APPENDIX B – Technical Papers and Presentations

The following list presents technical papers and/or presentations published and/or presented on behalf of the Nacimiento Water Project. A copy of each is included within Appendix B.

Paper and/or Presentation Title	***Technical Conference***	***Date***
Water Fundamentals Panel	Association of California Water Agencies	May 2004
Sustainability: Working Together to Secure the Future, The Nacimiento Water Project	CA-NV AWWA Conference	May 2006
Nacimiento Water Project Intake Facility	ASCE Pipelines 2007 Conference	July 2007
Nacimiento Lake Tap	North American Tunneling Conference	June 2008
How a Small Agency Manages a Mega Pipeline Project – A Success Story	ASCE Pipelines 2008 Conference	July 2008
Hot Tap Construction of Lake Nacimiento, California	The North American Society and the International Society for Trenchless Technology International No-Dig Show	March/April 2009
One Project, 6 HDDs: Nacimiento Water Project	The North American Society and the International Society for Trenchless Technology International No-Dig Show	March/April 2009
Achieving Sustainability by Designing for Efficiency – A Case History of the Nacimiento Water Project	33rd International Association of Hydraulic Engineering and Research Biennial Congress	August 2009
Nacimiento Water Project: Design and Hydraulics	ASCE Pipelines 2009 Conference	August 2009
Bidding Strategies Help Manage Construction Budgets: A Case History of the Nacimiento Water Project	ASCE Pipelines 2009 Conference	August 2009
Creative Financing Overcomes Financial/Political Obstacles for Regional Water Supply Project	APWA International Public Works Congress and Exposition	August 2010

Paper and/or Presentation Title	***Technical Conference***	***Date***
Transient Pressure Monitoring Program – Nacimiento Water Project	ASCE Pipelines 2010 Conference	Aug/Sep 2010
Managing Compliance with Environmental Permit Conditions on a 45-Mile Pipeline in California: Problems and Solutions	36th Annual National Association of Environmental Professionals Conference	April 2011
Transient Pressure Monitoring Results – Nacimiento Water Project	ASCE Pipelines 2011 Conference	July 2011 (pending)

ACWA
Water Fundamentals Panel
May 5, 2004

Nacimiento Water Project
New Surface Water Supplies to Serve the Central Coast

Your panelists

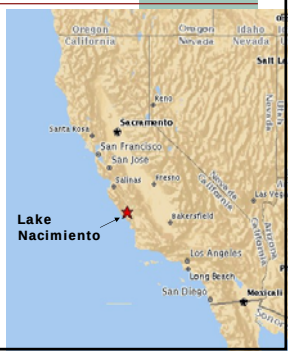
- Harry Ovitt, San Luis Obispo County Supervisor
- Jim App, City of El Paso de Robles City Manager
- Dave Hardan, Boyle Engineering Corp.
- Christine Ferrara, San Luis Obispo County Flood Control District

What sets this water project apart?

- Participants have spoken – they need water now
- Favorably contrasted to State Water Project
- Sensitivity to affected property owners
- Local control over terms of participation
- Quick turn-around on $ estimates
- State housing mandate

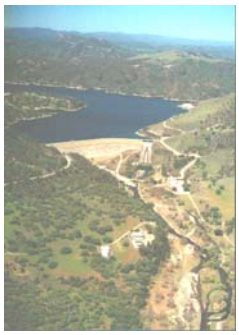
Lake Nacimiento

- 378,000 acre-feet
- 125,000+ AFY yield
- Primary water source for Monterey County
- SLO County holds 17,500 AFY entitlement, but…no pipeline to deliver it



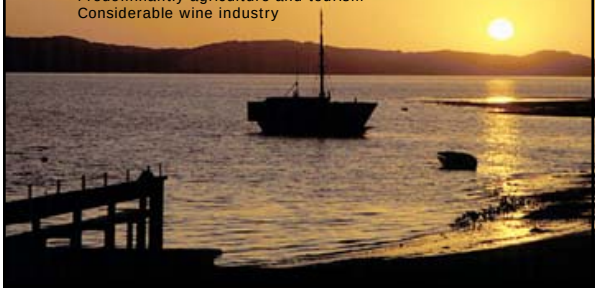
The proposed project

- Deliver 15,750 AFY
- New intake structure
- 48 miles of pipeline 20" to 36" dia.
- (3) Storage tanks
- (3) Pump stations
- Raw water deliveries
- $145m project estimate



About San Luis Obispo County

250,000 population
3,300 square miles
Predominantly agriculture and tourism
Considerable wine industry



SLO's water history

- Salinas Dam built to support Camp SLO during WW II
- Nacimiento built in '57; Whale Rock in '61; Lopez in '69
- Hold 25,000 AFY State Water, but…capacity for <5,000 AFY
- SLO City now implementing reclamation

San Luis Obispo County largely relies on ground water to meet needs -- agricultural and urban.

Overview of water supplies

- Groundwater supplies over ¾ of water needs
- Surface supplies (Santa Margarita, Lopez, Whale Rock, and Nacimiento Lakes)
- State Water
- Reclaimed Water
- Conservation

Today's water issues

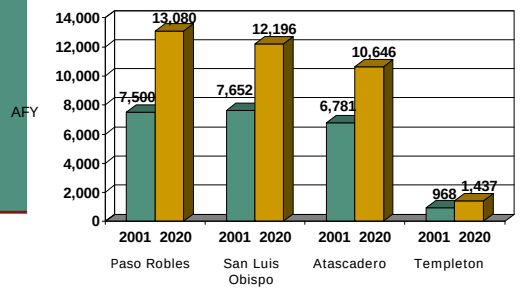
- Ground water levels in some areas declining
- Pumping along coastal streams discouraged
- Santa Maria and Los Osos GW Basins in litigation
- Cities seek enhanced reliability
- Water quality concerns

Countywide water needs

- 1986 DWR – Nacimiento, State Water, conservation, reclamation, desalination all needed to meet water needs
- 1998 EDAW – Water demand projected to increase 26% Countywide

Our Nacimiento entitlement plays a vital role in meeting foreseeable water needs.

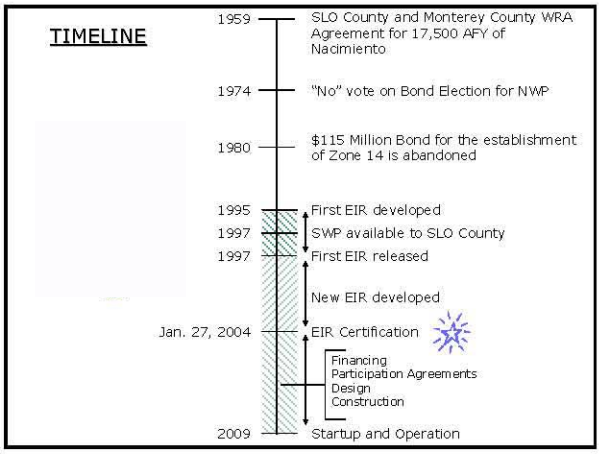
Demand Projections



*From 2001 County Master Water Plan

Other water supply options

- Remaining regional water projects:
  - Unused SWP entitlement (16,553 AFY)
  - Regional reclamation projects
- Conservation
- Nacimiento (15,750 AFY)



Regional value of Nacimiento

- Significant addition to water supplies
- Reduces competition for groundwater between urban and ag
- Potential to improve water quality
- Excellent drought protection

Value of Nacimiento to participants

- More supply
- Reliable 2nd source
- Potential to improve water quality and reduce dependence on softeners
- Lessen competition with ag pumpers

Paso Robles' water setting

- 27,000 population expected to increase to 44,000 (7,500 to 11,000+ AFY)
- 2nd largest city in county
- Surrounded by thriving vineyards
- Reliant on ground water and Salinas River underflow
- Ground water levels declining
- Widespread use of softeners affecting waste stream

City water policies

- #1 = secure additional water supply (not always the case…
- Take steps to reduce salt loading in waste stream
- Promote conservation

Key Nacimiento events

- 1999
  - New River Road alignment proposed
  - Engaged Todd Engineers and water rights attorney
  - Opposed SLO City's expansion to Salinas Dam spillway
  - RWQCB notice re: salts violations
- 2000
  - Major issues report for City utilities
  - Urban Water Mgt Plan
  - Recycling study
  - Salt management study
  - GW Basin study initiated

More key events

- 2001
  - Council goals focusing on water and sewer improvements
- 2002
  - GW basin study released
- 2003
  - PRIOR
  - WDR permit renewal
  - Malcom Pirney study Nacimiento = preferred option
- 2004
  - NPDES permit renewal
  - Nacimiento project commitment

Options for Paso Robles

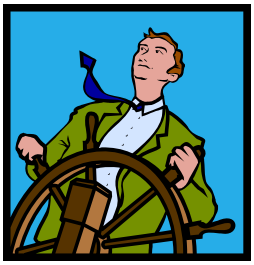
- Pump more ground water → Legal challenges
- Conservation → Won't entirely replace need for supplemental water
- Reclamation → Must address salts issue
- Nacimiento → Preferred option – 4,000 AFY

Why now?

- Just updated General Plan
- Supportive of economic growth
- Forward-looking Council
- Waste discharge concerns
- Water rate increase needed for capital projects plus new supply

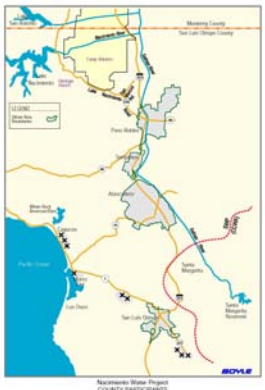
Paso Robles' leadership role

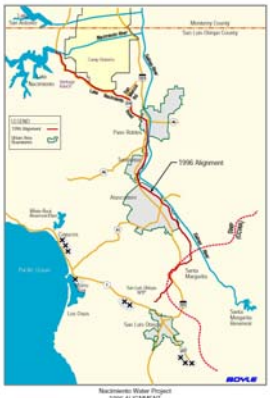
- Timing critical
- Aligned with City's #1 priority
- Partnering approach with Flood Control District



Project description

- How we arrived at current alignment
- Approach to ROW acquisition
- Setting terms of participation agreement





Success factors

- High participant involvement
- Smart ROW approach
- Sought advice of environmentalists
- State housing mandate vs. no-growth

SUSTAINABILITY: WORKING TOGETHER TO SECURE THE FUTURE

JOHN HOLLENBECK: SAN LUIS OBISPO COUNTY, CALIFORNIA • CHRISTINE HALLEY: T.J. CROSS • STEVE FOELLMI, PERRI STANDISH-LEE: BLACK & VEATCH

NWP NACIMIENTO WATER PROJECT
San Luis Obispo County Flood Control & Water Conservation District
www.nacimientoproject.org

BLACK & VEATCH
Building a world of difference.

THE NACIMIENTO WATER PROJECT – A CALIFORNIA RAW WATER PROJECT

The San Luis Obispo County Flood Control and Water Conservation District (District) entered into an agreement with Monterey County Water Resources Agency to utilize 17,500 acre-feet annually from the 377,800 acre-feet Nacimiento Reservoir. After decades of planning and studies, the Nacimiento Water Project (NWP) is now in the design and environmental permitting phase and will convey 15,750 acre-feet per year to regions within the County (1,750 acre-feet remains for lakeside uses). The NWP is scheduled to be operational in 2010.

IMPROVING RELIABILITY OF WATER SUPPLY

By providing a reliable raw water supply from Lake Nacimiento to water purveyors throughout San Luis Obispo County, the NWP will achieve sustainability goals for groundwater protection and renewal.

The Initial Participants currently rely on groundwater and river underflow for nearly all their raw water supply.

Recent groundwater studies reveal that with the thriving agriculture of the Central Coast as well as urban growth, reaching the safe yield of groundwater is in sight.

Supplemental water will augment well water in order to sustain a planned balance.

NACIMIENTO WATER PROJECT STAKEHOLDERS WORK TOGETHER

COMPREHENSIVE REGIONAL FACILITIES

The NWP is a regional raw water transmission facility that will deliver water from Lake Nacimiento to communities in San Luis Obispo County. Major NWP facilities include an intake and pump station at Lake Nacimiento, approximately 45 miles of transmission pipeline ranging in size from 30 to 12-inches in diameter, four storage tanks, two intermediate pump stations, and turnouts to divert water to project participants.

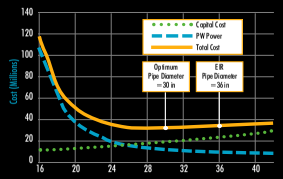
Stakeholder consensus has been a key factor in project success.

RESPONSIVE CONSENSUS APPROACH

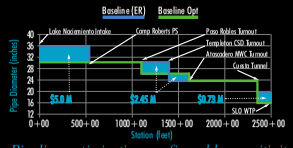
The Initial Participants are the City of El Paso de Robles (Paso), Atascadero Mutual Water Company (AMWC), Templeton Community Services District (TCSD), and the City of San Luis Obispo (SLO). Meetings and workshops are held to receive input and direction from the District, the Initial Participants, and other project stakeholders including the Technical Support Group (TSG) and the Nacimiento Project Commission (Commission).

COST MANAGEMENT THROUGH DESIGN OPTIMIZATION AND VALUE ENGINEERING

Holding the line on costs has been a major project challenge. In February 2005, the District approved an overall budget of $150 million. In September 2005, the Design Team established a baseline cost of approximately $179 million. Subsequent pipeline optimization analyses and modifications to the design assumptions used for distribution of the Reserve Capacity identified cost savings of $17 million. Value Engineering in the spring of 2006 identified an additional $12 million to $17 million in savings. The project team will continue to seek opportunities to reduce costs to achieve the original $150 million goal. Strategies include optimizing the contracting plan and implementing advanced risk management strategies.



Each Pipeline unit was evaluated to determine optimum balance between construction and operation (energy) costs.



Pipeline optimization confirmed by sensitivity analysis identified $8 million in construction cost savings.

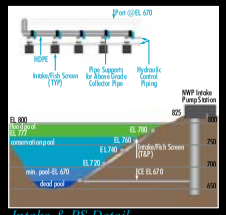
SOLVING TECHNICAL CHALLENGES WHILE SUSTAINING THE ENVIRONMENT

INTAKE PUMP STATION AND RIVER CROSSINGS

A key project feature is the Intake Pump Station at Lake Nacimiento. Preliminary design included review and analysis of water quality data for Nacimiento Reservoir and development of recommendations for intake port depths, chemical feed options for the raw water supply and water quality monitoring. The focus was protecting water quality and minimizing construction impacts.

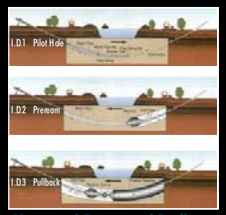
Environmental protection and minimized construction impacts are also central to design of the river crossings. As shown on the map, the NWP has major crossings on the Nacimiento and Salinas Rivers. Several trenchless construction methods were evaluated for pipeline installation, and horizontal directional drilling (HDD) was considered the best option. This technique will allow pipeline installation to proceed without construction impacts in sensitive portions of the waterways and minimal construction activities on the river banks.

Lake Nacimiento



Intake & PS Detail

Salinas River Crossing



Horizontal Directional Drilling

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Nacimiento Water Project Intake Facility

Presented At

2007 ASCE International Pipeline Conference
Boston, Massachusetts
July 10, 2007

Paul R. Kneitz, P.E.
John R. Hollenbeck, P.E.
Clay Haynes, P.E.

Authors

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John R. Hollenbeck, P.E.[2], 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.

Christopher G. Mueller, Ph.D., P.E.[3], is the Project Geotechnical Engineer with Black & Veatch Corporation. On the Nacimiento Water Project, he authored the Geotechnical Baseline Report included in Contract Package 01 for the intake structure at Lake Nacimiento. Mr. Mueller has more than 20 years experience in design of shafts and tunnels for water projects. He holds a M.S. in Civil Engineering from Northwestern University and a Ph.D. in Civil (Geotechnical) Engineering from the University of Illinois.

[1] in California
[2] in Kansas and California
[3] in Missouri

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Nacimiento Water Project Intake Facility

Paul R. Kneitz, P.E., John R. Hollenbeck, P.E., Clay Haynes, P.E.

ABSTRACT

Black & Veatch Corporation is directing a project team that is designing a new $185 million supplemental raw water supply from Lake Nacimiento for San Luis Obispo County. The project consists of a multi-port sloping intake facility and pump station, two intermediate pump stations, three storage tanks, control center, and approximately 45-miles of transmission pipeline ranging in diameter from 36-inches to 12-inches.

This paper discusses the planning and design of the intake facility, which is a 180-foot deep, 16- to 20-foot diameter vertical shaft connected to the lake via a single 48- to 72-inch diameter microtunneled intake tunnel with a lake tap. A surface-mounted sloping intake with seven ports will allow water to be drawn from various depths of the reservoir for optimal water quality control.

Also addressed are the intake alternatives considered during conceptual and preliminary design, and detailed construction planning with the use of geotechnical baseline report (GBR) in the construction contract documents.

Nacimiento Water Project Intake Facility

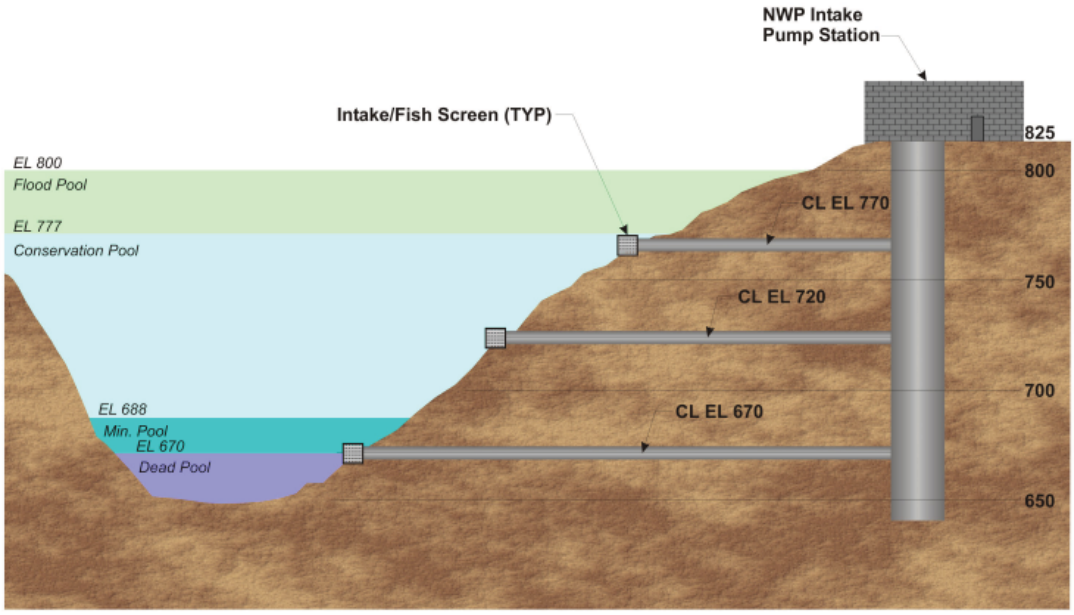
Paul R. Kneitz, P.E., John R. Hollenbeck, P.E., Clay Haynes, P.E.

Introduction

Located in the central coast of California, the San Luis Obispo County Flood Controll and Water Conservation District (District) is implementing the Nacimiento Water Project (NWP), a raw water conveyance system to deliver 15,750 acre-feet annually from Lake Nacimiento to participating agencies including City of Paso Robles, City of San Luis Obispo, Atascadero Mutual Water Company, Templeton Community Services District and County Service Area 10, Zone A (Figure 1).

In 2005, Black & Veatch Corporation, Irvine, California, was selected to perform preliminary and final design of the $185 million project, which is scheduled to be in operation by 2010. A key element of the Project is the NWP Intake, consisting of a 20-foot diameter, 180 foot deep, concrete-line vertical shaft connected to the Lake via a single 530-foot long, 48-inch diameter micro tunnel with a lake tap. A surface-mounted sloping intake with seven ports will allow water to be drawn from various reservoir depths for optimal water quality. Construction is scheduled to begin winter of 2007.

Figure 2. NWP Intake Configuration in the EIR



Source: Black & Veatch Corporation, December 2005

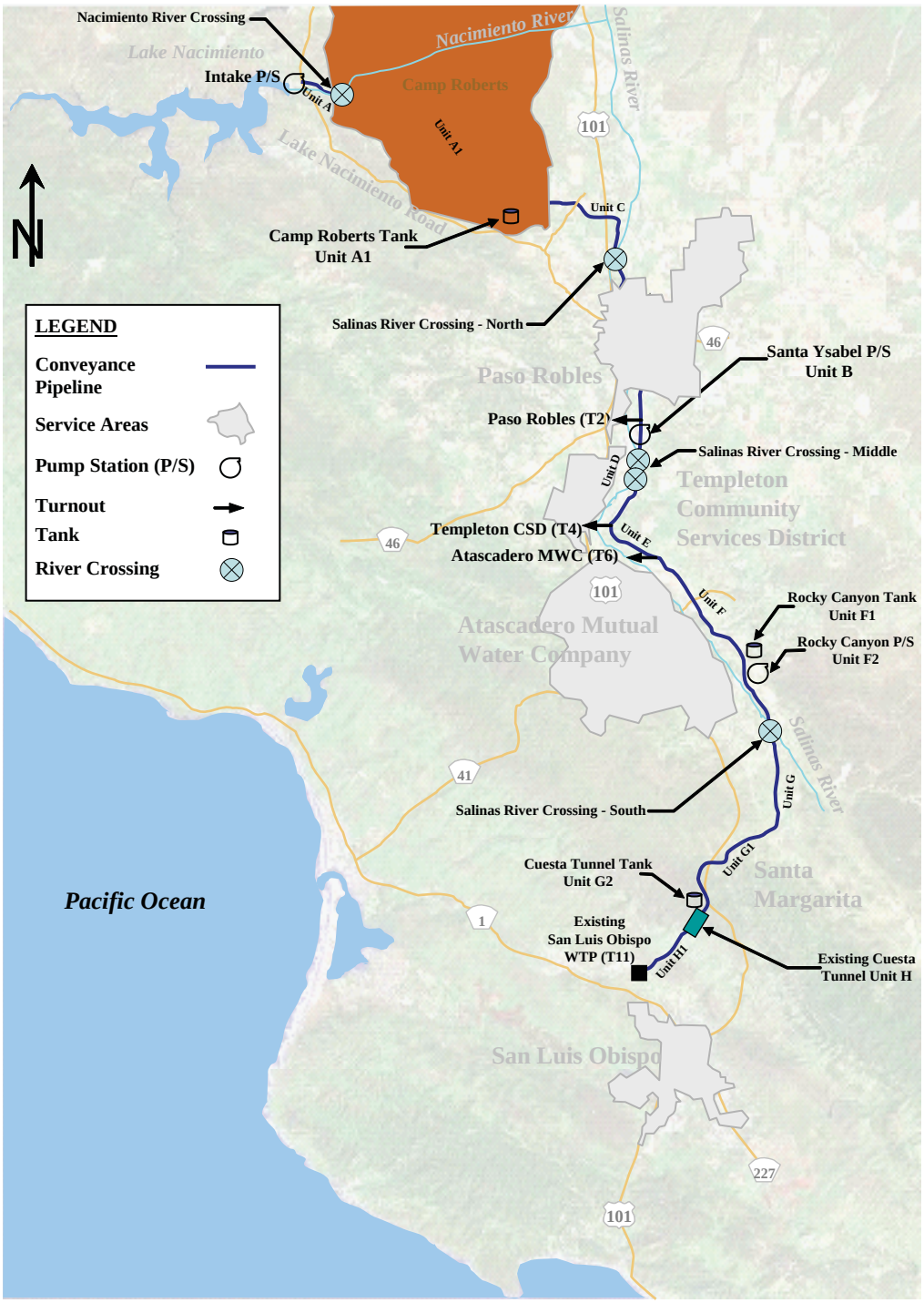
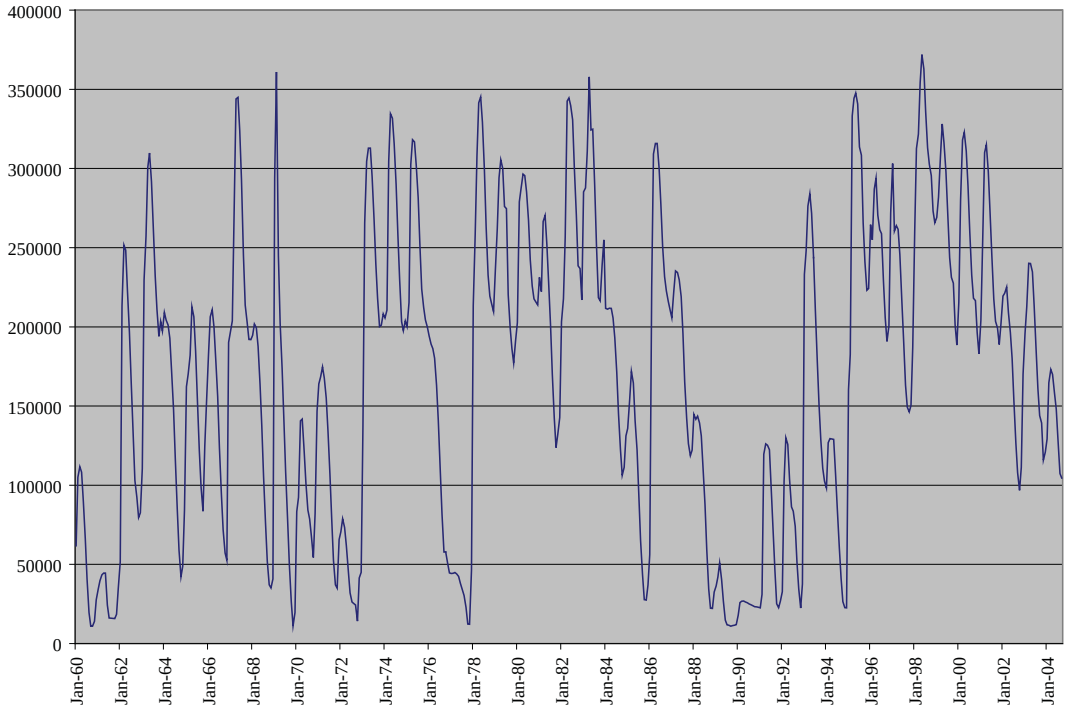


Figure 1. Nacimiento Water Project, San Luis Obispo County, California



Source: California Department of Water Resources

Figure 3. Nacimiento Storage Levels, Acre-Feet (1960 to 2004)

NWP Intake Alternatives

The Nacimiento Water Project Final Environmental Impact Report (FEIR), December 2003, represented the conceptual design of the intake facility as a fixed three-port lake intake, with each port connected to the lake via a 72-inch diameter inlet tunnel (Figure 2). As design development progressed, it became clear that the fixed-port intake did not offer enough flexibility to withdraw raw water from varying lake levels (Figure 3) sufficient to optimize the water quality in combination with the participating agencies' treatment process. A water quality investigation and review of intake alternatives was subsequently conducted by Black & Veatch in December 2005.

A technical memorandum (TM) was prepared to summarize the existing lake water quality data and to provide recommendations on intake port depths, chemical fed options for the raw water supply, and water quality monitoring. Black & Veatch reviewed water quality data for Nacimiento Reservoir obtained from the District, as well as historical water levels, for the purpose of analyzing the following lake characteristics:

- Determining the position of the thermocline in the water column;
- Describing water quality in the epilimnion and hypolimnion and identifying locations (depths) where water quality changes occur; and
- Identifying additional water quality

data and monitoring needs.

Figure 3, obtained from the California Department of Water Resources website shows historical reservoir storage volumes based on acre-feet of storage, which was converted to reservoir elevations for analysis.

As expected, the water quality data indicated that during the winter months the temperature profiles in the reservoir are fairly uniform and stratification is not present. Beginning in February or March, the surface water start to warm and a thermocline starts to form. Usually during May, epilimnion, thermocline, and hypolimnion areas become distinct. The surface waters reach their highest temperatures in July and August and then start to cool. As the surface water cools, the thermocline erodes and the temperature profiles again become uniform. Stratification disappears as early as October or as late as December.

During the periods of a well established thermocline (May through September), the top of the thermocline was observed to be at depths of 15 to 30 feet and the bottom of the thermocline was at depths of 30 to 55 feet. The thermocline was usually 15 to 25 feet thick.

Based on the water quality data results, the number and spacing of intake ports were also reviewed as part of this TM. Ultimately, the decision was made to incorporate seven intake ports spaced at approximately 20 feet vertically in order to provide the flexibility to withdraw optimal water quality for any operating lake level. Figure 4 shows a schematic of the intake configuration accepted for final design.

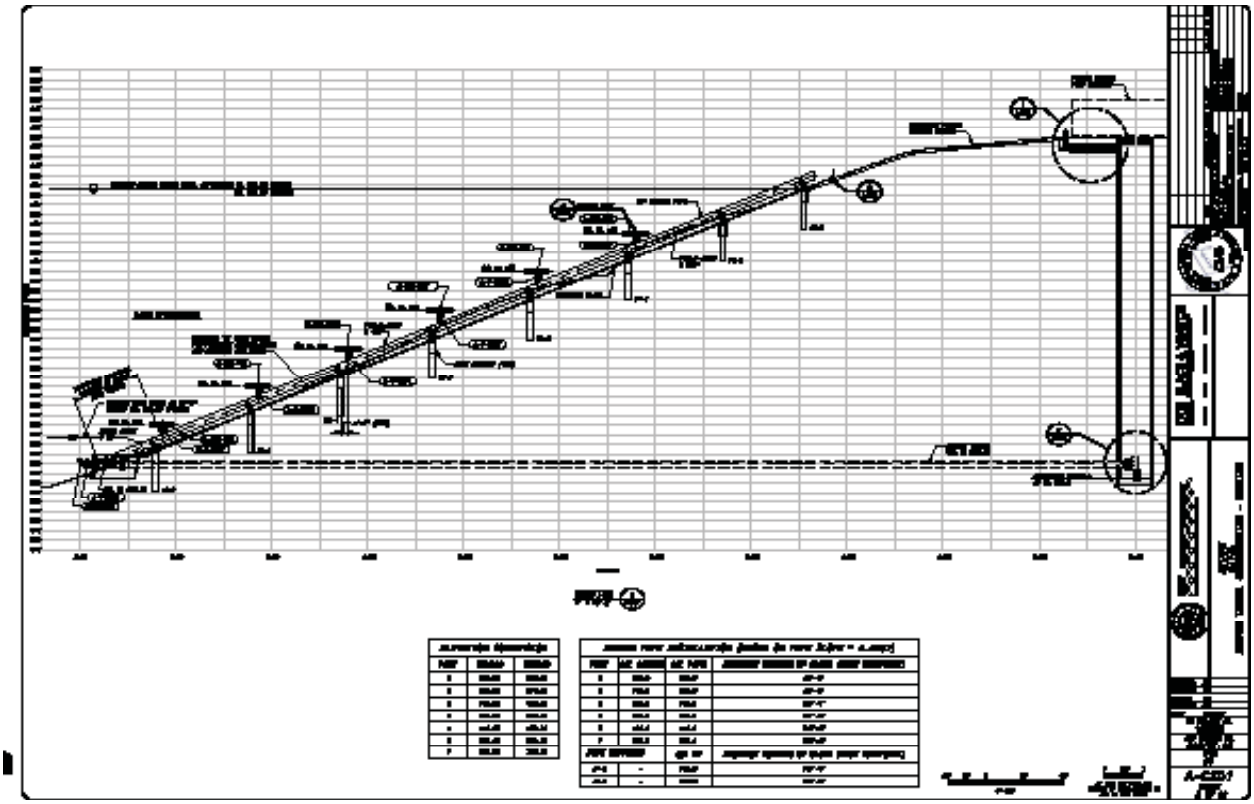
NWP Intake Design

Final design of the NWP Intake focused on construction of the four principal features of the intake, namely, vertical shaft, intake tunnel, sloping intake and intake ports, and marine works. The following discusses the considerations involved with each part.

Geologic & Geotechnical Considerations

The intake site is located in the central California Coast Ranges Geomorphic Province, characterized by moderately rugged terrain and north-northwest trending ridges and intervening alluvial valleys. The site is located in a tectonically and seismically active region dominated by the San Andreas Fault System.

As outline in the Geotechnical Baseline Report (GBR) for the intake, the intake shaft is located upstream of the existing Nacimiento Dam and adjacent to the north abutment and spillway. Geologic mapping indicates shaft and tunnel construction will take place in the Vaqueros Formation consisting of moderately lithified, massive, poorly- to well-graded sandstone. The formation is predominantly quartz with minor constituents that included feldspar and clay minerals. The formation can include conglomerates and granitic boulders, as well as thing partings of clay, claystone, or siltstone that separate the massive



Source: Black & Veatch Corporation, 2007

Figure 4. NWP Intake Configuration Accepted for Final Design

sandstone beds.

The Vaqueros Formation observed at the boring locations varies significantly in strength, hardness, and quality. In general, the formation consists of fine- to medium-grained sandstone whose mineral constituents are dominated by hard, abrasive minerals such as quartz and feldspar. Significant clay minerals ranging from clay-size to slit- and fine-sand size particles are also present in the formation.

One of the most significant characteristics of the Vaqueros Formation as relates to shaft tunnel construction is the presence of hard, abrasive minerals. Published literature indicates quartz content of 50 percent to more than 90 percent. Grain size analyses on samples of the sandstone indicate the presence of significant clay-, slit- and fine-sand size particles, ranging from 10 to 25 percent passing the No. 200 sieve. Much of this fraction of “fine” material, however, includes quartz and feldspar.

The structure of the Vaqueros Formation includes both bedding planes and tow orthogonal sets of joints. As shown in Figure 5, the bedding dips steeply into the slope (north-northeast) at angles of 50 to 78 degrees. The nature of the bedding planes is highly variable which typifies sedimentary deposits. In general, the

bedding planes are characterized by very thing (< 1mm) partings containing silt and clay. Elsewhere, the silt and clay can be absent entirely.

Joints are typically widely spaced, tight, and contain either precipitates of calcium carbonate ("healed") or evidence of weathering. Joints dip steeply from near vertical to between 45 to 80 degrees.

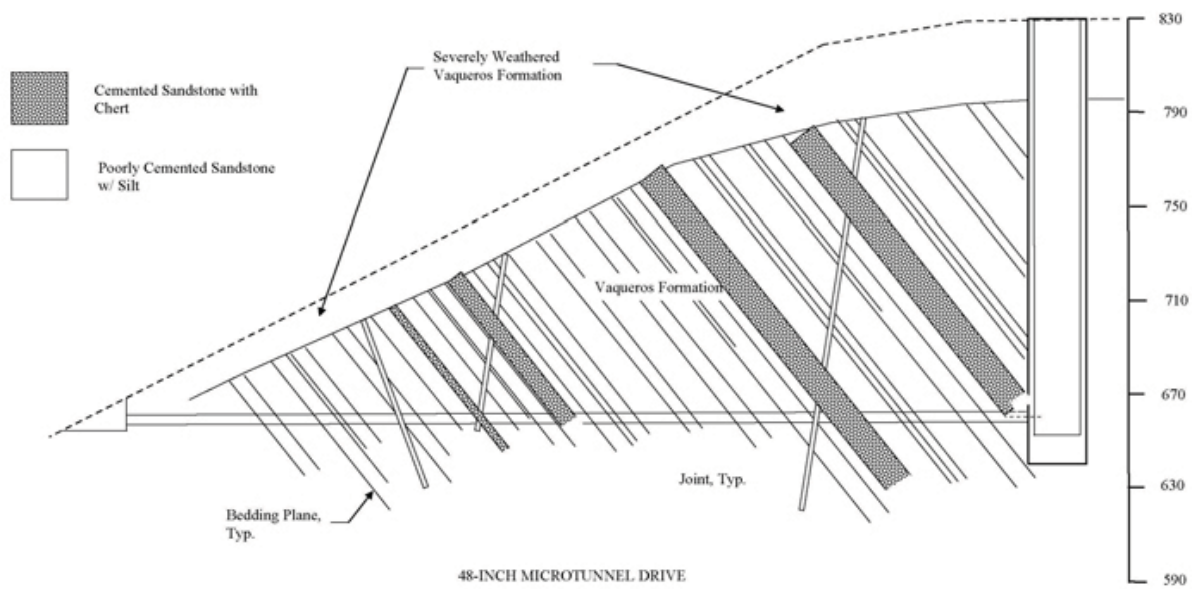
The intact strength of the rock varies between extremely weak and weak to moderately strong. Measured rock strength typically ranges from several hundred to several thousand pounds per square inch (psi), although lower and higher strengths were measured. The lowest measured uniaxial compressive strength was about 10 psi, while the largest measured values were on the order of 7,000 psi.

Ground water levels at the site will vary substantially with seasonal variation in precipitation within the watershed and with reservoir levels.

Shaft Design

Evacuation for the intake shaft will extend approximately 180 ft ± below ground surface and will require excavation through a combination of fill, residual soil and weather rock, and weak to moderately strong, intact rock. Plans for the project require a finished interior shaft diameter of 16- to 20-feet, with an excavation shaft diameter to be determined by the general contractor based on structural requirements shown in the contract documents and means and methods used for initial support.

Design of initial support for the shaft



Source: Black & Veatch Corporation, Intake GBR, 2007

Figure 5. Geologic Section through NWP Intake

excavation will be the responsibility of the contractor. Initial support may consist of linear plate and steel ribs, steel ribs with timber lagging, slurry panels walls, secant piles, or casing installed using drilling methods, such as blind auger drilling. Since slurry panel walls, secant piles, and blind auger drilling provide pre-support of the ground prior to substantial excavation prior to installation, including approved management of ground water inflows and significant reductions in excavation volumes.

Due to the unfavorable orientation of bedding planes within the Vaqueros Formation and the generally weak nature of the rock, the material is expected to squeeze and fast ravel within a cycle of bench excavation and erection of initial support. Thus, excavation volume 35 percent greater than those corresponding to a "neat" line would be anticipated for support systems requiring excavation prior to installation. In addition, for linear plate and/or steel rib installations, ground water inflows and corresponding requirements for treatment and disposal must be considered. Based on our analyses, sustained ground water inflows of 500 gpm should be anticipated. Flush flows of up to 2,000 gpm are possible and if encountered are to be grouted to reduce total flows into the shaft to a 500 gpm threshold.

Microtunneling

A single 530-foot long microtunneled intake tunnel will connect the shaft to the lake with a lake tap. The construction method will involve jacking a steel pipe casing following a microtunnel boring machine (MTBM), with the casing serving as initial support and final linear. Plans for the project require a finished intake tunnel diameter of 48- to 72-inches, with the actual diameter to be determined by the general contractor based on MTBMs available at bid time and allowable jacking space resulting from the selected shaft diameter. The contractor will be responsible for selection of the appropriate MTBM and casting thickness to carry the thrust of the jacking forces and other loads.

The MTBM will be driven from the shaft to the reservoir and retrieved "in the wet." The retrieval of the MTBM will be staged from an excavation into the slope of the reservoir side wall that will be prepared prior to initiation of microtunneling.

The MTBM will be a closed, pressurized face, steerable, laser-guided, articulated tunnel shield capable of exerting continuous, controlled pressure at the tunnel fact to prevent uncontrollable groundwater inflows and ground movement into the cutter chamber, with a reversible cutterhead drive system to minimize rotation of pipe during installation. It will also be capable of handling the various anticipated ground conditions to minimize loss of ground during tunneling and steerable and capable of controlling the advance of the heading to maintain line and grade within the specified tolerances. It will include a system to inject lubricant over and around the rear of the MTBM to reduce jacking friction and a slurry system

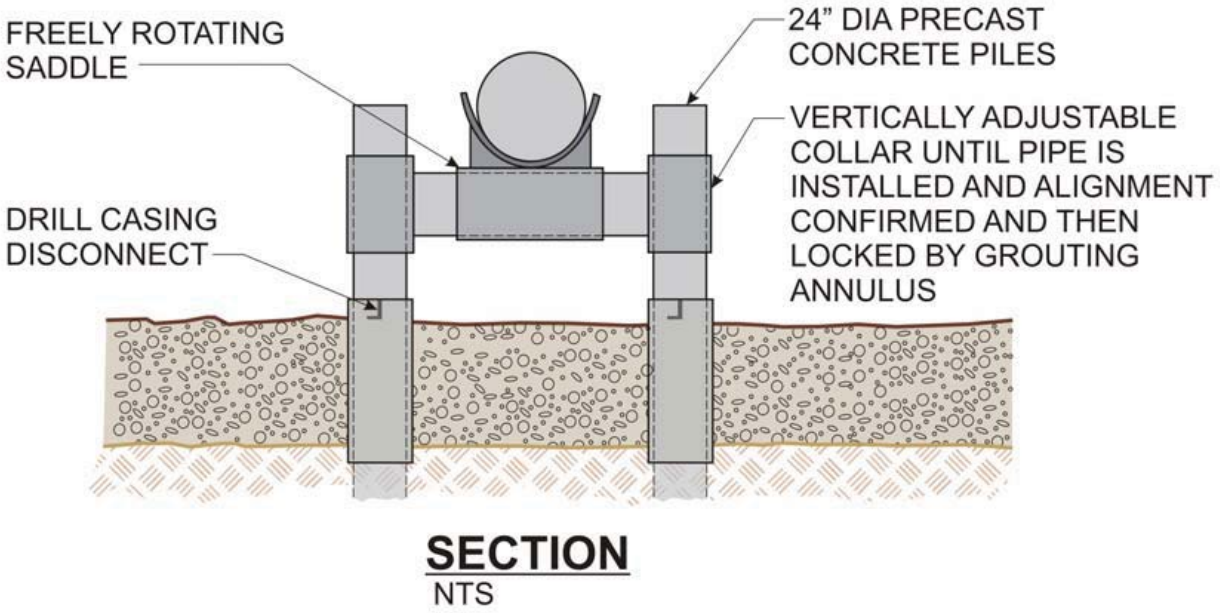
to balance ground and groundwater pressure up to 140 feet of hydrostatic head.

The overall tunneling system will also include a casing jacking system; launch seal affixed to the shaft wall and through which the MTBM and steel pipe passes; equipment to maintain proper air quality in case the contractor selects manned microtunnel operations during construction; lighting fixtures in watertight enclosures; and possible air lock to assist in cutter changes where changing cutters under atmospheric pressure is infeasible. The steel casing pipe will be either all welded steel pipe or Permalok pipe with gasketed joints.

The final push of the MTBM into the reservoir, the "lake tap," is expected to be the riskiest part of the job. During the lake tap operations, the contractor's principal focus will be on the safety of the work and personnel. The contractor will select its means and methods for performing the lake tap, including the type of removal bulkheads and/or flood valves to be used to ensure that the work is protected from flooding and unexpected water inflows given the relatively high head working conditions. The sequence for temporary support and removal of the MTBM to the lake surface will also be a critical activity.

Sloping Intake and Intake Ports

The seven-port sloping intake was selected to maximize the District's ability to withdraw water from the best locations depending on actual reservoir water

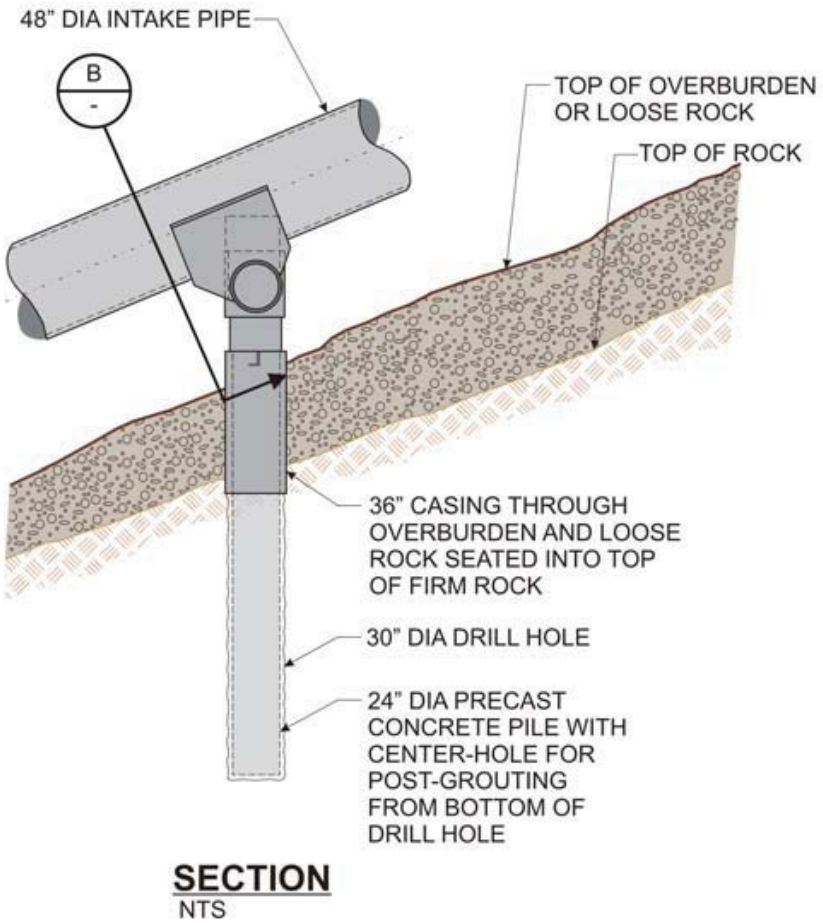


Source: Ben C. Gerwick, Inc., December 2006

Figure 6. Section through Intake Pipeline Saddle Support

Source: Ben C. Gerwick, Inc., December 2006

Figure 7. Pipe Support Foundations for NWP Intake Pipeline



surface elevation, and time of year. The inlet ports and uniformly spaced vertically at 20-foot centers. The intake consists of a 400-foot long, 48-inch diameter, free-standing pipeline anchored on pipe supports; 24-inch diameter inlet ports with isolation butterfly valve and screen; and hydraulic system for intake valve operation.

A key construction planning activity focused on how to quickly and efficiently install the pipe supports and pipeline segments underwater from the lake surface. As shown in Figures 6 and 7, the intake design team, including underwater specialists from Ben C. Gerwick, Inc., devised a pipe support system that involves construction of cased drilled holes, followed by insertion of precast concrete piers and subsequent grouting to solidly lock the piers in-place. The individual pipeline segments (50 foot each) will be connected into 100- to 150-foot lengths and lowered down onto the pipe supports and connected to the pier tops with a fabricated steel pipe saddle. The saddle details will be finalized prior to advertisement for bidding, and the means and methods and final installation

sequencing will be left to the installing contractor.

Marine Construction

Marine construction activities will support the installation of the sloping intake and retrieval of the MTBM. Associated with the marine construction will be the replacement / relocation of the existing log boom in the intake / spillway area.

Marine construction will involve establishing a floating marine operation with barge/crane and access to shore; diving operations; fuel transfer; underwater excavation; placement of tremie concrete; underwater construction of pile supports; and underwater placement of pipeline segments, valves and screens.

Summary / Lessons Learned

Although construction cost was a key factor, the NWP Intake design evolution was eventually driven by water quality requirements – to provide an intake with seven ports that will allow water to be drawn from various depths of the reservoir for optimal water quality control. As a result, a surface-mounted sloping intake was adopted.

With this change in concept, underwater construction and placement of the intake pipe became a key focus of the design team. Details of construction sequencing and the design of pipe supports that are adjustable underwater were developed to assure the project is constructed in a safe and timely manner.

Advertisement to bid for the NWP Intake will occur in Spring 2007, and construction is scheduled to commence in late 2007.

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Black & Veatch Corporation, Nacimiento Water Project Technical Memorandum (TM) 8, Water Quality Investigations, January 2006 (Final).

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Marine Research Specialists, Nacimiento Water Project, Environmental Impact Report (Final), December 2003, prepared for the San Luis Obispo County Department of Planning and Building

NOTES

NWP NACIMIENTO WATER PROJECT

San Luis Obispo County Flood Control & Water Conservation District

COUNTY GOVERNMENT CENTER, ROOM 207, DEPARTMENT OF PUBLIC WORKS
SAN LUIS OBISPO, CALIFORNIA, 93408

Nacimiento Lake Tap

Presented At

2008 North American Tunneling Conference
San Francisco, California
Jule 10, 2008

Clay Haynes, P.E.
John R. Hollenbeck, P.E.
Chris Mueller, PhD., P.E.

Authors

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John R. Hollenbeck, P.E.[2], 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.

Christopher G. Mueller, Ph.D., P.E.[3], is the Project Geotechnical Engineer with Black & Veatch Corporation. On the Nacimiento Water Project, he authored the Geotechnical Baseline Report included in Contract Package 01 for the intake structure at Lake Nacimiento. Mr. Mueller has more than 20 years experience in design of shafts and tunnels for water projects. He holds a M.S. in Civil Engineering from Northwestern University and a Ph.D. in Civil (Geotechnical) Engineering from the University of Illinois.

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[2] in Kansas and California
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Nacimiento Lake Tap

Clay Haynes, P.E., John R. Hollenbeck, P.E., and Chris Mueller, Phd., P.E.

ABSTRACT

In 2005, Black & Veatch Corporation began designing a raw water conveyance system for San Luis Obispo County from Lake Nacimiento to the city of San Luis Obispo. The first element of the water transfer system will be a raw water pump station and lake tap. The wetwell of the pump station will consist of a concrete lined shaft approximately 180 feet deep constructed in the very incompetent sandstone of the Vacqueros Formation. The lake will be wet tapped at approximately 172 feet below grade using a slurry earth pressure balance tunnel boring machine. The 48 to 72-inch finished diameter microtunnel will be approximately 500 feet in length. Construction is scheduled to begin in the Winter of 2007.

Nacimiento Lake Tap

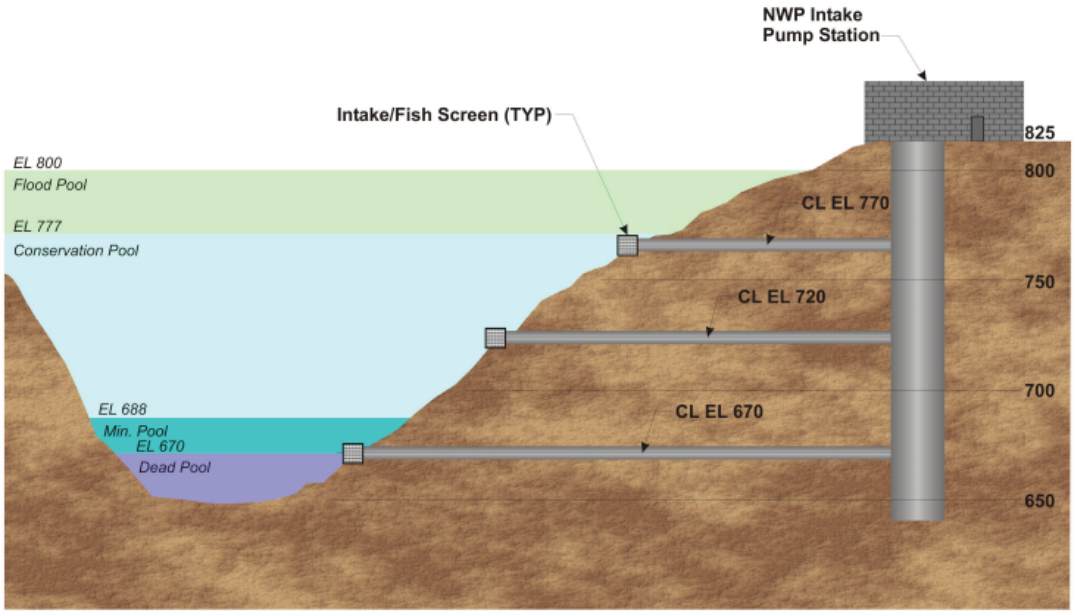
Clay Haynes, P.E., John R. Hollenbeck, P.E., and Chris Mueller, Phd., P.E.

Introduction

Located in the central coast of California, the San Luis Obispo County Flood Control and Water Conservation District (District) is implementing the Nacimiento Water Project (NWP), a raw water conveyance system to deliver 15,750 acre-feet annually from Lake Nacimiento to participating agencies including the City of Paso Robles, City of San Luis Obispo, Atascadero Mutual Water Company, and the Templeton Community Services District and County Service Area 10, Zone A (Figure 1).

In 2005, Black & Veatch Corporation, Irvine, California, was selected to perform preliminary and final design of the $185 million project, which is scheduled to be in operation by 2010. A key element of the Project is the NWP Intake, consisting of a 20-foot diameter, 180-foot deep, concrete-lined vertical shaft connected to the Lake via a single 500-foot long, 48-inch to 72-inch diameter micro tunnel with a lake tap. A surface-mounted sloping intake with seven ports will allow water to be drawn from various reservoir depths for optimal water quality. Construction is scheduled to begin winter of 2007.

Figure 2. NWP Intake Configuration in the EIR



Source: Black & Veatch Corporation, December 2005

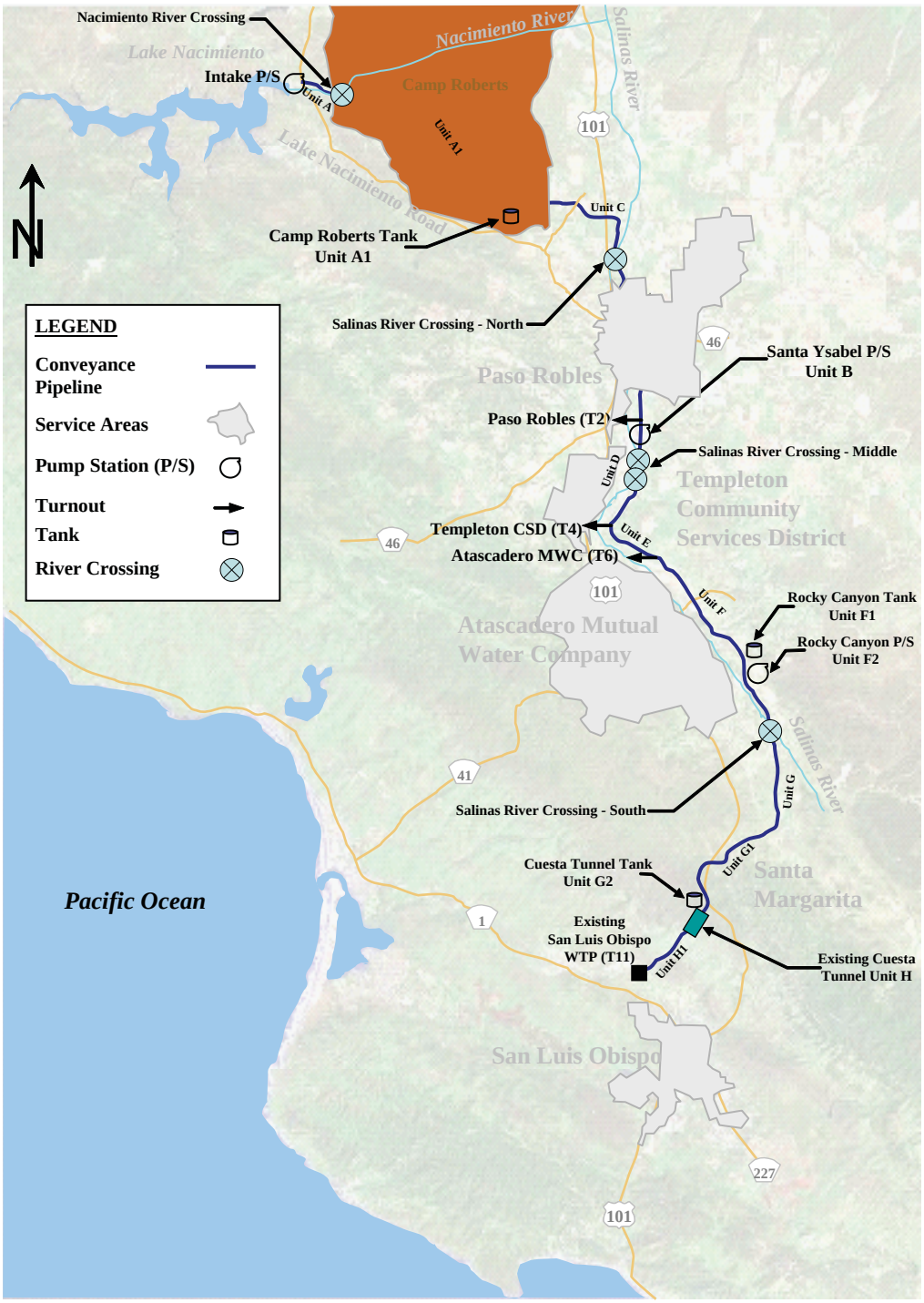
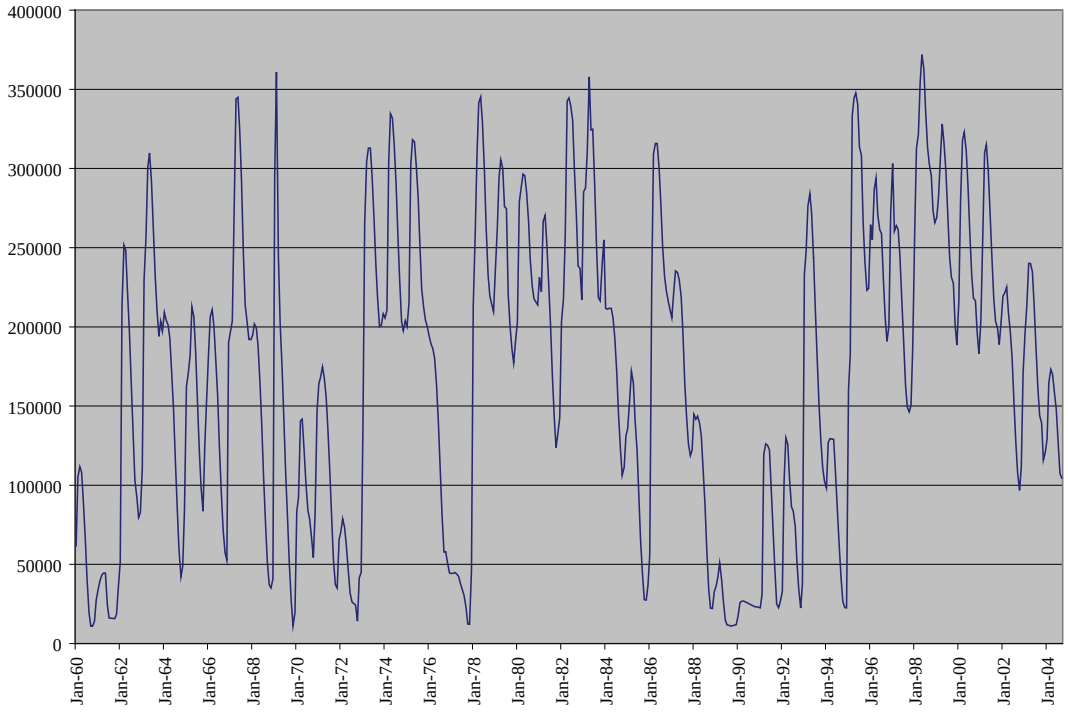


Figure 1. Nacimiento Water Project, San Luis Obispo County, California



Source: California Department of Water Resources

Figure 3. Nacimiento Storage Levels, Acre-Feet (1960 to 2004)

NWP Intake Alternatives

The Nacimiento Water Project Final Environmental Impact Report (FEIR), December 2003, represented the conceptual design of the intake facility as a fixed three-port lake intake, with each port connected to the lake via a 72-inch diameter inlet tunnel (Figure 2). As design development progressed, it became clear that the fixed-port intake did not offer enough flexibility to withdraw raw water from varying lake levels (Figure 3) sufficient to optimize the water quality in combination with the participants' treatment processes. A water quality investigation and review of intake alternatives was subsequently conducted by Black & Veatch in December 2005.

A technical memorandum (TM) was prepared to summarize the existing lake water quality data and to provide recommendations on intake port depths, chemical feed options for the raw water supply, and water quality monitoring. Black & Veatch reviewed water quality data for Nacimiento Reservoir obtained from the District, as well as historical water levels, for the purpose of analyzing the following lake characteristics:

- Determining the position of the thermocline in the water column;
- Describing water quality in the epilimnion and hypolimnion and identifying locations (depths) where water quality changes occur; and
- Identifying additional water quality

data and monitoring needs.

Figure 3, obtained from the California Department of Water Resources website, shows historical reservoir storage volumes based on acre-feet of storage, which was converted to reservoir elevations for the analysis.

As expected, the water quality data indicated that during the winter months the temperature profiles in the reservoir are fairly uniform and stratification is not present. Beginning in February or March, the surface waters start to warm and a thermocline starts to form. Usually during May, epilimnion, thermocline, and hypolimnion areas become distinct. The surface waters reach their highest temperatures in July and August and then start to cool. As the surface water cools, the thermocline erodes and the temperature profiles again become uniform. Stratification disappears as early as October or as late as December.

During the periods of a well established thermocline (May through September), the top of the thermocline was observed to be at depths of 15 to 30 feet and the bottom of the thermocline was at depths of 30 to 55 feet. The thermocline was usually 15 to 25 feet thick.

Based on the water quality data results, the number and spacing of intake ports were also reviewed as part of this TM. Ultimately, the decision was made to incorporate seven intake ports spaced at approximately 20 feet vertically in order to provide the flexibility to withdraw optimal water quality for any operating lake level. Figure 4 shows a schematic of the intake configuration accepted for final design.

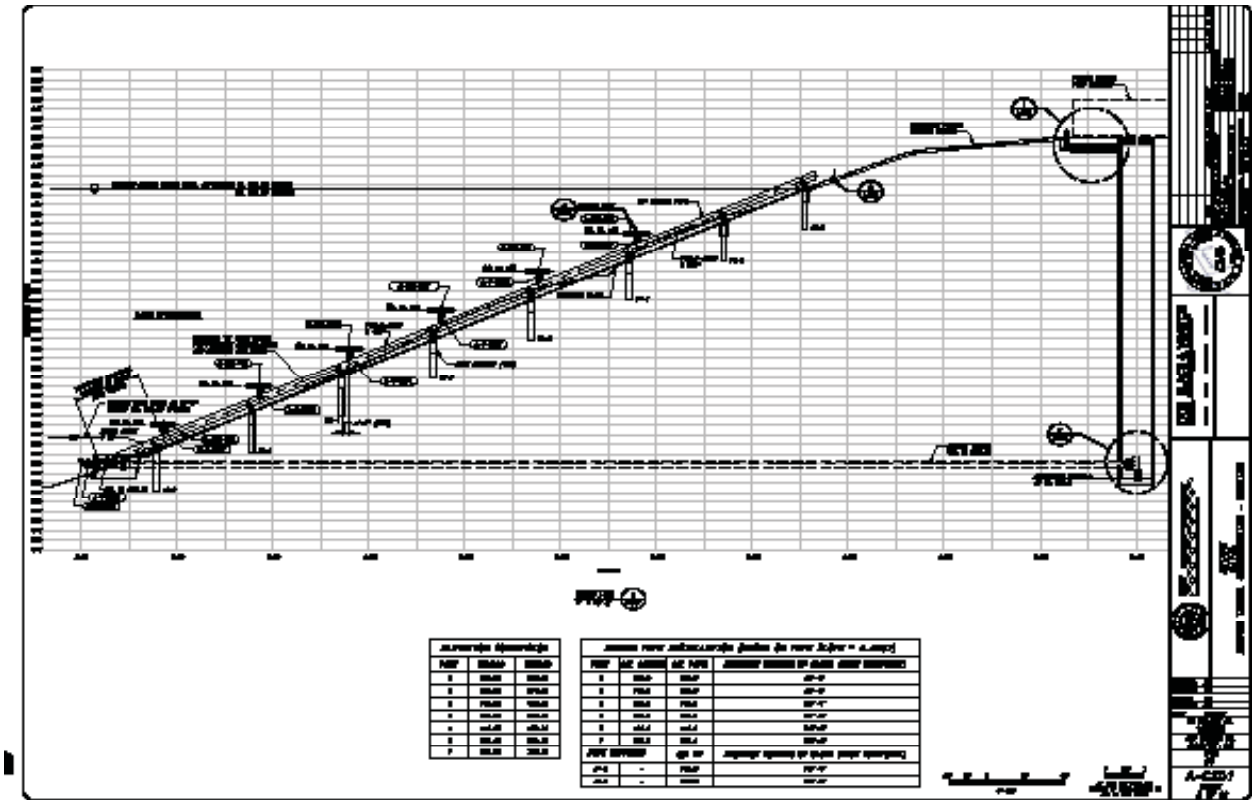
NWP Intake Design

Final design of the NWP Intake focused on construction of the four principal features of the intake, namely, vertical shaft, intake tunnel, sloping intake and intake ports, and marine works. The following discusses the considerations involved with each part.

Geologic & Geotechnical Considerations

The intake site is located in the central California Coast Ranges Geomorphic Province, characterized by moderately rugged terrain and north-northwest trending ridges and intervening alluvial valleys. The site is located in a tectonically and seismically active region dominated by the San Andreas Fault System.

As outlined in the Geotechnical Baseline Report (GBR) for the intake, the intake shaft is located upstream of the existing Nacimiento Dam and adjacent to the north abutment and spillway. Geologic mapping indicates shaft and tunnel construction will take place in the Vaqueros Formation consisting of moderately lithified, massive, poorly- to well-graded sandstone. The formation is predominantly quartz with minor constituents that include feldspar and clay minerals. The formation can include conglomerates and granitic boulders, as well as thin partings of clay, claystone, or siltstone that separate the massive sandstone beds.



Source: Black & Veatch Corporation, 2007

Figure 4. NWP Intake Configuration Accepted for Final Design

The Vaqueros Formation observed at the boring locations varies significantly in strength, hardness, and quality. In general, the formation consists of fine- to medium-grained sandstone whose mineral constituents are dominated by hard, abrasive minerals such as quartz and feldspar. Significant clay minerals ranging from clay-size to silt- and fine-sand size particles are also present in the formation.

One of the most significant characteristics of the Vaqueros Formation as relates to shaft and tunnel construction is the presence of hard, abrasive minerals. Published literature indicates quartz content of 50 percent to more than 90 percent. Grain size analyses on samples of the sandstone indicate the presence of significant clay-, silt- and fine-sand size particles, ranging from between 10 and 25 percent passing the No. 200 sieve. Much of this fraction of “fine” material, however, includes quartz and feldspar.

The structure of the Vaqueros Formation includes both bedding planes and two orthogonal sets of joints. As shown in Figure 5, the bedding dips steeply into the slope (north-northeast) at angles of 50 to 78 degrees. The nature of the bedding planes is highly variable which typifies sedimentary deposits. In general, the bedding planes are characterized by very thin (< 1mm) partings containing silt and

clay. Elsewhere, the silt and clay can be absent entirely.

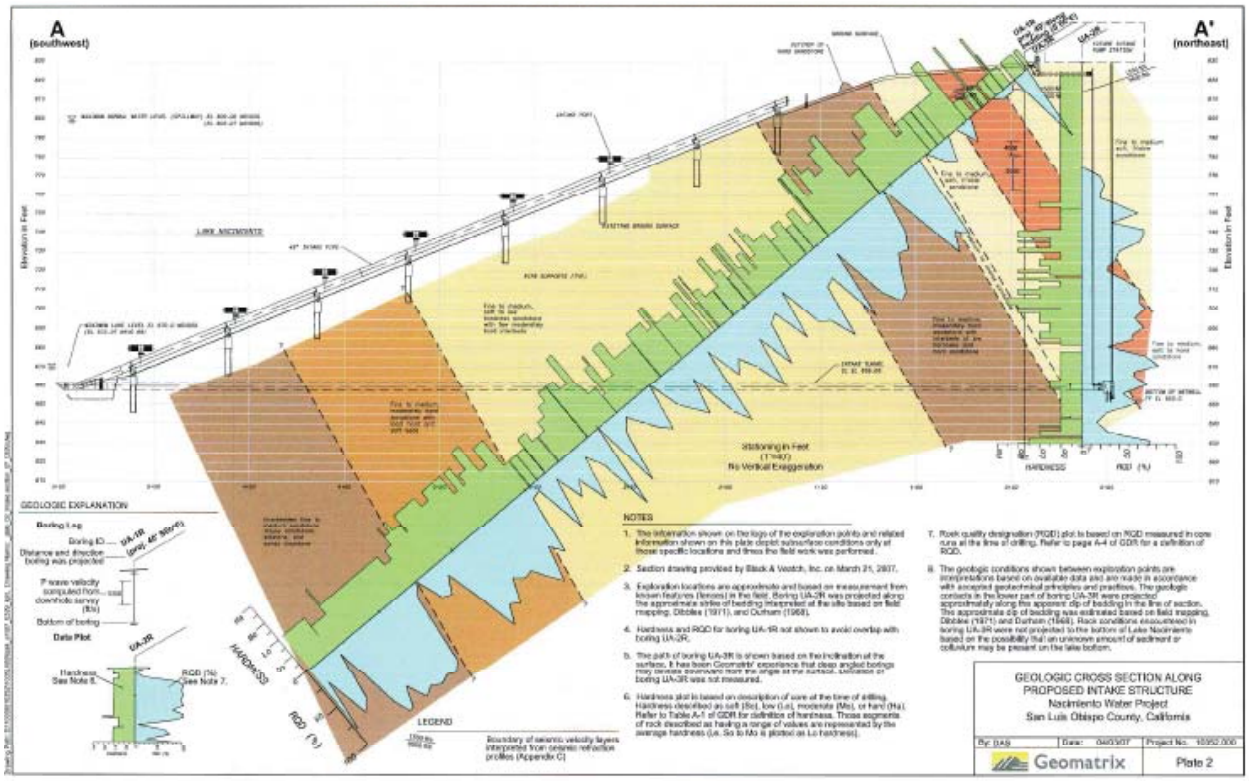
Joints are typically widely spaced, tight, and contain either precipitates of calcium carbonate ("healed") or evidence of weathering. Joints dip steeply from near vertical to between 45 and 80 degrees.

The intact strength of the rock varies between extremely weak and weak to moderately strong. Measured rock strength typically ranges from several hundred to several thousand pounds per square inch (psi), although lower and higher strengths were measured. The lowest measured uniaxial compressive strength was about 10 psi, while the largest measured values were on the order of 7,000 psi.

Ground water levels at the site will vary substantially with seasonal variations in precipitation within the watershed and with reservoir levels.

Shaft Design

Excavation for the intake shaft will extend approximately 180 ft ± below ground surface and will require excavation through a combination of fill, residual soil and weathered rock, and weak to moderately strong, intact rock. Plans for the project require a finished interior shaft diameter of 16- to 20-feet, with an excavated shaft diameter to be determined by the general contractor



Source: Black & Veatch Corporation, Intake GBR, 2007

Figure 5. Geologic Section through NWP Intake

based on structural requirements shown in the contract documents and means and methods used for initial support.

Design of initial support for the shaft excavation will be the responsibility of the contractor. Initial support may consist of liner plate and steel ribs, slurry panel walls, secant piles, or casing installed using drilling methods, such as blind auger drilling. Since slurry panel walls, secant piles, and blind auger drilling provide pre-support of the ground prior to substantial excavation, these systems offer significant advantages over support systems requiring excavation prior to installation, including improved management of ground water inflows and significant reductions in excavation volumes.

Due to the unfavorable orientation of bedding planes within the Vaqueros Formation and the generally weak nature of the rock, the material is expected to squeeze and fast ravel within a cycle of bench excavation and erection of initial support. Thus, excavation volumes 35 percent greater than those corresponding to a “neat” line would be anticipated for support systems requiring excavation prior to installation. In addition, for liner plate and/or steel rib installations, ground water inflows and corresponding requirements for treatment and disposal must be considered. Sustained ground water inflows of 500 gpm are projected.. Flush flows of up to 2,000 gpm are possible and if encountered are to be grouted to reduce total flows into the shaft to a 500 gpm threshold.

A mechanism was provided in the contract to mitigate excessive groundwater inflows into the shaft excavation. The first line of defense consisted of probe holes drilled in front of (below) the excavation face to detect any water bearing strata. The second line of defense consisted of drilling grout holes; connecting pumping equipment to the grout holes; and pumping grout into water bearing strata to reduce its permeability. The third line of defense was to provide a concrete protection system that would protect the shaft lining concrete from erosion and washout during placement and hydration.

Microtunneling

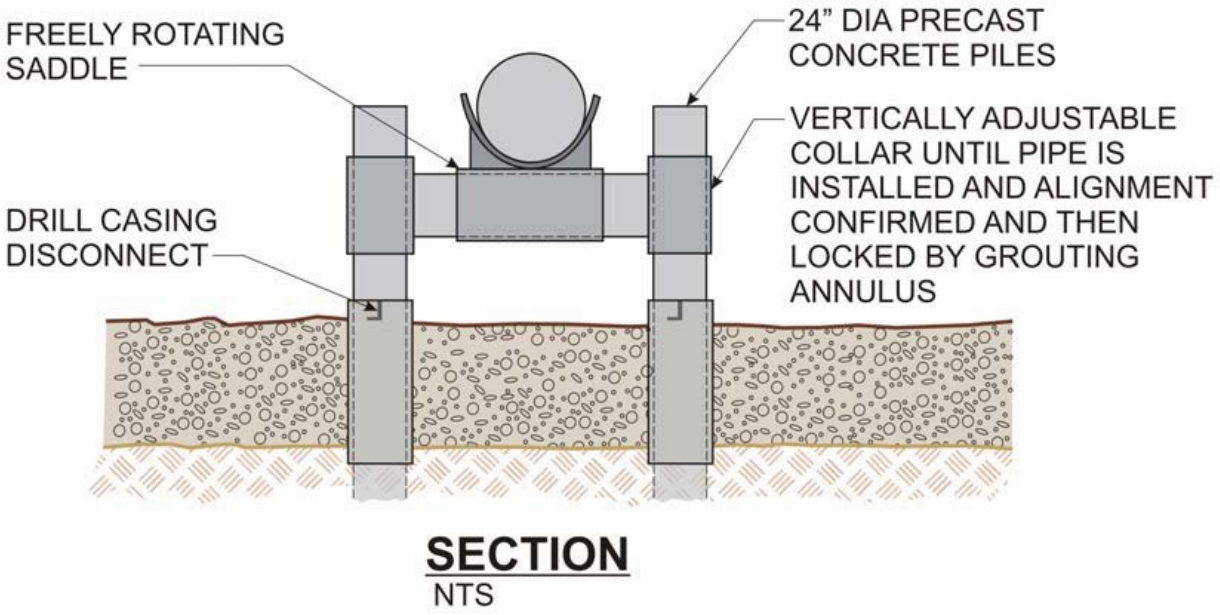
A single 500-foot long microtunneled intake tunnel will connect the shaft to the lake with a lake tap. The construction method will involve jacking a steel pipe casing following a microtunnel boring machine (MTBM), with the casing serving as initial support and final liner. Plans for the project require a finished intake tunnel diameter of 48- to 72-inches, with the actual diameter to be determined by the general contractor based on MTBMs available at bid time and allowable jacking space resulting from the selected shaft diameter. The contractor will be responsible for selection of the appropriate MTBM and casing thickness to carry the thrust of jacking forces and other loads.

The MTBM will be driven from the shaft to the reservoir and retrieved “in the wet.” The retrieval of the MTBM will be staged from an excavation into the slope of the reservoir side wall that will be prepared

prior to initiation of microtunneling.
The MTBM will be a closed, pressurized face, steerable, laser-guided, articulated tunnel shield capable of exerting continuous, controlled pressure at the tunnel face to prevent uncontrollable groundwater inflows and ground movements into the cutter chamber, with a reversible cutterhead drive system to minimize rotation of pipe during installation. It will also be capable of handling the various anticipated ground conditions to minimize loss of ground during tunneling and steerable and capable of controlling the advance of the heading to maintain line and grade within the specified tolerances. It will include a system to inject lubricant over and around the rear of the MTBM to reduce jacking friction and a slurry system to balance ground and groundwater pressure up to 140 feet of hydrostatic head.

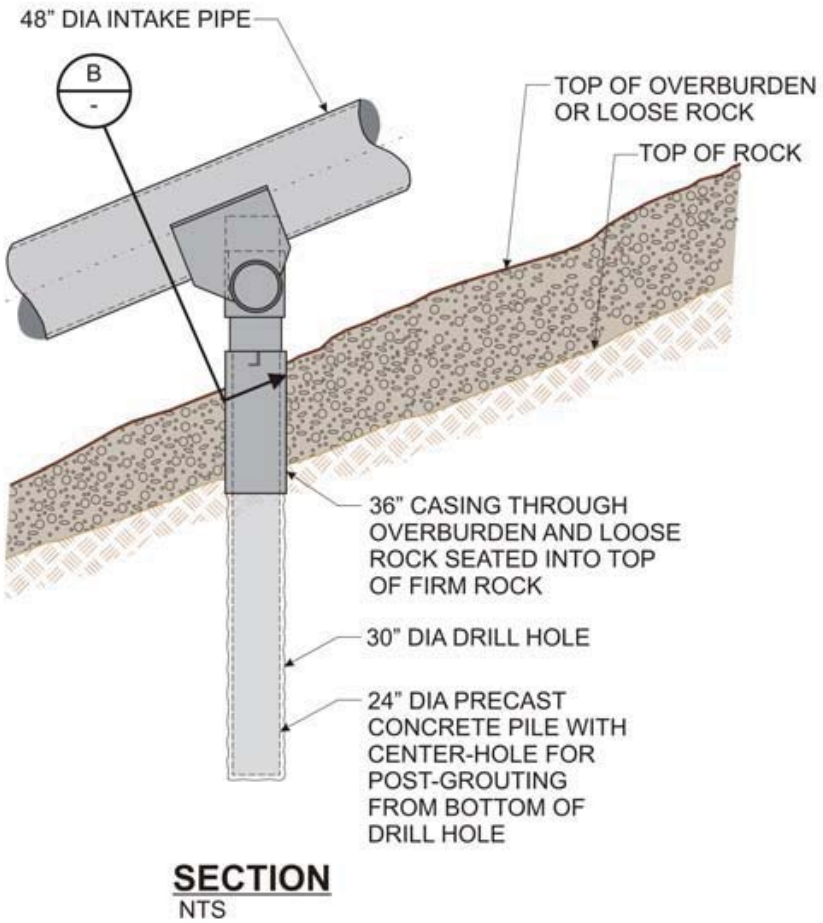
The MTBM will be equipped with drag picks for weaker ground and disc cutters for harder rock. Additionally, the MTBM will be equipped with a crushing chamber for rock fragments that are not “chipped” by the cutters.

The overall tunneling system will also include a casing jacking system; launch seal affixed to the shaft wall and through which the MTBM and steel pipe passes; equipment to maintain proper air quality in case the contractor selects manned microtunnel operations during construction; and lighting fixtures in watertight enclosures. The steel casing pipe will be either all welded steel pipe or



Source: Ben C. Gerwick, Inc., December 2006

Figure 6. Section through Intake Pipeline Saddle Support



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Permalok pipe with gasketed joints.

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Marine construction will involve establishing a floating marine operation with barge/crane and access to shore; diving operations; fuel transfer; underwater excavation; placement of tremie concrete; underwater construction of pipe supports; and underwater placement of pipeline segments, valves and screens.

Summary

Through preliminary and final design, the NWP Intake facility has evolved from an originally-conceived three-port tunneled intake facility to a surface-mounted sloping intake with seven ports to allow water to be drawn from various depths of the reservoir for optimal water quality control.

The District considers construction of the NWP Intake to be one of the riskier elements of the NWP. With detailed construction planning and the use of a geotechnical baseline report (GBR) in the construction contract documents, the risks to both the District and contractor become shared.
Construction of the NWP Intake is scheduled to commence in late 2007.

References

Black & Veatch Corporation, Nacimiento Water Project Technical Memorandum (TM) 8, Water Quality Investigations, January 2006 (Final).
Black & Veatch Corporation, Nacimiento Water Project, Intake - Geotechnical Baseline Report, April 2007 (Final).
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HOW A SMALL AGENCY MANAGES A MEGA PIPELINE PROJECT

A Success Story

San Luis Obispo County

John R. Hollenbeck, P.E.
Thomas C. Trott, P.E.

Flood Control & Water Conservation District

Presented At

ASCE International Pipelines Conference 2008
Atlanta, Georgia
July 25, 2008

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.

Thomas C. Trott, P.E.[2], is the Nacimiento Project Engineer witin the Public Works Department of San Luis Obispo County, California. He works full-time to assisst the management of the Nacimiento Water Project through its design, bidding and construction phases. Mr. Trott recieved his B.S. degree in Civil Engineering in 2003 from California Polytechnic State University, San Luis Obispo. He has experience in design and construction of a variety of facilities including roadways, sewer systems, storm water systems and water supply systems.

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How a Small Agency Manages a Mega Pipeline Project – A Success Story

John R. Hollenbeck, P.E. and Thomas C. Trott, P.E.

ABSTRACT

Infrastructure projects designed to meet the growing demands of a water district do not need to be limited in size just because a small public agency manages the district. Case history of the Nacimiento Water Project proves this point.

The Nacimiento Water Project (Project) consists of a sloping multi-port intake facility and pump station, two intermediate pump stations, three storage tanks, control center, and approximately 45 miles of transmission pipeline ranging in diameter from 36-inches to 12-inches, with the goal of delivering 15,750 acre-feet of raw water to communities spread across the county. The $176-million Project is owned, managed, and will be operated by the San Luis Obispo County Flood Control and Water Conservation District (District) located within the central coast of California, and is staffed full-time by only two county employees. Despite limited management resources, the District has produced a pipeline project that will successfully meet the growing water demands of San Luis Obispo County.

This paper discusses the District's undertaking of the Project. Specifically addressed is how the District made this regional Project successful by overcoming existing political obstacles and mending community relationships, recognizing its limitations as a small agency, establishing strategies and setting goals, staffing the Project with an "army" of consultants, attending to the details of design through pipeline optimization and value engineering, and positioning the Project for successful bidding and bond financing.

How a Small Agency Manages a Mega Pipeline Project – A Success Story

John R. Hollenbeck, P.E. and Thomas C. Trott, P.E.

Project Background

Nacimiento Reservoir

Nacimiento Reservoir is located entirely within San Luis Obispo County, California (County), just south of the Monterey County border. It was built by Monterey County Flood Control and Water Conservation District (now Monterey County Water Resources Agency) in 1957 for the purposes of abating seawater intrusion in the groundwater aquifers of the Salinas River Valley. The reservoir has a storage capacity of 377,900 acre-feet and is owned and operated by Monterey County Water Resources Agency.

District's Water Rights

In 1959, the District entered into an agreement with Monterey County Flood Control and Water Conservation District to secure rights to 17,500 acre-feet of water per year from Nacimiento Reservoir. At the time of this agreement, the District was merely planning for future water demands and had no feasible means of accessing or distributing this entitlement. The District contemplated and proposed means and methods of utilizing this water entitlement at various times over the following 40 years, but none came to fruition. The County experienced a severe drought in the late 1980's and early 1990's which significantly stressed the primary water supply (mainly groundwater) for both municipalities and agricultural businesses. The District began another series of studies in the mid-1990's to distribute Nacimiento water within the County as a supplemental water supply. This time, the participating water agencies realized the time had come for Nacimiento water to be the next affordable water resource within their water portfolio.

Nacimiento Water Project

The District's Board of Supervisors approved the Final Environmental Impact Report for the Project in January 2004. This approval directed District staff to move forward with executing agreements with local agencies, permitting, designing, financing, constructing and operating the Project.

The Project is a raw water transmission facility created to deliver 15,750 acre-feet of water per year from Nacimiento Reservoir to various communities within the County. The rest of the District's entitlement (1,750 acre-feet) is left in the Reservoir for lakeside use. The Project generally consists of a multi-port intake structure, three pump stations, three storage tanks, 45 miles of pipeline, four turnouts, a control center, and a Supervisory Control and Data Acquisition (SCADA) and Project control system. Its

estimated cost is $176-million, including design, construction, construction management, environmental permitting, and right-of-way. Four initial participants – City of Paso Robles, Templeton Community Services District, Atascadero Mutual Water Company, and City of San Luis Obispo – executed an agreement with the District to fund the design phase of the Project in August 2005, and a fifth new participant, San Luis Obispo County Service Area 10-A, entered into an agreement in October 2006. All agencies are collectively referred to as Participants.

Measures of Success

Project success is measured by the District's ability to attain and maintain the financial support of communities within the County. Without such support, the Project could not exist. In fact, lack of community financial support is the main reason the Project took nearly a half-century to officially commence. If the District could not present and maintain a financially viable Project to the Participants, the Project would not be built, just as it had not been built in the past. The District had to focus its resources on managing the Project's budget to attain success; thus, the District's priority became the details of the Project's design and bidding phases.

Water Delivery Entitlement Contracts and Opt-Out Period

At the onset of the Project, the District presented the Project to various communities in the County. Most communities evaluated the Project seriously, since the District's Nacimiento water rights had become the next feasible water resource for the County; however, all communities had concerns with the Project's preliminary estimated cost of $150-million. Interested communities wanted assurance that the Project's cost estimate was accurate and that they were not binding themselves to an open-ended budget. As a result, an opt-out period was placed in the Participants water delivery entitlement contracts, which gave participants the option of backing out of their contract within 30 days after 50 percent of the estimated construction value of the Project had been bid. In other words, if contractor bids came in too high, the Participants had the option to back out of their commitment to participate in the Project. This strategy provided a level of comfort to the Participants who executed water entitlement contracts with the District. Any Participant who chose to opt-out would forfeit their initial investment during the design phase. The design phase budget was $18.9-million and included environmental permitting, right-of-way, design, initial construction management review, and District administration.

Threshold of Financial Pain

With the opt-out period in place and a preliminary budget of $150-million, the District's first Project objective was to find out the limits of the Participants' "threshold of financial pain" (see Figure 1). In other words, the District understood the

Figure 1. Threshold of Financial Pain

challenge that a project of this magnitude could be designed, permitted, managed, and completed within a budget of $150-million and needed to know the upper Project cost limit that the Participants would allow before they would decide to opt-out of their water delivery entitlement contracts.

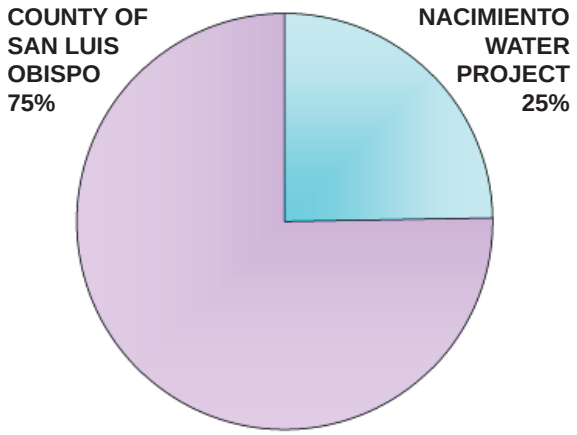
Discussion with the Participants led to a vague conclusion of an upper Project cost limit of $200-million. As long as the District could keep Project costs below $200-million, or within the "threshold of financial pain," the District believed that none of the Participants would opt-out and the Project would move forward to construction. The success of the Project hinged on the District's ability to manage the Project's budget within this threshold of financial pain.

Preliminary Project Planning

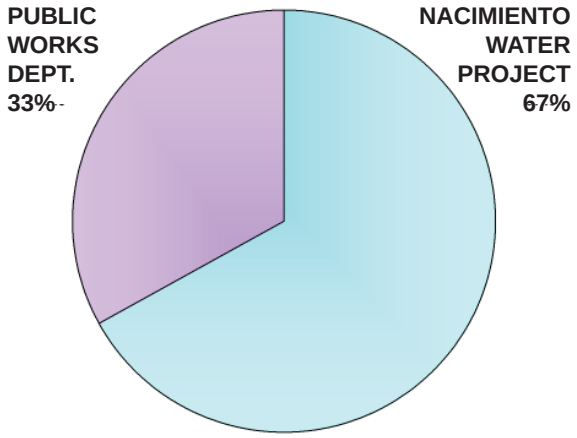
Recognizing the Limitations of the District

The District is a pseudo government organization created by California State legislation in 1945. It is governed by the same County Board of Supervisors acting on behalf of the District and supported by the County's Public Works Department (Public Works). Full-time staff members do not exist at the District. Staff support for the District comes from Public Works' engineering and accounting divisions and from the County Counsel office. Public Works is not staffed to support such a large one-time endeavor such as this Project. The magnitude of Project cost alone is nearly six times greater than any past District project and nearly five times greater than any past County project.

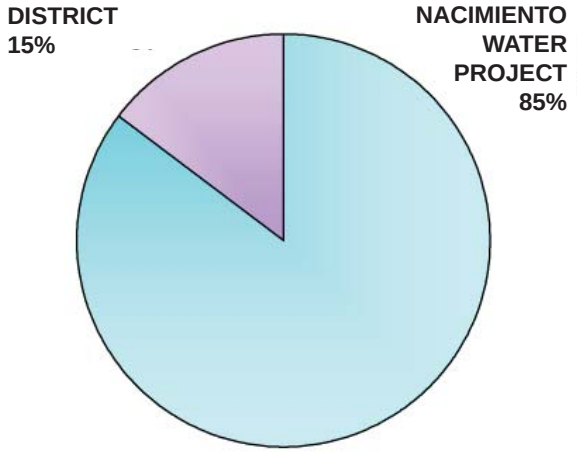
Figure 2 illustrates the financial magnitude of the Project (design and construction phases) compared to the annual internal budgets of the County. The Project makes up 25 percent of the entire annual County budget, including budgets for departments such as public works, sheriff, assessor, public health, regional transit, schools, courts and others. It makes up 67 percent of the annual Public Works budget, including budgets for divisions such as transportation, maintenance, design, utilities, development services, and others. Since the District manages the Project, the financial magnitude of the Project is most accurately conveyed as 85 percent of the District's entire annual budget. Public works realized early-on that the mega Project would have to be staffed and managed differently than



ANNUAL COUNTY BUDGET PERCENTAGE



ANNUAL PUBLIC WORKS BUDGET PERCENTAGE



ANNUAL DISTRICT BUDGET PERCENTAGE

Figure 2.
Project's Internal Financial Comparison

their other capital improvement projects.

Organization

Figure 3 illustrates the Project's organization and more detailed discussion of each component follows.

Nacimiento Project Commission. The first step in setting up a successful project organization structure is to establish a governing body that will guide the development of the project. District projects are normally governed by its Board of Supervisors; however, in order to maintain the comfort level of the Participants throughout the Project and to minimize the chances of opt-out, the District established a governing body that represented both the District and the Participants – the Nacimiento Water Commission (Commission). The Commission's membership consists of one commissioner representing each of the four initial Participants and a member from the District's Board of Supervisors. Duties of the Commission include review and approval of all substantive matters pertaining to construction and operation of the Project, including the annual budget. Any action required by the District's Board of Supervisors was first presented to the Commission for their support.

Nacimiento Project Manager. As Public Works began to strategize about establishing a successful Project organization structure, it immediately recognized the need for an experienced, full-time project manager that could effectively guide the Project into

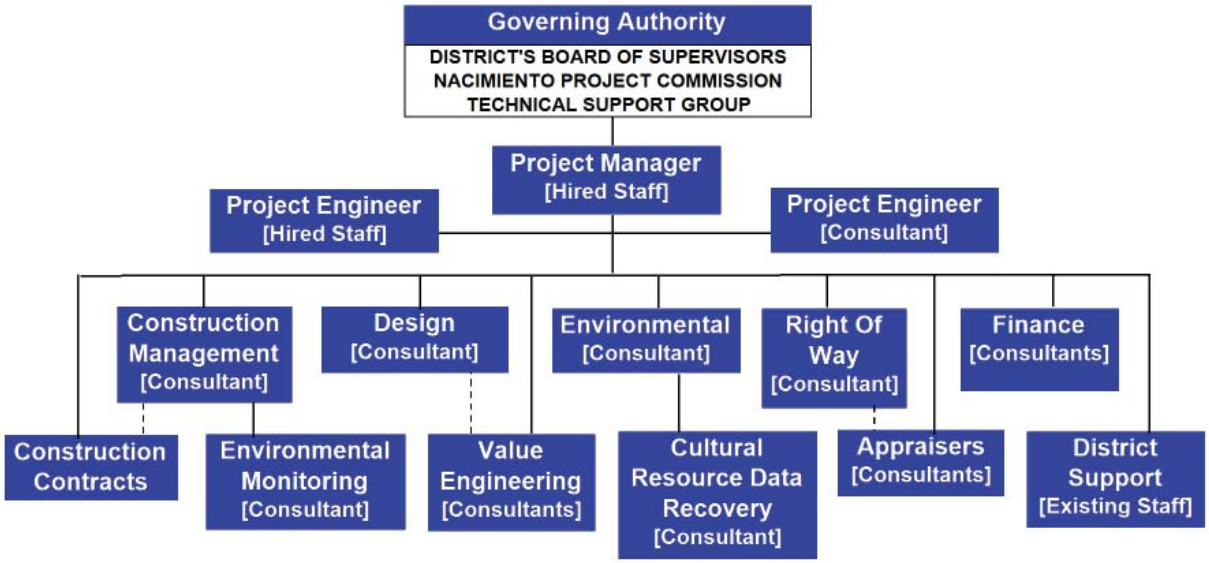


Figure 3. Project Organization Chart

completion while maintaining control of the budget. Public Works recommended to the Commission and the District's Board of Supervisors that the project manager be a contract employee position to assure that the duties being performed would not encounter conflicts with other clients or projects, which can occur when consulting forces are utilized to manage projects. The District, through an ordinance, added the Nacimiento Project Manager to the unclassified civil service system. The District advertised the position seeking an experienced registered civil engineer, or closely related field, and hired the project manager in April 2005. The successful candidate had 20-years experience leading design and managing hydraulic structure projects, and significant experience writing reports and making verbal presentations.

Technical Support Group. Led by the Nacimiento Project Manager, this Project established a Technical Support Group (TSG) that met monthly to review technical Project issues and to propose and prepare policy matters to be presented to the Commission. The TSG was supplemented by senior members of the engineering design team and a hired consultant serving as project engineer. The TSG provided valuable input to decisions made throughout the Project, and served as a link between the District and Commission.

Army of Consultants. The management and leadership structure was completed with the hiring of the Nacimiento Project Manager, and the next step was to assemble the remaining organization, informally known as the "army of consultants." The professional services needed to complete the organization is all available within Public Works;

however, as can be seen in Figure 2, this single Project accounts for 67-percent of the Public Works entire annual budget. Public Works staff are essentially fully allocated to their normal duties and could only provide part-time support; therefore, a team of consultants were hired to provide the following services:

- Management – Project Engineer (half-time) and student interns (part-time)
- Financial Services
- Right-of-Way Acquisition
- Right-of-Way Support (legal, appraisals)
- Engineering
- Environmental Permitting and Compliance
- Construction Management

Consultants working close with the District leadership are an efficient and effective extension of the District's limited staff.

Design Phase

Budget Management through Smart Design

Pipe Downsizing. Throughout the design phase, the District continually evaluated the Project's design in search of ways to save cost and avoid Participant opt-out. As a result, the District discovered ideas that may not have been identified otherwise. One example of this is pipe downsizing. The original Project design contemplated delivery of all reserve capacity (water not yet entitled to any Participant) to the south end of the 45-mile pipeline. Research revealed that there was a much higher probability that a large portion of the reserve capacity would be distributed to communities along the northern stretches of the pipeline. This knowledge initiated the redesign of the Project so that pipe diameter decreased as it proceeded south, saving the Project an estimated $9-million.

Value Engineering. The District assembled a value engineering team to evaluate the Project's design with the purpose of identifying design changes that could save the Project money. The team consisted of engineers, hand-picked by the Nacimimiento Project Manager, possessing experience in hydraulic projects similar to the Project. In order to discover and implement cost-saving design ideas without adding significant cost and time to the design, the District decided that the value engineering team would best serve its purpose at the 30 percent design submittal. The District also instructed its design team to prepare a preliminary design report to communicate design details and strategies to the value engineering team in an effective manner. These District actions helped maximize the success of the value engineering process.

Both the value engineering team and the design team participated in the value engineering session. The session cost the District nearly $66,000 and resulted in the generation of multiple cost-saving design suggestions. Fifty-two individual proposals were formulated during the value engineering session and, of those, four were implemented into the final

design, producing an estimated capital savings between $12- and $15-million.

Positioning the Project for the Most Favorable Bids

Contractor Outreach and Workshops. The District recognized that it could minimize Project costs by ensuring that a high number of contractors bid on the Project (the greater the competition, the lower the bids). To do this, the District developed and conducted a contractor outreach strategy during the Project's design phase. As the first step of this strategy, the District developed a list of general contractors located in the western United States that have performed work similar to that proposed by the Project. Each contractor was contacted and informed of the Project to determine which contractors expressed interest in the Project.

After contacting each contractor, the District held three contractor workshops to outreach to contractors before the District made an official call for bids. These workshops introduced all interested contractors to the Project with the purpose of building and maintaining contractor interest and, thus, increasing the number of contractors that would bid on the Project. In order to maximize contractor attendance, the District made workshop participation available via the internet. The workshops gave contractors an opportunity to provide input and feedback on the Project prior to the completion of design and specifications, allowing the District to implement contractor suggestions that would position the District to receive favorable Project bids.

Front-End Specifications. Bid prices for construction make up the majority of a project's budget. Because costs of construction and materials carry the most weight in these prices, agencies often overlook the price impacts created by the contractual front-end specifications. The amount of risk that the front-end specifications place on the contractor and the lack of clarity within them can also negatively impact bid prices with the contractor adding significant contingency monies to their bid; thus, the District spent significant amounts of time writing the front-end specifications in a manner that would keep bid prices low and ultimately enable the District to attain opt-out success.

Specifically, the District focused on writing the front-end specifications so that the District equitably shared risk with contractors in areas that most agencies tend to shed risk onto the contractor. For example, the District took ownership of differing site conditions, provided allowances for utility conflicts and hazardous materials, and offered a value engineering incentive to share the savings of contractor cost reduction proposals. The District also focused on providing clear requirements and procedures in the front-end specifications, including change order procedures, contractor obligations, and payment procedures. By sharing risk and minimizing vague or unstated requirements and procedures, the District succeeded in minimizing contingencies

within the bids.

Financing Strategy

The Project utilizes a 30-year term financing debt to fund the design and construction phases. Each Participant resolved to reimburse their design phase investment if they did not opt-out. The District hired a financial advisor, bond counsel, and bond underwriter to structure a taxable and non-taxable revenue bond sale to finance the total Project costs and finance costs[1]. Bonds were sold about two weeks after the opt-out date passed.

The rating of the District was judged on the lower rating of the individual agencies; however, the debt was secured through a bond insurance program which results in a AAA bond rating.

Partial funding through grant programs was explored and applications filed, but the Project was not selected through any state or federal programs.

Bidding Phase

Bid Sequencing Strategy

Five construction contracts combine to form the construction framework for the Project. These contracts are:

- Contract 1 – Intake
- Contract 2 – Facilities
- Contract 3 – Pipeline North (22 miles)
- Contract 4 – Pipeline Central (11 miles)
- Contract 5 – Pipeline South (12 miles)

The call for bids went out for Contracts 1, 3, 4, and 5 on May 22, 2007, and the call for bids for Contract 2 was issued on June 12, 2007. The bid strategy focused on the monetary sizing of the bid package and the bid opening time for the three pipeline packages. The time increment between the bid opening days for these packages was one-week, with Contract 3 bidding first, then Contract 4, followed by Contract 5. The strategy predicted that a large construction firm may win Contract 3, and then may likely be successful on the other two pipeline contracts since their mobilization to the County would already be funded. The unsuccessful bidders from Contract 3 would recognize this advantage and would seek more innovative ways to bid the work. The results were that all three pipeline contracts were awarded to three different contractors. Contractor interest was high, with nine bidders on both Contracts 3 and 4 (not all the same bidders), and seven on Contract 5.

The bidding strategy saved the District millions of dollars relative to the estimated bid values.

Opt-Out Success

As bid opening dates drew near, the Project's estimated cost neared $200-

[1] One of the Participating agencies is a taxable mutual water company, while the others are non-taxable governmental agencies.

million, bordering the upper limits of the Participant's "threshold of financial pain." The District expected construction costs, the last unknown variable in total Project costs, to come in at a value of $140.5-million; however, because of the District's preliminary planning, design phase management, and bidding phase strategies, construction bids came in at a total value of $123.8-million (12-percent less than the projected value). These bid prices lowered the total Project cost to $176-million, which is well within the "threshold of financial pain." As a result, none of the Participants decided to opt-out, allowing the District to conquer a feat that it had tried to overcome for nearly 50 years – a successful Project that would deliver its Nacimiento Reservoir water entitlement to the County's communities for future generations.

Conclusions

Several lessons towards a receipt for success have been learned through the implementation of this Project as of February 2008, and they are:

- The small water agency should recognize early that an experienced and full-time project manager should be employed by the agency to lead the endeavor from the beginning (very early in the design phase) through construction and start-up.
- The agency should be prepared to compensate the project manager an appropriate salary that reflects the project manager's past experiences and value brought to the agency.
- Assemble a technical support group consisting of members from the participating stakeholders and the engineering firm. The group will form the nucleus of decision making and policy development
- Hire an engineering firm with a hands-on project manager who is supported by a technically competent and well organized project engineer. These two people are crucial for technical success of a small agency. Be sure this duo has a long and successful working relationship. The engineering consultant should become a trusted advisor that will guide the agency through major decisions throughout the project.
- Track project budget at milestones during the design, for example, at the beginning, 30-, 50-, 75-, and near 100-percent design levels.
- Keep the governing authority updated on the budget trends.
- Conduct value engineering review early in the design process, such as at the 30-percent design milestone.
- Put together a complete financial team to serve as your advisor on debt financing. Their judgment on a bond sale date can benefit an agency with a lower debt interest rate.
- Securing right-of-way on private and public lands can be challenging. A firm with experience in both areas is critical when the project crosses private, state and federal lands.

- State and federal environmental permits require a long lead-time. Hire a firm with the experience in all aspects of these permits, and who can shepherd the permits through the regulatory agencies.
- Hire the construction management firm to participate in constructability review of the design at the near 50-percent design level. The investment in this early review can result in improved design, cost savings, and reduced contingencies carried by the contractors.
- Hire the environmental monitoring firm directly to control the quality of the selected firm, then assign that service to the construction management firm.
- Work with the designer, construction management firm, and legal counsel, to thoroughly review and edit the construction contract's bidding, contracting, and general requirements to be equitable among all parties.
- Conduct contractor outreach far in advance of the bidding. Increasing the interest in public works bidding creates a competitive bidding environment for the agency.
- Review the timing of the project's bid relative to other mega projects bidding in the geographical region. Avoid bidding on the same day, or even week, of those similar projects.

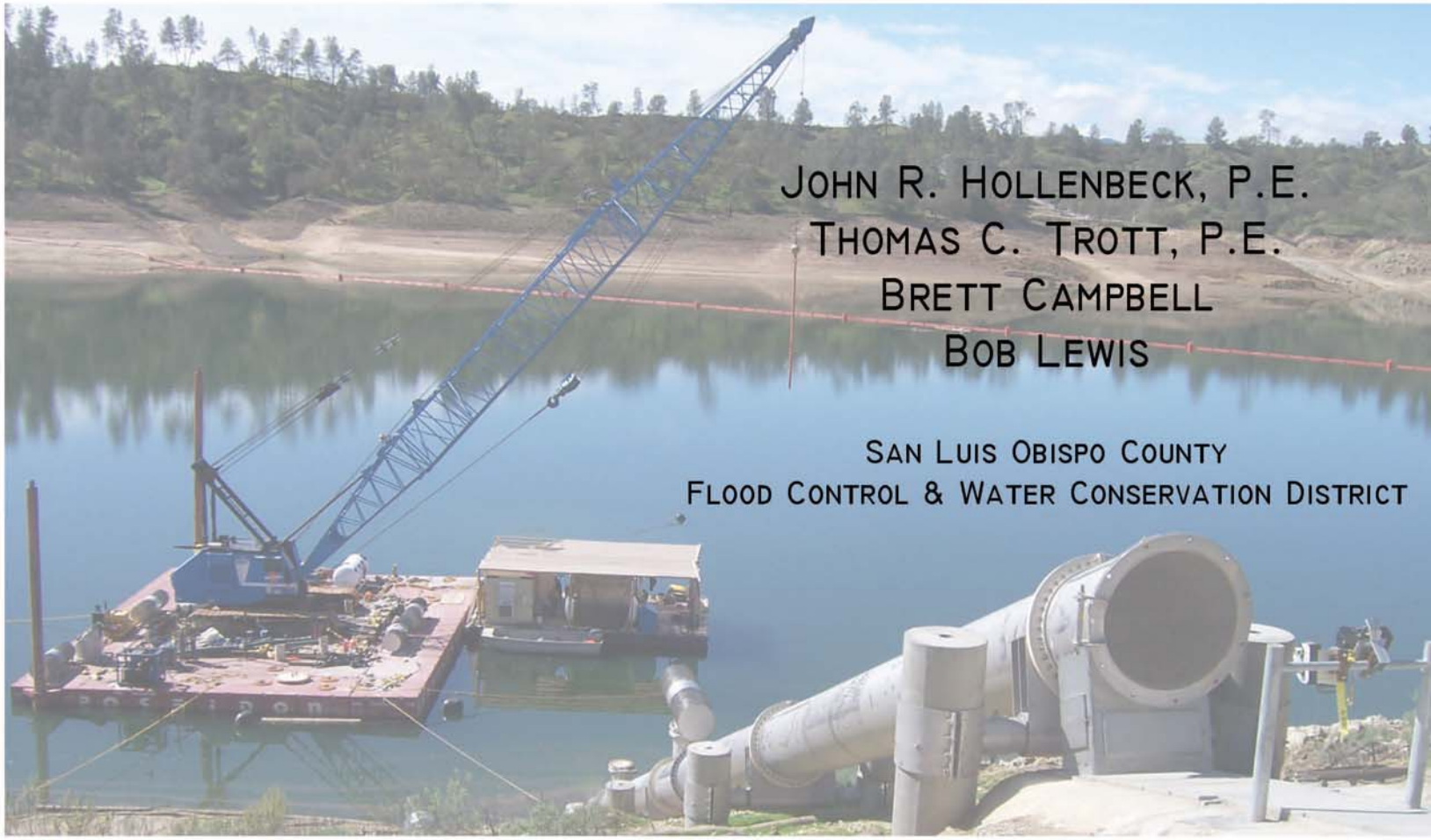
NOTES

NWP NACIMIENTO WATER PROJECT

San Luis Obispo County Flood Control & Water Conservation District

County Government Center, Room 207, Department of Public Works
San Luis Obispo, California, 93408

Hot Tap Construction of Lake Nacimiento, California



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San Luis Obispo County
Flood Control & Water Conservation District

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Brett T. Campbell has worked on many challenging tunneling projects across the United States, after receiving his Civil Engineering Degree at Michigan Technological University 1993. His current position is a Project Manager, with James W. Fowler Company and is completing the Naicimiento Lake Intake Project in San Luis Obispo County, California. He considers himself to be fortunate to have worked with many talented engineers and supervisors. He and his wife have four children and reside in San Diego, California.

Bob Lewis acted in the capacity of Resident Engineer as the construction management representative of the District for the construction of the Intake shaft, tunnel and 'snorkel' tube structure. He carried out these duties through the design constructability review and the field installation phases. Mr. Lewis has been involved in the planning, constructability review, installation and construction of marine structures and facilities, both domestically and internationally, since completing his education at Portsmouth Polytechnic in the United Kingdom in 1971.

[1] in Kansas and California
[2] in California

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HOT TAP CONSTRUCTION OF LAKE NACIMIENTO, CALIFORNIA

John R. Hollenbeck, P.E., Thomas Trott, P.E., Brett Campbell and Bob Lewis

ABSTRACT

The paper describes design and construction for the excavation and lining of a 20-foot diameter, 180-foot deep shaft; the microtunneling of a 54-inch diameter, 500-foot long tunnel and lake hot tap; and the underwater construction of an inclined, surface-mounted, multi-port, 48-inch diameter intake pipe for the Nacimiento Water Project located in San Luis Obispo County, California.

In late 2007, the San Luis Obispo County Flood Control and Water Conservation District (District), a relatively small government entity located on the central coast of California, commenced construction of a 45-mile long raw-water conveyance to withdraw 15,750 AFY of water from Lake Nacimiento to various communities within San Luis Obispo County (County). The $176-million project, known as the Nacimiento Water Project (Project), faced many challenging design and construction aspects, including the construction of an underground lake tap for the Project's intake pumping facility. The intake facility construction consists of three main elements:

- Shaft. Excavation of a 180-foot deep vertical shaft constructed in structurally incompetent sandstone and lined with concrete. The shaft will serve as the wet well for vertical turbine pumps.
- Tunnel and Lake Tap. A lake "hot" tap constructed by tunneling from within the excavated shaft using a slurry balance microtunnel boring machine. The microtunnel machine entered the lake at approximately 140 feet below the maximum lake surface elevation.
- Inclined Surface-Mounted Multi-Port Underwater Intake Pipe. The seven-port intake is 48 inches in diameter and about 400 feet long, and connects to the terminus of the lake-tap tunnel. Each port has actuating valves to allow water to be drawn from various lake depths.

This paper is a case history of the Project and describes a Project overview, the design, the prequalification of the general contractors, the construction of the intake facility, and concludes with lessons learned on this challenging work.

HOT TAP CONSTRUCTION OF LAKE NACIMIENTO, CALIFORNIA

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PROJECT OVERVIEW

Background. The District received annual rights to 17,500 acre-feet of water from the Lake Nacimiento impoundment in October 1959, when they executed an agreement with Monterey County Flood Control and Water Conservation District, now known as Monterey County Water Resources Agency, who owns the Nacimiento dam and reservoir. The District conducted several feasibility studies over the next four decades assessing the cost and benefit to build the infrastructure to distribute the water to various areas within the County. These studies indicated groundwater pumping as the most feasible water supply. The demands on the groundwater basins are currently nearing their safe yield; thus, an alternative water source is needed to protect them. The next feasible water source identified in the 1990's was the Nacimiento Water Project.

The Project is divided into two parts. The lakeside usage of the water equates to 1,750 acre-feet annually, and that water will reside in the lake for users around the lake. The remaining volume, 15,750 acre-feet per year, will be conveyed via pumps and pipeline.

Lake Nacimiento holds 377,900 acre-feet when at normal maximum pool elevation of 803.07 feet (NAVD88 Datum used herein).

The "Final Environmental Impact Report Recommended" Project. The District's Board of Supervisors adopted the Final Environmental Impact Report (Final EIR) (Marine Research Specialists 2003) on January 6, 2004, and directed the County's Public Works Staff to implement the recommended project consisting of a multi-port lake intake, three pump stations (one at the lake, and two booster stations), three water storage tanks, and 45-miles of pipeline. The initial phase of the Project will serve the communities of Paso Robles, Templeton, Atascadero, San Luis Obispo, and Cayucos. These communities are contracted to receive 9,655 acre-feet per year. The remaining 6,095 acre-feet per year is the reserve water that is available to the existing participants, or can be contracted by other communities or water agencies anywhere within the boundaries of the County.

The "Final EIR Recommended" Intake Configuration. The Final EIR recommended a vertical shaft drilled or excavated into the ground from the shoreline to a depth of about 160 to 170 feet, and this shaft would serve as a wet

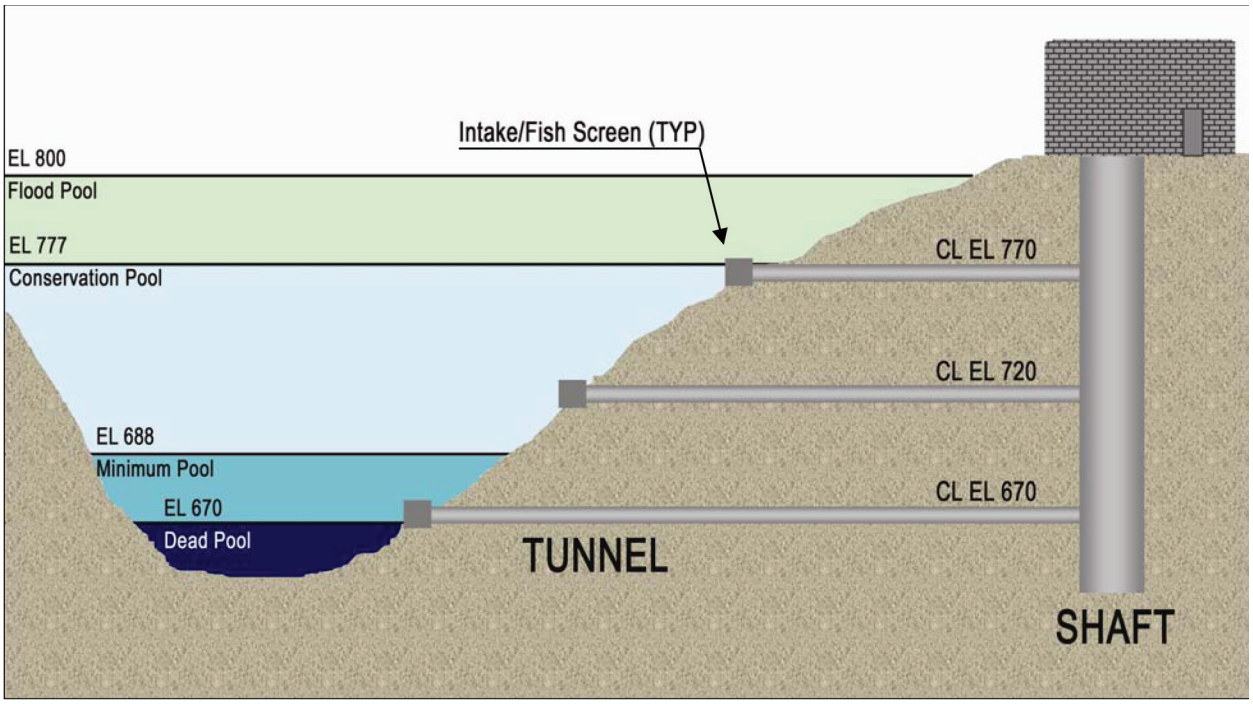

FIGURE 1. Intake Configuration Presented in Final EIR.

well for vertical turbine pumps. The shaft connects to the lake via three horizontal tunnels with approximate diameter from 36 to 72 inches bored at elevations 670, 720, and 770 feet. Figure 1 illustrates this configuration.

Value Engineering Assessment. The District assembled a value engineering team (VE Team) to review the Preliminary Design Report (Black & Veatch 2006) created by the design team at the 30-percent design phase. The VE Team evaluated the entire Project; however, only the assessment concerning the intake will be summarized herein.

Fifteen value engineering proposals were evaluated by the VE Team and presented in Value Engineering Workshop, Final Report (Value Management Institute 2006). Three were accepted immediately and implemented into the design, while five were declined immediately. The remaining seven were evaluated further. The value engineering concepts carried forward into final design were:

- Eliminate the upper two tunnels, and design a multi-port sloping intake pipe connected to the lower tunnel.
- Conduct additional geotechnical investigation and prepare a Geotechnical Baseline Study to include in the bidding documents.

The VE Team estimated that the net change in the bidding price for the intake would be approximately $4-million.

Final Configuration and Hydraulics of the Lake Intake. The final design configuration of the intake is a 16- to 20-foot diameter concrete lined vertical shaft,

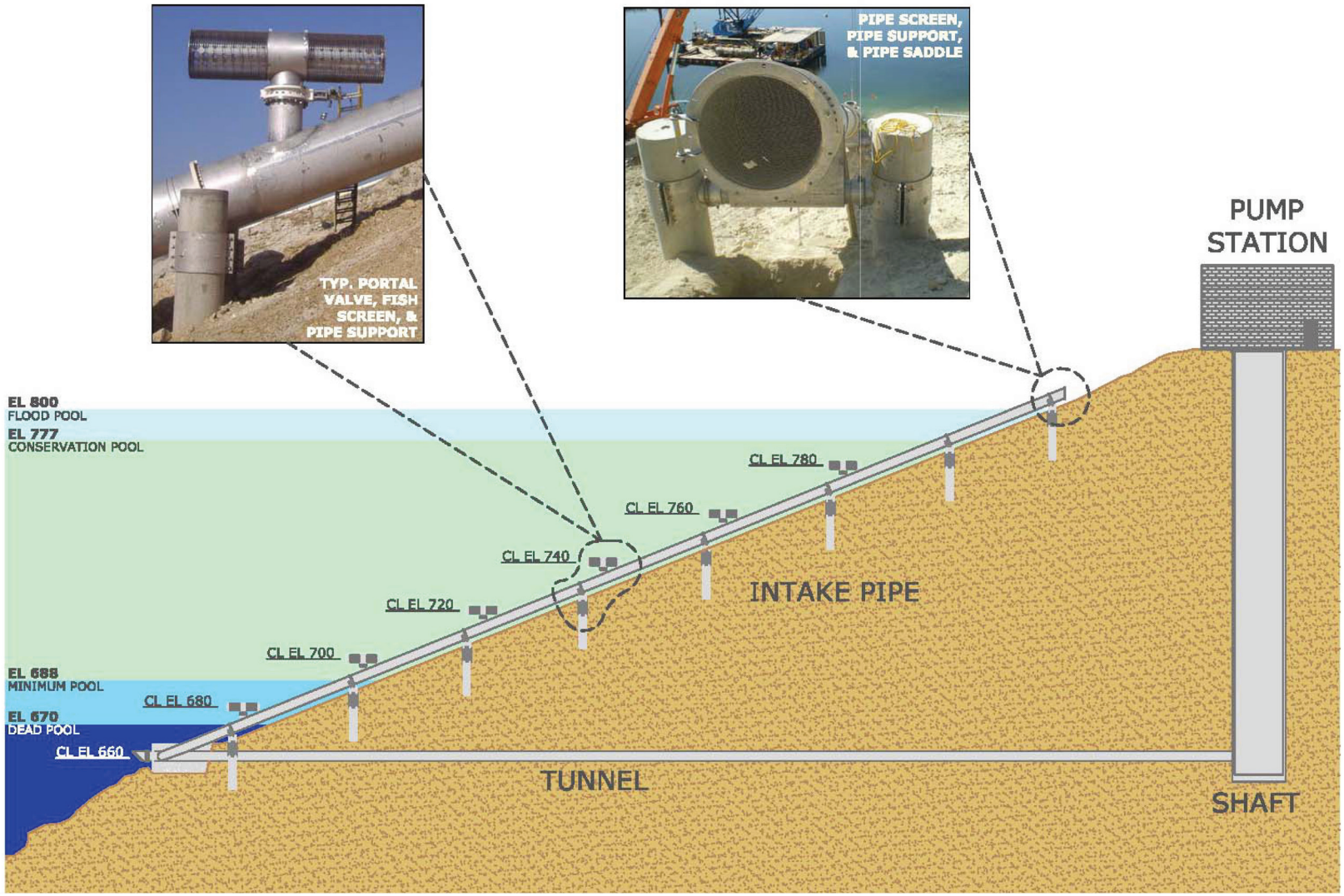

Figure 2. Final Design Configuration of Intake Shaft, Tunnel, and Intake Pipe.

180 feet deep, with a 500-foot long steel-lined horizontal tunnel with minimum diameter of 48 inches. Figure 2 illustrates the final design configuration.

The sloping intake pipe is 48 inches in diameter with seven intake portals. The first is at the centerline of the tunnel and is 48 inches in diameter. The other six are evenly spaced up the slope at 20-foot elevation intervals and are 24 inches in diameter. The quantity and spacing was chosen to maximize the quality of the water withdrawn and delivered to the Projects participants. Each portal is protected with a screen assembly to keep debris and fish from entering the system. The design approach velocity for the screens is about one-quarter foot per second.

The Project has a maximum hydraulic capacity of 32.79 cubic feet per second (cfs), expected to be realized during the summer months. The initial participants in the Project provided their peaking requirements, and the hydraulics of the Project was designed to meet their peak flow rates. The design velocity in the tunnel was set at a maximum three feet per second.

The intake shaft hydraulics were modeled at a hydraulic laboratory with a 1:3 scale model. Tests were run on prototype diameters of 15 and 20 feet. Slight modifications to the tunnel exit in the shaft and the configuration of the vertical turbine suction bell were proposed by the laboratory, as presented in the Intake Pump Station Physical Model Study (Northwest Hydraulic Consultants, 2006), and implemented into the design.

Constructability Review. The District selected a construction management firm just prior to the 90-percent design milestone. The review suggested a change in the supports of the sloping intake pipe. Originally, the supports were anchor blocks founded like a spread footing. The proposed change, which was implemented in the design, was to a "pipe support" system using drilled piers on both sides of the intake pipe, and adjustable custom hardware spanning between the piers used to support the intake pipe.

The construction management firm also conducted an independent opinion of probable cost, and confirmed the designer's opinion of cost; however, bidding yielded a much greater price. Factors that contributed to this will be discussed in the concluding remarks at the end of this paper.

DESIGN

Geology. (Geomatrix 2007a and 2007b) The intake site is located in the central California Coast Ranges Geomorphic Province. The intake shaft and tunnel construction take place in the Vaqueros Formation. This formation consists of moderately lithified, massive, poorly- to well-graded sandstone. The formation is predominantly quartz with minor constituents that include feldspar and clay minerals. The formation encountered in the subsurface exploration was further

subdivided into its characterization as Subunits A, B, or C.

Subunit A consists of generally fine to medium grained sandstone, which is weakly cemented to locally uncemented and friable, and breaks under modest hand pressure. The material was frequently washed out during coring operations and recovery, and Rock Quality Designation (RQD) was quite poor with an average of approximately 25-percent.

Subunit B has texture and mineralogical composition similar to that of Subunit A, yet the most significant difference between each is the strength of the deposit. Subunit B is comparatively strong with strength that ranges from weak cement grout to structural grade concrete, with an average RQD of approximately 50-percent.

Subunit C differs substantially in texture and mineralogical composition from either Subunits A or B. Subunit C will be encountered in the last 100-feet of the tunnel. This unit is blue-gray to green-gray, fine-grained, and comprised of interbedded siltstone, claystone, and clayey sandstone. This unit is bedded with intervening hard and soft layers and displays an average RQD of approximately 50-percent.

Groundwater inflows were estimated to be as much as 500 gallons per minute (gpm), with flush flows up to 2,000 gpm (Black & Veatch 2007). Design included pre-excavation grouting to mitigate these inflows. The discussion on the construction of the shaft explains the actual groundwater conditions encountered.

Shaft. The design gave the contractor the responsibility for selecting the methods appropriate for performing the shaft excavation and providing the initial support; however, the following four allowable methods were specified for shaft construction and lining:

1. Conventional excavation with steel liner plate for initial support
2. Slurry wall panels constructed with hydrofraise excavators
3. Secant piles
4. Blind shaft boring with a casing support

Other methods proposed by the contractor would be subject to review by the District and the construction management team. Ultimately, the contractor employed a method similar to the first method listed above, which will be discussed in the Construction section.

Tunnel. The tunnel design was to jack a coated (Powercrete J-HB liquid epoxy) and lined (Tenemec product, Pota-Pox 80, Series 141) steel pipe following a microtunnel boring machine (MTBM), with the pipe serving as the initial support and the final liner. The steel lined tunnel connected to a fabricated fitting placed underwater in the lake, and that fitting connected to the sloping intake pipe. The specified minimum diameter is 48 inches. The joints specified are all welded steel, or Permalok© pipe with Type 7 gasketed

joints.

A 48-inch, oil-hydraulic operated, stainless steel butterfly valve was mounted to the tunnel pipe at the bottom of the shaft. Mounted to the valve was a tee-fitting that redirected the water entering the shaft into a vertical direction (both up and down). The Intake Pump Station Physical Model Study (Northwest Hydraulic Consultants, 2006) identified unfavorable motions in the pump column for the two pumps located directly in front of the tunnel, and the tee-fitting resolved that condition.

Multi-Port Inclined Intake. The intake system was designed as a sloping seven-port intake pipe fabricated from ASTM A312 stainless steel. The lowest intake port is 48-inch in diameter, and the upper six intake ports are fabricated in a vertical direction with 24-inch diameter openings. Each port is equipped with a stainless steel fish/debris screen having maximum screen slot opening of 1.5 inches. The screen assembly in front of the bottom 48-inch intake was an elliptical shape screen mounted to a 45-degree mitered pipe configured in the downward-direction. The upper six screens were cylindrical shaped.

All ports are equipped with an isolation butterfly valve and oil hydraulic operated actuator. A single manufacturer was specified to design, furnish, and test the Intake Valve System that included the valves, hydraulic cylinder actuators, hydraulic power unit, and interconnecting hydraulic piping.

Isolation Butterfly Valves. Atop each of the upper six ports was a 24-inch diameter, oil-hydraulic actuated butterfly valve, with the oil being a food-grade product. The upper four valves were specified as AWWA C504 Class 150 ductile iron body valves, stainless steel body high performance valves, or stainless steel metal seated-triple offset valves. The ductile iron body valves were deemed acceptable because the lake fluctuates frequently over a large range, and these valves will be exposed for inspection several times over their technical life; however, the lower three valves will rarely be exposed, so they were specified as stainless steel, either high performance valves or metal seated-triple offset valves.

The lower intake port, centered on the centerline of the tunnel, is a 48-inch diameter port, equipped with 48-inch stainless steel butterfly valves, specified to be either a high performance type or metal seated-triple offset type.

Each valve will be operated by a double-acting hydraulic cylinder actuator. The actuators are specified for underwater use and stainless steel construction. The specified maximum working pressure is 1,500 pounds per square inch (psi).

Hydraulic Power Unit. The intake valve actuators are powered by a hydraulic power unit (HPU). The unit consists of two major components: the HPU Panel and the Valve/Piping Panel. Each is skid-mounted. The HPU Panel consists of the oil reservoir tank, oil pumps,

filters, strainers, and the control panel. The Valve/Piping Panel consists of the eight groups of solenoid control valves, pressure gages, piping, and flow control/ isolation valves. Stainless steel socket welded piping was specified to convey the hydraulic oil between the HPU and the valve actuator cylinders (see Figures 3 and 4).

Figure 3. Preparing for Hydraulic Line Installation

Figure 4. Hydraulic Lines in Intake Pipe.

PREQUALIFICATION OF GENERAL CONTRACTORS AND BIDDING

The District prequalified the general contractors for this work because of the unique nature of the construction, including the shaft, tunnel, lake hot-tap, and the marine work to support the intake portal piping. The District judged the need to have an experienced general contractor in one of the three major construction elements: the shaft, the tunnel, or the marine work. The prequalification statement, uniform system of rating, and the appeal process were derived from the templates developed by the California Department of Industrial Relations.

The District received eight prequalification submittals from contractors, and seven were judged qualified to bid the Intake work. Three bids were received on July 16, 2007, and opened, and the bid summary is as follows:

Engineer's Opinion of Probable Cost	$13.1-million
Low Bidder – James W. Fowler Co.	$20.8-million
Second Low Bidder	$21.2-million
Third Low Bidder	$29.4-million

The District believes the prequalification of general contractors is important even though the final quantity of bidders was lower than expected and the contract price was higher than estimated. The District predicts that having the best qualified general contractor to perform and manage this specialized work is an essential element for success. The District learned that an important strategy for managing the bid price would have been District-owned risk for the lake elevation, which was overlooked during

bidding. The bidding documents specified the contractor shall expect the lake to be at normal maximum elevation, whereas the actual lake elevation was much lower than that elevation. The bid price for all bidders accounted for a higher water level, and the bid values reflect that cost for the marine and underwater operations.

CONSTRUCTION

Shaft Construction. The contractor constructed a 23-foot rough diameter, 20-foot finished inner diameter, liner plate and ribbed shaft, 180 vertical feet deep, with conventional methods. The shaft was constructed in 12 to 15 vertical foot lifts, employing top down construction methods, as shown in Figures 5 and 6. As the shaft was excavated, liner plates were installed every 18-inch vertically as a complete course. In addition, an internal (circular) steel support (rib) was installed every four vertical feet. At the end of each shaft excavation day, the extrados of the liner plates and the ground were filled with a 200 psi backfill grout, followed by the entire 12 to 15-foot lift being filled with backfill grout. The ribs were then removed after each lift, and the reinforcing steel and 4,000 psi concrete were placed. As a contingency measure, these completed lifts planned on encountering high water inflows based on the pre-excavation probing and grouting plan defined in the contract; however, none of the defined probe holes encountered enough water to trigger the pre-excavation grouting program. Maximum groundwater inflow encountered during shaft excavation was five to seven gallons per minute. Drill and shoot methods were implemented for 72 vertical feet (40-percent) of the shaft excavation. The contractor executed ten rounds of explosives totaling 1,227.3 pounds with a powder factor 1.1 lbs/cyd. After bottoming out the shaft, and prior to the final wall pour, the MTBM's launch seal was cast within the shaft wall. The predicted jacking forces of the microtunnel

Figure 5. Preparing Shaft Concrete Form.

Figure 6. Pour for Lift 6 - Formwork in Place.

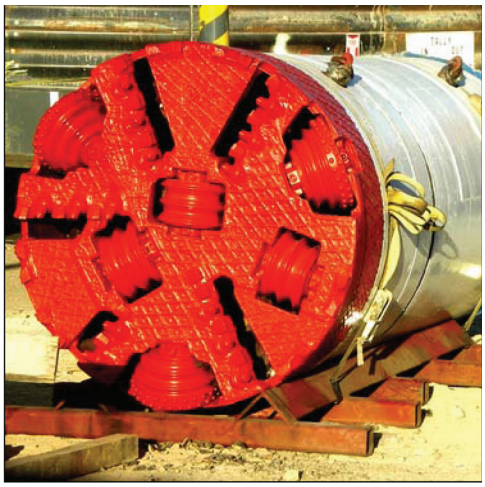

Figure 7. 54-inch Soltau RVS 600 MTBM.

Figure 8. Placing MTBM in Shaft.

did not require an augmented reaction block and/or an intermediate jacking system (IJS).

Tunnel and Lake Tap Construction. The MTBM hot tap (connection) to Lake Nacimiento posed significant engineering challenges. The designed process of having the MTBM engage a large body of water without jeopardizing the safety of the workers, the newly driven tunnel, and damage to the MTBM required many iterations of meetings and discussions in partnership with the District, construction manager, designer, contractor, and specialized suppliers. The contractor successfully completed the 504-foot long microtunneling operation using a 54-inch Soltau RVS 600 MTBM (see Figures 7 and 8) and 10-foot sections of Permalok steel pipe in October 2008.

The work required the installation of two individual bulkheads, within the tunnel and within the transition of the MTBM tapping the lake. Each bulkhead could be described as a welded intrados ring to the Permalok pipe, which later incorporated a specialized gasket/bolted door section. Both bulkheads also had porting which allowed the MTBM's utilities to pass through the bulkheads for continuous MTBM operations. The lead bulkhead was located three feet behind the interface of the MTBM's tail can and the leading edge of the lead section of Permalok pipe. The second bulkhead was located three feet behind the interface of the first/second Permalok pipe joint (10 feet behind first bulkhead). This spacing was engineered to account for the possibility that the MTBM could rapidly lose grade as it entered Lake Nacimiento and, thus, damage the Permalok pipe in such a way that would cause immediate flooding of the tunnel. If this were to happen, the second bulkhead was located far enough behind the first bulkhead to ensure the security of the employees and the tunnel. In other words, should the first one encounter a problem, a backup bulkhead

was in place.

Once the MTBM was stopped and fully exposed within the lake, the 10-foot chamber between the two bulkheads was flooded from the shaft side. This action equalized the chamber to the external pressure of the lake, which allowed divers to safely cut the MTBM and the first bulkhead from the tunnel. After this, the tunnel pipe was pushed to the final allowable stop point and the shaft and tunnel were flooded. Divers then cut the second bulkhead from the tunnel and used metrology jigs to connect the tunnel pipe to the multi-port inclined intake pipe with a specially fabricated piece of pipe.

Multi-Port Inclined Intake Construction. The construction sequencing specified in the Project's construction specifications called for construction to occur in the following order: shaft, tunnel, then multi-port inclined Intake pipe. The contractor chose to perform installation of the Intake pipe concurrent with shaft excavation and tunneling, saving valuable time for the overall Project. The design anticipated Intake pipe installation to be performed entirely by marine operation; however, low lake levels permitted drilling operations for three of the Intake pipe supports, installation of three isolation butterfly valves, implementation of three fish/debris screens (see Figure 9), and the placement of a portion of the pipe to be performed on dry land. The remaining installation activities were performed via marine operations and included, drilled piles, clam shell excavation, installation of three fish/debris screens, Intake pipe placement from a crane-mounted barge, critical lift and placement of 161-foot long section of Intake pipe (see Figures 10 and 11), Intake pipe support placement, underwater (tremie) concrete placement, and custom metrology sections to fabricate pipe closure sections (connection tunnel to Intake pipe).

Figure 9. Fish/Debris Screen.

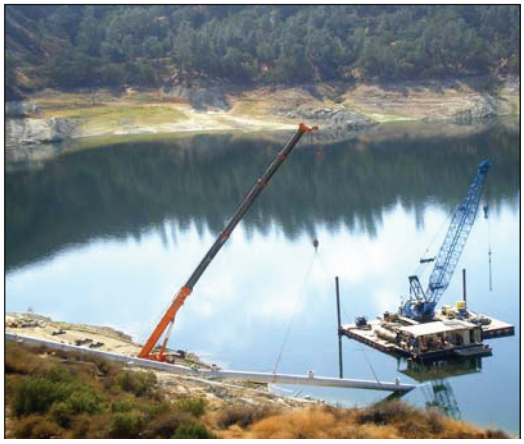

Figure 10. Placing Intake Pipe

Figure 11.
Intake Pipe, Barge, and Equipment.

CONCLUSIONS AND LESSONS LEARNED

Several lessons were learned through the design, implementation, and construction of the Project's intake, and they are:

1. The District should have taken ownership of the risk of lake level fluctuations. This could be accomplished by specifying a mean lake level in the bid documents and seeking a bid value on elevation intervals above and below said value. The owner would pay the contractor accordingly for higher lake levels and would be afforded deducts for lower lake levels. This strategy will likely lower high contingency values from the bids.
2. The District recommends including a Geotechnical Baseline Report (GBR) in the bid documents. This Project did have a GBR, and the contractor did benefit from using it to bid and plan his work. This document presents the engineer's anticipated groundwater levels and subsurface conditions for the intake site. Also include proposed construction methods for shaft and tunnel construction, which allowed the contractor to better anticipate the intake work.
3. The District recommends assembling a Disputes Review Board (DRB) to settle any disputes developed during construction. A DRB is especially effective when complex, specialty work is involved. The combination of shaft excavation, microtunneling, and marine construction on this Project created a need for an experienced, unbiased panel to help avoid claims and encourage partnering. This project assembled a three-person team, and at the time of publication of this paper, no hearings are scheduled.

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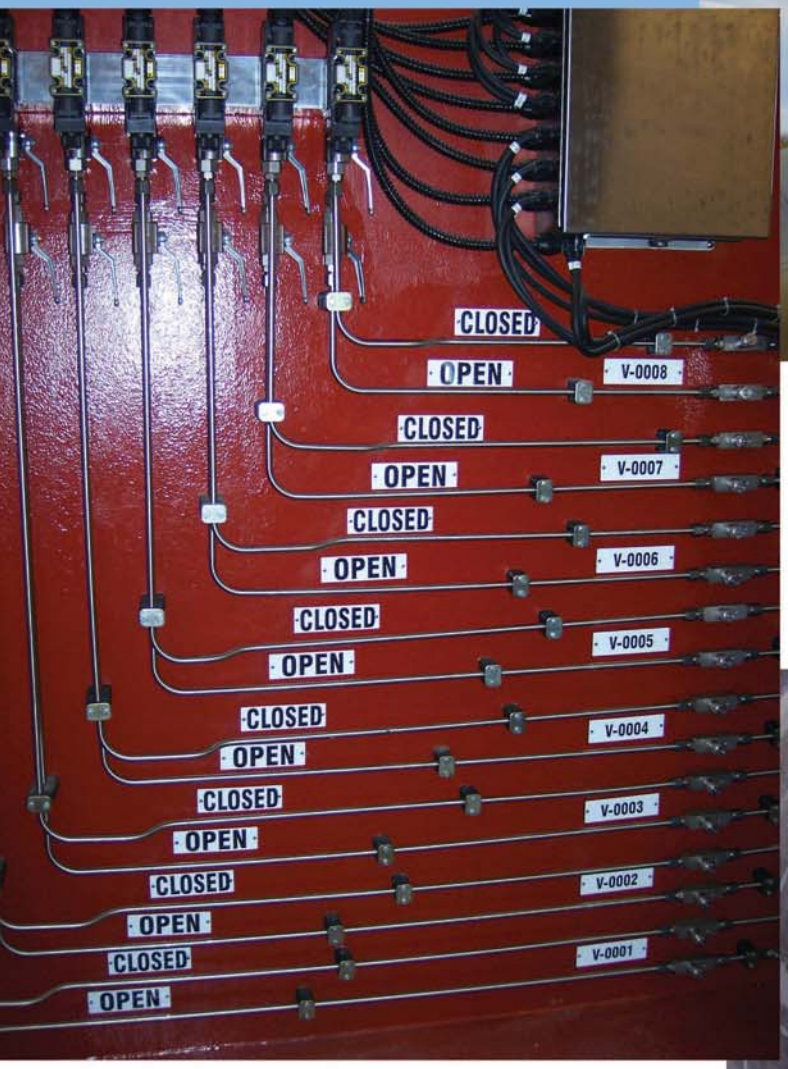
Figure 12.
Intake Site - PreConstruction

Figure 13.
Intake Site - During Construction

NOTES

Unit Conversion

1 mile = 1.6093 kilometers
1 foot = 12 inches = 0.3048 meters
1 acre = 0.4047 hectare
1 cubic foot = 0.02832 cubic meters
1 cubic yard = 0.765 cubic meters
1 pound per square inch = 6894.76 pascals
1 ton = 2,000 pounds = 907.18 kilograms
1 acre-foot = 1,233.5 cubic meters
1 horespower = 0.746 kilowatts



NWP Nacimiento Water Project

San Luis Obispo County Flood Control & Water Conservation District

County Government Center, Room 207, Department of Public Works
San Luis Obispo, California, 93408

ONE PROJECT, 6 HDDs: NACIMIENTO WATER PROJECT

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Thomas C. Trott, P.E.
Chuck Parker, P.E.
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San Luis Obispo County
Flood Control & Water Conservation District

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Craig Camp is a Senior Engineer with Jacobs Associates in San Diego, California. He has more than 25 years of experience in underground construction. He has been involved in over 100 microtunneling and other trenchless construction projects installing approximately 250,000 feet of pipelines throughout the country. This extensive experience covers virtually every aspect of trenchless construction. Craig is a member of the program committee for the North American Society for Trenchless Technology (NASTT), on the board of directors for WESTT of NASTT, is currently an instructor for NASTT's course on the Best Practices for New Trenchless Installation Methods, and has taught at the Colorado School of Mines Microtunneling short course. He has presented numerous papers involving trenchless construction for NASTT, RETC, as well as other organizations involved in the trenchless industry.

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Paper #F-1-05

One Project, Six HDDs: The Nacimiento Water Project

John R. Hollenbeck, P.E., Thomas Trott, P.E., Chuck Parker, P.E., and Craig Camp

ABSTRACT

In 2004, the San Luis Obispo County Flood Control and Water Conservation District (District), located in California, adopted the Final Environmental Impact Report for a 45-mile long raw-water conveyance to withdraw water from Lake Nacimiento, for delivery to several Participants (customers) along its route to the City of San Luis Obispo.

Horizontal directional drilling (HDD) under environmentally sensitive streams was selected as the economical and most expeditious means for obtaining environmental permits. Six stream crossings were designed, and construction began in 2008. The six crossings have diameters of 30, 30, 24, 24, 18, and 8 inches, and the respective length of each is 1,800, 1,300, 3,300, 1,900, 1,050, and 988 feet. The carrier pipe is welded steel having wall thicknesses of 0.50 inches for pipes larger than 18 inches, and 0.25 inches for pipes 18 inches and smaller.

Five of the crossings will be within a geologic unit known as the Paso Robles Formation, a weakly indurated alluvial conglomerate consisting of dense mixtures of pebble gravel, sand, silt, and clay. The other crossing is through two geologic units: the Monterey Formation, consisting of moderately-lithified deep marine rocks of late to middle Miocene age, and the Santa Margarita Formation, consisting of semi-lithified, semi-friable massive white sandstone of late Miocene age that was deposited in shallow marine environments.

This paper describes the pre-qualification process used to identify eligible HDD subcontractors, the project's environmental permit requirements, the physical designs unique to the project's construction, and construction performance case history for those HDDs completed prior to final submittal of this paper.

One Project, Six HDDs: The Nacimiento Water Project

John R. Hollenbeck, P.E., Thomas Trott, P.E., Chuck Parker, P.E., and Craig Camp

PROJECT BACKGROUND

The San Luis Obispo County Flood Control and Water Conservation District (District) received annual rights to 17,500 acre-feet of water from the Lake Nacimiento impoundment in October 1959, when it executed an agreement with the Nacimiento dam and reservoir owner, Monterey County Flood Control and Water Conservation District, now known as Monterey County Water Resources Agency (Monterey Agency). The District conducted several feasibility studies over the next four decades, assessing the cost and benefit of building the infrastructure to distribute the water to various areas within the County. The studies indicated groundwater pumping as the most feasible water supply. In the 1990's, demands on the County's groundwater basins were nearing their safe yield; thus, an alternative water source was needed to meet demands and protect the basins. The next feasible water source identified was the Nacimiento Water Project (Project).

The District's water entitlement is divided into two parts. The lakeside usage of the water equates to 1,750 acre-feet annually, and that water resides in the lake for users around the lake. The remaining volume, 15,750 acre-feet per year, will be conveyed by the Project via pumps and pipeline.

Overall, Lake Nacimiento holds 377,900 acre-feet when at normal maximum pool elevation of 803.07 feet (NAVD88 Datum used herein).

THE "FINAL ENVIRONMENTAL IMPACT REPORT RECOMMENDED" PROJECT

The District's Board of Supervisors adopted the recommendations contained in the Final Environmental Impact Report on January 6, 2004, and directed the County's Public Works Staff to implement the recommended project consisting of a multi-port lake intake, three pump stations (one at the lake, and two booster stations), three water storage tanks, and 45 miles of pipeline. The initial phase of the Project will serve the communities of Paso Robles, Templeton, Atascadero, Cayucos, and San Luis Obispo. These communities are contracted with the District to receive 9,655 acre-feet per year. The remaining 6,095 acre-feet per year is the reserve water that is available to the existing participants, or can be contracted by other communities or water agencies anywhere within the boundaries

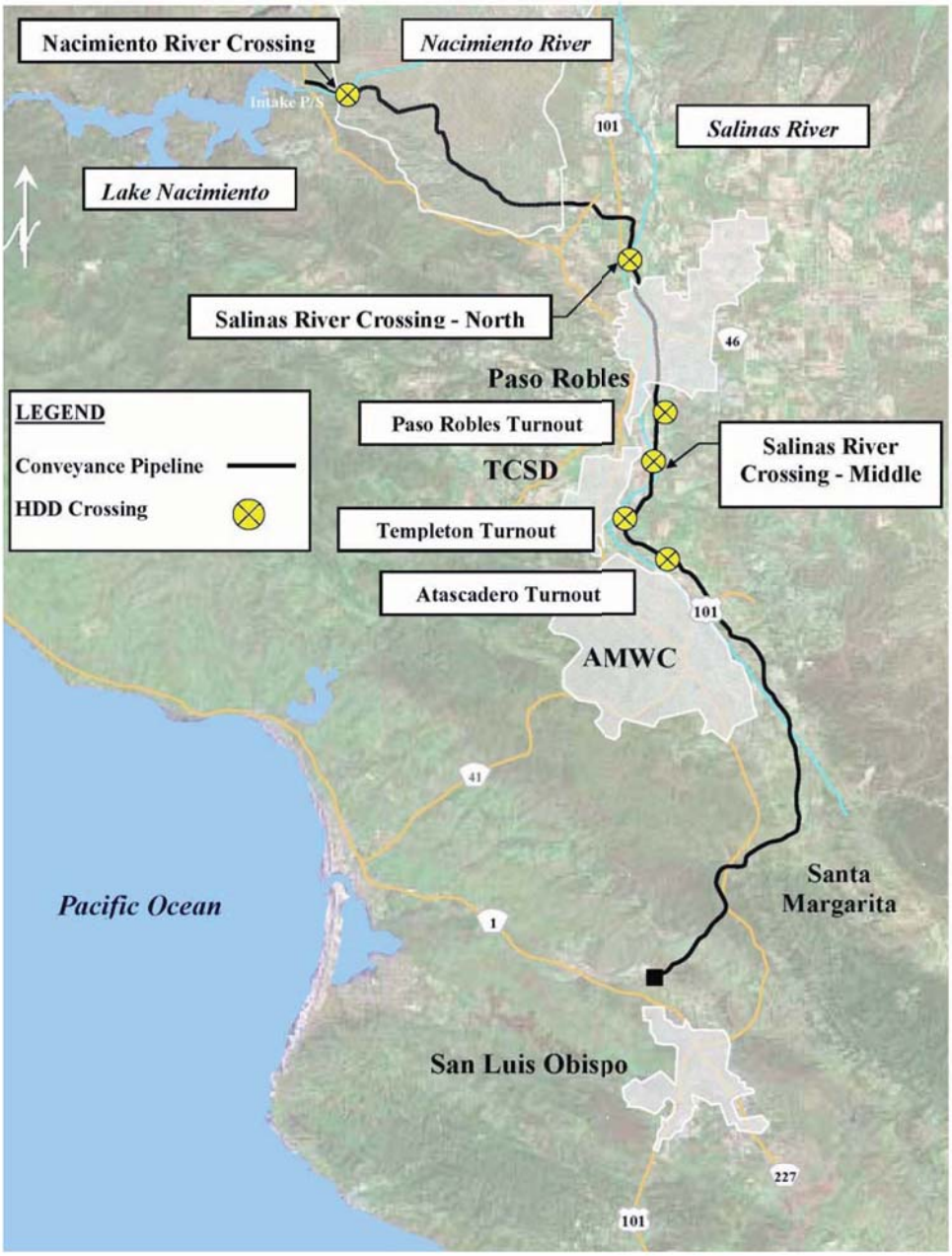

Figure 1. Nacimiento Water Project HDD Crossing Locations.

of the County.

CONCEPTUAL DESIGN

The Project's 45-mile length traverses challenging obstacles where trenchless construction needed to be considered, including: rivers, streams, railroads, roads, and highways. The conceptual design completed in 2001 (Carollo, 2001) identified two river crossings utilizing horizontal directional drilling (HDD). Other trenchless methods were judged more effective for incidental railroad, streams, and road crossings.

HDD was judged to be both economically and environmentally superior during conceptual design for the two crossings summarized in Table 1 and depicted in Figure 1. The most important reason for selecting HDD was the elimination of potential environmental damage caused by open-cutting across the Nacimiento and Salinas Rivers. Open-cut crossings were judged technically feasible, but environmentally challenging. The District judged such environmental risk as cost prohibitive and, thus, HDD was judged the best trenchless method given the geometry of these two crossings. The Project's turnouts that cross the Salinas River were not defined during conceptual design, although it was determined that river crossings, where required and viable, would be constructed using HDD.

River Crossing	Length (feet)
Nacimiento River	800
Salinas River – North	1,100

Table 1. HDD River Crossing Descriptions – Conceptual Design.

PRELIMINARY DESIGN

Engineering of the Project began with the development of the Preliminary Design Report (PDR) (Black & Veatch, 2006) by the District's design team. The PDR described the engineering criteria for all aspects of the Project, including all trenchless crossings. The trenchless portion discussed the HDD method and the unique features of HDD that could affect pipeline design, alignment, soils, pipe materials, environment, cost, and schedule. HDD features included both positive features, such as improved hydraulic performance when compared to a pipe jacked crossing, and negative features, such as long set back distances required to achieve the crossing depth.

All of the crossings were arranged using preliminary pipe sizes and topography within the proposed alignment. River scour depth was assumed to be 20 feet under the active river channel for the basis of design. Based upon this information, a drill path was laid out and the alignment was adjusted to accommodate the proposed drill path, as permitted by the allowable pipe materials and size. These alignments provided the basis for determining the depth and locations

for the geotechnical boreholes, which produced data that was developed and presented in the Geotechnical Data Report for pipelines (Geomatrix, 2007a) and the Geotechnical Interpretive Report for pipelines (Geomatrix, 2007b). They also helped determine where additional land survey data was required for final design. Once the preliminary pipeline designs were completed, the hydraulic design team reviewed pipe dimensions to ensure the hydraulic performance requirements had been met.

The PDR also presented suggested modifications to pipeline alignment. This alignment study affected the quantity of the HDD's needed for the Project. Near the middle of the alignment that parallels the Salinas River, the river has a tight meander and the pipeline was originally planned to parallel the outside of the river's curve. The design team proposed a single HDD crossing of the river through the inner part of the meander (the pipe would cross under the river twice). The crossing was estimated to be 24-inch pipe diameter with a final drill path of approximately 3,000 feet. This crossing was accepted by the District and identified as the Middle Salinas River (MSR) Crossing. This HDD alternative provided advantages by straightening the pipeline alignment and avoiding the length around the meander. Additionally, the extremely challenging topography along the outer-meander route was not suitable for open cut trenching and would require trenchless methods, such as bore and jack or microtunneling. The straighter, yet long HDD became an obvious choice to pursue.

FINAL DESIGN

The Final Design began knowing there were three known river crossings and three undetermined river crossings to deliver the water to the Participants. The latter three crossings are the Project's turnouts. The final number of HDD crossings designed and constructed is six: one on Nacimiento River and five on Salinas River (see Figure 1 for location). The six river crossings are summarized in Table 2.

The carrier pipe was specified to be welded steel in accordance with American Water Works Association (AWWA) specification C200 with a Powercrete™ PW (or equivalent) lining and a Powercrete™ R60 (or equivalent) coating, each having a minimum 80 mil thickness applied over three coats. See the discussion on Construction (below) for contractor-proposed alternatives.

The final design anticipates the five Salinas River crossings to be in a geological formation known as the Paso Robles Formation. The Paso Robles Formation is a weakly indurated alluvial conglomerate consisting of dense mixtures of pebble gravel, sand, silt, and clay. The designers expected that each Salinas River crossing would likely encounter some eroded and re-deposited soils originating as Paso Robles Formation and fill created by human activities such as, infrastructure development and farming. The river

River Crossing Name	Diameter (inches)	Steel Pipe Wall Thickness (inches)	Max Depth (feet) (1)	Drill Path Length (feet)(2)	Curve Data		
					Length (feet)	Radius (feet)	Delta (Degrees)
Nacimiento River	30	0.50	102	1,800	1,373	3,576	22.0
North Salinas River	30	0.50	42	1,300	1,007	2801	20.7
Middle Salinas River	24	0.50	167	3,300	2,410	6,276	22.0
Salinas River, Paso Robles Turnout	24	0.50	94	1,900	1,513	4,404	20.0
Salinas River, Templeton Turnout,	8	0.25	45	1,050	463	1,234	22.0
Salinas River, Atascadero Turnout,	18	0.25	52	988	669	1,915	20.0

(1) Maximum depth is measured below existing ground surface to top of pipe.
(2) Drill Path Length includes straight and curved lengths

Table 2. Final HDD Design Description.

scour assessment indicated minimum depths in the range of 30 to 40 feet on the Salinas River, and 20 to 30 feet on the Nacimiento River (Geomatrix 2007b).

The final design also included a requirement to install fiber optic conduits with the Project pipeline for installation of fiber optic communication associated with the Project's SCADA system. The fiber optic conduit design specified that four 1.5-inch diameter galvanized rigid steel conduits be pulled simultaneously with the carrier pipe. The District's goal was that two of the four conduits survive the pullback. The specifications required the general contractor to pull a mandrel through the conduits to first assure they were open before installing the fiber in one conduit and a pull rope in another spare conduit. The conduits were specified to be free-floating with the pull-back, with longitudinal joining by butt welding; no mechanical fittings were allowed.

The details of the final design required the District to obtain the California Department of Fish and Game Streambed Alteration permits, the US Army Corps of Engineers Section 404 Nationwide Permit, and the California's Division of Occupational Safety and Health's (CalOSHA) tunnel classification. The Section 404 permit required the entire HDD process be completed within the summer low flow season (June 15 through October 15) and called for complete stoppage if any drilling fluid entered any waterway. The CalOSHA permit required for all tunnels with an excavated diameter greater than 30 inches, included requirements for hydrocarbon monitoring to account for the oil wells that exist in the local geologic formations.

Final design specifications required extensive submittals to ensure the contractor understood that any spill entering a waterway would stop the project and could lead to substantial penalties; thus, the specifications required the contractor to actively monitor for

leaks and spills. Some of the submittals required locating and maintaining slurry clean-up resources available throughout construction, and conducting meetings to discuss and approve changes to the HDD operating parameters before resumption of drilling. All surface spills had to be contained and cleaned immediately upon discovery and before the end of that shift. The specifications also required the contractor to develop and submit contingency plans for other potential events or construction related issues that may affect the Project's completion or quality. Examples of potential events included the loss of steering information, the excavation tooling becoming stuck or lost in the hole, or the loss of drilling fluid in a subsurface formation. The contractor was also required to monitor and record slurry fluid pressure, thrust or pullback forces, torque, location and time. These documents were submitted to the construction manager during construction.

The specifications required minimum HDD rig sizes based upon each crossing's specific characteristics including pipe, drill path and soils. Table 3 presents a summary of the torque requirements for reaming. The HDD rig was also required to have the capacity to pull 1.2 times the static weight of the carrier pipe and the fiber optic conduits.

River Crossing Name	Torque (foot-pounds)
Nacimiento River	45,000
North Salinas River	45,000
Middle Salinas River	36,000
Salinas River Paso Robles Turnout	36,000
Salinas River Templeton Turnout	10,000
Salinas River Atascadero Turnout	22,000

Table 3. Specified HDD Rig Size Requirements

PREQUALIFICATIONS OF HDD CONTRACTORS AND BIDDING

The District conducted a prequalification process for the HDD contractors who would become subcontractors for the construction. The District highly regards the protection of the environmental setting of these river crossings, especially since they are habitat for the Steelhead Trout, a listed endangered species. Prequalification of the HDD specialty contractors was judged an effective management tool to assure success of this complicated work while also being assured that the successful HDD contractor would not be performing his first trenchless crossing on this Project. The prequalification statement, uniform system of rating, and the appeal process were derived from the templates developed by the California Department of Industrial Relations. Six HDD contractors were pre-qualified several months prior to bidding the Project. These six pre-qualified specialty subcontractors were listed in the bidding documents as the only firms which could perform the HDD work.

The Project's 45-mile pipeline work was bid in three segments: North, Central and South. The North and Central contracts contain the

Contract	No. of Bidders	Engineer's Opinion of Cost	Bid Range		Successful Bidder		Total HDD Bid Items
			Low	High	Firm	Bid	
Central	9	$28.6M	$22.7M	$29.3M	Whitaker	$22.7M	$7.0M
North	9	$49.8M	$38.4M	$51.3M	Teichert	$38.4M	$3.8M

Table 4.
Project Bidding Results of Pipeline Construction Contracts with HDD Work

six HDD crossings: the Nacimiento River and the Salinas River North are in the North contract, while the remaining four are in the Central Contract. The work for the Central contract was completed in 2008. The North contract HDD work will be completed in 2009.

The District judged the bidding of these two pipeline construction contracts to be very successful. Table 4 presents a summary of the bidding, along with the bid tabulation for the HDD work. Bidding occurred in July 2007.

CONSTRUCTION

The HDD work performed by the Central contract was completed by the time this paper was authored; thus, most discussion will center on that work effort.

The general contractor submitted a value engineering proposal (value engineering incentives are an element of the construction documents) to modify the carrier pipe material, and both the coating and lining systems. During the Spring of 2008, when steel pipe was being ordered for the HDD work, drastic pipe cost increases were seen on a daily basis. A search of the western states found that AWWA C200 pipe with "Powercrete" epoxy coating was challenging to locate and expensive. The contractor prepared a Value Engineering Cost Proposal for all HDD pipes based on using steel pipe meeting API 5L standards, which was in stock in a Louisiana yard, and coating it with fusion bonded epoxy. The pipe interior coating was 12 to 14 mils of DuPont NAP-Guard Mark X 7-2500. The pipe exterior corrosion coating was 12 to 14 mils of 3M Scotchkote 6233, followed by an abrasion coating of 30 mils of 3M Scotchkote 6352. The proposal was reviewed by the designer and the construction management team, and judged acceptable by the District. The change resulted in a 50-percent split of $940,000 in savings between the general contractor and the District.

The contractor also was concerned about the pullback of the four bundled fiber optic conduits. Their concern centered on the very small diameter conduits being wound around the carrier pipe and subsequently damaged during the pullback process. The API pipe approved for the carrier pipe had longitudinal seam welds, and the contractor thought that would greatly reduce the tendency of the carrier pipe to rotate during the pullback operation. The

design specified spiral welded pipe, and the contractor was concerned that the spiral welds would potentially promote rotation during pullback.

All four of the HDD river crossings were completed in a compact environmentally-constrained construction window (June 15- October 15) and inspected by the Project's construction management team. The general contractor listed Michels Corporation as their HDD subcontractor. Because of the narrow construction window, Michels Corporation elected to subcontract the Templeton and Atascadero HDD work to a second tier subcontractor, K-Comm. That work was done in parallel with the other two crossings. The District judged this subcontracting as acceptable with the mandate that the second tier subcontractor be managed full time by both the general contractor and the HDD subcontractor.

Work began on the Atascadero turnout on June 23, 2008. The HDD work consisted of installing an 18-inch diameter welded steel carrier pipe bundled with four 1.5-inch diameter galvanized steel fiber optic ducts. Drilling the pilot hole took four days, but three additional days were required to contain two "frac-outs" where bentonite slurry found its way to the ground surface. This issue was resolved by lowering the slurry pressure and building containment areas at these two locations. Reaming of the pilot hole followed from July 9 to July 20, 2008. The carrier pipe was pulled on July 22, 2008 starting at 5:00 AM and finishing at 2:00 PM, as shown in Figures 2 and 3. The contractor used a Ditch Witch JT 8020 Mach 1 for this HDD crossing. All four of the fiber optic ducts came through unharmed with the carrier pipe.

The Templeton turnout commenced on

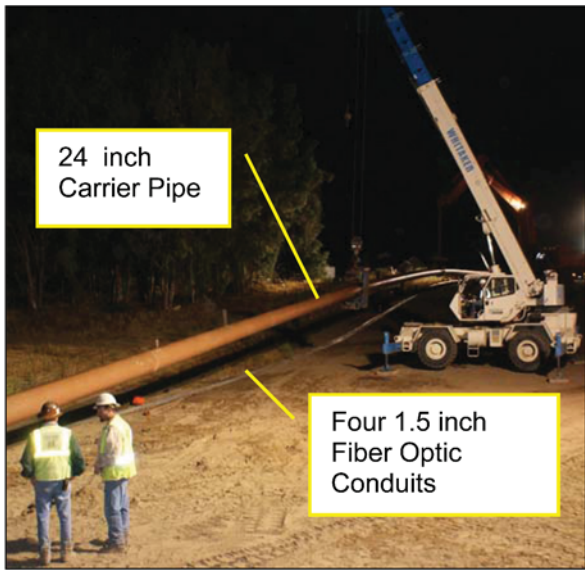

Figure 2. Atascadero Turnout HDD Night Preparation

Figure 3. Atascadero Turnout HDD Pullback

July 25, 2008. This work consisted of installing an 8-inch welded steel carrier pipe bundled with the four galvanized 1.5-inch diameter steel fiber optic conduits. Drilling the pilot hole took one day and reaming was completed in two days. Pulling the carrier pipe and four fiber optic ducts was completed in one day. The contractor used a Ditch Witch JT 8020 Mach 1 for this HDD crossing. All four fiber optic conduits were successfully installed.

Work on the Paso Robles turnout crossing began on July 16, 2008. The work consisted of installing a 24-inch diameter welded steel carrier pipe as well as the four galvanized 1.5-inch diameter steel fiber optic conduits. Drilling the pilot hole took two days and reaming was completed in eight days. Pulling the carrier pipe and four fiber optic ducts was completed in one day starting at 8:30 AM and finishing at 1:45 PM, as shown in Figure 4. All fiber optic conduits were successfully installed.

The MSR crossing work began on July 31, 2008. The MSR work consisted of installing a 24-inch diameter welded steel carrier pipe and four galvanized 1.5-inch diameter steel fiber optic conduits. Drilling the pilot hole took four days and reaming took seven days, see Figure 5. Pulling the carrier pipe was completed in one day, starting at 5:00 AM and finishing at 6:00 PM. The log tracking the thrust/pullback force for the pull revealed a force range between 80,000 and 100,000 pounds and a torque range between 5,000 and 10,000 foot-pounds. The largest pull force, 100,000 pounds, was encountered roughly two-thirds through the 3,000-foot pull. Unfortunately, only one of the fiber optic conduits made it through with the carrier pipe and the other three stopped 500 feet short of completion due to the cable rigging breaking on the conduit pulling harness. To remedy this problem the contractor performed a second HDD, at a later date, for a single fiber optic conduit so that two usable conduits were available for the Project.

At completion of each of the four HDD crossings, “as-built” surveys, pressure testing of the carrier pipe, and mandrel testing of the fiber optic conduits were performed. The mandrel test ensured that the conduit was intact and had maintained its round shape. The test consisted of pulling a ball or elliptical plug-shaped object, sized no less than 80-percent of the conduit’s inner diameter, through

Figure 4. Paso Robles Turnout HDD Pullback.

Figure 5. Adding drill stem for MSR HDD.

it. The carrier pipe "as-built" surveys showed the alignment met the specified requirements; the pressure tests also met the specified requirements. During the mandrel tests on the fiber optic conduits, it was found that at least two of the four passed the mandrel requirements.

The overall success during construction was due to a high-quality construction team, pre-planned work strategy, and specified submittals. The submittals conveyed what equipment would be used, how required quality would be maintained and documented, how work would be carried out safely, and how the necessary environmental protection measures would be implemented. After the pre-work activities were completed, the contractors worked closely to the schedule to coordinate, inspect, and install the HDD work in accordance to the agreed upon plan. Whenever challenges were encountered, the construction team members worked to arrive at an equitable solution that advanced the overall project completion.

CONCLUSION

Project contractors successfully completed the four Salinas River HDD crossings in a short environmentally-constrained window of time, meeting the specified construction standards. Success resulted from prequalifying eligible HDD subcontractors prior to bidding, adhering to the environmental permit requirements, and establishing the necessary physical designs unique to the Project's construction. It is anticipated that the two remaining HDD river crossings on the Project will be completed during the allowed environmental construction period in the summer of 2009.

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NOTES

Unit Conversion

1 mile = 1.6093 kilometers
1 foot = 12 inches = 0.3048 meters
1 acre = 0.4047 hectare
1 cubic foot = 0.02832 cubic meters
1 cubic yard = 0.765 cubic meters

1 pound per square inch = 6894.76 pascals
1 ton = 2,000 pounds = 907.18 kilograms
1 acre-foot = 1,233.5 cubic meters
1 horespower = 0.746 kilowatts

NWP NACIMIENTO WATER PROJECT

San Luis Obispo County Flood Control & Water Conservation District

County Government Center, Room 207, Department of Public Works
San Luis Obispo, California, 93408

Achieving Sustainability by Designing for Efficiency

A Case History of the Nacimiento Water Project

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August 13, 2009

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ACHIEVING SUSTAINABILITY BY DESIGNING FOR EFFICIENCY A CASE HISTORY OF THE NACIMIENTO WATER PROJECT

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ABSTRACT

The Board of Supervisors of the San Luis Obispo County Flood Control and Water Conservation District (District) adopted the Final Environmental Impact Report for the Nacimiento Water Project (Project) in January 2004, thus directing staff to design the raw water conveyance that will supply up to 15,750 acre-feet per year from Lake Nacimiento located in San Luis Obispo County, California.

The Project consists of a sloping multi-port intake and pump station facility, two intermediate pump stations, three storage tanks, control center, and approximately 45 miles of transmission pipelines ranging in diameter from 36-inches to 12-inches. 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 District began the design in 2005, set specific design objectives for a sustainable and reliable water supply and for the efficiency of the water conveyance system to minimize electrical operating costs. This paper describes the sustainability aspects of the Project's design that include water supply sustainability, reduced energy use through energy efficiency initiatives, and balancing of resources.

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ACHIEVING SUSTAINABILITY BY DESIGNING FOR EFFICIENCY
A CASE HISTORY OF THE NACIMIENTO WATER PROJECT

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PROJECT PURPOSE

The primary objective of the Project is to provide a reliable supplemental water source for a variety of uses within San Luis Obispo County (County) by supplementing the local groundwater and surface water supplies with a new water source. Other Project objectives are to increase reliability of existing water supplies, to improve water quality, to lessen the extent of future groundwater pumping, and to provide sufficient supplies to support planning objectives in various communities of the County. Overall, this will ensure better management of available water resources throughout the County.

WATER SUPPLY SUSTAINABILITY

Lake Nacimiento holds 377,900 acre-feet when at normal maximum storage, and has 10,700 acre-feet below the dead pool elevation. Monterey County Water Resources Agency (MCWRA), the reservoir owner, and the District hold their water entitlements between these limits. The reservoir yield is about 210,000 acre-feet per year (MCWRA 2000), and MCWRA's water rights permit with the State of California sets a maximum annual withdrawal of 180,000 acre-feet (California 1985). The District's total entitlement of 17,500 acre-feet annually from the lake (15,750 acre-feet for the Project, and 1,750 acre-feet for lakeside users) makes up a small portion of the overall yield of the reservoir, and past engineering reliability assessments, based on historic records from 1950 through 1990 (Boyle 1992) have indicated that the watershed would supply nearly 100-percent of the District's entitlement. Adding the Project to the local community's primary water supply portfolio will improve water supply reliability, even with the Project serving as a "supplemental" supply.

The growing City of Paso Robles (City), in the northern region of the County, population of approximately 30,000, overlies the Paso Robles Groundwater Basin (see Figure 1) and has always relied upon groundwater as its sole water supply. The City constantly faces challenges to meet water quality mandates specified by the local regulatory agency for the waste discharge requirements regarding TDS levels. The Total Dissolved Solids (TDS) measured from the City's wells range between 370 and 740 parts per million (ppm) (Paso Robles 2009) and the effluent from the City's wastewater treatment plant has even greater TDS levels. The treated wastewater is discharged into the

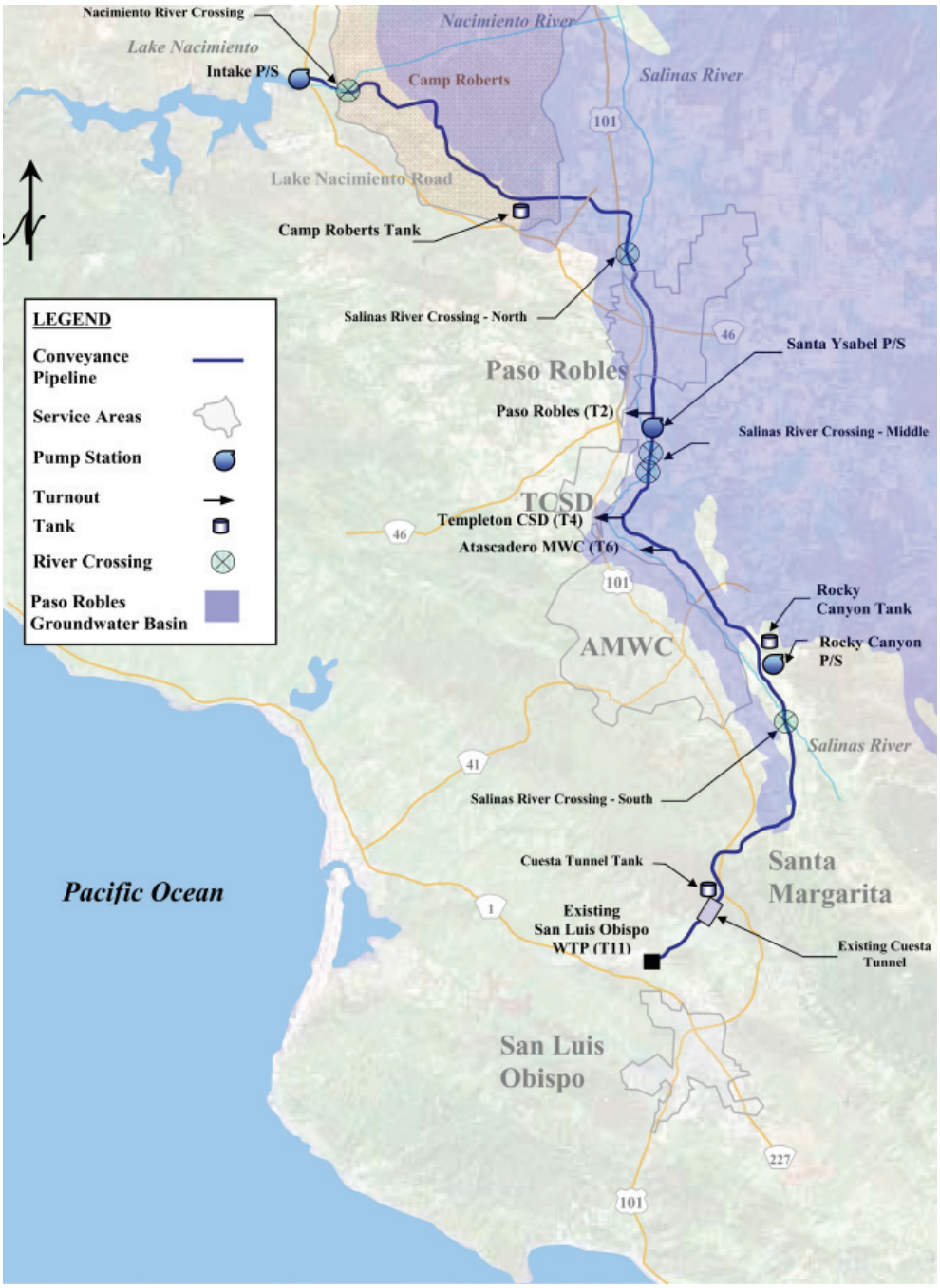

Figure 1. Nacimiento Water Project with Paso Robles Groundwater Basin Overlay

Salinas River and eventually recharges the groundwater basin. Furthermore, water softeners have been installed within homes and businesses, and these have further contributed to higher TDS levels in the waste stream. The City plans to construct a water treatment plant to treat the raw water delivered by the Project, which the City will then blend with their well water. This will result in reduced TDS levels in the potable water supply system. The City benefits from the Project in several ways: (1) receiving a reliable supplemental water supply, (2) lower TDS levels in the waste stream by receiving a lower TDS water supply, (3) reducing the need for an expensive wastewater treatment plant upgrade which would be needed to lower the effluent's TDS level, and (4) reducing the groundwater pumping, thus contributing to a more sustainable groundwater supply.

By contrast, the City of San Luis Obispo (SLO), in the south-central portion of the County, population of approximately 45,000, relies predominantly on surface water sources. The City of SLO utilizes such existing small surface water supplies as Salinas Reservoir and Whale Rock Reservoir, and has little access to large-scale groundwater resources. The City of SLO does not face growth concerns, but rather, they need a reliable secondary water supply as a reserve to manage drought cycles.

The communities of Templeton and Atascadero, located between the Cities of Paso Robles and SLO, are both supplied with groundwater from the Paso Robles Basin. Both are constructing groundwater recharge ponds (percolation ponds) and will use their deliveries to replenish the groundwater locally near their well fields.

REDUCED ENERGY USE - ENERGY EFFICIENCY

During the Project's preliminary and final design phases, the design team performed an on-going series of life-cycle cost evaluations to continually evaluate and optimize the Project facilities' size and capacity with the eventual goal of reducing overall Project energy usage in a cost-effective manner. As an example, the District participated in the Savings By Design program which is a California statewide nonresidential new construction and renovation/remodel energy efficiency program. Pacific Gas and Electric (PG&E) manages the program in the San Luis Obispo Project area. The program enables customers to improve the energy efficiency of their projects using design assistance and financial incentives available through the program.

The design of the Project's pump stations showed potential for feasibility of inclusion in Savings By Design program. By participating in this program, use of premium-efficiency pump motors and energy efficient electrical systems and lighting would pay for themselves within a reasonable payback period. The design team also reviewed the potential of upsizing several miles of Project pipeline to reduce hydraulic losses which would yield reduced pump station power

capacity and thus lower 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 the alternative bids was less than the breakeven point dictated by energy savings and incentives payments. Based on bid results, the northern-most reach (about nine miles) of the Project pipeline was upsized from 30 to 36 inches with a resulting reduction of the Intake Pump Station power capacity and expected lower pumping costs. As a result, the pump units were downsized from 700- to 500- horsepower (hp). The design team estimates the investment's payback period to be between 10 and 15 years.

BALANCING RESOURCES

The District sought to achieve a sustainable design by creating solutions that balanced the use of resources, including monetary (cost), electrical energy (temporary and permanent), raw materials, and manufactured equipment. Several applicable design evaluations were performed, including pipeline optimizations, renewable energy studies, the intake pump station wetwell optimization, and time-of-use pumping evaluations.

Pipeline Optimizations

The design team performed a series of ongoing life-cycle studies to confirm the optimal combination of pipeline diameter and pump station capacity by comparing upfront construction costs to long-term operating costs.

As part of Project sizing, a pipeline optimization analysis (Black & Veatch 2006) compared alternative pipeline diameters by Project Unit (the identifier for the pipeline reaches) in conjunction with variable pumping energy costs. This optimization defined the recommended Project pipeline diameters. The approach found the best combination and size of conveyance components that produced the least present-worth total of capital, operating, and maintenance costs.

The operation of the three pump stations will generate the largest operating electrical energy (power) cost component associated with the Project water delivery. The power required for pump operation is inversely proportional to changes in the pipeline diameter. As the pipe diameter increases, power costs decrease due

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 1. Assumptions Used for Pipeline Optimization Analysis

Table 2. Nacimiento Pipeline Optimization

Unit	Length (feet)	Flow (cfs)	Pipeline Diameters (inches)	
			Optimized	Constructed
A	7,524	32.79	30	36
A1	42,450	32.79	30	36
C	24,690	32.79	36 and 30	36 and 30
C1	38,935	32.79	30	30
D	20,851	19.89	24	24
E	9,294	18.62	24	24
F	27,678	8.40	18	18
G	36,679	8.40	18	18
G1	15,783	8.40	18	18
H1	13,704	8.40	12	12

to the decrease in friction loss in the pipeline, and vice-versa. Table 1 shows the assumptions used in the analysis:

To determine the optimal pipe diameter for a given system operating condition. the estimated pipeline construction cost was added to the estimated present worth cost of operating power for a series of increasing pipeline diameters. This combination resulted in a cost optimization curve. The lowest combined cost over the range of pipeline diameters indicated the optimized pipeline diameter. The pipeline optimization analysis utilized the Ultimate Project operating scenario, which is the full delivery of 15,750 acre-feet per year, including the peaking factors for each of the participating agencies. In general, the analysis found that pipe diameters could be reduced by six-inches. An example of the pipeline optimization analysis is shown in Figure 2. Table 2 presents results of the pipeline optimization.

Renewable Energy Studies

The design team reviewed options

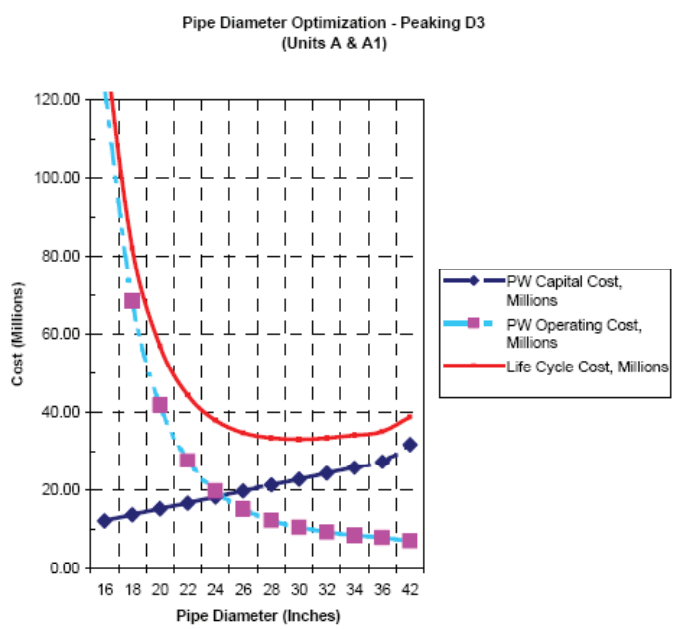

Figure 2.
Pipeline Diameter Optimization Results

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 PG&E. These evaluations resulted in neither option being economically feasible at this time; however, the District will continue to evaluate these options as an additional capital project once the Project becomes operational.

Intake Pump Station Wetwell Evaluation

The water delivery process begins at the Intake, which consists of an Intake Pipe with varying inlet valves to provide optimal water quality, an intake tunnel that moves water from the pipe into the wetwell, and the Intake wetwell. The wetwell is a 180-foot deep, 20-foot diameter, concrete-lined shaft that the pump columns sit in. The design team commissioned a physical hydraulic model study of the Intake Pump Station's wetwell to avoid the occurrence of pump operating problems. 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 appropriate mitigation measures to incorporate into the Project design.

The hydraulic modeling work was performed by a hydraulic laboratory in Edmonton, Canada (see Figures 3 and 4), under subconsulting contract with the design firm. Initially, the team reviewed the

Figure 3.
Wetwell at Hydraulic Modeling Laboratory.

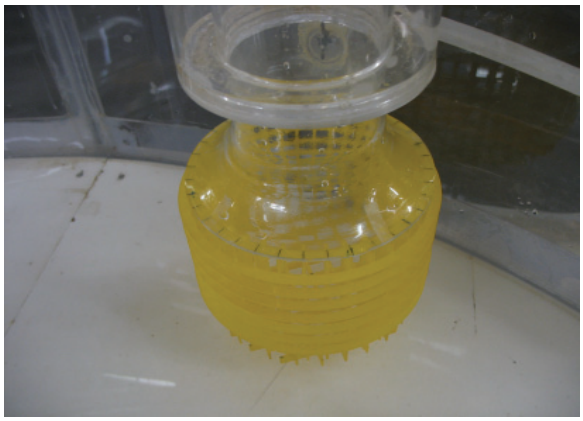

Figure 4. Pump Suction Bell and Assembly of Anti-Vortex Baffle.

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 the following.

- Raising all five pumps to provide a one-foot clearance between the wetwell floor and the pump inlet.

- Suspending a 36-vane basket (see Figure 4) with bottom grating and seven equally-spaced horizontal vane rings from all five pumps.

Time-of-Use Pumping Evaluation

Following the determination of optimal pipeline diameters for conveying Project flows, the feasibility of Time-of-Use (TOU) operation was evaluated. TOU operation means that the pump stations would be shutdown to avoid operating during the electrical peak demand period defined as 12:00 Noon to 6:00 pm weekdays, from May 1 to October 31. By avoiding peak period operation, the District could save on energy costs, depending on the alternative evaluated. To accommodate system operation in the summer peak period under a TOU scenario, the analysis showed that the Project facilities had to be sized accordingly to permit continued delivery of flows to the Participants while the system is shutdown from Noon to 6:00 pm. In this example, the increased costs for system storage (water tank volume) to accommodate TOU operation was found to be more than the present worth of energy savings expected. As a result, the Project was not designed to allow for TOU operation, but it may still be possible for the District to try it as an operating scenario if actual water deliveries in the early years of Project operation are well below system capacity.

CONCLUSION

The District conducted several analyses to create a new hydraulic structure that would satisfy, as best it can, design criteria that benefit the Participants (economic resources) and the environment (natural resources). The balance of both has yielded a successful project in the authors' judgment.

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NOTES

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NWP NACIMIENTO WATER PROJECT

San Luis Obispo County Flood Control & Water Conservation District

COUNTY GOVERNMENT CENTER, ROOM 207, DEPARTMENT OF PUBLIC WORKS
SAN LUIS OBISPO, CALIFORNIA, 93408

Nacimiento Water Project: Design and Hydraulics

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San Luis Obispo County
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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 .

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NACIMIENTO WATER PROJECT – *DESIGN AND HYDRAULICS*

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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.

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NACIMIENTO WATER PROJECT – *DESIGN AND HYDRAULICS*

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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

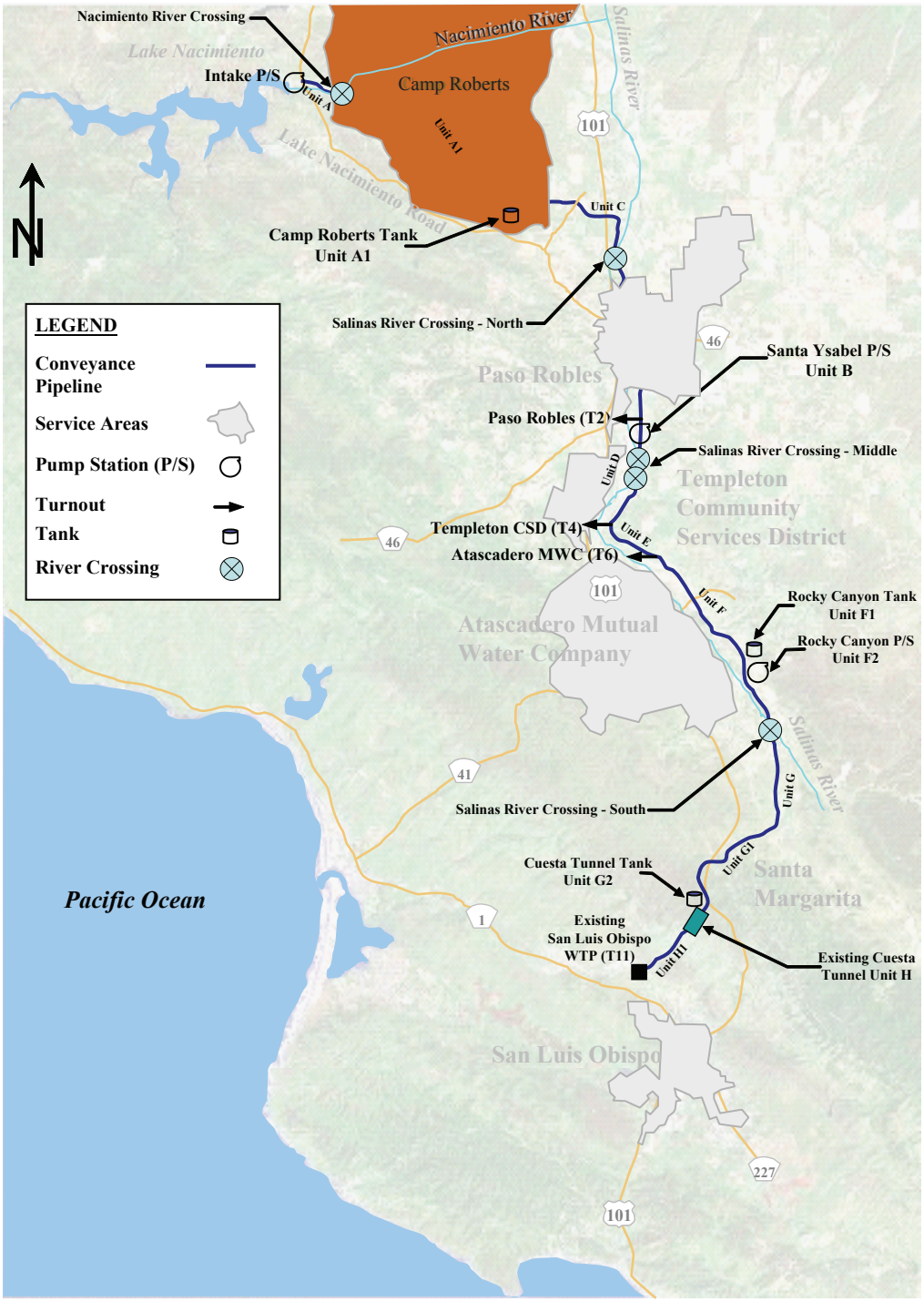

Figure 1. Nacimiento Water Project Unit Map

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.

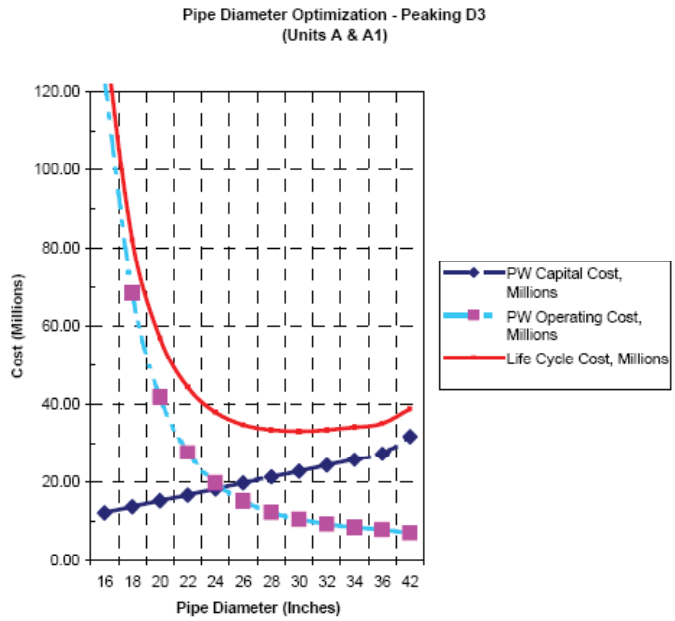

Figure 2.
Pipeline Diameter Optimization Results

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 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 pressue 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.

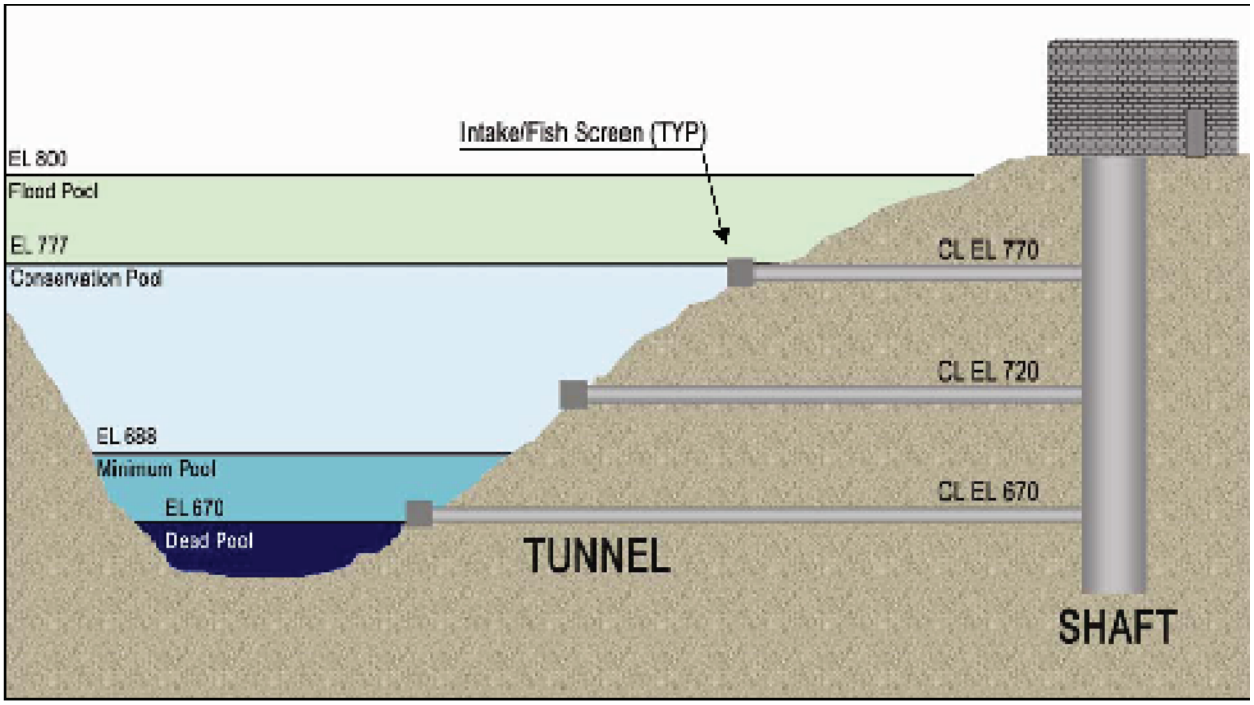

FIGURE 3. Nacimiento Water Project Configuration in the EIR

Value Engineering Study

The District commissioned a comprehensive value engineering (VE) study that was performed at the completion of the preliminary design report (30-precent 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

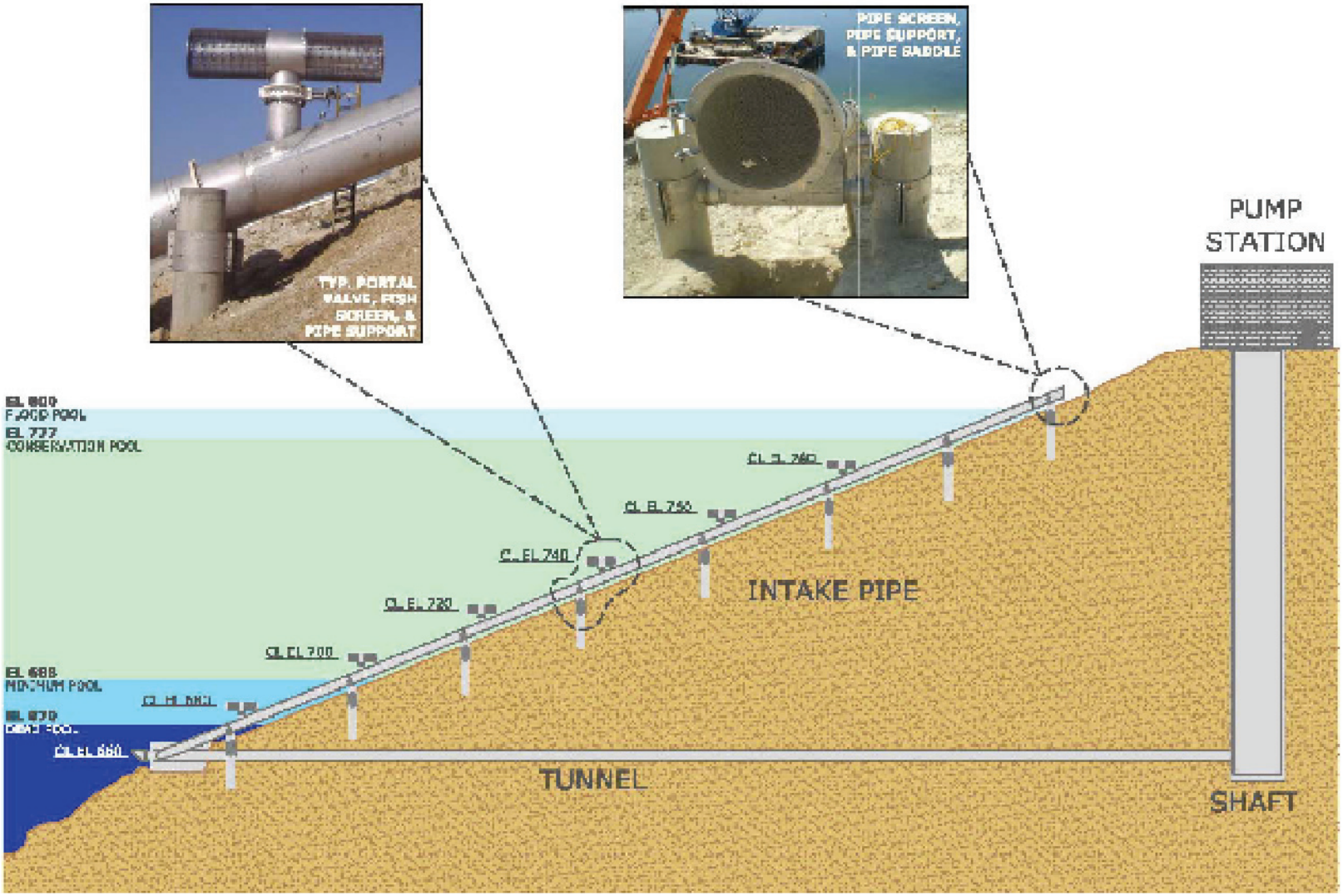

Figure 4. Nacimiento Water Project Confirguration Accepted for Final Design

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

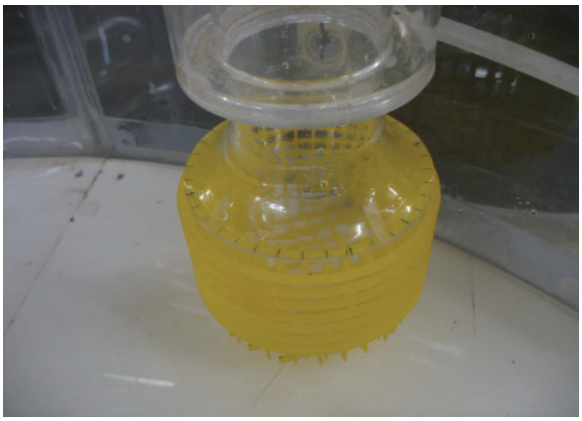

Figure 6. Pump Suction Bell and Assembly of Anti-Vortex Baffle.

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 manufacturer 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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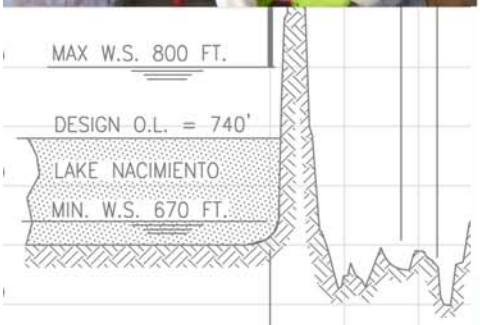

NWP NACIMIENTO WATER PROJECT

San Luis Obispo County Flood Control & Water Conservation District

County Government Center, Room 207, Department of Public Works
San Luis Obispo, California, 93408

BIDDING STRATEGIES HELP MANAGE CONSTRUCTION BUDGETS: A CASE HISTORY OF THE NACIMIENTO WATER PROJECT

John R. Hollenbeck, P.E.
Thomas C. Trott, P.E.
Paul R. Kneitz, P.E.
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San Luis Obispo County
Flood Control & Water Conservation District

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ABSTRACT

Management of a project's construction budget cannot be limited to managing the content of its design; consideration must be given to the project's bidding process. Taking a strategic approach to a project's bidding process can significantly increase the success of the management of the project's construction budget. Case history of the bidding of the Nacimiento Water Project proves this point.

The Nacimiento Water Project (Project) consists of a sloping multi-port intake facility and pump station, two intermediate pump stations, three storage tanks, control center, and approximately 45 miles of transmission pipeline ranging in diameter from 36-inches to 12-inches, with the goal of delivering 15,750 acre-feet of raw water to communities spread across the County of San Luis Obispo, California. The Project is owned and managed by the San Luis Obispo County Flood Control and Water Conservation District (District) and began its design phase in 2004. In 2007, the engineer's estimate predicted a construction value of $140.5-million; however, bids for the Project, opened in the fall of 2007, resulted in a construction value of $123.8-million. To date, the Project's construction is within budget.

This paper discusses the District's bidding of the Project. Specifically, the paper addresses how the District's implementation of bidding strategies such as division of project into contracts, bid timing, contractor outreach, contractor pre-qualification, bid packaging, and bid advertising improved the management of the Project's construction budget and positioned the Project to obtain favorable bids, quality contractors, and a stable budget throughout construction.

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PROJECT BACKGROUND

District's Water Rights

In 1959, the District entered into an agreement with Monterey County Flood Control and Water Conservation District (now Monterey County Water Resources Agency) to secure rights to 17,500 acre-feet of water per year from Nacimiento Reservoir. Nacimiento Reservoir is located entirely within San Luis Obispo County, California (County), and was built by Monterey County Flood Control and Water Conservation District, who continues to control reservoir ownership and operations. The reservoir has a storage capacity of 377,900 acre-feet and serves the purpose of abating seawater intrusion in the groundwater aquifers of the Salinas River Valley.

After a severe drought stressed the County's primary water supply (mainly groundwater) in the late 1980's, the District decided to take a close look at the feasibility of distributing Nacimiento water within the County as a supplemental water supply. The results pointed to Nacimiento water as the next affordable water resource for the County.

Nacimiento Water Project

The District's Board of Supervisors approved the Project's Final Environmental Impact Report (EIR) in January 2004, allowing District staff to move forward with the Project. The Project is a raw water transmission facility designed to deliver 15,750 acre-feet of water per year from Nacimiento Reservoir to various communities within the County. It generally consists of a multi-port intake structure, three pump stations, three storage tanks, 45 miles of pipeline, four turnouts, a control center, and a Supervisory Control and Data Acquisition (SCADA) and Project control system. The Project budget is $176-million, including design, construction, construction management, environmental permitting, and right-of-way. Five participants – City of Paso Robles, Templeton Community Services District, Atascadero Mutual Water Company, City of San Luis Obispo, and San Luis Obispo County Service Area 10-A – have executed an agreement with the District to obtain water rights and to fund the Project. All agencies are collectively referred to as Participants.

PROJECT BUDGET

Budget Limitations

All infrastructure projects have budget limitations. They usually result from both the amount of demand for the infrastructure the project will provide and the financial

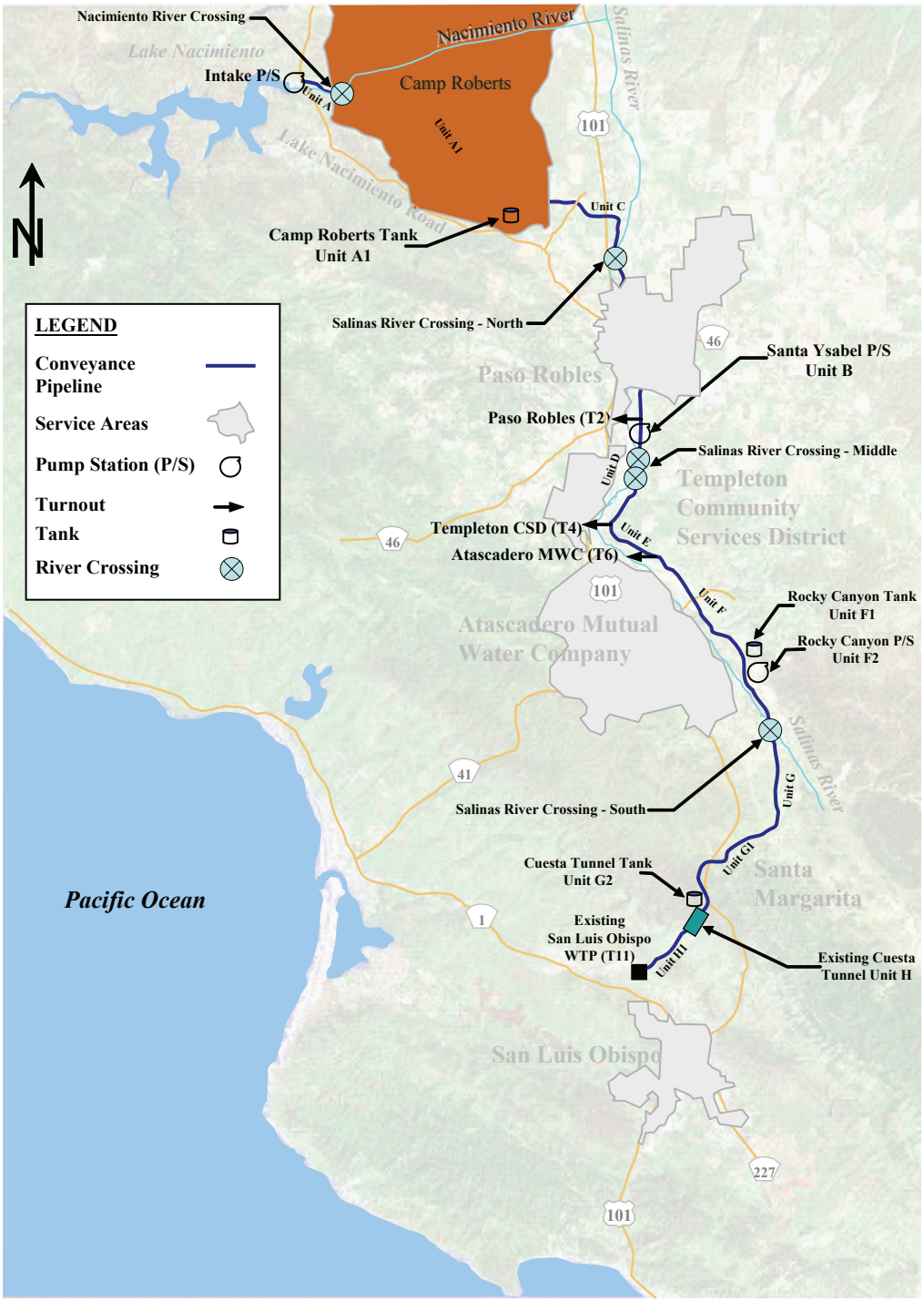


Figure 1. Nacimiento Water Project, San Luis Obispo County, California

capacity of the project's owner. This Project did not offer a high level of either attribute. Although the County's primary water sources experienced stress, the need for supplemental water had not yet become dire; and the County's small communities understood that the Project's cost would likely be greater than any single infrastructure project ever undertaken by the County. The combination of these two factors produced a Project environment that demanded the financial cooperation of multiple communities and the guarantee of a reasonable Project cost. If the District could not produce these, the Project would not be constructed.

The preliminary estimated Project budget was $150-million (excluding finance costs) when the District presented the Project to the County's communities. All communities evaluated the Project seriously, realizing that the need for supplemental water loomed in the near future; however, none of them could afford to bind themselves to a Project that had the potential to increase much greater than the presented price. As a result, the District placed an opt-out period in the Participants water delivery entitlement contracts. The opt-out period provided each Participant the option to back out of their contract within 30 days after 30 percent of the estimated construction value had been bid. In other words, if the Project bid too high, the Participants could back out and the Project would not move forward. Thus, the success of the Project became dependent on the District's management of the Project's budget.

To move the Project forward successfully, the District needed to identify the Participants' "threshold of financial pain." Said another way, the District understood that the details of designing, permitting, managing, and constructing a project of this magnitude could not be pinpointed nor guaranteed by a preliminary cost estimate and it needed to know the upper limits of Project cost that could occur without the Participants deciding to opt-out of their water delivery entitlement contracts. Discussion with the Participants led the District to believe that the Participants' "threshold of financial pain" had a rough upper limit of $200-million (see Figure 2). As long as the District kept the Project's budget within these limits, the Project could move forward to completion.

The Project's budget is comprised of costs attributable to five main components: preliminary engineering, environmental, design, right-of-way, and construction. Although these budget components were originally valued at $150-million in the preliminary budget, the early stages of the Projects' design phase indicated a likelihood that the Project, if designed and built according to the EIR, would cost much more than originally estimated. This caused the District to believe that, unless they implemented a variety of budget management strategies, the budget would likely exceed the $200-million threshold.

The District chose to focus its budget management efforts on managing construction costs. Construction had the highest cost and was the most fluid of the five budget components; thus,

Figure 2. Threshold of Financial Pain

the District reasoned that strategic decisions made in the Project's design and bidding phases would significantly impact construction costs and, thus, create the greatest impact on the overall budget. Strategies to manage the other four budget components were also put in place, but, since these components possessed a more fixed nature and a lesser value than construction costs, the strategies could not create the same magnitude of impact on the overall budget.

Managing the Budget with Smart Design

The District concentrated on smart design as its main strategy to cut construction costs, recognizing that the extra expense of generating innovative design ideas becomes negligible when compared to the construction savings realized by implementing the ideas. Tens of millions of dollars were shaved off the cost of construction by continually evaluating the Project's design and conducting a value engineering session at the 30 percent design submittal.

Despite these savings, the Project's budget continued to hover uncomfortably close to the $200-million mark. Near the end of the design phase, an estimate of construction costs (Engineer's Estimate), completed by the design engineer and confirmed by the construction management consultant, contributed to an overall Project budget estimate of $190-million (see Table 1). This estimate confirmed the need for the implementation of another budget management strategy that possessed the potential to significantly impact construction costs.

Managing the Budget with Bidding Strategies

Acknowledging that it would need more than smart design to keep the Project budget below the Participants' "threshold of financial pain," the District searched for another way to significantly impact construction costs. It deemed that the second most effective way to cut construction costs was to implement bidding strategies. With the Project's budget estimate at $190-million, the Project's success hinged on the ability of these bidding strategies to significantly impact construction costs.

BIDDING STRATEGIES

Theory

Each bidding strategy focused on obtaining favorable bids and limiting

Table 1. Project Budget Estimate – Design Phase Conclusion (Pre-Bid)

Project Components	Estimated Cost
Preliminary Engineering	$2.2 Million
Environmental	$8.1 Million
Design	$12.3 Million
Right-of-Way	$3.2 Million
Construction[1]	$164 Million
Total	**$190 Million**

[1] Engineer's Estimate ($140.5-million) + Other Construction-related costs ($23.5-million)

future construction costs. The District upheld four main theoretical principles to achieve these results:

1. Increases in the number of bidders results in increases in competition among bidders.
2. Increases in competition among bidders results in decreases in bid prices.
3. Quality contractors make few costly construction mistakes, resulting in low overall construction costs.
4. Contractual documents with clear conditions and shared risk reduce bid contingencies, resulting in low bid prices.

Division of Project into Contracts

Few contractors possess the financial capacity to undertake a Project with an estimated $140.5-million construction value; thus, the District divided the Project into five smaller contracts to avoid limiting the Project's potential pool of bidders. The five contracts are:

- Contract 1 – Intake
- Contract 2 – Facilities
- Contract 3 – Pipeline North (22 miles)
- Contract 4 – Pipeline Central (11 miles)
- Contract 5 – Pipeline South (12 miles)

The District divided the Project based on monetary value and type of work required for each bid package. The Intake work in Contract 1 required a general contractor with specialty experience in performing and managing microtunneling, marine work, and shaft excavation. The Facilities work in Contract 2 required a general contractor with specialty experience in performing and managing the construction and development of storage tanks, pump stations, and SCADA systems. Recognizing that few pipeline contractors possess the experience to successfully perform or manage these types of work, the District separated the Intake and Facilities work from the pipeline work. This ensured that pipeline contractors would not be discouraged from bidding the Project (increasing bidding competition) and not encouraged to bid work that their experience did not support (increasing contractor quality). Likewise, the District separated the Intake work from the Facilities work to

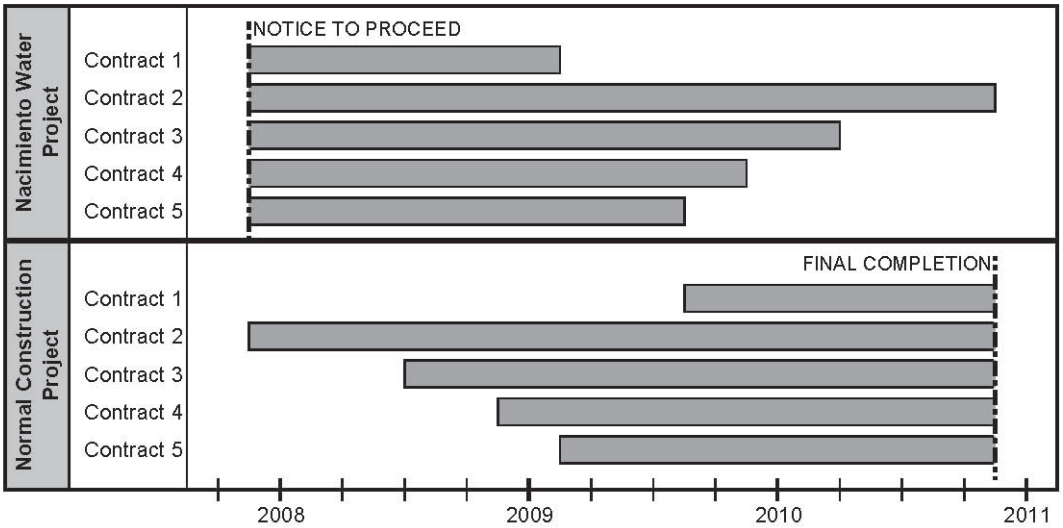


Figure 3. Bid Scheduling – Project vs. Normal

encourage bidding participation from experienced facilities contractors who did not possess experience in pipeline or intake construction. The Project's pipeline work was divided into Contracts 3, 4, and 5 so that the monetary value of each Contract would not be too great to deter small pipeline contractors and, yet, would still entice large pipeline contractors by presenting them the opportunity to win all three Contracts.

Bid Timing

Most projects with multiple contracts set bid opening dates based upon the timing required to issue notices to proceed that will allow all contracts to finish at a given time. The Distict had to rethink this type of bid scheduling in order to satisfy the opt-out clause in the Project's water delivery entitlement contracts. Since the opt-out required at least 30 percent of the estimated construction value to be bid before the opt-out period could pass, the District devised a plan to bid all contracts at the same time. This meant that all construction contracts would receive a notice to proceed at the same time and finish at different times. Figure 3 illustrates this phenomenon.

The District scheduled the opening of bids for all Contracts within the period of one month, allowing the District to strategically sequence and offset each Contract's bid opening date to obtain the best results. Bids for the Intake contract, Contract 1, opened first since it contained specialty work from contractors who could possibly choose to bid the other Contracts if awarded Contract 1. The pipeline contracts, Contracts 3, 4, 5, bids opened next, with one-week spacing between each. The strategy behind this sequencing predicted that a large construction company would bid aggressively to win Contract 3, the largest pipeline contract, giving them an advantage in the following two bid openings, since their mobilization costs would already be covered in the Contract 3 bid. The pipeline Contracts bid sequencing also created a bidding atmosphere where contractors who

were unsuccessful on previous pipeline contracts would bid more aggressively on remaining contracts. Contract 2, Facilities, was bid last, creating an opportunity for experienced facilities contractors who bid unsuccessfully on the Intake and pipelines Contracts to bid aggressively for the Facilities work. Overall, the sequencing elevated bidder competition and helped the District achieve low bid prices.

Since Project bid openings all occurred within the same month, the District benefitted from a consistent financial atmosphere in the construction industry. At the time of Project bidding, the construction industry experienced a reduction in work due to a lull in residential development. Project bid results reflected the hunger for work that the contractors experienced. Although an owner does not have the luxury of predicting the future or drastically rescheduling his project's bids, the District understood it would greatly benefit by working throughout the design phase to generate an educated prediction of the financial environment that Project's bids would experience. The information produced by this effort aided the District in determining the type and quantity of bidding strategies it needed to establish to attain success.

Contractor Outreach

In order to maximize the number of contractors bidding on the Project, the District had to maximize Project awareness amongst the contractor population. To do this, the District carried out a contractor outreach strategy during the design phase. The District, first, developed a list of general contractors located within the western United States who had performed work similar to that required by the Project. Each contractor on the list was then contacted and informed of the Project to determine contractor interest.

The District then devised a plan to conduct three contractor workshops to build and maintain contractor interest. All contractors that expressed interest in the Project received invitations to attend the workshop and the District made workshop participation available via the internet to maximize contractor attendance. The first workshop was held at the time of the 90 percent design submittal and provided contractors with an overview of key Project components. The second workshop took place during the development of the front-end specifications and discussed the contract terms that would be best suitable for the contractor and the District. The third workshop occurred approximately one month in advance of bid advertisement and presented the details of the Project's bidding phase. Each workshop lasted 90 minutes, including time for contractor questions and answers. The workshops provided contractors with an opportunity to give input on the Project prior to completion of its design and specifications. This early partnership demonstrated the good faith of the District and helped the District adjust the Project's design and specifications to obtain favorable bids.

Contractor Pre-Qualification

The District recognized that an average

general contractor did not have the experience to successfully perform some of the unique portions of the Project. Specifically, it was crucial to the Project that a highly qualified contractor performed the horizontal directional drilling (HDD) required for river crossings in Contracts 3 and 4 and the Intake's marine, microtunneling, and shaft excavation work in Contract 1. All subcontractors bidding the HDD work were subjected to a pre-qualification process that judged their previous HDD experience as well as their performance on HDD projects. All general contractors desiring to bid the Intake work had to engage in a pre-qualification process that required contractors to possess a high level of experience in self-performing and managing shaft excavation, microtunneling, and marine work. Contractor performance on other similar projects was also evaluated. The District developed the pre-qualification statement, uniform system of rating, and the appeal process from templates developed by the California Department of Industrial Relations.

The District received seven pre-qualification submittals from subcontractors desiring to bid the HDD work, six of which were deemed responsive. Eight general contractors submitted pre-qualification packages to bid the Intake work, seven of which were deemed responsive. While contractor pre-qualification guaranteed that the District would obtain a qualified Intake contractor, it also limited the number of bidders that could bid on Contract 1. Only three of the seven pre-qualified contractors bid on Contract 1, creating a low level of competition among bidders; however, the District deemed this as an acceptable risk based on the potential of extreme impacts to construction cost that could occur as a result of obtaining an unqualified contractor.

Assembling Bid Packages

In an effort to reduce unnecessary contingencies from bids, the District dedicated a significant amount of time during the design phase to assemble clear, consistent, and fair bid packages. With the contractual front-end specifications as the main focus, the District aimed to present a Project-specific contract, written to equitably share risk with contractors in areas where most owners shed risk onto the contractor. For example, the District took ownership of the risk of differing site conditions, offered a value engineering incentive to share the savings of contractor cost-reduction proposals, and provided allowances for utility conflicts and hazardous materials. The District also involved the Project's construction management team in the review process to make sure that the front-end specifications had clear and practical procedures and requirements, including change order procedures, contractor obligations, and payment procedures. As a result, the District presented a contractor-friendly bid package to contractors that helped avoid large bid contingencies.

Advertising for Bids

The call for Project bids went out on May 22, 2007, for Contracts 1, 3, 4, and 5 and on June 12, 2007, for Contract 2.

Contract	Bid Opening Date	No. of Bidders	Low Bid ($)	High Bid ($)
1	7/16/07	3	$20.8 Million	$29.4 Million
3	7/19/07	9	$38.4 Million	$51.3 Million
4	7/26/07	9	$22.7 Million	$29.3 Million
5	8/2/07	7	$16.3 Million	$24.0 Million
2	8/16/07	4	$25.6 Million	$32.3 Million

Table 2. Project Bid Opening Results

Recognizing the need to keep contractors apprised of their competition and of any contract revisions, the District utilized a professional reprographics company to organize the bidding process. This company efficiently reproduced and delivered bid packages, made daily updates to the plan holders list, and distributed all addenda. The District also developed a website for bidders to submit bidding questions. Both answers to questions, updated twice weekly, and the plan holders list, updated daily, were posted for contractors on the website. As bid opening dates approached, the District contacted interested contractors that had not purchased bid packages. The combination of these bid advertising strategies created a smooth bidding process that encouraged contractors to bid and increased bidding competition amongst contractors.

BID RESULTS

Bid Turn-Out

The District opened bids for the five Project contracts over a one-month period. The first bid opening revealed that less than half of the seven general contractors prequalified to bid Contract I (Intake) chose to pursue the Project. This low turnout is likely attributable to the complexity of the work (many prequalified contractors chose to bid the work as subcontractors instead of general contractors) and the fact that another comparable project opened bids during the same week as Contract 1. The three subsequent bid openings for the pipeline contracts, Contracts 3, 4, 5, produced a large number of bidders and highly competitive bids. Contract 2 (Facilities), the final bid opened, attracted a common number of bidders and fairly competitive bids. Table 2 summarizes the bid opening schedule as well as the bid results.

Bid Prices vs. Engineer's Estimate

Overall, Project bidding resulted in a construction value 12 percent ($16.7-million) lower than the Engineer's Estimate. Figure 3 illustrates a comparison of individual and total contract bid prices to their respective values taken from the Engineer's Estimate.

Only Contract 1 resulted in a bid price higher than expected, with a low bid 59 percent ($7.7-million) higher than the Engineer's Estimate. The District believes this large price differential is a

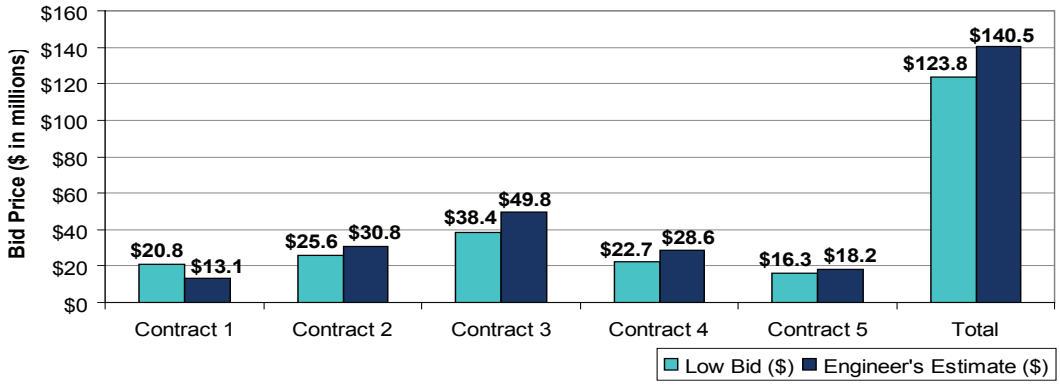


Figure 3. Bid Prices vs. Engineer's Estimate

product of two main bidding conditions. First, the Contract only yielded three bidders, reducing bidding competition levels below District expectations. The second condition had to do with the Project specifications regarding lake levels. The District understood, prior to bidding, that lake levels would affect contract pricing because Contract 1 required substantial marine work; however, it did not understand the financial weight the lake levels carried. Project specifications called contractors to assume maximum lake levels during construction, even though lake levels were anticipated to be at least 50-feet lower. The District later discovered that this was a costly risk for the contractor to bear since increasing depth of marine work substantially increases labor costs. Should the District have borne the risk, Contract 1 would likely have achieved a much lower bid price.

The following three contracts for pipeline work, Contracts 3, 4, and 5, resulted in bid prices much lower than the Engineer's Estimate. Respectively, each contract's bid price came in below the Engineer's Estimate by margins of 23 percent ($11.4-million), 21 percent ($5.9-million), and 11 percent ($1.9-million). All these contracts attracted large numbers of bidders, which likely had the greatest impact on bid prices.

Contract 2 resulted in a bid price 17 percent ($5.2-million) lower than the Engineer's Estimate. Although the Contract did not attract a large number of bidders, bidder competition levels remained high because contractors who had bid unsuccessfully on the four previous contracts made extra efforts to attain the work.

Opt-Out Success

Although the estimated total Project cost at the end of the design phase neared the $200-million mark, bidding strategies implemented by the District led the way to opt-out success. The district's bidding strategies, along with a favorable financial bidding environment, produced construction bids that totaled $123.8 million instead of the $140.5 million set forth in the Engineer's Estimate. This savings lowered the overall estimated Project budget to $176-million, resulting in opt-out success. The Project

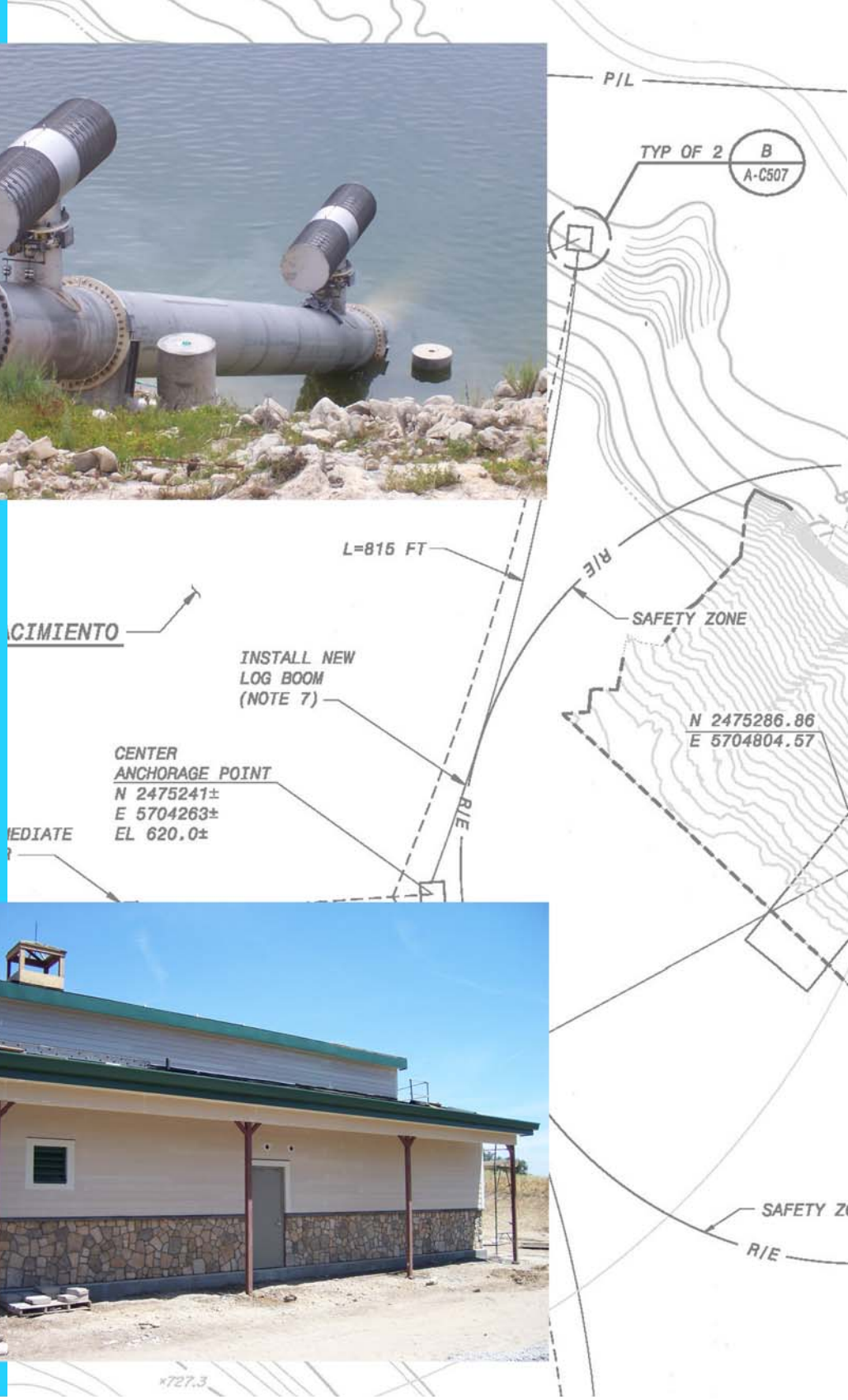
continues to remain within this budget midway through the construction phase.

LESSONS LEARNED

Over the course of the Project's design and bidding phases, the District learned the following lessons about using bidding strategies to manage construction costs:

- The implementation of bidding strategies can have the same magnitude of impact on the overall budget of a project as smart design.
- Development and implementation of bidding strategies need to begin near the onset of the project's design phase.
- Wherever possible, the owner should structure the contractual front-end specifications so that the risk of changed conditions is owned by the owner or shared with the Contractor.
- The owner should analyze the financial state of the construction industry to develop the most effective bidding strategies.
- Obtaining quality contractors is just as important as obtaining favorable bids.

NOTES



NWP NACIMIENTO WATER PROJECT

San Luis Obispo County Flood Control & Water Conservation District

COUNTY GOVERNMENT CENTER, ROOM 207, DEPARTMENT OF PUBLIC WORKS
SAN LUIS OBISPO, CALIFORNIA, 93408

Creative Financing Overcomes Financial/Political Obstacles for Regional Water Supply Project

American Public Works Association

International Public Works Congress & Exposition

Boston, MA

August 18, 2010

TODAY'S PRESENTERS

San Luis Obispo County (SLO), CA
Public Works Department

- Paavo Ogren, Director
- Will Clemens, Department Administrator
- John R. Hollenbeck, P.E. Nacimiento Project Manager

TODAY'S PRESENTATION

- Location
- History
- Politics
- Financing
- Design Phase
- Construction Phase
- Conclusions/Q & A

PROJECT LOCATION

Orienting Yourself to the Project

PROJECT LOCATION

San Luis Obispo County, California

PROJECT LOCATION

San Luis Obispo County, California

PROJECT LOCATION
San Luis Obispo County, California

PROJECT LOCATION
San Luis Obispo County, California

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MULTI-AGENCY COLLABORATION
Paavo Ogren

- History
- Political Barriers/Political Will
- Negotiating Water Delivery Contracts
- Treatment?

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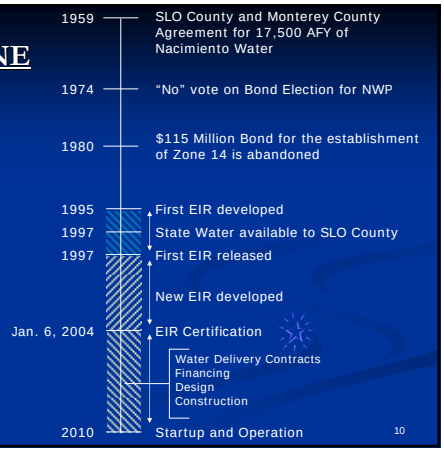
TIMELINE



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The Project Has Five Initial Participants

Participant		Nacimiento Water Usage (AF/yr)
	City of El Paso de Robles	4,000
	Templeton Community Services District	250
	Atascadero Mutual Water Company	2,000
	City of San Luis Obispo	3,380
	County Service Area 10A (Cayucos)	25
Participant Totals		**9,655**
*Reserve Capacity**		*6,095*
Nacimiento Total		**15,750**

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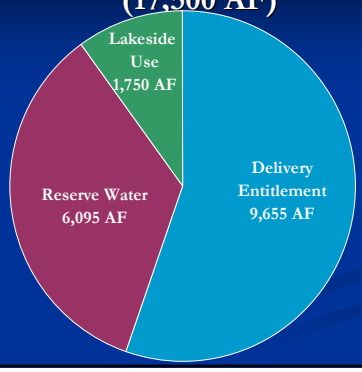
Nacimiento Water Allocation (17,500 AF)



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Contract Overview Table

Article #	Page	Article Title	Modify	Intake	Water Supply	Water Quality	Water Delivery	Municipal Finance	Financial Policy	Governance	Operations	Capital Projects	Other
1.	5.	Definitions			X	X	X	X	X	X	X	X	X
2.	13.	Term of Contract; Recission											X
3.	14.	Construction of Nacimiento Pipeline			X	X	X	X	X			X	X
4.	17.	Ownership, Operation and Maintenance of Nacimiento Project by District							X	X	X		
5.	18.	District's Existing Obligations: Master Water Contract; District's Prior Commitment Water			X								
6.	19.	Agency's Delivery Entitlement			X		X				X		
7.	20.	Time for Delivery of Agency's Delivery Entitlement					X				X		
8.	21.	Place of Delivery of Agency's Delivery Entitlement, Surplus Water			X		X				X	X	
9.	22.	District's Measurement of Agency's Delivery Entitlement and Agency's Surplus Water			X		X		X		X		
10.	22.	District Not Responsible for Delivery and Distribution of Agency's Delivery Entitlement or Surplus Water Beyond Place of Delivery				X	X						X
11.	23.	Water Quality				X							X
12.	23.	Surplus Water			X				X				
13.	26.	Curtailment of Nacimiento Project Water for Maintenance Purposes			X						X		
14.	26.	Nacimiento Project Water Shortages			X								X

Significant Issues

- Cost Allocation
- Water Supply Benefits
- Opt-Out Provision
- Governance/Commission

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Cost Allocation Options

- Specific Identification of Facilities
- Average Cost Per Unit of Water
- Hybrid

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Cost Allocation Option 1
Specific Identification of Facilities

- AKA "Railroad Ticket" – The further down the line, the more you pay
- Pay proportionate share of facilities used
- Technically sound allocation method
- System based (i.e. miles of pipeline)

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Cost Allocation Option 2
Average Cost Per Unit of Water

- Everyone pays the same per unit price
- Total Project Cost ($) / Total Participation (AF)
- Similar in approach to water rates
- Does not factor in facilities used
- Benefit based allocation method (i.e. acre foot of water)

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Cost Allocation Option 3
Hybrid

- Blends the previous two options
- Seeks to maximize participation by decreasing cost to distant participants while maintaining geographic cost benefit to closer participants
- Considers economy of scale (What is it worth to ensure participation of downstream agencies?)
- Regional cooperation – each benefits from participation of others

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Water Supply Benefits

- Who gets the extra water?
- Who pays?
- Who decides?

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Opt-Out Provision

- "Blank check" concerns
- Re-approve project after bids?
- Opt-Out
- Building confidence and trust

20

Governance/Commission

- Implement under District Authority vs. Joint Powers Authority
- Delegating specific powers to the Nacimiento Commission
- Preserving District Authority
- Powers not delegated to the Commission

21

Treated vs Raw Water

Treated Water

- Avoid impacts to Salinas River riparian areas
- Avoid water quality impacts associated with raw water discharge

Raw Water

- Avoid Impacts associated with Water Treatment Plant construction and operation

ENVIRONMENTAL STAKEHOLDERS

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PROJECT FINANCING
Will Clemens

- Project's Size
- Financing Vehicle
- Water Delivery Contract
- Rating Process
- Investment of Project Funds

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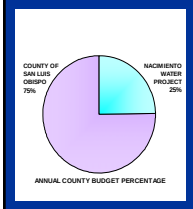
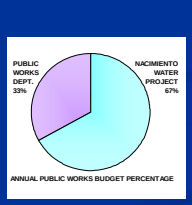
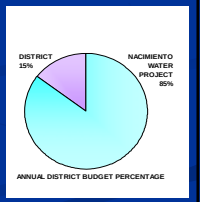
SLO County Government's Largest Public Works Project ($200 million)







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Financing Vehicle

San Luis Obispo County Financing Authority

- Joint Exercise of Powers Agreement
- Eliminates duplication of effort and enables multiple parties to borrow money through one issuer
- Original members were SLO County and Flood Control and Water Conservation District
- Open to any agency in SLO County

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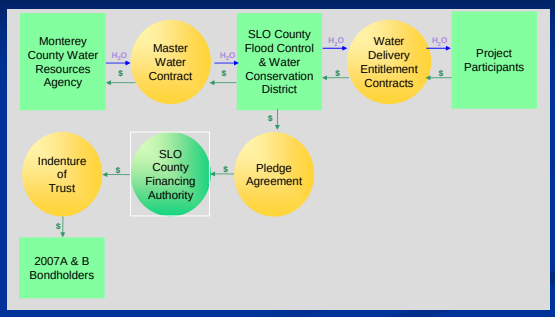
Project and Bond Legal Structure



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Water Delivery Contract

The Water Delivery Entitlement Contract Provides a Number of Protections to Bondholders

- Establishes a superior pledge on the gross water sales revenue of each Participant
- Includes 1.25x Coverage Factor from each Participant's combined Revenues and Available Capital Reserves
- Requires 100% prepayment of debt service on or before July 1 of each year
- Includes 25% cross-collateralized "Step-Up" in the event of a Participant payment default
- "Step-Up" must be exhausted before the District has recourse to the Debt Service Reserve Fund

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Ratings Process

Project Characteristics of a Strong "A" Category Credit

- Regional water supply project with strong demand and demonstrated local support
- SLO County has the project management experience to ensure timely and cost effective implementation
- Individual participants each have sound financial, demographic and operational characteristics
- Take-or-pay contracts with cross-collateralized step-up provision provide strong legal structure

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Three of the Five Participants Account for 96.8% of the Total Project Cost

Participant	% of Project Cost	Type of Agency	Water Credit Ratings (S&P/Fitch)	Population Served
City of San Luis Obispo	42.99%	Municipal Entity	A+/AA-	44,500
City of El Paso de Robles	34.24%	Municipal Entity	NR	28,000
Atascadero Mutual Water Company	19.61%	Mutual Water Company	"A" Category (Both)	29,601
Templeton Community Service District	2.84%	Municipal Entity	NR	5,400
CSA – 10A	0.32%	Municipal Entity	NR	1,900

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Rating Results

- Insured Rating (MBIA) – AAA
- Underlying Rating
  - Fitch – A+
  - Standard & Poor's – A
- Resulting Interest Rates
  - Tax Exempt – 4.66%
  - Taxable – 5.65%

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Investment of Project Funds

Financing Sources and Uses

Sources:	
Par Amount	$196,410,000
Net Premium	$6,370,687
Total	$202,780,687
Uses:	
Project (Net Funded)	$158,834,037
BAN Repayment	$6,678,571
Debt Service Reserve	$10,049,200
Capitalized Interest	$25,015,410
Cost of Issuance	$2,203,469
Total	$202,780,687

35

Net Funding

- Needed $176 million to complete project
- Only issued $159 million in bonds
- Interest earnings over 3 year construction period would fund the difference ($17 million)

36

Guaranteed Investment Contract

- Guarantees interest earnings for contract period
- Put out for bid to financial institutions
- Fixes the interest rate over contract period (4.8% for our deal)
- Any interest earned over the arbitrage yield must go to Federal Government

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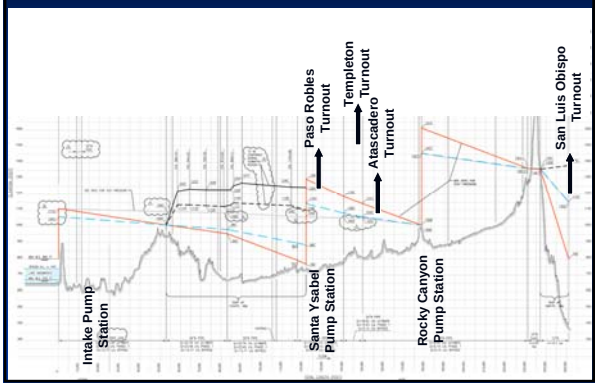
DESIGN & CONSTRUCTION
John R. Hollenbeck, P.E.

HYDRAULIC PROFILE



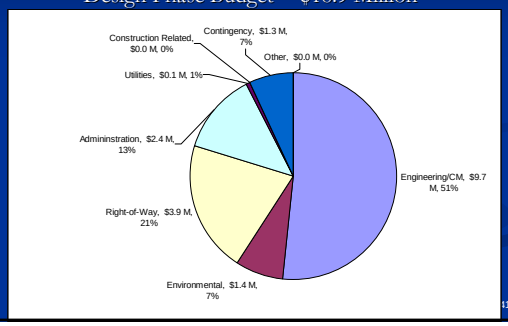
DESIGN PHASE MANAGEMENT

- Managing Budgets
- Managing Technology

It boils down to Risk Management.

40

Project Budget
August 2007
Design Phase Budget = $18.9 Million



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BUDGET MANAGEMENT FROM 2005-2007 – Design Phase

- Budgets Ranged from $150M to $200M
- Price Uncertainties in Construction
- Strategies Included
  - ✓ Hydraulic Downsizing ($8- to $9-Million)
  - ✓ Value Engineering Study ($12- to $15-Million)
  - ✓ Prequalifiation of Intake Contractor & HDD Subs
  - ✓ Contractor Workshop – MARKET THE PROJECT
- Attention to Front End Specifications

42

VALUE ENGINEERING

- Conducted at 30% Design
- Hand picked experienced team members
- Formulated 52 proposals – Implemented 5
- Savings of $12 million to $15 million

43

WORKSHOPS WITH CONTRACTORS

Contractor Outreach

- "Market the job" to Contracting Community
- Developed general contractors list
  - Make phone contact
  - Results in list of Interested Contractors
- Contractor Workshops
  - 90% Design Submittal - Key project components overview
  - Front End Specification Development – Contract terms
  - Just Before Bid Advertisement – Bidding phase details

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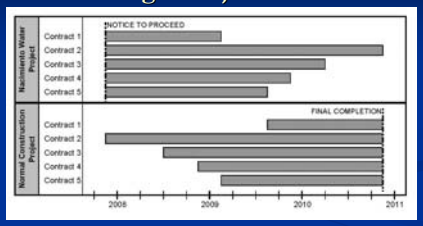
CONTRACTING TERMS

- Specific Front-End Documents
- Clear Payment, Change and Claim Processes
- Dispute Review Board
- Owner Provided Builders Risk Insurance
- Owner Controlled Insurance Program (ultimately not used)

45

BIDDING STRATEGIES

Bid Timing – Project vs. Normal



- Bids opened within 1 month
- Allowed strategic timing of bid openings
- Provided consistent economic atmosphere

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BIDDING STRATEGIES

Contractor Pre-Qualification

Ensured quality contractors for specialized work

- Horizontal Directional Drilling Subcontractors (Contracts 3 and 4)
- General contractor for Intake (Contract 1)
  - Marine
  - Microtunneling
  - Shaft excavation

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BIDDING STRATEGIES

Theory

1. Increase bidders = Increased competition
2. Increased competition = Lower bid prices
3. Clear contractual documents with shared risk = Lower bid prices

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BIDDING STRATEGIES
Contract Packages

- Divided based on monetary value and type of work
- Divided into five Contracts:
  - Contract 1 – Intake (3 Bidders)
  - Contract 2 – Facilities (4 Bidders)
  - Contract 3 – Pipeline North (22 miles) (9 Bidders)
  - Contract 4 – Pipeline Central (11 miles) (9 Bidders)
  - Contract 5 – Pipeline South (12 miles) (7 Bidders)

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Sleepless Nights Because of…. CONSTRUCTION BIDDING

Contract	Engineer's Opinion of Probable Cost	Bid Value	Variance
Intake	$13,100,000	$20,813,600	($7,713,600)
Facilities	$30,800,000	$25,588,000	$5,212,000
Pipeline North	$49,800,000	$38,355,245	$11,444,755
Pipeline Central	$28,550,000	$22,697,100	$5,852,900
Pipeline South	$18,200,000	$16,663,461	$1,536,539
Total	**$140,450,000**	**$124,117,406**	**$16,332,594**

11.6% Below Expectations

50

BUDGET MANAGEMENT STRATEGY
Project Timing

CONSTRUCTION PHASE

- Intake
  - 180' deep, 20' diameter concrete lined shaft
  - 48" diameter sloped multi-port intake pipe
  - 52" diameter, 520' long steel lined tunnel

- Pipeline
  - 22 miles, 36" to 24" diameter, WSP
  - 11 miles, 24" to 18" diameter, DIP
  - 12 miles, 18" to 12" diameter, DIP

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CONSTRUCTION PHASE

Pump Station

- Intake: 5 Units, 450 hp each, 32.79 cfs at 370 ft
- Santa Ysabel: 4 Units, 500 hp each, 20.1 cfs at 524 ft
- Rocky Canyon: 3 Units, 400 hp each, 8.4 cfs at 606 ft

CONSTRUCTION PHASE

Tanks (Welded Steel)

- Camp Roberts: 850,000 gallons
- Rocky Canyon: 850,000 gallons
- Cuesta Tunnel Tank: 300,000 gallons

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Construction Photographs

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INTAKE FACILITY

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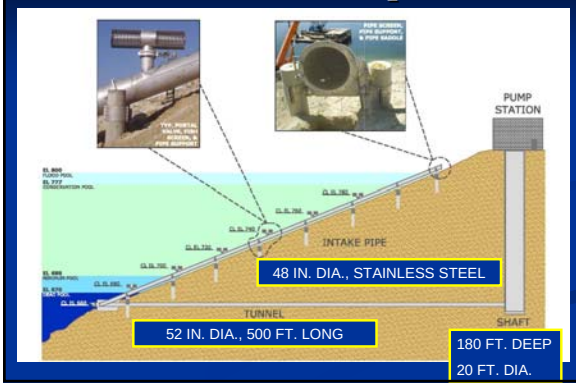
Lake Hot Tap

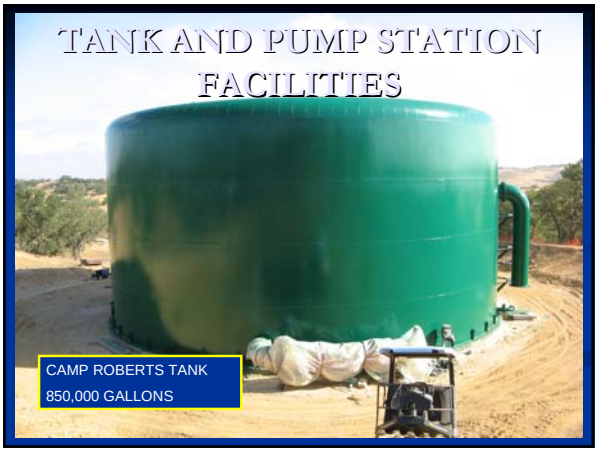


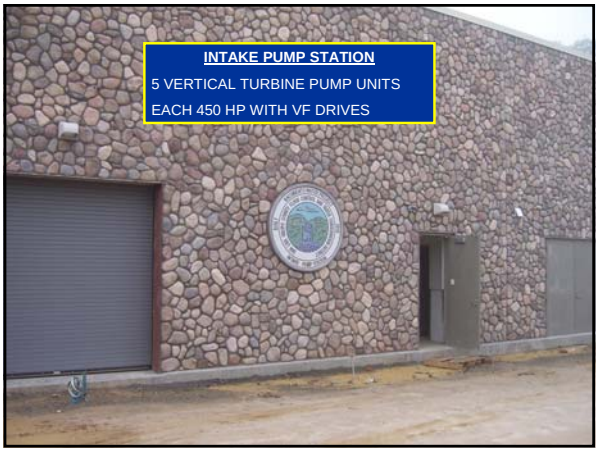
54 IN. MICROTUNNEL BORING MACHINE

48 IN. STAINLESS STEEL INTAKE PIPE AND 24 IN. INTAKE PORTAL WITH DEBRIS/FISH SCREEN

LAKE NACIMIENTO

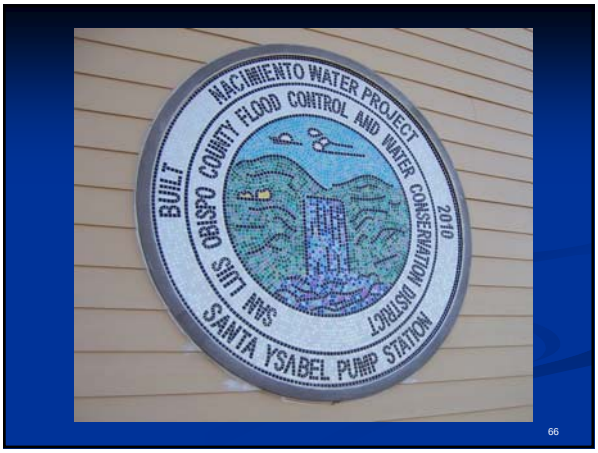
48 IN. STAINLESS STEEL INTAKE PIPE AND INTAKE PORTALS
LAKE NACIMIENTO


TANK AND PUMP STATION FACILITIES
CAMP ROBERTS TANK
850,000 GALLONS


INTAKE PUMP STATION
5 VERTICAL TURBINE PUMP UNITS
EACH 450 HP WITH VF DRIVES

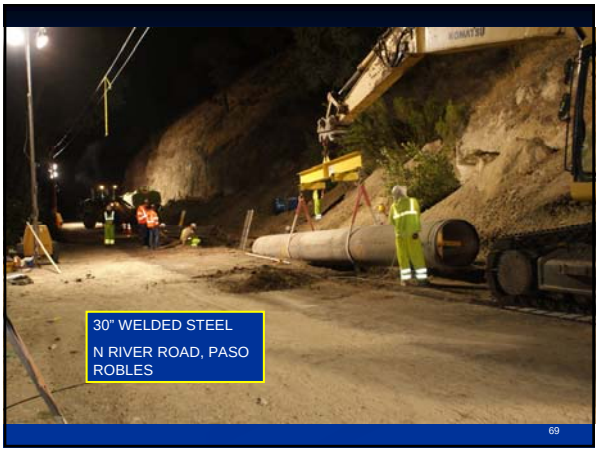
INTAKE PUMP STATION
5 VERTICAL TURBINE PUMP UNITS
EACH 450 HP WITH VF DRIVES

SANTA YSABEL PUMP STATION
4 VERTICAL TURBINE PUMPS
EACH 500 HP


NACIMIENTO WATER PROJECT
BUILT
SAN LUIS OBISPO COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT
2010
SANTA YSABEL PUMP STATION

PIPELINES

68



69

18 IN. DUCTILE IRON PIPE
EL CAMINO REAL ROAD

71

18 IN. DUCTILE IRON PIPE
N SIDE CUESTA GRADE

72

AIR/VACUUM VALVE

73

24 IN. STEEL PIPE
HDD PULLBACK FOR AMWC TURNOUT
SALINAS RIVER

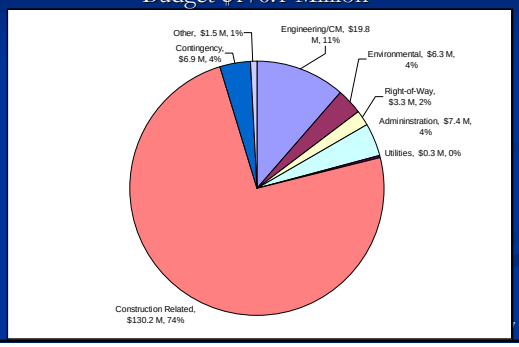
AMWC TURNOUT
DELIVERY POINT FOR NACIMIENTO WATER

75

GROUNDWATER RECHARGE POND
FOR AMWC TURNOUT

Project Budget

Budget $176.1 Million



If We had to do it again …

- Own the lake level
- Consider single pipeline contractor
- Extend Construction Manager procurement
- Increase District Staff (2 more full time engineers)

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QUESTIONS ???

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NWP NACIMIENTO WATER PROJECT

San Luis Obispo County Flood Control & Water Conservation District

http://www.slocounty.ca.gov/PW/NacWP.html

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Transient Pressure Monitoring Program – Nacimiento Water Project

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Abstract

The Nacimiento Water Project under construction in San Luis Obispo County, California, will deliver 15,750 acre-feet of raw water annually from Lake Nacimiento through 45 miles of pipeline to its service area. The Project includes three pumping stations, three storage tanks, 45 miles of pipeline ranging from 36- to 12- inches in diameter, and a SCADA system. The hydraulic aspects of the system dictated careful attention to hydraulic design, with due consideration of normal and transient pressures. As a follow-up to the hydraulic design, the project will include a very rigorous transient monitoring program, possibly the most intensive on any pipeline in the USA to-date. This transient monitoring program scheduled for installation in March 2010 includes nine TP-1 transient monitoring systems installed at locations most prone to severe hydraulic transients. These systems provide detailed information regarding transient pressures and are integrated into the SCADA system to provide real-time alerts if threshold pressures are exceeded. This paper describes the Nacimiento Water Project, the hydraulic design considerations, the network of transient monitoring systems that is installed, and the results of transient pressure monitoring collected to-date.

Project Description

The Nacimiento Water Project (Project), illustrated in Figure 1, will convey up to 15,750 acre-feet annually from Lake Nacimiento in San Luis Obispo County, California, through 45 miles of pipeline ranging from 36- to 12-inches in diameter. The Project includes three pump stations, three water storage tanks, and a supervisory and control and data acquisition (SCADA) system. Four turnouts are included to provide delivery to the Project participants: the City of Paso Robles, Templeton Community Services District, Atascadero Mutual Water Company, and the City of San Luis Obispo. Design of the $176-million Project began in 2004 and construction is currently in progress, with operational testing scheduled for completion in December 2010.

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 operating costs. The design gave careful attention to phased water deliveries, hydraulic efficiency, optimum pipe diameters, pump station characteristics, transient pressure control measures and potential energy recovery.

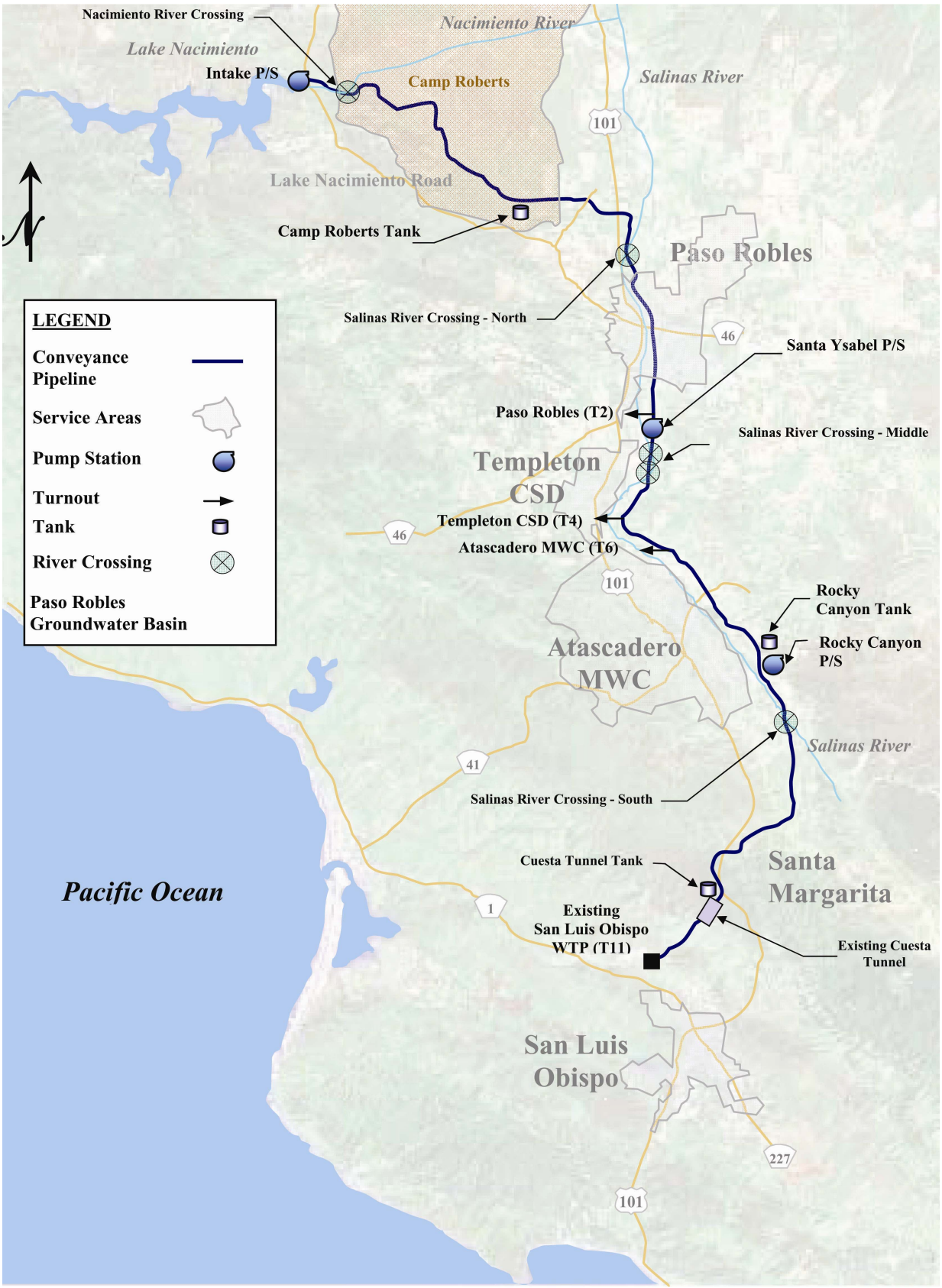

Figure 1. Nacimiento Water Project Unit Map

The Project will operate as a pumped system under normal operation, and as a result the most significant hydraulic event will likely be generated by emergency operation, sudden power loss at one or more of the pump stations, or malfunction at one of the turnouts. Extensive surge modeling of the pipeline allowed the design of surge control facilities conforming to two criteria:

- Minimum pressure due to downsurge would always be above atmospheric pressure, and
- Minimum pressure during upsurge would not exceed initial hydraulic grade line by more than 100 feet.

The hydraulic modeling guided the selection of these facilities to control surge due to pump station power failure:

- Air chambers on the discharge of the Intake, Santa Ysabel, and Rocky Canyon Pump Stations
- Slow closing air/vacuum valves at high points along pipeline
- Surge relief valves on the suction side of Santa Ysabel Pump Station

Characteristics and Capabilities - TP-1 Transient Pressure Monitoring System

The Project engineers recognized the importance of measuring transient pressures at critical points in the Project; and included standard digital data loggers which have become widely used within the water and petroleum pipeline industry. On this Project, however, there is a need to monitor for indefinite periods with the capability to detect and measure an unexpected transient that may last a fraction of a second. Not only are these events difficult to detect, they may be the most damaging of all and may go unnoticed for long periods of time. One of the most important aspects of digital sampling of pressure data is selection of an appropriate data sampling rate. An intensive sampling program might sample once per second generating 86,400 data points per day at each test station. Still this would be insufficient to accurately record an event lasting a fraction of a second. As is noted in Figure 2, an insufficient sample rate will lead to inaccurate and misleading portrayal of pressure.

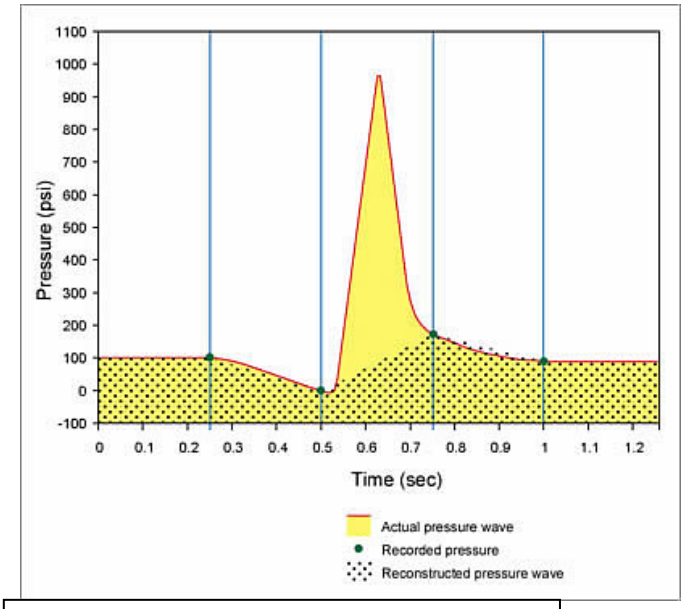

Figure 2 - Digital data collection with insufficient sample rate

Within the past several years, a system has been devised that overcomes several of the limitations of previous digital systems. It is capable of monitoring over extended period of time in a "snoozing" mode, recording background pressure at a user-set interval between once per second and once per day. Although the system appears to be snoozing, in reality it is very busy. It continuously samples the pressure 1000 times per

second and computes a running average. Effectively the system algorithm has a built-in alarm clock that goes off when a pressure is detected that differs significantly from the average – in other words when a transient is detected. When this occurs, the system "wakes up" and records all data at another user-set rate up to 100 Hz. This continues until the transient has passed, at which time the system goes back to the "snoozing" mode. The scheme is shown graphically in Figure 3.

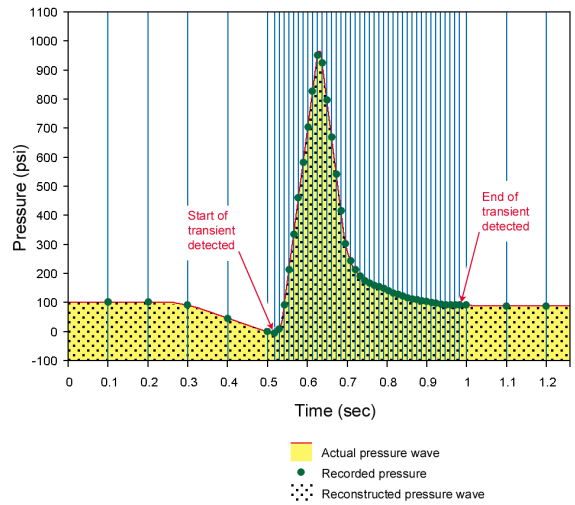

Figure 3 – TP-1 Data Recording Scheme

An additional feature of the TP-1 system is its inclusion of precision timing of pressure data using the GPS satellite constellation, thus providing the time that each data point was recorded in addition to the pressure data itself taken at 100 Hz. This capability provides an additional dimension to troubleshooting of pipeline problems and the analysis of transient data, allowing the localization of the source of a transient event where multiple TP-1 monitors are used and the instant of detection of a transient event is available to millisecond accuracy.

The TP-1 system allows users to set parameters that govern data analysis and recording, including the steady-flow background record rate, the transient event record rate, and criteria for transitioning from background to transient record modes. The system incorporates a transducer with a frequency response range to one KHz to capitalize on the high-speed data recording capability of the TP-1. It is connected hydraulically to the pipeline through standard ¼" NPT fittings, and is connected electrically to the TP-1 controller through a shielded cable. Cable lengths up to 300 feet have been successfully used. Pressure data recorded by the TP-1 system is stored on internal two-GB flash drive memory, providing storage for months of data storage under normal conditions. Data is uploaded from the TP-1 via wireless, LAN, or Ethernet connections for analysis by the user. Data is placed in a standard Microsoft Data Base for ease of analysis, and the analysis process is further facilitated by software that is part of the TP-1 system. The top graph in Figure 5 depicts a typical data upload of 18 days of data, with steady state shown in blue and transient events in red. Normal operating pressure of 130 psi is observed, however a maximum pressure of 270 was reached during one transient event. The lower graph in Figure 5 shows five seconds of data, including the details of that one-second event that produced that maximum pressure.

Figure 4 – TP-1 Transient Pressure Monitoring System

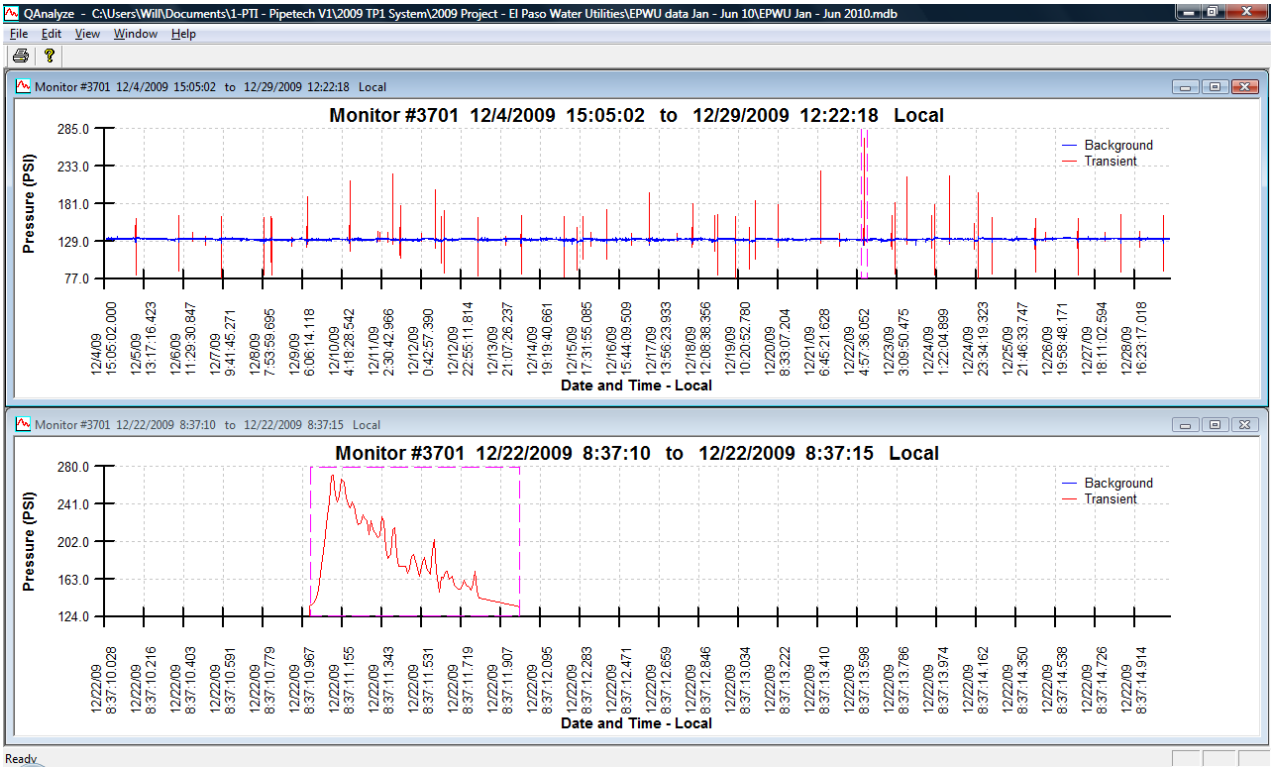

Figure 5 – TP-1 Pressure Data – Showing 18 days (Top) and 5 Seconds (Bottom)

Installation of Transient Pressure Monitoring System on the Nacimiento Water Project

Discussions among the Project manager and design engineers determined that the optimum locations of the TP-1 systems would be pumping station suction and discharge lines, high-volume turnouts, and points of highest elevation (and thus lowest pressure head). This resulted in a plan to install nine transient pressure monitoring devices on the Project, making if perhaps the most intensively monitored pipeline today, in terms of transient pressure recording. The locations selected:

- Intake pump station discharge header
- High point upstream of the Camp Roberts Tank
- Paso Robles, Atascadero, and San Luis Opbispo turnouts
- Suction and discharge headers at Santa Ysabel and Rocky Canyon Pump Stations

Figure 6 – Rodky Canyon Pump Station Installation

Figure 7 - Rocky Canyon Pump

Figure 8 – Camp Roberts Tank Construction Station Pumps

Figure 9 – Santa Ysabel Pump

The TP-1 requires 700 milliamps of 12 volt DC power, which is normally provided via 120 volt AC power through a converter. At the Camp Roberts Tank location, AC power is not available, so the installation there will include a solar panel and battery storage.

The TP-1's would be modified by the manufacturer to provide Ethernet communication with the Project SCADA system, providing the capability to access the TP-1 system to modify operational parameters and retrieve data. As an additional enhancement, the GPS time synchronization capability of the TP-1's would be used to synchronize time at the power monitor located in switch gear at each of the three pump stations.

The installation of the TP-1 systems will be accomplished through a modification to the general construction contract for appurtenant facilities on the Project. The general contractor in turn has entered into sub-contracts with the TP-1 supplier, the electrical sub-contractor, and the system coordinator to furnish and install the transient monitoring devices.

Status of Project Construction and Transient Pressure Monitoring

Construction of the Project began in February 2008, and is projected to be operationally tested and delivering water by December 2010.

Award of the contract modification for the TP-1 contract was accomplished in January 2010, several months later than originally anticipated. The TP-1 systems are scheduled to be installed in March 2010 and will allow recording of operational testing of the pipeline. We anticipate that the data will validate the hydraulic models and confirm the proper functioning of the surge control features of the Project.

The TP-1 contract includes data reviews and analysis at 30 days and again at 60 days of pressure monitoring. Results of this testing and conclusions will be included to the extent feasible in the final draft of this paper, as well as the paper presentation.

References

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Worthington, Will (2005), "Monitoring for Transient Pressures in Pipelines," ASCE Pipelines Conference, Houston

San Luis Obispo County, CA;
http://www.slocounty.ca.gov/PW/NacWP/Construction_Phase.htm

COVER SHEET

MANAGING COMPLIANCE WITH ENVIRONMENTAL PERMIT CONDITIONS ON A 45-MILE PIPELINE IN CALIFORNIA: PROBLEMS AND SOLUTIONS

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MANAGING COMPLIANCE WITH ENVIRONMENTAL PERMIT CONDITIONS ON A 45-MILE PIPELINE IN CALIFORNIA: PROBLEMS AND SOLUTIONS

Abstract. The Nacimiento Water Project (NWP) in San Luis Obispo County included 45 miles of pipelines, pump stations, and five construction contracts. Work began in August 2007 and was completed in late 2010. Employing different construction techniques, crossing over multiple streams and rivers, federal and local jurisdictions, and habitat for six endangered species, the NWP required the full suite of environmental permits. In this paper NWP Project Management and the Environmental Team review the design and construction phases and describe the principle issues confronted. For the design phase, the authors note the importance of early briefing of the agencies on the upcoming project. In the construction phase, the NWP team was careful in staffing the construction management group to integrate environmental and engineering specialists as early as possible. The significant issue confronted in the first months of construction, and one commonly encountered, was starting construction before all of the permits were complete, in this case because of very recent and numerous cultural resource discoveries.

In what the authors call "Permit Compliance and the Real World" we provide an overview, and specific examples of, addressing day-to-day changes in design and unanticipated discoveries of natural and cultural resources, and the total cost of compliance during the duration of the project. Lastly, we offer "Tools for Project Success." Chief among these was the use of a compliance instrument called the Master Compliance Table, a single source for alerting and updating project crews on what permitting issues applied to each segment. Also important was maintaining communication with the agencies during construction, and also knowing what decisions can and should be made by the project compliance staff. The authors conclude that projects of this size and scope are challenging, but an organized and coordinated program, one that starts far in advance of construction and yet is designed to adapt to frequent changes, can maintain schedule and contain costs. We conclude with a case study: encountering a Native American burial site on a National Guard training base.

MANAGING COMPLIANCE WITH ENVIRONMENTAL PERMIT CONDITIONS ON A 45-MILE PIPELINE IN CALIFORNIA: PROBLEMS AND SOLUTIONS

INTRODUCTION AND PROJECT BACKGROUND

Nacimiento Reservoir is located entirely within San Luis Obispo County, California (County), just south of the Monterey County border. It was built by Monterey County Flood Control and Water Conservation District (now Monterey County Water Resources Agency) in 1958 for the purposes of abating seawater intrusion in the groundwater aquifers of the Salinas River Valley. The reservoir has a storage capacity of 377,900 acre-feet and is owned and operated by Monterey County Water Resources Agency. In 1959, the San Luis Obispo County Flood Control and Water Conservation District (District) entered into an agreement with Monterey County Flood Control and Water Conservation District to secure rights to 17,500 acre-feet of water per year from Nacimiento Reservoir. At the time of this agreement, the District was merely planning for future water demands and had no feasible means of accessing or distributing this entitlement. The District contemplated and proposed means and methods of utilizing this water entitlement at various times over the following 40 years, but none came to fruition. The County experienced a severe drought in the late 1980's and early 1990's which significantly affected the primary water supply (mainly groundwater) for both municipalities and agricultural businesses. The District began another series of studies in the mid-1990's to distribute Nacimiento water within the County as a supplemental water supply. This time, the participating water agencies realized the time had come for Nacimiento water to be the next affordable water resource within their water portfolio.

The District's Board of Supervisors approved the Final Environmental Impact Report (Marine Research Specialists, 2004) for the Project in January 2004. This approval directed District staff to move forward with executing agreements with local water agencies, permitting, designing, financing, constructing and operating the Project. A project of this magnitude takes several years to coordinate and complete because of all the complexities involved. The Project's schedule is presented in Figure 1, below, illustrating the five phases of effort, including the environmental clearance (under the California Environmental Quality Act [CEQA]), design, bidding, construction, and operation. This paper will present discussions that center on the design and construction phases of the Project.

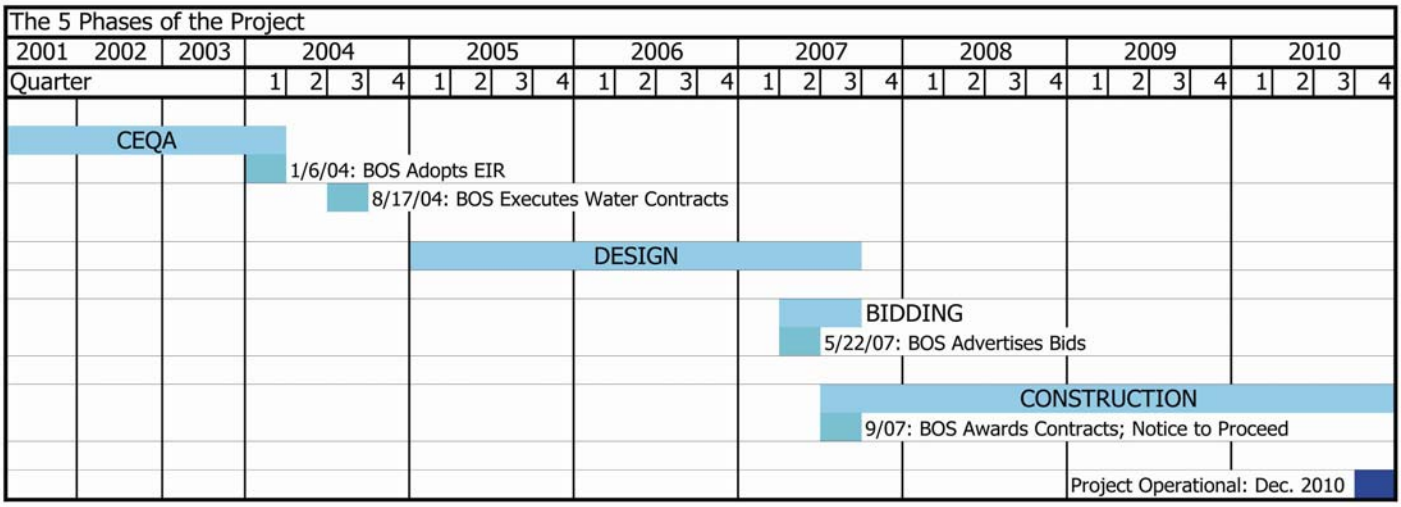

Figure 1 – Nacimiento Water Project Schedule

The Project is a raw water transmission facility created to deliver 15,750 acre feet of water per year from Nacimiento Reservoir to various communities within the County. The rest of the District's entitlement (1,750 acre-feet) is left in the Reservoir for lakeside

use. The Project generally consists of a multi-port intake structure, three pump stations, three storage tanks, 45 miles of pipeline, four turnouts, a control center, and a Supervisory Control and Data Acquisition (SCADA) and Project control system. Its estimated cost was $176-million, including design, construction, construction management, environmental permitting, and right-of-way (ROW). Figure 2 is a generalized map of the Project.

Figure 2 – Nacimiento Water Project Map

DESIGN AND BIDDING PHASE

The design phase of the Project was between 2005 and 2007, and bidding of the five construction contracts that together make up the Project was conducted between May and August, 2007. The District's resources were too limited to spare any staff to administer the Project's Design and Construction Phases; therefore, in April 2005, the District hired a full-time management level civil engineer, the Nacimiento Project Manager, to oversee the Project from the Design Phase through the beginning of the Operation Phase. The District then contracted for the following professional services during the Design, Bidding, and Construction Phases: Management (Project Engineer), Financial Services, Right-of-Way (acquisition, legal and appraisals), Engineering, Construction Management (which includes environmental compliance monitoring), and Environmental Permitting and Compliance. Five construction contractors were hired to execute the building of the Project during the Construction Phase. Figure 3 below presents the organization chart of the entire Project through the Design, Bidding and Construction Phases. During the Design Phase, the Project Team essentially comprised services provided by consultants, which were affectionately known as the "Army of Consultants" by the Nacimiento Project Manager.

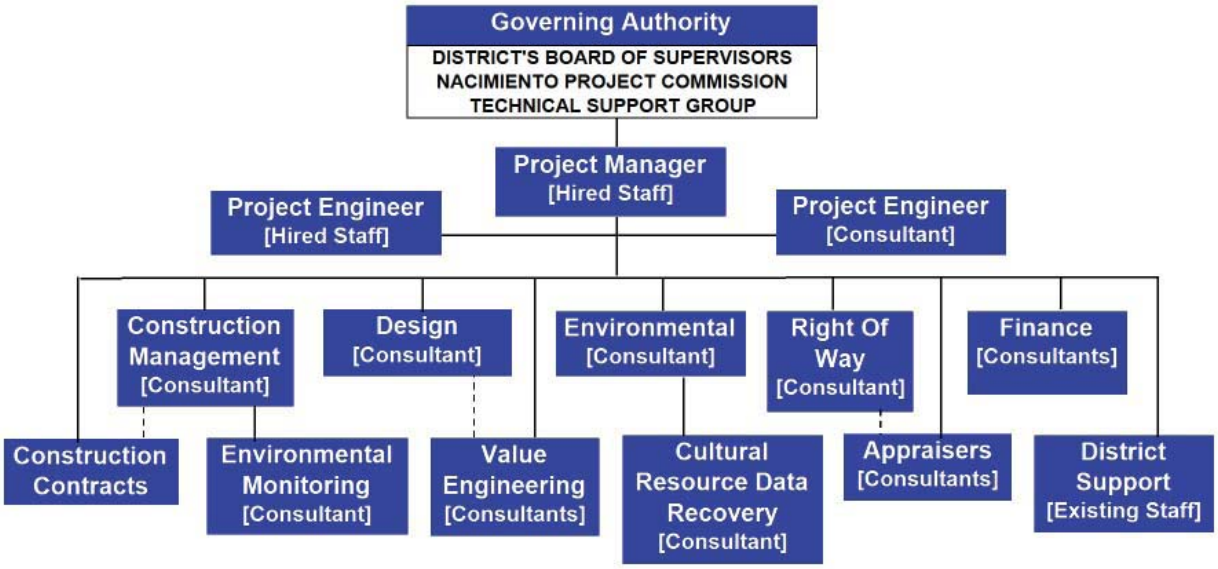

Figure 3 – Project Organization during Design, Bidding and Construction Phases

It is important to note that Permitting and Compliance services were hired well in advance of construction and early in the Design Phase. The consultant's prediction of one year to acquire all necessary permits was accurate. Protection measures needed to be developed for listed and protected species including least Bell's vireo, vernal pool fairy shrimp, San Joaquin kit fox, rare plants, bald eagle, nesting birds, steelhead, and California red-legged frog. Other sensitive resources included state and federal jurisdictional waters (over 70 stream crossings). Sensitive cultural resources were almost as extensive: Previous investigations for the Project identified 50 cultural resource sites along the pipeline route (Gibson and Parsons, 1996) – but it was assumed all could be avoided. Cultural survey work prior to initiating construction found 11 sites which could not.

PROJECT PERMITS AND REGULATORY OVERSIGHT

Project permits and agreements included but were not limited to:

Federal

- United States Fish and Wildlife Service (USFWS) Biological Opinion
- National Marine Fisheries Service (NMFS) Concurrence Letter
- U.S. Army Corps of Engineers (USACOE) Clean Water Act (CWA) Section 404 permit and Memorandum of Agreement for cultural resources

State

- Historic Preservation Officer Section 106 consultation and concurrence
- State Regional Water Quality Control Board RWQCB CWA Section 401
- Department of Fish and Game Stream Alteration Agreements

The complex multi-agency oversight was compounded by the pipeline's route across a National Guard training base (Camp Roberts), with its own unique set of rules and regulations and the requirement that the project have coverage under both state and federal environmental analysis laws, i.e. both the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA).

EXPEDITING THE PERMITS

In spring 2005, the permitting, cultural, and biological staff visited the length of the Project ROW and produced a Project *Constraints Analysis* to determine those resources which would be most sensitive to impact, i.e., could delay the permitting process. Permitting tends to move along a "critical path," and this early reconnaissance allowed the team to get the most difficult permitting endeavors started first. They identified vernal pool fairy shrimp, with known locations in the ROW (and coincidentally on the military base), an active nest site for the endangered least Bell's vireo (see Figure 4,

below), and the threatened steelhead trout, which is present in the area's perennial streams and at certain times of the year in seasonal tributaries. The team developed an animated aerial overhead projection, effectively a flyover of the ROW with all of the resources labeled. Presentations were made to both the USFWS and NMFS, at their offices in Ventura and Santa Rosa respectively. To avoid agency hesitation to engage at this very early point in the process, it was made clear to the regulators that this would be a brief, 15 minute presentation for information purposes only. Nothing was asked of them at that time, but the exposure to the Project, its landscape, and the Project staff made it more likely that the NWP would be treated more expeditiously and the permit application submittals read with greater familiarity.

Figure 4. The least Bell's vireo was observed at the North Salinas River Crossing.

The most basic principle of the permitting strategy was to minimize or avoid impacts wherever possible. This is something that can be done with the flexibility inherent in a pipeline project: a single site with an immoveable footprint can be a greater challenge. However, the approach needs very robust data on the locations of sensitive resources for

the avoidance promise to be credible. In-depth plant and animal surveys were begun early in the permitting year. With design proceeding concurrently, the results of the surveys were useful to the Design Team -- for example, knowing where to narrow the ROW to 30 feet in sensitive plant habitat. With the resources accurately mapped, the precise amount of impact could be calculated by full-time construction monitors in the field when avoidance was not possible, which increased the level of confidence of state and federal regulators in the accuracy of the information provided. This strategy carried with it a calculated risk, however. Avoidance of a resource can expedite the process, but it can be very hard to re-negotiate with the agencies if the Project finds, after construction begins, that avoidance is infeasible (see the story of Sam the Trout, below).

CONSTRUCTION PHASE

The Project entered the Construction Phase on August 28, 2007, when the District's Board of Supervisors approved the bid for the first four of five construction contracts. The bidding process results are presented in Table 1. The environmental permits were

Table 1. Nacimiento Water Project Construction Bidding

Construction Contract Name	Contractor	Bid Value
Spec 1 – Intake	James W. Fowler Company Dallas, Oregon	$20.8 million
Spec 2 – Facilities	Mountain Cascade Inc. Livermore, California	$25.6 million
Spec 3 – Pipeline North	Teichert Construction Sacramento, California	$38.4 million
Spec 4 – Pipeline Central	Whitaker Contractors Inc. Paso Robles, California	$22.7 million
Spec 5 – Pipeline South	Southern California Pipeline Construction Co. Tustin, California	$16.3 million

obtained prior to bidding the construction, and these permits were incorporated into the construction documents in several ways. A set of environmental plans were created as aerial images showing the features of the Project and populated with shading that represented specific environmental mitigation measures that were mandated in the Project's Final Environmental Impact Report (FEIR) and the environmental permits. A narrative of the environmental mitigation requirements was provided in the General Requirements of the Project's specifications. And finally, each permit was reproduced in the appendix of the construction documents. This linking of bid documents and compliance requirements, something not universally practiced, is made possible by the early start on permitting, and by having the environmental group part of the organization from the earliest possible point in time. Designs are developed consistent with both engineering and environmental priorities. They are vetted and cross checked. But making them part of the construction contracts puts a legal obligation on the contractors to know, understand, and follow the environmental, as well as the design specifications.

Environmental Team Structuring and Staffing. The Project's environmental compliance and reporting tasks were contracted to a single consultant who organized the archaeological, biological, and paleontological monitoring efforts. The Environmental Team was led by an Environmental Project Manager who interfaced with the Project's management personnel and when appropriate, regulatory staff on behalf of the District. The environmental field supervisor acted as the in-field task leader for environmental compliance, working alongside the Contractors to understand the construction schedules,

coordinate the appropriate resource monitors, and address day-to-day compliance issues as they arose.

The integration of the environmental specialists into the Construction Management Team was critical to the Project's success and was reinforced by their attendance at the Contractors' weekly progress meetings, planning sessions to resolve constructability issues related to environmental constraints, and frequent communication at all levels. The team provided responses to Contractor questions and submittals as requested by the Construction Management Team.

The Nature of Construction – Solving Issues Unresolved in the Design Phase. Perhaps the most profound challenge to the start of construction came in early December 2007 when the Project was faced with pipeline contractor mobilization in early January 2008 without a Memorandum of Agreement (MOA). This agreement, required under the Corps of Engineers 404 Nationwide permit, dictated the Project's treatment of cultural resources and their protection.

The Project developed a "Plan B" approach, which subdivided the 45-mile alignment into three categories: areas of known cultural resources, areas that had a potential to have buried resources, and those which had a low potential for cultural resources. The Project proposed that work could begin in areas that had a low potential for cultural resources. The other areas (with known or potential for buried resources) would be avoided by the Contractors until the MOA had been signed by the multiple signatories. By subdividing

the Project in this way, work could proceed outside of culturally sensitive areas, avoiding a suspension of work and demobilization by the Contractors.

The USACOE archaeologist agreed to the approach and pipeline mobilization went forward in early January 2008. The last signatory signed the MOA in March 2008; as pre-construction archaeological investigations were conducted and concluded at each segment, the area was made available to the Contractors.

OVERCOMING OBSTACLES

Permit Compliance and the Real World. Often, once a Project has received the regulatory permits and authorizations, the communication between the Project and the regulatory agencies dwindles to the required pre-construction notifications and report submissions. Given the high-profile of the Project, the Management Team agreed internally to give informal updates to the agency representatives on the Project's progress. These updates between the Environmental Team and the District to regulatory staff served to maintain a positive relationship, and when situations required notification and consultation, the agency representatives did not require lengthy reminders of the Project's components and environmental commitments.

The current regulatory environment governing sensitive resources is not organized to facilitate projects during construction, especially when unanticipated resources are discovered. As such, the Project must be prepared to find a design solution, when needed, rather than wait for a permit amendment or agency concurrence. For cultural

resources, a Project's Archaeological Research Design and Treatment Plan (ARD/TP) provides an action plan to help address cultural resources as they are encountered. For biological resources, there is not a comparable mechanism.

Sam The Trout. The Letter of Concurrence from NMFS enabled the Project to go forward without a lengthy consultation on the listed steelhead. It was predicated on the determination the Environmental Team had made that all 70 crossings of seasonal streams would occur when these tributaries to steelhead habitat would be dry. This was true for all but one, a tributary to the steelhead-bearing Santa Margarita Creek, where, during the summer of 2008, the creek was found to be live, that it supported a bathtub-

Figure 5. Sam's Place

sized pool, and that the pool contained steelhead, the largest of whom was fondly named "Sam the Trout" after the County's storm water protection mascot "Sammy the Steelhead." Figure 5 is a photograph of the small pool located downstream of a 36-inch culvert where Sam was found to be living. The pipeline's design called for an open cut-and-cover trench installation through this region of the stream. Crossings of other perennial streams avoided impacts by boring under the waterways, with a biological

monitor on the lookout for any problems, but there was no authority granted to the Project to physically move fish out of harm's way. This was considered "harassment" under the broad definitions of the Endangered Species Act, since the fish could be harmed during any rescue attempt. So the most obvious solution was illegal. The next alternative was to play by the rules established for the live crossings—bore underneath the stream. However, on September 9, the fisheries monitor advising a crew preparing to begin the bore concluded that dewatering the bore shaft would also drain the pool. The District contacted NMFS both formally and informally and was told in March, 2009 that the removal of a culvert blocking fish passage might have some merit as a trade-off for the risk to the fish, provided that extensive studies of the hydrology of the stream were performed. With time running out before the construction season for the stream crossing began, the District went back to the engineers, who designed a suspended crossing for the pipeline by placing the pipe within a large diameter steel casing that bridged across the stream (see Figure 6).

Figure 6. – Pipe Bridge over "Sam-the-Trout's" Habitat

The unanticipated Sam was observed early, both the permitting specialists and agencies contacted appropriately, and the engineers faced with a challenge they overcame with a

simple and elegant solution. If the plan for beginning construction within culturally safe areas (described as "Plan B," above), illustrates a flexible and reasonable way for regulator and proponent to accommodate both resource and the Project, Sam the Trout illustrates the opposite. However elegant the solution, it took a year to reach.

THE COST ASSOCIATED WITH THE PROJECT'S ENVIRONMENTAL COMPLIANCE

Any entity, whether private or public, that wishes to develop a project must adhere to certain environmental regulations intended to mitigate the anticipated environmental impacts of the project. Every environmental regulation and environmental permit mandate has impacts to both the design and construction, and these ultimately affect the project's schedule and budget. A public agency that develops a project passes the environmental compliance costs on to the public that benefit from the project. The Nacimiento Water Project was no different: the public that benefits is the population of the Project's participating agencies. The people of San Luis Obispo County, California, are stewards of this area's environment and they expect owners of a project to exercise good environmental stewardship practices; however, they rarely have an opportunity to see the cost implications of complying with the myriad of environmental regulations imposed on the projects which they are funding. What exactly are those costs for environmental compliance? Engineers have a much easier time answering the general public's questions on how much brick-and-mortar-type projects cost, but engineers and environmental specialists are not so well equipped with answers to the direct and indirect costs associated with environmental compliance. The purpose of this section of the paper

is to provide a case history presenting the actual itemization of the costs associated with the Project's environmental compliance. The Project's environmental costs are both direct and indirect, and examples of these are presented in Table 2.

Table 2. Examples of Direct and Indirect Costs Associated with Environmental Compliance for the Project

Direct Costs	Indirect Costs
➢ Costs for preparing the project's environmental impact documents ➢ Costs during the design phase for preparing the environmental permit applications ➢ Costs for implementing permit requirements into construction contract documents ➢ Costs for environmental monitoring during construction ➢ Costs for environmental reporting during construction ➢ Costs for adaptive management activities to respond to changed environmental conditions found during construction ➢ Costs for post-construction environmental reporting	➢ Costs associated with environmentally-driven design decisions associated with avoiding and/or mitigating environmental permitting impacts ➢ Costs associated with permit-mandated schedule restraints that affect efficiency of construction activities ➢ Unanticipated resource finds and rigid (inflexible) regulations that cannot rapidly mitigate for such finds and enable the project to proceed in a timely cost-effective manner ➢ Schedule slippage due to late and/or changed decisions by regulators

Costs for environmental compliance are billed to the Project's participating agencies as a pro-rata of the annual volume of water that they contracted for with the District regardless of where the participating agency is geographically located along the pipeline. Each agency recognized this method of cost allocation as the most fair as compared to allocating the cost to the specific area where the environmental impact occurred along the pipeline.

Direct Costs of Environmental Compliance. Table 3 presents a summary of the direct costs associated with the Project's environmental compliance obligations. The cost is about $9.8-million, or about 5.6 percent of the Design and Construction Phase budget.

The base-value (i.e., the initial budgeted value) was $6.8-million, and changes to the scope of work for both professional services and construction services increased this expenditure by about $3.0-million. Table 4 presents a description of the base and changed scope of work.

Table 3. Direct Costs for Environmental Compliance

Direct Cost Item	Cost
Environmental Impact Report (CEQA)	$1,310,000
Design Phase – District's Resources	$264,000
Design Phase – Base Professional Services	$800,000
Design Phase – Changed Professional Services	$1,623,000
Construction Phase – District's Resources	$340,000
Construction Phase – Base Professional Services	$2,400,000
Construction Phase – Changed Professional Services	$955,000
Construction Phase – Bid Environmental Mitigation	$1,687,000
Construction Phase – Changed Environmental Mitigation	$406,000
TOTAL	**$9,785,000**

Indirect Costs of Environmental Compliance. The indirect costs of environmental compliance include those design-based decisions that are made to avoid and/or mitigate environmental impacts. They also include unknown changes to the construction schedule when resources are discovered during the excavation process. The actual cost associated with these is often less precise; however, their order-of-magnitude value can be discussed and presented. The utilization of trenchless technology to cross the Nacimiento (one crossing) and Salinas Rivers (five crossings) will serve as an example. The District's management and environmental staff, in cooperation with the pipeline design and the environmental permitting consultants, took into consideration the cost to mitigate and the permit scheduling duration when evaluating the crossing of the rivers. Both rivers could be crossed using standard open cut-and-cover trenching technology, yet the

environmental regulatory community might consider this as too harmful to the habitat. Both rivers are considered habitat for steelhead.

Table 4. Base and Changed Scope of Work for Environmental Compliance

Base Scope of Work	Changed Scope of Work
<u>Design Phase</u> ➢ Environmental Permit Applications ➢ Prepare Construction Documents to Include Environmental Mitigation Measures	➢ EIR Addenda ➢ CA Dept of Fish & Game Permit for Geotechnical Exploration near Streams ➢ NEPA EIS Document* ➢ Phase 1 Pre-Excavation for cultural and paleontology resources ➢ Additional Phase 2 and 3 work
<u>Construction Phase</u> ➢ Environmental Compliance Monitoring ➢ Environmental Compliance Training ➢ Environmental Permit Reporting	➢ Treatment of Groundwater ➢ Limited Work Near Raptor Nest ➢ Tightened Work Area ➢ Shutdown for Discoveries ➢ Support of Additional Phase 2 and 3 Investigations ➢ Demobilize Around Environmental Work Areas ➢ Extend Bore and Jack Tunnel ➢ Hazardous Material Handling

*An unexpected expense was the cost to generate a NEPA Environmental Impact Study for the portion of the Project on Camp Roberts. Initial consultation with the National Guard and the Corps of Engineers led the District to understand that the CEQA EIR document, which was prepared to be a dual EIR and EIS document, would satisfy those agencies' requirements for environmental compliance reporting. The late decision requiring a NEPA EIS caused a ripple effect in the procurement of ROW on Camp Roberts, and delayed Contractor's access to the post for construction.

The Salinas River typically is a dry sand-bottom waterway during the summer, while the Nacimiento River is wetted with water conservation flows released from Nacimiento Dam. The use of horizontal directional drilling (HDD) trenchless technology was evaluated as the most advantageous to avoiding environmental constraints for crossing these streams (Hollenbeck 2009). Ten thousand feet of steel pipe was installed using HDD technology for these river crossings at an aggregate cost of $10.8-million. The unit

cost of installation is $1,080 per foot, albeit the diameters for these installations vary from 8-inches up to 30-inches. The weighted average of pipe diameter (i.e., summation of the product of HDD length times the HDD pipe diameter, divided by the aggregate HDD length) is 24-inches. The bid unit price for cut-and-cover trenched installation of 24-inch diameter pipe is $219 per foot, or about one-fifth the cost of the HDD installation. The unit cost for these installations cannot be compared with one another because the depth of trenched installation was a minimum 42-inches below grade, whereas the installation in the river (if trenched) would be closer to 20-feet below grade to avoid the scour zone of the river during significant floods. What can be inferred, however, from comparing these two costs is that trenched construction is significantly less expensive than HDD construction. The District recognized this when the Project was being designed, and nonetheless judged HDD technology as the better investment for the Project to cross the rivers when evaluating the impact to the environment, coupled with the reduced risk to environmental permit scheduling.

TOOLS FOR PROJECT SUCCESS

Team Building and Early, Open Communication. Surprises, mistakes, and disappointments occur during large projects; the Nacimiento Water Project was no exception. However, overall costs remained within budget and the Project was completed on time. And most of those involved still greet each other with a smile and a handshake. Success was due in part to attention paid to the environmental process throughout the Project. During the Design Phase, District staff began to look ahead to Construction, and how best to organize the team to ensure compliance with

environmental permit conditions. An environmental firm was needed with the capability to simultaneously monitor multiple construction sites with a variety of specialists. At the same time, Project Management debated the most efficient way to integrate the environmental firm into the team. Because of District staff's experience with the Project during the Design Phase, and familiarity with local environmental resources, staff solicited proposals and selected the environmental monitoring firm. Project leaders decided to place the environmental firm under the Construction Manager's oversight. This relationship ensured enhanced communication regarding construction schedules and activities, and the most effective use of the construction (compliance) monitor's personnel over the five construction contracts.

Prior to construction, half-day partnering workshops were held for each construction contract. A partnering specialist not otherwise involved in the Project facilitated these sessions. Participants included key members of each contractor's firm, the construction management firm, environmental monitoring staff, as well as the Nacimiento Project Manager and other key District staff. The sessions provided a forum for the players to get to know one another, build trust, and establish protocols for efficiently resolving differences. Most importantly, the sessions encouraged all parties to work together to complete the project without becoming adversaries. Also before construction began, environmental training for managers and supervisors was provided, tailored for each construction contract. A PowerPoint presentation focused on sensitive biological and cultural resources, permits, and highlighted date restrictions and pre-construction surveys required prior to mobilization to new sites. This training provided the opportunity for

each contractor to ask questions such as “What do we do if we encounter cultural resources?” Most importantly, managers were in the same room to openly discuss issues that could arise and how the Project would address them. Compliance issues had to be repeatedly addressed during construction, but the training for supervisors laid an important foundation by identifying key environmental and contractor representatives, and established the Construction Manager as the enforcer of environmental responsibilities.

Clear communication was also enhanced because the Nacimiento Project Manager and environmental staff were engaged in the environmental decision making throughout the Design and Construction Phases. This strong local agency presence provided a consistent foundation of leadership, while allowing the environmental monitoring staff to independently make decisions in most cases. When District input was sought, the Nacimiento Project Manager and environmental staff strived to respond in a timely manner. District staff provided constructive feedback on all draft reports and work products, and tried to work as a partner with the environmental consultants. Staff, consultants, and contractors do not always agree about environmental issues, or on the best approach to address environmental challenges. However, the Project succeeded in part because management worked to establish a cooperative team atmosphere, and to maintain this good will until water deliveries began.

The Master Compliance Table. Prior to the start of construction, the Project developed a Master Compliance Table (MCT) to consolidate the Project’s environmental requirements into a single document for use in the field. The MCT was organized by

stationing, resource type (biological, cultural or paleontological), and provided the protective measures and monitoring requirements at each resource. The MCT was issued to Project personnel including the Contractor, Environmental Team, and Construction Management. In the field, the Contractor's foremen and superintendents used the table to locate the Project's sensitive resources by pipeline stationing. This table was used to coordinate the level of biological, cultural, and paleontological monitoring (fulltime, part-time, or spot-check) and to determine mitigation measure implementation by the Environmental Team (flagging, pre-construction surveys) and the Contractor (avoidance measures, reduced ROW corridors, and site restoration). As a 'living document' the MCT was revised to update location of sensitive resources, unanticipated discoveries, and staging areas. The updated table was provided to the Construction Management Team and the Contractor after each revision.

And at the Eleventh Hour. By November 2009, the Project had overcome numerous challenges through creative design solutions and teamwork. Within a quarter mile of the pipeline's completion, the end was literally in sight when trench construction encountered a Native American burial on Camp Roberts, the National Guard base. Cranial fragments were first identified within the spoil piles by the onsite Native American monitor. Upon closer inspection of the trench wall, a portion of a skeleton was observed. Construction activities immediately ceased and the Project's Management Team notified. Under other circumstances, such a discovery could have put the Project on hold, indefinitely.

An onsite meeting was convened the next day with managers present from the District, Environmental Team, Design Team, Contractor, and representatives from the Native American community and the California National Guard. An action plan to proceed with trench excavation through the archaeological site was developed and with the USACOE's permission, construction resumed the next day with supplemental archaeological and Native American monitors. With the burial location secured, both for trench safety and as protection from possible looting, the Project turned its attention to the skeleton, which was still within the trench wall. Several conundrums were immediately clear: 1) the Project's MOA did not identify a most-likely descendant (MLD) tribe for the National Guard base and the tribe conducting the Native American monitoring on the base was not federally-recognized; 2) without a federally-recognized tribe to participate in the Native American Graves Protection and Repatriation Act (NAGPRA) process, the skeleton could remain in a secure storage facility indefinitely; and 3) the process on a National Guard base was unclear.

The Project contacted the USACOE archaeologist for guidance. On behalf of the project, the archaeologist voluntarily took the lead to coordinate with the other MOA signatories, guiding the project through the NAGPRA process, avoiding regulatory limbo. The Native American Heritage Commission (NAHC) and the USACOE archaeologist contacted the local federally-recognized tribe who agreed to represent the most-likely descendents.

Pipeline trenching was completed adjacent to the archaeological site four days after the discovery of the burial; the remainder of the pipeline was then installed. The burial was removed within 30 days. The NAGRPRA process proceeded and the skeleton was re-interred nearby within 90 days of its discovery. From the beginning of construction, the Project had established strong internal and external communication channels amongst the Project's participants. As described above, from the first days of construction, the Project developed and then maintained an ongoing dialogue with the USACOE's archaeologist. The positive relationship with the lead agency resulted in the effective, swift and respectful resolution of the burial amongst all the MOA the signatories.

CONCLUSION

Complying with environmental commitments on a large infrastructure project can be expensive and frustrating. Regulators can be difficult to reach, and demands on their time (and the way environmental process guidelines are written) can make original positions inflexible, even when it seems to fly in the way of common sense. Why couldn't Sam the Trout have been moved with a bucket and a dip net? On the other hand, several Fish and Game Agreements were successfully amended to accommodate changed conditions, the Project instituted a procedure for evaluating extra work spaces without having to refer back to the Corps for permission, and were able to observe improvements in the way construction crews operated through a combination of admonition, education, and providing them with up-to-date information via the MCT. Until federal regulatory budgets are increased or permit processes streamlined, environmental compliance will continue to require imagination, cooperation and a lot of hard work.

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Transient Pressure Monitoring Results – Nacimiento Water Project

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Abstract

The Nacimiento Water Project in San Luis Obispo County, California, was completed in late 2010, and is now capable of delivering 15,750 acre-feet of raw water annually from Lake Nacimiento through 45 miles of pipeline to its service area. The Project includes three pumping stations, three storage tanks, 45 miles of pipeline ranging from 36- to 12- inches in diameter, and a Supervisory Control and Data Acquisition (SCADA) system. The hydraulic aspects of the system dictated careful attention to hydraulic design, with due consideration of normal and transient pressures. The construction contract was modified to add a very intensive hydraulic transient monitoring system. This transient monitoring program was installed during construction, and includes nine TP-1 transient pressure monitoring systems installed at locations most prone to severe hydraulic transients. These systems provide detailed information regarding transient pressures and are integrated into the SCADA system to provide real-time alerts if threshold pressures are exceeded. This paper describes the Nacimiento Water Project, the hydraulic design considerations, the network of transient monitoring systems that is installed, construction considerations, lessons learned, and the results of transient pressure monitoring collected during initial startup and testing. Results will include analysis of actual pipe rupture data that occurred during construction, and validation of hydraulic models.

Project Description

The Nacimiento Water Project (Project), illustrated in Figure 1, will convey up to 15,750 acre-feet annually from Lake Nacimiento in San Luis Obispo County, California, through 45 miles of pipeline ranging from 36- to 12-inches in diameter. The Project includes three pump stations, three water storage tanks, and a supervisory and control and data acquisition (SCADA) system. Four turnouts are included to provide delivery to the Project participants: the City of Paso Robles, Templeton Community Services District, Atascadero Mutual Water Company, and the City of San Luis Obispo.

Design of the $176-million Project began in 2004 and construction was effectively complete with operational testing in December 2010.

The Project's hydraulic design [Hollenbeck 2009] played an important role in the engineering effort. It established key Project features that significantly affected the Project construction and operating costs. The design gave careful attention to phased water deliveries, hydraulic efficiency, optimum pipe diameters, pump station characteristics, transient pressure control measures and potential energy recovery.

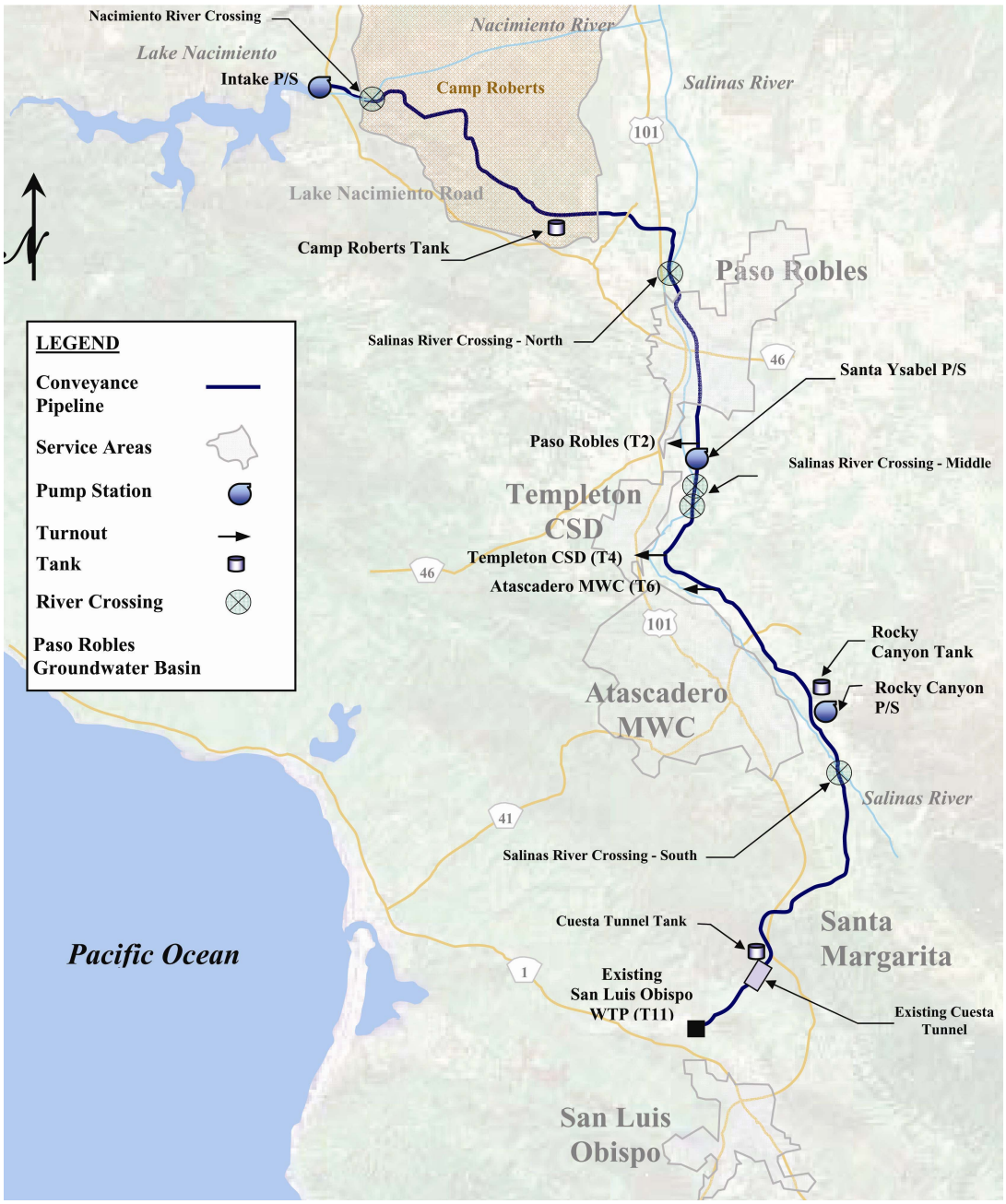

Figure 1. Nacimiento Water Project Map

The Project will operate as a pumped system under normal operation and as a result the most significant hydraulic event will likely be generated by emergency operation including sudden power loss at one or more of the pump stations or malfunction at one of the turnouts. Extensive surge modeling of the pipeline allowed the design of surge control facilities conforming to two criteria:

- Minimum pressure due to downsurge would always be above atmospheric pressure, and
- Minimum pressure during upsurge would not exceed initial hydraulic grade line by more than 100 feet.

The hydraulic modeling guided the selection of the following facilities to control surge due to pump station power failure:

- Air chambers on the discharge of the Intake, Santa Ysabel, and Rocky Canyon Pump Stations
- Slow closing air/vacuum valves at high points along pipeline
- Surge relief valves on the suction side of Santa Ysabel Pump Station

Characteristics and Capabilities - TP-1 Transient Pressure Monitoring System

The Project engineers recognized the importance of measuring transient pressures at critical points in the Project; and included standard digital data loggers which have become widely used within the water and petroleum pipeline industry. On this Project, however, there is a need to monitor for indefinite periods with the capability to detect and measure an unexpected transient that may last a fraction of a second. Not only are these events difficult to detect, they may be the most damaging of all and may go unnoticed for long periods of time. One of the most important aspects of digital sampling of pressure data is selection of an appropriate data sampling rate. An intensive sampling program might sample once per second generating 86,400 data points per day at each test station. Still this would be insufficient to accurately record an event lasting a fraction of a second. As is noted in Figure 2, an insufficient sample rate will lead to inaccurate and misleading portrayal of pressure.

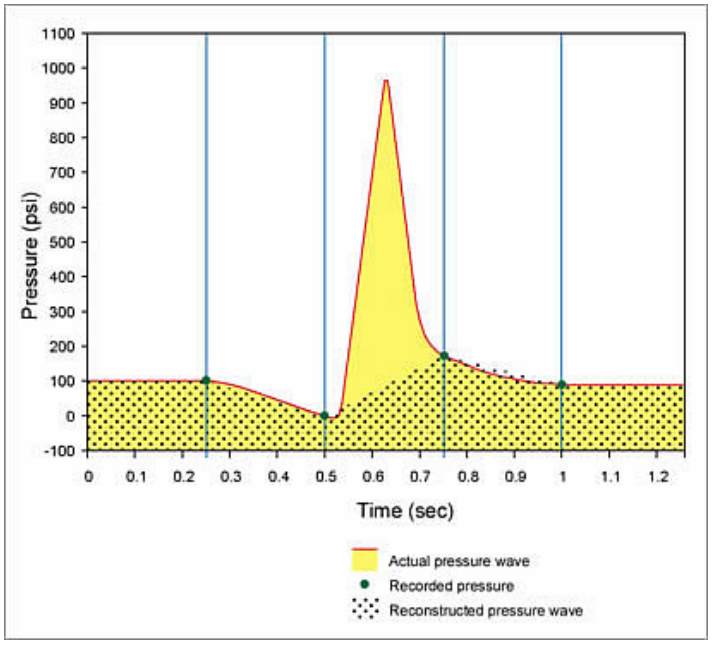

Figure 2 - Digital data collection with insufficient sample rate

Within the past several years, a system has been devised that overcomes several of the limitations of previous digital systems. It is capable of monitoring over extended period of time in a "snoozing" mode, recording background pressure at a user-set interval between once per second and once per day. Although the system appears to be snoozing, in reality it is very busy. It continuously samples the pressure 1000 times per second and computes a running average. Effectively the system algorithm has a built-in alarm clock that goes off when a pressure is detected that differs significantly from the average – in other words when a transient is detected. When this occurs, the system "wakes up" and records all data at another user-set rate up to 100 Hz. This continues until the transient has passed, at which time the system goes back to the "snoozing" mode. The scheme is shown graphically in Figure 3.

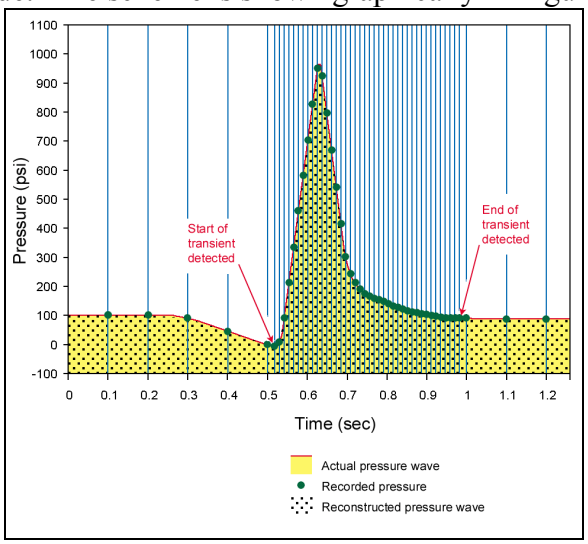

Figure 3 – TP-1 Data Recording Scheme

An additional feature of the TP-1 system is its inclusion of precision timing of pressure data using the GPS satellite constellation, thus providing the time that each data point was recorded in addition to the pressure data itself taken at 100 Hz. This capability provides an additional dimension to troubleshooting of pipeline problems and the analysis of transient data, allowing the localization of the source of a transient event where multiple TP-1 monitors are used and the instant of detection of a transient event is available to millisecond accuracy.

The TP-1 system allows users to set parameters that govern data analysis and recording, including the steady-flow background record rate, the transient event record rate, and criteria for transitioning from background to transient record modes. The system incorporates a transducer with a frequency response range to one KHz to capitalize on the high-speed data recording capability of the TP-1. It is connected hydraulically to the pipeline through standard ¼" NPT fittings, and is connected electrically to the TP-1 controller through a shielded cable. Cable lengths up to 300 feet have been successfully used. Pressure data recorded by the TP-1 system is stored on an internal 2-GB memory flash drive, providing storage for months of data under normal conditions. Data is uploaded from the TP-1 via wireless, LAN, or Ethernet connections for analysis by the

user. Data is placed in a standard Microsoft Data Base for ease of analysis, and the analysis process is further facilitated by software that is part of the TP-1 system.

Installation of Transient Pressure Monitoring System on the Nacimiento Water Project

Discussions among the Project manager and design engineers determined that the optimum locations of the TP-1 systems would be pumping station suction and discharge lines, high-volume turnouts, and points of highest elevation (and thus lowest pressure head). This resulted in a plan to install nine transient pressure monitoring devices on the Project, making it perhaps the most intensively monitored pipeline today, in terms of transient pressure recording. The locations selected:

- Intake pump station discharge header
- High point upstream of the Camp Roberts Tank
- Paso Robles, Atascadero, and San Luis Obispo turnouts
- Suction and discharge headers at Santa Ysabel and Rocky Canyon Pump Stations

Figure 4 – Rocky Canyon Pump Station

Figure 5 - Rocky Canyon Pumps

Figure 6 – TP-1 Installation at Pipeline Highpoint on Camp Roberts

The TP-1 requires 700 milliamps of 12 volt DC power, which is normally provided via 120 volt AC power through a converter. At the pipeline highpoint near the Camp Roberts Tank location, AC power is not available, so the installation there is powered by a solar panel and battery storage.

The popularity of the TP-1's has increased since the first installation in 2005, and several improvements have been added to the system. For the Nacimiento project, several first-time features were seen:

- All nine TP-1's included Ethernet connection over the Project's fiber optic communication with the Project SCADA system, providing the remote capability to access the TP-1 system to modify operational parameters and retrieve data.

Figure 7 – Santa Ysabel Pump Station Pumps

- The GPS time synchronization capability of the TP-1's would be used to synchronize time at the power monitor located in switch gear at each of the three pump stations.
- An alarm is transmitted to the SCADA control room each time a transient is detected.
- The installation was accomplished concurrent with construction of the pipeline so that all testing operations could be recorded in detail

Status of Project Construction and Transient Pressure Monitoring Results

Construction of the Project began in October 2007, and substantially completed November 2010, by the completion of the contractor's startup and testing activities. The District's operators then performed a 30-day startup "run-in" test whereby various modes of operations were tested, or in other words, the Project was ran through its paces! The 30-day testing concluded on January 7, 2011, and the participating agencies

have begun to take the delivery of the raw water, making a milestone of a new water source for several communities in northern San Luis Obispo County.

The District had TP-1 units installed as a change order to the Facilities construction contract. The installation consisted of nine TP-1 installations, and included connection into the SCADA system via the Project's fiber optic communication network. Installation included mechanical plumbing for the pressure transducers, electrical power, and instrument and control wiring. SCADA programming was also part of the installation. Training and software support by the supplier was also included. The cost of the Project's TP-1 system was $418,904 executed by change order.

The District judges the TP-1 instruments as an indirect insurance against the potential of future failure on this new hydraulic system, and that is why the installation was approved by the District's Board of Supervisors. A properly operated hydraulic system should never experience a detrimental transient condition; however, if a regularly occurring transient event does happen and goes undetected by operators and a severe rupture occurs, then the consequential and direct damage costs likely would be significant. The District's manager judges damage costs to be in the order of several times more than the initial investment of the TP-1 system. The District's manager also places a great significance on being able to understand the performance of this new hydraulic pipeline/pumping system, and once the TP-1 product was discovered on the market, it was simply a matter of design and executing a change order to have it implemented into the construction of the Project. The District's operators are now trained to review each transient alarm and to analyze the data to try to understand its cause. Each month, the operations staff reviews the previous month's pressure recordings and prepares a simple report to be shared with the District's engineering staff. The goal is – know what the system is doing, understand it, and work to eliminate any potentially detrimental transient problems.

Monitoring During Construction. The TP-1 recordation of pressures during the startup and testing phase of construction show interesting results when pressures greater than design values were recorded. Investigation as to why determined that the startup team operated the system outside the boundaries presented on the Project's design hydraulic grade line drawing when the system was being flushed. No damage occurred, fortunately, and the result was a lesson learned by the contractor's startup team members.

Figure 8 – Pipe Joint Separation at Stenner Creek Bridge

Transient Event When Pipeline Joints Abruptly Separated. On October 22, 2010, an above-grade stream crossing experienced a sudden release of water from the pipeline when the joints of the ductile iron pipe separated. Figure 10 is a photograph of this event. The 12-inch pipe was encased in a steel casing pipe that bridged across Stenner Creek very near the end of the pipeline. The static head at this location is about 928 feet (402 psi). The cause of the pipe joint separation was later determined as the improper use of a restraining joint product. The contractor repaired the separation with the correct restraining joint and the crossing has functioned properly.

TP-1 recorded the event, and the graphical representation is presented in Figure 11. The recording station is at the turnout to the City of San Luis Obispo (Unit T11), which is located about 3,000 feet downstream from this stream crossing. The sudden change in flow from this pipe failure resulted in a downsurge pressure change of about 400 psi that occurred in about 0.2-seconds. Pipe ruptures are infrequent events, yet with TP-1, the examination of the impact of the rupture (i.e., the impact of the sudden change in water velocity) is easily evaluated. Analysis of the recorded TP-1 data also confirmed that the pipe rupture was not the direct result of a transient event.

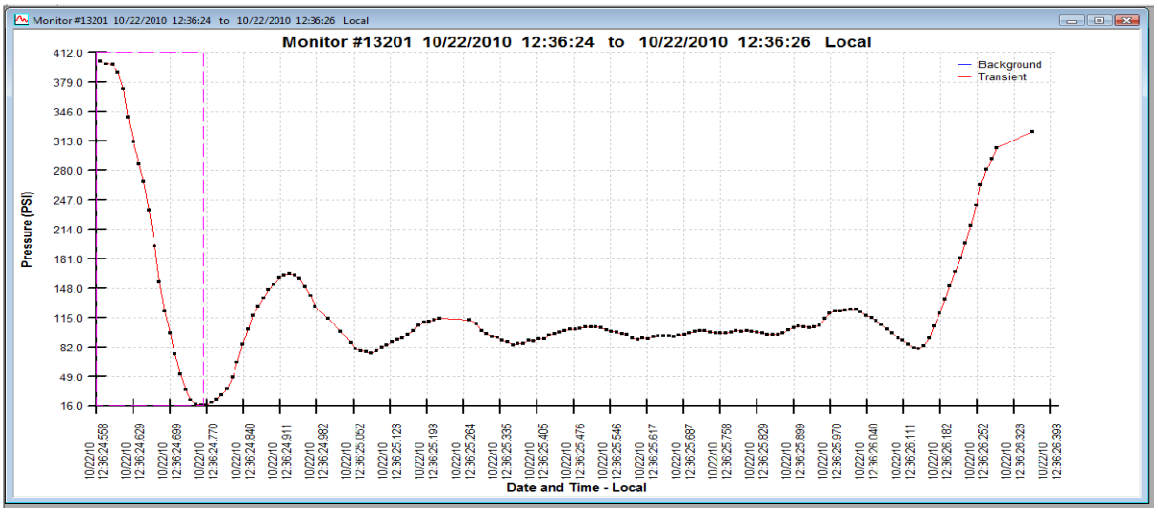

Figure 9 – TP-1 Graphical Results for Pipeline Rupture on 22 Oct 2010 at Stenner Creek

Comparison in Operating vs. Design Pressures. Table 1 presents a summary of the pressures measured and recorded with TP-1 compared to the design pressures predicted for these nine locations. The range of historical data is short since the project has recently completed construction.

Table 1 – Comparison of Pressures at the Nine TP-1 Locations

TP-1 Location	Date of Pressure Event	Measured Pressure (psi)	Design Limit (psi)	Comment
Intake Pump Station	27 Aug 2010 Jan 2011	164 126	128	Misoperation (flushing) Near Normal
Camp Roberts Pipe High Point	21 Oct 2010 Jan 2011	150 49	62	Misoperation of pumps
Paso Robles Turnout (T2)	4 Nov 2010 Jan 2011	435+ 158	165	Frozen pipe/transducer Near Normal
Santa Ysabel Pump Station (suction side)	30 Nov 2010 Jan 2011	192 160	160	Misoperation of pumps Near Normal
Santa Ysabel Pump Station (discharge side)	26 Oct 2010 10 Nov 2010 Jan 2011	394 275 240	241	Field Testing (test loop) Near Normal Near Normal
AMWC Turnout (T6)	25 Nov 2010 Jan 2011	435+ 175	146	Frozen pipe/transducer Under investigation
Rocky Canyon Pump Station (suction side)	29 Nov 2010 Jan 2011	45 17	17	Misoperation Near Normal
Rocky Canyon Pump Station (discharge side)	12 Oct 2010 Jan 2011	312 265	274	Field Testing (test loop) Near Normal
San Luis Obispo Turnout (T11)	20 Oct 2010 Jan 2011	461 426	430	Near Normal Near Normal

Conclusions

The District is very satisfied with the installation and operation of the TP-1 system, and judges the implementation as a good investment in this new Project.

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