VCGP STORM DRAINAGE SYSTEMS DESIGN CRITERIA

1. PIPED COLLECTION SYSTEMS

a. The preliminary design (initial pipe sizing and profile design) of piped collection systems shall be based upon conveyance of the peak flows associated with a fully developed 25-year storm with the hydraulic grade line (HGL) being one foot or more below the top of each structure, gutter line or proposed final ground surface elevation, whichever is lowest.

b. Once the preliminary design of a piped collection system has been prepared, it shall be analyzed for its behavior during conditions of 100-year flow, with the objective of this analysis being to ascertain the quantities of flow and flow paths followed by flows exceeding the capacity of the system, whether these pond at inlets or flow along the ground's surface.

c. Based on the analysis of 100-year conditions, the preliminary design shall be revised where necessary to produce a final design for which the likelihood of burial section or building flooding, major property damage, or substantial public access and/or utility interruption shall be less than one chance in 100 years.

d. The minimum allowable pipe diameter shall be 15 inches.

e. Catch basins shall be spaced so that the spread in the street for a 10-year design flow shall not exceed 8 feet as measured from the face of the curb.

f. Complete flow, velocity, and hydraulic grade line computations, shall be provided for all portions of a piped collection system. Hydraulic grade lines shall be shown on the storm drainage profiles contained with the development plans for the 25-year storm.

2. PIPE LENGTH

a. Culverts shall extend to where the crown of the pipe intersects finished grade.

b. The length requirement, however, shall be subject to requirements for maintaining stream buffers in accordance with State, Tribal and local regulations.

3. DESIGN SLOPE

a. Velocities over 10 fps in a pipe of any material shall be considered a special design with particular attention required to pipe invert protection and the ability of the receiving waterway or detention facility to accept the flow without damage.

b. The minimum allowable slope shall be one (1) percent.

c. The maximum allowable slope for a concrete storm drainage pipe shall be 10 percent and for a HDPE pipe shall be 14 percent. Greater slopes may be approved if installation is in accordance with manufacturer's recommendations. In cases where the slope is in excess of 10 percent, anchor collars may be required.

d. A minimum pipe cover of 18 inches shall be required.

4. OUTLET LOCATION - CULVERTS AND PIPE SYSTEMS

a. Outlet structures (such as headwalls) shall not be located closer to the project site's property line than the greater of the distance necessary to construct any velocity protection or a flow distance equal to six (6) pipe diameters. For non-circular conduits, this distance shall be six (6) times the rise dimension of the conduit.

b. The invert elevation of a culvert or pipe outlet shall be no more than 2 feet above the elevation of the bottom of the receiving watercourse at the outlet.

5. DISCHARGE OF CONCENTRATED FLOWS.

a. The discharge of concentrated flows of storm water into public roadways shall be avoided.

6. CULVERTS

a. Frequency Flood:

The design storm for a culvert for all roads is the 100-year storm using future development land use conditions, assuming no detention. The design of lateral systems shall be based on a 25-year storm event, using future development land use conditions assuming no detention. The 100-year frequency storm shall be routed through all culverts to be sure burial sections and building structures are not flooded or increased damage does not occur to the roadways or adjacent property for this design event. Culverts or pipe systems designed to convey water from one side of the roadway to the other shall be designed to pass the fully developed peak flow associated with a 100-year storm with at least 1.5 feet of freeboard between the 100-year ponding elevation and the centerline of the road, without raising the 100-year flood elevation on the upstream properties. Fully developed flows shall be based on the approved cemetery Master Plan.

b. Velocity Limitations:

Both minimum and maximum velocities should be considered when designing a culvert. The maximum velocity should be consistent with channel stability requirements at the culvert outlet. There is no specified maximum allowable velocity for reinforced concrete pipe, but outlet protection shall be provided where discharge velocities will cause erosion problems. To ensure self-cleaning during partial depth flow, a minimum velocity of 2.5 feet per second, for the 2-year flow velocity, when the culvert is flowing partially full is required. Velocities over 10 fps in a pipe of any material shall be considered a special design with particular attention required to pipe or structure invert protection and to fill slope, stream bed, and stream bank stability.

c. Buoyancy Protection:

Headwalls, endwalls, slope paving or other means of anchoring to provide buoyancy protection should be considered for all flexible culverts.

d. Length and Slope:

The culvert length and slope should be chosen to approximate existing topography, and to the degree practicable: the culvert invert should be aligned with the channel bottom and the skew angle of the stream, and the culvert entrance should match the geometry of the roadway embankment. The maximum slope using concrete pipe is 10% before pipe restraining methods must be taken. Maximum drop in a drainage structure is 10 feet.

e. The following criteria related to headwater should be considered:

- The allowable headwater for design frequency conditions should allow for the following upstream controls.
- 18 inch freeboard.
- Avoid upstream property damage.
- Elevations established to delineate flood plain zoning.
- Low point in the road grade that is not at the culvert location.
- Ditch elevation of the terrain that will permit flow to divert around culvert.
- Following HW/D criteria.
- For drainage facilities with cross-section area equal to or less than 30 sq. ft - HW/D = to or < 1.5.
- For drainage facilities with cross-section area greater than 30 sq. ft - HW/D = to or < 1.2.
- The headwater should be checked for the 100-year flood to ensure that the culvert is sized to maintain flood-free conditions on roadway with 18 inches freeboard at the low-point of the road.
- The maximum acceptable outlet velocity should be identified. Either the headwater should be set to produce acceptable velocities or stabilization or energy dissipation should be provided where these velocities are exceeded.
- Other site-specific design considerations should be addressed as required.
- In general the constraint which gives the lowest allowable headwater elevation establishes the criteria for the hydraulic calculations.

7. TAILWATER CONSIDERATIONS

The hydraulic conditions downstream of the culvert site must be evaluated to determine a tailwater depth for a range of discharge. At times there may be a need for calculating backwater curves to establish the tailwater conditions. The following conditions must be considered:

- If the culvert outlet is operating with a free outfall, the critical depth and equivalent hydraulic grade line should be determined.
- For culverts which discharge to an open channel, the stage-discharge curve for the channel must be determined.
- If an upstream culvert outlet is located near a downstream culvert inlet, the head water elevation of the downstream culvert may establish the design tailwater depth for the upstream culvert.
- If the culvert discharges to a lake, pond, or other major water body, the expected high water elevation of the particular water body may establish the culvert tailwater.

8. Storage

If storage is being assumed upstream of the culvert, consideration should be given to:

- The total area of flooding.
- The average time that bankfull stage is exceeded for the design flood up to 6 hours.

9. OPEN CHANNEL

a. Channels with bottom widths greater than 10 feet shall be designed with a minimum bottom cross slope of 12 to 1.

b. Low flow sections shall be considered in the design of channels with large cross sections (Q > 100 cfs).

c. Channel side slopes shall be stable throughout the entire length and side slope shall depend on the channel material. A maximum of 3:1 is allowed for vegetation and 2:1 for riprap, unless otherwise justified by calculations.

d. Superelevation of the water surface at horizontal curves shall be accounted for by increased freeboard.

e. Trapezoidal or parabolic cross sections are preferred and triangular shapes should be avoided. "V" shaped cross sections are not permitted in grassed channels. The channel shall be shaped to the dimensions specified on the approved plans and shall be free of overfalls, gullies, or other irregularities.

f. For vegetative channels, if the channel slope exceeds 10 percent special design procedures presented in HEC-15 and HEC-14 should be used.

g. For vegetative channels, design stability should be determined using low vegetative retardance conditions (Class D) and for design capacity higher vegetative retardance conditions (Class C) should be used. Protective cover in grassed channels shall be installed as soon as the earthwork is completed.

h. For vegetative channels, flow velocities within the channel should not exceed the maximum permissible velocities given in Tables 1 and 2.

i. Relocation of a stream channel is not permitted.

j. Streambank stabilization should be provided, when appropriate, as a result of any stream disturbance such as encroachment and should include both upstream and downstream banks as well as the local site.

k. All new proposed channels shall be designed to carry at least the fully developed 25-year storm with freeboard equal to 20% of the design flow depth. The 100-year design storm should be routed through the channel system to determine if the 100-year plus applicable burial section and building elevation restrictions are exceeded, structures are flooded, or flood damages increased.

l. Sediment transport should be considered for conditions of flow below the design frequency. A low flow channel component within a larger channel can reduce maintenance by improving sediment transport in the channel.

m. In cases of potential erosion due to irregular channel alignment, extreme velocities, or excessive slopes, a paved ditch may be required. However, if, in the opinion of the VCGS, the expected long-term maintenance of a surface drainage system could prove impractical, a pipe design may be required.

n. If the channel will be affected by backwater from culverts, bridges, other structures or floodplains, backwater curves shall be shown in profiles of the channel.

10. CHANNEL TRANSITIONS

The following criteria shall be considered at channel transitions:

a. Transition to channel sections shall be smooth and gradual. A straight line connecting flow lines at both ends of the transition shall not make an angle greater than 12.5 degrees with the axis of the main channel without additional design considerations.

b. Transition sections should be designed to provide a gradual transition to avoid turbulence and eddies.

c. Energy losses in transitions should be accounted for as part of the water surface profile calculations.

d. Scour downstream from rigid-to-natural and steep-to-mild slope transition sections should be accounted for through velocity slowing and energy dissipating devices.

e. Transition channels shall be provided at the inlet and outlet ends of all culverts and pipe systems, unless otherwise provided herein.

11. VELOCITY LIMITATIONS

The final design of artificial open channels should be consistent with the velocity limitations for the selected channel lining. Maximum velocity values for selected lining categories are presented in Table 1. Seeding and mulch should only be used when the design value does not exceed the allowable value for bare soil. Velocity limitations for vegetative linings are reported in Table 2. The maximum flow velocity at the project site's downstream property line shall not exceed the pre-developed velocity. Channels in fills shall be lined.

TABLE 1 Maximum Velocities for Comparing Lining Materials

Material	Maximum Velocity (ft/s)
Sand	2.0
Silt	3.5
Firm Loam	3.5
Fine Gravel	5.0
Stiff Clay	5.0
Graded Loam or Silt to Cobbles	5.0
Coarse Gravel	6.0
Shales and Hard Pans	6.0

TABLE 2 Maximum Velocities for Vegetative Channel Linings

Vegetation Type	Slope Range (%) (1)	Maximum Velocity (2) (ft/s)
Bermudagrass	0->10	5
Bahia		4
Tall Fescue Grass Mixtures (3)	0-10	4
Kentucky bluegrass	0-5	6
Buffalo grass	5-10	5
	>10	4
Grass mixture	0-5(1)	4
	5-10	3
Sericea Lespedeza, Weeping Lovegrass Alfalfa	0-5(4)	3
Annuals (5)	0-5	3
Sod		4
Lapped sod		5

(2) Do not use on slopes steeper than 10 percent except for side-slope in combination channel.
(3) Use velocities exceeding 5 ft/s only where good stands can be established and maintained.
(4) Mixtures of Tall Fescue, Bahia, and/or Bermuda
(5) Do not use on slopes steeper than 5 percent except for side-slope in combination channel.
(6) Annuals - used on mild slopes or as temporary protection until permanent covers are established.