Chapter Forty

GENERAL DRAINAGE PROCEDURES

BUREAU OF DESIGN AND ENVIRONMENT MANUAL

Chapter Forty
GENERAL DRAINAGE PROCEDURES

Table of Contents

Chapter Forty
GENERAL DRAINAGE PROCEDURES

This Chapter provides guidance on the drainage requirements of projects designed for the State highway system. It discusses the division of responsibility between the districts and the Central Office, general drainage policies, design criteria, and the content of drainage studies for various project types.

The *IDOT Drainage Manual* provides a detailed discussion on drainage policies and procedures to be used on all design projects. This Chapter refers to the *IDOT Drainage Manual* extensively to direct the reader to specific areas of interest.

40-1 ADMINISTRATION

40-1.01 Responsibilities

The Hydraulics Unit of the Bureau of Bridges and Structures is responsible for all drainage functions completed within the Offices of Program Development and Highways Project Implementation. In District 1, the Hydraulic Engineer and support staff are located in the Bureau of Programming. In Districts 2 through 9, the Hydraulic Engineer and support staff are located in the Bureau of Program Development.

The Hydraulics Unit of the Bureau of Bridges and Structures is responsible for the development and administration of the roadway, culvert, and bridge drainage policies used by the Offices of Program Development and Highways Project Implementation within IDOT. The districts are responsible for initiating drainage and hydraulic studies, coordinating and monitoring drainage work performed by consultants, completing Phase I reports, and ensuring that the appropriate policies and procedures are followed throughout project development. Chapter 1 of the *IDOT Drainage Manual* provides a comprehensive description of drainage responsibilities of the Central Office and the districts.

40-1.02 General Overview

The critical impact of drainage decisions and their influence on plan preparation, implementation, and operation requires a continuous consideration of drainage features throughout project development. Typically, project development occurs in two phases, and drainage is a principal feature of both phases.

Drainage Studies are one of several types of Phase I studies, which are then incorporated into the Phase I report that is used to make and document design decisions. On major construction projects, it may also be necessary to prepare an Environmental Impact Statement, which uses the findings of a Drainage Study. On most projects, the district Hydraulic Engineer and the

Operations Field Engineer will examine drainage issues during Phase I and recommend needed improvements or identify items that require evaluation.

Drainage Studies are completed during Phase I to identify the drainage needs and/or problems associated with highway projects. They also provide an excellent coordination tool to consider and document local agency concerns, regulations, and needs. The complexity of the drainage study during Phase I depends on the type of project under study.

For highways on a new location, which require a Design Report or Combined Report, the Drainage Study examines the overall drainage patterns of the area, and the Study identifies the location, type, and relative size of drainage structures required for each alignment. This includes such structures as bridges, culverts, storm drains, ditches, pumping stations, or other special structures. The Study may be rather complex and assist in setting the alignment and profile of the proposed highway project. The Study will also address any special drainage problems that may be encountered by a specific alignment or any problems precipitated by a proposed alignment. The completed Drainage Study for projects on new alignment becomes a technical report to the Design Report or Combined Report.

A 3R project could involve investigating:

- the need to widen and deepen existing highway ditches;
- the hydraulics of existing bridges and culverts;
- flooding problems; and
- storm sewer capacities or the need for new storm sewers and the need for compensatory or detention storage or larger outflow facilities.

See Figure 40-1.A, which summarizes the type of drainage information needed for projects.

Type of Work Type of Project	Phase I (Location/Design Studies)	Phase II (Preparation of Construction Plans)
1. Freeway or expressway construction on new alignment.	Prepare Drainage Study that documents the overall drainage plan for project and indicates preliminary culvert sizes, highwater elevations for proposed bridges, areas of sheet flow, width of ditches for detention storage, etc. Document results in Drainage Study.	Use Drainage Study to develop a Drainage Report for project.
2. Freeway or expressway reconstruction on existing alignment.	Determine if existing drainage facilities can adequately accommodate storm water and what changes may be needed. Document results in Drainage Study. Check with field maintenance engineers and local agencies for any flooding problems. The preparation of Hydraulic Reports are necessary in this Phase.	Use Preliminary Drainage Study to develop a Drainage Report for project. Urban freeways/ expressways will have the most potential for significant drainage changes.
3. Expressway construction along existing alignment.	Prepare Drainage Study that documents the overall drainage plan for project and indicates culvert sizes, highwater elevations for existing and proposed bridges, areas of sheet flow, width of ditches for detention storage, location of any gutters and storm sewers in restricted ROW areas, etc. Document results in Drainage Study. Because of existing bridges, multiple box culverts, and other special drainage problems along an existing route, this type of project will require the preparation of Hydraulic Reports. The Hydraulic Report will be submitted in conjunction with each Bridge Condition Report.	Use Drainage Study to develop a Drainage Report for projects. In highly urbanized areas, the drainage investigations required in Phase I may be quite extensive with little work remaining to be done in Phase II.
4. Reconstruction of existing urban arterial or collector streets.	Prepare Drainage Study that documents the overall drainage plan for project and indicates preliminary storm sewer sizes, preliminary culvert sizes, highwater elevations for any bridges, detention storage needed, main outflow storm sewer locations, pump stations, etc. Document results in Drainage Study.	Use Drainage Study to develop a Drainage Report for projects. In highly urbanized areas, the drainage investigations required in Phase I may be quite extensive with little work remaining to be done in Phase II.

TYPICAL DRAINAGE INFORMATION
(Projects on the State Highway System)

Figure 40-1.A

Type of Work Type of Project	Phase I (Location/Design Studies)	Phase II (Preparation of Construction Plans)
5. Reconstruction of existing rural arterial or collector highways including any bypass around a community (could include major realignments in both the horizontal and vertical planes).	Prepare Drainage Study that will document the overall drainage plan for project. Study should indicate culvert sizes, highwater elevations for bridges, areas of sheet flow, width and depth of ditches for detention storage, etc. Document results in Drainage Study. Check with field operations engineers for any flooding problems. The preparation of Hydraulic Reports should be completed in this Phase.	Use Drainage Study to develop a Drainage Report for project. If Hydraulic Reports are not prepared in Phase I, they will have to be prepared in this Phase.
6. All 3R projects.	Check with field operations engineers and local agencies for any flooding problems. Examine the need to deepen ditches to improve highway drainage. If flooding problems occur in urban areas, determine and document causes and recommend solutions. If bridges or large box culverts exist within project, Hydraulic Reports may be prepared during this phase of work in conjunction with each Bridge Condition Report and then submitted for review and approval to the Bureau of Bridges and Structures (BB&S) or the District.	From information documented in approved Phase I Report, the designer submits a TS&L drawing to the BB&S for each major drainage structure. The approved TS&L drawing is then used to prepare the final plans for the drainage structure.
6a. Superstructure replacement on existing piers and abutments.	Project could be part of roadway improvement or a stand-alone project. Requirements as described above for Item 6 will apply.	Requirements as described above for Item 6 will apply.
6b. Complete structure replacement on existing alignment.	Project could be part of roadway improvement or a stand-alone project. Project could involve a runaround detour over waterway that would require a special hydraulics analysis. Requirements as described above for Item 6 will apply.	Requirements as described above for Item 6 will apply.
6c. Existing box culvert or bridge replaced with a multiple-barreled box culvert.	Project could be part of roadway improvement or a stand-alone project. Requirements as described above for Item 6 will apply.	Requirements as described above for Item 6 will apply.

TYPICAL DRAINAGE INFORMATION
(Projects on the State Highway System)

Figure 40-1.A
(Continued)

40-2 STUDIES

40-2.01 Introduction

Drainage Studies and Hydraulic Reports are investigations of the existing and proposed drainage patterns and the hydraulic performance of highway drainage structures. These drainage investigations are a vital component in the design of every highway project. Runoff, ponding of water, and the adequacy of the outlet must be addressed early in the project development stage to ensure that projects are designed through a process that involves consideration and balancing of a number of factors including:

- flood hazards to highway users and neighboring property owners,
- legal considerations,
- functional needs,
- environmental and social concerns,
- local stormwater management ordinances,
- costs, and
- other site conditions.

The analyses listed below are commonly conducted as a part of both a Drainage Study and a Hydraulic Report:

- hydrologic analysis;
- hydraulic analysis;
- engineering evaluation of selected alternatives; and,
- addressing Illinois Department of Natural Resources, Office of Water Resources (IDNR-OWR) permitting requirements.

The detail of analysis for either study is commensurate with the scope of work and the hydraulic risk associated with the drainage facility and other economic, engineering, social, or environmental concerns. Chapter 2 of the *IDOT Drainage Manual* provides a complete description of Drainage Studies and Hydraulic Reports.

40-2.02 Drainage Studies

A Drainage Study includes the hydraulic investigation and analysis of minor drainage facilities such as roadside and median ditches, detention ponds, storage pipes, storm sewers, and single barrel culverts. The Drainage Study becomes the basis for judging the adequacy of existing facilities, improvements needed, compliance with existing policies and standards, consideration of local stormwater management ordinances, and coordination with other agencies. The Study will typically include the analysis and evaluation of all applicable drainage features within the project reach. In District 1, the Drainage Study is completed during Phase I. However, the Drainage Study is often completed during Phase II work in Districts 2 through 9. The detailed

hydraulic analysis for major drainage structures such as bridges, multi-barrel culverts, and pumping stations are contained in a separate Hydraulic Report. Where a Hydraulic Report is required, it is completed in Phase I in all districts, and the Drainage Study summarizes the findings.

The Drainage Study must begin with an investigation of existing drainage patterns to establish a basis for judging the adequacy of drainage features included in the highway project and to identify the drainage parameters that will be encountered by the highway project. Address the following specific items:

- an evaluation of floodplain impacts,
- permitting requirements,
- identification of all drainage paths,
- highest known water levels,
- reports of flooding of both adjacent property and the highway facility, and
- outlet conditions.

The Drainage Study should also identify the general type, size, and location (including right-of-way requirements) of all highway drainage facilities necessary to accommodate local conditions and design requirements, and it should contain the complete hydraulic analysis of the proposed design.

Where the project involves the replacement or rehabilitation of an existing facility, the Drainage Study should document the adequacy of the existing system during past storm events. This will include consideration for erosion and sediment control of ditches and drainage structures, storm sewer capacities, and locations of pavement flooding and adjacent property flooding. The need for drainage improvements on rehabilitation projects is determined from the investigation of existing conditions and the evaluation of problems or inadequacies encountered. A theoretical hydraulic analysis is performed to determine the proposed changes.

However, if the theoretical analysis indicates the need for major changes but the Drainage Study reveals that no problems have been encountered during past flood events, the theoretical analysis may be determined by the engineer to be overly conservative and not representative of local conditions. The experience of problems with the existing facility, as identified by district Operations personnel, adjacent property owners, or local agencies that maintain State Routes by agreement is normally required to justify major drainage improvements to existing facilities on 3R projects.

When the final Drainage Study is scheduled to be completed with Phase II work, a Preliminary Drainage Study is prepared in Phase I. This Study defines existing drainage features and identifies the type and relative size of drainage structures required to complete the project. The Preliminary Drainage Study should contain mapping or USGS quadrangle maps that identify drainage patterns, adjacent land usage, and the location of affected structures. The Study should include a centerline profile, an adjacent groundline profile, existing and proposed roadway templates, right-of-way or easement requirements, and the relative size and configuration of existing and proposed drainage structures. It should identify known problems

such as pavement flooding, ditch erosion, bridge or culvert scour, concerns of other agencies, and complaints by property owners.

The Preliminary Drainage Study, when finalized and approved, becomes the Drainage Report for the project. The final Drainage Report should identify all changes made to the preliminary study affecting the number, type, size, and location of drainage structures.

40-2.03 Hydraulic Reports

A Hydraulic Report is similar to a Drainage Study, except that it typically focuses on a single structure location because of the greater volume of computations and support data required for the structure involved. Hydraulic Reports are required for bridges, multiple-barrel culverts, single-barrel culverts that are identified by the district as requiring a special study, pumping stations, and all special or unusual drainage structures. For all projects where the structural design will be reviewed by the district Hydraulic Engineer, Hydraulic Reports must be prepared and submitted to the Central Office with the submittal of a Bridge Condition Report. The content of a Hydraulic Report is similar to a Drainage Study in that it includes an evaluation of existing conditions, hydraulic calculations of the proposed design, details of structure type and size, and all supporting data. Bridge and culvert crossings should also be investigated for problems associated with scour and siltation, debris and ice blockage, stream alignment, highwater clearances, headwater and tailwater elevations, and complaints of flooding.

Early in the Hydraulic Report preparation, it should be determined if the project will require a construction permit from the IDNR, Office of Water Resources. See Chapter 28. If a permit is required, the type of permit and the permit requirements should be identified, and the proposed design must be evaluated for those requirements. Where local conditions dictate a higher design standard than the permit requirement, the Hydraulic Report must identify and document these conditions in accordance with the Floodplain Encroachment Policy in Section 1-302 of the *IDOT Drainage Manual*. The jurisdictional limits and the permit requirements of the Office of Water Resources are described in Section 1-400 of the *IDOT Drainage Manual*. The design decisions of projects that do not require a construction permit should be based on a cost evaluation of alternatives which satisfy the project design criteria, local site conditions, legal requirements, and project objectives. These conditions and decisions must also be documented in accordance with the Floodplain Encroachment Policy.

40-3 DESIGN CONSIDERATIONS

40-3.01 Introduction

Section 40-3 addresses the types of design considerations that relate to the drainage aspects of a highway project. There are often numerous design features that will satisfy the design objectives of the project and, therefore, many tasks and requirements must be considered during the early phases of project development to ensure the selection of the most cost-effective and beneficial design features.

Coordination among the various Central Bureaus and the district is a very important function. Also, notification of proposed projects must be made to other agencies and the public, and the permits and regulations of other agencies applicable to the project should be identified and documented as soon as practical. Often project delays are due to the legal process. Problems that may arise during design, construction, or maintenance should be considered in Phase I studies.

The above factors and other considerations may not always allow items to be separated into the planning phase and the design phase. Often, there will be overlap, and sometimes the separation of work between the phases will be indistinct. Therefore, it is essential that the design concepts developed in Phase I be evaluated for their constructability. This includes right-of-way needs, because this consideration reduces the likelihood that Phase I decisions will be revisited during Phase II. When Phase II work is allowed to proceed before Phase I studies are complete, many problems are exacerbated and conflicts between the various parties and schedules often occur. The district is responsible for coordination and guidance on these issues. This ensures that project schedules are maintained.

40-3.02 Storm Drainage Facilities

40-3.02(a) General

Highway storm drainage facilities collect stormwater runoff and convey it along and/or away from highway right-of-way to adequately drain the roadway and minimize the potential for flooding and the erosion to properties adjacent to the right-of-way. Stormwater includes the runoff from precipitation falling within the right-of-way and the surface runoff from adjacent properties which flows into the roadside ditches or the storm drainage system. Storm drainage facilities consist of curbs, gutters, inlets, storm drains, ditches, and culverts. The placement and hydraulic capacities of storm drainage structures and conveyances should be designed to avoid/minimize damage to adjacent property and to secure a low degree of risk of traffic interruption by flooding. Interruption by flooding should commensurate with the importance of the road, the design traffic service requirements, and available funds.

There are two basic types of roadway sections to be considered for pavement drainage—a rural section and a curbed section. A rural section consists of a crowned pavement that drains laterally to the shoulders and down the embankment slope to a roadside ditch or that continues as sheet flow down slope from the right-of-way. The ditches are sloped to carry the runoff to the

nearest natural outlet. A curbed section consists of a sloped pavement that drains to a curb and gutter system. The curb and gutter channels the flow to a series of inlets which capture the runoff and outlet into a storm drain. Both section types may include a median to separate traffic. The rural section is normally more cost effective and is the section of choice where other factors are equal, because it allows the unhindered drainage of the pavement without concern for encroachment on the traveled way. Costs of the rural section include wider right-of-way, longer/wider cross drainage structures, and the maintenance costs of mowing, debris pickup, and ditch erosion repairs. Curbed sections are required in urban settings where sidewalks, storefronts, residential lawns, and/or intersections do not allow room for roadside ditches and the wider right-of-way required for a rural section. The policies and procedures for the design of storm drain systems are presented in Chapter 8 of the *IDOT Drainage Manual*.

40-3.02(b) Rural Cross Sections

Because rural sections usually require wider right-of-way, the scheduling of widening or reconstruction projects must include sufficient time for the purchase of additional right-of-way and the right-of-way requirements must be determined early in project development. Actual right-of-way required is determined by roadway geometrics and drainage needs. Existing drainage conditions and the design highwater elevation plus the freeboard requirements (see Section 1-304 of the *IDOT Drainage Manual*) may control the roadway profile. Basic geometrics with consideration of key drainage elements are established first and then detailed drainage needs and type and size of drainage facilities are determined. These are based on the roadway geometrics and the runoff from adjacent properties. If drainage problems are encountered, it may be necessary to review geometric design decisions and/or to use special drainage structures.

Drainage considerations for rural sections include the discharge to be carried, typical ditch sections and gradients, ditch erosion protection requirements, and suitable outlet conditions. The source of discharge must consider the width of pavements, appurtenant vegetation and/or paved areas of the right-of-way, and adjacent property. Ditch sections must conform to acceptable side slopes and depth to accommodate errant vehicles and mowing equipment. The width, depth, and gradient of ditches may need adjustment to accommodate the design discharge and minimum depth requirements. Chapter 9 of the *IDOT Drainage Manual* presents complete design procedures for roadside ditches.

40-3.02(c) Curbed Cross Sections

Curbed sections are normally more expensive than rural sections because of the number of appurtenant structural items involved. These include the curb and gutter section, inlets, laterals, storm drains, manholes, and outlet structures. A major consideration in the design of a curbed section is the location of the main storm drain. Locations outside the pavement structure are preferred because they provide easier access for maintenance and repairs, and they do not involve the expense of special backfill required for storm drains placed beneath the pavement structure. However, potential conflicts with utilities must be fully evaluated and often will influence the location of storm drains. The most cost-effective design is determined by an analysis considering a balance of sizes, slopes, and depths of storm drains that satisfy the

storm drain policies and drainage needs of the project. Chapter 34 discusses the drainage of selected medians (raised-curb, traversable, or flush). The drainage of each median considers the traffic safety concerns with additional cross flow, and it also considers minimizing ice melt flowing onto and refreezing on the traveled way.

Inlet types are selected from the *IDOT Highway Standards* based on the location and situation to be served by the inlet. Spacing of inlets is determined by analysis to control the spread of water onto the traveled way and at predetermined locations such as at sag vertical curves, intersections, and pedestrian cross walks. These details are normally addressed during Phase II work.

The Drainage Study prepared with Phase I work must address proposed hydraulic improvements for existing conditions such as the conversion of open ditches to a storm drainage system including the suitability of outfalls, pumping stations, and detention basins. Both the functionality and constructability of these changes must be addressed, and impacts such as right-of-way needs, environmental impacts, agency coordination, and permit requirements considered.

40-3.02(d) Joint Participation

Many highway projects involve joint participation in both the use and funding of storm drain systems. Joint participation normally involves a municipality or a county in conjunction with the Department. This may result in either the State connecting to a local agency storm drain because there is no other feasible outlet or the local agency tying into a State storm drain. The possibility of joint participation should be determined early in project development to allow an investigation of the full area to be served by the system and a determination of the storm drain size. Also, adequate time must be allowed for negotiations and development of an agreement between the Department and the local agency involved. Chapter 5 of the *BDE Manual* discusses the policies on Joint Participation.

40-3.03 Stormwater Management

Stormwater management is defined as the control of runoff to satisfy a predetermined objective. The Department's policy on stormwater management is found in the Department's *Storm Water Management Plan*. The basic objective is to ensure that runoff from a highway project does not result in any detrimental effects to upstream or downstream property and flooding conditions. The primary tool in reducing runoff for stormwater management is detention storage; however, it is also possible to reduce runoff rates by lengthening flow paths, flattening slopes, and using open ditches instead of enclosed storm drains. Where storage is necessary, it may be provided in any one of several locations (e.g., medians, roadside ditches, open basins, oversized storm drains). A roadway project may involve a combination of storage features and methods to reduce runoff.

Stormwater management considerations in accordance with Department policies must be analyzed on all projects to ensure that drainage problems are not increased and all legal

obligations are satisfied. The stormwater management ordinances of local agencies must also be considered and incorporated into a project design when feasible and cost-effective.

40-3.04 Bridges and Culverts

Highways which cross a watercourse are often referred to as a transverse encroachment. The cross drainage to the highway, whether by swale, stream, or river system, must be carried across the highway to preserve the natural and existing drainage courses. A hydraulic investigation and analysis of both the upstream and downstream reaches of the watercourse is necessary to determine the best location, size, and elevation of the proposed crossroad structure, whether a culvert or a bridge. The investigation should ensure that any highway structure or roadway embankment that encroaches on or crosses the floodplain of a watercourse will not cause a significant adverse effect to the floodplain and will be capable of withstanding the flood flow with minimal damage. The analysis should also clearly indicate the path and approximate elevations of flow and existing conditions at any location where water comes to or leaves a proposed project. To ensure that adequate attention is provided to this aspect of design, all construction plans submitted for approval shall show the magnitude, frequency, and pertinent water surface elevations for the design flood, the 100-year flood, and the overtopping or 500-year flood for all structures in accordance with the criteria in the *IDOT Drainage Manual.*

Where hydraulic structure sizes can affect the selection of alignments or grades, a detailed hydraulic analysis should be performed with Phase I work, and included in a Hydraulic Report. Likewise, 3R projects that have experienced hydraulic problems (severe scour, inundation, debris, flooding complaints, etc.) require a detailed hydraulic analysis in Phase I to identify any necessary countermeasures or drainage features that should be incorporated into the design. This is pursuant to the policy on Documentation of Floodplain Encroachment Designs in Section 1-302.01 of the *IDOT Drainage Manual.* Abbreviated Hydraulic Reports can be completed for some minor projects which have no impact on the hydraulic performance as described in Section 1-302.02 of the *IDOT Drainage Manual*.

Proposed designs for replacement bridge and culvert structures may be considered acceptable for hydraulic design during location studies provided the proposed replacement does not cause more restriction to flood flows than the existing structure and provided the existing structure will not cause significant flood damage during a normally anticipated flood event up to and including the 100-year frequency flood. A Hydraulic Report is required to verify that these conditions are met.

The selection of a bridge versus a culvert structure will be based on a cost comparison of equal hydraulic alternatives considering acceptable levels of backwater, structure clearance, debris and ice, foundation stability, overtopping flows, scour potential, and local site conditions. The normal break point for considering a culvert alternative is approximately 300 ft^2 (28 m^2) of opening; however, site conditions will allow the use of larger culverts in some situations. The bridge and culvert alternatives must reasonably conform to the shape of the stream channel section to minimize the occurrence of siltation. Consideration of construction staging and the

benefits of precast versus cast in place (culvert or bridge) may also influence the selection of structure type.

Projects involving a Regulatory Floodplain of the IDNR-OWR must consider the compensatory storage requirements of the permit rules. Any fill material placed in a designated floodway must be compensated for at the approximate elevation of the fill. If a highway fill is placed between the normal water elevation and the 10-year flood elevation, it must be compensated for between the normal and 10-year elevation. Likewise, for fill material placed between the 10-year and the 100-year flood elevations, this must be compensated for between the 10-year and 100-year flood elevations. The Drainage Study must address the issue of compensatory storage and identify suitable locations for providing adequate storage.

The policies and procedures for the hydraulic design of culverts are presented in Chapter 6 and those for bridges are presented in Chapter 7 of the *IDOT Drainage Manual.*

40-3.05 Longitudinal Encroachments

Longitudinal encroachments are those where the highway is within the boundary of the stream and its floodplain and runs along the stream approximately parallel to the floodplain. This contrasts with a transverse encroachment which crosses the channel from one side of the floodplain to the other. The policies and procedures for flood plain encroachments are in Section 1-302 and Chapter 3 of the *IDOT Drainage Manual*.

Avoid longitudinal encroachments, especially those that encroach upon the floodway. Where a longitudinal encroachment cannot be avoided, the degree of encroachment should be minimized. Longitudinal encroachments can have a critical impact on floodplain conveyance and storage requiring additional right-of-way and excavation for compensatory storage and enhancement of conveyance sections. Where required, compensatory storage will be provided in accordance with Section 40-3.04. Environmental and highway impacts must be evaluated and mitigated. Highway impacts include overtopping flows, erosive velocities, accumulation of debris, and migrating channel bends. The obvious disadvantages of an encroaching location are the increased flood risk, potential for damaging the highway, cost to protect the facility, environmental impacts, and permit requirements.

40-3.06 Pump Stations

Stormwater pump stations are necessary to remove stormwater from highway sections that cannot be drained by gravity. Because of high costs and the potential problems associated with pump stations, their use is recommended only where other systems are not feasible. Where operation and maintenance costs are capitalized, a considerable expenditure can be justified for a gravity system.

Pump station design presents the designer with a challenge to provide a cost-effective drainage system that meets the needs of the project. Considerations in pump station design include:

- location,
- wet-pit vs. dry-pit,
- type of pumps,
- number and capacity of pumps,
- pump cycling sequence,
- peak flow vs. storage,
- force main vs. gravity,
- above grade vs. below grade,
- site and location of receiving water,
- outlet restrictions,
- monitoring systems,
- backup systems, and
- maintenance requirements.

The procedures recommended for the hydraulic design of pumping stations are found in Chapter 13 of the *IDOT Drainage Manual.*

40-3.07 Pipe Culverts and Storm Sewers

Section 40-3.07 establishes design guidelines for the use of pipe culverts and storm sewers.

40-3.07(a) Diameter Limitations

The following limitations apply:

1. Reinforced Concrete Pipe may be used for diameters up to 108 in. (2700 mm) and equivalent, round sizes up to 72 in. (1800 mm).

2. Corrugated Steel Pipe may be used for diameters up to 144 in. (3600 mm) and equivalent, round sizes up to 120 in. (3000 mm).

3. Corrugated Aluminum Alloy Pipe may be used for diameters up to 120 in. (3000 mm) and equivalent, round sizes up to 120 in. (3000 mm).

4. Polyvinyl Chloride (PVC) Pipe and Corrugated PVC Pipe with a Smooth Interior may be used for diameters up to 36 in. (900 mm). PVC Profile Wall Pipe may be used for diameters up to 48 in. (1200 mm).

5. Polyethylene (PE) Pipe may be used for diameters up to 48 in. (1200 mm).

40-3.07(b) End Treatments

For all pipe culverts, with the exception of entrance culverts, a non-plastic end treatment must be specified. An end treatment for entrance culverts, which can protect the culvert ends from being crushed and allow for proper grading of the transverse slopes, will be at the designers' option.

40-3.07(c) pH Limitations

When the soil pH levels are outside the range of 5 to 9, the designer should consult the Central Bureau of Materials for the appropriate material type to use.

40-3.07(d) Class of Pipe Culverts and Storm Sewers

The classes of pipe culverts and storm sewers are defined in Figures 40-3.A and 40-3.B. In the plans, the designer should specify the appropriate pipe class and allow the contractor to bid the most cost effective material type. To specify, any one particular material type must be examined as a design exception and supported by proper justification.

Figure 40-3.A presents the class of pipe culvert to be specified for specific conditions. See Section 542 of the *Standard Specifications for Road and Bridge Construction* for a listing of pipe materials allowed in each class.

Figure 40-3.B presents the class of storm sewer to be specified for specific conditions. See Section 550 of the *Standard Specifications for Road and Bridge Construction* for a listing of pipe materials allowed in each class.

Conditions	Class
Entrances, regardless of ADT; and Roadways with ADT < 4000	D
Roadways with 4000 ≤ ADT < 10000	C
Roadways with ADT ≥ 10000	A

PIPE CULVERT CLASSES

Figure 40-3.A

Conditions	Class
Roadways with ADT < 1500; or pipe location is > 12 ft (3.6 m) from the edge of traveled way	B
Roadways with ADT ≥ 1500 and pipe location is ≤ 12 ft (3.6 m) from the edge of the traveled way	A

STORM SEWER CLASSES

Figure 40-3.B

40-3.07(e) Minimum Permissible Diameter of Pipe Culverts and Storm Sewers

Figure 40-3.C presents the minimum permissible diameter for pipe culverts.

The minimum permissible size for storm sewer is 12 in. (300 mm). However, the *IDOT Drainage Manual* contains additional information on sizing and a discussion of possible exceptions.

Functional Class	Minimum Diameter
Entrances	15 in. (375 mm)
All roadways except arterials	18 in. (450 mm)
All arterials	24 in. (600 mm)

MINIMUM PERMISSIBLE DIAMETER FOR PIPE CULVERTS

Figure 40-3.C

40-4 DOCUMENTATION

40-4.01 Introduction

The definition of hydrologic and hydraulic documentation as used in this chapter is the compilation and preservation of the design and related details and all pertinent information on which the design and decisions were based. Appropriate documentation for the design of any hydraulic facility is essential because of:

- the importance of public safety;
- justification of expenditure of public funds;
- future reference by engineers (when improvements, changes, or rehabilitations are made to the highway facilities);
- information leading to the development of defense for litigation;
- public information;
- IDNR-OWR rule and regulatory conformance (where appropriate); and
- local agency concerns/criticism.

Documentation permits evaluation of the performance of structures after flood events to determine if the structures performed as anticipated or to establish the cause of unexpected performance, if such is the case. In the event of a failure, documentation may aid in the identification of contributing factors that can be avoided or mitigated to prevent recurring damage after repairs or reconstruction.

The documentation shall include drainage area and other maps, field survey information, source references, photographs, methodology, engineering calculations and analyses, other data, and flood history including narratives from newspapers and individuals such as highway maintenance personnel and local residents who witnessed or had knowledge of a significant flood event.

There are three basic types of documentation that shall be considered—preconstruction, design, and construction or operation. The following discusses each type:

1. Preconstruction. This documentation includes the following if available or within the constraints of the project:

    - aerial photographs;
    - contour mapping;
    - watershed map or plan including:

        + flow directions,
        + watershed boundaries,

+ watershed areas, and
+ natural storage areas;

- surveyed data reduced to include:

  + existing hydraulic facilities;
  + existing horizontal and vertical controls;
  + profiles (roadway, channel, driveways); and
  + cross sections (roadway, channels, faces of structures);

- flood insurance studies and FEMA maps;
- Natural Resources Conservation Service soil maps;
- field trip report(s) which may include:

  + video cassette recordings,
  + audio tape recordings,
  + still camera photographs,
  + movie camera films, and
  + written analysis of findings with sketches; and

- reports from other agencies (local, State, or Federal), IDOT personnel, newspapers, and abutting property owners.

2. Design. This documentation includes all information used to justify the design, including:

   - reports from other agencies,
   - drainage study,
   - hydrological report,
   - hydraulic report, and
   - permits and approvals.

3. Construction/Operation. This documentation includes:

   - plans;
   - revisions;
   - as-built plans and subsurface borings;
   - photographs; and
   - record of operation during flood events, complaints, and resolutions.

It is important to prepare and maintain, in a permanent file, the as-built plans for every drainage structure to document subsurface foundation elements (e.g., footing types, (driven) tip elevations). There may be other information that should be included or may become evident as the design or investigation develops.

40-4.02 Purpose

The major purpose of providing good documentation is to define the design procedure that was used and to show how the final design and decisions were determined. Documentation should be viewed as the record of reasonable and prudent design analysis based on the best available technology. Documentation can provide the following:

- evidence that reasonable and prudent actions were, in fact, taken;
- identification of the situation at the time of design;
- documentation that rationally accepted procedures and analyses were used at the time of the design which were commensurate with the perceived site importance and flood hazard;
- identification of the criteria and considerations used in design and evidence that they were adhered to;
- a continuous site history to facilitate future reconstruction;
- the file data necessary to quickly evaluate any future site problems that might occur during the facilities' service life;
- an expedition of plan development by clearly providing the reasons and rationale for specific design decisions; and
- identification and an explanation for design variations from standard policy, practice, and procedures.

40-4.03 Documentation Procedures

A complete hydrologic and hydraulic design and analysis file for each drainage feature shall be maintained by the Section responsible for design approval. Figure 40-4.A provides a tabulation of the items to be included in the documentation file for the various types of drainage facilities. Although the Department's documentation requirements for existing and proposed drainage facilities are similar, the data retained for existing facilities are often slightly different than that for proposed facilities. The intent is not to limit the data to only those items listed except to establish a minimum requirement consistent with the hydraulic design procedures as outlined in the *IDOT Drainage Manual.*

Documentation of hydraulics analyses and studies for pump stations and bridges are included in the approved Hydraulic Reports. These reports are retained in the district files and/or in the Bureau of Bridges and Structures files. Documentation of hydraulic analyses and studies for culverts are included in the Hydraulic Reports approved by the districts and retained in district files.

Other drainage studies and analyses prepared during Phase I become part of the Phase I report(s) and are retained in the district and in the Bureau of Design and Environment.

Detailed design calculations for drainage work, prepared during Phase II, are placed in the district files for each project.

If circumstances are such that the drainage facility is sized by other than normal procedures or if the size of the facility is governed by factors other than hydrologic or hydraulic factors, a narrative summary detailing the design basis shall appear in the documentation file. Additionally, include the file items not listed in Figure 40-4.A but which are useful in understanding the analysis, design information, findings, and final recommendations. The preparer should initial and date all calculations, methods used, and work. Identify the engineer (P.E.) who directed or completed the work.

Item	Bridges	Culverts	Open Channels	Roadside & Median Ditches	Storm Drains	Pump Stations
Criteria and assumptions	X	X	X	X	X	X
Contributing watershed area size and identification of source (map name, etc.)	X	X	X	X	X	X
Design frequency and decision for selection	X	X	X	X	X	X
Hydrologic discharge and hydrograph estimating method and findings	X	X	X	X	X	X
Flood frequency curves to include design, 100-year, and the overtopping or 500-year flood discharge hydrographs and any historical floods when applicable	X	X	X			
Expected level of development in upstream watershed over the anticipated life of the facility (include sources of and basis for these development projections)	X	X	X	X	X	X
Field reconnaissance	X	X	X	X	X	X
Design, 100-year, and overtopping or 500-year high-water for natural, existing, and proposed conditions (include 10-year frequency on regulated streams)	X	X	X			
Cross sections used in the design high-water determination	X	X	X	X		
Roughness coefficient assignments	X	X	X	X		
Observed high-water, dates, and discharges	X	X	X			
Copies of all computer analyses (hard copy and disk)	X	X	X	X	X	X
Complete Drainage Study or Hydraulic Report (when required)	X	X	X	X	X	X
Roadway geometry (plan and profile)	X	X	X	X	X	X
Potential flood hazards to adjacent properties	X	X	X	X	X	X
Structure plan with waterway information table	X	X				
Type of culvert entrance condition		X				
Culvert performance curves		X				
Allowable headwater elevation and basis for its selection or related probable damage	X	X				X
Stage discharge curve for natural, existing, and proposed conditions to include the depth and velocity measurements or estimates and locations for the design, 100-year, and 500-year or overtopping floods (include scour calculations where appropriate)	X	X	X	X		X
Permit requirements	X	X	X			

ITEMS TO BE INCLUDED IN DOCUMENTATION FILES

Figure 40-4.A

Item	Bridges	Culverts	Open Channels	Roadside & Median Ditches	Storm Drains	Pump Stations
Policy waivers	X	X	X	X	X	X
Regulatory or flood insurance studies	X	X	X			
Energy dissipation calculations and designs for outlet appurtenances		X				
Copies of standard computation sheets	X	X		X	X	
Information on the method used for design water surface determinations	X	X	X	X		
Water surface profiles through the reach for the design, 100-year, and any historical floods	X	X	X	X		X
Design or analysis of materials proposed for the channel bed and banks	X	X	X	X		
Energy dissipation calculations and designs			X	X		
Explanation of selected ditch section and gradient				X		
Layout of ditch capacity and storage (if required)				X		
Layout of complete drainage system			X	X	X	X
Special considerations at outlet		X	X	X	X	X
Computations for gutter capacity, pavement encroachment, inlet spacing, and by-pass flow					X	
Information concerning outfalls, existing storm drains, and other design considerations				X	X	X
A schematic indicating storage and storm drain system layout (type and size)					X	X
Identification of flood route					X	X
Inflow design hydrograph from drainage area to pump						X
Stage storage calculations					X	X
Starting sequence and elevations						X
Pump dimensions						X
Pump sizes and operations						X
Pump calculations						X
Mass curve routing						X

ITEMS TO BE INCLUDED IN DOCUMENTATION FILES

Figure 40-4.A
(Continued)