CHAPTER 4
DOCUMENTATION

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4.1 OVERVIEW

Introduction

An important part of the design or analysis of any hydraulic facility is the documentation. Appropriate documentation of 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 in matters of litigation; and
- Public information.

Frequently, it is necessary to refer to plans, specifications and analysis long after the actual construction has been completed. Most often this occurs when a developer wants to build near one of CDOT's drainage structures. 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 behavior, if such is the case. In the event of a failure, it is essential that contributing factors be identified to avoid recurring damage.

4.1.1 Purpose

This chapter presents the minimum documentation that is required to be placed in the hydraulic design files and on the construction plans. This chapter focuses on the documentation of the findings obtained in using the other chapters of this manual. The designers should be familiar with all the hydrologic and hydraulic design procedures associated with this chapter. This chapter identifies the procedures for organizing the documentation of hydraulic designs and reviews. The hydraulic documentation should provide a complete history of the design process.

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. Often there is the misconception that avoiding documentation will prevent or limit litigation losses by not providing the plaintiff with incriminating evidence. This is seldom the case, and documentation should be viewed as the record of reasonable and prudent design analysis based on the best available technology. Thus, good documentation can provide the following:

- Protecting the Agency and the design engineer by proving that reasonable and prudent actions were 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 existing conditions and their implications to the drainage design at the time the design was completed, which might be important if legal action occurs at a later date;
- Documenting that rationally accepted procedures and industry standard analyses were used at the time of the design that 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; and
- Expediting plan development by clearly providing the reasons and rationale for specific design decisions.

4.1.2 Scheduling

During the preconstruction phase of plan development, there are three key milestones leading to the advertisement date. These are the:

- Design Scoping Review (DSR) meeting;
- Field Inspection Review (FIR); and
- Final Office Review (FOR).

These milestones are explained in the *Project Development* and the *Roadway Procedures* manuals.

DSR Meeting The Hydraulics Engineer will provide the scope of drainage work and the amount of field survey needed for design.

FIR Meeting Prior to FIR, all preliminary information should be provided to the Project Manager of the project except for structures that need special structural design such as bridges. Final hydraulic design for individually designed structures (i.e., bridges) should be completed before submitting to the bridge designer.

Consultants should provide the preliminary hydraulics report when the FIR plans are transmitted. Reports shall follow the Hydraulic Design Report Outline detailed in the appendix of this chapter. FIR reports should at a minimum include a discussion of how each item in the outline will be addressed for the FOR submittal.

FOR Meeting The final hydraulic design should be provided to the Project Manager as soon as possible after the FIR. This will allow the Project Manager time to get the information into the plans, compute quantities and run a cost estimate for the FOR.

Consultants should submit the final hydraulics report with the FOR plans or sooner if there are potential changes from the review. All changes in the analyses, drainage patterns, or structural designs shown in the FIR report shall be clearly presented in the FOR submittal.

4.1.3 Responsibility

The CDOT Hydraulics Engineer will be responsible for determining what hydrologic analyses, hydraulic design, and related information is to be documented during the plan development process. The Hydraulics Engineer will make a determination that complete documentation has been achieved during the plan development process including the final design.

The Hydraulics Engineer will sign off on the hydraulic design in the plans on the CDOT Form 1048. The record plan set will be sealed or stamped by the CDOT Hydraulics Engineer.

The reviewing CDOT Hydraulics Engineer will sign off on consultant designs on the CDOT Form 1048. Consultants shall stamp or seal their plans and the corresponding record plan set for CDOT documentation file.

4.2 PROCEDURE

4.2.1 Practices

The following are practices for documenting 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 alternatives of structure size and location, shall be compiled in a documentation file;

- All design assumptions and selected criteria including the related decisions shall be documented. Design decisions shall be based on sound engineering principles and not personal opinions;
- The detail of documentation for each design or analysis shall be commensurate with the risk and the importance of the facility;
- Uncertainties should be stated in less than specific terms (e.g., the culvert may backwater rather than the culvert will backwater);
- All related references should be provided in the documentation file, including published data and reports, memos and letters, and interviews. Include dates and signatures where appropriate;
- Data and information shall be documented from the conceptual stage of project development through service life so as to provide successors with all information;
- Documentation shall be organized chronologically to be as concise and complete as practicable so that knowledgeable designers can readily retrieve and use the information more effectively in the future; and
- Documentation shall be organized to logically lead the reader from the past through the problem background, into the findings, and through the performance.

4.2.2 Storage of Design Documentation

The Hydraulics Unit will maintain the documentation files including paper files, compact and floppy disks, microfilm, or microfiche for use during construction, for defense of litigation and future replacement or extension. To reduce file bulk, keep only documentation that is not retained elsewhere. Original plans, project correspondence files, construction modifications, geology drill logs and inspection reports are the types of documentation that do not need to be duplicated in the Hydraulics Unit's files.

Hydrologic/hydraulic documentation shall 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.

4.3 DOCUMENTATION PROCEDURES

4.3.1 Introduction

The intent of documentation is not to limit the data to only the items listed, but rather to 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 shall appear in the project file. Additionally, the designer will include in the project file items not listed below but which are useful in understanding the analysis, design, findings, and final recommendations. These could include photographs, public meeting minutes, newspaper clippings and interviews with local residents, adjacent property owners or maintenance forces.

4.3.2 Hydrology

The following items used in the design or analysis shall be included in the project file:

- Contributing watershed area size and identification of source (such as topographic map name);
- Geology, land use, soil type and classification as appropriate;
- Design frequency and justification of decision for selection;
- Hydrologic discharge and hydrograph estimating method and findings;

- Flood frequency curves including the design flood, the 100-year flood, the 500-year flood for bridges;
- Discharge hydrograph curves for the design flood, the 100-year flood, the 500-year flood, and other significant 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). This may be a basis for funding from other sources.

4.3.3 Hydraulic Data for Bridges

The construction plans should contain the following:

- Completed Bridge Hydraulic Information Sheet for new bridges; and
- Hydraulic information on the general layout for bridge widening and special designs.

The project file should contain the following:

- Complete hydraulic study report;
- Highwater surface elevations corresponding to the design, the 100-year, and the 500-year floods;
- Stage-discharge curve for proposed structure;
- Cross-section locations used in the design highwater determination;
- Roughness coefficient (Manning's "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 the design and the 100-year floods;
- Calculated backwater, velocity and scour for the design and the 500-year floods;
- Magnitude and frequency of overtopping flood;
- Copies of all computer analyses;
- Economic analysis of design and alternatives when required;
- Risk analysis (assessment) if design is based on non-conventional design frequency floods;
- Bridge scour results for the design, the 100-year, and the 500-year floods; and
- Potential flood hazards to adjacent properties.

4.3.4 Hydraulic Data for Culverts

For cross culverts, the construction plans should contain the following for culverts 30 inches and larger or if the conventional design frequency peak flow is 20 cfs or larger:

D.A. = _____ Square miles or acres (drainage area of contributing basin)

Q_{Design} = _____ cfs (design discharge associated with the frequency indicated by the subscript)

DHW = _____ ft (design headwater elevation for the design discharge not to inundate the roadway)

AHW = _____ ft (allowable headwater elevation)

MHW = _____ ft (maximum headwater that can be tolerated due to "non-hydraulic" features i.e., private buildings, roadway profile, flow line of ditches that would pass water into an adjacent basin)

Q_{100} = _____ cfs (The 100-hundred year discharge)

HW = _____ ft (headwater elevation corresponding to the 100-year discharge)

In the above definitions for DHW, AHW, MHW, HW all elevations pertain to the inlet side of the culvert.

For irrigation culverts only water right flow, stage (DHW), and freeboard are required.

For culvert designs, the following items shall be included in the project file:

- Allowable headwater elevation and basis for its selection;
- Cross-sections used in the design highwater determinations;
- Roughness coefficient assignments (Manning's "n" values);
- Observed highwater elevations, dates, and discharges;
- Stage-discharge curves for the undisturbed, the existing and the proposed conditions;
- Depth and velocity measurements (or estimates) and locations for the design, the 100-year and other check floods if deemed necessary;
- Performance curves showing the calculated backwater elevations, outlet velocities and scour for the design, the 100-year and historical floods;
- Type of culvert entrance and outlet conditions;
- Culvert outlet appurtenances and energy dissipation calculations and designs;
- Copies of all computer analyses (input data files as well as output files) and standard culvert computation sheets given in the Culvert Chapter of this manual;
- Potential flood hazard to adjacent properties; and
- Type of culvert pipe construction material.

Following are examples of hydraulic data that need to be shown on the project plan sheets.

A. Culverts smaller than 42 inches in diameter

Drainage Basin: Big Gulch Basin
Station 26+512.9
Required: 36-inch culvert pipe with end sections at inlet and outlet.
D.A. = 955 acres
Q_{Design} = 47 cfs
DHW = 8208.5 ft
AHW = 8210.5 ft
Q_{100} = 62.5 cfs
HW_{100} = 8210.8 ft (overtopping)

Notes:

1. If the water surface elevation corresponding to the 100-year flood (HW_{100}) exceeds the AHW of 8210.5 ft, then denote HW_{100} by “overtopping” instead of a specific elevation.

2. If the existing culverts need to be extended, the project plan should revise the above text after the "Required:" with the following:

   "Required: Extend the existing culvert __ft left (inlet) and/or __ ft right (outlet) with end sections. The extended culvert should be of the same material as the existing culvert."

B. Concrete Box Culverts (CBC) and culvert pipes larger than 42 inches in diameter

Drainage Basin: Big Gulch Sub Basin No. 1
Station 26+959.0
Required: 60-inch culvert pipe with **full headwalls, wingwalls,** and **aprons** at inlet and outlet.

D.A. = 3080 acres
Q_{Design} = 110 cfs
DHW = 8193.4 ft
AHW = 8197.0 ft
Q_{100} = 155 cfs
HW_{100} = 8195.4 ft

Notes:

1. If the water surface elevation corresponding to the 100-year flood (HW_{100}) exceeds the AHW of 8197.0 ft, then denote HW_{100} by "overtopping" instead of a specific elevation.
2. If the existing culverts need to be extended, the project plan should revise the above text after the "Required:" with the following:

   "Required: Extend the existing culvert __ ft left (inlet) and/or __ ft right (outlet) with full headwalls, wingwalls and aprons. The extended culvert should be of the same material as the existing culvert."

4.3.5 Open Channels

The project plans shall include the following:

1. For roadways with longitudinal encroachments into the floodplain, the water surface profiles corresponding to the 100-year and the design flood.
2. For open channel designs
   a) Stage-discharge curves for the design and the 100-year floods;
   b) Cross-sections used in the design water surface determinations and their locations;
   c) Roughness coefficient assignments (Manning's "n" values);
   d) Description of the method used for water surface determinations;
   e) Observed highwater, dates, and discharges;
   f) Channel velocity measurements or estimates and locations;
   g) Water surface profiles through the reach for the design, the 100-year, and historical floods;
   h) Design or analysis of materials proposed for the channel bed and banks;
   i) Energy dissipation calculations and designs;
   j) Copies of all computer analyses (including input data files);
   k) Freeboard.

4.3.6 Storm Drains

On the plan view of the trunkline, the project plans for storm drains shall contain the following information:

a) The length, size and type of pipe material;

b) Inlet labels, invert and rim elevations; and

c) Flow direction.

On the profile view of the trunkline, the project plans for storm drains shall contain the following information:

a) The stationing;

b) The design flow and frequency for each reach of pipe;

c) The design flow hydraulic grade line for each reach of pipe;

d) The length, size and slope for each reach of pipe;

e) The invert inlet and outlet elevations for each reach of pipe including inlet labels, invert and rim elevations;

f) The exact location (stations and offset distance).

The project hydraulic design file for storm drains shall contain the following:

- Computations for inlets and pipes, including hydraulic grade lines;
- Copies of the computation sheets;
- Complete drainage area topographic map, grading plans;
- Design frequency;
- Justification is required if a frequency other than the conventional frequency (2-, 5-, or 10-year) recommended by the design manual is utilized;
- Information concerning outfalls, existing storm drains, and other design considerations; and
- A schematic layout indicating the overall storm drain system.

A separate storm drain system is required for the construction phase of the project. The documentation for the construction phase should follow the above guidelines.

4.3.7 Detention and Water Quality Ponds

A. The project plans for detention ponds shall include the following:

- Drainage area;
- Design storage volume and stage;
- Design discharge, frequency for inflow and outflow; and
- Grading plan for the project area including the pond.

B. The project file for water quality ponds shall contain the following additional information:

- Hydrological analyses;
- Storage-discharge calculations;

- Stage vs. storage volume graph;
- Stage vs. outflow graph; and
- The 2-year, the 100- year, and the design water surface elevations shall be shown on the graphs.

4.3.8 Computer Generated Files

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

- Input data listing;
- Location and stationing of cross–sections;
- Computer output files showing the results of selected alternatives and existing structures;
- Detailed computer runs for different design discharges;
- Summary tables including, as a minimum, station, distance, discharge, water surface elevation, channel bottom elevation, average flow velocity, surface width, area, Froude number, energy gradeline, left overbank station, overtopping flow depth (whenever applicable), and overtopping weir length (whenever applicable); and
- A short narrative describing the version of the models used, and the files associated with each run.

APPENDIX A - Hydraulic Design Report Outline

1. Table of Contents

2. Introduction

- Project location shown on an area map.
- Site location: stationing, state highway number, stream name, geographic reference (county, nearest town), legal description, (section, township, range).

3. Hydrology

Drainage basin map showing basin boundaries, areas, structure locations, direction of flow, north arrow, scale, name, date, and source of map, etc.

Basin description including: area, length, width, shape, elevation range, topography, factors influencing runoff (e.g. soil type, vegetal cover, detention structures and natural storage, development).

Channel description including: cross-section geometries, classification of stream form, bed material composition, channel bed and bank stability, sediment transport, conveyance factors, debris and ice problems, 100-year floodplain limits, and ordinary high water elevations.

Precipitation data including**:** intensity, duration, frequency, principal cause of runoff, peak season, annual and seasonal distribution.

Flood history including: recorded floods, technical and media reports, visual observations, interviews with property owners and maintenance personnel.

Design flood frequency: Use conventional flood frequency recommended by the design manual. Use different frequency only if supported by risk analysis.

Prediction of design discharge including: methods of analysis, parameters, criteria for design discharge selection, recurrence interval curve for 2, 25, 50, and 100-year (and 500-year for bridges) discharges.

4. Existing Structure

*Description***:** type of structure, size, structure ID number, year built, color photos showing the structure and its vicinity (upstream, downstream, and roadway).

*Capacity and adequacy problems***:** information pertaining to the flood marks, scour holes, head cutting, bed and bank degradation and aggradation, debris accumulation, ice jams, wetlands, cattle and wildlife crossing and other maintenance and operational related issues.

5. Design Discussion

- Discuss circumstances influencing the design; concerns by CDOT Region, local municipality and landowners.
- Document the need for channel or other improvements, debris control, present and future land use, and roadway grade.
- Document the allowable highwater elevation, its location and the basis for the selection (including right-of-way and environmental limitations).

- Evaluate potential damage to surrounding property and roadway for both the design and 100-year flood (500-year for bridges).
- Indicate measures proposed to mitigate impacts and to restore and preserve the natural and beneficial values impacted by the construction. Discuss practical alternatives and justification for longitudinal and significant encroachments.
- Determine requirements for compliance with Section 402 National Pollutant Discharge Elimination System (NPDES) and Section 404 of the Clean Water Act.
- List structure alternatives and discuss reasons for the type and size selection. Include any cost comparisons in the discussion.

6. Recommended Design

Document the size, location, skew of structure. For bridges, give the net and excavated width of encroachment at the flowline (thalweg) elevation. Also for bridges, list minimum low girder elevation, design water surface elevation plus the required freeboard, the estimated scour profile, training dikes, guide banks, spur dikes and detour culvert requirements. For irrigation structures, document water right, freeboard and trash rack if required. For irrigation structures that include inverted siphons, provide documentation for spillway, trash rack, and safety warning signs.

Document the required channel improvements and bank protection needed for the safe operation of the structure.

7. Appendix (if needed)

Document computer runs with input files and tabulated trial runs to fulfill the reporting requirements for the design outlined in the text.

Document Bridge Hydraulic Information Sheet.

For storm drains, show inlet calculations, hydraulic gradeline calculations, spread sheet column definitions, etc.

APPENDIX B -- PROJECT CHECKLISTFOR HYDRAULIC DESIGN

Check Appropriate Items

Project Engineer: _____

Project Number: _____ Project Sub Account Code (SA): _____

Location (include City and County)_____

A. REFERENCE DATA

Maps:

( ) USGS Quad Map Name:

Scale: Date:

( ) USGS 1:250,000

( ) CDOT Other

( ) 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:

( ) FEMA-USACE Floodplain Information Report

( ) NRCS Watershed Studies

( ) Local Watershed Management

( ) USGS Gages and Studies

( ) Interim/Final Flood Plain Studies

( ) Water Resource Data

( ) Regional Planning Data

( ) Utility Company Plans

Studies by CDOT Internal Sources:

( ) Quarterly Reports

( ) Hydraulics Section Records

( ) Region Drainage Records

( ) Flood Records (High Water, Newspaper, Maintenance)

B. HYDROLOGY DATA

Technical Resources:

( ) CDOT Drainage Design Manual

( ) Technical Library

Discharge Calculations:

( ) Drainage Areas

( ) Rational Formula

( ) HEC-1, HEC-HMS

( ) NRCS

( ) Gaging Data

Regional Analysis

Regression Equations

Area-Discharge Curves

( ) Log-Pearson Type III Gage Rating

( ) Computer Programs

( ) Log Pearson,

( ) HYDRO, ( ) TR 55, ( ) HEC 1,

( ) HEC HMS, ( ) WMS

( ) NRCS Watershed Studies

( ) BRI – STARS Sediment modeling

High Water Elevations:

( ) CDOT Survey

( ) External Sources

( ) Personal Reconnaissance

( ) US Forest Service

Flood History:

( ) External Sources

( ) Personal Reconnaissance

( ) Maintenance Records

( ) Photographs

( ) Aerial photographs

C. HYDRAULIC DESIGN

Calibration of Highwater (HW) Data:

( ) Discharge and Frequency of High Water elv.

( ) Influences Responsible for High Water elv.

( ) Analyze Hydraulic Performance of Existing Facility for Min. Flows

( ) Analyze Hydraulic Performance of Proposed Facility for Min. Flows

Design Appurtenances:

( ) Energy Dissipators

( ) Riprap

( ) Erosion and Sediment Control

( ) Fish and Wildlife Protection

Technical Aids:

( ) CDOT Drainage Design Manual

( ) FHWA publications

( ) AASHTO publications

( ) CDOT Procedural Directives

( ) Technical Library

Computer Programs:

( ) FHWA Bridge Backwater Program, WSPRO

( ) Log-Pearson Type III Analysis

( ) FHWA's Culvert Design Program, HY8

( ) FHWA's HYDRAIN

( ) FHWA's Finite Element Model, FESWMS-2DH

( ) USA COE's Water Surface Profile Programs HEC-2 and HEC-RAS

( ) FHWA's BRI-STARS Bridge Streamtube Alluvial River Simulation Model

( ) Other