Sanitary Sewer Overflow (SSO) Control and Wastewater Facilities Program

Conveyance Design Requirements

City of Baton Rouge/Parish of East Baton Rouge Department of Public Works

Submitted by

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Revision Control Log

Revision	Date Issued	Description of Changes	Pages Affected
1	8/2009	Revision of Program Requirements	All
2	9/2010	Revision of Program Requirements	All
3	7/2011	Added Attachment A: Major Utility Crossing Information Sheet; Edits to Section 3.2.5, 4.3, 6, 10.1, 10.4, 11.2, 11.3, 11.5, and 12.5.1	VII, 3-3, 4-2, 6-1, 10-1, 10-2, 11-1, 11-2, 12-2, 12-3
4	9/2012	Edits to Section 4.4.2, 4.4.3, 4.4.4, 4.5, 5.2.1, 5.2.2	4-4, 4-3, 4-4, 4-5, 4-6, 5-1, 5-2

Contents

1. Introduction

This document provides requirements for the design of gravity sanitary sewers and forcemains for projects associated with the City of Baton Rouge/Parish of East Baton Rouge (C-P) Sanitary Sewer Overflow (SSO) Control and Wastewater Facilities Program. The term Engineer is defined as an engineering design firm under contract with the C-P and producing engineering design work on the Program. These requirements are provided to encourage consistency in the design approach used by various Engineers.

While the purpose of these requirements is to assure uniformity, it is not intended to stifle Engineer's creativity, design innovation, and ingenuity. Engineers shall review these requirements and adapt them for design of the facilities for which they are responsible. Engineers are ultimately responsible for their design, and this responsibility is no way diluted or absolved by these requirements.

The Engineer may on occasion prefer to deviate from the requirements. This deviation could be prompted by conflicts in the document, a design concept or a feature that the Engineer believes is better or more cost-effective than the suggested remedy, or the development of a new process or equipment. In such cases, the Engineer shall immediately bring this matter to the attention of the Program Manager (PM), who will review project-specific deviations. The proposed deviation shall be discussed verbally with the PM within one week of the date on which the need for such deviation is recognized by the Engineer. The Engineer shall also request permission to deviate from the requirements by completing and submitting the form included in the *Requirements for Engineers*. The proposed deviation may be accepted as presented, accepted with identified changes, or not accepted. If the decision cannot be made immediately, the PM will notify the Engineer of the turnaround time expected to make a determination on the proposed deviation; this period of time will vary depending on the deviation request. Accepted deviations will also be further considered for possible changes to the requirements on a program-wide basis. The PM reserves the right to disallow the deviation from the requirements.

2. Design Flows

All sanitary sewers shall be designed to carry the estimated wet weather design peak flow from the area ultimately contributing to the respective reach of the sanitary sewer. The PM will provide design flow information to the Engineer. It shall be the responsibility of the Engineer to review this data, and based on detailed survey information and field review of the project collection system, note any potential inconsistencies in the provided flow data and present them to the PM. The Engineer is responsible for submitting written requests to the PM for confirmation of the selected alternative and recommendations based on the hydraulic model.

2.1 Wastewater Flow Components

Peak wet weather hydraulic design for gravity sewers and forcemains shall be based on the flow data, as described above. The PM will furnish the Engineer with the following design flow hydrographs:

- Dry weather flow (DWF)
- Wet weather flow (WWF), the Design Flow

2.1.1 Dry Weather Flow

DWF is sanitary and process flow contributed by residential, commercial, industrial, and other permitted users of the sewer system. DWF also includes groundwater infiltration (GWI). GWI is groundwater that enters the sanitary sewer system through defects in pipes, pipe joints, manholes, and structures. DWF rates primarily depend on development tributary to the interceptor. However, because DWF includes GWI, the physical condition of the sewer system and depth to groundwater are also factors.

The DWF rate in a sewer system typically varies based on time of day, area of contributing basin, land use of contributing area, depth to groundwater, day of the week, and condition of the collection system. The cumulative influence of each of these factors determines the relationship between minimum, average, and peak daily flow rates. The 24-hour average of the DWF is defined as Average Dry Weather Flow (ADWF).

Diurnal peaking of the wastewater flow was accomplished through gathering extensive flow monitoring information and subsequent model calibration.

2.1.2 Wet Weather Flow

WWF is commonly referred to as Rain Dependent Inflow/Infiltration (RDI/I). RDI/I is extraneous water that enters the sewer system as a direct response to rainfall. RDI/I may enter the sewer system by means of cross-connections between the storm drain and sanitary sewer systems or through direct connections to the system, such as roof drains and yard drains. RDI/I may also be caused by missing or poorly sealed cleanout caps and manhole covers. In shallow sewer systems, RDI/I may enter the system similar to GWI: through cracked pipe, leaking joints, and poorly constructed or deteriorated manholes and structures.

RDI/I flow volumes are directly related to the intensity and duration of the rainfall storm event, and generally rise rapidly and then recede gradually after the storm event. In addition to being dependent on rainfall, RDI/I varies with soil moisture content and tends toward higher volumes late in the wet weather season or after extended periods of rainfall when the soil is highly saturated.

2.1.3 Design Flow

The Design Flow is determined by combining the dry weather and RDI/I hydrographs. The peak of the RDI/I hydrograph for each sewer basin is intentionally set to coincide with that basin’s peak diurnal dry weather flow, thereby estimating a worst-case scenario of design flows for that sewer basin.

3. Hydraulic Design

This section provides basic hydraulic information together with coefficients or constant factors for hydraulic formulas that shall be used. This section has been divided into two subsections: gravity systems and forcemain system.

3.1 Gravity Systems

Major factors to consider in analyzing gravity systems include hydraulic design, roughness coefficient, and velocity and slope.

3.1.1 Pipe Sizing

Gravity sanitary sewers shall be sized to provide sufficient capacity for the required peak flow rates and design flow, which shall be provided to the Engineer, as stated above. The minimum allowable size for any gravity sewer, other than service laterals, shall be 8 inches in diameter. The minimum allowable size for service laterals is 6 inches.

3.1.2 Hydraulic Design Equation

The formula used for hydraulic design and sizing of gravity sewers shall be Manning's Equation with a roughness coefficient, "n," value of 0.013. The value of "n" may be assumed constant in partly full or completely full pipes. Although pipe manufacturers claim lower values for some pipe materials and linings, this slightly conservative value compensates for offset joints, poor alignment, grade settlement, sediment deposition, and the effect of slime and grease build-up in sanitary sewers.

3.1.3 Velocity and Slope

All sanitary collector and trunk sewers shall be designed and constructed to provide a minimum velocity of 2 feet per second (fps) when flowing full (for pipe 42-inches in diameter and less), or a minimum velocity of 3 fps when flowing full (for pipe greater than 42-inches in diameter), and a maximum velocity of 10 fps when flowing full, as calculated using Manning's equation. Table 3-1 presents the minimum and maximum slopes that shall be used as design criteria. Velocity shall be calculated at the design flow.

TABLE 3-1
Minimum and Maximum Gravity Sanitary Sewer Slopes

Sanitary Sewer Pipe Diameter (inches)	Minimum Slope (%)	Maximum Slope (%)
8	0.40	8.40
10	0.28	6.23
12	0.22	4.88
15	0.15	3.62
18	0.12	2.83
21	0.10	2.30
24	0.08	1.93
27	0.067	1.65
30	0.058	1.43

TABLE 3-1
Minimum and Maximum Gravity Sanitary Sewer Slopes

Sanitary Sewer Pipe Diameter (inches)	Minimum Slope (%)	Maximum Slope (%)
36	0.046	1.12
42	0.037	0.92
48	0.070	0.77
54	0.060	0.65
60	0.052	0.57
66	0.045	0.50

Note: Minimum slope for other diameters shall be determined by Manning's Equation, such that a minimum velocity of 2 fps (for 42-inch diameter pipe and less) or 3 fps (for 48-inch diameter pipe and greater) and a maximum velocity of 10 fps while the pipe is flowing full.

Minimum slopes less than those indicated shall be considered on a case-by-case basis as field conditions dictate, and may be approved by the PM. Velocities greater than 10 fps will be considered on a case-by-case basis, with proper consideration of pipe material, abrasive characteristics of the wastewater, turbulence, thrust at changes of direction, and protection against pipe and bedding displacement.

3.2 Forcemain Systems

Forcemains are designed in conjunction with the pump stations. Major factors to consider in analyzing pressure systems are hydraulic design, roughness coefficient, velocity, pressure surges, air and vacuum relief valves, and minimum and maximum flow ranges.

3.2.1 Pipe Sizing

Forcemains shall be sized to provide sufficient capacity for required peak flow rates, design flow, which shall be provided to the Engineer, as stated previously. The minimum allowable size for any forcemain shall be 4-inches in diameter. Pipe thickness design for operating pressures, surge pressures, and test pressures shall be calculated by the Engineer. Actual internal diameter of the pipe shall be considered when calculating head loss in the system.

3.2.2 Hydraulic Design Equation and Operating Pressure

The formula used for hydraulic design and sizing of forcemains shall be the Hazen-Williams formula. The roughness coefficient, "C," varies with velocity, pipe material, size, and age. The "C" values to be utilized shall be as follows:

- Boundary condition: C=100
- Design point 8-inch pipe and smaller: C=110
- Design point 10-inch to 18-inch pipe: C=115
- Design point 20-inch to 42-inch: C=120
- Design point greater than 42-inch: C=130
- Boundary condition: C=150 (run-out)

Minor losses from bends, valves, expansions, contractions, pipe entrance, pipe discharge, and other minor losses shall be accounted for as a function of velocity. These minor losses shall then be added to the friction losses determined using the Hazen Williams equation. Specific equations for minor losses may be found in various hydraulic reference manuals.

High points along the forcemain route shall be determined and accounted for so that the hydraulic grade line is always above the forcemain elevation.

The total dynamic head of a pump and forcemain system is the sum of the total static head and the friction head, including minor losses.

3.2.3 Surge Pressure

On most projects, Engineers performing the pump station design will be required to perform a surge analysis in accordance with the Pump Station Design Requirements. The Engineer performing the forcemain design shall incorporate any forcemain design features recommended by the surge analysis such as air relief/air vacuum valve assemblies or the pressure rating of the forcemain.

3.2.4 Pipe Design Pressure

The pipe design pressure shall take into account the normal operating pressures, surge pressures, and test pressures. The test pressure shall always be greater than the pump shutoff pressure or the maximum calculated surge pressure, whichever is greater. The pipe pressure class shall be suitable to withstand all pipeline pressure conditions. The minimum pressure class for all forcemain materials shall be 150 pounds per square inch (psi).

The Engineer shall develop a plot of the hydraulic grade line (HGL), energy grade line (EGL), ground elevation, and forcemain invert elevation versus the forcemain horizontal station to ensure that the pipe design pressure is not exceeded at any location.

3.2.5 Velocity

Forcemains shall be designed such that maximum velocity at design peak flow does not exceed 8 fps (higher velocities will be considered by the PM for special cases). Acceptable operating range during typical flow conditions is between 5 and 8 fps.

Forcemains shall be designed such that they are always full and that no point in the vertical alignment is located above the energy grade line. Low and high points in the vertical alignment shall be avoided and an uphill slope shall be maintained from the pumping station to the discharge point.

4. Pipe Design

4.1 General

The structural design of a gravity sewer requires that the supporting strength of the pipe, divided by an appropriate factor of safety, be sufficient to resist external loads. The equations for determining loads vary by type of installation, namely trench, embankment (positive and negative projecting), and tunnel. The design of a forcemain differs from the design of a gravity line in that internal pressures need to be considered for the forcemain. Internal pressure includes static and dynamic heads plus allowances for surge. Design of forcemains and the design of upstream pump stations shall be coordinated to ensure that pipelines will be capable of withstanding the discharge pressures of pumps and for development of an overall surge prevention methodology.

Pipes used in forcemains shall be capable of withstanding the maximum internal pressure and the maximum external loading configuration acting independently. No reduction of external loads due to internal pressures will be allowed.

Gravity sewers and forcemains shall not be designed to be installed parallel within drainage ways, nor shall they be designed to be installed under any structure.

Deflection of Polyvinyl Chloride Pipe (PVC) shall not be allowed.

These requirements do not cover information on design of the sewer pipe cross sections. Resources for design of the pipe cross sections include the standard specifications, applicable ASTM and AWWA standards, and manufacturer literature.

External load calculations shall consider dead loads, concentrated live loads, construction loads, and distributed loads acting upon the pipeline.

A geotechnical investigation is part of the project scope and the unit weight of soil shall be as indicated in the geotechnical report. For purposes of fee proposal negotiation, the Engineer shall assume a minimum of one, 20-foot soil boring for every 500 linear feet of gravity sewers and pipelines.

The ground profile shown on the drawings shall be the profile located directly above the pipe, not at a different such as the center line of a road.

4.2 Thrust Restraint

Forcemains are subject to hydraulic thrust forces at locations where there are changes in direction or diameter, tees, or termination at a plug or valve. Thrust is generated by internal hydrostatic pressure and dynamic forces. Dynamic forces are usually not significant in pipelines unless velocity head is large in comparison with hydrostatic pressure. In high velocity pipelines, however, dynamic thrust may be sizeable. Hydrostatic pressure is the greatest pressure to which the pipeline is subjected (test pressure) and governs the design of thrust anchorage. The Engineer shall submit thrust calculations to the PM for information purposes.

Anchorage of pipelines to withstand thrust forces shall be accomplished through the use of restrained joints which shall be specified. The use of concrete thrust blocks shall not be permitted. These Requirements do not cover the design of restrained joint systems, however, most pipe manufacturers provide literature on the subject for use with their pipe materials. In addition, several soil factors shall be identified and taken into consideration, including safe bearing load of undisturbed soil, soil cohesion, angle of internal friction, and soil unit weight.

Restrained lengths shall be shown on all applicable plan and profile drawings at each location needed.

4.3 Air Release / Vacuum Valves

The location of air release/vacuum valves along the forcemain route requires careful consideration. Forcemain vertical profile and horizontal alignment shall be controlled to minimize the requirements for air release/vacuum valves. Air release/vacuum valves are a potential source for odor and corrosion. Forcemain design shall mitigate potential odor and corrosion. Sizing of air release/vacuum valves shall be appropriate for the conditions in the forcemain, and the Engineer shall submit valve sizing calculations to the PM for information purposes.

At a minimum, high points of forcemains shall be provided with air release/vacuum valves. Air release/vacuum valves shall also be provided at intermediate high points and along long runs of flat forcemain at minimum 1,000-foot intervals. Air release/vacuum valves shall be located to facilitate the required maintenance operations, and shall be in accordance with the C-P standards. Additional air release/vacuum valve locations could be required as a result of the surge analysis.

Air release/vacuum valves shall be connected to the mainline via a tapped blind flange on the branch of a tee; a manual isolation valve shall also be provided.

4.4 Construction Requirements

4.4.1 Trench Width

The width of the trench at and below the top of the gravity sanitary sewer/forcemain shall be only as wide as necessary for proper installation and backfilling, and consistent with safety requirements. The trench width shall be in accordance with C-P standard details.

4.4.2 Bedding and Backfill—Sanitary Sewers and Forcemains

Minimum requirements for the bedding of pipe and the backfilling of trenches are provided in C-P standard details. Pipe bedding and initial backfill shall be provided from minimum 6 inches below the bottom of the pipe to 12 inches above pipe crown for pipe trenches in the road right-of-way or to 6 inches above pipe crown for pipe trenches in unimproved surfaces. The Engineer shall consider these requirements when designing pipeline alignments to ensure minimum dimensions are achievable.

Uniform, compacted bedding material provides radial support to the pipe, maintaining the pipe shape and abating settlement. Poor bedding material and/or poor compaction will lead to pipe deflection, flat profiles, low spots, ovaling of the pipe cross section, splitting, cracking, or collapse. Bedding material shall be a mixture of sand and pea gravel. Crushed stone and stone with angular shapes or sharp edges can damage the pipe and are not allowed for bedding material.

Forcemains shall have a minimum of 36 inches of cover, and shall be designed at a continuous slope between high and low points to minimize the formation of air pockets. There shall be a minimum cover of 60 inches at high points to accommodate buried air release/vacuum valve vaults.

The design plans and specifications submitted to the PM and C-P for review, approval, and issuance of a construction permit shall include the detailed trench drawing.

4.4.3 Backfilling Pipe Trenches

Compaction

Trench backfill compaction is necessary to prevent pavement settlement. Loose backfills will consolidate over time, and pavement failures will occur during the construction contract duration, during the warranty period, and/or over time. Compaction is achieved by reducing the void ratio in granular backfill and obtaining substantially the maximum density at the optimum moisture content for clays and silts. Compaction is dependent upon the:

1. Weight of the compaction equipment.
2. Number of passes over each lift.
3. Loose lift thickness control.
4. Moisture content control.

Paved Areas

Under highways, roads, streets, parking lots, and utilities, a well graded limestone backfill shall be provided from 12 inches above the crown of pipe to the pavement subgrade and shall include the full excavated trench cross section, per C-P standards. The locally available backfill material is 610 Stone.

Trenches adjacent to pavements and structures require the same materials as those under pavements. Trenches within a 45 degree influence line of the edge of the curb, edge of the shoulder, or the edge of a foundation, shall also be backfilled with well graded limestone.

Geotextile Fabric

Granular trench backfill can be subject to mixing and migration with trench wall and bottom materials where the existing materials are relatively soft. Mixing and migration is promoted when groundwater is present. Separating coarse granular backfill from fine granular backfill and separating granular backfill from the natural materials in the trench sides and bottoms with geotextile fabric will prevent mixing and migration, hence abating settlement.

Flowable Fill

In accordance with C-P Standards, flowable fill, also known as Controlled Low Strength Material, shall be provided if the Engineer determines it is needed (see examples below), if required by the local highway authority, or if special conditions exist that make flowable fill necessary. The placement of flowable fill creates hydrostatic uplift forces on the pipe, which may deflect or damage the pipe. The pipe must be ballasted to resist the uplift forces, and the ballast must be designed by the Engineer. Casting flowable fill in lifts minimizes uplift forces. Examples of locations where flowable fill would be considered include:

1. At high traffic volume sites.
2. At signalized intersections.
3. At hospital, fire department, and police station entrances.
4. At interstate highway entrance ramps.
5. At public school entrances.
6. Adjacent to or crossing electrical and communication duct banks.

Unpaved Areas

Backfill shall generally be the material excavated from the trench in accordance with C-P standards, beginning 6 inches above the crown of the pipe. Excavated soils may be unsuitable for backfill if the soils contain waste materials, organic materials, fat clays, wet sands, or a combination thereof. Unsuitable materials shall become the property of the Contractor, shall be removed from the site, and shall be legally disposed. If the Contractor imports clay, then prior to hauling, the borrow site must be identified, a test pit must be dug and inspected by a geotechnical engineer, and a soil sample must be delivered to a testing laboratory. A Standard Proctor test will be performed and the optimum moisture content will be measured. Hauling may then commence.

The compaction of clays and silts, whether imported or usable excavated material, requires placement in 8-inch loose lifts, use of a sheepsfoot roller, and soils substantially at the optimum moisture content. Lack of loose lift control, compacting without a sheepsfoot roller, and/or too dry or too wet soils will lead to settlement.

The material shall be placed in accordance with C-P standards.

Deep Trenches

Deep trenches require methods that achieve compaction behind the trench box while maintaining worker safety. Backfilling behind the trench box requires placement of materials in 8-inch loose lifts and compaction with remote controlled compaction equipment. The number of passes must be calibrated with that equipment on the same backfill material and then counted during the operation. The compacted material must be benched along the length of the trench with maximum bench heights of three lifts. Full height fills leave a tall, uncompacted slope toward the trench box. Attempts to integrate the next backfill sequence into the tall slope will lead to settlement in that length of the trench. The Engineer shall specify the material to be utilized for deep trench backfill.

4.4.4 Trench Protection

Trench protection in accordance with local, state, and federal guidelines shall be provided for all areas of trench excavation. For permitting purposes, the Engineer shall design the trench protection required (including sheeting and shoring, if needed). However, during construction, the Contractor shall be required to have a detailed trench protection plan that shall be prepared, signed, and sealed by an Engineer licensed in the State of Louisiana.

During Non-working Hours

One of the following methods of trench protection shall be provided as a minimum:

- Steel plate (minimum 5/8-inches thick) shall be provided over the entire trench excavation.
- Approved barriers shall be placed around the entire trench excavation.
- The entire trench shall be backfilled.

School areas or high pedestrian areas shall be covered with a steel plate or backfilled at the end of each day.

If there has been NO work on the trench excavation for 3 days or more, the entire trench excavation shall be backfilled by the end of the third day.

During Working Hours

The maximum amount of exposed pipe trench shall be 50 feet of pipe or two pipe joints, whichever is shorter.

Traffic Control

Traffic control shall be designed by the Engineer to meet local, state, or federal standards, whichever apply.

Excavation Support Systems

When the soil borings indicate strata of wet sands, loose silts, loose clays, or fat clays, an excavation support system shall be designed by the Engineer. Excavations down through such strata will cause flowing of sands, silts, or clays laterally, undermining adjacent soil, utilities, pavements, or foundations. The excavation support system shall be designed to resist the active lateral soil pressure plus hydraulic head.

The choice of an excavation support system is dependent upon the proximity of adjacent buildings and structures. Driving of steel sheeting with impact or vibratory hammers can cause damage or settlement of adjacent homes or buildings. Where impact or vibratory damage is a risk, the Engineer will choose one of the following:

1. Steel sheeting which can be pushed into place with hydraulic pressure.
2. Columnar drilled pier wall.
3. Grouted slurry wall with soil anchors.
4. Soil grouting.
5. Soil freezing.

4.5 Geotechnical Investigation

Soil borings shall be taken during design, as discussed in Section 4.1, to determine the feasibility of open trench excavation. The following tests shall be performed:

1. Standard Penetration Tests at 2′-6″ intervals.
2. Split Spoon Sampling at 2′-6″ intervals.
3. Unconfined Compressions Tests of cohesive soils.
4. Moisture Content Tests.
5. Atterberg Limit Tests of potentially plastic clays.
6. Groundwater Readings at the completion of the borings.
7. Groundwater Readings 24 hours after boring or later.

The soil strata and groundwater readings will be shown on the profiles.

5. Surface Restoration Design Considerations

5.1 Non-Paved Areas Surface Restoration

5.1.1 Open Fields and Wooded Areas

Open fields and wooded areas shall be restored in accordance with C-P standards. Erosion control matting in accordance with C-P Standards shall be applied to slopes greater than 3:1.

5.1.2 Lawn Areas

Lawn areas of businesses or residences shall be restored in accordance with C-P standards. Erosion control matting in accordance with C-P Standards shall be applied to slopes greater than 3:1.

Previously established/maintained lawns areas (any residence, business, or rights-of-way) shall be restored with sod.

Sod shall be of the same type grass as exists at the site disturbed and/or shall be in accordance with C-P standards.

5.1.3 Gravel Drives

Gravel drives shall be replaced to their existing thickness or with a minimum thickness and material according to C-P standards.

5.2 Paved Areas Surface Restoration

5.2.1 Temporary Asphalt Concrete Pavement Patching

The temporary pavement patch shall be in accordance with C-P standards. The thickness of the temporary pavement patch shall be in accordance with C-P standards. Temporary patches must be maintained over the duration of the contract and the warranty period.

5.2.2 Permanent Pavement Patching

Permanent Asphalt Concrete Pavement Patching

Prior to placing a permanent pavement patch, the temporary pavement patch shall be removed.

The permanent pavement patch shall be asphalt concrete hot mix in accordance with C-P standards. The thickness of the pavement patch and methods and materials for installing pavement patch shall be according to C-P standards.

The existing asphalt road base shall be evaluated and must be replaced with materials of equal or better stiffness. It is impractical to install soil-cement base in small areas, and compacted stone base is not of equal stiffness. Therefore excavated base must be replaced with full depth hot mix asphalt concrete.

Portland Cement Concrete

The permanent pavement patch shall be Portland Cement Concrete in accordance with C-P standards. The thickness of the pavement patch and methods and materials for installing pavement patch shall be according to C-P standards.

5.3 Street Repaving Criteria

5.3.1 General

For transverse or longitudinal cuts, the area of pavement removed shall be replaced with new pavement to match existing pavement.

5.3.2 Asphalt Concrete Streets

Longitudinal Pavement Cut

All existing pavement removed for trench excavation shall be removed in accordance with C-P Standards.

The typical residential street shall be repaved from "curb to curb" or "edge of road to edge of road." Existing pavement for "curb to curb" repaving shall be milled, and for "edge to edge" repaving shall be overlaid.

The minimum overlaying width shall be one full lane. Multi-lane streets shall be overlaid one full lane or two full lanes. Partial overlaying of lanes is not allowed.

Transverse Pavement Cut or Pavement Cut for Lateral Installation

All existing pavement removed for trench excavation shall be removed in accordance with C-P Standards. Transverse pavement cuts shall be in accordance with C-P Standards.

Pavement shall be replaced for trench excavation in accordance with C-P Standards. Where street milling or overlay is required, pavement restoration shall be asphalt concrete with thickness and placement methods in accordance with C-P standards.

Surface overlaying per the above criteria shall be performed by the contractor within 4 months of installation of the pipeline of the project.

5.3.3 Portland Cement Concrete

All existing pavement removed for trench excavation shall be removed by full depth saw cutting of the existing pavement. The Engineer shall refer to C-P Standards for information regarding when to remove up to existing joint.

6. Forcemain Additional Design Considerations

Forcemains that are 24 inches and smaller, shall enter lift station wet wells just above the normal high water level in the wet well. Should an elevation drop be required to obtain the outlet connection, the downslope of the forcemain prior to the terminal facility shall not exceed 45 degrees, and adequate air venting shall be provided at the profile breakpoint.

Forcemains shall enter gravity sewer manholes at the invert of the manhole, according to C-P standards. Should an elevation drop be required, the downslope of the forcemain prior to the terminal manhole shall not exceed 45 degrees, and adequate air venting shall be provided at the profile breakpoint.

Special attention shall be given to gravity lines or lift station wet wells that receive flow from sanitary sewer forcemains to ensure excessive flow rates do not create surcharge conditions downstream. If the forcemain velocity is greater than 2.5 fps at the termination, the forcemain pipe size shall be increased at least one pipe size for the last two pipe joints to help dampen the velocity. If the forcemain velocity is less than or equal to 2.5 fps at the termination, then no upsizing of the pipe shall be required. The forcemain shall have a series of 45 degree bends, as shown in the C-P standards.

If the receiving manhole is an existing manhole, it shall be lined per C-P Standards.

Interconnections between new and existing forcemains shall be designed and detailed by the Engineer.

90 degree bends shall not be used (multiple 45 degree bends shall be used). Wyes shall not be used (tees shall be used).

All sewer forcemains shall be hydrostatically tested in accordance with C-P standards.

Vertical and horizontal separation requirements of forcemains from other utilities shall be in accordance with C-P and utility agency requirements.

Existing forcemains located below buildings shall be relocated around the buildings as part of this Program.

7. Gravity Sewer Additional Design Considerations

Existing gravity sewer pipe located below buildings shall be relocated around the buildings as part of this Program.

Vertical and horizontal separation requirements of gravity sewer mains from other utilities shall be in accordance with C-P and utility agency requirements.

All gravity sewers shall have plastic warning tape with a metallic strip along the sewer alignment, buried a maximum of 12 inches below finished grade.

All gravity sewers and service laterals shall be tested in accordance with C-P standards.

The peak wet well elevation shall be maintained at one foot below the lowest inlet pipe invert discharging into the wet well for influent pipes less than 25 inches in diameter. Upon approval from the PM, and based upon a case-by-case analysis, the high water level may be allowed to back up into the pump station influent sewer, for influent sewers greater than 29 inches, at a maximum depth of 0.5D above the sewer invert where it enters the wet well, and where D is the inside diameter of the influent sewer.

8. Sewer Structures and Manholes

8.1 General

Sanitary sewer manholes shall be installed at the end of each gravity line segment; at all changes in grade, size, materials, and/or alignment; and at all intersections. Cleanouts shall not be substituted for manholes.

Positive drainage away from the manhole shall be provided.

8.2 Manholes

New manholes shall be precast concrete in accordance with C-P Standards. For major streets, wooded non-landscaped areas, and manholes that are required to be lined, manhole replacements shall be circular flat-top manholes. Offset (eccentric) manhole cones shall be used in landscaped areas and residential streets.

Fiberglass manholes in accordance with C-P Standards may be considered as an alternate to precast concrete only in non-traffic areas, for industrial or corrosive areas. Cost shall be a consideration in evaluating the use of fiberglass manholes.

8.2.1 Manhole Spacing

The maximum center-to-center distance between manholes for collection system piping up to 16-inch diameter shall be 300 feet per C-P Standards.

The maximum center-to-center distance between manholes for 18-inch diameter trunk lines and larger is 500 feet.

Greater spacing may be permitted for larger sewers upon review and approval of the PM and C-P.

8.2.2 Manhole Diameters

The internal diameter of manholes shall be minimum 4 feet for lines 16 inches and less in diameter.

The internal diameter of manholes shall be minimum 5 feet for lines from 18 inches to 24 inches in diameter.

The internal diameter of manholes shall be minimum 6 feet for lines larger than 24 inches in diameter.

Manhole diameter sizing, however, is contingent upon the limitations of the manufacturer due to pipe sizes and pipe deflections at the manhole. The Engineer shall verify, based on the proposed manhole pipe configuration and pipe sizes, that the proper manhole diameter is provided. Manhole sizing shall be approved by the PM and C-P.

8.2.3 Manhole Steps

Manhole steps are not allowed.

8.2.4 Manhole Joints

Manholes shall have as few joints as possible to minimize infiltration. A flexible watertight rubber gasket conforming to ASTM C443 or ASTM C990 shall be used at each joint. Additionally, an external seal wrap shall be used on the outside of each manhole joint.

A manhole shall be constructed with a minimum 48-inch base section (maximum 8-foot base section), and the minimum number of sections possible that the precaster can provide to minimize the number of joints in the manhole.

A minimum manhole section shall be 16 inches in depth.

The height of the manhole sidewall shall be such that a maximum of one adjustment ring is used to bring the manhole frame and cover to the required elevation.

8.2.5 Manhole/Pipe Connections

Pipe connections to precast concrete manholes shall be made with flexible rubber boot connectors or integrally cast flexible connectors.

Pipe to pipe connections shall be made with non-shear adjustable repair coupling, as specified in C-P Standards.

Channels and benches shall be factory grouted only. There shall be no field grouting of channels or benches.

A minimum line drop of 0.1 foot shall be provided across new manholes.

Where pipes of differing sizes enter and exit manholes, the pipes shall align at the 0.8 pipe diameter point.

Manholes set more than 2 feet abovegrade shall have hinged covers with large, minimum 6-foot by 6-foot flat top slabs in accordance with C-P Standards.

8.2.6 Manhole Frames and Covers

Manhole frames and covers shall be replaced as necessary. Existing manhole frames or covers shall not be reused and shall be turned over to C-P if requested.

A C-P standard watertight frame and cover with gasketed “pan” seal and with locking handle and bar shall be used in flood prone areas, and areas where water ponds or could pond, including traffic areas. Vents shall be installed in long runs of trunk line sewers with watertight frames and covers where applicable. Vents shall be designed to preclude water entering the sewer system during storm events through the vents. Vents shall not be installed in the right-of-way.

C-P standard frame and cover shall be used in all other areas. Cover shall be provided with an inset gasket.

Manhole rim elevations shall be set at grade in traffic areas and finished landscaped areas (finished grade is at the top of mulch in finished landscape areas), shall be set at 3 inches abovegrade in non-finished landscaped areas, and shall be set at 2 feet above finish grade in non-traffic and non-landscaped areas.

8.3 Special Manhole—Drop Connections

No internal drop manhole connections shall be allowed for new sewer construction. Outside drop pipe connections, per C-P Standards, shall be provided for all sanitary sewer or laterals entering a manhole at an elevation greater than 24 inches above the invert of the manhole.

8.4 Manhole Testing

All manholes shall be vacuum tested in accordance with C-P standards.

9. Servitudes

Whenever possible, sanitary sewers and forcemains shall be constructed within the public right-of-way. Should the boundaries of required servitudes extend outside the limits of the public right-of-way, recorded servitudes shall be acquired, dedicated, and recorded solely for the benefit of the C-P. Existing servitude boundaries shall be shown on the plans as "Sanitary Sewer Servitude" and proposed servitude boundaries shall be shown on the plans as "Required Sanitary Sewer Servitude" (to be used for gravity sewers and forcemains).

The dimensions of the required servitudes shall be as defined in the Program *Right-of-Way Map/Real Estate Requirements*, Attachment A.

All pipes shall be centered in the servitude. For pipes constructed in the public right-of-way, the servitude shall extend the distance outside the right-of-way necessary to provide the required servitude width.

The servitudes shall be exclusively under the discretion and control of the C-P. Ingress and egress shall be available to the C-P at all times. No utility companies are allowed to use the sewer servitudes for installation of their utility lines. All plan sheets shall clearly identify the sanitary sewer servitude and the location of all other proposed utilities. The horizontal and vertical plans shall identify all utilities proposed to cross the sanitary sewer servitude.

Temporary construction servitudes may be necessary when it is evident to the Engineer that additional area or width is needed for construction, staging, or set-up. Temporary construction servitudes shall be shown on the plans.

10. Sewers in Relation to Streams, Water Supplies, Storm Sewers, and Location of Existing Utilities

10.1 Sanitary Sewer Crossing Drainage Ways

Whenever applicable, the sanitary sewer crossing the drainage way shall be pressure tested from manhole to manhole to assure 100 percent watertightness. Minimum pipeline cover under drainage ways shall be 60 inches, or the minimum required by the governing agency, whichever is greater.

Gravity sewers and forcemains shall generally follow their respective uniform slopes through the crossing, if at all possible. If this is not possible for forcemains, then uniform upward arched pipelines shall be designed instead of buried downward arched lines. The use of mounted siphons shall be avoided.

10.2 Protection of Water Supplies

There shall be no physical connections between a public or private water supply system and a sanitary sewer or appurtenances thereto that would permit the passage of any polluted water into the potable supply. Sanitary sewers shall be designed to be installed at least 10 feet horizontally, measured edge-to-edge, from any existing or proposed water line. The distance shall be measured edge-to-edge. In cases where it is not practical to maintain a 10-foot separation, the appropriate reviewing agency may allow deviation on a case-by-case basis if supported by data from the Engineer. Such deviations may allow installation of the sewer closer to a water main, provided that the following conditions exist:

- Water main is in a separate trench or on an undisturbed earth shelf located to one side of the sewer
- Water main is at an elevation such that the bottom of the main is at least 18 inches above the top of the sewer

Sanitary sewers crossing water mains shall be designed to be installed to provide a minimum vertical separation distance of 18 inches between the outside of the water main and the outside of the sewer. This shall be the case where the water main is either above or below the sewer. The crossing shall be designed so that the sewer joints will be equidistant and as far as possible from the water main joints. Where a water main crosses under a sewer, adequate structural support shall be provided for the sewer to prevent damage to the water main. When it is impossible to obtain proper horizontal and vertical separation as stipulated above, both the water main and sewer shall be constructed of slip-on or mechanical joint pipe restrained and complying with the public water supply design standards and shall be pressure tested to 150 psi to assure watertightness before backfilling (Recommended Standards for Wastewater Facilities, 1990 Edition).

10.3 Sanitary Sewers in Proximity with Storm Sewers

For new parallel sewer construction the minimum horizontal separation shall be greater than or equal to 3 feet outside-to-outside.

For new sewer crossings, the minimum vertical separation shall be greater than or equal to 12 inches.

When horizontal separations are less than 3 feet, the minimum sanitary sewer pipe material specification shall be AWWA C900 or AWWA C905 (DR 18) PVC pipe or Class 150 DIP with Protecto 401 from manhole to manhole. When vertical separations are less than one foot, a neoprene pad shall be placed between the two pipes.

Storm sewers shall not be connected to sanitary sewers. Storm waters that are known or are found to be connected to sanitary sewers, during construction activities, field activities, or surveying, shall be disconnected.

10.4 Location of Existing Utilities

The Engineer shall locate existing utilities as required for completion of the design and to avoid interference with existing utilities during construction. Utility location work shall conform to the applicable provisions of CI/ASCE 38-02, "Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data." A copy of the provisions may be obtained from the American Society of Civil Engineers at www.asce.org.

The Engineer shall submit the Major Utility Crossing Information sheet, included in Attachment A, for each major utility crossing at each design submittal. The sheet will be provided to the Engineer in Microsoft Word format if requested.

The minimum level of utility location required shall be Quality Level C (QL C) as defined by CI/ASCE 38-02, and shall include the tasks in Sections 10.4.1 through 10.4.9.

10.4.1 Records and Information Research

Conduct appropriate investigations (e.g., owner records, Department of Transportation and Development (DOTD) records, Louisiana One Call records, C-P records, personal interviews, visual inspections, etc.), to help identify utility owners that may have facilities within the project limits or that may be affected by the project.

10.4.2 Records Collection

Collect applicable records (e.g., utility owner base maps, "as-built" or record drawings, permit records, field notes, geographic information system data, oral histories, etc.), on the existence and approximate location of existing involved utilities.

10.4.3 Records Review

Review records for: evidence or indication of additional available records; duplicate or conflicting information; need for clarification.

10.4.4 Aerial or Ground-Mounted Facilities

Include records research, identification, and depiction of aerial or ground-mounted utility facilities.

10.4.5 Compilation and Presentation of Data

Transfer information on all involved utilities to appropriate plan sheets, electronic files, and/or other documents. All plan sheets shall clearly identify the horizontal and vertical location of all utilities.

Exercise professional judgment to resolve conflicting information.

For information depicted, indicate: utility type and ownership; date of depiction; quality level(s); end points of any utility data; line status (e.g., active, abandoned, out of service); line size and condition; number of jointly buried cables; encasement.

10.4.6 Identification of Surface Utility Features

Identify surface features from project topographic data and from field observations that are surface appurtenances of subsurface utilities.

10.4.7 Aerial or Ground-Mounted Facilities

Include survey and correlation of aerial or ground-mounted utility facilities.

10.4.8 Surveys

Survey surface features of subsurface utility facilities or systems, if such features have not already been surveyed by a Registered Professional. If previously surveyed, check survey data for accuracy and completeness.

The survey shall also include (in addition to subsurface utility features visible at the ground surface): determination of invert elevations of any manholes and vaults; sketches showing interior dimensions and line connections of such manholes and vaults; any surface markings denoting subsurface utilities, furnished by utility owners for design purposes.

10.4.9 Correlation, Interpretation, and Presentation of Data; Resolution of Discrepancies

Exercise professional judgment to correlate data from different sources and to resolve conflicting information.

Prepare plan sheets, electronic files, and/or other documents to reflect the integration of existing utility information.

Recommend follow-up investigations (e.g., additional surveys, consultation with utility owners, etc.) as may be needed to further resolve discrepancies.

Once all the data have been gathered and incorporated into the design, the Engineer shall arrange a meeting in the field with each utility owner involved and review the findings. After this meeting, the Engineer shall incorporate all appropriate comments and then send the completed drawings to the utility owner for their records and final review. The PM Team’s Project Manager may attend these meetings.

On some projects, the Engineer may determine that more precise determination of the horizontal and vertical locations of existing utilities is desirable. In these cases, the Engineer shall notify the PM of the need for additional utility locations and the PM will determine whether the requested utility locations will be performed and how the work will be accomplished.

Because of the existing general soil conditions in the Program area, Quality Level B (QL B), as defined by CI/ASCE 38-02, “Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data” is not allowed.

Quality Level A (QL A) as defined by CI/ASCE 38-02, “Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data” is required at critical utility crossings and on all trenchless designs, including but not limited to jack and bore and horizontal directional drilling.

11. Materials of Construction

11.1 Introduction

This section describes materials acceptable for the construction of forcemain and gravity sanitary sewers, manholes, and their appurtenances.

11.2 Gravity Sewers

The following pipe materials are approved for the construction of gravity sanitary sewers. Pipe material shall not change from manhole to manhole. See the Qualified Products List for approved manufacturers:

- Polyvinyl Chloride Pipe (PVC): Sizes 8 inches to 15 inches shall be PVC (ASTM D3034, DR 35 minimum) solid wall pipe; Sizes 16 inches to 24 inches shall be PVC (ASTM F679, DR 35 minimum) solid wall pipe. Where pipe depth is greater than 20 feet, DR 26 minimum solid wall pipe shall be provided
- Fiberglass Reinforced Polymer (FRP): Gravity sewer sizes 18 inches and above shall be FRP, minimum SN 46 pipe (ASTM D3262)
- Ductile Iron Pipe (DIP): Minimum pressure class 150 with Protecto 401 Ceramic Epoxy lining shall be used for pipe sizes of 24 inches and larger, and are only to be used for sewer pipe or if required by a permitting agency. Smaller DIP shall be considered for use for shallow bury, road crossings, and creek crossings (encasement may be required)
- High Density Polyethylene Pipe (HDPE): Minimum DR 11 with heat fusion welded joints. HDPE or fusible PVC pipe shall only be used for trenchless design and construction.
- Pipe materials for trenchless methods are described further below.

11.3 Forcemains

The following pipe materials are approved for the construction of forcemain sanitary sewers. See the Qualified Products List for approved manufacturers:

- PVC: AWWA C900, minimum DR18 for 4 inches to 12 inches for both non-fusible and fusible; C905, minimum DR25, for 14 inches to 24 inches for both non-fusible pipe and fusible pipe.
- HDPE: Minimum DR 11, AWWA C906 with heat fusion welded joints
- DIP: Minimum pressure class 150 for diameters greater than 24 inches, with Protecto 401 Ceramic epoxy lining.
- Pipe materials for trenchless methods are described further below.

11.4 Gravity Sewer Service Laterals

All service laterals shall be replaced to the property line or permanent servitude line with minimum 6-inch PVC (SDR 35) service laterals with a minimum slope of one percent.

A new PVC cleanout, with a tee wye shall be provided at the ROW line or servitude line. Transition to 4-inch house lateral shall be made with a 6″x 4″ PVC concentric reducer.

Service laterals connected to DIP shall use ductile iron wyes with Protecto 401 Ceramic Epoxy lining.

Service lateral connections to CCFRPM or GFRP pipe shall use an "Inserta-Tee" (Inserta Fittings Company).

Service lateral connections to high density polyethylene (HDPE) pipe shall use an electrofusion branch saddle.

11.5 Other Pipe Material Considerations

Fusible polyvinyl chloride pipe (PVC) and HDPE pipe shall be considered in trenchless construction methods for gravity sewer or forcemains (See Section 12). If the Engineer desires to design using these types of materials in the traditional open cut construction method for forcemains or change the minimum DR requirements for these materials, then the Engineer shall submit a Deviation from Program Requirements Form along with the appropriate paperwork and calculations.

At a minimum, all 36-inch and smaller DIP shall be designed and installed with polyethylene encasement. Where larger DIP is being considered for installation the Engineer shall either contact DIPRA or hire a Specialty Firm to perform soil survey tests and observations, evaluate the tests, and make design recommendations. At a minimum the following factors shall be considered: earth resistivity, pH, oxidation-reduction (redox) potential, sulfides, moisture content, soil description, potential stray direct current, and experience with the existing installations in the area per AWWA C105/A21.5.

Should the recommendations indicate the use of anything other than passive protection (polyethylene encasement), then the Engineer shall incorporate such findings into the contract documents.

There are several different types of gas and petroleum pipe lines in the Program area. It is the responsibility of the Engineer to contact the owner of these pipe lines and adhere to the owner's requirements and to design the new pipe for complete cathodic protection. This may include but may not be limited to wire connections from pipe segment to pipe segment (crosses pipe joints), the use of the same type of cathodic protection, and the use of isolation flanges.

12. Alternative Construction Methods Design Considerations (Forcemain and Gravity Sewer)

12.1 Considerations

Alternative construction methods have several advantages and limitations, as outlined below.

Advantages:

Construction can be performed in difficult ground conditions with minimal or no dewatering.

Pipes can be installed at great depths without a drastic effect on cost. Depth can be a factor if there is underground congestion (many utilities in the area) or there is a high water table.

Workers will not need to enter the construction pit/tunnel, so safety is increased. Piping can be jacked directly without the need for casing pipe.

Limitations:

Capital cost is increased.

Some alternative construction methods have difficulty in soils with boulders with a size that is more than 20 or 30 percent of the machine diameter.

Cannot use flexible or low strength piping, such as PVC.

Obstructions, such as boulders, trees, roots, or man-made structures, can prevent the use of an alternative construction method.

12.2 Microtunneling / Pilot Tube Microtunneling Gravity Sewer

Pipe for microtunneling shall be Extra Strength Clay pipe (ASTM 1208) or centrifugally cast fiberglass reinforced polymer mortar (CCFRPM, SN greater than 72) pipe (ASTM D3262).

12.3 Hand Tunneling or Microtunneling Forcemain

A steel liner plate or steel casing pipe shall be used for hand tunneling.

The annular space between the liner plate and the soil shall be grouted-in-place.

The casing pipe shall be steel pipe meeting the latest approved American Railway Engineering Association “Specifications for Pipeline Carrying Flammable or Non-Flammable Substances.” See Jack and Bore requirements below.

Carrier pipe shall be the same as open cut and meet the requirements of the permitting agency.

12.4 Directional Drilling for Gravity Sewers

Directional Drilling Gravity Sewer shall be considered only when the pipe slope is greater than one percent for gravity sewer and there is a drop of greater than 1 foot at the downstream manhole. Pipe for directional drilling shall be HDPE minimum DR 11 (AWWA C906) with heat fusion welded joints or fusible PVC (minimum DR 18 AWWA C900 or minimum DR25 AWWA C905).

12.5 Horizontal Directional Drilling for Forcemains

Design consultants shall adhere to the horizontal directional drilling (HDD) requirements contained in the following design resources: C-P Standard Specifications, ASTM Standards, AWWA Standards, and approved manufacturer's information.

12.5.1 General Requirements

Fusible PVC will be allowed for HDD installations in nominal diameters up to 16 inches in maximum lengths as presented in Table 12-1. HDD Installations in diameters larger than 16 inches or in lengths that exceed that shown in Table 12-1 must use HDPE as the pipe material.

TABLE 12-1
Fusible PVC Maximum Length for HDD Installation

Fusible PVC Nominal Diameter (Inches)	Maximum Installed Length of HDD (Feet)
6	900
8	900
10	840
12	700
14	600
16	525

HDD Installations using HDPE will be limited to a maximum length as shown in Table 12-2. HDD installations in excess of the maximum lengths shown would be evaluated on a case-by-case basis.

TABLE 12-2
HDPE Maximum Length for HDD Installation

HDPE Nominal Diameter (Inches)	Maximum Installed Length of HDD (Feet)
6	2000
8	2000
10	2000
12	2000
14	2000
16	1891
18	1676
20	1513
22	1371
24	1261

TABLE 12-2
HDPE Maximum Length for HDD Installation

HDPE Nominal Diameter (Inches)	Maximum Installed Length of HDD (Feet)
26	1160
28	1077
30	1008
32	942
34	887
36	840
42	720
48	630
54	558

Pipe used in HDD shall be capable of withstanding the maximum internal pressure, the maximum external loading configuration acting independently, and the maximum pulling forces during HDD installation.

The external load calculation shall consider dead loads, concentrated live loads, construction loads, and distributed loads acting on the pipe.

The minimum required safety factor is 2.0. Safety factors between 1.5 and 2.0 may be considered on a case-by-case basis and requires PM approval.

The design consultant is encouraged to consult with both an experienced HDD contractor and an experienced engineer, but shall abide by the following requirements:

a. Select the crossing route to keep it to the shortest reasonable distance.

b. Find routes and sites where the pipe can be constructed in one continuous length.

c. Avoid compound curves.

d. Maintain a minimum cover of 15 feet over the installed pipeline at canals, bayous, creeks, and so forth to minimize the potential for lost fluids.

e. Avoid entry and exit pit elevation differences in excess of 25 feet.

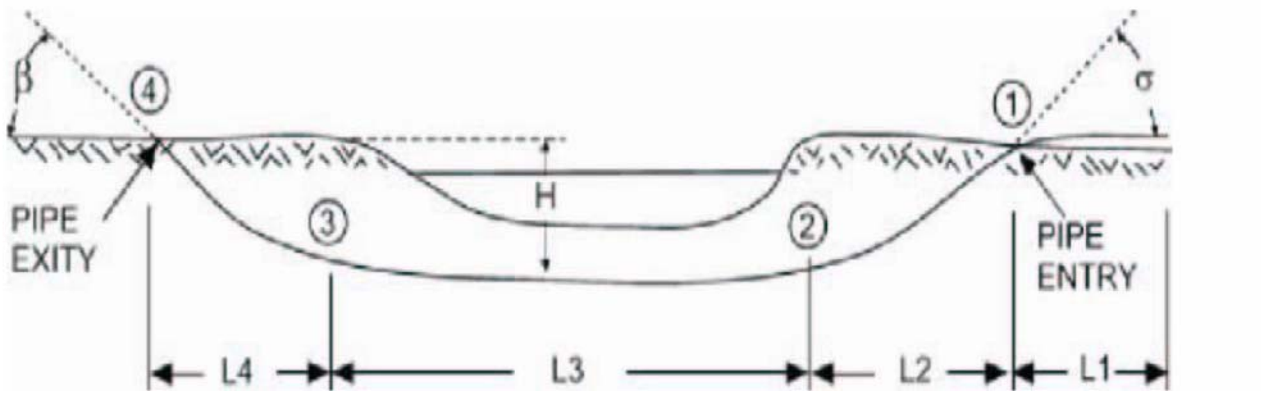
f. Locate all buried structures and utilities within 25 feet area of the drill path.

g. Avoid design where the drill rig is directly below aboveground structures such as power lines.

h. Identify and lay out site space to accommodate the required drill equipment and pipe size and length. (Site space varies depending on the crossing distance, pipe diameter and soil type.)

    1. Long crossings with large diameter pipe need bigger and more powerful equipment and drill rig
    2. As pipe diameter increases, larger volumes of drilling fluids shall be pumped, thus requiring more/larger pumps and mud cleaning and storage equipment
    3. Rig and pipe side layout requirements are outlined further in this document

FIGURE 1
Diagram of Locations and Distances Referenced in Calculations Below



12.5.2 Engineer Requirements

a. Pullback calculations shall be performed by the Engineer for all approved pipe materials. The following minimum pullback calculations shall be performed:

1. Average radius of curvature for both the pipe entry and exit points
2. Horizontal distance required to achieve depth or rise to the surface at the pipe entry and exit points
3. Axial bending stress
4. Bending stress
5. Weight of empty pipe
6. Net upward buoyant force on empty pipe surrounded by mud slurry
7. Pullback force acting on pipe at Points 1, 2, 3, and 4
8. Compare axial tensile stress with allowable tensile stress during pullback at Points 1, 2, 3, and 4
9. External static head pressure
10. Combine static head pressure with hydrokinetic pressure
11. Determine the reduction factor
12. Calculate the critical buckling pressure due to head of drilling fluid water
13. Determine the safety factor against ring collapse during pullback
14. Refer to Figure 1 and the following assumptions when performing the pullback calculations:
    i. Minimum depth (H) = 15 feet
    ii. Pipe drag on surface (this value starts at total length of pull, then decreases with time) assume L1 = 100 feet remaining at end of pull
    iii. Minimum distance for L3 shall be no less than 100 feet
    iv. Entry and exit pit angles shall be between 8 to 12 degrees

    v. Assume pipe is empty during pull back
    vi. Hydrokinetic pressure = 10 psi
    vii. Ovality compensation factor (for 3 percent ovality) = 0.76

b. The following calculations shall be performed at a minimum for the long term operation of the pipe:

  1. Approximate arching factor
  2. Approximate external earth pressure. A geotechnical engineer shall determine earth pressure value based on the properties of the soil formation. This is an estimated value for a typical case (or preliminary calculations) and shall not apply to the actual application
  3. Ring deflection
  4. Determine long term total external hydrostatic and buoyant soil load on pipe
  5. Critical unconstrained buckling pressure
  6. Long term operational safety factor against buckling for pipe in service
  7. The following initial assumptions can be made in the long term operational calculations. However, these are only to be used for preliminary calculations and shall be replaced with actual data collected during the geotechnical evaluation:
     i. Unit weight of soil = 120 pcf
     ii. Groundwater elevation = H depth, as shown on Figure 1
     iii. Unit weight of water = 62.4 pcf
     iv. Internal angle of friction = 30 degrees
     v. Angle of wall friction = internal angle of friction divided by 2
     vi. Earth pressure coefficient = 0.5

c. The Engineer shall conduct a geotechnical investigation that adheres to the SSO Program *Geotechnical Requirements* and adheres to the following criteria. The comprehensive geotechnical investigations shall identify the following:

  1. Type of soil
  2. Where rocks exist, if any
  3. Existence of gravely soils, loose deposits, discontinuities, and hardpan
  4. Soil strength and stability characteristics
  5. Existence of ground water
  6. For crossings greater than 1,000 feet in length, borings shall be taken at 700-foot intervals. For short (1,000 feet) crossings, three borings shall be performed, specifically one boring near the entry pit, one boring near the exit pit, and one in the approximate middle of the HDD path. Borings shall be made at a minimum depth of 20 feet or a maximum of 50 feet from the bore path and shall be taken to at least 20 feet below the design depth (H).

d. The Engineer shall estimate the rig side land requirements to conduct the HDD, assuming that the contractor will use the following equipment at a minimum: rig unit, control cab power unit, drill pipe, water pump, slurry mixing tank, cuttings separation equipment, slurry pump, bentonite storage, power generators, spares storage, site office (if needed), entry point slurry containment, and a cuttings settlement pit.

The Engineer shall estimate the pipe side land requirements to conduct the HDD, assuming that the contractor will use the following equipment at a minimum: cuttings settlement pit, exit point slurry containment pit, pipe rollers, pipe product (with enough room to fuse the pipe together and leave it on the rollers), drill pipe, and spares storage.

Example calculations are included in Attachment B.

12.6 Jack and Bore (Auger Boring)

Jack and Bore design shall be in accordance with C-P Standard Section 817 and the standard details, as applicable.

The casing pipe shall be steel pipe meeting the latest approved American Railway Engineering Association "Specifications for Pipeline Carrying Flammable or Non-Flammable Substances."

The carrier pipe shall be in accordance with the pipe materials allowed above and shall be installed in accordance with C-P Standards and the requirements of the governing agency.

Minimum wall thickness of piping shall be as shown in Table 12-3.

TABLE 12-3
Table of Minimum Wall Thickness for Steel Casing Pipe for E72 Loading

Carrier Pipe Nominal Diameter	Minimum Casing Pipe Diameter (O.D.)	Nominal Thickness
6	12	0.344 inch
8	16	0.375 inch
10	20	0.407 inch
12	24	0.469 inch
14	27	0.505 inch
16	30	0.505 inch
18	30	0.505 inch
20	36	0.595 inch
24	36	0.595 inch
30	42	0.625 inch
36	48	0.688 inch
42	60	0.844 inch

If carrier piping is greater than 42-inches in nominal diameter, then the casing pipe diameter (OD) shall be great enough to provide a minimum of 6-inches clear between the casing pipe and the "bell" OD of the carrier pipe.

12.7 Slip Lining

(See Sewer Rehabilitation Design Requirements)

12.8 Pipe Bursting

(See Sewer Rehabilitation Design Requirements)

13. Pipeline Design Project Checklists

The Pipeline Design Project Checklists are included in Attachment C. The checklists shall be completed by the Engineer and submitted as part of each applicable design submittal

The checklists are intended to serve as a tool for all Engineers involved in wastewater pipeline design projects. The checklists are applicable to gravity sewers and forcemains. They provide an outline of the design process and alert the user to issues sometimes overlooked in the process. The checklists are not intended to be used as detailed design tools, or as a source of fundamental design principles and formula.

The checklists are designed to correspond to the design phases defined in the *Standard Scope of Engineering Services*, which is included in the Program *Requirements for Engineers*.

The checklists are the minimum requirements for each submittal. The Engineer shall submit information in addition to the items included in the checklists if requested by the PM.

If an item is not applicable to the project under design, it shall have "NA" inserted in the "checked" line.

13.1 Preliminary Route Analysis (15% Design)

This checklist is intended to guide the project from first client contact through the development of the 15% design submittal. The list identifies the regulatory and legal issues that shall be addressed early in each conveyance project. It establishes the data collection efforts needed for subsequent design work. The 15% design includes a Preliminary Route Analysis, identifies proposed land acquisition and utility relocation needs, and identifies issues that require early input from the C-P.

13.2 Preliminary Design (30% Design)

The 30% design checklist shall be followed in the development of project plan and profile drawings, environmental documentation, quantities estimated for a budgetary cost estimate by the PM, and the Preliminary Design Report. Field data collections needs are identified, specific to the route selected in the Preliminary Route Analysis. A list of specifications and special provisions to be used on the project shall be developed during this phase. The 30% Design Phase includes the bulk of the hydraulic analysis, as is appropriate to establish the actual design elements.

13.3 Detailed Design (60% Design)

The 60% Design checklist shall be followed in the development of the project from preliminary design through detailed design including the 60% design submittal. The detailed checklists include pipeline design, specifications, piping detail sheets, plan and profile drawings and a general Quality Assurance (QA) checklist for the drawings. Quantity take-offs shall be provided for a cost estimate by the PM.

13.4 Final Design and Contract Documents (90% and 100% Design)

The 90% design checklist shall be followed in the development of the project from 60% design through the completion of design including specifications and the 90% design submittals. Only PM and C-P comments shall be incorporated after the 90% submittals. The detailed checklists include pipeline design, specifications, piping details, final arrangements for servitude acquisition and permitting, bidding procedures and a general Quality Assurance (QA) checklist.

Attachment A
Major Utility Crossing Information Sheet

<Project Name>

<DPW Project No. >

Major Utility Crossing Information

PREPARED FOR: Michael Johnson

PREPARED BY:

Date

Purpose: This document is intended to detail the actions and correspondence that has taken place to date relating to major utility crossing, possible relocations, and corridor encroachments so as to define the path forward and minimize project delays. The outline below should be filled out to the fullest extent possible and modified as needed to fit the specific project.

Copy & Paste this table as many times as necessary for project.

Utility Owner	
Utility Type	<gas pipeline, railroad, electric transmission, etc.>
Crossing or Corridor	<does the alignment cross or run alongside utility>
Number of Crossings or Length of Corridor Encroachment	Give Station Numbers, if possible.
Coordination Effort to Date	<give detailed explanation of whom with the utility company has been contacted, what discussions were had, etc. If documented correspondence exists on Prolog or Server, simply include path to document.>

Attachment B
Example Calculations

CH2MHILL SUBJECT

SF Summary Chart

BY Doug Jenkins

SHEET NO. ____ of ____ DATE ____

PROJECT NO. ____

Pipe Materials Specified

HDPE, DR 13.5, 42-inch (IPS)

fPVC, DR 32.5, 36-inch (DIP)

*Also looked at fPVC, DR 25, 30-inch (DIP)

SF at 10 feet bellow River Bed

Pipe Material	SF no water in pipe	SF water in pipe
HDPE 42-inch DR 13.5	1.4	2.6
fPVC 36-inch DR 32.5	0.6	1.1
fPVC 30-inch DR 25	1.9	3.4

* note: Per the hydraulic model a 30-inch diameter pipe will work at the crossing.

Per specifications Contractor can go 10 ft below low point, That would give us 20ft below River Bed.

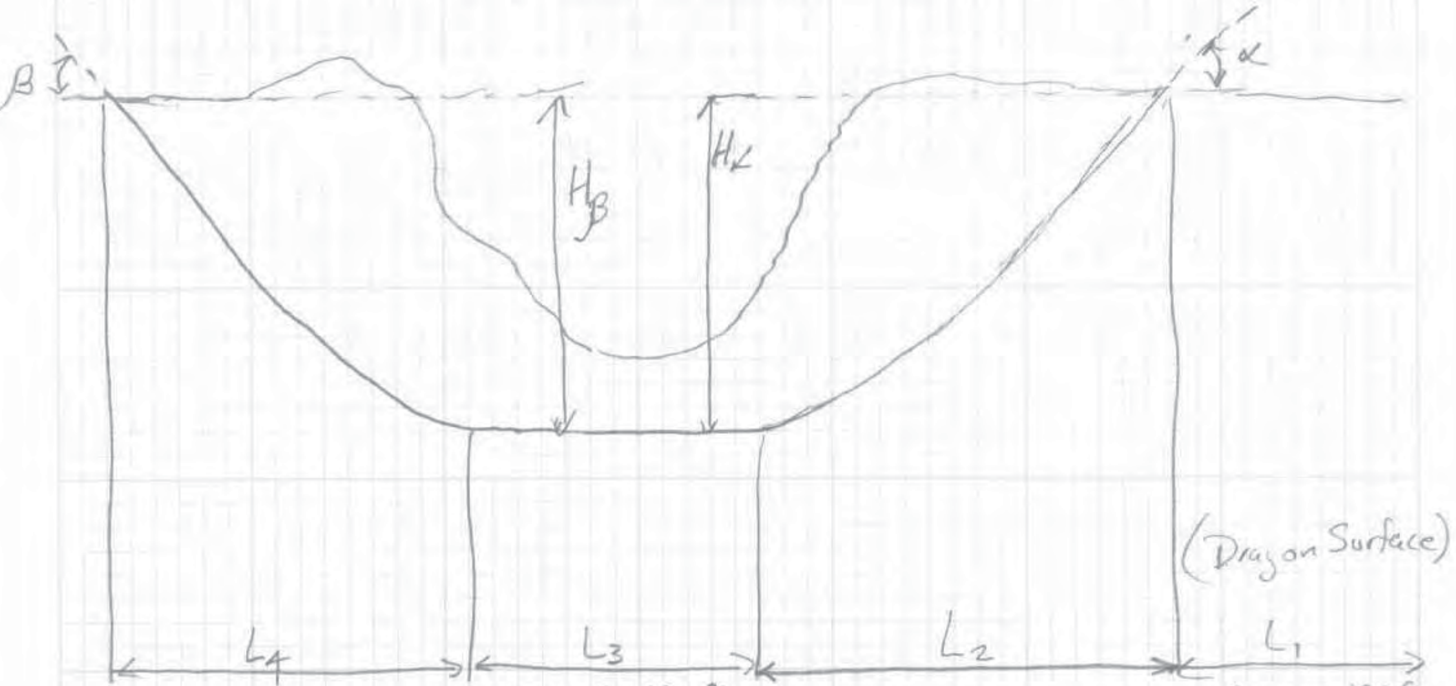
SF at 20 feet bellow River Bed

Pipe Material	SF no water in pipe	SF water in pipe
HDPE 42-inch DR 13.5	1.09	2.1
fPVC 36-inch DR 32.5	Did not Calculate	
fPVC 30-inch DR 25	1.04	2.1

CH2MHILL SUBJECT

BY Doug Jenkins
SHEET NO. 9 of 45 DATE 13April 2010
PROJECT NO.

References:
① Handbook of Polyethylene Pipe
② Handbook of PVC Pipe
③ Underground Solutions Catalog
④ AWWA Manual M55



assume 100ft
[minimum length that should be used before changing into direction]

assume 100ft

Look @
α & β of 8°, 10°, 12°

8° = 0.1396 rad
(note 1 rad = 57.295779°)
10° = 0.1745
12° = 0.2094

Pipe materials specified
HDPE, DR 13.5, 42-inch (IPS)
FPVC, DR 32.5, 36-inch (DIPS)
H = depth of Bore (from Contract drawings & specs)
H_α (Range) = 34, 44 ft
H_β (Range) = 32, 44 ft

$\alpha = 8^\circ$
$\beta = 8^\circ$

Determine Average Radius of Curvature @ α and β

$R_{avg} = \frac{2H}{g^2}$ where R_{avg} = Average Radius required
$g = \alpha$ and β in radians $= 0.1396$

$H_\alpha = 34$ ft

$R_{avg\alpha} = \frac{2(34)}{0.1396^2}$

$R_{avg\alpha} = 3{,}489.30$ ft
Say 3,490 ft

$H_\alpha = 44$ ft

$R_{avg\alpha} = \frac{2(44)}{0.1396^2}$

$R_{avg\alpha} = 4{,}515.56$ ft
Say 4,516 ft

$H\beta = 32$ ft

$R_{avg\beta} = \frac{2(32)}{0.1396^2}$

$R_{avg\beta} = 3{,}284.04$ ft
Say 3,284 ft

$H\beta = 42$ ft

$R_{avg\beta} = \frac{2(42)}{0.1396^2}$

$R_{avg\beta} = 4{,}310.31$ ft
Say 4,311 ft

Determine Path Length (L_2 & L_4) 8° α & β

$L = \frac{2H}{g}$

$H_\alpha = 34$ ft

$L_{2\alpha} = \frac{2(34)}{0.1396}$

$L_{2\alpha} = 487.1$ ft
Say 487 ft

$H_\alpha = 44$ ft

$L_{2\alpha} = \frac{2(44)}{0.1396}$

$L_{2\alpha} = 630.4$ ft
Say 631 ft

$H_\beta = 32 ft$

$H_\beta = 42 ft$

$$L_4 = \frac{2H}{g}$$

$$L_4 = \frac{2(32)}{0.1396}$$

$$L_4 = \frac{2(42)}{0.1396}$$

$L_4 = 458.5 ft$
say 459 ft

$L_4 = 601.7 ft$
say 602 ft

Summary for α and or $\beta = 8°$

$H_\alpha = 34 ft \rightarrow R_{avg\alpha} = 3{,}490 ft, L_{\alpha 2} = 487 ft$

$H_\alpha = 44 ft \rightarrow R_{avg\alpha} = 4{,}516 ft, L_{\alpha 2} = 631 ft$

$H_\beta = 32 ft \Rightarrow R_{avg\beta} = 3{,}284 ft, L_{\beta 4} = 459 ft$

$H_\beta = 42 ft \Rightarrow R_{avg\beta} = 4{,}311 ft, L_{\beta 4} = 602 ft$

$\alpha = 10°$, $\beta = 10°$

Determine Average Radius of Curvature @ α, β

$R_{avg} = \frac{2H}{g^2}$ Where R_{avg} = Average Radius required

$g = \alpha = \beta$ in radius

$10° = 0.1745$

$H_\alpha = 34$ ft

$R_{avg\alpha} = \frac{2(34)}{0.1745^2}$

$R_{avg\alpha} = 2,233.2$ ft

Say 2,233 ft

$H_\alpha = 44$ ft

$R_{avg\alpha} = \frac{2(44)}{0.1745^2}$

$R_{avg\alpha} = 2,889.9$ ft

Say 2,890 ft

$H\beta = 32$ ft

$R_{avg\beta} = \frac{2(32)}{0.1745^2}$

$R_{avg\beta} = 2,101.8$ ft

Say 2,102 ft

$H\beta = 42$ ft

$R_{avg\beta} = \frac{2(42)}{0.1745^2}$

$R_{avg\beta} = 2,758.6$ ft

Say 2,759 ft

Determine Path Length (L_2 & L_4) 10° α & β

$$L = \frac{2H}{g}$$

α

$H_\alpha = 34$

$L_2 = \frac{2(34)}{0.1745}$

$L_2 = 389.7$ ft
say 390 ft

$H_\alpha = 44$

$L_2 = \frac{2(44)}{0.1745}$

$L_2 = 504.3$ ft
say 505 ft

β

$H_\beta = 32$ ft

$L_4 = \frac{2\ (32)}{0.1745}$

$L_4 = 366.8$ ft
say 367 ft

$H_\beta = 42$ ft

$L_4 = \frac{2\ (42)}{0.1745}$

$L_4 = 481.4$ ft
say 482 ft

Summary for α and or β = 10°

$H_\alpha = 34$ ft $\Rightarrow R_{avg\alpha} = 2{,}333$ ft, $L_{2\alpha} = 390$ ft

$H_\alpha = 44$ ft $\rightarrow R_{avg\alpha} = 2{,}890$ ft, $L_{2\alpha} = 505$ ft

$H_\beta = 32$ ft $\rightarrow R_{avg\beta} = 2{,}102$ ft, $L_{4\beta} = 367$ ft

$H_\beta = 42$ ft $\rightarrow R_{avg\beta} = 2{,}759$ ft, $L_{4\beta} = 482$ ft

$\alpha = 12^\circ, \beta = 12^\circ$

Determine Average Radius of Curvature @ α, β

$$R = \frac{2H}{\delta^2}$$

$H_\alpha = 34$ or 44

$H\beta = 32$ or 42

$\delta = 12^\circ = 0.2094$ rad

$H_\alpha = 34$ ft

$$R_{avg\alpha} = \frac{2(34)}{0.2094^2}$$

$R_{avg\alpha} = 1{,}550.8$ ft

Say 1,551 ft

$H_\alpha = 44$ ft

$$R_{avg\alpha} = \frac{2(44)}{0.2094^2}$$

$R_{avg\alpha} = 2{,}006.9$ ft

Say 2,007 ft

$H\beta = 32$ ft

$$R_{avg\beta} = \frac{2(32)}{0.2094^2}$$

$R_{avg\beta} = 1{,}459.6$ ft

Say 1,460 ft

$H\beta = 42$ ft

$$R_{avg\beta} = \frac{2(42)}{0.2094^2}$$

$R_{avg\beta} = 1{,}915.7$ ft

Say 1,916 ft

Determine Path Length (L_2 & L_4) 12° α & β

$$L = \frac{2H}{g}$$

α $H = 34$

$$L_2 = \frac{2(34)}{0.2094}$$

$L_2 = 324.7$ ft

Say 325 ft

$H = 44$

$$L_2 = \frac{2(44)}{0.2094}$$

$L_2 = 420.3$ ft

Say 421 ft

β $H = 32$

$$L_4 = \frac{2(32)}{0.2094}$$

$L_4 = 305.6$ ft

Say 306 ft

$H = 42$

$$L_4 = \frac{2(42)}{0.2094}$$

$L_4 = 401.2$ ft

Say 402 ft

Summary for α and $\beta = 12°$

$H_\alpha = 34$ ft $\Rightarrow R_{avg\,\alpha} = 1{,}551$ ft, $L_{2\alpha} = 325$ ft

$H_\alpha = 44$ ft $\Rightarrow R_{avg\,\alpha} = 2{,}007$ ft, $L_{2\alpha} = 421$ ft

$H\beta = 32$ ft $\Rightarrow R_{avg\,\beta} = 1{,}460$ ft, $L_{2\beta} = 306$ ft

$H\beta = 42$ ft $\Rightarrow R_{avg\,\beta} = 1{,}916$ ft, $L_{2\beta} = 402$ ft

Summary Table

▨	H_α feet	H_β feet	$R_{avg\alpha}$ feet	$R_{avg\beta}$ feet	$L_{2\alpha}$ feet	$L_{4\beta}$ feet
8°	34	32	3,490	3,284	487	459
	44	42	4,516	4,311	631	602
10°	34	32	2,333	2,102	390	367
	44	42	2,890	2,759	505	482
12°	34	32	1,551	1,460	325	306
	44	42	2,007	1,916	421	402

For fusible PVC radius of curvature should not exceed 250 times the pipe outside diameter (Unibell Handbook of PVC) (2.5 SF)

36" fPVC OD = 38.30 inches DIP

for HDPE raidus of curvature should nox exceed 100 timer the pipe outside diameter (AWWA Manual M55) (2,0 SF)

42" HDPE OD = 42-incher IPS

fPVC

$$r = 250 \times \left[\frac{38,30}{12}\right]$$

$$r = 797,9 \text{ ft}$$

HDPE

$$r = 100 \times \left[\frac{42}{12}\right]$$

$$r = 350 \text{ ft}$$

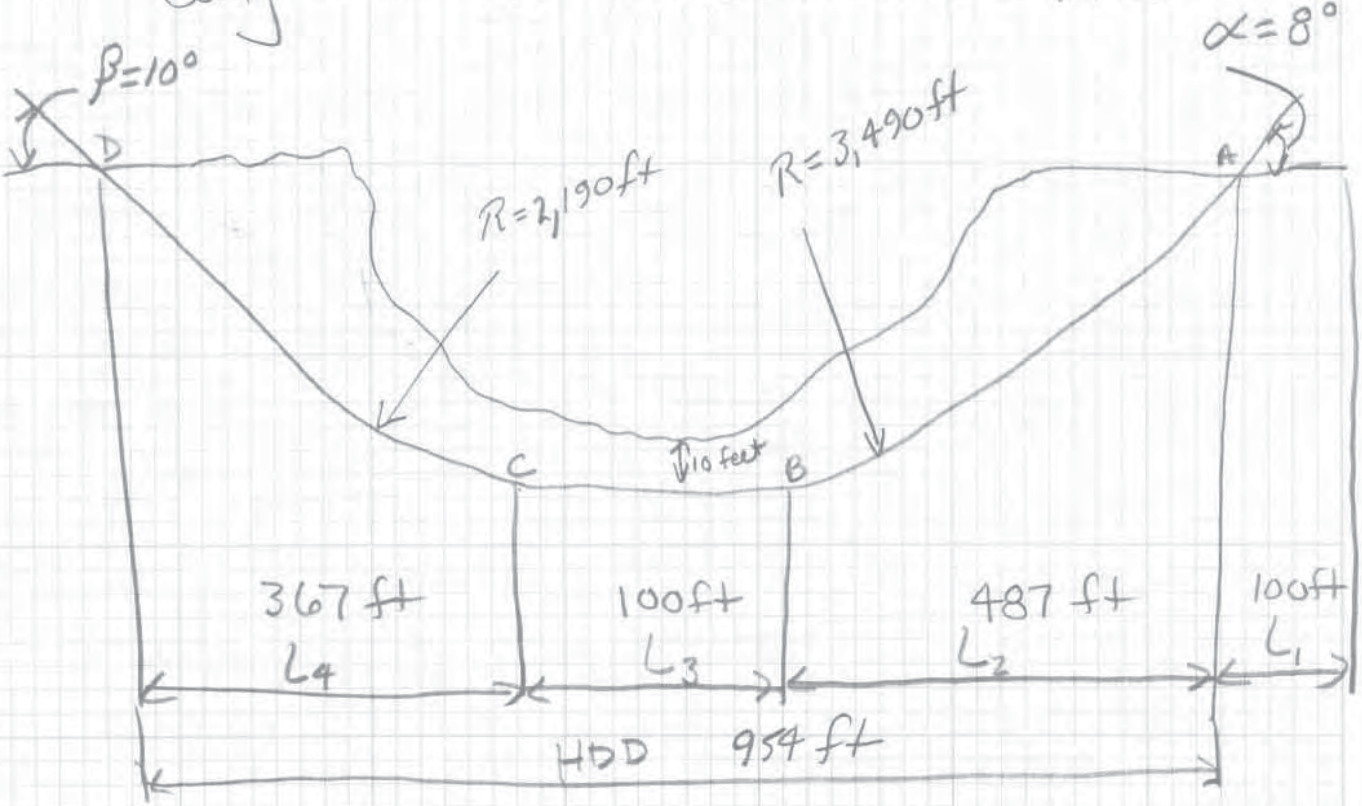
all Ravg > both r, OK ✓

Select entry & exit angle (10 feet below river)

Use α of 8° as pipe entry point
at H_α of 34 ft, gives $R_{avg\alpha} = 3{,}490$ ft
and a $L_{2\alpha}$ of 487 ft

Use β of 10° as pipe exit point
@ H_β of 32 ft, gives $R_{avg}\,\beta = 2{,}190$ ft
and a L_4 of 367 ft

Using this our HDD should look like

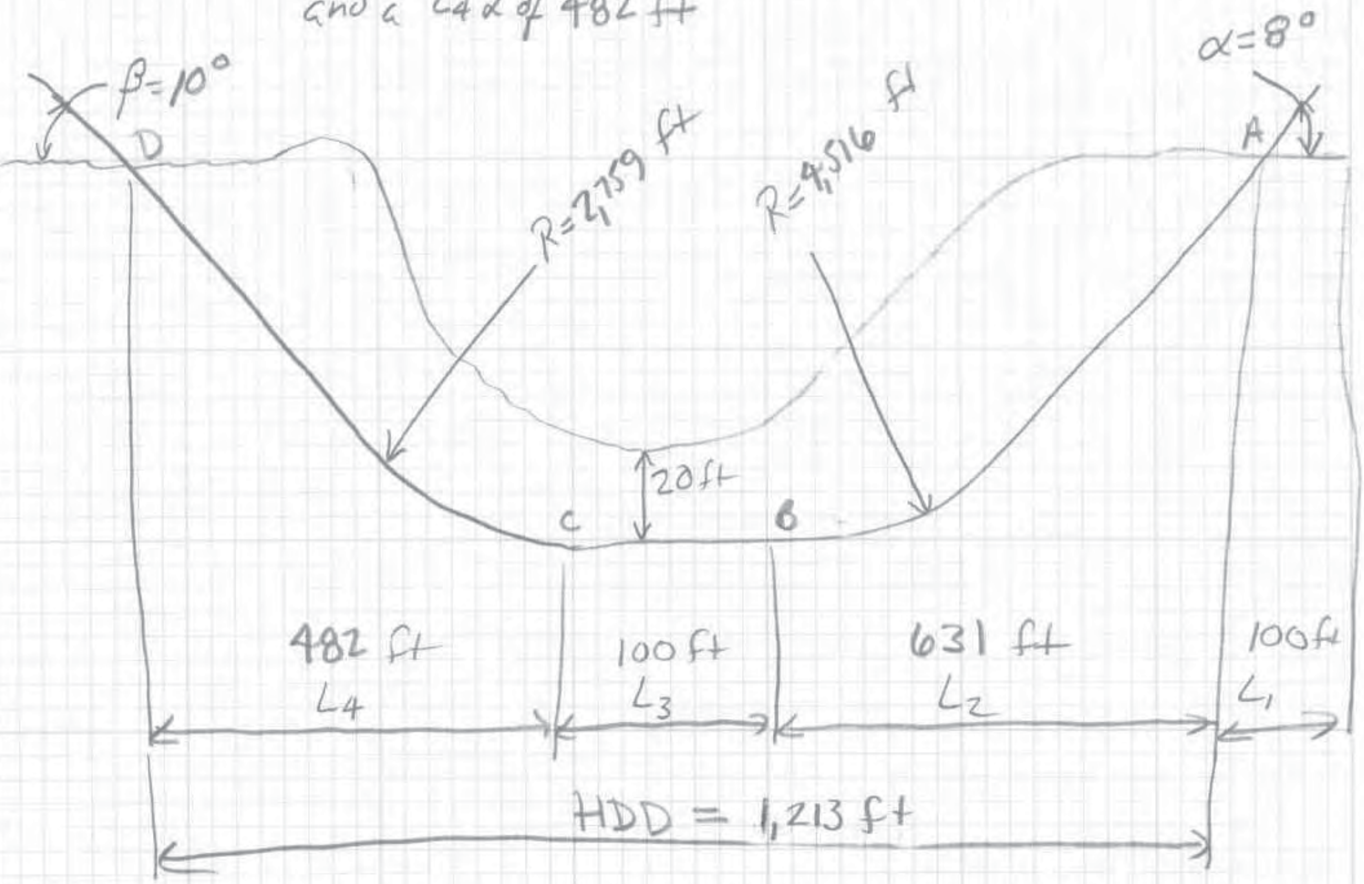


Now per specifications Contract can go down vertically -10 ft, this means the pipe could be installed 20ft below Creek bed.

Select entry + exit angle (20 feet below river)

Use α of 8° as pipe entry point
at H_α of 44 ft, gives $R_{avg\alpha}$ = 4,516. ft
and a $L_{2\alpha}$ of 631 ft

Use β of 10° as pipe entry point
at H_β of 42 ft, gives $R_{avg\beta}$ = 2,759 ft
and a $L_{4\alpha}$ of 482 ft



Calculations for HDD 10 feet below river bed

Bending strain

$$e_a = \frac{OD}{2R}$$

Where e_a = bending strain (in/in)

OD = OD of pipe (in)

R = minimum radius of curvature (in)

R = 2,190 ft

fPVC

OD = 38.30 inches

$$e_a = \frac{38.30}{2(2{,}190 \times 12)}$$

e_a = 0.0007 in/in

HDPE

OD = 42 inches

$$e_a = \frac{42}{2(2{,}190 \times 12)}$$

e_a = 0.0008 in/in

Bend Stress

$$S_a = \mathcal{E}_{24hr}\, e_a$$

Where S_a = bend stress

$\mathcal{E}_{24hr}$ = 24 hr modulus

fPVC = 400,000 psi

HDPE = 56,500 psi

fPVC

S_a = (400,000)(0.007)

S_a = 291.48 psi

HDPE S_a = 56,500 (0.008)

S_a = 45.15 psi

Find Pulling Force

Weight of fPVC empty pipe = 96.96 lbs (w_a)

Weight of HDPE empty pipe = 166.80 lbs (w_a)

Find Pulling Force continued

Density of water $r_w = 0.0361\ lb/in^3$ $(62.4\ lb/ft^3)$

Specific gravity of fPVC pipe material, $G_a = 1.38$

Specific gravity of HDPE pipe material, $G_a = 0.95$

Specific gravity of mud slurry, $G_b = 1.5$

Net Upward Buoyant Force on Empty Pipe
Surrounded by Mud Slurry

$$W_b = \pi\left(\frac{OD^2}{4}\right) r_w g_b - W_a$$

fPVC

$$W_b = \pi\left(\frac{3.1917^2}{4}\right)(62.4)(1.5) - 96.96$$

$$W_b = 748.88 - 96.96$$

$$\underline{W_b = 651.92\ lb/ft}$$

HDPE

$$W_b = \pi\left(\frac{3.5^2}{4}\right)(62.4)(1.5) - 166.80$$

$$W_b = 900.54 - 166.80$$

$$\underline{W_b = 733.74\ lb/ft}$$

W_b = net upward buoyant force on empty pipe
surrounded by Mud slurry

SUBJECT

BY

SHEET NO. 13 of 45 DATE

PROJECT NO.

FPVC

Determine pullback force acting on Pipe (10ft below river bed)

$L_1 = 100$ ft

$V_a = 0.50$ (coefficent of friction @ surface)

$L_2 = 487$ ft

$V_b = 0.30$ (coeffient of friction lubed bore hole)

$L_3 = 100$ ft

$L_4 = 367$ ft

$L_{cross} = L_2 + L_3 + L_4 = 487 + 100 + 367 = 954$ ft

$\alpha = g_{in} = 8^\circ = 0.139$ rad

$\beta = g_{ex} = 10^\circ = 0.1745$ rad

$H = 34$ ft

T_A = pull force on pipe @ point A, lbf

T_B = pull force on pipe @ point B, lbf

T_C = pull force on pipe @ point C, lbf

T_D = pull force on pipe @ point D, lbf

$$T_A = \exp(V_a \alpha) * [V_a W_a (L_1 + L_2 + L_3 + L_4)]$$

$$T_B = \exp(V_b \alpha) * (T_A + V_b W_b L_2 + W_b H - V_a W_a L_2 \exp(V_b \alpha))$$

$$T_C = T_B + V_b W_b L_3 - \exp(V_b \alpha) * (V_b W_a L_3 * \exp(V_a \alpha))$$

$$T_D = \exp(V_b \beta) * [T_C + V_b W_b L_4 - W_b H - \exp(V_b \alpha) * (V_a W_a L_4 \exp(V_b \alpha))]$$

fPVC (10 ft below river bed)

OD=38.30 in
DR = 32.5

Determine pull back force acting on Pipe

10
fPVC $W_a = 96.96$ lbs

$T_A = \exp(0.5\times0.139) * [0.5\times 96.96(100+487+100+367)]$

$T_A = 1.0720 * 51{,}097.92$

$\underline{T_A = 54{,}776.97 \text{ lbf} \quad \text{say } 54{,}777 \text{ lbf}}$

$T_B = \exp(0.3\times0.139) * (54{,}777+(0.3)(651.92)(487) + (651.92)(34)$
$-(0.5)(96.96)(487)\exp(0.3\times0.139))$

$T_B = 1.0426 * (54{,}777 + 95{,}245.51 + 22{,}165.28 - 24{,}615.10)$

$T_B = 1.0426 * 147{,}572.69$

$\underline{T_B = 153{,}859.29 \quad \text{say } 153{,}860 \text{ lbf}}$

$T_C = 153{,}860 + (0.3)(651.92)(100) - \overset{1.0426}{\exp(0.3\times0.139)} * ((0.3)(96.96)(100)$
$* \underset{1.0720}{\exp(0.5\times0.139)})$

$T_C = 153{,}860 + 19{,}557.60 - 3{,}251.07$

$\underline{T_C = 170{,}166.53 \quad \text{say } 170{,}167 \text{ lbf}}$

$T_D = \exp(0.30 * 0.1745) * [170{,}167 + (0.3)(651.92)(367) - (651.92)(34)$
$- \underset{1.0426}{\exp(0.3\times0.139)} * ((0.5)(96.96)(367)$
$* \underset{1.0426}{\exp(0.3\times0.139)})]$

$T_D = 1.0537 * [170{,}167 + 71{,}776.39 - 22{,}165.28 - 19{,}340]$

$T_D = 1.0537 * 200{,}438.11$

$\underline{T_D = 211{,}201.64 \quad \text{say } 211{,}202 \text{ lbf}}$

fPVC con't (10ft below riverbed)

Hydrokinetic Pressure

↳ hydrokinetic force, during pulling, pipe movement is resisted by drag force of the drilling fluid. This hydrokinetic force is difficult to estimate & depends on the drilling slurry, slurry flow rate pipe pullback rate, and borehole and pipe size. Typically the hydrokinetic pressure is estimated to be in the 4+8 psi range. for Calculations generally assume 10 psi.

Hydrokinetic Pressure $\Delta P = 10$ psi

Bore hole, $D_h = 1.5 * OD$, $D_h = 1.5 \times 38.30 = 57.45$ inches

Pulling force increment ΔT (lbf)

$$\Delta T = \Delta P \left(\frac{\pi}{8}\right)(D_h^2 - OD^2)$$

$$\Delta T = (10)\left(\frac{\pi}{8}\right)(57.45^2 - 38.30^2)$$

$$\underline{\Delta T = 7{,}200.58 \text{ lbf} \quad \text{say } 7{,}201 \text{ lbf}}$$

Compare Axial Tensile Stress with Allowable Tensile Stress During Pullback of 2,800 psi

Average Axial Stress acting on Pipe Cross Section @ Points A, B, C, D

$$S_i = (T_i + \Delta T)\left(\frac{1}{\pi OD^2}\right)\left(\frac{DR^2}{DR-1}\right)$$

$T_i = T_A, T_B, T_C, T_D$ lbf

S_i = Corresponding stress, psi

fPVC con't (10ft below riverbed)

Point A $S_A = (\overset{61,978}{54,777 + 7,201}) \left(\overset{0.0002}{\frac{1}{\pi(38.3)^2}}\right) \left(\overset{33.53}{\frac{32.5^2}{31.5}}\right)$

$S_A = \underline{450.95\ psi} < 2,800\ psi$ ✓

$S_B = (\overset{161,061}{153,860 + 7,201}) \left(\frac{1}{\pi(38.3)^2}\right) \left(\frac{32.5^2}{31.5}\right)$

$S_B = \underline{1,080.08\ psi} < 2,800\ psi$ ✓

$S_C = (\overset{177,368}{170,167 + 7,201}) \left(\frac{1}{\pi\ 38.3^2}\right) \left(\frac{32.5^2}{31.5}\right)$

$S_C = 1,189.43\ psi < 2,800\ psi$ ✓

$S_D = (\overset{218,403}{211,202 + 7,201}) \left(\frac{1}{\pi\ 38.3^2}\right) \left(\frac{32.5^2}{31.5}\right)$

$S_D = 1,464.61\ psi < 2,800\ psi$ ✓

Break away links should be set that Pullback force applied to pipe does not exceed 2,800psi stress

$F_b = (\text{Safe pull stress}) \left(\frac{\pi}{4}\right) (OD^2 - ID^2)$

$F_b = (2,800) \left(\frac{\pi}{4}\right) (38.30^2 - 35.80^2)$

$F_b = 407,386\ lbf$

Determine Pullback force (F_{pb})

$F_{pb} = T_D + \Delta T$

fPVC con't (10ft below river bed)

$F_{pb} = 211{,}202 + 7{,}201$

$F_{pb} = 218{,}403$ lbf

Compare safe pull force with pullback force.

$F_b > F_{pb}$

$F_b = 407{,}386$ lbf , $F_{pb} = 218{,}403$ lbf

$F_b > F_{pb}$ ok ✓

Determine safety factor against ring collapse during Pullback

External Static Head Pressure

$Gb = 1.5$

$r_w = 62.4$

$H = 34$ max pressure during pull back

$$P_{ha} = \frac{G_b\, r_w\, H}{144}$$

$$P_{ha} = \frac{(1.5)(62.4)(34)}{144}$$

$P_{ha} = 22.1$ psi

Internal Hydraulic load

$$P_{int} = \frac{(H)(62.4)}{144}$$

$$P_{int} = \frac{(34)(62.4)}{144}$$

$P_{int} = 14.73$ psi

$P_{net} = P_{ha} - P_{int}$

$P_{net} = 22.1 - 14.73$

$P_{net} = 7.37$ psi

Combine Hydraulic Load with hydrokinetic Pressure

$P_{effec} = P_{net} + \Delta P$

$P_{effec} = 7.37 + 10$

$P_{effec} = 17.37$ psi

fPVC (10 ft below river bed)

Critical Collapse Pressure

Resistance to external hydraulic load during pull back

$f_0 = 0.76$ (ovality compensation factor (for 3% ovality)

$$r = \frac{S_D}{2(2800)} = \frac{1,464.61}{2(2,800)} = 0.2615$$

r = tensile reduction ratio

f_R (tensile reduction factor)

$$f_R = \sqrt{5.57 - (r + 1.09)^2} - 1.09$$

$$f_R = \sqrt{5.57 - (0.2615 + 1.09)^2} - 1.09$$

$$f_R = 0.8448$$

$$P_{CR} = \frac{2\,E_{24hr}}{(1-\mu^2)} \left(\frac{1}{Dr-1}\right)^3 \times f_0 \times f_R$$

μ (Poison Ratio) 0.38

$$P_{CR} = \frac{2(400,000)}{1-0.38^2} \left(\frac{1}{32.5-1}\right)^3 \times 0.76 \times 0.8448$$

$$P_{CR} = 935,016.37 \times 3.1994E\text{-}5 \times 0.76 \times 0.8448$$

$$P_{CR} = 19.21 \text{ psi}$$

Safety factor against collaps during pull back

$$SF = P_{CR}/P_{effec} = \frac{19.21}{17.37}^{*} = 1.1$$ low

*if pipe full

if not ≈ 1

Would suggest different DR or other material.

OD 42"
DR 13,5

HDPE (10ft below river bed)

Determine Pullback force acting on Pipe

$L_1 = 100$ ft

$L_3 = 100$ ft

$H = 34$ ft

$V_a = 0{,}50$

$L_4 = 367$ ft

$W_a = 166.80$ lb/ft

$L_{cross} = 954$ ft

$W_b = 733.74$ lb/ft

$L_2 = 487$ ft

$\alpha = \theta_{in} = 8° = 0{,}139$ rad

$V_b = 0{,}30$

$\beta = \theta_{ex} = 10° = 0.1745$ rad

$T_A = \exp(0{,}50 \times 0{,}139) * [(0{,}5)(166{,}80)(1054)]$

$T_A = 1{,}072 * 87{,}903{,}60$

$\underline{T_A = 94{,}232.7 \text{ lbf} \quad \text{say } 94{,}233 \text{ lbf}}$

$T_B = \exp(0{,}30 \times 0{,}139) * (94{,}233 + (0{,}3)(733.74)(487) + (733.74)(34)$
$- (0{,}5)(166{,}80)(487) * \exp(0{,}30 \times 0{,}139))$

$T_B = 1.0426 * (94{,}233 + 107{,}199.42 + 24{,}947.16 - 42{,}345{,}29)$

$T_B = 1.0426 * 184{,}034.29$

$\underline{T_B = 191{,}874.2 \text{ lbf} \quad \text{say } 191{,}875 \text{ lbf}}$

$T_C = 191{,}875 + (0{,}30)(733.74)(100) - \overset{1{,}0426}{\exp(0{,}30 * 0{,}139)} * ((0{,}30)(166.80)(100)$
$* \underset{1{,}0426}{\exp(0{,}30 \times 0{,}139)})$

$T_C = 191{,}875 + 22{,}012.20 - 5{,}439.33$

$\underline{T_C = 208{,}447.9 \text{ lbf} \quad \text{say } 208{,}448 \text{ lbf}}$

$T_D = \exp(0{,}30 * 0.1745) * [208{,}448 + (0{,}30)(733.74)(367) - (733.74)(34)$
$- \exp(0{,}30 \overset{1{,}0426}{*} 0{,}139) * (0{,}3)(166{,}80)(367)$
$\overset{1{,}0426}{* \exp(0{,}30 * 0{,}139)}]$

$T_D = 1{,}0537 * [208{,}448 + 80{,}784.8 - 24{,}947.16 - 19{,}962.33]$

$T_D = 1{,}0537 * 244{,}329.91$

$\underline{T_D = 257{,}443.1 \quad \text{say } 257{,}444 \text{ lbf}}$

HDPE (10 ft below river bed) con't

Hydrokinetic Pressure $\Delta P = 10$ psi

Bore hole $Dh = 1.5 * OD$

$$Dh = 1.5 \times 42$$

$$Dh = 63 \text{ inches}$$

Pulling force increment

$$\Delta T = \Delta P\left(\frac{\pi}{8}\right)\left(Dh^2 - OD^2\right)$$

$$\Delta T = (10)\left(\frac{\pi}{8}\right)\left(63^2 - 42^2\right)$$

$$\Delta T = 8,659 \text{ lbf}$$

Compare Axial Tensile Stress with Allowable Tensile Stress During Pullback of 1,280 PSI

$$S_A = (94,233 + 8,659)\left(\overset{0{,}0002}{\frac{1}{\pi\, 42^2}}\right)\left(\overset{14.58}{\frac{13{,}5^2}{13{,}5-1}}\right)$$

$$S_A = (102,892)(0{,}0002)(14.58)$$

$$S_A = 300.03 \text{ psi} < 1,280 \text{ psi} ✓$$

$$S_B = (191,875 + 8,659)(0.0002)(14.58)$$

$$S_B = 584.76 \text{psi} < 1,280 \text{ psi} ✓$$

$$S_c = (208,448 + 8,659)(0{,}0002)(14.58)$$

$$S_c = 633.08 \text{psi} < 1,280 \text{psi} ✓$$

$$S_D = (257,444 + 8,659)(0{,}0002)(14{,}58)$$

$$S_D = 775.96 \text{psi} < 1,280 \text{ psi}$$

HDPE (10 ft below river bed)

Safe Pull stress

$$F_b = (1,280)\left(\frac{\pi}{4}\right)(42^2 - 35.78^2)$$

$$\underline{F_b = 486,360.4 \text{ lbf} \quad \text{say } 486,361 \text{ lbf}}$$

Pullback force F_{pb}

$$F_{pb} = 257,444 + 8,659$$

$$\underline{F_{pb} = 266,103 \text{ lbf}}$$

Compare safe pull force with pullback force

$F_b > F_{pb}$ ✓ ok

Determine safety factor against ring collapse during pullback

Internal Hydraulic load

$$P_{int} = \frac{(34)(62.4)}{144}$$

$$P_{int} = 14.73 \text{ psi}$$

External Static head pressure

$$P_{ha} = \frac{(1.5)(62.4)(34)}{144}$$

$$P_{ha} = 22.10 \text{ psi}$$

$$P_{net} = 22.10 - 14.73$$

$$P_{net} = 7.37 \text{ psi}$$

$$P_{effec} = 7.37 + 10$$

$$P_{effec} = 17.37 \text{ psi}$$

HDPE (10 ft below River bed)

$f_o = 0.76$

$r = \frac{775.96}{2(1280)} = 0.3031$ (tensile reduction ratio)

f_R (tensile reduction factor)

$f_R = \sqrt{5.57 - (.3031 + 1.09)^2} - 1.09$

$f_R = 0.8151$

0.45 Poissons ratio (μ)

$P_{CR} = \frac{2(56{,}500)}{(1-0.45^2)} \left(\frac{1}{13.5-1}\right)^3 \times 0.76 \times 0.8151$

$P_{CR} = (141{,}692.79)(0.0005)(0.76)(0.8151)$

$P_{CR} = 44.94$ psi

$SF = \frac{44.94}{17.37} = 2.6$ (pipe full)

$SF = \frac{44.94}{32.1} = 1.4$ (pipe empty)

note add cost if HDPE 42" if selected
Post-installation Calculations will need to
be prefromed

Assume 30-inch PVC DR 25 used, note per hydraulic model a 30-inch can be used at the Comite River Crossing

OD = 32 in (3 ft)
ID = 29.29

$L_1 = 100$ ft $L_4 = 367$ ft
$V_a = 0.50$ $L_{cross} = 954$ ft
$L_2 = 487$ ft $\alpha = \theta_{in} = 8° = 0.139$ rad
$V_b = 0.30$ ft $\beta = \theta_{ex} = 10° = 0.1745$
$L_3 = 100$ ft $H = 34$ ft

$W_a = \underline{80.14 \text{ lb/ft}}$
$W_b = \pi\left(\frac{3^2}{4}\right)(62.4)(1.5) - 80.14$
$\underline{W_b = 581.48 \text{ lb/ft}}$

$T_A = \exp(0.50 \times 0.139) * [(0.5)(80.14)(1054)]$
$T_A = 1.072 * 42{,}233.78$
$\underline{T_A = 45{,}274.6 \text{ lbf} \quad \text{say } 45{,}275 \text{ lbf}}$

$T_B = \exp\overset{1.0426}{(0.30 * 0.139)} * (45{,}275 + (0.30)(581.48)(487) + (581.48)(34)$
$- (0.50)(80.14)(487) * \exp\overset{1.0426}{(0.30 \times 0.139)})$
$T_B = 1.0426 * (45{,}275 + 84{,}954.23 + 19{,}770.32 - 20{,}345.39)$
$\underline{T_B = 135{,}177.43 \text{ lbf} \quad \text{say } 135{,}178 \text{ lbf}}$

$T_C = 135{,}178 + (0.3)(581.48)(100) - \exp(0.30 * 0.139) \times ((0.30)(80.14)(100)$
$\times \exp(0.30 \times 0.139))$
$T_C = 135{,}178 + 17{,}444.40 - 2{,}613.36$
$\underline{T_C \ 150{,}009 \text{ lbf}}$

$T_D = \exp(0.30 \times 0.1745) * [150{,}009 + (0.3)(581.48)(367) - (581.48)(34)$
$- \exp(0.30 \times 0.139) * (0.5)(80.14)(367) * \exp(0.3 \times .139)$
$T_D = 1.0537 * [150{,}009 + 64{,}020.95 - 19{,}770.32 - 15{,}985.30]$
$\underline{T_D = 187{,}847.7 \text{ lbf} \quad \text{say } 187{,}848 \text{ lbf}}$

30-inch fPVC

Hydrokinetic Pressure $\Delta P = 10\,psi$

Bore hole $D_h = 1.5 * OD$, $D_h = 1.5 \times 32 =$ 48 inches

Pulling Force increment

$$\Delta T = \Delta P\left(\frac{\pi}{8}\right)\left(Dh^2 - OD^2\right)$$

$$\Delta T = 10\left(\frac{\pi}{8}\right)\left(48^2 - 32^2\right)$$

$$\Delta T = 5{,}026.6\ lbf \quad say\ 5{,}027\ lbf$$

Compare Axial Tensile Stress with allowable tensile stress during pullback of 2,800 psi

$$S_A = (45{,}275 + 5{,}027)\left(\frac{1}{\pi\, 32^2}\right)\left(\frac{25^2}{25-1}\right)$$

$$S_A = (50{,}302)(0.0003)(26.04)$$

$S_A = 392.98\ psi < 2{,}800\ psi$ ✓

$$S_B = (135{,}178 + 5{,}027)\ (0.0003)(26.04)$$

$S_B = 1{,}095.28\ psi < 2{,}800\ psi$ ✓

$$S_C = (150{,}009 + 5{,}027)\ (0.0003)\ (26.04)$$

$S_C = 1{,}211.14\ psi < 2{,}800\ psi$ ✓

$$S_D = (187{,}848 + 5027)\ (0.0003)\ (26.04)$$

$S_D = 1{,}506.74\ psi < 2{,}800\ psi$ ✓

30-inch fPVC

Safe pull force (F_b) (safe pull stress 2,800)

$F_b = 2{,}800(\frac{\pi}{4})(32^2 - 29.29^2)$

$F_b = 365{,}263.96$ lbf

Determine pullback force Fpb

$F_{pb} = T_0 + \Delta T$

$F_{pb} = 187{,}848 + 5{,}027$

$F_{pb} = 192{,}875$ lbf

$F_b > F_{pb}$ ok ✓

Determine safety factor against ring collapse during Pullback

Internal Hydraulic Load

$P_{int} = \frac{(H)(62.4)}{144}$

$P_{int} = 14.73$

External Static Head Pressure

$P_{ha} = \frac{(1.5)(62.4)(34)}{144}$

$P_{ha} = 22.1$ psi

Max pressure during pullback

Pipe empty	Pipe full
$P_{net} = P_{ha}$	$P_{net} = P_{ha} - P_{int}$
	$P_{net} = 22.1 - 14.73$
$P_{net} = 22.1$ psi	$P_{net} = 7.37$ psi

Combine Hydraulic load with hydrokinetic pressure

Pipe empty $P_{effec} = P_{net} + \Delta P$

$P_{effec} = 22.1 + 10$

$P_{effec} = 32.1$ psi

Pipe full $P_{effec} = 7.37 + 10$

$P_{effec} = 17.37$ psi

$f_0 = 0.76$

$\eta = \frac{S_0}{2(2800)} = \frac{1,506.74}{(2)(2800)} = 0.2691$

$f_R = \sqrt{5.57 - (0.2691 + 1.09)^2} - 1.09$

$f_R = 0.8395$

$$P_{CR} = \frac{2(400,000)}{1 - .38^2} \left(\frac{1}{25-1} \right)^3 \times 0.76 \times 0.8395$$

$P_{CR} = 935,016.36 \, (0.0001) \times 0.76 \times 0.8395$

$P_{CR} = 59.66$ psi

Safety Factor against collaps during pull back

Pipe empty

$SF = \frac{59.66}{32.1}$

$SF = 1.9$

Pipe full

$SF = \frac{59.66}{17.37}$

$SF = 3.4$ ok

Calculations for 20ft depth

36-inch DR 32.5 fPVC elimated after 10ft depth

Calculate 20ft depth for

HDPE 42-inch DR 13.5

&

fPVC 30-inch fPVC DR 25

—HDPE 20 ft Deep 42-inch, DR 13.5

$V_a = 0.50$ $L_1 = 100ft$ $\alpha = 8° = 0.139$ rad $R_\alpha = 4{,}516 ft$

$V_b = 0.30$ $L_2 = 631ft$ $\beta = 10° = 0.1745$ $R_\beta = 2{,}759 ft$

$L_3 = 100ft$ $H = 44 ft$ $\varepsilon_{24hr} = 56{,}500 psi$

$L_4 = 482ft$ $W_a = 166.80$ lb/ft, $W_b = 733.74$ lb/ft

Bending Strain

$$e_a = \frac{42}{(2 \times 2{,}759 \times 12)} = 0.0006 \text{ in/in}$$

Bending Stress

$$S_a = (56{,}500)(0.0006)$$

$$S_a = 35.84 \text{ psi}$$

Pull force

$$T_A = \exp(0.5 * 0.139) * [(0.5)(166.80)(1{,}313)]$$

$$T_A = (1.0720) * 109{,}504.2$$

$$T_A = 117{,}388.5 \text{ lbf} \quad \text{say } \underline{117{,}389 \text{ lbf}}$$

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42-inch HDPE, 20ft deep cont

$$T_B = \exp(0.3 * 0.139) * (117,389 + (0.3)(733.74)(631) \overset{+(733.74)(44)}{\downarrow} - (05)(166.8)(631) * \exp(0.3 * 0.139))$$

$$T_B = 1.0426 * (117,389 + 138,896.98 \overset{+}{\downarrow} - 54,867.24)$$

$$T_B = 233,703.3 \text{ lbf say } \underline{233,704 \text{ lf}}$$

$$T_C = 233,704 + (0.3)(733.74)(100) - \overset{1.0426}{\exp(0.3 * 0.139)} * ((0.3)(166.8)(100) * \exp(0.5 * \underset{1.072}{0.139}))$$

$$T_C = 233,704 + 22,012.20 - 5,592.8$$

$$T_C = 250,123.4 \text{ lbf say } \underline{250,124 \text{ lbf}}$$

$$T_D = \exp(0.3 * 0.1745) * [250,124 + (0.30)\underset{1.0426}{(733.74)}(482) - (733.74)(44) - \exp(0.3 * 0.139) * ((0.3)(166.8)(482) * \exp(0.3 \times \underset{1.0426}{0.139})$$

$$T_D = 1.0537 * [250,124 + 106,098.8 - 32,284.6 - 26,217.6]$$

$$T_D = 313,708.3 \text{ lbf say } \underline{313,709 \text{ lbf}}$$

Hydrokinetic Pressure $\Delta P = 10$ psi

Bore hole, $Dh = 1.5 * OD$, $Dh = 1.5 * 42 = 63$ inches

Pulling Force Increment ΔT(lbf)

$$\Delta T = (10)\left(\frac{\pi}{8}\right)(63^2 - 42^2)$$

$$\underline{\Delta T = 8,659 \text{ lbf}}$$

42-inch, HDPE cont

Compare Axial Tensile Stress will allowable Tensile Stress During Pull back of 1,280 psi

$$S_A = (117,389 + 8,659)\left(\overset{0.0002}{\frac{1}{\pi(42)^2}}\right)\left(\overset{14.58}{\frac{13.5^2}{13.5-1}}\right)$$

$$\underline{S_A = 367.56 \text{ psi}} < 1,280 \text{ psi} \quad \text{ok} \checkmark$$

$$S_B = (233,704 + 8,659)(0.0002)(14.58)$$

$$\underline{S_B = 706.73 \text{ psi}} < 1,280 \text{ psi} \quad \text{OK} \checkmark$$

$$S_C = (250,124 + 8,659)(0.0002)(14.58)$$

$$\underline{S_C = 754.61 \text{ psi}} < 1,280 \text{ psi} \quad \text{ok} \checkmark$$

$$S_D = (313,709 + 8,659)(0.0002)(14.58)$$

$$\underline{S_D = 940.1 \text{ psi}} < 1,280 \text{ psi} \quad \text{ok} \checkmark$$

Breakaway links should be set that Pullback force applied to pipe does not exceed 1,280 psi stress

Safe Pullback force (F_b)

$$F_b = (1,280)\left(\frac{\pi}{4}\right)(42^2 - 35.78^2)$$

$$\underline{F_b = 486,361 \text{ lbf}}$$

Determine pull back force (F_{pb})

$$F_{pb} = 313,709 + 8,659 = 322,368 \text{ lbf}$$

$$F_b > F_{pb} \quad \text{OK} \checkmark$$

42-inch HDPE, cont

Determine safety factor against ring collapse during Pullback

Internal Hydraulic load

$$P_{int} = \frac{(44)(62.4)}{144}$$

$$P_{int} = 19.1 \text{ psi}$$

External Static head Pressure

$$P_{ha} = \frac{(1.5)(62.4)(44)}{144}$$

$$P_{ha} = 28.6 \text{ psi}$$

Pnet (water in pipe)

$P_{net} = 28.6 - 19.1 = 9.5$ psi

Pnet no water = 28.6 psi

Combine Pnet with hydrokinetic pressure

Water in pipe

$P_{effec} = 9.5 + 10 = 19.5$ psi

No water in pipe

$P_{effec} = 28.6 + 10 = 38.6$ psi

42-inch, HDPE con't

Critical Collapse Pressure

$f_o = 0.76$ (3% ovality)

$\eta = \frac{940.1}{(2)(1,280)} = 0.3672$

$f_R = \sqrt{5.57 - (0.3672 + 1.09)^2} - 1.09$

$f_R = 0.7665$

$P_{CR} = \frac{(2)(56,500)}{1 - 0.45^2}\left(\frac{1}{13.5-1}\right)^3 \times 0.76 \times 0.7665$

$P_{CR} = 141,692.79(0.0005)(0.76)(0.7665)$

$P_{CR} = 42,26$ psi

SF (no water in pipe) $\frac{42,26}{38.6} = 1.09$

SF (with water in pipe) $\frac{42.26}{19.5} = 2.1$

Would not recommend.

Note SF (water in pipe assumes water all the way up in pipe to the elevation of pipe entry point.

Would use DR11

would need to calculate

30-inch f PVC DR 25 ft Deep, DR 25

OD = 32 inches
ID = 29.29

$L_1 = 100 ft$ $R_\alpha = 4,516 ft$ $V_a = 0.50$

$L_2 = 631 ft$ $R_\beta = 2,759 ft$ $V_b = 0.30$

$L_3 = 100 ft$ $\varepsilon_{24hr} = 400,000$ $W_a = 80.14 lb/ft$

$L_4 = 482 ft$ $H = 44 ft$ $W_b = 581.48 lb/ft$

$\alpha = 8° = 0.139 rad$

$\beta = 10° = 0.1745 rad$

Bending Strain $e_a = \frac{32}{(2)(2759 \times 12)} = 0.0005 in/in$

Bending Stress

$S_a = (400,000)(0,0005)$

$S_a = 193.31 psi$

Pullforce

$T_A = exp(0,5 * 0,139) * [(0,5)(80,14)(1,313)]$

$T_A = 1.072 * 52,611.91$

$T_A = 56,399.97 lbf$ say $\underline{56,400 lbf}$

$T_B = exp(0,3 \times 0,139) * (56,400 + (0,3)(581.48)(631) + (631)(44) - (0,5)(80,14)(631) exp(0,3 * 0,139)$

$T_B = 1,0426 \times (56,400 + 110,674.16 + 27,764 - 26,360.81)$

$T_B = 175,028.9 lbf$ say $\underline{175,029 lbf}$

$T_C = 175,029 + (0,3)(581.48)(100) - \overset{1.0426}{exp(0,3 * 0,139)} * ((0,3)(80,14)(100) * \underset{1.072}{exp(0,5 * 0,139)})$

$T_C = 175,029 + 17,444.4 - 2,687.1$

$T_C = 189,786.3 lbf$ say $\underline{189,787 lbf}$

$T_D = exp(0,3 \times 0,1745) * [189,787 + (0,3)(581.48)(482) - (581.48)(44) - exp(0,3 \times 0,139) * ((0,3)(80,14)(422) * exp(0,3 \times 0,139))$

$T_D = 1,0537 * [189,787 + 84,082 - 25,585.12 - 11,028.55]$

$T_D = 249,995.9 lbf$ say $\underline{249,996 lbf}$

30-inch fPVC, 20 feet deep Con't

Hydrokinetic Pressure $\Delta P = 10\,psi$

Bore hole, $D_h = 1.5 * 32$, $D_h = 48$ inches

Pulling Force increment ΔT (lbf)

$$\Delta T = 10\left(\frac{\pi}{8}\right)(48^2 - 32^2)$$

$$\Delta T = 5{,}026.6\ lbf \text{ Say } \underline{5{,}027\ lbf}$$

Compare Axial Tensile Stress with Allowable Tensile Stress During Pullback of 2,800 psi

$$S_A = (56{,}400 + 5{,}027)\overset{0.0003}{\left(\frac{1}{\pi(32)^2}\right)}\overset{26.04}{\left(\frac{25^2}{25-1}\right)}$$

$S_A = 479.9$ psi $<$ 2,800 psi OK ✓

$$S_B = (175{,}029 + 5{,}027)(0.0003)(26.04)$$

$S_B = 1{,}406.6$ psi $<$ 2,800 psi OK ✓

$$S_C = (189{,}787 + 5{,}027)(0.0003)(26.04)$$

$S_C = 1{,}521.9$ psi $<$ 2,800 OK ✓

$$S_D = (249{,}996 + 5{,}027)(0.0003)(26.04)$$

$S_D = 1{,}992.3$ psi $<$ 2,800 OK ✓

Break away links should be set that Pullback force applied to pipe does not exceed 2,800 psi stress

Safe pull back force (F_b)

$$F_b = 2{,}800\left(\frac{\pi}{4}\right)(32^2 - 29.29^2)$$

$$F_b = 365{,}263.96\ lbf \quad \text{Say } \underline{365{,}264\ lbf}$$

30-inch fPVC, 20 feet deep cont

Determine Pullback force (F_{pb})

$F_{pb} = 249,996 + 5,027$

$F_{pb} = 255,023$ lbf

$\underline{F_b > F_{pb} \quad OK}$ ✓

Determine safety factor against ring collapse during pullback

Internal Hydraulic Load

$P_{int} = \frac{(44)(62.4)}{144}$

$P_{int} = 19.1$ psi

External Static Head Pressure

$P_{ha} = \frac{(1.5)(62.4)(44)}{144}$

$P_{ha} = 28.6$ psi

P_{net} (water in pipe)

$P_{net} = 28.6 - 19.1$

$P_{net} = 9.5$ psi

P_{net} (no water) $P_{net} = 28.6$psi

Combine Hydraulic Load with hydrokinetic pressure

Water in Pipe

$P_{effec} = 9.5 + 10 = 19.5$ psi

No water

$P_{effec} = 28.6 + 10 = 38.6$ psi

30-inch fPVC, 20 feet deep Cont

Critical Collapse Pressure

$f_o = 0.76$ (3% ovality)

$r = \frac{1,992.3}{(2)(2800)} = 0.3558$ (tensile ratio)

Tensile factor $f_R = \sqrt{5.57 - (0.3558 + 1.09)^2} - 1.09$

$f_R = 0.7754$ 0.0001

$$P_{CR} = \frac{(2)(400,000)}{(1 - 0.38^2)} \left(\frac{1}{25 - 1}\right)^3 (0.76)(0.7754)$$

$P_{CR} = (935,016.36)(0.0001)(0.76)(0.7754)$

$P_{CR} = 39.9$ psi

SF(water in pipe) $= \frac{39.9}{19.5} = 2.1$ same as 42" HDPE

SF(no water) $= \frac{39.9}{38.6} = 1.04$

Same issues as the 42-inch DR13.5

Net Upward Buoyant Force on Full pipe

$$W_b = \pi\left(\frac{OD^2}{4}\right)\left(\overset{62.4}{r_w}\right)\overset{1.5}{g_b} - W_a - W_w \qquad S_b = 1.5$$

W_a = weight of pipe

$$W_b = \pi\left(\frac{OD^2}{4}\right)(r_w)g_b - W_a - r_w\left(\frac{ID^2}{4}\right) \qquad W_w = r_w \frac{ID^2}{4}\pi$$

fPVC

36", $OD = 38.3'' = \underset{96.96\ lb/ft}{3.1917\ ft}$, $ID = 35.80'' = 2.9833\ ft$

30", $OD = 32'' = \underset{80.14\ lb/ft}{2.6667\ ft}$, $ID = 29.29'' = 2.4408\ ft$

HDPE, $OD = 42'' = 3.5\ ft$, $ID = \underset{166.80\ lb/ft}{35.78''} = 2.9817$

fPVC Full Pipe

→36"

$$W_b = \overset{748.8759}{\pi\left(\frac{3.1917^2}{4}\right)(62.4)(1.5)} - 96.96 \cdot \overset{10.4852}{(1.5)\left(\frac{2.9833^2}{4}\right)\pi}$$

$$\underline{W_b = 641.43\ lb/ft}$$

fPVC Full Pipe

30"

$$W_b = \overset{522.7741}{\pi\left(\frac{2.6667^2}{4}\right)(62.4)(1.5)} - 80.14 - \overset{6.7904}{\pi(1.5)\left(\frac{2.4008^2}{4}\right)}$$

$$\underline{W_b = 435.84\ lb/ft}$$

HDPE Full Pipe

42"

$$W_b = \overset{900.5379}{\pi\left(\frac{3.5^2}{4}\right)(62.4)(1.5)} - 166.8 - \overset{10.4739}{\pi(1.5)\left(\frac{2.9817^2}{4}\right)}$$

$$\underline{W_b = 723.26\ lb/ft}$$

fill pipe

fPVC 36", DR = 32.5,

$L_1 = 100 ft$

$V_a = 0.5$

$L_2 = 487 ft$

$V_b = 0.3$

$L_3 = 100 ft$

$L_4 = 367 ft$

$\alpha = 8° = 0.139 rad$

$\beta = 10° = 0.1745 rad$

$H = 34 ft$

$OD = 38.30 in$

$ID = 35.80 in$

$w_a = 96.96 \ lb/ft$

$W_b = 641.43 \ lb/ft$

$$T_A = \underline{54,777 \ lbf}$$

$$T_B = \exp(0.3 \times 0.139) * (54,777 + (0.3)(641.43)(487) + (641.43)(34) - (0.5)(96.96)(487) \underset{1.0426}{\exp(0.3 \times 0.139)})$$

$$T_B = 1.0426 * (54,777 + 93,712.92 + 21,808.62 - 24,615.54)$$

$$T_B = 151,889.1 \ lbf \quad \text{say } \underline{151,890 \ lbf}$$

$$T_C = 151,890 + (0.3)(641.43)(100) - \overset{1.0426}{\exp(0.3 \times 0.139)} * ((0.3)(96.96)(100) \overset{1.0720}{\exp(0.5 \times 0.139)})$$

$$T_C = 151,890 + 19,242.90 - 3,250.99$$

$$T_C = 167,881.9 \ lbf \quad \text{say } \underline{167,882 \ lbf}$$

$$T_D = \exp(0.3 \times 0.1745) * [167,882 + (0.3)(641.43)(367) - (641.43)(34) - \exp(0.3 \times 0.139) * (0.3)(96.96)(367) \exp(0.3 \times 0.139)]$$

$$T_D = (1.0553) * (167,882 + 70,621.44 - 21,808.62 - 11,642.05)$$

$$T_D = 216,392.19 \quad \text{say } 216,393 \ lbf$$

$D_h = 57.45$

Hydrokinetic pressure

$\Delta P = 10 psi$

Pull force increment

$$\Delta T = 10 \left(\frac{\pi}{8}\right)(57.45^2 - 38.30^2)$$

$$\Delta T = 7,200.58 \quad \underline{7,201 \ lbf}$$

fPVC 36", DR 32.5 10 ft deep

Axial Stress 2,800 psi

$$S_A = (54,777 + 7,201)\left(\overset{0.0002}{\frac{1}{\pi(38.3)^2}}\right)\left(\overset{33.53}{\frac{32.5^2}{31.5}}\right)$$

$S_A = 415.6$ psi $< 2,800$ ok

$S_B = (151,890 + 7,201)(0.0002)(33.53)$

$S_B = 1,023.28$ psi $< 2,800$ ok

$S_C = (167,882 + 7,201)(0.0002)(33.53)$

$S_C = 1,174.11$ psi $< 2,800$ ok

$S_D = (216,393 + 7,201)(0.0002)(33.53)$

$S_D = 1,499.42$ psi $< 2,800$ ok

Safe pull

$$F_b = (2,800)\left(\frac{\pi}{4}\right)(38.3^2 - 35.8^2)$$

$F_b = 407,386$ lbf

Determine Pullback force

$F_{pb} = T_D + \Delta T$

$F_{pb} = 216,393 + 7,201$

$F_{pb} = 223,594$

$F_{pb} < F_b$ ok

Safety factor against collapse

P_{int} 14.73

P_{hw} 22.1

P_{net} 7.37

$P_{effect} = 17.37$

Critical Collapse Pressure

$f_0 = 0.76$

$$\Omega = \frac{1,499.42}{(2)(2,800)} = 0.2678$$

TRF

$$f_R = \sqrt{5.57 - (0.2678 + 1.09)^2} - 1.09$$

$f_R = 0.84$

$$P_{CR} = \frac{2(400,000)}{1 - 0.38^2}\left(\frac{1}{31.5}\right)^3 \times 0.76 \times 0.84$$

$P_{CR} = 935,016.36(3.1994E\text{-}5)(.76)(.84)$

$P_{CR} = 19.09$

$$SF = \frac{19.09}{17.37} = \underline{1.1}$$

36" HDPE, DR11 IPS, OD = 36", ID = 29.062"

$W_a = 146.78$ lb/ft

10 ft deep

$H = 34$ ft

$L_1 = 100$ ft $V_a = 0.5$

$L_2 = 487$ ft $V_b = 0.3$ $R_\alpha = 3{,}490$

$L_3 = 100$ ft $\alpha = 9{:}1 = 8° = 0.139$ rad $R_\beta = 2{,}190$

$L_4 = 367$ ft $\beta = 5{:}1 = 10° = 0.1745$ rad

HDPE $\varepsilon_{24hr} = 56{,}500$ psi

Bending Strain

$$e_a = \frac{36}{(2)(2{,}190)}$$

$$e_a = 0.0082 \text{ in/in}$$

Bend Stress

$$S_a = 56{,}500(0.0082)$$

$$S_a = 452 \text{ psi}$$

Net Upward Buoyant Force on Empty Pipe

$$W_b = \pi\left(\frac{3^2}{4}\right)(62.4)(1.5) - 146.78$$

$$W_b = 514.84 \text{ lb/ft}$$

On Full Pipe

$$W_b = 514.84 - (1.5)\pi\left(\frac{2.4218^2}{4}\right)$$

$$W_b = 507.93 \text{ lb/ft}$$

Dry Pipe

$$T_A = \overset{1,072}{\exp(0.5 \times 0.139)} * \left[(0.5)(146.78)(1{,}054)\right]$$

$$T_A = 82{,}922.48 \quad \text{Say } \underline{82{,}923 \text{ lb/ft}}$$

$$T_B = \overset{1,0424}{\exp(0.3 \times 0.139)} \times \left(82{,}923 + \overset{75,218.12}{(0.3)(514.84)(487)} + \overset{17,504.56}{(514.84)(34)} - \overset{37,263.49}{(0.5)(146.78)(487)}\right) * \underset{1,0424}{\exp(0.3 \times 0.139)}$$

$$T_B = 144{,}277.3 \quad \text{say } \underline{144{,}278 \text{ lb/ft}}$$

36" HDPE DR 11   10 ft deep con't

$T_C = 144,278 + \overset{15,445.2}{(0.3)(514.84)(100)} - \overset{4,921.54}{(1.0426)(0.3)(196.78)(100)(1.072)}$

$T_C = 154,801.66$ say $\underline{154,802 \text{ lb/ft}}$

$T_D = \overset{1.0537}{\exp(0.3 * 0.1745)} * [154,802 + 56,683.88 - 17,504.56 - 29,373.27]$

$T_D = 164,608.05$ say $164,609$ lb/ft

Hydrokinetic Pressure $\Delta P = 10$ psi

Bore hole $D_h = 1.5 \times 36 = 54$ inches

Pulling force increment ΔT (lbf)

$\Delta T = 10 \left(\frac{\pi}{8}\right)(54^2 - 36^2)$

$\Delta T = 6,361.7$ psi $\underline{\text{Say } 6,362 \text{ psi}}$

Compare Axial tensile stress will allowable tensile Stress during pullback of 1,280 psi

$S_A = (82,923 + 6,362) \overset{0.0002}{\left(\frac{1}{\pi\, 36^2}\right)} \overset{12.1}{\left(\frac{11^2}{10}\right)}$

$S_A = 216.1$ psi $< 1,280$ ok ✓

$S_B = (144,278 + 6,362)(0.0002)(12.1)$

$S_B = 364.6$ psi $< 1,280$ ok ✓

$S_C = (154,802 + 6,362)(0.0002)(12.1)$

$S_C = 390$ psi $< 1,280$ ok ✓

$S_D = (164,609 + 6,362)(0.0002)(12.1)$

$S_D = 413.75 < 1,280$ ok ✓

36" HDPE, DR11 IPS 10 feet deep cont

Pullback

$F_b = (1,280)\left(\frac{\pi}{4}\right)\left(36^2 - 29.062^2\right)$

$F_b =$ 453,796.9 lbf

Determine Pullback force F_{pb}

$F_{pb} = 164,609 + 6,362$

$F_{pb} =$ 170,971 lbf

$F_{pb} < F_b$ OK ✓

Determine safety factor against ring collapse during pullback

Internal pressure $P_{int} = 14.73$ (water in pipe)

External pressure $P_{ha} = 22.1$

Pnet (water) 7.37 psi

Pnet (no water) 22.1

Water

Peffec = 7.37 + 10 = 17.37 psi

Peffec (no water) = 22,1 + 10 = 32,1 psi

$f_o = 0,76$

$\mu = \frac{413,75}{(2)(1280)} = 0.1616$

$f_R = \sqrt{5.57 - (0.1616 + 1.09)^2} - 1.09$

$f_R = 0.9109$

$$P_{CR} = \frac{2(56,500)}{(1-0.45^2)}\left(\overset{0.001}{\frac{1}{11-1}}\right)^3 \times 0.76 \times 0.9109$$

$$P_{CR} = (141,692.79)(0.001)(0.76)(0.9109)$$

$$P_{CR} = 98.09 \text{ psi}$$

$$SF(\text{water}) = \frac{98.09}{17.37} = 5.7$$

$$SF(\text{no water}) = \frac{98.09}{32.1} = 3.1$$

36" HDPE, DR11 IPS, OD 36", ID = 29.062"

$W_a = 146.78$ lb/ft

$L_1 = 100$ ft $V_a = 0.5$ $W_b = 514.84$ lb/ft

$L_2 = 631$ ft $V_b = 0,3$ $H = 44$

$L_3 = 100$ ft $\alpha = 8^\circ = 0.139$ rad

$L_4 = 482$ ft $\beta = 10^\circ = 0.1745$ rad

$T_A = 1,072 \times (0.5)(146.78)(1,313)$

$T_A = \underline{103,299 \text{ lb/ft}}$

$T_B = 1.0426 * (103,299 + 97,459.21 + 22,652.96 - 48,281.86)$

$T_B = 182,589.8$ say $\underline{182,590 \text{ lb/ft}}$

$T_c = 182,590 + 15,445.2 - 4,921.54$

$T_c = 193,113.66$ say $\underline{193,114 \text{ lb/ft}}$

$T_D = 1.0537 * (193,114 + 74,445.86 - 22,652.96 - 38,452.04)$

$T_D = 217,541.49$ say $\underline{217,542 \text{ lb/ft}}$

Hydrokinetic Pressure $\Delta P = 10$psi

Bore hole = 54 inches

Pull force increment

$\Delta T = 6,362$ psi

Compare Axial Tensile Stress with Allowable Tensile Stress of 1,280 psi

$S_A = (103,299 + 6,362)(0.0002)(12,1) = 265.38$psi $< 1,280$ ✓

$S_B = 457.26$psi $< 1,280$ ✓

$S_c = 482.73$ psi $< 1,280$ ✓

$S_D = 541.85$psi $< 1,280$ ✓

$F_b = 453,796.9$

$F_{pb} = 217,542 + 6,362$

$F_{pb} = 223,904$

$F_{pb} < F_b$ OK ✓

Safety Factor against ring collapse during

$P_{int} = 19.1$ psi

$P_{ha} = 28.6$

$P_{net\ water} = 9,5$ psi

$P_{net\ no\ water} = 28.6$ psi

$P_{effec\ water} = 19.5$

$P_{effec\ no\ water} = 38,6$

$f_o = 0,76$ $f_R = \sqrt{5.57 - (0,2117 + 1,09)^2} - 1,09$

$\mu = 0,2117$ $f_R = 0,88$

$P_{CR} = (141,692.79)(0,001)(0.76)(0,88)$

$P_{CR} = 94.62$ psi

$SF_{water} = \frac{94.62}{19,5} = \underline{4,9}$

$SF_{no\ water} = \frac{94,62}{38.6} = \underline{2,5}$

Attachment C
Design Checklists

15% Design – Project Feasibility and Preliminary Route Analysis Checklist

15% Design Summary

1. _____ Overall Project Definition
2. _____ Regulatory/Financial/Political/Land Acquisition/Permitting
3. _____ Utilities
4. _____ Mapping
5. _____ Preliminary Route Analysis
6. _____ General System Hydraulics
7. _____ Design Criteria
8. _____ Quality Assurance and Quality Control Review

Lead Engineer Date

QC Reviewer Date

Overall Project Definition

_____ Define C-P goals and expectations.

_____ Briefly define overall project.

_____ Define design level (concept, capital project, program).

_____ Prepare preliminary design and construction schedule.

_____ Define project delivery method.

Regulatory/Financial/Political/Land Acquisition/Permitting

_____ Identify legal advisor to C-P.

_____ Define agencies with jurisdiction.

_____ Identify ROW/servitude needed and land owners.

_____ Identify permits needed for project.

Utilities

_____ Identify utilities and responsible agencies involved for all routes.

_____ Identify utility contacts, names, and phone numbers.

_____ Identify major conflicts and crossings.

_____ Identify tunneling requirements.

_____ Identify specialty utility location company.

Mapping

_____ Collect quad maps and aerial photographs.

_____ Define general mapping and surveying needs.

Preliminary Route Analysis

_____ Field review alternative routes.

_____ Define alternatives and list advantages and disadvantages of each.

_____ Rank and/or recommend alternative.

_____ Obtain C-P's direction regarding preferred route.

_____ Identify flood plain.

_____ Identify areas where tunneling or jack and bore may be required or preferred.

_____ Characterize local rock and soil conditions.

General System Hydraulics

_____ Perform preliminary hydraulic analysis of alternate routes.

_____ Identify significant high points.

Design Criteria

_____ Identify optional pipe materials.

_____ Identify known corrosion issues.

Quality Assurance and Quality Control Review

_____ Perform QC review in accordance with QA Plan included in the Project Work Plan.

Lead Engineer Date

QC Reviewer Date

Preliminary Design Checklist (30% Design)

30% Design Summary

1. _____ Overall Project Definition
2. _____ Standards/Preferences/Constraints
3. _____ Environmental Documentation/Regulatory/Permitting
4. _____ Mapping
5. _____ Utilities
6. _____ Design Criteria
7. _____ Preliminary Pipeline Design
8. ______ Specifications
9. _____ Quantity Take-Offs for Construction Cost Estimate by PM
10. _____ Quality Assurance and Quality Control Review
11. _____ Preliminary Design Deliverables

Lead Engineer Date

QC Reviewer Date

Overall Project Definition

_____ Confirm C-P goals and expectations developed in Phase I.

_____ Prepare updated design and construction schedule.

_____ Confirm project delivery method.

_____ Complete Project Instructions.

Standards/Preferences/Constraints

_____ Client CAD standards/preference.

_____ Client preferences for specifications, source, and word processing software.

_____ Client preferences for pipe material(s), pipe suppliers, contractors.

_____ Determine applicable C-P standard plans and specifications.

_____ Determine if sole-source restrictions apply and to what they apply to.

_____ Define safety plan/requirements and limitations.

_____ Develop pipe procurement and bid strategy.

Environmental Documentation/Regulatory/Permitting

_____ Phase I Environmental Site Assessment (ESA).

_____ Define environmental mitigation requirements.

_____ Define permits required (Federal, State, and local road crossings, railroad crossings, waterway crossings, wetlands, buffer variances, historic/archeological)

_____ Develop NPDES erosion control plan.

_____ Begin Stormwater Pollution Prevention Plan.

_____ Perform hazardous materials survey.

_____ Begin permit submission when able/required (note timing of agency review period): DOTD/RR/utility crossings, wetlands.

Mapping

_____ Compile and organize existing mapping and survey data.

_____ Define and complete mapping and surveying needed—aerial and/or field survey

_____ Determine/define 2D/3D, phased or final design level mapping, coordinate system.

_____ Determine method to acquire/depict property lines.

_____ Define ROW/ servitudes needed.

_____ Identify special areas: flood plain, hazardous materials areas, archaeologically important sites, wetlands, geotechnical investigation areas and borings.

Utilities

_____ Identify all utilities (water/sewer, storm drain, gas, electric, telephone, cable, etc.).

_____ Collect all available utility record drawings.

_____ Have utilities mark-up utility locations on drawings.

_____ Define separation and crossing requirements (horizontal, vertical).

Design Criteria

_____ Complete geotechnical field investigation, laboratory analysis, and report/recommendations.

_____ Perform corrosion investigation and summarize recommendations.

_____ Analyze hydraulics as needed.

_____ Hydraulic profiles (max/min flow, test pressure).

_____ Define horizontal/vertical drawing scale.

_____ Analyze for scour conditions at stream/river crossings.

_____ Obtain structural design input as needed: junction structures, seismic design parameters, seismic monitoring required or not.

_____ Determine level of instrumentation and control to be provided, if any (generally none).

Preliminary Pipeline Design

_____ Generate plan and profile. Coordinate connection to existing system.

_____ Identify all crossings and determine preliminary vertical alignment.

_____ Determine any utility relocation and/or demolition.

_____ Determine traffic control required.

_____ Determine pipe material and/or alternatives (obtain input from corrosion engineer).

_____ Locate valves: isolation, air release, blowoff.

_____ Locate test stations (corrosion control).

_____ Prepare preliminary design report (PDR).

_____ Perform preliminary pipe design calculations.

Specifications

_____ List of specifications and special provisions to be used on the project.

Cost Estimate Quantities

_____ Determine quantity take-offs (base on plan and profile).

_____ Include all crossings and tunneling operations.

_____ Include any utility relocation.

Quality Assurance and Quality Control Review

_____ Perform QC review in accordance with QA Plan included in the Project Work Plan.

Preliminary Design Deliverables

_____ Prepare and submit preliminary design deliverables to client.

_____ Prepare and submit regulatory deliverables (Preliminary Design Report)

_____ Provide preliminary PE stamp & note (conforming to requirements of LAPELS Board) on cover page/sheet of all Draft deliverables

____ ________________________

Lead Engineer Date

____ ________________________

QC Reviewer Date

Detailed Design (60% Design)

Summary

1. _____ Mapping/Utilities/Permits/Environmental Documentation
2. _____ Pipeline Design
3. _____ Specifications
4. _____ Details
5. _____ Plan and Profile Drawing Checklist
6. _____ Quantity Take-Offs for Construction Cost Estimate by PM
7. _____ Quality Assurance and Quality Control Review

Lead Engineer ______________________ Date ______________________

QC Reviewer ______________________ Date ______________________

Mapping/Utilities/Permits/Environmental Documentation

_____ Final ROW/servitude Maps:

    _____ Write legal descriptions.

    _____ Begin legal process—recording documents (utilize process outlined for Green Light Plan).

    _____ Signed and sealed by a Professional Land Surveyor, licensed in the State of Louisiana.

_____ Verify "special areas" are identified.

_____ Phase II Environmental Site Assessment if required.

_____ Verify environmental documentation complete and mitigation requirements addressed.

_____ Organize all collected utility information and verify that all pertinent information has been transferred to plan and profile drawings.

_____ Water and sewer pipeline separation criteria identified and incorporated into design.

_____ Finalize Stormwater Pollution Prevention Plan.

_____ Begin permit submission when able/required (note timing of agency review period): traffic control, Building/construction, environmental/regulatory (stream buffer/variances), DHH permit.

Pipeline Design

_____ Finalize horizontal and vertical alignments.

_____ Hydraulic analysis

_____ Detail all crossings with attention to separation requirements.

_____ Pipe material:

    _____ Define pipe class and test pressures.

    _____ Define joint types.

    _____ Scour analysis.

    _____ Consider corrosion analysis and input of corrosion engineer (protective coatings, active/passive protection systems)

  _____ Coordinate pipe material and trench backfill material, details, and specifications.

  _____ Coordinate pipe material and thrust restraint requirements.

  _____ Consider capital/operating cost analysis (as applicable).

_____ Trench backfill:

  _____ Specify materials (consult geotechnical recommendations).

  _____ Create/modify trench backfill details.

  _____ Coordinate detail references with plan and profile drawings.

_____ Corrosion control:

  _____ Locate test stations as required.

  _____ Design/locate cathodic protection as required.

  _____ Check pipe transitions/couplings for recommendations and verify inclusion of appropriate details.

_____ Thrust restraint:

  _____ Calculate thrust at bends and valves.

  _____ Determine restraint method; specify and provide required details.

  _____ Calculate pipe lengths requiring restrained joints.

_____ Air release valves:

  _____ Locate high points.

  _____ Determine criteria for adding air release valve.

  _____ Specify air valve.

  _____ Determine need for surge checks on air valves—coordinate with surge analysis.

_____ Isolation valves:

  _____ Finalize location.

  _____ Design access structures.

  _____ Determine need for pipeline fill and drain valves.

_____ Locate blow-offs at designated low points (determine criteria to establish distance between low points).

_____ Manholes/Junction boxes/vaults

  _____ Locate junctions based on access requirements/regulations and direction changes (for gravity system).

  _____ Access and cover requirements

  _____ Structural analysis/review of junction boxes and vaults

  _____ Means to drain vault by gravity or pumping

  _____ Pipe and valve supports

Specifications

_____ Prepare final geotechnical report and information for inclusion into specifications.

_____ Determine and specify any sewer flow control (bypass pumping) requirements.

_____ Prepare any technical specifications needed that are not included in the C-P standard specifications.

Details

_____ Use standard details per C-P, as available.

_____ Trench excavation and backfill, including pipe location tape

_____ Civil, including surface restoration/repair

_____ Erosion control, coordinated with local, state, and federal requirements and specified

_____ Levee/River/Stream Crossings, including casing pipe, jacking pits, casing details, bore and jacking, micro-tunneling, etc.,

_____ Corrosion, as prepared by corrosion engineer, including test stations, joint bond, cathodic protection, special joint coatings, etc.

_____ Structural, including wall penetration details, reinforcing, etc., as prepared by structural engineer.

_____ Manholes/junction boxes/vaults

_____ Buried valves

_____ Air release valves (including valve vaults and connection piping and valves)

_____ Thrust restraint

_____ Special, including pig launching/catching stations

_____ Detail all connections to existing pipes

Plan and Profile Drawing Checklist

_____ Location and vicinity maps provided

_____ Drawing order and numbers correct

_____ Sheet numbers, drawing numbers, and names match index

_____ Title block correct including initials and date

_____ Title block includes address and phone number of design office.

_____ Space reserved for PE stamp/signature.

_____ For aerial photos, date flown is shown.

_____ North arrows

_____ Drawing scales correct

_____ Standard detail references correct

_____ Trench section references correct

_____ Section references correct

_____ All cross-references to other drawings correct

_____ Specification references on drawings correct and specification covers item in question

_____ Legend symbols and abbreviations agree—add abbreviations as necessary.

_____ Dimensions shown as required and correct.

_____ Survey control established and referenced, correctly shown, and control points identified.

_____ List coordinates for proposed manholes.

_____ Existing manholes labeled with corresponding C-P manhole number.

_____ Locations of soil borings.

_____ Incorporate recommendations of geotechnical report on drawings.

_____ Elevations shown as required and match grid (grade, inverts, crossings, etc.).

_____ Eliminate inconsistencies within drawings.

_____ Detail or describe all connections with existing utilities.

_____ Drawing notes correct

_____ Match lines match and station listed.

_____ Pipeline label on each sheet

_____ Utility labels on each sheet

_____ Utility scale, line-weight correct

_____ Horizontal curve data included.

_____ Vertical curve data included (station, invert).

_____ Station ticks included.

_____ Bearings and distances listed and consistent format.

_____ Horizontal, vertical, and combined bend data included.

_____ All call-outs include station.

_____ ROW/servitude label

_____ Work limits and easement labels; servitudes, property lines and property owner's name (where necessary). Crosscheck servitudes, ROW widths between Plan and Profile). Show limits of contractor staging, storage, and/or access areas and off-site access corridors.

_____ Show work limits for environmental/special construction (wetlands, stream buffers)

_____ Names of streets and roads identified.

_____ Traffic control details and notes provided. Traffic control plan finalized.

_____ Drawings reviewed by appropriate entity requiring encroachment permit (city, parish, DOTD).

_____ Coordinate data included as appropriate.

_____ All pipe slopes listed and shown correctly.

_____ Restrained joint call-outs included and consistent.

_____ Existing and proposed grade shown.

_____ Pipeline cover is adequate and meets permitting agency requirements, or 3 feet minimum, whichever is greater.

_____ Pipeline marker and guard posts called out and specified.

_____ Elevation and station grid numbers correct

_____ Existing utilities shown, including water, wastewater, underground and overhead power, phone, and cable TV, natural gas lines, fiber optics. Cross check all utility crossing clearances and separation requirements. Provide any required utility relocation plans.

_____ Call Before You Dig or Underground Service Alert (USA) label with applicable phone number on each plan and profile drawing.

Cost Estimate Quantities

_____ 60% provide revised cost estimate quantities.

_____ Provide Schedule of Pay Items

Quality Assurance and Quality Control Review

_____ Perform QC review in accordance with QA Plan included in the Project Work Plan.

_____ Provide preliminary PE stamp & note (conforming to requirements of LAPELS Board) on cover of Specs and Drawings included in all preliminary review submittals to client.

Lead Engineer

Date

QC Reviewer

Date

Contract Document Preparation Checklist (90% Submittal)

Summary

1._____Mapping/Utilities/Permits/Environmental

2._____Pipeline Design

3._____Specifications

4._____Details

5._____Plan and Profile Drawing Checklist

6._____Cost Estimate Quantities

7._____Bidding Procedures

8._____Quality Assurance and Quality Control Review

______________________________ ____________________

Lead Engineer Date

______________________________ ____________________

QC Reviewer Date

Mapping/Utilities/Permits/Environmental

_____ Final ROW/servitude Maps:

- _____ Make corrections to legal descriptions where required.
- _____ Complete legal process—recording documents (utilize process outlined for Green Light Plan).
- _____ Signed and sealed by a Professional Land Surveyor, licensed in the State of Louisiana.

_____ Finalize the verified “special areas” as identified.

_____ Submit all collected utility information.

_____ Water and sewer pipeline separation criteria identified and incorporated into design.

_____ Address all agency review comments where required: traffic control, Building/construction, environmental/regulatory (stream buffer/variances), DHH permit.

Pipeline Design

_____ Verify that correct dimensions are shown and address all comments on horizontal and vertical alignments, hydraulic analysis, pipeline crossing details, pipe material, trench backfill, corrosion control, thrust restraint, air release valves, isolation valves, blowoffs, manholes, junction boxes and vaults as required.

Specifications

_____ Address comments and incorporate, where appropriate, the sewer flow control (bypass pumping) requirements.

_____ Address comments and incorporate, where appropriate, the prepared technical specifications that are not included in the C-P standard specifications.

Details

_____ Verify the use of standard details is applicable for this design.

_____ Address comments and incorporate, where appropriate, the erosion control measures meet the requirements of all local, state, and federal specifications

_____ Address comments and incorporate, where appropriate, all Levee/River/Stream Crossings, including casing pipe, jacking pits, casing details, bore and jacking, micro-tunneling, etc.,

_____ Address comments and incorporate, where appropriate, the corrosion protection system, including test stations, joint bond, cathodic protection, special joint coatings, etc.

_____ Address comments and incorporate, where appropriate, the structural details, including wall penetration details, reinforcing, etc., as prepared by structural engineer.

_____ Address comments and incorporate, where appropriate, special manhole/junction boxes/vault details, buried valve details, air release valve (valve vault, connection piping and valve) details, thrust restraint details, pig launching and catching station details, and detail connections, etc.

Plan and Profile Drawing Checklist

_____ Address comments and incorporate, where appropriate all comments found on the plan and profile sheets

Cost Estimate Quantities

_____ Provide final construction cost estimate quantities

Bidding Procedures

_____ PE stamp/signature on specification fly sheet

_____ PE stamp/signature on each drawing

_____ QC the bid documents

_____ Prepare Legal Notice, Invitation, or Advertisement

    _____ Project identification

    _____ Description of work

    _____ Time of completion

    _____ Date, time, place of bid receipt/opening

    _____ Document availability, bid security requirements

    _____ Other statements required by law

    _____ Prequalification requirement

_____ Provide Schedule of Pay Items

_____ Pre-bid Contact with Bidders

    _____ Attend Pre-bid conference and/or site tour

_____ Prepare Addenda as Needed

_____ Award/Execution

    _____ Prepare Conformed Drawings.

Quality Assurance and Quality Control Review

_____ Perform QC review in accordance with QA Plan included in the Project Work Plan.

_____ Provide PE stamp & note (conforming to requirements of LAPELS Board) on cover of Specs and Drawings included in submittal to client.

Lead Engineer	Date
QC Reviewer	Date