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GRAND COUNTY DESIGN CRITERIA FOR DRAINAGE STUDIES WITHIN SPANISH VALLEY

GRAND COUNTY

HORROCKS ENGINEERS

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DECEMBER 2011

Prepared for
Grand County



By
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1 INTRODUCTION

1.1 GENERAL INFORMATION

The *Grand County Design Criteria for Drainage Studies Within Spanish Valley* is a document by which the County can regulate all drainage studies and designs and ensure all drainage studies and designs are consistent with the methodology and recommendations outlined in the *Spanish Valley Storm Drain Master Plan Update* (2011). The criteria set forth in this document are not all inclusive of design criteria and design procedures that shall be used when performing drainage studies and designs. The current editions of the Hydraulic Engineering Circulars (HEC) and the Hydraulic Design Series (HDS) produced by the Federal Highway Administration of the U.S. Department of Transportation shall be used as reference and further guidance to appropriate analysis and design techniques and procedures but will not supersede any criteria outlined in this document. All drainage studies and designs must be approved by the County Engineer. This document does not cover drainage details and construction specifications. APWA standard details and specifications apply.

2 DESIGN STANDARDS

The following Design Standards apply to the design of all storm water management improvements whether public or private, whether within new development or drainage from off-site, whether above or below drainage outfall locations, whether within a 100-year flood plain or not, or within a natural channel or not. Drainage studies and designs for areas within the Spanish Valley must follow standards outlined in this document and any additional standards and criteria set forth by the current County Engineer. For the analysis and design standards and approach for items not discussed in this document, refer to the current editions of the Hydraulic Engineering Circulars (HEC) and the Hydraulic Design Series (HDS) produced by the Federal Highway Administration of the U.S. Department of Transportation or other materials approved by the current County Engineer.

All hydrologic and hydraulic evaluation and design for a proposed development shall be performed in accordance with sound and accepted engineering practice. All drainage studies and designs must be reviewed and approved by the County Engineer and shall conform to the *Spanish Valley Storm Drain Master Plan Update* (2011).

2.1 HYDROLOGIC EVALUATION

Watershed storm water management requires the determination of two runoff parameters: peak rate of discharge and volume. Both parameters shall be used in the comparison of pre-development and post-development conditions.

Peak rate of discharge calculations shall be used to determine the configurations and sizes of pipes, channels, and other routing or flow control structures. Runoff volume calculations shall be used to determine the necessity for, and sizing of, detention and retention facilities.

All components of the storm drainage system shall be sized based on the design frequency in Table 2-1. A more in depth description of the design frequency and all design criteria for each component of the storm drainage system is given later in the chapter. The size of the drainage area shall include on-site and off-site lands contributing to the design point.

Table 2-1: Design Frequency

Design Storm	Facilities
10-year	Inlets, laterals, minor trunk lines, and roadway spread
100-year	Storage basins, culverts, major trunk lines, and major conveyance facilities

2.1.1 RUNOFF PEAK RATE OF DISCHARGE CALCULATION

The peak rate of runoff for areas of up to 10 acres may be calculated by the Rational Method or one of its derivatives. The Rational Method shall be used with caution if the time of concentration exceeds 30

minutes and shall never be used when the time of concentration exceeds 1 hour. Computer software adaptations of the Rational Method calculations are acceptable provided that their data and graphic printout allow review and evaluation. The peak rate of runoff for all areas which do not use the Rational Method, or are greater than 10 acres, shall be calculated with the Natural Resources Conservation Service (NRCS) unit hydrograph and curve number method, also known as the SCS method. Computer programs such as TR-20, TR-55, HEC-1, or HEC-HMS may be used.

Depending on the shape and size of the drainage basin, the quick runoff from the streets and adjacent impervious areas may be the worst case, producing a greater peak runoff rate than from the whole drainage basin. This scenario shall be checked and the time of concentration and drainage area shall be adjusted as necessary if this case produces the largest peak rate of runoff.

2.1.2 Runoff Volume Calculation

Runoff volume shall be calculated based on the NRCS method within TR-20, TR-55, HEC-1, or the HEC-HMS computer program. The NRCS method shall be used for watersheds with drainage areas of less than 5 square miles. The design of storage facilities shall be based on the NRCS method within a computer program such as HEC-1, HEC-HMS, or PondPack. Other computer software adaptations of these runoff value calculations may be acceptable provided that their data and graphic printout allow review and evaluation.

For detention design, a 100-year 24-hour storm shall be used to calculate basin inflow. Detention basin outflow shall be based on the 10-year historic release rate for the land within the project area and off-site contributing areas, unless special circumstances are involved. In the case of special circumstances, the designer must obtain approval from the current County Engineer. The 10-year historic release rate is defined as the runoff rate that would have occurred due to a 10-year storm assuming the area is in a natural condition before man-made changes were introduce. The 10-year historic release rate is discussed in section 2.3.2 and shown in Figure 2-1.

2.1.3 Design Storms

Table 2-2 and Table 2-3 give the precipitation depth and precipitation intensity to be used for all projects within the portion of Spanish Valley under Grand County jurisdiction. This data was obtained from NOAA Atlas 14 (January 2009) via the National Oceanic and Atmospheric Administration's (NOAA) Precipitation Frequency Data Server (http://hdsc.nws.noaa.gov/hdsc/pfds/sa/ut_pfds.html).

The values given in the tables are the weighted average of several different locations within the Spanish Valley, covering areas from the valley to the upper ridges. The data is based on the NOAA Atlas 14 partial duration series, with ARI representing the Average Recurrence Interval. In all instances, a minimum time of concentration of 5 minutes shall be used. When using the NRCS method of analysis, the NRCS Type II-24 hour precipitation temporal distribution and the NRCS unit hydrograph shall be used, along with 24 hour duration precipitation values.

Table 2-2: Spanish Valley Average Precipitation Depth/Duration/Frequency.

Precipitation Depth (inches)										
ARI (years)	5 min	10 min	15 min	30 min	60 min	2 hr	3 hr	6 hr	12 hr	24 hr
1	0.11	0.17	0.21	0.28	0.35	0.43	0.48	0.60	0.74	0.93
2	0.14	0.22	0.27	0.36	0.44	0.55	0.60	0.75	0.93	1.17
5	0.19	0.29	0.36	0.49	0.60	0.73	0.79	0.95	1.16	1.47
10	0.24	0.36	0.45	0.60	0.75	0.91	0.96	1.13	1.36	1.74
25	0.31	0.47	0.59	0.79	0.98	1.21	1.24	1.41	1.65	2.13
50	0.37	0.57	0.71	0.95	1.18	1.48	1.52	1.65	1.90	2.45
100	0.45	0.69	0.85	1.14	1.42	1.81	1.85	1.95	2.17	2.82

Table 2-3: Spanish Valley Average Precipitation Intensity/Duration/Frequency.

Precipitation Intensity (inches/hour)										
ARI (years)	5 min	10 min	15 min	30 min	60 min	2 hr	3 hr	6 hr	12 hr	24 hr
1	1.34	1.01	0.83	0.57	0.35	0.22	0.16	0.10	0.06	0.04
2	1.71	1.29	1.07	0.72	0.44	0.27	0.20	0.12	0.08	0.05
5	2.30	1.74	1.44	0.97	0.60	0.37	0.26	0.16	0.10	0.06
10	2.82	2.16	1.79	1.21	0.75	0.45	0.32	0.19	0.11	0.07
25	3.72	2.83	2.34	1.58	0.98	0.60	0.41	0.24	0.14	0.09
50	4.47	3.41	2.82	1.90	1.18	0.74	0.51	0.28	0.16	0.10
100	5.40	4.12	3.40	2.29	1.42	0.90	0.62	0.32	0.18	0.12

2.1.4 TIME OF CONCENTRATION

Several different methods and equations may be used to determine the time of concentration of a watershed. Some equations, such as the NRCS lag equation, are calibrated for the entire watershed; whereas, other methods include the summation of the travel time for sheet flow, shallow concentrated flow, and open channel flow along the principal flow path. The designer shall select the appropriate methods and equations for the flow path and design approach used.

When computing the travel time along natural channels, the channel shall be approximated as trapezoidal. Values of Manning's n to be used for natural channels and floodplains shall be obtained from *Hydraulic Design Series No. 3 – Design Charts for Open Channel Flow*. Note that the average slope for a natural stream shall exclude the influence of short drops or rapid flow sections. In natural alluvial streams, flow velocity does not exceed critical velocity except at control sections. These control sections are usually limited in extent and represented by riffles, cascades, and waterfalls. Within the Spanish Valley, these control sections can be identified by rock outcrops within the channels. After an initial analysis, it may be necessary to revise the Manning's n and channel slope along the natural channel flow path to reduce the velocity to a maximum of critical velocity. The NRCS lag equation is not influenced by

the abrupt channel drops, since it is based on the average watershed slope, not the slope along the principal flow path.

2.2 HYDRAULIC EVALUATION

The hydraulic evaluation and design for a proposed development shall be performed in accordance with sound and accepted engineering practice. A system emphasizing a natural as opposed to an engineered drainage strategy is encouraged. The applicability of a natural approach depends of such factors as site storage capacity, open channel hydraulic capacity, and maintenance needs and resources. Hydraulic capacity for open channel or closed conduit flow shall be determined by the Manning Equation.

Velocities in open channels at design flow shall not be greater than that velocity which will begin to cause erosion or scouring of the channel. Velocities in closed conduits at design flow shall be at least 2 ft/sec but not more than the velocity which will cause erosion damage to the conduit. Refer to section 2.8.1 regarding the design for erosion control.

2.3 STORAGE CRITERIA

Provision of storage can: reduce peak runoff rates; aid in the recharge of groundwater; provide an attenuation mechanism if storm water is to be treated; lessen the possibility of downstream flooding, stream erosion, and sedimentation; and can be used in the development of upstream areas to avoid increasing the runoff peaks which impact existing downstream facilities. Types of storage basins include those used for detention and retention.

Retention facilities are used as infiltration basins, with the only outlet being the emergency spillway. Due to concerns with sedimentation and inadequate infiltration capacities, retention basins are not allowed in Grand County, unless approved by the County Engineer. When retention basins are allowed, extensive soil studies of the saturated and unsaturated zones are required in order to ensure that the retention basin will function properly over the life of the basin. Furthermore, a strict maintenance plan must be approved by the County Engineer to ensure the basin is kept clean of sediment, and debris.

Detention facilities are used to temporarily detain storm water runoff and release it at a controlled rate. The controlled rate is outlined in section 2.3.2 Design Requirements. These facilities shall be designed to completely drain within 24 hours after the end of a storm event. If this is not possible due to requirements for water quality or maximum release rate, a design exception must be approved by the County Engineer to allow for longer detention times. Detention storage facilities may include large basins, small landscaped basins, parking lot storage, roof tops, underground storage vaults, parks, and recreational fields, or an appropriate combination.

Other types of storage basins include permanent ponds, lakes and reservoirs. Design criteria for these types of storage basins are not included in this document. The installation and design of these types of structures must be approved by the County Engineer.

2.3.1 PARKING LOT PONDING

Parking lot ponding shall be arranged so that pedestrians can reach their destinations without walking through ponded water. The ponding shall be relegated to those portions farthest from the use served or

to overflow parking areas, and shall be a reasonable portion of the total area so that sufficient parking remains available for use. Ponding areas shall not interfere with routes and parking spaces needed for compliance to the Americans with Disabilities Act (ADA). The maximum design depth of ponding can vary depending upon the location. An overflow outlet shall be provided so that runoff from major storms is limited to a seven-inch depth. Debris may accumulate at outlet drains, which may reduce the capacity of the drain and become unsightly; therefore, provisions shall be made for periodic cleaning. The use of semi-paved/semi-grassed areas for overflow parking which will permit infiltration of rainfall and reduce the total runoff associated with parking lot pavements is encouraged.

2.3.2 DESIGN REQUIREMENTS

Regional detention basins are those identified in the *Spanish Valley Storm Drain Master Plan Update* (2011). These detention basins are sized based on runoff from a 100-yr 24 hour storm under existing (2009 conditions) land use. All new development must provided sufficient storage to account for the additional runoff created by the development.

The allowable post-developed discharge rate within Spanish Valley is based on the 10-yr historic peak runoff rate. Spanish Valley is divided into two regions, each region having a unique 10-year historic runoff rate, designated as Region 1 and Region 2. Region 1 includes Types A and B hydrologic soil groups and has an allowable discharge rate of 0.03 cfs per acre for the 100-yr 24 hour storm. Region 2 includes Types C and D hydrologic soil groups and has an allowable discharge rate of 0.3 cfs per acre for the 100-yr 24 hour storm. The two different regions and their allowable discharge rate are shown in Figure 2-1. In Figure 2-1, the shaded areas are Region 2 and the areas of the clear aerial image are Region 1.

Adequate storage shall be provided such that each of the following applies:

- Post-developed discharge rates shall not exceed pre-developed discharge rates for the same storm.
- The peak discharge rate from the post-developed 100-yr 24 hour storm shall not exceed 0.03 cfs per acre for Region 1 or 0.3 cfs per acre for Region 2, when routed through the principal outlets.
- The entire 100-yr 24 hour storm shall be routed through the principal outlet without entering the emergency spillway.
- The peak 100-yr discharge rate from the detention basin shall not exceed the capacity of the downstream conveyance system, with considerations given to inflows occurring below the detention basin.
- Retention basins, if allowed by the County Engineer, must be sized with a storage volume equal to the entire 100-yr post-developed runoff volume.

Runoff greater than that occurring from the 100-year, 24-hour storm will be passed over an emergency spillway. The emergency spillway must be designed to safely pass the entire post-developed 100-year



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GRAND COUNTY

DESIGN CRITERIA FOR DRAINAGE STUDIES
WITHIN SPANISH VALLEY

GRAPHIC SCALE

0 1,062.5 2,125 3,187.5 4,250 Feet

1 inch equals 2,125 feet

SPANISH VALLEY
ALLOWABLE RELEASE RATE PER ACRE
PER REGION

FIGURE 2-1

flood, routed through the detention basin assuming the principal outlets are not functioning. Furthermore, the peak emergency spillway flow rate shall not exceed the existing 100-yr flow rate entering the detention basin (based on conditions existing before the basin is constructed). A minimum of 1 foot of freeboard above the emergency spillway design water surface elevation is required.

The Principal Outlet Outflow Hydrograph is generated by routing the post-developed 100-yr 24 hour storm through the principal outlet without any flow entering the emergency spillway. The Emergency Spillway Outflow Hydrograph is generated by routing the post-developed 100-yr 24 hour storm through the emergency spillway assuming the principal outlets are not functioning. Conveyance systems below detention basins must have sufficient capacity for the greater of the following:

- Sufficient capacity to safely convey the 100-yr 24 hour peak flow obtained from combining the Principal Outlet Outflow Hydrograph with downstream inflow hydrographs.

- Sufficient capacity to safely convey the 100-yr 24 hour peak flow obtained from combining the Emergency Spillway Outflow Hydrograph with downstream inflow hydrographs.

In order to account for storage loss due to sedimentation of storage facilities, the required storage volume below the emergency spillway crest shall be increased by 20%. Storage facilities shall be constructed first in a project's construction sequence in order to reduce the amount of sediment carried further downstream. Temporary structures may be necessary during the construction phase to trap sediment before it enters the storage facility. Furthermore, storage facilities shall be cleaned at the completion of the project construction such that the entire required storage volume is available for runoff storage.

Storage facilities shall be located as far horizontally from surface water bodies and as far vertically from the seasonal high-water table as possible. The bottom of storage facilities shall not intercept the post-developed seasonal high-water table of underlying aquifers.

If the detention basin is classified as a dam, the facility shall also comply with prevailing dam safety standards as outlined by the Utah State Dam Safety Act and the Utah Division of Water Rights.

The following list of general structural criteria shall be used to design storm water detention basins. Due to the uniqueness of each storm water detention basin and the variability of soil and other site conditions, these criteria may be modified or appended at the discretion of the County Engineer.

Structural Components: Principal Outlets

To minimize the chance of clogging and to facilitate cleaning, principal outlet pipes shall be at least 18 inches in diameter. Orifice plates may be used on the upstream end of the principal outlet pipe to reduce the maximum release rate as needed. The minimum orifice plate diameter of the principal outlet shall be no less than 6 inches. Similarly, riser pipes, if utilized, shall be at least 8 inches in diameter.

Structural Components: Water Quality Outlets

A water quality storm event shall be used to maintain water quality downstream of detention facilities. The water quality storm event is defined as a one-year frequency 24-hour storm. Water quality control shall be maintained by providing an amount of storage at the bottom of the detention facility such that the runoff produced by the water quality storm is routed through a 3-inch diameter water quality outlet (orifice plate) without entering the principal outlet. The 3-inch orifice plate shall discharge into an 18-inch minimum outlet pipe (the same outlet pipe may be used as the principle outlet). The invert of the principal outlet shall be located at the water surface elevation resulting from routing the water quality storm event through the detention facility and discharging through the water quality outlet only. In all cases, the basin shall be considered initially empty (i.e., the storage provided for the water quality event and the discharge capacity of the water quality outlet shall be utilized during the routing of the larger 100-yr design storm).

Structural Components: Outlets

This section applies to all principal and water quality outlets.

All pipe joints shall be watertight. In addition, trash racks and/or anti-vortex devices are required where necessary. Seepage along outlet conduits shall be controlled using the latest engineering standards and practice, and may include methods such as filters, drainage diaphragms, and anti-seep collars, etc. Regardless of the seepage control method used, designs must be approved by the County Engineer. Where necessary, a concrete cradle shall be provided for outlet pipes. All outlet structures shall be reinforced concrete. All construction joints shall be watertight.

Suitable lining and energy dissipators shall be placed upstream and downstream of outlets as necessary to prevent scour and erosion. Such lining and energy dissipators shall conform to the criteria contained in current editions of *Hydraulic Engineering Circular No. 15 – Design of Roadside Channels with Flexible Linings* and *Hydraulic Engineering Circular No. 14 – Hydraulic Design of Energy Dissipators for Culverts and Channels*, both published by the Federal Highway Administration of the U.S. Department of Transportation.

Structural Components: Emergency Spillways

Design emergency spillways to safely pass the entire post-developed 100-year flood, routed through the detention basin assuming the principal outlets and water quality outlet are not functioning. A minimum of 1 foot of freeboard above the emergency spillway design water surface elevation is required.

Emergency spillway side slopes shall not exceed 2 horizontal to 1 vertical or the angle of repose of the soil or lining material, whichever is less. Vegetated emergency spillways shall have side slopes not exceeding 3 horizontal to 1 vertical. Emergency spillways shall be suitably lined and shall comply with criteria contained in the current edition of *Hydraulic Engineering Circular No. 15 – Design of Roadside Channels with Flexible Linings*. Maximum velocities and shear stresses in emergency spillways shall be checked based on the velocity and peak flow in the spillway resulting from the routed Emergency Spillway Hydrograph. Suitable lining shall be provided for the maximum velocities and shear stresses expected. Energy dissipators at the bottom of the emergency spillway shall be designed as needed

based on the current edition of *Hydraulic Engineering Circular No. 14 – Hydraulic Design of Energy Dissipators for Culverts and Channel.*

Structural Components: Dams and Embankments

The required minimum top widths of all dams and embankments are listed in Table 2-4 below.

Table 2-4: Minimum Top Widths

Height (feet)	Min. Top Width (feet)
0-20	12
20-25	14

The design top elevation of all dams and embankments after all settlement has taken place shall be equal to, or greater than, the maximum water surface elevation in the basin resulting from the routed Emergency Spillway Outflow Hydrograph plus one foot of freeboard. Therefore, the design height of the dam or embankment, defined as the vertical distance from the top down to the bottom of the deepest cut, shall be increased by the amount needed to ensure that the design top elevation will be maintained following all settlement. Consolidation tests of the undisturbed foundation soil are required to determine the necessary increase. This increase shall not be less than 5 percent. Side slopes for all dams and embankments are no steeper than 3 horizontal to 1 vertical. Cutoff trenches shall be excavated along the dam or embankment centerline to impervious subsoil or bedrock, unless otherwise approved by the County Engineer (and State Engineer if the Utah State Dam Safety Act applies).

Storage Facilities in Flood Hazard Areas

No off-line storage facilities are allowed within any flood plain. On-line storage facilities must have adequate storage to detain the flood caused by the 100-yr 24 hour storm as previously outlined. For storage facilities located within FEMA mapped floodways, any changes to FEMA mapping caused by the storage facility must be considered and any appropriate CLOMAR and LOMAR must be obtained.

2.3.3 Storage Facilities: Maintenance and Repair

Operation, maintenance, and repair of storage facilities, including periodic removal and disposal of accumulated particulate material and debris, is required and remains the responsibility of the property owner. Storage facilities shall be inspected and cleaned and repaired as necessary after every storm event. All storage facilities must provide adequate access for maintenance and cleaning.

2.4 Streets and Curbs

Planning a drainage system shall be done simultaneously with street layout and gradient planning, and careful consideration shall be given to the following:

- The functions of streets as parts of the storm water management system.
- Street slopes in relation to storm water capacity and flow velocity in gutters and/or street swales.

- The location and sizing of street culverts. Culverts may be sized to create temporary upstream storage if there is proper consideration given to earth bank stability, proper freeboard, upstream backwater effects and potential overflow effects during major flood conditions as outlined further in section 2.7 Culverts.

- Location of streets in relation to natural streams, storage ponds and open channel components of the system.

- Location and capacity of inlet points to pipes in relation to gutter slopes, low points, the spread of water across streets and the flow of water across intersections.

2.4.1 Street Flooding Evaluation

The design criteria for allowable spread for the 10-year storm event are based on roadway classification as shown in Table 2-5.

Table 2-5: Allowable Spread Criteria for 10-year Storm Event

Roadway Classification		Allowable Spread
Local (residential)		Flow may spread to crown of road.
Minor Collector (residential)		Flow spread must leave one lane free of water.
Major Collector		Flow spread must leave at least two travel lanes free of water (one lane in each direction)
Arterial:	< 45 mph	Allowable spread is shoulder + 3 ft.
	> 45 mph	Allowable spread is shoulder only.

In addition to the above table, the following criteria also apply for allowable spread and amount of street flooding for the 10-year design storm:

- The allowable spread in the above table is based on a minimum shoulder width of 6 feet. A minimum allowable spread of 6 feet shall be considered for all roadway classifications, regardless of shoulder width.

- At no time shall street flooding extend above the height of the curb.

- Localized street flooding is acceptable in residential areas if the duration is less than 2 hours.

For the 100-year design storm, the following design criteria apply for allowable spread and amount of street flooding:

- Streets must be able to route the 100-year flood to adequate downstream conveyance facilities. 100-year flows must be contained within the street right-of-way and adjacent drainage easements with at least 1.0 foot of freeboard to all building structures.

- Street flooding shall not cause dangerous situations to occur with vehicular traffic.

- Street flooding shall at no time exceed 2 feet in depth.
- Street flooding shall not exceed 2 hours in duration.
- Pedestrian access is not required to be maintained during a 100-year flood.
- Flooding can extend into all vehicular traffic lanes.

2.4.2 Hydraulic Capacity

The hydraulic capacity of a street and gutter section to convey water can readily be calculated with a modified version of Manning's equation as outlined in *Hydraulic Engineering Circular No. 22, Second Edition – Urban Drainage Design Manual*, published by the Federal Highway Administration of the U.S. Department of Transportation. Table 2-6 lists Manning's n values to be used for street and gutter pavements.

Table 2-6: Manning's n for Street and Pavement Gutters.

Type of Gutter or Pavement	Manning's n
Concrete gutter, troweled finish	0.012
Asphalt Pavement:	
Smooth texture	0.013
Rough texture	0.016
Concrete Gutter with Asphalt Pavement:	
Smooth	0.013
Rough	0.015
Concrete Pavement:	
Float finish	0.014
Broom finish	0.016
For gutters with small slope, where sediment may accumulate, increase above values of n by:	0.002

Source: USDOT, FHWA, HDS-3.

2.4.3 Maximum Velocity in Gutters

The velocity in the deepest part of the gutter shall not exceed 10 feet per second. This velocity is readily computed by the Manning equation using the depth at a point six inches from the face of the curb as the hydraulic radius. The mean velocity for the entire cross section is not a good measure. If the calculated velocity exceeds ten feet per second, the allowable discharge in the gutter shall be reduced until velocity is within the limit.

2.4.4 Estimating Runoff in Streets

The peak flow contributed to a gutter or swale from impervious areas and adjacent contributing areas of less than 10 acres shall be estimated by the Rational Method. Inlets are usually sized so that a portion of the flow is bypassed; the actual flow in the next reach of gutter includes this bypass flow. The flow reaching the second inlet is a portion of the flow contributed from its drainage subarea plus the flow bypassing the previous upstream inlet. The low point or sump inlet catches the remaining flow from

both directions and shall be sized accordingly. Locations and required capacities of inlets are established by computing estimated flow rates, depth and velocity of flow, and spread across street. The procedures and equations which shall be used for estimating runoff in streets as well as calculating inlet intercept and bypass flows are found in the latest edition of *Hydraulic Engineering Circular No. 22 – Urban Drainage Design Manual*.

2.4.5 Flow Across Intersections

Flow across collector or arterial street intersections or cross-walks is not allowed for the 10-year event and more frequent storms. Controlled flow across local streets is acceptable as long as the Street Flooding Evaluation criteria in section 2.4.1 is met and the maximum velocity does not exceed 10 feet per second.

2.5 Storm Water Inlets

Storm water inlets provide the transition between open surface flow and a closed conduit system. They are either constructed as part of the street's curb and gutter system, located in street swales or used to drain open areas. The inlets shall be located to remove runoff from surfaces when the flows exceed the criteria for velocity, spread of water across streets, or flow across intersections or cross-walks. Inlets shall also be located upstream of superelevations in order to prevent flow from crossing the roadway. Inlets in street swales also remove flow when it exceeds swale capacity. Drainage of open areas is often picked up by an inlet in a depressed area.

2.5.1 Design of Inlets

Inlets shall be analyzed and designed according to the type of inlet being used. Inlet capacity shall be calculated as outlined in the current edition of *Hydraulic Engineering Circular No. 22 – Urban Drainage Design Manual*. Inlets on grade in gutter sections shall consist of grates depressed 2 inches below the gutter flow line. Inlets at sump locations shall include an open curb in order to reduce the effect of clogging. The design and analysis of all inlets shall include a 50 percent clogging. The clogging factor is applied to inlets on grade by reducing the effective length of the grate by 50% when calculating the splash-over velocity. The clogging factor is applied to inlets at sump locations by reducing the effective perimeter by 50% when in weir flow and by reducing the clear open area by 50% when in orifice flow. Flanking inlets at sump locations may be necessary, depending on the potential damage and flooding that may occur if the primary low-point inlet becomes clogged or its capacity exceeded. When flanking inlets are determined to be necessary, they shall be designed according to the current edition of *Hydraulic Engineering Circular No. 22 – Urban Drainage Design Manual*.

Catch basins shall not include a sediment trap formed by lowering the floor of the box below the elevation of the outlet pipe. Inlets, catch basins and manholes shall be designed in accordance with the latest APWA details and standard specifications. Frames and grates shall be bicycle safe in areas of potential bicycle traffic.

2.6 Storm Drain Systems

2.6.1 Layout of the Storm Drain System

Storm drain systems shall be used when runoff can no longer be carried in open channels, swales or gutters due to hydraulic capacity and the limitations and criteria outlined in section 2.4. Storm drain systems shall also be used when the installation of channels is not feasible due to limited right-of-way and other constraints. The underground storm drain system consists of a series of inlets, pipes, and manholes.

2.6.2 Storm Drain Location and Alignment

The storm drain system shall be located within the street right-of-way. Storm drain alignments outside of the street right-of-way shall be approved by the County Engineer and a perpetual drainage easement for the county shall be obtained. The size of the drainage easement shall be dictated by working needs. In general, the minimum width of drainage easements shall be 20 feet for one utility and five additional feet, if practicable, for each additional utility located in the same easement.

2.6.3 Hydraulics

Storm drain systems shall be designed to convey the peak 10-yr 24 hour runoff when flowing full. The capacity of major trunk lines and pipe conveyance systems shall be sufficient for the 100-yr 24 hour post-developed flow without surcharging at structures. Major trunk lines and pipe conveyance systems include those which convey flow from upstream culverts, channels, and storage basins. Trunk lines and pipe conveyance systems conveying flow from upstream storage basins shall have the capacity outlined in section 2.3.2. Hydraulic capacity shall be determined by the Manning Equation with the use of appropriate Manning's n for the pipe material used.

The hydraulic grade line shall be computed for all storm drain systems, accounting for all head losses throughout the system, including head losses due to pipe friction, momentum changes, and losses at junctions, bends, and structures. These calculations shall conform to the latest edition of *Hydraulic Engineering Circular No. 22 – Urban Drainage Design Manual*.

For minor storm drain systems controlled by the 10-yr 24 hour storm event, it shall be shown that the hydraulic grade line does not rise above the pipe soffit in the 10-yr event. Larger events may surcharge the pipe. However, an analysis combining the capacity of street and storm drain flow must show that the 100-yr 24 hour peak flow is contained within the street section as outlined in section 2.4.1 Street Flooding Evaluation. For major trunk lines and pipe conveyance systems, it must be shown that the 100-yr hydraulic grade line does not surcharge at any structure along the storm drain system.

The minimum allowable pipe size in the storm drain system is 18-inch diameter. The minimum diameter of major trunk lines and pipe conveyance systems is 24-inches. Storm drain pipes shall not decrease in size in the downstream directions.

Storm drain pipes shall be designed to ensure self-scouring velocities. The minimum allowable velocity shall be 2.5 feet per second when flowing full or 2.0 feet per second when flowing at the design flow, whichever results in a steeper pipe slope. The minimum pipe slope shall be 0.3 percent.

2.6.4 MATERIALS

Storm drains are usually constructed of reinforced concrete, or high density polyethylene, or corrugated metal pipe; however, other materials may be used. The selected pipe material shall be consistent with the loads generated from the bury depth and highway loading. Pipe materials shall be analyzed to be appropriate for the soil characteristics. The selected pipe material shall be approved by the County Engineer. All storm drain pipes shall include water tight joints.

All discharge pipes and culverts shall terminate with a precast concrete, high density polyethylene, or corrugated metal end section matching the material of the pipe. Alternatively, a cast-in-place concrete headwall with or without wing-walls as conditions require may be installed. All outlets greater than or equal to 48 inches in diameter shall have a cast-in-place concrete headwall, with or without wing-walls as conditions require.

To allow the County to plan better for system management, the name of the county, the year installed, and the words "STORM SEWER" shall be cast integrally on manhole covers.

2.6.5 ACCESS HOLES

The principal purpose of access holes is to provide access for cleaning and inspection. Access holes shall be provided at all junctions of two or more storm drains, where pipe sizes change, and at changes in grade or alignment. Inlet boxes shall also provide access through the grate or manhole openings. The maximum access hole spacing per pipe size is given in Table 2-7.

Table 2-7: Access Hole Spacing

Pipe Diameter (inches)	Maximum Spacing
24 or less	300 ft
27 – 36	400 ft
42 – 54	500 ft
60 +	1000 ft

2.7 CULVERTS

All culverts shall be designed to convey the 100-yr peak runoff. The minimum culvert diameter allowed is 24-inches. The minimum allowable slope is 1.0 percent. Culverts shall be designed to have a minimum velocity of 2.5 feet per second at the design flow rate.

The maximum allowable headwater shall be the minimum of the following criteria:

- Shall be at least 1 ft below upstream structures and shall be non-damaging to upstream property.
- Shall be below the outside edge of the shoulder.
- Shall be equal to the elevation where the flow begins to divert around the culvert.

Any culvert may cause an increase in water level in the upstream channel. This backwater can flood property and overflow into the streets. The channel backwater surface upstream of culverts shall be limited to at least 1 ft below upstream structures and property lines.

All culverts shall have flared end sections or cast-in-place headwalls and wing-walls at both ends of the culvert for good appearance and hydraulic characteristics. The criteria outlined in section 2.6.4 apply.

Suitable lining and energy dissipators shall be placed upstream and downstream of culverts and storm drain outlets as necessary to prevent scour and erosion. Such lining and energy dissipators shall conform to the criteria contained in latest editions of *Hydraulic Engineering Circular No. 15 – Design of Roadside Channels with Flexible Linings* and *Hydraulic Engineering Circular No. 14 – Hydraulic Design of Energy Dissipators for Culverts and Channel.*

2.8 Open Channels

Natural drainage channels shall be preserved as much as possible in order to maintain natural drainage patterns and hydrology. When natural drainage channels are used, considerations shall be given to the affects of added runoff from upstream developments. Adequate access for maintenance of natural channels shall be provided. Existing abandoned irrigation channels shall also be maintained and used for runoff conveyance. However, irrigation ditches shall not be used as outfall channels for culverts or storm drain systems, unless approved by the owner and the County Engineer.

Open channels shall have capacity for the 100-yr design storm with minimum 1 foot of freeboard. Small roadside channels conveying runoff from less than 10-acres shall have capacity for the 10-yr design with 1 foot of freeboard to the outside edge of the shoulder. Open channel capacity shall be evaluated and designed based on Manning's equation. Values of Manning's n to be used for man-made channels shall be obtained from the latest edition of *Hydraulic Engineering Circular No. 15 – Design of Roadside Channels with Flexible Linings.* Channel side slopes shall not exceed 2 horizontal to 1 vertical or the angle of repose of the soil or lining material, whichever is less. Adequate access for maintenance shall be provided.

2.8.1 Control of Erosion

Erosion control design applies to man-made channels as well as natural channels when flows are increased above the natural capacity. Channels shall be designed for erosion control based on the permissible tractive force method as outlined in the latest edition of *Hydraulic Engineering Circular No. 15 – Design of Roadside Channels with Flexible Linings*. Supercritical velocity shall not be allowed in channels unless they are concrete lined. Drop structures and/or energy dissipators shall be installed as needed to maintain velocities below subcritical in all other channels.

2.9 Other Design Considerations

2.9.1 Soil Erosion

Control of erosion during residential construction requires an examination of the entire site to pinpoint potential problem areas, such as steep slopes, highly erodible soils, soil areas that will be unprotected for long periods or during peak rainy seasons and natural drainage ways. Steps shall be taken to assure

erosion control in these critical areas. After a heavy storm the effectiveness of erosion control measures shall be evaluated. Periodic maintenance and cleaning of the facilities is also important.

Construction activities that disturb one or more acres of land must be authorized under the UPDES General Permit for Construction Activities as administered by the Utah Division of Water Quality. The UPDES permit requires control and elimination of storm water pollution through the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP) which must include appropriate Best Management Practices (BMPs)

The basic requirements for controlling erosion during and after construction include:

- Earth slopes: concentrations of water at the top of the slope flowing down an unprotected bank shall be avoided or controlled. Runoff shall be diverted to safe outlets. Slopes shall be protected from erosion by quick establishment of vegetative cover, benches, terraces, slope protection structures, mulches, or a combination of these practices as appropriate.

- Waterways or Channels: Waterways shall be designed to avoid erosion by limiting maximum velocities and providing appropriate erosion protection. These will both vary based on the character of the channel material. Every effort shall be made to preserve natural channels.

- Erosion Control Methods: Erosion may be controlled by the use of vegetative and rock linings, grade control structures, energy dissipators, special culverts, and various types of pipe structures. Structures are expensive and should be used only after it has been determined that recommended vegetation, rock revetment or other measures will not provide adequate erosion control.

- Existing Vegetation: Existing vegetation shall be preserved wherever possible.

- Soil Treatment, Seeding and Mulching: The use of vegetation for erosion control is limited to situations where the vegetation can be sustained through irrigation. The determination of proper soil treatment, seed mixture and long-term maintenance requirements shall be done by a licensed landscape architect.

- Outfall Design: Every effort shall be made to keep the elevation of an outfall pipe as close to the downstream grade as possible. Outfall pipes shall not be elevated above the level of the downstream ground without providing appropriate erosion protection and energy dissipation. The velocity of the outfall pipe shall be minimized as much as possible. Appropriate erosion protection and energy dissipation shall be provided. Special attention must be given if the outfall is to an overland flow area with a steep slope.

2.9.2 Siltation and Sediment Control

Proper control of soil erosion during and after construction is the most important element of siltation and sediment control. However, it is physically and economically impractical to entirely eliminate soil erosion. Secondly, erosion is a natural function and is required in certain portions of the drainage system

to provide future stream capacity. Therefore, provisions shall be made to trap eroded material at specified points. Some measures that shall be implemented as appropriate are:

- Temporary ponds which store runoff and allow suspended solids to settle out can be used during construction and may be retained as part of the permanent storage system after construction.

- Protection of inlets to the underground pipe system can be accomplished during construction by placing straw bales or drop inlet barriers around the structure. Temporary erosion control must be removed prior to final acceptance.

- Silt fences along the down slope edges of construction sites to trap sediments which are carried by overland flows.

- Storm drain systems shall be protected from Aeolian (or wind blown) sediments by the proper use and placement of silt fencing.

- Egress points from construction sites shall be controlled, so that sediment is not carried off-site by construction traffic.

2.9.3 Storm Water Runoff Pollution

In 1990, Phase I of the US Environmental Protection Agency's (EPA) Stormwater Program was promulgated under the Clean Water Act. In 1999, EPA issued the Final Rule for Phase II of its Stormwater Program.

Phase I relies on National Pollutant Discharge Elimination System (NPDES[1]) permit coverage to address stormwater runoff from: (1) “medium” and “large” municipal separate storm sewer systems (MS4s) generally serving populations of 100,000 or greater, (2) construction activity disturbing 5 acres of land or greater, and (3) ten categories of industrial activity. The Stormwater Phase II Final Rule is the next step in EPA’s effort to preserve, protect, and improve the Nation’s water resources from polluted stormwater runoff. The Phase II program expands the Phase I program by requiring operators of certain regulated small MS4s in urbanized areas, operators of small construction sites, as well as small MS4s outside the urbanized areas that are designated by the permitting authority, to obtain NPDES permit coverage for their stormwater discharges and to implement programs and practices to control polluted stormwater runoff.

Generally, Phase I MS4s are covered by individual permits and Phase II MS4s are covered by a general permit. Each regulated MS4 is required to develop and implement a stormwater management program (SWMP) to reduce the contamination of stormwater runoff and prohibit illicit discharges.

Grand County does not currently meet the EPA definition of an urbanized area and is not considered a regulated MS4 under the EPA Phase II rules. However, it is certain the stormwater regulations will

1 Note that in Utah, the Division of Water Quality administers the NPDES program via DWQ’s UPDES program.

become increasingly stringent on a state and federal level. Grand County can position itself for future regulations by considering the following areas which represent Minimum Control Measures under the Phase II program. Additional information on each of these areas can be found by following the link provided.

1) Public education and outreach: Develop a public education program that uses a mix of local strategies and reaches a diverse audience. (http://www.epa.gov/npdes/pubs/fact2-3.pdf)

2) Public participation and involvement: Include the public in developing, implementing, updating, and reviewing a stormwater management programs. (http://www.epa.gov/npdes/pubs/fact2-4.pdf)

3) Illicit discharge detection and elimination: Implement and enforce program to eliminate non-stormwater discharges via the storm water system. (http://www.epa.gov/npdes/pubs/fact2-5.pdf)

4) Construction site runoff control: Develop, implement, and enforce a program to reduce pollutants in stormwater runoff from construction activities that result in a land disturbance of greater than or equal to one acre. (http://www.epa.gov/npdes/pubs/fact2-6.pdf)

5) Post construction runoff control: Develop, implement, and enforce a program to reduce pollutants in post-construction runoff from new development and redevelopment projects that result in the land disturbance of greater than or equal to 1 acre. (http://www.epa.gov/npdes/pubs/fact2-7.pdf)

6) Pollution prevention and good housekeeping: Develop and implement a good storm water system operation and maintenance program, employee storm water training program. (http://www.epa.gov/npdes/pubs/fact2-8.pdf)

2.9.4 Mosquito Control

The design of all storm drainage system design shall consider mosquito control measures. Some mosquito species in Spanish Valley can, during hot weather, complete their development in standing water in as little as 4 days. However, most species, including the major West Nile virus vectors (*Culex* spp.), require at least 7 days for development. At least one species of *Culex* is known to breed in enclosed and underground water containers that it can access.

- Storm water detention ponds shall be designed so that they empty completely within 96 hours.
- Mosquito control shall be considered in the design of manholes and other subsurface storm drainage structures.

2.10 Operation and Maintenance

Adequate provision for short- and long-term maintenance of the storm water system is an important design consideration. Maintenance and replacement needs and costs shall be part of economic analyses. Maintenance shall be included for all drainage facilities in order to ensure they function properly during storm events. Proper right-of-way and easements shall be provided for maintaining all drainage facilities.

REFERENCES

Horrocks Engineers. *Spanish Valley Storm Drain Master Plan Update*. Grand County, Utah. 2011.

U.S. Department of Agriculture, Natural Resources Conservation Service. Soil Survey Geographic (SSURGO) Database. *Canyonlands Area, Utah – Parts of Grand and San Juan Counties*. Obtained from the Soil Data Mart (http://soildatamart.nrcs.usda.gov/).

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service. *NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 1, Version 4, Semiarid Southwest.* 2006. Extracted from the Precipitation Frequency Data Server January 2009 (http://hdsc.nws.noaa.gov/hdsc/pfds/sa/ut_pfds.html).

U.S. Department of Transportation, Federal Highway Administration. *Design Charts for Open Channel Flow, Hydraulic Design Series No. 3.* FHWA-EPD-86-102. 1961.

U.S. Department of Transportation, Federal Highway Administration. *Design of Roadside Channels with Flexible Linings, Hydraulic Engineering Circular No. 15, Third Edition.* FHWA-NHI-05-114. Sep 2005.

U.S. Department of Transportation, Federal Highway Administration. *Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Circular No. 14, Third Edition.* FHWA-NHI-06-086. July 2006.

U.S. Department of Transportation, Federal Highway Administration. *Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22, Second Edition.* FHWA-NHI-01-021. Aug 2001.

U.S. Environmental Protection Agency, Office of Wastewater Management, Water Permits Division, National Pollution Discharge Elimination System (NPDES). (http://cfpub.epa.gov/NPDES/).

Utah Department of Environmental Quality, Division of Water Quality, Utah Pollutant Discharge Elimination System (UPDES). (http://www.waterquality.utah.gov/UPDES/stormwater.htm).

Utah Department of Administrative Service, Division of Administrative Rules. *Title R655 – Natural Resources, Water Rights*. (http://www.rules.utah.gov/publicat/code/r655/r655.htm).

Utah State Legislature. *Utah Code-Title 73-Chapter 05a-Dam Safety.* (http://le.utah.gov/~code/TITLE73/73_05a.htm).