United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

IRRIGATION PIPELINE

CODE 430

(ft)

DEFINITION

A pipeline and appurtenances installed to convey water for storage or application as part of an irrigation water system.

PURPOSE

This practice is used to accomplish one or more of the following purposes:

- Convey water from a supply source to an irrigation system, storage pond, or reservoir
- Reduce irrigation conveyance water losses by converting from open channel to pipeline
- Reduce energy use

CONDITIONS WHERE PRACTICE APPLIES

This standard applies to water conveyance and distribution pipelines installed above or below ground.

This standard does not apply to multiple-outlet irrigation system components (e.g., surface gated pipes, sprinkler lines, or microirrigation tubing). Use NRCS Conservation Practice Standards (CPSs) Irrigation System, Surface and Subsurface (Code 443), Sprinkler System (Code 442), and Irrigation System, Microirrigation (Code 441) for these components.

This practice does not apply to pipelines in systems for animal watering or waste transfer. Use NRCS CPS Livestock Pipeline (Code 516) to supply animal watering facilities. Use NRCS CPS Waste Transfer (Code 634) to transfer waste material.

CRITERIA

General Criteria Applicable to All Purposes

Ensure that the quantity and quality of the water supply is sufficient for the planned conservation practice(s) and the system(s) supplied by the pipeline.

Select pipeline materials suitable for the specific soils, topography, and environmental conditions.

Design the pipeline to meet all service requirements so that internal pressure at any point, including hydraulic transients or static pressure, is less than the pressure rating of the pipe.

Notify landowner and/or contractor of their responsibility to locate all buried utilities in the project area, including drainage tile and other structural measures. The landowner is also required to obtain all necessary permits for project installation prior to construction.

Capacity
Design sufficient pipeline capacity to convey the design flow rate for the planned conservation practices. Include reasonable water losses during application or use of the water in the design capacity.

Friction and other losses
For design purposes, compute head loss for hydraulic grade line computations using one of the following equations: Manning's, Hazen-Williams, or Darcy-Weisbach. Base the equation selection on the given flow conditions and the pipe materials used. Evaluate and include other head losses (called minor or local losses) from a change in velocity and direction of flow due to inlet type, valves, bends, enlargements, or contractions . For pressurized systems, maintain the hydraulic grade line for all pipelines above the top of the pipeline at all locations for all flows unless specifically designed for negative internal pressures.

Flexible conduit design
Design flexible conduits, such as plastic pipe, steel pipe, aluminum pipe, corrugated metal pipe, or ductile iron pipe, using NRCS National Engineering Handbook (NEH) (Title 210), Part 636, Chapter 52, "Structural Design of Flexible Conduits," and the criteria below.

Plastic pipe (smooth, currugated, or profile wall)
When operating at design capacity, do not exceed 5-feet-per-second velocity in the full-pipe flow in pipelines with valves or some other flow control appurtenance placed within the pipeline or at the downstream end. As a safety factor against surge, keep the working pressure at any point at or below 72 percent of the pressure rating of the pipe. If either of these limits is exceeded, provide measures to adequately protect the pipeline against transient pressures.

Smooth wall steel pipe
Determine the specified maximum allowable pressure using the hoop stress formula, limiting the allowable tensile stress to 50 percent of the yield-point stress for the material selected. Design stresses for commonly used steel pipe are shown in 210-NEH-636-52.

Corrugated metal pipe
Keep maximum allowable pressure for the pipe at—

- Twenty feet of head for annular and helical pipe with sealed seams and watertight coupling bands.
- Thirty feet of head for helical pipe with welded seams, annular ends, and watertight couplings.

Smooth wall aluminum pipe
Determine the maximum allowable pressure of the pipe using the hoop stress formula, limiting the allowed tensile stress to 7,500 pounds per square inch (psi).

Rigid conduit design
Design rigid conduits, such as concrete pipe or plastic mortar pipe, using the criteria below.

Nonreinforced concrete pipe with mortar joints
Keep the maximum allowable pressure at or below one-fourth of the certified hydrostatic test pressure as determined by the test procedure described in ASTM C118-15, "Standard Specification for Concrete Pipe for Irrigation or Drainage." Also, keep the maximum allowable pressure at or below the amounts indicated in table 1.

Table 1: Maximum Allowable Pressure for Nonreinforced Concrete Pipe with Mortar Joints

Diameter (inches)	Maximum Allowable Pressure (feet)
6 through 8	40
10 and greater	35

Nonreinforced concrete pipe with rubber gasket joints
Keep the maximum allowable pressure at or below one-third the certified hydrostatic test pressure as determined by the test procedure described in ASTM C505, "Standard Specification for Nonreinforced

Concrete Irrigation Pipe with Rubber Gasket Joints." Also, keep the maximum allowable pressure at or below the amounts indicated in table 2.

Table 2: Maximum Allowable Pressure for Nonreinforced Concrete Pipe with Rubber Gasket Joints

Diameter (inches)	Maximum Allowable Pressure (feet)
6 through 12	50
15 through 18	40
21 and greater	30

Cast-in-place concrete pipe
Limit the maximum working pressure to 15 feet above the centerline of the pipe. Use cast-in-place concrete pipe only in stable soils that are capable of being used as the outside form for approximately the bottom half of the conduit.

Reinforced concrete pipe with gasket joints
Limit the maximum allowable pressure at or belowthe rated hydrostatic pressure for the specified pipe according to appropriate ASTM or American Water Works Association (AWWA) standards.

Reinforced plastic mortar pipe
Design the pipeline to meet all service requirements without a static or working pressure at any point greater than the maximum allowable working pressure of the pipe used. Include freeboard in the static or working pressure of pipelines open to the atmosphere. Use 50 psi as the minimum acceptable pipe pressure rating.

Support of pipe
Provide support against external and internal forces for both above and below ground pipelines where needed. Design the pipe support using 210-NEH-636-52.

Joints and connections
Design and construct all connections to withstand the pipeline working pressure without leakage and leave the inside of the pipeline free of any obstructions that would reduce capacity.

Use the permissible joint deflection from the manufacturer for the joint type and pipe material used.

For sloping steel pipe, place expansion joints adjacent to and downhill from anchors or thrust blocks.

For welded pipe joints, install expansion joints, as needed, to limit pipeline stresses to the allowable values.

For suspended pipelines, design pipe loading using 210-NEH-636-52. Include the effects of water in the pipe, wind, ice, thermal expansion and contraction, and the joints and fittings in the suspended pipeline design.

Use similar materials, whenever possible, for joints and connections for metal pipes. If dissimilar materials are used, protect the joints or connections against galvanic corrosion.

Depth of cover
Install buried pipe at sufficient depth below the ground surface to provide protection from hazards imposed by traffic loads, farming operations, freezing temperatures, or soil cracking.

Ensure pipelines have sufficient strength to withstand all external loads on the pipe for the given installation conditions. Use appropriate live loads for the anticipated traffic conditions. Refer to 210-NEH-636-52, for procedures to analyze external loads on buried pipe.

Where it is not possible to achieve sufficient cover or sufficient strength, use a carrier (encasement) pipe or other mechanical measures to protect the pipe.

Pressure reduction
Incorporate pressure reduction in circumstances such as head gain exceeding pressure loss by a significant amount, excessive line pressures for the type of irrigation system, or excessive static pressures.

Inlets
Design inlets with adequate size for the type of entrance condition to ensure design flow capacity without excessive head losses.

Provide measures to prevent the inflow of trash or other materials into the pipeline if these materials would be detrimental to the pipe capacity or performance of the system supplied by the pipeline.

For gravity flow inlets with square-edged or gated orifices, vent the nappe created by the inflow at the orifice entrance.

Water control structures, stands, Z-pipes, and doglegs are all acceptable inlet devices. When using these inlets, ensure the removal of entrained air.

Check valves and backflow prevention
Install a check valve between the pump discharge and the pipeline if detrimental backflow may occur. Check valves can cause extreme internal pressures due to water hammer if they close too fast as flow reversal occurs. “Non-slam” type check valves or solenoid-operated valves may be required.

Use approved backflow prevention devices (such as a chemigation check valve) on all pipelines in which fertilizer, pesticides, acids, or other chemicals are added to the water supply.

Valves and other appurtenances
Ensure the pressure ratings of valves and other appurtenances equals or exceeds the pipeline working pressure. When lever-operated valves are used, perform an analysis to evaluate the potential for surge/water hammer assuming an instantaneous valve closure.

Stands open to the atmosphere
Stands open to the atmosphere are used when water enters the pipeline to avoid entrapment of air, to prevent surge pressures and collapse because of vacuum failure, and to prevent pressure from exceeding the design working stress of the pipe. Design the stand to—

- Allow a minimum of 1 foot of freeboard. The maximum height of the stand above the centerline of the mainline pipeline must not exceed the maximum working head of the pipe.
- Have the top of each stand at least 4 feet above the ground surface except for surface gravity inlets or where visibility is not an issue. Equip gravity inlets and stands with trash racks and covers.
- Limit the downward water velocity in the stand to no more than 2 feet per second. Ensure that the inside diameter of the stand is not less than the inside diameter of the pipeline

The cross sectional area of a stand open to the atmosphere may be reduced no less than 1 foot above the top of the upper inlet. If a reduced section is used, design it to allow discharge of the design flow at no more than 10 feet per second.

If the water velocity of an inlet pipe exceeds three times the velocity of the outlet, ensure that the centerline of the inlet has a minimum vertical offset from the centerline of the outlet at least equal to the sum of the diameters of the inlet and outlet pipes.

Construct stands of steel pipe or other approved material. Design the stand base to bear the weight of the stand when full and to prevent movement or undue stress on the pipeline.

Ensure that sand traps, when combined with a stand, have a minimum inside dimension of 30 inches and are constructed so the bottom is at least 24 inches below the invert of the outlet pipeline. Ensure that the downward velocity of flow of the water in a sand trap does not exceed 0.25 feet per second. Make suitable provisions for cleaning sand traps.

Design gate stands so that their dimensions are adequate to accommodate the required gates. Ensure that gate stands allow adequate access for gate repair.

Design float stands so that they are large enough to provide accessibility for maintenance.

Construct stands so that vibration from the pump discharge pipe does not transfer to the stand.

Pressure-relief (PR) valves are used as an alternative to stands open to the atmosphere. Ensure that all PR valves serve the PR function of the open stand or vent for which it is an alternative.

Stands closed to the atmosphere
If PR valves and air-and-vacuum (AVR) valves are used instead of open stands, all requirements detailed in the section above, “Stands open to the atmosphere” apply except as modified below.

Ensure that the inside diameter of the closed stand is equal to or greater than that of the pipeline for at least 1 foot above the top of the uppermost inlet of outlet pipe. To facilitate attaching the PR valve and the air-and-vacuum valve, the stand can be capped at this point. If additional height is required, the stand can be extended to the desired elevation by using the same inside diameter or a reduced cross section. If a reduced section is used, ensure that the cross-sectional area is such that it would produce an average velocity of no more than 10 feet per second if the entire flow were discharged through it. If no vertical offset is required between the pump discharge pipe and the outlet pipeline and the discharge pipe is “dog-legged” below ground, extend the stand at least 1 foot above the highest part of the pump discharge pipe.

Use either of the following two alternative designs for stands requiring no vertical inlet offset (when inlet velocity is less than three times that of the discharge pipeline):

- Construct the dogleg section of the pump discharge pipe with the same nominal pipe diameter as that of the pipeline.
- Install the PR valve and the air-and-vacuum valve on top of the upper horizontal section of the dogleg.

Install PR and air-and-vacuum valves on stands with the nominal size pipe required to fit the valves’ threaded inlets.

Surge tanks and air chambers
If surge tanks and/or air chambers are required for control of hydraulic transients or water column separation, ensure that their size meets the water volume needs of the pipeline without the tank/chamber being emptied, and that the required flow into the pipeline for the calculated pressure drop is met.

Pressure-relief valves
Install a PR valve between the pump discharge and the pipeline if excessive pressure can build up when all valves are closed. If needed to protect the pipeline against pressure reducing valve malfunction or failure, install PR valves downstream of pressure-reducing valves.

Manufacturers of PR valves marketed for use under this standard must provide capacity tables that give the discharge capacities of the valves at the maximum permissible pressure and differential pressure settings. These tables must be based on performance tests, and must be the basis for acceptance of these valves and selection of the design pressure setting.

Set PR valves to open at a pressure as low as practical, but no greater than 5 psi above the pressure rating or maximum allowable pressure of the pipe. Ensure that the valves have sufficient flow capacity to reduce the excessive pressures in the pipeline.

Indicate or mark the pressure at which the valves start to open on each PR valve. Seal or otherwise alter adjustable PR valves to prevent changing the adjustment from that marked on the valve.

Air-release valves

Five types of air vents/valves commonly used on irrigation pipelines are continuous-acting air-release valves (CAV), vacuum-relief valves (VR), air-release and vacuum-relief valves (AVR), combination air valves (COMB), and open vents. Open vents are described in the section “Vents” below.

Where the accumulation of air occurs during operation, use a CAV at the appropriate location to release air from the filled pipeline while under pressure. Normal orifice venting diameter is 1/16 to 3/8 inch.

Use VR valves for relief of vacuum pressures (i.e., negative pressures) due to sudden gate or valve closure, pump shutoff, or drainage of the pipeline.

AVR valves can be used for the same requirements described for VR valves. Use AVR valves to release air from the pipeline on filling prior to the pipe being pressurized. Use AVR valves to alleviate flow restrictions, air locks, and water surging due to the presence of air within pipelines. Include air valves at all high points along the pipeline. Install an air valve at least every 2,500 feet on horizontal runs.

COMB valves have the combined function of all three valves (CAV, VR, and AVR) in one body. COMB valves can be used for any of the conditions in which a CAV, VR, or AVR is required.

If needed to provide positive means for air escape during filling and air entry while emptying, install an AVR, VR, or COMB valve at all summits, upstream and downstream of all in-line valves as needed, at the entrance, and at the end(s) of the pipelines. Such valves are needed at these locations if the pipeline is closed to the atmosphere. However, they are not needed if other features of the pipe system, such as permanently located sprinkler nozzles or other unclosed service outlets, adequately vent the particular location during filling and emptying operations. Analyze the use of these system features for airflow rate and the proper use of such features described in the operation and maintenance (O&M) plan. High points in the pipeline require a CAV unless an outlet is located at that point.

In addition to the locations described above, place an AVR or COMB valve at changes of grade in downward direction of flow in excess of 10 degrees to ensure adequate air release during filling. On long pipelines (i.e., over 2,500 feet), additional AVR or COMB valves may be required to vent the pipe during filling.

For air release, size the AVR or COMB valve to exhaust air from the pipeline at the rate needed to prevent operational problems with the pipeline, while maintaining the proper operation of the valve. For design purposes, limit the exhaust pressure differential to 2 psi.

For vacuum relief, size the AVR, VR, or COMB valves for air entry into the pipeline, ensuring the pipeline does not collapse due to vacuum created during drainage of the pipeline. For design purposes, limit the vacuum pressure differential to 5 psi.

If the required vacuum relief orifice diameter is significantly larger than the required air release orifice diameter, separate valves may be required to help eliminate excessive water hammer caused when the air is released too fast from the pipeline.

Use CAV or COMB valves as needed to permit air to escape while the line is at working pressure. Size small orifices of these valve types according to the design working pressure and venting requirements recommended by the valve manufacturer.

Ensure that the location of the CAV or COMB valves is a sufficient distance downstream from the introduction of air into the system (under pressure conditions) to allow the air to be collected at the top of the pipe. Under some circumstances (e.g., pumped system with low pressure or velocity) consideration should be given to installing vent chambers for CAV or COMB valves. Construct the vent chamber according to the requirements under the second criteria in the section “Vents” below.

In lieu of a detailed design, for the corresponding pipe material below, use the following air valve sizes:

- For plastic ≤ 50 psi - 0.22 x pipe diameter
- For plastic > 50 psi - 0.10 x pipe diameter
- For metal - 0.125 x pipe diameter
- For concrete - 0.125 x pipe diameter

Document that the manufacturers of air valves marketed for use under this standard provide dimensional data or a capacity table based on performance tests, and use these data for the selection and acceptance of these valves.

Vents
Vents that are open to the atmosphere provide for the removal and entry of air and protection from surge. Use the following design criteria:

- Ensure that vents have a minimum freeboard of 1 foot above the hydraulic grade line at design capacity. The maximum height of the vent above the centerline of the pipeline must not exceed the maximum allowable working pressure of the pipe.
- Construct a vent chamber to intercept and/or capture air within the pipeline. Ensure that the chamber intercepts the circumference arc of 75 degrees at the top of the pipe (i.e., a vent chamber diameter of two-thirds the diameter of the pipeline). Extend the chamber vertically at least one pipeline diameter up from the centerline of the pipeline. Above this elevation, the vent chamber can be reduced to a minimum diameter of 2 inches.
- When an AVR or COMB valve is used instead of a vent, use the above requirements. In addition, size the reduced section to meet the nominal pipe size required to fit the valve's threaded inlet. An acceptable alternative is to install the valve(s) in the side of a service outlet, provided that the service outlet riser is properly located and adequately sized. If both AVR and PR valves are required at the location, apply the 10-feet-per-second velocity criterion given under the section above, "Stands open to the atmosphere," to the reduced section.
- Install vent chambers on all open vents and closed vents with air valves when the normal operating pressure of the pipe is 10 psi or less.
- Place a vent at the downstream end of laterals, at summits in the line, and at points where the grade changes more than 10 degrees in a downward direction of flow.

Outlets
Appurtenances that deliver water from the pipe system to the field, ditch, reservoir, or surface pipe system are known as outlets. Ensure that the outlets have adequate capacity to deliver the required flow to—

- The hydraulic grade line of a pipe or ditch,
- A point at least 6 inches above the field surface,
- The design surface elevation in a reservoir, or
- An individual sprinkler, lateral line, hydrant, or other device at the required operating pressure.

Design outlets to minimize erosion, physical damage, or deterioration due to exposure.

Filling
Ensure that the pipe system has a means of controlling the filling of the pipeline to prevent entrapped air and excessive transient pressures.

Filling velocities greater than 1 foot per second in a closed to the atmosphere pipe system (i.e., all outlets closed) requires special evaluation and provisions to remove entrapped air and prevent transient pressures.

If filling the pipeline at a low flow rate is not possible, design the system for air removal and mitigate transient pressures at the higher filling rates.

Flushing
If the sediment load in the water is significant, design the pipeline to provide adequate velocity to move sediment through and be flushed out of the pipeline.

If provisions are needed for flushing sediment or other foreign material, install a suitable valve at the distant end or low point of the pipeline.

Draining
Make provisions for the complete removal of water from the pipeline by gravity or other means when—

- Freezing temperatures are a hazard.
- The pipe manufacturer requires draining.
- Draining the pipeline is recommended.

Ensure that the water drained from pipelines does not cause water quality, soil erosion, or safety problems upon release.

Safe discharge of water
Make provisions for water discharged from valves, especially air valves and PR valves. Place these valves so that flows from the valves are directed away from system operators, livestock, electrical equipment, and other control valves or hook-ups.

Thrust control
Abrupt changes in pipeline grade, horizontal alignment, tees, or reduction in pipe size, normally require an anchor or thrust blocks to absorb pipeline axial thrust. Thrust control is typically needed at the end of the pipeline and at in-line control valves.

Follow the pipe manufacturer’s recommendations for thrust control. In absence of manufacturer’s data, design thrust blocks using 210-NEH-636-52.

Longitudinal bending
For plastic pipe, base the allowable longitudinal bending for the pipeline on the material type and the pressure rating. Ensure that the longitudinal bending is in accordance with industry standards or as described in 210-NEH-636-52.

Thermal effects
For plastic pipe, thermal effects must be properly factored into system design. Pressure ratings for pipes are normally based on a pipe temperature of 73.4 ºF. Reduce the effective pressure rating by an appropriate amount when the operating temperature is higher than 73.4 ºF.

Ensure that values and procedures for pressure rating reduction follow information described in the 210-NEH-636-52.

Physical protection
Ensure that steel pipe installed above ground is either galvanized or protected with a suitable protective paint coating, including a primer coat and a minimum of two final coats.

Ensure that plastic pipe installed above ground is resistant to ultraviolet light throughout the intended life of the pipe or measures taken to protect the pipe from damage due to ultraviolet light.

Protect all pipes from hazards presented by traffic loads, farm operations, freezing temperatures, fire, thermal expansion and contraction. Take reasonable measures to protect the pipe from potential vandalism.

Corrosion protection
Ensure that all metal to metal fittings, such as risers, bends, tees, and reducers, are of similar metals. If dissimilar metals are used, protect the fittings against galvanic corrosion (e.g., separate dissimilar metals with rubber or plastic insulator).

Galvanize bolts used to join galvanized steel, plastic coated, stainless steel, or otherwise protected to prevent galvanic corrosion. Bolts used to join aluminum, other than aluminum alloy bolts, must be plastic coated or otherwise protected to prevent galvanic corrosion.

Provide interior protective coatings when the pH of the water falls outside the ranges shown in table 3.

Table 3: Ranges in Water pH Values Used to Determine the Need for Interior Protective Coatings

Material	Water pH
Aluminized steel	Less than 5 or greater than 9
Galvanized steel	Less than 6 or greater than 10
Aluminum alloy	Less than 4 or greater than 10

Unlined steel pipelines can experience corrosion from very pure water (e.g., snowmelt). Provide corrosion protection if the Langelier Saturation Index is less than -1.

Galvanized steel pipe can be used when the soil resistivity is greater than 4000 ohms-centimeter (ohm-cm).

Use hot-dipped asphalt or polymeric-coated galvanized steel pipe if the soil resistivity along any part of the pipeline is between 3000 and 4000 ohm-cm. In addition to the above coatings, provide cathodic protection for galvanized steel pipe if the soil resistivity is less than 3000 ohm-cm.

Aluminized steel pipe can be used when the soil resistivity is greater than 1500 ohm-cm and the soil pH is between five and nine.

Aluminum alloy pipe can be used when the soil resistivity is greater than 500 ohm-cm and the soil pH is between four and ten.

When cathodic protection is required, electrically bridge joints and connecting bands to ensure continuous flow of current. Place a dielectric connection between the pump and the pipeline and between pipes with different coatings.

Design the total current required, kind and number of anodes needed, and life expectancy for the cathodic protection in accordance with NRCS Technical Note (Title 210), Design Engineering, Design Note 12, “Control of Underground Corrosion.”

Resistivity measurement requirements for metal pipe
If risk of corrosion is “high” based on the Cooperative Soil Survey’s Soil Features Report, conduct soil-resistivity measurements to determine corrosion protection requirements. For this purpose, make field resistivity measurements or take samples for laboratory analysis at least every 400 feet along the proposed pipeline route and at points where a visible change in soil characteristics occurs. If adjacent readings differ markedly, take additional measurements to locate the point of change. Make resistivity determinations at two or more depths in the soil profile at each sampling station, with the lowest depth at the stratum in which the pipe will be laid. Use the lowest value of soil resistivity found at each sampling station as the design value for that station.

After excavation of the pipe trench, make a detailed soil resistivity survey as a verification of the final required cathodic protection. At this time, make resistivity measurements in each exposed soil horizon at intervals not exceeding 200 feet. Use the lowest value of soil resistivity found at each sampling station as the design value for that station. If design values for adjacent stations differ significantly, make additional intermediate measurements.

Electric fields
An electric field can develop where a metal pipeline is installed adjacent to an existing metal pipeline. This situation can adversely affect the new pipeline. Protect the new pipeline from this condition.

Environmental constraints for aluminum
Evaluate water quality for aluminum pipeline installations. A copper content in excess of 0.02 parts per million produces nodular pitting and rapid deterioration of the pipe if water is allowed to become stagnant. When the copper content exceeds this limit, design the pipeline to allow draining after each use, or avoid the use of aluminum pipe.

Provide protection from corrosion for aluminum pipe installed in contact with concrete.

Environmental constraints for concrete
Do not install concrete pipelines on sites where the sulfate concentration in the soil or soil water exceeds 1.0 percent. On sites where the sulfate concentration is more than 0.1 percent but not more than 1.0 percent, concrete pipe can be used only if the pipe is made with Type V or Type II cement, with tricalcium aluminate content not exceeding 5.5 percent.

Additional Criteria for Reducing Energy Use

Provide analysis to demonstrate reduction of energy use from practice implementation.

Calculate the reduction of energy use by comparing the planned average annual or seasonal energy use to previous operating conditions.

CONSIDERATIONS

Additional Considerations for Safety

Pipelines may present a threat to the safety of people during both installation and operation. Consider safety as follows:

- Address trench safety in design and during construction.
- Provide protection for people from inlets of pipelines and open stands.
- Provide protection for people from water blowing from PR, air-release, and other valves.
- Determine the existence or nonexistence of underground utilities prior to construction.
- Install a locate wire or safety tape above a buried pipe for future reference. Survey with GPS to mark grade and alignment changes.

Additional Considerations for Economics

Economics can be a major factor in pipeline design, as follows:

- Select pipe based on lifetime energy requirements, as well as initial costs of materials.
- Select pipe material based upon expected life of practice.
- Consider hydropower applications as alternatives to use of pressure reduction valves or reduced pipe diameter to induce friction loss.

Additional Considerations for Water Quality and Quantity

Consider the effects of an irrigation pipeline on water quality and quantity when designing an irrigation pipeline. Consider the effects—

- On the water budget, especially on infiltration and evaporation.
- On downstream flows or aquifers that would affect other water uses or users.
- On potential use for irrigation management.
- Of installing a pipeline on vegetation that may have been located next to the original conveyance.

- Of installing the pipeline (replacing other types of conveyance) on channel erosion or the movement of sediment and soluble and sediment-attached substances carried by water.
- On the movement of dissolved substances into the soil and on percolation below the root zone or to ground water recharge.
- Of controlled water delivery on the temperatures of water resources that could cause undesirable effects on aquatic and wildlife communities.
- On wetlands or water-related wildlife habitats.
- On the visual quality of water resources.

Additional Considerations for the Environment

Base pipe material selection on exposure considerations (such as soil resistivity, pH, sunlight, and traffic). Soil texture, resistivity, pH, moisture content, redox potential, and depth are important soil properties to be aware of for pipelines and in reducing soil limitations related to corrosivity or packing of soil material. Refer to soil survey information of the area, and onsite soil investigations should be considered during planning.

The Langelier Saturation Index and related indices may be a factor in determining type of material to use for a pipeline.

Pipelines installed below the ground surface should have a soil plan describing soil reconstruction of disturbed soil during and after pipeline installation so original soil productivity is restored after pipeline installation. Appropriate vegetation should be established to stabilize disturbed areas that will not be cropped.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for irrigation pipelines that describe the requirements for applying the practice according to this standard. Include, at a minimum, in the plans and specifications—

- A plan view of the layout of the pipeline.
- Profile of the irrigation pipeline if not parallel to the ground surface with a uniform minimum depth of cover.
- Pipe material and sizes.
- Pipe joint requirements.
- Site-specific construction specifications that describe in writing the installation of the irrigation pipeline. Include the specification for leak testing of the irrigation pipeline.
- Depth of bedding, embedment, and backfill requirements.
- Thrust block design.
- Location and sizing of—
    - PR valves.
    - Continuous-acting air-release valves.
    - Vacuum-relief valves.
    - Air-release/vacuum-relief valves.
    - Combination air valves.
    - Open vents.
- Disposal requirements for excess soil material.
- Vegetative establishment requirements.
- Location of utilities and notification requirements.

OPERATION AND MAINTENANCE

Develop an O&M plan for each pipeline system installed. Ensure that the plan describes the required actions so that the pipeline system performs adequately throughout its expected life.

Include procedures for—

- Draining the pipeline.
- Marking crossing locations.
- Valve operation to prevent pipe or appurtenant damage.
- Appurtenance or pipe maintenance.
- Recommended operating procedures, as needed within the O&M plan.

Include the procedure to monitor any cathodic protection systems.

Describe the filling procedure, which details allowable flow rates and appurtenance operation at the various phases of the filling process, to ensure safe filling of the pipeline. Use flow measuring appurtenances such as flow meters or weirs, or other means (e.g., number of turns of a gate valve) to determine the rate of flow into the pipeline system. Provide this information to the operator, and incorporate it in the O&M plan as appropriate.

REFERENCES

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