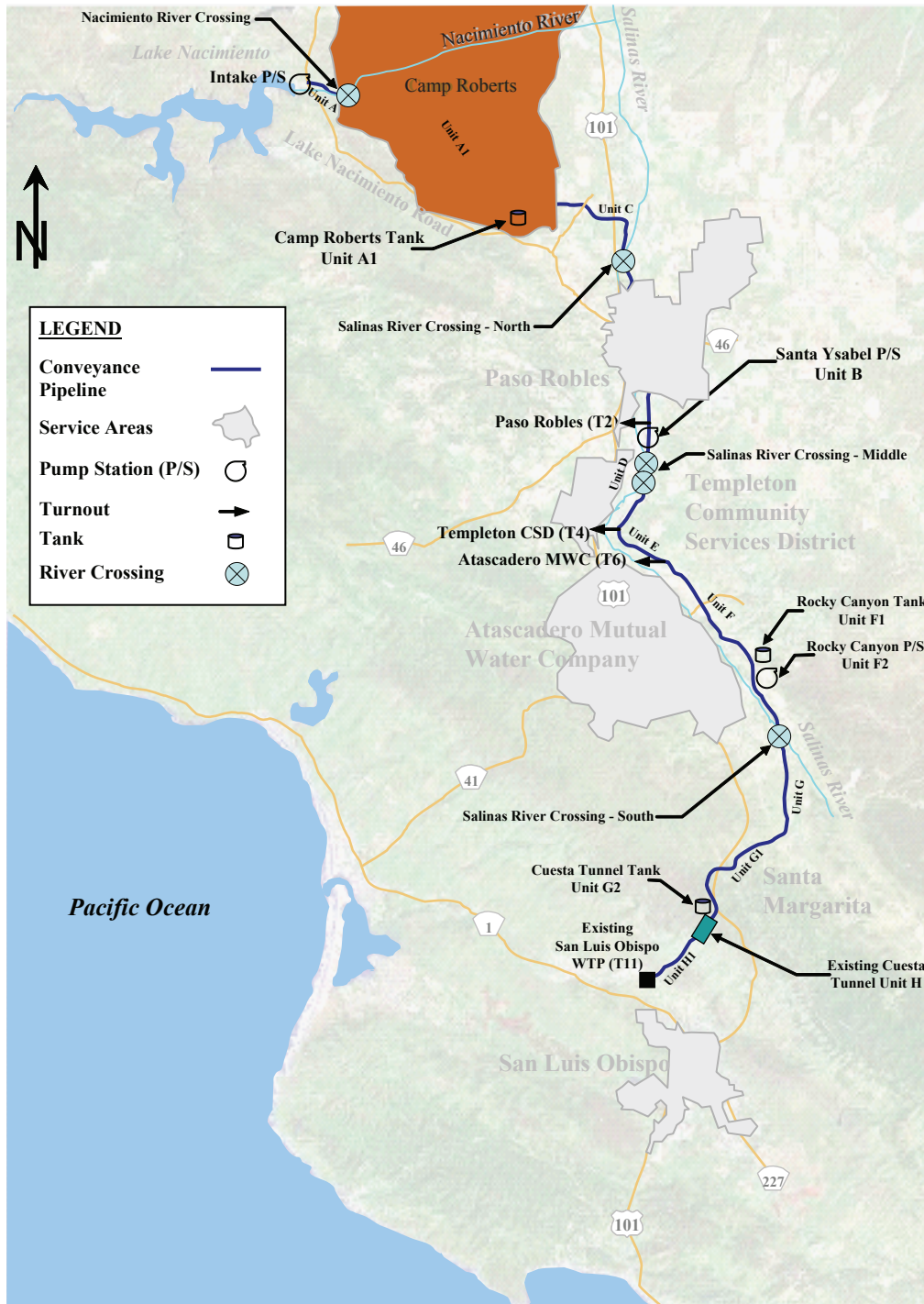


Figure 1. Nacimiento Water Project Unit Map

Hydraulic Feature	Governing Elevations (feet, NAVD88)		
	High	Low	Operating Mean
Lake Nacimiento	800	670	740
Camp Roberts Tank	1013	1005	1009
Rocky Canyon Tank	993	983	988
Cuesta Tunnel Tank	1367	1360	1363.5

Table 1. Governing Water Surface Elevations

Participant	Monthly Flows (cubic feet per second)											
	J	F	M	A	M	J	J	A	S	O	N	D
Paso	2.06	2.58	3.09	4.64	9.03	9.03	9.03	9.03	9.03	4.38	3.09	2.06
TCSD	0.0	0.0	0.0	0.0	0.0	1.03	1.03	1.03	1.03	0.0	0.0	0.0
AMWC	0.0	0.0	0.0	0.0	0.0	0.0	8.29	8.29	8.29	8.29	0.0	0.0
SLO	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14	5.14
Phase 1 Subtotal	7.20	7.72	8.23	9.78	14.17	15.2	23.49	23.49	23.49	17.81	8.23	7.20

Table 2. Final Design Maximum Rates of Participant Phase 1 Deliveries

Pipeline Construction Cost, \$/foot dia-inch	12
Manning's n	0.011
Power Cost, \$/kWh (First Year)	0.15
Life Cycle, years	30
Present Worth Discount Rate, %	7.00
Power Escalation Rate, %	3.00

Table 3. Assumptions Used for Pipeline Optimization Analysis

- All pipeline diameters are set equal to the nominal internal diameter
- Minor losses were calculated in detail based on the 30-percent design drawings

The operational water surface elevations for the Project are presented in Table 1. The monthly Phase 1 flow rates are presented in Table 2.

Pipeline Optimization

A pipeline optimization analysis was performed to compare alternative pipeline

diameters by Project Unit (the identifier for the pipeline reaches), in conjunction with variable pumping energy costs. The approach found the optimal combination of pipeline size and pump station power that produces the least present-worth of capital operating costs.

Power Costs

The operation of the three pump stations will likely generate the largest operating electrical energy (power) cost component associated with the delivery of water to the Participants. The power required for pump operation is inversely proportional

to changes in the transmission pipeline diameter. As the pipe diameter increases, power costs decrease due to the decrease in friction loss in the pipeline, and vice-versa. Table 3 shows the assumptions used in the analysis.

Method of Analysis

The estimated pipeline construction cost was added to the estimated present worth cost of operating power for a series of increasing pipeline diameters to determine the optimal pipe diameter for a given system operating condition. This combination resulted in a cost optimization curve. The pipeline optimization analysis utilized the Ultimate Project operating scenario. In general, the analysis found that pipe diameters could be reduced by six-inches. An example of the analysis is shown in Figure 2.

Transient Control Systems

The Project will operate as a pumped system under normal operation. As a result, the most significant hydraulic event will likely be controlled by the emergency operation and/or malfunction of one or more of the pump stations and/or turnouts. To determine these effects, and to design surge protection measures, engineers computed a detailed surge analysis for the final project configuration. The analysis divided the overall system into four independent hydraulic units as follows: Intake Pump Station to Camp Roberts Tank; Camp Roberts Tank to Rocky Canyon Tank (with Santa Ysabel Pump Station in-between); Rocky Canyon

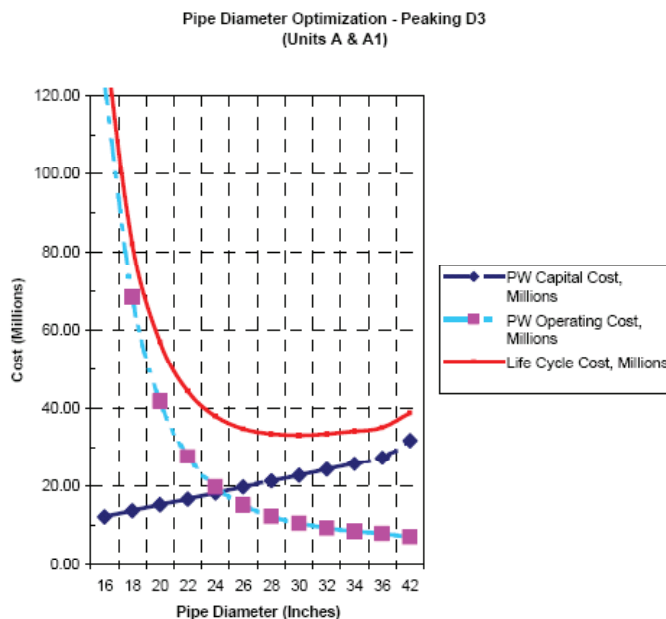


Figure 2.
Pipeline Diameter Optimization Results

Pump Station to Cuesta Tunnel Tank; and Cuesta Tunnel Tank to San Luis Obispo Turnout. The surge modeling employed the following series of assumptions and criteria to define each hydraulic unit:

- Power failure, within any segment containing a pump station, occurs with the pump station operating at 105-percent of the design flow rate.
- All pipelines have a Hazen-Williams roughness factor “C” of 130.
- All pipeline internal diameters are set equal to the nominal diameter of the pipeline.
- Acoustic velocities are based upon the use of either cement-mortar lined and coated steel pipe or ductile-iron pipe.
- All inline isolation valves are fully open.

- Turnout valves remain open upon power failure with the flow rate reducing as the pressure in the pipeline drops.
- All system reservoirs are at the midpoint of their operating band at power failure.

The following criteria were defined to determine the minimum surge control facilities required to control surge pressures to acceptable levels:

- Minimum pressure due to down surge shall always be above atmospheric pressure.
- Maximum pressure due to upsurge shall not exceed the initial hydraulic grade line on the discharge side of the pump stations by more than 100 feet.

The following surge control facilities were selected to control surge due to pump station power failure:

- Intake Pump Station to Camp Roberts Tank: requires an air chamber on the discharge side of the pump station with total volume of 2,900 cubic feet and 18-inch inlet/outlet; also, requires that slow-closing air/vacuum valves be installed downstream at high points in the pipeline.
- Camp Roberts Tank to Rocky Canyon Tank: requires two 10-inch surge relief valves to be located on the suction side of Santa Ysabel Pump Station, set to open when the hydraulic grade line exceeds elevation 1100 feet, which is the overflow elevation of the Camp Roberts Tank; also requires an air

chamber with total volume of 2,100 cubic feet at Santa Ysabel Pump Station with a 16-inch inlet/outlet.

- Rocky Canyon Pump Station to Cuesta Tunnel Tank: 320 cubic feet air chamber on the discharge side of the pump station and a 10-inch inlet/outlet.

Renewable Energy Studies

The design team reviewed options for the District to reduce its overall energy operating costs through either self-generation of electrical power, by constructing and operating solar or hydroelectric facilities, or by selling wholesale power to Pacific Gas and Electric Company (PG&E). These evaluations resulted in neither option being economically feasible at this time.

RELATED ENGINEERING ELEMENTS OF THE PROJECT DESIGN

The District and design team focused on managing the Project budget and reducing construction costs where feasible. A number of initiatives were launched to achieve cost reductions, including: conducting a value engineering study; specifying alternative pipe materials to achieve cost reductions during bidding; and implementing the “Savings by Design” program offered by PG&E. Other project features involving cost control studies included, evaluating alternatives for the communications and SCADA system, performing a physical hydraulic model of the lake intake wet well, and evaluating alternatives for roads and streams crossings.

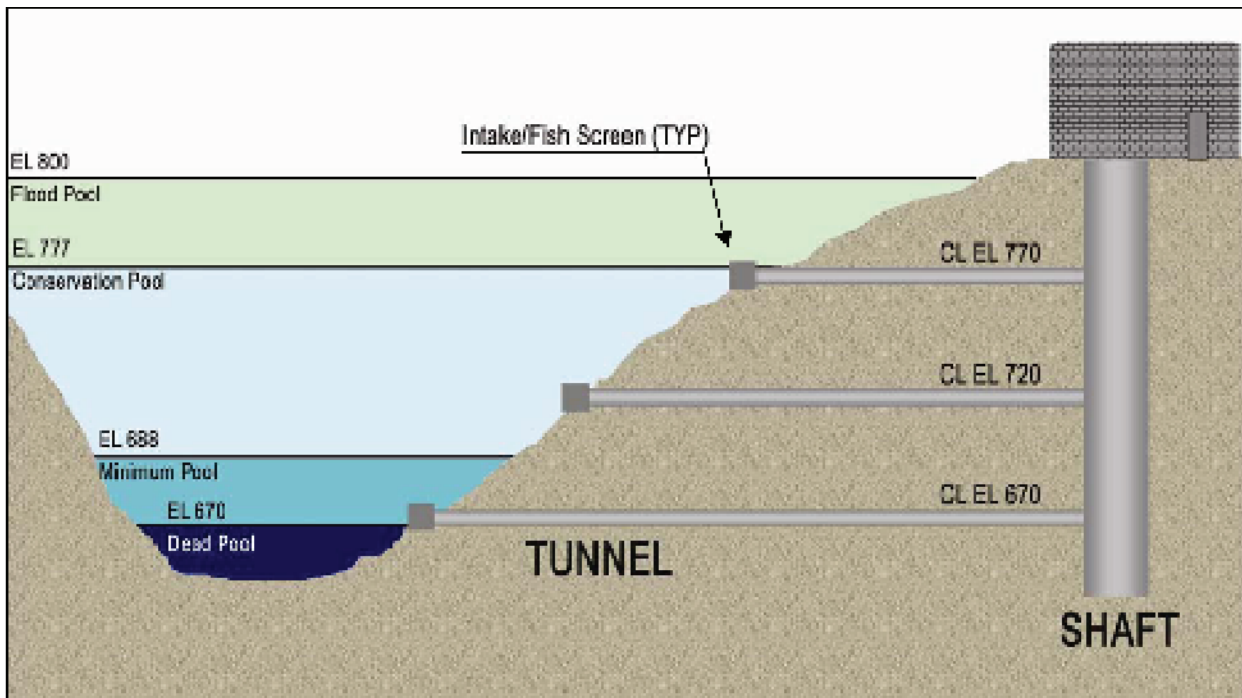


FIGURE 3. Nacimiento Water Project Configuration in the EIR

Value Engineering Study

The District commissioned a comprehensive value engineering (VE) study that was performed at the completion of the preliminary design report (30-percent design completion) (Value Management Institute 2006). The VE team sought opportunities for efficiently designed facilities that focus on capital cost savings and appeal to the construction industry, with the objective of reducing projected construction costs by several million dollars. In addition, modifications that could reduce construction time, thus resulting in cost industry, with the objective of reducing projected construction costs by several million dollars. In addition, modifications that could reduce construction time, thus resulting in cost savings, were of interest. As part of its approach, the VE team

initially identified which Project elements represented the highest construction costs, and focused its efforts on these items. As a result, the preliminary design concepts for several facilities received extra attention, including:

- Intake and Intake Pump Station Design. The VE team looked at a number of options, including barge-mounted or track-mounted pumps placed in the lake, or moving the intake shaft closer to the lake. Ultimately, they recommended changing the preliminary design from a multi-tunnel intake (Figure 3), as conceived for the EIR, to a single tunnel intake with a multi-port sloping intake pipe (Figure 4).
- Storage Tanks. The VE team proposed open cut reservoirs

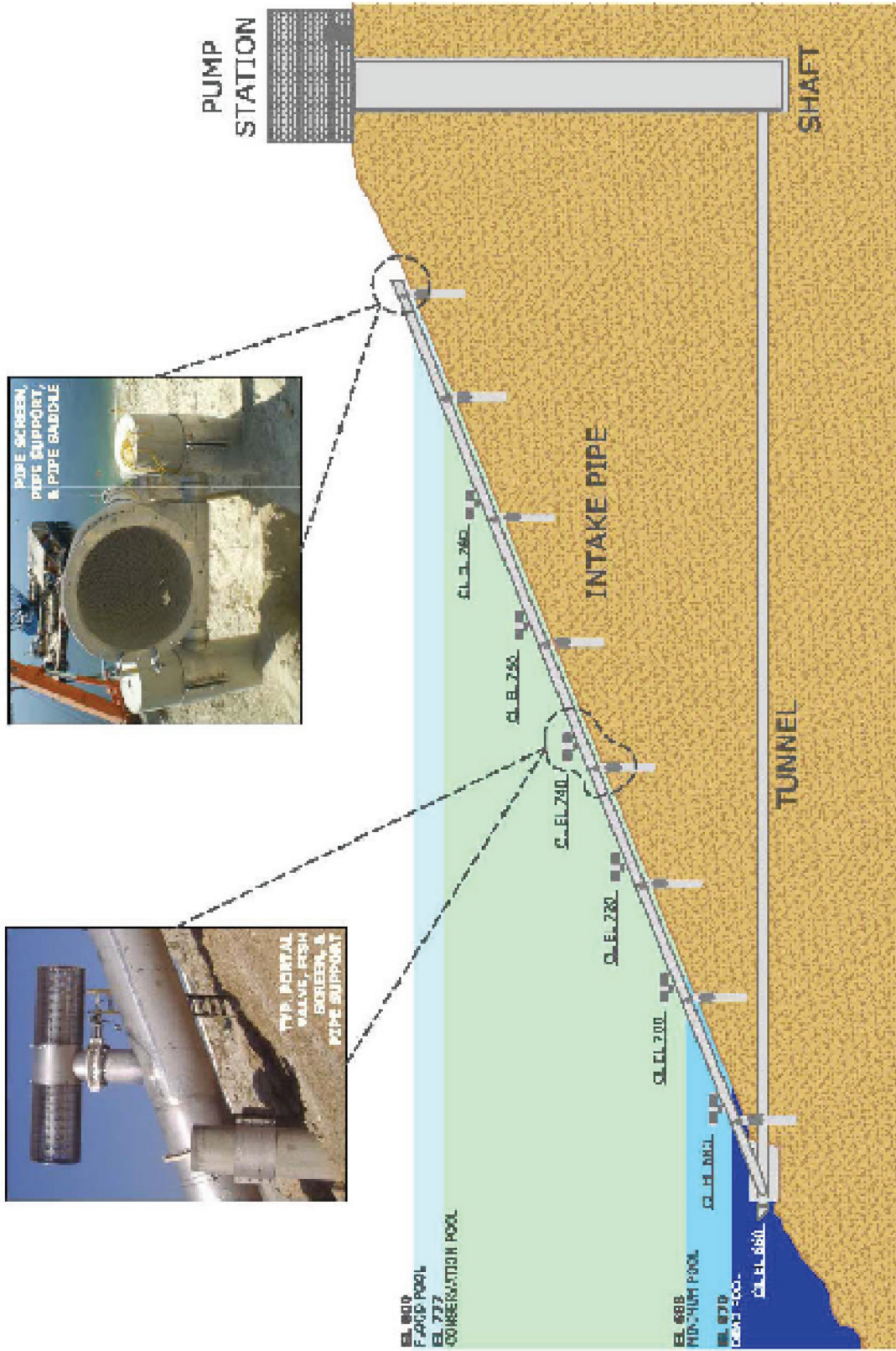


Figure 4. Nacimiento Water Project Configuration Accepted for Final Design

in lieu of tanks; ultimately, the design team elected to forego this opportunity to have time-of-use pumping and reduce the overall volume of storage as a means of reducing construction costs.

- Relocate Camp Roberts Pump Station. The VE team suggested that reducing operating pressures in the pipeline system would result in significant cost savings. The design found that re-locating the Camp Roberts Pump Station to a location several miles south (downstream) would achieve this objective; thus, the idea was adopted.

The District expects the VE proposals implemented in the Final Design saved the Project between \$10- and \$15-million.

Alternative Pipe Materials Specified for Bidding Purposes

As part of its cost control strategy, the design team organized the design and bid documents to allow bids for alternative pipe materials over the 45 miles of pipeline required. The documents allowed either welded steel pipe or ductile iron pipe as pipe materials alternatives. The material specifications for both pipe types were set-up and carefully reviewed to achieve parity between pipeline installation requirements for the two pipe material options.

The results rewarded the effort of bidding alternative pipe materials. Pipeline contract bids came in much lower than estimated, and most of the savings was

attributed to price competition between pipe materials.

PG&E Savings by Design Program

Savings By Design is a statewide nonresidential new construction and renovation/remodel energy efficiency program. PG&E manages the program in this Project area. The program enables customers to improve the energy efficiency of their projects using design assistance and financial incentives available through the program. Participation in the *Savings By Design* program was voluntary, and the District was under no obligation to modify the Project's design or construction based on resulting recommendations. Furthermore, the District would receive financial incentives only after PG&E deemed the design eligible, the Project performance meets the program requirements, and the energy efficiency strategies are installed and verified.

The decision to participate is based on a financial comparison of the initial cost of the energy-savings measure offset to the life-cycle energy savings plus the incentives payments. For example, the design of the pump stations showed potential for feasibility of inclusion in *Savings By Design*. The use of premium-efficiency pumps and energy efficient electrical systems and lighting would pay for themselves within a reasonable payback period.

Of greater significance, the team reviewed the potential of upsizing several miles of pipeline to reduce hydraulic losses and therefore, pump station capacity and

pumping costs. The team developed a plan to receive alternative bids for upsizing entire pipeline reaches, provided that the cost for upsizing the pipe based on alternative bids was less than the breakeven point dictated by energy savings and incentives payments.

Based on bid results, the northern-most reach of the Project pipeline was upsized from 30-inches to 36-inches with a resulting reduction of the Intake Pump Station capacity and expected lower pumping costs. The pump units were downsized from 700- to 500-hp. The payback on this investment is estimated to be between 10 and 15 years.

Communications and SCADA System

The method for communicating the control and monitoring signals from beginning to end had to be carefully evaluated, due to the 45 mile conveyance length. Alternatives included installing a fiber optic network, a radio system with repeater station, or a microwave system.



Figure 5.

Wetwell at Hydraulic Modeling Laboratory.

A radio system appeared to be the most economical, but the District elected to install a fiber optic network. The fiber optic network was sized to handle Project communications with allowance for the County IT Department to utilize spare fibers to establish a fiber backbone throughout the County.

Concurrent installation of the fiber optic conduit and pipeline within the pipe trench simplified the construction process. Pullboxes were placed at approximately 1,500-foot intervals for cable installation, within which the County identified several splice points for future connection into the County-wide fiber network.

Physical Hydraulic Model (Lake Intake Wetwell)

The design team commissioned a physical hydraulic model study of the Intake Pump Station. The model study investigated the possible presence of hydraulic conditions in the pump station wetwell that would adversely impact operation and maintenance of the vertical turbine pumps. Such hydraulic conditions could include flow pre-swirl entering pumps, vortex formation, and flow velocity imbalance approaching the impeller(s), all of which could lead to pump vibration, cavitation damage, accelerated bearing wear, reduction of pump capacity, and/or deviation from the best efficiency point.

The hydraulic model looked to optimize the intake shaft and inlet port diameters for hydraulic purposes. In addition, if adverse hydraulic conditions were present, the model could investigate

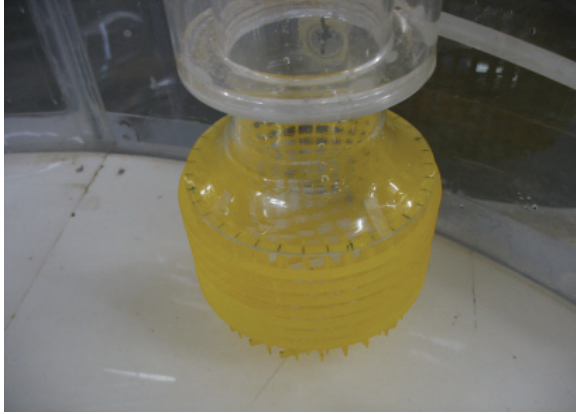


Figure 6. Pump Suction Bell and Assembly of Anti-Vortex Baffle.

mitigation measures to incorporate into the Project design.

The hydraulic modeling work was performed by a hydraulic laboratory (see Figure 5), under subconsulting contract with the design firm. Initially, the team reviewed the intake concept, focusing on determining the minimum wetwell diameter, minimum intake tunnel diameter, floor elevation of the pump station (submergence), and pump spacing and layout. An analysis using computational fluid dynamics (CFD) followed to verify expected hydraulic conditions. The CFD results aided in determining the recommended geometry for the physical hydraulic model.

The hydraulic model study (Northwest Hydraulic Consultants 2006) determined

that the initial wet well configuration did not meet established performance criteria. Several modifications to the initial design were developed and tested in the physical model, including:

- Raising all five pumps to provide a one-foot clearance between the wetwell floor and the pump inlet; and
- Suspending a 36-vane basket with bottom grating and seven equally-spaced horizontal vane rings from all five pumps (see Figure 6).

CONCLUSION

The time span for designing the Project was April 2005 through April 2007 – a two year period that seems long at the onset; however, several important design decisions must be made to manage budget (economic resources) and the environment (natural resources). The District is responsible for the prudent management of the public's monies being invested in this new hydraulic structure. Additionally, the District must make wise design choices to save, when possible, the natural resources needed to not only manufacture the materials placed in the Project, but the future resources (mainly electrical) needed to operate this Project. The District judges that all of these have been effectively managed for the Project.

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Black & Veatch (2006). “Nacimiento Water Project, Final Preliminary Design Report”, July 2006.

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