Ontario

MINISTRY OF TRANSPORTATION

Highway Drainage Design Standards

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Standards & Contracts Branch

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MINISTRY OF TRANSPORTATION

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Preface

In 1979, the Drainage and Hydrology Section of the Ministry of Transportation and Communications (MTC) undertook the task of developing a manual to provide designers with a comprehensive and up-to- date guide to all major aspects of highway drainage. The resulting MTC Drainage Manual provided "designers with the tools for producing cost-effective hydraulic designs that would satisfy environmental, stormwater management and other contemporary concerns". It was expanded over a period of 10 years between 1980 and 1989 as drainage management policy and design methodologies continuously evolved. In 1989, the MTO Drainage Management Technical Guidelines were prepared to provide standards and a framework of methodologies that could be used by the MTO to achieve its drainage management goals. It was intended to supplement the "MTO Drainage Management Policy and Practice" set forth by Provincial Highway Directive B-237 and was viewed as a complementary document to the MTC Drainage Manual.

In 1997, the MTO Drainage Management Manual (DMM) was issued to replace the MTC Drainage Manual and the MTO Drainage Management Technical Guidelines. Applicable material from the previous two publications was incorporated into the DMM. It was viewed as a tool to be used by the MTO on its provincial highway projects, in conjunction with Ministry directives that set forth objectives of practice and general design criteria. Although applicable standards of practice are included in the discussion of various practices and their design methodology, the DMM does not present specific design policies and criteria. Exclusion of specific standards allows for a more flexible use of the DMM by both highway designers as well as parties external to the MTO to whom MTO directives may not apply. Specific design objectives, criteria, and options for an individual highway project, including the drainage management components, will be established by the project through the class environmental assessment process. The DMM provides the general groundwork for developing project specific requirements and is to be read and used in this context.

In 2008 the MTO Highway Drainage Design Standards (HDDS) was issued. The intent of the HDDS is to document existing standards, which have been updated as needed, for use in the design and rehabilitation of highway drainage infrastructure under MTO jurisdiction in Ontario. This manual collates the design standards documented in the old MTC Drainage Manual, old MTO Drainage Management Technical Guidelines (1989), Directive B-100 and accepted Ontario standards that have been adopted by MTO and published in other MTO documents and on the MTO Drainage Management website.

Since 2008, methods being developed to adapt to the non-stationarity of precipitation and other climate parameters have focused on the Annual Exceedance Probability (AEP) of climate parameters. The 2023 update to the HDDS introduces the AEP terminology into MTO drainage design standards and incorporates Memorandum DCSO #2016-14 – Implementation of the Ministry's Climate Change Consideration in the Design of Highway Drainage Infrastructure on Climate Change and Memorandum DCSO #2016-03 Implementing the New Unified Ontario Flood Method for Calculating the Design Flow Rates for Water Crossings.

Introduction

The purpose of this document is to document existing MTO Standards for use in the design and rehabilitation of highway drainage infrastructure under MTO jurisdiction in Ontario. The standards have been reviewed and updated as needed to provide the MTO Highway Drainage Design Standards (HDDS) included in this publication. Each standard provided in this document is intended to cover specific highway design elements. The intent of this document, therefore, is to provide a series of individual "standard sheets" which can be referenced when carrying out a highway drainage design. It must be recognized, however, that there may be some interrelationship between the standards, which lead to cross-referencing between standards as needed to cover the various elements of design.

This manual is to be used in conjunction with the MTO Drainage Management Manual (DMM) and other relevant technical references, as required. An approach has been taken to integrate these standards with current policies, criteria and methodologies, and to minimize any overlap.

The objectives of the HDDS are as follows:

- Document the most up-to-date drainage design standards for use by MTO road and bridge designers for the design of drainage components that constitute part of the highway infrastructure.
- Document required commentary to aid designers in the implementation of the standards and understanding their rationale and background.
- Reflect the variation of the standards with road classifications, rural/urban environment, physical characteristics and runoff receiver classification for normal highway operations and during construction.
- Address identified deficiencies in the existing standards based on the latest state of knowledge and standards from other jurisdictions with the most similar condition to Ontario.

The HDDS focus on the hydrologic and hydraulics standards for the design of the different components of the highway drainage infrastructure. These include the following elements:

- Highway surface drainage (SD)
- Water crossings of (WC)
- Stormwater management (SWM)
- Temporary works (TW)

It should be noted that this document is the first step in a process to determine highway drainage design standards. The Highway Drainage Design Standards are intended to be a "living document". Each standard has been developed in an individual "fact-sheet" format with a unique reference number. It is intended that this document will be updated and/or revised on a regular basis and that additional standards may be added to the document as they are developed. This modular approach has been followed to allow for replacement of individual standards sheets, rather than production of a revised document in its entirety.

How to Use This Document

The Standards contained in the Highway Drainage Design Standards (HDDS) are to be used in the design and rehabilitation of roads under the jurisdiction of the MTO. They are intended to complement the information in the MTO Drainage Management Manual. The HDDS do not specify technical design analysis procedures or methods but include information for the designers to define the applicability and rationale for highway design elements. This document is not intended to be a stand-alone document, but rather requires designers to refer to other relevant documents for procedures and methods necessary for proper implementation of the drainage design elements (e.g. TAC Geometric Design Guide for Canadian Roads and the MTO Design Supplement, Canadian Highway Bridge Design Code and MTO Structural Manual, Ontario Provincial Standards and Specifications and others as applicable). References to specific documents to be consulted by designers are included in the individual standards. The designer should not consider this document in isolation of other MTO drainage manuals, standards, policies, or specifications. Roads under the jurisdiction of other authorities (e.g. Federal. Municipal, Ministry of Natural Resources) may have their own standards.

The standards represent the requirements for design of highway drainage elements, primarily based upon current MTO practices. There may be requirements in addition to the drainage standards (e.g. for navigation, environmental, etc.), in which case the designer is responsible for consulting supplementary reference documents for this information.

References are also made to various government agencies throughout this document and it is the designer’s responsibility to contact the appropriate MTO sections and other agencies (Ministry of the Environment, Conservation and Parks, Ministry of Natural Resources and Forestry, Department of Fisheries and Oceans, Environment Canada, local Conservation Authority, etc.), where appropriate, to determine the specific requirements of each agency.

These standards apply to roads and bridges that fall under the MTO jurisdiction. For roads and bridges that are within the jurisdiction of other agencies, it is the responsibility of the designer to be aware of the requirements and standards that would apply. This would include municipalities, federal agencies and provincial agencies (such as MNRF).

The standards apply to new highway drainage infrastructure and to retrofit projects on existing infrastructure. It should be noted, however, that the standards may not always be applicable/achievable on retrofit projects due to site constraints or other factors.

The majority of standards developed are quantitative, meaning they have a set value or range of values, such as a minimum, desirable and/or a maximum. In some cases, qualitative standards were developed (e.g. SW-2 Quality Control) to reflect provincial guidelines where quantitative targets are either site specific or remain generic.

Minimum and/or desirable standards have been developed for each standard:

- The **desirable standard** should be met during a design, if at all possible. There may be specific site constraints that make it impossible or impractical to meet the desirable standard. Cost shall not be the only factor in determining if a desirable standard can be met. Evaluation must be based upon technical, economic, environmental and management considerations. These might include physical site conditions, potential impact to adjacent lands and road design objectives.

- The **minimum standard** must be met by the design if the desirable cannot be met. It is not as stringent as the desirable standard but is judged to be the minimum acceptable. The designer should strive to meet the highest standard (desirable). For example in SW-3 Stormwater Management Ponds, the desirable length-to-width ratio associated with wet pond design is 5:1. The designer shall attempt to meet this; however, if site constraints do not allow for this ratio, the minimum standard of 3:1 shall be met.

When a **desirable or minimum standard cannot be met** (or is recommended to not be met) the deviation from the standard and justification for not meeting the standard must be documented. This documentation must be included in the project documentation and brought to the attention of the MTO project manager.

Each standard includes the following elements:

- **Scope** – a description of what is intended to be covered by a particular standard.
- **Design References** – list of documents to be referenced when applying the standard. In some references the chapter is included for guidance. It is the designer's responsibility to be familiar with the complete reference document where appropriate and to use other information in the reference as needed.
- **Hydrology** – description of the hydrologic aspects of the standard including flow conditions that must be met, such as design flow annual exceedance probability (AEP) (with return period equivalent provided). Each of the surface drainage standards cross reference Standard SD-1 Design Flows for Highway Surface Drainage Systems for the basic hydrology component for the surface drainage standards. Each of the water crossing standards cross reference Standard WC-1 Design Flows (Bridges and Culverts) for the basic hydrology component. SD-1 and WC-1 provide the basic hydrologic information; however, additional hydrologic standards maybe provided in the hydrology section of the individual standards.
- **Hydraulics -** description of the hydraulic aspects of the standard including flow capacity or hydraulic characteristics to be provided, such as freeboard.
- **Physical Characteristics -** description of the physical characteristics of the standard including descriptions of dimensions, sizes, depths, etc.
- **Commentary** – instructions to the designer for use in applying the standard. This section contains important information and should be carefully reviewed.

A series of definitions of the terms used in the standards is included in the first part of this document. Similarly, a list of abbreviations is provided and what they represent.

Prelude to Annual Exceedance Probability

Historically, drainage engineers and designers have used the term "return period" to signify the recurrence interval of extreme storm events (e.g., 2-year, 10-year, 100-year return period, etc.). Moving forward, the MTO is recommending a change of terminology to Annual Exceedance Probability (AEP) to provide unity and clarity between climate related disciplines, and to better address climate change and extreme events in the design of hydraulic structures.

The Annual Exceedance Probability (AEP), also referred to as the probability of exceedance, is the probability of a specified magnitude rainfall event to occur or be exceeded each year. The AEP is determined as the inverse of the return period. For example, a rainfall event with a 25-year return period has a 1/25 (or 4%) chance of being equaled or exceeded in a year. The chart below outlines common return period lengths and their corresponding AEP.

Return Period (years)	AEP (%)
2	50%
5	20%
10	10%
25	4%
50	2%
100	1%

The shift to Annual Exceedance Probability is to foster clearer communications between engineers and design professionals, climate scientists, and the public, using a common definition. As well, AEP provides an easier mode of understanding of the likelihood of exceedance over the design life of a structure through risk analysis methods such as confidence intervals and Bernoulli Trials. Over the expected lifespan of a structure, exceedances may occur multiple times. The longer the design life, the greater the risk of an extreme event occurring. The probability that a design flood will be equaled or exceeded at least once during the design life of the project is:

$$P = 1-(1-AEP)^{n}$$

Where: P = probability that the design flood level will be equaled or exceeded in n years

n = design or expected service life, years

AEP = the Annual Exceedance Probability, expressed as a decimal

For example, for a structure with a 4% AEP design storm (25-year return period), and a design life of 50-years, then AEP = 0.04, n = 50, and the probability of occurrence of a flood equaling or exceeding the design flood at least once during the design life is P=1-(1-0.04)^50=0.87 or 87%.

While return-period terminology tends to be more understandable for flood intensity comparisons, AEP terminology emphasizes that a rare flood does not reduce the chances of another rare flood within a short period. A 50-year storm does not necessarily only occur once in every 50 years, but has a 2% chance of occurring every year. Thus, understanding and using AEP terminology is essential in design and development of drainage practices.

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AADT	Average Annual Daily Traffic
AEP	Annual Exceedance Probability
BMP	Best Management Practice
CA	Conservation Authority
c/l	Centreline
CHBDC	Canadian Highway Bridge Design Code
CSP	Corrugated Steel Pipe
D	Diameter
DFO	Department of Fisheries and Oceans
DOT	Department of Transportation (U.S.)
ECC	Environment and Climate Change Canada
ES	Span of the Equivalent Rectangular Culvert
FHWA	Federal Highway Administration
ha	Hectare
HDDS	Highway Drainage Design Standards
HDPE	High Density Polyethylene
HW	High Water
HWL	High Water Level
m	Metre
mm	Millimetre
MNRF	Ministry of Natural Resources and Forestry
MECP	Ministry of the Environment, Conservation and Parks
m/s	Metre per Second
MSC	Meteorological Services of Canada
MTC	Ministry of Transportation and Communications
MTO	Ministry of Transportation
OPSD	Ontario Provincial Standard Drawings
PVC	Polyvinyl Chloride
PWQO	Provincial Water Quality Objectives
N/A	Not Applicable
NWL	Normal Water Level
ROW	Right of Way
RP	Return Period
SD	Highway Surface Drainage
SS	Suspended Solids
SSD	Structural Standard Drawings
SW	Stormwater
SWM	Stormwater Management
TAC	Transportation Association of Canada
TAFA	Total Available Flow Area
TFPS	Temporary Flow Passage System
TW	Temporary Works
US	United States
WC	Water Crossing
yr	Year

Definitions

Aggrading Stream - stream reach that is actively depositing sediment in its channel or floodplain because it is being supplied with more sediment load than it can transport.

Annual Exceedance Probability (AEP) - the probability of a specified magnitude event to occur or be exceeded each year. Determined as the inverse of the return period (e.g. a 5-year return period event has a 0.2 or 20% chance of occurring or being exceeded in a given year). Also referred to as the Probability of Exceedance.

Armoring - the use of rock material to minimize and control the erosion of the watercourse and embankments.

Apron - an area of protective material laid on a streambed to control local scour around a feature requiring protection.

Arterial Road - a road primarily for through traffic.

Backwater - the rise of water level caused by a downstream obstruction or constriction in a channel under subcritical flow conditions.

Bankfull Flow - the flow rate that results in a water elevation in the watercourse that corresponds to the elevation of the top of the channel banks. Typically, the Bankfull Flow occurs 1-2 times per year (50-100 percent probability of being exceeded in any given year). Bank Full Flow is also referred to as the channel forming flow.

Best Management Practice (BMP) - the use of a management practice or facility application that provides an effective approach in the protection of the environment or receiving system from detrimental impacts. Typically one of a set of measures that demonstrates the most effective mitigation of impacts.

Bridge - a structure that provides a roadway or walkway for the passage of vehicles across an obstruction, gap or facility and that is greater than 3m in span.

Catchment Area - the total area of land radiating from a reference point, including all drainage work and stream channels, contributing stormwater runoff.

Check Flow (Bridges and Culverts) - a flow greater than the design flow used to check that a waterway designed for the design flow will withstand a larger flow without embankment failure or structural collapse.

Check Flow (Depressed Roadway) - a flow greater than the design flow used to check the performance of a drainage system under severe conditions.

Clearance - the distance between the High Water Level and the lowest point of the soffit (note this does not refer to the Energy Grade Line).

Closed-Footing Culvert - structure supported by a bottom section that is integrated into the sides of the culvert.

Collector Road - a road on which traffic movement and access to property have similar importance.

Control Level – the level of control provided through a stormwater management (SWM) facility to meet downstream requirements for flow.

Culvert - a structure that forms an opening through soil (soil over structure) whose primary function is to convey surface water through an embankment. A Culvert is distinguished from a bridge by the following factors: it is located within an embankment fill, and its perimeter is composed of a continuous structural material. Culverts include Closed-Footing structures (structural bottom) and Open Footing structures (bottom formed by rock, soil or watercourse channel).

Culvert Embedment - the portion of the culvert opening that is countersunk below the natural stream bed.

Culvert End Treatments - include structures at culvert ends, such as headwalls, cutoff walls and anchorages, as well as culvert inlet treatments, such as projecting, mitred and flared ends.

Culvert Extension - a new section of a culvert installed at one or both ends of the existing structure to provide for highway widening or other road related works.

Culvert Substrate - the mix of granular material that will be used to create the low flow channel within the proposed culvert.

Cutoff Wall - a wall of impervious material (e.g. concrete) located beneath a culvert which forms a water barrier, reduces seepage under a culvert, and prevents undermining of the culvert due to erosion.

Deck Drains - provide an opening through the bridge deck to convey bridge deck surface water through the deck and away from the bridge and include a frame and a grate.

Degrading Channels - channels where the invert is lowering over time through erosion and/or general weathering of the stream bottom.

Depressed Roadway - a roadway with a sag that is lower than the elevation of the surrounding area, and there is not a defined overland flow path from the low point in the road (sag) to the receiving watercourse. A railway underpass is a typical example of a Depressed Roadway. Outflow from a Depressed Roadway may be conveyed by gravity or may be pumped.

Design Flow - the peak flow generated by the Design Storm or calculated using a frequency analysis of recorded flows. The Design Flow will typically have a specific AEP (or Return Period equivalent)(e.g. 1% AEP or 100-year flow).

Design Storm - the rainfall event with a specified AEP (or Return Period equivalent) , where the rainfall is assumed to occur in a specified distribution (e.g. AES 12 hour, Chicago 3-hour).

Ditch Inlets – catch basins or catch basin-maintenance holes covered by grates that are used to intercept runoff from roadside ditches and swales, and convey the runoff to a storm sewer, culvert, or a watercourse.

Down Pipe - a pipe extending from the downspout to convey water to the ground or a storm sewer.

Down-Spout - a vertical pipe extending from a deck drain to below the bridge superstructure.

Dry Pond - an active storage facility used to detain water during a storm event and release it at a rate that is selected to minimize downstream flood risk. There is no permanent pool or wetland component to the facility.

Dykes - a barrier designed to contain flooding to the floodplain, and thus prevent flooding of adjacent lands located outside of the dyke.

Energy Grade Line - the elevation calculated by adding the velocity head to the water surface elevation on the upstream side of the bridge or culvert and associated with the Design Flow without ice jams.

False Grading - local grading designed to achieve drainage in the opposite direction to that of the overall longitudinal profile of the highway.

Fish Passage - the migration and movement of all life stages of fish to obtain access to food, shelter or spawning habitat through bridges, culverts or other obstructions.

Fish Passage Design Flow - Design Flow used for designing bridges and culverts from the perspective of fish passage.

Flood Depth at a Culvert - the vertical distance from the upstream invert of the culvert to the upstream High Water Level of the Design Flow.

Floodline Mapping - mapping approved by the MNRF or local Conservation Authority that illustrates the limits of flooding associated with the Regulatory Flow.

Flow Spread - flowing or ponded water that extends from a curb, barrier, or ditch onto travel lanes.

Freeboard (Bridges and Culverts) - a factor of safety used in the design of bridges and culverts that represents the vertical distance between either the HighWater Level or the Energy Grade Line for the Design Flow and the lowest point of the road profile at the edge of the travelled lane.

Freeboard (Parallel Flow) - a factor of safety used in the design of highways that represents the vertical distance from the top of the Design Flow elevation to the edge of the travel lane or to the top of the subgrade.

Freeboard (Roadside Ditch) - a factor of safety used in the design of roadside ditches that represents the vertical distance between maximum water level associated with the Minor System Design Storm and the top of the subgrade of the adjacent roadway.

Freeway - a fully controlled-access road limited to through traffic with access through interchanges.

General Scour - the scour in a streambed that occurs at a structure as a result of general stream velocities exceeding the competent velocity of the channel bed material.

Gutter Outlet - a surface outlet from a gutter. It is usually connected to a spillway that leads to a Roadside Ditch.

Headwall - a wall at the end of a culvert normally extending from the invert to above the soffit or crown of the culvert and aligned parallel to the roadway or normal to the longitudinal axis of the culvert.

Highway Embankment - the embankment that extends from the outer edge of the shoulder to the invert of the Roadside Ditch.

High Vulnerability - a rating given to a bridge that can be washed away or be significantly damaged during flooding. High vulnerability bridges include log bridges, bridges with timber beams and deck, and light trusses.

High Water Level - the water level on the upstream side of the bridge or culvert and associated with the Design Flow without ice jams.

Impermeable Barrier – a barrier that prevents the flow of water across it (e.g. concrete median barrier, noise wall).

Inlet - drainage structure that is used to intercept surface water through grate or curb openings and convey it to storm sewers and culverts.

Inlet Blockage - a reduction of the effective inlet flow area resulting from accumulation of debris on the inlet.

Inlet Spacing - the lateral distance between two consecutive inlets.

Inspection and Maintenance Clearance - the vertical distance between the normal water level and the lowest point of the soffit.

Lane Shift Across Median – where the highway is detoured across the median then along the lanes that will ultimately be used for opposing traffic (e.g. southbound traffic detoured across median to northbound lane(s)).

Lane Shift to Shoulder – where the lanes are temporarily shifted such that the shoulder adjacent to a curb or median barrier is used as a travel lane.

Lateral Sewers - sewers that convey runoff from a ditch inlet or a catch basin to the Trunk Sewer.

Live Storage (temporary erosion control) - component of temporary SWM pond designed to contain runoff generated by a prescribed design storm.

Local External Catchment Area - land upgradient of the highway right-of-way that naturally drains to the highway drainage system or culvert crossing of the highway and is not channeled through a Natural Watercourse. Flow may be channeled through a constructed ditch or channel (eg. Municipal Drain).

Local Road - a road intended to provide access to development only.

Local Scour - scour in a streambed adjacent to an obstruction, such as a pier or abutment, resulting from the disruption of flow caused by the obstruction.

Longitudinal Grade - the rate of rise or fall with respect to the horizontal distance; usually expressed as a percentage.

Low Flow Channel - the channel that is formed within a culvert to convey the Fish Passage Design Flow.

Low Volume Road - a road with an average annual daily traffic (AADT) in both directions that is less than 400.

Low Vulnerability - a bridge that will not experience significant damage during flooding. Low vulnerability bridges include rigid frames, integral abutment bridges, and slab or voided slab bridges.

Maintenance Hole - a sewer access large enough for a person to enter to trouble-shoot service problems or perform maintenance work. Maintenance Holes are located at pipe junctions, or at changes in pipe slope, size or diameter.

Major System - the Major (Drainage) System provides an overland flow route for stormwater runoff exceeding the capacity of the Minor System. The Major System excludes Natural Watercourse flow that is conveyed across the highway. In the context of the highway, the Major System includes the portion of the roadway that carries the flow in excess of the capacity of the Minor System. This can include roadside ditches, or the shoulder and the allowed portion of the travel lane.

Major System Design Flow - the peak flow used for the design of the Major System.

Maximum Allowable Spread - is defined by one of the following:

- The Maximum Lateral Spread Distance of the flow parallel to the highway (longitudinal flow) that extends onto a travel lane measured from the lowest edge of the travel lane; or
- The Maximum Depth of the flow parallel to the highway (longitudinal flow) at the lowest edge of the travel lane.

Maximum Maintenance Hole Spacing - the maximum horizontal distance between two consecutive Maintenance Holes.

Mean Diameter (d50) - the Mean Diameter by weight of substrate such that 50 percent of the substrate will have a diameter greater that the Mean Diameter.

Minimum Allowable Velocity - is specified to minimize the risk of sediment deposition in the pipe. It is based on the peak flow generated by the applicable Design Storm.

Minimum Cover - above the pipe refers to the vertical distance between the outside edge of the pipe obvert to the finished grade directly above the pipe.

Minimum Pipe Diameter - the smallest sewer pipe diameter to be used in the storm sewer system.

Minimum Size of a Culvert - defined by diameter for circular culverts and by height (rise) for box, arch and elliptical culverts.

Minor System - the Minor (Drainage) System consists of the components of the drainage system that are designed to carry runoff generated by the more frequent storm events. These components include curbs, gutters, swales, ditches, inlets, manholes, and storm sewer pipes.

Minor System Design Flow - the peak flow used for the design of the Minor System.

Native Substrate - the native material that lines the bottom of the natural channel in the vicinity of the proposed culvert.

Natural Watercourse - a channel caused by the natural flow of water where water flows between banks that are more or less defined. The flow of water does not need to be constant, but the channel must be a permanent landmark. The watercourse may also, at some point, spread over a level area without defined banks, before flowing again as a defined channel.

Normal Water Level - the average summer water level.

Open-Footing Culvert - a three-sided structure supported by strip footings where the bottom of the culvert is defined by soil, rock or the existing watercourse channel.

Open Roadway - is defined as the middle of the roadway that remains above the flooded portion of the roadway. Typically, it is located along the crown of an undivided roadway.

Outlet Pool - the section of channel located at the outfall of a culvert where the depth and/or width have been increased in relation to the downstream channel, such that velocities are reduced, energy is dissipated, and migrating fish have an opportunity to rest.

Parallel Flow - a watercourse or lake that is parallel to a highway but does not necessarily cross the highway, walkway or dyke.

Pavement Cross-fall - the average grade between edges of a cross-section element perpendicular to the centerline of the road. Cross-fall provides for the drainage of water off the roadway surface to the shoulders.

Perched Structure - a structure which is founded at or above the elevation of the native material.

Perforated Subdrains - perforated pipes which transmit water from the backfill along the structure wall to alleviate hydrostatic pressure on the wall.

Permanent Pond (temporary erosion control) - component of temporary erosion control basin designed for storage without any outlet. Will typically remain full of water unless loss due to infiltration or evaporation.

Pipe Obvert - the highest point of the inside of the pipe at the transverse section.

Probability of Exceedance – see Annual Exceedance Probability

Rating Curve - A curve illustrating water levels upstream of a structure, such as a bridge or culvert opening, that identifies the relationship of Design Flow to water elevation. This should include the full range of Design Flows including 1, 2, 4, 10 and 20 percent AEP (100, 50, 25, 10 and 5 year return period) Design Flows and the Regulatory Flow.

Regulatory Flow (or Regulatory Flood) - a Design Flow adopted by the MNRF for floodplain management purposes. In many instances the Regulatory Flow is also referred to as Regulatory Flood. Figure 1 illustrates the three Flood Hazard Zones in Ontario. Depending on the zone, the Regulatory Flow is either the 1% AEP (100-year return period) Design Flow or the greater of the 1% AEP (100-year return period) Design Flow and the peak flow generated by the Regional Storm (Timmins Storm or Hurricane Hazel).

Regulated Watercourse - watercourses that are subject to provincial legislation for flood protection as administered by the Ministry of Natural Resources and Forestry or Conservation Authority.

Relief Flow - the fraction of the Regulatory Flow that bypasses the main structure at a stream crossing by flowing over the roadway or through a relief culvert or bridge.

Retained Soil System - a proprietary system which uses mechanical soil stabilization to retain horizontal loads or to retain vertical loads for applications such as embankments over soft ground.

Return Period - the average number of years based upon probability, between the occurrence of events equaling or exceeding the Design Flow. The Return Period typically ranges between 2-years and 100- years. Determined as the inverse of the Annual Exceedance Probability.

Revetment - a vertical or inclined facing of rip-rap or other material protecting a soil surface from erosion.

Rigid Connection - a secure mechanical connection.

Roadside Ditch - a ditch that runs parallel to the roadway that has been constructed to facilitate positive drainage of the pavement structure, and to convey runoff from the highway to the receiver.

Rural Cross-section - a road cross-section where there is no storm sewer system and all runoff is conveyed by a Roadside Ditch.

Safety End Treatments - sloped culvert ends that allow vehicles to safely traverse the culvert end openings.

Sag Inlet – a drainage inlet located at the low point in a road profile to which runoff flows from both directions.

Scour - erosion and the resulting lowering of a streambed by the action of flowing water.

Scupper Deck Drains - a drain which has small rectangular or V-shaped holes which permit the passage of water.

Soffit - refers to the underside of the bridge superstructure.

Standard Road Classifications – a classification system used by MTO to define roads, including freeway, arterial, collector, and local roads.

Static Ice Width - width of the water body which is associated with the Winter Flow Depth.

Storm Sewer System - comprises a network of trunk sewers, lateral sewers, maintenance holes and catch basins.

Stormwater Management Pond - a land depression or impoundment facility created for the detention or retention of stormwater runoff for the purposes of controlling stormwater flows or provision of water quality controls.

Stormwater Management Quality Controls - storage facilities that provide for improvement to the water quality using physical, biological or chemical process. These include wet ponds, extended dry detention ponds and best management practices suitable for use on highway infrastructure.

Structures in Cut - a structure which is founded below the elevation of the native material.

Sub-Drainage - the system of perforated or slotted collector pipes installed at the bottom of the subgrade or a short distance below the subgrade, which conveys water from the pavement structure to suitable outlets outside the roadway limit.

Subgrade – top of graded soil that interfaces with the granular layers associated with the pavement structure of a roadway.

Substrate - the composition of the material used to line the channel through a culvert, including either mineral or organic materials. Substrate within the culvert may include larger rock to withstand scour during flood flows.

Temporary Alignment - the alignment of the highway which is created to carry traffic temporarily.

Temporary Flow Passage System - the temporary flow control devices, channels, pipes, pumps and operation plans used to manage sustained flow and flow resulting from precipitation events in order to separate and/or isolate a work area within an existing waterbody.

Total Scour - the sum of the maximum depth of general scour and the depth of local scour.

Total Span – For the purpose of selecting Design Flow criteria, Total Span is defined as the sum of the individual clear spans or diameters, measured parallel to the centreline of the roadway in the case of a bridge, and perpendicular to the longitudinal axis in the case of a culvert.

Treatment Train - a set of stormwater management facilities applied in series to cumulatively mitigate detrimental impacts on the receiving system.

Trunk Sewers - the primary Storm Sewer System, excluding the Lateral Sewers.

Urban Cross-section - A road cross-section where the Minor System Design Flow is conveyed by a storm sewer. Typically, there will be a curb and/or median barrier.

Wall Drains - perforated pipes which transmit water from the backfill through the structure wall to alleviate hydrostatic pressure on the wall.

Waterbody - any permanent or intermittent, natural or constructed body of water including lakes, ponds, wetlands and watercourses, excluding sewage works as defined in the Ontario Water Resources Act.

Watercourse - a stream, creek, river, or channel including ditches, in which the flow of water is permanent, intermittent, or ephemeral.

Wetland – a stormwater management control facility consisting of a permanent pool for the treatment of stormwater runoff which is of less depth than a wet pond to allow for the growth of emergent vegetation.

Wet Pond - stormwater management control facility consisting of a permanent pool of water that never drains (except during maintenance), and additional capacity above the permanent pool that is designed to retain runoff that enters the pond during a storm event. The stored water is gradually released to a receiving water body. The permanent pool provides extended settling time equal to the interval time between storms, and allows the dilution of the discharge during a storm event by mixing the incoming flow with the existing pool of water (clean water).

Width of a Culvert – the culvert diameter for circular structures and the culvert span for box, arch and elliptical culverts.

Winter Flow Depth - average depth of flow measured during winter months (December to March, inclusive).

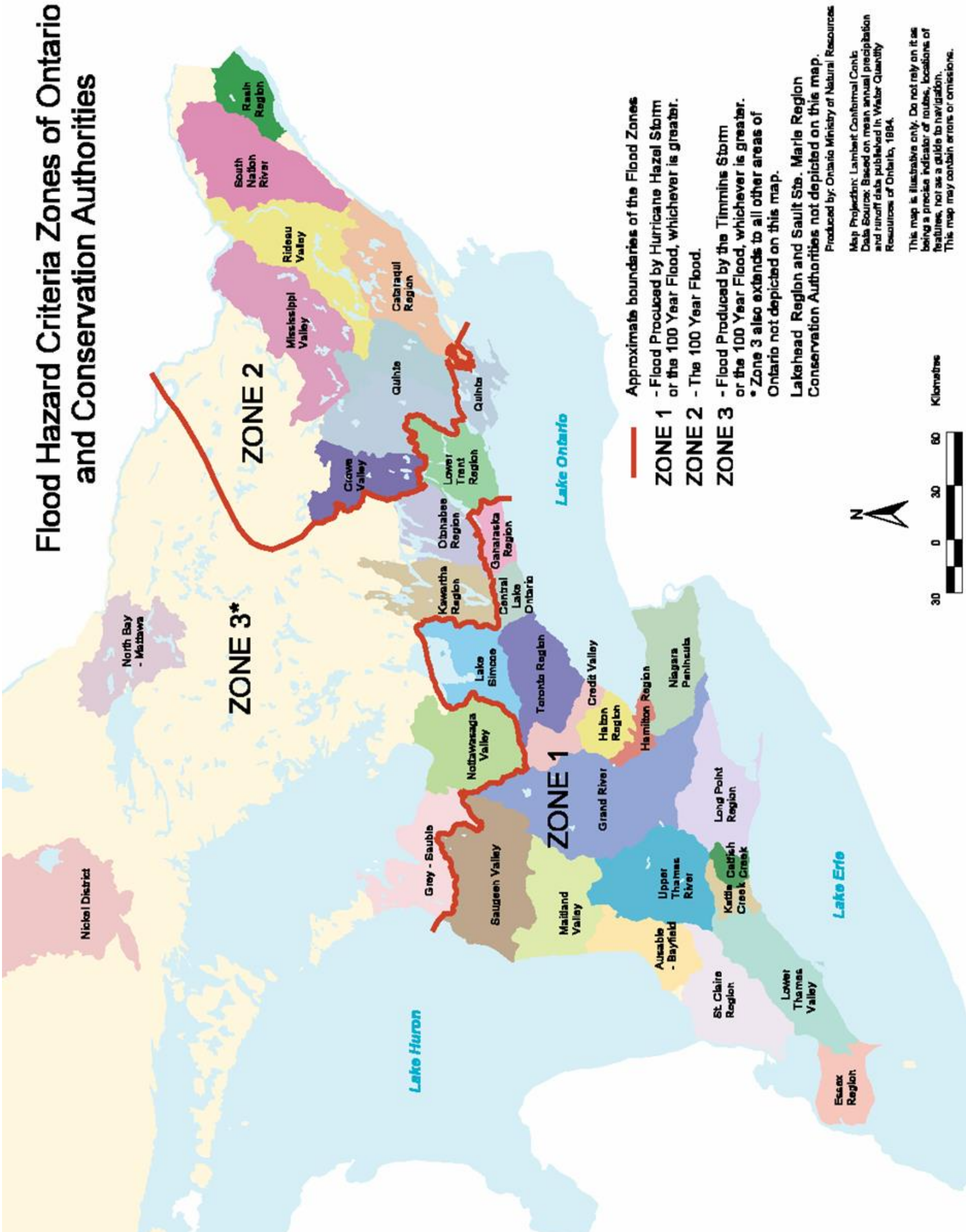


Figure 1: Flood Hazard Criteria Zones of Ontario

Source: Ontario Ministry of Natural Resources and Forestry

SD –1 Design Flows for Surface Drainage Systems

SCOPE

This standard identifies the minimum Design Flows that shall be used for the sizing of road surface drainage systems. The selected Design Flow shall be applied to size the minor and major drainage systems (piped and surface flow) for various MTO road types. This standard provides the hydrologic basis for all Surface Drainage Standards (SD-2 to SD-13).

DESIGN REFERENCES

MTO Drainage Management Manuals

1. HYDROLOGY

1.1 Design Flows

Design flows shall be determined for the annual exceedance probability specified in Table SD1-1 below using appropriate deterministic or statistical methods.

Table SD1-1: Design Flow for Minor System and Major System

Functional Road Classifications	Drainage System Type	Design Flow Probability of Occurrence	
		AEP	RP
Freeway, Arterial (Urban and Rural), Collector (Urban and Rural)	Minor System	10%	10 yr
	Major System	1%	100 yr
Local Road (Urban and Rural)	Minor System	20%	5 yr
	Major System	-	-
Depressed Roadways	Minor System	4%	25 yr
	Major System	1%	100 yr

1.2 Local External Catchment Areas Draining to the Highway Right-of-Way

1.2.1 External runoff shall be conveyed through an overland flow route (swale, ditch, etc.) or a storm sewer system from the point of interception to the receiving watercourse.

1.2.2 For a proposed highway, the capacity of the conveyance system shall be sufficient to convey the major system design flow.

1.2.3 For an existing highway subject to modification, the capacity of the conveyance system shall be sufficient to ensure the following:

- No increase in flood risk to properties adjacent to the highway right-of-way including significant natural areas/habitats: and
- The design of the overland flow route adheres to the requirements for the design of Roadside Ditches (Standard SD-9).

1.3 Climate Change

Climate change shall be considered in the design of Ministry of Transportation drainage infrastructure.

1.3.1 All performance standards prescribed in SD-2 through SD-13 shall be met throughout the design life of the structure for the applicable AEP/return period from the table in 1.1 and, where specified, the Regulatory Flow.

1.3.2 The design of conveyance, erosion, scour and stormwater management components shall ensure that the drainage infrastructure will accommodate future rainfall values for the year corresponding to the end of the Design Service Life of the structure.

1.3.3 Designers shall use the MTO IDF Curve Lookup application to determine the future rainfall predictions. Any additional/alternate climate change considerations/deviation shall be approved by the MTO.

1.3.4 Where analysis methods that do not rely on IDF curves are used, the design flow rates shall be increased by a factor to calculate the end of the Design Service Life design flows. The factor shall be equal to the ratio of future rainfall values to the current values determined using the MTO IDF Curve Lookup application.

1.3.5 Any additional/alternate climate change considerations/deviation shall be approved by the MTO.

1.4 The Unified Ontario Flood Method (UOFM)

The Unified Ontario Flood Method shall be used in the design of Ministry water crossing infrastructure when accurate flow data are not available and watershed conditions meet the limitations of this method. The UOFM shall be applied as follows:

a. If the flow value from the UOFM is higher than from any other applicable method, then the UOFM mean quantile values shall be used as design flows.
b. If the flow value from the UOFM is lower than from any other applicable method, then the value at the upper limit of the range shall be applied in design.
c. For low flows used in the assessment of fish passage, the flow value from the UOFM shall be applied in the design.

2. HYDRAULICS

Hydraulic performance standards under the design flows in Section 1 are addressed in Standards SD-2 to SD-13.

3. PHYSICAL CHARACTERISTICS

There are no Physical Characteristics specific to this Standard.

4. COMMENTARY

As part of the design process the following shall be addressed:

- Include downstream capacity constraints in the design of the Minor System and the Major System. The analysis should extend as far downstream as the change in flow may have an impact on downstream erosion potential or flood risk.
- Include planned future road widening when determining design flows.
- Include interception of groundwater as a component of the conveyed flows.
- Ensure that the drainage system accommodates conveyance of the Major System Design Flow.

SD–2 Longitudinal Grade and Cross-fall

SCOPE

This standard identifies the minimum longitudinal grade and cross-fall for highway surface drainage. The standard considers different road cross-sections, pavement types, and the number of lanes draining in one direction.

DESIGN REFERENCES

MTO Drainage Management Manuals
TAC Geometric Design Guide (GDG) for Canadian Roads
MTO Design Supplement for TAC Geometric Design Guide (GDG) for Canadian Roads

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD-1, Design Flows for Surface Drainage.

2. HYDRAULICS

This standard shall be read in conjunction with Standard SD-3, Flow Spread on to Travel Lanes, and Standard SD-7, Depressed Roadways and Underpasses.

3. PHYSICAL CHARACTERISTICS

3.1 Drainage Standards for Longitudinal Grade:

Longitudinal Grade requirements are summarized as follows:

Table SD3-1: Desirable and Minimum Standards for Sustainable Longitudinal Grade

Design Elements	Longitudinal Grade	
	Desirable Standard (%)	Minimum Standard (%)
Curbed roads (gutter grade) (1, 2)	≥ 0.5	0.3
Road With Impermeable Barrier (2)	≥ 0.5	0.3
Uncurbed roads with Adequate Cross-slope (1, 3)	≥ 0.5	0.0
Unlined Ditches(1)	≥ 0.5	0.1

(1) Source: Exhibit-30 MTO Design Supplement to TAC GDG for Canadian Roads.
(2) In cases with a grade less than the Minimum Standard, with a curb or impermeable barrier, False Grading of the gutter or shoulder may have to be provided to produce a minimum slope of 0.3% to the inlet.
(3) On uncurbed roads where the lateral surface drainage is not obstructed, level grades are permissible provided that the minimum slope for the roadside ditch can achieve the requirements of Standard SD-9.

3.2 Drainage Standards for Pavement Cross-fall

3.2.1 Pavement Cross-fall requirements for cases where three lanes or less drain in one direction are summarized as follows:

Table SD3-2: Minimum Design Cross-fall For Three Lanes or less draining in one direction

	Minimum Design Cross-fall (m/m)
Traffic Lanes Concrete or Bituminous pavement Gravel or crushed stone	 0.02 0.03 to 0.04
Shoulders(1) Paved or treated Gravel or crushed stone Earth or turf	 0.04 0.06 0.08
Grassed Areas	0.04
Sidewalks	0.02
Note: 1): On the high side of a super-elevated section, the minimum cross-fall shall be 0.02 m/m	

3.2.2 It is desirable that no more than four lanes (travel lanes and auxiliary lanes) of pavement drain in the same direction on a tangent section.

3.2.3 On a tangent section when four or more lanes drain in the same direction, the first two lanes adjacent to the crown shall have a minimum Cross-fall of 0.02 m/m. The Cross-fall for each successive pair of lanes shall increase by 0.005 m/m.

3.2.4 On a super-elevated curve with super-elevation less then 0.03 m/m, and with four or more lanes draining in the same direction; the first two lanes adjacent to the crown shall be super-elevated in accordance with the Geometric Design Standards for Ontario Highways. The Cross-fall for each successive pair of lanes shall increase by 0.005 m/m to a maximum of 0.03 m/m.

4. COMMENTARY

- This standard provides the minimum slopes to achieve highway surface drainage objectives. Other standards and site conditions may affect the slopes required to satisfy other highway design objectives.
- For the application of Desirable Standards and Minimum Standards, refer to the "How to use this Document" at the front of the Drainage Design Standard.
- The crown of the road should be located close to the centre of the roadway with generally more drainage directed to grassed areas (i.e. ditch, grassed median) than to curbed areas (i.e. concrete median, curb) to reduce the size of the median storm sewer and Flow Spread at the median.
- In order to reduce the potential for standing water and hydroplaning in transitions from standard cross-sections to super-elevated cross-sections, the design should account for the overall drainage slope (combination of cross-fall and longitudinal slope) at the transition.

SD –3 Flow Spread on to Travel Lanes

SCOPE

This standard identifies the Maximum Allowable Spread Distance onto the travel lanes of a highway. It also defines the Maximum Depth of flow at the edge of the travel lanes.

DESIGN REFERENCES

MTO Drainage Management Manuals

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD-1, Design Flow for Surface Drainage.

2. HYDRAULICS

There are no standard specific to Hydraulics.

3. PHYSICAL CHARACTERISTICS

3.1 Allowable Spread for Minor System Design Flow (from Curbs and Barriers) for Freeways, Arterials and Collectors

3.1.1 As a Desirable Standard, the Maximum Lateral Spread Distance shall be zero, such that the full lane width adjacent to a concrete barrier or curb remains clear of any flooding.

3.1.2 As a Minimum Standard, the Maximum Lateral Spread Distance shall be such that a minimum of 2.5 metres of the lane width adjacent to a concrete barrier or curb remains clear of any flooding.

3.1.3 The Maximum Depth of flooding at the lowest edge of the travel lanes shall not exceed 25 mm as shown in Figure SD3.1.

3.2 Allowable Spread for Minor System Design Flow (from Curbs and Barriers) for Local Roads

The Maximum Lateral Spread Distance shall be such that a minimum of 2.5 metres of the lane width adjacent to a concrete barrier or curb remains clear of any flooding.

3.3 Maximum Allowable Flow Spread for Major System (from Curbs and Barriers)

The following standard applies to Freeway, Arterial Roads and Collector Roads. It shall also apply to Local Roads if they are considered to be a vital link for emergency response vehicles.

3.3.1 The Maximum Lateral Spread Distance for a two lane roadway shall be such that the minimum width of the Open Roadway is 3.5 metres.

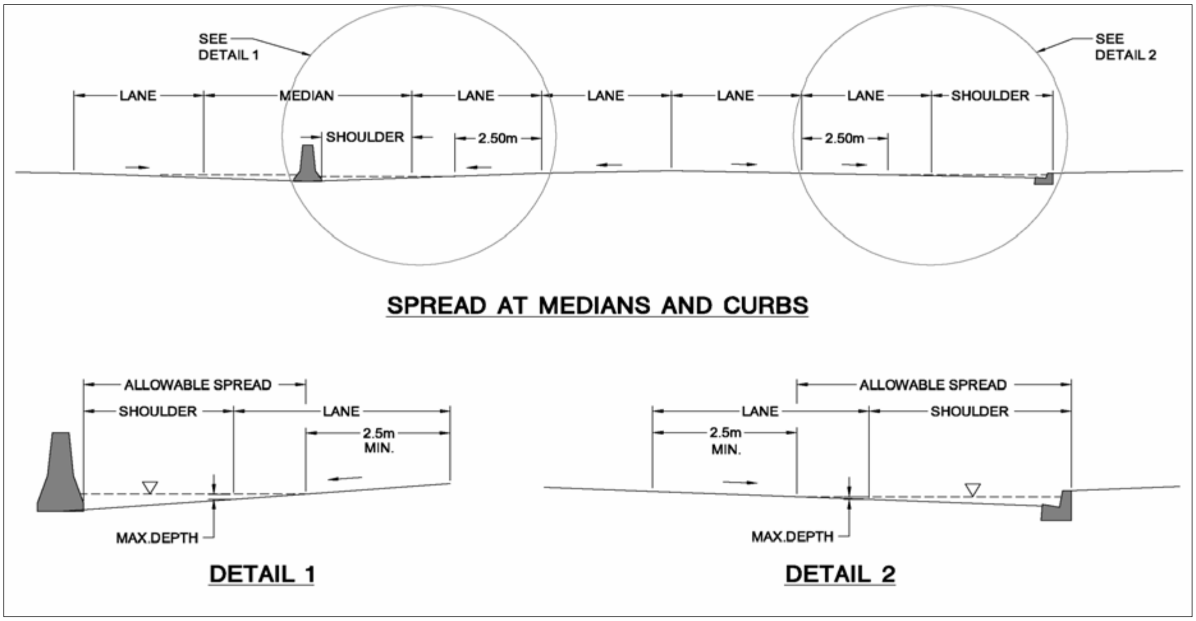
3.3.2 The Maximum Lateral Spread Distance for a roadway with two lanes in each direction shall be such that a minimum of one lane remains open in each direction.

3.3.3 The Maximum Lateral Spread Distance for a roadway with more than two lanes in each direction shall be such that a minimum of two lanes remains open in each direction.

3.4 Maximum Allowable Flow Spread (from Ditches)

There shall be no Flow Spread beyond the ditch on to the shoulder or travel lane, for flow up to and including the Major System Design Flow.

Figure SD3.1: Spread at Medians and Curbs



4. **COMMENTARY**

- For the application of Desirable Standards and Minimum Standards, refer to the "How to use this Document" at the front of the Drainage Design Standards.
- This standard is intended to apply to all sections of a highway. Flow Spread for bridges is defined in Standard WC-4, Bridge Deck Drainage.
- It is desirable that the drainage system for a Freeway be designed such that there is no Spread onto the travel lane. The ability of the designer to meet this objective will be dependent upon the width of the shoulder. Where the shoulder equals or exceeds 3.0 metres, it is desirable that the designer endeavor to prevent Flow Spread onto the travel lane for the Minor System Design Flow.
- The extent of Flow Spread onto a travel lane should not change abruptly as a result of a change in highway cross-fall, the width of the shoulder, or the longitudinal profile of the roadway. This consideration is particularly noteworthy where there is a reduction in shoulder width across a bridge or where there is a transition between a standard cross-section and a super-elevated cross- section.
- The calculation of Flow Spread should be based on the maximum flow conveyed by the highway and the adjacent shoulder. Any runoff captured by the catch basins and conveyed by the Minor System (storm sewer system) shall be discounted from the calculations.
- This Standard also applies to depressed roadways. Refer to Standards SD-9 for the standards associated with Roadside Ditches.

SD –4 Storm Sewer System

SCOPE

This standard addresses the design of Storm Sewer Systems and identifies the minimum allowable velocity, the minimum pipe diameter, the maximum spacing of maintenance holes, and the minimum slope of lateral sewers.

DESIGN REFERENCES

MTO Drainage Management Manuals

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD-1, Design Flows for Surface Drainage.

2. HYDRAULICS

2.1 Minimum Allowable Velocity

2.1.1 Desirable Standard - the Minimum Allowable Velocity in a Trunk Sewer shall be 0.75 m/s for smooth walled pipes, and 0.9 m/s for corrugated pipes. The Minimum Allowable Velocity in a Lateral Sewer shall be 1.5 m/s.

2.1.2 Minimum Standard - the Minimum Allowable Velocity in a Trunk Sewer shall be 0.5 m/s where the pipe can be flushed.

2.2 Maximum Velocity

The maximum velocity in the Trunk Sewer or Lateral Sewer is subject to pipe supplier specifications and energy dissipation/erosion control works located downstream of the sewer outlet.

3. PHYSICAL CHARACTERISTICS

3.1 Minimum Pipe Diameter

The Minimum Pipe Diameter of the trunk and lateral storm sewers shall be 300 mm in order to facilitate maintenance.

3.2 Maximum Maintenance Hole Spacing

The Maximum Maintenance Hole Spacing is defined as follows:

3.2.1 For pipe diameters less than or equal to 1200 mm, the Maximum Maintenance Hole Spacing shall be 150 m. The spacing shall be reduced to 100 m where the Desirable Minimum Allowable Velocity is not achieved.

3.2.2 For pipe diameters greater than 1200 mm the Maximum Maintenance Hole Spacing shall be 350 m. The spacing shall be reduced to 200 m where the Desirable Minimum Allowable Velocity is not achieved.

3.3 Minimum Slope of Lateral Sewers

The minimum slope of Lateral Sewers shall be 0.015 m/m.

4. COMMENTARY

- For the application of Desirable Standards and Minimum Standards, refer to the "How to use this Document" at the front of the Drainage Design Standards.
- The Minimum Cover is dictated by design loads and the depth of frost penetration.
- Sewer alignments may be curved in both plan and profile provided that the manufacturer's limitations on allowable deviation are observed.
- The maximum allowable slope of the pipe is determined by the maximum allowable velocity in the pipe, which is subject to the specifications of the pipe manufacturer.
- In some cases, the Minimum Pipe Diameter may be increased to match the municipal criteria.
- Where Maintenance Holes include an inlet, the spacing shall be dictated by Standard SD-5, Storm Sewer Inlets on a Continuous Grade.
- Standards for the design of catch basins, maintenance holes and drop structures are provided in the Ontario Provincial Standards and the MTO Drainage Management Manuals.
- Standards for lateral and transverse culverts are provided elsewhere in this document.

SD –5 Storm Sewer Inlets on a Continuous Grade

SCOPE

This standard identifies the maximum spacing between adjacent storm sewer inlets along a curb or a median barrier on roads with continuous grade.

DESIGN REFERENCES

MTO Drainage Management Manuals

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD-1, Design Flows for Surface Drainage.

2. HYDRAULICS

2.1 Inlet Blockage

Inlets on a continuous grade shall be designed assuming that the capacity has not been reduced as a result of blockage associated with debris.

3. PHYSICAL CHARACTERISTICS

3.1 Maximum Inlet Spacing

As dictated by maintenance considerations, the maximum spacing between inlets shall be 150 metres. Inlet spacing shall be designed to ensure that design criteria for Flow Spread (Standard SD-3) are met and that flow capacity of the Minor System is not exceeded at the inlet locations.

4. COMMENTARY

- The Maximum Inlet Spacing of 150 metres may be reduced if it is excessive for the type of maintenance equipment available, or if dictated by design requirements.
- There is no requirement regarding the maximum distance from the crest of a vertical curve to the first inlet on a grade, but on the basis of information from Operations Services Offices, a limit of 150 metres is recommended so as to avoid the possibility that a large drainage area could contribute an excessive quantity of sand and debris to the first inlet.
- Where the Flow Spread exceeds the requirements of Standard SD-3, Flow Spread on to Travel Lanes, it may be necessary to decrease the spacing of Inlets.
- Where catch basins outlet directly to the outside ditch, rather than continuing in the median as a trunk sewer, the inlet spacing shall be dictated by the requirements of Standards SD-3, Flow Spread on to Travel Lanes.

SD–6 Storm Sewer Inlets at Highway Sags

SCOPE

This standard identifies the placement of storm sewer inlets and quantifies the blockage at highway sags.

DESIGN REFERENCES

MTO Drainage Management Manuals

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD-1 Design Flows for Surface Drainage and SD-7 Depressed Roadways and Underpasses.

2. HYDRAULICS

2.1 Inlet Blockage

Inlets at a highway sag shall be designed assuming that the capacity has been reduced by 50 percent as a result of blockage associated with debris.

3. PHYSICAL CHARACTERISTICS

3.1 Maximum Allowable Spread

3.1.1 Sufficient inlet capacity shall be provided such that any Flow Spread onto the travel lanes conforms to the Flow Spread requirements of Standard SD-3 (Flow Spread onto Travel Lanes).

3.1.2 As a minimum, twin inlets shall be placed at the bottom of the sag. Design of these inlets shall be in accordance with Section 2.1 of this Standard.

3.1.3 For locations where the twin inlets are not sufficient to prevent flooding onto the travel lanes additional inlets are to be provided. As a minimum an additional inlet shall be provided on each approach (flanking inlets) at a point where the elevation of the inlet is 0.06 m higher than that at the bottom of the sag. Design of flanking inlets is not subject to the inlet blockage requirements of Section 2.1 of this Standard.

4. COMMENTARY

- Subject to MTO approval, alternatives may be investigated to increase inlet capacity at sags. Alternatives may include triple inlets, depressed inlets, and high capacity curb inlets sized to provide the required capacity.

SD –7 Depressed Roadways and Underpasses

SCOPE

This standard identifies the maximum depth of flooding, the maximum allowable spread, and the percent inlet blockage for the design of drainage conveyance systems in Depressed Roadways and Underpasses. This standard includes cases where there is no Major System outlet, including cases where pumping is required.

DESIGN REFERENCES

Design References not available.

1. HYDROLOGY

The Minor System and Major System shall be designed in accordance with the Design Flow identified in Standard SD-1, Design Flows for Surface Drainage. In addition to the above, a Check Flow equal to the greater of the flow resulting from the Regulatory Storm or 1.3 times the 100-year flow (or 1% AEP) shall be used to calculate the maximum depth of flooding at the sag (See Section 3.2.3 of this standard).

2. HYDRAULICS

2.1 Inlet Blockage

Inlets at a highway sag shall be designed assuming that the capacity has been reduced by 50 percent as a result of blockage associated with debris.

3. PHYSICAL CHARACTERISTICS

3.1 Maximum Allowable Spread

The Maximum Allowable Spread for Depressed Roadways and Underpasses shall be in accordance with the requirements of Standard SD-3, Flow Spread onto Travel Lanes. As a minimum, the inlets shall be designed in accordance with the requirements of Standard SD-6, Storm Sewer Inlets at Highway Sags.

3.2 Depressed Roadway

3.2.1 In cases where there is no overland flow path or gravity outlet, a pump station shall be provided. The allowable high water elevation in the pump station shall be set so that the water surface elevation in the collection system for the Major System Design Flow provides at least 0.3 metres of freeboard below the lowest roadway inlet.

3.2.2 Flow from sections of the roadway up-gradient of the depressed section shall be diverted from the roadway in order to minimize the drainage area and the volume of water directed to the sag.

3.2.3 For the Check Flow the maximum depth of flooding at the sag of the roadway shall be 0.3 metres measured from the crown of the roadway.

4. COMMENTARY

- The Check Flow depth standard (Section 3.2.3) is provided to ensure that emergency vehicles can access or transverse a depressed roadway.
- In order to meet Standard SD-7 it will often be necessary to construct an outlet (channel or pipe) from the sag point to the receiving watercourse that is substantially larger than what would typically be required to convey the Major System Design Flow.

- Pump cycling and pump storage should be optimized, and stand-by pumps should be provided to minimize the risk of failure of the pump station and thus protect the Depressed Roadways from flooding.
- In some case mechanical means may be required to prevent backflow from the receiving watercourse or water body.
- Subject to MTO approval, alternatives may be investigated to increase inlet capacity at sags. Alternatives may include triple inlets, depressed inlets, and high capacity curb inlets sized to provide the required capacity.

SD –8 Gutter Outlets

SCOPE

This standard addresses the placement of Gutter Outlets on grades and in sags leading to a roadside ditch.

DESIGN REFERENCES

Design References not available.

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD-1, Design Flows for Surface Drainage.

2. HYDRAULICS

There are no hydraulic standards applicable to Gutter Outlets.

3. PHYSICAL CHARACTERISTICS

3.1 Gutter Outlet Angles

On longitudinal grades, Gutter Outlets shall be set at an angle of 45 degrees from the shoulder longitudinal alignment. At sags, Gutter Outlets shall be set at 90 degrees from the shoulder longitudinal alignment, such that they collect water equally from both directions leading to the sag. Figure SD8.1 illustrates orientation of the Gutter Outlets.

Figure SD8.1 Gutter Orientation

3.2 Gutter Outlet Spacing

Gutter Outlets shall be spaced to ensure Flow Spread conforms to the requirements of Standard SD-3 Flow Spread onto Travel Lanes.

4. COMMENTARY

No Commentary specific to Gutter Outlets.

SD –9 Roadside Ditches (Conveyance Only)

SCOPE

This standard identifies the minimum design requirement of Roadside Ditches for the conveyance of flow. It does not address the design of roadside ditches for improvement of water quality.

DESIGN REFERENCES

MTO Drainage Management Manuals

1. HYDROLOGY

Roadside Ditches shall be designed to convey both the Minor System Design Flow and the Major System Design Flow, as defined in Standard SD-1, Design Flows for Surface Drainage.

2. HYDRAULICS

2.1 Maximum Flow Depth

2.1.1 The maximum depth of flow in the Roadside Ditch associated with the Minor System Design Flow shall be 1.0 m.

2.1.2 There is no maximum depth of flow in the Roadside Ditch associated with the Major System Design Flow.

2.2 Containment of Flow in Ditch

2.2.1 For the Major System Design Flow, the design of the roadside ditch shall ensure that Design Flow will not spread onto either the shoulder or the travel lane.

2.2.2 As a Desirable Standard, for the Major System Design Flow, water shall not extend beyond the Right-of-Way, and as a Minimum Standard any flow spread beyond the Right-of-Way shall not increase the existing extent of flooding.

2.3 Maximum Permissible Velocity

The Maximum Permissible Velocity is governed by the channel lining, which shall be designed to resist erosion for the Major System Design Flow. In no case shall the velocity in a grass-lined channel exceed 1.5 m/s unless bioengineering techniques (e.g. reinforcing grid or mat) are used.

3. PHYSICAL CHARACTERISTICS

3.1 Minimum Freeboard

3.1.1 The minimum freeboard to the top of Sub-Grade shall be 0.3 metres for the Minor System Design Flow.

3.1.2 There is no minimum freeboard associated with the Major System Design Flow.

3.2 Physical Parameters

The physical ditch parameters include: Side Slopes, Longitudinal Slope, Base Width, Minimum Depth, and invert location. These are listed in the following table.

Table SD9-1: Roadside Ditch Design Parameters

Maximum Side Slope [1]	2H:1V
Minimum Longitudinal Slope	0.3 percent
Base Width – Desirable Standard – Minimum Standard	1.0 metre Zero (V-ditch)
Minimum Ditch Depth for Minor System Design Flow: • Normal Ditch (road at grade or in cut) • Ditch at toe of Fill Slope	0.50 metres 0.25 metres
Distance that roadside ditch invert shall be below the road subgrade elevation: • Desirable Standard • Minimum Standard	0.5 metres 0.3 metres
Note (1): Flatter side slopes may be incorporated into the design in accordance with the Roadside DesignManual (formerly the Roadside Safety Manual) and geotechnical characteristics.	

4. COMMENTARY

- In cases where the depth of the ditch is to be reduced (e.g. safety consideration or grading constraints), the need for subdrains in accordance with Standard SD-11 shall be evaluated.
- Any backwater effect associated with flow in the Roadside Ditch during the Minor System Design Flow should be accounted for in the design of the Minor System.
- See Standard SW-3 for water quality standards applicable to Roadside Ditches.
- Roadside Ditches should be designed to carry runoff from the highway right-of-way as well as from Local External Catchment Areas that naturally drain to the right-of-way.
- Roadside Ditches may drain to a stormwater management facility if required to meet treatment objectives.
- Where fish habitat has been identified the designer shall consult the MTO Environmental Guides for Fisheries.
- The establishment of a suitable vegetative cover, rock lining, or approved equivalent is essential if Roadside Ditches are to remain effective in improving water quality.
- Reference should be made to the MTO Drainage Management Manuals, Environmental Guide for Erosion and Sediment Control During Construction of Highway Projects and other MTO documents for the design of erosion control measures and turf management.
- The design shall be consistent with the Ontario Provincial Standards.
- Where groundwater is intercepted, a subdrain system may be installed to prevent baseflow in the ditch.
- Where a Natural Watercourse also serves as a Roadside Ditch, refer to Standard SD-12 (Freeboard above Adjacent Natural Watercourses or Water Bodies.

SD –10 Roadside Ditch Inlets

SCOPE

This standard identifies the positioning, grading slope, and design blockage requirements for Roadside Ditch Inlets.

DESIGN REFERENCES

MTO Drainage Management Manuals

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD -1, Design Flows for Surface Drainage.

2. HYDRAULICS

Roadside Ditch Inlets shall be designed assuming 50 percent blockage of the inlet grate.

3. PHYSICAL CHARACTERISTICS

3.1 Roadside Ditch Inlet Placement Across a Roadside Ditch

Where the Roadside Ditch Inlet is placed across a roadside ditch and may be in contact with vehicles that have left the roadway, the grating slope shall be 6H:1V or flatter.

3.2 Roadside Ditch Inlet Placement on a Slope

Where the Roadside Ditch Inlet is placed on the front slope or back slope of the roadside ditch, the grating slope shall match the graded slope.

3.3 Spacing of Ditch Inlets

When Roadside Ditch Inlets are installed directly on-line with a storm sewer and they also serve as the maintenance access point, then the maximum spacing between consecutive inlets shall be in accordance with Standard SD-4 (3.2), Storm Sewer System.

4. COMMENTARY

- With the exception of minimum spacing required for maintenance (Standard SD-4 (3.2)), spacing of Ditch Inlets is primarily dictated by the capacity of the inlet and the contributing catchment area to that inlet.
- Where debris traps are required at the inlet, the trap should be accounted for in the hydraulic analysis used to determine the inlet size and performance.

SD –11 Sub Drainage – Collector System & Outlets

SCOPE

This standard identifies the minimum diameter and the minimum slope for road subdrains and defines the desirable elevation of subdrain outlets.

DESIGN REFERENCES

Design References not available.

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD-1, Design Flows for Surface Drainage.

2. HYDRAULICS

There are no standards specific to Hydraulics.

3. PHYSICAL CHARACTERISTICS

3.1 Slopes of Collector Pipes

The slopes of collector pipes shall not be less than 1.0 percent for smooth bore pipes and 2.0 percent for corrugated pipes.

3.2 Minimum Pipe Diameter

The minimum diameter specified shall be 100 mm for all pipe types.

3.3 Invert of Outlet Pipe

Whenever possible, the invert at the end of the outlet pipe shall be at least 0.3 m above the invert elevation in the roadside ditch (Refer to SD-9 for Roadside Ditches).

3.4 Groundwater

The design of subdrain systems shall account for existing groundwater flow patterns and minimize the potential of drawdown of groundwater levels. In cases where the subdrain will impact groundwater levels the designer should assess alternative design measures such as adjusting the road profile.

3.5 Maintenance Holes and Catch Basins

If the subdrain outlet is located in a maintenance hole or catch basin with a storm sewer, then whenever possible, the invert at the end of the subdrain outlet pipe should be at least 0.15 m above the design water surface in the receiving maintenance hole or catch basin.

4. COMMENTARY

- Where groundwater is intercepted, an underdrain system may be installed to prevent baseflow in the ditch.
- In order to reduce the possibility of damage, the outlet pipe should consist of unperforated corrugated steel pipe for a minimum length of 2.5 m from the discharge end, in accordance with MTO standards.

- The minimum 100 mm subdrain diameter has been specified in accordance with the CDED Manual.
- To ensure interception of lateral flows in pervious material, it is preferable that collector drains be recessed into the underlying soil.
- The sizing of subdrains should be based on the contributing area.

SD-12 Freeboard above Adjacent Natural Watercourses or Waterbodies

SCOPE

This standard identifies the minimum required Freeboard for roadways that are constructed adjacent to Natural Watercourses or Waterbodies.

DESIGN REFERENCES

Design References not available.

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD-1, Design Flows for Surface Drainage.

1.1 Freeboard to the Edge of the Travel Lane

The Regulatory Flow (watercourses) or Regulatory Water Level (reservoirs) shall be used for determining the Freeboard to the edge of the travel lane for freeways, arterial, and collector roads. Reservoirs include natural and regulated waterbodies. Water Level includes wind set-up.

1.2 Freeboard to the Top of Subgrade

A 1% AEP (100-year return period) Design Flow (watercourses) or Design Water Level (reservoirs) shall be used for determining the Freeboard to the top of subgrade for all roadways.

Reservoirs include natural and regulated water bodies. Water Level includes wind set-up.

2. HYDRAULICS

2.1 Freeboard for Parallel Flow

The freeboard for Parallel Flow is as follows, unless restricted by local constraints:

Table SD12-1: Freeboard for Parallel Flow

Functional Road Classification	**Freeboard to the Top of Subgrade** ***Design Flow / Design Water Level:*** **1% AEP (100-yr RP)**	**Freeboard to the Edge of Travel Lane** ***Design Flow / Design Water Level:*** **Regulatory**
Freeways, Arterial and Collector	0.5 m	0.3 m
Local Roads	0.5 m	n/a

3. PHYSICAL CHARACTERISTICS

There are no standards specific to Physical Characteristics.

4. COMMENTARY

- The 0.5 m freeboard to the top of the subgrade is required to provide positive drainage of the granular base of the road and to prevent it from being saturated.
- This standard also applies where the watercourse also serves as a Roadside Ditch.
- The road embankment design should account for erosion potential and loss of embankment fines due to rapid changes in flood levels in parallel watercourses and adjacent reservoirs.
- For new construction, the road should be located outside of the meander belt width of the watercourse channel.
- Where available, a Dam Operation Plan should be used in determining high water levels and establishing Flooding Rights on dammed reservoirs that are adjacent to the roadway.

SD-13 Design Flows and Freeboard for Road Surface Drainage Culverts

SCOPE

Removed. See WC-7 Culvert Crossings for design flows and freeboard requirements for Road Surface Drainage Culverts.

WC-1 Design Flows Natural Watercourse Crossings (Bridges and Culverts)

SCOPE

This standard identifies the minimum Flows to be used for the sizing of bridge and culvert water crossings of Natural Watercourses for flow conveyance.

It also identifies the requirement for accommodating the Regulatory Flow on Regulated Watercourses, and for determining the maximum allowable increase in flood elevations upstream of a bridge or culvert. This standard provides the hydrologic basis for all water crossing standards, WC-1 to WC-13, except as noted.

DESIGN REFERENCES

Canadian Highway Bridge Design Code
MTO Structural Manual

1. HYDROLOGY

Design flows shall be determined for the Annual Exceedance Probability specified in Table WC1-1 and Table WC-2 using appropriate deterministic or statistical methods.

1.1 Standard Road Classifications

1.1.1 As a minimum, bridges and culverts of Provincial Highways shall be designed to the criteria shown in the following table, except as outlined in Section 1.1.2 to Section 1.1.4 of this standard:

Table WC1-1: Design Flows for Bridges and Culverts

Functional Road Classification	Probability of Occurrence of Flow			
	Design Flow for Structure Sizing, Flood Depth, Clearance, Freeboard		Scour Analysis and Check Flow	Backwater Assessment Range of Flows[3]
	Total Span less than/equal to 6.0 m	Total Span Greater than 6.0 m		
Freeway, Urban Arterial	2% AEP *(50 yr RP)*	1% AEP *(100 yr RP)*	130% of the 1% AEP *(130% of the 100 yr RP)*	Flows with AEP of: 1%, 2%, 4%, 10% & 20% *(Flows with RP of 100, 50, 25, 10, 5 years)*
Rural Arterial, CollectorRoad	4% AEP *(25 yr RP)*	2% AEP *(50 yr RP)*	115% of the 1% AEP *(115% of the 100 yr RP)*	
Local Road	10% AEP *(10 yr RP)*	4% AEP *(25 yr RP)*	100% of the 1% AEP *(100% of the 100 yr RP)*	

Notes:

1. The listed design flows apply to roads under the jurisdiction of the Ministry of Transportation.
2. The Fish Passage Design Flow for culverts is defined in WC-12 Fish Passage Requirements Through Culverts.
3. The existing and proposed upstream water surface elevations shall also be calculated for Regulated Watercourses where the Regulatory Flow estimate is required.

1.1.2 On Regulated Watercourses the Regulatory Flow shall be calculated in all cases where:

- Floodline Mapping is available,
- There is a potential risk to public safety, or
- There is potential damage to adjacent properties, as applied in Section 2.3 of this standard.

1.1.3 The Design Flow Probability of Occurrence may be modified in exceptional cases, such as for unusually large structures, or for vital routes which must remain useable during Regulatory Flow conditions. Use of Regulatory Flow as a Design Flow in the latter case shall be justified by a cost-benefit analysis.

1.1.4 If the road classification is likely to be upgraded or downgraded within 5 years of construction, the Annual Exceedance Probability (Return Period) shall be based on the future classification.

1.2 Low Volume Roads (Bridges only)

Design Flow Return Periods for Bridges on Low Volume Roads were developed to achieve economies without compromising safety. These requirements apply only to bridges. Culverts shall be designed in accordance with Section 1.1 of this standard.

1.2.1 As a minimum, bridges shall be designed to accommodate the Design Flow without damage to the structure or approaches. Relief Flow over the road shall be in accordance with Standard WC-13 Relief Flow (Bridges and Culverts). Drainage facilities for Low Volume Roads shall be designed to the criteria shown in the following table, except as provided in Section 1.2.2 to 1.2.6 of this standard:

Table WC1-2: Design Flows for Bridges on Low Volume Roads

Road Function	**Vulnerability**	**Probability of Occurrence of Flow**		
		Design Flow for Structure Sizing, Clearance, Freeboard, Scour Analysis		**Backwater Assessment Range of Flows[3]**
		Total Span less than/equal to 6.0 m	**Total Span Greater than 6.0 m**	
Collector and Arterial	High	4% AEP *(25 yr RP)*	2% AEP *(50 yr RP)*	Flows with AEP of: 1%, 2%, 4%, 10% & 20% *(Flows with RP of 100, 50, 25, 10, 5 years)*
	Low	4% AEP *(25 yr RP)*	2% AEP *(50 yr RP)*	
Local	High	10% AEP *(10 yr RP)*	4% AEP *(25 yr RP)*	
	Low	10% AEP *(10 yr RP)*	4% AEP *(25 yr RP)*	
Resource Access	High	20% AEP *(5 yr RP)*	10% AEP *(10 yr RP)*	
	Low	20% AEP *(5 yr RP)*	10% AEP *(10 yr RP)*	
Recreation	High	20% AEP *(5 yr RP)*	10% AEP *(10 yr RP)*	
	Low	50% AEP *(2 yr RP)*	50% AEP *(2 yr RP)*	

1.2.2 The Check Flow need not be considered.

1.2.3 On Regulated Watercourses the Regulatory Flow shall be calculated in all cases where:

- Floodline Mapping is available,
- There is a potential risk to public safety, or
- There is potential damage to adjacent properties, as applied in Section 2.3 of this standard.

1.2.4 Low water crossings, which accommodate the Design Flow but overtop during more severe flooding, may be considered as an alternative, but not for Collector or Arterial Roads.

1.2.5 The AEP (Return Period) of the Design Flow should be determined by the owner by establishing the acceptable length of time the structure is impassable. Where required, approval shall be sought from other agencies having jurisdiction.

1.2.6 The hydrology criteria may be modified in exceptional cases, such as for unusually large structures or for vital routes which must remain useable during more severe storm conditions. Use of a more severe design storm in the latter case shall be justified by a cost-benefit analysis.

1.3 Climate Change

Climate change shall be considered in the design of Ministry of Transportation drainage infrastructure.

1.3.1 All performance standards prescribed in WC-2 through WC-13 shall be met throughout the design life of the structure for the applicable AEP (Return Period) flows from the Table in WC1-1 and WC1-2 and, where required, the Regulatory Flow.

1.3.2 The design of conveyance, erosion, scour and stormwater management components shall ensure that the drainage infrastructure will accommodate future rainfall values for the year corresponding to the end of the Design Service Life of the structure.

1.3.3 Designers shall use the MTO IDF Curve Lookup application to determine the future rainfall predictions. Any additional/alternate climate change considerations/deviation shall be approved by the MTO.

1.3.4 Where analysis methods that do not rely on IDF curves are used, the flow rates shall be increased by a factor to calculate the end of the Design Service Life flows. The factor shall be equal to the ratio of future rainfall values to the current values determined using the MTO IDF Curve Lookup application. Any additional/alternate climate change considerations/deviation shall be approved by the MTO.

1.4 The Unified Ontario Flood Method (UOFM)

The Unified Ontario Flood Method shall be used in the design of Ministry water crossing infrastructure when accurate flow data are not available and watershed conditions meet the limitations of this method. The UOFM shall be applied as follows:

a. If the flow value from the UOFM is higher than from any other applicable method, then the UOFM mean quantile values shall be used as Design Flows.

b. If the flow value from the UOFM is lower than from any other applicable method, then the value at the upper limit of the range shall be applied in design.

c. For low flows used in the assessment of fish passage, the flow value from the UOFM shall be applied in the design.

1.5 Channel Realignment or Diversion

Channel realignment or channel restoration upstream or downstream of a water crossing that will alter the storage or discharge characteristics upstream of the crossing, shall be designed to meet the design standards of the crossing. As a minimum the combined capacity of the watercourse and floodplain shall convey the 4% AEP (25-year Return Period) Design Flow. The main channel is to be designed to a lower Design Flow such that a stable channel is maintained.

2. HYDRAULICS

2.1 Design Flow and Upstream Water Surface Elevations

The existing and proposed upstream water surface elevations shall be calculated for Design Flow identified in Sections 1.1.1 and 1.2.1 of this standard and shall be used for the design of the Water Crossing.

2.2 Range of Flows and Upstream Water Surface Elevations

The existing and proposed upstream water surface elevations shall be calculated for the Backwater Assessment Range of Flows identified in Sections 1.1.1 and 1.2.1 of this standard. The estimated water surface elevations will be used for assessing impacts on Rating Curves and floodlines upstream of the water crossing.

2.3 Regulatory Flow and Upstream Water Surface Elevations

The existing and proposed upstream water surface elevations shall also be calculated for Regulated Watercourses where the Regulatory Flow estimate is required.

2.4 Check Flow

The AEP (Return Period) for the Check Flow is identified in Section 1.1.1 of this standard. The Check Flow shall be used for scour analysis to assess structural integrity where required.

2.5 Winter Flow Condition

The Winter Flow Depth shall be used to evaluate icing conditions where required.

3. PHYSICAL CHARACTERISTICS

There are no physical characteristic standards applicable to Design Flows (Bridges and Culverts).

4. COMMENTARY

- The decision whether there would be any risk to public safety or potential damage to adjacent properties as a result of change in flood elevations shall be determined in consultation with the Municipality, Conservation Authority or the Ministry of the Natural Resources given their responsibilities under the Conservation Authorities Act and Lakes and Rivers Improvement Act.
- In the case where a drainage system that is not subject to regulations for conveyance or flood protection (e.g. municipal drain) is being conveyed under the highway, the design approach shall be followed for the protection of the highway.
- Where, through consultation with the Conservation Authority and/or MNR, there is an increase in flood elevation on private land that will adversely impact the landowners, an agreement will be made with the affected landowners.
- Design Flows for water crossings shall normally be based on existing land use runoff conditions, but, at the request of the municipality concerned, and subject to the Ministry's cost sharing policies, may be based on land use runoff conditions anticipated 20 years from the time of design.
- Upstream water surface elevations are calculated for all design storms in recognition that any increase in flood elevation may represent an increase in flood risk.
- Assessment of the Check Flow is not normally required if the structure is designed to the larger Regulatory Flow criteria.
- Performance of culverts on fish migration routes shall be checked with the Standard WC-12, Fish Passage through Culverts.
- Upstream water surface elevations are calculated for all design storms in recognition that any increase in flood elevation may represent an increase in flood risk.
- The calculation of upstream elevations for a range of Design Flows under existing and proposed conditions is to be used to evaluate the impact of the structure on the upstream Rating Curve. If there is a negative impact, based upon the effect on private property or drainage systems, it may be necessary to change the proposed opening size to mitigate potential impacts.

WC-2 Freeboard and Clearance at Bridge Crossings

SCOPE

This standard identifies the soffit clearance and freeboard for bridges carrying both Standard Road Classification roads and Low Volume Roads over waterbodies. The standard also identifies the Freeboard requirement for walkways, bikeways and maintenance roads that are constructed under a bridge.

DESIGN REFERENCES

Canadian Highway Bridge Design Code
MTO Structural Manual
MTO Guide for Preparing Hydrology Reports for Water Crossings

1. HYDROLOGY

This standard shall be read in conjunction with Standard WC-1, Design Flows (Bridges and Culverts), and Standard WC-13, Relief Flow (Bridges and Culverts).

2. HYDRAULICS

This standard shall be read in conjunction with Standard WC-1, Design Flows (Bridges and Culverts), Section 2.1.

3. PHYSICAL CHARACTERISTICS

3.1 Measurement of Freeboard and Clearance

The Freeboard and Clearance for Standard Road Classifications and Low Volume Roads shall be measured as follows (See Figures WC2.1, WC2.2, WC2.3, and WC2.4):

3.1.1 The Desirable Freeboard is measured vertically from the Energy Grade Line elevation for the Design Flow to the edge of the travelled lane.

3.1.2 The Minimum Freeboard is measured vertically from the High Water Level for the Design Flow to the edge of the travelled lane.

3.1.3 The Clearance is measured vertically from the High Water Level for the Design Flow to the lowest point on the soffit.

Figure WC2.1-Freeboard and Clearance for Design Storm

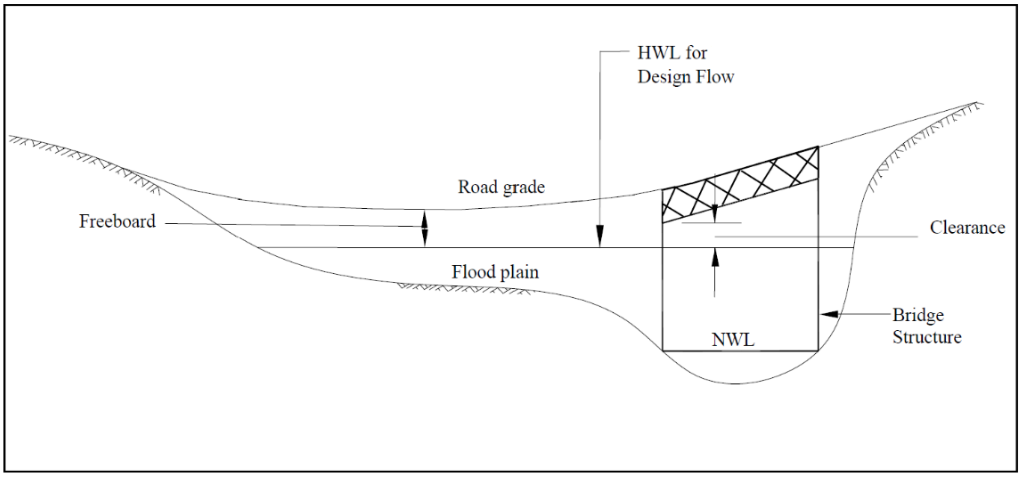


Figure WC2.2-Freeboard and Clearance for Regulatory Flow with Relief Flow

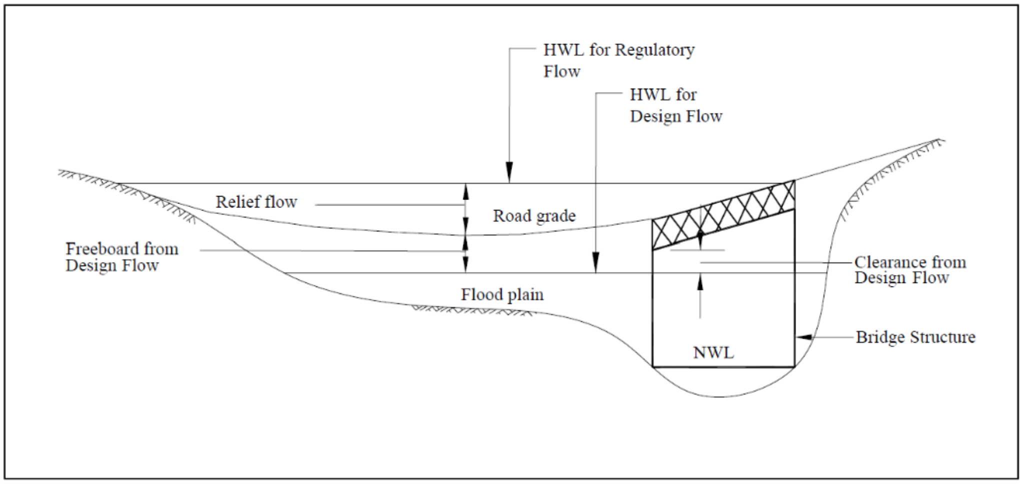


Figure WC 2.3-Freeboard and Clearance for Regulatory Flow and No Relief Flow

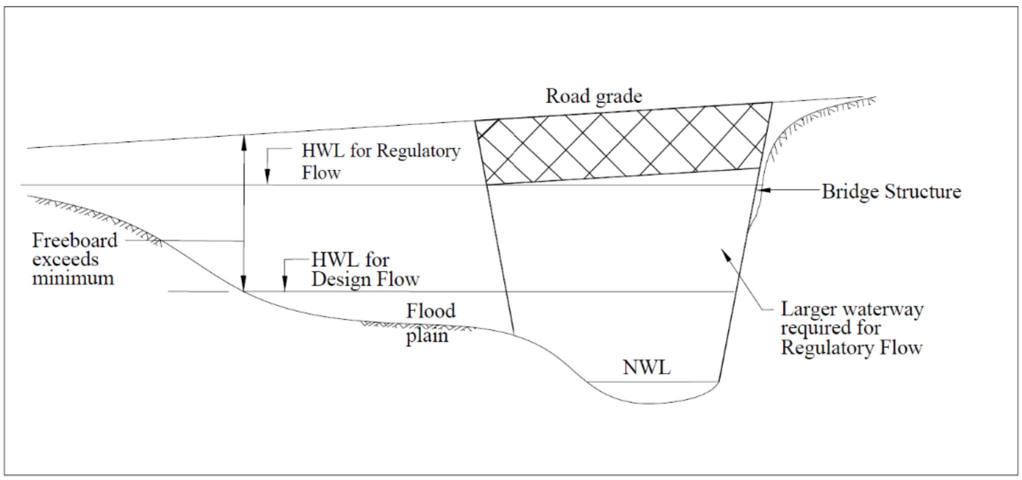
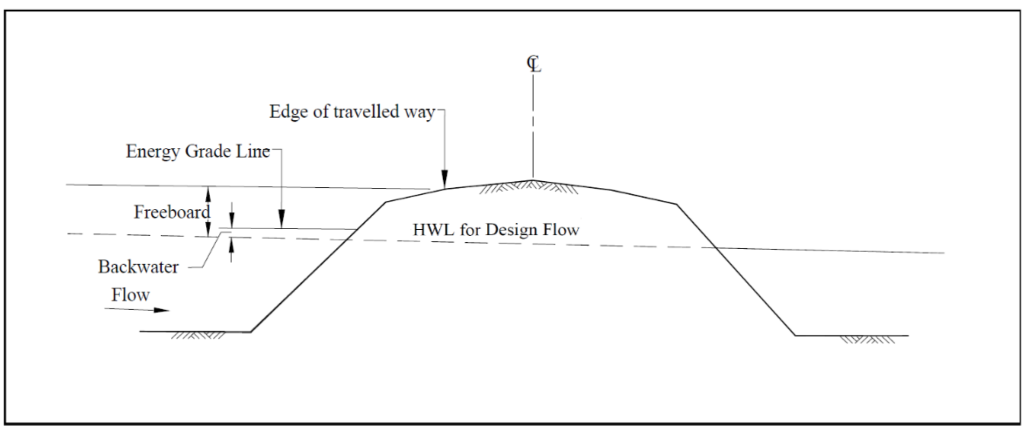


Figure WC2.4-Minimum Freeboard Standard



3.2 Standard Road Classifications

The following values are to be applied to Standard Road Classifications.

3.2.1 The Freeboard at bridge crossings shall be greater than or equal to 1.0 m for freeways, arterials and collectors. The Freeboard at bridge crossings shall be greater than or equal to 0.3 m for local roads. These freeboard requirements also apply to roadways which are parallel to the watercourse under the bridge.

3.2.2 The Clearance for freeways, arterials and collector roads shall be greater than or equal to 1.0 m. The Clearance for local roads shall be greater than or equal to 0.3 m

3.2.3 The water level used to establish the minimum clearance shall be the higher of:
- the High Water Level associated with Design Flow established in Standard WC-1, and;
- the water level caused by ice jams having an AEP (Return Period) equal to that of the Design Storm.

3.2.4 Where the structure is required to convey the Regulatory Flow, clearance shall be based on the Design Flow as defined in Standard WC-1, Section 1.1.1. Zero clearance is required for the Regulatory Flow (see Figure WC 2.3). The freeboard for the Regulatory Flow may be less than the minimum required for the Design Flow

3.2.5 The Water Level generated by the Check Flow shall not exceed the elevation of the edge of the travelled lane for Standard Road Classifications. Refer to Standard WC-1 for Check Flow. The water level associated with the Check Flow is not subject to the Freeboard, Clearance and Flow Depth criteria.

3.2.6 Where walkways, bikeways, or maintenance roads are constructed under a bridge, the elevation of the walkway shall be set 0.5 m above the average summer water level for bridges that have a span up to 6.0 m, and 1.0 m for bridges with a span greater than 6.0 m.

3.3 Low Volume Roads

The following values are to be applied to Low Volume Roads.

3.3.1 There are no Freeboard requirements for Low Volume Roads.

3.3.2 Clearance shall be as identified in the following table.

Table WC2-1: Minimum Clearance – Low Volume Roads

Road Function	Vulnerability	Clearance (m)
Collector and Arterial	High	$\geq$ 1.0
	Low	$\geq$ 0.3
Local	High	$\geq$ 0.3
	Low	$\geq$ 0.0
Resource Access	High	$\geq$ 0.3
	Low	$\geq$ 0.0
Recreation	High	$\geq$ 0.3
	Low	$\geq$ 0.0

3.3.3 The water level used to establish the Clearance shall be the higher of:
- the High Water Level associated with Design Flow established in Standard WC-1, and;
- the water level caused by ice jams having a AEP (Return Period) equal to that of the Design Storm.

3.3.4 The Clearance used to calculate the soffit elevation shall be based on the table in Section 3.3.2 of this standard. Where this is not practical, the soffit elevation may be determined from an existing opening that has proven to perform satisfactorily in the past (with approval). Any deviation from Section 3.3.2 of this standard shall be approved by the Manager of Engineering.

3.4 Navigation Clearance

The vertical and horizontal Navigational Clearances shall be determined in accordance with the Navigable Waters Protection Act.

4. COMMENTARY

- For the application of Desirable Standards and Minimum Standards, refer to "How to use this Document" at the front of the Drainage Design Standards.
- Clearance shall be sufficient to prevent damage to the structure by the action of flowing water, ice floes, or debris. Any deviation from the standard shall be approved by the Manager of Engineering.
- Road design, property, and other requirements may impact clearances.
- Where the minimum Freeboard cannot be met, the process for approving a lower standard is outlined in the MTO online document "Guide for Preparing Hydrology Reports for Water Crossings".
- Increasing the Clearance should be considered for crossings subject to icing, very severe debris, and long spans, especially of light construction. The increase in Clearance would be determined by an analysis of the potential size of material to be passed through the structure.
- The Clearance for a structure having an arched soffit shall be taken from the lowest point on the arch (at top of sidewalls). Site specific conditions should be considered if this is judged as impractical. Any deviation from the standard shall be approved by the Manager of Engineering.

WC-3 Scour and Armouring

SCOPE

This standard identifies the requirements for the protection of bridge and culvert foundations against scour and includes the minimum depths of footings.

DESIGN REFERENCES

MTO Drainage Management Manuals
MTO Structural Manual
Canadian Highway Bridge Design Code

1. HYDROLOGY

This standard shall be read in conjunction with Standard WC-1, Design Flows (Bridges and Culverts).

1.1 Scour Protection – Standard Road Classifications

Scour protection for structure foundations shall be determined on the basis of the Design Flow, and shall be modified, if necessary, to ensure that structural failure will not occur as a result of the Check Flow (see Standard WC-1 (1.1.1)). If abnormal flood conditions (e.g. artificial obstruction such as a Beaver Dam) can occur at the site, a design flood discharge based on the lowest downstream water level likely to coincide with the Design Flow shall be considered.

1.2 Scour Protection – Low Volume Roads

Scour protection for structure foundations shall be determined on the basis of the Design Flow. If abnormal flood conditions (e.g. artificial obstruction such as a Beaver Dam) can occur at the site, a design flood discharge based on the lowest downstream water level likely to coincide with the design flood shall be considered

2. HYDRAULICS

This standard shall be read in conjunction with Standard WC-1 (2.4), Design Flows (Bridges and Culverts).

3. PHYSICAL CHARACTERISTICS

Foundations shall be assumed to include abutment, pier and retaining wall foundations (e.g. foundations on spread footings or piles) as applicable.

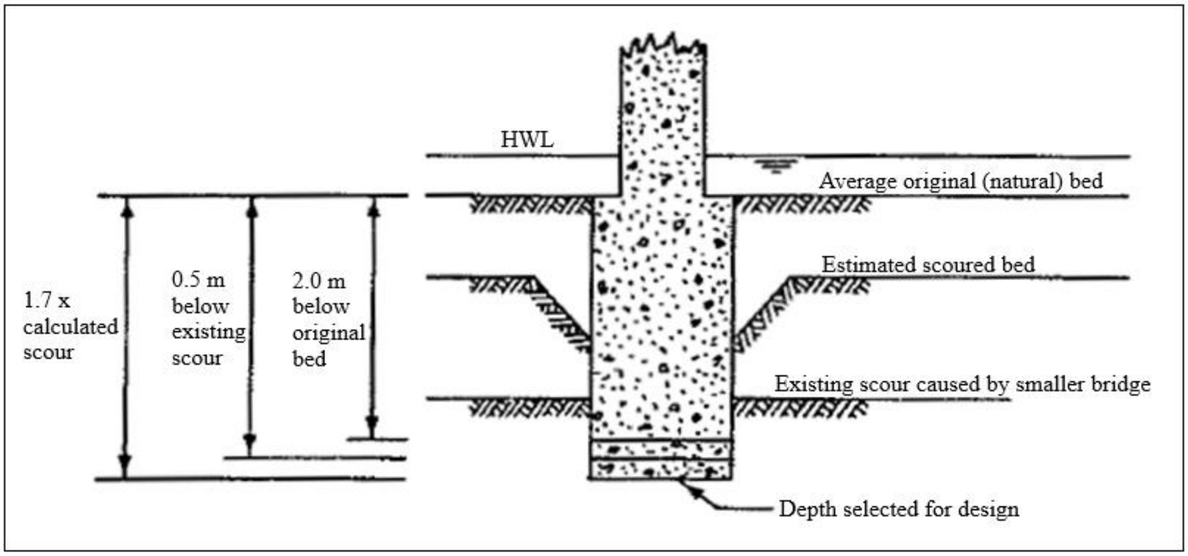
3.1 Scour

3.1.1 Foundations within the channel shall meet the following requirements unless the structure opening has a concrete or steel invert or the footings are protected against undermining by either sheet piling along the inside face and ends of the footings or by other approved means. Spread footings near the channel and without protection are vulnerable to failure and shall meet the following minimum requirements unless the footings are protected by a concrete revetment.

Table WC 3-1: Founding Depths of Footings: Scour Protection (See Figure WC 3.1)

Component		Measure
Minimum depth of spreadfootings that may be exposed to stream flow shall be determined by the greatest of:	a) At Abutments except arches	1.50 m below original bed
	b) At Piers and Arch Abutments	2.00 m below original bed
	c) Calculated Total Scour	At least 1.7 times the estimated scour depth below original bed
	d) Minimum below past scour	At least 0.50 m below level ofexisting or past scour
Bottom of footing elevation of abutments and retaining walls supported on piles exposed to flowing water shall be a minimum of:		1.0m below ultimate streambed elevation

Figure WC 3.1 – Spread Footing Depth Selection at Pier (Not to scale)



Notes:

- Spread footings may be founded on scour-resistant, durable bedrock at a higher elevation provided that the depth is sufficient to ensure that they remain unaffected by scour, freezing, weathering, degradation or artificial deepening.
- For temporary piers, abutments and retaining walls constructed of gabions or timber cribs, the depths given in a), b) and d) shall be reduced by half and the factor given in c) shall be reduced from 1.7 to 1.3.
- On degrading channels that are not stabilized, the footing depth given in c) shall not be less than the expected amount of degradation plus the estimated depth of scour.
- On channels expected to be artificially deepened, the footing depths a) and b) shall be measured below the expected streambed elevation after deepening.
- Spread footings shall not be founded at a depth less than that given by Section 3.1.1 of this standard unless; the structure opening has a concrete or steel invert, or the footings are protected against undermining by either sheet piling along the inside face and ends of the footings, or by other approved means. Sheet piling shall have sufficient stiffness and strength to maintain the bearing capacity of the soil within the sheet piling, with the soil outside the sheet piling at the ultimate bed elevation.

3.1.2 Spread footings adjacent to the stream channel shall not be founded at an elevation higher than the streambed on material other than bedrock or fill, unless protected by a concrete revetment.

3.1.3 Concrete and steel inverts and revetments that are required to stabilize a channel at a structure shall be provided with cutoff walls of sufficient depth and strength to protect against stream erosion and associated undermining. Cutoff walls shall be integral with or securely attached to the invert or revetment.

3.1.4 Where a paved invert or revetment is required to stabilize a degrading streambed, the following shall be provided:

- Cutoff walls – The downstream cutoff wall shall be designed to resist the maximum depth of degradation likely to occur during the design life of the structure or up to the time of scheduled streambed maintenance.
- An apron, energy dissipater, or other device to control erosion caused by the discharge from the structure.
- If the invert is lower than the adjacent upstream bed, a sill, weir, or other effective control at the inlet.
- Toe protection shall be provided to prevent undermining of the slope revetments. Geotextile fabric, a graded granular filter blanket, or other approved material shall be provided where necessary to prevent loss of underlying material.
- Unless otherwise approved, a concrete revetment specified to protect structure footings shall comprise concrete paving, reinforced, tied, or interconnected in such a way as to ensure that the underlying material remains protected for the design life of the structure.

3.2 Armouring - Standard Road Classifications

3.2.1 Rip Rap Stones for protective aprons are designed for a velocity of 1.5 times the average velocity of the Design Flow. The thickness of the apron shall be not less than 1.5 times median stone size.

3.3 Armouring - Low Volume Roads

3.3.1 Scour and erosion protection is required only for susceptible structures. The stone sizes for scour and erosion protection shall be as follows:

Table WC 3-2: Stone Sizes For Scour And Erosion Protection – Low Volume Roads

Velocity (m/s)	< 2.0	< 2.6	< 3.0	< 3.5	< 4.0	< 4.7	< 5.2
Nominal Stone Size(1) (mm)	100	200	300	400	500	800	1000

Notes

1) Maximum stone size to be 1.5 times the nominal stone size. 80% of stones (by mass) must have a diameter of at least 60% of nominal stone size.

4. COMMENTARY

- Scour can spread upstream and downstream. In order to control the spread of scour, it may be necessary to look at scour susceptibility upstream and downstream of the structure.
- Substructures on piles requirement may be waived if the footings are protected against undermining by sheet piling along the inside face and ends of the footing as per Section 3.1.1 of this Standard, or by other approved means.
- It is necessary to consider both sub-critical and super-critical flow (whichever may occur) when assessing scour.

- Penetration and structural strength of piles shall be sufficient to ensure their stability with the streambed at its ultimate bed elevation with scour.
- Local scour may be substantially increased by ice or debris accumulations around a pier. The recommendations account for these conditions.
- Non-structural armouring for bridges is intended to supplement the structural protection. This type of protection is generally less permanent than the structural type, since it is more susceptible to disturbance, deterioration or failure. Armouring is permitted to reduce local scour. Reliance on armouring to reduce general scour is not permitted.
- Where necessary, embankments shall be protected against erosion to prevent damage to the structure, roadway, property affected by the crossing or impacts to the environment.
- Streambanks shall be protected against erosion to prevent damage to the structure, roadway, property affected by the crossing or impacts to the environment.
- If armouring is required around a pier, the protection material should be placed to a depth equal to the estimated pier scour depth.
- Large bridges – Special consideration shall be given to increasing depths of spread footings for unusually high or long bridges.

WC-4 Bridge Deck Drainage

SCOPE

This standard identifies the Maximum Allowable Spread Distance onto the travel lanes of highway bridges. It also defines the Maximum Depth of flow at the edge of the travel lanes.

This standard shall be read in conjunction with Standard WC-5: Bridge Deck Drains.

DESIGN REFERENCES

Canadian Highway Bridge Design Code

1. HYDROLOGY

A Design Storm with a minimum 10% AEP (10-year Return Period) shall be used to calculate Flow Spread.

2. HYDRAULICS

There are no hydraulic standards applicable to bridge decks.

3. PHYSICAL CHARACTERISTICS

Physical characteristics of deck drains are described in Standard WC-5.

3.1 Maximum Allowable Spread

3.1.1 Freeways

- As a Desirable Standard, the Maximum Lateral Spread Distance shall be zero, such that the full lane width adjacent to a concrete barrier or curb remains clear of any flooding.
- As a Minimum Standard, the Maximum Lateral Spread Distance shall be such that a minimum of 2.5 metres of the lane width adjacent to a concrete barrier or curb remains clear of any flooding.
- As a Minimum Standard, the Maximum Depth of flooding at the lowest edge of the travel lanes shall not exceed 25 mm as shown in Figure WC 4.1.

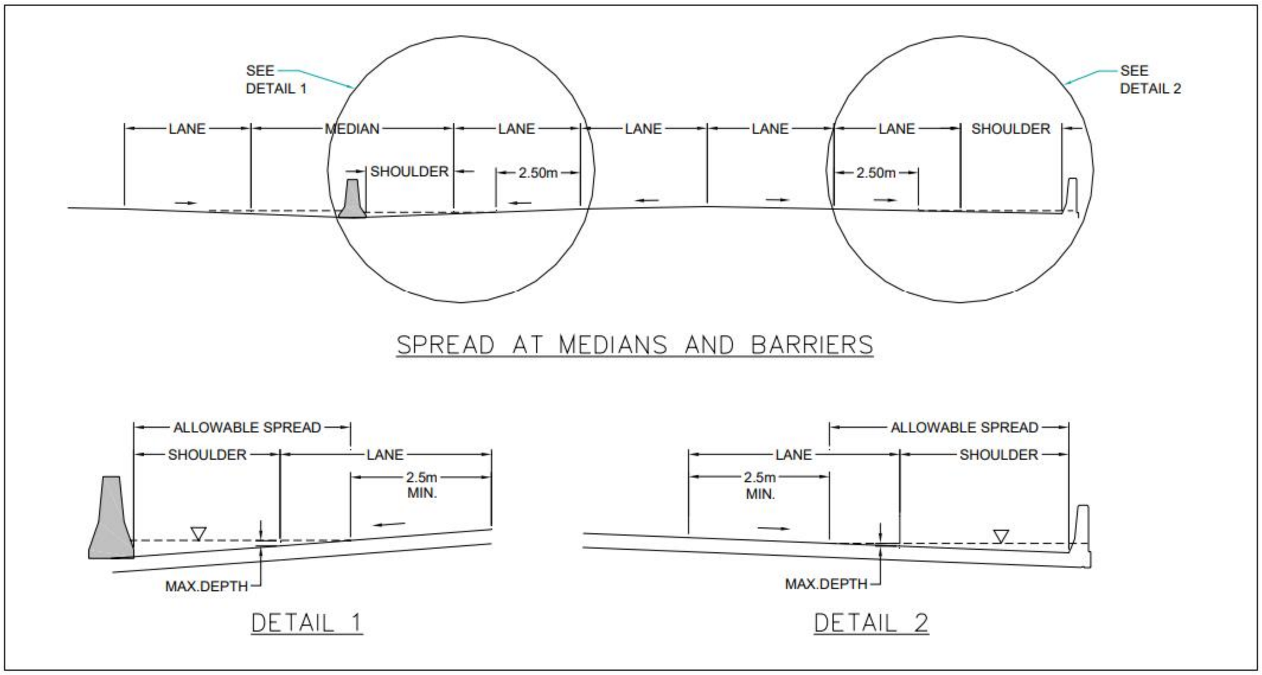
3.1.2 Collector, Arterial and Local Roads

The Maximum Lateral Spread Distance shall be such that a minimum of 2.5 m of the lane adjacent to median barrier or curb remains clear of any flooding.

3.1.3 Geometry

- Minimum longitudinal road grade shall be 0.5 percent except where vertical curves preclude this.
- Minimum crossfall shall be 2 percent except where there is a superelevation transition.
- Sag vertical curves shall not be located on bridges except where unavoidable.
- All sidewalks, safety curbs, tops of barriers, raised medians, or other deck surfaces that are raised above the roadway and are wider than 300 mm shall have a minimum transverse crossfall of 2 percent to direct surface runoff inwards from the bridge fascia or away from median longitudinal expansion joints.

Figure WC 4.1 – Spread at Medians and Barriers



4. COMMENTARY

- For the application of Desirable Standards and Minimum Standards, refer to "How to use this Document" at the front of the Drainage Design Standards.
- Deck Drains shall only be provided where required to ensure that the Maximum Allowable Spread standard is adhered to.
- To meet the Maximum Allowable Spread requirements, the use of a modified gutter section (e.g. wider shoulders, steeper shoulders) should be considered if deck drains are required with a conventional gutter.
- This standard is intended to apply to bridge decks. Flow Spread for roadway cross-sections is defined in Standard SD-3, Flow Spread on to Travel Lanes.
- Bridge Deck Surface Drainage: For bridges on grades or sag curves, the roadway surface runoff shall be intercepted by catch basins or other means located on the approaches to minimize flow onto the bridge deck.
- Wearing Surface Subdrainage: Provision shall be made for the release of pressure between waterproofing membranes and asphaltic concrete wearing surfaces. Drains shall be as per Ontario Provincial Standards.
- Direct discharge from deck drains to waterbodies should be avoided.
- Deck drains shall be avoided where possible in order to avoid deck structural deterioration which commonly occurs where deck drains are used.

WC-5 Bridge Deck Drains

SCOPE

This standard identifies the requirements for drains in bridge decks.

DESIGN REFERENCES

Canadian Highway Bridge Design Code
MTO Structural Manuals

1. HYDROLOGY

This standard shall be read in conjunction with Standard WC-4, Bridge Deck Drainage

2. HYDRAULICS

The hydraulic capacity of the deck drains shall be designed to meet the Standard WC-4 Bridge Deck Drainage.

3. PHYSICAL CHARACTERISTICS

3.1 Location and Configuration

The location and configuration of deck drains and downpipes shall be such that water will not be discharged onto railway property, pavements, sidewalks, unprotected embankment slopes, pedestrian paths or waterways.

3.2 Splash Pads

Concrete or rip-rap splash pads shall be provided on embankments below deck drain outlets. Splash pads shall be designed to ensure that water is directed toward the waterbody and the embankment shall be protected such that no erosion will occur.

3.3 Drainage Inlets

Drainage inlets at the deck surface shall have grates with a clear spacing between bars from 40mm to 75mm. For roads on which cyclists are permitted, grate bars shall be at an angle to the roadway centreline of between 45° and 90°. Drainage inlets shall be as per Ontario Provincial Standards.

3.4 Drain Inlet Grate

The top surface of a drain inlet grate shall be a minimum of 15mm and a maximum of 25mm below the plane of the wearing surface.

3.5 Wearing Surface

The wearing surface around the drain inlet shall be sloped toward it from the general plane of the wearing surface at a slope of approximately 1 in 20.

3.6 Down-spouts and Downpipe Size and Material

Downspouts and downpipes shall be a minimum diameter or width of 200mm and shall be rigid and be made of a corrosion resistant material.

3.7 Pipe Angle

If water must be moved laterally, pipes shall be run as near to vertical as possible. Changes in direction shall be no greater than 45°.

3.8 Downspout Location

Downspouts will be located so that water is not discharged or blown against any structural component, assuming that water will spread from the outlet at 45o from the vertical.

3.9 Downspout Projection

Downspouts shall project a minimum 150mm below any adjacent component except where prohibited by minimum vertical clearance requirements.

3.10 Inlet Size

To prevent local ponding only, 200mm diameter inlets may be used instead of a Deck Drain. Inlets shall be as per Ontario Provincial Standards.

3.11 Roadway Surface Runoff

For bridges on grades or sag curves, runoff from the roadway surface shall be intercepted by catch basins or other means located on the approaches to prevent flow onto the bridge deck.

3.12 Drip Grooves

Continuous drip grooves shall be provided along the soffit on both sides of all concrete decks, including on each side of the joint between abutting bridges, even if the joint is sealed. Inlets shall be as per Ontario Provincial Standards.

3.13 Deck Drain Modification

The modification of round vertical deck drains, scupper deck drains and inclined deck drains shall be as per Ontario Provincial Standards.

3.14 Drainage Outlets

Drainage outlets in round void and trapezoidal void forms shall be as per Ontario Provincial Standards.

4. COMMENTARY

- Deck drains shall be avoided where possible in order to avoid deck structural deterioration which commonly occurs where deck drains are used.
- Direct discharge from deck drains to waterbodies should be avoided.
- Vertical clearance for Navigable Waterways shall be checked such that no drain shall extend into the navigable clearance.
- The probable performance of drainage laterals (angles etc.) during freezing temperatures shall be checked.
- Aesthetic requirements shall be considered in accordance with the MTO Report, “Aesthetic Guidelines for Bridges”.

WC-6 Abutment, Culvert and Retaining Wall Drainage

SCOPE

This standard identifies the requirements for Perforated Subdrains and Wall Drains through abutments, retaining walls (including Retained Soil Systems) and culverts for the release of hydrostatic pressure from the surrounding ground.

DESIGN REFERENCES

MTO Structural Manual

1. HYDROLOGY

This standard shall be read in conjunction with Standard WC-1, Design Flows (Bridges and Culverts).

2. HYDRAULICS

There are no hydraulic standards applicable to abutment, culvert and draining wall drainage.

3. PHYSICAL CHARACTERISTICS

Drainage of the granular fill behind retaining walls and abutments shall be as provided in the following standards:

3.1 Drainage for Perched Structures

For perched structures, 150 mm diameter Perforated Subdrains behind abutments and retaining walls and within granular limits shall be provided. Perforated sleeves for wingwalls shall be as per Ontario Provincial Standards.

3.2 Drainage for Structures Constructed in Cuts

For cut situations, 150mm Perforated Subdrains behind abutments and retaining walls and within granular limits, and Wall Drains shall be provided. Perforated sleeves for wingwalls shall be as per Ontario Provincial Standards.

3.3 Wall Drains

3.3.1 Wall Drains shall be shown on the drawings by reference to Ontario Provincial Standards or if this is not appropriate, they shall be shown as 75 mm diameter non-metallic wall drains at 3000 mm centre-to-centre. The elevation shall be determined by the Design Engineer.

3.3.2 Generally, elevations should be set as low as possible, but at least 300 mm above the level of the ground or normal water level in front of the wall. A pocket of "open graded 19.0 mm clear stone in accordance with Ontario Provincial Standards" should always be shown 0.05 m^3 in volume around the inlet to each drain.

3.4 Granular Backfill Requirements

Minimum granular backfill requirements for abutments and retaining walls shall be per Ontario Provincial Standards.

3.5 Rock Backfill Requirements

Minimum rock backfill requirements for abutments shall be per Ontario Provincial Standards.

4. COMMENTARY

- Where aquifer interference is likely, the recommendations of a hydrogeological report shall be incorporated into the design of wall drainage.
- Where there is a sidewalk in front of an abutment or retaining wall, provision shall be made to prevent the accumulation of water/ice on the sidewalk. Otherwise, drainage away from the sidewalk shall be provided by some other means.
- Drainage requirements for Retained Soils Systems are provided by the manufacturer.

WC-7 Culvert Crossings

SCOPE

This standard identifies the minimum Freeboard, the minimum Clearance, and the maximum Flood Depth at culvert crossings. The standard also identifies the Freeboard requirement for walkways, bikeways and maintenance roads that are constructed within a culvert.

DESIGN REFERENCES

MTO Drainage Management Manuals
Canadian Highway Bridge Design Code

1. HYDROLOGY

1.1 Culvert crossings of Natural Watercourses

For culvert water crossings of Natural Watercourses under Freeways, Arterial Roads, Collector Roads and Local Roads, this standard shall be read in conjunction with Standard WC-1 (Section 1.0)), Design Flows Natural Watercourse Crossings Bridges and Culverts).

1.2 Culvert crossings for surface drainage of the highway right-of-way and Local External Catchment Areas only

For culvert crossings of surface water runoff from the highway right-of-way and Local External Catchment Areas only this standard shall be read in conjunction with Standard SD-1 Design Flows for Surface Drainage and Standard SD-9 Roadside Ditches (Conveyance Only). The culverts may cross the highway, adjacent roadways, interchange ramps or private entrances such as driveways and maintenance accesses.

1.2.1 Design Flow for Culverts under Private Entrances

Culverts under private entrances such as driveways and maintenance accesses shall be designed for the same Design Flow as the Roadside Ditch (SD-9) leading up to the entrance of the culvert. As a minimum they shall be designed to convey the Minor System Design Flow as defined in Standard SD-1, Design Flows for Surface Drainage.

1.2.2 Design Flow for Culverts under Highways, Highway Ramps, and adjacent Roadways.

Culverts under highways, highway ramps and adjacent roadways shall be designed to convey the Minor System Design Flow and the Major System Design Flow as defined in Standard SD-1, Design Flows for Surface Drainage.

For Fish Passage this standard shall be read in conjunction with Standard WC-12 (Section 1.1 and 1.2).

2. HYDRAULICS

2.1 Culvert water crossings of Natural Watercourses

For culvert water crossings of Natural Watercourses under Freeways, Arterial Roads, Collector Roads and Local Roads, this standard shall be read in conjunction with Standard WC-1 (Section 2.1 to 2.4), Design Flow (Bridges and Culverts).

2.2 Culvert crossings for surface drainage of the highway right-of-way and Local External Catchment Areas only

For culvert water crossings of surface water runoff from the highway right-of-way and Local External Catchment Areas only the conveyance capacity of the culvert shall be set to match the hydraulic design and physical characteristics of the Roadside Ditch located immediately upstream of the culvert, as prescribed in Standard SD-9 Roadside Ditches.

3. PHYSICAL CHARACTERISTICS

3.1 Measurement of Freeboard

The required culvert Freeboard is as follows:

3.1.1. The Desirable Freeboard is measured vertically from the Energy Grade Line elevation for the Design Flow to the edge of the travelled lane.

3.1.2. The Minimum Freeboard is measured vertically from the High Water Level for the Design Flow to edge of the travelled lane.

3.2 Freeboard for Culvert crossings of Natural Watercourses

The following is the Freeboard design standard for culverts that cross under roadways:

Table WC 7-1: Freeboard for Culvert Water Crossings of Natural Watercourses

Road Type	Freeboard
Freeways, arterials, collectors	≥ 1.0 m
Highway Ramps	≥ 1.0 m
Local Roads including Private Entrances	≥ 0.3 m

3.3 Freeboard for Culvert crossings for surface drainage of the highway right-of-way and Local External Catchment Areas only

The conveyance capacity of the culvert shall be set to match the hydraulic design and physical characteristics of the Roadside Ditch located immediately upstream of the culvert, as prescribed in Standard SD-9 Roadside Ditches.

3.3.1 The minimum freeboard to the top of Sub-Grade upstream of the culvert shall be 0.3 m for the Minor System Design Flow.

3.3.2 There is no minimum freeboard associated with the Major System Design Flow.

3.4 Freeboard for Walkways, Bikeways and Maintenance Roads

Where walkways, bikeways, or maintenance roads are constructed within a culvert, the elevation of the walkway shall be set 0.3 m above the average summer water level for culverts that have a span up to 3.0 m, 0.5 m for culverts with a span up to 6.0 m, and 1.0 m for culverts with a span greater than 6.0 m.

3.5 Clearance (Open-Footing Culverts Only)

The following is the Clearance design standard for Open-Footing Culverts with erodable bottom for all road crossings:

3.5.1 The minimum Clearance for culverts with a straight soffit (rectangular cross section) shall be 0.3 m.

3.5.2 The minimum Clearance for culverts with irregular cross sections (other than rectangular cross sections) such as High Span Arch, Low Span Arch and Concrete Span Open Footing Culverts shall be measured 0.3 m below the Effective Rise of the culvert, where:

ER = Effective Rise of the culvert = TAFA/ES

TAFA = Total available flow area of the structure in square metres; and

ES = Effective Span of the equivalent rectangular culvert in metres (see examples below).

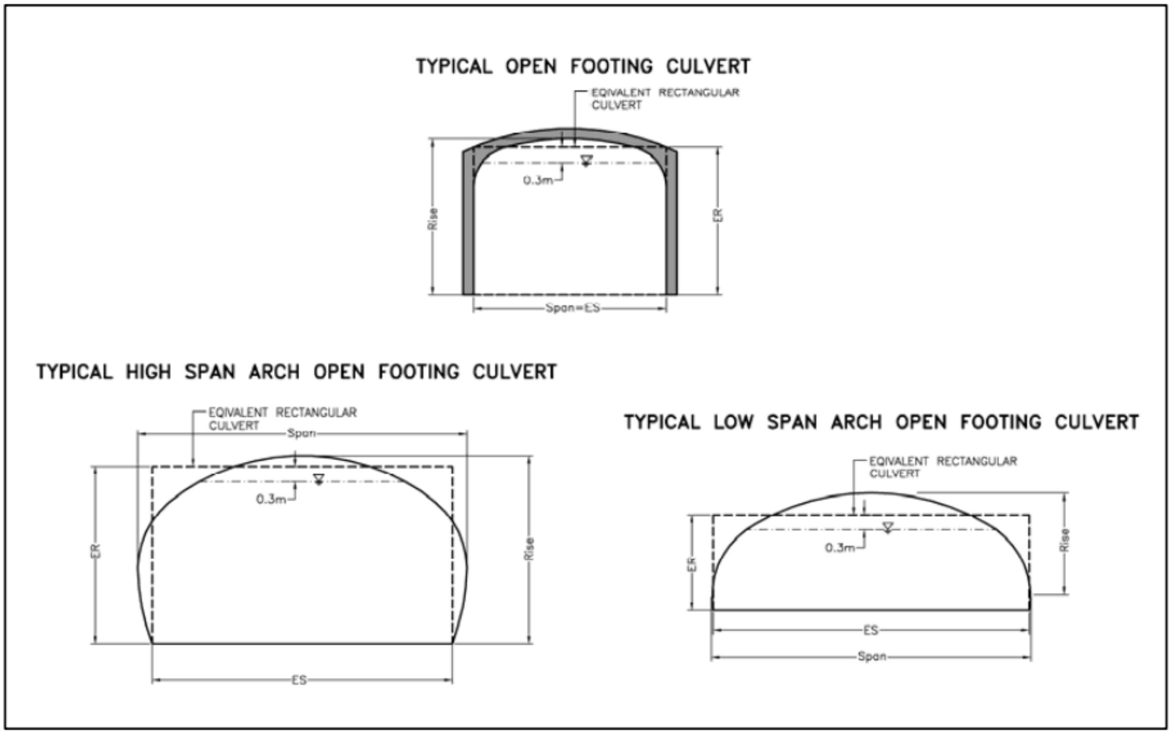
Note:

The cross sectional area of the actual culvert = the cross sectional area of the equivalent rectangular culvert

and

The cross sectional area of the actual culvert above the clearance elevation = 0.3 m x the span of the equivalent rectangular culvert

Figure WC 7.1 – Clearance for Non-Rectangular Culverts



3.5 Flood Depths at Culverts

The following is the design standard for Flood Depth at the upstream face of a culvert. It is expressed as a ratio of the Flood Depth at the upstream face of the culvert to the diameter or rise of the culvert (HW/D). This standard applies to Closed-Footing Culverts and Open-Footing Culverts with non-erodable bottom.

Table WC 7-2: Flood Depth at Culvert Crossings

Watercourse	Design Flow	HW/D Ratio
Natural Watercourse	See Standard WC-1	Culverts with diameter or rise < 3.0 m HW/D ≤ 1.5 Culverts with diameter or rise 3.0 to 4.5 mHW ≤ 4.5 m Culverts with diameter or rise > 4.5 m HW/D ≤ 1.0
Surface drainage of the highway right-of-way and Local External Catchment Areas only	See Clause 1.2	

3.6 Water Level Generated By the Check Flow

The Water Level generated by the Check Flow shall not exceed the elevation of the edge of the travelled lane for Freeways, Arterial and Collector Roads. Refer to WC-1 for Check Flow for Natural Watercourse Crossings. The water level associated with the Check Flow is not subject to the Freeboard, Clearance and Flow Depth criteria.

For surface water runoff culverts see SD-9 Roadside Ditches (2.2 Containment of Flow in Ditch).

4. COMMENTARY

- This standard requires that culverts in Roadside Surface Water runoff Ditches carry a minimum of the Minor System Design Flow and adhere to the hydraulic and physical requirements of Standard SD-9 (Roadside Ditches).
- Since lateral ditch crossings serving adjacent roadways are often designed to a lower standard than highway crossings, additional hydraulic analyses should be carried out to ensure that the major system component of the highway drainage is not adversely impacted.
- There are situations where downstream drainage characteristics will affect the design of the ditch system.
- The flood depth used as the basis for backwater and scour computations is the natural unobstructed depth corresponding to the design discharge under ice-free conditions. The designer should assess the need for oversizing the structure where significant debris or ice problems have been identified. Culverts should be designed to accommodate debris, or proper provisions should be made for debris maintenance.
- The High Water Level used for establishing the minimum road grade should include the backwater caused by the culvert.
- For conditions with ice or debris refer to standard WC-11.
- The designer shall ensure that potential increase in the flood elevation upstream of the structure is maintained within allowable limits, in accordance with Standard WC-1, Design Flow (Bridges and Culverts).
- There is no Clearance requirement for Closed-Footing Culverts and Open-Footing Culverts with non-erodable bottom.
- For Open-Footing Culverts with erodable bottoms the more restrictive of the freeboard standard (3.2) and the Clearance standard (3.3) shall be used.
- Wherever possible, the designer should avoid the creation of pressure flow, particularly in larger span culverts.
- For Freeboard, Clearance and Flood Depth the designer should address requirements from other agencies (e.g. Navigational Clearance requirements, fish and wildlife passage, a Dam Operating Plan when crossing regulated water bodies).
- Multiple barrel culverts should be avoided when: the approach flow has a high velocity, fish passage is required, a high potential of debris problems exist, and a meander bend is present immediately upstream.
- It may not be possible to achieve the required Freeboard and/or Clearance in some retrofit applications. Where the Freeboard and/or Clearance standard cannot be met the designer shall justify deviation from the standard, and must consider factors such as buoyancy and cavitation. Where potential deviation from the standard exists, the Designer must follow the procedures as outlined in MTO Guide for Preparing Hydrology Reports for Water Crossings.
- Where a walkway, bikeway or maintenance access road is to be incorporated into the design of a culvert, the local municipality or Conservation Authority should be contacted.

WC-8 Minimum Culvert Size

SCOPE

This standard identifies the Minimum Culvert Sizes based on maintenance considerations.

DESIGN REFERENCES

MTO Drainage Management Manuals

1. HYDROLOGY

There is no hydrology standard applicable to minimum culvert size.

2. HYDRAULICS

This standard shall be read in conjunction with other standards that may dictate culvert size. These include Standards WC-1, Design Flows (Bridges and Culverts), WC-3, Scour and Armouring, WC-13, Relief Flow (Bridges and Culverts), WC-12, Fish Passage through Culverts, and SD –1 Design Flows for Surface Drainage Systems.

3. PHYSICAL CHARACTERISTICS

3.1 Minimum Culvert Sizes

The standards for Minimum Culvert Sizes are dictated by maintenance considerations, which require a sufficient height to access the barrel for cleaning and repairs. The Minimum Culvert Size Standards are as follows:

Table WC 8-1: Minimum Culvert Sizes

Road Type	Minimum Culvert Size
Freeways, Urban Arterials, and Highway Ramps	800 mm minimum diameter for circular culverts 800 mm minimum rise for elliptical or arch culverts 900 mm minimum rise for box culverts
Rural Arterials, Collector Roads	600 mm minimum diameter for culverts 600 mm minimum rise for elliptical or arch culverts 900 mm minimum rise for box culverts
Local Roads and Private Entrances	500 mm minimum diameter or culvert rise if length > 10 m 400 mm minimum diameter or culvert rise if length ≤ 10 m

4. COMMENTARY

- Culvert crossings of Natural Watercourses shall be designed to satisfy the following requirements.
  - to convey the Design Flow (Refer to Standard WC-1, Design Flows (Bridges and Culverts);
  - to account for increased sedimentation inside the barrel and ice built up;
  - to allow for fish passage (Refer to Standard WC-12, Fish Passage through Culverts);
  - to account for fluvial geomorphology characteristics;
  - to account for other factors such as wildlife passage, navigation, and trail access; and
  - to countersink the culvert and install substrate material to restore fisheries habitat.

- Open-Footing culverts may be required to satisfy fish passage and agency requirements (e.g. Conservation Authorities, Department of Fisheries and Oceans).
- In some cases the minimum standard may need to be increased to facilitate maintenance, fish passage, other site specific conditions, or situations where there is substantial sediment load.
- In cases where embedment is required the minimum will need to be increased to ensure that the resulting opening meets the minimum standard.

WC-9 End Treatments and Cutoff Walls for Culverts

SCOPE

This standard defines requirements associated with Culvert End Treatments including the use of Safety End Treatments, minimum depth of embedment of Cutoff Walls and the minimum height of concrete Culvert Headwalls.

DESIGN REFERENCES

MTO Drainage Management Manual
Canadian Highway Bridge Design Code

1. HYDROLOGY

This standard shall be read in conjunction with Standard WC-1, Design Flows (Bridges and Culverts) and SD –1 Design Flows for Surface Drainage Systems.

2. HYDRAULICS

2.1 Safety End Treatment

Where Safety End Treatments are used their impacts on culvert capacity shall be accounted for in establishing culvert sizes.

3. PHYSICAL CHARACTERISTICS

3.1 Safety End Treatments

Safety End Treatments may be used for culverts that convey highway or localized runoff but shall not be used for natural watercourses that cross the highway.

3.2 Minimum Depth of Embedment for Concrete Cutoff Walls

Concrete Cutoff Walls shall extend to the lower of the following:

- at least 0.5 m below the estimated limit of scour elevation, or
- the elevation determined by the minimum depth below culvert invert specified by Ontario Provincial Standards or by the Concrete Culvert Design and Detailing Manual.

Note: The minimum depth requirements shall not apply if highly scour-resistant material is encountered at a higher elevation, or if the End Treatment is intended primarily as a counterweight against buoyancy forces acting on a metal culvert.

3.3 Minimum Height of Concrete Headwalls

Full headwalls shall extend at least 0.3 m above the High Water Level (HWL) and both full and partial headwalls shall be long enough to keep the fill out of the waterway. Headwalls on skewed culverts shall be placed normal to the direction of flow.

4. COMMENTARY

- Scour protection at the culvert inlets and outlets should be provided to minimize erosion. The selection of an appropriate Culvert End Treatment is driven by design aspects relating to structural, hydraulic and fish passage considerations:

- Structural factors (e.g. use of concrete collars on large diameter CSP culverts).
- Hydraulic factors (e.g. mitered ends vs. projecting ends lower entrance losses).
- Fish passage and cost factors, (e.g. using headwalls to reduce culvert length).

- The depth of embedment of concrete Cutoff Walls and headwalls on fisheries watercourses should be assessed in terms of impacts on fisheries habitat and fish passage requirements.
- The construction of an Outlet Pool at the culvert outfall shall be investigated where there is a risk of future outlet erosion.
- Where fish habitat has been identified additional design requirements may apply.

WC-10 Culvert Extensions

SCOPE

This standard identifies the desirable Slope, Material, and Alignment for designing culvert extensions.

DESIGN REFERENCES

Design Reference not available.

1. HYDROLOGY

This standard shall be read in conjunction with Standard WC-1, Design Flows (Bridges and Culverts) and SD –1 Design Flows for Surface Drainage Systems.

2. HYDRAULICS

This standard shall be read in conjunction with Standard WC-1 and SD-1. In particular, hydraulic impacts of Culvert Extensions must be examined to ensure no upstream impacts.

3. PHYSICAL CHARACTERISTICS

Extensions to existing culverts shall be designed to prevent internal blockages caused by changes in direction, changes in the shape of the cross-section, or changes in the number of openings or cells. Culvert Extensions shall be designed as follows.

It is desirable that: the slope of the Culvert Extension not be less than the slope of the original structure, Culvert Extensions be of the same material as the original structure, and the alignment and shape of the original structure be maintained.

4. COMMENTARY

- As part of foundation design, subsurface investigation may be required at each culvert location.
- Culverts should only be extended if the estimated material service life (EMSL) can meet or exceed the Design Service Life (DSL) for the crossing.
- The connection between existing culverts and the extensions shall be a Rigid Connection designed and installed to minimize transition losses and to prevent separation or debris deposition at the joint.
- Where the original culvert material is no longer available alternative materials may be used.
- Site conditions may require that extensions have different slopes and alignments than the existing culvert.
- Culvert extensions on fisheries watercourses should be assessed in terms of fisheries habitat and fish passage requirements (e.g. substrate requirements).
- When extending culverts the designer should account for design service life for both the existing culvert and the extension.

WC-11 Icing and Debris

SCOPE

This standard identifies the requirements for the accommodation of ice and debris build-up at closed bottom culverts where winter ice or debris conditions have been identified as a problem.

DESIGN REFERENCES

Not Applicable

1. HYDROLOGY

This standard shall be read in conjunction with Standard WC-1, Design Flows (Bridges and Culverts) and Standard WC-2, Freeboard and Clearance at Bridge Crossings and SD –1 Design Flows for Surface Drainage Systems.

2. HYDRAULICS

There are no hydraulic standards applicable to Icing and Debris.

3. PHYSICAL CHARACTERISTICS

Culvert soffit clearance shall be 0.3 m above the maximum observed debris build-up or ice build-up plus Winter Flow.

4. COMMENTARY

- The timing of occurrence of debris and ice in relation to the occurrence of floods can have a significant effect on the ice build-up or debris magnitude.
- Debris control is a significant issue where experience or physical evidence indicates that the watercourse will transport a heavy volume of controllable debris, where culverts are located in mountainous or steep regions, where culverts are under high fills, and where clean out access is limited.
- The use of a bridge may be required in cases where a culvert cannot be designed to accommodate the ice or debris.
- External dissipaters may be used to control ice and debris.

WC-12 Fish Passage through Culverts

SCOPE

This standard identifies requirements to facilitate Fish Passage through Culverts on fish bearing waterbodies. The standard defines the width of the culvert, embedment depth, substrate materials to be used, and shape of the low flow channel within the culvert.

DESIGN REFERENCES

MTO Drainage Management Manuals
MTO Environmental Guides for Fisheries

1. HYDROLOGY

The Hydrology for Fish Passage provided in this standard shall be read in conjunction with the Hydrology for Flow Conveyance provided in standard WC-1, Design Flows (Bridges and Culverts).

1.1. Fish Passage Design Flow

A Design Flow with a 50% AEP (2-year return period) shall be used for calculating fish passage requirements. Generally, the 50% AEP Design Flow is representative of Bankfull Flow conditions. Based on the type of resident fish species, the DFO may specify an alternative for the Fish Passage Design Flow.

1.2 Design Flow for Sizing Culvert Substrate

The design flow for sizing of Culvert Substrate is defined in standard WC-1 (1.1), Check Flow for Scour.

2. HYDRAULICS

The hydraulic requirements for Fish Passage provided in this standard shall be read in conjunction with the hydraulic requirements for flow conveyance provided in other standards.

2.1 Maximum Velocity for Fish Passage

The maximum velocity in the culvert for Fish Passage Design Flow shall not exceed the natural channel velocity, unless otherwise agreed to by the DFO.

2.2 Minimum Flow Depth for Fish Passage

The depth of water in a culvert shall be consistent with the average depth immediately upstream and downstream of the culvert.

2.3 Changes in Water Levels

There shall be no sudden drops in the water surface exceeding 0.15 m in or adjacent to the culvert for the Fish Passage Design Flow.

3. PHYSICAL CHARACTERISTICS

The Physical Characteristics for Fish Passage provided in this standard shall be read in conjunction with the Physical Characteristics requirements for flow conveyance in standards WC-7, WC-8, WC-9, WC-10, WC-11 and WC-13.

3.1 Minimum Width of Culvert Relative to Channel Width

The minimum culvert width shall be sufficient to maintain the natural bankfull channel function (width, depth, and velocity) for the Fish Passage Design Flow.

3.2 Minimum Size and Depth of Substrate

3.2.1 The minimum Mean Diameter (D_{50}) of the Culvert Substrate shall be sized to withstand scouring by the Check Flow [refer to standard WC-1 (1.1)]. Rock required to prevent scour shall be mixed with either the Native Substrate or with smaller stone that is representative of the Native Substrate.

3.2.2 The minimum depth of the Culvert Substrate shall be 1.5 times the Mean Diameter (D_{50}) of the Culvert Substrate and not less than 0.3 m.

3.2.3 The gradation of the Culvert Substrate shall be evenly graded with a range of material sizes including finer materials to fill voids and reduce the potential flow through the Culvert Substrate.

3.2.4 Native Substrate shall be placed above the Culvert Substrate, to a minimum depth of 0.1 m.

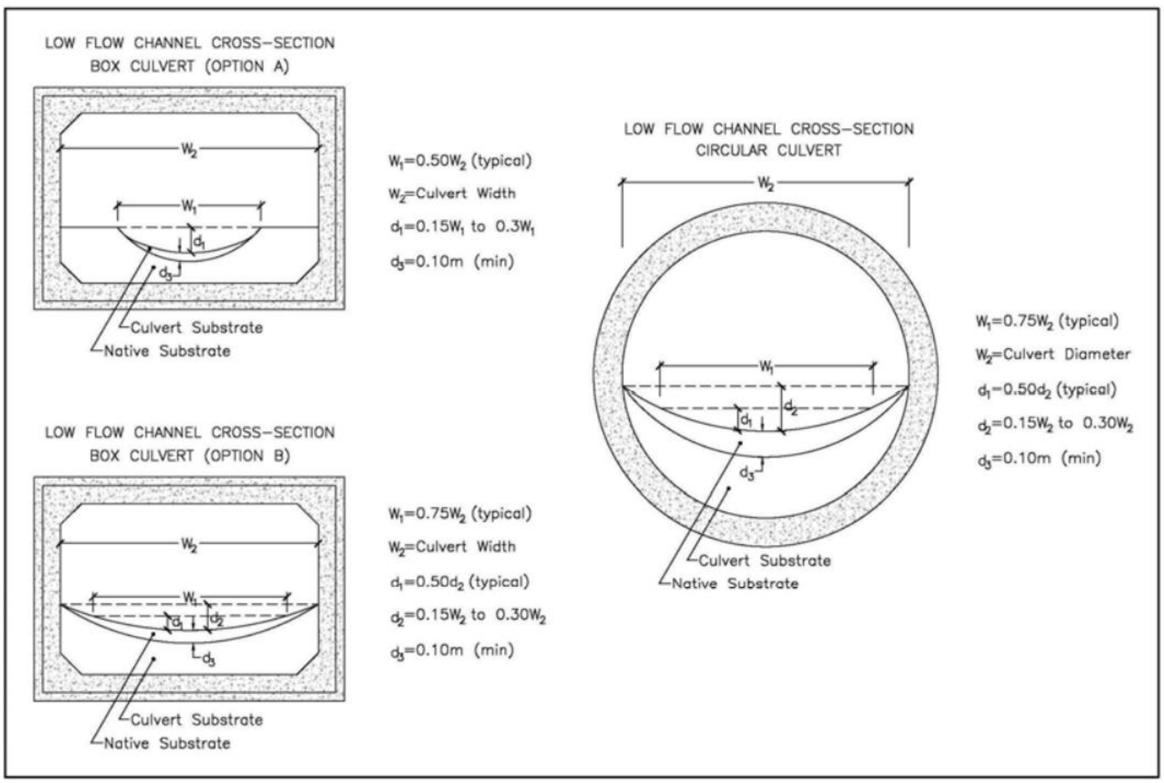
3.2.5 The hydraulic analysis of the culvert shall account for the Culvert Substrate and Native Substrate that is to be placed in the culvert.

3.3 Low Flow Channel Shape

3.3.1 The Culvert Substrate and Native Substrate within the culvert shall be shaped to form the Low Flow Channel.

3.3.2 The shape of the Low Flow Channel including the culvert walls shall generally conform to the average shape of the natural channel such that the flow depth for a range of flows up to the Fish Passage Design Flow shall be consistent with conditions in the natural channel immediately upstream and downstream of the culvert. The diagrams shown in Figure WC12.1 shall serve as a guide in the design of the Low Flow Channel.

Figure WC 12.1 – Low Flow Channel Shape



3.4 Culvert Embedment for Closed-Bottom Culverts

3.4.1 The invert of closed-bottom culverts (box or circular) on migratory fish routes shall be embedded to a minimum of 0.3 m below the natural streambed. Greater embedment depths can be used where necessary, to accommodate substrate materials.

3.5 Invert of the Channel

The top of the Native Substrate that is placed in the culvert shall be 0.05 m to 0.10 m below the average bed elevation associated with the natural channel immediately upstream and downstream end of the culvert.

4. COMMENTARY

- Based on factors such as fish species, the DFO may require that the design flow be based on the 3Q10 high flow rate generated from available flow data for the subject watercourse.
- This standard includes the minimum standards that must be incorporated into the design of culverts requiring the accommodation of fish passage.
- This standard does not address fish habitat requirements. However, fish habitat requirements may also influence the design of the culvert and the low flow channel through the culvert.
- To reduce the risk of loosing substrate during flooding events, the substrate may be protected by constructing sills or other measures, provided there is no potential for scouring or dislodging of these features. In addition, in some cases it may be desirable to widen the culvert to reduce velocities and rock size.
- The primary design objective for the channel within the culvert should be to maintain (or approximate) the slope, dimensions, substrate characteristics of the existing channel, and the related general morphology and physical conditions of the ‘bankfull’ channel.
- Baffles may be used in culvert retrofit applications where the velocity criteria cannot be met by simple modifications to the culvert design.
- If pools are required at the culvert outlet, they should be designed such that they do not impede fish passage.
- On degrading streams it may be necessary to increase the depth of culvert embedment.
- In some cases the combination of the culvert size and the substrate size is such that the required low flow channel would not be constructible. In such cases it will be necessary to either increase the culvert size or develop other alternatives to satisfy Agency requirements.
- In the case of multi-cell culverts, fish passage requirements should only be provided in one of the cells.
- The designer should refer to MTO’s Environmental Guides for Fisheries and the MNR/DFO/MTO Fisheries Protocol for additional information.
- On smaller culverts, filling by natural bedload movement may be the only practical method for providing the required substrate material.

WC-13 Relief Flow (Bridges and Culverts)

SCOPE

This standard addresses the control of flood flows conveyed over the roadway as Relief Flow at water crossings. The standard identifies the maximum depth and the maximum velocity of flow over the roadway.

DESIGN REFERENCES

MTO Drainage Management Manuals
Canadian Highway Bridge Design Code

1. HYDROLOGY

This standard shall be read in conjunction with Standard WC-1, Design Flow (Bridges and Culverts).

2. HYDRAULICS

This standard shall be read in conjunction with Standard WC-1, Design Flow (Bridges and Culverts).

3. PHYSICAL CHARACTERISTICS

3.1 Relief Flow over Roadway

The design of a water crossing shall incorporate passage of the Relief Flow over the Roadway in cases where the Regulatory Flow exceeds the Design Flow of the bridge or the culvert. Relief Flow need not be incorporated into the design in cases where the Regulatory Flow must be conveyed through the structure.

3.2 Depth and Velocity of Relief Flow

Where Relief Flow is provided, the following parameters shall not be exceeded at the cross section of the road for the Regulatory Flood:

3.2.1 The maximum depth of flow on the roadway shall not exceed 0.3 m; and

3.2.2 The product of the velocity and depth on the roadway shall not exceed 0.8 m^2/s.

4. COMMENTARY

- Whenever possible, the lowest point of the road profile at a stream crossing should be located at a distance from the culvert of at least 3 to 4 times the culvert height, in order to prevent or minimize the damage to the culvert in the event of road washout.
- The sag should extend as long as the geometric design will permit to minimize the depth of road overflow.
- The culvert and bridge design must account for the impacts of Relief Flow on flood control in downstream subcatchments, including the impacts to the floodplain immediately downstream of the crossing. The potential impacts to the floodplain downstream of the crossing should also be addressed when replacing an existing structure with a larger structure.
- The road design should include measures to minimize the risk of significant erosion and road washout under Relief Flow conditions, which will minimize:
  - Undercutting of the embankment and premature failure of the roadway; and

    - Impacts associated with road washout on water quality, and aquatic and terrestrial habitats in areas downstream of the highway, which are vulnerable to sediment deposition (i.e. wetlands, fisheries watercourses)

- The design should identify the land and grading requirements to convey the Relief Flow back to the main channel downstream of the roadway.
- Where Relief Flow is required, any barriers will need to be impervious to prevent flow blockage.

SW-1 Stormwater Management-Level of Control

SCOPE

This standard identifies the level of control requirements for the design of stormwater management facilities for highways.

DESIGN REFERENCES

Stormwater Management Planning and Design Manual, Ministry of Environment, March 2003

1. HYDROLOGY

1.1 Design Control Level – Quantity Control

Stormwater management (SWM) facilities shall be designed to control Design Flows to a Control Level that will depend upon either:

1. An evaluation of the capacity of the receiving system; or
2. Criteria that has been set through a watershed, subwatershed, or master drainage plan that has been endorsed by MTO (as per the requirements of Directive B-014).

The receiving system does not require quantity control as supported by local agency criteria and detailed study.

The more stringent of the two conditions outlined above shall dictate the control level to ensure that the flood potential downstream will not increase.

1.2 Design Flow Analysis

Peak flow rates for storms with the following AEP: 50%, 20%, 10%, 4%, 2%, 1% (return periods: 2, 5, 10, 25, 50, 100-year) and the Regulatory Flow are to be included in any quantity control considerations.

1.3 Quality Control Criteria

1.3.1 If a subwatershed study (as endorsed by MTO through Directive B-014) has been carried out for a receiving stream, and differing or additional water quality control requirements are specified, they are to be applied in the design of a SWM facility for quality control.

1.3.2 The levels of protection identified in this standard are intended to conform with the provincial approach for water quality control as outlined in the MECP Stormwater Management Planning and Design Manual (March 2003). The requirements are based upon the level of removal of suspended solids for water quality control, directed to fisheries protection:

- Enhanced protection or greater shall be used when sensitive aquatic habitat will be impacted by discharge from highway drainage system. This leads to SWM facilities that provide the equivalent of 80 percent long-term suspended solids removal.
- Normal protection shall be used when conditions for enhanced protection is not required. This leads to SWM facilities that provide the equivalent of 70 percent long-term suspended solids removal.
- Basic protection shall only be acceptable where receiving aquatic habitat is demonstrated to be insensitive to stormwater impacts and has little potential for immediate or long-term rehabilitation. This leads to SWM facilities that provide the equivalent to 60 percent long- term suspended solids removal.

2. HYDRAULICS

Stormwater Management (SWM) Ponds that are designed to improve water quality or to provide a Level of Control shall be designed such that the pond remains stable during the full range of design storms, and that the receiving system capacity and flood potential are not increased.

3. PHYSICAL CHARACTERISTICS

There are no physical characteristics applicable to Level of Control.

4. COMMENTARY

- The capacity of the receiving conveyance system is to be assessed to determine if undercontrol, control or possibly overcontrol will be required. Peak flow rates must be determined on a site-by-site basis. It should be noted that hydraulic capacity is only one of a number of considerations (e.g. ecological) to determine the level of control required. The designer should be aware that these considerations may dictate a need to be aware of how flow rates and water levels affect downstream environments.
- It must be recognized that SWM ponds may have multiple control objectives other than just peak flow control. This is to be considered in the design approach.
- Consideration should be given to the effects of hydrograph time-of-peak and watercourse travel time in the receiving stream, when impacts are suspected, to ensure that analysis is representative.
- The conditions of the receiving system (e.g. stream or other type of open watercourse) may require a degree of erosion control to protect against increased erosion within the receiving system. The MOE Stormwater Management Planning and Design Manual (2003) outlines an approach for technical analysis and identification of SWM control. As part of this analysis a site visit and field measurements (e.g. survey of the channel cross-section, characterization of bank materials, etc.) are required to assess the existing conditions.
- If a subwatershed study exists (as endorsed by MTO through Directive B-014), the designer shall follow the applicable recommendations.
- The designer shall consult with the MTO environmental planner to determine the appropriate level of stormwater control required.
- If, during design, it is determined that, due to site conditions, the quality target cannot be met, the designer is to consult with the environmental planner.

SW- 2 Stormwater Management Ponds

SCOPE

This standard identifies design standards for the design of stormwater quantity and or quality pond components (wet, wetlands and dry).

DESIGN REFERENCES

Stormwater Management Planning and Design Manual, Ministry of Environment, March 2003
MTO Drainage Management Manual

1. HYDROLOGY

Hydrology as defined in Standard SW-1 Stormwater Management Level of Control.

2. HYDRAULICS

Hydraulics as defined in Standard SW-1 Stormwater Management Level of Control.

3. PHYSICAL CHARACTERISTICS

The following tables provide a summary of design elements for wet and dry ponds.

The tables include desirable and minimum standards as defined in the definitions section of this document. The desirable standard is the same as the minimum standard unless otherwise stated. These tables are not intended to provide an all inclusive listing of design elements. In highway design applications, the design of ponds may be limited by site or property conditions.

3.1 Wet Pond

The Table SW2-1 provides a summary of design elements for Wet Ponds.

3.2 Wetlands

The Table SW2-2 provides a summary of design elements for Wetlands.

3.3 Dry Pond

The Table SW2-3 provides a summary of design elements for Dry Ponds.

Table SW2-1: Wet Pond Design[1]

Design Element	Design Objective	Desirable Standard	Minimum Standard
Drainage Area	Volumetric sustainability and turnover	Greater than or equal to 5 hectares	Dependant on local hydrologic conditions
Treatment Volume	Provision of appropriate level of protection	Permanent pool volume associated with minimumstandard increased by expected maximum ice volume Extended storage volume associated with Minimum Standard increased to include the 25mm event runoff volume	As per Table 3.2 in the MOE SWM Manual
Active Storage Detention	Suspended solids settling	Increase total extended detention time to 60 hours maximum to include runoff resulting from the 25mm event Maximum 0.5m extended storage depth and 1.5m total active storage depth before overflow	24 hour detention of the 40m^3/ha volume Reduce total extended detention time to 12 hours if required to provide minimum 75mm orifice size Maximum 2.0m total active storage depth before overflow
Forebay	Pre-treatment	Minimum depth: 1.5m Maximum volume: 20% oftotal permanent pool	Minimum depth: 1.0m Maximum area: 33% of total permanent pool
Length-to-Width Ratio	Maximize path and minimize short-circuiting potential	Overall pond minimum: 5:1 See Minimum	Overall pond minimum: 3:1 Forebay minimum: 2:1
Permanent Pool Depth	Minimize re-suspension, avoid anoxic conditions	Preferred maximum depth: 2.5m Mean depth: 1m to 2m	Maximum depth: 3m
Side Slopes	Safety (personal safety) Maximize the functionalityof the pond	Minimum 6:1 for 3.0m both sides of permanent pool edge,walkways or retaining walls with a mean slope of 4:1 or greater elsewhere	Minimum 5:1 for 3.0m around perimeter of permanent pool and a minimum of 2:1 elsewhere oras dictated by geotechnical requirements
Inlet	Avoid clogging/freezing	See Minimum See Minimum See Minimum	Minimum: 450mm Preferred pipe slope>1% If submerged, obvert 150mm below expected maximum ice depth
Outlet	Avoid clogging/freezing	See Minimum See Minimum See Minimum	Minimum: 450 mm Reverse sloped pipe minimum diameter 150mm Preferred pipe slope>1%
Outlet Orifice Plate		Minimum 100mm orifice	Minimum 75mm orifice

[1] Modified from Table 4.6 Summary of Design Guidance, from MOE Stormwater Management Planning and Design Manual to address a highway context.

Table SW2-2: WetLand Design[1]

Design Element	Design Objective	Desirable Standard	Minimum Standard
Drainage Area	Volumetric sustainability and turnover	Greater than or equal to 5 hectares	Dependant on local hydrologic conditions
Treatment Volume	Provision of appropriate level of protection	Increase extended storage associated with Minimum Standard to include the 25mm rainfall event runoff volume	As per Table 3.2 in the MOE SWM Manual
Active Storage Detention	Suspended solids settling	Increase total extended detention time to 60 hours maximum to include runoff resulting from the 25mm event Maximum 0.3m extended detention storage depth and 1.0m total active storage depth before overflow	24 hour detention of the $40m^3$/ha volume Reduce total extended detention time to 12 hours if required to provide minimum 75mm orifice size Maximum 1.2m active storage depth before overflow
Forebay	Pre-treatment	Minimum depth: 1.5m Maximum volume: 20% oftotal permanent pool	Minimum depth: 1.0 m Maximum area: 33% of total permanent pool
Length-to-Width Ratio	Maximize path and minimize short-circuiting potential	Overall pond minimum: 5:1 See Forebay Minimum	Overall pond minimum: 3:1 Forebay minimum: 2:1
Permanent Pool Depth	Minimize re-suspension, avoid anoxic conditions	Maximum depth: 300mm Minimum depth: 50mm Mean depth: 200mm	Maximum depth: 300mm
Side Slopes	Safety (personal safety) Maximize the functionalityof the pond	Minimum 6:1 for 3.0m around perimeter of permanent pool, 6:1 for 3m both sides of walkways or retaining walls, and a mean slope of 4:1 or greater elsewhere	Minimum 5:1 for 3.0m around perimeter of permanent pool, and a minimum slope of 2:1 elsewhere or as dictated by geotechnical requirements
Inlet	Avoid clogging/freezing	See Minimum See Minimum	Minimum: 450mm Preferred pipe slope>1%
Outlet	Avoid clogging/freezing	See Minimum See Minimum	Minimum: 450 mm Preferred pipe slope>1%
Outlet Orifice Plate		Minimum 100mm orifice	Minimum 75mm orifice

[1] Modified from Table 4.6 Summary of Design Guidance, from MOE Stormwater Management Planning and Design Manual to address a highway context.

Table SW2-3: Dry Pond Design[1]

Design Element	Design Objective	Desirable Standard	Minimum Standard
Drainage Area	Volumetric turnover	Less than 5.0 hectares	No maximum or minimum
Active Storage Detention	Suspended solids settling	Increase total extended detention time to 48 hours maximum to include runoff resulting from the 25mm event	24 hour detention of the 40m^3/ha volume Reduce total extended detention time to 12 hours if required to provide minimum75mm orifice size
Length-to-Width Ratio	Maximize path and minimize short-circuiting potential	Minimum: 5:1	Minimum: 4:1
Active Storage Depth	Storage/flow control	1.0m	Maximum: 1.5m
Side Slopes	Safety Maximize the functionality of the pond	6:1	Minimum 2:1 or as dictated by geotechnical requirements
Inlet	Avoid clogging/freezing	See Minimum See Minimum	Minimum: 450mm Preferred pipe slope>1%
Outlet	Avoid clogging/freezing Principle spillway and emergency overflow	See Minimum See Minimum	Minimum: 450 mm Preferred pipe slope>1%
Outlet Orifice Plate		Minimum 100mm orifice	Minimum 75mm orifice

[1] Modified from Stormwater Management Guidelines for the Province of Alberta, 1999 (Alberta Environmental Protection) and from Table 4.6 Summary of Design Guidance, from MOE Stormwater Management Planning and Design Manual to address a highway context

4. COMMENTARY

- To determine the water quality storage requirements for wet ponds refer to Table 3.2 of the MOE Stormwater Management Planning and Design Manual. MOE water quality sizing criteria allow for several types of end-of-pipe facilities – Infiltration, Wetlands, Hybrid Wet Pond/Wetland, Wet Pond, and Dry Pond (for Basic Protection only).
- Wetlands are not generally constructed as a stormwater management measure for highway drainage, primarily due to associated land requirements.
- Wet ponds have been shown to perform consistently for removal of suspended solids and other highway related pollutants and are recommended for use in Ontario. The high length to width ratios recommended in the criteria are ideal for ponds treating highway drainage because the linear type design fits in well along right-of-ways. Ponds located in the cloverleaf centre areas may have more difficulty meeting the length to width ratios desired since these areas tend to be more circular in shape. However, baffles or berms incorporated in the design can effectively produce the same ratios.
- Infiltration measures are not generally used due to the maintenance and operational requirements needed to prevent blockage of the infiltration function. In addition, concerns regarding the potential for contamination of the groundwater table may exist.
- A treatment train approach is possible, which would consist of more than one stormwater management method in series. An example of this would include a grassed swale drainage system followed by a SWM pond.

- When standards for wet and dry ponds cannot be met, consideration may be given to the application of other best management practices (BMPs). This could include the use of grassed swales, particularly for water quality control.

SW-3 Roadside Ditches for Water Quality

SCOPE

This standard provides the minimum design requirement for Roadside Ditches to achieve water quality control.

DESIGN REFERENCES

The Effectiveness of Embankments and Grass-lined Highway Ditches in Improving Water Quality, MTO 2006.
Stormwater Management Practices Planning and Design Manual, MOE 2003.

1. HYDROLOGY

This standard shall be read in conjunction with Standard SW-1, Stormwater Management – Level of Control.

2. HYDRAULICS

There are no standards specific to Hydraulics.

3. PHYSICAL CHARACTERISTICS

3.1 Removal Efficiency

Roadside Ditches and Highway Embankments shall be designed such that the sediment trapping efficiency for all ditches draining to a common receiving watercourse will conform to the quality control criteria identified in Standard SW-1.

3.2 Highway Embankments

Where used to improve water quality, Highway Embankments shall be a minimum of 3 metres in length measured transversely from the outside of the shoulder to the invert of the adjacent Roadside Ditch. To improve water quality the embankment shall be planted with a dense vegetation cover sufficient to prevent erosion of the embankment.

3.3 Minimum Ditch Base Width

Where used to improve water quality, the Roadside Ditch shall have a minimum base width of 1.0 metres. To improve water quality the Roadside Ditch shall be planted with a dense vegetation cover sufficient to prevent erosion of the ditch.

3.4 Minimum Ditch Length

Where used to improve water quality, the minimum desirable length of the Roadside Ditch shall be 40 metres, as measured from the furthest downstream storm sewer outfall to the receiving watercourse.

4. COMMENTARY

The methodology for designing a roadside ditch to meet the removal objectives is documented in the MTO document entitled The Effectiveness of Embankments and Grass-Lined Highway Ditches in Improving Water Quality (MTO 2006).

TW-1 Temporary Flow Passage Systems and Temporary Drainage Facilities

SCOPE

This standard identifies the Annual Exceedence Probability (AEP) or Return Period of the Design Flow and hydraulic performance standards for the sizing of temporary drainage works (e.g. pumps, channels, pipes, culverts and bridges)

The standard applies to:

- Temporary Flow Passage Systems (TFPS) implemented to separate/isolate a work area within a watercourse (ditch or natural channel) during construction.
- Temporary drainage facilities (e.g. channels, pipes, culverts and bridges).

The Return Period associated with the design of temporary erosion control basins is also included.

DESIGN REFERENCES

MTO Drainage Management Manuals
Environmental Guide for Erosion and Sediment Control During Construction of Highway Projects

1. HYDROLOGY

1.1 Design Flows

Design Flows shall be determined using appropriate deterministic or statistical methods.

The AEP (Return Period) of the Design Flow shall be assessed independently for each project. The AEP (Return Period) shall be determined by the duration the temporary drainage works will be in place and the potential consequences in terms of public safety, traffic delays, property damage due to flooding, and environmental impacts.

For each TFPS or type of temporary drainage facility (e.g. culvert, by-pass channel), the consequence of failure or capacity exceedance shall be determined for each of the four categories (Public Safety, Traffic Delays, Damage due to Flooding, Natural Habitat Impacts). The worst-case impact (low, medium, high) from the four categories shall be used for selecting the AEP (Return Period) of the Design Flow.

1.1.1 Consequence of Failure or Capacity Exceedance Definitions

The following definitions apply to assessing the consequence of failure or capacity exceedance from the perspective of Public Safety, Traffic Delays, Damage due to Flooding, and Natural Habitat Impacts.

Low:

- Public Safety – failure or capacity exceedance is not a significant risk to public safety.
- Traffic Delays – there would be no significant traffic delays as there are alternative routes.
- Damage due to Flooding –flooding would be local or would be limited to unimproved rural lands that would not be adversely affected by the flooding.
- Natural Habitat Impacts – any impacts will be temporary. (i.e. fish habitat not permanently affected and vegetation damage will generally recover within two growing seasons)

Medium:

- Public Safety – failure or capacity exceedance is not a greater risk to public safety.
- Traffic Delays – there may be road closure causing delay or detouring (nuisance).

- Damage due to Flooding – land uses such as croplands or parking will be flooded.
- Natural Habitat Impacts – temporary impacts anticipated that may take more than two growing seasons to recover.

High:

- Public Safety –failure or capacity exceedance represents a significant risk to public safety
- Traffic Delays – road closure causing significant impact on traffic or emergency vehicles
- Damage due to Flooding – buildings will be flooded
- Natural Habitat Impacts – permanent damage anticipated, requiring mitigation and/or habitat compensation

1.1.2 Annual Exceedence Probability (AEP/Return Period) of the Design Flow

The minimum AEP (Return Period) for temporary drainage works shall be as follows:

Table TW1-1: Minimum Minor AEP (Return Period) For Temporary Drainage Works

Design Flow Probability of Occurrence						
Duration of Temporary Drainage Works	Consequence					
	Low		Medium		High	
	AEP (%)	RP (Yrs)	AEP (%)	RP (Yrs)	AEP (%)	RP (Yrs)
Less than 2 months	50%	2	50%	2	50%	2
Up to 4 months	50%	2	20%	5	20%	5
Up to 8 months	20%	5	20%	5	10%	10
Up to 12 months	20%	5	20%	5	5%	20
Up to 18 months	20%	5	10%	10	4%	25
Greater than 18 months	10%	10	10%	10	4%	25

For durations under 12 months, the AEP (Return Period) of the event should be based on frequency analysis of the months that the temporary drainage works are to be in place, where practicable to determine.

1.1.3 Temporary Erosion Control Basins

A 25 mm Design Storm with a duration of four hours shall be used to size temporary erosion control basins.

2. HYDRAULICS

There are no standards specific to Hydraulics

3. PHYSICAL CHARACTERISTICS

3.1 Temporary Flow Passage Systems

The Temporary Flow Passage devices shall be designed and the operation plan developed using the flow determined in Section 1.1 as the Design Flow such that when the TFPS is in the watercourse:

- There shall be no Flow Spread beyond the ditch or channel onto the shoulder or travel lane for flow up to and including the Design Flow.
- The Maximum Velocity shall not result in erosion of the ditch/channel or inlet/outlet.

- For durations greater than 12 months, the minimum freeboard to the top of Sub-Grade shall be 0.3 m for the Design Flow.
- Provisions for fish passage are included on fish bearing streams.
- The is no displacement or damage to property, buildings, structures, Utilities and other facilities adjacent to the Working Area.
- The flow of water and the natural functions of a natural waterbody upstream and downstream of the work area are maintained and shall not interfere with other uses of the water.
- Embankments and/or structures in public use, either existing or to be constructed as part of the work, shall not be used to control or stop water flow.

3.2 Temporary Drainage Facilities

Temporary drainage facilities shall be designed such that:

- Temporary drainage facilities for water crossings shall adhere to the Physical Characteristics requirements of WC-2 to WC-13 using the flow determined in Section 1.1 as the Design Flow.
- Other temporary drainage facilities shall adhere to the Physical Characteristics requirements of SD-2 to SD-13 for surface water drainage using the flow determined in Section 1.1 as the Minor System Design Flow.

3.3 Temporary Erosion Control Basins

Temporary Erosion Control Basins shall be sized to include both a Permanent Pool and Live Storage.

The Permanent Pool shall have a capacity of 125 cubic metres per hectare of upstream catchment area.

The Live Storage shall be large enough to contain the runoff generated by the 25 mm design storm noted in 1.1.3.

4. COMMENTARY

- Where it is not practicable to design the hydraulic capacity of TFPS devices to convey the design flow, measures must be included in the TFPS operation plan to meet the performance standards in section 3.1. Measures may include providing for nondestructive relief flow into the construction area, staging construction during low flow months or dry days, or monitoring of precipitation and removal of the TFPS when exceedance of the TFPS conveyance capacity is predicted.
- The following table illustrates the method of determining the consequence of failure or capacity exceedance. The worst case from Column 1 to 4 will be used for establishing the AEP (Return Period) for temporary drainage works.

Typical Measures	**Consequences**				
	Public Safety (1)	**Traffic Delays (2)**	**Damage due to Flooding (3)**	**Natural Habitat Impacts(4)**	**Worst Casefrom Column 1 to 4**
Temporary Culvert/Bridge	LOW	MEDIUM	LOW	LOW	MEDIUM
Diversion Channel	LOW	LOW	HIGH	MEDIUM	HIGH
Note: The above ratings are for illustrative purposes only.					

TW-2 - Highway Drainage Management for Lane Shifts and Temporary Alignments

SCOPE

This standard provides drainage requirements for temporary highway drainage associated with lane shifting and temporary alignments. In particular, the temporary drainage management standards will apply to lanes shifts across the median, lane shifts to the shoulder, and temporary alignments.

DESIGN REFERENCES

Design References not available.

1. HYDROLOGY

This standard shall be read in conjunction with Standard SD-1, Design Flows for Surface Drainage.

2. HYDRAULICS

There are no standards specific to Hydraulics.

3. PHYSICAL CHARACTERISTICS

3.1 Lane Shift Across Median

3.1.1 Where the lane shift crosses a grass median, a culvert shall be constructed to convey flows along the median. The culvert shall be sufficiently sized to convey the 1% AEP (100-year RP) Design Flow.

3.1.2 Where the lane shift crosses paved shoulders drained by a storm sewer system, the following standards shall apply:

- A temporary barrier shall be placed adjacent to the set of catchbasins located immediately up-gradient of the lane shift, such that the catchbasins intercept all flow in the shoulder without any carry-over to the temporary lanes that cross the median;
- The catchbasin grate shall be modified to maximize inlet capacity;
- A positive outlet shall be provided on the down-gradient side of the point of the cross-over; and
- Where inlet capacity (or storm sewer capacity) is less than the 1% AEP (100-year RP) Design Flow, signage shall be provided indicating that water may accumulate on the road during a rainfall event. Required signage shall be approved by the Manager of Engineering.

3.2 Lane Shift to Shoulder

Where the lanes are temporarily shifted such that the shoulder adjacent to a curb or median barrier is used as a travel lane, the following standards shall apply:

3.2.1 Where possible, a sufficient shoulder shall be provided to ensure that spread into the travel lanes adheres to Standard SD-3, Flow Spread onto Travel Lanes;

3.2.2 Otherwise, catchbasin inlet capacity shall be increased to ensure that spread into the travel lanes adhere to Standard SD-3; and

3.2.3 Where Standard SD-3 cannot be adhered to, signage shall be provided indicating that water may accumulate on the road during a rainfall event. Required signage shall be approved by the Manager of Engineering.

3.3 Temporary Alignment

3.3.1 Where temporary alignments are constructed with a rural cross-section, the ditch system shall adhere to the requirements of Standard SD-9, Roadside Ditches (Conveyance Only).

3.3.2 Where temporary alignments are constructed with an urban cross-section the storm sewer system and catch basin spacing shall be designed in accordance with Standard SD-4, Storm Sewer System and Standard SD-5, Storm Sewer Inlets on a Continuous Grade.

4. COMMENTARY

In many cases it will not be possible to adhere to the standards outlined herein. In such cases, signage and speed limits should be established to minimize the consequence of any flooding that may occur.