MODELING STORMWATER MANAGEMENT SYSTEMS THE BASICS WITH EMPHASIS ON GROUND WATER / SURFACE WATER INTERACTION

GROUND WATER/SURFACE WATER INTERACTION MODELING

- List of "Essential Tools" needed by design engineer
- Review capabilities & typical applications of demonstration software
- Review the typical conceptual models & their input data requirements
- Minimum requirements for soils reports. Geotechnical investigation to estimate aquifer parameters.
- Construction considerations for stormwater ponds
- Example problems using commercially available software

ESSENTIAL TOOLS

PUBLICATIONS

- USGS 7.5 minute series quadrangle map
- NRCS Soil Survey Book
- Aerial photos (if available). REDI, County, FDOT, WMD
- Potentiometric surface map of Floridan aquifer for area
- SJRWMD Special Publication SJ93-SP10. This is a free publication on stormwater pond design which can be obtained by calling the SJRWMD library at 904-329-4132.
- Florida's Geological History & Geological Resources, Florida Geological Survey Special Publication #35
- Seasonal high water table paper by Devo & SWFWMD Training Workshop Course Notes

ESSENTIAL TOOLS (Continued)

SITE-SPECIFIC DATA

- Plan of property with topographic contours and location of pond; predevelopment ground surface elevations
- Characteristics of the predevelopment & postdevelopment contributing drainage area
- Stage-area data of pond, including proposed pond bottom elevation relative to existing grade
- Geotechnical report with borings and recommended aquifer parameters (will discuss minimum requirements for geotech reports)
- Conseqeunce of failure of pond - how sensitive?
- Proximity of proposed pond(s) to adjacent ponds

ESSENTIAL TOOLS (Continued)

SOFTWARE

- TR 55 Version 2 - used for computing time of concentration and weighted curve numbers. Available free from NRCS office in Gainesville (904-338-9555, ask for Gene Daugherty or Jesse Wilson)
- PONDS Version 3.2 (or equivalent software)
- May need USGS MODFLOW for more complicated situations. Will explain why later. However, this should only be used by experienced modelers.
- May need adICPR or CHAN or equivalent to interface with PONDS if dealing with complicated system of interconnected ponds.

TYPICAL COMPUTATIONAL MODULES IN SOFTWARE

WATER QUALITY RECOVERY ANALYSES

- Dry retention & wet retention ponds (unlined or partially lined)
- Exfiltration trenches
- Wet detention ponds (with & without ground water baseflow component)
- Dry detention ponds (with & without percolation)
- Underdrain ponds (with & without ground water baseflow component)
- Filtration systems including side-bank, pond-bottom, and VVRS filters
- Swales and overland flow (VNB's)

TYPICAL HYDROGRAPHS

- SCS Unit hydrographs (can include recovery time following storm)
- Water quality recovery volume hydrographs (automatic setup of time steps for SJRWMD & SWFWMD criteria)
- Baseflow Hydrographs
- Continuous simulation hydrographs
- Perc Pond Hydrographs
- Multiple basin SCS Hydrographs / interconnected ponds (new)
- Manually input of hydrograph

ROUTING HYDROGRAPHS

- True routing with or without credits for infiltration during the storm event. True routing means that the model can predict the peak stage, discharge rates, etc.

- Critical duration analysis is now possible with more recent software where up to 200 hydrographs can be routed and critical hydrograph identified based on parameter.

- Ability to analyze interconnected ponds and/or interface with conventional surface water models such as adICPR, CHAN, etc.

TYPICAL COMPUTATIONAL MODULES IN SOFTWARE (Continued)

WATER TABLE DEWATERING & DRAWDOWN

- Compute dewatering rates and water table drawdown impact distances for the following applications:

  - Borrow pits,
  - Ditches,
  - Interceptor trenches,
  - Wet detention ponds,
  - Road underdrains,
  - Utility line dewatering,
  - Etc.

- Assess setback distances from wetlands
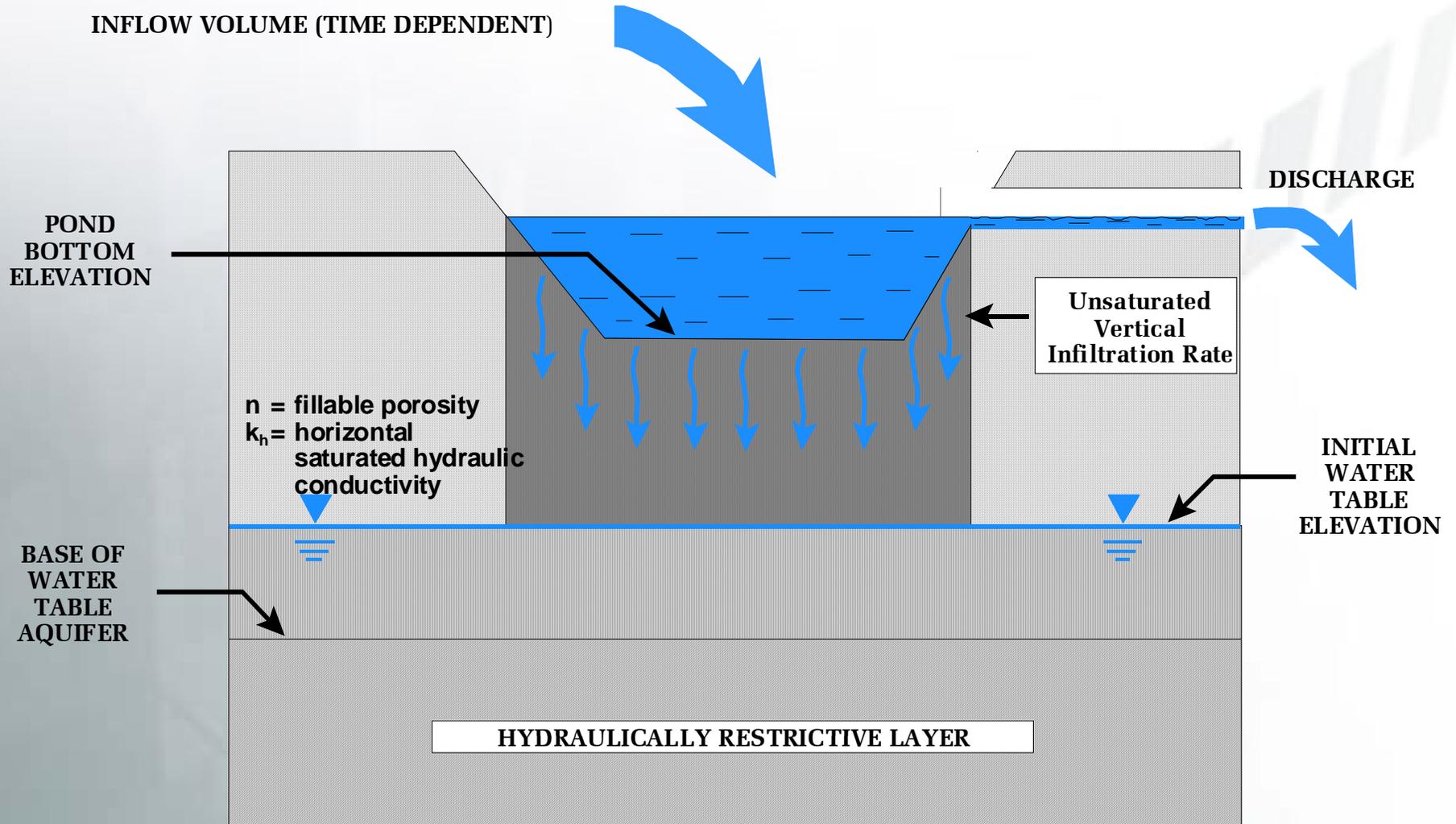
WHAT IS A CONCEPTUAL MODEL?

Ground Water/Surface Water Interaction

A conceptual model is a pictorial representation of the ground water flow system. In the practice of developing a conceptual model, it is desirable to strive for parsimony, by which it is implied that the conceptual model has been simplified as much as possible yet retains enough complexity so that it adequately reproduces system behavior.

The conceptual models described in this workshop can be applied to the majority of design situations in Florida.
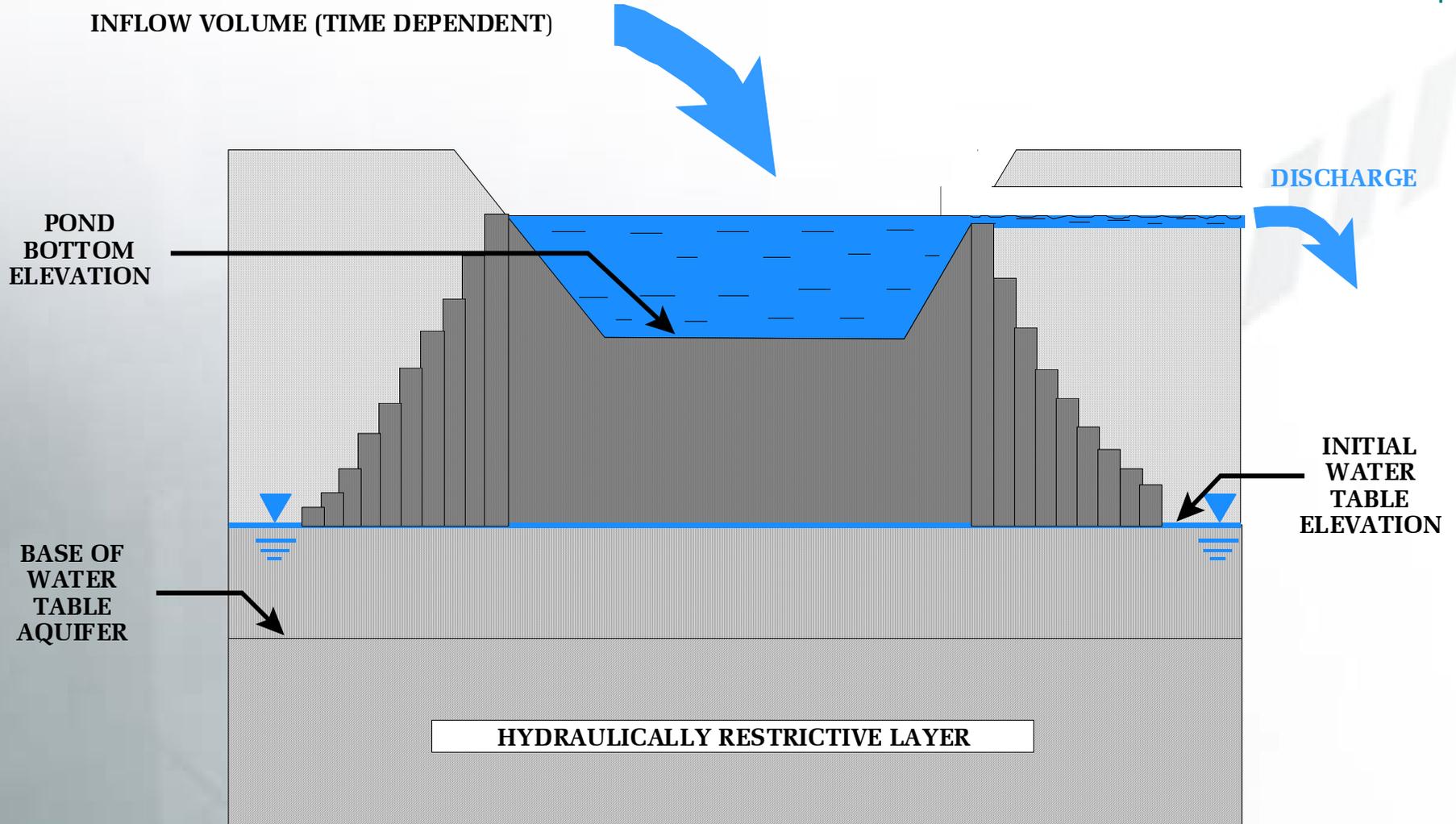
DRY RETENTION - STAGE I FLOW
UNSATURATED VERTICAL INFILTRATION ONLY

INFLOW VOLUME (TIME DEPENDENT)

DISCHARGE

POND
BOTTOM
ELEVATION

Unsaturated
Vertical
Infiltration Rate

n = fillable porosity
k_h = horizontal saturated hydraulic conductivity

INITIAL
WATER
TABLE
ELEVATION

BASE OF
WATER
TABLE
AQUIFER

HYDRAULICALLY RESTRICTIVE LAYER

2007 ADS Stormwater Workshop

DRY RETENTION - STAGE II RECOVERY
SATURATED LATERAL FLOW

INFLOW VOLUME (TIME DEPENDENT)

DISCHARGE

POND BOTTOM ELEVATION

INITIAL WATER TABLE ELEVATION

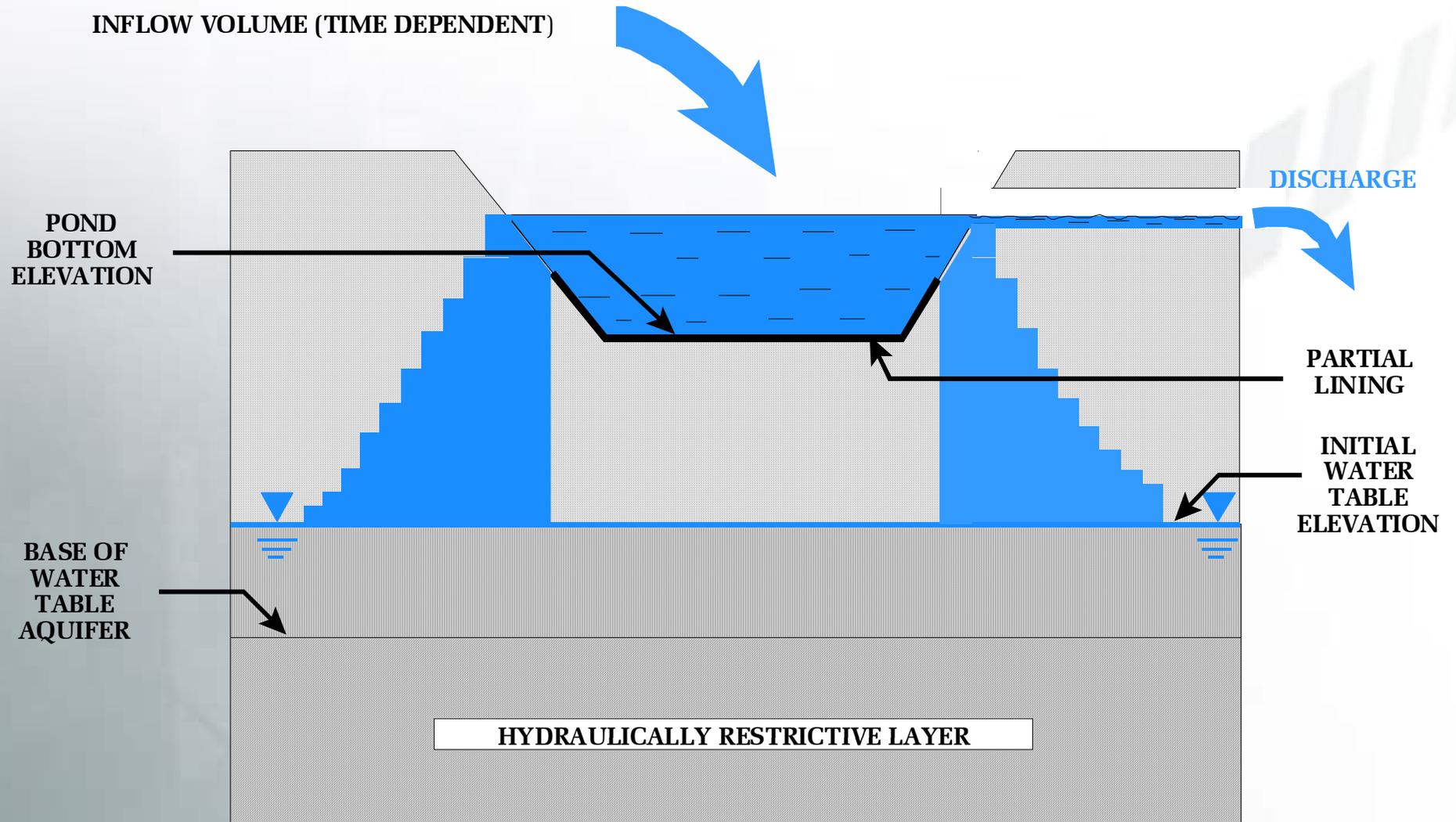BASE OF WATER TABLE AQUIFER

HYDRAULICALLY RESTRICTIVE LAYER

note: initial flat water table assumption is not unrealistic when the natural gradient is considered together with the duration of loading and the corresponding radius of influence.
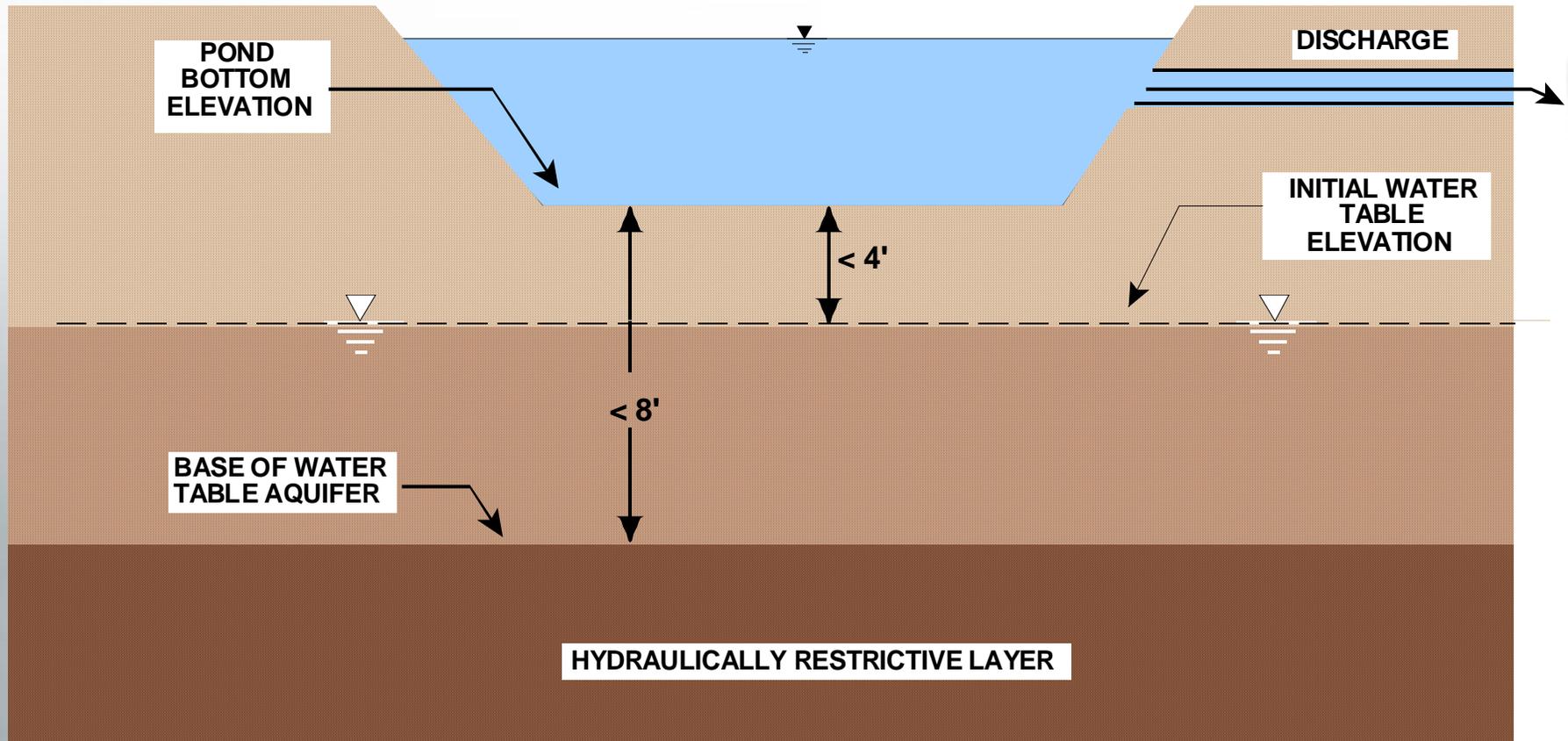
PARTIALLY LINED RETENTION POND (STAGE I FLOW)
UNSATURATED VERTICAL INFILTRATION ONLY

INFLOW VOLUME (TIME DEPENDENT)

DISCHARGE

POND BOTTOM ELEVATION

PARTIAL LINING

VERTICAL INFILTRATION

n   = fillable porosity
k_h = horizontal saturated hydraulic conductivity

INITIAL WATER TABLE ELEVATION

BASE OF WATER TABLE AQUIFER

HYDRAULICALLY RESTRICTIVE LAYER
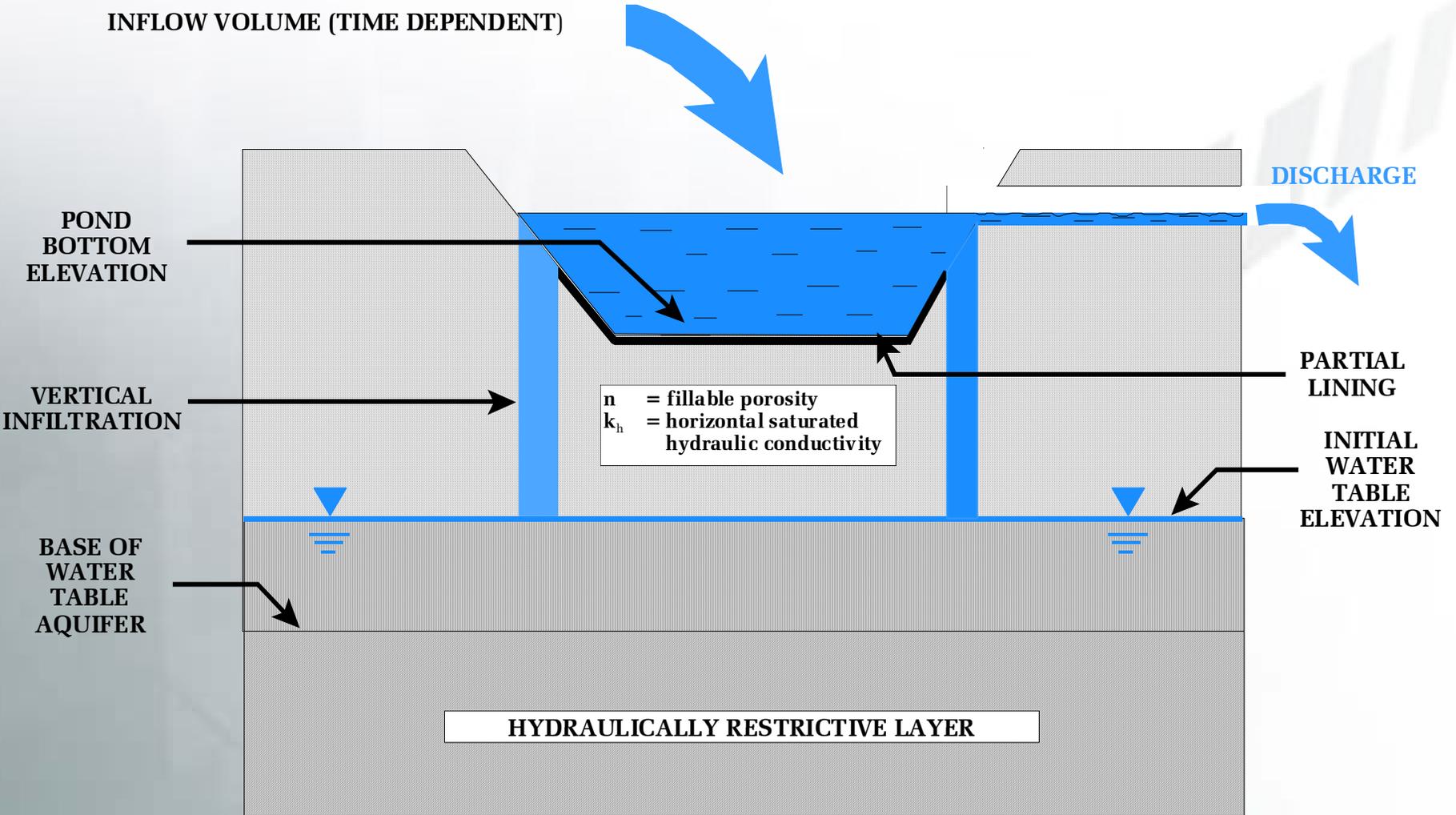
PARTIALLY LINED RETENTION POND (STAGE II FLOW) SATURATED LATERAL FLOW

INFLOW VOLUME (TIME DEPENDENT)

DISCHARGE

POND BOTTOM ELEVATION

PARTIAL LINING

INITIAL WATER TABLE ELEVATION

BASE OF WATER TABLE AQUIFER

HYDRAULICALLY RESTRICTIVE LAYER

Model #1 - Dry or Wet Retention With Thin Aquifer & Shallow Water Table

POND BOTTOM ELEVATION

DISCHARGE

INITIAL WATER TABLE ELEVATION

< 4'

< 8'

BASE OF WATER TABLE AQUIFER

HYDRAULICALLY RESTRICTIVE LAYER

Notes:

1. Do not use unsaturated infiltration if SHWT within 1.5 ft of pond bottom
2. For stormwater modeling, assume soil is confining layer is k <0.1 ft/day (typical permeability values for soils in Florida from SJRWMD publication)
3. If no confining layer, base of aquifer should not extend below depth of boring
4. Review computation of weighted horizontal hydraulic conductivity
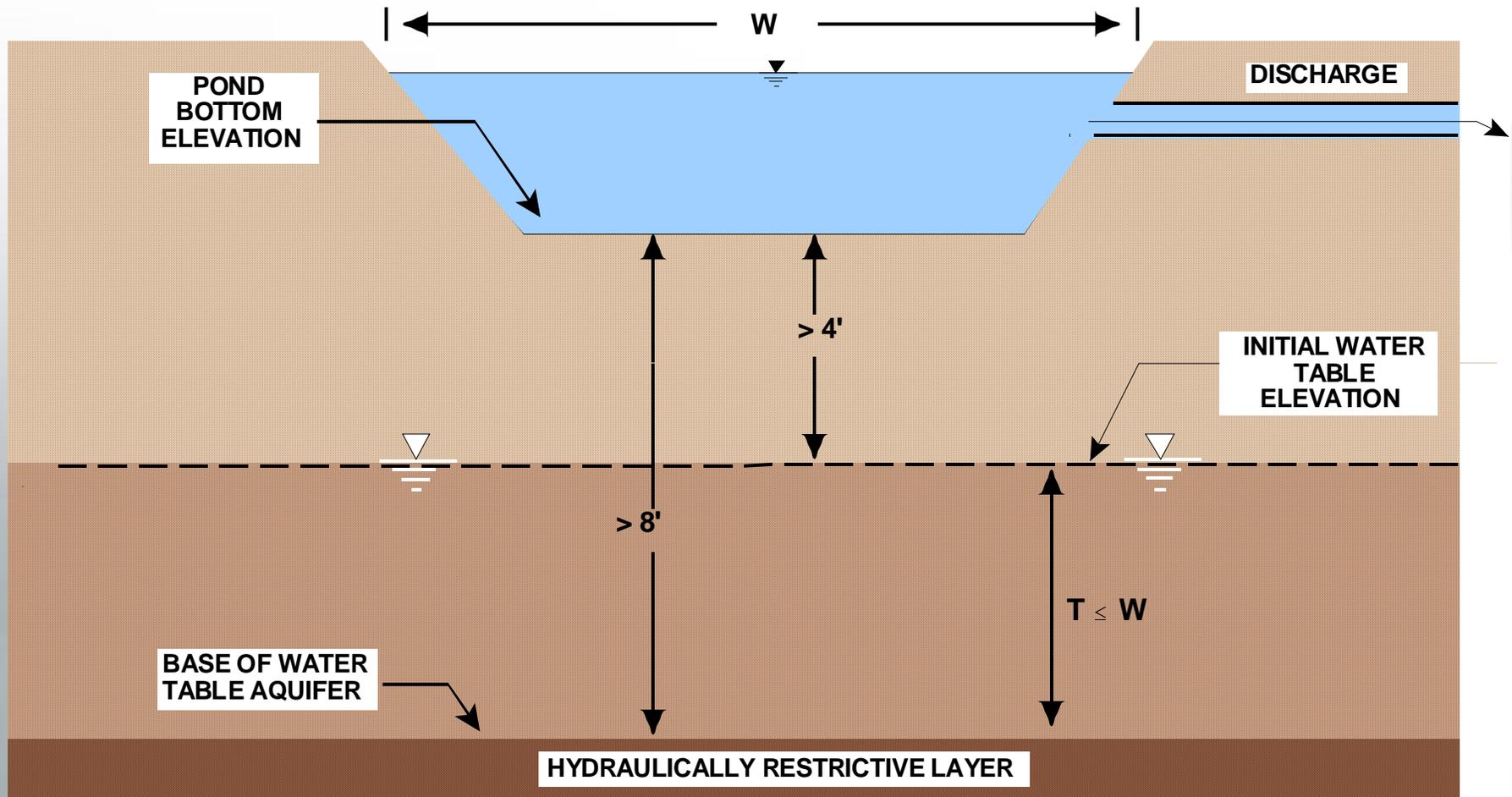5. Wet bottom or dry bottom

Model #2 - Dry Retention With Thick Aquifer & Shallow Water Table
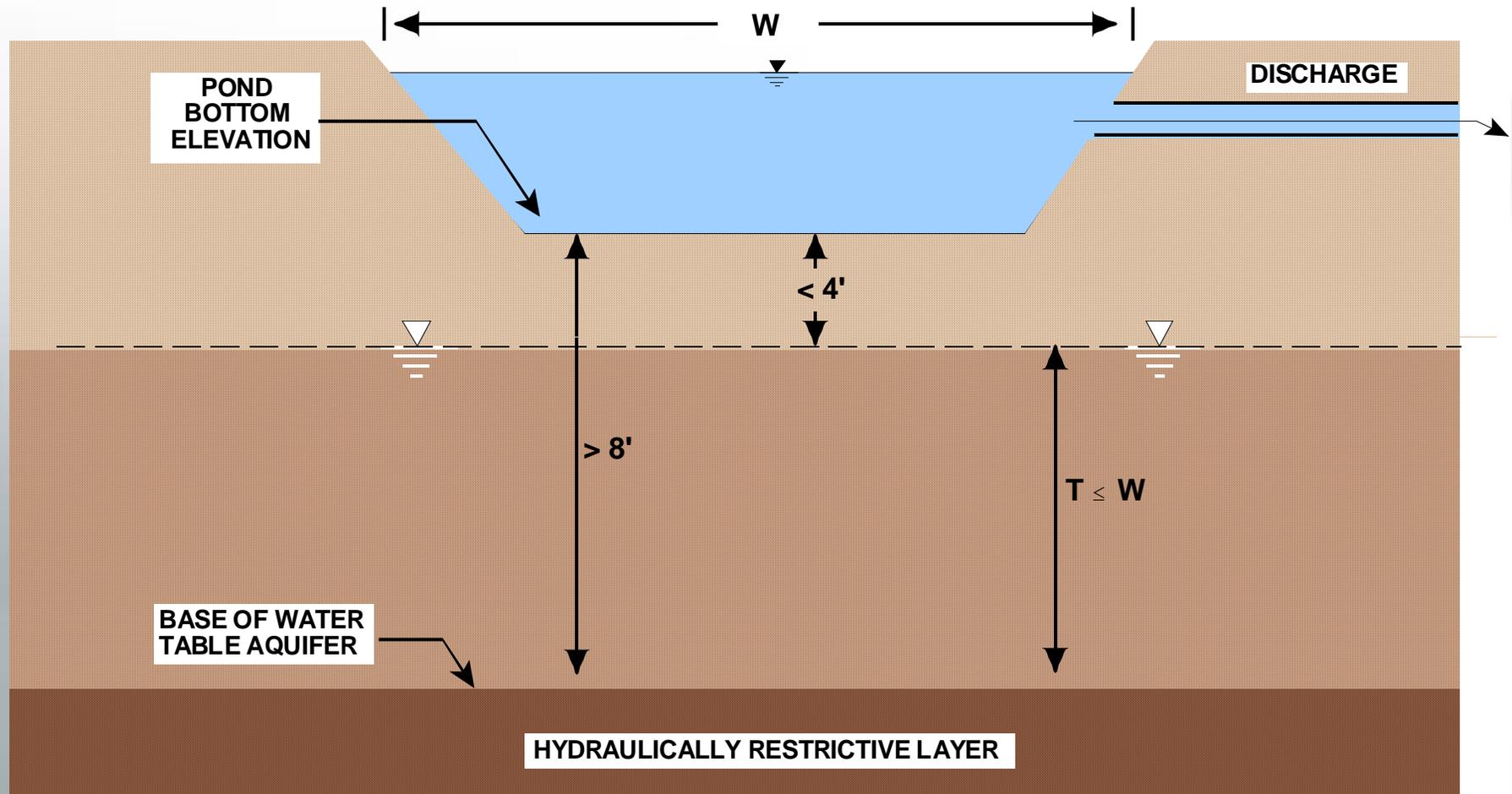
Notes:

1. Saturated thickness restricted to width of pond or trench. Important to remember this when modeling exfiltration trenches, narrow ponds or swales, or areas where there are deep saturated sand deposits such as the Lake Wales Ridge in Lake County and west Orange County, the Deland Ridge in Volusia County, and some of the deep sand and shell along some parts of the Atlantic Coastal Ridge in Volusia and Brevard County.

2. Do not use unsaturated infiltration if SHWT within 1.5 ft of pond bottom

2007 ADS Stormwater Workshop

Model #3 - Dry Retention With Thick Aquifer & Deep Water Table

W

POND BOTTOM ELEVATION

DISCHARGE

> 4'

INITIAL WATER TABLE ELEVATION

> 8'

T ≤ W

BASE OF WATER TABLE AQUIFER

HYDRAULICALLY RESTRICTIVE LAYER

Notes:

1. Saturated thickness restricted to width of pond or trench.

2. Do not use unsaturated infiltration if SHWT within 1.5 ft of pond bottom

3. Peak stage usually occurs during unsaturated perched flow. Competing software such as MODRET do not have this capability.

# Model #4 - Dry Retention In Leaky Aquifer With Deep Water Table

Sand

Slightly clayey fine sand

Clayey fine sand

Limestone
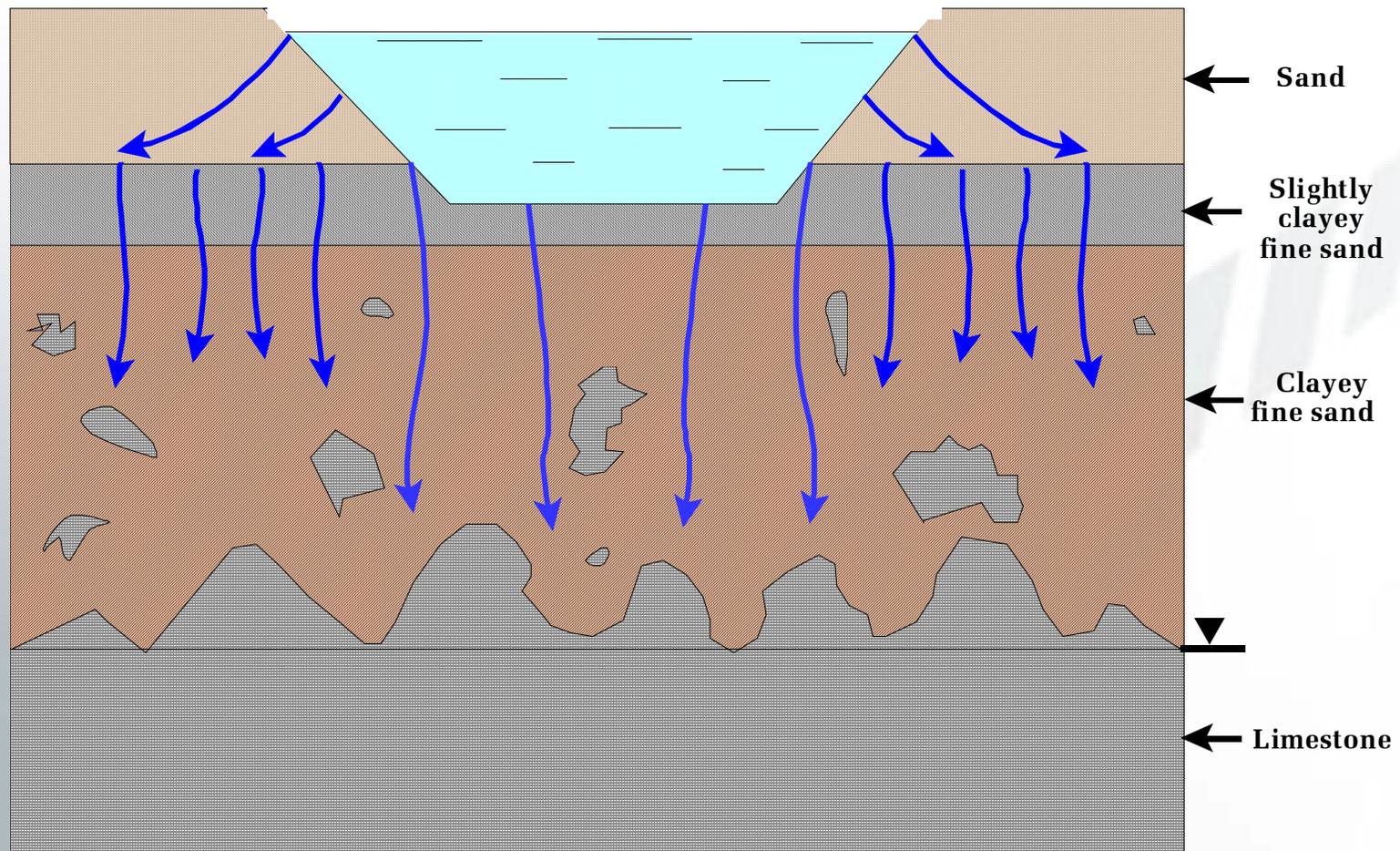
Notes:

1. Typical of the Marion County area
2. Peak stage usually occurs during unsaturated perched flow
3. Pond bottom excavated into first clayey sand layer. important not to remold & compact clayey sand layer
4. Loading rate is rapid, water does not have much time to spread out in the upper sand for design storm event modeling
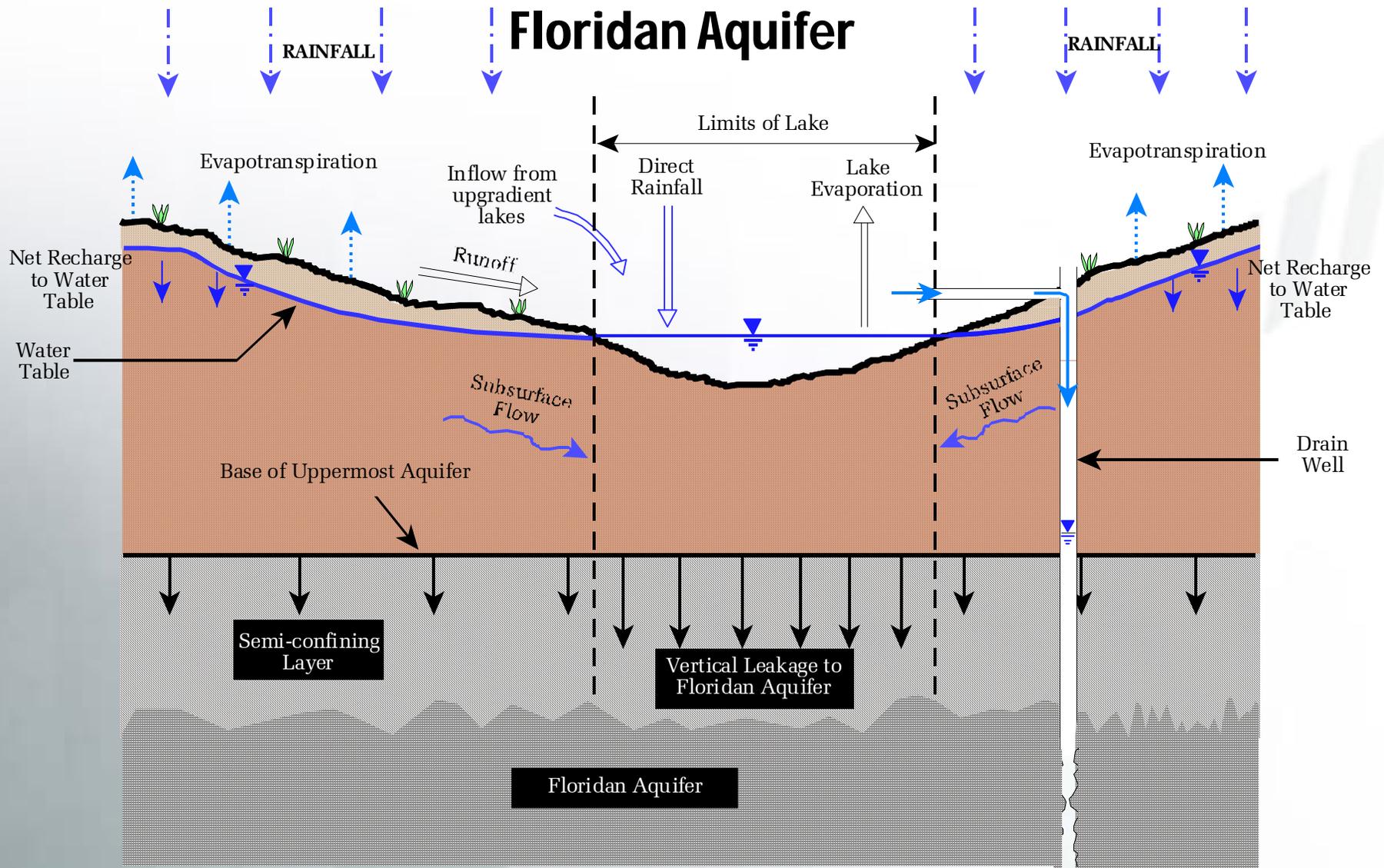
Model #5 - Over excavate confining layer to access underlying secondary layer
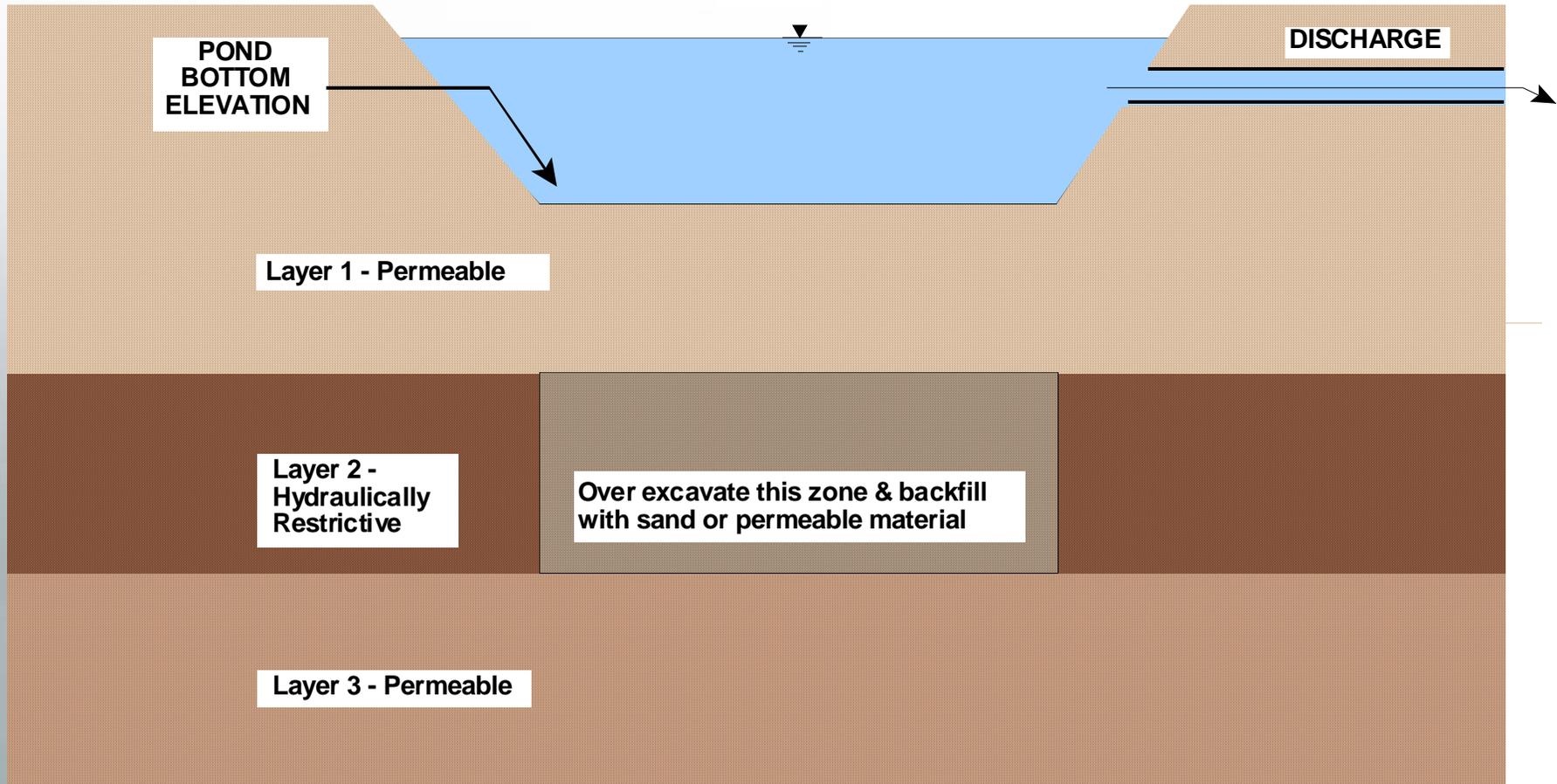
Notes:

1. Typical in Brevard and Indian River County where the hardpan layer can be removed to access the lower zone of sand and shell
2. Must be inspected by geotechnical engineer
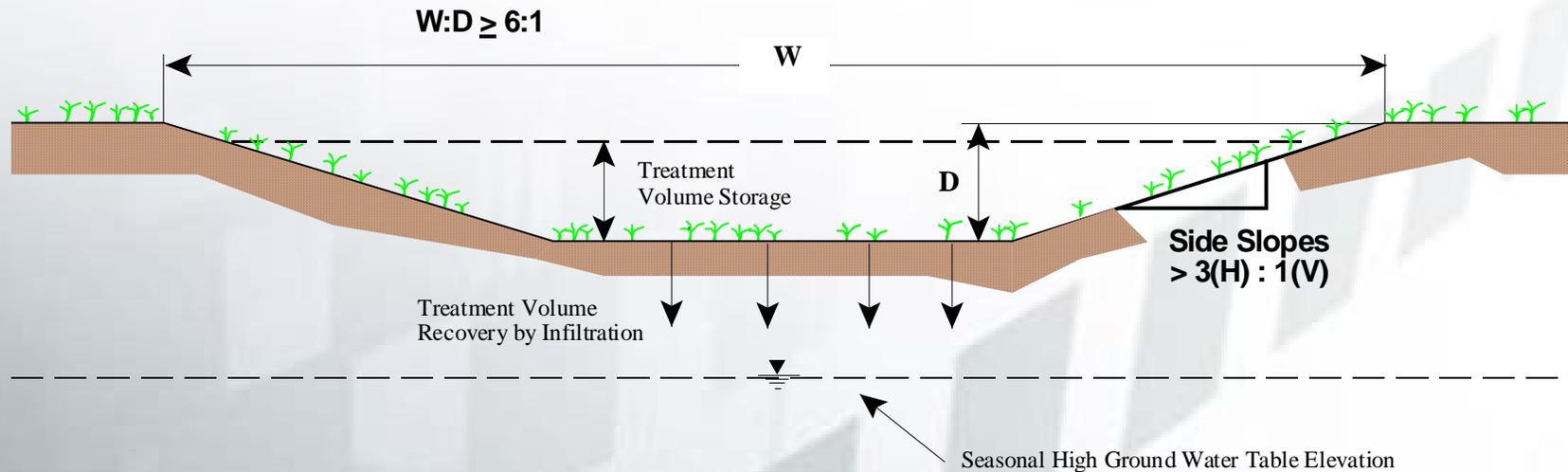3. Weighted horizontal hydraulic conductivity

Model #6 - Closed Basin With Low or High Vertical Leakage to Floridan Aquifer

RAINFALL

RAINFALL

Evapotranspiration

Inflow from
upgradient
lakes

Limits of Lake

Direct
Rainfall

Lake
Evaporation

Evapotranspiration

Net Recharge
to Water
Table

Runoff

Net Recharge
to Water
Table

Water
Table

Subsurface Flow

Subsurface Flow

Drain
Well

Base of Uppermost Aquifer

Semi-confining
Layer

Vertical Leakage to
Floridan Aquifer

Floridan Aquifer

Notes:

1. Difference between pot surface and water (or water table elevation) is more than 5 to 10 ft
2. These are more susceptible to flooding and may require continuous simulation analysis
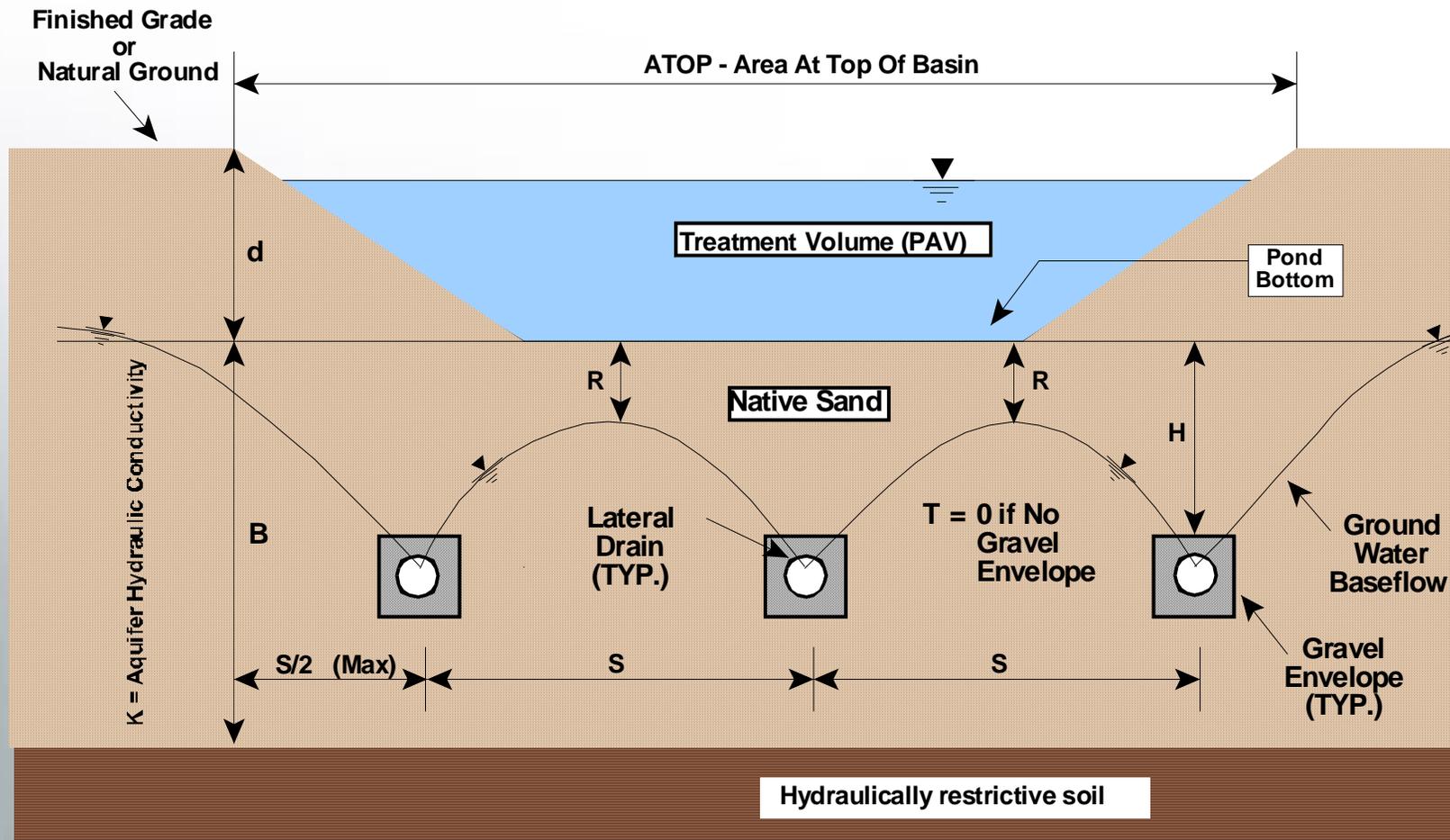
Model # 7 - Swales

W:D ≥ 6:1

W

Treatment
Volume Storage

D

**Side Slopes
> 3(H) : 1(V)**

Treatment Volume
Recovery by Infiltration

Seasonal High Ground Water Table Elevation

Notes:

1. Unlike a pond, there is open channel flow while the water is infiltrating
2. Recommend that this be applied only for unsaturated infiltration. Suitable for sites with HSG "A" soils with sand and deep water table.
3. Most engineers do not analyze this properly
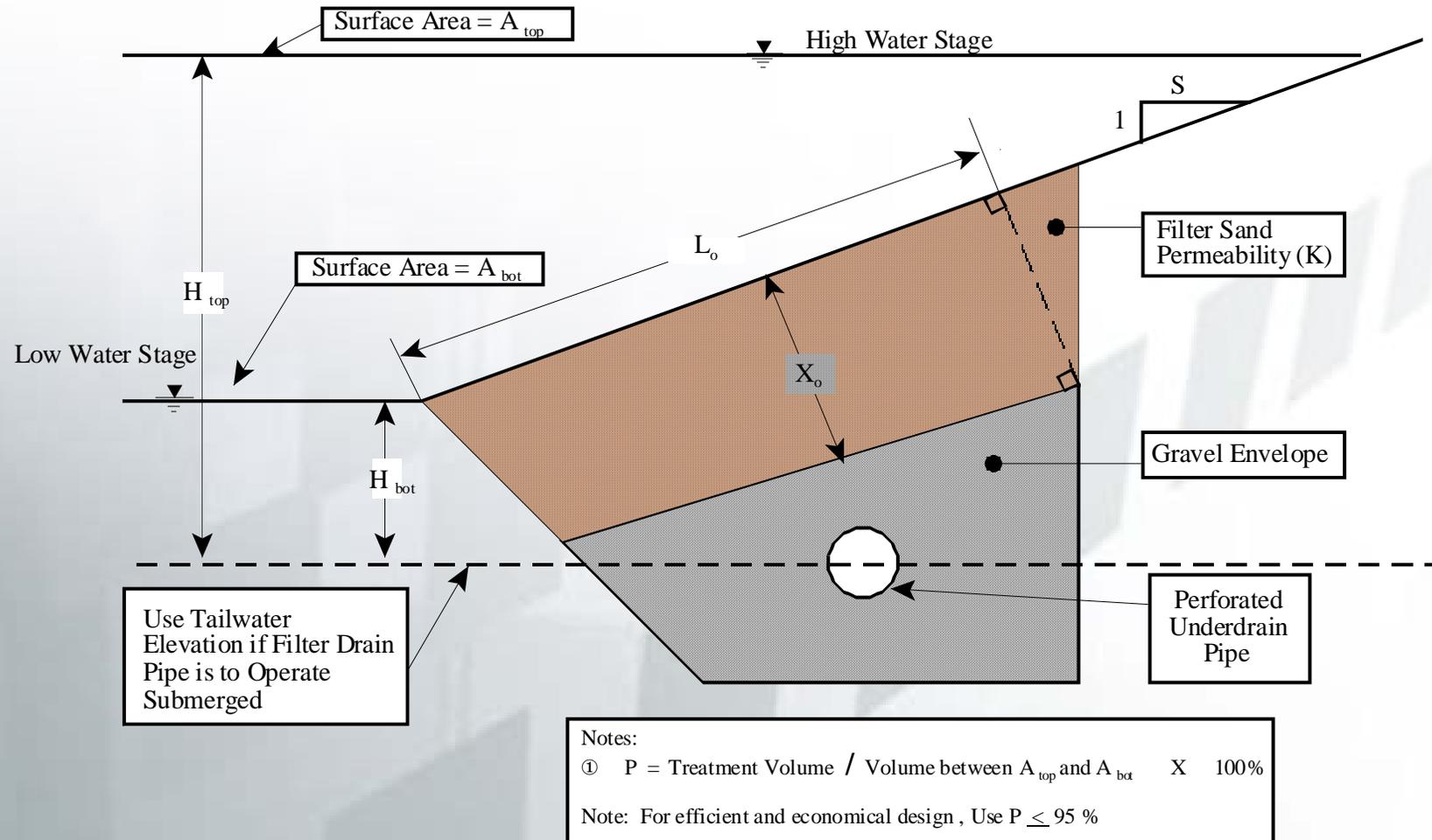4. 3yr/1 hr storm; analyze to see is 80% of volume can be percolated.

Model #8 - Dry Retention Using Underdrain System

Finished Grade or Natural Ground

ATOP - Area At Top Of Basin

Treatment Volume (PAV)

Pond Bottom

d

K = Aquifer Hydraulic Conductivity

B

Native Sand

R

R

H

Lateral Drain (TYP.)

T = 0 if No Gravel Envelope

Ground Water Baseflow

Gravel Envelope (TYP.)

S/2 (Max)

S

S

Hydraulically restrictive soil

Notes:

1. This system is popular since the retention volume requirements are the same as dry retention ponds
2. Main limitation is finding gravity outfall for the underdrain pipes
3. Baseflow must be included
4. Sometimes hydraulically restrictive soil can be overexcavated from base of pond and replaced with free draining fine sand from onsite source

Model # 9 - Side-bank filtration system

Surface Area = A_{top}

High Water Stage

S

1

L_o

Filter Sand
Permeability (K)

Surface Area = A_{bot}

H_{top}

X_o

Low Water Stage

H_{bot}

Gravel Envelope

Perforated
Underdrain
Pipe

Use Tailwater
Elevation if Filter Drain
Pipe is to Operate
Submerged

Notes:

① P = Treatment Volume / Volume between A_{top} and A_{bot} X 100%

Note: For efficient and economical design , Use P ≤ 95 %

Notes:

1. Now an individual permit
2. Subject to clogging especially next to wetland type solis
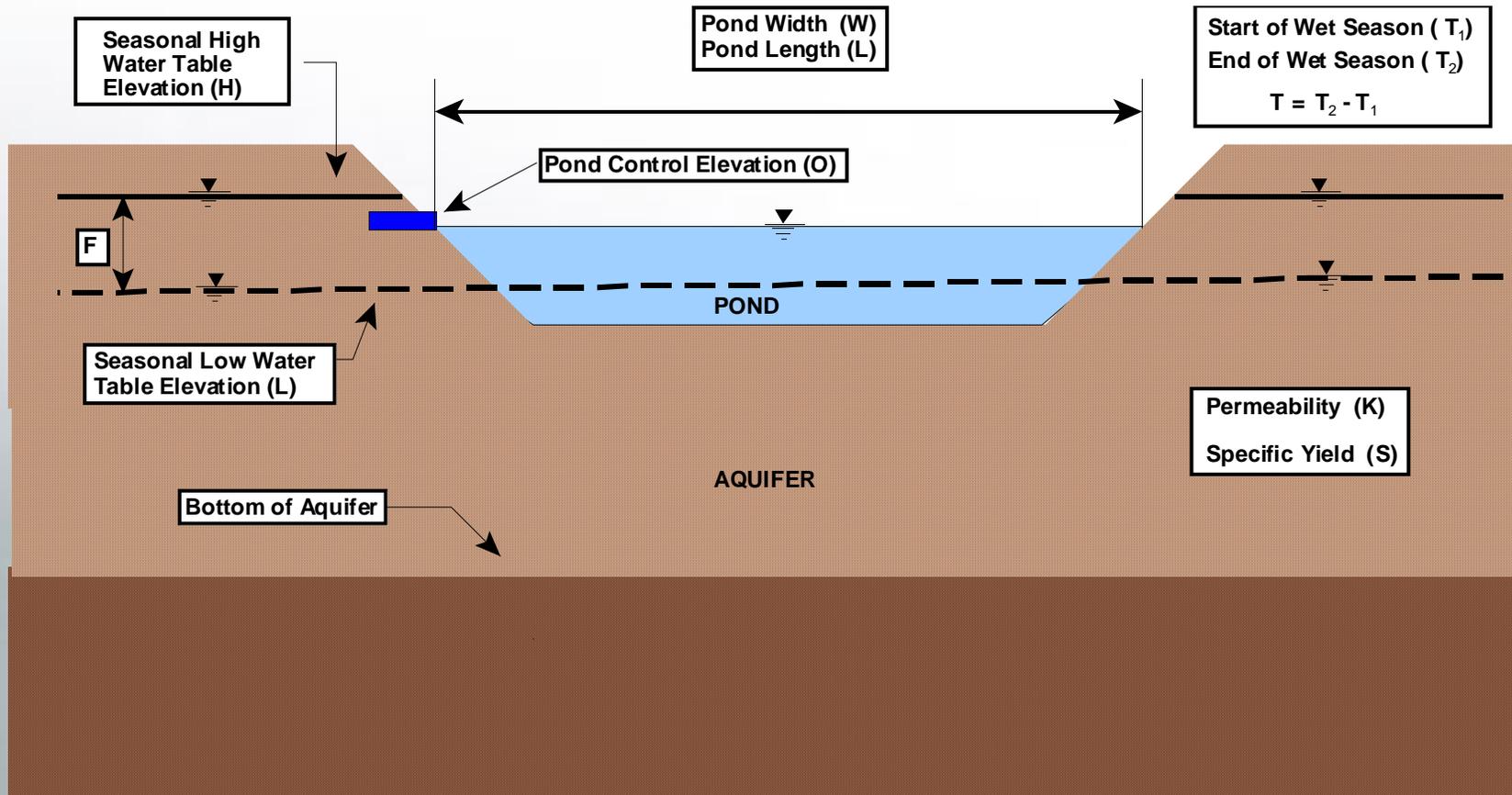3. Include ground water baseflow

Model # 10 - Vertical Volume Recovery Structures
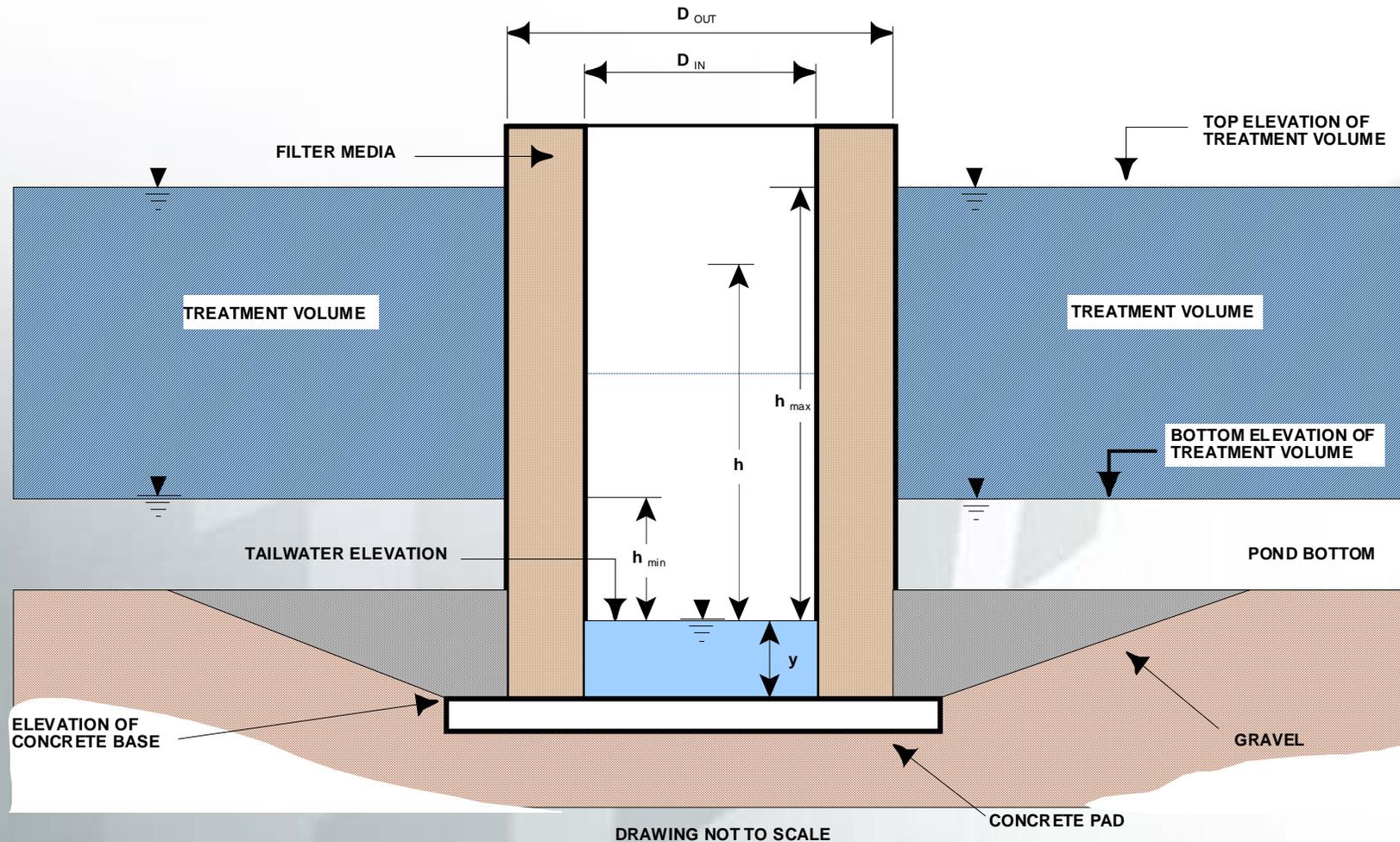
Notes:

1. Now an individual permit
2. Subject to clogging especially next to wetland type soils
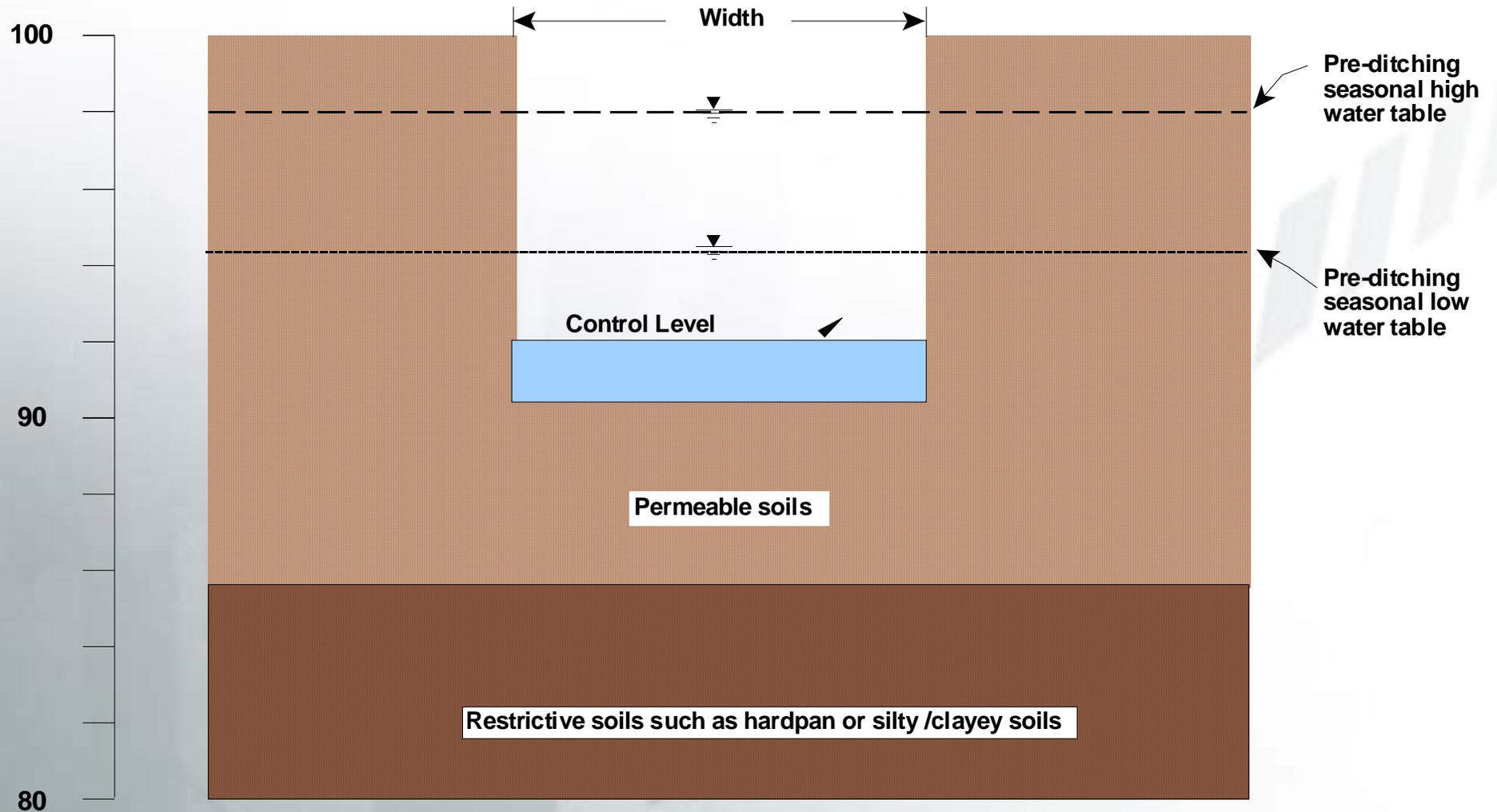3. Include ground water baseflow

Model #11 - Ground Water Baseflow or Wet Detention

Seasonal High Water Table Elevation (H)

Pond Width (W)
Pond Length (L)

Start of Wet Season (T_1)
End of Wet Season (T_2)

$$T = T_2 - T_1$$

Pond Control Elevation (O)

F

Seasonal Low Water Table Elevation (L)

POND

Permeability (K)

Specific Yield (S)

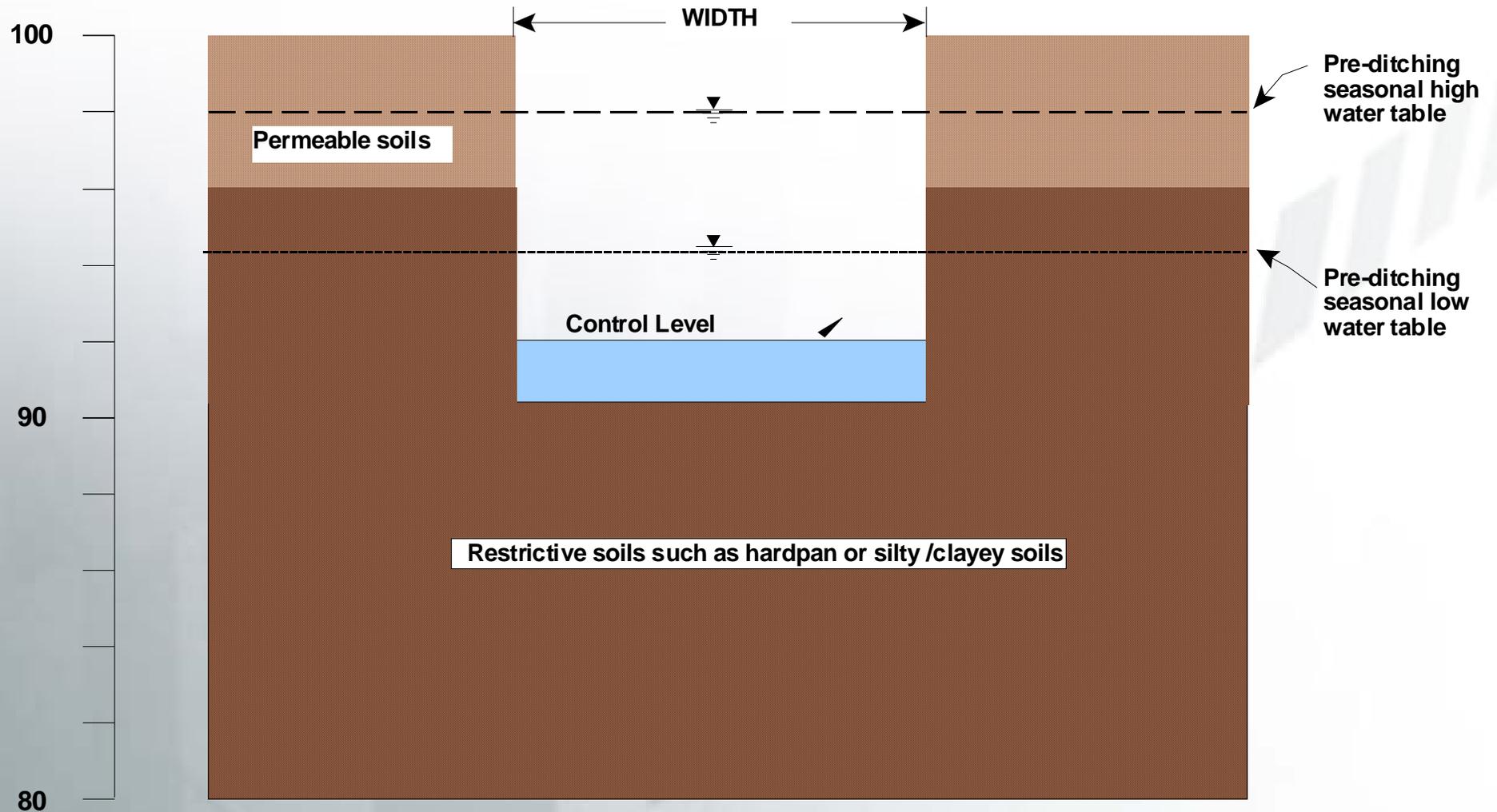AQUIFER

Bottom of Aquifer

Notes:

1. 40C-42 allows us to set the control level at the average wet season water table elevation
2. Important to include baseflow in residence time calculations
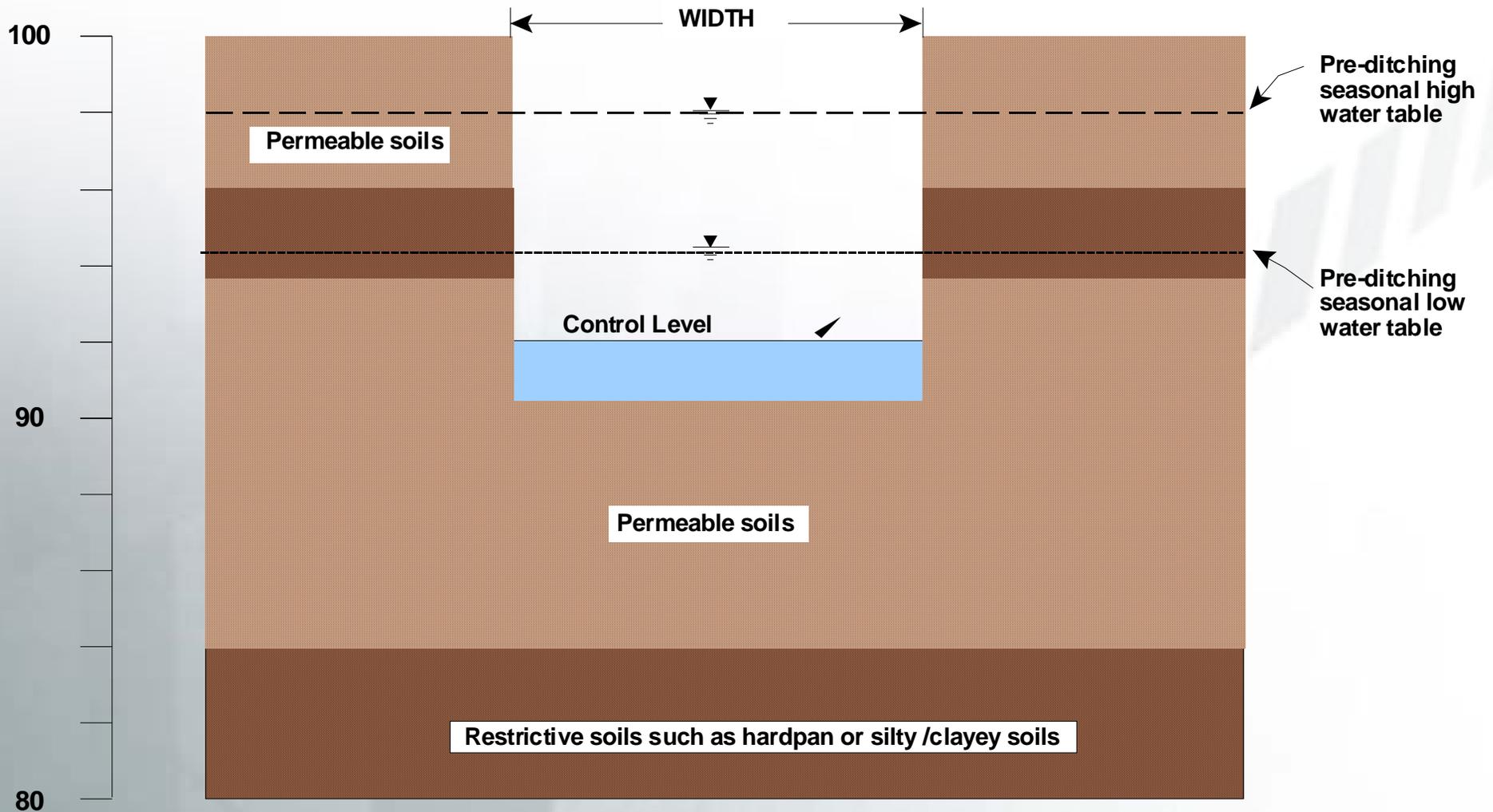3. Weighted horizontal hydraulic conductivity
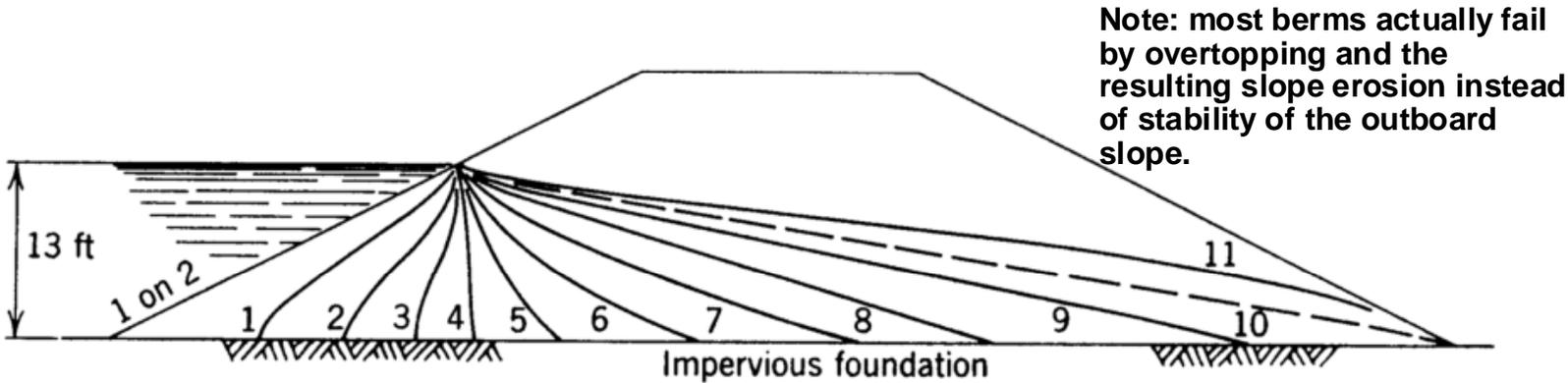
Model # 12a - Ditch Dewatering Scenario #1

Width

Pre-ditching seasonal high water table

Pre-ditching seasonal low water table

Control Level

Permeable soils

Restrictive soils such as hardpan or silty /clayey soils

100

90

80

Model #12b - Ditch Dewatering Scenario # 2

Model # 12c - Ditch Dewatering Scenario # 3

WIDTH

100

90

80

Permeable soils

Pre-ditching seasonal high water table

Control Level

Pre-ditching seasonal low water table

Permeable soils

Restrictive soils such as hardpan or silty /clayey soils

SEEPAGE THROUGH FILL BERM

Note: most berms actually fail by overtopping and the resulting slope erosion instead of stability of the outboard slope.

13 ft

1 on 2

1 2 3 4 5 6 7 8 9 10 11

Impervious foundation
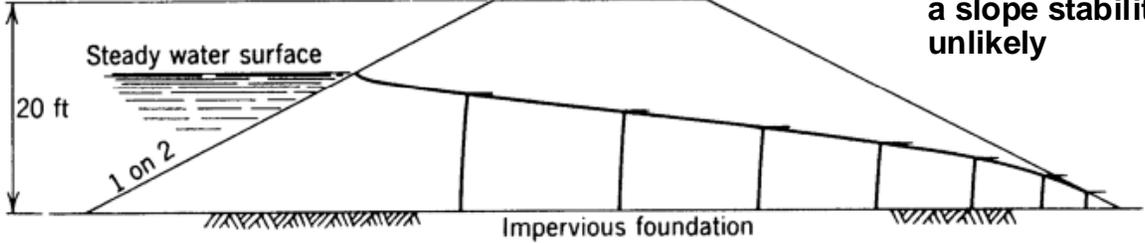
Transient flow situation

important when more than 3 ft of fill above natural grade

Note: if the pond recovers before the transient flow net exits the outboard slope, then a slope stability failure is unlikely

Steady water surface

20 ft

1 on 2

Impervious foundation

Steady state flow situation

Illustration of Theory for Slope Stability Analysis of Infinite Slopes (with & without seepage forces)
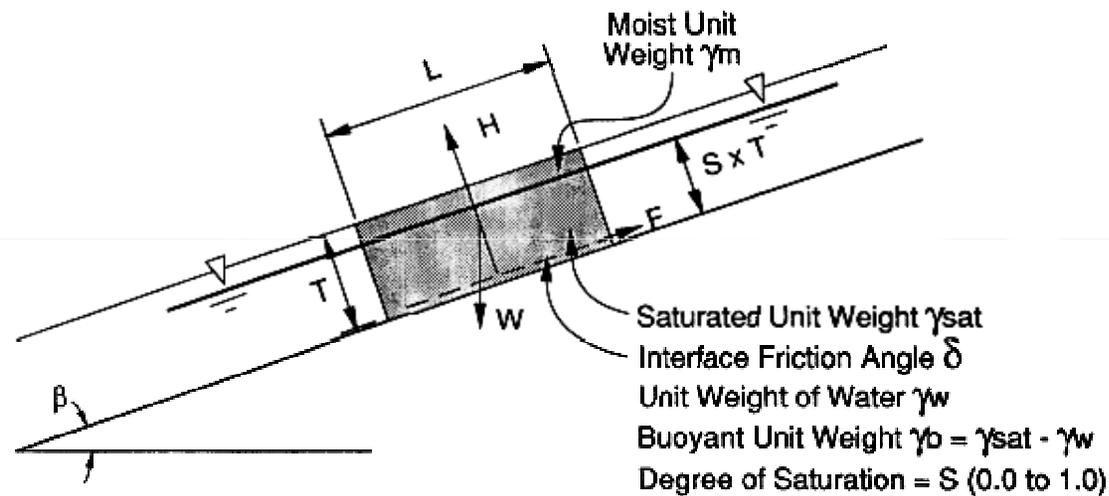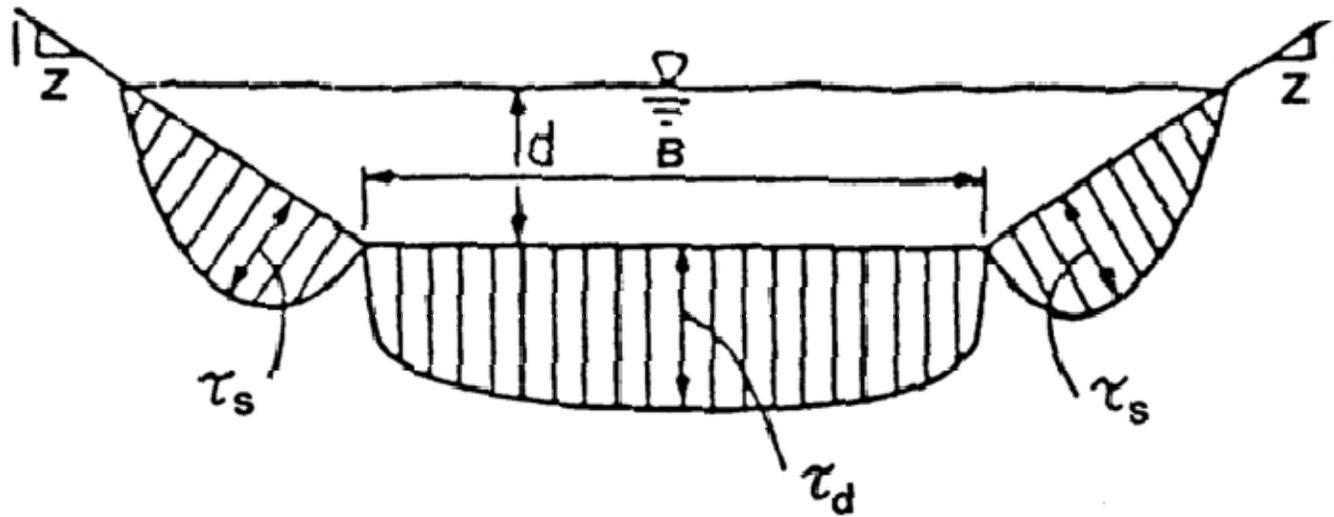

Σ Forces parallel to slope

Resisting Force: $F = \{ \gamma_m T (1-S) L + L \gamma_b T S \} \tan \delta \cos \beta$

Seepage Force: $= \gamma_w T S L \sin \beta$

Weight: $= \{ \gamma_m T (1-S) L + L \gamma_b T S \} \sin \beta$

$$\text{Factor of Safety} = \frac{\text{Resisiting Force}}{\text{Seepage Force} + \text{Weight}} = \frac{\tan \delta}{\tan \beta} \left\{ \frac{\gamma_m (1-S) + \gamma_b S}{\gamma_w S + \gamma_m (1-S) + \gamma_b S} \right\}$$

CHANNEL LINING ANALYSIS FOR SWALES & DITCHES

Maximum shear stress criteria as per HEC-15