Standard Guideline for Recording and Exchanging Utility Infrastructure Data

White Paper

Introduction

Poor utility records increase risk and costs for civil projects, private developments, and utility infrastructure installations. These risks and costs can be reduced by capturing and recording standardized utility data at the time of installation, and systematically recording standardized data on existing utilities exposed during ongoing construction. The Standard Guideline for Recording and Exchanging Utility Infrastructure Data (also referred to as the utility as-built standard) is being developed under the auspices of ASCE's Construction Institute (CI) and Utility Engineering and Surveying Institute (UESI). Committee members developing this standard guideline represent a wide range of backgrounds and experience, including, but not limited to, utility engineering, surveying, computer-aided design (CAD); geophysics; geodetics; geographic information systems (GIS); civil infrastructure design and construction; right-of-way management; and geotechnical engineering.

Purpose

The purpose of this paper is to:

1) Introduce summarized content of a pre-ballot draft of the Standard Guideline for Recording and Exchanging Utility Infrastructure Data under development by the American Society of Civil Engineers (ASCE).
2) Promote testing of concepts included in the document by agencies who are developing systems to gather "as-built" utility data.
3) Accelerate use of the principles proposed to be embodied in the new ASCE standard guideline prior to formal adoption.

The draft standard guideline is currently under development and additional data items are being considered. ASCE welcomes feedback from early users of these draft concepts and principles to test and improve them, and for sharing lessons learned. Please submit your comments to CI Director Katerina Lachinova (at klachinova@asce.org) by March 1, 2018. If you have suggested edits please use the Track Changes function in Word.

The new standard guideline is intended to provide non-binding guidance to assist right-of-way and utility owners in establishing their own standards. Some agencies have already used earlier versions of this draft standard guideline in development of their as-built processes and data repositories.

The intent of the standard guideline is to present a common definition for communicating the positional accuracy of utility assets and define a minimum set of data attributes necessary to communicate the position along with the type, function, ownership, materials, status and other information related to the asset. Furthermore, the standard guideline is intended to encourage the adoption of standard practices, contract requirements and jurisdictional requirements resulting in permanent records of location determined by direct measurement methods, and collection of data attributes on all new utility infrastructure.

The standard guideline specifies essential elements for the documenting the location and attributes of underground and aboveground utility infrastructure. This includes a particular focus on the documentation of newly installed or exposed infrastructure. It complements ASCE 38 (current version), *Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data*.

Administration

The standard guideline will describe the necessary functions to promote long-term reliable, functional, and secure data. The purpose is to facilitate data collection, data management, and data exchange among stakeholders. The standard guideline will recommend best practices with respect to administration of data, data exchange, and data governance.

Utility Infrastructure Data Content and Accuracy

The standard guideline will specify the level of reliability and accuracy of data collected and used to depict utility infrastructure locations, and provide a framework for data exchange that relies on utility location data and relevant attribute data.

The standard guideline specifies all relative positioning be transformed to absolute positions for mapping and data exchange purposes. Relative spatial positioning depends heavily on local conditions and is inappropriate for data exchange purposes.

Example: depth is a measurement to existing ground level and is subject to variations over time. These limitations make depth inadequate for recording vertical positions. To resolve this problem, all vertical measurements shall be recorded and exchanged as orthometric height elevations referenced to the vertical datum of the U.S. National Spatial Reference System (NSRS).

Example: it is common practice to define locations by measurements from other local features, such as locating a water valve by taped distances from face of curb and a nearby power pole. Since the reference objects themselves can be moved or lost over time, these measurements are unreliable for data usage. All relative measurements shall be transformed to a georeferenced system that represents X, Y, Z locations for recording and exchanging.

The standard guideline will specify that horizontal and vertical locations be shown by reference to the horizontal and vertical datums of the NSRS or some other commonly recognized horizontal and vertical coordinate system so data can be readily shared with others. If a recognized system cannot be used, e.g., a localized reference system, the necessary parameters for transforming the data from the local system to the NSRS horizontal and vertical datums are to be included with the infrastructure data. The horizontal and vertical datums shall be managed and exchanged at the record level (See Appendix A).

The standard guideline proposes requirements for levels of positional accuracy of utility infrastructure as shown in Table 1.

Table 1. Positional Accuracy Requirements

Accuracy Level	Positional Accuracy[1]	Applies to	Comment
1	±0.1 feet (±25 mm) Vertical	Z data	Coincides with requirements in ASCE 38 (current edition) quality level A (QLA).
	±0.2 feet (±50 mm) Horizontal	X and Y data	
2	±0.2 feet (±50 mm)	X, Y, and Z data	Substantially identical to Level 1, but removes the close tolerance on vertical methods and thus can be generally achieved without the need for survey bench leveling.
3	±0.5 feet (±150 mm)	X, Y, and Z data	Generally possible using GPS equipment and RTK methods.
4	±1 foot (±300 mm)	X, Y, and Z data	Generally achievable by post-processed mapping grade GPS equipment.
5	±3+ feet (±1000 mm)	X, Y, and Z data	Generally achievable with mapping grade GPS.
6	±3+ feet (±1000 mm)	X and Y data	Positional accuracies of Z data are unreliable or not available.
7	Indeterminate		Positional accuracies of X, Y, and Z data are indeterminate.

[1] At the 95% confidence level, using the root-mean-square error (RMSE) in accordance with FGDC-STD-007.3-1998. "Positional Accuracy" is in direct reference to the actual geodetic positional coordinates as referenced to the National Spatial Reference System (NSRS) maintained by the National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS). Geodetic positional coordinates (latitude, longitude, and orthometric heights) reference to the official U.S. datums, currently, the North American Datum of 1983 (NAD 83) and the North American Vertical Datum of 1988 (NAVD 88).

Note that the positional accuracy of suspended aerial cables and wires is variable due to environmental factors and therefore shall be classified as Level 7, except at the points where they are anchored to support structures such as poles. The positional accuracy of points measured in the field should be assessed separately from the positional accuracy of derived features.

Framework for Data Exchange

The standard guideline does not provide a prescriptive utility data model but rather by consensus defines the elements of utility data needed to facilitate utility data exchange with sufficient information to enable virtual regeneration of a 3-D model representation of the utility infrastructure with appropriate attribution that is consistent and useful for civil engineering purposes. The standard guideline describes a framework for data exchange of utility infrastructure data. Appendix A contains a detailed list of the components and their data attributes.

Utility Infrastructure Data to Measure and Record

Documents

Documents such as inspection reports, specifications and photographs often provide additional information about the utility asset that is advantageous to exchange with others. These documents and photos augment, but do not replace the geographic information about a specific asset. To be useful, these associated documents and photographs should be associated with the specific utility asset(s) they describe. A unique identifier (ID) should be used to link associated documents and photographs to the associated asset.

Trenchless Technology

Where part or all of the installation of a pipeline is to be achieved by trenchless technology methods, collect the spatial pipeline feature data at points where the pipe enters and leaves the borehole and at all required test pit verification points through which the boring passes at an accuracy level meeting or exceeding the positional accuracy requirements.

For that portion of pipeline between the entrance and exit of the borehole, horizontal and vertical spatial data should be gathered using indirect means (e.g., bore logs with recorded inertial navigation data for the boring tip or 3-D electromagnetic sonde observations recorded along the surface) and shall be recorded with an accuracy meeting or exceeding Positional Accuracy Level 6. This is especially important for deep borings that exceed practical limitations of electromagnetic detection and vacuum excavation methods as well as inaccessible borings, such as channel crossings or beneath structures.

Where other underground utilities cannot be exposed or designated (e.g., when it passes below a structure or body of water) its position should be measured where the utility was last observed when it enters and when it exits the obscured area. The portion of utility that is obscured shall be clearly indicated that it has not been measured or designated. Any portion of a trenchless feature not directly measured or designated shall be designated in accordance with ASCE 38 and Positional Accuracy Level 7.

Considerations When Exchanging Data

Metadata should be provided with all exchanged data. At a minimum, features that are exchanged include the metadata elements described in Table 2. In addition, include metadata that describes how and when the data was collected, the coordinate reference system and datum used, the individual(s) who certified the data, and any known limitations.

Several attributes defined in Table 2 are to be conveyed as real numbers. In these cases, the number of digits after the decimal point should correspond to the accuracy of the data. For example, a feature's width that is recorded to within a tenth of a foot should be specified as X.X feet (which in practice means X.X plus or minus 0.05 feet).

Utilities are an essential element of critical infrastructure. Utility data should be treated as sensitive information and handled accordingly. Utility data that support security operations may be considered sensitive security information (SSI) and must be labelled, distributed, and handled in accordance with 49 CFR 1520.

Each entity is responsible for the data it collects and disseminates; therefore, each entity must decide how to handle sensitive data. The following guidelines are recommended:

- Establish and document policies for exchanging utility data.
- Inform employees, consultants, and others with data access about the policies.
- Determine which data are defined as SSI by 49 CFR 1520. Label, disseminate, and handle the data accordingly.
- Classify data by level of sensitivity, label and handle in an appropriate manner.
- Clearly document in the metadata all data usage restrictions, including restrictions on access to the data.

Appendix A. Framework for Utility Data Exchange

The standard guideline will define a minimum set of data types and data attributes required for data exchange. Each feature is described using the following tables:

- Type as shown in Table 2.
- Geometry type as shown in Table 3.
- Attributes as shown in Table 4 and Table 5.

Table 2. Feature Types

Feature Type	Definition	Comment
Segment	A linear utility feature represented by a series of connected points.	Examples include water line, electric cable, and communication line.
Device	A discrete utility feature that is directly involved with the conveyance, control, or distribution of a particular utility service.	Examples include valve, splice, and transformer.
Access Point	An opening that provides access to utility devices, segments, and containing structures. This feature type is only a point or two-dimensional.	Examples include lid, cover, door, and grate.
Support Structure	A structure used to support utility lines and devices.	Examples include pole, tower, and thrust block.
Containing Structure	A structure or chamber that houses or provides access to utility devices and typically provides a junction area for multiple utility lines.	Examples include pull box, junction box, manhole, vault, and valve box.
Secured Utility Area	An area typically fenced off to restrict access to utility facilities.	
Encasement	A structure that encloses and protects utility facilities and surrounding infrastructure, environment, and the public.	Examples include concrete cap, steel pipe, and tunnel.
Marker	A visible or remotely detectable sign or device used to reference the location of a utility facility.	
Tracer	A wire or tape used to reference the location of a linear utility facility.	

Table 3. Geometry Types

Feature Type	Geometry Type (Minimum Required[1])	Geometry Type (Optional[2])
Segment	Line String	3D Object[3]
Device	Point	Polygon or 3D Object
Access Point	Point	Polygon
Support Structure	Point	Polygon or 3D Object
Containing Structure	Polygon	3D Object
Secured Utility Area	Polygon	
Encasement	Line String	3D Object
Marker	Point	
Tracer	Line String	

[1] Minimum required geometry type corresponds to the simplest geometric depiction of a feature type that conforms to this standard.

[2] Optional geometry type corresponds to alternative geometric depictions of a feature type that may be used under this standard.

[3] If using a 3D Object geometry type, the 3D Object shall include all the necessary transformation data to convert local coordinate data to real world coordinate data.

Table 4. Feature Attributes

Feature Attribute	Applies to Feature Type								
	Segment	Device	Access Point	Support Structure	Containing Structure	Secured Utility Area	Encasement	Marker	Tracer
ID	M	M	M	M	M	M	M	M	M
Owner	M	M	M	M	M	M	M	M	M
Operator	O	O	O	O	O	O	O	O	O
Utility Type	M	M	M	M	M	M	M	M	M
Device Type	M	M	M	M	M		M	O	O
Conveyance Purpose	M	M		M	M		M	O	O
Intended Permanence	M	M	M	M	M	M	M	M	M
Buried Status	O	O	O	O	O	O	O	O	O
Operational Status	M	M	M	M	M	M	M	M	M
Horizontal Spatial Reference	M	M	M	M	M	M	M	M	M
Vertical Spatial Reference	M	M	M	M	M	M	M	M	M
Accuracy Level	M	M	M	M	M	M	M	M	M
XYZ	M	M	M	M	M	M	M	M	M
Azimuth		C	C	C	C	C			
XYZ Observed	O	O	O	O	O	O	O	O	O
XY Relative Position	C	C	C	C	C	C	C	C	C
Z Relative Position	C	C	C	C	C	C	C	C	C
XYZ Junction Point	O	O	O	O	O	O	O	O	O
Quality Level	O	O	O	O	O	O	O	O	O
Linked File	O	O	O	O	O	O	O	O	O
Date Data Collected	O	O	O	O	O	O	O	O	O
Data Sensitivity Level	O	O	O	O	O	O	O	O	O
Is Certified	O	O	O	O	O	O	O	O	O
Certification Summary	O	O	O	O	O	O	O	O	O
Material	O			O			O		O
Is Cathodic Protected	O			O			O		O
Is Encased	O						O		O
Is Filled	O				O		O		
Fill Material	O						O		O
Conveyance Method	O	O							
Cross Section Configuration	O								
Number of Conduits	O								
Inside Height	O				O		O		
Inside Width	O				O		O		
Inside Length					O				
Outside Height	O	O		O	O		O		
Outside Width	O	O	O	O	O	O	O		
Outside Length		O	O	O	O	O			
Wall Thickness	O				O		O		

M = Minimum requirement
O = Optional
C = Conditional (applies if the geometry type used is a 3D object or if observed data are available)
Blank = Does not apply

Table 5. Feature Attribute Definitions

Attribute	Definition	Domain
ID	Alphanumeric utility feature identifier	
Owner	Name of the entity that owns the utility feature	
Operator	Name of the entity or entities that operate the utility feature	
Utility Type	Type of utility feature (see definitions of various utility types in Table 6)	Chemical Communication Compressed Air or Other Gas Disposal Electric Heating and Cooling Natural Gas Non-Potable Water Petroleum Reclaimed (or Recycled) Water Steam Storm Water Wastewater Water Joint Use Other Unknown
Device Type	Type of device	Air Eliminator Amplifier Anchor Anode Antenna Armor Attenuator Capacitor Cable Catch Basin Cathodic Test Station Clean Out Cap Conduit Cover Culvert Culvert End Curb Inlet Door Downspout Drain Drain Separator Drop Inlet Duct Duct Bank Fill Point Filter

Attribute	Definition	Domain
		Fire Connection Point Generator Glycol Recovery Pit Grate Grease Trap Grit Chamber Ground Ground Point Ground Rod Guy Anchor Guy Pole Guy Wire Hand Hole Head Bolt Outlet Headwall Hydrant Impedance Matching Point Inlet Intake Junction Box Lid Lift Station Light Lighting Circuit Point Lighting Service Point Line Line Clean Out Load Capacitor Load Coil Manhole Marker Sign Marker Post Media Converter Meter Motor Network Systems Site Neutralizer Oil Water Separator Outlet Paging Device Panel Pedestal Pig Launch Point Pipe End Pole Pre-Conditioned Air Unit Pressure Reducing Station Pull Box Pump Pump Booster Station Pump Ejector Station

Attribute	Definition	Domain
		Pump Station Pump Station Ejector Push Brace Radio Receptacle Rectifier Reducer Regulator Regulator Reducer Relay Repeater Reservoir RFID Marker Riser Sample Point Satellite Sensor Service Loop Service Point Solar Panel Speaker Splice Splice Box Splitter Sprinkler Stilling Basin Stormceptor Storm Filter Storm Gate Stub Out Switch Tank Tape Telephone Terminal Terminator Thrust Block Tower Transformer Treatment Unit Trench Tunnel Undefined Utility Point Vault Valve Valve Box Vent Wing wall Wire Other Unknown

Attribute	Definition	Domain
Conveyance Purpose	Primary purpose of service of the utility feature	Cathodic Protection Control Monitoring Cooling Data Transfer Distribution Fire Gathering Heating Irrigation Lighting Service Sign Illumination Trace Traffic Control Transmission Other Unknown
Intended Permanence	Intended longevity of the utility feature	Permanent Temporary
Buried Status	Indicator of whether the feature is partially or completely underground.	Completely Buried Partially Buried Aboveground
Operational Status	Operational status of the utility feature (see definition of various operational status options in Table 7).	Proposed In Service Out of Service Abandoned in Place Removed Unknown
Horizontal Spatial Reference	Coordinate system and datum associated with the X and Y coordinates	
Vertical Spatial Reference	Coordinate system and datum for the Z coordinate	
Accuracy Level	Numerical code describing the positional accuracy of points defining the utility feature, as described in Table 1.	
XYZ	X, Y, and Z coordinates representing the center of the utility feature for data exchange purposes. Depending on the implementation, the X, Y, and Z coordinates may be stored as separate fields in a table or as part of an array that contains spatial data in a single field. For non-linear structures, XYZ represents an anchor point used for 3D representations, which may or not coincide with the feature's centroid. In many cases, XYZ coincides with the observed location in the field (e.g., center of manhole lid). For proper orientation in a 3D space, the Azimuth attribute is also necessary.	

Attribute	Definition	Domain
Azimuth	Horizontal angle (measured clockwise) of the length dimension of a utility feature with respect to a north base line.	
XYZ Observed	X, Y, and Z coordinates of the utility feature as measured in the field. Depending on the implementation, the X, Y, and Z coordinates may be stored as separate fields in a table or as part of an array that contains spatial data in a single field.	
XY Relative Position	Relative position of XYZ Observed with respect to the horizontal alignment of the utility feature.	Left Edge Center Right Edge
Z Relative Position	Relative position of XYZ Observed with respect to the elevation of the utility feature.	Crown/Top Soffit Center Invert Bottom
XYZ Junction Point	X, Y, and Z coordinates of the junction point where two features connect (e.g., the point where a pipe into a manhole or vault, or the point where a manhole chimney connects to a vault).	
Quality Level	Quality level in accordance with ASCE/CI 38-02	A B C D
Linked File	Name of file or files that contain information about the utility feature. Examples of files include photographs, CAD files, sketches, video, permit files, agreement files, replacement cost estimates, and other supporting information. Depending on the implementation, the file names may be stored as separate field entries in a table or as part of an array that contains file names in a single field.	
Date Data Collected	Date when a utility feature was surveyed in the field.	
Data Sensitivity Level	Indicator of the sensitivity level of the data recorded for a utility feature. If the data are considered sensitive security information (SSI), the data must be labeled on any output produced and handled in accordance with 49 CFR 1520.	Unrestricted Restricted SSI
Is Certified	Indicator of whether the data have been certified	True False
Certification Summary	Name and credentials of the party that certified the data	
Material	Predominant material of which the utility feature is constructed. For features that	Acrylonitrile Butadiene Styrene Aluminum Asbestos Cement

Attribute	Definition	Domain
	transmit a signal or electrical power, material refers to the conductor material.	Asphalt Block Brick Canvas Clay Coaxial Cable Composite Concrete Corrugated Metal Corrugated Plastic Copper Ductile Iron Earthen Fiberglass Fiber Optic (or Optical Fiber) Galvanized Steel Geotextile Glass Gravel High Density Polyethylene (HDPE) Iron Multiple Nickel Other Pitch Fiber Plastic Polyethylene Polypropylene Polystyrene Polyvinyl Chloride (PVC) Reinforced Concrete Steel Stone Terracotta Tile Titanium Transite Twisted Pair Copper Wood Wrapped Steel
Is Cathodic Protected	Indicator of the presence of a cathodic protection	True False
Is Encased	Indicator of the presence of encasement to insulate or protect the utility feature	True False
Is Filled	Indicator of the presence of filling material inside the infrastructure feature	True False
Fill Material	Material used to fill the space between a utility feature and its encasement or an out-of-service feature.	Flowable Fill Foam Sand Styrofoam

Attribute	Definition	Domain
Conveyance Method	Method to move or convey matter through the utility feature	Gravity High Pressure Low Pressure Pressurized Other Unknown Not Applicable
Cross Section Configuration	Configuration of the cross section of the utility feature	Arch Box Cable Circular Pipe Duct Duct Bank Horizontal Ellipse Pear Trench Other
Number of Conduits	Number of conduits within a pipe or duct bank	
Inside Height	For circular shaped segments, inside diameter of the utility feature cross section. For non-circular shaped segments, maximum inside height of cross-sectional shape. For features other than segments, maximum inside height of feature.	
Inside Width	For circular shaped segments, not applicable. For non-circular shaped segments, maximum inside width of cross-sectional shape. For features other than segments, maximum inside width of feature.	
Inside Length	For segments, not applicable. For features other than segments, maximum inside length of feature (measured in the horizontal plane, perpendicular to the width).	
Outside Height	For circular shaped segments, outside diameter of the utility feature cross section. For non-circular shaped segments, maximum outside height of cross-sectional shape. For features other than segments, maximum outside height of feature.	
Outside Width	For circular shaped segments, not applicable. For non-circular shaped segments, maximum outside width of cross-sectional shape.	

Attribute	Definition	Domain
	For features other than segments, maximum outside width of feature.	
Outside Length	For segments, not applicable. For features other than segments, maximum outside length of feature (measured in the horizontal plane, perpendicular to the width).	
Wall Thickness	Maximum wall thickness.	

Table 6. Domain Definitions for Utility Type

Utility Type	Carries
Chemical	Chemical substances other than petroleum and natural gas.
Communication	Data, voice, and/or video signals. Depending on the carrier technology and other factors, a communication feature can include optical fiber, coaxial cable, or twisted pair copper.
Compressed Air or Other Gas	Compressed air or a gas other than natural gas.
Disposal	Disposal substances, typically in connection with the extraction of hydrocarbon products.
Electric	Electrical power.
Heating and Cooling	Fluids used to heat or cool buildings and other facilities.
Natural Gas	Flammable gas, mostly methane, that occurs naturally underground.
Non-Potable Water	Non-potable water. Non-potable water is water that has not been tested, treated, and approved for human consumption.
Petroleum	Raw or refined petroleum products in a liquid state.
Reclaimed (or Recycled) Water	Water that has been reclaimed or recycled and can be used for new, usually non-drinking, purposes.
Steam	Pressurized steam.
Storm Water	Storm water.
Wastewater	Water that has been used at homes, businesses, and industrial processes.
Water	Potable water.
Joint Use	More than one type of utility.

Table 7. Domain Definitions for Operational Status

Operational Status	Description
Proposed	Proposed utility feature that has not been built yet
In Service	Active, in-service utility feature (including short-term service interruptions for maintenance activities)
Out of Service	Temporary non-usage of a functioning utility feature in which property rights are maintained
Abandoned in-Place	Permanent non-usage (i.e., the utility feature will not be used again) in which property rights are relinquished but liabilities (e.g., environmental liabilities) are maintained
Removed	Physically removed from the field
Unknown	

Appendix B. Data Collection Intervals along Linear Features

This section provides guidance on factors to consider when assessing the interval between data collection observations along linear features. Data collection intervals along linear features depend on factors such as physical characteristics of the features and accuracy level requirements. Data collection methods might also vary depending on the specific application, e.g., exposed trench direct survey versus remote sensing data collection. Although the general principles described are generic and should be familiar to those in the engineering, utility investigation, and surveying fields, nothing described here replaces professional expertise and judgment.

Collecting data along linear features normally involves collecting data at specific locations. For traditional surveying methods, the spacing between points is relatively coarse. For remote sensing methods, the point density could be very high, but the resulting dataset is a collection of data points that define a linear feature. The alignment of a linear feature and required accuracy level control the data collection interval. Guidance for data collection intervals is discussed as follows:

- **Straight Alignments.** For straight alignments, data point spacing should be such that the positional error of any data point along the linear feature does not exceed the limits in Table 1.
- **Curved Alignments.** Figure 1 shows a curve linear feature. The curve could be horizontal, vertical, or a combination. In this situation, a line string (dashed line) passing through the collection of data points varies from the true alignment of the curve (solid line). For an accuracy level to apply to a linear feature, the positional error due to the chord offset (i.e., distance A in Figure 1) cannot exceed the limits in Table 1.
- **Deflections.** Figure 2 shows a diagram that illustrates the effects of curvature and deflection. Deflection may occur at any point horizontally or vertically. The offset error at point A is the error due to curvature as discussed in the previous section. Errors at points B and C are due to deflection. For an accuracy level to apply to a linear feature with deflection points, additional points must be collected at points B and C so that the offset errors are less than the limits in Table 1. Curves may be present concurrently in

any combination with points of deflection (horizontally or vertically), therefore, it is necessary to consider linear features in segments. For each segment, a point collection interval should produce a modeled feature whose position compared to the true position does not exceed the limits in Table 1 at any point along the segment.

- **Computed Splines or Curves.** It is increasingly common to use software functions to generate modeled splines or curves through a collection of points. In principle, similar positional error requirements as those for chords could apply. However, data exchange could be problematic if the parameters of the computed curve are not properly identified and documented. For this reason, it is generally preferable and simpler to use chords when assessing positional accuracy requirements along linear features.
- **Flexible Features.** Utility infrastructure, like other civil infrastructure, can shift over time. This effect can be particularly evident in the case of flexible materials. In some situations, it may not be possible to achieve the highest levels of positional accuracy described in Table 1.

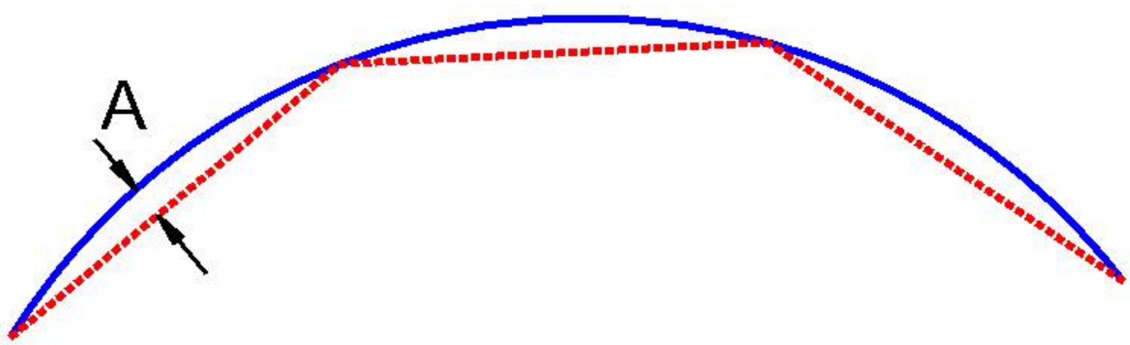

Figure 1. Offset Error of Chorded Line String

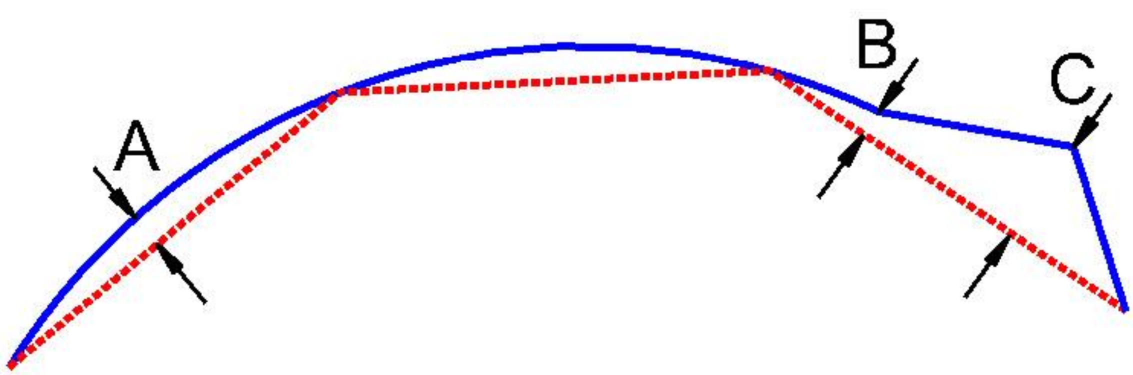

Figure 2. Offset Error Due to Deflection

The surveyor should assess potential error situations that can arise for any installation and increase the density of data collection observations to 1) provide adequate statistical accuracy and confidence for a least squares fit alignment or position depiction, and 2) minimize the risk of distorting the spatial representation of the utility facility. Survey observations should include:

- All deflection points (vertical and horizontal), as described above.
- All joints (noting that the collection point is at a joint and at maximum geometric deviations such as flairs for bell joints), and at locations where facilities join or diverge, such as at tees, Ys, splice joints, and valves.
- All non-segment features (see Table 2).
- Rigid feature segments (e.g., reinforced concrete pipe installed at fixed grades). A recommended practice is an observation interval of 20 feet.
- Flexible feature segments (e.g., direct bury fiber optic). A recommended practice is an observation interval of 10 feet.