

COACHELLA CANAL LINING PROJECT: COST EFFECTIVE CONSTRUCTION FOR LARGE SCALE WATER CONSERVATION

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ABSTRACT

The Coachella Canal Lining Project (CCLP), completed in 2007, is conserving over 26,000 AF of water per year. The project assists California in meeting its water needs while staying within its entitlement of Colorado River water of 4.4 million AFY and achieving water usage goals established under the Quantification Settlement Agreement. The project also provides water to settle a long standing water rights issue on the San Luis Rey River in California. To date, the total cost of the project is approximately \$120 million including design, construction, environmental mitigation, and supervision and administration. Funding was provided by the California Department of Water Resources in the amount of \$83.65 million, with the San Diego County Water Authority responsible for the remaining costs.

The Bureau of Reclamation completed construction of the Coachella Canal in 1948. The canal is operated and maintained by Coachella Valley Water District (CVWD). CVWD administered the design, construction, and environmental aspects of the CCLP. The project was designed and constructed in accordance with Reclamation standards and administered by the CCLP Coordinating Committee composed of CVWD, SDCWA, and a mutually agreed chairman with participation by Reclamation, the San Luis Rey Settlement parties, and other interested parties.

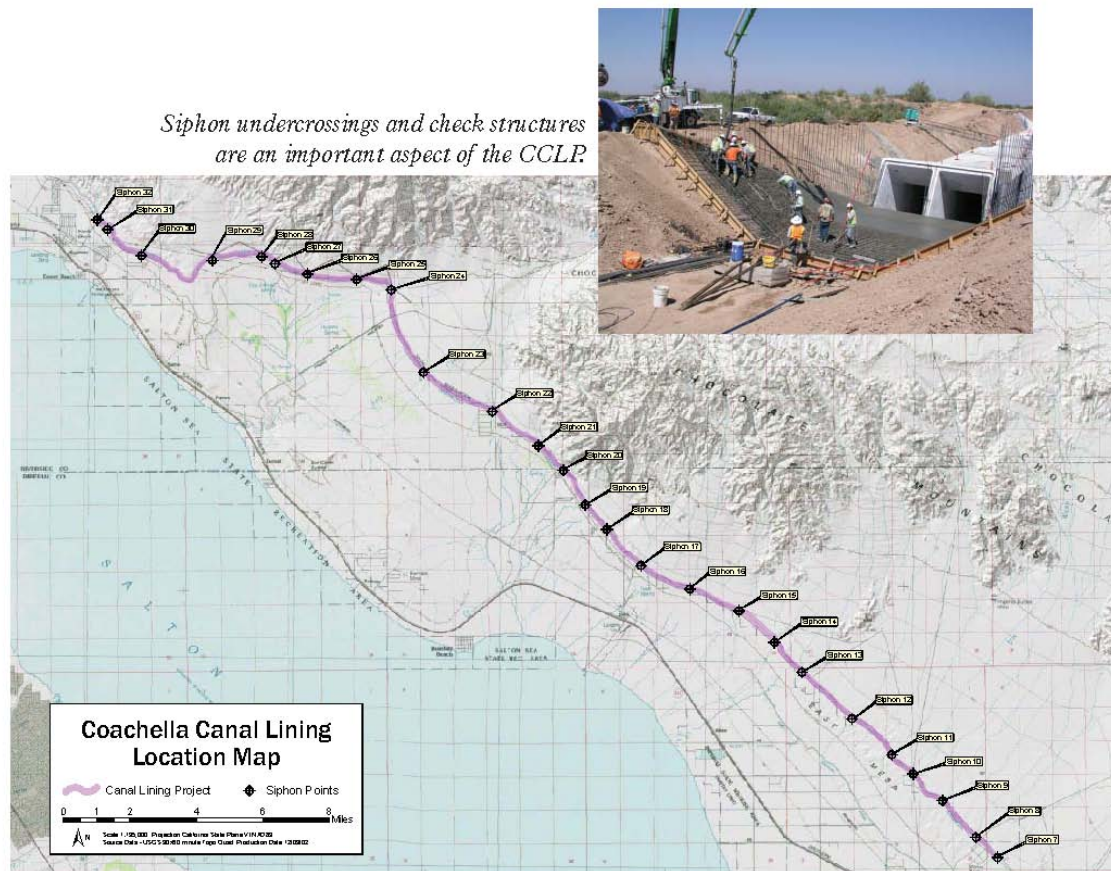
The CCLP lined approximately 36.5 miles or about one-third, of the 123 mile canal. The northern 38 miles of the canal was lined in 1948 during original construction and the southern 49 miles of the canal was lined in 1981 by the Bureau of Reclamation. The project was originally envisioned to consist of lining the existing canal section, however, following the 60 percent design review, the project was revised to construct a new adjacent parallel canal at significant cost savings. The project involved 5.7 million cy of excavation, 1.3 million sq yds of 3-inch thick concrete paving, construction of 25, 10.5 by 10.5-foot double barrel inverted siphons, six new check structures, over 60 miles of deer fence and 56 wild game drinkers.

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HISTORICAL PERSPECTIVE

Located partially in Imperial County and partially in Riverside County, California, the Coachella Canal is situated between the Salton Sea and the Chocolate Mountain range. The canal headworks consist of a turnout on the All-American Canal located near the Mexico border, with the canal extending northwest 123 miles to the Coachella Valley. The Coachella Canal conveys Colorado River water to cities and agriculture north of the Salton Sea, within the lower Coachella Valley.



The Coachella Canal branches off the All-American Canal and extends 123 miles northwest.

The All-American and Coachella canals were authorized for construction by the Boulder Canyon Project Act of 1929. Although excavation for the Coachella Canal started in 1938, final construction was not complete until 1948 due to delays resulting from World War II. Only the last 38 miles of the canal were concrete-lined during the original construction.

Starting in the 1960s, several significant system improvements were made to the Coachella Canal including (1) installation of a supervisory remote control and telemetering system to operate the canal and distribution system; (2) construction of a regulating reservoir (Lake Cahuilla) at the terminus of the canal; (3) construction of two flood control dikes; (4) addition of 10 traveling de-mossing screens; and (5) construction of a new check gate and rehabilitation of an existing check gate. In the 1980s, the first 49 miles of the Coachella Canal were concrete-lined, leaving about 36.5 miles of the canal unlined.

The recent Coachella Canal Lining Project (CCLP) was developed as a water conservation action to comply with provisions contained in the 2003 Quantification Settlement Agreement (QSA). This historic agreement consensually settles longstanding disputes regarding priority use and transfer of Colorado River water. A QSA-related agreement, the Allocation Agreement, was entered into by the U.S. Bureau of Reclamation (USBR), Metropolitan Water District of Southern California, Coachella Valley Water District (CVWD), Imperial Irrigation District (IID), San Diego County

Water Authority (SDCWA), the San Luis Rey Indian parties, the City of Escondido, and the Vista Irrigation District. In addition to other objectives, the Allocation Agreement identifies the quantity of water to be conserved by lining the remaining portion of the Coachella Canal, and names the California Department of Water Resources (DWR) as the source of funding for the project.

The CCLP consisted of constructing approximately 36.5 miles of concrete-lined canal adjacent to the existing canal, which included 25 inverted siphon undercrossings (to convey rainfall runoff flows from the Chocolate Mountains across the canal), one railroad crossing, six check structures, and a variety of consequential environmental mitigation measures.

In addition to the numerous construction components of the project listed below, at least five innovative and unique construction methods (discussed in a later section) were developed and employed during the project. The methods included using (1) contractor-designed and fabricated traveling forms; (2) a mobile sprinkler coined the “Dust-Abator”; (3) drain tile and sump system for dewatering; (4) a very large excavator; and (5) a multiple unit paving train.

Canal construction was complex and incorporated many components including clearing and grubbing, dust abatement, constructing a sediment control weir, pre-wetting canal and spoil excavation, compacting embankments, trimming earth foundation, placing concrete, installing safety ladders, constructing canal contraction joints, installing a road drain pipe, and replacing various existing pipelines. Canal construction also included reinforced concrete broad-crested weir flow measuring structures and canal tie-ins.

An important aspect of the project was construction of the siphon undercrossings and check structures, which included reinforced concrete transition structures, earthwork, roadways, riprap, sheet piling, safety cable and floats, metalwork and chain link fencing. Construction of check structures also included control buildings, stilling wells, commercially designed radial gates, complete with appurtenances, electrical and instrumentation.

Environmental mitigation was and continues to be important to the success of the project. Several environmental groups were formed with agency representatives to collaborate on solutions to unique environmental concerns. Environmental mitigation encompassed cultural resource surveys, construction monitoring, mitigation for aquatic and riparian habitat, desert riparian habitat, tree replacement, fishery mitigation, and large mammal monitoring and mitigation measures which included wildlife fencing and watering ponds located outside fenced areas to provide wildlife access to water.

Construction of the CCLP proved to be environmentally challenging. Mitigation measures included development of a 17-acre marsh; maintenance of Dos Palmas core marsh/aquatic habitat; 325.5 acres of desert riparian habitat; desert riparian re-vegetation; 2:1 tree replacement; animal fencing/drinking troughs; construction of a stocked fish pond; and an endowment for the long-term maintenance of mitigation land.

Through exceptional cooperation and resourcefulness among the project partners, the CCLP was built on schedule, within budget constraints, and with an extraordinary safety record. The CCLP included the proficient collaboration of multiple coordinating committees, consistent construction team meetings, oversight by project partners, and environmental management and stewardship to bring about a successful project.

PROJECT DESCRIPTION

The following table presents a comprehensive listing of project statistics.

PROJECT STATISTICS OF INTEREST	
▪ 26,000 afy of conserved water	▪ 525 human safety ladders
▪ 35 miles of concrete-lined canal	▪ 325.5 acres of desert riparian habitat developed
▪ 25 inverted siphon undercrossings totaling approximately 1.6 miles in length	▪ 875 acres private land for habitat
▪ 6 check structures, including gates and control buildings; solar power in 2008	▪ 17-acre created marsh
▪ linear feet of pipe overcrossing 1,400	▪ 1 fish pond stocked with fish
▪ 1.3 million square yards of concrete for 3-inch thick canal lining	▪ 3,500 linear feet of tortoise fencing
▪ 37,000 cubic yards of concrete for siphons and check structures	▪ 65,000 linear feet of chain link fencing
▪ 5.7 million cubic yards of dirt excavated	▪ 138,500 linear feet of woven-wire wildlife/large mammal fencing; additional fencing between Siphons 7 and 21 in 2008
▪ 385 million gallons of water for dust control	▪ 42 large mammal permanent watering ponds; 14 additional in 2008
▪ Approximately 260 acres of clearing and grubbing	▪ 3,000 large trees

The crowning achievement of the completed CCLP is an average annual conserved water savings of over 26,000 acre-feet. This conserved water, by an agreement between SDCWA and the Metropolitan Water District of Southern California, is conveyed through the Colorado River Aqueduct to the city of San Diego and the SLR Settlement Parties for urban use. Additionally, the CCLP advances the economic stability of the collective regions by meeting the goals of the water transfer requirements. During construction, it was imperative to continue water flowing in the canals so that the deliveries to the Coachella Valley agricultural community would not be interrupted. Unique construction of the parallel canal with tie-ins accomplished this requirement.

Economic Feasibility and Budget Performance

In 1998, SB 1765 authorized \$235 million for implementing the QSA. Of this amount, \$200 million was appropriated for the two canal lining projects: the CCLP and the All-American Canal Lining Project. Of this total, \$83.65 million was provided for the CCLP. With a total CCLP cost of approximately \$120 million, the SDCWA provided about \$36 million toward the cost of the project. Total yield of conserved water from the CCLP is estimated at 30,850 acre-feet per year (afy). Of this total, 4,850 afy is allocated for environmental mitigation water; 21,500 afy to SDCWA; and 4,500 to the SLR Parties. The agreement provides that in any year of the 110-year term if mitigation water or any portion of it is not used, the balance of that water is to go to SDCWA. SDCWA has purchased and developed a parcel of land in the project area that generates groundwater that can also be used to supplement environmental mitigation water. Based on findings to date, it is estimated that 2,500 afy of groundwater will be produced and used for environmental mitigation. Based on this straightforward analysis, the cost to SDCWA per acre-foot of conserved water is highly competitive with other water supply opportunities. Further, the CCLP provides a long-term reliable water supply, particularly when the reliability of State Water Project water is in question, and contributes in meeting the SDCWA water supply diversification targets. The following factors were considered by SDCWA when accepting responsibility for the implementation of the CCLP and the benefits received from the additional water supply:

Supply Reliability. There is no other readily available water supply that possesses the priority level, comparative low cost, amount and the duration of water supply resulting from the canal lining projects; CCLP and AACLP.

Narrowing the Water Reliability Gap. The acquisition of additional water supply from the CCLP is consistent with SDCWA goals to enhance water supply diversification and reliability, creating less dependence on more costly, and sometimes unavailable, MWD imported water.

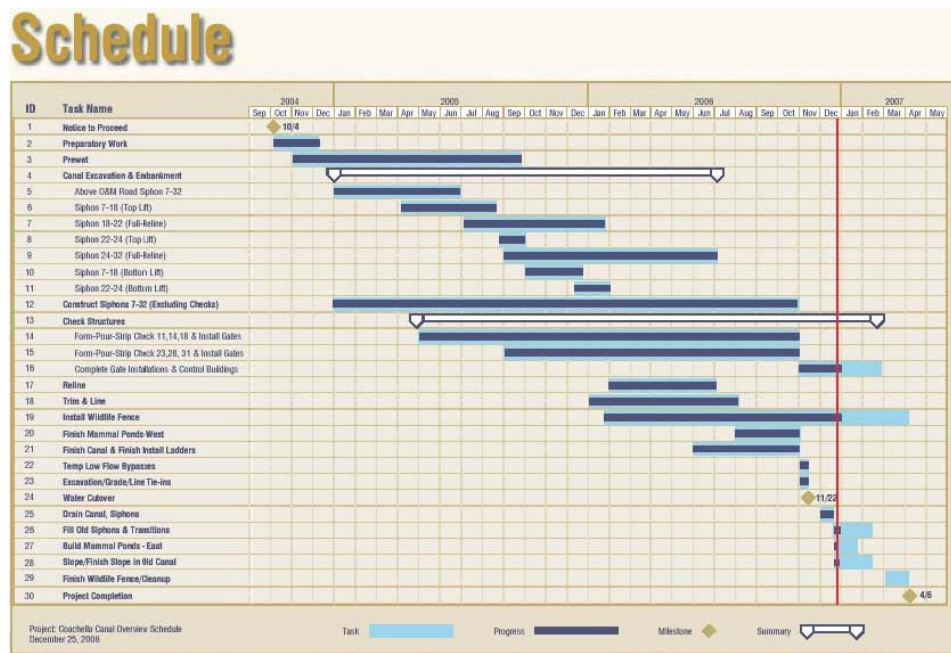
More Economical than Other Supply and Reliability Options. SDCWA is committed to increasing water reliability through a multifaceted approach, including infrastructure improvements, water transfers, and local development. Each of these measures comes with a cost. The CCLP was a cost-competitive opportunity to acquire at least 21,500 acre feet of additional firm water supplies for 110 years. The marginal cost of the CCLP compares favorably to other water transfers and supply options. Additionally, the supply risks have been shown to be significantly lower than other options.

Original Budget	\$99.63 million
Revised Budget	\$119.70 million
Over/Under Budget	\$20.07 million
Contract Breakdown:	
Design	\$2,500,000
Construction	\$88,306,000
Construction Management	\$3,950,000
Environmental Services/Permitting	\$4,890,000
Environmental Mitigation/Land Acquisition	\$12,046,410
Various Environmental Mitigation Contracts	\$808,600
Agency Project Costs	\$7,199,000
Sources of Funding:	
DWR (70%):	\$83.65 million
SDCWA (30%):	\$36.05 million
Approximate Capital Value	\$88.3 million

Unprecedented State Funding for Water Supply Project. Through the QSA, the State of California provided \$83.65 million toward a water supply capital improvement project. Never before have the project partners been presented with such a funding opportunity. Additionally, CVWD benefits from a new canal with modern technology and function, providing for efficient operations and maintenance. Additionally, CVWD will receive reimbursement by SDCWA for 110 years for the cost to operate and maintain the CCLP portion of the canal above the agreed 10-year average of costs for operations and maintenance prior to lining of the canal. Finally, as owner of the canal, the USBR receives 36.5 miles of new canal and a fully lined Coachella Canal, completing what began in the 1980s with lining of the first 49 miles. The QSA and the CCLP will have a profound and lasting effect on the San Diego and Coachella Valley regions for generations to come. The CCLP was constructed based on sound economic feasibility with the vision of the future and appreciation for the long-term beneficial impacts on future generations.

PROJECT SCHEDULE

Notice to Proceed:	October 4, 2004
Ribbon Cutting Ceremony:	November 2006
Project Completion:	April 2007
Notice of Completion Filed:	September 7, 2007 (with Riverside County) September 10, 2007 (with Imperial County)



PROJECT TEAM, MANAGEMENT STRUCTURE AND ADMINISTRATION

Project Owner

U.S. Department of the Interior, Bureau of Reclamation

Project Operation and Maintenance

Coachella Valley Water District

Project Partners

Coachella Valley Water District — Responsible for all contracting for services and overall management of the design and construction of the project.

San Diego County Water Authority — Responsible for eligible project costs beyond the DWR-funded amount. Provided essential project oversight and due diligence review of construction, property acquisition, and environmental mitigation activities.

US Bureau of Reclamation — Reclamation is the project owner and had a vested interest in partnering for the success of the project. Reclamation participated in review of project design and construction, provided additional QA/QC of project construction.

California Department of Water Resources — Contributed \$83.65 million to fund the project.

Advisors

- California Department of Fish and Game (DFG)
- U.S. Bureau of Land Management (BLM)
- U.S. Fish and Wildlife Service (FWS)
- San Luis Rey Indian Parties (SLR Parties)

Project Designer/Construction Manager

MWH/GEI Consultants, Inc. team provided design, construction support and construction management services.

Environmental Coordination

Harvey Consulting Group, LLC coordinated the overall environmental effort for the project, and provided assistance with environmental permitting, development of conservation plans and environmental documents, including estimating mitigation costs for approximately seven different mitigation efforts.

AMEC Earth and Environmental, Inc. provided permitting assistance, mitigation measures identification, field survey, CEQA assistance, and general environmental services.

ASM Affiliates, Inc. provided services for the preparation of the cultural resources and historical context report.

Project Constructor

R & L Brosamer, Inc.

Special Consultant to San Diego County Water Authority

R.W. Beck, Inc. provided project management, engineering support and construction support through due diligence review of construction, property acquisition, and environmental mitigation activities.

Coordinating Committees

A key factor in the success of the CCLP was the strong coordination and collaboration among the project partners through the establishment of a Coordinating Committee and an Operations, Maintenance, and Repair (OM&R) Coordinating Committee. These committees were instrumental in moving the project forward on schedule in an organized approach.

Coordinating Committee. The Coordinating Committee was established by means of an agreement among the USBR, CVWD, and SDCWA. The Coordinating Committee serves to secure effective cooperation and interchange of information and provide consultations, reviews, recommendations, approvals on a prompt and orderly basis, and to make recommendations to the USBR.

The Coordinating Committee includes three voting members, one each appointed by CVWD and SDCWA, and the third member jointly appointed by the two agencies. Non-voting members include USBR, IID, Palo Verde Irrigation District (PVID), SLR Parties, and DWR. The SLR Parties and DWR also are advisory to provide viewpoints regarding

specific matters. Reclamation is an advisory member for technical information to assist in making recommendations to USBR.

The Coordinating Committee met monthly to review and make recommendations on matters relating to the design and construction of the CCLP. This includes design and construction, documentation, schedules, water capacity in the Coachella Canal, and remedial measures for public health and safety. The Committee continues to meet bi-monthly to discuss and address ongoing work activities related to environmental mitigation.

Operations, Maintenance, and Repair (OM&R) Coordinating Committee. The OM&R Coordinating Committee, required by the Allocation Agreement, was formed to secure “prompt, orderly and effective cooperation and exchange of information and providing consultation, review, recommendation, and/or approval among the parties in connection with additional costs of operation, maintenance, and repairs of the...Coachella Canal.”

Committee members include representatives from CVWD, SDCWA, IID, and SLR Parties. The Committee meets monthly to review operations and maintenance activities and scheduling, environmental activities, and overall project expenses, work elements, and invoice approval.

Environmental Groups

The CCLP environmental groups provide essential and technical knowledge on environmental issues of the project related to environmental mitigation. These groups are advisory to the Coordinating and OM&R Committees.

Biological Working Group. The Biological Working Group includes CVWD, SDCWA, USBR, DFG, FWS, BLM, and CNLM (Center for Natural Land Management). This group provides coordination with and technical environmental advice to of the CCLP mitigation effort as it affects land and habitat management activities within the larger Dos Palmas Area of Critical Concern.

Environmental Management Group. The Environmental Management Group includes representatives from each of the project partners. This group tracks and evaluates mitigation requirements and provides recommendations to the Coordinating Committees for initiating and funding mitigation efforts, including large mammal management, desert riparian re-vegetation restoration, marsh creation, and offsite fishery enhancement.

TEAMWORK IN DESIGN

The Preferred Alternative included in FEIS/EIR consisted of lining the existing canal using multiple pipe barrels and movable pumping stations to divert and convey the required 600 cfs to maintain canal deliveries. It was determined early in the design phase that the EIS-listed Preferred Alternative could not be constructed within the time and

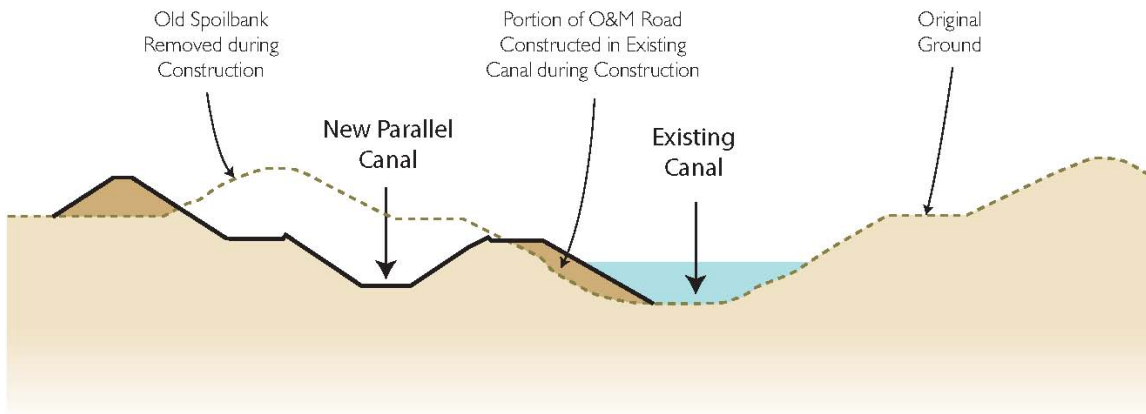
funding limits of the project. The estimated cost would be about \$30 million above budget and as much as two years past the required completion date.

Developing an alternative concept for design of the CCLP was complicated due to a significant number of varied conditions that had to be met, along with funding and schedule constraints. The following summarizes these conditions.

- The project had to be completed without interruption to CVWD deliveries to its valley growers. A minimum 600 cfs capacity had to be available for these deliveries at all times.
- The CCLP traverses the base of the Chocolate Mountains. Rainfall runoff from the uphill watershed is trained to pass the canal in 25 washes that cross the canal within the project area. These washes can have relatively large, flashing, and unpredictable flows. If the existing canal were to be lined as originally planned, canal diversions to maintain the 600 cfs deliveries described above would cross and block the washes leaving a relatively high risk for interruption to irrigation deliveries if and when the washes flowed. This risk condition had to be considered in the design.
- Commitments made in the EIS/EIR, including:
 - In order to minimize environmental impacts, no additional rights of way would be acquired.
 - Provide features for large mammal escapes consisting of constructing canal ridges in the new canal side slopes.
- Concepts other than the Preferred Alternative could require amendment to the FEIS/EIR which might delay the project.
- A completion date was set to satisfy concerns of the other Colorado River Basin states that California was indeed working to meet its commitment to reduce its use of Colorado River water to the limits of its allocation.
- The DWR provided the majority of the funding (70%) for the project. The attempt to keep the project within the DWR funding limits was a significant driver in the design concepts and related decision making.

After much consideration and study, an alternative was developed for lining the existing canal by constructing a bypass canal for diversion of the 600 cfs canal deliveries. The Bypass Alternative essentially substituted a temporary canal for the pipeline and pump station concept included in the FEIS/EIR - Preferred Alternative. This alternative would fit within the funding available for the project and was developed to nearly 100 percent completion. It would involve constructing the bypass channel across the washes which at first was considered an acceptable risk for the project. However, as the design

progressed, this risk of failure to maintain a reliable delivery capability to CVWD during and immediately after a desert rainfall event became more and more of a concern.



The selected alternative used excess excavation material to create a sufficiently-wide O&M road by encroaching on the old canal, thus lowering hauling costs.

As the design of the Bypass Alternative was underway, a new parallel canal concept emerged that would become the only concept that would meet all of the constraints and criteria and ultimately be implemented into the project design. Based on preliminary estimates, the cost to construct an entirely new parallel canal including new siphons would be approximately the same as the estimated cost for the Bypass design. The existing double box siphons are over 60 years old. The concrete headwalls of a number of the siphon transition structures showed signs of deterioration. From inspection and testing of the concrete it was determined that the deterioration was from carbonation and on many structures the face of the concrete had actually split away from the reinforcing.

As it turned out, the decision to avoid risk at the wash crossings was an exceptional one. The year 2005 was a very wet hydrologic year with over 2.5 times the normal rainfall at the project site. The washes had very heavy flows a number of times. During construction of the CCLP, it was discovered in some areas along the alignment that this wet cycle had resulted in increased groundwater levels than what was originally found during the design phase.

Implementation of the new parallel canal concept required a number of innovative, perhaps unorthodox, design and construction elements. Also, as the design of the parallel canal was underway, additional boring logs were taken along the new centerline. High groundwater was discovered in the areas of Siphons 9, 10, and 18.

In order to design and construct a parallel canal within the existing right-of-way and meet all of the conditions set forth above, the following design elements were required:

- The new canal was designed to be exactly parallel and offset from the existing canal. In some areas there was not enough existing right-of-way to construct

the new canal without constructing a portion of the O&M road in the existing canal while under operation.

- In order to reduce costs for hauling excess excavated material, the design allowed the contractor to deposit the material in the existing canal while under operation.
- To prevent transport of suspended sediment into the CVWD service area from the two above described operations, a rock weir was constructed at the downstream end of the existing canal to form a 10-mile-long sediment control pond.
- As the design progressed, an idea was developed to extend the project upstream into the end of the first 49 miles of lining that was completed in the 1980s by removing the Parshall flume that was part of the lining project. The Parshall flume operated with a four foot drop in water surface across the structure.

By eliminating the flume, the invert of the new canal was raised four feet. This change resulted in a significant reduction in required excavation and a reduction in dewatering concerns. It also reduced the overall width of the new canal section for a better fit in the existing right-of-way.

To replace the measurement function of the Parshall flume, a long-throated flume was constructed in the new canal. This type of flow measurement structure can function within acceptable accuracy with only 0.60 feet of differential head across the structure.

During design, the canal ridges required (for large mammal access and egress) in the original EIS were determined to be incompatible with canal lining without having a PVC liner beneath the concrete canal lining. Construction of the ridges would not be conducive to modern production lining operations, and the cost would be prohibitive. To meet the EIS obligation for large mammal protection, the EIS was amended to include wildlife fencing and ponds to provide access to water for deer and other large mammals.

TEAMWORK IN CONSTRUCTION

The construction contractor, R&L Brosamer, Inc., used a variety of innovative methods and equipment for completing construction of the CCLP. These methods and equipment are listed below.

- **Design/Fabrication of Traveling Forms:** The contractor designed and fabricated its own traveling forms for construction of the 1.6 miles of double 10.5' x 10.5' box siphons for the project. The traveling forms used hydraulic cylinders that caused the top of the form and the sides to collapse and fold in during stripping. This made it possible to strip, move forward, and be in place for the next placement in a matter hours

- **“Dust Abator”:** The contractor developed a piece of equipment that was coined the “Dust Abator” that consisted of large pump suspended from the boom of a rubber-tired mobile crane and fire nozzle to spray water over the work area for dust control.
- **Drain Tile and Sump System for Dewatering:** The contractor employed a drain tile and sump system for dewatering the canal. Their dewatering subcontractor used a specially designed trenching machine to insert the drain tile and pea gravel pack in the invert of the canal in the same operation. The work could be accomplished even with water in the invert of the canal.
- **Hitachi 1900 Excavator:** Due to the nature of the excavation for this project, a large portion of the work was accomplished with excavators. The contractor purchased a new Hitachi 1900 that was shipped from Japan for this work. The excavator had a 2000 cy/hr production rating.
- **High-Production Paving Train:** The contractor’s canal lining paving train included a trimmer, paver, joint inserter, finishing jumbo, and curing jumbo, which reached production rates of nearly ½ mile per day. The joint inserters inserted PVC water stop at 12’ centers longitudinally along the canal and transverse to the canal.

CONCLUSION

The Coachella Canal Lining Project (CCLP) is a substantial accomplishment in meeting a goal of the 2003 Quantification Settlement Agreement to conserve Colorado River water for beneficial use. The CCLP represents a significant and timely achievement in the history of the Coachella and Imperial Valleys, and the San Diego and Imperial Valley regions. The CCLP advances the economic stability and contributes to the well being of the regions by meeting the goals of the water transfer requirements by conserving 26,000 acre-feet per year of water to be transferred to San Diego County for urban use. Notably, the CCLP overcame challenges of keeping water flowing in the canals during construction by innovatively designing and building a parallel canal adjacent to the old canal in the same 200 foot-wide right-of-way. The two canals, from centerline to centerline, are only 80 to 100 feet apart.