SUBSURFACE DRAIN

(Feet)
Code 606

Natural Resources Conservation Service
Conservation Practice Standard

I. Definition

A conduit, such as corrugated plastic tubing, tile, or pipe, installed beneath the ground surface to collect and/or convey drainage water.

II. Purpose

The purpose of subsurface drainage is to:

A. Improve the soil environment for vegetative growth, reduce erosion, and improve water quality by:

- regulating water table and ground water flows,
- intercepting and preventing water movement into a wet area,
- relieving artesian pressures,
- removing surface runoff,
- leaching of saline and sodic soils,
- serving as an outlet for other subsurface drains, and
- regulating subirrigated areas or waste disposal areas.

B. Collect ground water for beneficial uses.

C. Remove water from heavy use areas, such as around buildings, roads, and play areas; and accomplish other physical improvements related to water removal.

D. Regulate water to control health hazards caused by pests such as live fluke, flies, or mosquitoes.

III. Conditions Where Practice Applies

This practice applies to areas having a high water table where the benefits of lowering the water table or controlling ground water or surface runoff justify installing such a system.

This practice also applies to areas suitable for the intended use after installation of required drainage and other conservation practices. The soil shall have enough depth and permeability to permit installation of an effective and economically feasible system. The ability to drain and treat saline and sodic soils shall be considered where this is a problem.

This practice also applies in areas where an outlet is available, either by gravity flow or by pumping, the outlet shall be adequate for the quantity and quality of effluent to be discharged.

IV. Federal, State, and Local Laws

Users of this standard should be aware of potentially applicable federal, state and local laws, rules, regulations or permit requirements governing subsurface drains. This standard does not contain the text of federal, state, or local laws.

V. Criteria

The following criteria apply to all purposes.

A. Capacity

The required capacity shall be determined by one or more of the following:

1. Application of a locally tried and proven drainage coefficient to the acreage drained, including added capacity required to dispose of surface water entering through inlets. The minimum coefficients are shown in Tables 1 and 2.

2. Yield of ground water based on the expected deep percolation of irrigation water from the overlying fields, including the leaching requirement.

3. Comparison of the site with other similar sites where subsurface drain yields have been measured.

4. Measurement of the rate of subsurface flow at the site during a period of adverse weather and ground water conditions.

5. Application of Darcy's law to lateral or artesian subsurface flow.

6. Estimates of lateral or artesian subsurface flow.

Table 1
Drainage Coefficients
(No Open Inlets)

Soil	Field Crops (inches)	Truck Crops (inches)
Mineral	⅜ to ½	½ to ¾
Organic	½ to ¾	¾ to 1½

The condition in Table 1 assumes that surface drainage is adequate. The selected drainage coefficient applies to the entire area being drained.

Table 2
Drainage Coefficients
(Surface Inlets in Subsurface Drains)

Soil	Field Crops		Truck Crops	
	Blind Inlets (inches)	Open Inlets (inches)	Blind Inlets (inches	Open Inlets (inches)
Mineral	½ to ¾	½ to 1	¾ to 1	1 to 1½
Organic	½ to 1	½ to 1½	¾ to 2	2 to 4

Note: A ½-inch coefficient may be used if the organic soil occurs only as a small pocket in the vicinity of the inlet.

The selected drainage coefficient from Table 2 will apply to the entire watershed contributing runoff to the surface inlet, except where only a small amount of runoff will be impounded at the location of the inlet with the remainder flowing away in a confined channel. For the latter case, the drain (tile) shall be large enough to remove the impounded water in 24 hours, plus providing additional capacity for the required internal drainage. Blind inlets should only be used in areas where surface drainage will handle most of the surface water.

B. Size

The size of subsurface drains shall be computed by applying Manning's formula. The size shall be based on the required capacity and computed by using one of the following assumptions:

1. The hydraulic gradeline is parallel to the bottom grade of the subsurface drain with the conduit flowing full at design flow.

2. The conduit flowing partly full where a steep grade or other conditions require excess capacity.

3. The conduit flowing under pressure with hydraulic gradeline set by site conditions on a grade that differs from that of the subsurface drain. This procedure shall be used only if surface water inlets or nearness of the conduit to outlets with fixed water elevations permit satisfactory estimates of hydraulic pressure and flows under design conditions.

For assumptions 1 or 2 above, the minimum size of subsurface drains may be determined using the drainage charts in the NRCS National Engineering Handbook (NEH) Part 650, Engineering Field Handbook, Chapter 14.

All subsurface drains shall have a nominal diameter that equals or exceeds 4 inches.

C. Depth, Spacing, and Location

The depth, spacing, and location of the subsurface drain shall be based on site conditions, including soils, topography, ground water conditions, crops, land use, outlets, and saline or sodic conditions.

The minimum depth of cover over subsurface drains in mineral soils shall be 2 feet. This minimum depth shall apply to normal field levels and may exclude sections of line near the outlet or sections laid through minor depressions where the conduit is not subject to damage by frost action or equipment travel.

The minimum depth of cover in organic soils shall be 2.5 feet for normal field levels, as defined above, after initial subsidence. Structural measures shall be installed if it is feasible to control the water table level in organic soils within the optimum range of depths.

Continuous pipe shall be used where it is not feasible to obtain cover as specified, such as where drain lines cross waterways, or roads, the

outlet end of mains, or near structures. The continuous pipe shall be of sufficient strength and durability to withstand expected loadings and weathering.

The depth of laterals to intercept hillside seepage will vary according to the depth of the impervious layer. The drain line must be placed so that it intercepts the seepage flow.

The maximum depth of cover for standard duty corrugated plastic tubing shall be 10 feet for trench widths of 2 feet or less (measured at tubing and to 1 foot above top of tubing). Heavy-duty tubing shall be specified for depths greater than 10 feet, trench widths more than 2 feet, or in rocky soils.

For computation of maximum allowable loads on subsurface drains, use the trench and bedding conditions specified and the crushing strength of the kind and class of drain. The design load on the conduit shall be based on a combination of equipment loads and trench loads. Equipment loads are based on the maximum expected wheel loads for the equipment to be used, the minimum height of cover over the conduit, and the trench width. Equipment loads on the conduit may be neglected when the depth of cover exceeds 6 feet. Trench loads are based on the type of backfill over the conduit, the width of the trench, and the unit weight of the backfill material. A safety factor of not less than 1.5 shall be used in computing the maximum allowable depth of cover for a particular type of conduit.

D. Minimum Velocity and Grade

In areas where sedimentation is not a hazard, the minimum grades shall be based on site conditions and a velocity of not less than 0.5 feet per second. If a hazard exists, a velocity of not less than 1.4 feet per second shall be used to establish the minimum grades if site conditions permit. Otherwise, provisions shall be made for preventing sedimentation by use of filters or by collecting and periodically removing sediment from installed traps, or by periodically cleaning the lines with high-pressure jetting systems or cleaning solutions.

E. Maximum Velocity

Excessive flow velocity in the drain may induce piping of soil material into the drain line. The maximum permissible flow velocities shall be as given in Table 3.

F. Maximum Grade and Protection

On sites where topographic conditions require that drain lines be placed on steep grades and design velocities will be greater than indicated in Table 3 under "Drains Without Protection," special measures shall be used to protect the conduit or surrounding soil. These measures shall be specified for each job according to the particular conditions of the job site. The protective measure shall include one or more of the following:

1. Enclose continuous perforated pipe or tubing with fabric-type filter material or properly graded sand and gravel.

2. Use nonperforated continuous tubing, a watertight pipe, or seal the joints.

3. Place the conduit in a sand and gravel envelope or blinding with the least erodible soil available.

4. Select rigid butt end pipe or tile with straight, smooth sections and square ends to obtain tight fitting joints.

5. Wrap open joints of the pipe or tile with tar impregnated paper, burlap, or special fabric-type filter material.

6. Install open air risers for air release or entry.

Table 3
Maximum Velocities in Feet Per Second

Soil Texture*	Drains Without Protection	Drain Tile with Tamped Clay Joints, Graded Gravel Filter, or Filter Fabric	Continuous Pipe or Sewer Pipe with Sealed Joints (Unperforated)
Sand/loamy sand/fine sandy loam/loamy coarse sand/loamy very fine sand/fine sand/very fine sand/muck (sapric)/coarse loam/sandy loam	3.5	5.0	no limit
Silt/silt loam/mucky peat (hemic)/very fine sandy loam	5.0	6.0	no limit
Loam/silty clay/silty clay loam/sandy clay/sandy clay loam	6.0	7.0	no limit
Clay/clay loam/peat (fibric)	7.0	9.0	no limit
Coarse sand or gravel	9.0	10.0	no limit

*Where a soil horizon includes more than one texture, the most restrictive texture will be used.

G. Iron Ochre Protection

If drains are to installed in sites where iron ochre problems are likely to occur, provisions should be made to provide access for cleaning the lines. Each drain line should outlet directly into an open ditch and/or should have entry ports as needed to provide access for cleaning equipment. Drain cleaning provisions should be installed in such a way that the drains can be cleaned in an upstream or rising grade direction. If possible, drains in ochre-prone areas should be installed during the dry season when the water table is low and the iron is in its insoluble form.

Where possible, in areas where the potential for ochre problems is high, protection against ochre development can be provided by designing an outlet facility to ensure permanent submergence of the drain line.

H. Protection Against Root Clogging

Problems may occur where it is necessary to place drains in close proximity to perennial vegetation. Roots or water-loving trees, such as willow, cottonwood, elm, and soft maple, or some shrubs and grasses growing near subsurface drains may enter and obstruct the flow.

Nonperforated tubing or drains with closed joints should be used through the root zone area. Where this is not possible, water-loving trees should be removed or the drains routed to provide a distance of at least 100 feet from the drain. A distance of 50 feet should be maintained from other species of trees except for fruit trees. Orchards can often be drained by drains located close to the fruit trees.

Where crops and grasses may cause trouble on drain lines, facilities may be installed to provide a means for submerging the line to terminate the root growth as desired or to maintain a water table above the drain lines to prevent growth into the system.

I. Materials

Subsurface drains include conduits of plastic, clay, concrete, bituminized fiber, metal, or other materials of acceptable quality.

The conduit shall meet strength and durability requirements of the site. All conduits shall meet

or exceed the minimum requirements indicated in the Materials section of the specifications.

J. Foundation

If soft or yielding foundations are encountered, the lines shall be stabilized and protected from settlement by adding gravel or other suitable materials to the trench, by placing the conduit on a treated plank that will not readily decompose or on other rigid supports, or by using long sections or perforated or watertight pipe having adequate strength to insure satisfactory subsurface drain performance. The use of a flat treated plank is not recommended for corrugated plastic tubing.

K. Filters and Filter Material

Filters will be used around conduits, as needed, to prevent movement of the surrounding soil material into the conduit. The need for a filter will be determined by the characteristics of the surrounding soil material, site conditions, and the velocity of flow in the conduit. A suitable filter should be specified if:

- local experience indicated a need,
- soil materials surrounding the conduit are dispersed clays, low plasticity silts, or fine sands (ML or SM with P.I. less than 7),
- where deep soil cracking is expected, or
- where the method of installation may result in voids between the conduit and backfill material.

If a sand-gravel filter is specified, the filter gradation will be based on the gradation of the base material surrounding the conduit within the following limits:

- D_{15} size smaller than 7 times d_{85} size but not smaller than 0.6 mm
- D_{15} size larger than 4 times d_{15} size
- Less than 5 percent passing No. 200 sieve
- Maximum size smaller than 1.5 inches

The letter "D" represents the filter material and the letter "d" represents the surrounding base material. The number following each letter is the percent of the sample, by weight, that is finer than that size. For example, D_{15} size means that 15 percent of the filter material is finer than that size.

Specified filter material must completely encase the conduit so that all openings are covered with at least 3 inches of filter material except that the top of the conduit and side filter material may be covered by a sheet of plastic or similar impervious material to reduce the quantity of filter material required.

Artificial fabric or mat-type filter materials may be used, provided that the effective opening size, strength, durability, and permeability are adequate to prevent soil movement into the drain throughout the expected life of the system. Guidance for use of geotextiles is contained in NEH Part 650, Chapter 17, Wisconsin Supplements.

L. Envelopes and Envelope Material

Envelopes shall be used around subsurface drains if they are needed for proper bedding of the conduit or to improve the characteristics of flow of ground water into the conduit.

Materials used for envelopes do not need to meet the gradation requirements of filters, but must not contain materials that will cause an accumulation of sediment in the conduit or that will render the envelope unsuitable for bedding of the conduit.

Envelope materials shall consist of sand-gravel, organic, or similar material. Sand-gravel envelope materials shall all pass a 1.5-inch sieve; not more than 30 percent shall pass a No. 60 sieve; and not more than 5 percent shall pass the No. 200 sieve. ASTM-C-33 fine aggregate for concrete has been satisfactorily used and is readily available.

Where organic or other compressible materials are used, they shall be used only around a rigid wall conduit or above the centerline of flexible tubing. All organic or other compressible material shall be of a type that will not readily decompose.

M. Placement and Bedding

The conduit should not be placed on exposed rock or stones more than 1.5 inches in diameter. Where such conditions are present the trench must be over-excavated a minimum of 6 inches and refilled to grade with a suitable bedding material.

The conduit must be placed on a firm foundation to insure proper alignment. If installation will be below a water table or where unstable soils are present, special equipment, installation procedures, or bedding materials may be needed. These special requirements may also be necessary to prevent soil movement into the drain or plugging of the envelope if installation will be made in such materials as quicksand or a silt slurry.

For trench installations or corrugated plastic tubing 8 inches or less in diameter, one of the following bedding methods will be specified:

- A shaped groove or 90-degree V-notch in the bottom of the trench for tubing support and alignment.
- A sand-gravel envelope, at least 3 inches thick, to provide support.
- Compacted soil bedding material beside and to 3 inches above the tubing.

For trench installations of corrugated plastic tubing larger than 8 inches, the same bedding requirements will be met except that a semi-circular or trapezoidal groove shaped to fit the conduit will be used rather than a V-shaped groove.

For rigid conduits installed in a trench, the same requirements will be met except that a groove or notch is not required.

All trench installations should be made when the soil profile is in its driest possible condition in order to minimize problems of trench stability, conduit alignment, and soil movement into the drain.

For trench installations where a sand-gravel or a compacted bedding is not specified, the conduit should be blinded with selected material containing no hard objects larger than 1.5 inches in diameter. Blinder should be carried to a minimum of 3 inches above the conduit.

N. Auxiliary Structures and Protection

Structures installed in drain lines must not unduly impede the flow of water in the system. Their capacity must be no less than that of the line or lines feeding into or through them. The use of internal couplers for corrugated plastic tubing will be allowed.

If the drain system is to carry surface water flow, the capacity of the surface water inlet shall not be greater than the maximum design flow in the drain line or lines. Covers, orifice plates, and/or trash racks should be used to ensure that limited foreign materials are allowed in the drain lines.

Relief wells shall be installed where steep sections of drains change to flat sections unless the flatter section has 25 percent greater capacity than the steeper section.

The capacity of a relief well system for reducing artesian water head shall be based on the flow from the aquifer, the well spacing, and other site conditions and will be adequate to lower the artesian water head to the desired level.

The size of relief wells is generally based on the available materials rather than on hydraulic considerations. Such wells will not be less than 4 inches in diameter.

Breathers shall be constructed where drain lines change from a flat to a steep grade and full flow conditions exist in the line with the flatter grade.

Junction boxes, manholes, catch basins, and sand traps must be accessible for maintenance. A clear opening of not less than 2 feet will be provided in either circular or rectangular structures.

The drain system must be protected against velocities exceeding those provided under "Drains Without Protection" in Table 3 and against turbulence created near outlets, surface inlets, or similar structures. Continuous or closed-joint pipe must be used in drain lines adjoining the structure where excessive velocities will occur.

Junction boxes shall be installed where three or more lines join or if two lines join at different elevations. In some locations it may be desirable to bury junction boxes. In a cultivated field, a solid cover should be used, and the junction box should have a minimum of 18 inches of soil cover.

If not connected to a structure, the upper end of each subsurface drain line will be capped with a tight-fitting cap of the same material as the conduit or other durable materials.

O. Outlets and Outlet Structures

An outlet channel shall be large enough to remove surface runoff from the watershed in a period of time sufficient to prevent serious crop damage. Required capacity will be based on NRCS Field Office Technical Guide (FOTG), Section IV, Standards 582, Open Channel; 607, Surface Drainage, Field Ditch; or 608, Surface Drainage, Main or Lateral. The channel shall be deep enough to provide the minimum of one foot of clearance between the invert of the drain at its outlet and low-water stage in the channel. This clearance may be reduced: (1) where the outlet channel is on such a grade that silting will not occur; (2) where the tile will flow freely within 24 hours after a storm; or (3) where definite scheduled plans have been made for outlet improvement within the next 12 months.

A pump outlet shall have a capacity capable of providing a free outlet for the drain system within 3 or 4 hours of the peak outflow from the system.

Sink holes and wells are not to be used as outlets.

The outlet pipe must be protected against erosion and undermining of the conduit, entry of tree roots, damaging periods of submergence, and entry of rodents or other animals into the subsurface drain. A continuous section of rigid pipe without open joints or perforations will be used at the outlet end of the line. The minimum length of the continuous section of pipe shall be in accordance with Table 4. Corrugated plastic tubing is not suitable for the outlet section. The visual impact of projecting outlets should be minimized.

Table 4
Minimum Outlet Lengths

Drain Size (inches)	Outlet Length (feet)
4, 5	10
6, 8	16
10 and larger	20

Continuously submerged outlets will be permitted for water table control systems if planned and designed according to the NRCS National Handbook of Conservation Practices standards for Regulating Water in Drainage Systems (554) or Water Table Control (641).

The outlet pipe and its installation will conform to the following requirements:

1. If burning vegetation on the outlet ditch band is likely to create a fire hazard, the material from which the outlet pipe is fabricated must be fire resistant. If the likelihood is great, the outlet pipe must be fireproof.

2. Two-thirds of the pipe will be buried in the ditch bank, and the cantilever section must extend to the toe of the ditch side slope or the side slope protected from erosion.

3. If ice or floating debris may damage the outlet pipe, the outlet shall be recessed to the extent that the cantilevered part of the pipe will be protected from the current in the ditch.

4. The minimum thickness for metal pipe shall be 0.064 inches.

5. When surface water must enter the channel at the location of the outlet pipe, some approved type of structure shall be installed to safely lower the surface water into the ditch and protect the outlet. Headwalls used for subsurface drain outlets must be adequate in strength and design to avoid washouts and other failures. At least 8 feet of rigid pipe shall be used to connect the drain line with the structure.

Watertight conduits strong enough to withstand the expected loads will be used if subsurface drains cross under irrigation canals, ditches, or other structures. Conduits under roadways must be designed to withstand the expected loads. Shallow subsurface drains through depressed or low areas and near outlets must be protected from damage caused by farm machinery and other equipment and from freezing and thawing.

P. Alignment

The change in horizontal direction of the tile drains shall be made by one of the following methods:

1. The use of manufactured fittings.

2. The use of junction boxes or manholes.

3. A gradual curve of the drain trench on a radius that can be followed by the trenching machine and maintain grade. A gradual curve may be made by hand shaping the inner side of the trench, but in no case shall the radius be less than 5 feet. In either case, rigid tile must then be shaped or chipped so that no crack between tile exceeds 1/8 inch, unless adequately covered.

VI. Considerations

Additional recommendations relating to design that may enhance the use of, or avoid problems with, this practice but are not required to ensure its basic conservation functions are as follows.

A. Effects on base flow and runoff to water uses and users.

B. Effects on the delivery of sediment and dissolved and sediment-attached substances.

C. Effect of changes in the delivery of dissolved salts, such as nitrates, on downstream water uses and users.

D. Effect on downstream water temperatures.

E. On long lines, consider locating a breather or inspection well every 1/4 mile.

F. Effects on wetlands adjacent to areas where subsurface drains will be installed.

G. Consideration shall be given to possible damages above or below the point of discharge that might involve legal actions under state or local laws.

VII. Plans and Specifications

Plans and specifications for installing subsurface drains shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

VIII. Operation and Maintenance

An Operation and Maintenance Plan shall be developed that is consistent with the purpose of this practice, intended life of the components, and criteria for design.

IX. References

USDA, NRCS, Wisconsin Field Office Technical Guide, Section IV, Conservation Practice Standards and Specifications.

USDA, NRCS, National Handbook of Conservation Practices.

USDA, NRCS, National Engineering Handbook, Part 650, Engineering Field Handbook.