capacity of the channel. Provide maintenance access to the culvert inlet to assist with removal of this material by maintenance crews.

c. Mountainous roads in the cut section, with roadside waterfalls, need to be provided with large inlet structures designed with barriers, such that high-flow volumes, debris, and bed loads will not affect the traffic area, but be contained by the inlet, to flush through the culvert to the downstream side of the roadway.
d. Energy dissipaters may be required to slow high-velocity flows to acceptable velocities before transitioning to a side of roadway channel, or where the channel is discharging from a rock-lined channel to an earth channel.
e. The Design Engineer shall refer to a speciality reference for additional design details and considerations, such as the FHWA publications HEC-15 and HEC-20 .

18. For evaluating the capacity of natural channels and wadis, geometric elements are usually not well defined. Irregular channel cross sections (i.e., those with a narrow deep main channel and a wide shallow overbank channel) must be subdivided into segments so flow can be computed separately from the main channel and for overbank portions. This same process of subdivision may be used when different parts of the channel cross section have different roughness coefficients.

    a. When computing the hydraulic radius of the subsections, the water depth common to the two adjacent subsections is not counted as a wetted perimeter.
    b. Use of surveyed cross sections and a channel modelling programme, such as the U.S. Army Corps of Engineers' (USACE) hydrologic engineering centre's River Analysis System Programme (HEC-RAS), will help to facilitate the analysis.

A5.1.1.4. Design method

Channel design is a trial-and-error process using the following general steps:

1. Determine the catchment area and the existing ground level/ topography conditions and calculate the design storm peak runoff flow rate.
2. Select a trial channel cross section and longitudinal slope. Typically these will be assumptions based on the Design Engineer's experience that best fits the existing or proposed terrain and the required roadway cross-sections and ROW.
3. Calculate the flow capacity of the trial channel using Manning's equation 1.3 and compare calculated capacity against the design flows. If the channel capacity is less than the required design flows, increase the bottom slope or increase the cross-section dimensions and recalculate.
4. Calculate the design velocity. Compare to the allowable velocities in Table A5-2 Adjust channel geometry and longitudinal slopes as necessary to reduce velocity to less than allowable. If this is not possible, then provide the necessary channel erosion protection at the bottom and side slope armouring or lining.
5. Check and provide calculations for additional criteria items, such as freeboard, clearance of design water surface below pavement, and critical depth.

Before finalising a channel design, the Design Engineer must verify that the normal depth of a channel is either greater or less than the critical depth. Generally, open channels shall be designed with greater than critical depths for laminar, uniform flows. Designs within this flow regime will help assure that the channels and ditches are stable and non-erosive.

Hydraulic principles of open-channel flow are based on steady state uniform flow conditions. Though these conditions are rarely achieved in the field, generally the variation in channel

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