11.0 Culverts

11.1 Introduction

A culvert is defined as a conveyance conduit for surface water drainage beneath a driveway, street, highway, railroad, canal, or other embankment. The hydraulic analysis of culvert flow is complicated by the variety of discharge-dependent flow conditions that can occur. Culvert conveyance capacity is a function of both inlet and discharge flow conditions.

11.2 Culvert Classifications

Culverts are classified hydraulically by the type of flow control that exists at the design discharge. Culverts functioning under inlet control are limited in conveyance capacity by entrance losses. Culverts functioning under outlet control are limited in capacity by the material properties, geometry of the conduit, and downstream flow conditions. Culverts designed for inlet control require analysis of the entrance headloss at the inlet. A well-designed inlet can dramatically increase the hydraulic performance of the culvert. Culverts designed for outlet control require analysis of the hydraulic properties of the conduit, such as slope, roughness, shape, and diameter. The possible backwater conditions at the point of discharge of the culvert must also be considered and may decrease the capacity of the culvert.

11.3 Design Criteria

The hydraulic analysis and design of culverts shall be in accordance with the criteria presented in the Culverts Chapter, Volume 2 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. Detailed design criteria and design procedures specific for the City of Greenwood Village (Village), are highlighted in the following Sections.

Additional design procedures for concrete culverts are described in Concrete Pipe Design Manual, American Concrete Pipe Association. Additional design procedures for corrugated metal conduits are described in the Handbook of Steel Drainage and Highway Construction Products, American Iron and Steel Institute.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and are not intended to replace site-specific analysis and design requirements of individual projects. For instance, the presence of corrosive soils may prevent the use of corrugated steel pipe.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Section 17.0.

11.3.1 Construction Material and Pipe Size

Conduit materials acceptable for use in culvert construction include reinforced concrete (RCP), corrugated metal (CMP), and high density polyethelene pipe (HDPE). The use of CMP shall require a soil analysis to ensure that the corrosivity of the soil will not shorten the design life of the culvert. The Village will consider use of other construction materials. The minimum size for culverts is provided in Table 11-1.

Table 11-1: Minimum Culvert Size

Shape of Culvert	Minimum Equivalent Pipe Diameter (in^2)		Minimum Cross-Sectional Area (ft^2)	
	Streets	Driveways	Streets	Driveways
Circular	24	12	3.1	0.75
Arch	24	12	2.8	0.70
Elliptical	24	12	3.3	0.82

11.3.2 Inlet and Outlet Configuration

All culverts shall be designed with headwalls and wingwalls or flared-end sections at the inlet and outlet. Erosion protection shall be provided at the outlet in accordance with the criteria presented in Chapter 12.0. All culverts shall be designed and installed to be resistant to damage from errant vehicular traffic.

11.3.3 Hydraulic Design Criteria

11.3.3.1 Frictional Losses

Culvert capacity and velocity shall be computed using the Manning roughness coefficient (n) in accordance with the manufacturer's criteria.

11.3.3.2 Velocity

Culverts are designed for both a minimum and a maximum allowable velocity. A minimum cleansing velocity of 3 fps is required for the minor storm. The maximum allowable velocity is 15 fps for the major storm.

11.3.3.3 Headwater Criteria

The maximum headwater for the major storm flow shall be 1.5 times the culvert diameter or rise dimension.

11.3.4 Structural Criteria

As a minimum, all culverts shall be structurally designed to withstand a minimum H-20 loading condition in accordance with AASHTO "Standard Specifications for Highway Bridges" or in accordance with the pipe manufacturer's recommendations.

11.3.5 Trash Racks

The use of trash racks at culvert inlets and outlets reduces long-term maintenance requirements of the conduit and increases public safety. Field experience has demonstrated, however, that trash racks routinely become blocked with sediment and debris, requiring regular maintenance to ensure adequate conveyance capacity of the conduit during storm events. Use of trash racks shall be evaluated with respect to project-specific constraints. All trash racks shall be designed and installed to be resistant to damage from errant traffic. Breakaway designs are acceptable to the Village and will be reviewed on a case by case basis consistent with generally accepted culvert and trash rack manufacturer's recommendations.

11.4 Design Procedures

The culvert is sized in accordance with minor and major storm design criteria governed by allowable street inundation. Culverts shall be sized in accordance with the criteria presented in Table 8-1. In addition, street overtopping is not allowed for the minor storm. Private driveways crossing roadside ditches shall be designed to prevent overtopping during the minor storm.

The following procedure shall be used as a minimum design standard for culvert street crossings and modified, as required in response to site-specific constraints. For example, removal of structures from the 100-year floodplain may require increasing the size of the culvert by increasing the design frequency of the storm to lower the floodplain elevation.

1) The allowable street overtopping shall be determined from overflow rating curves developed for the street profile assuming proposed conditions of development and drainage for the major storm. Design shall be in accordance with criteria governing allowable street inundation for major storm events, as shown in Table 8-1.
2) The culvert is sized to convey the difference between the major storm peak discharge and the allowable street overtopping.
3) If the resulting culvert is smaller than that required to pass the minor storm peak discharge without overtopping, the culvert shall be increased in size to pass the minor storm peak discharge.

11.0 CULVERTS 1

11.1 INTRODUCTION 1
11.2 CULVERT CLASSIFICATIONS 1
11.3 DESIGN CRITERIA 1
11.3.1 Construction Material and Pipe Size 2
11.3.2 Inlet and Outlet Configuration 2
11.3.3 Hydraulic Design Criteria 2
11.3.3.1 Frictional Losses 2
11.3.3.2 Velocity 2
11.3.3.3 Headwater Criteria 2
11.3.4 Structural Criteria 3
11.3.5 Trash Racks 3
11.4 DESIGN PROCEDURES 3