Chapter 1 INTRODUCTION

1.1 INTRODUCTION

The Minnesota Department of Transportation (Mn/DOT) Drainage Manual is based on the Model Drainage Manual (AASHTO, 1991 and 1999) produced by the American Association of State Highway and Transportation Officials (AASHTO) Task Force on Hydrology and Hydraulics. The manual has been developed to give basic working knowledge of hydrology and hydraulic design so that typical highway drainage features can be designed with minimal assistance. However, this manual cannot provide guidance on all hydrologic or hydraulic problems and is no substitute for experience or engineering judgment.

1.1.1 Updates

Comments and or recommendations, which may lead to revision of the manual, should be submitted in writing to the State Hydraulics Engineer. These comments and/or recommendations will be reviewed by the Office of Bridges and Structures. It is anticipated that revisions will be developed periodically and issued under a transmittal letter. All transmittal letters should be recorded on the Transmittal Record Sheet in the front of the manual. More complete reviews will be performed approximately biannually and revisions to the manual may be issued.

1.1.2 Drainage Manual Organization

The Drainage Manual contains eight chapters and five appendices.

Chapter 1	Introduction
Chapter 2	Materials and Structural Design
Chapter 3	Hydrology
Chapter 4	Channels
Chapter 5	Culvert
Chapter 6	Energy Dissipator
Chapter 7	Storage Facilities
Chapter 8	Storm Drain Systems
Appendix A	Risk Assessment
Appendix B	TP-40 Rainfall Intensity Curves
Appendix C	Pipe Flow Design Charts
Appendix D	Open Channel Flow Charts
Appendix E	Computer Programs and References

1.1.3 User Instruction

The purpose of the Drainage Manual is to provide a basis for uniform design practice for typical roadway drainage. Unfortunately, it is impractical to provide precise rules and methods for all design situations. Situations will arise where these standards do not apply. The use and adherence to standards does not exempt the engineer from the professional responsibility of developing an appropriate design. The engineer is responsible for identifying standards that are inappropriate for a particular project, and for obtaining the necessary variances to achieve proper design.

Each page shows the date of issuance and the page number. The pages are numbered according to the first index number appearing on that page. Revisions and supplements will be accompanied by a numbered Transmittal Letter. The number of the Transmittal Letter, date and subject should be recorded in the Transmittal Record Sheet located in the front of the manual.

References to specific computer programs, AASHTO guidelines, manuals and regulations are noted within the manual. It is assumed that the designer is knowledgeable in the use of the referenced items. Designers are responsible for obtaining computer program user manuals and keeping up-to-date with these programs and the latest drainage-related Federal regulations. Designers and agencies are responsible for keeping themselves up-to-date on changes to hydraulic design policy, procedures or practices.

The Drainage Manual is intended to be used in conjunction with other Mn/DOT design aids. Standard Specifications for Construction, Standard Plates, CADD standards, Technical Memorandums and other design manuals all provide information that will influence hydraulic design.

1.2 METRIFICATION

This manual is based on English units with all equations, tables and figures provided in English units. Two systems of units are currently used in transportation design, English and SI. SI is the symbol for the International System of Units (modern metric). Since some of the information sent to the hydraulic designer may be in metric units, or the plan is being developed as a metric plan, it is necessary to be able to convert between the two sets of units. Although this manual is in English, each engineer will decide to perform calculations in English or SI based on the format of input data (surveys, roadway design files, Quad maps); format of design aids (manuals, charts and programs); the preferences of the engineer; and the required format of the drainage output, (English or Metric).

This section is intended to assist with the conversion of units so that the designer can perform computations in English, and convert the final hydraulic design into metric for inclusion in a metric plan. For designers performing computations in metric units, SI versions of the equations, tables and figures are available in the metric version of the *Model Drainage Manual, Metric Edition* (AASHTO, 1999). In addition, many of Federal Highway Administration's (FHWA) Hydraulic Engineering Circular (HEC) and Hydraulic Design Series (HDS) manuals have been converted to metric or dual units and are available for reference.

1.2.1 Hard and Soft Conversion

Soft conversion is an exact conversion and hard conversion is a rounded off conversion. When using soft conversion, the English unit is converted to an exact metric equivalent. However, for hard conversion, the English unit is rounded off to a rationalized metric equivalent that is easier to work with and is appropriate for the particular conversion at hand. Soft conversion shall be used for proprietary items that do not yet have standard metric sizes and for values such as discharge and drainage area. Appropriate rounding should comply with the Mn/DOT Technical Manual. Hard conversion is used for items such as concrete pipe, and catch basin grates.

1.2.2 Conversion Procedure

Step 1 Make a decision to work in Metric or English units. The decision is based on units of input, design aids, and desired output units.

Step 2 Convert any information or equations that is not in the correct units. Maintain correct number of significant digits during conversion.

Step 3 Perform calculations.

Step 4 Convert discharges, flood elevations or any other necessary information to go on the plan to the correct format. Use correct type of conversion, soft or hard.

1.2.3 Conversion Tables

Expression	SI prefixes	Symbol	Example
.001	milli -	m	mm
1	-		m
1000	kilo -	k	km
1,000,000	mega -	M	Mg

Table 1.1 Unit Conversion

Unit Conversion Table				
Quantity	**Common Variables**	**English (Symbol)**	**Multiply by to get**	**SI (Symbol)**
Length	Pipe Diameter Precipitation Infiltration	inches (in)	25.4	millimeters (mm)
	Depth Head Length Elevation Headwater Tailwater Cross sections Profile plots Contour intervals Friction losses	feet (ft)	0.3048	meters (m)
	Distance	miles (mi)	1.609344	Kilometers (km)
Area	Drainage Area	square feet (ft^2) acres square miles (mi^2)	0.0929 0.4047 2.59	square meters (m^2) hectares (ha) square kilometers (km^2)
Volume	Storage Volume	cubic feet (ft^3)	0.0283	cubic meters (m^3)
Mass (weight)		pound (lb) ton	0.4536 0.9072	kilogram (kg) metric ton (t)
Force		pound force (lb_f)	4.45	newton (N)
Pressure		pounds per square foot (psf) poundforce per square inch (psi)	47.880 6.895	pascal (Pa) = N/m^2 kilopascal (kPa)
Rate	Flow Rate Discharge	cubic feet per second (cfs)	0.02832	cubic meters per second (m^3/s)
	Rainfall Intensity	inches per hour	25.4	millimeter per hour
	Flow Velocity	feet per second (fps)	0.3048	meters per second (m/s)
Acceleration	Acceleration Due to Gravity	32.174 ft/s^2	equals	9.807 m/s^2
Specific Gravity		dimensionless	no change	dimensionless
Angle		degree - minute - second (° ' ")	no change	degree - minute - second (° ' ")
Temperature		degree Fahrenheit (°F)	5/9(°F-32)	degree Celcius (°C)

Table 1.2 Pipe Hard Conversion

Hard Conversion of Pipe Diameters

Round Pipe
Mn/DOT Standard Plate 3000 & M3000

Inner Diameter Inches	Metric Size Nominal Millimeters
12	300
15	375
18	450
21	525
24	600
27	675
30	750
33	825
36	900
42	1050
48	1200
54	1350
60	1500
66	1650
72	1800
78	1950
84	2100
90	2250
96	2400
102	2550
108	2700
114	2850
120	3000

nominal diameters of 27" and 33" not provided for corrugated metal pipe

Pipe Arch, Span x Rise
Mn/DOT Standard Plate 3040 & M3040
2 2/3" x ½" (68 mm x 13 mm) corrugations

Span x Rise Inches	Metric Size Nominal Millimeters
17 x 13	430 x 330
21 x 15	530 x 380
24 x 18	610 x 460
28 x 20	710 x 510
35 x 24	885 x 610
42 x 29	1060 x 740
49 x 33	1240 x 840
57 x 38	1440 x 970
64 x 43	1620 x 1100
71 x 47	1800 x 1200
77 x 52	1950 x 1320
83 x 57	2100 x 1450

Reinforced Concrete Pipe Arch
Mn/DOT Standard Plate 3014 & M3014

Nominal Span Inches	Nominal Span Millimeters
22	560
28	725
36	920
44	1110
51	1300
58	1485
65	1650
73	1855
88	2235
102	2590
115	2920
122	3100
138	3505
154	3910
169	4285

Pipe Arch, Span x Rise
Mn/DOT Standard Plate 3041 & M3041
3" x 1" (75 mm x 25 mm) corrugations

Span x Rise Inches	Metric Size Nominal Millimeters
40 x 31	1010 x 790
46 x 36	1160 x 920
53 x 41	1340 x 1050
60 x 46	1520 x 1170
66 x 51	1670 x 1300
73 x 55	1850 x 1400
81 x 59	2050 x 1500
87 x 63	2200 x 1620
95 x 67	2400 x 1720
103 x 71	2600 x 1820
112 x 75	2840 x 1920
117 x 79	2970 x 2020
128 x 83	3240 x 2120
137 x 87	3470 x 2220
142 x 91	3600 x 2320

1.3 DATA COLLECTION

Efficient design requires the ability to identify possible sources of data, experience as to which sources will most likely yield desired data and knowledge of procedures for acquiring it. The effort necessary for data collection and compilation shall be tailored to the importance of the project. Not all of the data discussed in this chapter will be needed for every project.

1.3.1 Types and Sources of Data

The following items may be required depending on the nature of the project:

- watershed characteristics,
- site characteristics,
- geomorphic characteristics,
- hydrologic and meteorologic information, and
- environmental considerations and regulations.

Specific design parameters are often obtained from field reconnaissance. Moreover, it is easier to interpret published sources of data after an on-site inspection. Only after a thorough study of the area and a complete collection of all required information should the designer proceed with the final design of a hydraulic facility.

<u>Watershed Characteristics</u>

Data needed to define watershed characteristics includes:

- Contributing Drainage Area - Determine the boundaries and size of the contributing drainage area. Check for changes in the topographic contributing area.
- Slope - The slope of streams and ditches and the average slope of the watershed (basin slope), should be determined. Hydrologic and hydraulic procedures in other chapters of this manual are dependent on watershed and channel slopes.
- Watershed Land Use - Define and document present and expected future land use, particularly the location, and degree of anticipated urbanization.
- Soils - Determine soil type and classification.

Sources of watershed information include:

- field reviews;
- photos;
- field survey with conventional survey instruments;
- aerial photographs (conventional and infrared);
- zoning maps and master plans;
- land use maps;
- topographic, drainage area and other maps;
- soil and geological maps;
- municipal planning agencies;
- public ditch maps;
- landsat (satellite) images; and
- files.

Watershed data is available from agencies such as:

- State Agencies,
- Municipal Agencies,
- Local Agencies,
- County Agencies,
- Public Ditch Authorities,
- Watershed Districts and Watershed Management Organizations (WMO),
- Metropolitan Council or other local planning agencies,
- United States Geologic Society (USGS),
- Local Developers,
- Private Citizens,
- Private Industry, and
- Natural Resources Conservation Service (NRCS).

Site Characteristics

Any work being performed, proposed or completed, that changes the hydraulic characteristics of a stream or watercourse must be evaluated to determine its effect on the stream flow. The designer should be aware of plans for channel modifications, and any other changes which might affect the facility design.

- Pavement Alignment and Cross-sections
- Channel Geometry
  - Stream Profile - Stream bed profile should extend sufficiently upstream and downstream to determine the average slope and to encompass any proposed construction or aberrations.
  - Stream Cross-sections - Stream cross-sections shall be obtained that represent the conditions at proposed and existing structures. Stream cross-section data should also be obtained at other locations where stage-discharge and related calculations will be necessary.
  - Channel modifications
- Overbank or Floodplain Conditions
  - Roughness Coefficients - Roughness coefficients, ordinarily in the form of Manning's "n" values should be estimated for the flood limits of the stream.
  - Acceptable Flood Levels - Development and property use adjacent to the proposed site, both upstream and downstream, may determine acceptable flood levels. Floor elevations of structures or fixtures should be noted. In the absence of upstream development, acceptable flood levels may be based on tailwater and freeboard requirements of the highway itself. In these instances, the presence of downstream development may determine flood levels when an overtopping design of the highway is considered.
- Obstructions
  - Existing Structures - The location, size, description, condition, observed flood stages, and channel section relative to existing structures on the stream reach and near the site should be obtained in order to determine their capacity and effect on the stream flow. Any structures, downstream or upstream, which may cause backwater or retard stream flow should be investigated. In addition, the manner in which existing structures have been functioning with regard to such things as scour, overtopping, debris and ice passage, fish passage, etc. should be noted. For bridges, these data should include span lengths, type of piers, and substructure orientation which usually can be obtained from existing structure plans. Necessary culvert data includes size, inlet and outlet geometry, slope, end treatment, culvert material, and flow line profile.
  - Controls Affecting Design Criteria - Determine what natural or man-made controls should be considered in the design. Any ponds or reservoirs, along with their spillway elevations and design levels of operation, should be noted as their effect on backwater and/or stream bed aggradation may directly influence the proposed structure. Conservation and/or flood control reservoirs in the watershed may reduce peak discharges. Capacities and operation designs for these features should be obtained.
  - Debris and Ice -The quantity and size of debris and ice carried or available for transport by a stream during flood events should be investigated and such data obtained for use in the design of structures. In addition, the times of occurrence of debris and ice in relation to the occurrence of flood peaks should be determined; and the effect of backwater from debris and ice jams on recorded flood heights should be considered in using stream flow records.
- Storage Potential - Define parameters of all streams, rivers, ponds, lakes, and wetlands that will affect or may be affected by the proposed structure or construction. These data are essential for stream hydrology and may be needed for regulatory permits.
  - Outline the boundary (perimeter) of the water body for the ordinary highwater.
  - Elevation of normal as well as high water for various frequencies.
  - Detailed description of any natural or manmade spillway or outlet works including dimensions, elevations, and operational characteristics.
  - Determine classification of state waters.
  - Description of adjustable gates, soil and water control devices.
  - Profile along the top of any dam and a typical cross section of the dam.
  - Determine the use of the water resource (stock water, fish, recreation, power, irrigation, municipal or industrial water supply, etc.).
  - Note the existing conditions of the stream, river, pond, lake or wetlands as to turbidity and silt.
  - Determine riparian ownership(s).
- Flood History - Research the history of past floods and their effect on existing structures. Changes in channel and watershed conditions since the occurrence of the flood shall be evaluated in relating historical floods to present conditions.

Sources of site data include:

- site visit;
- photographs, aerial photographs (conventional and infrared), landsat (satellite) images;
- field survey with conventional survey instruments;
- highwater or flood data;
- flood insurance studies (FIS);
- zoning maps and master plans;
- topographic, and USGS quadrangle maps;
- site and location maps;
- soil and geological maps;
- municipal planning agency reports;
- plansheets (existing, as-built and proposed);
- existing conservation and/or flood control reservoirs design or structure operation records;
- files, plans, design data and hydraulic recommendations for existing and nearby structures;
- past flood scour data;
- maintenance records; and
- project files and correspondences (planning, budgeting, previous recommendations and scoping documents).

Site data is available from agencies such as:

- State Agencies,
- Local Agencies and Municipal Agencies,
- County Agencies,
- Surveyor,
- Field Review,
- U.S. Army Corps of Engineers (USACE),
- Natural Resources Conservation Service (NRCS),
- Federal Emergency Management Agency (FEMA),
- Private Citizens,
- U.S. Geological Survey (USGS),
- Federal Highway Administration (FHWA),
- Watershed Districts and Watershed Management Organizations (WMO),
- Public Ditch Authorities, and
- Reservoir Sponsors.

Geomorphological Data

Geomorphology is important in the analysis of channel stability and scour. The use of an alluvial river computer model will increase the need for geomorphological data to calibrate the model. Also, geomorphological data is needed to determine the presence of bed forms so a reliable Manning's n as well as bed form scour can be estimated. The need for geomorphological data will be determined by the designer.

- Stream Classification - Define stream classification parameters.
- Sediment Transport - Investigate degradation, aggradation and sediment movement.
- Form Stability - Define stability of stream form over time.
- Scour Potential - Research scour history and evidence of scour. Scour potential is a function of the stability of the natural materials at the facility site, tractive shear force exerted by the stream and sediment transport characteristics of the stream.
- Bed and Bank Material - Identify bed and bank material.

Sources of Geomorphological information include:

- bed and bank material samples,
- geotechnical study, and
- soil maps.

Geomorphological data is available from:

- Natural Resources Conservation Service (NRCS), and
- Site Investigations.

Hydrologic Data

Hydrologic data is collected to determine the runoff rate or volume for which a hydraulic facility must be designed.

- Rainfall
- Discharge

Sources of hydrologic data include:

- meteorological data (precipitation records),
- gaging station data (peak and continuous),
- regional regression studies,
- site studies,
- flood insurance studies (FIS),
- TP-40,
- rainfall-intensity-duration curves,
- hydrologic studies for nearby structures,
- watershed districts overall plan, and
- regional and local flood studies.

Hydrologic data is available from agencies such as:

- National Oceanic and Atmospheric Administration (NOAA),
- Climatic Data Center,
- State Agencies,
- National Weather Service (NWS),
- Department of Natural Resources (DNR),
- U.S. Corps of Engineers (USACE),
- U.S. Geological Survey (USGS),
- Federal Highway Administration (FHWA), and
- Natural Resources Conservation Service (NRCS).

Environmental Considerations

The need for environmental information stems from the need to investigate and mitigate potential impacts. The environmental sensitivity of a site is a function of the design configuration and surface water attributes (water use, water quality and standards, aquatic and riparian wildlife biology, and wetlands). Environmental data needs may be categorized as follows.

- Regulatory and Permits
- Environmentally Compatible Design - Physical, chemical and biological information may be required to identify environmental impacts relevant to the facility design. For instance, a culvert may be designed to accommodate fish migration by creating a low flow channel. Other factors that should be considered include: fish habitat, sediment transport, water supply, recreational use, water velocity, and water quality.
- Wetlands - Each wetland is unique and evaluation should be coordinated with the appropriate permitting authorities.

Sources of environmental information include:

- flood plain delineations and studies,
- FHWA design criteria and practices,
- Minnesota state laws,
- local ordinances and master plans,
- Corps of Engineers Section 404 permit program,
- boat passage,
- fish migration,
- national wetland inventory (NWI),
- U.S. Geological Survey maps ("Quad" sheets),
- wetland mitigation plans,
- protected waters (DNR),
- right of way limitations,
- water quality studies (MPCA),
- permit applications, and
- project files and correspondences (planning, previous commitments and scoping documents).

Environmental, permitting or regulatory information is available from agencies such as:
- Department of Natural Resources (DNR),
- Federal Emergency Management Agency (FEMA),
- Federal Highway Administration (FHWA),
- U.S. Environmental Protection Agency (EPA),
- Board of Soil and Water Resources (BWSR),
- Watershed Districts or Watershed Management Organization (WMO),
- U.S. Fish and Wildlife Service (USFWS),
- U.S. Forest Service (USFS),
- Natural Resources Conservation Service (NRCS),
- U.S. Corps of Engineers (USACE), and
- Minnesota Pollution Control Agency (MPCA).

1.3.2 Survey Information

Complete and accurate survey information is necessary to develop a design that will best serve the requirements of a site. The project surveyor is not likely to have a good knowledge of drainage design, and will need to coordinate with the drainage designer to identify the extent of the survey. The drainage designer should inspect the site and its contributing watershed to determine the required field and/or aerial drainage survey needed for the hydraulic analysis and design. Survey requirements for small drainage facilities such as 36 inch culverts are less extensive than those for major facilities such as bridges. However, the purpose of each survey is to provide an accurate picture of the conditions within the zone of hydraulic influence of the facility. Data collection should be as complete as possible during the initial survey in order to avoid repeat visits.

The following data can be obtained or verified during a field survey:
- contributing drainage area characteristics,
- stream reach cross sections and thalweg profile,
- location and survey of existing structures,
- elevation of flood prone property,
- general ecological information about the drainage area and adjacent lands,
- high water elevations including the date of occurrence, and
- ordinary highwater elevation.

At many sites photogrammetry (aerial photo survey) is an excellent method of securing the topographical components of a drainage survey. Planimetric and topographic data covering a wide area are easily and cost effectively obtained . A supplemental field survey is required to provide data in areas obscured on the aerial photos (underwater, under trees, etc.).

1.3.3 Field Reviews

Field reviews are usually initiated for one of several reasons, data is needed for a design project, documentation of performance during a flood event, or operation and maintenance review.

<u>Project field review</u>

Field reviews allow the drainage designer to become familiar with the site. The most complete topographic survey cannot adequately depict all site conditions or substitute for personal inspection by someone experienced in drainage design. Factors that most often need to be confirmed by field inspection are:
- selection of roughness coefficients,
- evaluation of apparent flow direction and diversions,
- flow concentration,
- observation of land use and related flood hazards,
- geomorphic relationships,
- highwater marks or profiles and related frequencies, and
- existing structure size and type.

Photographs are taken during a field review. For centerline culverts and bridges, photos should be taken looking upstream and downstream from the site as well as along the contemplated highway centerline in both directions. Details of the stream bed and banks should also be photographed along with structures in the vicinity both upstream and downstream. Close up photographs complete with a scale or grid should be taken to facilitate estimates of the stream bed gradation.

When drainage areas are checked in the field, or when the drainage survey is conducted, the size of all inplace structures in the vicinity should be noted, and highwater information should be obtained from local citizens or agencies. The performance of structures, which have been conveying runoff from a watershed for a long time, is an excellent source of information for estimating design discharges. Upstream structures may throttle the runoff and reduce the peak discharge. Downstream channels or structures may cause a backwater effect on the structure being designed, and thereby affect its operation and design.

Flood field review

Each District should be interested in maintaining a permanent file of highwater or flood data. Every year there are claims for flood damages caused or partially caused by highway drainage structures, new and old. Many times it can be proven that the Department is not at fault, but there also are instances where the complaints are justified or where claims cannot be disproven. Therefore, it is strongly recommended that each District established a permanent file on highwater data which will be available for design purposes as well as for settlement of claims.

During a flood or major runoff event, measure flow parameters so the discharge can be calculated and hydraulic models calibrated. A suggested flood analysis form is shown at the end of this section. All of the information called for on this form is important for determination of the discharge which occurred, the adequacy of the structure, and the possible liability of the State for damages. The following is information that should be collected during a flood event.

- Locate the structure precisely with enough accuracy and detail for positive identification.
- The location of highwater marks must be documented.
- Record of the date of the highwater is important.
- Record the date of the observation or measurements which may be taken some time after the peak has passed the structure.
- General information on the size and type of structure is important for descriptive purposes and for estimating the discharge. In the case of culverts, every one of the items listed (size, type, length, inlet and outlet elevations and type of inlet) have a direct influence on the hydraulic capacity.
- Presence of ice or debris at the structure is important in determining whether or not the structure was operating at capacity. Sometimes remedial measures, such as debris barriers or splitter walls, are needed rather than additional waterway opening to alleviate flooding.
- Silt deposits or erosion should be noted where significant, so that proper maintenance work can be done to protect the efficiency and stability of the structure and to prevent erosion from progressing onto private property and becoming a basis for a claim.
- Information on the drainage area characteristics is important for hydrological reasons and also for estimating the general severity of flood damage.
- Where water flows over the highway, a profile of the road which will cover more than the inundated section should be taken after the flood has subsided. With this profile, and the upstream and downstream highwater elevations, the discharge over the road can be estimated.
- Record other factors, such as the influence of dikes, dams, or water overflowing the road, which need elaboration. If the form lacks sufficient space for a thorough description of these effects, such information may be recorded on the back of the form or on extra sheets.

When recording elevations, it may not always be convenient to use mean sea level datum. A local benchmark set to assumed datum will suffice. The objective is to have all levels at a site on the same datum. Such benchmarks should be recorded on the form so they can be found in the future for subsequent measurements or for tying into sea level datum. District personnel can mark the highwater levels if properly informed where to make the marks in relation to the inlet and outlet of the structure. Later, survey crews can determine the elevations and complete the form. Both dates should be accurately recorded.

Highwater elevations upstream and downstream of a structure or flooded roadway are the most important data and are often incorrectly obtained. When water enters a structure, the water surface is drawn down due to the increased velocity, and there is turbulence at the outlet. Elevations should not be taken in these disturbed areas. Water level elevations should be taken a short distance away from the inlet and outlet, where the water level is representative of the general pool or flow before it is affected by the drawdown or after the turbulence has dissipated. This distance may be as little as five or ten feet for small pipe culverts and up to one bridge length away from the opening for larger structures. In case of uncertainty, make several highwater marks so they can be checked later with a level. Usually the highest water levels will occur on both sides at the same time, so it is possible to use visual highwater marks (such as trash lines) with fair reliability if the peak flow cannot be observed. It is important that elevations be taken both upstream and downstream of structures so the restrictive effects and discharge can be estimated. One elevation at the inlet end is of little real value either for discharge measurements or for determination of damages.

Return to District Hydraulics Unit

FIELD OBSERVATION INFORMATION
FOR
FLOOD ANALYSIS

1. Location of Structure: S.P.____________________ T.H. ____________________

   Name of Stream:____

   Sta., Mile Point, Sec. etc.:__________________________________

2. Date of Highwater:____________________ Date of Observation:__________________

3. General Information:

   A. Bridge No._______________ Low Beam Elev._______________________

   B. Culvert Size__________ Type: ☐ CMP ☐ CMPA ☐ RCP ☐ RCPA ☐ BOX

   ☐ Other: _____________________________

   Length______________ Inlet Elev._______________ Outlet Elev.____________

   Type of Inlet: ☐ Apron ☐ Headwall ☐ Sloped or Beveled ☐ Square End

   ☐ Other: ____

4. Highwater Information:

   A. Elev. upstream of structure or roadway __________________________________

   B. Elev. downstream of structure or roadway ________________________________

   C. Elevation at centerline when roadway is flooded ____________________________

5. Give statement as to effect of ice, debris, silting, or erosion.

   ____

   ____

   ____

6. If structures upstream or downstream affect this site give same information as above on separate sheet and attach.

7. Information on Drainage Area:

   A. Type of Soil: ☐ Granular ☐ Semi Granular ☐ Plastic ☐ Exposed Ledge Rock

   B. Land Use: ☐ Swamp ☐ Forest ☐ Cultivated ☐ Pasture ☐ Urbanized ☐ Other: __________

   C. Topography: ☐ Steep Rugged ☐ Hilly ☐ Moderately Rolling ☐ Gently Rolling ☐ Flat

8. Record any other pertinent information here and on the reverse side as necessary.

Note: During unusually high water conditions contact the Hydraulics Unit at once. See Drainage Manual Section 1.3.3 for instructions on obtaining data.

1.3.4 Data Evaluation

Once the needed data and information have been collected, the next step is to compile it into a usable format. The designer must ascertain whether the data contains inconsistencies or other unexplained anomalies which might lead to erroneous calculations or results. The main reason for analyzing the data is to draw all of the various pieces of collected information together, and to fit them into a comprehensive and accurate representation of the hydrologic and hydraulic characteristics of a particular site.

Experience, knowledge, and judgment are important parts of data evaluation. Historical information should be reviewed to determine whether significant changes have occurred in the watershed and whether the data can be used. Data acquired from the publications of established sources such as the USGS can usually be considered as valid and accurate. Data should always be subjected to careful study by the designer for accuracy and reliability. Basic data, such as stream flow data derived from non-published sources, should be evaluated and summarized before use. Maps, aerial photographs, satellite images, and land use studies should be compared with one another and with the results of the field survey and any inconsistencies should be resolved. General reference material should be consulted to help define the hydrologic character of the site or region under study and to aid in the analysis and evaluation of data.

Often sensitivity studies can be used to evaluate data and the importance of specific items to the final design. Sensitivity studies consist of conducting a design with a range of values for specific data items. The effect on the final design can then be established. This is useful in determining what specific data items have major effects on the final design and the importance of possible data errors. Time and effort should then be spent on the more sensitive data items making sure these data are as accurate as possible. This does not mean that inaccurate data are accepted for less sensitive data items, but it allows prioritization of the data collection process given a limited budget and time allocation. The results of this type of data evaluation should be used so that as reliable a description as possible of the site can be made within the allotted time and the resources committed to this effort. The effort of data collection and evaluation should be commensurate with the importance and extent of the project and/or facility.

1.4 DOCUMENTATION

The design of highway drainage facilities must be well documented. Frequently, it is necessary to refer to plans and specifications after construction is completed. Information will be needed in the case of litigation, failure, or just for future reference. Documentation should be easy to understand, and include all design assumptions and enough data and computations to allow someone to understand why the facility was designed as it was. Documentation should include: engineering calculations and analysis, drainage area and other maps, filed survey information, project correspondence relative to hydraulic considerations, and permit information. These documents should be in the appropriate format.

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 arrived at. Often there is expressed the myth that avoiding documentation will prevent or limit litigation losses as it supposedly precludes providing the plaintiff with incriminating evidence. This is seldom if ever the case and documentation should be viewed as the record of reasonable and prudent design analysis based on the best available methodology. Thus, good documentation can provide the following:

- protection for the Agency by proving that reasonable and prudent actions were, in fact, taken, (such proof should certainly not increase the potential court award and may decrease it by disproving any claims of negligence by the plaintiff);
- identifying the situation at the time of design which might be very important if legal action occurs in the future;
- documenting that rationally accepted procedures and analysis were used at the time of the design which were commensurate with the perceived site importance and flood hazard, (this should further disprove any negligence claims);
- providing a continuous site history to facilitate future reconstruction;
- providing the file data necessary to quickly evaluate any future site problems that might occur during the facility's service life; and
- expediting plan development by clearly providing the reasons and rationale for specific design decisions.

Documentation should not be considered as occurring at specific times during the design or as the final step in the process which could be long after the final design is completed. Documentation should rather be an ongoing process and part of each step in the hydrologic and hydraulic analysis and design process. This will increase the accuracy of the documentation, provide data for future steps in the plan development process, and provide consistency in the design even when different designers are involved at different times of the plan development process.

1.4.1 Documentation Procedures

A complete hydrologic and hydraulic design and analysis documentation file for each waterway encroachment or crossings should be maintained by the hydraulic section. The documentation file should contain design/analysis data and information which influenced the facility design and which may not appear in other project documentation. Following are the Agency's practices related to documentation of hydrologic and hydraulic designs and analyses.

- Hydrologic and hydraulic data, preliminary calculations and analyses and all related information used in developing conclusions and recommendations related to drainage requirements, including estimates of structure size and location, should be compiled in a documentation file.
- The drainage designer should document all assumptions and selected criteria including the decisions related thereto.
- The amount of detail of documentation for each design or analysis shall be commensurate with the risk and the importance of the facility.
- Organize documentation to be as concise and complete as practicable so that knowledgeable designers can understand years hence what was done by predecessors.
- Provide all related references in the documentation file to include such things as published data and reports, memos and letters, and interviews. Include dates and signatures where appropriate.
- Documentation should include data and information from the conceptual stage of project development through service life so as to provide successors with all information.
- Organize documentation to logically lead the reader from past history through the problem background, into the findings, and through the performance.
- An executive summary at the beginning of the documentation will provide an outline of the documentation file to assist users in finding detailed information.
- Hydrologic/Hydraulic documentation should be retained in the project plans or other permanent location at least until the drainage facility is totally replaced or modified as a result of a new drainage study.

1.4.2 Documentation Content

The following items should be included in the documentation file. Figure 1.1 is a example of a documentation project check list. The intent is not to limit the data to only those items listed, but rather establish a minimum requirement consistent with the hydraulic design procedures as outlined in this manual. 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 should appear in the documentation file. Additionally, the designer should include in the documentation file items not listed below, but which are useful in understanding the analysis, design, findings, and final recommendations.

It is very important to prepare and maintain in a permanent file the as-built plans for every drainage structure to document subsurface foundation elements such as footing types and elevations, pile types and (driven) tip elevations, etc. There may be other information which should be included or may become evident as the design or investigation develops. This additional information should be incorporated at the discretion of the designer.

<u>Drainage Design</u>

The following list recommends file contents for all types of drainage projects including bridges, culverts and storm drain systems. Design documentation should include all the information used to justify the design, including:

- photographs (ground and aerial);
- contour mapping;
- vicinity maps and topographic maps;
- watershed map or plan including:
  - flow directions,
  - watershed boundaries,
  - watershed areas,
  - natural storage areas;
- surveyed data reduced to include:
  - existing hydraulic facilities,
  - existing controls,
  - profiles - roadway, channel, driveways, cross sections - roadway, channels, faces of structures;
- flood insurance studies and maps by FEMA;
- soil maps;
- field trip report(s) which may include:
  - video cassette recordings,
  - audio tape recordings,
  - still camera photographs,
  - movie camera films,
  - written analysis of findings with sketches;
- reports from other agencies (local, State or Federal);
- newspapers clippings;
- interviews (local residents, adjacent property owners, and maintenance forces);
- reports from other agencies;
- hydrological investigations and report;
- hydraulic report; and
- approvals.

<u>Hydrology</u>

The following items used in the design or analysis should be included in the documentation file:

- contributing watershed area size and identification of source (map name, etc.);
- design frequency and decision for selection;
- hydrologic discharge and hydrograph estimation method and findings;
- flood frequency curves to include design flood, check floods, discharge hydrograph, and any historical floods; and
- expected level of development in upstream watershed over the anticipated life of the facility (include sources of and basis for these development projections).

Storm Drains

The following items should be included in the documentation file:

- computations for inlets and pipes, including hydraulic grade lines;
- complete drainage area map;
- design frequency;
- information concerning outfalls, existing storm drains, and other design considerations;
- a schematic indicating storm drain system layout;
- design notes, and correspondence relating to design decisions;
- history of performance of existing structure(s); and
- assumptions.

Open Channels

The following items should be included in the documentation file:

- stage discharge curves for the design, 100-year and any historical water surface elevation(s);
- cross-section(s) used in the design water surface determinations and their locations;
- roughness coefficient assignments ("n" values);
- information on the method used for design water surface determinations;
- observed highwater, dates, and discharges;
- channel velocity measurements or estimates and locations;
- water surface profiles through the reach for the design event, 100 year event, and any historical floods;
- design or analysis of materials proposed for the channel bed and banks;
- energy dissipation calculations and designs; and
- copies of all computer analyses.

Bridges

The following items should be included in the documentation file:

- design and highwater for undisturbed, existing and proposed conditions;
- stage-discharge curve for undisturbed, existing and proposed conditions;
- cross-section(s) used in the design and 100 year highwater determination;
- roughness coefficient ("n" value) assignments;
- information on the method used for design highwater determination;
- observed highwater, dates, and discharges;
- velocity measurements or estimates and locations (include both the through-bridge and channel velocity) for design and 100-year floods;
- performance curve to include calculated backwater, velocity and scour for design floods, 100 year flood, and 500-year flood for scour evaluation;
- magnitude and frequency of overtopping flood;
- copies of all computer analyses;
- complete hydraulic study report;
- economic analysis of design and alternatives;
- risk assessment;
- bridge scour results;
- roadway geometry (plan and profile);
- potential flood hazards to adjacent properties;
- identification and location of the facility;
- design notes, and correspondence relating to design decisions;
- history of performance of existing structure(s); and
- assumptions.

Culverts

The following items should be included in the documentation file:

- culvert performance curves;
- allowable headwater elevation and basis for its selection;
- cross-section(s) used in the design highwater determinations;
- roughness coefficient assignments ("n" values);
- observed highwater, dates, and discharges;
- stage discharge curve for undisturbed, existing and proposed conditions to include the depth and velocity measurements or estimates and locations for the design event, 100 year event , and check floods;
- performance curves showing the calculated backwater elevations, outlet velocities and scour for the design event, 100 year event, and any historical floods;
- type of culvert entrance condition;
- culvert outlet appurtenances and energy dissipation calculations and designs;
- copies of all computer analyses and standard computation sheets;
- roadway geometry (plan and profile);
- potential flood hazard to adjacent properties;
- identification and location of the facility;
- design notes, and correspondence relating to design decisions;
- history of performance of existing structure(s); and
- assumptions.

Construction and Operations

Construction or operation documentation should include:

- plans,
- revisions,
- as-built plans and subsurface borings,
- photographs,
- record of operation (during flooding events, complaints and resolutions),
- engineering cost estimates, and
- actual construction costs.

Computer Files

The following items should be included in the documentation file and be clearly labeled:

- input data listing, and
- output results of selected alternatives.

Figure 1.1 Documentation Project Check List

(Check Appropriate Items)

Engineer ______________________________

City/County ____________________________

Project ______________________________

Description ____________________________

REFERENCE DATA

Maps:

- ☐ USGS Quad Scale: _________ Date: _________
- ☐ Mn/DOT
- ☐ Local Zoning Maps
- ☐ Flood Hazard Delineation (Quad.)
- ☐ Flood Plain Delineation (HUD)
- ☐ Local Land Use
- ☐ Soils Maps
- ☐ Geologic Maps
- ☐ Aerial Photos Scale: _________ Date: _________

Studies By External Agencies:

- ☐ USACE Flood Plain Information Report
- ☐ SCS Watershed Studies
- ☐ Local Watershed Management
- ☐ USGS Gages & Studies
- ☐ Interim Flood Plain Studies
- ☐ Water Resource Data
- ☐ Regional Planning Data
- ☐ Forestry Service
- ☐ Utility Company Plans

Studies By Internal Sources:

- ☐ Hydraulics Section Records
- ☐ District Drainage Records
- ☐ Flood Records (High Water, Newspaper)

Technical Aids:

- ☐ Mn/DOT Drainage Manual
- ☐ Mn/DOT & FHWA Directives
- ☐ Technical Library

HYDROLOGIC-HYDRAULIC REPORTS

Data Reports:

- ☐ Agency Data
- ☐ Other Agency Data
- ☐ Environmental Reports
- ☐ Surface Water Environmental Study
- ☐ Surface Water Environmental Revisions
- ☐ Reconnaissance Report
- ☐ Reconnaissance Revisions Report
- ☐ Location Report
- ☐ Location Revisions Report
- ☐ Drainage Survey Inspection Report
- ☐ Drainage Survey Inspection Report Revisions
- ☐ Hydraulic Design Report
- ☐ Hydraulic Design Report - Revisions
- ☐ Construction Report
- ☐ Construction Report - Revisions
- ☐ Hydraulic Operation Report
- ☐ Hydraulic Operation Report - Revisions

HYDRAULIC DESIGN

Calibration Of High Water Data:

- ☐ Discharge and Frequency of H.W. elevation
- ☐ Influences Responsible for H.W. elevation

Analyze Hydraulic Performance

- ☐ Existing Facility for Minimum Flow through design event
- ☐ Proposed Facility for Minimum Flow through design event

Design Appurtenances:

- ☐ Dissipators
- ☐ Rip Rap
- ☐ Erosion & Sediment Control
- ☐ Fish & Wildlife Protection

Computer Programs:

- ☐ Culvert Design: HY8, CDS
- ☐ Water Surface Profile: HEC-2, HEC-RAS
- ☐ WSPRO Bridge Backwater
- ☐ HYDRAIN module: _________
- ☐ FESWMS-2DH
- ☐ Geopak Drainage
- ☐ Other: __________________

HYDROLOGY

Flood History:

- ☐ External Sources
- ☐ Personal Reconnaissance
- ☐ Maintenance Records
- ☐ Photographs

High Water Elevations:

- ☐ Mn/DOT Survey
- ☐ External Sources
- ☐ Personal Reconnaissance

Discharge Calculations:

- ☐ Drainage Areas
- ☐ Rational Formula
- ☐ SCS: peak flow, or hydrograph
- ☐ Gaging Data
- ☐ Regression Equations
- ☐ Area-Discharge Curves
- ☐ Log-Pearson Type III Gage Rating
- ☐ Computer Programs: HYDRO, TR 20, TR 55, HEC-1

  Other: __________________

1.5 REFERENCES

American Association of State Highway and Transportation Officials. 1982. Highway Drainage Guidelines.

American Association of State Highway and Transportation Officials (AASHTO), 1991. *Model Drainage Manual.* ISBN I-56051-010-2.

American Association of State Highway and Transportation Officials (AASHTO), 1999. *Model Drainage Manual, Metric Edition.* ISBN I-56051-106-0.