Chapter 10

Trenchless Installation of PVC Pipe

As our water and wastewater infrastructure ages, there is constant need for repair and replacement and as cities grow, there is a continual need for additional underground pipelines in already densely populated, complex environments. There are also situations that make traditional excavation costly and difficult (such as that presented by rivers or major roadway and wetlands that must be crossed). In all these applications, trenchless (or "no-dig") pipe installation methods are being used effectively. This chapter covers recommended and common practices for trenchless installation of PVC pipe.

Construction methods for trenchless installation have progressed to computer-operated directional-drilling rigs capable of pulling in thousands of feet of assembled PVC pipe (fused or segmented) in one pull, as well as slip-lining and pipe-bursting of pipe in disrepair. Meanwhile, PVC materials, pipe, and specialized joints have been developed to accommodate various trenchless installation methods.

Because unique loads are placed on trenchless pipe during installation, special attention must be given to the axial compressive and/or tensile forces on the pipe. These forces arise from pulling and pushing during installation and from the external loads on the pipeline once it is fixed in place.

PVC PROPERTIES FOR TRENCHLESS CONSTRUCTION

PVC plastic pipe possesses properties that are conducive for trenchless installations. Table 10-1 summarizes these and their importance.

Table 10-1 Important material properties for trenchless installation

Material Property	Value	Importance
Tensile strength	7,000 psi	Trenchless installation requires axial strength to allow restrained joined pipe to be pulled into place
Modulus of elasticity	400,000 psi	Key stiffness property for external load resistance
Coefficient of thermal expansion	3.0×10^{-5} in./in./°F	Low expansion and contraction, compared to the other common thermoplastic pipe material, minimizes axial forces generated by temperature changes
Hardness	≈ 117 (Rockwell R scale)	High resistance to abrasion and scratching during trenchless installation
Elasticity	No value	While PVC is classified as a thermoplastic and therefore visco-elastic in behavior, it behaves elastically over nearly all its stress–strain range, resulting in no wait period for reversion after tensile pull-in
Hydrostatic design basis (HDB)	4,000 psi	Greater long-term strength, higher HDB, than the other common pipe thermoplastic, which allows for thinner pipe walls, greater flow capacity, and less weight for the same pressure capacity/strength
Specific gravity	1.4	Having a density greater than water, PVC pipe will not float when ballasted with water
Allowable strain capacity for bending	Recommended minimum bend radii are provided in Chapter 12	Less strain capacity than the other common thermoplastic pipe material but more strain capacity than all other commonly used pipe materials and enough to accommodate the curvature requirements generally associated with trenchless installation

TRENCHLESS INSTALLATION JOINTS AVAILABLE WITH PVC

There are several PVC pipe joint options that can be used for trenchless installation. The strength and size of the joint will vary as well as the suitability for each trenchless method discussed.

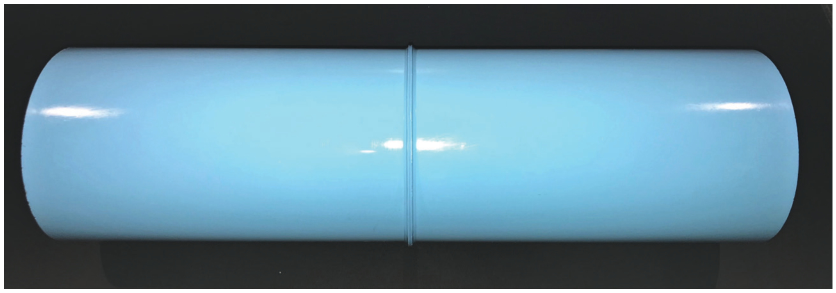
For installation by horizontal directional drilling (HDD), the outside diameter of the joint (ODJ) will determine the size of the bore hole. Typical guidance is for the bore hole to be at least 1.5 times the ODJ up to 4-in. pipe and then ODJ plus 12 in. for larger sizes. Tensile and compression load capacity of each joint type will vary. Check with the pipe manufacturer/supplier for maximum ODJ and recommended load limits for each joint type. The manufacturer/supplier should also indicate and confirm what safety factor has been used in determining the recommended tensile load limit for both the pipe and joint.

Trenchless Joint Types

Butt fused joints. Plain end lengths of PVC pipe are joined by the thermal butt fusion process (Figure 10-1). The result is a continuous pipe that has practically no external profile when the fusion bead is removed.

Spline and grooves joints. A groove is cut into the outside of the pipe near the spigot end and also inside either the bell or coupling. When the inside and outside grooves are aligned, a plastic spline is inserted to restrain the connection (Figure 10-2). A gasket provides the watertight seal.

Pins and groove joints. The bell and spigot of the PVC pipe are thickened during extrusion and a groove is machined into the spigot with evenly spaced holes drilled into the bell. The spigot is then inserted into the bell to align the groove with the bell holes.



Source: Underground Solutions, Inc.

Figure 10-1 Butt fused pipe

Source: NAPCO Pipe & Fittings

Figure 10-2 Spline and grooves restraint

Source: Underground Solutions, Inc.

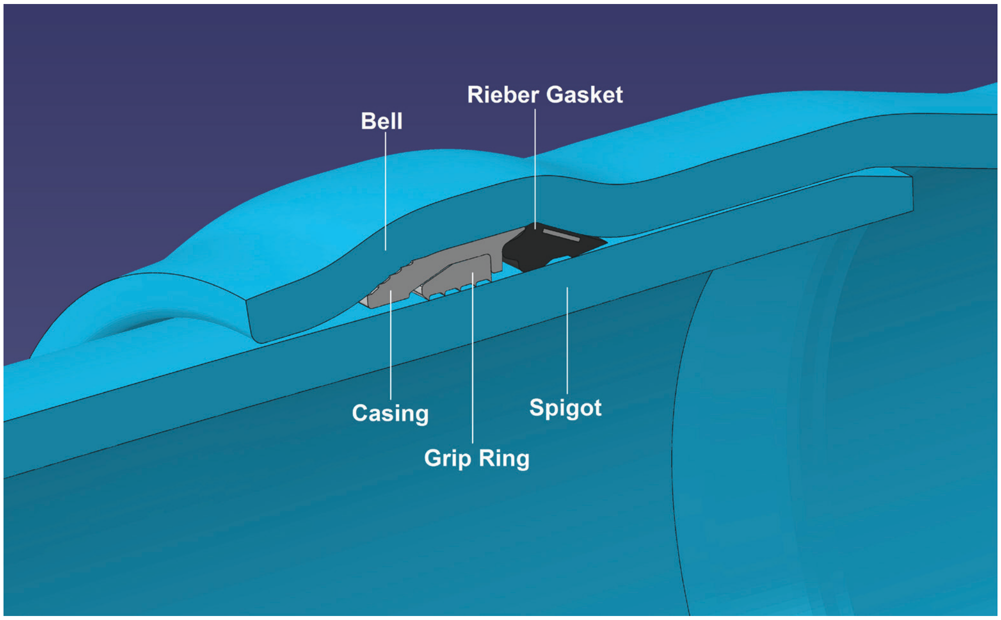
Figure 10-3 Pins and groove restraint

Fiberglass pins are then tapped through the bell into the spigot groove. A gasket makes the watertight seal (Figure 10-3).

Grip ring and casing joints. The gasket race-way in the pipe bell is extended to accommodate a tapered metal casing and metal grip-ring. The metal casing inside the pipe bell forces the grip ring into the pipe spigot when a pull-force is applied. A gasket makes the watertight seal (Figure 10-4).

Allowable Pull and Push Forces for PVC Pipe Joints

The anticipated maximum pull load during a trenchless pull-in should not exceed the allowable pipe joint pull force. The most severe pull loads are generally associated with the HDD installation method. The value is derived from the tensile properties of the pipe, as in the case of fusion-joined PVC, or from the strength of the mechanical connection, such as the pins and groove, spline and grooves, grip ring and casing, or externally harnessed restrained joint. An example is shown in Table 10-2. The provider of each joint type should be contacted to obtain their recommended allowable pull and push forces for their available joint sizes and dimension ratios (DRs). The recommended values should be evaluated to ensure that they exceed the expected maximum pull or push force needed for a specific project.



Source: S&B Technical Products

Figure 10-4 Grip ring and casing

Table 10-2 Recommended straight (no bending) pull and push force values, along with the safety factors used to calculate them, for 8-in. DR 18 PVC pipe

Joint Type	Allowable Tensile (Pull) Force, lb	Allowable Compression (Push) Force, lb	Applied Safety Factor
Fused	37,800	37,800	2.5
Spline-locked	27,500	27,500	2.0
Pinned	25,800	25,800	2.0
Grip-ring	30,000	N/A*	1.6

* Compressive forces are not applicable and/or applied to this joint.

In addition to the pipe properties noted in Table 10-1, other assumptions or properties must be considered to determine the maximum installation pull and push forces. For HDD installations, this will include a friction factor between the PVC pipe and drill mud (0.3 is commonly used), a friction factor between the PVC pipe and either the ground (0.5 is a typical value) or on rollers (values of 0.1–0.2 are typical). Soil densities and drill mud densities are also properties that impact the HDD pull force calculation. The general layout of the bore alignment including insertion/exit angles, radii of curvature, and depth may also need to be considered.

TRENCHLESS CONSTRUCTION AND TRENCHLESS REHABILITATION

Trenchless installation can be classified into two groups:

1. *Trenchless construction*: The installation of an entirely new pipeline with minimal open-cut excavation. Methods for new construction include
   a. Horizontal directional drilling (HDD)
   b. Installations through casing (jack and bore)

2. *Trenchless rehabilitation*: The repair of an existing deteriorated pipeline with minimal open-cut excavation. The primary rehabilitation methods are
   a. Sliplining
   b. Pipe bursting
   c. Tight-fit structural lining

Trenchless Construction—Horizontal Directional Drilling

HDD is the most commonly used trenchless process for installing new pipelines. HDD is performed with a drilling rig and involves three steps.

1. A pilot hole is bored.
2. The hole is reamed to its final size.
3. The pipe is pulled in.

In smaller diameters (<12 in.) and shorter length installations (<500 ft), the second and third steps are sometimes performed simultaneously. The design considerations of typical HDD alignment are depicted in Figure 10-5.

Bending. HDD bore alignments require some amount of bending of pipe and/or joints. Each PVC pipe joint technology provider publishes guidance on allowable minimum bend radii for pipe with its particular joining system (Figure 10-6). This guidance must be followed in the design of bore alignment as well as during pipe layout and installation.

The recommended degrees of allowable angular deflection at bell-and-spigot joints and couplers are dependent upon the joint geometry and gasket design and generally range from zero to five degrees. The recommended minimum bending radii for fusion-joined PVC pipe are included in Chapter 12, Table 12-2.

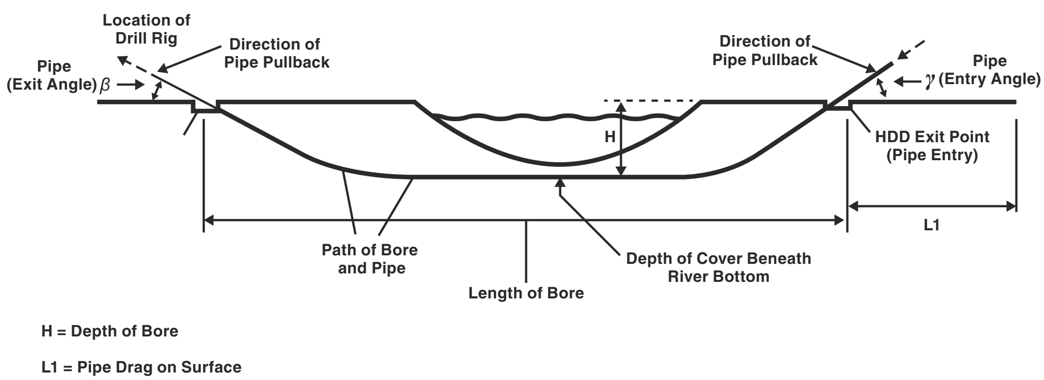
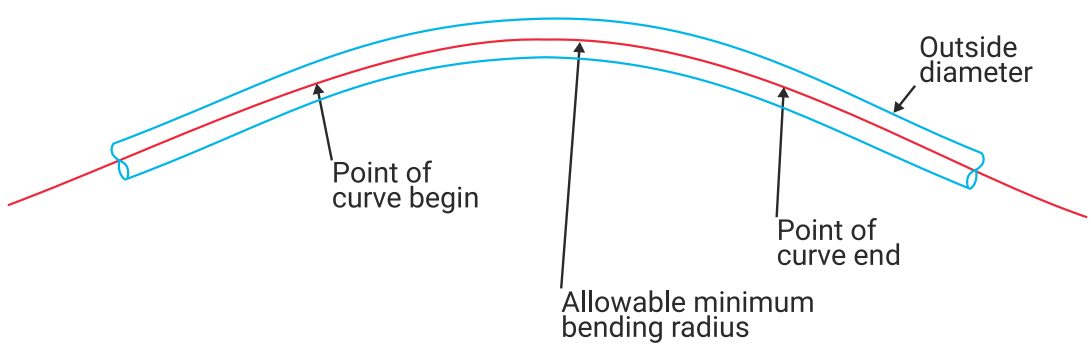


Figure 10-5 Typical HDD alignment shown schematically for design considerations



Source: Adapted from Underground Solutions, Inc.

Figure 10-6 Illustration of minimum bend radius

Pullback force. The combined effects of all of the frictional and resistive forces on the pipe create the pullback force required for successful pipe installation. The resultant pullback force required must not exceed the tensile capabilities of the pipe and/or joint together with an appropriate safety factor. Monitoring and controlling the density of the drilling fluid is critical for minimizing the required pull force.

Information on how to estimate pullback forces and allowable tensile stresses may be obtained by contacting the manufacturer or technology provider of the particular PVC pipe and restrained joining system selected for use.

Elongation and connections. With PVC pipe, the magnitude and duration of pulls do not result in significant pipe elongation. Therefore, connections to PVC pipe can be made immediately following pullback. Joint restraint is recommended when joining a directional drilled portion of a pipeline to another section of pipe, a fitting, or other appurtenance.

Pressure testing. Installers pressure testing HDD lines should be aware that the combination of drilling fluid and a reamed hole can allow the pipe to move and therefore all connection points should be adequately restrained for any thrust prior to the testing. For trenchless installations, the pressure test in ground after installation is the only test that occurs after all loading of the pipe is realized. Above-grade hydrotesting is not recommended.

Methods to reduce friction and minimize exterior scratching. Moving long lengths of pipe on roller stands, timbers, or short pipe sections or dragging pipe on grass or soft soil will help prevent potential damage to the pipeline and reduce the force needed to install the pipe.

Supporting the pipeline on rollers reduces the frictional drag coefficient and the pull force required to complete an installation (Figures 10-7 and 10-8). Steep insertion angles require additional support consideration so that the manufacturer's recommended angles and bend radii are not exceeded at the installation point.

The generally recommended minimum lengths between roller supports are listed in Table 10-3. The pipe supplier should be contacted for specific minimum spacing

Table 10-3 Pre-installation, recommended support spacing for restrained-joint PVC pipe (empty)*

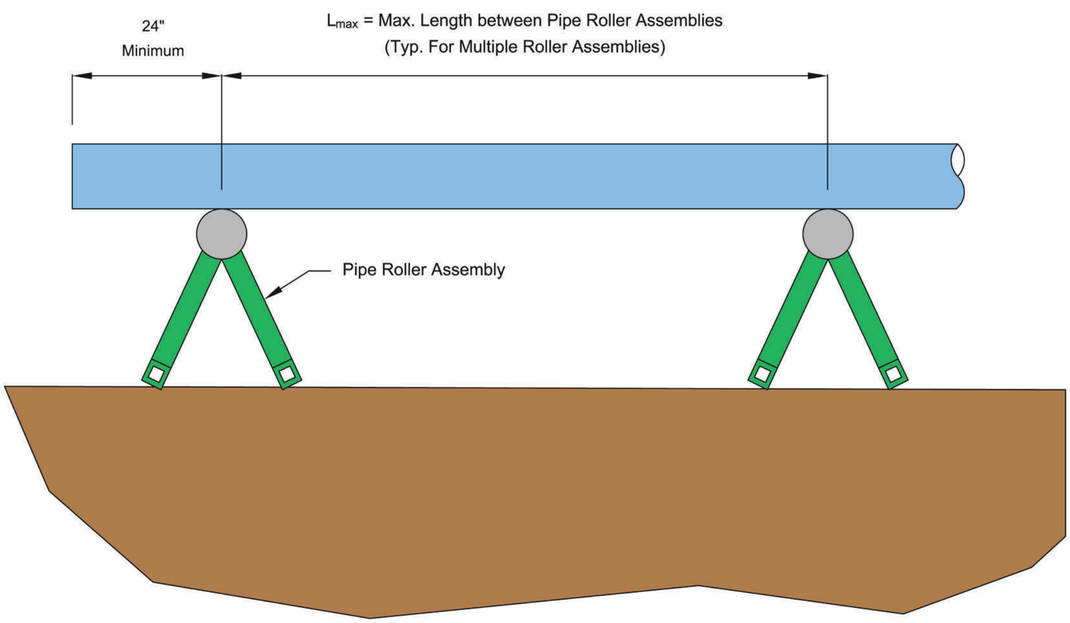
Nominal Pipe Diameter		Max. Support Spacing†	
(in.)	*(mm)*	*(ft)*	*(m)*
4	100	13	4.0
6	150	17	5.2
8	200	21	6.4
10	250	25	7.5
12	300	28	8.5
14	350	30	9.1
16	400	35	11
18	450	39	12
20	500	42	13
24	600	46	14
30	750	57	17
≥36	**900**	**65**	**20**

* Support spacing recommendations are primarily governed by pipe diameter. However, pipe DR and joint design may decrease or increase recommended support spacing. For specific guidance, contact the pipe supplier.

† The recommended spacing should be reduced for sustained temperatures above 80°F (27°C). For specific guidance, contact the pipe supplier.

Source: Underground Solutions, Inc.

Figure 10-7 Example of short pipe sections being used to reduce drag friction

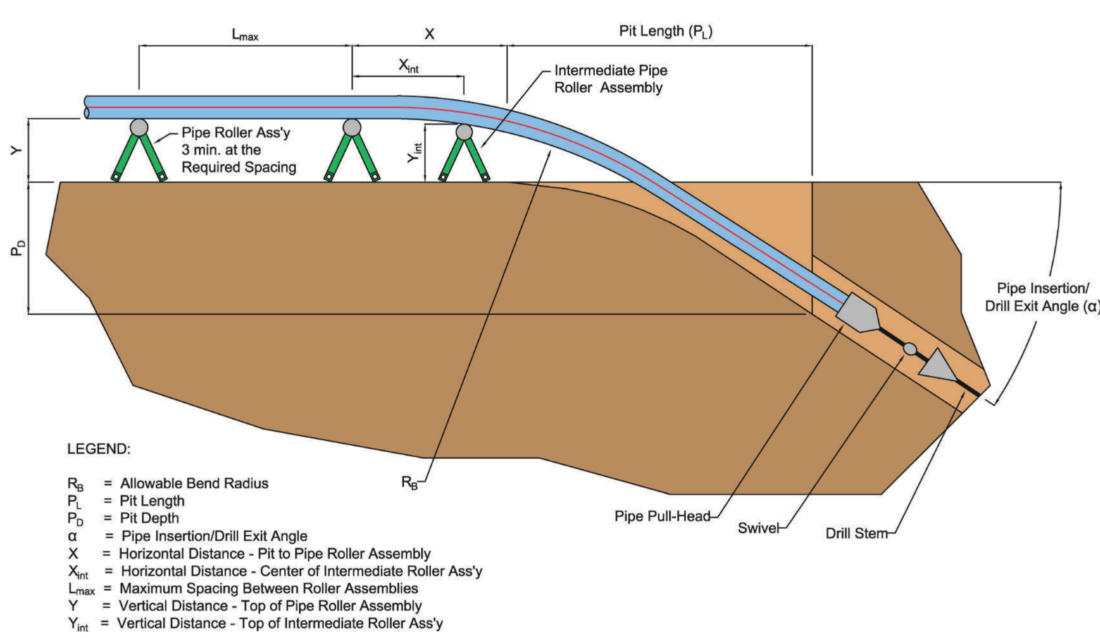


Source: Underground Solutions, Inc.

Figure 10-8 Typical roller placement

recommendations. A variety of means of roller insertion are depicted in Figures 10-9 through 10-12.

Pilot holes. The pilot hole is drilled with defined entry angle and exit angles. These angles are dependent on the minimum radius of curvature allowed within the right-of-way provided. The radius of curvature, at all locations during and after installation, must meet



Source: Underground Solutions, Inc.

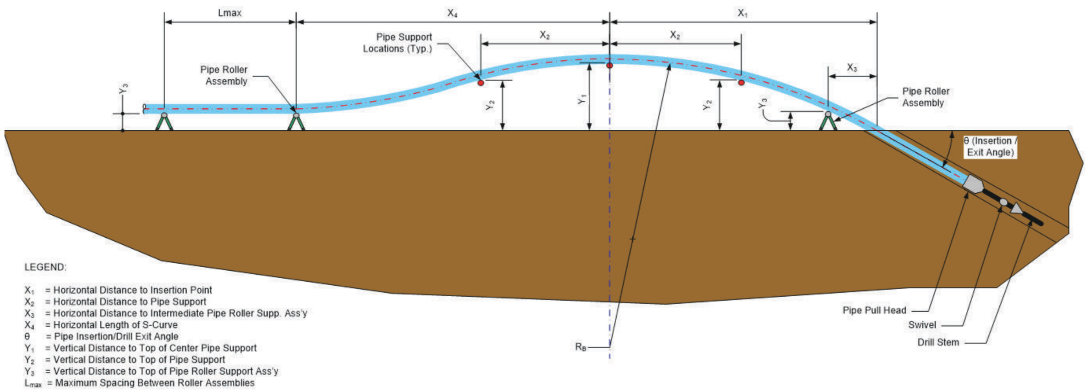
Figure 10-9 Insertion schematic for rollers

Source: Underground Solutions, Inc.

Figure 10-10 Field application of roller-supported insertion

or exceed the minimum allowable radius of curvature for the restrained-joint PVC pipe system used.

Reaming the pilot hole. Special cutters called reamers are successively pulled through the pilot hole to produce a bore large enough for installation of a pipe of the required diameter. Simultaneously, drilling fluid is pumped into the hole. The reamed hole allows drilling fluid to fill the annular space and to flow around the pipe.



Source: Underground Solutions, Inc.

Figure 10-11 Schematic for an aerial insertion with rollers

Source: Underground Solutions, Inc.

Figure 10-12 Proper use of aerial slings, with rollers to reduce friction, for an HDD insertion

Borehole diameter. Soil type and water table may affect the borehole size. Generally, the diameter of the finished borehole should be as follows.

- For pipe sizes up to 24 in., the borehole should be 50 percent larger than the outside dimension of the pipe, pipe joint, pipe coupling, or external restraint—whichever is greatest.
- For pipe sizes larger than 24 in., the borehole should be no less than 12 in. larger than the outside dimension of the pipe, pipe joint, pipe coupling, or external restraint—whichever is greatest.

Drilling fluids. Drilling fluids lubricate the drill rod, drill head, reamer, and pipe. Ends of PVC pipe should be covered, capped, or plugged to prevent drilling fluid from entering the pipeline during installation. The drilling plan should include provisions to prevent the drilling fluid from escaping to the environment. When drilling under waterways with limited clearance, the frac-out potential of the bore and inadvertent surface return potential should be considered. The frac-out potential is not a pipe-driven parameter but is derived from soil type, depth, and drilling fluid pressure which can lead to inadvertent surface returns or future settlement.

Pullback. A pulling head, in combination with a swivel eye to prevent torsional stresses, connects the drilling rod or reamer to the leading end of the PVC pipe string. Pulling heads must comply with recommendations of the pipe manufacturer or the technology provider. The pullback operation should happen as soon as a reamed hole is completed to minimize the possibility of borehole collapse. Pullback forces can be monitored to ensure they remain within allowable limits. Safe pull (and push) forces vary with the type of joint used in combination with the pipe diameter and DR.

Pullback with butt-fused PVC pipe is usually performed in a continuous length. If necessary, intermediate fusions are performed during the pullback process. Segmented PVC pipe (pins and groove, splines and grooves, and grip ring joints) are usually strung out in long lengths or can be installed one joint at a time.

Trenchless Construction—Installation in Casings

A casing is the larger diameter pipe through which the smaller diameter carrier pipe is installed. When PVC pipe is installed under highways, runways, or railways, a casing may be required for the following reasons:

1. to prevent damage to structures due to soil erosion or settlement in the pipe zone,
2. to facilitate pipe removal and replacement in the future, or
3. to accommodate regulations or requirements imposed by public or private owners of property where pipe is installed.

PVC pipe may be used as the casing pipe and/or the carrier pipe. When PVC pipe is installed inside the casing pipe, casing spacers may be required to prevent damage to the pipe or pipe joints during installation and to provide proper long-term line support for belled end or mechanical jointed pipe. Maximum support spacing values for PVC pipe casing spacers should be limited to those given in Table 8.10 of the *Handbook of PVC Pipe Design and Construction*, 5th edition.

For pipe that will be pushed into position, casing spacers should be securely installed adjacent to the spigot-end insertion marks. Restrained joints suitable for compressive loads may be required if installation forces exceed the slippage resistance of casing spacers. For pipe that will be pulled into position, restrained joints having adequate allowable pull force resistance need to be used.

Casings are normally sized to provide an inside diameter at least 2 in. (50 mm) greater than the maximum outside diameter of the pipe joint, i.e., bell, casing spacer, or joint restraint device. Casing spacers also keep the pipe in position inside the casing. Various configurations are available to allow for a centered spacing or on a set distance from the invert of the casing. Care should be taken to provide adequate soil support for the carrier pipe just outside of the casing ends to avoid point loads from developing at the casing spacer contact points. For pipe joined by butt fusion with no external profile increase, laying the pipe on the invert of the casing where it is continuously supported is the preferred method.

Installing pipe through casings. After installation of the casing pipe, which is often bored or jacked into place itself, the restrained-joint PVC pipe can be pulled or pushed ("jacked") through casings. Installation should be done at a steady, controlled pace.

Annular space. The ODJ and OD of the carrier pipe is less than the inside diameter of the casing, which leaves an annular space between the two. In many cases, this annulus is filled with grout after installation. The method and material used for backfilling the annular space will affect the minimum clearance needed. In cases where the carrier pipeline may need to be removed from the casing, casing spacers can be used with the ends of the casing pipe sealed to prevent groundwater and soil from entering the annular space. See "Filling the Annular Space" at the end of this chapter.

Trenchless Rehabilitation—Sliplining

Sliplining is accomplished by inserting a lining pipe into a host pipe that needs rehabilitation. Unlike some other trenchless methods, the PVC lining pipe is fully structural, i.e., capable of carrying both the internal and external loads, and is not dependent upon the host pipe. PVC reliner pipe is usually pushed or pulled into the existing host pipe. Before installation, the host pipe is cleaned of debris and any service buildup (sediments and/or tuberculation), then surveyed for internal clearance, alignment, and obstructions.

In some cases, spot repairs are required on the host pipe in areas where the replacement pipe cannot pass. The largest PVC slipliner pipe that will fit is selected and inserted. Sizing of the slipliner pipe must take into account the maximum outside dimension of the reliner joints. For long insertion lengths, approximately 2 in. of clearance between the host pipe inside diameter and the maximum outside diameter of the reliner joints is recommended.

Hydraulic capacity can often be maintained despite the diameter reduction due to PVC pipe's low hydraulic friction, i.e., Hazen–Williams flow coefficient (C = 150) and Manning's 'n' = 0.009.

Loading. If portions of the PVC slipliner will extend beyond the host pipe the differences in loading conditions installation must be considered and accommodated in the design of the system. Loading conditions are not identical since there are differences in the two regions' ring deformation and longitudinal pipe deflection.

Annular space. Sliplining pipes are usually grouted in place. This prevents surface settlement that could be caused by the further deterioration of the host pipe. Installation material that approximates soil strength around the host pipe is recommended. See "Filling the Annular Space" later in this chapter.

Installation. There are two general methods used for sliplining installations:

1. *Segmental sliplining*—Liner is installed one pipe length at a time.
2. *Continuous sliplining*—Carrier pipe lengths are assembled, then installed in one long string or several strings with intermediate connections.

Segmental sliplining. With this method, PVC pipe may be assembled in segments at entry points along the length of the deteriorated host pipe. Pipe is inserted directly into the host pipe by either pulling or pushing. Joints capable of withstanding the pulling and/or pushing forces are required. Joint assembly shall be in accordance with manufacturer's instructions. Open-cut trenches are required to access the host pipe at strategic installation points.

Services need to be excavated, disconnected, and reconnected to the new PVC sliplining. Making connections to different materials also involves exposing both the lining pipe and the pipe to be connected with open cut excavation.

Continuous sliplining. In continuous sliplining, PVC carrier pipe is preassembled in long lengths before it is pulled into the deteriorated host pipe. The pull-in can be done in one unsegmented length or in sections that require an intermediate joint or butt-fusion. When required, taps are made after the new pipe is pulled into the host pipe.

The two primary components of the forces required for sliplining are:

1. Friction caused by the length of pipe being pulled above grade
2. Friction between the new pipe and the host pipe