CHAPTER 201

General Hydrology Information

Design Memorandum	Revision Date	Sections Affected
13-01	Jan. 2013	201-1.02
13-04	Mar. 2013	201-1.05 through 201-1.08, 203-2.02(10)
13-11	May 2013	201-1.07
23-13	Sep. 2023	201-1.02

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 201

GENERAL HYDROLOGY INFORMATION

201-1.0 INTRODUCTION

For a highway application, hydrology is the science of estimating surface-water runoff that will arrive at a specific location. Hydraulics is the science of collecting, transporting, and disposing of surface water originating on or near the highway right of way or flowing in a stream crossing or bordering such right of way. Drainage design is one of the essential elements of highway construction. A large percent of highway construction costs is devoted to culverts, bridges, or other drainage structures.

The designer must rely on engineering judgment, experience, and common sense to achieve meaningful results. Methodologies available are only tools to aid in making judgments. The designer must understand each method that is employed, especially its limitations.

Drainage design should address drainage issues that can result due to highway construction through the activities as follows:

1. anticipating the amount and frequency of storm runoff;
2. determining natural points of concentration and discharge and other hydraulic controls; and
3. providing the most efficient facility consistent with cost, the importance of the highway, maintenance, and legal obligations.

In drainage design, the primary objectives are to mitigate off-site flooding due to a new highway project, and to protect the highway against damage from surface waters, considering the effect of the project on traffic and property. Improvements in drainage outside the highway right of way will not be considered unless there is an advantage to the transportation system.

201-1.01 General Policies

The purpose of this Section is to outline specific policies that guide and determine the variables which influence drainage design. An adequate drainage design is defined as one which satisfies INDOT policies. Hydrologic and hydraulic analyses, and engineering evaluation of suitable alternatives, are considered part of the design of a highway-drainage facility. All final hydraulic analysis and calculations should be signed and sealed by a professional engineer licensed in Indiana. Final hydraulic calculations are defined as calculations to be used for construction.

The engineering design process involves consideration and balancing of the following:

1. legal considerations;
2. flood hazards to highway users or neighboring property owners;
3. hydraulic efficiencies;
4. costs, such as construction, serviceability, maintenance, life cycle, right of way, etc.;
5. environmental concerns;
6. overtopping flood consideration in addition to design flood; and
7. other site-specific concerns.

201-1.02 Responsibilities [Rev. Sep. 2023]

This section outlines the responsibilities for design and review of a highway-drainage facility. However, INDOT reserves the right to review each aspect of the drainage design at any point during plan development.

201-1.02(01) Engineering Assessments (Scoping)[Rev. Sep. 2023]

The Division of Hydraulics will be responsible for the hydraulic design for the following.

1. Existing culverts with a span or diameter ≥ 48 in., and
2. Existing culverts with a span or diameter < 48 in. where there are drainage issues, e.g. scour holes, history of overtopping, ponding, or debris.

The district will be responsible for the hydraulic design for existing culverts with a span or diameter < 48 in., unless there are existing drainage issues. The Division of Hydraulics will provide design training for the district as needed. Culverts with a span or diameter < 48 in. should be considered for in-kind replacement. See 203-2.08 for the Replacement in Kind Policy.

201-1.02(02) Hydraulic Design, INDOT Projects [Add. Sep. 2023]

For a consultant-designed project, the consultant will be responsible for all hydraulic design. Review will be performed in accordance with 201-1.02(03) for INDOT projects and 201-1.02(04) for LPA projects.

For a project designed in-house, the Division of Hydraulics will perform all hydraulic design.

201-1.02(03) Hydraulic Review, INDOT Project [Add. Sep. 2023]

For an INDOT project, hydraulic models and design computations are required to be submitted to the Division of Hydraulics for review and approval for the following. LPA projects are discussed in 201-1.02(04).

1. All bridges (replacement and rehabilitation).
2. Culvert replacement with a span or diameter ≥ 48 in. These structures have the asset ID prefix "CV".

   Culvert replacement with a span or diameter < 48 in. should be considered for in-kind replacement. See 203-2.08 for the Replacement in Kind Policy. Culvert replacement within the limits of a pavement reconstruction project requires hydraulic analysis but is not required to be submitted for review and approval. The analysis should be included with the project design computations.
3. Storm sewers with a diameter ≥ 36 in.
4. All median drains.
5. All detention or infiltration basins.
6. All drainage issues and drainage complaints.
7. All pipe liners and rehabilitations, regardless of size.
8. All culverts on a fully access-controlled corridor. See 40-5.0 for access control definitions.
9. All driveway permits with drainage onto INDOT right-of-way.
10. All culverts on new alignment

201-1.02(04) Hydraulic Design and Review - LPA Projects [Add. Sep. 2023]

The LPA or its consultant is responsible for all hydraulic designs. The following are required to be submitted to the Division of Hydraulics for review and approval.

For an LPA project on a state route or locally-owned NHS route hydraulic designs are required to be submitted for review and approval in accordance with 201-1.02(03).

For an LPA project on a locally owned, non-NHS route, the following apply.

1. Pipes/Small Culverts. The Division of Hydraulics will not review culverts with a span or diameter < 48 in.

2. Bridges (span > 20 ft) and Small Structures/Large Culverts (span ≥ 4 ft and ≤ 20 ft). Review and approval by the Division of Hydraulics is required when any one or more of the following conditions are met.

   a. The structure is one mile or less downstream of an INDOT structure (measured along the stream).
   b. The proposed backwater does not dissipate before reaching an upstream INDOT structure.
   c. The structure is 1/2 mile or less upstream of an INDOT structure (measured along the stream).
   d. There are levees within the proposed project limits.

3. Storm Drains. Review and approval by the Division of Hydraulics is required when one or more of the following conditions are met.

   a. Where any drainage from the LPA project is received by INDOT right of way.
   b. Where any drainage from INDOT right of way is received by the LPA system.

201-1.03 Documentation and Procedures

The purpose of providing documentation is to define the design procedure that was used, and to show how the final design and decisions were selected. The documentation should be viewed as the record of reasonable and prudent design analysis based on the best available technology.

Documentation is an important part of the design or analysis of a drainage facility due to the following:

1. the importance of public safety;

2. justification of expenditure of public funds;

3. future reference where improvements, changes, or rehabilitations are made to the highway facility;

4. information leading to the development of defense in litigation; and

5. public information.

It may be necessary to refer to plans, specifications, or analyses after the actual construction has been completed. Documentation permits evaluation of the performance of a structure after a flood event to determine if the structure performed as anticipated, or to establish the cause of unexpected behavior. If the structure fails, the contributing factors should be identified so that recurring damage can be avoided.

The documentation requirements for hydrology and hydraulics are provided in their respective Chapter or Section for each drainage-facility type.

201-1.04 Legal Considerations

201-1.04(01) Legal Aspects

The drainage laws and rules that are applicable to a drainage facility are discussed below. It should not be treated as a basis for legal advice or legal decisions. It is not a summary of all existing drainage laws, and it is not intended as a substitute for legal counsel. The following generalizations can be made regarding drainage liability.

1. A goal in drainage-facility design should be to perpetuate natural drainage as practical.

2. The courts look with disfavor upon infliction of injury or damage that can be reasonably avoided by a prudent designer, including where some alteration in flow is legally permissible.

3. The descending order to law supremacy is Federal, State, and then local. Except as provided for in the statutes or constitution of a higher level of government, the higher level is not bound by laws, rules, or regulations of a lower level.

The designer is responsible for making the determination as to which agencies may have jurisdiction with regard to site-specific drainage requirements. Regulatory and local jurisdictions and requirements should be identified and investigated early in the project development and documented by the designer. This will also identify the potential regulatory requirements that may differ from INDOT design requirements. The procedure followed should be continuously documented throughout the review process.

The designer should have knowledge of updates and changes to regulations that can affect a drainage-facility project. Sources for legal information pertaining to drainage facilities include, but are not limited to, the following.

1. Federal Regulatory Agencies.

    a. FEMA, Federal Emergency Management Agency
    b. FHWA, Federal Highway Administration
    c. NRCS, Natural Resource Conservation Service
    d. USACE, United States Army Corp of Engineers
    e. USCG, United States Coast Guard
    f. USEPA, United States Environmental Protection Agency
    g. USFWS, United States Fish and Wildlife Service
    h. USGS, United States Department of the Interior, Geological Survey

2. State Regulatory Agencies.

    a. IDEM, Indiana Department of Environmental Management
    b. IDNR, Indiana Department of Natural Resources
    c. SHPO, State Historic Preservation Office

3. Local Agencies.

    a. City engineer
    b. Conservancy district
    c. County drainage board
    d. County surveyor

201-1.04(02) Local-Law Policy

INDOT will, as practical, satisfy local ordinances as a courtesy, especially if it can be done without imposing a burden on the State.

201-1.04(03) Legal Drains

Most counties have established a system of legal drains which are maintained by the county surveyor. State law grants each such county certain privileges where a project impacts an established legal drain. More detailed information on legal-drain regulations appears in IC 36-2-12-15 and IC 36-9-27.

201-1.05 Pipe Material Selection [Added Mar. 2013]

Pipe Materials Selection Software has been developed to perform the required material selection analysis for Type 1, 2, 3, or 5 pipe. Unless otherwise specified, material selection analysis is not required for a Type 4 pipe. The Pipe Material Selection software uses structure site information to determine the acceptable pipe materials for each structure for the specific site conditions. Input requirements are shown below. See Section 201-1.06, Structure Site Analysis for additional input information.

201-1.05(01) Pipe Material Selection Software Input

The input required for the Pipe-Material-Selection software includes the following:

1. required pipe type (see INDOT *Standard Specifications*);
2. required pipe-interior designation (smooth or corrugated), if applicable;
3. pipe size;
4. cover;
5. required service-life duration;
6. abrasive or non-abrasive site designation; and
7. structure pH

201-1.05(02) Pipe Material Selection Software Output

Software output may include the following:

1. Software Indicates No Acceptable Materials for Structure. If this occurs, the cause is likely to be incorrect-input-data entry. If a review of the input reveals that there are no errors, the designer must contact the INDOT Hydraulics Team for additional instructions.

2. Software Indicates Only One Acceptable Material for Structure. By definition, a pipe-type designation indicates that a contractor may select from a list of materials that have been determined to be acceptable for an individual structure. If the list includes only one acceptable material, the pipe-type designation is meaningless. If this occurs, the structure cannot refer to a pipe type.

3. Software Indicates Two or More Materials are Acceptable for Structure. By definition, a pipe-type designation remains appropriate for this structure. The protective coating or invert treatment for each corrugated metal pipe is considered to define a unique material. For example, a materials list indicating both zinc-coated corrugated steel pipe and zinc-coated corrugated steel pipe with bituminous-paved invert as acceptable is considered to include two materials.

4. Software Indicates More than One Corrugation Profile and Material Thickness Combination is Acceptable for Structure. If the Pipe-Material-Selection Software may indicates that more than one corrugation profile and material thickness combination is acceptable for a structure, then it is necessary to determine the optimum corrugation profile. The procedure for determining the optimum corrugation profile is as follows:

    a. Select the Profile with the Minimum Thickness. If the acceptable corrugation profiles require different material thicknesses, select the profile with the minimum thickness.

    b. Select the Smallest Profile. If all acceptable corrugation profiles require the same material thickness, select the smallest profile. By definition, a 2⅔” x ½” corrugation profile is considered smaller than a 3” x 1” profile.

201-1.06 Structure Site Analysis [Added Mar. 2013]

A Structure Site Analysis is required for each type 1, 2, 3, or 5 pipe structure. Unless otherwise specified, the analysis is not required for a type 4 pipe. The scope of the analysis is discussed in the following sections and is used as input for the Pipe Material Selection Software. See Section 201.-1.05 for additional information.

201-1.06(01) Cover

Cover is discussed in Section 203-202(09).

201-1.06(02) Pipe-Service-Life Duration

This indicates the desired length of service for the drainage structure. The duration is based on the functional classification of the mainline roadway. If the mainline roadway is a freeway or expressway, or is functionally classified as an arterial, the required service-life duration for each type 1, 2, 3, or 5 pipe structure is 75 years. If the mainline roadway is functionally classified as a collector or local road, the required service-life duration for each such structure is 50 years.

201-1.06(03) Abrasive or Non-Abrasive Site Designation

A site is considered abrasive if it is probable that runoff will transmit material which can damage the pipe. Each mainline culvert site or each site where a public-road-approach or drive culvert is installed in a natural channel is considered abrasive.

A storm-drain site or public-road-approach or drive culvert site on a constructed side-ditch line is considered non-abrasive. However, the designer must use judgment to confirm that abrasive elements are not likely to impact such a site. If the designer concludes that a storm-drain- or side-ditch-culvert site can have abrasive materials transported by runoff, an abrasive site designation must be assigned to each affected structure.

201-1.06(04) Structure pH

Acidic runoff may have contributed to service-life problems with a pipe structure. To mitigate these problems, the designer must determine a pH value for each type 1, 2, 3, or 5 pipe structure. The pH data may be provided in the Engineer's or Geotechnical Reports. The data should include the stream pH-test result for each type of existing structure as follows:

1. mainline culvert;
2. public-road-approach or drive culvert in a natural channel;
3. storm-drain-system outlet pipe; or
4. the most-downstream culvert on each constructed ditch line.

The designer will use the following guidelines to establish each proposed structure's pH value.

1. Culvert. Assign the data provided for each existing mainline culvert to the corresponding proposed pipe structure. Likewise, assign the data associated with each existing public-road-approach or drive culvert located in a natural channel to the corresponding proposed structure. Each proposed public-road-approach or drive culvert installed on a constructed ditch line should be assigned the report's pH value for the most-downstream culvert on the corresponding existing ditch line.

2. Storm Drain. If a proposed storm-drain system will replace an existing system, assign the pH value obtained at the existing system's outlet pipe to each pipe structure in the proposed system. If the proposed system is replacing an existing open-drainage system, apply the pH value collected at the most-downstream existing side-ditch culvert to each structure in the proposed system.

The final structure pH is the lowest of the following values.

1. Preliminary Field Check Plans pH Value. This value is obtained from one of the following sources.

    a. Engineer's Report.

    b. pH Testing. If pH data is not available from the Engineer's Report, the designer is required to perform pH testing of water samples taken at the structure. The scope of the testing required is below and is illustrated by the flowcharts included in the following figures.

201-1A	Structure pH Determination Procedure for Proposed Mainline Culvert or Other Culvert in Natural Channel (Area Where Map pH = 7.0)
201-1B	Structure pH Determination Procedure for Proposed Storm-Drain Structure (Area Where Map pH = 7.0)
201-1C	Structure pH Determination Procedure for Proposed Side-Ditch Culvert (Area Where Map pH = 7.0)
201-1D	Structure pH Determination Procedure for Proposed Mainline Culvert or Other Culvert in Natural Channel (Area Where Map pH < 7.0)

201-1E	Structure pH Determination Procedure for Proposed Storm-Drain Structure (Area Where Map pH < 7.0)
201-1F	Structure pH Determination Procedure for Proposed Side-Ditch Culvert (Area Where Map pH < 7.0)

c. pH Map. If the Engineer's Report does not provide structure pH data, and pH testing is not appropriate, Figure 201-1G, pH Map, is used to determine the Preliminary Field Check pH value.

2. Final Check Prints pH Value. This value is obtained from one of the following sources.

   a. Geotechnical Report.

   b. pH Testing. If a structure pH value is not available from the Geotechnical Report and testing is appropriate (see Item 1.b. above), pH testing of a water sample taken from the corresponding existing structure site is required.

   c. pH Map. Use of the pH map is appropriate only if a structure pH value is not available from the two sources listed above.

3. Final Tracings pH Value. If the pH values from Items 1 and 2 for a structure are not within 0.5 of each other, a third value must be obtained for comparison. The third value is obtained from one of these two sources.

   a. pH Testing. If pH testing is appropriate, testing of water samples at the corresponding existing structure is required.

   b. pH Map. If pH testing is not appropriate, the pH map is the appropriate source for the third pH value.

Before pH testing is performed, the project location must be determined from Figure 201-1G, pH Map. If the project is located in a county with a posted 7.0 pH value, the testing scope is as follows:

1. Identify Structure Requiring Testing. The structure type to be considered for testing is as follows:

   a. mainline culvert;
   b. public-road-approach or drive culvert located in a natural channel;
   c. outlet pipe of storm-drain system; or
   d. the most downstream culvert on a constructed ditch line.

2. Structure Inspection. The testing process begins by inspecting the structure. If an existing structure does not show signs of corrosion, pH testing is not required. If the structure shows signs of corrosion, a water sample at the structure must be obtained and the pH of the sample must be determined.

If the project is located in a county with a pH map value < 7.0, the structure-inspection step described in Item 2 does not apply. Each structure identified in Item 1 requires obtaining a water sample for pH determination.

The following apply to the determination of a structure pH value, regardless of the source of the data.

1. Maximum Structure pH Value. The pH value for a structure cannot exceed the map pH value for the project location. If the pH value obtained from a report on pH testing is greater than the map pH value, the obtained value is ignored and the map value is used for the structure.

2. Precision of pH Value. The pH value is expressed to the nearest 0.5. If a report or pH testing yields a value that is more precise, the structure pH is rounded to the next lower 0.5.

3. Lack of Sample Availability. If pH testing is required, but a sample is not available at a structure site, the structure pH value will equal the value for the nearest adjacent structure. If a water sample is not available at an appropriate structure within the project limits, the pH map value is used for all structures.

4. Storm-Drain-Structure pH Determination. The structure pH assigned to the outlet pipe of a storm-drain system is assigned to each structure in the proposed system.

5. Side-Ditch-Culvert Structure pH Determination. The structure pH assigned to the most downstream pipe in a segment of side ditch is assigned to each culvert installed in that ditch line segment.

201-1.07 Pipe-Extension Structure [Added Mar. 2013, Rev. May 2013]

By definition, a pipe-extension structure is a structure that involves attaching a new pipe to an existing pipe. A pipe extension requires the selection of a specific material. If possible, the selected material should match the existing pipe material. When metal pipe is selected, the base metal and coating specified shall match the existing pipe. However, the material thickness and coating combination or material-strength classification must satisfy the cover and service-life-criteria requirements.

201-1.08 Draintile Structure [Added Mar. 2013]

If it is known that the proposed construction will require the removal of existing field tile, the drainage will be perpetuated in the following manner.

1. Tile Replacement Within Temporary Right of Way. Type 4 pipe is used to perpetuate the drainage. The pipe size will match the existing tile and must be perforated in accordance with the INDOT *Standard Specifications*.

2. Tile Outlet in Ditch Prior to Crossing Mainline Pavement. Type 4 non-perforated pipe and a 10-ft long segment of draintile terminal section are required between the right-of-way line and the proposed outlet. If necessary, a concrete collar is used to connect to the existing pipe at the right-of-way line, and a rodent screen is required at the terminal-section outlet. Revetment riprap or other gradation [as required to satisfy the clear-zone criteria (see Chapter 49)] is required between the tile outlet and the ditch flow line to prevent erosion.

3. Tile Outlet in Ditch After Crossing Mainline Pavement. Type 1 pipe is required between the right-of-way line and the proposed outlet. The concrete collar, rodent screen, and riprap requirements described in Item 2 above will apply to the type 1 pipe installation. The acceptable type 1 pipe materials must satisfy the cover and service-life criteria. The site is assumed to be non-abrasive and the map pH can be assigned to the structure.

4. Tile Outlet in Storm Drain System. Type 2 pipe is required between the right-of-way line and the outlet location. A concrete collar is required. The acceptable type 2 pipe materials must satisfy the cover and service-life criteria. The site is assumed to be non-abrasive, and the structure pH must match the value for the storm-drain structure that serves as the tile outlet.

5. Tile is Perpetuated Across Right of Way. Type 1 pipe is required from right-of-way line to right-of-way line. A concrete collar is required. The acceptable type 1 pipe materials must satisfy the cover and service-life criteria. The site is assumed to be non-abrasive, and the pH map value for the project location is assigned to the structure.

201-1.09 References

201-1.09(01) Uncited References

The designer should be familiar with the following references that pertain to drainage design. More-specific references will be provided in Part 2's respective chapters.

1. AASHTO *Model Drainage Manual*, Chapter 2, American Association of State Highway and Transportation Officials, Washington, DC.

2. AASHTO *Highway Drainage Guidelines*, American Association of State Highway and Transportation Officials, Washington, DC.

3. Indiana Administrative Code, Indiana General Assembly – Indiana Register. Appears on http://www.in.gov/legislative/iac/iac_title?iact=105.

4. *Code of Federal Regulations*.

5. *Stormwater Drainage Manual.* Burke, Christopher B., and Thomas T. Burke, West Lafayette, IN, Purdue Research Foundation, 2008.

6. Indiana Department of Natural Resources statutes and Indiana Code rules.

201-1.09(02) Cited References

1. *ASCE Hydrology Handbook*, Manuals and Reports on Engineering Practice, No. 28, American Society of Civil Engineers, 1949.

2. *ASCE Nomenclature for Hydraulics*. Manuals and Reports on Engineering Practice, No. 43, American Society of Civil Engineers, 1962.

3. *Chemical Quality of Water and Sedimentation in the Moreau River Drainage Basin, South Dakota*, Colby, B. R., Hembree, C. H., and Jochens, E. R. U.S. Geol. Survey Circ. 270, 1953.

4. *Federal Glossary of Selected Terms: Subsurface-Water Flow and Solute Transport*, USGS Groundwater Subcommittee of the Federal Interagency Advisory Committee on Water Data. U.S. Geological Survey, Office of Water-Data Coordination, 1989.

5. *General Introduction and Hydrologic Definitions. Manual of Hydrology: Part 1. General Surface-Water Techniques*, Langbein, W. B., and Iseri, K. T. U.S. Geological Survey Water-Supply Paper 1541-A, 1960.

6. *Guide for Collection, Analysis and Use of Urban Stormwater Data*, Alley, W. M., ed. Conference Report presented Nov. 28 – Dec. 3, 1976, at Easton, Maryland. Cosponsored by the Urban Water Resources Research Council, American Society of Civil Engineers, 1976.

7. *Guidelines for Determining Flood Flow Frequency, Bulletin 17B*, Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data. U.S. Geological Survey, Office of Water Data Coordination, 1982.

8. *Guidelines on Community Local Flood Warning and Response Systems*, Hydrology Subcommittee of the Federal Interagency Advisory Committee on Water Data. U.S. Geological Survey, Office of Water Data Coordination, 1985.

9. *Stream-Gaging Procedure, a Manual Describing Methods and Practices of the Geological Survey*, Corbett, D. M., et al. U.S. Geological Survey Water-Supply Paper 888, 1943.

10. *USGS National Engineering Handbook*, Section 4 Hydrology, Chapter 22, Glossary. U.S. Geological Survey, Office of Water-Data Coordination, 1956, reprinted with minor revisions, 1971.

11. *WRD Data Reports Preparation Guide*, 1985 Edition, Novak, C. E. U.S. Geological Survey, 1985.

201-2.0 DEFINITIONS

A parenthetical number which follows a definition corresponds to the number of the cited reference shown in Section 201-1.09(02).

Abutment. The superstructure support at either end of a bridge or similar type structure, usually classified as spillthrough or vertical. Considered part of the bridge substructure. See Spillthrough Abutment and Vertical Abutment.

Aggradation. 1. General and progressive upbuilding of the longitudinal profile of a channel, or within a drainage facility due to the deposition of sediment. Compare with Sedimentation. 2.

Permanent or continuous aggradation is an indicator that a change in the stream's discharge and sediment load characteristics is taking place.

Allowable-Headwater, AHW, Depth. The depth or elevation of the flow impoundment for a drainage facility above which damage, some other unfavorable result, or a significant flood hazard can occur. Compare with Headwater Depth.

Alluvial. Deposits of silts, sands, gravels, or similar detrital material that has been transported by running water.

Analysis, Hydraulic. An evaluation of a drainage-related circumstance or condition based on measured or computed findings coupled with prudent judgment. Compare with Assessment, Hydraulic.

Analysis, Economic. See Economic Analysis. Compare with Economic Assessment.

Approach Section. A cross section of the stream channel, normal to thread of current and for the discharge of interest, located in the approach channel. See Approach Channel.

Apron. 1. Protective material laid on a streambed to prevent scour commonly caused by a drainage facility. More specifically, a floor lining of concrete, timber, or riprap, to protect a surface from erosion, such as the pavement below a chute, spillway, at the toe of a dam, or at the outlet of a culvert. 2. Material placed on the banks is commonly termed a blanket. Compare with Channel Lining and Blanket.

Armor. Artificial surfacing of a channel bed, bank, or embankment slope to resist streambed scour or lateral-bank erosion. Compare with Apron, Blanket, Channel Lining, and Revetment.

Articulated-Concrete Mattress. Rigid concrete slabs that can move without separating as scour occurs, usually hinged together with corrosion-resistant fasteners. Primarily used for a lower-bank-protection armor blanket.

Backfill. The material used to refill a ditch or other excavation, placed adjacent to or around a drainage structure, or the process of doing so.

Backwater. The increase in water-surface elevation induced upstream from a bridge, culvert, dike, dam, another stream at a higher stage, or other similar structure or condition that obstructs or constricts a channel relative to the elevation occurring under natural channel and floodplain conditions. Otherwise, water backed up or retarded in its course as compared with its normal or natural conditions of flow. Also applies to the water-surface profile in a channel or conduit. See Backwater Curve.

The difference between the observed stage and that indicated by the stage-discharge relation is reported as backwater (8).

Other definitions and examples are as follows:

1. a flow retarding influence due to a dam, other constriction such as a bridge or culvert, or another stream;

2. the increase in water-surface elevation due to a bridge constriction above the normal unconstricted elevation at an approach section located one bridge length upstream from the bridge constriction;

3. water backed up or retarded in its course as compared with its normal or natural condition of flow; or

4. in stream gaging, a rise in stage produced by a temporary obstruction such as ice or weeds, or by the flooding of the stream below the backwater area. The low-lying lands adjacent to a stream that can become flooded due to backwater effects. Compare with Floodplain.

Backwater Flooding. The backup of water into a stream from a river or lake having a higher water elevation (6).

Baffle. 1. A structure constructed on the bed of a stream or drainage facility to deflect or disturb the flow. 2. Vanes or guides, a grid, grating, or similar device placed in a conduit to check eddy currents below them, and effect a more uniform distribution of velocities. 3. A device used in a culvert or similar structure to facilitate fish passage.

Bank. 1. The side slopes or margins of a channel between which the stream or river is normally confined. More formally, the lateral boundaries of a channel or stream, as indicated by a scarp, or on the inside of bends, by the streamward edge of permanent vegetal growth. 2. The margins of a channel. Banks are identified as right or left as viewed facing downstream (8). See Upper Bank, Lower Bank, Left Channel Bank, and Right Channel Bank.

Bankfull Discharge. 1. Discharge that, on average, fills a channel to the point of overflowing. Commonly considered as the mean annual discharge, $Q_{2.33}$, or two- to three-year discharge, Q_2,

Q_3, in a channel that has been relatively stable for a number of years without the occurrence of a large, bank-destroying flood. 2. The discharge at which maximum sediment transport occurs.

Bankfull Stage. 1. Stage at which a stream first overflows its natural banks. Compare with Flood Stage. Bankfull stage is a hydraulic term, whereas flood stage implies damage (8). 2. The water elevation that reaches the top of the banks along a stream (6).

Barrel Width. The inside, horizontal extent of a drainage facility.

Basin, Detention. 1. A basin or reservoir incorporated into the watershed whereby runoff is temporarily stored, thus attenuating the peak of the runoff hydrograph. 2. A stormwater management facility that temporarily impounds runoff and discharges it through a hydraulic outlet control structure.

Basin, Infiltration. A basin or reservoir wherein water is stored for regulating a flood. It does not have an controlled outlet. The stored water is disposed by such means as infiltration, injection or dry wells, or by release to the downstream drainage system after the storm event. The release can be through a gate-controlled gravity system or by means of pumping.

Basin, Sedimentation. A basin or tank in which floodwater or stormwater containing settleable solids is retained to remove by means of gravity or filtration a part of the suspended matter.

Bed-Load Discharge. The quantity of bed load passing a cross section of a stream in a unit of time.

Berm. 1. A narrow shelf or ledge, also a form of dike, such as the space left between the upper edge of a cut and the toe of an embankment, or a horizontal strip or shelf built into an embankment to break the continuity of an otherwise long slope. 2. The top surface or plane of a shoulder, ledge, or bank constructed in connection with the roadway embankment at a bridge abutment, waste along a fill slope, or a canal or ditch bank.

Bridge, Relief. An opening through an embankment located on a floodplain for the purpose of permitting passage of overbank flow.

Carryover. See Flow, Bypass.

Catch Basin. A structure, sometimes with a sump, for inletting drainage from a gutter or median and discharging the water through a conduit. In common usage it is a grated inlet, curb opening, or combination inlet with or without a sump. A sump in a catch basin can cause environmental hazards by further polluting first-flush runoff and subsequent runoff passing through the catch basin.

Causeway. Rock or earth embankment carrying a roadway across water.

Check Dam. 1. A relatively low dam or weir across a channel for the diversion of irrigation flows from a small channel, canal, ditch, or lateral. 2. A low structure, dam, or weir, across a channel for the control of water stage or velocity, or the control of channel bank erosion and channel-bed scour from headcutting.

Check Dam, Modified. A modified check dam that is a runoff control structure, consisting of geotextile fabric, revetment riprap and a filter course of # 5 or 8 stone aggregate, placed across drainage channels to slow and filter storm water runoff.

Check Dam, Revetment. A check dam that is a runoff control structure, consisting of geotextile fabric and revetment riprap, placed across drainage channels to slow storm water runoff.

Check Dam, Traversable. A check dam that is a runoff control structure, consisting of soft material such as straw bales, fiber, rolls, or filter socks anchored in place across a drainage channel to slow and filter storm water runoff in areas where safety concerns or special site conditions exist.

Chemical Stabilization. Channel-bank protection technique involving the application of chemical substances to increase particle cohesiveness and to shift the size distribution toward the coarser fraction. The net effect is to improve the erosion resistance of the material.

Code of Federal Regulations, CFR. Federal regulations that are codified and published at least annually, and currently in force. The CFR is kept current through individual issues of the Federal Register. The two publications should be used together to determine the latest version of a given rule.

Confluence. The junction of two or more streams.

Construction in a Floodway, CIF, Permit. A permit required from IDNR for such construction if the drainage area is 50 sq mi or greater in a rural area, or 1 sq mi or greater in an urban area.

Continuity Equation. Discharge equals velocity times cross section area, $Q = VA$. For steady flow there is a continuity of discharge through succeeding sections of channel, expressed as: $Q = A_1V_1 = A_2V_2 = A_nV_n$ = a constant.

Contracted Section. A cross section at the narrowing of the natural channel, typically near a bridge or culvert.

Conveyance. 1. A measure of the ability of a stream, channel, or conduit to convey water. 2. A comparative measure of the water-carrying capacity of a channel; that portion of the Manning discharge formula that accounts for the physical elements of the channel. 3. A measure of the water-transporting capacity of a channel, floodplain, drainage facility, storm drain, or other natural or artificial watercourse feature traversed by flow such as runoff or irrigation water. For the design storm(s), conveyance can include that associated with overtopping flow and flood plain relief at a cross-drainage structure.

Cost-Effective. 1. A measure of a drainage-design strategy's acceptability is based on a judgment where either expected first costs or, where appropriate, the economic analysis costs are weighed against the selected design criteria. 2. The relationship between the benefits derived from a system and the cost of purchasing, operating, and maintaining it (6).

Countermeasure. A measure, either incorporated into the design of a drainage facility or installed separately at or near the facility that serves to prevent, minimize, or control hydraulic problems.

Cover. The vertical extent of soil above the crown of a pipe or culvert to the bottom of the pavement.

Critical Depth. Where the energy head is a minimum and the velocity head equals one-half the mean depth, the corresponding depth is Belanger's critical depth (3). The depth at which the specific energy, equal to depth plus velocity head, for a particular discharge is a minimum. It is the depth at which, for a given energy content of the water in a channel, maximum discharge occurs or the depth at which, in a given channel, a given quantity of water flows with minimum content of energy.

Cutoff Wall. A wall, usually constructed of sheet piling or concrete, that extends from the end of a drainage structure or flow line downward to prevent structure undermining.

D_{50}. Median size of riprap or granular material. The particle diameter at the 50-percentile point on a size-versus-weight-distribution curve such that half of the particles, by weight, are larger and half are smaller.

Deposition. The settling of material from the stream flow onto the bed.

Depth, Normal. 1. The depth of water in an open conduit that corresponds to uniform velocity for the given flow. It is a hypothetical depth under conditions of steady non-uniform flow. 2. The depth for which the water surface and bed are parallel. Normal depth and velocity apply only to uniform flow with a free water surface.

Depth, Outlet. The depth of water in an open conduit at the downstream end.

Design Criteria. Criteria, coupled with prudent judgmental factors, that are used to design a drainage facility.

Design Discharge. 1. The maximum rate of flow or discharge for which a drainage facility is designed, and thus expected to accommodate without exceeding the adopted design constraints. 2. The maximum flow that a bridge, culvert, or other drainage facility is expected to accommodate without contravention of the adopted design criteria. 3. The peak discharge, volume, stage, or wave-crest elevation, and its associated probability of exceedence selected for the design of a roadway culvert or bridge over a channel, floodplain, or along a shoreline. See Exceedance Probability.

Dike. An impermeable linear structure for the containment or control of overbank flow. It trends parallel with a river bank and differs from a levee only in that a dike extends for a much shorter distance along the bank.

Dike, Spur. An outdated term for a guide bank.

Discharge. Volume of water passing a point during a given time.

Diversion Interceptor. A storm water control structure consisting of a temporary ridge, excavated channel, or combination of a channel and supporting ridge constructed on a predetermined grade across a slope to collect storm water runoff and divert it to a treatment device or stable outlet.

Drainage Area. The catchment area for rainfall or other forms of precipitation that is delineated as the drainage area producing runoff, i.e., contributing drainage area. Also known as drainage basin or watershed.

Drainage Divide. 1. The rim of a drainage basin. 2. The divide separating one drainage basin from another.

Drain, Storm. A conduit for carrying off stormwater.

Drawdown. The difference in elevation between the water-surface elevation at a constriction in a stream or conduit and the elevation that exists if the constriction were absent. Drawdown also occurs at a change from a mild to a steep channel slope or at a weir or vertical spillway.

Economic Analysis. A probabilistically-based analysis that compares the estimated construction costs with the expected average flood-related operational costs and risks that can be quantified for the anticipated service life of a project to identify an optimum design flood frequency.

Economic Assessment. A less rigorous, more judgmental economic analysis.

Eminent Domain. In law, the right of a government to take or to authorize the taking of private property for public use, just compensation being given to the owner.

Encroachment. Construction within the limits of a floodplain. A longitudinal encroachment roughly parallels a channel or floodplain. A transverse encroachment crosses a channel or floodplain.

End Section. A structure, commonly made of concrete or metal, that is attached to the end of a culvert for retaining the embankment from spilling into the waterway, improving the appearance, providing anchorage, improving the discharge coefficient, or limiting some scour at the outlet.

Energy Dissipation. The phenomenon whereby energy is dissipated or used up. In highway drainage, this is the energy in flowing water.

Energy Grade Line. 1. A line joining the elevation of energy heads of a stream. 2. A line drawn above the hydraulic grade line a distance equivalent to the velocity head of the flowing water at each cross section along a stream or channel reach or through a conduit. 3. An inclined line representing the total energy of a stream flowing from a higher to a lower elevation. 4. An energy gradient. 5. The slope of the energy line with reference to a plane or, more simply, the slope of the energy grade line. 6. The slope of this line represents the rate of loss of head, and it should always slope downward in the direction of flow. Compare with Hydraulic Gradient and Friction Slope.

Entrance Head. 1. The head required to cause flow into a conduit or other structure. It includes both entrance loss and velocity head. Equivalent to headwater height. 2. Energy head at approach section to culvert or bridge.

Entrance Loss. The head lost in an eddy and friction at the inlet to a conduit or structure, expressed as a coefficient, K_e.

Equalizer. An opening, such as a culvert or bridge, placed where it is desirable to equalize the water level on both sides of an embankment.

Equivalent Diameter. The diameter of a circular pipe that has the same area as a known deformed pipe.

Erosion. 1. Displacement of soil particles on the land surface due to water or wind action. 2. The wearing away or eroding of material on the land surface or along channel banks by flowing water or wave action on a shore.

Exceedance Probability (EP). Probability that a random event will exceed a specified magnitude in a given time period, usually one year unless otherwise indicated (7).

Field Data. All stormwater data collected in the field regardless of whether or not it was analyzed in the field (1).

Fill Slope. Side or end slope of an earth-fill embankment. Where a fill slope forms the streamward face of a spillthrough abutment, it is regarded as part of the abutment.

Filter. 1. A layer of synthetic fabric, sand, gravel, or graded rock placed, or developed naturally where suitable in-place materials exist, between the bank revetment and soil, to prevent the soil from moving through the revetment by means of piping, extrusion, or erosion (exfiltrating); to prevent the revetment from sinking into the soil; or to permit natural seepage from the stream bank, thus preventing buildup of excessive hydrostatic pressure. 2. A device or structure for removing solid or colloidal material from stormwater and floodwater or preventing the migration of fine-grained soil particles as water passes through soil, that is, water is passed through a filtering medium, usually a granular material or finely woven or non-woven geotextile. Depending on context, can be used to remove material other than soils from a substance.

Flood. An event that overflows the normal flow banks or runoff that has escaped from a channel or other surface waters. In technical usage, it refers to a given discharge based, typically, on a statistical analysis of an annual series of events.

Floodplain. 1. A plain that borders a stream and is covered by its waters in time of flood. Topographic area adjoining a channel that is covered by flood flows and those areas where the path of the next flood flow is unpredictable, such as a debris cone, alluvial fan, or braided channel. 2. A nearly flat, alluvial lowland bordering a stream and formed due to stream processes, that is subject to inundation by floods.

Flow, Bypass. Flow that bypasses an inlet on grade and is carried in the street or channel to the next inlet downstream. Also termed carryover.

Flow Distribution. The estimated or measured spatial distribution of the total streamflow from the landward edge of one floodplain or stream bank to the landward edge of the other floodplain or stream bank.

Flow, Gradually-Varied. Flow in which changes in depth and velocity take place slowly over large distances, resistance to flow dominates, and acceleration forces are neglected.

Flowline. 1. The line or path, such as a rill, connecting the lowest flow points along the bed of a channel. The line does not include local depressions. 2. The path that very low flow follows in proceeding down a stream, river, swale, or channel. 3. The line extending along a channel profile that follows the lowest elevation of the bed. Also known as thalweg.

Fluvial Geomorphology. A study of the structure and formation of the earth's features that result from the forces of water. Sometimes incorrectly identified in discussions to morphology.

Freeboard, Channel. The difference between the water surface elevation and the top of bank in a channel.

Freeboard, Serviceability. The difference between the headwater elevation and the edge of pavement on a roadway.

Freeboard, Structural. Vertical clearance between the Q_{100} elevation and the lowest structural member of a bridge superstructure, the culvert soffit.

Free-Water Surface. The water surface of flow in an open channel or in a closed conduit not flowing full.

Friction Loss, or Head. The head or energy loss as the result of disturbances set up due to the contact between a moving stream of water and its containing conduit.

Froude number, F_r. 1. A dimensionless number that represents the ratio of inertial to gravitational forces, i.e., at a Froude number of 1 the flow velocity and wave celerity are equal. A high Froude number can be indicative of a high velocity associated with supercritical flow and thus the potential for scour and high momentum forces. 2. A number that varies in magnitude inversely with the relative influence of gravity on the flow pattern. $F_r > 1$ indicates rapid, or supercritical, flow. $F_r < 1$ indicates tranquil, or subcritical, flow.

Gabion. A rectangular basket made of steel wire fabric or mesh that is filled with rock or similar material of suitable size and gradation. It is used to construct a flow-control structure, bank protection, groin, jetty, permeable dike, or riparian spur dike. If filled with cobbles, masonry remnants, or other rock of suitable size and gradation, the gabion becomes a flexible and permeable block with which the foregoing structures and devices can be built.

Gage, or Gauge. 1. A staff graduated to indicate the elevation of a water surface. 2. A device for registering water level, flow, velocity, or pressure.

Gaging Station. A particular site on a stream, canal, lake, or reservoir where systematic observations of gage height or discharge are obtained (9). Used synonymously with gage (8).

Geotextile. Fabric material that is used under the placement of riprap for soil stabilization.

Groundwater. 1. Subsurface water occupying the saturation zone, from which wells and springs are fed. 2. A source of base flow in a stream. The term applies only to water below the water table.

Grout. A fluid mixture of cement and water, or of cement, sand, and water used to fill joints and voids.

Guide Bank. Formerly termed spur dike. Relatively short embankment in the shape of a quarter of an ellipse and constructed at the upstream side, or sometimes the downstream side, of either or both bridge ends as an extension of the abutment spillslope. The purpose is to align the flow with the bridge opening so as to decrease scour at the bridge abutment by spreading the flow and resultant scour throughout the bridge opening.

Gutter. That portion of the roadway section adjacent to the curb that is utilized to convey stormwater runoff.

Head. 1. The height of water above a point, plane, or datum of reference. Used also in computations as energy head, entrance head, friction head, static head, pressure head, lost head, etc. 2. The height of the free surface of a body of water above a given point.

Headcut. 1. Channel degradation associated with abrupt changes in the bed elevation, or headcut, that migrates in an upstream direction. 2. Channel-bed erosion moving upstream through a basin indicating that a readjustment of the basin’s profile slope, channel discharge, and sediment load characteristics is taking place.

Headwall. The structural appurtenance usually applied to the end of a culvert inlet and outlet or stormdrain outlet to retain an adjacent highway embankment and protect the culvert ends or storm-drain outlet and highway embankment or storm-drain outfall from bank erosion or channel-bed scour.

Headwater Depth. 1. Depth of water above the inlet flow line at the entrance of a culvert or similar structure. 2. Natural flow depth plus backwater caused by a drainage structure. 3. The depth of water impounded upstream of a culvert, bridge, or similar contracting structure due to the influence of the structures constriction, friction and configuration.

High-Water Elevation. The water surface elevation that results from the passage of flow. It may be an observed high-water-mark elevation as a result of someone actually viewing and recording a runoff event or a calculated high-water elevation as part of a design process.

High-Water Mark. A mark left as evidence of the height to which a flood reached, usually in the form of deposited sediment, debris, or detritus.

Historical Flood. 1. A past flood event of known or estimated magnitude. 2. A known flood event predating systematic flow measurements at a given site.

Hydraulic Grade Line. 1. In a closed conduit, a line joining the elevation to which water can stand in risers. In an open conduit, the hydraulic grade line is the water surface. 2. In open-channel flow, it is the water surface.

Hydraulic Jump. The sudden and usually turbulent passage of water from a stage below critical depth, or supercritical flow, to a stage above critical depth, or subcritical flow, during which the velocity passes from supercritical to subcritical.

Hydraulic Radius. The cross section area of a stream divided by its wetted perimeter.

Hydrograph. By definition, a hydrograph is a plot of the variation of discharge with respect to time. It can also be the variation of stage or other water property with respect to time. Discharge is the volume of water flowing past a location per unit time, usually in cubic feet per second (cfs).

Hydrograph, Unit. The hydrograph of direct runoff from a storm uniformly distributed over the drainage basin during a specified unit of time. The hydrograph is reduced in vertical scale to correspond to a volume of runoff of 1 in. from the drainage basin (2).

Hydrologic Soil Group. A group of soils having the same runoff potential under similar storm and cover conditions (10).

Infiltration. The downward entry of water into the soil or rock (11).

Infiltration Rate. The rate at which water enters the soil under a given condition. The rate is expressed in inches per hour, feet per day, or cubic feet per second.

Inflow. The rate of discharge arriving at a point in a stream, structure, or reservoir.

Inlet. 1. A surface connection to a closed drain. 2. A structure at the diversion end of a conduit. 3. The upstream end of a structure through which water can flow. 4. An inlet structure for capturing concentrated surface flow.

Inlet Control. A condition in which the relation between headwater elevation and discharge is controlled by the upstream end of a structure through which water may flow. For example, a culvert on a steep slope and flowing partly full is operating under inlet control.

Inlet, Drop. Drainage structure with a vertical fall used as an energy dissipator.

Inlet Efficiency. The ratio of flow intercepted by an inlet to the total flow.

Inlet, Flanking. Inlets placed upstream and on either side of a storm-drain inlet that is located at the low point in a sag vertical curve.

Inlet, Improved. Flared, depressed, or tapered culvert inlet that decreases the amount of energy needed to pass the flow through the inlet and thus increase the capacity of a culvert with inlet control or supercritical flow. Improved inlets are generally used when there are potential problems due to backwater elevation and other factors such as road profile are fixed.

Inlet, Mitered. A flush-entrance culvert where the barrel is mitered to the slope of the embankment.

Inlet, Projecting. The culvert barrel projects beyond the plane of the slope or headwall, sometimes referred to as a re-entrant entrance.

Inlet, Square-Edged. An approximately 90-deg corner formed by the inside of the barrel and the upstream end of a culvert. Small chamfers ordinarily used in concrete construction are considered as producing a square-edged entrance, i.e., no hydraulic improvement.

Inlet, Tapered. A type of culvert design having an entrance face area larger than the main barrel.

Invert. The lowest point in a pipe or culvert.

Karst Topography. Irregular topography characterized by sinkholes, streamless valleys, or streams that disappear into the underground, all developed by the action of surface and underground water in soluble rock such as limestone.

Lag Time, TL. 1 The difference in time between the centroid of the excess rainfall producing runoff and the peak of the runoff hydrograph. Often estimated as 60% of the time of concentration, or TL = $0.6T_c$ (10).

Land Use. A term that relates to both the physical characteristics of the land surface and the human activities associated with the land surface (1).

Levee. 1. An embankment, generally landward of a top bank, that confines flow during high-water periods, thus preventing overflow into lowlands. 2. A linear embankment outside a channel for containment of flow (compare to Dike).

Manhole. A structure through which one can access a drainage system.

Mitigation. 1. The act of lessening, offsetting, or compensating an impact on surface waters. To moderate a qualifying or condition in force or intensity. 2. To decrease or rectify an adverse condition or action.

Navigable Waters. A regulatory term as it applies to highway-drainage planning, design and construction in jurisdictional surface waters, as waters of the United States including the territorial seas.

Normal Flow. 1. Flow at normal depth. 2. Average flow prevailing during the greater part of the year.

Open-Channel Flow. Flow in an open or closed conduit where the water surface is free, at atmospheric pressure.

Ordinary High Water. The Ordinary High Water Mark means that line on the shore of a waterbody established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, natural destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.

Outfall. The point where water flows from a conduit, the mouth or outlet of a drain or sewer, or drainage discharges from a channel or storm drain.

Outlet Control. A condition where the relation between headwater elevation and discharge is controlled by the conduit, outlet, or downstream conditions of a structure through which water can flow.

Peak Discharge. Maximum discharge rate on a runoff hydrograph for a given flood event.

Piping. The action of water passing through or under an embankment and carrying some of the finer material with it to the surface at the downstream face. Removal of soil material through subsurface flow or seepage water that develops channels or pipes within the soil bank.

Rainfall Intensity. Amount of rainfall occurring in a unit of time, converted to its equivalent in inches per hour at the same rate.

Reach. 1. A segment of stream or valley, selected with arbitrary bounds for purposes of study. 2. A comparatively short length of a stream or channel.

Receiving Stream. A natural body of water that one or more catchments enters into.

Regional Analysis. Flood-frequency-relationship line for a gaged watershed in a similar homogeneous physiographic area or region is used to develop a flood-frequency line for an ungaged watershed in that same region.

Regulatory Floodway. The floodplain area that is reserved in an open manner by Federal, State, or local requirements, i.e., unconfined or unobstructed either horizontally or vertically, to provide for the discharge of the base flood so that the cumulative increase in water surface elevation is not more than a designated amount.

Reservoir Routing. 1. Flood routing through a reservoir (10). 2. Flood routing of a hydrograph through a reservoir taking into account reservoir storage, spillway, and outlet-works discharge relationships.

Revetment. Rigid or flexible armor placed on a bank or embankment as protection against scour and lateral erosion.

Sand. 1. Soil material that can pass the No. 4 U.S. Standard Sieve and can be retained on the No. 200 sieve [FHWA, HIRE, 1987]. 2. Granular material that is smaller than 0.08 in. and coarser than 0.0024 in. [FHWA, HIRE, 1990].

Scour. 1. The displacement and removal of channel-bed material due to flowing water, usually considered as being localized as opposed to general bed degradation or headcutting. 2. The result of the erosive action of running water that excavates and carries away material from a channel bed.

Scour, Contraction. The response of a river or drainage facility such as bridge to the change in its bed load requirement as a result of a natural or constructed contraction of flow, i.e., the flow contraction is due to an encroachment of either the main channel or the floodplain by a natural constriction or the highway embankment.

Scour Depth. The vertical distance that a streambed is lowered by scour below the flowline elevation.

Scour, Pier. . 1. Scour in a channel or on a floodplain that is localized at a pier.

Sediment. Fragmental material that originates from weathering of rocks and is transported by, suspended in, or deposited by water or air, or is accumulated in a bed by other natural agencies (4).

Sediment Trap. A temporary sediment trap is a sediment control structure consisting of a small, temporary settling pool formed by constructing an embankment and/or excavated basin with an outlet control structure.

Sewer, Combined. A sewer that conveys stormwater and, at times, sanitary sewage.

Sheet Flow. See Flow, Overland.

Shoulder. The portion of the roadway contiguous with the traveled way for accommodating stopped vehicles, for emergency use, or for lateral support of the road's base and surface courses.

Side Slope. The slope of the sides of a embankment or bridge abutment, measured as a horizontal distance to vertical distance, i.e., 2:1.

Silt. 1. Material passing the No. 200 U.S. Standard Sieve that is nonplastic or very slightly plastic and exhibits little or no strength if air-dried. 2. According to the Unified Soil Classification System, material finer than 0.0025 in. and coarser than 0.00015 in.

Sinuosity. The ratio of the length of a river thalweg to the length of the valley proper.

Skew. The measure of the angle of intersection between a line normal to the roadway centerline and the direction of the flow in a channel at flood stage in the linear direction of the main channel.

Soffit. The inside top of a culvert.

Soil. Finely-divided material composed of disintegrated rock mixed with organic matter, as the loose surface material in which plants grow.

Soil-Cement. A designed mixture of soil and portland cement compacted at a proper water content to form a veneer or structure that can prevent the erosion of a channel bank, dam face, or inlet and outlet of a drainage structure.

Spillthrough Abutment. A bridge abutment having a fill slope on the channel side. The term originally referred to the spillthrough of fill at an open abutment but is now applied to each abutment having such a slope.

Spillway, Emergency. A rock or vegetated earth waterway around a dam, built with its crest above the normally used principal spillway. Used to assist or supplement the principal spillway in conveying extreme amounts of runoff safely past the dam so as to minimize damage and flood hazards (10).

Spillway, Principal. Conveys all ordinary discharges coming into a reservoir and the portion of an extreme discharge that does not pass through the emergency spillway or outlet works.

Spread. 1. The accumulated flow in and next to the roadway gutter. 2. The transverse encroachment of stormwater onto a street. This water often represents an interruption to traffic flow, splash-related problems, and a source of hydroplaning during a storm. 3. The lateral distance of roadway ponding extending out from the curb or edge of the traveled way.

Spread Footing. A pier or abutment footing that transfers load directly to the earth.

Stage. Height of water surface above a specified datum.

Stage-Discharge Curve. A graph showing the relation between the gage height, and the amount of water flowing in a channel, expressed as volume per unit of time (8).

Stage-Storage Curve. A graph showing the relation between the surface elevation of the water in a reservoir, plotted as ordinate, against the volume below that elevation, plotted as abscissa, or the amount of water flowing in a channel, expressed as volume per unit of time, plotted as abscissa. Compare with Stage-Discharge Curve and Rating Curve.

Stilling Basin. A device or structure placed at or near the outlet of a structure for the purpose of inducing energy dissipation where flow velocity is expected to cause unacceptable channel-bed scour and bank erosion.

Storage. Water detained in a drainage basin, such as groundwater, channel storage, or depression storage. The term drainage-basin storage or basin storage is used to refer collectively to the amount of water in storage in a drainage basin.

Stream. A general term for a body of flowing water.

Stream-Bank Erosion. Removal of soil particles or a mass of particles from a bank surface due primarily to water action. Other factors such as weathering, ice and debris abrasion, chemical reactions, and land-use changes can also directly or indirectly lead to stream-bank erosion.

Stream-Bank Protection. A technique used to prevent erosion or failure of a channel bank.

Stream, Braided. A stream whose surface is divided at normal stage with small middle bars or small islands.

Stream Gaging. The process and art of measuring the depth, area, velocity, and rate of flow in a natural or artificial channel (5).

Stream-Gaging Station. A gaging station where a record of discharge of a stream or river is obtained. This term is used only for a gaging station where a continuous record of discharge is obtained (8).

Stream, Intermittent. A stream that flows only at certain times of the year once it receives water from a spring or from a surface source such as melting snow in a mountainous area (8).

Stream Reach. A length of stream channel selected for use in hydraulic or other computations (10).

Submerged Inlet. An inlet of a culvert-like structure having a headwater greater than approximately 1.2D, where D is the culvert rise.

Submerged Outlet. A culvert-like outlet having a tailwater elevation greater than the soffit of the culvert.

Substructure. All of the structure below the bearings of simple or continuous spans, skewbacks of arches and tops of footings or rigid frames, together with the backwalls, wingwalls, and wing-protection railings.

Superelevation. 1. The increase in water-surface elevation at the outside of an open-channel bend. 2. A transverse tilting of the channel bed in a lined channel with predominately supercritical flow.

Superflood. A 0.2% Annual EP flood.

Surcharge. Increase in headwater elevation above existing conditions.

Swale. 1. A wide, shallow ditch usually grassed or paved and without well-defined bed and banks. 2. A slight depression in the ground surface where water collects and that can be transported as a stream. Often vegetated and shaped so as not to provide a visual signature of a bank.

Synthetic Mattress, Matting, or Tubing. A grout, or sand-filled, manufactured, semiflexible casing placed on a channel bank to prevent erosion.

Tailwater, TW. The depth of flow in a channel directly downstream of a drainage facility. Often calculated for the discharge flowing in the natural stream without the highway effect.

Time of Concentration, T_c. The time required for water to flow from the farthest point on the watershed to the measuring point.

Toe. The portion of a stream cross section where the lower bank terminates and the channel bottom or the opposite lower bank begins.

Tractive Force. The drag on a stream bank caused by passing water that tends to pull soil particles along with the streamflow.

Travel Time. The average time for water to flow through a reach or other stream or valley length that is less than the total stream or valley length. Travel time is part of T_c, but not all of it (10).

Tributary. A lesser branch of a watershed-stream system.

Two-Dimensional Water-Surface Profile. An estimated water-surface profile that recognizes flow only in the upstream-downstream and transverse direction. Vertical velocity vector components are ignored.

Vertical Abutment. An abutment, usually with wingwalls, that has no fill slope on its channel side. See Abutment. Compare with Spillthrough Abutment.

Watershed. See Drainage Area.

Water-Surface Elevation. A point on the water-surface profile at a specific location of interest.

Water-Surface Profile. A graph of water levels plotted against stream distance at a particular time or for a particular condition, such as for a flood peak or for a low-flow period.

Waterway-Opening Area. Area of bridge opening at or below a specified stage, measured perpendicular to principal direction of flow.

Wave Attack. Impact of waves on a channel bank or shore.

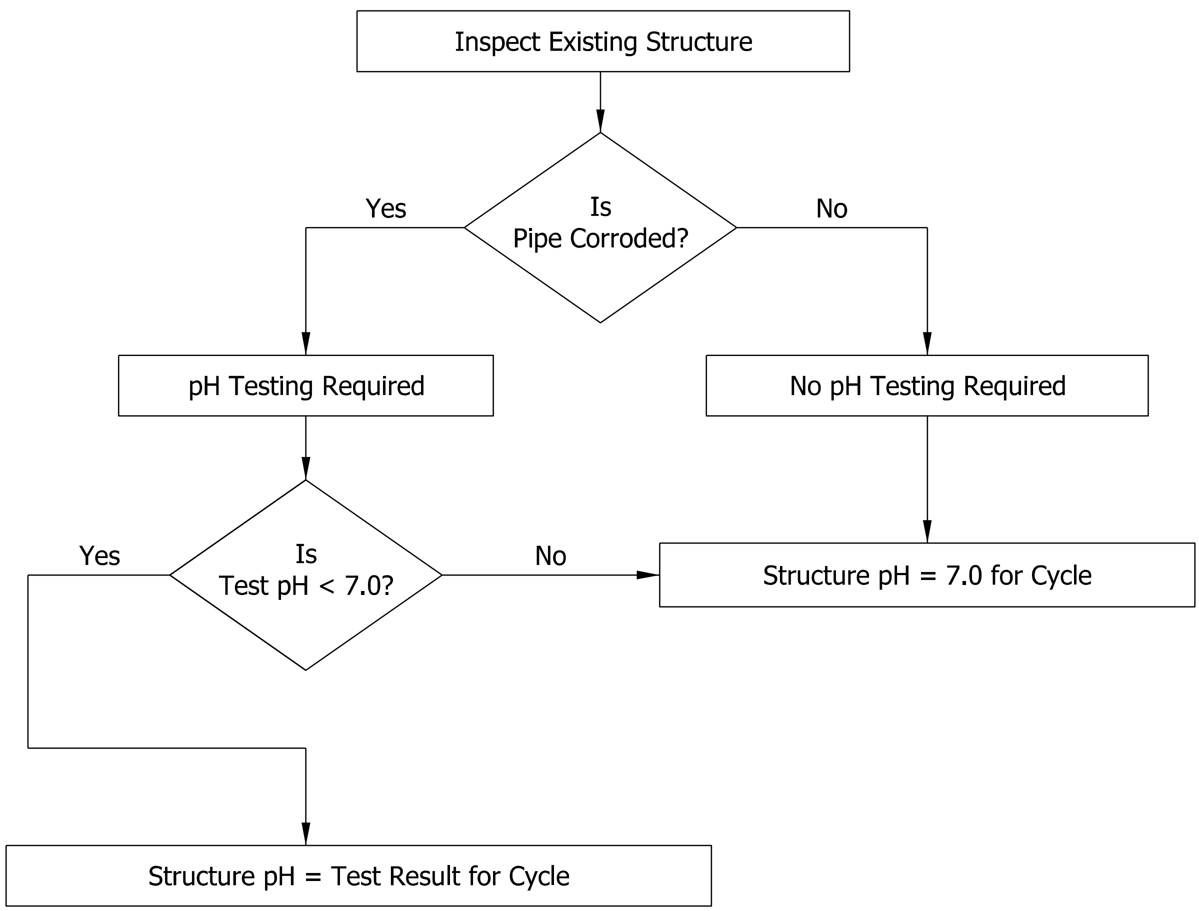
Wave Run-Up. Height to which water rises above still-water level where waves meet a beach, wall, embankment, or causeway.

Wetted Perimeter. The length of the wetted contact between a stream and its containing conduit, measured along a plane at right angles to the flow in question.

201-3.0 NOTATIONS

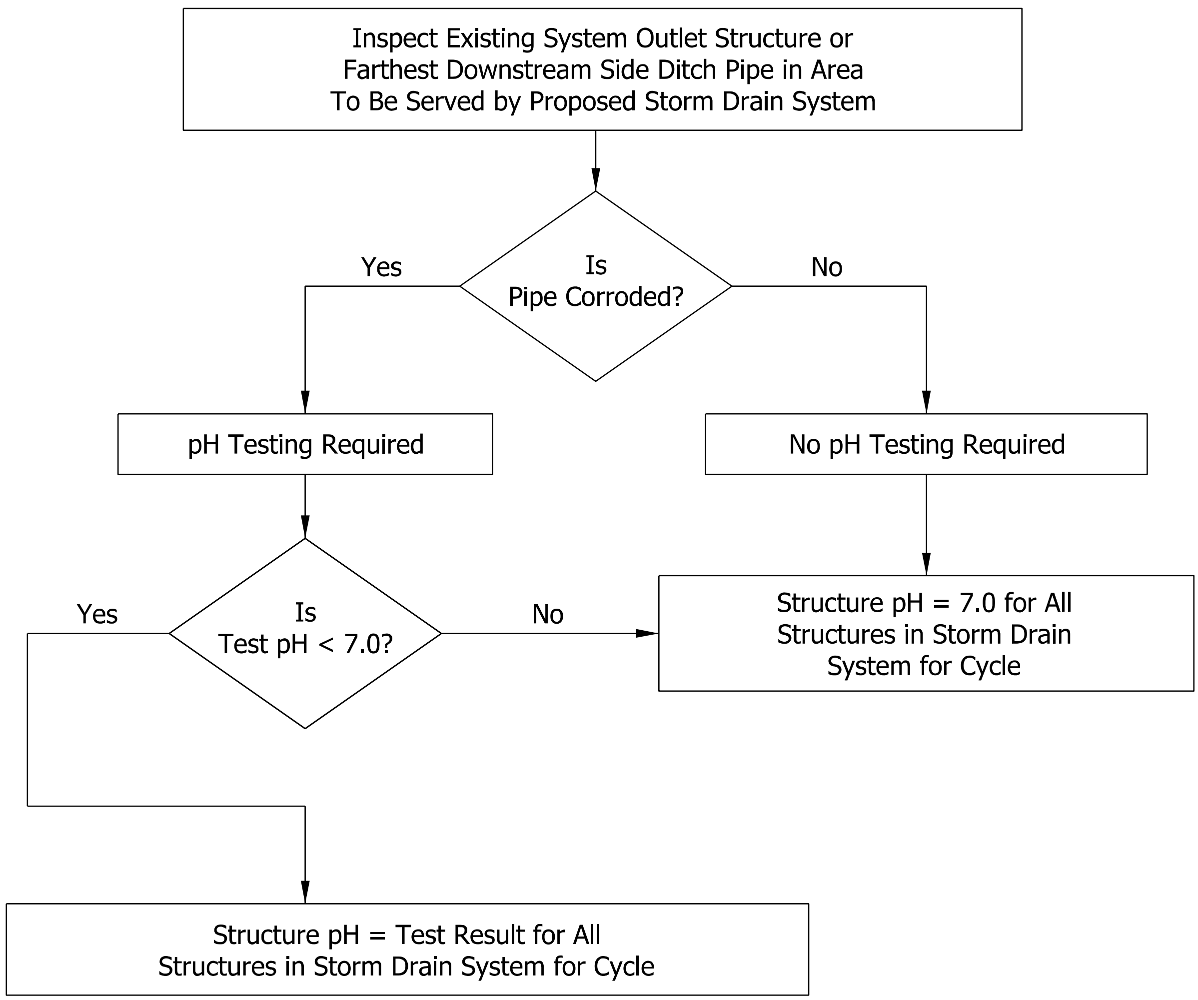
A	Area of pipe, ft^2
A	Algebraic difference in approach grades, %
A	Cross sectional area of the channel, ft^2
A_B	Amount of assessment to beneficiary
C	Rational Method Coefficient reflecting land use and soil type
C_F	Cost of drainage facility
CN	Curve Number
D	Maximum depth of flow in the channel for the design discharge, ft
D	Diameter of circular pipe, ft
d_{50}	Median particle or rock diameter
D_E	Equivalent diameter
d_{max}	Maximum particle or rock diameter

EP	Exceedance probability
F_r	Froude number
G	Longitudinal road profile grade, %
h_s	Dissipator pool depth, ft
I	Intensity, in./h
K	Flanking inlet spacing coefficient
K_e	Entrance Loss Coefficient
L	Length of the vertical curve, ft
L	Flow length, ft
L_B	Length of basin
L_s	Length of dissipating pool
n	Manning's roughness coefficient for sheet or channel flow
P_2	2-year, 24-h rainfall, in., from NOAA Atlas 14
P_w	Wetted Perimeter, ft
Q	Flow Rate, ft^3/s
Q_{OR}	Discharge from storm sewer draining from outside INDOT right of way
Q_T	Total discharge of drainage facility
R	Hydraulic Radius, ft
r	Hydraulic Radius, ft
s	Watercourse slope, ft/ft
S	Watercourse slope, ft/ft
S_x	Gutter cross slope, ft/ft
T	Riprap or revetment thickness
T	Water spread, ft
t_c	Time of Concentration, h or min
t_O	Overland flow time,
T_t	Total travel time, h or min
TW	Tailwater depth
V	Average velocity, ft/s
V_B	Basin exit velocity
W_o	Width of culvert opening
y_o	Outlet depth, also known as y_e
γ	Unit weight of water, 62.4 lb/ft^3
τ	Shear stress in channel at maximum depth, lb/ft^2
τ_p	Permissible shear stress, lb/ft^2



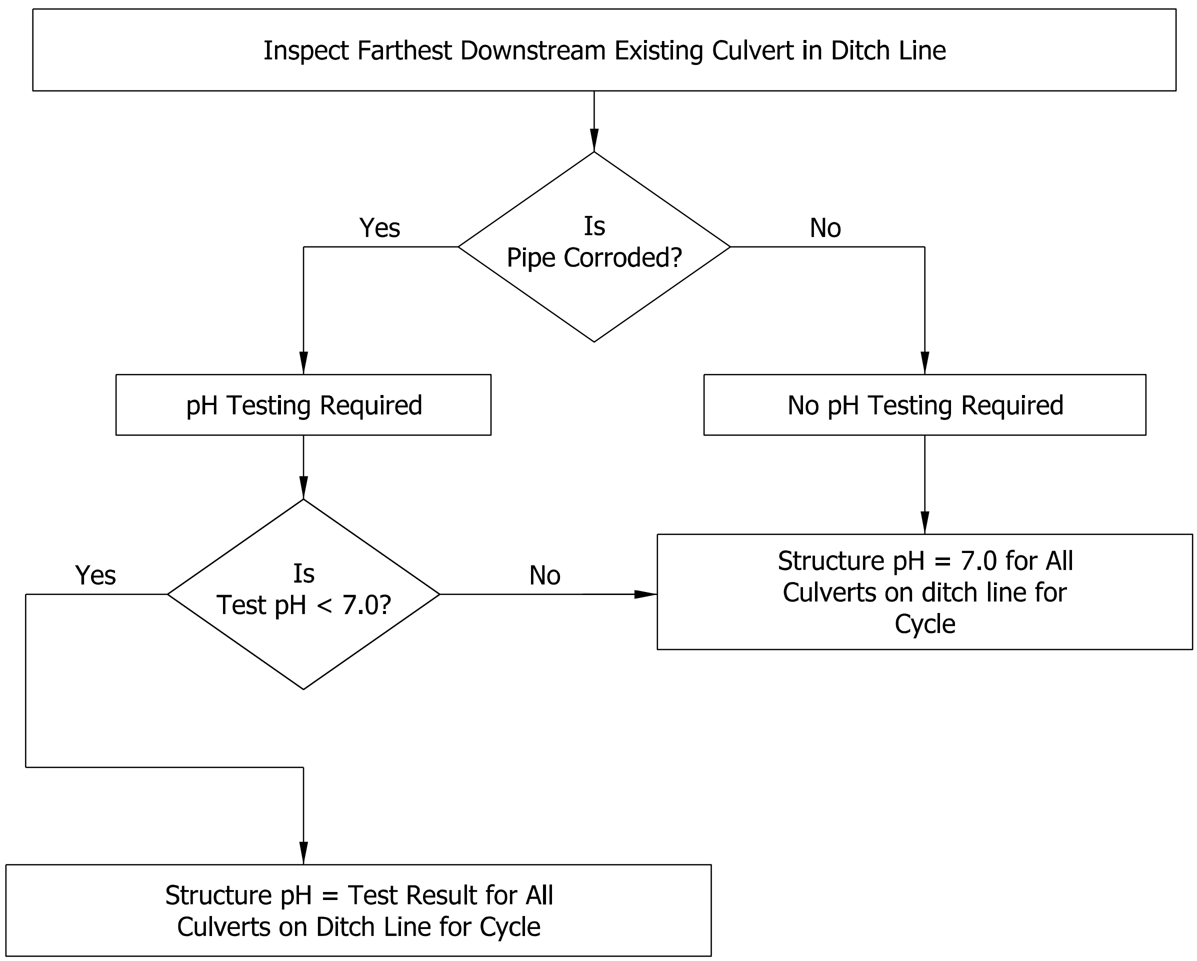
STRUCTURE pH DETERMINATION PROCEDURE
Proposed Mainline Culverts and Other Culverts in Natural Channels
Project in Area Where Map pH = 7.0

Figure 201-1A



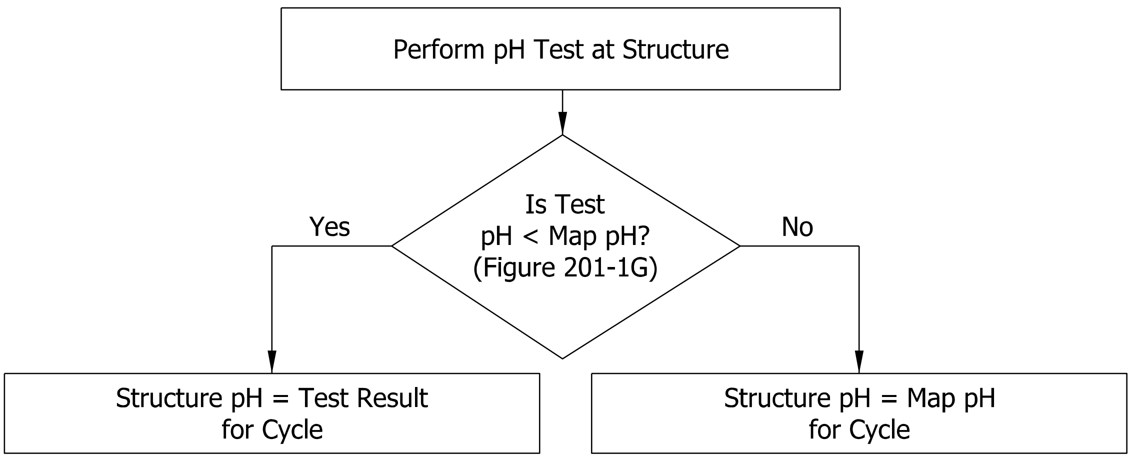
STRUCTURE pH DETERMINATION PROCEDURE
Proposed Storm Drain Structures
Project in Area Where Map pH = 7.0

Figure 201-1B



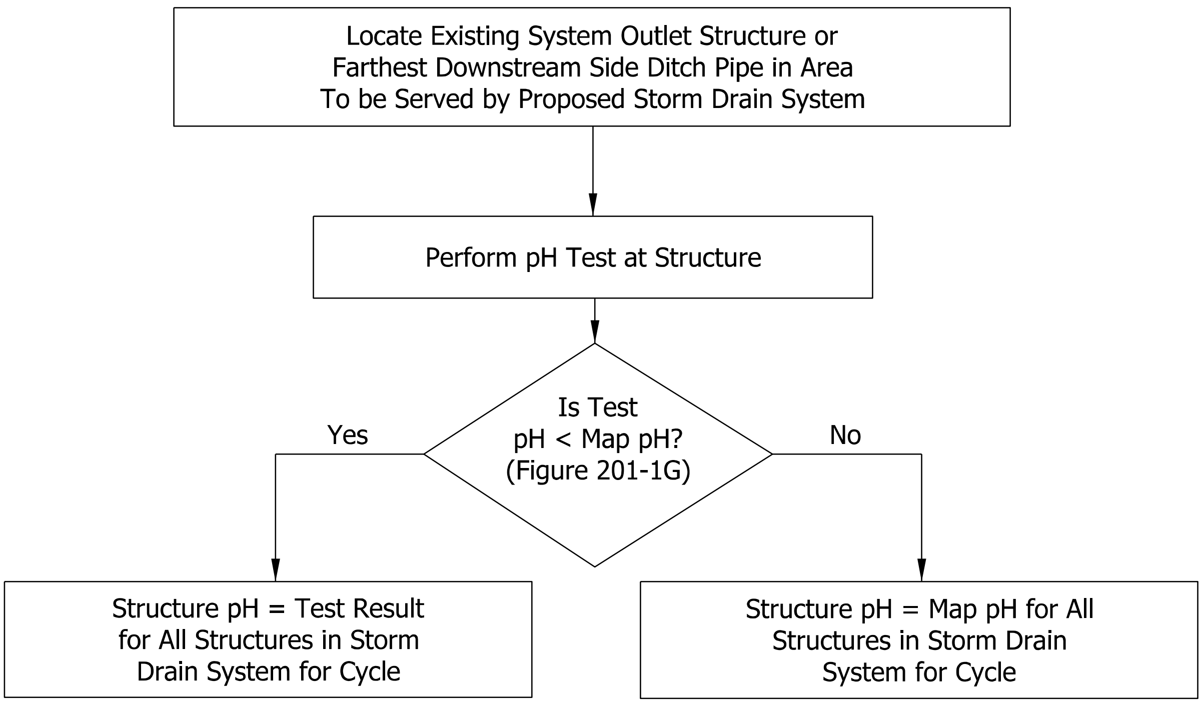
STRUCTURE pH DETERMINATION PROCEDURE
Proposed Side Ditch Culverts
Project in Area Where Map pH = 7.0

Figure 201-1C



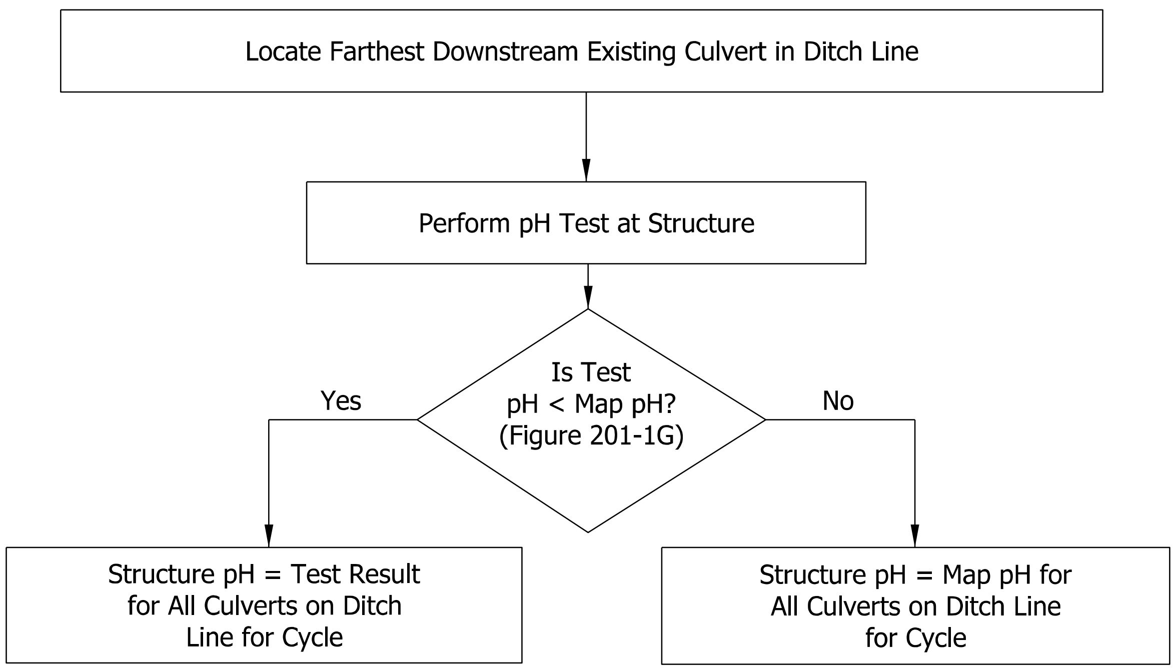
STRUCTURE pH DETERMINATION PROCEDURE
Proposed Mainline Culverts and Other Culverts in Natural Channels
Project in Area Where Map pH = 7.0

Figure 201-1D



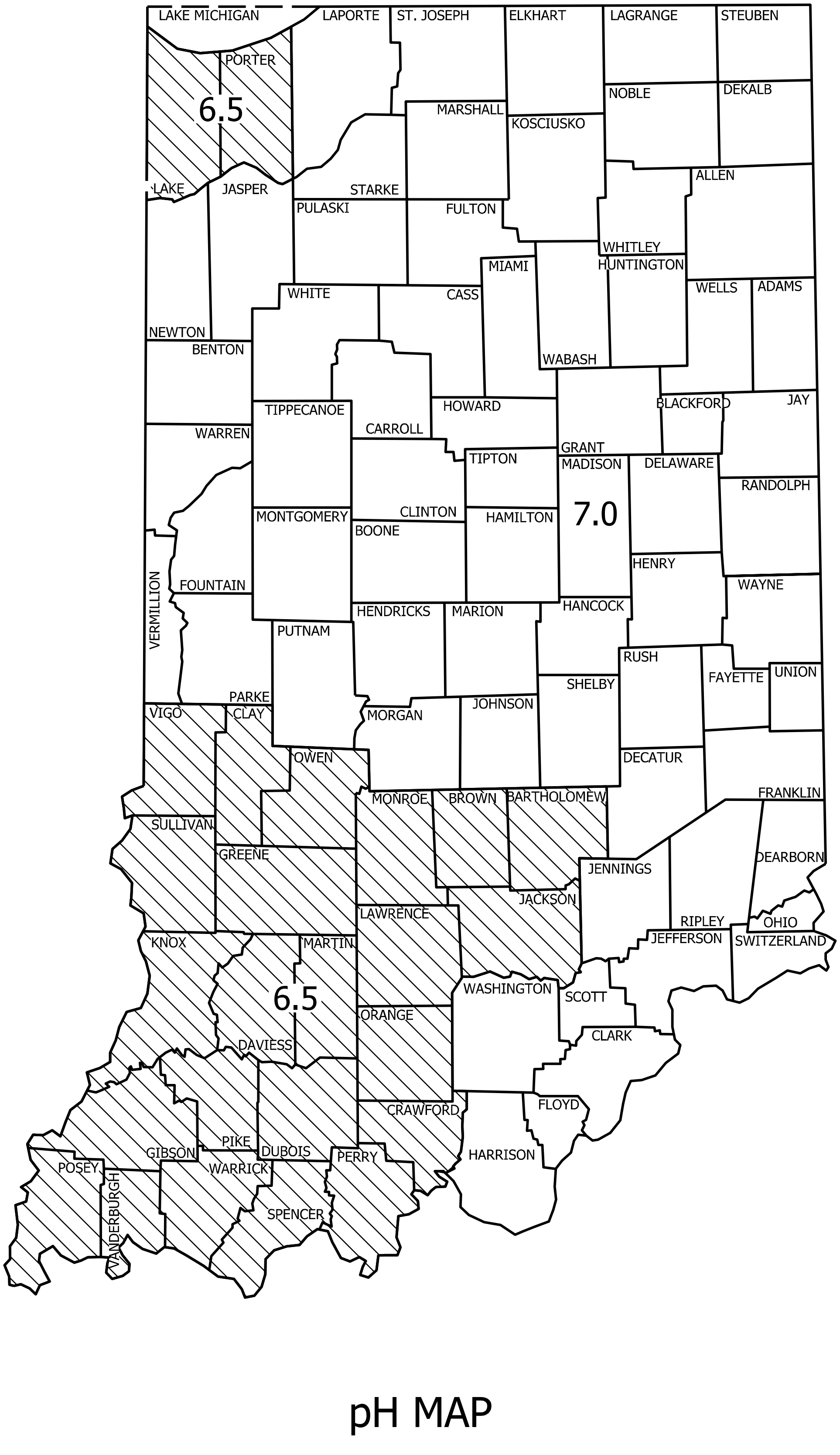
STRUCTURE pH DETERMINATION PROCEDURE
Proposed Storm Drain Structures
Project in Area Where Map pH = 7.0

Figure 201-1E



STRUCTURE pH DETERMINATION PROCEDURE
Proposed Side Ditch Culverts
Project in Area Where Map pH = 7.0

Figure 201-1F



pH MAP

Figure 201-1G