5. Highway Drainage

- **Drainage Facilities – for the flow of water away from the *__surface__* and *__subsurface of the pavement__* to properly designed channels and then discharge to the natural waterways.**

- **Sources of water – surface water(**which occurs as rain or snow)

  – subsurface water (which flows in underground streams)

- **Design principles involve**

  - **Surface drainage facilities**
  - **Subsurface drainage facilities**

5.1. Surface Drainage

- Surface drainage encompasses all means by which surface water is removed from the pavement and right of way of the highway or street
- **The facility minimizes damage to highway due to water seeping through cracks**
- **The system includes**
  - **Transverse slopes**
  - **Longitudinal slopes**
  - **Longitudinal channels**
  - **Curbs and gutters**
  - **Cross-Drainage structures**
- **The design may be divided into three major phases:**
  - **An estimate of the quantity of water**
  - **The hydraulic design of each element of the system**
  - **The comparison of alternative systems, materials, and other variables**

5.1.1. Flood Estimation

- **methods:**
  - **analysis of stream flow data,**
  - **runoff modeling, and**
  - **regionalized flood formula**
- ***Rational method – (under category of runoff modeling)***
  - **used rainfall runoff relation for "ungauged" areas**
  - **suitable for small catchments of sizes up to five square kilometres**
  - **the basic form of the equation is:**

$$Q = \frac{C \times I \times A}{360}$$

where: Q = flood peak at catchment's exit (m^3/sec);

C = rational runoff coefficient;

I = average intensity over the whole catchment (mm/hr) for a duration corresponding to the time of concentration; and

A = catchment area (hectares)

The time of concentration is defined as the time required for the surface runoff from the remotest part of the drainage basin to reach the point where the drainage facility is located

5.1.1. Flood Estimation

- **The runoff coefficient, C,**
  - **is an integrated value representing the ratio of runoff to rainfall for the drainage area.**
  - **depends on the type of *ground cover*, the *slope* of the drainage area, storm *duration*, and prior *wetting*.**
  - **In case where the drainage area consists of *different ground characteristics with different runoff coefficients*, a representative value C_w is computed by determining the weighted coefficients as:**

$$C_w = \frac{\sum_{i=1}^{n} C_i A_i}{\sum_{i=1}^{n} A_i}$$

5.1.2. Hydraulics Design

- ***Aim*** **– providing suitable structure size**
  - **economically and efficiently dispose of the expected runoff without detrimental *erosion* and *sedimentation* problem**

- **Design of Side Ditches**
  - **Capacity – using Manning's formula:**

$$Q = Av = A\frac{R^{2/3}S^{1/2}}{n}$$

  - **Design Procedure**
    - ***Select n and side slopes***
    - ***Compute the maximum R from Manning's formula***
    - ***Calculate the minimum A using continuity equation***
    - ***Solve for b and y***
    - ***Check for $y > y_c$ >>>> add free board***
    - ***Check for $y < y_c$ >>>> reduce S***

5.1.2. Hydraulics Design

Manning's *n* and maximum permissible velocity

Ditch lining	n	V_{max} (m/sec)
Rock	0.035–0.045	4.5-6.1
Soil	0.022–0.025	0.3-2.4
Vegetation		
Avg. turf	0.030–0.070	0.9-1.5
Dense turf	0.040–0.200	1.2-2.4
Paved channel	0.012–0.033	2.4-6.1

5.1.2. Hydraulics Design

- **Design of Cross-Drainage structures**
  - **Depending on the *highway class*, *stream flow volume*, *site conditions* and *economic factors*,**
    - **Fords:**
      - **utilize the existing riverbed**
      - **for shallow, slow moving watercourses**
      - **about 100 vehicles per day**
      - **Gravel or stones can be used**
    - **Drifts:**
      - **concrete slab is used (when the bed of the river is not able to carry vehicles.**
      - **used where fords cannot be used due to risk of flood**

5.1.2. Hydraulics Design

- **Design of Cross-Drainage structures**
  - **Culverts:**
    - **convey water below the road**
    - **span of 6 m or less**
    - **sometimes designed to flow full and does not form part of the roadway**
    - **located at bottom of depressions, point where natural streams intersect the roadway and points required for passing surface drainage in side ditches**
  - **Highway bridges:**
    - **to carry the roadbed over an established waterways**
    - **span of more than 6 m**
    - **designed to pass floating debris or vessels**
    - **form part of the travelled roadway**

5.1.2. Hydraulics Design

- ***Hydraulic Design of Culverts.*** **involves the following general procedure:**
  - **obtain all site data and plot a *roadway cross section* at the culvert site, including a profile of the stream channel.**
  - **establish the culvert invert elevations at the inlet and outlet and determine the culvert length and slope**
  - **determine the allowable depth of headwater and tail water**
  - **select a type and size of culvert that will accommodate the design flow under the established conditions.**
  - **provide protective devices to prevent destructive channel erosion.**

- ***The allowable level of the headwater upstream of the culvert entrance is generally the principal control on the culvert size and inlet geometry*.**

5.1.2. Hydraulics Design

- ***Culvert types and materials***
  - **Types of culverts of different sizes:**
    - **Circular**
    - **Box**
    - **Elliptical**
    - **Arch**
  - **Materials**
    - **Reinforced concrete**
    - **Corrugated metal**
    - **Stone masonry, etc**
- **Selection of the type depends on**
  - **hydraulic requirements**
  - **strength required to sustain the weight of a fill or moving wheel loads**
  - **economics**

5.1.2. Hydraulics Design

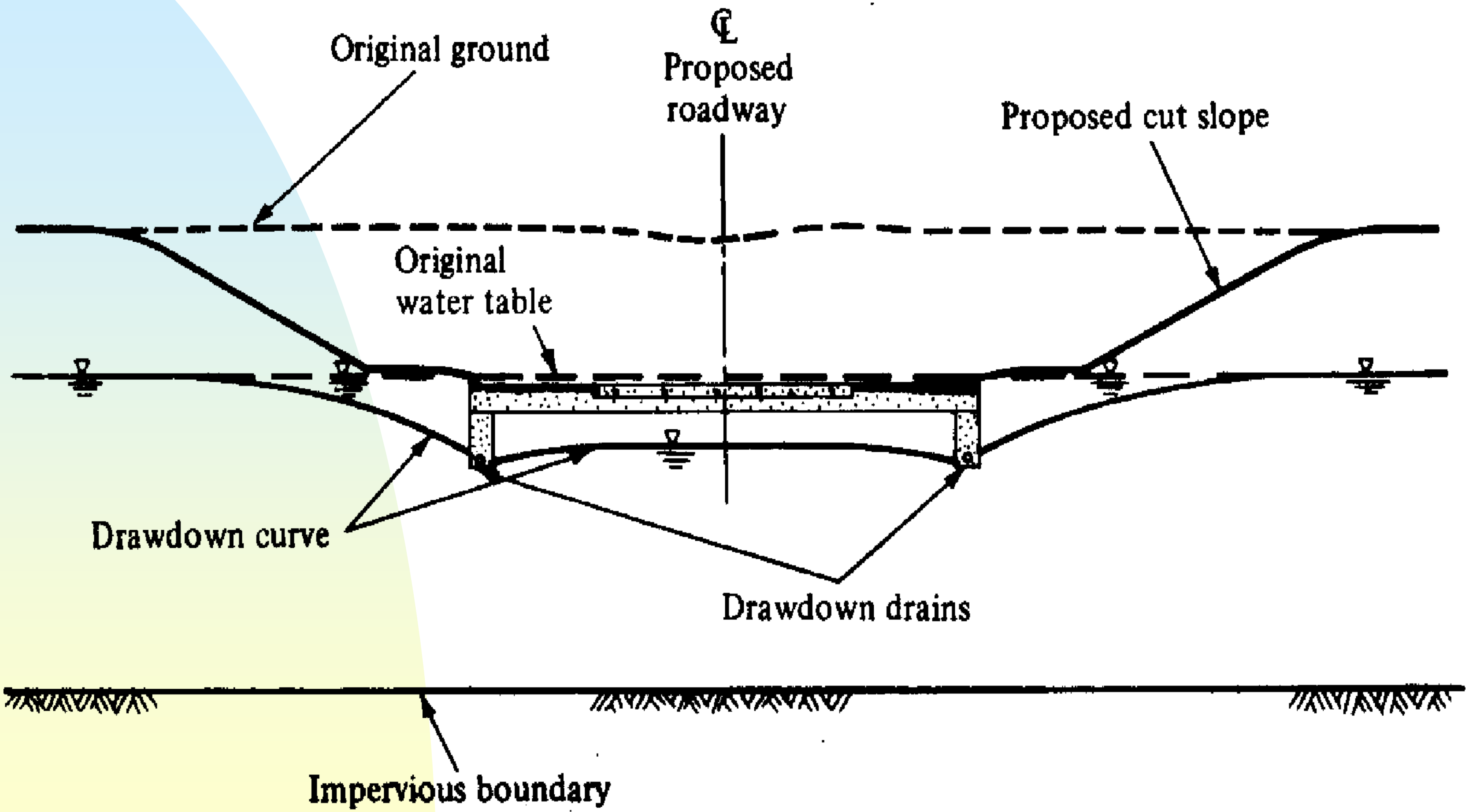
- ***Highway bridges***
  - ***Design principle involves***
    - **Location**
    - **Alignment**
    - **Foundation**
    - **Traffic safety, operating conditions, and fulfilment of the purposes of the road**
    - **Constriction of flow**
    - **Velocity of flow**
    - **Scouring**
    - **Flooding**
    - **Economics**

5.2. Subsurface Drainage

- **provided within the pavement structure to drain water that has:**
  - **percolated through cracks and joints**
  - **moved upward as a result of capillary action**
  - **existed as ground water**

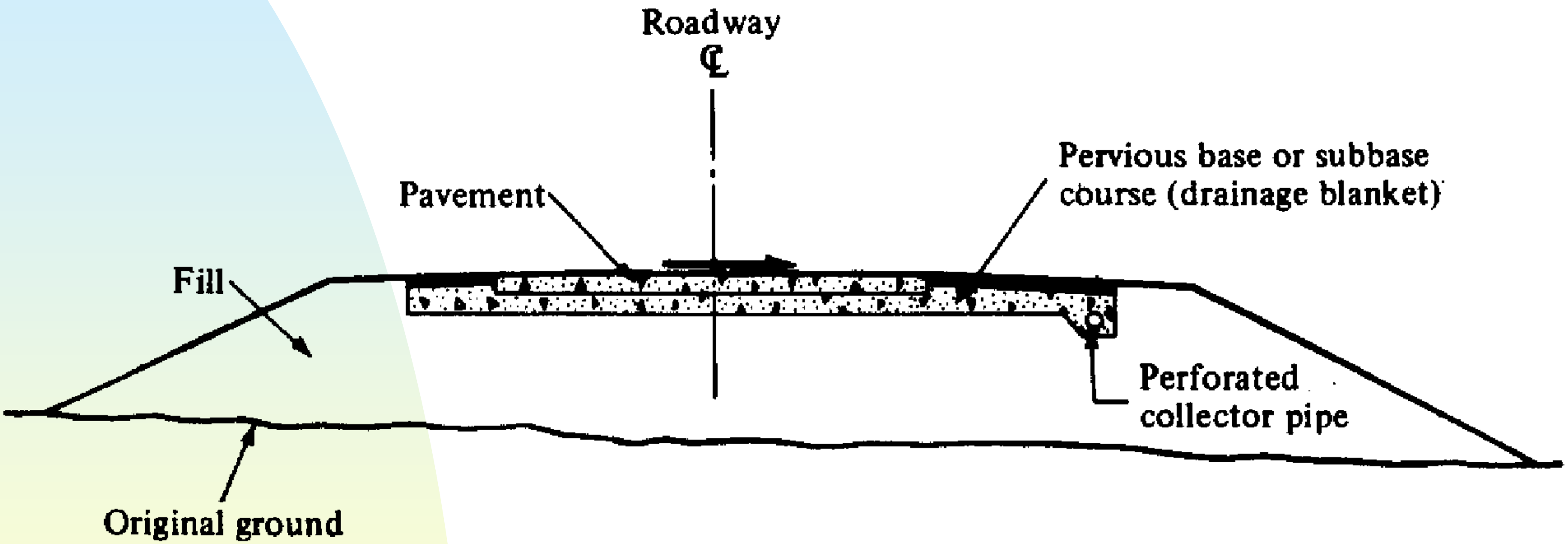
- **Subsurface drainage systems are usually classified into five general categories:**
  - **Longitudinal drains**
  - **Transverse drains**
  - **Horizontal drains**
  - **Drainage blankets**
  - **Well systems**

5.2. Subsurface Drainage



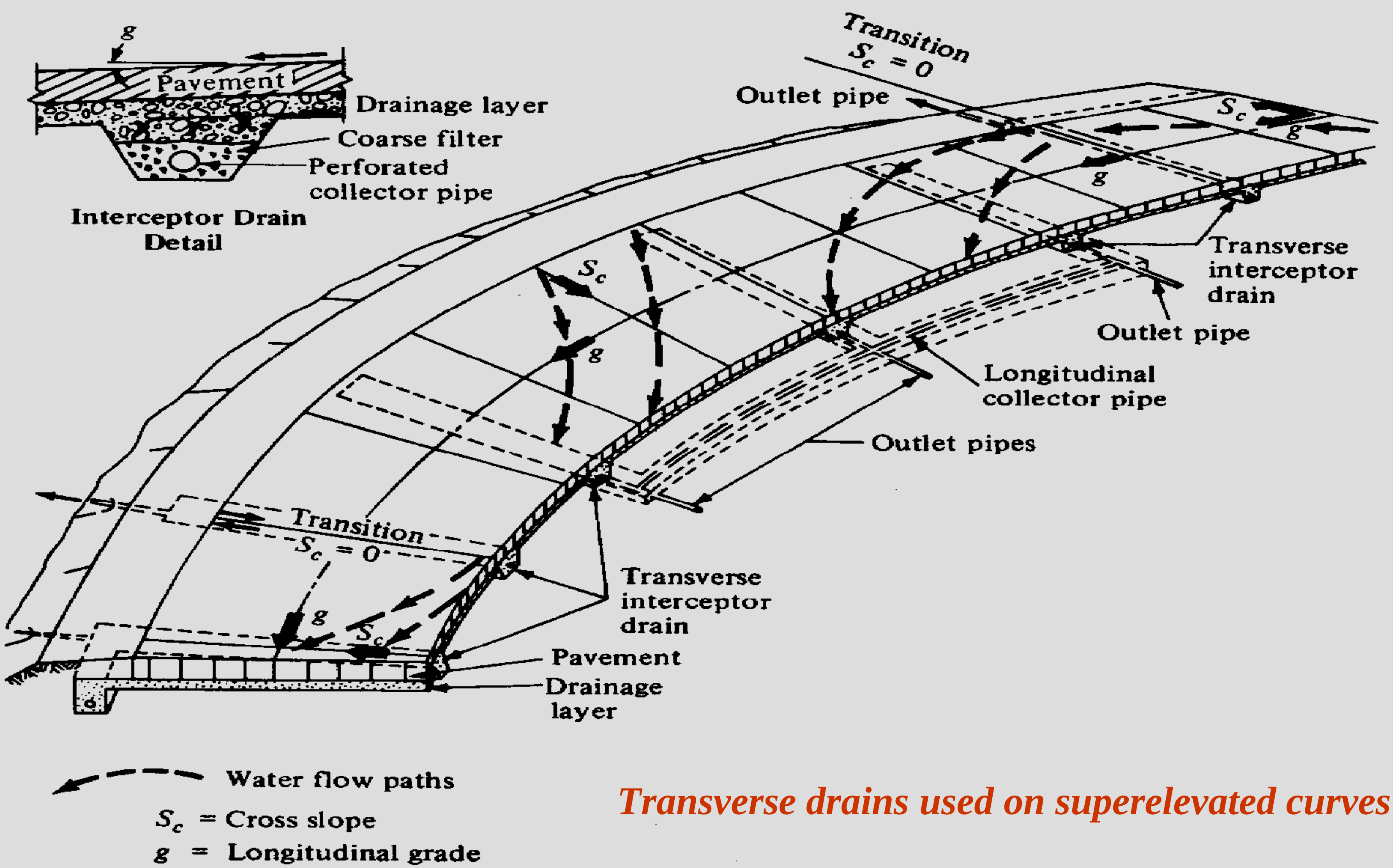
Longitudinal drains used to lower the ground water level

5.2. Subsurface Drainage



Longitudinal drains used to remove seeping water

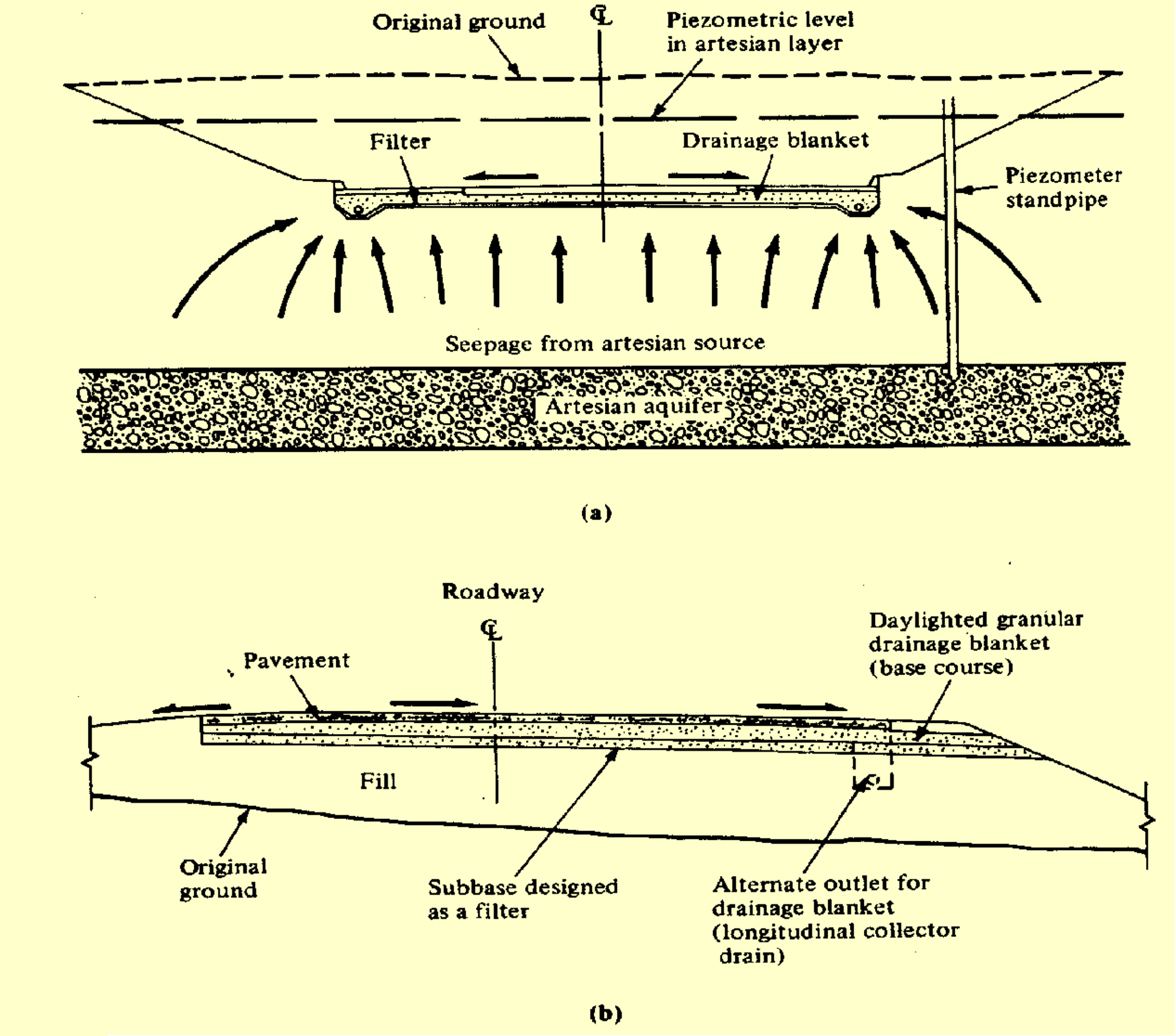
5.2. Subsurface Drainage



Transverse drains used on superelevated curves

5.2. Subsurface Drainage

Drainage Blankets



5.2.1. Design of Subsurface Drainage

- **The design procedure for subsurface drainage involves:**
  - **Summarize the available data**
    - **the flow geometry**
    - **properties of materials**
    - **hydrological and climatic characteristics, etc**
  - **Determine the quantity of water**
  - **Determine the drainage system required**
  - **Determine the capacity and spacing of longitudinal and transverse drains and select filter material, if necessary**
  - **Evaluate the design with respect to economic feasibility and long-term performance**

5.2.1. Design of Subsurface Drainage

- **Determination of Discharge Quantity**
  - **The net amount of water to be discharged consists of;**
    - **Water due to infiltration**
    - **Ground water**
    - **Evaporation**
    - **Water due to melting of ice,** ***but not a significant problem in the tropics***
  - ***(i) Water due to infiltration, q_i***

$$q_i = I_c \left[\frac{N_c}{W} + \frac{W_c}{W\,C_s} \right] + k_p$$

5.2.1. Design of Subsurface Drainage

(ii) Ground Water

$L_i = 3.8\,(H - H_0)$

Average inflow rate to the drainage layer and the drain pipe

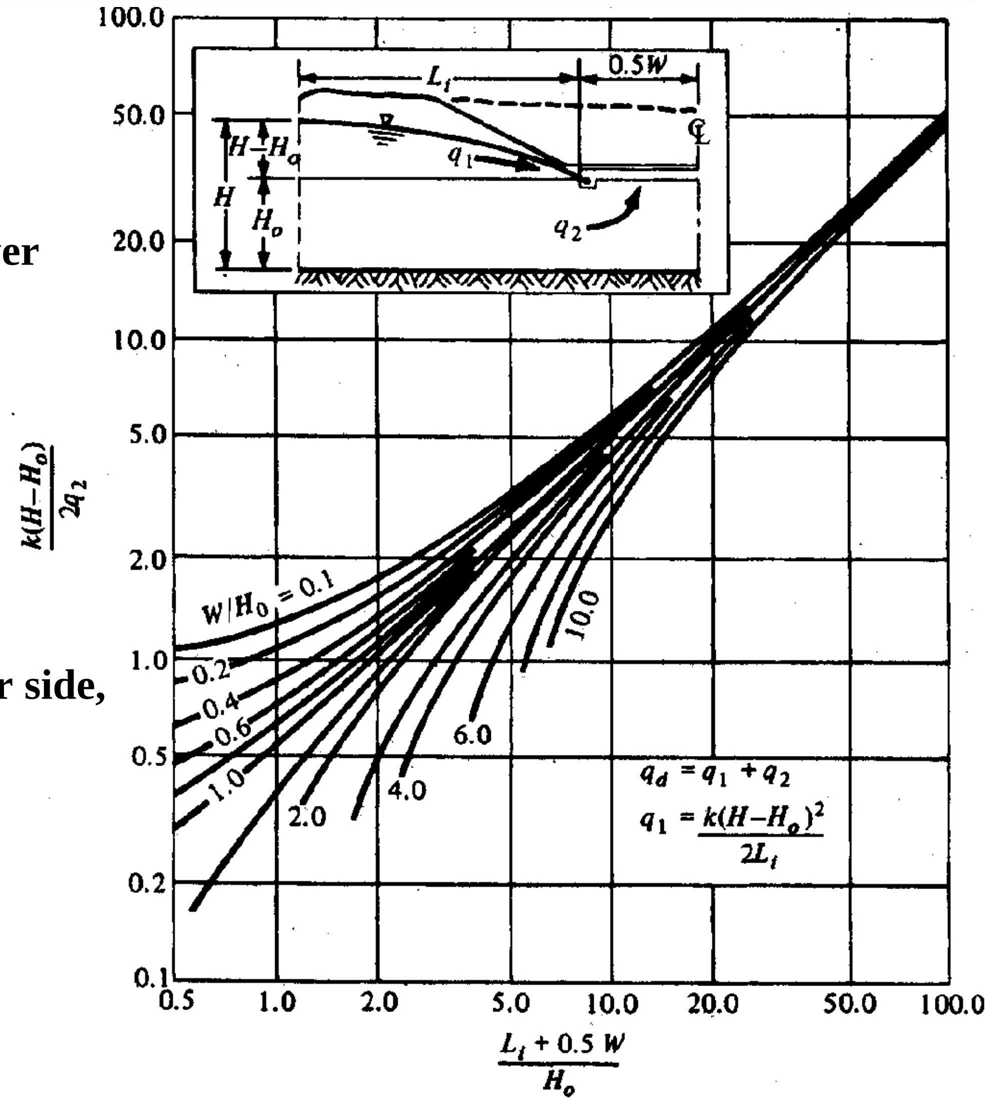
$$q_g = \frac{q_2}{0.5\,W}$$

$$q_L = (q_1 + q_2)$$

If there is no drainage pipe on the other side, the average inflow rates

$$q_g = \frac{q_1 + 2q_2}{W}$$

$$q_L = 2(q_1 + q_2)$$



5.2.1. Design of Subsurface Drainage

- ***(iii) Vertical outflow, or Evaporation, q_v***
  - **Considered when the evaporation of some of the accumulated water through the subgrade is significant.**
- ***Artesian flow, the average inflow rate***

$$q_a = K\frac{\Delta H}{H_0}$$

- ***Net design flow***
  - **The net design inflow is the sum of inflow rates from all sources less any amount attributed to vertical outflow through the underlying soil.**
  - **If there is no frost, no ground water, and no artesian flow,**

$$q_d = q_i - q_v$$

  - **If there is no frost and artesian flows, and the inflows are only due to infiltration and ground water,**

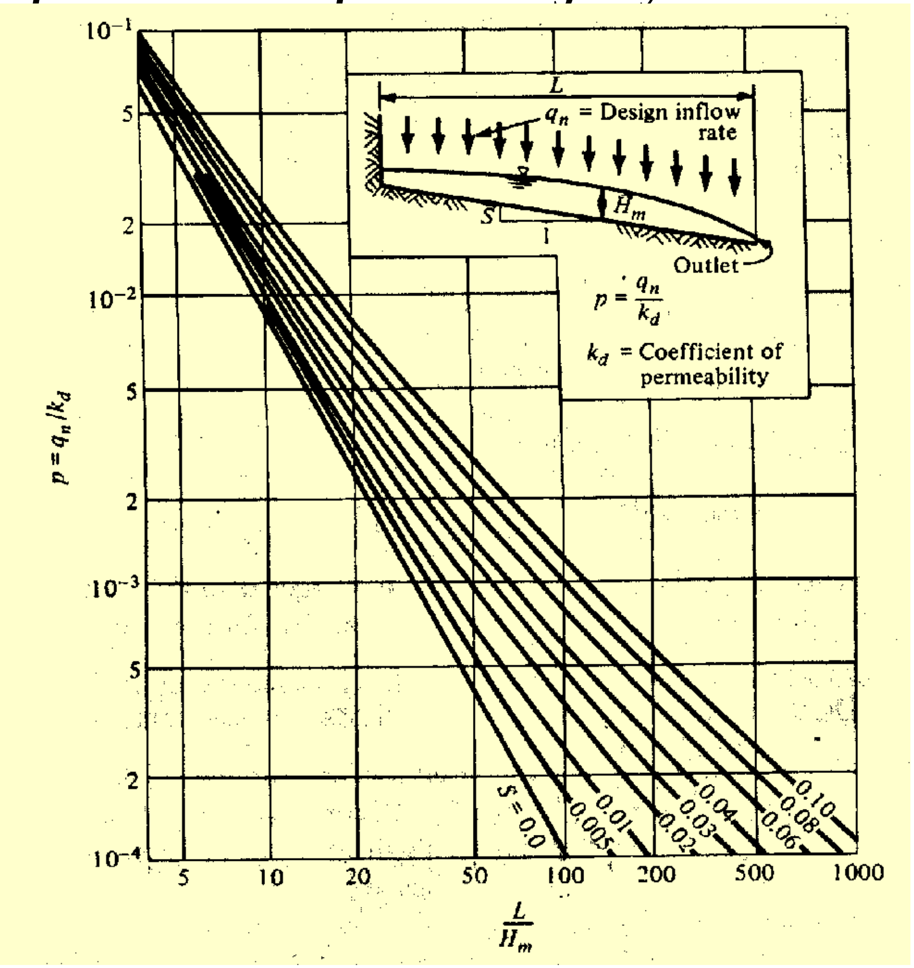
$$q_d = q_i + q_g - q_v$$

  - **If the inflows are only due to infiltration and artesian, then**

$$q_d = q_i + q_a - q_v$$

5.2.1. Design of Subsurface Drainage

- ***Design of Drainage Layer - involves***
  - ***Determination of the thickness of the drainage layer***



5.2.1. Design of Subsurface Drainage

- ***Design of Longitudinal Collector Pipes***
  - ***involves the determination of pipe diameter and the identification of a suitable backfill material***

$$D = \left(\frac{3.208 L_0 q n}{S^{0.5}} \right)^{0.375}$$

5.2.1. Design of Subsurface Drainage

- ***Design of Longitudinal Collector Pipes [alternative approach]***