Chapter Thirty-eight

DRAINAGE DESIGN

BUREAU OF LOCAL ROADS AND STREETS MANUAL

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Chapter Thirty-eight
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Chapter 38 presents drainage design criteria specifically for local agency projects. For information on design procedures, the designer should reference the *IDOT Drainage Manual*. In addition, the *Illinois Drainage Code* (42 ILCS) provides the laws relative to rights of drainage, as well as those regarding the construction, maintenance, and repair of drains, ditches, and levees.

38-1 ROADSIDE DITCHES

In addition to Section 38-1, the designer should refer to the following in the *BLRS Manual*:

- Section 31-2 “Roadside Elements,” and
- Chapter 32 “Geometric Design Tables,” which presents criteria for the configuration of roadside ditches.

38-1.01 Definition

A roadside ditch is defined as an open channel paralleling the highway embankment within the limits of the highway right-of-way. Its primary function is to collect runoff from the highway and areas adjacent to the right-of-way and to transport this accumulated water to an acceptable outlet point. A secondary function of a roadside ditch is to drain the base of the roadway to prevent saturation and loss of support for the pavement.

38-1.02 Flood Frequencies

Flood frequencies for the design of ditches and ditch linings for rural roadways are given in Figure 38-1A. Figure 38-1B provides the flood frequencies for urban collector and local streets. For urban arterials, use a 30 year flood frequency for ditch designs and a 10 year flood frequency for ditch lining designs. The use of higher frequencies may be warranted in areas especially sensitive to flooding or erosion.

Design Traffic	Flood Frequency Ditches	Flood Frequency Ditch Lining	
		Arterials	All Others
Under 400 ADT	15 years	10 years	5 years
ADT 400 - 2000	20 years	10 years	5 years
ADT over 2000	30 years	10 years	10 years

FLOOD FREQUENCIES FOR RURAL ROADWAYS

Figure 38-1A

Design Traffic	Flood Frequency Ditches	Flood Frequency Ditch Lining
Under 1000 ADT	15 years	5 years
ADT 1000 – 5000	20 years	5 years
Over 5000	30 years	10 years

Note: For all urban arterials, the flood frequency for ditches is 30 years and the flood frequency for ditch linings is 10 years.

FLOOD FREQUENCIES FOR URBAN STEETS
(Urban Collectors and Local Streets)

Figure 38-1B

38-1.03 Ditch Cross Section

Design features that should be considered include the following:

1. Depth. A depth of 2 ft (600 mm) for a standard trapezoidal ditch, or 1.5 ft (450 mm) for V-ditches where the ADT < 250, is recommended but not required. To provide adequate subbase drainage and to minimize the effect of freeze-thaw cycles on the pavement structure, the depth of the roadside ditch below the shoulder should be equal to the maximum depth of frost penetration for the locale.

2. Shape. Except for low-volume roads (under 250 ADT), all permanent ditches should be trapezoidal shaped with a bottom width of at least 2 ft (600 mm) or curved bottom ditches, which are ideal for hydraulic and safety purposes. Triangular ditches are highly susceptible to erosion and easily blocked by debris. When a ditch bottom width of over 4 ft (1.2 m) is used, the bottom should be sloped at 1V:20H toward the center of the

ditch. This "V"-shaped bottom will deter the forming of a meandering low-flow channel and will minimize standing water in the ditch.

3. Vegetation. Consider the difficulties associated with establishing and maintaining vegetation on steep slopes. Slopes steeper than 1V:2H may require special erosion control measures. In areas of very erosive soils, 1V:2H or even flatter slopes may require special attention.

4. Sideslopes. Sideslopes for ditches should comply with the design criteria for the road. See Chapter 31 for more detailed information.

5. Transitions. Changes between different ditch cross sections should be made with gradual transitions to avoid the creation of turbulent flow conditions and to improve the appearance of the finished project. Recommended transition rates are 25 ft per 1 ft (25 m per 1 m) change in ditch bottom width, and 100 ft (30 m) for each change in side slope from 1V:2H to 1V:3H, 1V:3H to 1V:4H, etc.

38-1.04 Ditch Gradient

To minimize ponding and silting accumulation, a grade of at least 0.3% should be provided on all roadside ditches. Grades in the range of 0.4% to 0.6% are usually more desirable. There is no upper limit on ditch gradients; however, the steeper the grade, the greater the expense may be for erosion control requirements.

38-1.05 Ditch Capacity

Analyze a proposed roadside ditch at critical locations to verify that it will provide adequate hydraulic capacity to carry the peak rate of runoff that is expected to occur with the design frequency. The Rational Method or the regression equations developed by the US Geological Survey are recommended methods for determining design discharges. See the *IDOT Drainage Manual* for guidance in determining discharges.

38-1.06 Ditch Linings

The investigation of the need for protective linings may be necessary for ditch design. If adequate protection is not provided, unsightly gullies appear, maintenance costs increase, and highway structures may be damaged. Include a lining if the side slope or bed material of the ditch will erode at the flow velocity that would occur during a storm that occurs with a flood frequency of 5 or 10 years. Use 10 years only if the design traffic is over 2000 ADT in rural areas and 5000 ADT in urban areas for collectors and local roads and streets. Use 10 years for all arterials; see Figure 38-1B. Note that ditch lining frequencies are lower than those used for other aspects of design, because the extra cost of protecting ditches against velocities of higher frequency floods almost always outweighs any resulting reduction in maintenance costs.

A lining is recommended when the design velocity is above the values for bare soil as shown in Figure 38-1C.

Soil Type	Bare Soil ft/sec (m/sec)	With Grass ft/sec (m/sec)
Fine Sand (Non-Colloidal)	2.0 (0.6)	4.0 (1.2)
Sandy Loam (Non-Colloidal)	2.0 (0.6)	5.0 (1.5)
Silt Loam (Non-Colloidal)	2.5 (0.75)	6.0 (1.8)
Alluvial Silts (Non-Colloidal)	3.0 (0.9)	6.0 (1.8)
Ordinary Firm Loam	3.0 (0.9)	6.0 (1.8)
Fine Gravel	4.0 (1.2)	—
Alluvial Silts (Colloidal)	4.0 (1.2)	7.0 (2.1)
Stiff Clay (Non-Colloidal)	4.5 (1.4)	8.0 (2.4)
Graded Loam to Cobbles (Non-Colloidal)	4.5 (1.4)	8.0 (2.4)
Graded Silt to Cobbles (Colloidal)	5.0 (1.5)	8.0 (2.4)
Coarse Gravel (Non-Colloidal)	6.0 (1.8)	—
Cobbles and Shingles	7.0 (2.1)	—
Shale and Hard Pans	8.0 (2.4)	—

AVERAGE MAXIMUM PERMISSIBLE VELOCITIES

Figure 38-1C

If the design velocity for a grass-lined ditch is below the maximum permissible velocity for the soil with a grass surface, the ditch should be lined with sod, or it should be seeded and lined with a fibrous material (e.g., jute mat, other suitable measures) to protect the earth surface until the vegetation becomes established. If greater protection is required, provide a mechanical lining (e.g., riprap, bituminous material, concrete) or other suitable measures.

After the minimum limits of lining are established, each section of lining should be extended downstream a sufficient distance to allow the flow to slow down before it enters the unprotected or less protected ditch. Figure 38-1D provides the recommended lengths for this transitional lining.

Scouring Slopes*	Length of Transition
0% - 4%	25 ft (7.5 m)
4% - 6%	50 ft (15 m)
6% - 10%	75 ft (23 m)
Over 10%	100 ft (30 m)

** This is the ditch gradient at the lower end of the section of ditch where lining is required.*

TRANSITIONAL DITCH LINING

Figure 38-1D

38-1.07 Outlet Treatment

The final step in designing a roadside ditch is the determination of any required special measures at the points where ditch flow is outletted onto adjacent properties. In general, if the flow conditions caused by the improvement will not cause “undue harm” to the downstream property, expensive protection measures are probably not warranted. The definition of “undue harm” must be left to the judgment of the designer.

For more detailed information, see the *IDOT Drainage Manual*.

38-2 STORM SEWERS

38-2.01 Design Procedures

Design the storm sewer system by determining the drainage area, computing the runoff using the Rational Method and computing the capacity using the Manning Equation. Other design methods may be used subject to district approval. The complete storm sewer design should meet the requirements in the following Sections. For more information, see the *IDOT Drainage Manual*.

38-2.02 Design Frequency

A 10 year flood frequency is recommended. For approved combined sewers in the city of Chicago, a 5 year frequency is permissible. A higher flood frequency may be used if consistent with the design standard of the local system.

At underpasses where the storm sewer system is the only outlet for stormwater, use a 25 year flood frequency.

38-2.03 Drainage Area

The drainage area eligible for MFT or Federal-aid funding will be the tributary area determined by the topography (natural drainage area) of the location. For interconnected systems, drainage will be determined based on conveyance through the project area from existing systems. Design the new system to accept the “Q” (discharge) of the adjacent system or the discharge needed solely for highway purposes, whichever is greater.

38-2.04 Pipe Size

The minimum size for storm sewers is 12 in (300 mm) for main lines and 8 in (200 mm) for lateral lines.

38-2.05 Location

When economically practical, locate storm sewers outside the roadway pavement. Where storm sewers are located under the pavement or within 2 ft (600 mm) of the pavement edge, provide for trench backfill and ensure the top of the pipe is at least 6 in (150 mm) below the bottom of the pavement structure. At other locations, provide a minimum cover of 3 ft (1 m).

38-2.06 Slopes

Maintain a uniform slope that provides a velocity between 3 and 10 ft/sec (0.9 and 3 m/sec). The minimum velocity allowed in storm sewer systems is 3 ft/sec (0.9 m/sec). A flatter slope that is sufficient enough to maintain a velocity of 2 ft/sec (0.6 m/sec) will be permitted only in special cases. Where it is necessary to exceed 10 ft/sec (3 m/sec), consider using drop structures.

38-2.07 Manholes

To permit the inspection, cleaning, and removal of obstructions, manholes should be located as follows:

- where two or more storm sewers converge,
- where pipe size changes,
- where an abrupt change in alignment occurs,
- where an abrupt change of the grade occurs, and
- at spacings meeting the criteria in Figure 38-2A.

Avoid placing manholes in the traveled way. Where it is necessary, do not place them in the normal wheel tracks, unless their avoidance is impractical. The designer should ensure that new or relocated manholes and inlets are not placed within accessibility routes based on the ADA criteria; see Section 41-6.

Pipe Size	Maximum Distance
8 in - 24 in (200 mm - 600 mm)	350 ft (100 m)
27 in - 36 in (675 mm - 900 mm)	400 ft (120 m)
42 in - 54 in (1050 mm - 1350 mm)	500 ft (150 m)
≥ 60 in (1500 mm)	1,000 ft (300 m)

MAXIMUM MANHOLE SPACING

Figure 38-2A

38-2.08 Catch Basins

Catch basins are designed to collect and distribute storm or surface waters. Most catch basins use an outlet pipe to disperse the water to a natural source of outlet. Some catch basins are designed with leaching chambers or pits to percolate in the soil.

The designer should check that the locations of the catch basins are located at low points of sags. The locations should also be checked to determine if conflicts exist with curb ramps, in-place utilities, approaches, or other features. For additional guidance on catch basins, see the *IDOT Drainage Manual*.

38-2.09 Inlets

Inlets should be spaced and designed so that diversion from the natural course will not occur. Inlets located at low points in the roadway grade should be designed to receive all flow presented to it. Provide two inlets at the low point of sag vertical curves. Inlets at other locations will allow overflow.

Combination curb-and-gutter grates are recommended for sump and debris-clogging locations (e.g., on a very flat grade). Gutter grates only are recommended for all remaining locations. For additional information on grate types, see the *IDOT Highway Standards*.

The following encroachment limitations are the maximum allowable for determining inlet spacing:

1. Shoulders. For sections with full shoulders (6 ft (1.8 m) or more), no encroachment is allowed in the travel lanes. The maximum spread is limited to the shoulder width.

2. Parking Lanes. For sections with permanent parking lanes, no encroachment is allowed into the travel lanes. The maximum spread is limited to the parking lane.

3. Two-Lane Streets. For sections with one lane in each direction, the maximum encroachment into the traveled way is 4 ft (1.2 m). However, where the surface width is less than 30 ft (9 m), then the maximum encroachment is 3 ft (1 m).

4. Multilane Streets. The following will apply:

    a. Two or More Lanes in Each Direction. Maximum encroachment may be up to half of the outside travel lane.

    b. Three or More Lanes in Each Direction. With one lane draining to the median, the maximum encroachment into the traveled way is 4 ft (1.2 m) on median side and a maximum half of the travel lane for the outside travel lane.

38-3 CULVERT DESIGN

38-3.01 General

A culvert is a drainage structure consisting of a closed conduit that conveys water from a natural channel or waterway transversely under a roadway. General criteria for various classes of highway are outlined in Figure 38-3A. The design procedures in this Section should be followed for each design after identifying the basic criteria from Figure 38-3A.

Use the following general procedure when designing a culvert:

1. Obtain all necessary field data from survey books, USGS maps, contour maps, etc. Conduct a field inspection to verify design assumptions (e.g., effects of ponding, streambed elevations, size of existing culverts, size and volume of debris). A field reconnaissance is required for all large culverts, defined as 48 in (1200 mm) in diameter or greater.

2. Assemble the design features pertaining to the proposed roadway (e.g., profile grade, class and type of highway).

3. Assemble the design criteria for selection of the culvert (e.g., velocity; allowable headwater; design discharge; inlet and outlet conditions; slope, smoothness, and length of culvert).

4. Determine the volume of runoff from the drainage area using the *IDOT Drainage Manual*.

5. Determine the geometric proportions of the culvert required to accommodate the non-erodible runoff along the highway and abutting properties.

Maintained By	Usage (Road Class)	Kind of Drainage Structure Permitted	Minimum Permissible Diameter	Headwalls or End Sections
Local Agency	Across Road	Any one kind of pipe culvert may be specified to the exclusion of all other kinds.	24 in (600 mm) 18 in (450 mm) for Counties and Road District	Where needed
	Entrances		12 in (300 mm) 10 in (250 mm) for municipalities	Where needed

Notes:

1. *The width of roadbed for field and private entrances should not be less than 16 ft (5 m).*
2. *Multiple pipe installations that are 48 in (1.2 m) in diameter or larger should be spaced one-half diameter or 3 ft (900 mm) apart. Smaller pipe should be spaced 2 ft (600 mm) apart.*
3. *Where head room is critical, pipe arches will be permitted.*

GENERAL CULVERT DESIGN POLICIES

Figure 38-3A

38-3.02 Design Requirements

Design all across-road culverts to carry the design flood frequency discharge without property damage upstream or downstream. Culverts may be designed below head provided the property damage restriction is not violated.

Consider the following structural criteria as part of the culvert selection and design:

1. Minimum Culvert Lengths. The minimum allowable culvert length will be the roadway width (i.e., traveled way plus shoulder).

2. Clearance. Where there is too little cover above the top of culvert for circular pipes, consider the following alternatives:

   - box culverts,
   - elliptical reinforced concrete pipe,
   - corrugated structural plate pipe arches, and
   - multiple circular pipes of smaller diameter.

   Select the appropriate alternative based on the hydraulic equivalent and economic analysis.

3. Earth Loads. Embankment fills up to 35 ft (10.5 m) above the top of pipe culverts are addressed in the *IDOT Standard Specifications for Road and Bridge Construction*, which specifies the class of concrete and thickness of metal to be used for various fill heights.

   Fill heights in excess of 35 ft (10.5 m) require special design consideration and may result in the use of reinforced concrete box culverts installed by the "Imperfect Trench Method of Construction" or, in some cases, corrugated structural plates or pipe arches. In all cases of special design, an economic analysis of the various culvert alternatives should be made, including all acceptable methods of installation, before making a final selection.

4. Foundation Conditions. Where expensive structures will be constructed beneath high, wide fills, conduct foundation explorations to an appropriate depth (i.e., soil borings) to determine subsurface conditions and to check the uniformity of the material through the length of the culvert barrel. Consult with the District Geotechnical Engineer for guidance. See Section 36-2.02 for more information.

5. Culvert Rigidity. Structural adequacy of special non-standard design culverts should be confirmed by an Illinois licensed structural engineer.

6. Impact. For pipe culverts, provide a minimum cover of 6 in (150 mm) between the top of the pipe and the bottom of the pavement subbase. Check minimum fill height

requirements in the *IDOT Standard Specifications*. Reinforced concrete box culverts may be designed with no cover.

7. Erosion Control. Evaluate the potential for scour at the culvert outlet by determining outlet velocities. Provide channel protection if the average maximum permissible velocity for bare soil is exceeded.

8. Headwalls/End Sections. For culverts not typically requiring headwalls or end sections (see Figure 38-3A), several conditions may require their use. Headwalls and end sections may be required to:

   - reduce the length of culvert pipe,
   - meet hydraulic requirements, and/or
   - provide additional strength for the ends of corrugated metal pipes subject to crushing loads.

38-4 DRAINAGE AND LEGAL RESTRICTIONS

The following legal restrictions apply to drainage design:

1. Discharge of Sewage into Open Ditches. Section 605 ILCS 5/9-123 prohibits the discharge of sewage into open ditches along any public street or highway. Form BLR 38410 may be procured from the district for notifying violators of this law.

   Effluent from septic tanks is not allowed to outlet within 10 ft (30 m) of the right-of-way.

2. Water Flow Interferences in Highway Ditches. Section 605 ILCS 5/9-117 prohibits encroachments by fencing, plowing, or ditching or in any other manner interfering with the flow of water in highway ditches. Written permission from a highway authority is required for changing drainage patterns by draining farmland into highway ditches that did not drain in that direction previously.