Whale Rock Dam –Pipeline Replacement Study

City of San Luis Obispo

Alternative Analysis Report

January 2, 2025

This page is intentionally left blank.

Contents

1 Purpose 1
2 Background 1
3 Design Considerations 6
3.1 Geotechnical 6
3.2 Mechanical 6
3.2.1 Replacement Pipeline Material 6
3.2.2 Rehabilitation Pipeline Material 6
3.2.3 Pipe Pressure 7
3.2.4 Appurtenances 7
3.2.5 Methodology 7
3.2.6 Opinion of Probable Construction Cost (OPCC) 8
4 Alternatives 9
4.1 Alt 1: Do Nothing 9
4.2 Alt 2: Golf Course Pipeline Project 10
4.3 Alt 3: Replace All Broken Bar Wraps & Localized Cylinder Wall Loss 12
4.4 Alt 4: Alt 3 + Broken Bar Wrap 12
4.5 Alt 5: Alt 4 + Localized Cylinder Wall Loss 13
4.6 Alt 6: 100% Pipeline Replacement 13
4.7 Discussion 14
4.8 Summary 14
5 Recommendation 15
6 References 15

Figures

Figure 1. Pure Technologies pipeline inspection limits 1
Figure 2. Pipeline as-built drawing overlaid onto Google Earth to approximate pipeline alignment 8
Figure 3. Approximate pipeline alignment and appurtenance location recreated in Google Earth 8
Figure 4. Relationship between historical break count and future performance 10
Figure 5. Golf course pipeline project 11
Figure 6. Sample sketch of pipeline replacement section with broken pipeline identified with red "X". The intermediate and end pipeline sticks will be replaced in addition to the broken pipelines. 11
Figure 7. Pipeline installed in paved road schematic A-3
Figure 8. Pipeline installed in unpaved road schematic A-4
Figure 9. Whale Rock Pipeline MS Excel hydraulic analysis spreadsheet for analyzing hydraulic performance with potential reduced pipeline inside diameters B-1
Figure 10. Pipeline alignment and elevations from Google Earth B-2
Figure 11. Whale Rock Pipeline hydraulic analysis results in graphical format. 30-IN ID blue line represents original pipeline. 25-IN ID with 30-IN OD red line represents 100% length structural CIPP rehabilitation. 20-IN ID with 24-IN OD green line represents 100% length

structural HDPE pipeline slip lining. 15-IN ID with 20-IN OD yellow line represents 100% length structural HDPE pipeline slip lining. B-3

Tables

Table 1. Summary of pipeline materials, lengths, and lengths between stops 2
Table 2. Summary of pipeline defects 3
Table 3. AWWA C-303 BWP broken bar wrap, quantity 10 4
Table 4. Localized cylinder wall loss, quantity 15 4
Table 5. AWWA C-303 BWP broken bar wrap and localized cylinder wall loss, quantity 5 4
Table 6. Localized Anomalies Different than Broken Bar Wraps and Cylinder Wall Loss, quantity 6 5
Table 7. Less certainty, quantity 22 5
Table 8. Pipeline material EULs 9
Table 9. Pure Technologies identified broken bar wrap and localized cylinder wall loss at golf course 11
Table 10. Pipeline replacement priority 12
Table 11. Pure Technologies identified broken bar wrap and localized cylinder wall loss for Alternative 3 12
Table 12. 100% pipeline replacement as a function of total replacement years 13
Table 13. Pipeline replacement alternatives summary 14
Table 14. Pipeline installed in paved road per linear foot A-3
Table 15. Pipeline installed in unpaved road per linear foot A-4
Table 16. Alternative OPCC summary A-5
Table 17. Alt 2: Golf Course Pipeline Project OPCC A-6
Table 18. Alt 3: Replace All Broken Bar Wraps and Localized Cylinder Wall Loss OPCC A-7
Table 19. Alt 4: Alt 3 + Broken Bar Wrap OPCC A-8
Table 20. Alt 5: Alt 4 + Localized Cylinder Wall Loss OPCC A-9
Table 21. Alt 6A: 100% Pipeline Replacement minus Alt 3 OPCC A-10
Table 22. Alt 6B 100% Pipeline Replacement OPCC A-11
Table 23. 30-IN diameter pipeline reduced flow rates, velocities, and TDHs B-5
Table 24. HDPE IPS Pressure Pipe DR and diameters for slip lining B-5

Appendices

Appendix A. OPCC A-1
Appendix B. Hydraulics Analysis B-1

1 Purpose

The purpose of the alternative analysis report (report) is to describe potential projects to replace and/or rehabilitate the aging Whale Rock Dam Pipeline (pipeline) infrastructure. Six (6) alternates are provided with their opinion of probable construction costs (OPCC), and timeline (immediate, intermediate, and/or extended).

2 Background

The 30 IN pipeline was installed in 1959, 65 years old, and conveys raw water from Whale Rock Reservoir to the San Luis Obispo Treatment Plant for a total distance of approximately 16 miles northeast of San Luis Obispo, California, Figure 1. The pipeline is owned by the Whale Rock Commission (Commission), consisting of the California Polytechnic State University (Cal Poly), California Men's Colony, and the City of San Luis Obispo (City).

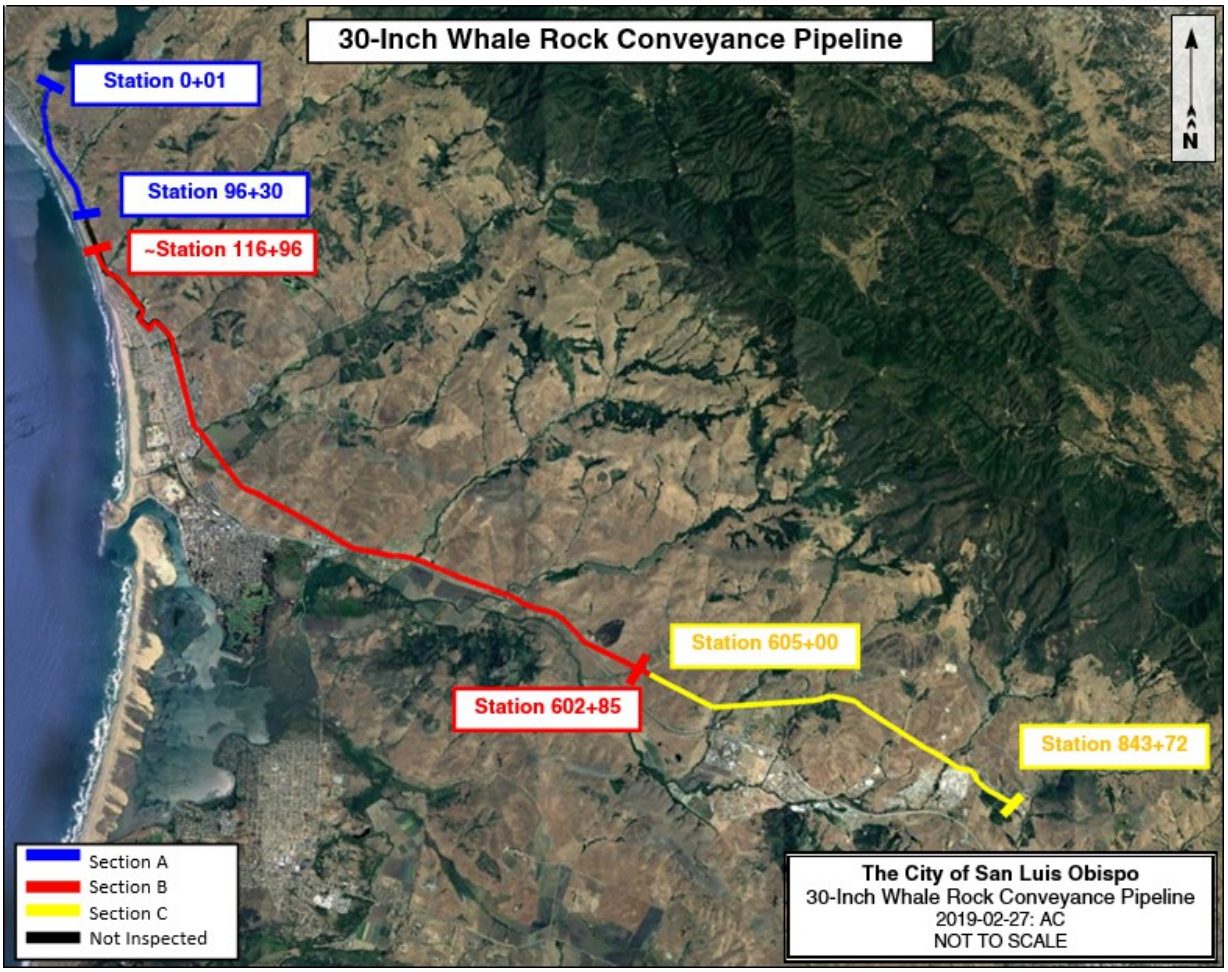

Figure 1. Pure Technologies pipeline inspection limits

The pipeline is comprised of two pipeline materials:

- AWWA M11 welded steel pipeline (WSP) at approximately 18,321 FT or 21.9% of total length; and
- AWWA C-303 bar wrapped concrete cylinder pipeline (BWP) at approximately 65,523 FT or 78.1% of total length

Due to the pipeline age, the City procured Pure Technologies, a Xylem brand, in October 2018 to conduct pipeline non-destructive interior testing with 99.0% tested, Table 1. Pure Technologies' free-swimming electromagnetic inspection platform robot inspected, located, and identified pipe sections with broken bar wraps, localized cylinder wall loss, broken bar wraps and localized cylinder wall loss, and other anomalies not aforementioned.

Table 1. Summary of pipeline materials, lengths, and lengths between stops

Section	Pipe Material	Start Station	End Station	Distance (Mile)
A	BWP, 30-IN	0+01	96+30	1.83
Pump Station	Unknown	96+30	116+96	0.39
B	Steel, 30-IN	116+96	227+00	2.34
	BWP, 30-IN	227+00	295+05	1.29
	Steel, 30-IN	295+05	313+00	0.34
	BWP, 30-IN	313+00	387+46	1.42
	Steel, 30-IN	387+46	402+05	0.28
	BWP, 30-IN	402+05	559+30	2.98
	Steel, 30-IN	559+30	579+00	0.38
	BWP, 30-IN	579+00	602+85	0.45
Pump Station	Unknown	602+85	605+00	0.04
C	BWP, 30-IN	605+00	843+72	4.51
Total Distance				15.82 (inspected) 16.25 (total length)

Note(s):

1. The piping portions of the pump stations were not inspected.

From Pure Technologies' Pipeline Condition Assessment Report Appendix B, Pure Technologies' inspection platform accuracy decreases and uncertainties increase with the following occurrences:

- Change in pipeline; and
- Electromagnetic data noise

Additionally, Pure Technologies results did not quantify the following:

- Wall loss depths; and

- Quantity of broken bar wrap per pipeline stick

Lastly,

- In 2021, City replaced approximately 60-FT of pipeline near STA 368+35 due to corroded cylinder wall failure. This defect was not detected by Pure Technologies in 2018;
- In 2023, City replaced approximately 17-FT of pipeline at STA 583+64 due to failed bar-wrapping. This defect was detected by Pure Technologies in 1998; and
- Pure Technologies inspection is six years old and out of date. Pure Technologies recommends an inspection frequency of every five years

Table 2. Summary of pipeline defects

Number of Pipe	Include Uncertainties	Include Uncertainties
Inspected	100%	83,844 FT
w/ Broken Bar Wraps	0.19%	160 FT
w/ Localized Cylinder Wall Loss	0.57%	481 FT
w/ Broken Bar Wraps and Localized Cylinder Wall Loss	0.19%	160 FT
w/ Localized Anomalies Different than Broken Bar Wraps and Cylinder Wall Loss	0.36%	301 FT
w/ less certainty due to flow changes	0.80%	671 FT
Pump station sections (no data)	2.72%	2,281 FT
Number of Total Defects (excluding PS sections)	2.11%	1,773 FT

Adjusted for uncertainties and uninspected in Table 2, the total pipeline uncertainty is approximately 1,773 FT or 2.11% of the pipeline. However, because of the undetected STA 368+35 pipeline failure, the actual uncertainty might be higher than 2.11%. Therefore, HDR has the following disclaimers:

1. HDR's analysis is based on Pure Technologies October 2018 inspection and assumes the following:
    a. 2018 data as-is is accurate in 2024
    b. The pipeline has not experience additional deteriorations since October 2019
2. Pipeline hydraulic transient, water hammering, pressure fluctuations, surge pressures, thrusts, etc. are not issues;
3. Seismic events / earthquake ground shaking resulting in pipeline failures are not issues;
4. No bypass or backup will be required during pipeline replacement and/or rehabilitation; and
5. No environmental or culturally sensitive areas in the pipeline alignment for pipeline replacement and/or rehabilitation due to previous ground disturbance

The pipeline defects from Table 2 are further summarized in Table 3 to Table 7.

Table 3. AWWA C-303 BWP broken bar wrap, quantity 10

Ref #	Piece #	Start STA	Stop STA	PL L (FT)	PL Mat	Reported Class	Break Positional Range (FT from Start STA)
36	93	11+04	11+36	32	BWP	230	15.0-18.0
2511	1056	583+64	583+96	32	BWP	320	5.5-8.5
3262	737	686+59	686+90	32	BWP	340	6.5-8.5
3263	736	686+90	687+22	32	BWP	320	2.5-6.0
3264	735	687+22	687+54	32	BWP	340	2.5-5.5; 11.5-14.5
3266	733	687+86	688+18	32	BWP	340	3.5-5.5
3496	504	759+63	759+95	32	BWP	230	2.0-4.0
3545	455	774+58	774+89	32	BWP	230	2.5-4.0
3649	350	806+79	807+11	32	BWP	230	22.0-25.0
3662	337	810+93	811+25	32	BWP	230	22.5-27.0

Table 4. Localized cylinder wall loss, quantity 15

Ref #	Piece #	Start STA	Stop STA	PL L (FT)	PL Mat	Reported Class
279	2044	87+71	88+03	32	BWP	230-B
1085	N/A	145+87	146+23	36	STEEL	N/A
1087	N/A	146+58	146+94	36	STEEL	N/A
1189	N/A	176+82	177+17	36	STEEL	N/A
1414	160	237+00	237+32	32	BWP	380
1501	1959	264+53	264+85	32	BWP	400
1508	1952	266+77	267+09	32	BWP	400
1532	1928	274+44	274+76	32	BWP	380
1775	1736	351+91	352+08	17	BWP	230
2480	N/A	573+31	573+66	36	STEEL	N/A
3061	936	622+91	623+23	32	BWP	460
3066	932	624+18	624+50	32	BWP	480
3067	931	624+50	624+82	32	BWP	480
3068	930	624+82	625+14	32	BWP	480
3260	739	685+95	686+27	32	BWP	340

Table 5. AWWA C-303 BWP broken bar wrap and localized cylinder wall loss, quantity 5

Ref #	Piece #	Start STA	Stop STA	PL L (FT)	PL Mat	Reported Class
3262	737	686+59	686+90	32	BWP	340
3263	736	686+90	687+22	32	BWP	320
3264	735	687+22	687+54	32	BWP	340
3266	733	687+86	688+18	32	BWP	340
3496	504	759+63	759+95	32	BWP	230

Table 6. Localized Anomalies Different than Broken Bar Wraps and Cylinder Wall Loss, quantity 6

Ref #	Piece #	Start STA	Stop STA	PL L (FT)	PL Mat	Reported Class
194	2128	60+70	61+02	32	BWP	230-B
241	2082	75+71	76+03	32	BWP	230-B
3034	963	615+40	615+72	32	BWP	400
3437	563	741+59	741+91	32	BWP	240
3464	N/A	749+88	750+29	41	STEEL	N/A
3523	477	767+89	768+21	32	BWP	300

Table 7. Less certainty, quantity 22

Ref #	Piece #	Start STA	Stop STA	PL L (FT)	PL Mat	Reported Class
3397	603	728+89	729+21	32	BWP	230
3398	602	729+21	729+53	32	BWP	230
3541	459	773+31	773+62	32	BWP	230
3542	458	773+62	773+94	32	BWP	230
3543	457	773+94	774+26	32	BWP	230
3715	284	826+50	826+82	32	BWP	230
3716	283	826+82	827+14	32	BWP	230
3738	261	833+86	834+17	32	BWP	230
3739	260	834+17	834+49	32	BWP	230
3740	259	834+49	834+81	32	BWP	230
3741	258	834+81	835+13	32	BWP	230
3742	257	835+13	835+45	32	BWP	230
3743	256	835+45	835+77	32	BWP	230
3744	255	835+77	836+09	32	BWP	230
3745	254	836+09	836+41	32	BWP	230
3746	253	836+41	836+73	32	BWP	230
3747	252	836+73	837+05	32	BWP	230
3748	251	837+05	837+37	32	BWP	230
3749	250	837+37	837+44	9	BWP	230
3750	249	837+44	837+67	32	BWP	230
3751	248	837+67	837+89	23	BWP	500
3752	247	837+89	838+21	32	BWP	500

3 Design Considerations

3.1 Geotechnical

No geotechnical data was provided to support the pipeline alternative analysis. The assumption will be to rehabilitate or replace the pipeline existing alignment potentially reducing the need for geotechnical data. For pipeline replacement, bedding and pipeline embedment material will be imported, and excavated soil will be used for trench backfill. To minimize environmental impacts, the trenches will be excavated vertically with the use of trench boxes. For rehabilitation, the launch and receiving pits be shored with sheet piles, which will be specified by the designers and designed by the contractor's shoring sub. The pipeline is installed in paved and unpaved areas and the condition of the surface will be replaced to its original condition.

3.2 Mechanical

3.2.1 Replacement Pipeline Material

Based on discussions with the City, BWP is not a preferred material for the new pipeline segments based on maintenance and replacement issues. The following materials are potential replacement alternatives:

- WSP with cement mortar lining and coating. Cement mortar will be applied in the field at all joints on the interior and exterior of the pipe;
- Plastic without additional cathodic protection. Use of plastic pipe would potentially cause discontinuities in the existing cathodic protection system requiring bridging of the currents; and
- Ductile iron pipeline (DIP) with cement mortar lining and coating. DIP has better corrosion protection and material costs but heavier than WSP. Additionally, DIP has an intrinsic +100 pound per square inch (PSI) surge protection over its pressure class

The new pipeline material internal diameter should be equal or greater than the existing 30-IN diameter. A 30-IN nominal diameter plastic pipeline will have an inside diameter smaller than 30-IN potentially effecting hydraulic performances negatively. WSP is more costly than DIP for similar performance. Therefore, DIP was selected as the alternative analysis pipeline replacement material. However, the other replacement materials can be selected during design.

3.2.2 Rehabilitation Pipeline Material

Pipeline rehabilitation requires the original pipeline as the host. Rehabilitation can either be liner or structural type. Rehabilitation requires bonding to the host pipeline. Rehabilitation liner is thinner requiring the host pipeline to be structurally sound. A structural rehabilitation is thicker, becomes the structural member, and utilized when the host pipeline is corroded, cracked, broken, and/or otherwise structurally compromised with the host pipeline acting as the conduit to install the structural liner. The following materials are potential rehabilitation alternatives for non-structural liners and full structural rehabilitation:

- Cured-in-place pipe (CIPP) for structural and non-structural rehabilitation

- Slip-lining for structural and non-structural rehabilitation
- Close-fit lining / die-draw lining / roll-down lining / fold-and-form lining for non-structural rehabilitation
- Spiral wound lining for non-structural rehabilitation
- Centrifugal cast concrete pipe lining (CCCPL) for non-structural rehabilitation
- Geopolymer lining for non-structural rehabilitation
- Manufactured-in-place composite pipe (MICP) for non-structural rehabilitation

CIPP liner rehabilitations might reduce inside diameters by 2 to 3-IN to 27 to 28-IN inside diameter. Whereas, CIPP structural rehabilitations might reduce inside diameters by 4 to 5-IN to 25 to 26-IN inside diameter. For this alternative analysis, CIPP is assumed as the choice for rehabilitation. Approximately 30-IN outside diameter (OD) CIPP installation span is limited to approximately 400-FT or less between launching and receiving pits and limited to 1-90 degree elbow bend or 2-45 degree elbow bends. However, other rehabilitation alternatives can be selected during design.

For slip lining rehabilitation, a smaller diameter carrier pipeline is inserted into the existing larger 30-IN diameter casing pipeline with the annual space between the carrier and casing pipelines filled with grout or controlled low-strength material (CLSM). The slip lining carrier pipeline can be either a lining if the casing pipeline is structurally sound or structural if the casing pipeline is not structurally sound. Slip lining cannot accommodate elbow bends and will require launching pits at every elbow bend. Depending on the slip lining pipeline diameter, launching pits might be required at the casing pipeline joint deflections.

3.2.3 Pipe Pressure

Minimum pipe pressure should meet or exceed the existing pipeline pressure class that ranges from 230 to 500 PSI. WSP and DIP can meet or exceed the required pressures, whereas, plastic pipeline and rehabilitation (liner and structural) might not meet the higher required pressures.

Because plastic pipeline and rehabilitation (liner and structural) reduce pipeline inside diameter, reduce hydraulic performance, and do not meet higher pressures, they have limited applications and will not be recommended for the alternative analysis.

Refer to the appendix for additional pressure and hydraulic discussions.

3.2.4 Appurtenances

The pipeline appurtenances including but not limited to isolation valves, air release valves (ARVs), combination ARVs, blowoffs (BOs), and cathodic test stations will be replaced as required with the pipeline.

3.2.5 Methodology

The provided background data was reviewed the pipeline as-built drawing overlaid onto Google Earth to determine the approximate pipeline alignment and appurtenance location, Figure 2 and Figure 3, respectively.

Figure 2. Pipeline as-built drawing overlaid onto Google Earth to approximate pipeline alignment

Figure 3. Approximate pipeline alignment and appurtenance location recreated in Google Earth

The as-built drawing data was inserted into worksheet, compared with Pure Technologies data, and analyzed. All pipeline rehabilitation and replacement materials and installation methods were analyzed with the following criteria for evaluating rehabilitation or replacement methods:

- To maintain or improve performance (hydraulics, corrosion resistance, etc.);
- To extend pipeline estimated useful life (EUL) / remaining useful life (RUL);
- To prevent unnecessary pipeline breaks;
- To identify most cost-effective methods to rehabilitate or replace including accessibility; and
- To increase confidence in decision making

3.2.6 Opinion of Probable Construction Cost (OPCC)

An AACE Class 5 estimate (-50% to +100% accuracy range) was developed for the pipeline alternatives. Quantities were prepared based on the anticipated construction method and sequence. Costs were applied based on AACE methodology for the Class 5 estimate level. The detailed breakdown of costs is included in Appendix A.

Additional soft costs are included in Appendix A to provide additional indirect costs that may be anticipated, including:

- Estimate and design contingency reflective of design
- Market volatility contingency due to supply chain issues, labor shortages, fuel prices, COVID, inflation
- Construction risk contingency and post-award changes
- Non-contract costs such as permitting, right of way and construction management

The total project cost or total capital cost is the OPCC including soft costs:

- Engineering design

- Engineering services during construction
- Construction management
- Permitting

4 Alternatives

This section summarizes the six (6) alternatives:

1. Alt 1: Do Nothing
2. Alt 2: Golf Course Pipeline Project
3. Alt 3: Replace All Broken Bar Wraps and Localized Cylinder Wall Loss
4. Alt 4: Alt 3 + Broken Bar Wrap
5. Alt 5: Alt 4 + Localized Cylinder Wall Loss
6. Alt 6: 100% Pipeline Replacement

4.1 Alt 1: Do Nothing

The Alternative 1 Do Nothing Alternative is reactive repairing pipeline section as it fails. This is similar to the current practice. The historical repair costs can be adjusted for inflation and applied for budgetary planning purposes. However, this will not be an accurate estimate going forward. Pipeline material EUL is summarized in Table 8.

Table 8. Pipeline material EULs

Material	Estimated Useful Life (EUL)
Welded steel pipe (WSP)	50 – 70 YR
AWWA C303 bar wrapped pipe (BWP)	75-100 YR
Ductile iron pipe (DIP)	60-100+ YR
Polyvinyl chloride (PVC)	70 YR
High-density polyethylene (HDPE)	50-100 YR

The existing pipeline is approximately 65 years old. Therefore, the WSP RUL is approximately 10 to 35 years or (75 – 65) to (100 – 65). The WSP RUL is approximately -15 to +5 years. With good soil conditions / environment, corrosion protection, and maintenance, the pipeline can last much longer than their statistical EULs. However, as the pipeline ages and breaks, the breaks will become more frequent, Figure 4.

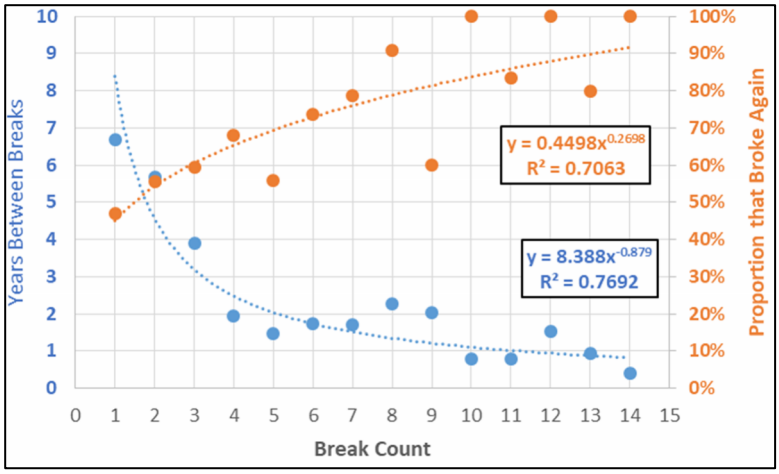

Figure 4. Relationship between historical break count and future performance

Figure 4 quantifies the relationship between historic break count and future performance for a particular pipeline by calculating the proportion of pipeline that break again and the average duration between subsequent breaks. This data indicates that as a pipeline experiences more breaks, the duration until the next break becomes shorter. Both trends support the theory that historic break count is a good indicator of future performance of a pipeline with the average break rate in California and Nevada at 9.7 annual breaks per 100 miles per Folkman's 2018 report titled Water Main Break Rates in the USA and Canada: A Comprehensive Study. Average durations between subsequent breaks shown in blue are two breaks in 6.7 years, four breaks in 3.9 years, and 11 breaks in 0.78 years. The proportions that will break again shown in orange are 47% after one break, 56% after two breaks, and 100% after ten breaks.

Therefore, the Do Nothing Alternative is not viable due to the unpredictability, potential runaway high maintenance and potential property damage costs, loss of service, and low of confidence by the public and regulatory agencies. This alternative is not recommended.

4.2 Alt 2: Golf Course Pipeline Project

The Alternative 2 Golf Course Pipeline Project Alternative implements the Whale Rock Dam Transmission Pipeline Replacement Project (STA 685+00 to 690+00) 100% Design Project, Figure 5. The construction project was previous put on hold for various reasons.

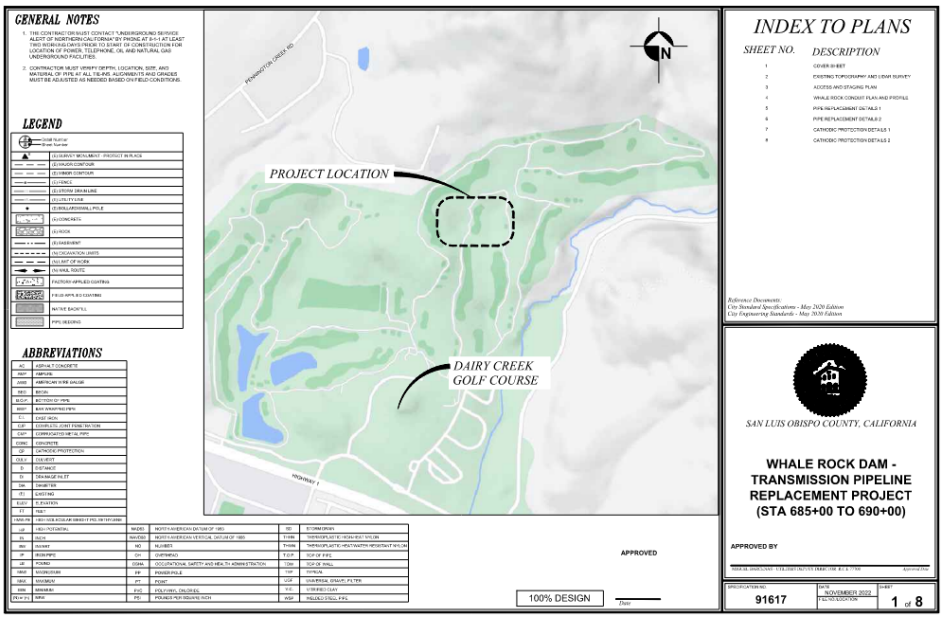

Figure 5. Golf course pipeline project

This alternative replaces pipeline sections that have broken bar warps and localized cylinder wall loss as previously identified by Pure Technologies, Table 9. The replacement total length of 223-FT is greater than the identified length of 128-FT because the intermediate pipeline sections and ends are also replaced, Figure 6. Applicable appurtenances are included in this alternative.

Table 9. Pure Technologies identified broken bar wrap and localized cylinder wall loss at golf course

Ref #	Piece #	Start STA	Stop STA	PL L (FT)	PL Mat	Reported Class
3262	737	686+59	686+90	32	BWP	340
3263	736	686+90	687+22	32	BWP	320
3264	735	687+22	687+54	32	BWP	340
3266	733	687+86	688+18	32	BWP	340

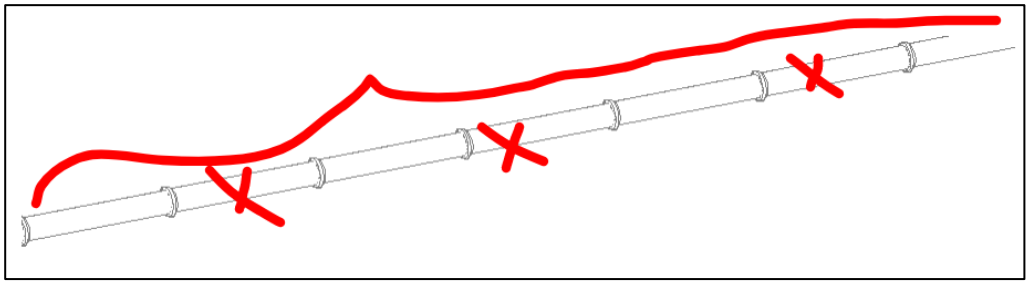

Figure 6. Sample sketch of pipeline replacement section with broken pipeline identified with red “X”. The intermediate and end pipeline sticks will be replaced in addition to the broken pipelines.

Per 2023 Golf course pipeline project OPCC is approximately $1,071,000. With a 6% annual escalation, the 2024 OPCC is approximately $1,136,000. However, through this OPCC effort, the

2024 total construction OPCC is approximately $768,000 instead of $1,136,000. There total project OPCC is approximately $1.11M.

4.3 Alt 3: Replace All Broken Bar Wraps & Localized Cylinder Wall Loss

The Alternative 3 Replace All Broken Bar Wraps & Localized Cylinder Wall Loss is Alternative 2 with one additional broken bar wrapped and localized cylinder wall loss pipeline section. This alternative requires interior pipeline reinspection because reinspection is recommended every five (5) years and because there had been an additional unidentified break.

The alternative analysis pipeline replacement priority is summarized in Table 10.

Table 10. Pipeline replacement priority

Priority	Description
1	Broken bar wraps and localized cylinder wall loss
2	Broken bar wraps
3	Cylinder wall loss

Alternative 3 adds one additional location at approximately 100-FT of pipeline to Alternative 2, Table 11.

Table 11. Pure Technologies identified broken bar wrap and localized cylinder wall loss for Alternative 3

Ref #	Piece #	Start STA	Stop STA	PL L (FT)	PL Mat	Reported Class
3262	737	686+59	686+90	32	BWP	340
3263	736	686+90	687+22	32	BWP	320
3264	735	687+22	687+54	32	BWP	340
3266	733	687+86	688+18	32	BWP	340
3496	504	759+63	759+95	32	BWP	230

The 2024 Construction and Project OPCCs are approximately $851,200 and $1,217,200, respectively.

4.4 Alt 4: Alt 3 + Broken Bar Wrap

Alternative 4 includes all broken bar warps and localized cylinder wall loss and broken bar warps damaged pipeline sections, Table 3 and Table 5 plus five locations and approximately 623-FT. This alternative requires interior pipeline reinspection because reinspection is recommended every five (5) years and because there had been an additional unidentified break. The 2024 Construction and Project OPCCs are approximately $1.10M and $1.57M, respectively.

4.5 Alt 5: Alt 4 + Localized Cylinder Wall Loss

Alternative 5 includes all broken bar warps and localized cylinder wall loss, broken bar warps, and cylinder wall loss damaged pipeline sections, Table 3 to Table 5 plus fifteen locations and approximately 2,623-FT. This alternative requires interior pipeline reinspection because reinspection is recommended every five (5) years and since there had been an additional unidentified break. Alternative 5 includes. The 2024 Construction and Project OPCCs are approximately $2.76M and $3.94M, respectively.

4.6 Alt 6: 100% Pipeline Replacement

Alternative 6 eventually replaces 100% of the pipeline based on the criticality identified in Table 10 and budget constraints. This alternative requires interior pipeline reinspection because reinspection is recommended every five (5) years and since there had been an additional unidentified break. After reinspection, the pipeline section will be prioritized to develop a five-to-ten-year capital improvement plan (CIP) for pipeline replacement. Near the end of the CIP, the pipeline again will be reinspected to prioritize remaining pipeline replacement. This repeats until 100% of the pipeline will be replaced.

Referring to Table 12, the options refer to the quantity of pipeline replacement per year and the number of year for 100% pipeline replacement. For Alt 6 Option 3, assuming there is an annual $2.79M budget and $3.99M for construction and project, respectively. Under Alt 6 Option 3, 100% of the pipeline will be replaced in 25-years and 0.64 miles per year or 4.00% per year of the total pipeline length.

Table 12. 100% pipeline replacement as a function of total replacement years

Option	Replacement (MI/YR)	Replacement (%/YR)	# of YR for 100% Replacement	Constr OPCC ($/YR)	Project OPCC ($/YR)
1	0.46	2.86	35.0	$1.99M	$2.85M
2	0.53	3.33	30.0	$2.33M	$3.33M
3	0.64	4.00	25.0	$2.79M	$3.99M
4	0.80	5.00	20.0	$3.49M	$5.00M
5	0.93	5.81	17.2	$4.06M	$5.80M
6	1.07	6.67	15.0	$4.65M	$6.65M
7	1.33	8.33	12.0	$5.82M	$8.31M
8	1.60	10.00	10.0	$6.98M	$9.98M
9	3.20	20.00	5.0	$13.95M	$19.95M
10	16	100.00	1.0	$69.77M	$99.77M

4.7 Discussion

Table 12 and Appendix A opinion of probable construction costs (OPCCs) are based on traditional cut-and-cover.

Detailed rehabilitation method (CIPP and slip lining) OPCCs are not provided because of unknown variables required to develop reasonable accurate OPCCs in the current alternative analysis phase included acceptable flow capacity reductions resulting from rehabilitation methods. At a high level, the material cost for 30-IN OD non-structural lining is similar to new 30-IN diameter pipeline per linear foot. Whereas the material cost for 30-IN OD structural lining is more than new 30-IN diameter pipeline per linear foot. The excavation savings along the cut-and-cover pipeline alignment are offset by the relatively large CIPP launch and receiving pits at approximately every 400-FT. Additionally, CIPP equipment mobilization and demobilization cost is approximately $300,000. Therefore, Alternatives 1, 2, and 3 construction OPCCs are higher for CIPP (non-structural and structural) than traditional cut-and-cover. Alternatives 5 and 6 CIPP and cut-and-cover OPCCs would be more similar to each other.

Slip ling and CIPP OPCCs would be more similar. However, slip lining will significantly reduce flow rates due to the inside diameter (See Appendix B Figure 11) and potentially requiring excavation as every elbow fittings; therefore, slip lining is not recommended for pipeline rehabilitation. Flow capacity reductions of transmission mains are generally not preferred in the industry. Therefore, the traditional cut-and-cover is preferred for the alternative analysis especially with a phased approach to replace 100% of the pipeline over time.

4.8 Summary

Table 13 summarizes the pipeline replacement alternatives by method of cut-and-cover.

Table 13. Pipeline replacement alternatives summary

Alt	Interior Reinspection	# of Location [1]	Length [2] (FT)	OPCC Construction	OPCC Project
1	NA	NA	NA	Unknown	Unknown
2	NA	1	223	$777,800	$1.11M
3	√	2	323	$851,200	$1.22M
4	√	5	623	$1.10M	$1.57M
5	√	15	2,623	$2.76M	$3.94M
6 [3]	√	Varies	3,379	$2.79M/YR	$3.99M/YR
6 [4]	√	Varies	323 (Yr 1) & 3,362 (Yr 2-26)	$851,200 (Yr 1) & $2.76M/YR (Yr 2-25)	$1.22M (Yr 1) & $3.94M/YR (Yr 2-26)

Notes:
1. Distinct locations of pipe segments
2. Approximate length
3. Assumes 100% pipeline replacement in a period of 25 years. The 100% OPCC is amortized over the replacement period.
4. Assumes 100% pipeline replacement period of 25 years after executing Alt 3 in year one

5. Alternatives: Alt 1-Do Nothing; Alt 2-Golf Course Pipeline Project; Alt 3-Replace All Broken Bar Wraps and Localized Cylinder Wall Loss; Alt 4-Alt 3 + Broken Bar Wrap; Alt 5-Alt 4 + Localized Cylinder Wall Loss; Alt 6-100% Pipeline Replacement

5 Recommendation

The recommendations are to first execute Alternate 3: Replace All Broken Bar Wraps & Localized Cylinder Wall Loss, then reinspect the pipeline, and execute Alternative 6: 100% Pipeline Replacement. The recommended installation method is cut-and-cover.

The recommendation Year One (Alternate 3) costs are approximately $851,200 and $1.22M for construction and project costs, respectively. The recommendation Year 2 to 26 (Alternative 6 minus Alternative 3) costs are approximately $2.76M/YR and $3.94M/YR for construction and project costs, respectively.

6 References

1. List of Whale Rock Pipeline Leaks since 2013 (2013 to 2023)
2. Whale Rock Dam – Transmission Pipeline Replacement Project, November 2022 (Golf Course Pipeline Project)
3. Condition Assessment of 30-Inch Whale Rock Conveyance Conduit V 2.0, Pure Technologies, a Xylem brand, December 2019
4. Whale Rock Pipeline Relocation Project, Plans for the Construction of a 30 Inch Raw Water Pipeline, 11 pages, Parsons Engineering Science, Inc., October 1999
5. Whale Rock Conveyance Conduit Plan and Profile STA 0+00 to STA 903+78 As-Built Drawings, 80 pages, State of California Department of Water Resources Southern California District, 1959

List of Appendices

Appendix A Opinion of Probable Construction Cost (OPCC)

Appendix B Hydraulic Analysis

Appendix A. OPCC

Notes on opinion of probable construction cost (OPCC) development:

1. The 30 IN pipeline (pipeline) conveys raw water from Whale Rock Reservoir to the San Luis Obispo Treatment Plant for a total distance of approximately 16 miles
2. Pipeline material:
    a. Existing AWWA M11 welded steel pipeline (WSP) is approximately 18,321-FT, 3.47 mile, or 21.9% of total length
    b. Existing AWWA C-303 bar wrapped concrete cylinder pipeline (BWP) is approximately 65,523-FT, 12.41 mile, or 78.1% of total length
    c. Replacement pipe is 100% AWWA C151 ductile iron pipe
3. Pipeline outside diameter:
    a. Existing AWWA M11 outside diameter is unknown
    b. Existing AWWA C-303 BWP has maximum outside diameter of 35-IN
    c. For OPCC, replacement pipe is AWWA C151 ductile iron pipe has outside diameter of 32-IN
4. Pipeline installation:
    a. The pipeline is installed in paved road approximately 2.5 mile or 15.6%
    b. The pipeline is installed in unpaved road approximately 13.5 mile or 84.4%
    c. Pipeline installed in paved road schematic and quantities per linear foot are shown in Figure 7 and Table 14, respectively
    d. Pipeline installed in unpaved road schematic and quantities per linear foot are shown in Figure 8 and Table 15, respectively
5. Pipeline appurtenances
    a. Appurtenances (isolation valves, air release / vacuum valves, blowoffs, etc.) are assumed to be 20% of pipeline OPCC
    b. Pipeline restraints (thrust blocks, collars, fasteners, harness, tie rods, etc.) are assumed to be 5% of pipeline OPCC
    c. Pipeline cathodic protection (bond straps, galvanic anode system, polyethylene encasement, etc.) is assumed to be 5% of pipeline OPCC

6. Miscellaneous:
    a. Trench box / shoring box assumed
    b. No dewatering and water treatment required
    c. The cost for pipeline reinspection is excluded
    d. Traffic control is assumed to be 10% of paved pipeline OPCC
    e. Golf course lost income and site restoration are assumed at $250,000
7. OPCC:
    a. AACE International class 5 with an accuracy range of -50% to +100%
    b. Material and labor total costs are based on RSMeansOnline.com
    c. This OPCC is for capital improvement projects (CIP)
8. Exclusions:
    a. CIPP OPCC was excluded due to too many variables and unknown unknows
    b. Slip lining OPCC was excluded due to too many variables and unknown unknows

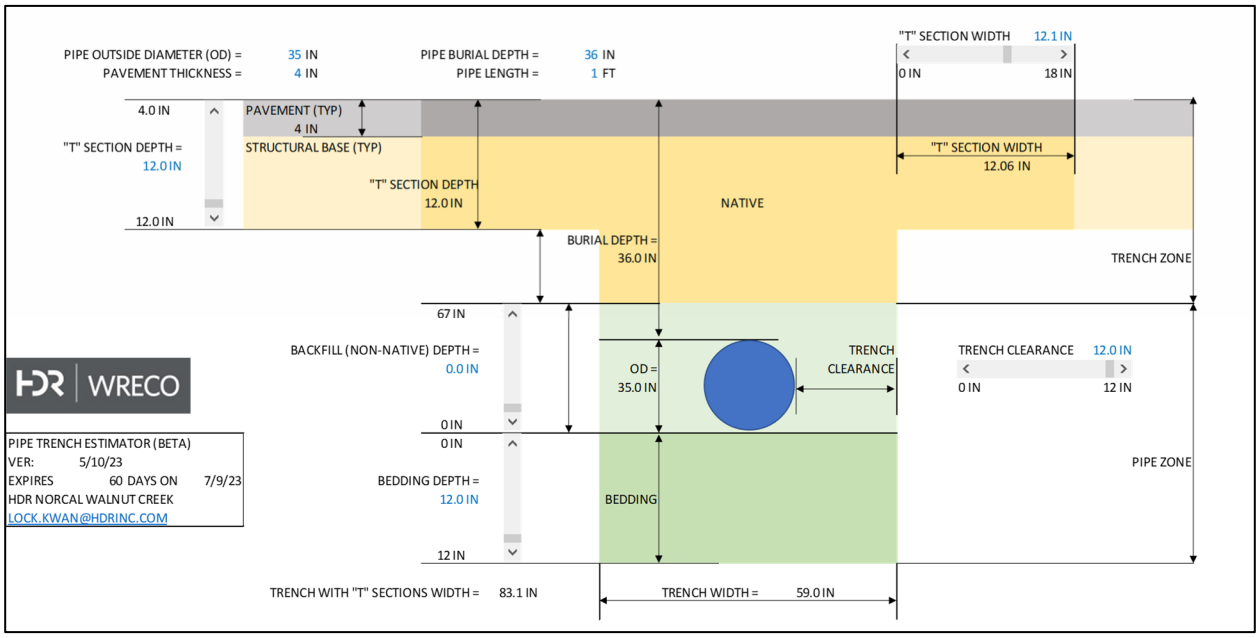

Figure 7. Pipeline installed in paved road schematic

Table 14. Pipeline installed in paved road per linear foot

DESCRIPTION	AREA		VOLUME	
	(IN^2)	(FT^2)	(FT^3)	(YD^3)
PAVEMENT	332.48	2.31	2.31	0.086
"T" SECTION (WINGS)	192.96	1.34	1.34	0.05
NATIVE	3953	27.45	27.45	1.02
BACKFILL	0	0	0	0
PIPE	962.11	6.68	6.68	0.25
BEDDING	708	4.92	4.92	0.18

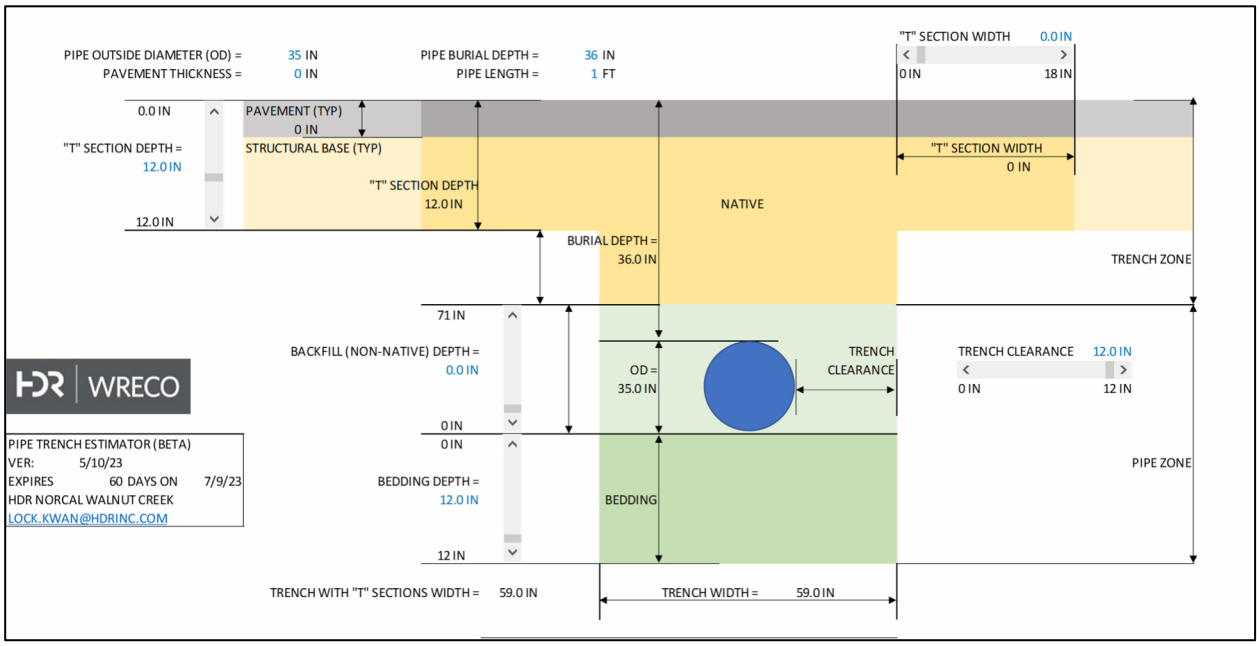

Figure 8. Pipeline installed in unpaved road schematic

Table 15. Pipeline installed in unpaved road per linear foot

DESCRIPTION	AREA		VOLUME	
	(IN^2)	(FT^2)	(FT^3)	(YD^3)
PAVEMENT	0	0	0	0
"T" SECTION (WINGS)	0	0	0	0
NATIVE	4189	29.1	29.1	1.08
BACKFILL	0	0	0	0
PIPE	962.1128	6.68	6.68	0.25
BEDDING	708	4.92	4.92	0.18

Table 16. Alternative OPCC summary

Description	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6A	Alt 6B
Subtotal Constr Cost	$332,400	$363,758	$469,508	$1,178,371	$29,452,432	$29,814,674
General Conditions (10%)	$33,240	$36,376	$46,951	$117,837	$2,945,243	$2,981,467
Contractor OH&P (12%)	$39,888	$43,651	$56,341	$141,405	$3,534,292	$3,577,761
Mob / Demob (5%)	$16,620	$18,188	$23,475	$58,919	$1,472,622	$1,490,734
Bonds and Insurance (3%)	$9,972	$10,913	$14,085	$35,351	$883,573	$894,440
Subtotal	$432,121	$472,885	$610,361	$1,531,883	$38,288,161	$38,759,077
Contingency (50%)	$216,060	$236,443	$305,181	$765,941	$19,144,081	$19,379,538
Subtotal w/ Contingency	$648,181	$709,328	$915,542	$2,297,824	$57,432,242	$58,138,615
Mkt Volatility Adj (20%)	$129,636	$141,866	$183,108	$459,565	$11,486,448	$11,627,723
Total Construction Cost	$777,817	$851,194	$1,098,650	$2,757,389	$68,918,690	$69,766,338
High End of Range (100%)	$1,555,634	$1,702,387	$2,197,300	$5,514,778	$137,837,381	$139,532,676
Low End of Range (-50%)	$388,909	$425,597	$549,325	$1,378,695	$34,459,345	$34,883,169
Total Project Cost						
Engineering Design (12%)	$93,338	$102,143	$131,838	$330,887	$8,270,243	$8,371,961
Engr Serv Sur Constr (10%)	$77,782	$85,119	$109,865	$275,739	$6,891,869	$6,976,634
Constr Mgmt (15%)	$116,673	$127,679	$164,797	$413,608	$10,337,804	$10,464,951
Permitting (Excl Envir) (6%)	$46,669	$51,072	$65,919	$165,443	$4,135,121	$4,185,980
Total Capital Cost	$1,112,279	$1,217,207	$1,571,069	$3,943,066	$98,553,727	$99,765,863
High End of Range (100%)	$2,224,557	$2,434,414	$3,142,138	$7,886,133	$197,107,454	$199,531,726
Low End of Range (-50%)	$556,139	$608,603	$785,535	$1,971,533	$49,276,864	$49,882,932

Table 17. Alt 2: Golf Course Pipeline Project OPCC

Item	Description	QT	Unit	Unit Cost	Total Cost	Comments
2 - Existing Conditions						
2.1	Demolition, saw cutting, asphalt, <=3" deep	0	LF	$1.63	$0.00	Paved
2.2	Demolish, piping & fittings, 30" diameter	234	LF	$15.85	$3,708.90	
2.3	Disposal: (E) pavement, bedding & pipeline	100	CY	$15.36	$1,536.00	
3 - Concrete						
3.1	Sand, washed, for pipeline bedding (new)	43	CY	56.64	$2,415.13	
13 - Special Construction						
13.1	Pipeline cathodic protection: bond straps, galvanic anode system, polyethylene encasement, etc. at *m* % of PL length	1	LS	$3,000	$3,000.00	5%
22 - Plumbing						
22.1	Appurtenances: isolation valves, air release/vacuum valves, blowoffs, etc. at *n* % of PL length	1	LS	$11,000	$11,000.00	20%
31 - Earthwork						
31.1	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	300	CY	$4.44	$1,332.00	Unpaved portion
31.2	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	0	CY	$4.44	$0.00	Paved portion
31.3	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	0	CY	$10.97	$0.00	(E) pavement & bedding for disposal
31.4	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	100	CY	$10.97	$1,097.00	(E) pipeline for disposal
31.5	Backfill, sand and native, 300 HP dozer, 50' haul	300	CY	$0.68	$204.00	
31.6	Compaction, 4 passes, 6" lifts, riding, sheepsfoot or wobbly wheel roller	600	CY	$0.99	$594.00	
32 - Exterior Improvements						
32.1	Asphalt paving, plant mixed asphaltic base courses for roadways, 4" thick	0	SY	$25.79	$0.00	
32.2	Golf course lost of income and site restoration	1	LS	$250,000.00	$250,000.00	$250,000
33 - Utilities						
33.1	Piping, ductile iron, mechnical joint, cement lined, 30" diameter	234	LF	$228.69	$53,513.46	
33.2	Pipeline restraints: thrust blocks, collars, fasteners, harness, tie rods, etc. at *p* % of PL length	1	LS	$3,000	$3,000.00	5%
34 - Transportation						
34.1	Traffic control at *q* % of paved PL length	1	LS	$1,000	$1,000.00	10%
Subtotal Construction Cost					**$332,400.49**	
	General Conditions		10%		$33,240.05	
	Contractor OH&P		12%		$39,888.06	
	Mobilization/Demobilization		5%		$16,620.02	
	Bonds and Insurance		3%		$9,972.01	
Subtotal					**$432,120.64**	
	Contingency		50%		$216,060.32	
Subtotal w/ Contingency					**$648,180.95**	
	Market Volatility Adjustment		20%		$129,636.19	
Total Construction Cost					**$777,817.15**	$3,324.00/LF
	High End of Range		100%		$1,555,634.29	$6,648.01/LF
	Low End of Range		-50%		$388,908.57	$1,662.00/LF
Total Project Cost						
	Engineering Design		12%		$93,338.06	
	Engineering Services During Construction		10%		$77,781.71	
	Construction Management		15%		$116,672.57	
	Permitting (Excluding Environmental)		6%		$46,669.03	
Total Capital Cost					**$1,112,278.52**	$4,753.33/LF
	High End of Range		100%		$2,224,557.04	$9,506.65/LF
	Low End of Range		-50%		$556,139.26	$2,376.66/LF

Table 18. Alt 3: Replace All Broken Bar Wraps and Localized Cylinder Wall Loss OPCC

Item	Description	QT	Unit	Unit Cost	Total Cost	Comments
2 - Existing Conditions						
2.1	Demolition, saw cutting, asphalt, <=3" deep	0	LF	$1.63	$0.00	Paved
2.2	Demolish, piping & fittings, 30" diameter	324	LF	$15.85	$5,135.40	
2.3	Disposal: (E) pavement, bedding & pipeline	100	CY	$15.36	$1,536.00	
3 - Concrete						
3.1	Sand, washed, for pipeline bedding (new)	59	CY	56.64	$3,344.03	
13 - Special Construction						
13.1	Pipeline cathodic protection: bond straps, galvanic anode system, polyethylene encasement, etc. at *m* % of PL length	1	LS	$4,000	$4,000.00	5%
22 - Plumbing						
22.1	Appurtenances: isolation valves, air release/vacuum valves, blowoffs, etc. at *n* % of PL length	1	LS	$15,000	$15,000.00	20%
31 - Earthwork						
31.1	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	500	CY	$4.44	$2,220.00	Unpaved portion
31.2	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	0	CY	$4.44	$0.00	Paved portion
31.3	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	0	CY	$10.97	$0.00	(E) pavement & bedding for disposal
31.4	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	100	CY	$10.97	$1,097.00	(E) pipeline for disposal
31.5	Backfill, sand and native, 300 HP dozer, 50' haul	500	CY	$0.68	$340.00	
31.6	Compaction, 4 passes, 6" lifts, riding, sheepsfoot or wobbly wheel roller	1,000	CY	$0.99	$990.00	
32 - Exterior Improvements						
32.1	Asphalt paving, plant mixed asphaltic base courses for roadways, 4" thick	0	SY	$25.79	$0.00	
32.2	Golf course lost of income and site restoration	1	LS	$250,000.00	$250,000.00	$250,000
33 - Utilities						
33.1	Piping, ductile iron, mechnical joint, cement lined, 30" diameter	324	LF	$228.69	$74,095.56	
33.2	Pipeline restraints: thrust blocks, collars, fasteners, harness, tie rods, etc. at *p* % of PL length	1	LS	$4,000	$4,000.00	5%
34 - Transportation						
34.1	Traffic control at *q* % of paved PL length	1	LS	$2,000	$2,000.00	10%
Subtotal Construction Cost					**$363,757.99**	
	General Conditions		10%		$36,375.80	
	Contractor OH&P		12%		$43,650.96	
	Mobilization/Demobilization		5%		$18,187.90	
	Bonds and Insurance		3%		$10,912.74	
Subtotal					**$472,885.38**	
	Contingency		50%		$236,442.69	
Subtotal w/ Contingency					**$709,328.07**	
	Market Volatility Adjustment		20%		$141,865.61	
Total Construction Cost					**$851,193.69**	$2,627.14/LF
	High End of Range		100%		$1,702,387.37	$5,254.28/LF
	Low End of Range		-50%		$425,596.84	$1,313.57/LF
Total Project Cost						
	Engineering Design		12%		$102,143.24	
	Engineering Services During Construction		10%		$85,119.37	
	Construction Management		15%		$127,679.05	
	Permitting (Excluding Environmental)		6%		$51,071.62	
Total Capital Cost					**$1,217,206.97**	$3,756.81/LF
	High End of Range		100%		$2,434,413.94	$7,513.62/LF
	Low End of Range		-50%		$608,603.49	$1,878.41/LF

Table 19. Alt 4: Alt 3 + Broken Bar Wrap OPCC

Item	Description	QT	Unit	Unit Cost	Total Cost	Comments
2 - Existing Conditions						
2.1	Demolition, saw cutting, asphalt, <=3" deep	0	LF	$1.63	$0.00	Paved
2.2	Demolish, piping & fittings, 30" diameter	630	LF	$15.85	$9,985.50	
2.3	Disposal: (E) pavement, bedding & pipeline	200	CY	$15.36	$3,072.00	
3 - Concrete						
3.1	Sand, washed, for pipeline bedding (new)	115	CY	56.64	$6,502.27	
13 - Special Construction						
13.1	Pipeline cathodic protection: bond straps, galvanic anode system, polyethylene encasement, etc. at *m* % of PL length	1	LS	$8,000	$8,000.00	5%
22 - Plumbing						
22.1	Appurtenances: isolation valves, air release/vacuum valves, blowoffs, etc. at *n* % of PL length	1	LS	$29,000	$29,000.00	20%
31 - Earthwork						
31.1	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	800	CY	$4.44	$3,552.00	Unpaved portion
31.2	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	0	CY	$4.44	$0.00	Paved portion
31.3	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	0	CY	$10.97	$0.00	(E) pavement & bedding for disposal
31.4	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	200	CY	$10.97	$2,194.00	(E) pipeline for disposal
31.5	Backfill, sand and native, 300 HP dozer, 50' haul	800	CY	$0.68	$544.00	
31.6	Compaction, 4 passes, 6" lifts, riding, sheepsfoot or wobbly wheel roller	1,600	CY	$0.99	$1,584.00	
32 - Exterior Improvements						
32.1	Asphalt paving, plant mixed asphaltic base courses for roadways, 4" thick	0	SY	$25.79	$0.00	
32.2	Golf course lost of income and site restoration	1	LS	$250,000.00	$250,000.00	$250,000
33 - Utilities						
33.1	Piping, ductile iron, mechnical joint, cement lined, 30" diameter	630	LF	$228.69	$144,074.70	
33.2	Pipeline restraints: thrust blocks, collars, fasteners, harness, tie rods, etc. at *p* % of PL length	1	LS	$8,000	$8,000.00	5%
34 - Transportation						
34.1	Traffic control at *q* % of paved PL length	1	LS	$3,000	$3,000.00	10%
Subtotal Construction Cost					**$469,508.47**	
	General Conditions		10%		$46,950.85	
	Contractor OH&P		12%		$56,341.02	
	Mobilization/Demobilization		5%		$23,475.42	
	Bonds and Insurance		3%		$14,085.25	
Subtotal					**$610,361.01**	
	Contingency		50%		$305,180.51	
Subtotal w/ Contingency					**$915,541.52**	
	Market Volatility Adjustment		20%		$183,108.30	
Total Construction Cost					**$1,098,649.82**	$1,743.89/LF
	High End of Range		100%		$2,197,299.65	$3,487.78/LF
	Low End of Range		-50%		$549,324.91	$871.94/LF
Total Project Cost						
	Engineering Design		12%		$131,837.98	
	Engineering Services During Construction		10%		$109,864.98	
	Construction Management		15%		$164,797.47	
	Permitting (Excluding Environmental)		6%		$65,918.99	
Total Capital Cost					**$1,571,069.25**	$2,493.76/LF
	High End of Range		100%		$3,142,138.50	$4,987.52/LF
	Low End of Range		-50%		$785,534.62	$1,246.88/LF

Table 20. Alt 5: Alt 4 + Localized Cylinder Wall Loss OPCC

Item	Description	QT	Unit	Unit Cost	Total Cost	Comments
2 - Existing Conditions						
2.1	Demolition, saw cutting, asphalt, <=3" deep	900	LF	$1.63	$1,467.00	Paved
2.2	Demolish, piping & fittings, 30" diameter	2,628	LF	$15.85	$41,653.80	
2.3	Disposal: (E) pavement, bedding & pipeline	1,100	CY	$15.36	$16,896.00	
3 - Concrete						
3.1	Sand, washed, for pipeline bedding (new)	479	CY	56.64	$27,123.76	
13 - Special Construction						
13.1	Pipeline cathodic protection: bond straps, galvanic anode system, polyethylene encasement, etc. at *m* % of PL length	1	LS	$31,000	$31,000.00	5%
22 - Plumbing						
22.1	Appurtenances: isolation valves, air release/vacuum valves, blowoffs, etc. at *n* % of PL length	1	LS	$121,000	$121,000.00	20%
31 - Earthwork						
31.1	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	2,800	CY	$4.44	$12,432.00	Unpaved portion
31.2	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	600	CY	$4.44	$2,664.00	Paved portion
31.3	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	400	CY	$10.97	$4,388.00	(E) pavement & bedding for disposal
31.4	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	700	CY	$10.97	$7,679.00	(E) pipeline for disposal
31.5	Backfill, sand and native, 300 HP dozer, 50' haul	3,400	CY	$0.68	$2,312.00	
31.6	Compaction, 4 passes, 6" lifts, riding, sheepsfoot or wobbly wheel roller	6,800	CY	$0.99	$6,732.00	
32 - Exterior Improvements						
32.1	Asphalt paving, plant mixed asphaltic base courses for roadways, 4" thick	350	SY	$25.79	$9,026.50	
32.2	Golf course lost of income and site restoration	1	LS	$250,000.00	$250,000.00	$250,000
33 - Utilities						
33.1	Piping, ductile iron, mechnical joint, cement lined, 30" diameter	2,628	LF	$228.69	$600,997.32	
33.2	Pipeline restraints: thrust blocks, collars, fasteners, harness, tie rods, etc. at *p* % of PL length	1	LS	$31,000	$31,000.00	5%
34 - Transportation						
34.1	Traffic control at *q* % of paved PL length	1	LS	$12,000	$12,000.00	10%
Subtotal Construction Cost					**$1,178,371.38**	
	General Conditions		10%		$117,837.14	
	Contractor OH&P		12%		$141,404.57	
	Mobilization/Demobilization		5%		$58,918.57	
	Bonds and Insurance		3%		$35,351.14	
Subtotal					**$1,531,882.80**	
	Contingency		50%		$765,941.40	
Subtotal w/ Contingency					**$2,297,824.20**	
	Market Volatility Adjustment		20%		$459,564.84	
Total Construction Cost					**$2,757,389.04**	$1,049.23/LF
	High End of Range		100%		$5,514,778.07	$2,098.47/LF
	Low End of Range		-50%		$1,378,694.52	$524.62/LF
Total Project Cost						
	Engineering Design		12%		$330,886.68	
	Engineering Services During Construction		10%		$275,738.90	
	Construction Management		15%		$413,608.36	
	Permitting (Excluding Environmental)		6%		$165,443.34	
Total Capital Cost					**$3,943,066.32**	$1,500.41/LF
	High End of Range		100%		$7,886,132.64	$3,000.81/LF
	Low End of Range		-50%		$1,971,533.16	$750.20/LF

Table 21. Alt 6A: 100% Pipeline Replacement minus Alt 3 OPCC

Item	Description	QT	Unit	Unit Cost	Total Cost	Comments
2 - Existing Conditions						
2.1	Demolition, saw cutting, asphalt, <=3" deep	26,300	LF	$1.63	$42,869.00	Paved
2.2	Demolish, piping & fittings, 30" diameter	84,048	LF	$15.85	$1,332,160.80	
2.3	Disposal: (E) pavement, bedding & pipeline	32,200	CY	$15.36	$494,592.00	
3 - Concrete						
3.1	Sand, washed, for pipeline bedding (new)	15,315	CY	56.64	$867,465.01	
13 - Special Construction						
13.1	Pipeline cathodic protection: bond straps, galvanic anode system, polyethylene encasement, etc. at *m* % of PL length	1	LS	$962,000	$962,000.00	5%
22 - Plumbing						
22.1	Appurtenances: isolation valves, air release/vacuum valves, blowoffs, etc. at *n* % of PL length	1	LS	$3,845,000	$3,845,000.00	20%
31 - Earthwork						
31.1	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	89,400	CY	$4.44	$396,936.00	Unpaved portion
31.2	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	16,600	CY	$4.44	$73,704.00	Paved portion
31.3	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	11,400	CY	$10.97	$125,058.00	(E) pavement & bedding for disposal
31.4	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	20,800	CY	$10.97	$228,176.00	(E) pipeline for disposal
31.5	Backfill, sand and native, 300 HP dozer, 50' haul	106,000	CY	$0.68	$72,080.00	
31.6	Compaction, 4 passes, 6" lifts, riding, sheepsfoot or wobbly wheel roller	212,000	CY	$0.99	$209,880.00	
32 - Exterior Improvements						
32.1	Asphalt paving, plant mixed asphaltic base courses for roadways, 4" thick	10,220	SY	$25.79	$263,573.80	
32.2	Golf course lost of income and site restoration	0	LS	$0.00	$0.00	$250,000
33 - Utilities						
33.1	Piping, ductile iron, mechnical joint, cement lined, 30" diameter	84,048	LF	$228.69	$19,220,937.12	
33.2	Pipeline restraints: thrust blocks, collars, fasteners, harness, tie rods, etc. at *p* % of PL length	1	LS	$962,000	$962,000.00	5%
34 - Transportation						
34.1	Traffic control at *q* % of paved PL length	1	LS	$356,000	$356,000.00	10%
Subtotal Construction Cost					**$29,452,432**	
	General Conditions		10%		$2,945,243	
	Contractor OH&P		12%		$3,534,292	
	Mobilization/Demobilization		5%		$1,472,622	
	Bonds and Insurance		3%		$883,573	
Subtotal					**$38,288,161**	
	Contingency		50%		$19,144,081	
Subtotal w/ Contingency					**$57,432,242**	
	Market Volatility Adjustment		20%		$11,486,448	
Total Construction Cost					**$68,918,690**	$819.99/LF
	High End of Range		100%		$137,837,381	$1,639.98/LF
	Low End of Range		-50%		$34,459,345	$410.00/LF
Total Project Cost						
	Engineering Design		12%		$8,270,243	
	Engineering Services During Construction		10%		$6,891,869	
	Construction Management		15%		$10,337,804	
	Permitting (Excluding Environmental)		6%		$4,135,121	
Total Capital Cost					**$98,553,727**	$1,172.59/LF
	High End of Range		100%		$197,107,454	$2,345.18/LF
	Low End of Range		-50%		$49,276,864	$586.29/LF

Table 22. Alt 6B 100% Pipeline Replacement OPCC

Item	Description	QT	Unit	Unit Cost	Total Cost	Comments
2 - Existing Conditions						
2.1	Demolition, saw cutting, asphalt, <=3" deep	26,400	LF	$1.63	$43,032.00	Paved
2.2	Demolish, piping & fittings, 30" diameter	84,372	LF	$15.85	$1,337,296.20	
2.3	Disposal: (E) pavement, bedding & pipeline	32,300	CY	$15.36	$496,128.00	
3 - Concrete						
3.1	Sand, washed, for pipeline bedding (new)	15,374	CY	56.64	$870,809.04	
13 - Special Construction						
13.1	Pipeline cathodic protection: bond straps, galvanic anode system, polyethylene encasement, etc. at *m* % of PL length	1	LS	$965,000	$965,000.00	5%
22 - Plumbing						
22.1	Appurtenances: isolation valves, air release/vacuum valves, blowoffs, etc. at *n* % of PL length	1	LS	$3,860,000	$3,860,000.00	20%
31 - Earthwork						
31.1	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	89,700	CY	$4.44	$398,268.00	Unpaved portion
31.2	Excavation, trench, loam or sandy clay, 1 C.Y. excavator, <=6' deep	16,700	CY	$4.44	$74,148.00	Paved portion
31.3	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	11,400	CY	$10.97	$125,058.00	(E) pavement & bedding for disposal
31.4	Hauling, 30 min/load/unload, 8 CY truck, 8 mi, 30 MPH	20,900	CY	$10.97	$229,273.00	(E) pipeline for disposal
31.5	Backfill, sand and native, 300 HP dozer, 50' haul	106,400	CY	$0.68	$72,352.00	
31.6	Compaction, 4 passes, 6" lifts, riding, sheepsfoot or wobbly wheel roller	212,800	CY	$0.99	$210,672.00	
32 - Exterior Improvements						
32.1	Asphalt paving, plant mixed asphaltic base courses for roadways, 4" thick	10,260	SY	$25.79	$264,605.40	
32.2	Golf course lost of income and site restoration	1	LS	$250,000.00	$250,000.00	$250,000
33 - Utilities						
33.1	Piping, ductile iron, mechnical joint, cement lined, 30" diameter	84,372	LF	$228.69	$19,295,032.68	
33.2	Pipeline restraints: thrust blocks, collars, fasteners, harness, tie rods, etc. at *p* % of PL length	1	LS	$965,000	$965,000.00	5%
34 - Transportation						
34.1	Traffic control at *q* % of paved PL length	1	LS	$358,000	$358,000.00	10%
Subtotal Construction Cost					**$29,814,674**	
	General Conditions		10%		$2,981,467	
	Contractor OH&P		12%		$3,577,761	
	Mobilization/Demobilization		5%		$1,490,734	
	Bonds and Insurance		3%		$894,440	
Subtotal					**$38,759,077**	
	Contingency		50%		$19,379,538	
Subtotal w/ Contingency					**$58,138,615**	
	Market Volatility Adjustment		20%		$11,627,723	
Total Construction Cost					**$69,766,338**	$826.89/LF
	High End of Range		100%		$139,532,676	$1,653.78/LF
	Low End of Range		-50%		$34,883,169	$413.44/LF
Total Project Cost						
	Engineering Design		12%		$8,371,961	
	Engineering Services During Construction		10%		$6,976,634	
	Construction Management		15%		$10,464,951	
	Permitting (Excluding Environmental)		6%		$4,185,980	
Total Capital Cost					**$99,765,863**	$1,182.45/LF
	High End of Range		100%		$199,531,726	$2,364.90/LF
	Low End of Range		-50%		$49,882,932	$591.23/LF

Appendix B. Hydraulic Analysis

As part of the scope of work, this section summarizes the high level hydraulic analysis considering theoretical flow capacities, pipeline diameters, materials, and pressure ratings, elevations, and pump station operations based on piping replacement, structural lining techniques, and slip lining techniques. Whereas a detailed hydraulic analysis requires more in-depth examination of the aforementioned.

The hydraulic analysis was created as a Microsoft Excel spreadsheet with Swanee-Jain equation used to solved directly for the Darcy-Weisbach friction factor, Figure 9. Minor loses were assumed to be a percentage of major loses. Only the approximate start (EL 187 FT), end (EL 420 FT), and highest (EL 540 FT) elevations were considered with values determined from as-built drawings and Google Earth, Figure 10. The pipeline segments were assumed to have their full pressure ratings assuming the deteriorated segments are replaced for non-structural CIPP and slip lining pipeline renovation. The pipeline pressure rating was 230 to 500 PSI with the higher pressure rating immediately downstream of the booster pump station. The entire length of the pipeline was assumed to have the homogeneous/same diameter. The booster pump station was assumed to be upgraded as required. This hydraulics analysis excludes surge / transient pressure analysis that could be significant due to volumes and velocities conveyed.

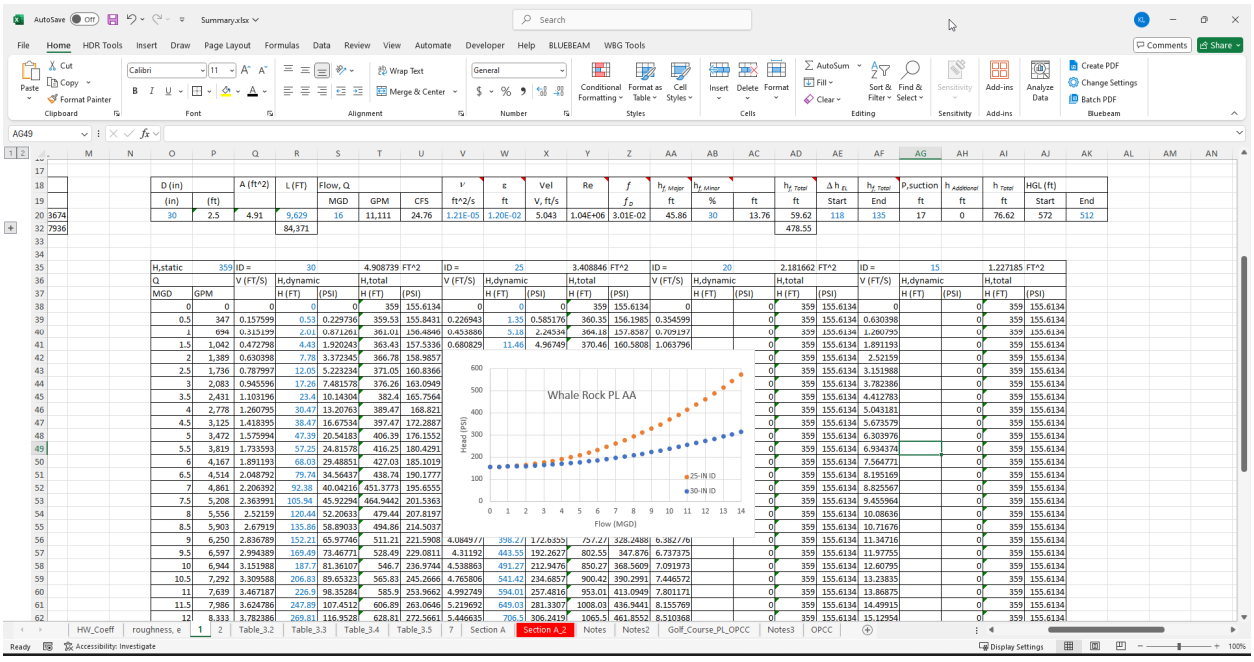

Figure 9. Whale Rock Pipeline MS Excel hydraulic analysis spreadsheet for analyzing hydraulic performance with potential reduced pipeline inside diameters

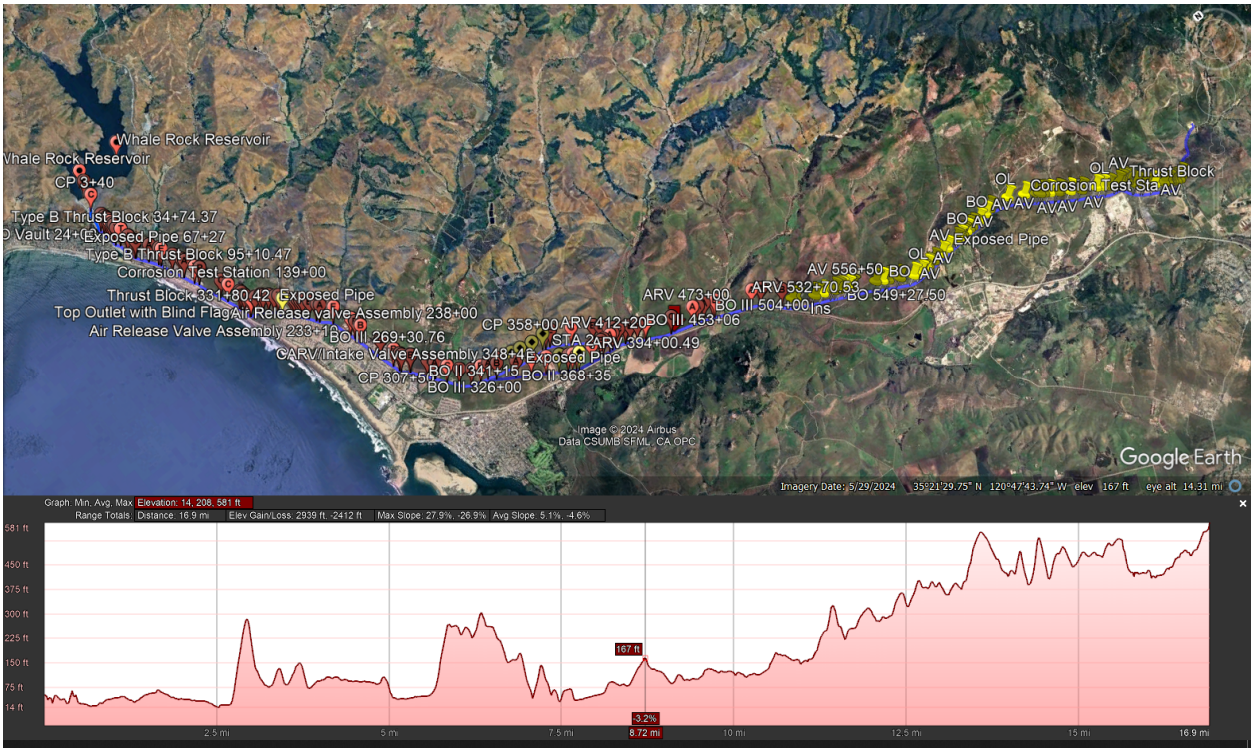

Figure 10. Pipeline alignment and elevations from Google Earth

The Whale Rock Pipeline hydraulic analysis results in graphic format is illustrated in Figure 11. The x-axis represents the booster pump station pumping flow rate in million gallon per day (MGD). The y-axis represents the energy, head, or total dynamic head (TDH) the booster pump station must add to convey given flow rates from Whale Rock Reservoir to the San Luis Obispo Treatment Plant. The booster pump station must provide a minimum head of approximately 150 PSI to overcome the static elevation head from Whale Rock Reservoir to the San Luis Obispo Treatment Plant and the highest elevation.

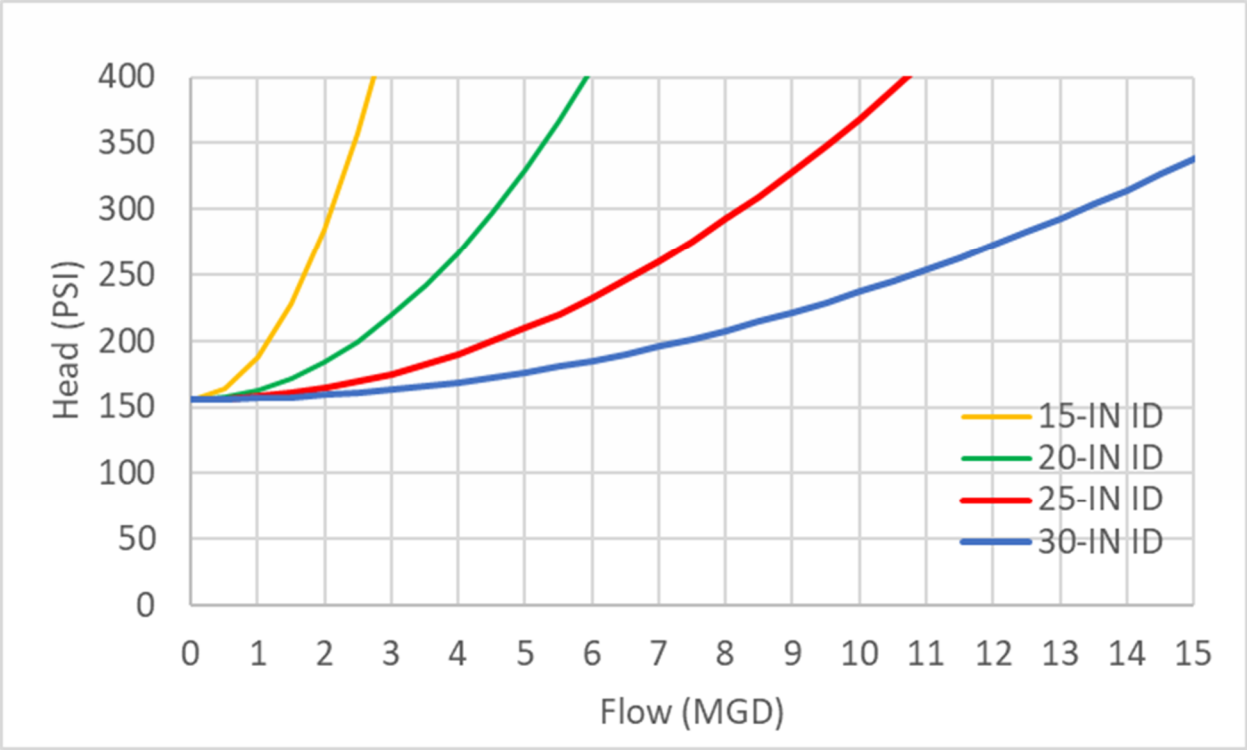

Figure 11. Whale Rock Pipeline hydraulic analysis results in graphical format. 30-IN ID blue line represents original pipeline. 25-IN ID with 30-IN OD red line represents 100% length structural CIPP rehabilitation. 20-IN ID with 24-IN OD green line represents 100% length structural HDPE pipeline slip lining. 15-IN ID with 20-IN OD yellow line represents 100% length structural HDPE pipeline slip lining.

Figure 11 blue line represents the existing theoretical 30-in diameter pipeline. The theoretical hydraulic limitations are either the booster pump station pump TDH, pipeline pressure rating including surge pressure, and/or recommended flow velocity. Assuming a recommended maximum flow velocity of seven feet per second (FT/S), the maximum theoretical flow rate results in the pump TDH and pipeline pressure ratings exceeding system design and acceptable ranges. Therefore, recommend maximum velocity will not be the limiting factor. Existing pipeline pressure rating ranges from 230 to 500 PSI. Assuming, a pipeline maximum pressure rating of 500 PSI (outside the range of Figure 11) results in flow velocity and rate of approximately 6.3 FT/S and 20 MGD, respectively. However, 500 PSI exceeds the existing booster pump station TDH and reasonable new pump TDH. Assuming a maximum pipeline pressure rating is 230 PSI (minimum pressure rating of the existing pipeline as new pipeline), the flow velocity and rate are limited to approximately 5.0 FT/S and 10 MGD, respectively. 230 PSI could result in a reasonable pump TDH assuming the pipelines are at their full pressure rating excluding surges. However, with the existing pipeline deteriorated conditions, the unknown wall loss depths, and without having performed a surge analysis, the pipeline flow velocities and rates should be reduced, resulting in reduced pump station TDH and resulting surges,

Table 23.

Table 23. 30-IN diameter pipeline reduced flow rates, velocities, and TDHs

Q (MGD)	V (FT/S)	TDH (FT)	TDH (PSI)
4.0	1.26	389	169
4.5	1.42	397	172
5.0	1.56	406	176
5.5	1.73	416	180
6.0	1.89	427	185

Figure 11 red line represents the existing 30-in diameter pipeline with 2.5-IN thick CIPP lining reducing pipeline inside diameter to 25-IN.

Table 24 summarizes HDPE iron pipe size (IPS) pressure pipe dimensional ratio (DR) and diameters.

Table 24. HDPE IPS Pressure Pipe DR and diameters for slip lining

		Outside Diameter (OD)			
		28	26	24	20
DR 9 (250 PSI)	Min Wall	3.111	2.889	2.667	2.222
	Avg ID	21.40	19.88	18.35	15.29
DR 11 (200 PSI)	Min Wall	2.545	2.364	2.182	1.818
	Avg ID	22.60	20.99	19.37	16.15
DR 13.5 (160 PSI)	Min Wall	2.074	1.926	1.778	1.481
	Avg ID	23.60	21.92	20.23	16.86

Figure 11 green line represents the existing 30-IN diameter pipeline with HDPE 24-OD, 20-IN ID, DR 13.5 (160 PSI) slip lining with the existing 30-IN diameter pipeline casing as the structural member. Figure 11 yellow line represents the existing 30-IN diameter pipeline with HDPE 20-IN OD, 15-IN ID, DR 9 (250 PSI) slip lining with the HDPE slip lined pipeline as the structural member.

It is assumed that a relatively more rigid 20-IN OD HDPE DR-9 or less rigid 24-IN OD HDPE DR 13.5 slip lining can accommodate the existing 30-IN diameter pipeline joint deflections without significant additional launching pits, whereas, 26 and 28-IN OD HDPE pipelines are too large in diameters to accommodate the existing 30-IN diameter pipeline joint deflections requiring significant additional launching pits.

Figure 11 red, green, and yellow lines assume that 100% of the 30-IN diameter pipeline length are structurally CIPP or slip lined. 100% length structurally CIPP or slip lining are unlikely due to relatively high costs and reduction in hydraulic performance. It is more likely that structurally CIPP or slip lining will be applied as a phased approach similar to Alternative 6. Assuming if 50% of the 30-IN diameter pipeline length is eventually structurally slip lined with 20-IN ID pipeline, graphically the hydraulic performance could be represented in Figure 11 as the 25-IN ID red line. However, if structurally CIPP or slip lining will be applied as a phased approach, there will be significant costs for mobilization with CIPP mobilization at approximately $300,000 per project.