DRAINAGE MANUAL

Prepared for the

City of Hurricane
147 North 870 West
Hurricane, UT 84737

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SECTION 1
GENERAL

The purpose of this Drainage Manual is to provide guidelines for planning & designing storm drain and flood control facilities in the City of Hurricane (City). The objective of these guidelines is to ensure that drainage planning and facility design for small areas and local developments within the City are consistent with the City's Storm Drain Master Plan. Recommendations provided in this manual are general in nature, and guidelines and recommendations should be tailored to specific project conditions.

All drainage projects shall conform to requirements in this Drainage Manual, the Storm Drain Master Plan, and shall be approved by the City.

Drainage facilities shall be designed using currently accepted civil engineering standards of care, applicable safety standards, and City or other approved design specifications. Facilities shall be designed and constructed to ensure that impacts of new development shall not cause increases in pre-project peak storm water runoff for 10-year and 100-year design events. Facilities should also mitigate changes to original flows conditions in order to prevent damage to downstream property.

Local storm drain collection facilities, including catch basins and collector pipes, shall be designed to provide flood protection in a 10-year flood event. Streets shall be designed to minimize risk of damage or personal injury in cases where 100-year flood events overburden local storm water runoff collection facilities. Major storm drain detention and conveyance facilities, including storm drain trunklines, regional detention basins, bridges, creeks, and washes, shall be designed to provide flood protection in a 100-year flood event.

SECTION 2
HYDROLOGIC ANALYSIS

INTRODUCTION

There are a wide variety of methods that can be used to perform hydrologic analyses under accepted engineering standards of practice. The purpose of this section is to provide a general framework for hydrologic analyses, so that drainage master planning and facility design efforts for developments within the City are consistent with the City's Storm Drain Master Plan.

DRAINAGE BASIN DELINEATION

For the purposes of storm water runoff analysis, major drainage patterns should be identified based on topography and the location of major natural drainage channels. The primary natural drainage conveyances in Hurricane are Frog Hollow, Gould Wash, and the Virgin River

Within major drainage basins, subbasins should be delineated for storm water runoff analysis using available local information including, but not limited to:

- Topography
- Aerial photography
- Locations of storm water collection, conveyance, and detention facilities
- Land use and zoning maps
- Soil type maps.

For regional hydrologic analysis, drainage basins are delineated on a watershed scale, with basin areas typically greater than 1.0 square mile. For municipal master planning, drainage basins are typically divided into subbasins ranging in size from approximately 0.1 to 1.0 square mile. Planning and design for local development involves subbasin delineation at small scales associated with the size of developed parcels.

PROJECTED FUTURE LAND USE CONDITIONS

Impacts of future development in a subbasin on downstream drainage conveyance and detention facilities should be evaluated. New development will nearly always increase storm water runoff volume and peak flow. In analyzing the effect of future development in a subbasin, three factors should be evaluated:

1. Increase in percent of impervious area
2. Decrease in subbasin lag time due to local storm drain improvements
3. Decrease in runoff routing time due to trunkline and main channel improvements.
4. Concentration of runoff to discharge points where the undeveloped condition was predominantly shallow concentrated flow.

Projected land use for a given area can typically be obtained from City projected land use maps.

PRECIPITATION

In general, precipitation producing design magnitude runoff events in southwestern Utah are typically in the form of short duration, high intensity cloudburst storms during the summer months and early fall months. For this reason, these types of rainfall events are commonly used for drainage master planning and design purposes. There are four basic elements to any design rainfall event. These are: rainfall depth, rainfall duration, rainfall frequency, and rainfall distribution.

Design Storm Depth

Historical records of rainfall depth collected at climate stations throughout the United States are used to estimate the depth, frequency, and duration of design storms. The major climate stations nearest to Hurricane are located in La Verkin, approximately 2 miles to the north, and St. George, approximately 17 miles to the southwest. These climate stations have rainfall records dating back to 1950 and 1892, respectively. Data from these and numerous other climate stations have been compiled by the National Oceanic and Atmospheric Administration (NOAA) to estimate point precipitation depth, duration, and frequency for all locations in Utah. The resulting estimates for Hurricane were taken from the NOAA Atlas 14 (2006) via the Precipitation Frequency Data Server (http://hdsc.nws.noaa.gov/hdsc/pfds/sa/ut_pfds.html) and are summarized in Table 2-1.

Table 2-1
Precipitation Depth-Frequency Estimates for Hurricane, Utah*

Estimated Precipitation Depth (inches)						
Duration	**Annual Exceedance Probability**					
	2-yr	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
5 min	0.16	0.23	0.29	0.38	0.45	0.54
10 min	0.24	0.35	0.44	0.58	0.69	0.82
15 min	0.29	0.43	0.55	0.71	0.86	1.02
30 min	0.40	0.58	0.74	0.96	1.15	1.38
60 min	0.49	0.72	0.91	1.19	1.43	1.70
2 hr	0.58	0.83	1.03	1.32	1.56	1.84
3 hr	0.65	0.91	1.10	1.38	1.62	1.89
6 hr	0.80	1.11	1.33	1.63	1.87	2.14
12 hr	0.99	1.35	1.60	1.92	2.17	2.42
24 hr	1.16	1.57	1.85	2.21	2.48	2.76
2 day	1.31	1.77	2.08	2.48	2.79	3.10
4 day	1.52	2.04	2.40	2.86	3.21	3.56

* From NOAA Atlas 14, 2006 (see Appendix A).

Design Storm Duration

Cloudburst rainfall events in southwestern Utah typically have durations ranging from a few minutes to three hours. Storms producing general rainfall over longer periods of time are rare, and are typically associated with slow-moving tropical storm remnants. It is recommended that design storm duration be at least four times basin response time, defined as the time required for the peak rainfall to translate to peak runoff at a concentration point of interest within a given basin. The storm durations that should be evaluated for this area are the 3-hour storm and the 24-hour storm (for detention basin volumes).

Design Storm Frequency

The likelihood of rainfall of a given depth and duration occurring is expressed as annual exceedance probability or return period. The probability of precipitation in excess of a given depth (estimated based on local historical rainfall records) occurring in a given year is expressed as 1/N, or as an N-year return period. For example, the estimated return period for a rainfall event with an estimated annual exceedance probability of 1/10 (10 percent) is 10 years. The 10-year and 100-year design storms should be evaluated for sizing detention and conveyance facilities. Other storm frequencies such as the 25-year, 50-year, and 500-year may need to be considered depending on the importance and size of the facility.

Design Storm Distribution

The temporal distribution of rainfall during a rainfall event has a significant effect on resulting peak runoff. Cloudburst storms are characterized by short periods (or bursts) of intense rainfall, with lighter rainfall before and after. The Farmer-Fletcher distribution, developed using cloudburst storm data from climate stations in central and north central Utah, is commonly used to develop temporal distributions of rainfall for one hour design cloudburst events (Farmer and Fletcher, 1972). A three hour storm distribution for a given frequency can be created by nesting the one hour Farmer-Fletcher rainfall distribution within a three hour period, with the difference between the three hour and the one hour rainfall depths distributed either uniformly or symmetrically about the nested one hour Farmer-Fletcher storm. For longer duration storms such as the 24-hour storm, rainfall distributions such as the SCS Type II synthetic rainfall distribution can be used.

Sample storm distributions for Hurricane for 10-year and 100-year one-hour rainfall events are shown in Table 2-2. Appendix A contains the Farmer Fletcher distributions for the 3-hour 10-year and 100-year events, as well as the SCS Type II distribution for the 24-hour, 100-year event.

Table 2-2
Hurricane 10-Year and 100-Year
1-Hour Rainfall Temporal Distribution

Time (min)	Cumulative Distribution		
	Percent of Total Rainfall Depth (%)	10-Year Rainfall (in)	100-Year Rainfall (in)
5	28.5	0.26	0.48
10	51.0	0.46	0.87
15	66.7	0.61	1.13
20	76.7	0.70	1.30
25	82.7	0.75	1.41
30	87.3	0.79	1.48
35	90.7	0.83	1.54
40	93.3	0.85	1.59
45	95.3	0.87	1.62
50	97.1	0.88	1.65
55	98.7	0.90	1.68
60	100.0	0.91	1.70

Areal Reduction of Rainfall

Severe cloudburst thunderstorms typically occur over relatively small areas. Rainfall records measured at climate stations represent rainfall depth at a point. Areal reduction factors have been developed to adjust estimated point rainfall depths to be applied to large drainage areas. For cloudburst storms with durations of three hours or less, the U.S. Army Corps of Engineers has developed areal reduction factors based on a study of severe thunderstorms in Salt Lake County. For longer duration general storms, NOAA Atlas areal reduction factors apply. A summary of areal reduction factor equations for various storm durations is shown in Table 2-3. Areal reduction factors should not be used on basins with areas less than a square mile, and may be unnecessary for basins with areas less than 10 square miles. This area should include the areas of all sub-basins within the basin being evaluated.

Table 2-3
Areal Reduction Factor Equations*

Storm Duration	Areal Reduction Factor Equation
5 min	0.01 * (100 - 18.5 * AREA^0.46)
10 min	0.01 * (100 - 14.2 * AREA^0.46)
15 min	0.01 * (100 - 12.0 * AREA^0.46)
30 min	0.01 * (100 - 9.2 * AREA^0.46)
60 min	0.01 * (100 - 7.0 * AREA^0.46)
2 hr	0.01 * (100 - 5.3 * AREA^0.46)
3 hr	0.01 * (100 - 4.5 * AREA^0.46)
6 hr	0.01 * (100 - 3.5 * AREA^0.46)
12 hr	0.01 * (100 - 2.6 * AREA^0.46)

24 hr	0.01 * (100 - 2.0 * AREA^0.46)
2 day	0.01 * (100 - 1.5 * AREA^0.46)
3 day	0.01 * (100 - 1.3 * AREA^0.46)

RAINFALL RUNOFF ANALYSIS

For regional drainage studies that include major washes and creeks, and where stream gage data are available, FEMA guidelines recommend use of a flood frequency analysis of annual peak discharges to develop peak flood flows for planning and design (USGS, 1981). Where stream gage data are not available, FEMA guidelines recommend developing flood hydrology using appropriate regional flood flow frequency relationships from published USGS reports.

For local drainage studies and design, storm water runoff data are typically not available, and study scales are generally too small for application of regional flood flow frequency relationships. For these situations, or for large-scale drainage studies where USGS regional flood flow frequency reports have not been developed or are not applicable due to flow regulation, storage, rapid watershed development, or other unique basin characteristics, a computer model may be developed to simulate the rainfall-runoff process in a watershed. In these cases, model results should be compared with data from nearby watersheds (where available) and with results of similar local studies. Several different methods should be compared and reported on in the drainage study in an effort to identify and justify the design parameters for use in sizing proposed facilities.

HEC-1 and HEC-HMS

The U.S. Army Corps of Engineers (USACE) has developed the HEC-1 Flood Hydrograph Package computer program for rainfall runoff analysis. HEC-1 is a mathematical watershed model designed to simulate the surface water runoff response of a drainage basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. The result of the modeling process is a computation of runoff hydrographs at desired locations within the drainage basin. HEC-1 algorithms have been incorporated in a variety of commercially-available rainfall runoff analysis software packages. The USACE has developed HEC-HMS, incorporating HEC-1 algorithms in a Windows-based environment, with additional pre- and post-processing capabilities. A complete description of HEC-HMS and HEC-1 modeling methods and capabilities is present in the USACE HEC-HMS and HEC-1 User's Manuals. Model input parameters are assembled using multiple data sources, including drainage basin delineations, soil surveys, land use maps, recent aerial photography, and model input data used in similar hydrologic studies within or in the vicinity of the study area.

Runoff Modeling Methods and Assumptions

Within HEC-HMS and HEC-1, there are a numerous methods of hydrologic analysis available. These methods all include three primary components: calculation of the amount of rainfall lost to interception and infiltration; routing of rainfall runoff; and runoff baseflow.

Interception and Infiltration

A portion of rainfall is typically intercepted and stored in local depressions or infiltrates into the soil at the ground surface. For undeveloped natural and agricultural drainage areas, use of the U.S. Department of Agriculture Soil Conservation Service (SCS) Curve Number Method is generally appropriate to estimate rainfall interception and infiltration. The curve number (CN) defines the amount of precipitation that will be lost to interception and infiltration. Curve numbers for various types of climate, soil and vegetation cover have been developed and are summarized in SCS Technical Release 55 (SCS, 1986).

For urban drainages, it is generally appropriate to divide these areas into pervious and impervious areas, and to use initial and constant loss rates to simulate interception and infiltration. Impervious area in small urban areas can be estimated by direct measurements from aerial photography. Typical values of effective percent impervious area based on land use are shown in Table 2-4.

Table 2-4
Average Percent Impervious Area by Land Use Category

Land Use Category	Average Percent Impervious Area (%)	Housing Density (Residential Only)
Commercial	95	
Business / Industrial	60	
Institutional	60	
High Density Multi-family Residential	50	10 to 12 units/acre
Medium Density Multi-family Residential	45	6 to 10 units/acre
High Density Single Family Residential	35	3 to 6 units/acre
Medium Density Single Family Residential (Traditional Neighborhood)	20	2 to 3 units/acre
Low Density Single Family Residential	15	1 to 2 units/acre
Very Low Density Single Family Residential	8	< 1 unit/acre
Parks	1	
Open Space	1	

Initial losses simulate initial interception and infiltration at the beginning of rainfall. Initial losses for pervious area under dry conditions (such as are typical in non-irrigated areas during summer periods of peak cloudburst potential) can be quite high. Initial losses for impervious areas are small, typically range from 0.02 to 0.08 inches. Initial losses for pervious areas can range from 0.2 to 1.0 inches, depending on soil type and vegetation cover.

Constant loss rates reflect ongoing infiltration during rainfall events. Infiltration rates are dependent on soil types. The SCS has classified soils into four hydrologic categories (A, B, C, and D) based on infiltration rates after prolonged wetting. Type A soils exhibit low runoff potential, and typically consist of gravels and sands. Type D soils exhibit high runoff potential, and typically consist of silts or clays. Constant loss rates for impervious areas are insignificant (generally less than 0.02 inches per hour) in a design storm event. Constant loss rates for pervious areas can range from 0.02 to 2.0 inches per hour depending on soil type and vegetation cover. For urban lawns and landscaping, constant loss rates typically range from 0.5 to 2.0 inches per hour.

Routing of Rainfall Runoff

Within a drainage subbasin, estimated lag time simulates the attenuation and translation of peak rainfall to peak runoff. Lag time for natural drainage areas, basin lag times can be estimated based on approximate collection channel lengths and slopes using the Corps of Engineers version of Snyder's equation for lag time (USBR, 1989). For Hurricane, the constant C_t is estimated to be 1.3. C_t can also be estimated as $26*K_n$, where K_n is the average Manning's n value for the principal watercourses in a drainage basin.

$$\text{Lag Time} = C_t \left(\frac{LL_{ca}}{S^{0.5}}\right)^{0.33}$$

For urban subbasins, the kinematic wave method can be used to simulate rainfall runoff routing. This method takes into account travel time for overland flow, gutter flow, collector pipe flow, and main channel or trunkline flow. Using the kinematic wave method in HEC-HMS, these components are combined to attenuate and translate subbasin rainfall to runoff. Typical overland flow parameters are shown in Table 2-5.

Table 2-5
Overland Flow Parameters
(Flow Depths less than 2 inches)

Surface	Manning's n for Overland Flow	Maximum Overland Flow Distance (ft)
Pavement: Smooth	0.02	50 - 200
Pavement: Rough/Cracked	0.05	50 - 200
Bare Soil: Newly Graded Areas	0.10	100 - 300
Range: Heavily Grazed	0.15	100 - 300
Turf: 1-2" - Lawns/Golf Courses	0.20	100 - 300
Turf: 2-4" - Parks/Medians/Pasture	0.30	200 - 500
Turf: 4-6" - Natural Grassland	0.40	200 - 500
Residential Landscaping	0.30 - 0.60	100 - 300
Desert Shrub: < 30% ground cover	0.50	300 - 600
Desert Shrub: 30% to 70% ground cover	0.60	300 - 600
Desert Shrub: > 70% ground cover	0.80	300 - 600

Total travel time can also be calculated independently using the travel time component method found in SCS Technical Release 55 (SCS, 1986). For small urban subbasins, lag time is approximately equal to total time of travel. For basins over 500 acres, lag time is typically 70 to 80 percent of the sum of travel time components. Care should be taken that lag times used in the drainage model provide reasonable velocities through the basin. Typical average velocities calculated from a lag time should range from 2-3 feet per second for an undeveloped condition and 3-5 feet per second for a developed basin.

Runoff from subbasins within a drainage area is combined using channel and storage routing elements to simulate primary storm drain conveyance and detention facilities. The Muskingum-Cunge channel routing method can be used for routing runoff from subbasins to and through the primary storm drain conveyances. Detailed information on channel geometry, slope, and roughness collected during surveys should be used where appropriate. Typical Manning's n values for storm drain conveyance facilities area shown in Table 2-6.

In natural alluvial streams, flow velocity does not exceed critical velocity except at control sections, which are usually limited in extent and are represented by riffles, cascades, and waterfalls. The mean channel slope calculated from topographic maps usually overestimates typical actual slopes since abrupt drops are included in the elevation difference. Channel velocities in naturally vegetated alluvial streams rarely exceed 8 ft/sec and are usually in the range of 4 to 6 ft/sec.

In ditches and pipes, prudent hydraulic design would limit velocities to non-damaging or non-erodible values by use of drop structures and energy dissipaters. Recommended maximum velocities are 12 ft/sec for concrete ditches, 10 ft/sec for pipes, 8 ft/sec for riprapped channels, 6 ft/sec for grass channels, and 4 ft/sec for earth channels. Supercritical velocity is sometimes allowed for concrete ditches and pipes, but great care is required in design and construction.

Storage routing elements are included in the model to simulate detention basins. Where available, stage-volume-discharge relationships for existing detention facilities should be used.

Table 2-6
Manning's n for Pipes, Open Channels, and Floodplains

Surface	Manning's n
Plastic pipe	0.012
Steel/cast iron pipe	0.013
Concrete pipe	0.013
Corrugated metal pipe	0.024
Corrugated multiplate arch culverts	0.030
Concrete-lined channel	0.016
Earth channel-straight/smooth	0.022
Earth channel-dredged	0.028
Grass trapezoidal ditch-straight/mowed	0.030
Natural channel-straight/clean/uniform	0.035
Natural channel-straight/pools and riffles	0.040
Natural channel-winding/pools/uneven/aquatic weeds	0.045
Natural channel-winding/stony/uneven/aquatic weeds	0.050
Natural channel-winding/stony 5-20% vegetation-stiff weeds/cattails/brush	0.060

Table 2-6
Manning's n for Pipes, Open Channels, and Floodplains
(continued)

Surface	Manning's n
Natural channel-debris/pools/rocks 20-50% stiff vegetation (weeds/cattails/willows)	0.070
Natural channel-winding/stony/pools 50-70% stiff vegetation	0.080
Natural channel-winding/stony/pools 70%-100% stiff vegetation	0.100
Floodplain-pasture/short grass/smooth	0.035
Floodplain-isolated trees/high grass/smooth	0.040
Floodplain-isolated trees/high grass/uneven	0.050
Floodplain-few trees/shrubs/tall weeds	0.060
Floodplain-few trees/shrubs/tall weeds/uneven	0.080
Floodplain-scattered shrubs/trees/tall weeds	0.100
Floodplain-scattered trees/shrubs/rocky	0.120
Floodplain-numerous trees/shrubs/vines	0.150
Floodplain-dense trees/shrubs/vines	0.200

Base Flow

HEC-HMS and HEC-1 includes provisions to account for base flow. Where base flow from groundwater springs or irrigation return flows is significant, a base flow component should be included in the hydrologic analysis.

Hydrologic Modeling Methods

Initial and Constant Loss

The Initial and Constant Loss method can be used to determine the runoff from undeveloped and developed conditions. However, it is typically conservative and should be checked with other methods.

SCS Composite Curve Number Method

The SCS composite curve number method uses a composite CN that represents all of the different soil groups and land use combinations within the sub-basin. The drainage study should document how the CN was calculated. An initial abstraction is automatically calculated by one of the two HEC programs. This method typically works well for undeveloped basins. However, it has provided unrealistic runoff amounts for developed basins in the Hurricane area and should be checked carefully against other methods if it is used.

SCS Pervious Curve Number Method

The SCS pervious curve number method uses a composite pervious CN that represents all of the different soil groups and land use combinations (such as lawn and xeriscape) within the sub-basin for the PERVIOUS areas only. The directly connected impervious area should then be determined. The CN representing the pervious areas only and the percent impervious should then be entered into the sub-basin model. This method has provided realistic runoff amounts and should be used to calculate the runoff from developed sub-basins. The drainage study should document how the pervious CN and percent impervious were calculated.

Rational Method

The Rational formula may be used in designing capacities for drainage collection facilities for 10-year flood recurrence for drainage areas less than 10 acres. Time of concentration can be calculated from travel time components. In general, time of concentration should not be shorter than 10 minutes. Rainfall intensity can be interpolated from Table 2-1. Rational Formula runoff coefficients are shown in Table 2-7. These coefficients should be area weighted for land use and soil type. While the Rational method is typically conservative, it can provide a quick check for other methods.

Table 2-7
Rational Method Runoff Coefficients

Land Use/Land Cover Category	Soil Type			
	A	B	C	D
Commercial	0.95	0.95	0.95	0.95
Business / Industrial	0.90	0.90	0.90	0.90
Institutional	0.90	0.90	0.90	0.90
High Density Multi-family Residential	0.70	0.75	0.80	0.85
Medium Density Multi-family Residential	0.60	0.65	0.70	0.75
High Density Single Family Residential	0.50	0.55	0.60	0.65
Medium Density Single Family Residential (Traditional Neighborhood)	0.25	0.30	0.35	0.40
Low Density Single Family Residential	0.15	0.20	0.25	0.30
Very Low Density Single Family Residential	0.08	0.12	0.17	0.22
Urban Lawns/Parks	0.00	0.02	0.10	0.20
Urban Landscaping/Gardens	0.00	0.01	0.05	0.10
Bare Soil: Newly Graded Areas	0.02	0.10	0.30	0.50
Irrigated Pasture/Agriculture	0.02	0.05	0.15	0.25
Wetlands	0.99	0.99	0.99	0.99
Desert Shrub: < 30% ground cover	0.01	0.10	0.15	0.20
Desert Shrub: 30% to 70% ground cover	0.01	0.05	0.10	0.15
Desert Shrub: > 70% ground cover	0.01	0.02	0.05	0.10

Model Calibration

In general, calibration of a HEC-based hydrologic model should proceed according to the following guidelines:

- Actual flow records for modeled drainage channels should be used whenever possible
- Streamflow records from hydrologically similar drainages in the vicinity of the study area can be used when actual flow records for the studied drainage are not available
- Regional streamflow data can be used in the event that streamflow records for the local area are not available. The most commonly used data of this type are the regional regression equations developed by the U.S. Geological Survey (USGS, 1994).

As noted previously, peak runoff records are typically not available for local drainage studies. An effort should, however, be made to ensure that rainfall runoff analysis results for local drainage studies are consistent and compatible with the City's Storm Drain Master Plan and other pertinent local drainage studies. It should be noted that the term "calibration" in this case refers to the process of adjusting parameters to achieve results consistent with available reference information, rather than adjusting for actual stream flow observations from the study area. Multiple hydrologic methods should be evaluated and compared to identify reasonable runoff amounts. These methods may include the Rational formula, the SCS Curve Number Method, the SCS Previous CN Method, and the Constant and Initial Loss Method. Regional regression equations may also be used to evaluate results depending on the basin size.

SECTION 3
DESIGN CRITERIA

STREETS

Streets are a significant and important component in urban drainage and may be made use of in storm runoff within reasonable limits. Reasonable limits for the use of streets for runoff shall be set by the City Engineer. Design criteria for gutter capacity and associated lane encroachment will depend on the roadway type as shown in Table 2-1. Street designs must include surface drainage relief points (inlets). This is especially important for flat gradient areas, local sumps or depressions and cul-de-sacs. Catch basins should be located on both sides of the street, in general, and the spacing between catch basin locations should not exceed 400 feet.

For pedestrian safety, street flows must be limited such that the product of the depth (feet) and velocity (feet/second) does not exceed six for the 10-year flow and eight for the 100-year flow. Curb overtopping is not permitted in the 10-year event. When street encroachment limits are met, an underground storm sewer system shall be required. Where this underground conveyance is required to limit street flows, it will be designed for the 10-year design storm or greater.

Table 3-1
Street Gutter Capacity for 100-Year Event

Street Classification	Maximum Encroachment
Local (Residential)	No curb overtopping.* Flow may spread to crown of street.
Minor collector (Residential)	No curb overtopping.* Flow spread must leave one lane free of water.
Major Collector	No curb overtopping.* Flow spread must leave at least two lanes of travel free. (One lane in each direction)
Arterial	No Curb overtopping.* All travel lanes to remain open.
Major Arterial	No Curb overtopping.* No encroachment is allowed on any traffic lane.

*Where no curb exists, encroachment shall not extend over property lines.

Streets must also provide for routing of the 100-year design storm to adequate downstream conveyance facilities. The 100-year flood flows in streets should be contained within street right-of-way and adjacent drainage easements. Provision should be made to allow flows within the street to enter any downstream detention basins or other such facilities.

While the 100-year flow is the largest storm required in this manual, consideration should be given to requiring a flood easement to convey the 500 year storm through the natural lowpoint of a basin. While this area could be used for roads and recreation type facilities, buildings would not be allowed within this corridor.

STORM DRAINS

Storm drain design conveyance capacity will be sized for a minimum of the 10-year, 3-hour design flood. The storm drain system should be of sufficient capacity to prevent significant damage to property during the 100-year, 3-hour design flood as the streets will most likely not be able to convey the difference between the 10-year and 100-year storms. Inlets must have sufficient capacity to prevent local ponding during the 10-year event, with 50 percent blockage of inlets by debris. Analysis of combined street and storm drain capacity for the 100-year flood must determine maximum ponding depths and water levels and show that these depths are non-damaging. In instances where sufficient combined capacity does not exist, the storm drain size may have to be increased beyond that of the 10-year design.

In areas where underground water is anticipated to be added to the drainage system, the pipe size should be increased accordingly. In general, ground water will not be allowed to flow in streets and gutters and in other overland flow situations.

Design considerations will be given for differences in interception capacity of inlets on a gradient as compared to interception capacity of inlets in sag locations. Inlet spacing and locations will be for continuous grade or sag situations as appropriate. Inlets will be spaced so as to keep the street encroachment of flood waters to the minimum. Sag points may be required to have additional inlets spaced to control the maximum level of ponding. Curb inlets are typically only capable of catching two to three cfs and should be of sufficient number to allow the pipe to flow full. The Clark County Hydrologic Criteria and Drainage Design Manual has nomographs that can be used to estimate the capacity of various configurations.

All storm drains will be designed by application of the Manning's equation. Minimum design velocity shall be 2.0 feet/second flowing one-half full. The Manning's n value shall represent that value that will be seen during the useful life of pipe which may differ from that of a new pipe. The hydraulic grade line will be shown for all pipe systems. The minimum storm drain diameter shall be 15-inch.

Storm drains shall not be designed for surcharged (pressure) pipe conditions unless otherwise approved by the City Engineer. When storm drains are designed for full pipe flow, or surcharged pipe conditions, the designer shall establish the hydraulic grade line considering head losses caused by flow resistance in the pipe, and changes of momentum and interferences at junctions, bends and structures. The water surface elevation profile and hydraulic grade line will be shown for the 10-year and the 100-year design.

CULVERTS

In general, culverts are used to carry runoff from an open channel or ditch under a roadway to a receiving open channel or ditch. The minimum culvert diameter shall be 24 inches. All culvert crossings under a roadway shall be designed to convey the 100-year storm. No road overtopping will be permitted for culvert crossings under arterial roads. Any other road overtopping shall be limited by the velocity/depth ratio.

A culvert entrance blockage factor of up to 50 percent shall be used for small diameter culverts and culverts placed in drainages with upstream debris as determined by the City. The 100-year design storm water backwater surface upstream will be determined (using HEC-2 or HEC-RAS) unless otherwise not required by the City. The back water must be shown to be non-damaging and be approved by the affected property owner. Potential paths of embankment overtopping flows will be determined and redirected, if necessary, so that no significant flood damage occurs. Entrance and exit structures must be installed to minimize erosion and maintenance. The minimum culvert slope shall be 1 percent unless otherwise approved.

BRIDGES

Bridges consist of major structures crossing major washes or drainages. The roadway facility handled can be any classification of roadway. Low water crossings are generally not permitted. Bridges can consist of free span structures, box culverts, multiple box culverts, multiple precast bridges and others.

Free-span bridges must pass the 100-year event with a minimum of 2.0 feet of freeboard. No significant increases are allowed in upstream water levels. A HEC-2 or HEC-RAS analysis of potential upstream water surface may be required by the City. Local and regional scour analyses are required on the structure, upstream and downstream, and embankments. All potential scour will be mitigated. Appropriate references for this include the UDOT Manual of Instruction for Roadway Drainage (2004); Stream Stability at Highway Structures, Hydraulic Engineering Circular No. 20, Federal Highway Administration; Evaluating Scour at Bridges, Hydraulic Engineering Circular No. 18, Federal Highway Administration; and Bridge Scour and Stream Instability Countermeasures, Hydraulic Engineering Circular No. 23, Federal Highway Administration.

For structures crossing FEMA designated flood plains and drainages, other requirements will be used, as directed by the City.

OPEN CHANNELS

Generally, there are two types of channels: man-made and natural. Natural channels can be further subdivided into several sub-categories such as un-encroached, encroached, partially encroached, bank-lined and others. The 100-year recurrence flood will be used for design for all channels unless otherwise approved by the City. All open channels must be designed as permanent in nature and have a minimum freeboard of 1 foot. They must be designed as generally low maintenance facilities and must have adequate maintenance access for the entire length.

Man-made Channels

Man-made channel side slopes will generally be limited to a maximum slope of 2H:1V. Flatter slopes are generally recommended for maintenance and safety reasons. Safety is a primary concern. A channel should be designed such that a person falling into it could climb out within a reasonable distance. A channel that is shallow in depth or in remote areas, or in areas of restricted right-of-way may, upon approval, have a steeper slope. Maximum velocities will depend on the type of material used for the channel lining. Supercritical velocities are not permitted for any material used. Drop structures and other energy dissipating design may be required to limit velocities to control erosion and head cutting.

Maximum velocities for grass lined channels depend on the type of grass mixture. The designers should consult appropriate design literature for details. It is assumed that grass lined channels will be mowed at least annually. The minimum bottom width of a grass lined channel will be 6 feet unless otherwise approved by the maintenance agency. The minimum bottom width of all man-made channels shall be designed to facilitate access and maintenance.

Natural Channels

The use and preservation of natural drainage ways shall be encouraged. Natural channels for drainage conveyance can reduce long term maintenance costs, can reduce initial costs associated with drainage, and can enhance passive recreation and open space uses. When natural channels are incorporated into the drainage control plan, consideration shall be given to the impact of increased flows due to improvements to upstream drainage basins and areas, adequate access for maintenance and debris removal, long-term degradation and erosion potential, and the need for additional set-backs for structures.

STORAGE FACILITIES

Generally, there are two types of storm water storage facilities: retention and detention. Retention ponds which are normally intended for infiltration of stored water may require extensive subsoil and groundwater studies as well as extensive maintenance requirements and safety concerns and are generally not allowed.

Detention facilities (basins) are used to temporarily store runoff and reduce the peak discharge by allowing flow to be discharged at a controlled rate. The controlled discharge rate is based on either limited down stream capacity, as in regional basins, or on a limit on the increase in flows over pre-development conditions, as in local facilities, and in some instances both.

Regional detention facilities are those identified by the City and will be identified in the Storm Drain Master Plan and other regional studies. Generally, these facilities control flow on major washes or drainage basins, are of major proportion, and are built as part of major development or mitigation plans.

Local detention facilities are usually designed by and financed by developers or local property owners desiring to improve their property. These facilities are intended to allow development of property by protecting a site from existing flooding and/or to protect downstream property from increased runoff caused by development. In small facilities, detention storage volume may be provided in small landscaped basins, parking lots, underground vaults, excess open space, or a suitable combination. In larger facilities, dual functions may be served. These larger facilities are required to reduce existing flooding to allow a development and/or control increased runoff caused by the development itself. These larger facilities may store significant flood volumes and may handle both off-site and on-site flows.

Detention facilities will generally be used to prevent local increases in the 10-year, 24-hour and the 100-year, 24-hour peak flows, or the 100-year 3-hour storm, whichever case requires the largest volume. Post-development discharges must not exceed pre-development discharges or .2 cfs per acre, whichever is less. If downstream facilities lack adequate capacity to handle the flow, lower release rates must be used.

Standard engineering practice shall be used in determining the volume of the required facilities. A minimum of 1 foot of freeboard is required above the maximum water surface elevation. Emergency spillways or overflows will be incorporated into all designs. Structures and facilities shall be design so as not to be damaged is case of emergency overflow. Detention basins must empty within 24 hours of a storm event. The maximum depth of a basin should be 3 feet unless otherwise approved. Below grade basins are preferred. Partially wet basins may be allowed for recreational or aesthetic purposes, but storage below permanent spillways or low-level outlets cannot be included in control calculations. Groundwater should not be introduced into detention basins without approval of the City. Multi-use (e.g. recreation) should be considered for all detention basins.

Energy dissipation and erosion protection is required at all outlet structures where storm drainage is released into a natural or erodible channel, unless otherwise approved by the City. All basins are required to function properly under debris and sedimentation conditions. Adequate access must be provided to allow for cleaning and maintenance. All basins shall be designed as permanent facilities unless otherwise approved in writing by the City.

FLOODPLAINS

Flood plains are generally classified as FEMA and non-FEMA. Any work in and around FEMA designated and mapped floodplains should refer to the local ordinance governing their use. All work in the FEMA floodplain requires an appropriate permit.

Non-FEMA Floodplains

In general, all building floor levels should be constructed two feet above the 100-year flood level. Encroachments into the 100-year floodplain for natural water courses will not be permitted unless otherwise permitted by the City. All natural drainages, washes, and waterways that convey a developed 100-year flow of greater that 150 cfs will be left open unless otherwise approved. Developments located adjacent to or in floodplains may be required to stabilize the continual degradation and erosion of the channel by installing grade control structures and/or by other effective means. Any alteration of the floodplain is not permitted unless the proposed use can be shown to have no significant negative influence on the flood conveyance, the floodplain, or the alteration itself.

In the layout and design of new developments, adequate access to floodplains and erosion protection shall be provided. It is preferred that streets be positioned between floodplains and structures. Where not possible or feasible, additional structural setbacks will be required.

Hydrologic, hydraulic, erosion, and geomorpholigic studies will be required of developments adjacent to floodplains.

EROSION CONTROL

Necessary measures shall be taken to prevent erosion due to drainage at all points in new developments. During grading and construction, the developer shall control all potential storm runoff so that eroded soil and debris cannot enter any downstream water course or adjoining property. All drainage that leaves a new development shall be adequately addressed to mitigate all erosion on adjacent properties. Erosion mitigation shall be permanent unless otherwise approved. A comprehensive reference on erosion control is Sedimentation Engineering by the ASCE.

IRRIGATION DITCHES

In general, irrigation ditches shall not be used as outfall points for drainage systems, unless such use is shown to be without unreasonable hazard substantiated by adequate hydraulic engineering analysis.

In general, irrigation ditches are constructed on very flat slopes and with limited carrying capacity. It is obvious, based on experience and hydraulic calculations, that irrigation ditches cannot, as a general rule, be used as an outfall point for storm drainage because of physical limitations. Exceptions to the rule are when the capacity of the irrigation ditch is adequate to carry the normal ditch flow plus the maximum storm runoff with adequate freeboard to obviate creating a hazard to property and persons below and around the ditch. Ditches are seldom for use as a storm drain.

Irrigation ditches are sometimes abandoned in areas where agricultural use has subsided. Provisions must be made for ditch perpetuation prior to its being chosen and used as an outfall for drainage. Use of irrigation ditches for collection and transportation of storm runoff shall be made only when in accordance with the Storm Drain Master Plan.

SECTION 4
DRAINAGE CONTROL REPORT AND PLAN

Prior to approval of construction drawings for new development a drainage control plan and report shall be prepared by a licensed professional civil engineer registered in the State of Utah.

DRAINAGE CONTROL PLAN AND REPORT

The report portion of the Drainage Control Plan and Report shall contain the following:

1. Title page showing project name, date, preparers name, seal and signature.

2. Description of property, area, existing site conditions including all existing drainage facilities such as ditches, canals, washes, structures, etc.

3. Description of off-site drainage upstream and downstream.

4. Description of on-site drainage.

5. Description of master planned drainage and how development conforms.

6. Description of FEMA floodplain if applicable.

7. Description of other drainage studies that affect the site.

8. Description of proposed drainage facilities.

9. Description of compliance with applicable flood control requirements and FEMA requirements if applicable.

10. Description of design runoff computations.

11. Description of drainage facility design computations.

12. Description of all easements and rights-of-way required.

13. Description of FEMA floodway and floodplain calculations if applicable.

14. Conclusions stating compliance with drainage requirements and opinion of effectiveness of proposed drainage facilities and accuracy of calculations.

15. Appendices showing all applicable reference information.

A drainage plan on separate 24-inch by 36-inch sheet(s) shall be submitted with the Drainage Control Plan and Report showing the following information if applicable.

1. Existing and proposed property lines.

2. Existing and proposed streets, easements, and rights-of-way.

3. Existing drainage facilities.

4. FEMA floodplain, floodway and meander boundaries.

5. Drainage basin boundaries and subbasin boundaries

6. Existing flow patterns and paths.

7. Proposed flow patterns and paths.

8. Location of proposed drainage facilities.

9. Details of proposed drainage facilities.

10. Location of drainage easements required.

11. Scale, north arrow, legend, title block showing project name, date, preparers name, seal and signature.

CONCEPTUAL DRAINAGE CONTROL PLAN AND REPORT

Prior to Planning Commission or review of Planned Development Zone Changes, Preliminary Plats, or Conditional Use Permits, the City Engineer may require a Conceptual Drainage Control Plan and Report containing the following information:

1. General description of the development.

2. General description of existing drainage facilities

3. General description of property, area, existing site conditions including all existing drainage facilities such as ditches, canals, washes, structures, and any proposed modifications to drainage facilities.

4. General description of off-site drainage upstream and downstream and known drainage problems.

5. General description of on-site drainage and potential drainage problems.

6. General description of master planned drainage facilities and proposed drainage measures and how development conforms.

7. Existing FEMA floodplain boundaries if applicable.

8. Exhibit showing required information.

9. Preliminary Drainage Calculations if required by the City Engineer.

SECTION 5
REFERENCES

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Humphrey, John H., CH2MHill, June 1996, Drainage Guidelines and Hydrology Manual, prepared for the City of St. George.

National Oceanic and Atmospheric Administration, 2006, NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume I, Version 4, Semiarid Southwest.

Thomas, B.E., H.W. Hjalmarson and S.D. Waltemeyer, 1994, Methods for Estimating the Magnitude and Frequency of Floods in the Southwestern United States, U.S. Geological Survey, Open File Report 93-419.

U.S. Army Corps of Engineers, December 1979, Project Cloudburst, Salt Lake County, Utah, Internal File Report.

U.S. Department of Agriculture, Soil Conservation Service, June 1986, Urban Hydrology for Small Watersheds, Technical Release 55.

U.S. Department of the Interior, Bureau of Reclamation, 1989, Flood Hydrology Manual.

U.S. Department of the Interior, Geological Survey, March 1982. Interagency Advisory Committee on Water Data, Office of Water Data Coordination, Hydrology Subcommittee, Bulletin No. 17B.

WRC Engineering, Inc., October 1990. Hydrologic Criteria and Drainage Design Manual, Clark County Regional Flood Control District, Las Vegas, Nevada.

APPENDIX
STORM DISTRIBUTIONS
Farmer Fletcher 3-Hour Storms

Time (min)	10yr 3-hr (Inches)	100yr 3-hr (Inches)
0	0.000	0.000
5	0.008	0.008
10	0.008	0.008
15	0.008	0.008
20	0.008	0.008
25	0.008	0.008
30	0.008	0.008
35	0.260	0.484
40	0.200	0.382
45	0.150	0.267
50	0.090	0.170
55	0.050	0.102
60	0.040	0.078
65	0.040	0.058
70	0.020	0.044
75	0.020	0.034
80	0.010	0.031
85	0.020	0.027
90	0.010	0.022
95	0.008	0.008
100	0.008	0.008
105	0.008	0.008
110	0.008	0.008
115	0.008	0.008
120	0.008	0.008
125	0.008	0.008
130	0.008	0.008
135	0.008	0.008
140	0.008	0.008
145	0.008	0.008
150	0.008	0.008
155	0.008	0.008
160	0.008	0.008
165	0.008	0.008
170	0.008	0.008
175	0.008	0.008
180	0.008	0.008

SCS TYPE II 100-Year, 24-Hour Storm Distribution

Time (min)	100yr 24-hr (Inches)	Time (min)	100yr 24-hr (Inches)
0	0.000	750	0.198
30	0.015	780	0.103
60	0.015	810	0.073
90	0.015	840	0.057
120	0.016	870	0.051
150	0.017	900	0.044
180	0.017	930	0.038
210	0.018	960	0.034
240	0.019	990	0.031
270	0.020	1020	0.029
300	0.021	1050	0.026
330	0.022	1080	0.025
360	0.023	1110	0.023
390	0.025	1140	0.022
420	0.027	1170	0.021
450	0.029	1200	0.020
480	0.031	1230	0.019
510	0.035	1260	0.018
540	0.038	1290	0.018
570	0.044	1320	0.017
600	0.051	1350	0.016
630	0.065	1380	0.015
660	0.085	1410	0.015
690	0.133	1440	0.015