Case History: Pima County Regional Wastewater Reclamation District

PCRWRD Information: The PCRWRD maintains a system consisting of 3300 miles of sewer lines, 230 miles of which includes major trunk lines or interceptors. There are 34 lift stations, 2 major treatment facilities in the metro area, and another 8 smaller treatment facilities in the non-metro area.

The ROMP Initiative: The Regional Optimization Master Plan (ROMP) program forecasts the needs of the system through 2030. 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 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 ROMP Plant is valued at $720 million and includes the following major projects:

- Expand Ina Road WRF to 50 mgd (from 37.5 mgd)
- Construct new 32 mgd Water Reclamation Campus (in vicinity of existing Roger Road WRF)
- Plant Interconnect – 36 mgd average, 81 mgd peak flow
- Good neighbor facilities
- Decommission existing 41 mgd Roger Road WRF
- Meet growth needs to year 2030

The presentation focused on a specific portion of the Plant Interconnect Project, a 5-mile pipeline consisting of 60-inch and 72-inch pipe. Two wash-crossings that were a part of this line consisted of the use of 42-inch polyurethane coated welded-joint welded steel pipe (WSP). This was the primary focus of the presentation. The Plant Interconnect had a budget of $41 million.

Procurement Method: The Engineer on this project was Brown and Caldwell. The Contractor was the Sundt-Kiewit joint venture. The procurement method for the project was Construction Manager at Risk (CM@R), instead of the traditional design-bid-build process. This allowed for a tightly coordinated effort between the Owner, Contractor and Engineer to quickly and efficiently explore and design the most cost effective alternative to install the plant interconnect pipeline.

Design Selection for the Wash Crossings: Aims of the Wash Crossings design and construction included the following:

- 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

Several options were considered for the wash crossings, and the final solution was to construct a multi-barrel siphon (two parallel 42-inch pipelines). While this resulted in high depths of bury for the siphon, it allowed for the use of pipe diameters that were 6-inch to 12-inch smaller than the diameters needed on the other design options, and also allowed for shallow burials of the remainder of the main interceptor line, and most importantly, allowed for the construction to remain within budget.

Pipe Material Selection: For Wash Crossings, the ADEQ required the use of only ductile iron pipe (DIP) with restrained joints, or pipe with equivalent tensile strength, compressive strength, shear resistance, and scour protection. Materials considered by the Owner and Engineer included DIP, WSP, and high density polyethylene (HDPE). Fiberglass pipe (FRP) was not considered because its physical/mechanical characteristics did not compare favorably to those of DIP. HDPE was removed from the list due to the myriad of installation issues that make it unique when compared to other traditional materials such as DIP and WSP.

The key to using an alternate material in lieu of DIP would be to first prove to the ADEQ that the alternate material is as good as or better than DIP for the application, then to receive formal approval from ADEQ. To this end, a formal package was submitted to ADEQ by the Owner, the contents of which were discussed in this presentation.

Physical/Mechanical Comparison of DIP to WSP: The table below provides a summary of the comparisons between DIP and WSP.

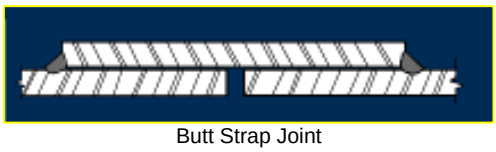
Physical / Mechanical Properties	DIP (AWWA C151)	WSP (AWWA C200)
Tensile Strength	60,000 psi	60,000 psi
Yield Strength	42,000 psi	42,000 psi
Elongation	10 %	22 %
Thickness	0.410-inch	0.250-inch
Pressure Rating	150 psi	250 psi

The wall thickness for the steel pipe considered was much more conservative than was needed, as can be seen from the pressure rating of the pipes. But since this was the Owner's first consideration for the use of steel pipe in their system, this approach was taken. From the table presented above, clearly, the WSP was an equal to the DIP.

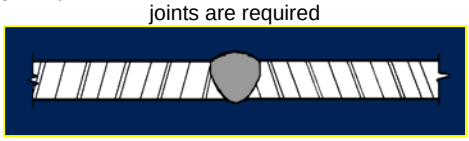
Joint Selection: 42-inch diameter steel pipe could be supplied with a variety of joint types, including bell-and-spigot gasket-sealed joint, welded joint, and other configurations, some of which are shown below. Since restrained joints were needed on this project, steel pipe with lap welded joints was selected. The DIP could be supplied with gasket-joints restrained with either lug-type external joint restraint hardware, or by proprietary-type joints which incorporate a gasket and a restraint mechanism built into the joint.

Rolled-grove Gasket-sealed Joint

Single Lap-welded Joint, recommended when restrained joints are required



Butt Strap Joint



Single Butt-welded Joint, recommended in applications where pressures are in excess of 400 psi

Coating and Lining System Selection: For both DIP and WSP, the Engineer conducted a thorough survey of various coating and lining options. Existing Standards consulted for this purpose included the following:

- 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).

The table below summarizes all six of the products considered and their essential properties:

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.

The Manufacturer of the steel pipe, Northwest Pipe Company, recommended the LifeLast, Inc. polyurethane system as their preferred choice. Many miles of polyurethane coated and lined steel pipe have been placed into service to date.

The manufacturer of the polyurethane, LifeLast, Inc. was required to provide the Owner and Engineer with third party testing of their product to prove compliance with **AWWA C222**, *Standard for Polyurethane Coatings for the Interior and Exterior of Steel Water Pipe and Fittings*. This information included:

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

Additionally, LifeLast, Inc. had to supply information on the maximum weight change of the product after immersion in 50% sulfuric acid, something that is not required by AWWA C222 but was a requirement of the Owner and Engineer based on the Pima County/City of Tucson 2003 Standard Specifications for Public Improvements (PC/COT 2003 SSPI)

Cost Comparison of DIP Option Versus WSP Option: The table below shows costs comparisons of the pipe material options considered. On this project, a savings of $320,000 was realized in material and installation costs by using the WSP with polyurethane coating and lining.

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

Final Pipe Material Selection and Approval: Based on the information presented thus far, the Owner selected the use of WSP for the wash crossings instead of DIP, which was approved by the ADEQ.

Northwest Pipe Company's Polyurethane Capabilities: Northwest Pipe Company's plants are equipped with all necessary equipment for the application of polyurethane coating and lining systems when specified for a project. The company has made considerable equipment investments in order to provide cost-effective capabilities to meet market requirements for high tech corrosion resistant materials such as polyurethane. This includes:

- Internal blast equipment that prepares the pipe surface to SSPC-SP10/ NACE No. 2 requirements.
- Equipment for the spraying on the pipe's lining
- Equipment for spraying on the pipe's coating
- Equipment for hand-spraying polyurethanes on fittings and other appurtenances

Blast Equipment for Surface Preparation

Polyurethane Spray-on Systems for Pipe Lining

Polyurethane Spray-on Systems for Pipe Coating

Each ISO-certified facility follows application procedures established by Northwest Pipe Company's quality policy in accordance with Manufacturer's recommendations. Over 700,000-ft (130+ miles) of pipe has been lined by the Company since 2000, which equates to over 85,000 tons of steel.

Polyurethane Specifiers: A partial list of polyurethane coated and lined steel pipe Specifiers is provided below.

- Cascade Water Alliance, WA, Central Utah Water Conservancy District, City of Ottawa, ON, City of Tacoma, WA, City of Virginia Beach, VA, Colorado River Water Conservation District, US Army Corps of Engineers, Denver Water Board, Des Moines Water Reclamation Authority, El Paso Water Utilities, Everett Public Works, WA, King County, WA, Metro Vancouver (Formerly GVRD), BC, Metro Wastewater Reclamation District, CO, Northern Colorado Water Conservancy District, San Francisco Public Utility Commission, Southern Nevada Water

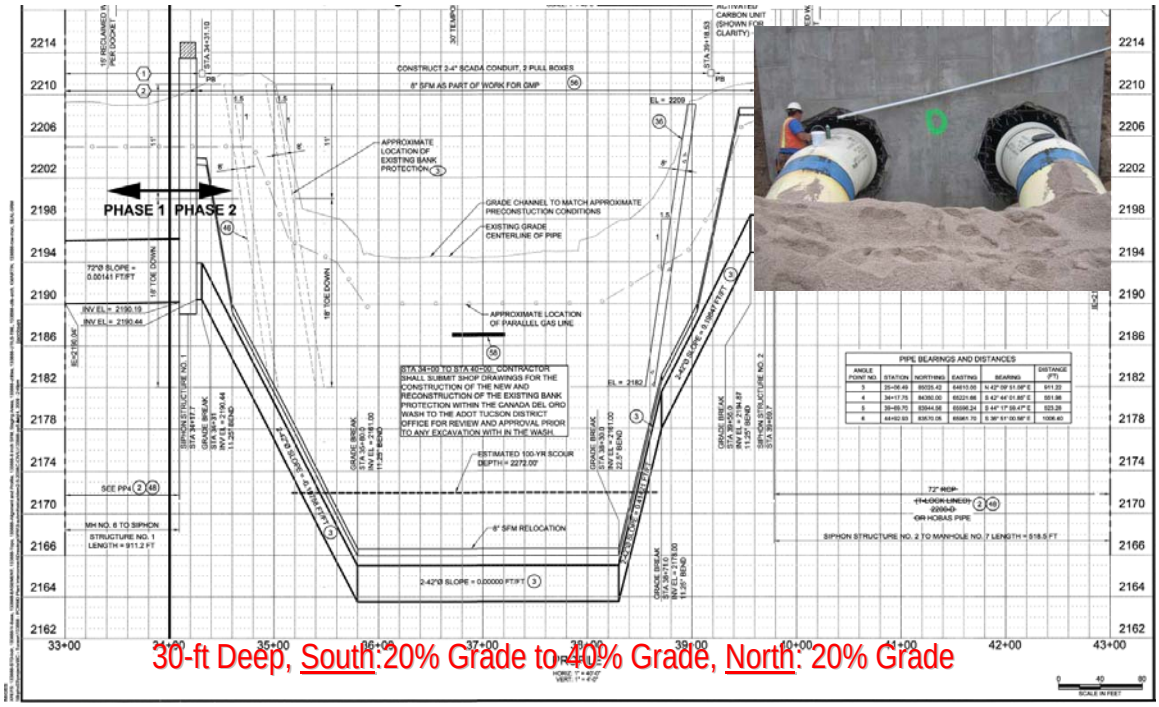
Authority, Tacoma Public Utilities, WA, Tennessee Valley Authority, Washington County Water Conservancy District, UT

Project Design Details: The table below presents parameters for the steel pipe that was used on the project.

Design Parameters			
Pipe Outside Diameter, **OD**	42.5-inch	Maximum allowable Deflection, ΔX_{al}	3 % (1.26-inch)
Wall Thickness, **t**	0.25-inch	Soil Density, **w**	120 lb/ft^3
Maximum Height of Cover, H_c	40-ft	Bedding Constant, **K**	0.1
Polyurethane Coating Thickness	25 mils	Deflection Lag Factor, 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.



The profile drawing above is that of the Canada Del Oro wash crossing. The unusually steep grades and depth of bury highlight the complexities of the construction of the steel siphons on the project. The Rillito River wash crossing had similar parameters.

Field Construction Issues: The joints of the pipe, as already stated, were lap welded. After completion of the welding, the "holdback" areas of the pipe in the vicinity of the welded joints, which were not externally coated by the polyurethane, were fitted with heat-shrink sleeves. Internally, the holdback areas were cleaned, then blasted by trained workers, following which polyurethane was sprayed on. This ensured that the bare steels were both internally and externally lined and coated following joint assembly.

Joints being welded, heat-shrink sleeves

In one segment of the project, two of the parallel siphons had to be trimmed 4-ft to bring the line back into station. This was accomplished using the following steps:

1. Pipe cut circumferentially
2. Remove burrs from saw cut
3. New holdback area marked and scored w/ knife
4. Heat applied on polyurethane in holdback area, then polyurethane lining and coating scraped off
5. Remaining paint wire brushed off

CONCLUSION

This is a summary of the use of polyurethane coated and lined welded steel pipe in the ROMP Plant Interconnect project currently being built by the Pima County Regional Wastewater Reclamation District. It highlighted project details, selection of WSP in lieu of DIP, selection of appropriate joint types, selection of polyurethane as the coating and lining system, and construction and installation issues. If there are any questions, please forward them to:

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