Minnesota Public Drainage Manual

Chapter 3 – V. Engineering and Environmental Considerations - Adequacy of outlet

Summary

Drainage law requires the drainage authority to make a determination that "the outlet is adequate" for all drainage projects as defined in **103E.005**. An evaluation of the adequacy of the outlet is conducted by the project engineer during the preliminary survey and reported by the engineer to the drainage authority in the preliminary survey report. (See **Chapter 3, Section V, A**).

There is no statutory definition of an adequate outlet provided, as such, it is recommended that the engineer include a description of what was considered and how the adequacy was determined. **Chapter 3, Section V, B** describes how an adequate outlet can be defined within the engineer's reports.

Basic requirements of an adequate outlet are provided in **Chapter 3, Section V, C**.

Depending upon the magnitude of the proposed drainage project, there are several hydrologic and hydraulic methods of analysis available to the engineer for developing the assessment of outlet adequacy. **Chapter 3, Section V, D** describes various methodology that are utilized in determining an adequate outlet, including field survey data, outlet hydrology, and outlet hydraulic analysis.

The engineer must make a determination of outlet adequacy in the engineer's preliminary report. This determination must be supported by an acceptable engineering analysis of pre-project and post-project outlet conditions. A special section of the engineer's preliminary report must be provided to include a complete discussion of the analysis, results, assessment of potential damages, and recommendations concerning outlet adequacy. (See **Chapter 3, Section V, E**).

A. General

Drainage law requires that the drainage authority make a determination that "the outlet is adequate" for all drainage projects defined in **Minn. Stat. § 103E.005, subd. 11**. As delineated earlier in this chapter, the evaluation of the adequacy of the outlet is accomplished during the preliminary survey and reported by the engineer to the drainage authority in the preliminary survey report. The requirement for the drainage authority and the engineer to evaluate the adequacy of the outlet is found in the criteria of **Minn. Stat. § 103E.015, Subd. 1(4)** and the responsibility of the drainage authority to make a determination of adequacy is found in **Minn. Stat. § 103E.261, Subd. 5(4)**. As noted previously in **Section III** of this chapter, the preliminary report must address "the character of the outlet and whether it is sufficient" (see **Minn. Stat. § 103E.245, Subd. 4(3)**. The basis for the drainage authority's determination is information contained in the engineer's preliminary report, statements in the commissioner's (and Board of Water and Soil Resources', as applicable) preliminary advisory report, and other testimony which may be presented at the preliminary hearing.

Drainage Law has no provisions for making an outlet adequacy determination for repairs to existing drainage systems. Existing drainage systems are expected to be maintained to their original hydraulic condition, with the presumption being that the current outlet was originally determined to be adequate.

Therefore, any repair would merely restore the system to its as-constructed and subsequently improved condition, and restore its function as originally intended.

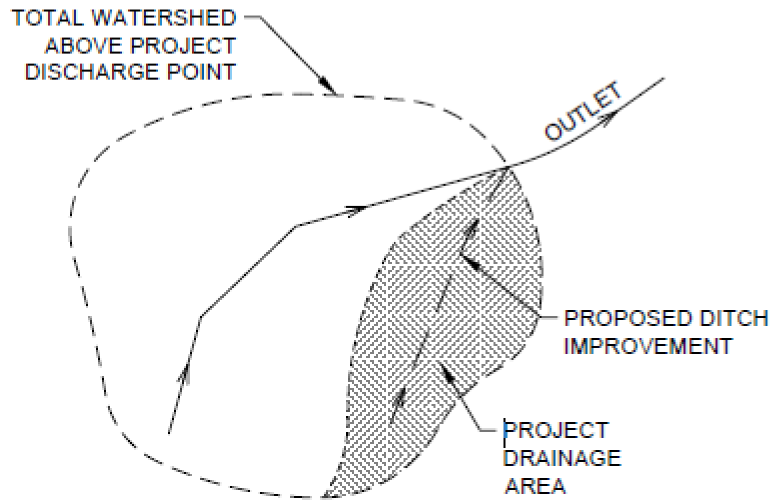
B. Definition of an Adequate Outlet

For the purposes of discussion in this manual, the outlet is defined as the terminal point of the drainage system under consideration (inclusive of proposed improvements or new construction). There is no statutory definition provided. The extent of the outlet includes whatever downstream reaches that might be impacted by increased discharges from the proposed project. The outlet may consist of a river, creek, lake, pond, altered watercourse or another public drainage system. Thus, outlets may be classified as natural (e.g. Public Waters) or artificial (e.g. a public drainage system). It is recommended that the engineer include a description of what was considered and how the adequacy was determined. This will allow for decision makers and reviewers to fully understand and comment on the adequacy of the outlet.

One of the most important considerations in all drainage planning is to determine the adequacy of the outlet for the proposed drainage system. If the outlet is determined to be inadequate, it must be made adequate, an alternative outlet must be found, the project must be redesigned to meet the limitations of the outlet, or the project must be abandoned. The overall feasibility of a drainage project is greatly affected by the requirement for an adequate outlet.

Ideally, drainage projects would be designed to reduce or maintain the existing outlet flows in order to minimize downstream flooding, erosion, and transport of excess nutrients. However, depending on the design and site conditions, drainage projects may increase the peak discharge for the more frequently recurring storms or runoff events. The effect which this increase in peak discharge has on water levels in the outlet depends upon several factors. These factors include the relationship of the size, shape, and hydrologic characteristics of the project area improved, as compared to the size, shape, and hydrologic characteristics of the watershed of the outlet above the point of discharge of the proposed system (see figure below). Since public drainage systems are normally designed for the more frequent runoff events (i.e., the 2-year or 5-year return period), it is necessary to analyze the 50- year return period as specified in **Minn. Stat. § 103E.015 Subd. 1(4)**. Generally, the 50-year storm event will exceed system hydraulic design capacity and cause the hydrologic response of the proposed project's drainage area to regress toward pre-project conditions. Any official concept of outlet adequacy should therefore be viewed within a range of hydrologic events (e.g., project design storm up to the 50-year flood.

The definition of what is an adequate outlet depends on several factors and individual viewpoints. From the perspective of the petitioners, an adequate outlet must be one that will drain the project area effectively. Conversely, an individual residing at the outlet or immediately downstream from the outlet may be more concerned about increased frequency of high flows along the course of the outlet channel. This situation essentially mandates the question - will the outlet handle post-project outflow without increased downstream damages in comparison to pre-project conditions? The analysis of outlet adequacy should include an assessment of the current condition of the downstream system including known flooding, designated floodways and floodplains, channel stability, culvert capacity, water control structures, and dams that may be impacted by increased flows. In making an assessment of outlet adequacy, the engineer must address all of these concerns viewed within a range of hydrologic events.



C. Basic Requirements of an Adequate Outlet

In determining the adequacy of outlets for drainage systems, the following basic requirements should be met:

1. The design flow from the proposed project's drainage area will discharge at a stage (elevation) equal to or less than that required for adequate drainage of the land in the project:

- A stage-discharge relationship of the outlet channel should be determined from gaging records, by computing normal depth or by developing water surface profiles.
- A frequency-discharge-stage relationship of the outlet channel should be determined by using commonly accepted hydrological frequency assessment procedures. The stage in the outlet for post-project hydrologic conditions should not exceed the hydraulic gradient (water surface profile) at the lower end of the proposed drainage system. This stage comparison should be done at the same frequency for both the outlet and the project drainage system using the project design frequency (e.g., 10-year event).
- If the outlet consists of a pond, lake, or reservoir, the design water surface at the outlet of the proposed drainage system should be at or above the normal water surface elevation of the water body.
- The elevation of the water surface at normal low flow in the outlet should permit any needed subsurface drainage to be discharged. The hydraulic gradeline for low water flow, from the

outlet through the system of mains and laterals to the uppermost subsurface drain in the project, should be determined to ensure that all needed drains can be discharged above it.

2. There should not be excessive scour or deposition of sediment in the outlet channel or waterbody:

- The drainage system design should avoid accelerated erosion or deposition in the outlet channel or waterbody.
- The drainage channel and side inlets should be designed such that sediment delivery to the outlet is minimized using **grade control strategies (see Chapter 5)** in accordance with generally accepted engineering practice.
- If the proposed drainage system's hydraulic gradient is significantly higher than that of the outlet, an outlet structure should be provided to accomplish the required dissipation of excess hydraulic head and to avoid accelerated channel erosion potential in the outlet. Such a structure should be designed in accordance with generally accepted engineering practice.

3. The capacity of the outlet must be such that the discharge from the project, after the proposed project is constructed, will not result in stage increases in the outlet that will cause or increase damages downstream for a range of flood events, unless compensation is made to those landowners that may potentially be damaged:

- Available watershed district overall plans, county local water plans, or One Watershed, One Plan plans should be reviewed to ascertain past flooding problems along the outlet channel. Additionally, previous unsuccessful attempts at drainage improvements along the outlet channel should be evaluated to determine the extent of past flooding problems.
- Increased damages may arise due to increased frequency, magnitude, and duration of flood events. Existing downstream land use activities along the course of the outlet should be analyzed for increased damage potential due to more frequent exposure to flood events. Such land use activities could include buildings, bridges, culverts, roads, farmland, and other similar uses. **Minn. Stat. § 103E.015, Subd. 1**, stipulates that the drainage authority must consider the impacts of the project on, "flooding characteristics" of property in the drainage project or system and downstream for the 5-, 10-, 25- and 50-year flood events. This may be addressed within the engineer's report in several different ways, including tabulating downstream peak flood elevations and flows for a range of rainfall events, or plotting flow or stage probabilities on a graph. The engineer's report should include an evaluation of multiple flood events that enables the drainage authority to infer how properties in the drainage project or downstream may be affected during the range of floods specified in **Minn. Stat. § 103E.015**.
- Current State of Minnesota floodplain management standards that numerous local governmental units have adopted utilize the 100-year flood event as a base flood condition. When a community has an adopted floodplain ordinance (not all have), these standards generally allow a 0.5-foot stage increase due to an encroachment or impoundment in a designated floodplain (except where damage potential exists). If damage potential exists, then a reduced, and in some cases, no stage increase criterion is used. For public drainage system projects that place fill in a designated floodplain or increase flows, the engineer must evaluate

pre-project and post-project 100-year flood stages and check for compliance with the state floodplain standards found in local governmental ordinance. If the proposed project increases the flood damage potential, then the affected land use(s) need to be protected (i.e., flood proofing, floodwalls/levees, etc.) or the proposed drainage project redesigned.

- The engineer should make an assessment of all damages arising from the proposed project and include the estimate of the cost to mitigate these damages as part of the overall project costs in the engineer's preliminary report. Any increased damage potential downstream of the outlet which cannot be mitigated should be identified by the engineer.
- If the outlet for the proposed drainage system is another public drainage system, then the hydraulic capacity of the outlet drainage system and its structures must not be adversely affected such as to hamper its intended design and function.
- An existing outlet drainage system may have ample excess hydraulic capacity to accommodate increased outflow from the proposed project. If so, then this capacity must be analyzed and documented by the engineer. Appropriate hydraulic calculations should be presented to support this determination.
- If the public drainage system outlet for the proposed project is determined to be inadequate, then the engineer must so report and recommend appropriate remedies, with the support of hydraulic analyses.

D. Methods of Outlet Analysis

Depending upon the magnitude of the proposed drainage project, there are several hydrologic and hydraulic methods of analysis available to the engineer for developing the assessment of outlet adequacy. The methods of analysis outlined herein are considered to represent good engineering practice.

Each engineering approach involves various levels of effort, field survey requirements, and cost. Smaller drainage projects, whose outlet impacts will be minimal, may only warrant a basic, less expensive engineering analysis. Larger projects could require substantial analyses of outlet conditions and could represent a significant portion of the engineering budget. The engineer must consider the potential significance of outlet impact and downstream damages. When selecting the analytical approach for larger projects, it is recommended that the engineer coordinate the selected outlet analysis approach with the DNR, at the earliest practical time during project development. In this way, the project sponsors and the drainage authority will have sufficient time to incorporate an adequate level of outlet analysis in the project engineering budget and be kept informed of ongoing project costs.

1. Field Survey Data

A field survey will determine the geometry and critical elevations of existing structures within the affected reach of the outlet, such as culverts.

All hydrologic and hydraulic analyses will require some level of field survey information reflecting existing outlet conditions. An office review of aerial photographs of the outlet and state-wide LiDAR topography will indicate locations where field survey data should be collected. Depending on the anticipated significance of outlet impact, the following information is considered a minimum requirement for a field survey:

- Outlet channel cross sections at the point of project discharge, as well as selected locations upstream and downstream;
- Geometry and critical elevations of bridges, culverts, dams, and other structures within the affected reach of the outlet;
- Critical elevations of buildings and adjacent land uses, and the elevation of the onset of flooding along the potentially impacted reach of the outlet; and
- Historical high water marks in the vicinity of the outlet.

(Note: The suggested information should be collected as far downstream along the outlet as there may exist a potential impact from the proposed project. Since the collection of field survey information can be an expensive item of the engineering budget, the engineer should coordinate the scope of this work with the DNR Division of Ecological and Water Resources before commencement of the field survey. All field survey information should be documented in the engineer's preliminary report).

2. Outlet Hydrology

All outlet analyses should provide an estimate of the discharge-frequency relationship for both the "with" and "without" project condition. Depending on the magnitude and potential significance of the proposed project's impact, required information may vary from simple stage-discharge relationships to full runoff hydrographs. In a few instances, a **USGS** or **State of Minnesota gaging station** may be conveniently located close to the proposed project's outlet. Gaging station records may vary from recording only peak stages and discharges to providing a continuous daily discharge record. This is considered to be the best available hydrologic information. Such information can provide a direct relationship between discharge, stage, and duration of the hydrograph.

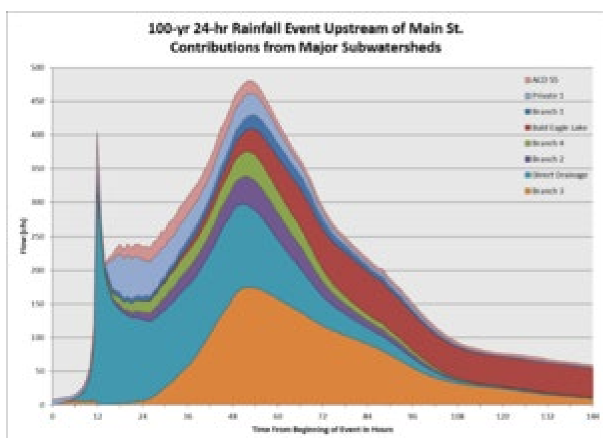
However, most proposed drainage projects are not conveniently located adjacent to or near a gaging station. In such cases, approximate methods incorporating regional hydrological analyses are available. These methods only provide peak discharge-frequency information. This information is then converted to stage-frequency relationships via channel hydraulic calculations, to be discussed later. Regionalized hydrological relationships that are commonly accepted for drainage system design in Minnesota include the following publications / web pages (publication "references" are found at the following link):

- **USGS "StreamStats" web application** (based on the publication **"Techniques for Estimating the Magnitude and Frequency of Peak Flows on Small Streams in Minnesota")**;
- **Minnesota Department of Transportation (MnDOT) "Drainage Manual"** ; and
- **Natural Resource Conservation Service (NRCS) "Engineering Field Handbook", Chapter 2**, which incorporates rainfall-frequency and peak runoff related by the curve number concept.

Of these three, the Engineering Field Handbook is preferred for outlet analysis because it provides an estimate of both peak discharge and time to peak. The timing of the arrival of peak discharges at the outlet can be critical in assessing the impact of a drainage project.

The above methodologies are usually adequate for most drainage projects in Minnesota. However, some projects may be of such a magnitude that a hydrograph analysis may be warranted. Hydrograph analysis is usually appropriate where the duration and timing of the peak discharges of the outlet channel and the proposed drainage system is critical to outlet adequacy. This type of analysis usually involves the development of a rainfall-runoff hydrograph model for both the project drainage area and the total watershed of the outlet above the point of project discharge. Many proprietary computer models are available for this type of analysis, most of which use some derivation of either the historic Soil Conservation Service's TR-20 Model or the Environmental Protection Agency's SWMM model). This type of approach to outlet analysis does represent an additional engineering cost to the project but due to advances in technology and available data, the cost of developing a hydrology model has been substantially reduced in recent years. The need for this approach should be coordinated with the DNR Division of Ecological and Water Resources, early in the project development phase.

3. Outlet Hydraulic Analysis



Modeling will not only calculate water surface profiles efficiently, but also analyze culverts, bridges, and roadway overtopping.

The outlet hydraulic analysis should provide a reliable relationship between peak discharges over a range of frequencies and stages (see section C, **Basic Requirements of an Adequate Outlet**). A stage-frequency relationship can then be developed for pre-project and post-project conditions. The difference between these two stage relationships can be used to assess the adequacy of the outlet to accommodate the increased peak discharges, if any, associated with the proposed project. In addition, the two stage-frequency relationships will provide a basis for assessing increased damages along the outlet, if any.

There are several analytical techniques for developing a stage-discharge-frequency relationship (rating curve). If a gaging station exists near the outlet of the proposed project, an outlet rating curve may already be available. It may also be possible to transpose an existing rating curve from a nearby gaging station to the proposed drainage system's point of discharge by an elevation-correction relationship.

		At Subwatershed Outlet		"Routed" to I-35 E		"Routed" to Main St.	
		Peak Flow	Yield	Peak Flow	Yield	Peak Flow	Yield
	Area (acres)	(cfs)	(cfs/acre)	(cfs)	(cfs/acre)	(cfs)	(cfs/acre)
Bald Eagle Lake	19,246	43.8	0.0023	30.6	0.0016	32.3	0.0017
Branch 1	251.0	30.9	0.1230	17.4	0.0695	19.5	0.0777
Branch 2	648.4	162.2	0.2502	35.5	0.0548	42.5	0.0655
Branch 3	3,048	131.6	0.0432	155.2	0.0509	175.1	0.0575
Branch 4	431.4	169.3	0.3924	30.3	0.0703	37.6	0.0872
ACD 55	954.3	28.3	0.0296	NA	NA	19.0	0.0199
Private Ditch	549.9	74.1	0.1348	NA	NA	33.5	0.0609
Direct Drainage	1,715/2,080			93.927	0.0548	120.745	0.0581

Example results of an outlet analysis.

If an existing gaging station's rating curve does not exist for the outlet, then an engineering hydraulic analysis of the outlet channel is required. When significant damage potential exists along the outlet channel, it is recommended that water surface profiles be calculated for a range of discharges, including the project design frequency and the range of flood events. Commonly accepted hydraulic models for calculating water surface profiles include the U.S. Army Corps of Engineers'[1] HEC-RAS model and a variety of proprietary models based on the historic Soil Conservation Service's TR-20 Model or the Environmental Protection Agency's SWMM model. All of these models not only calculate water surface profiles efficiently, but also analyze culverts, bridges, and roadway overtopping.

For smaller drainage projects, where it can be assumed that damages at the outlet will be insignificant, less sophisticated hydraulic analyses may be appropriate. The standard approach for this type of analysis would be a normal depth calculation using Manning's Equation. Where downstream culverts and bridges may be affected, hydraulic analyses of these structures may be required. It is recommended that normal depth be calculated for a range of discharges, including the project design frequency and the range of discharges discussed earlier.

[1] Subsequent to the development of the TR-20 model, the Soil Conservation Service was reestablished as the "Natural Resource Conservation Service" (NRCS). The historic TR-20 is no longer supported by the NRCS. However, the SCS method of unit hydrograph generation and the TR-20 routing methodology are still utilized by many proprietary hydrology and hydraulics models.

E. Documentation of Outlet Adequacy

The engineer must make a determination of outlet adequacy in the engineer's preliminary report (see **Minn. Stat. § 103E.245, Subd. 4 (3)**). This determination must be supported by an acceptable engineering analysis of pre-project and post-project outlet conditions. A special section of the engineer's preliminary report must be provided to include a complete discussion of the analysis, results, assessment of potential damages, and recommendations concerning outlet adequacy.

As indicated previously, all critical field survey data pertaining to the outlet and its relationship to the proposed drainage project should be documented in the engineer's preliminary report. Typical outlet channel cross sections should be shown on the preliminary plans, along with historical high water elevations. All structures, facilities, or other land uses along the outlet channel which could be adversely affected by the project should be shown, along with their critical floor and/or ground elevations.

If damage potential along the outlet is significant, the water surface profiles for the design frequency event and all other critical flood events should be shown on a profile drawing of the outlet channel adversely affected. At a minimum, the engineer should document pre-project and post-project outlet channel hydraulic conditions in the engineer's preliminary/final report, with a tabulation of supporting calculated data (either normal depth or water surface profile calculations). If potential damage is anticipated, then the project should be modified to reduce outlet flows or the potential damages need to be mitigated in coordination with downstream landowners. This data, along with other field data collected, will enable an adequate review by DNR staff and other agencies.