SEEPAGE COLLECTION & CONTROL SYSTEMS: THE DEVIL IS IN THE DETAILS

Presented by

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WHY IS THIS IMPORTANT?

- Seepage is the second leading cause of dam failures
- Seepage collection and control systems are a common rehabilitation solution
- Seepage collection and control systems are typically included in dam enlargements and new dams
- These systems are key elements in safety of a dam
- Success of systems depends on the details

SPECIFIC DETAILS TO BE DISCUSSED

- Drain pipes embedded in sand
- Verification of pipe installation
- Access to pipes for inspection and maintenance
- Sand filter gradations
- Use of standard gradations
- Chimney drain width
- One-stage versus two-stage filters

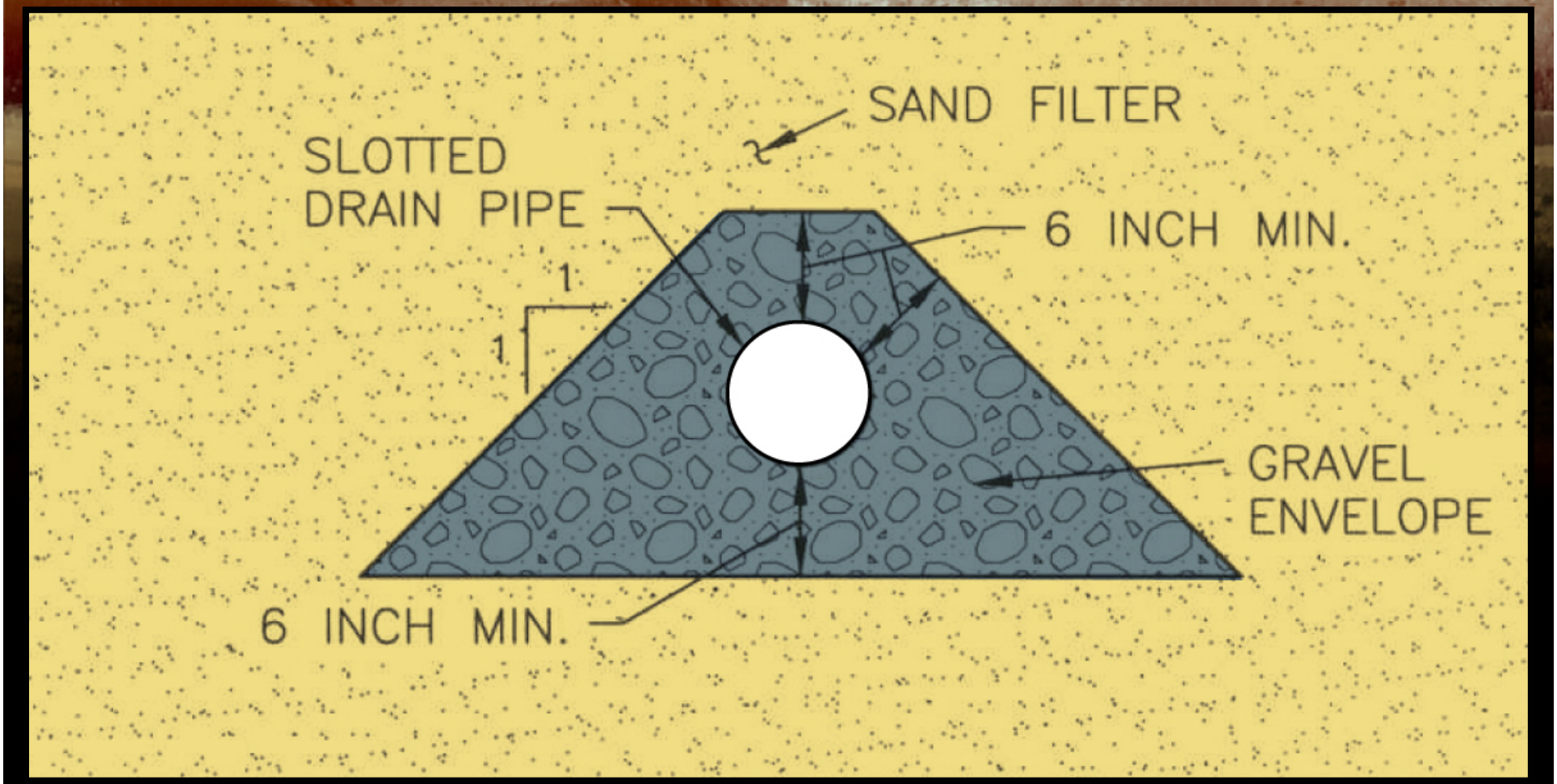
DRAIN PIPES EMBEDDED IN SAND

- Have been used on many dams
- Author has used them
- Recent experience has indicated potential problems

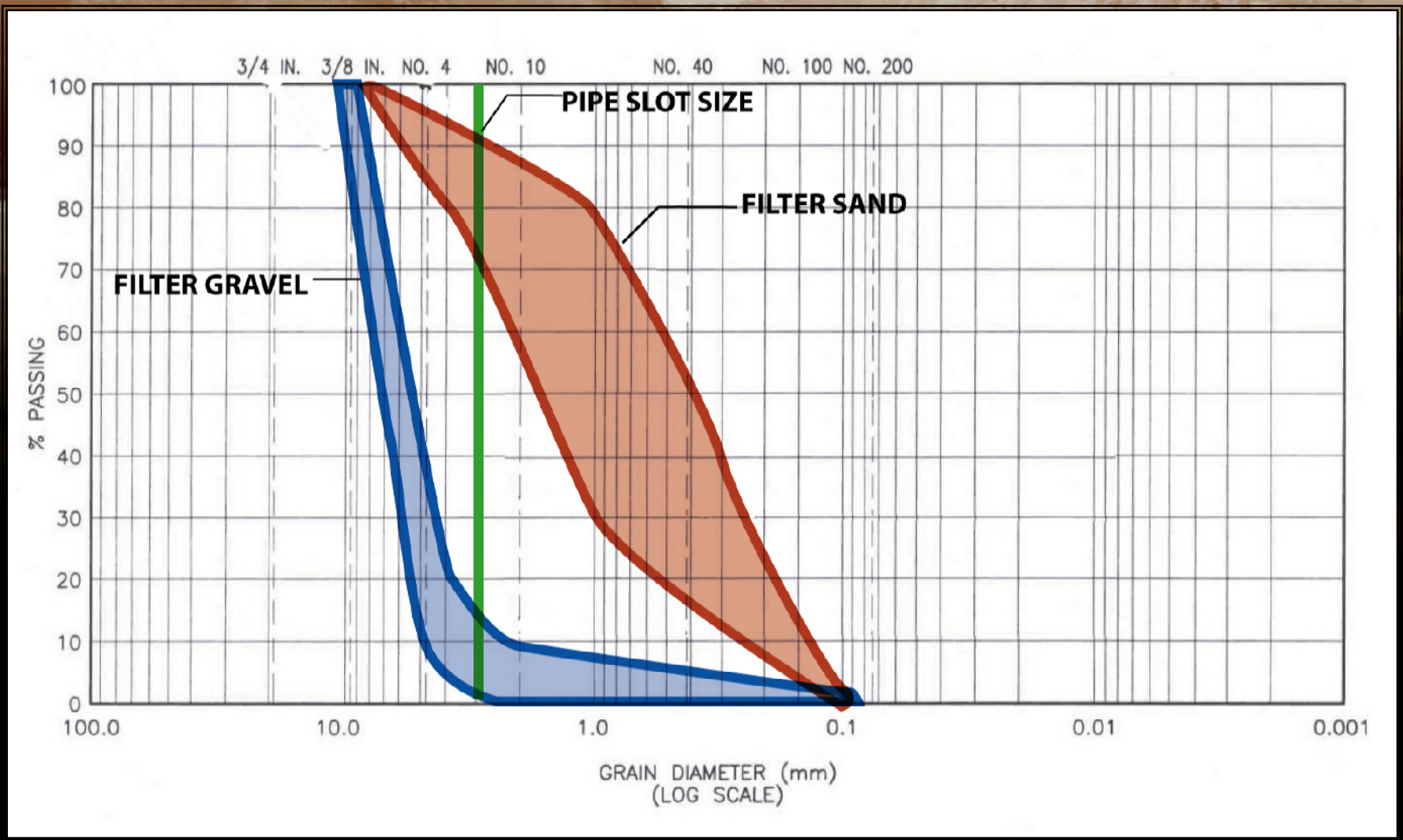
EXAMPLE

- 6-inch diameter pipes with 0.02 inch slots, embedded directly in sand chimney
- ASTM C33 fine aggregate sand
- Sand and pipe slots designed according to current filter criteria
- With 10 feet of head in the chimney, flow through the slots was limited (less than 30 gpm)
- Limited flow confirmed with camera survey
- Replaced with pipes in gravel – produced > 500 gpm
- Similar experience reported by others

RECOMMENDED DESIGN – PIPE IN GRAVEL ENVELOPE



EXAMPLE – PIPE IN GRAVEL ENVELOPE

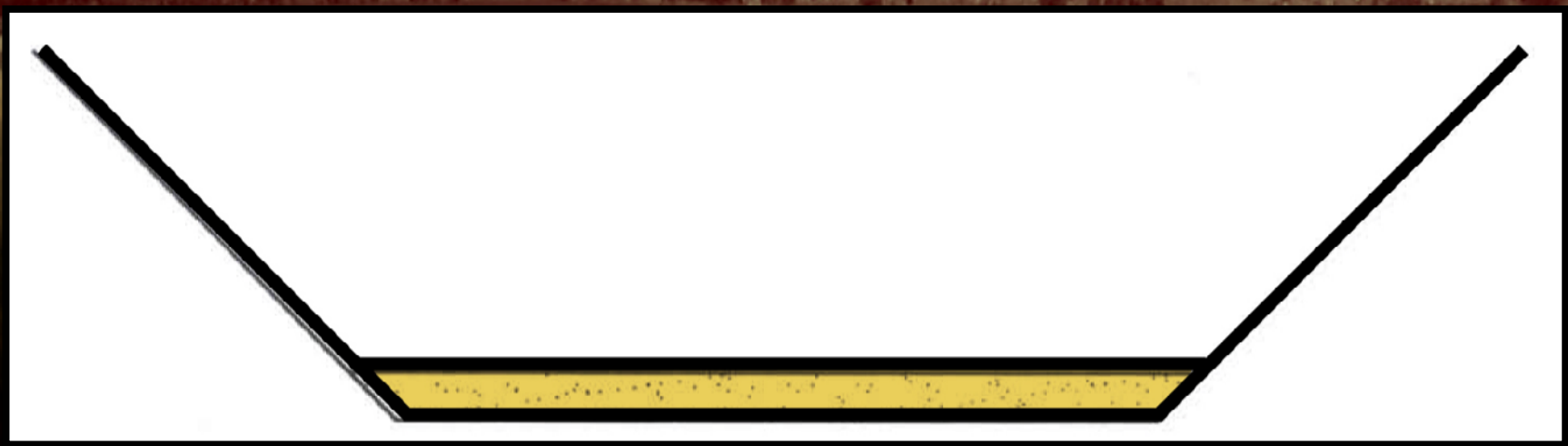


ADVANTAGES OF RECOMMENDED DESIGN

- Water flows freely
  - Sand to gravel
  - Gravel to pipe
- Pipe capacity is fully realized
- Gravel allows for larger pipe slots – less prone to clogging

Design is more expensive, but much more robust!

PRACTICAL CONSTRUCTION SEQUENCE



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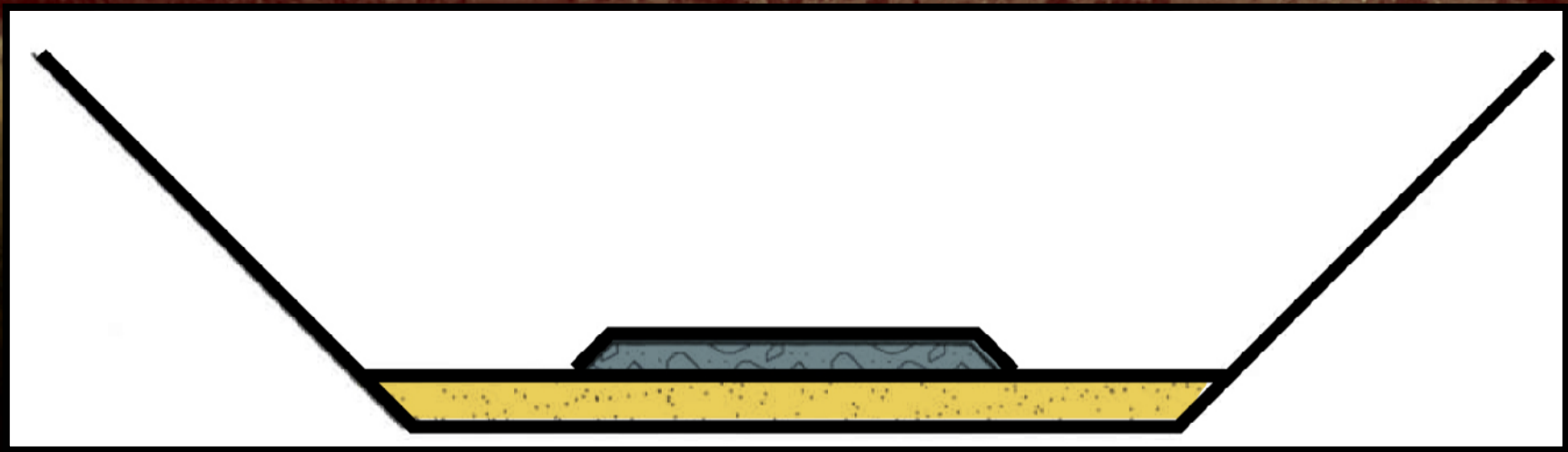

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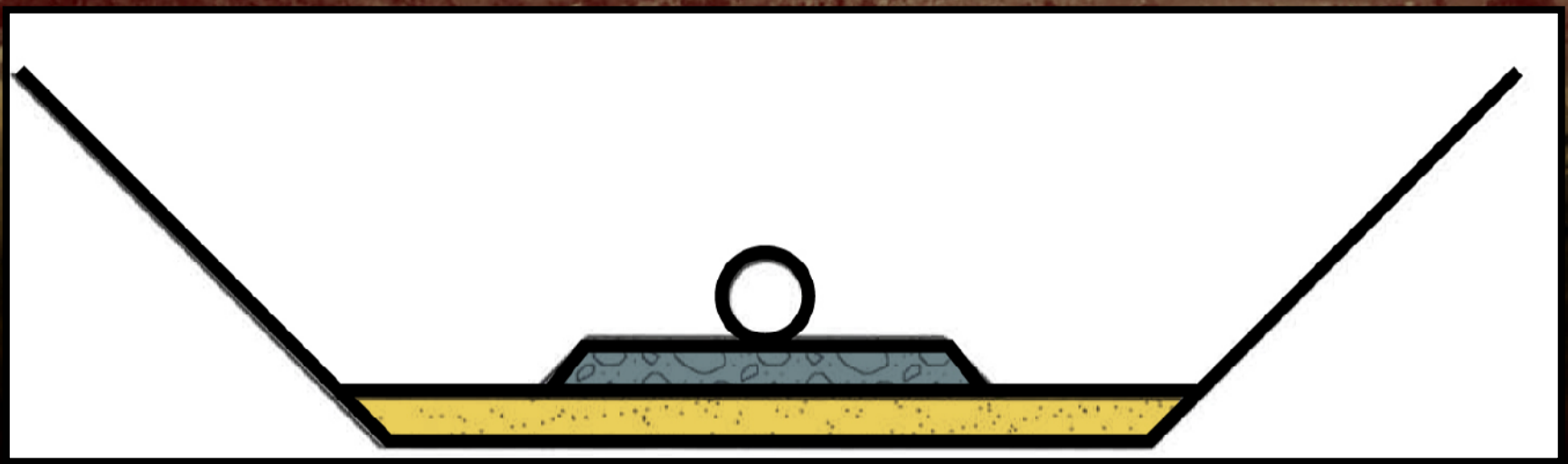
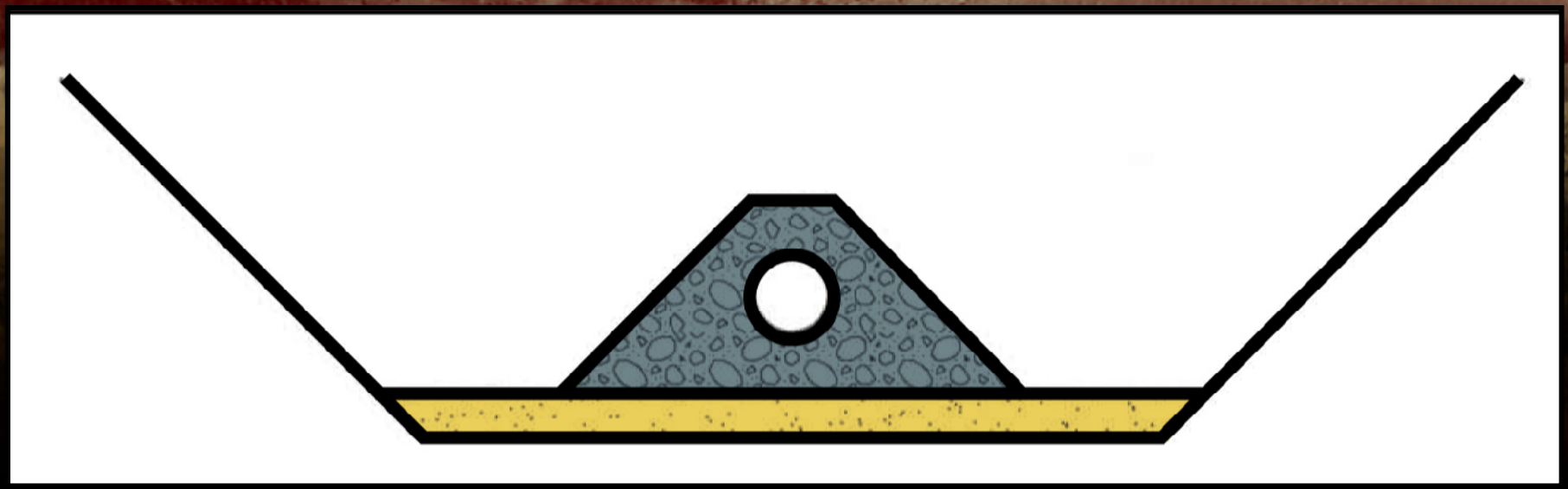


PRACTICAL CONSTRUCTION SEQUENCE



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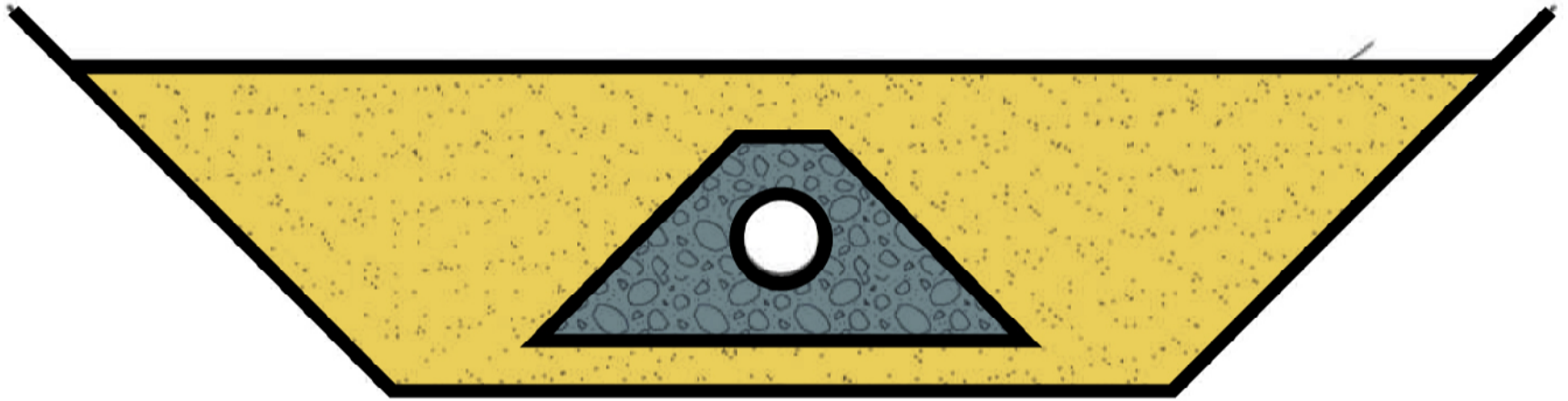


UNCERTAINTIES WITH GEOTEXTILE SLEEVES

- May improve flow into slotted pipes
- Susceptible to installation damage
- May clog or deteriorate
- Not accepted by all regulators
- Not as robust as gravel envelope

VERIFICATION OF DRAIN PIPE INSTALLATION

- Important to verify undamaged installation
- Important to verify at a time when corrective actions are practical
- Damage could include:
  - Open joints
  - Cracked or punctured walls
  - Crushed or distorted pipes

SPECIFICATIONS AND OBSERVATION

- Compaction limitations in the vicinity of the pipe
- Observation of installation
- With limitations and full-time observation, damage is still possible

EXAMPLE

- 12-inch diameter pipe in gravel envelope
- Installed with qualified, full-time observation
- Puncture in the pipe wall occurred
- Likely due to construction equipment impact

RECOMMENDED VERIFICATION

- Camera survey
  - With no more than 3 to 5 feet of fill
  - After completion of construction
- Cameras preferred over torpedoes or balloons
  - Need to verify condition as well as continuity
  - Camera costs are reasonable

ACCESS TO DRAIN PIPE

- Access for future inspection and maintenance is highly desirable
- Need to avoid long sections and inaccessible ends
- Design to accommodate internal camera surveys will provide adequate access
  - Minimum 6-inch diameter
  - Manholes or cleanouts at 500- to 1,000-foot intervals
  - Bends no sharper than 22.5 degrees
  - Sufficient straight sections between bends

SAND FILTER GRADATION

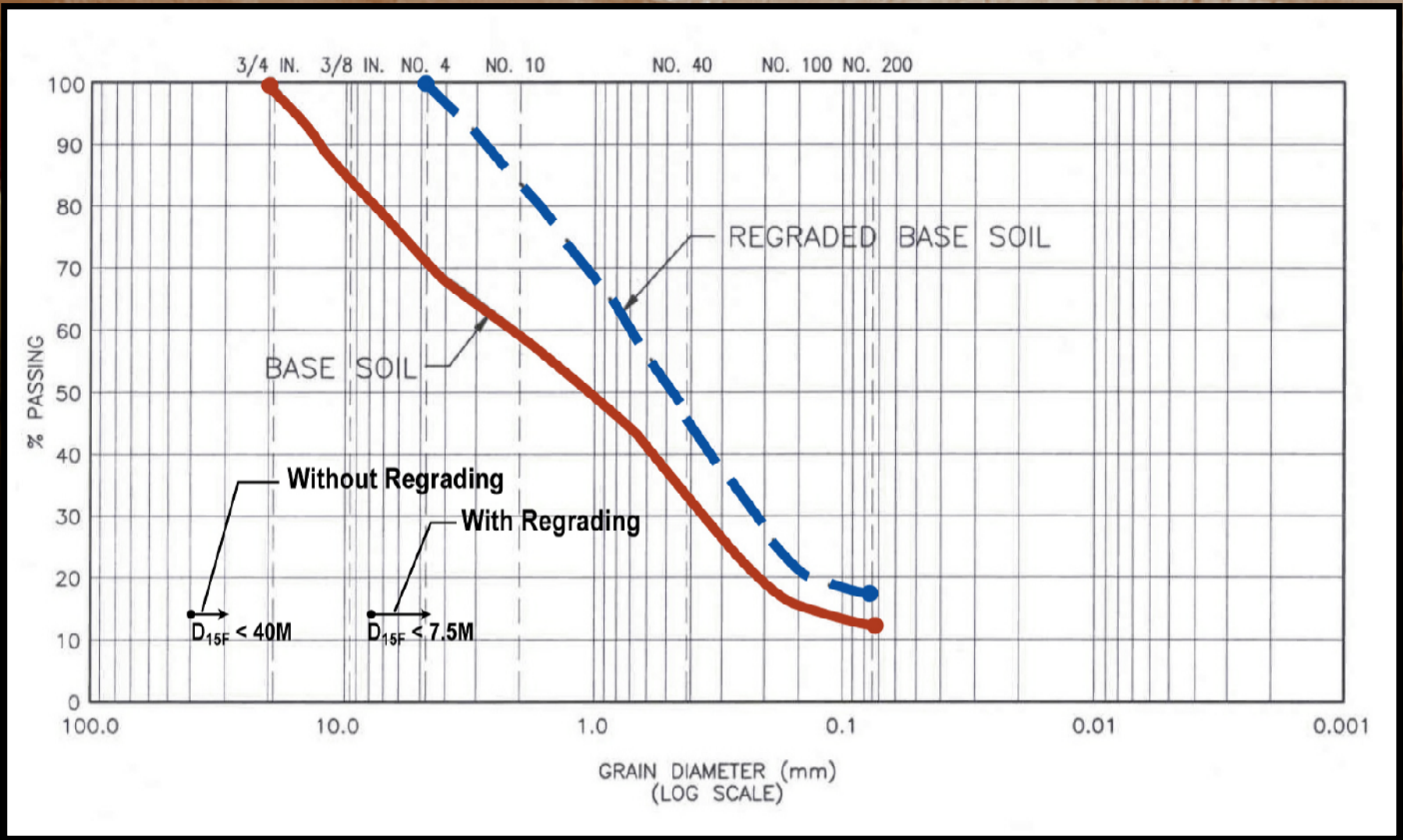
- Key factor in a successful seepage collection and control system
- Must prevent piping of all embankment and foundation soils
- Based on most recent design guidelines: NRCS (1994), USBR (1999), USACE (1993)
  - Base soils divided into four categories
  - Regrading of base soil

BASE SOIL CATEGORIES

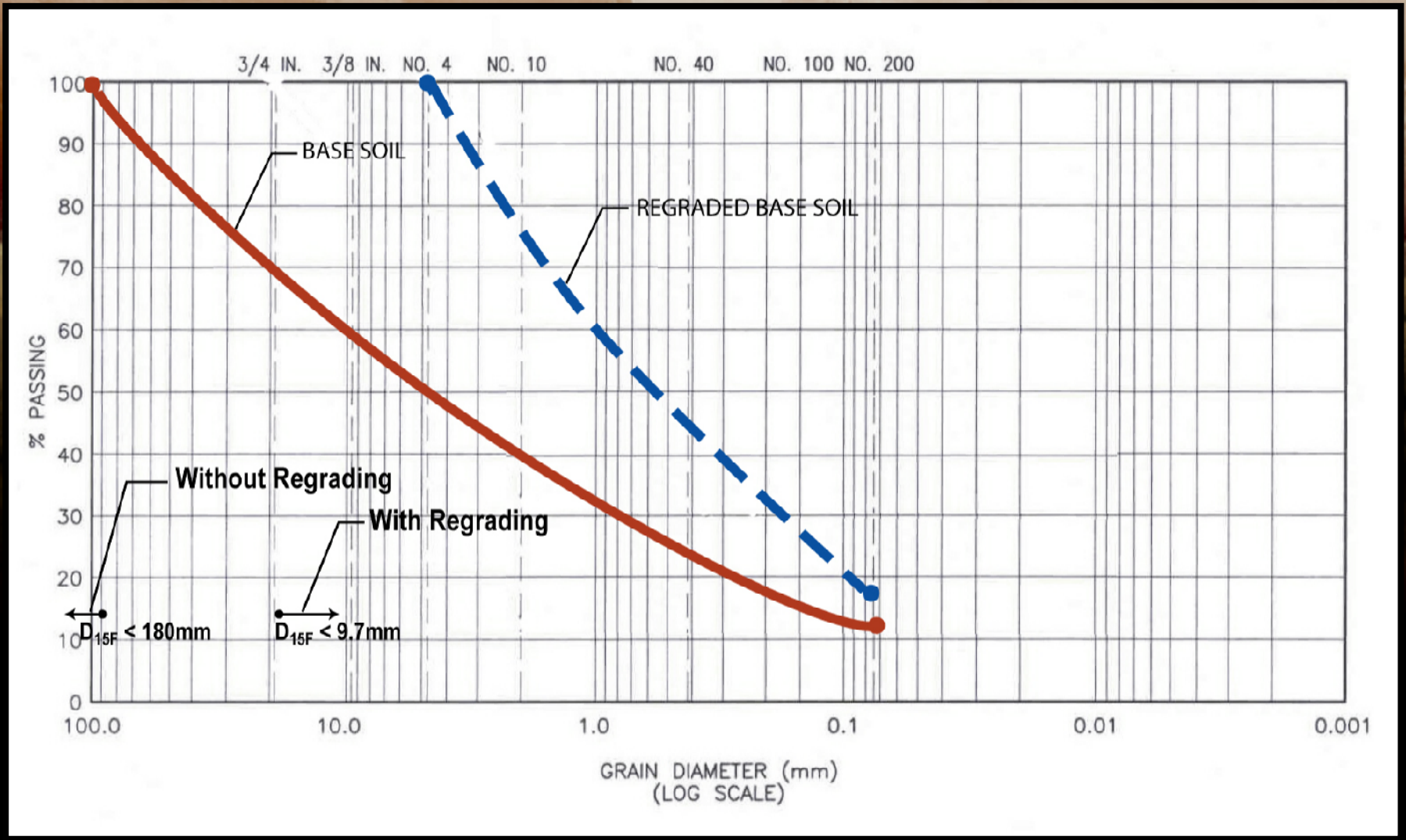
Criteria for Filters and Base Soil Categories, from USBR (1999)

Base Soil Category	Percent Finer than No. 200 sieve	Base Soil Description	Filtered Criteria
1	>85	Fine silts and clays	$D_{15}F \leq 9 \times D_{85}$, but not , 0.2mm B
2	40 – 85	Sands, silts, clays, and silty and clayey sands	$D_{15}F \leq 0.7$ mm
3	15 – 39	Silty and Clayey sands and gravels	$D_{15}F \leq 0.7 \text{ mm} + \frac{(40-A)(4 \times D_{85}B - 0.7m)}{25}$
4	<15	Sands and gravels	$D15F \leq 4 \times D_{85}B$

BASE SOIL REGRADING No. 1



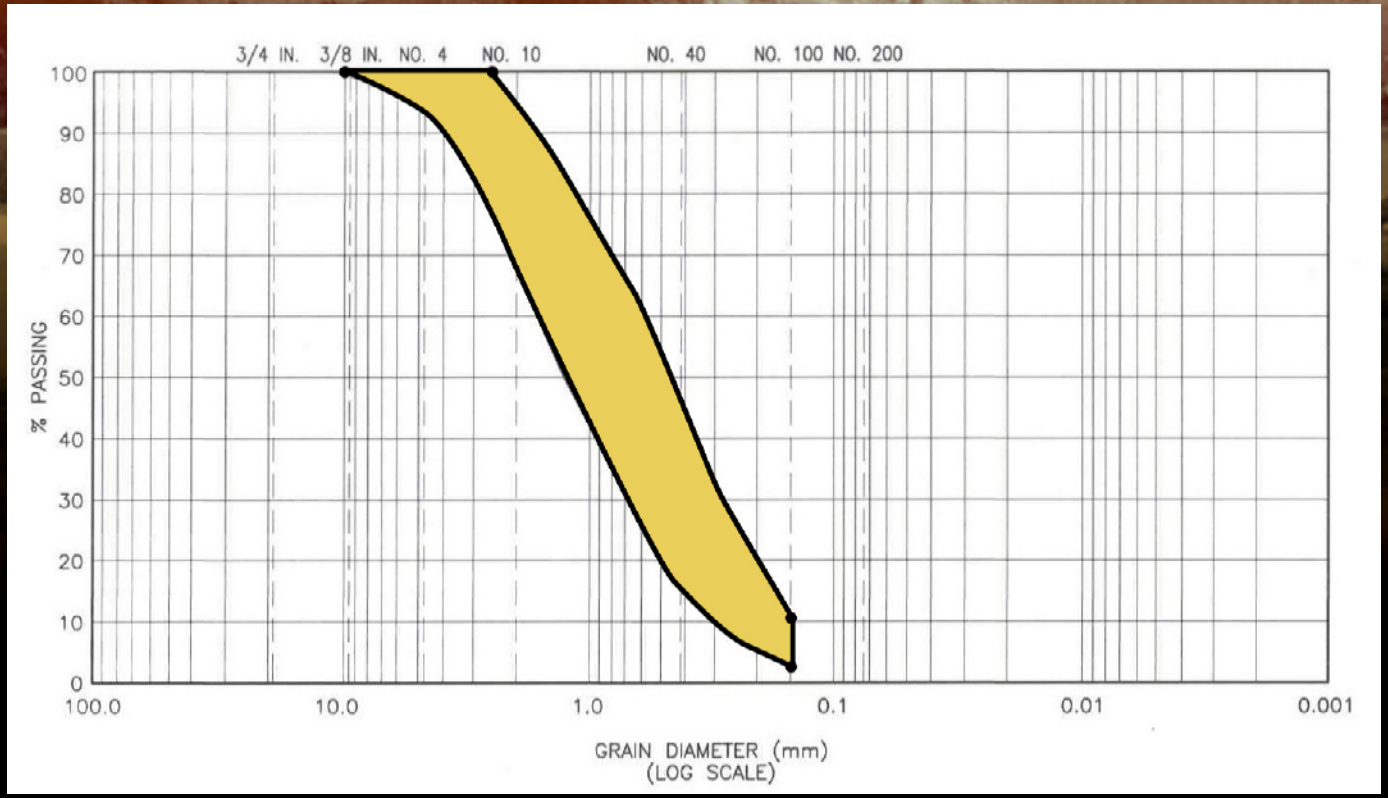
BASE SOIL REGRADING No. 2



USE OF ASTM C33 FINE AGGREGATE

- Suitable for almost all base soils
- Readily available from commercial sources in most locations
- Must add a 200 sieve size requirement to specifications
- Similar gradations can be used, if available at less cost
- May not be suitable for some clays and silts (Category 1 base soils)

ASTM C33 FINE AGGREGATE SAND



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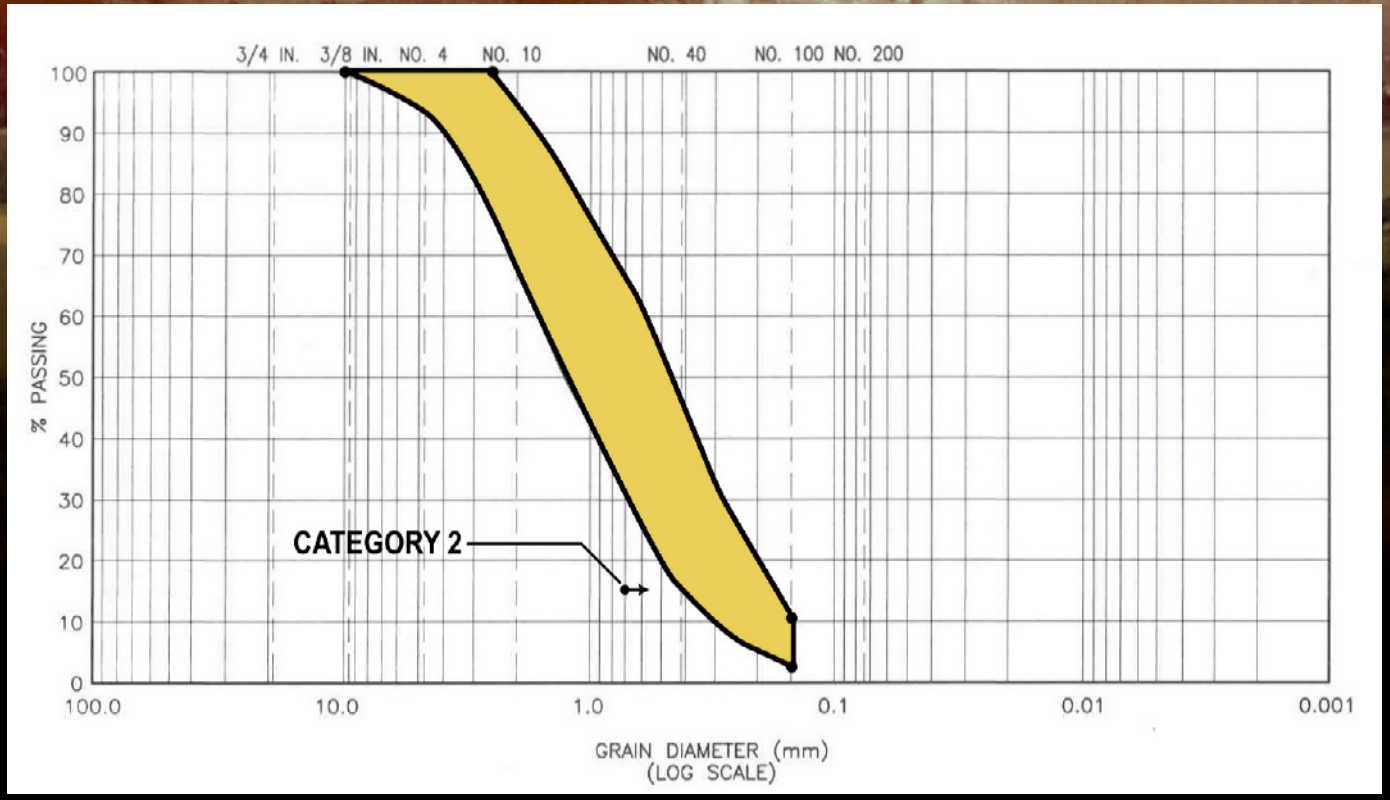

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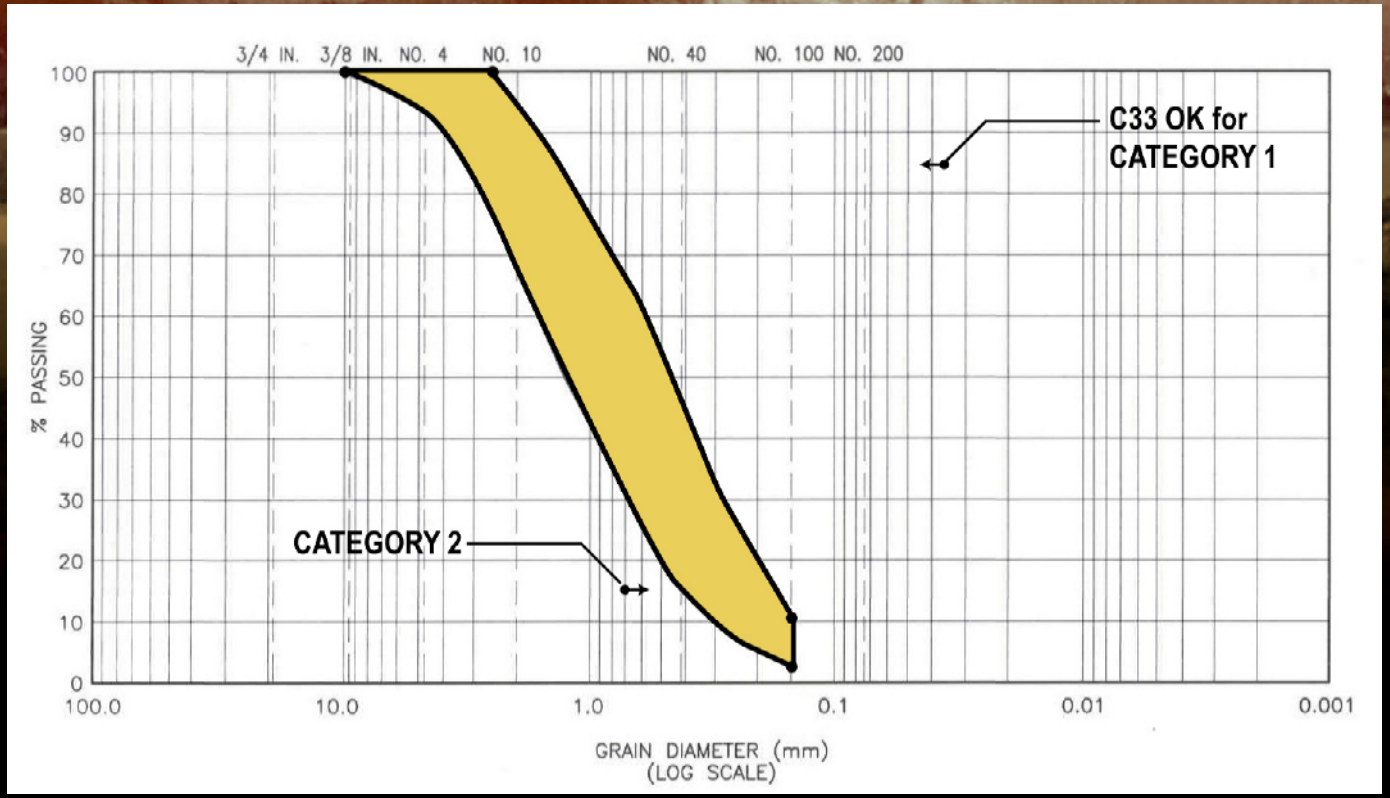

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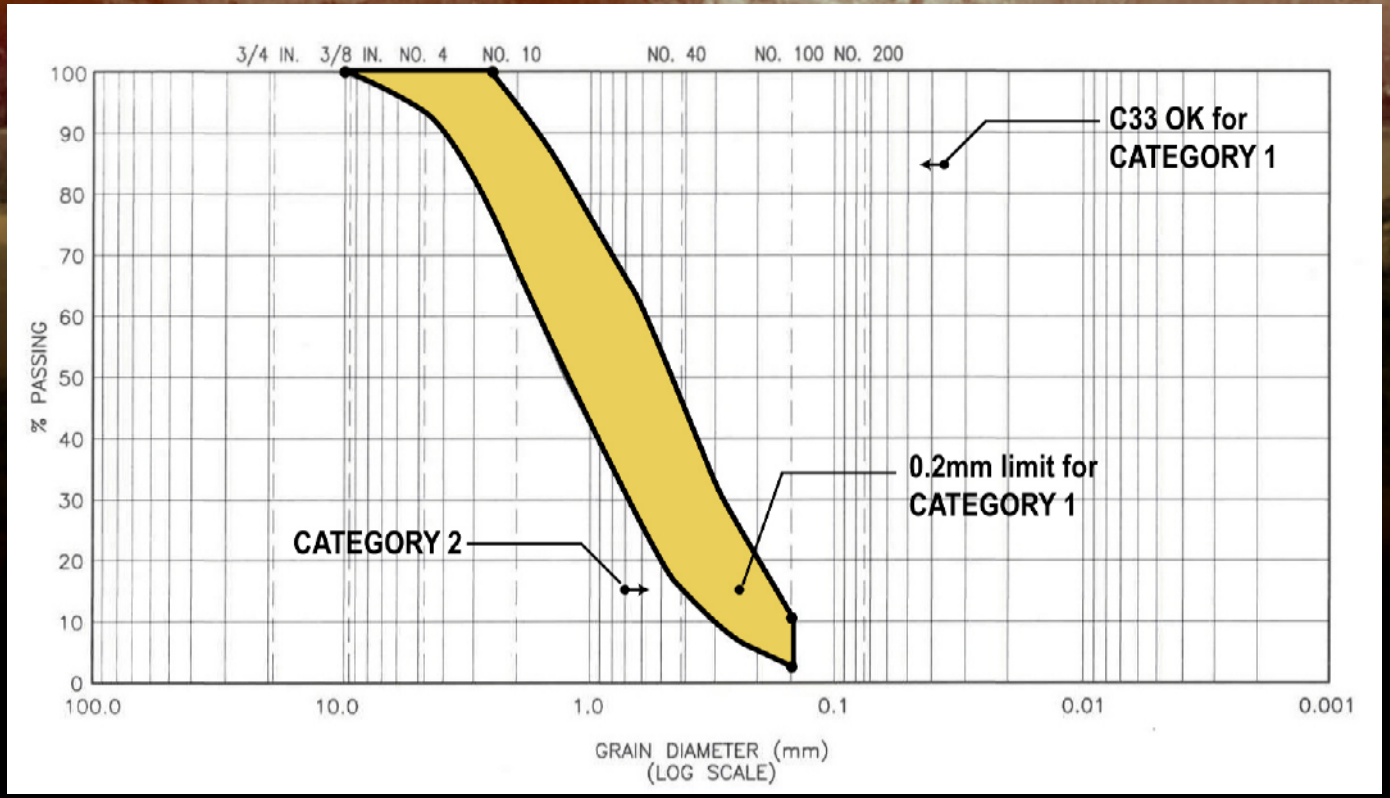

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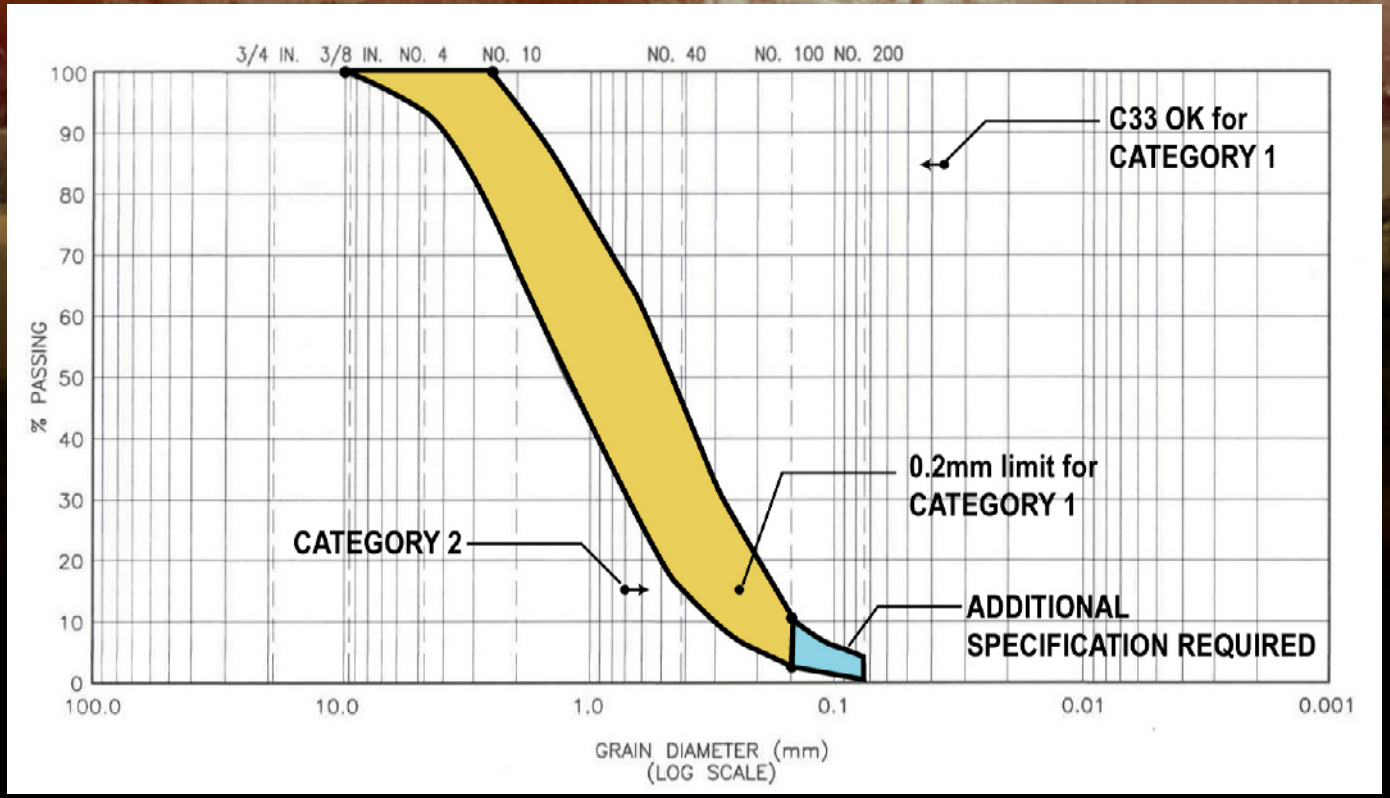


USE OF STANDARD GRADATIONS

- Advantageous if off-site sources are anticipated
- Specify locally available sand and gravel materials that fall within the latitude in the filter requirements
- Sources for standard gradations include:
  - State DOT specifications
  - AASHTO gradations
  - ASTM gradations
  - Products of local aggregate producers
- Verify local availability

CHIMNEY DRAIN WIDTH

- Recent trend toward smaller widths – inclined filters 2- to 3-feet wide
- False economy, if effectiveness of filter is compromised
- Constructability and construction QC must be considered in design
- Misalignment of layers can cause lack of continuity


AS CONSTRUCTED
DESIGN LIMITS

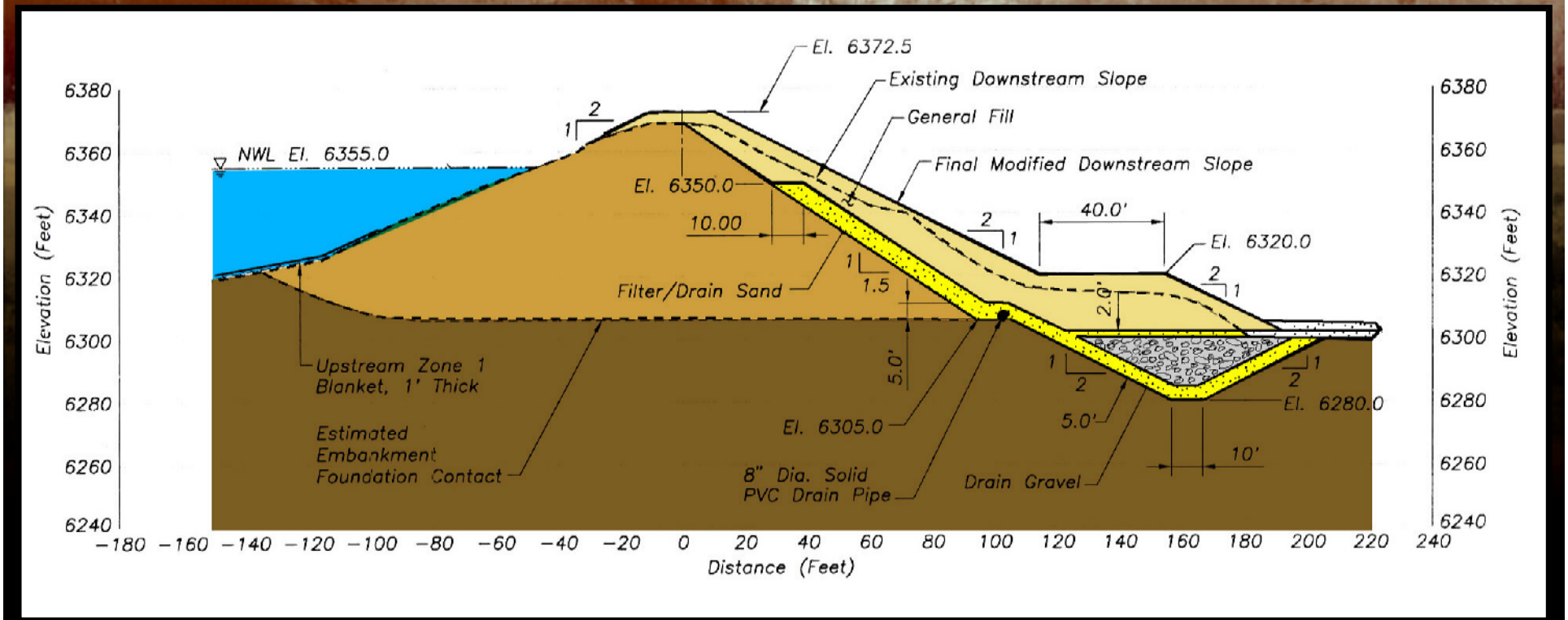
RECOMMENDATIONS

- 3-feet minimum, if placed against an excavated slope
- 5-feet minimum, if placed together with upstream and downstream zones
- Specifications must require prevention of contamination
  - Slope adjacent zones away from filter
  - Maintain filter at least 6-inches above adjacent layers

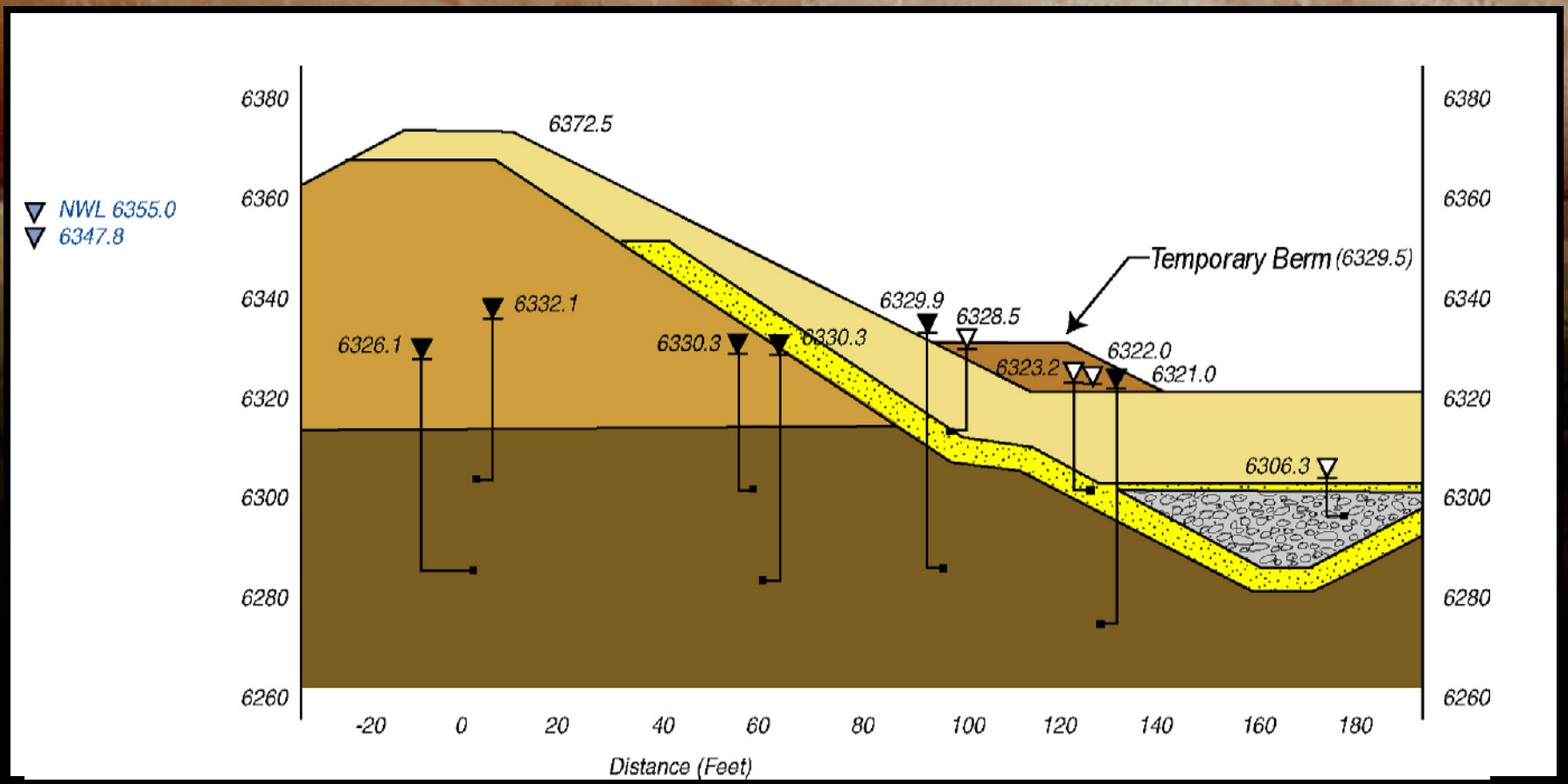
ONE-STAGE VERSUS TWO-STAGE FILTERS

- One-stage filter adequate in most cases for average seepage
- Coarse filter may be needed between sand filter and coarse shell
- Two-stage filter needed, if concentrated seepage is expected

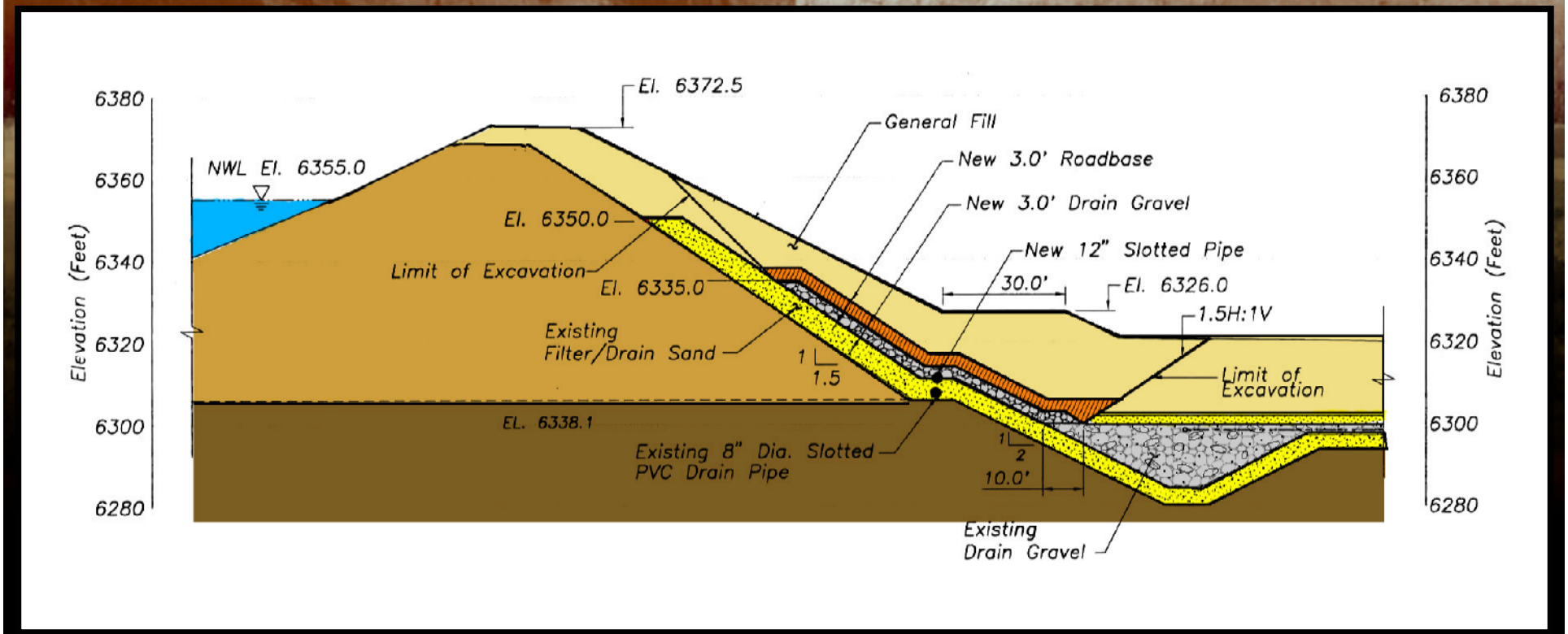
EXAMPLE


El. 6372.5
Existing Downstream Slope
General Fill
Final Modified Downstream Slope
NWL El. 6355.0
El. 6350.0
10.00
40.0'
El. 6320.0
Filter/Drain Sand
1.5
2.0'
5.0'
Upstream Zone 1
Blanket, 1' Thick
Estimated
Embankment
Foundation Contact
El. 6305.0
8" Dia. Solid
PVC Drain Pipe
Drain Gravel
El. 6280.0
10'
Elevation (Feet)
Distance (Feet)
6380
6360
6340
6320
6300
6280
6260
6240
−180 −160 −140 −120 −100 −80 −60 −40 −20 0 20 40 60 80 100 120 140 160 180 200 220 240

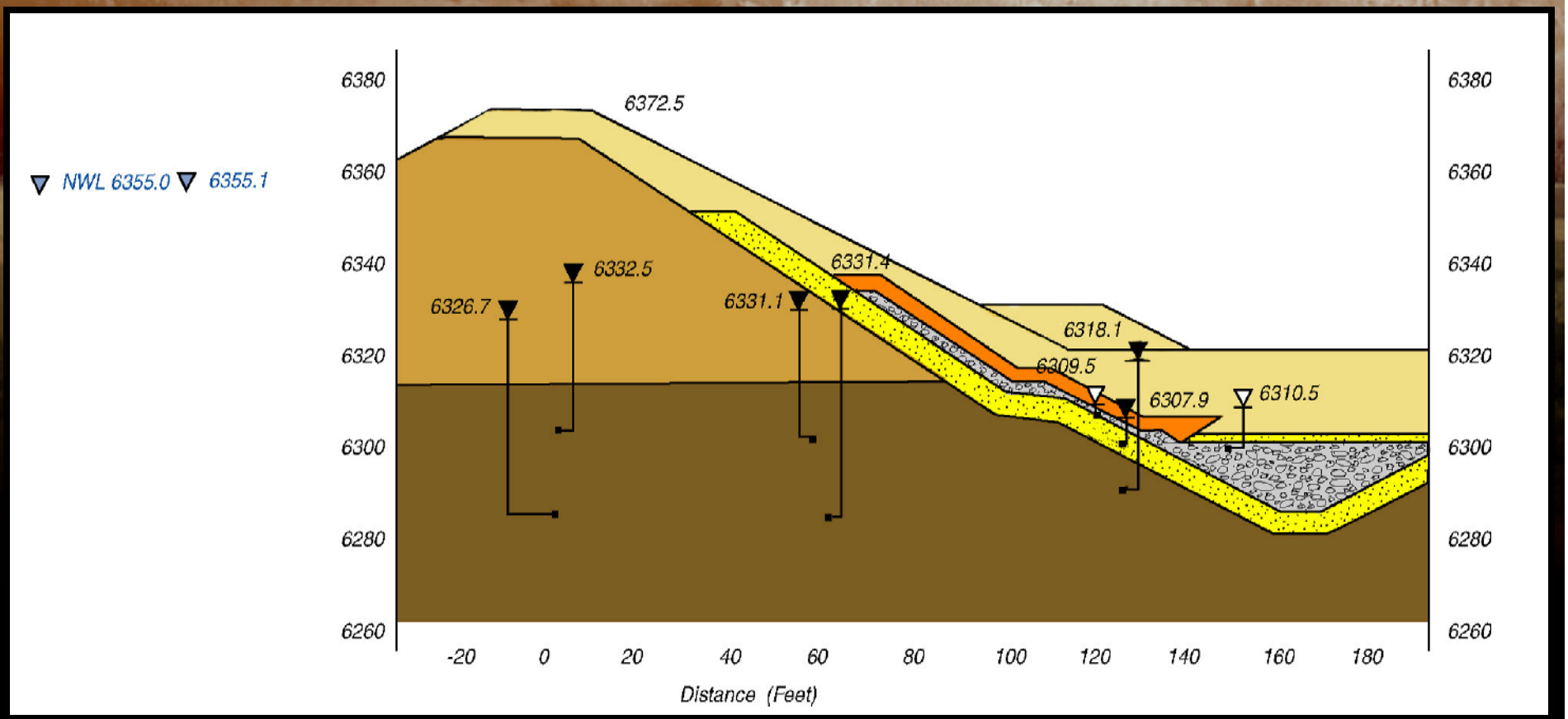
EXAMPLE


NWL 6355.0
6347.8
6380
6360
6340
6320
6300
6280
6260
6372.5
6332.1
6326.1
6330.3
6330.3
6329.9
6328.5
Temporary Berm (6329.5)
6323.2
6322.0
6321.0
6306.3
-20
0
20
40
60
80
100
120
140
160
180
Distance (Feet)

EXAMPLE


El. 6372.5
General Fill
New 3.0' Roadbase
New 3.0' Drain Gravel
NWL El. 6355.0
El. 6350.0
New 12" Slotted Pipe
Limit of Excavation
El. 6335.0
30.0'
El. 6326.0
1.5H:1V
Existing
Filter/Drain Sand
1
1.5
Limit of
Excavation
EL. 6338.1
Existing 8" Dia. Slotted
PVC Drain Pipe
1
2
10.0'
Existing
Drain Gravel
6380
6360
6340
6320
6300
6280
Elevation (Feet)

EXAMPLE


NWL 6355.0
6355.1
6380
6360
6340
6320
6300
6280
6260
6372.5
6332.5
6326.7
6331.1
6331.4
6318.1
6309.5
6307.9
6310.5
-20
0
20
40
60
80
100
120
140
160
180
Distance (Feet)

CLOSING

- Several details of seepage collection and control systems have been discussed
- Opinions offered for appropriate treatments
- Seepage collection and control systems will remain a key element of the dam safety engineer's toolbox
- With appropriate attention to details these systems make dams safer


QUESTIONS?

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