Raw Sewage through Steel Pipe: A Unique Application on the Pima County Plant Interconnect

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ABSTRACT

The Regional Optimization Master Plan (ROMP) is the largest capital improvements program in the history of Pima County Regional Wastewater Reclamation Department (PCRWRD), Arizona, valued at over $720 million in construction, project management and inspection services. One phase of this major undertaking, the ROMP Plant Interconnect Project, consisted of a 5-mile pipeline, with two wash crossings, connecting two metropolitan treatment facilities. Two parallel siphon structures across two wash crossings had to meet more stringent regulatory requirements than the gravity sewer itself. During the Value Engineering stage, welded steel pipe (WSP) was identified as an acceptable material substitution to ductile iron pipe (DIP) for the two siphons. The use of WSP enabled the Owner to meet and/or exceed the performance requirements for strength and corrosion protection of the Arizona State Rule governing the design of sanitary sewers. After reviewing the rigorous testing performed on polyurethane as a dielectric barrier against corrosion, the PCRWRD approved the use of WSP, lined and coated with polyurethane, for the project siphon crossing application. The two parallel steel pipelines were buried at depths of 30 feet, and the use of lap-welded joints provided a fully restrained piping system. A portion of the funding for this project came from the stimulus package provided as part of the American Recovery and Reinvestment Act (ARRA). This paper presents project details, and descriptions of the processes for adopting an alternate pipe material, the justification for selecting WSP over DIP, qualification of the dielectric coating and lining system, and challenges in the design and construction of the deep parallel siphons.

INTRODUCTION

Pima County Regional Wastewater Reclamation Department (PCRWRD) owns and operates regional wastewater conveyance and treatment systems serving Eastern Pima County, Arizona. The regional systems consist of over 3,300 miles of sewer lines (of which 230 miles are major trunk lines or interceptors), 34 conveyance system lift stations, two major wastewater reclamation facilities (WRF) in the metropolitan area, and eight smaller wastewater reclamation facilities in the non-metro region.

A significant element affecting the Department's strategy and future planning is the need for a reduction in ammonia and nitrogen concentrations discharged into the Santa Cruz River to comply with current and future environmental regulatory requirements set forth by the

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Arizona Department of Environmental Quality (ADEQ). ADEQ has set a deadline of 2015 for PCRWRD to comply with all new ammonia and nitrogen removal requirements at all the treatment facilities. To that end, PCRWRD commissioned the development of a Master Plan for future wastewater conveyance and treatment in the PCRWRD service area and a Capital Improvement Program (CIP) plan to achieve the removal requirements set by ADEQ.

The Pima County Regional Optimization Master Plan (ROMP) forecasted the need for increased wastewater treatment capacity throughout the PCRWRD service area due to anticipated population growth, and the facilities required to meet those needs through the year 2030. One finding was that the Roger Road WRF would have insufficient capacity to accommodate additional flows in the near future. Therefore a major element of the conveyance evaluation was a detailed analysis of transferring flows from the Roger Road WRF to the Ina Road WRF by means of a Plant Interconnect. Other key features of the ROMP included upgrade and expansion of the Ina Road WRF from 37.5 MGD to 50 MGD, construction of a new 32 MGD water reclamation campus in the vicinity of the Roger Road WRF, construction of good neighbor facilities such as odor control structures, and the eventual decommissioning of the existing 41 MGD Roger Road WRF.

PROJECT BACKGROUND

The ROMP Plant Interconnect sewer line consisted of a 60-inch to 72-inch gravity sewer designed to transfer year 2030 peak wet weather flows of up to 145 MGD from the existing Roger Road WRF to the new Roger Road WRF, and 81 MGD from the future Roger Road WRF to the Ina Road WRF, Figure 1a. The Interconnect was designed for a service life of 100 years and consisted of a 5-mile alignment with two wash crossings, the Canada del Oro (CDO) near the Ina Road WRF and the Rillito River near the Roger Road WRF, Figures 1b.

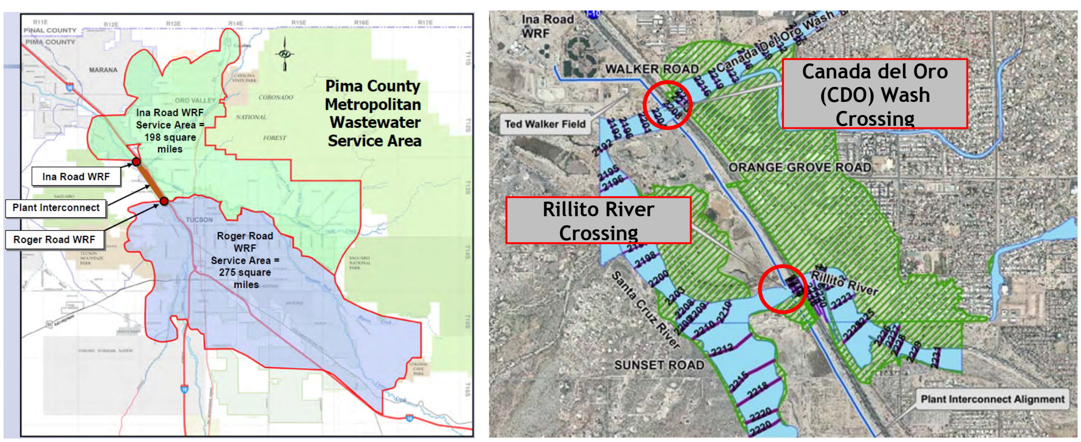

Figure 1a, b: Service Areas and Interconnect Location, Wash Crossing Locations

While centrifugally-cast fiberglass reinforced pipe was utilized for construction of the gravity sewer, ADEQ rule R18-9-E301 (D) 2.c. stated the following for the wash crossings: "*If sewer lines cross floodways, place the lines at least two feet below the 100-year storm scour depth and construct the lines using ductile iron pipe or pipe with equivalent tensile strength, compressive strength, shear resistance, and scour protection.*" (ADEQ 2001). Fiberglass pipe was ruled out for use in the crossings based on its inability to meet the equivalency requirements and ductile iron or an equivalent alternate pipe material was explored. This paper focuses on the selection of pipe material, design and construction of the wash crossings.

<u>Procurement Method</u>: The budget for the entire interconnect line was $41M. The regulatory-driven deadline was December 2010. Due to both a tight schedule and budget, the Construction Manager at Risk (CMAR) procurement method was selected over the traditional Design-Bid-Build (DBB). The intent was to have a tightly coordinated effort between the owner, contractor and engineer to quickly and efficiently design and explore the most cost effective alternative to install the pipeline within the required timeframe. The selected Project Engineer was Brown and Caldwell who had previously completed a study of the possible alignment routes for the Plant Interconnect and was familiar with the project requirements. The selected Construction-Manager-at-Risk was the Sundt-Kiewit Joint Venture, who possessed extensive experience in similar large pipeline installations. Don Kelly Construction, Inc. was selected as the pipeline installation contractor for the mainline and siphon crossings through an installation sub-contractor bid process.

<u>Stimulus Funding</u>: The Plant Interconnect project also received the maximum amount offered under the ARRA rules for Arizona with a $2M grant and $8M low interest loan through the State Water Infrastructure Finance Authority (WIFA). The use of the ARRA funded grant and loan meant the project contractors and suppliers would have to comply with Federal "Buy American" and "Davis-Bacon Act" requirements.

WASH CROSSING DESIGN OPTIONS

The crossing of washes, as with all waters of the US, is a complex design exercise where the owner's performance requirements needed to be considered along the regulatory requirements set by Federal and State agencies. On the ROMP wash crossing segment, this included:

- 100-year service life
- Meeting all regulatory requirements of
    a. US Army Corps of Engineers (COE) 404 Requirements
    b. ADEQ 401 Requirements and Design guidance
- Low maintenance requirements
- Low risk of failure due to scour
- Meeting project budget requirements

Section 404 of the Clean Water Act regulates the discharge of dredged, excavated, or fill material in wetlands, streams, rivers, and other U.S. waters. The U.S. Army Corps of Engineers is the federal agency authorized to issue Section 404 Permits for certain activities conducted in wetlands or other U.S. waters. Depending on the scope of the project and method of construction, certain farming activities may require this permit. Examples include ponds, embankments, and stream channelization. With this guidance, three crossing design alternatives were evaluated:

1. <u>Single Barrel Siphon with an At-Risk Gravity Line</u>: Evaluation of this alternative determined that it would require increasing the pipe size and deeper burial depths along the main interceptor. Both items would have added to construction costs, resulting in an overall project construction cost in excess of the available budget. Additionally, due to an extremely mild slope entering the Ina Road WRF, backwater would remain in the pipeline. Finally, a COE 404 permit would have pushed the schedule past the regulatory driven completion date, which could have potentially resulted in long-term operational issues for PCRWRD Staff. This alternative was therefore abandoned.

2. <u>Gravity Line Only with Grade Stabilization Structure</u>: This alternative, like the previous one, would require increasing the pipe size and burial depths along the main

interceptor, once again adding to construction costs. Another added cost would have been the design and construction of stabilization structures at each crossing. Backwater from the Ina Road WRF would also remain in the pipeline. And once again, a COE 404 permit would have pushed the schedule past the regulatory driven completion date. This alternative, too, was abandoned.

3. Multi-Barrel Siphon: With this alternative, though deeper depths would be needed at the two crossings, the pipe diameters could be reduced (6-in to 12-in smaller) and the remainder of the main interceptor would have shallower depths. After consultations with the Construction Manager at Risk, it was determined that this alternative could be designed and constructed within budget.

NAVIGATING REGULATORY CHALLENGES

The design approach for the wash crossings started by first exploring the options that would provide the most efficient and lowest maintenance solutions. A gravity sewer would provide this, as well as the lowest odor control mitigation requirements. The submittal of the Final Scour Evaluation, however, verified that while the gravity sewer with an at-grade control structure was feasible, its impact on the bank floor downstream of the pipe structure would be such that the depth of the existing bank protection toe-in would have to be increased by 3-ft to 6-ft in depth for a length of 200-ft on each side of the bank protection for both crossings. This additional work would have likely required a full COE 404 permit package as well as an estimated additional $1M bank protection work.

Due to the US Supreme Court ruling that redefined the term "Navigable Waters of the United States," known as the Rapanos Decision, published prior to the design of the Interconnect, the EPA and the COE were at odds as to their respective areas of responsibilities (Supreme Court of the United States 2006). COE 404 permit reviews had come to a halt pending further clarification by the Court or the EPA/COE Headquarters. After various meetings with the Tucson office of the COE to establish a Jurisdictional Delineation for the Santa Cruz River, and to use it as the basis for the 404 permit package, it was evident that pursuing the gravity option would not allow for the timely completion of the project.

The Tucson office of the COE did offer the alternative that the wash-crossings could use the Nationwide Permit (NWP) 12 as long as the bank was returned to its original state, and the construction stayed below the Pre-Construction Notification (PCN) thresholds, which included:

- that post construction disturbance be less than 1/10-acre
- that the utility be limited to less than 500 feet in length in Waters of the U.S.

The gravity sewer crossing option was therefore abandoned and the design of a siphon crossing was selected as the best alternative for the project.

DETERMINATION OF DESIGN PARAMETERS

Along with a 100-year service life goal and the project construction budget, one of the main factors driving the selection of the siphon crossing option was the ability to avoid triggering any requirement for a COE 404 Permit or Arizona 401 Certification. The intent was to design the wash-crossing pipelines and structures such that the post construction land disturbance would be less than 1/10 acre and that each wash-crossing length of approximately 400-ft was within the maximum allowable disturbance length of 500-ft.

The Engineer's sub-consultant, Tetra Tech, performed a scour analysis for the Rillito River and the CDO Wash Crossings that evaluated the maximum scour potential to be expected at each crossing. Tetra Tech's report found the following:

- Maximum scour potential depth for each crossing is approximately 23 to 25 feet.
- Recommended burial depth, providing for a factor of safety, is set at 30 feet below the wash channel.
- Where bank protection does not currently exist, extend the pipeline at the recommended burial depth for a length of 200 feet beyond the bank.

With these minimum parameters thus established, the Engineer proceeded with the design of the crossings.

SIPHON MATERIAL SELECTION

During the early material selection process for the siphon crossings, DIP, High Density Polyethylene (HDPE) pipe and WSP were evaluated. Current ADEQ rules call for the use of DIP for all wash crossings. Any alternate pipe material would need to have equal or better physical/mechanical properties (tensile strength, compressive strength, shear resistance, and scour protection) as DIP and also have restrained joints.

While HDPE provided some cost advantages, concerns about post-installation floatation of the pipe, the desire for ease of installation by the open cut installation method, and the ADEQ requirements for equivalent physical/mechanical properties as DIP narrowed the selection process to DIP and WSP. Prior to this project, the PCRWRD had had no experience with the use of WSP in their system.

A due diligence process was quickly established to review the steel pipe material's physical/mechanical properties and track record in which both the Department Staff as well as the Engineer worked together and consulted public improvement specifications of nearby states such as California, Oregon, and Washington. Table 1 shows a comparison of DIP with WSP for the project.

Table 1: Properties of DIP versus WSP

Physical / Mechanical Properties	DIP (AWWA C151)	WSP (AWWA C200)
Tensile Strength	60,000 psi	60,000 psi
Yield Strength	42,000 psi	42,000 psi
Elongation	10 %	22 %
Thickness	0.410-inch	0.250-inch
Pressure Rating	150 psi	250 psi

In addition to all the physical/mechanical similarities and differences between the two materials, there would also be a significant weight difference between 20-ft sections of DIP and WSP. The DIP would weigh 3,765 lbs per 20 foot section while the WSP would weigh 2,350 lbs per 20 foot section.

Joint Selection: DIP is typically supplied with gasket-joints that are non-restrained. When required, DIP gasket-joints are restrained utilizing either lug-type external joint restraint systems, or by proprietary-type joints which incorporate a gasket and a restraint mechanism that is built into the joint. Steel pipe is also available with gasket-joints. When joint restraint is required, welded-joints are used in the appropriate locations. For the project's cathodic protection system, steel pipe with welded joints would provide an improved electrical connection, as compared to the cad-welded jumpers required for DIP. Steel pipe with welded joints was selected for the project.

COATING AND LINING SELECTION

The Engineer reviewed and compared various coating and lining systems for both the DIP and WSP. Five products were reviewed and compared, including:

- Sauereisen SewerGard™ Epoxy-No. 210
- Induron Protecto™ 401 Ceramic Epoxy
- LifeLast DuraShield™ 210 and 310
- Novocoat™ SP2000
- HJ3 Composite Tech WW-RFCOAT™

The products were evaluated for acceptability under the following standards:

- Pima County/City of Tucson 2003 Standard Specifications for Public Improvements (PC/COT 2003 SSPI)
- Uniform Standard Specifications for Public Works Construction Sponsored and Distributed by the Maricopa Association of Governments (MAG)
- Greenbook Standard Specifications for Public Works Construction
- Department of Ecology, State of Washington, Criteria for Sewage Works Design, Water Quality Program August 2008 ("ORANGE BOOK" for Washington State Sanitary Agencies).

A comparison of the physical properties of the five products is shown in Table 2. It was concluded that the Sauereisen SewerGard™ Epoxy-No. 210, LifeLast DuraShield™ 210 and Novocoat™ SP2000 would be acceptable systems to protect either DIP or WSP against the aggressive environments of the sanitary sewer line.

It should be noted that the values shown in Table 2 are "lab values" and not what can be expected in a production setting. Hence project specifications should follow AWWA standards and not be developed from lab values.

Based on the pipe manufacturer's experience with polyurethane lined and coated steel pipe, use of the DuraShield™ 210/310 polyurethane system was recommended for lining and coating on this project. This system is fully compliant with AWWA C222. Again, as part of their due-diligence, the Engineer directly consulted agencies with experience with polyurethane coated and lined steel pipe. This included the Los Angeles County Sanitation District in California, and the King County Wastewater Dept. in Washington. The latter had selected polyurethane coated and lined steel pipe for both influent and effluent pipelines in the $1.75B Brightwater Tunnel Project that included treatment, conveyance and outfalls. As part of their overall submittal package to the Engineer, the polyurethane manufacturer provided third-party testing documentation of all properties shown in Table 3. Additional testing was requested from the manufacturer to address County-specific sulfuric acid resistance limits.

Table 2: Comparison of Coating and Lining Systems to PC/COT SSPI Section 1010 Criteria

Standards	PC/COT 2003 SSPI Section 1010 Criteria	Sauereisen SewerGard™ Epoxy-No. 210	Induron Protecto 401™ Ceramic Epoxy ##	LifeLast: DuraShield™ 210 and 310	Novocoat™ SP2000	HJ3 Composite Technologies WW-RFCOAT ™
Nominal / Minimum Applied Dry Film Thickness (mils)	40 / 35 mils	210S – 60 mils 210G – 20 to 40 mils	401 – 60 mils	210 – 20 to 250 mils 310 – 20 mils	SP2000W – 40 to 250 mils SP2000R – 40 to 250 mils SP2000M – 40 to 250 mils	40-125 mil
ASTM D 2794 Direct Impact Resistance at 35 mil DFT	100 inch-pounds	210S – 42 in-lbs 210G – 42 –in-lbs	401 – 72 in-lbs tested per ASTM G14 (DIP)	210 and 310 per ASTM G14 (WSP) 210 – 180 in-lbs 310 – 120 in-lbs	SP2000W – 140 in-lbs SP2000R – 150 in-lbs SP2000M – 100 in-lbs	Data Not Available
Maximum Coating Weight Loss per ASTM D 4060 (CS-17 Wheel, 1000 gram / 1000 cycles)	300 milligrams	210S – 49 mg 210G – 49 mg	401 - 0.39 mg (H-18 Wheel)	210 – 69 mg 310 – 45 mg	SP2000W – 84 mg SP2000R – 38 mg SP2000M – 24 mg	Data Not Available
Minimum Adhesive Value IAW ASTM D 4541	2,000 psi	210S – Concrete failure 210G – Not determined for Steel Pipe or DIP	401 – 250-400 psi (DIP with Cement Mortar Lining)	210 – 2950 psi 310 – 2680 psi	SP2000W – > 2500 psi SP2000R – > 2500 psi SP2000M – > 2500 psi	Data Not Available
Maximum Weight Change after Immersion in 50% sulfuric Acid	1%	210S – 1% 210G – 1% 40% sulfuric acid, not 50%	Data Not Available	210 – 1% maximum 310 – 1% maximum	SP2000W – < 1% SP2000R – < 1% SP2000M – < 1%	Data Not Available

The Protecto 401 Ceramic Epoxy for the protection of DIP is not currently listed as an option in the Pima County / City of Tucson 2003 SSPI Section 1010. Though used extensively in the past, a ban was placed on the use of Protecto 401 in late 2007 after several defects were found in DIP lined with Protecto 401. Further investigation lead to the discovery that the lining system had limitations on pressure cleaning and mandrel testing.

NOTE: values shown in table are "lab values" and not what can be expected in a production setting --- project specifications should follow AWWA standards and not be developed from lab values.

Table 3: Third-Party Testing of Polyurethane

Standard	Test	Standard	Test
ASTM G6	Abrasive Wear	ASTM-D570	Water Absorption
ASTM-D4541	Tensile Adhesion (Pull Test)	ASTM-D2240	Hardness (durometer)
ASTM-G95	Cathodic Disbonding	ASTM-D149	Dielectric Strength
ASTM-D522	Flexibility (Mandrel)	ASTM-D6677	X-Cut Adhesion
ASTM-G14	Impact Resistance	ASTM-D412	Tensile Strength-Elongation
ASTM-D4060	Taber Abrasion Resistance	ASTM-D543	Chemical Resistance

ADEQ APPROVAL PROCESS

To expedite the ADEQ approval process and allow for construction to begin as scheduled, the DIP material option was specified in the Project Plans, but to allow for future flexibility in the final selection of a pipe material for the siphon crossings, the Engineer was asked to develop a specification for WSP to be included in the completed project specifications.

With the help of the Engineer and the steel pipe manufacturer, an "alternate pipe material" package was compiled for submission to ADEQ for their review and approval. The package included detailed documentation of all items discussed thus far. Approval was granted by ADEQ within a few weeks. Immediately upon approval, the procurement process proceeded for the purchase of over 2,300-ft of 42-inch polyurethane coated and lined WSP. During the approval process, construction of the main gravity sewer line was underway, ensuring that the project was kept on track.

COST COMPARISONS AND SAVINGS

The use of WSP instead of DIP would save the PCRWRD over $300,000 when material and installation costs were taken into account. Table 4 outlines pricing for various product options. This lower overall cost of the polyurethane coated and lined WSP was yet another justification for its selection.

Table 4: Product Pricing for Pipe Materials and Coating/Lining Systems

Pipe Material / Coating & Lining	Rillito Crossing	Canada Del Oro Crossing	Total Amount	Price Difference w/ Steel Pipe
Steel Pipe w/ DuraShield 210/310 Restrained (welded)	$321,305.00	$ 268,460.00	$ 589,765.00	
PC 150 DIP w/ SP2000, Restrained	$526,645.64	$ 487,081.78	$1,013,727.42	$ 423,962.42
PC 150 w/ DIP Protecto 401, Restrained (Price 1)	$534,705.95	$ 476,042.62	$1,010,748.57	$ 420,983.57
PC 150 DIP w/ Protecto 401, Restrained (Price 2)	$582,439.06	$ 517,515.65	$1,099,954.71	$ 510,189.71

Note: See Table 2 for details on DuraShield 210/310, SP2000, and Protecto 401 Linings & Coatings

DESIGN DETAILS

The project specifications for the WSP required that the pipe, fittings, connections and welding details be designed in accordance with AWWA C200, AWWA M11, ASME Section IX and AISI Volume 3, and also be stamped by a Registered Professional Engineer in the State of Arizona. The pipe manufacturer was required to provide a Registered Engineer's stamped verification that under the given design parameters, the pipeline's vertical deflection would remain within the allowable 3%. Design parameters are shown in Table 5.

Table 5: Wash Crossing Design Parameters

Design Parameters			
Pipe Outside Diameter, **OD**	42.5-inch	Max. Allowable Defl., $\mathbf{\Delta X_{al}}$	3 % (1.26-inch)
Wall Thickness, **t**	0.25-inch	Soil Density, **w**	120 lb/ft^3
Max. Height of Cover, $\mathbf{H_c}$	40-ft	Bedding Constant, **K**	0.1
Polyurethane Coating Thickness	25 mils	Deflection Lag Factor, $\mathbf{D_L}$	1.0
Polyurethane Lining Thickness	60 mils	Modulus of Soil Elasticity, **E'**	1800##

##per AWWA M11, Table 6.1 for >15-ft bury, at 95% compaction Standard Proctor

The predicted deflection of the wash crossings, based on the above design parameters and utilizing the Modified Iowa Equation per AWWA M11, was found to be 1.24-inch at 40-ft of soil cover, less than the 3% allowable deflection per specification. Since the height of cover for the pipe was 30 ft, the actual corresponding deflection was only 0.93-in. Also of note is that while the allowable deflection per project specifications was only 3%, the maximum allowable deflection per AWWA M11 would have been 5% since the steel pipe had both a flexible lining and coating. Selection of the 3% limit was therefore conservative. Finally, specification of the 60 mil thick polyurethane lining was also conservative as the recommended lining thickness per AWWA C222 is 25 mils.

CONSTRUCTION DETAILS

Don Kelly Construction, Inc. (Pipe Contractor) was selected as the pipeline installation contractor for the mainline and siphon crossings through an installation sub-contractor bid process. This ensured that the CMAR joint venture sought the best installation prices from contractors proficient in large sewer installations. Northwest Pipe Company supplied the polyurethane lined and coated steel pipe.

Figure 2 shows the profile drawing for the CDO wash crossing. Clearly, the challenges of construction can be seen: the parallel siphons would be buried to a depth of 30-ft below the channel grade. On the south side, the parallel pipes had to be laid first at a 20% slope, then transition to a steeper slope of 41%. On the north side, the pipe once again was laid at a steep slope of 20%. The alignments for the Rillito River crossing had very similar profile and design parameters.

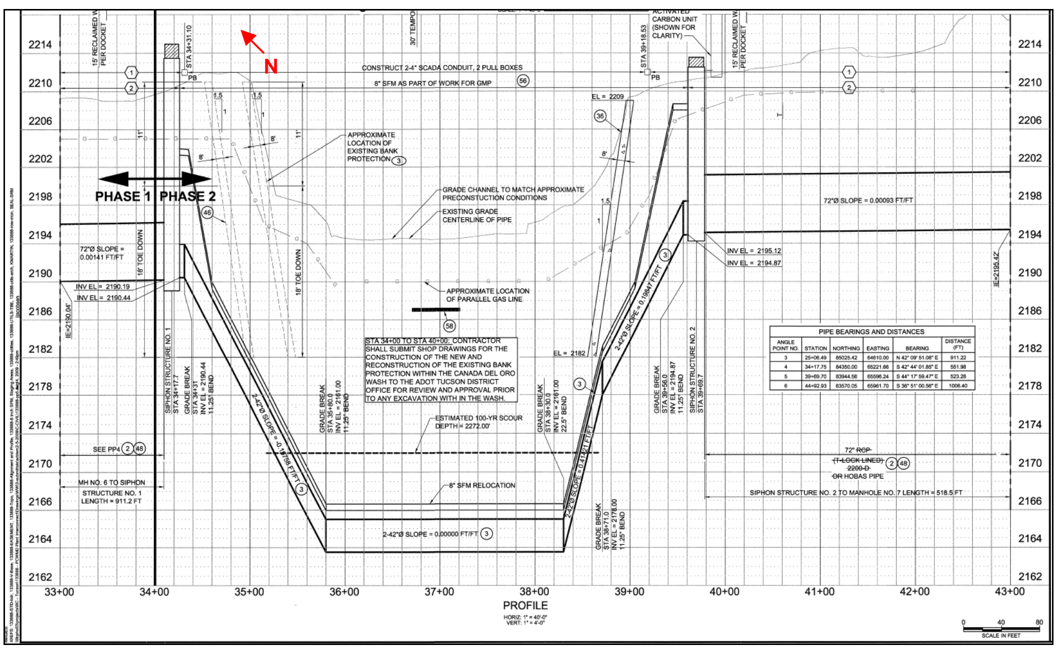

Figure 2: Profile Drawing of the Canada Del Oro (CDO) Wash Crossing.

The siphon outlet structures on the south end of both crossings were the first structures to be built. The Pipe Contractor elected to create a knock-out section in each structure face for future embedment of the steel pipe. For restraint, the steel pipe was manufactured with a wall ring for embedment. This method allowed the Pipe Contractor to best utilize construction space while moving in a south-to-north build direction.

An engineered shoring design was required due to the deep covers involved. The Rillito and CDO wash crossings were both under 30-ft top-of-pipe cover heights respectively. To accomplish this deep excavation, the Pipe Contractor used a Hitachi EX1200 and an 8 cubic yard bucket to perform a 20 foot deep rough-cut. This prepared the alignment for final trenching operations. A 24 foot long by 18 foot tall trench box was used during final excavation to shore up trench walls to protect crew personnel working in the area. When working in the deepest cover sections, a second trench box was stacked on top of the first.

Construction began on the Rillito siphon first, with pipe laying operations progressing in the south-to-north direction. The CDO siphon was also constructed in a south-to-north direction and with similar steel pipe slopes. Pipe sections were provided in 20 foot lengths, enabling the pipe to stay inside the trench box. Pipe was lowered into the trench with a fabric sling on the Hitachi excavator. Pipe joints were laid with the bell end incoming over the adjoining spigot. A tack weld was placed at the field top position on the joint once final alignment and grade were achieved. This was especially critical on up-slope and down-slope laying operations.

Joint Selection and Assembly: Double lap welded joints were selected for the siphon crossings, even though a single lap weld would have been adequate to meet design conditions. Double lap welds are typically specified in seismic prone areas or whenever high longitudinal forces are anticipated. On this project, double lap welded joints virtually eliminated the potential for raw sewage leakage in the future. Welding functions were sub-contracted out by the Pipe Contractor, and included both inside and outside welds, Figure 3a, as well as joint air testing. The air test in WSP is accomplished by pressurizing the minute void between the inside face of the bell joint and the outside face of the spigot joint. This ensures welds were performed without pin holes or defects. In an industry where welding costs are often seen as cost prohibitive or difficult to perform, this project was able to utilize double lap welds while saving money over the DIP option. A two-man crew was able to weld each joint and perform the air test in approximately 40 minutes.

Joint Installation: After welding was complete at each joint, a Canusa™ heat-shrink sleeve was applied to the exterior of the joint in accordance with AWWA C216, Figure 3b. The sleeve was wrapped around the pipe joint and heated with a portable propane heat source. The heated sleeve then shrank down to the pipe surface and completely encapsulated the joint from external moisture and dirt. Each sleeve took approximate 15 minutes to install. Like the polyurethane, the heat shrink sleeve serves as a dielectic exterior coating to protect those external regions of a joint where the polyurethane coating was not applied to allow for welding.

Backfilling Operation: Once the pipe joint was complete, backfill operations could begin. The backfill material used was #4 (4.8 mm) minus. This material was selected for its excellent lateral flow-ability and high e-prime (E') values that result when compacted to 95% Proctor Density. The ease of flow of the material is especially important to ensure sound support in the lower haunch region between the parallel pipelines as well as the haunch regions between the pipes and the trench walls. Placed into the trench using a 5 cubic yard bucket attached to the excavator, the backfill material was mechanically compacted as it reached the pipe's spring line. A vibratory plate tamper was used when space allowed, and "jumping jacks" in tighter work areas, Figure 3c.

Figure 3a, b, c: Joint Welding, Heat Shrink Sleeve Installation, Backfill Compaction

Interior Joint Patches: The north siphon inlet structures were cast once pipe laying operations were complete. This allowed the final section of pipe to be cast into the structure for restraint. With pipe installation complete, the 60-mil interior polyurethane lining was patched at the joints. Interior joint patch was necessary to coat the narrow section of pipe where the interior weld was performed. Workers entered the pipe from each end and performed their blast/abrade work before applying the polyurethane patching. This ensured a consistent lining thickness from siphon end-to-end without a decrease in lining thickness at the joint.

Field Modifications: Field modifications to maintain pipe alignment are necessary on most projects. During the construction of the Rillito crossing, it was found that both pipe barrels would need a 4-ft piece trimmed to get back on station. The Pipe Contractor was able to accomplish this task in less than 2 hours for both trim pieces, highlighting the versatility of a well engineered steel pipe system. Line was snapped and the steel pipe was cut circumferentially. A slight camphor was ground in the bell ID and spigot OD to remove burrs from the saw cut. The new holdback area was marked and the end was scored with a razor knife. A portable heat source was then used to direct heat specifically at the new holdback area. Heated polyurethane lining / coating from pipe ends were scraped. Any remaining paint on pipe surface was wire brushed.

CONCLUSION

The use of polyurethane coated and lined welded steel pipe in lieu of ductile iron pipe on the wash crossings of this project resulted in saving of over $300,000. In order for the Arizona Department of Environmental Quality to approve the substitution of ductile iron pipe, as specified in rule R18-9-E301 (D) 2.c, required that the alternate material have an equal to or better tensile strength, compressive strength, shear resistance, and scour protection than the DIP. All of these conditions were met by the WSP. The dielectric polyurethane coating and lining option met the stringent Pima County/City of Tucson 2003 SSPI Section 1010 Criteria and will complement the pipeline's cathodic protection system well to provide a minimum service life of 100 years. This first experience with the design and installation of WSP in the Pima County Regional Wastewater Reclamation Department's system has been a success and will serve as a model for future projects with similar challenging design parameters in the region.

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