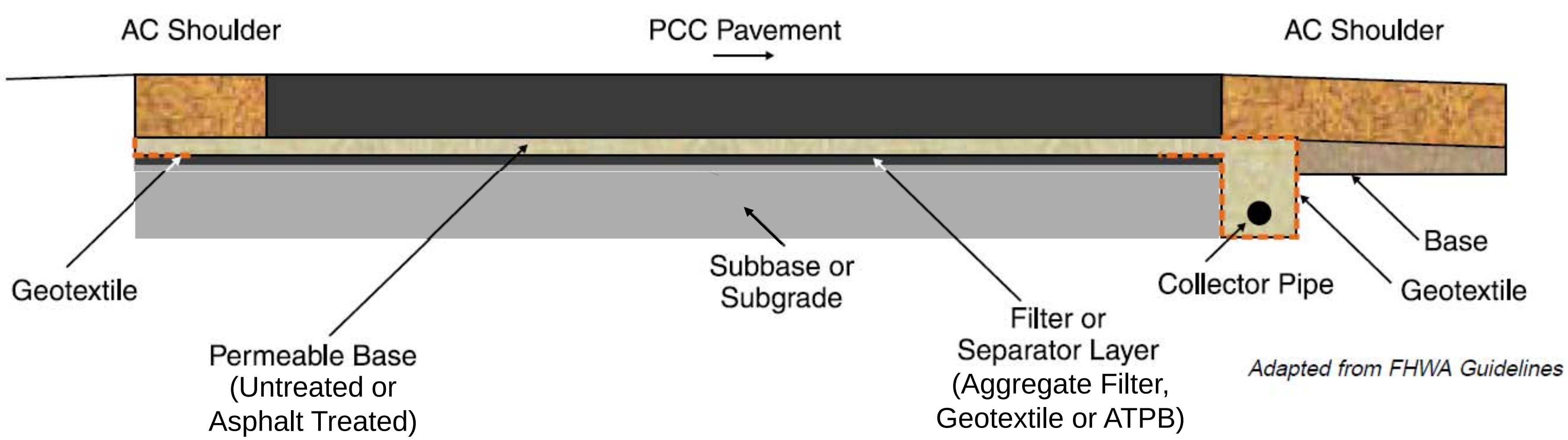
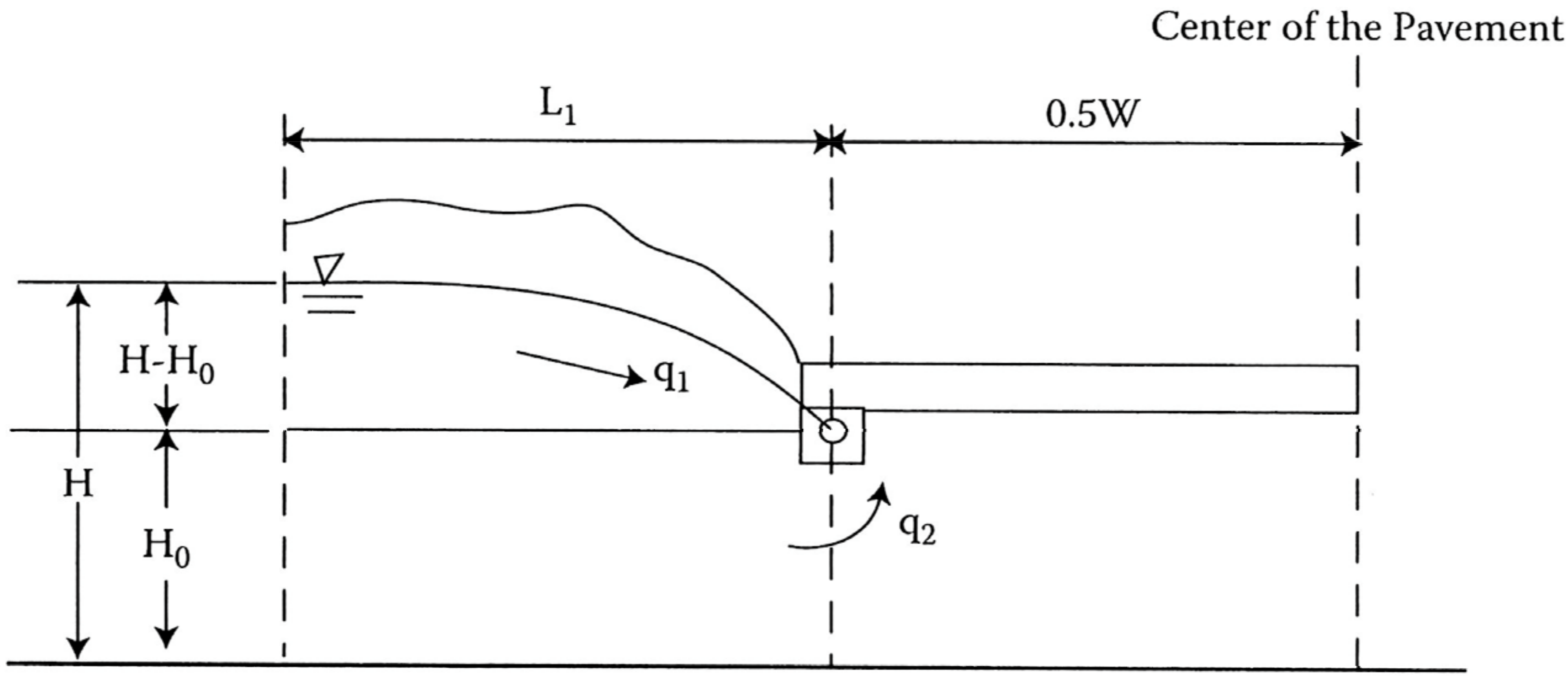
Subsurface Drainage

Subsurface Drainage

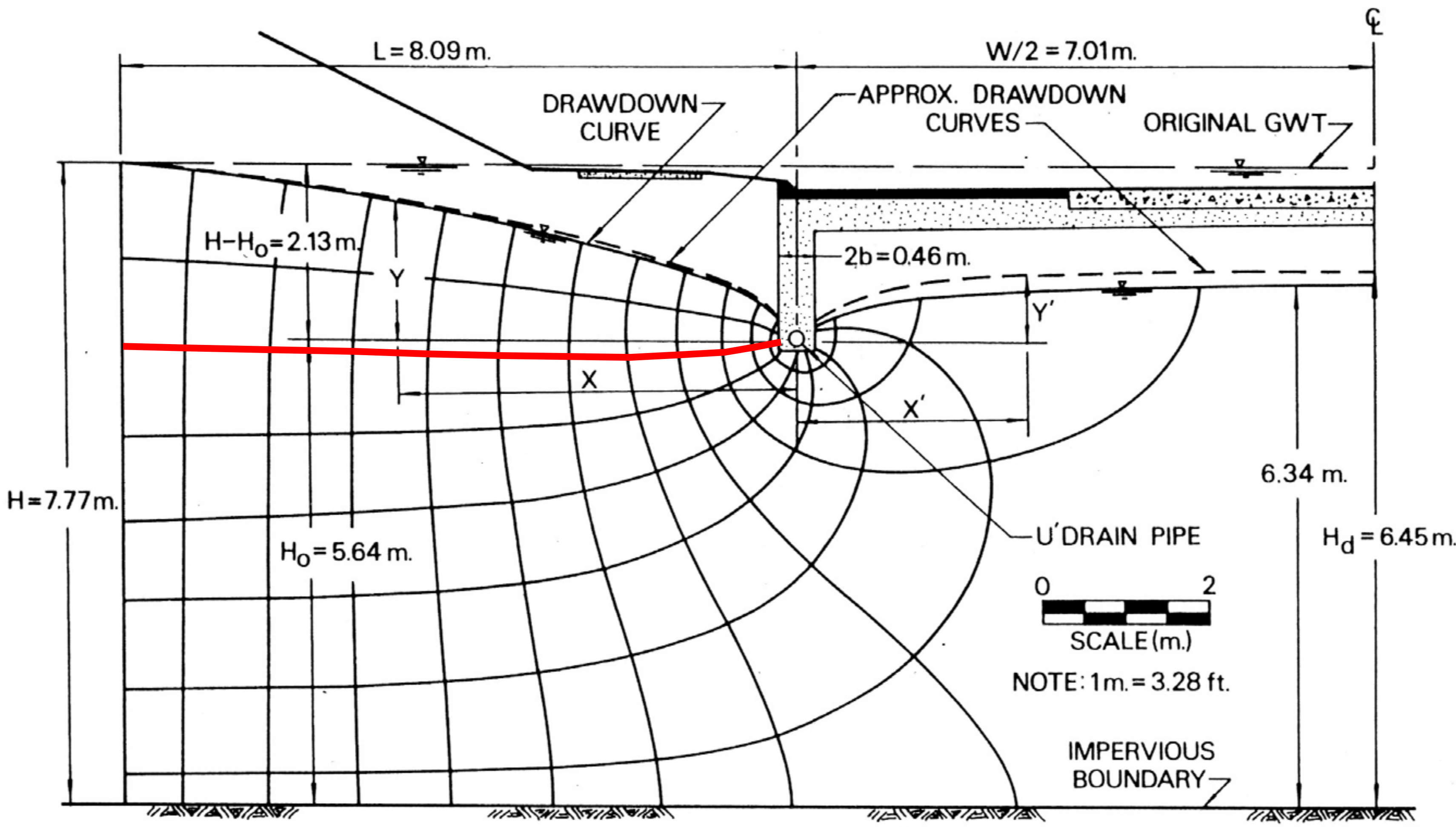


Source: "Making Edge Drains Work," *Better Roads*, January 2007

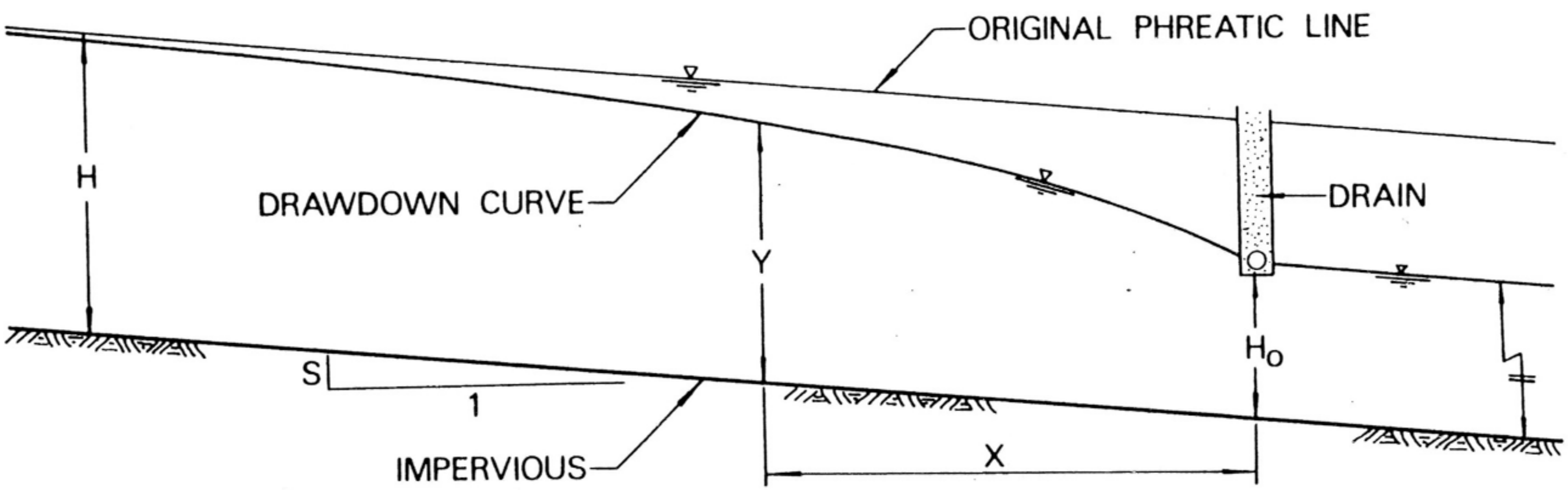
Flow from Groundwater



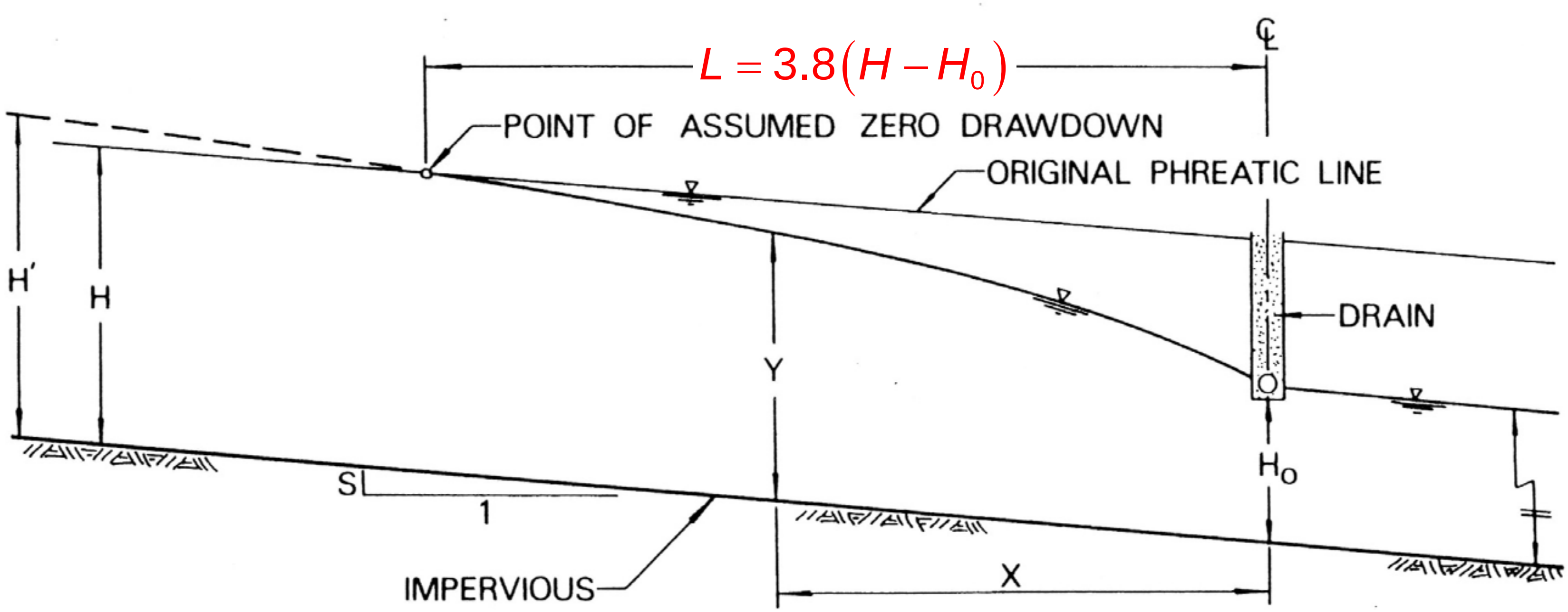
Flow from Groundwater



Flow from Groundwater



Flow from Groundwater



Flow from Groundwater

permeability — drawdown

$$q_1 = \frac{k\left(H - H_0\right)^2}{2L_i}$$

radius of influence

Note that the equation in the book is missing the square!

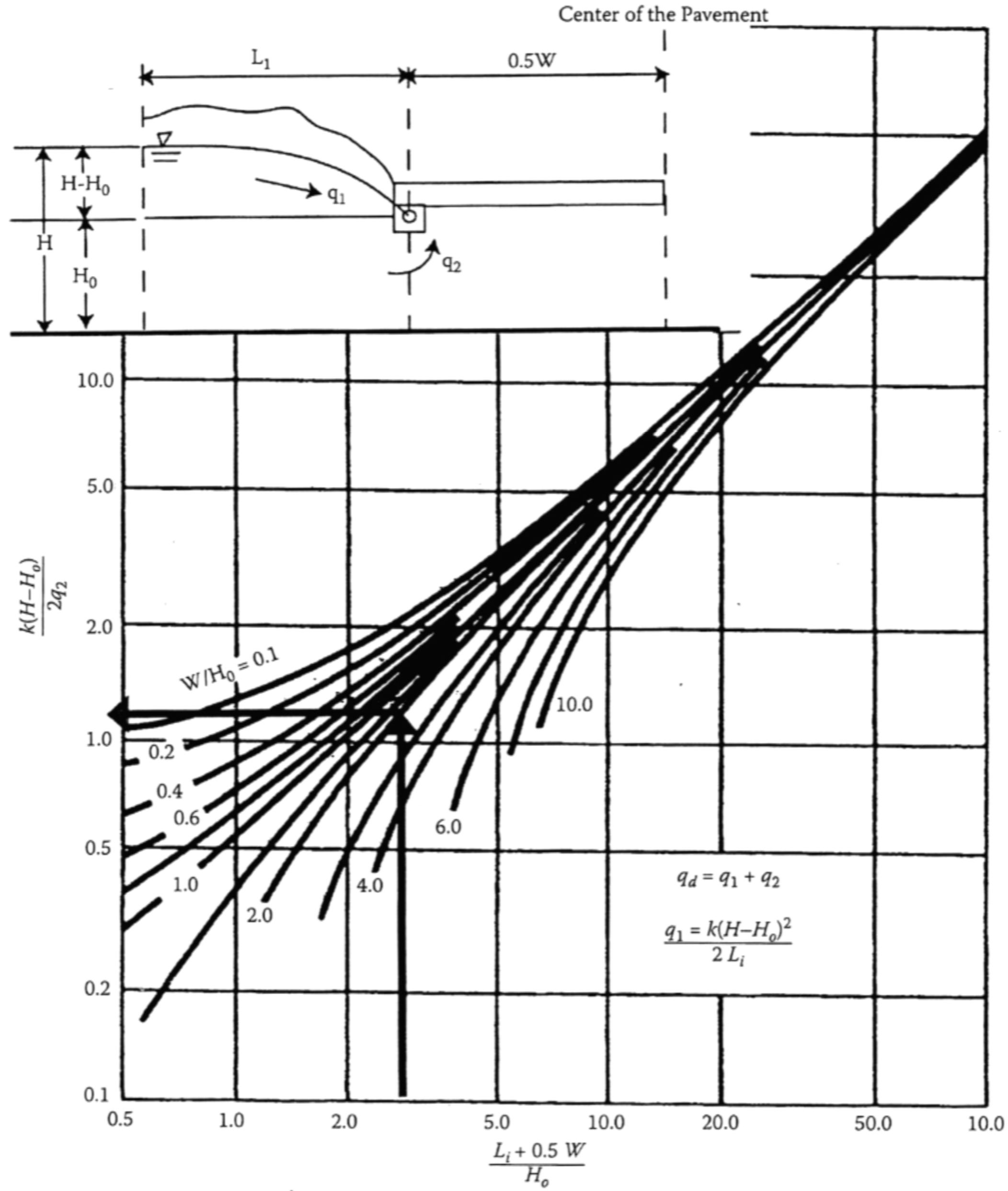
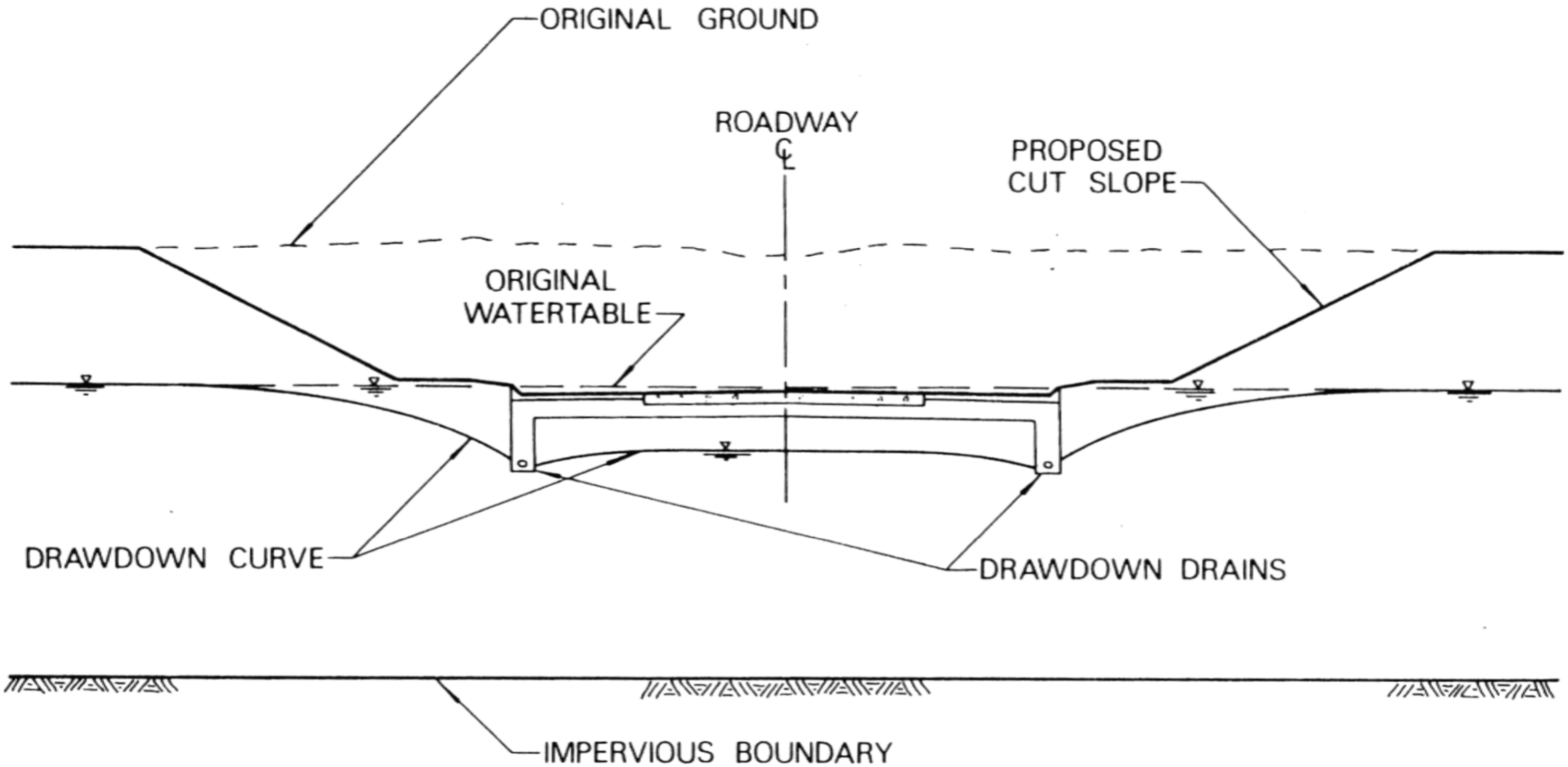


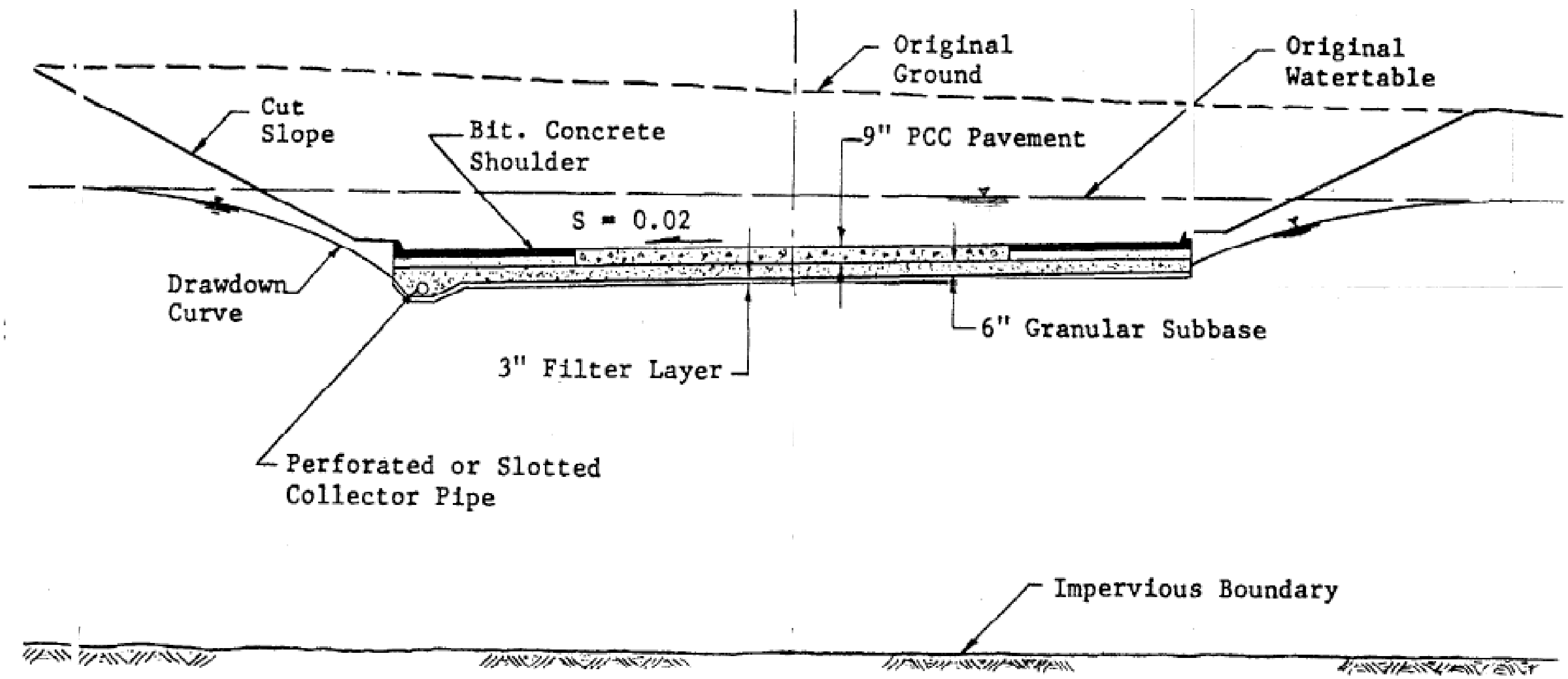
FIGURE 6.11 Estimation of K.

Source: From Garber/Hoel. *Traffic and Highway Engineering*, 3 E. © 2002 Nelson Education Ltd. Reproduced by permission. www.cengage.com/permissions.

Flow from Groundwater



Flow from Groundwater



Flow from Groundwater

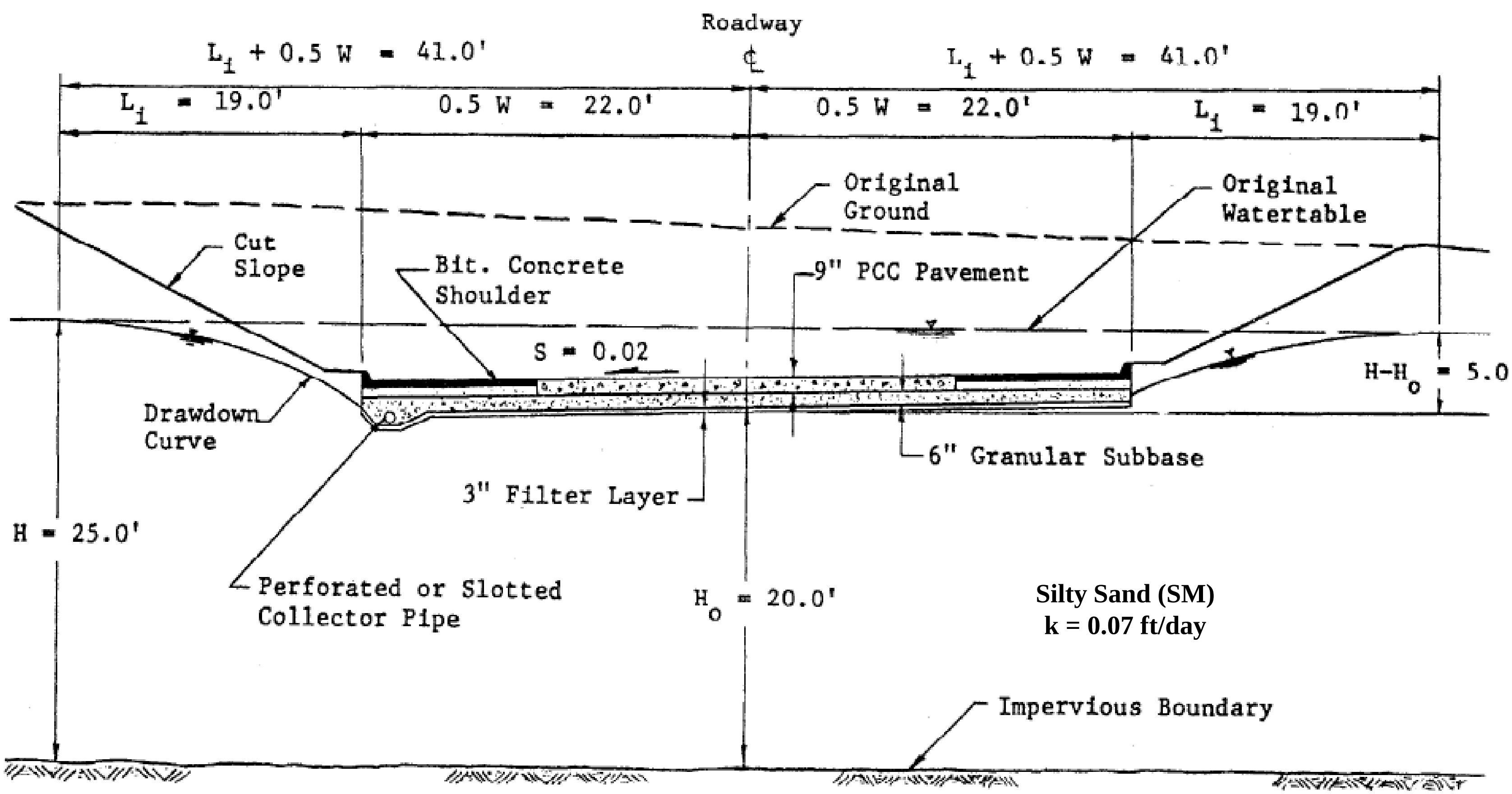
Two Edge Drains

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

One Edge Drain

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

Example 1



Roadway
℄
Li + 0.5 W = 41.0'
Li + 0.5 W = 41.0'
Li = 19.0'
0.5 W = 22.0'
0.5 W = 22.0'
Li = 19.0'
Original Ground
Original Watertable
Cut Slope
Bit. Concrete Shoulder
9" PCC Pavement
S = 0.02
H-Ho = 5.0'
Drawdown Curve
6" Granular Subbase
3" Filter Layer
H = 25.0'
Perforated or Slotted Collector Pipe
Ho = 20.0'
Silty Sand (SM)
k = 0.07 ft/day
Impervious Boundary

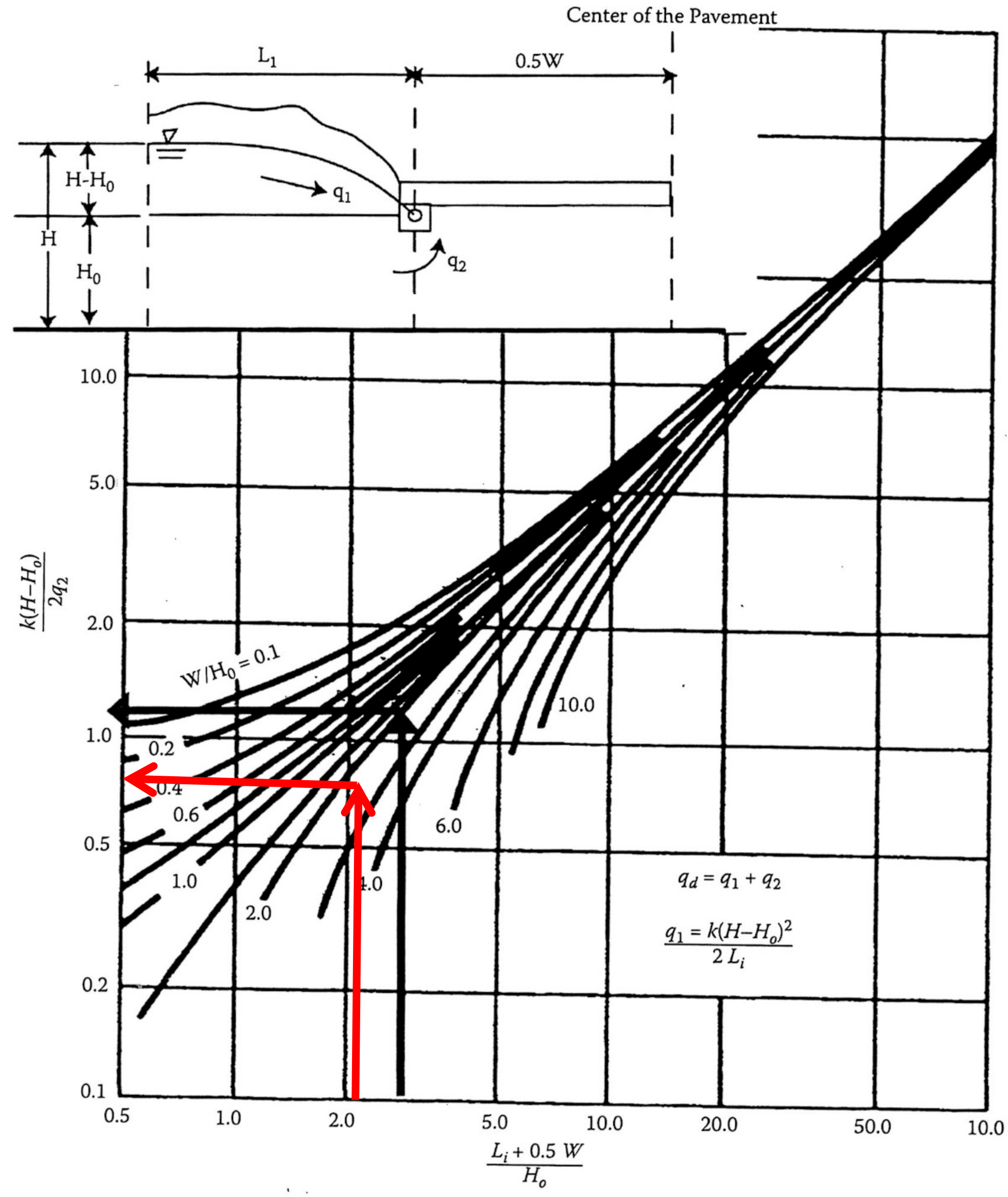
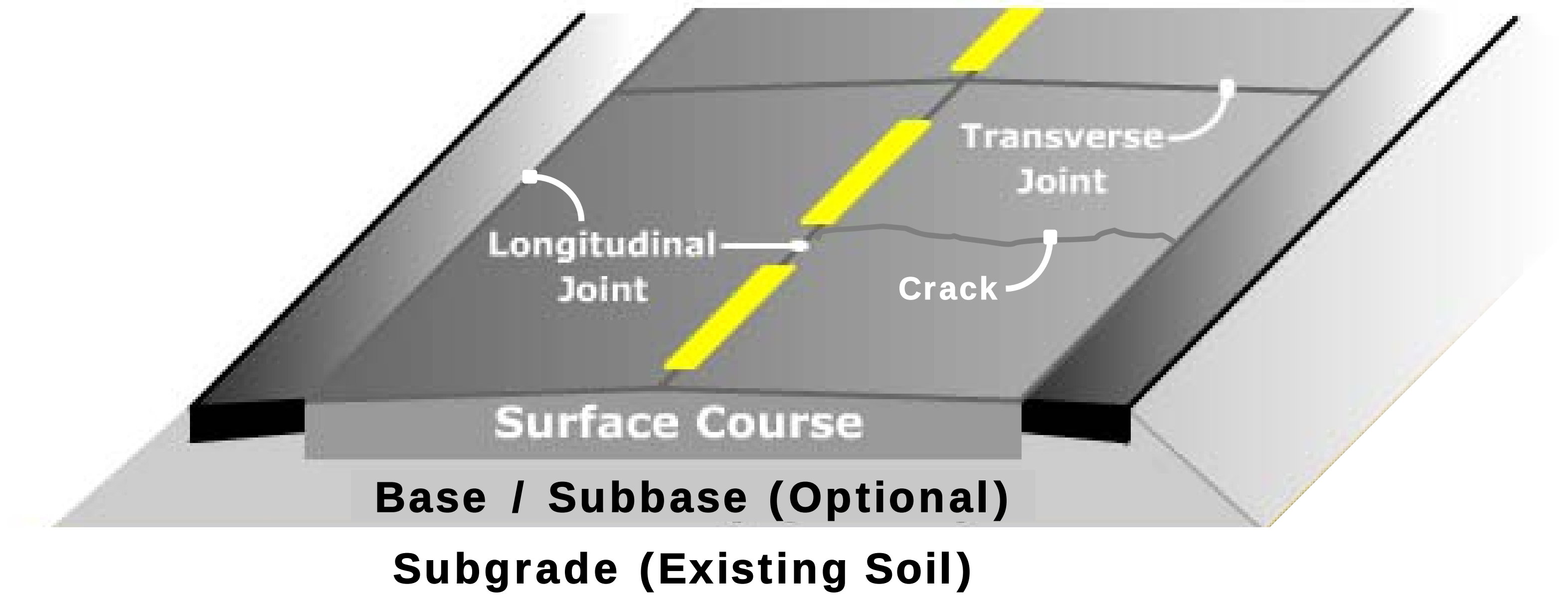


FIGURE 6.11 Estimation of K.

Source: From Garber/Hoel. *Traffic and Highway Engineering*, 3 E. © 2002 Nelson Education Ltd. Reproduced by permission. www.cengage.com/permissions.

Flow from Infiltration



Source: WSDOT Pavement Guide Interactive CD-ROM

Typical Soil Permeability

Soil	*Permeability Coefficient, k (cm/sec)*	*Relative Permeability*
Coarse gravel	Exceeds 10^{-1}	High
Sand, clean	10^{-1} to 10^{-3}	Medium
Sand, dirty	10^{-3} to 10^{-5}	Low
Silt	10^{-5} to 10^{-7}	Very low
Clay	Less than 10^{-7}	Impervious

Flow from Infiltration

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

I_c: crack/joint infiltration rate

N_c: number of longitudinal cracks/joints

W_c: length of transverse cracks/joints

k_p: uncracked permeability

W: distance between the outermost longitudinal cracks/joints

C_s: spacing of transverse cracks/joints

Flow from Infiltration

I_c = design infiltration rate (volume per day per foot of crack)

W = width of drainage blanket subjected to infiltration

N_c = number of contributing longitudinal cracks or joints

W_c = length of contributing transverse cracks or joints

C_s = spacing of transverse cracks or joints

FHWA Highway Subdrainage Design Manual
Publication FHWA-TS-80-224 dated July 1990

Flow from Infiltration

infiltration per foot of crack/joint

avg. length of longitudinal cracks/joints per foot of travel

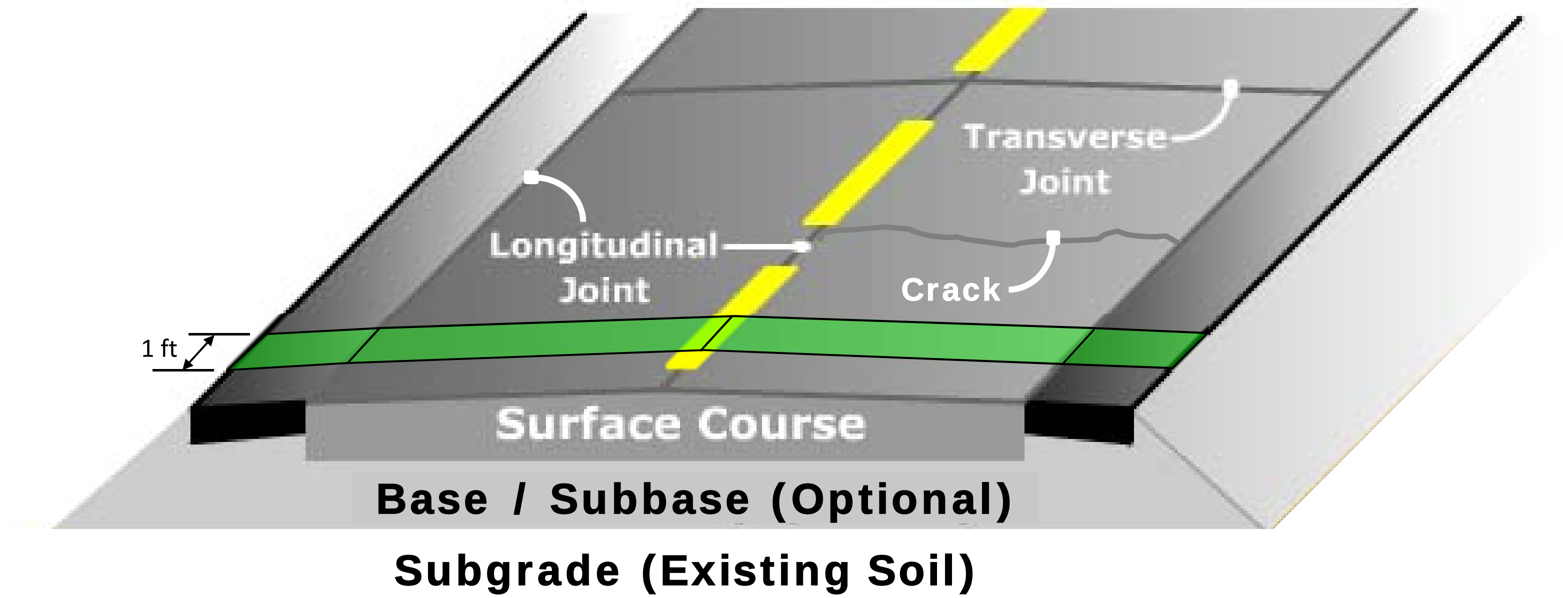
uncracked permeability

$$q_i = \frac{I_c}{W}\left[\, L_L + L_T \,\right] + k_p$$

distance between the outermost longitudinal cracks/joints

avg. length of transverse cracks/joints per foot of travel

Flow from Infiltration



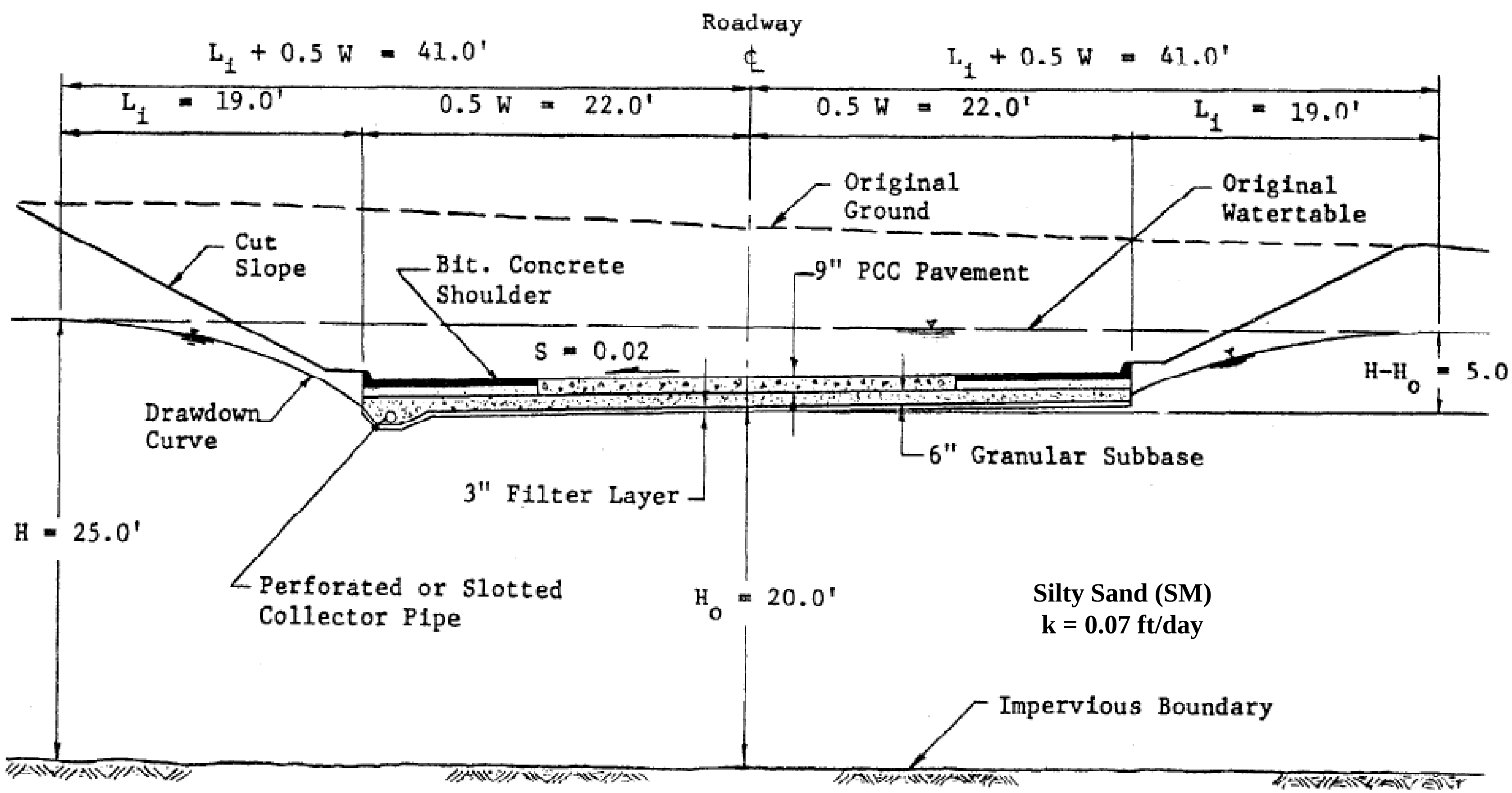
Source: WSDOT Pavement Guide Interactive CD-ROM

Flow from Infiltration

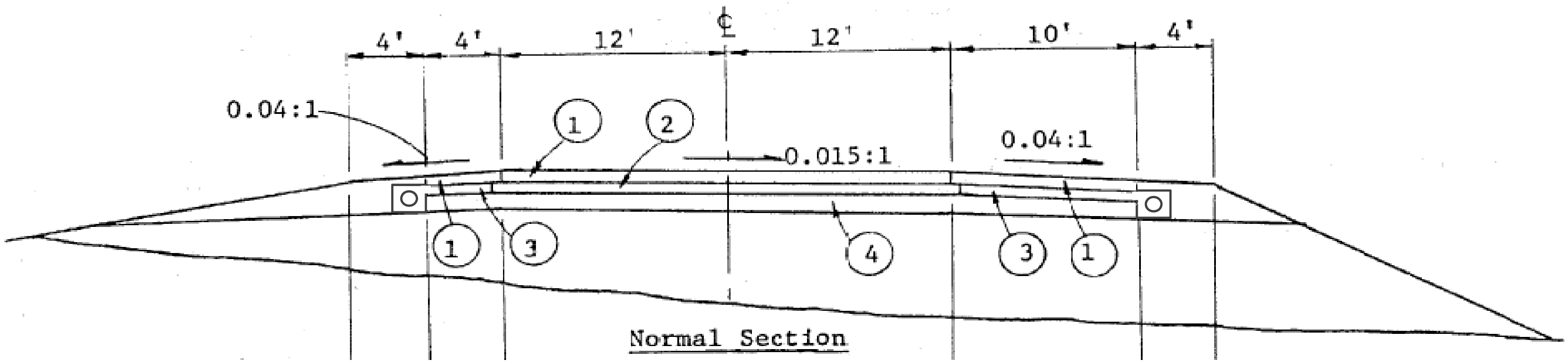
It is recommended that the “normal” values of C_s be taken as the transverse joint spacing for new JPCP and JRCP and as the anticipated average transverse crack spacing for new CRCP and asphalt concrete pavements. A value of 40 feet has been suggested for new asphalt pavements; however “normal” transverse cracking as a result of thermal and moisture changes can be extremely variable.

FHWA Highway Subdrainage Design Manual
Publication FHWA-TS-80-224 dated July 1990

Example 1 (Continued)



Example 2



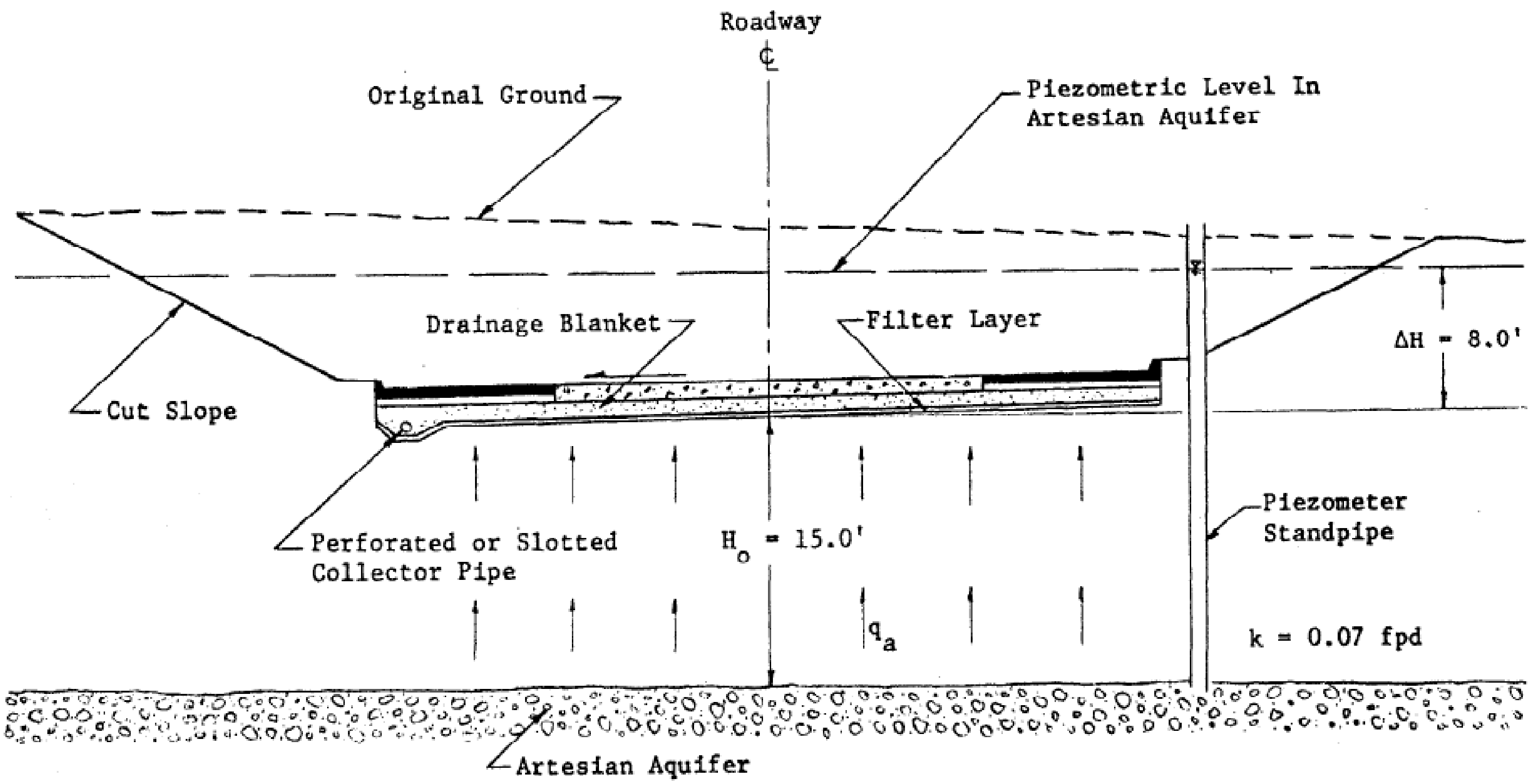
(1) - 6" Hot Mixed Asphaltic Concrete (3" Surf., 3" Binder)
(2) - 6" Cement Stablized Aggregate Base
(3) - 6" Aggregate Base
(4) -12" Dense Graded Aggregate Subbase

Artesian Flow

Excess
hydraulic
head

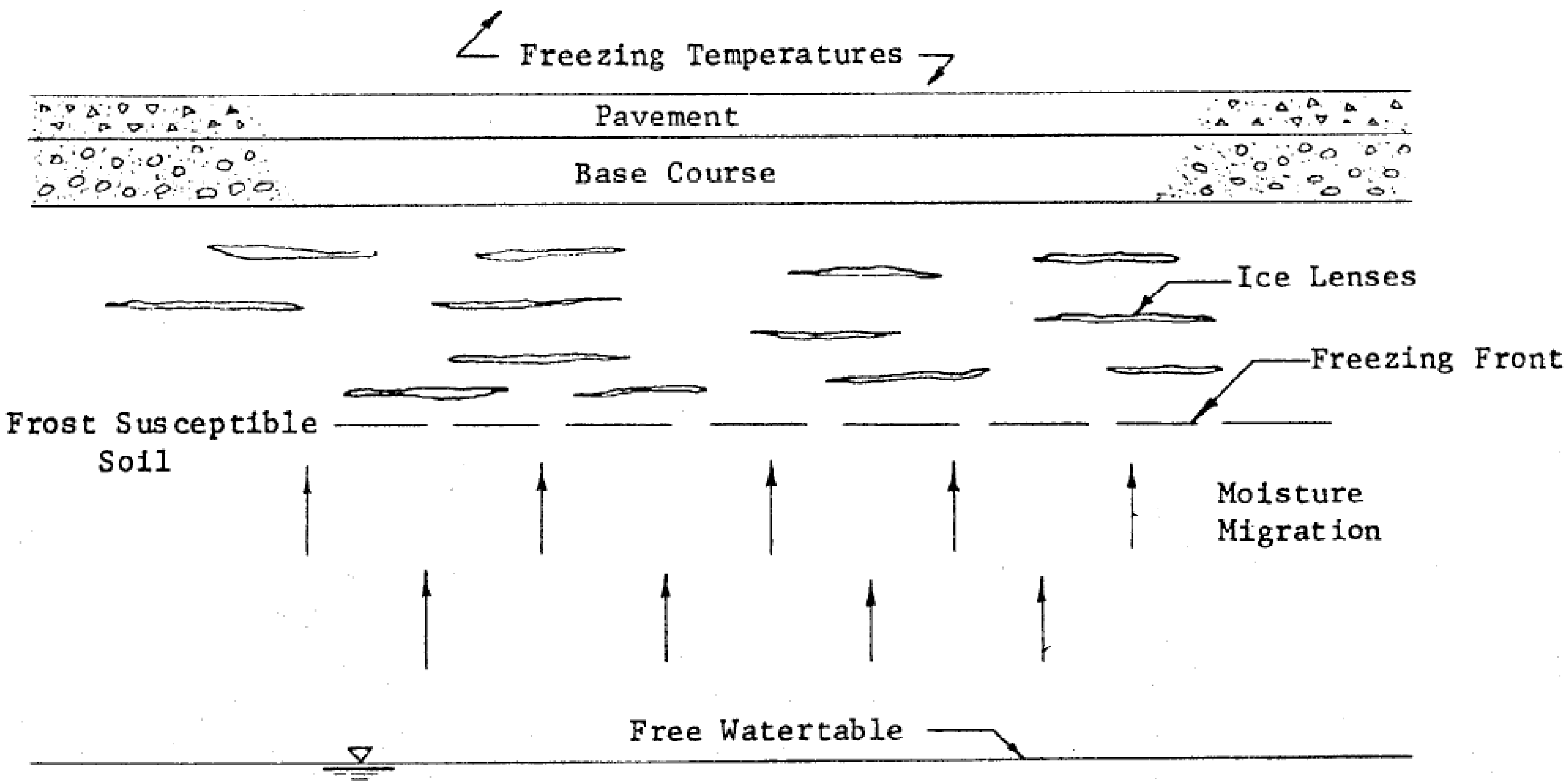
$$q_a = \frac{k \Delta H}{H_0}$$

Example 3

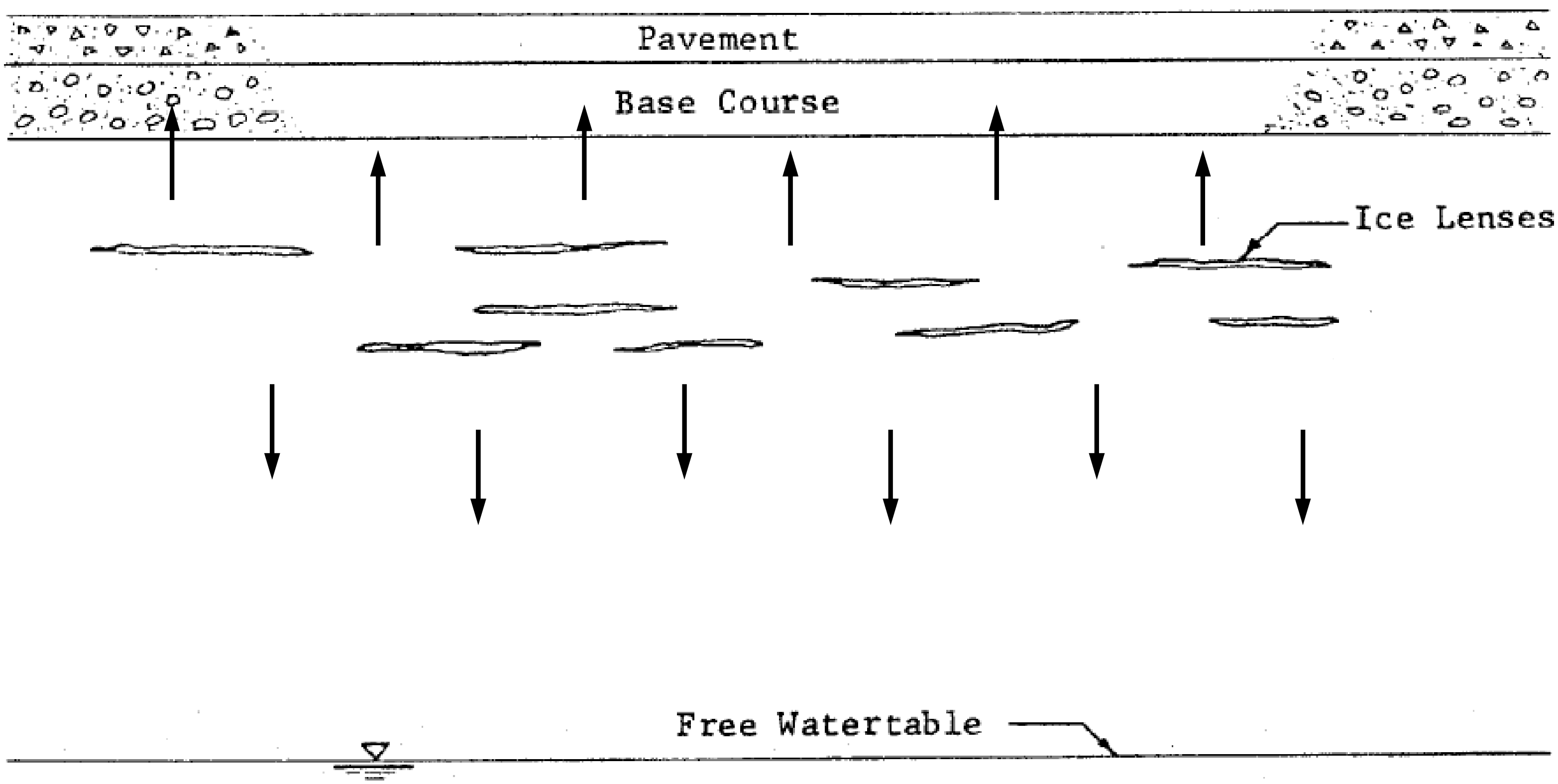


Roadway
℄
Original Ground
Piezometric Level In Artesian Aquifer
Drainage Blanket
Filter Layer
Cut Slope
ΔH = 8.0'
Perforated or Slotted Collector Pipe
H_o = 15.0'
Piezometer Standpipe
q_a
k = 0.07 fpd
Artesian Aquifer

Flow due to Spring Thaw



Flow due to Spring Thaw



Flow due to Spring Thaw

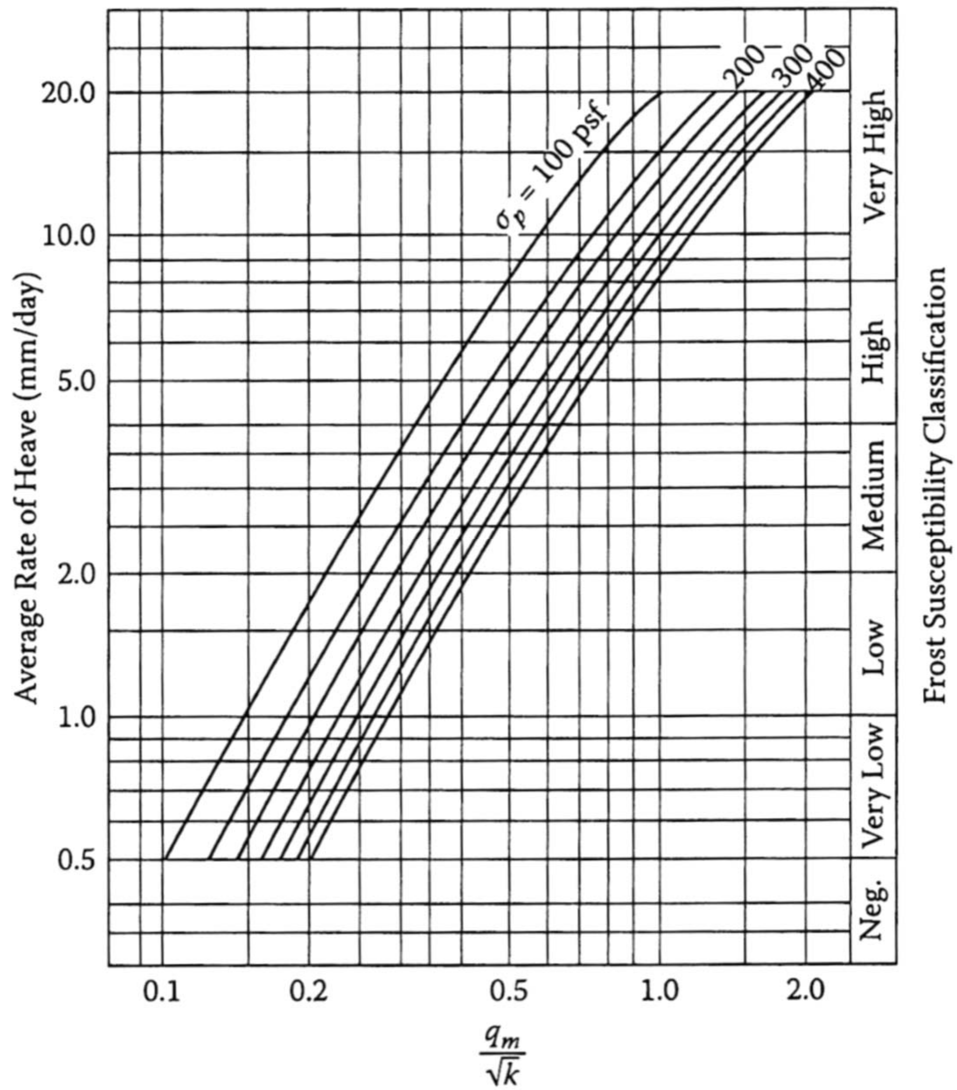
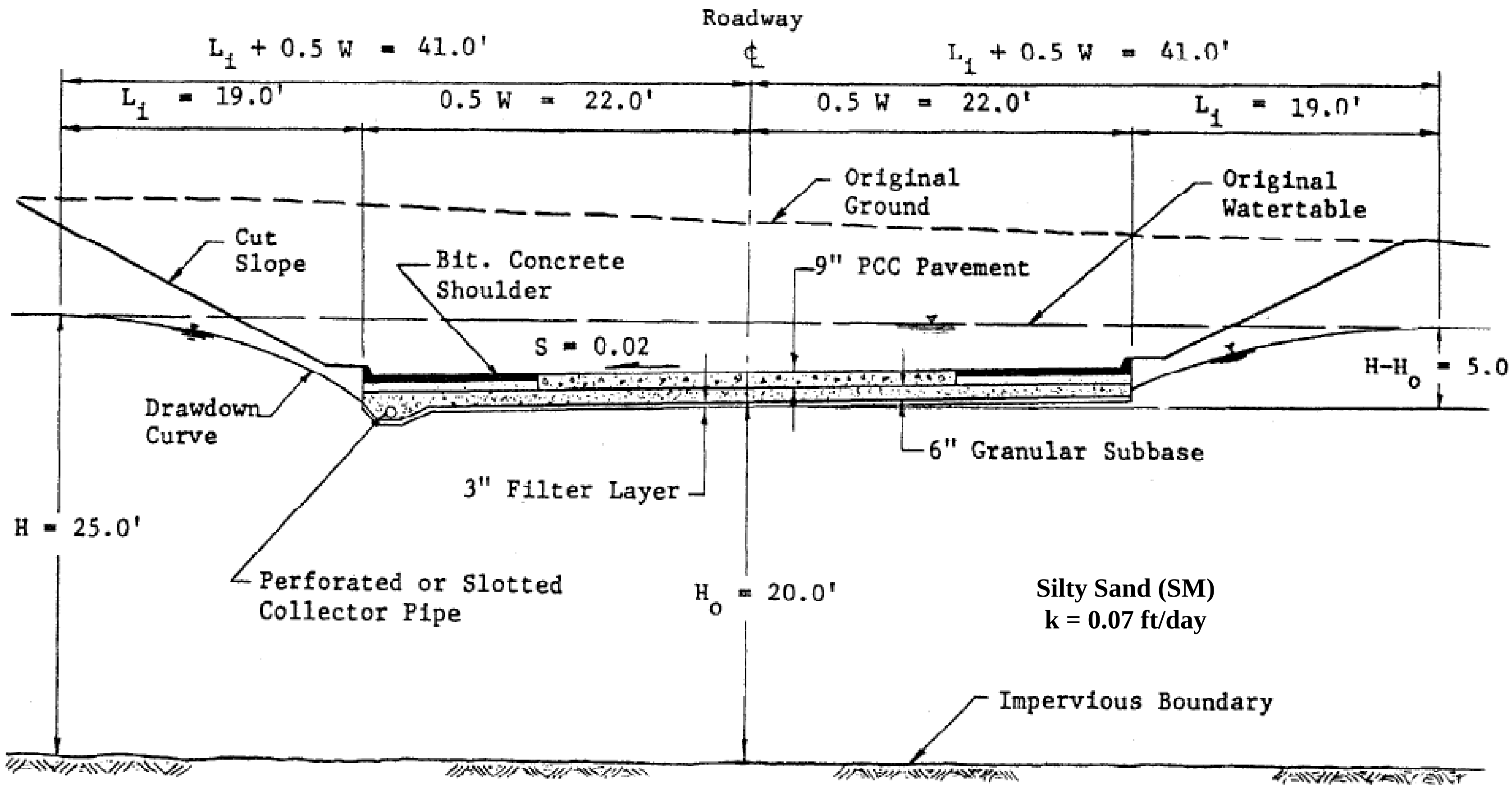


TABLE 6.4
Heave Rates for Various Soil Types

Unified Classification	Symbol	% < 0.02 mm	Heave Rate (mm/day)	Frost Susceptibility
Gravels and sand gravels	GP	0.4	3.0	Medium
Gravels and sand gravels	GW	0.7–1.0	0.3–1.0	Low
Gravels and sand gravels	GW	1.0 –1.5	1.0–3.5	Low to medium
Gravels and sand gravels	GW	1.5–4.0	3.5–2.0	Medium
Silty and sandy gravels	GP—GM	2.0–3.0	1.0–3.0	Low to medium
Silty and sandy gravels	GW—GM and GM	3.0–7.0	3.0–4.5	Medium to high
Clayey and silty gravels	GW—GC	4.2	2.5	Medium
Clayey and silty gravels	GM—GC	15.0	5.0	High
Clayey and silty gravels	GC	15.0–30.0	2.5–5.0	Medium to high
Sands and gravelly sands	SP	1.0–2.0	0.8	Very low
Silty and gravelly sands	SW	2.0	3.0	Medium
Silty and gravelly sands	SP—SM	1.5–2.0	0.2–1.5	Low
Silty and gravelly sands	SW—SM	2.0–5.0	1.5–6.0	Low to high
Silty and gravelly sands	SM	5.0–9.0	6.0–9.0	High
Clayey and silty sands	SM—SC and SC	9.5–35.0	5.0–7.0	High
Silts and organic silts	ML—OL	23.0–33.0	1.1–14.0	Low to high
Silts and organic silts	ML	33.0–45.0	14.0–25.0	Very high
Clayey silts	ML—CL	60.0–75.0	13.0	Very high
Gravelly and sandy clays	CL	38.0–65.0	7.0–10.0	High
Lean clays	CL	65.0	5.0	High
Lean clays	CL—OL	30.0–70.0	4.0	High
Fat clays	CH	60.0	0.8	Very low

Source: Moulton (1980).

Example 1 (Continued)



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Gravels and sand gravels	GW	1.0 –1.5	1.0–3.5	Low to medium
Gravels and sand gravels	GW	1.5–4.0	3.5–2.0	Medium
Silty and sandy gravels	GP—GM	2.0–3.0	1.0–3.0	Low to medium
Silty and sandy gravels	GW—GM and GM	3.0–7.0	3.0–4.5	Medium to high
Clayey and silty gravels	GW—GC	4.2	2.5	Medium
Clayey and silty gravels	GM—GC	15.0	5.0	High
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Silty and gravelly sands	SP—SM	1.5–2.0	0.2–1.5	Low
Silty and gravelly sands	SW—SM	2.0–5.0	1.5–6.0	Low to high
Silty and gravelly sands	SM	5.0–9.0	6.0–9.0	High
Clayey and silty sands	SM—SC and SC	9.5–35.0	5.0–7.0	High
Silts and organic silts	ML—OL	23.0–33.0	1.1–14.0	Low to high
Silts and organic silts	ML	33.0–45.0	14.0–25.0	Very high
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Lean clays	CL	65.0	5.0	High
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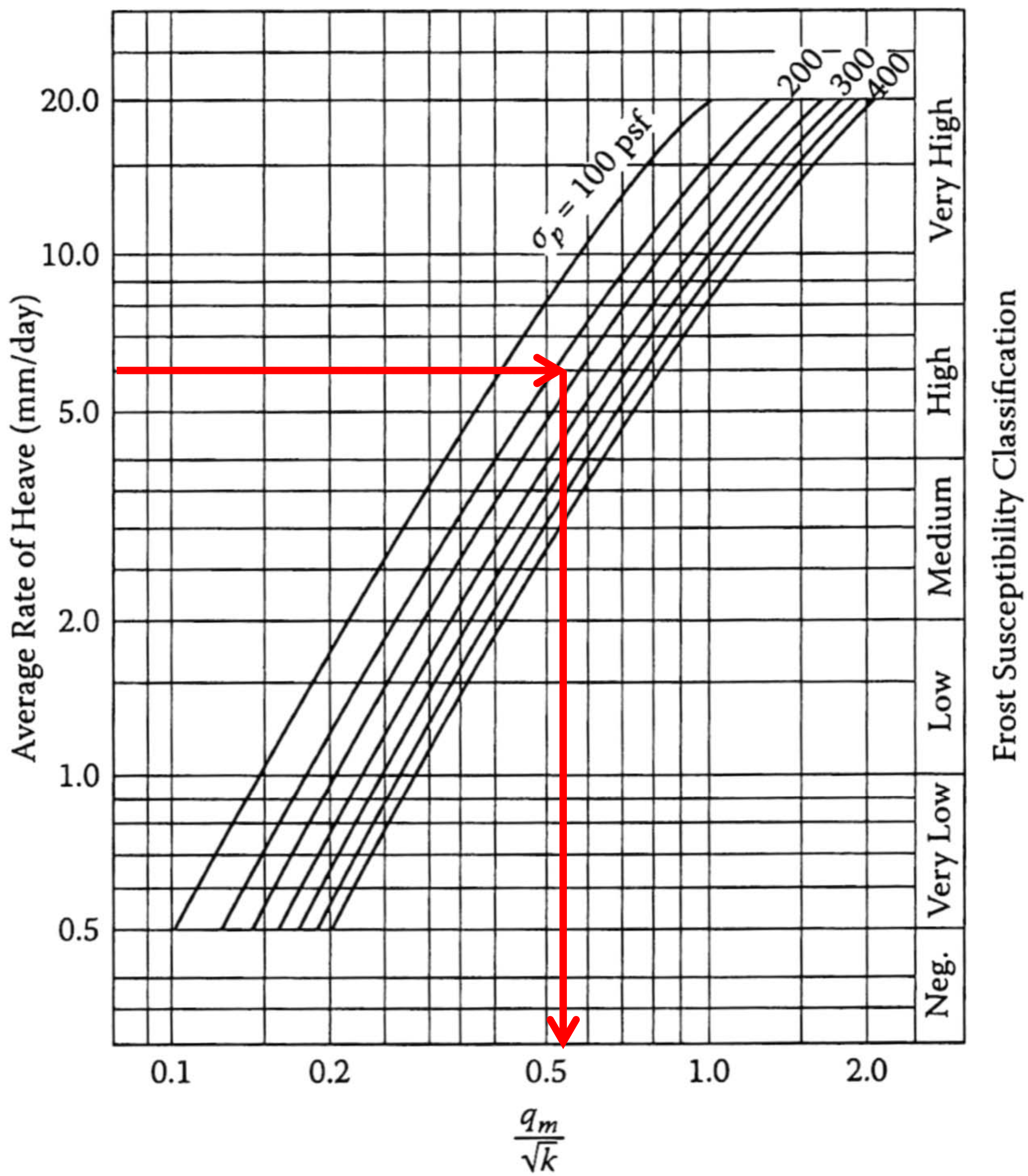
Fat clays	CH	60.0	0.8	Very low

Source: Moulton (1980).



Average Rate of Heave (mm/day)
20.0
10.0
5.0
2.0
1.0
0.5
0.1
0.2
0.5
1.0
2.0
$\frac{q_m}{\sqrt{k}}$
σ_p = 100 psf
200
300
400
Very High
High
Medium
Low
Very Low
Neg.
Frost Susceptibility Classification

Drainage Blanket Design Flow

$$q_n = q_i + \max\left(q_g, q_a, q_m\right)$$

Edge Drain Design Flow

One Edge Drain

$$q_d = q_1 + q_n W$$

Two Edge Drains

$$q_d = q_1 + q_n \frac{W}{2}$$