APPENDIX 8-4

RCC STABILITY ANALYSIS
EMBANKMENT ALTERNATIVE NO. 5

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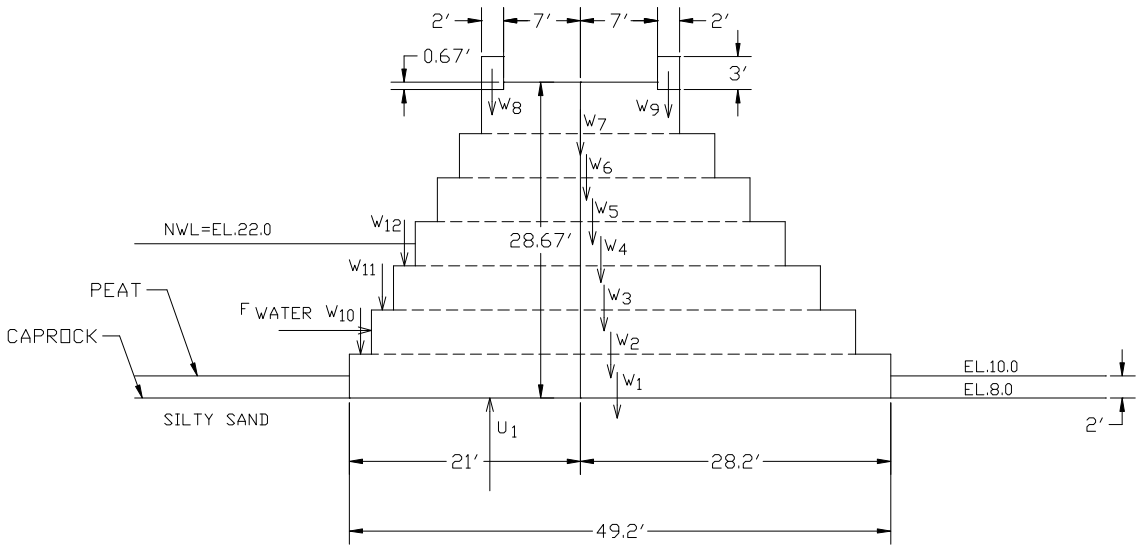
1. STABILITY ANALYSIS TO USACE EM 1110-2-2200

1.1 Usual Loading Condition – Normal water level, minimum tail water

1.1.1 Overturning Stability



EMBANKMENT ALTERNATIVE NO. 5
ROLLER COMPACTED CONCRETE-RCC

$$\sum M_{TOE} = W_{12}d_{12} + W_{11}d_{11} + W_{10}d_{10} + W_9d_9 + W_8d_8 + W_7d_7 + W_6d_6 + W_5d_5 + W_4d_4 + W_3d_3 + W_2d_2 + W_1d_1 - 0.5\gamma d^2 d_y$$
$$- 0.5\gamma d_{total} x_{base} x_{toe}$$

$W = V\rho$

Ex : $W_1 = (4')(49.2')(1')(138\,{}^{lb}\!/_{ft^3}) = 27{,}158$ lb

$$\sum M_{TOE} = (249.6)(44.2) + (748.8)(46.2) + (1248)(48.2) + (828)(20.2) + (828)(36.2) + (11230)(28.2) + (12806)(27.6)$$
$$+ (15677)(27) + (18547)(26.4) + (21418)(25.8) + (24288)(25.2) + (27158)(24.6) - 0.5(62.4)(12)^2(6) - 0.5(62.4)(14)(49.2)(32.8)$$
$$= 2{,}836{,}413\,\text{lb} - \text{ft}$$

$$\sum V = W_{12} + W_{11} + W_{10} + W_9 + W_8 + W_7 + W_6 + W_5 + W_4 + W_3 + W_2 + W_1 - U_1$$
$$= 249.6 + 748.8 + 1248 + 828 + 828 + 11230 + 12806 + 15677 + 18547 + 21418 + 24288 + 27158 - 21491$$
$$= 113{,}535 \text{ lb}$$

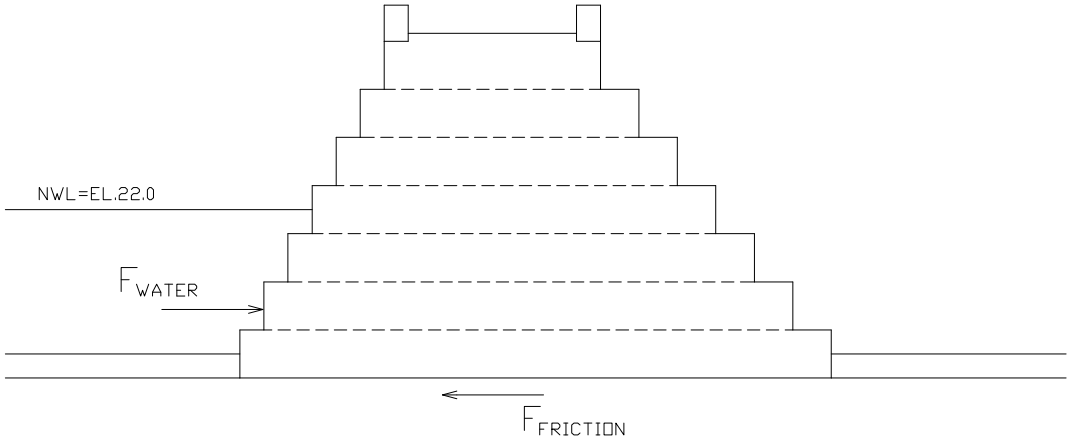
$$\text{Resultant Location} = \frac{\sum M}{\sum V}$$
$$= \frac{2836413}{113535}$$
$$= 24.98 \text{ ft}$$

Requirement: Usual Load Condition requires resultant location in Middle 1/3

Middle 1/3 = 16.4 ft < x < 32.8 ft

Therefore, resultant location meets requirement

1.1.2 Sliding



$$
\begin{aligned}
F.S. &= \frac{T_F}{T} \\
&= \frac{\mu W_{TOTAL}}{F_{WATER}} \\
&= \frac{\mu W_T}{\gamma_W d^2} \\
&= \frac{(0.7)(113535)}{0.5(62.4)(12)^2} \\
&= 17.69
\end{aligned}
$$

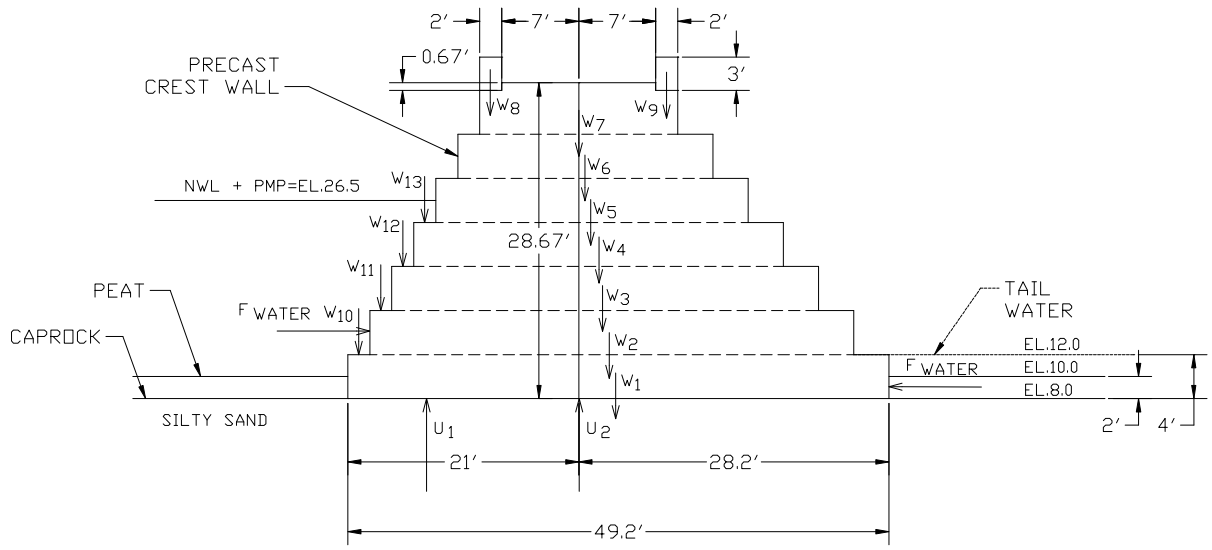
Requirement: Usual Load Condition requires factor of safety > 2.0

17.69 > 2.0

Therefore, sliding requirement is met.

1.2 Extreme Loading Condition – Water level at maximum flood (PMP), tail water pressure

1.2.1 Overturning



EMBANKMENT ALTERNATIVE NO. 5
ROLLER COMPACTED CONCRETE-RCC

$$\sum M_{TOE} = W_{13}d_{13} + W_{12}d_{12} + W_{11}d_{11} + W_{10}d_{10} + W_9d_9 + W_8d_8 + W_7d_7 + W_6d_6 + W_5d_5$$
$$+ W_4d_4 + W_3d_3 + W_2d_2 + W_1d_1 + 0.5\gamma d^2 d_{y1} - 0.5\gamma d^2 d_{y2} - (0.5\gamma d_{base}(d_{water_1} - d_{water_2})\left(\frac{2d_{base}}{3}\right) - 0.5\gamma d_{water_{21}} d_{base}\left(\frac{d_{base}}{2}\right)$$

$W = V\rho$

Ex : $W_7 = (4')(49.2')(1')(138^{lb}/_{ft^3}) = 27158$ lb

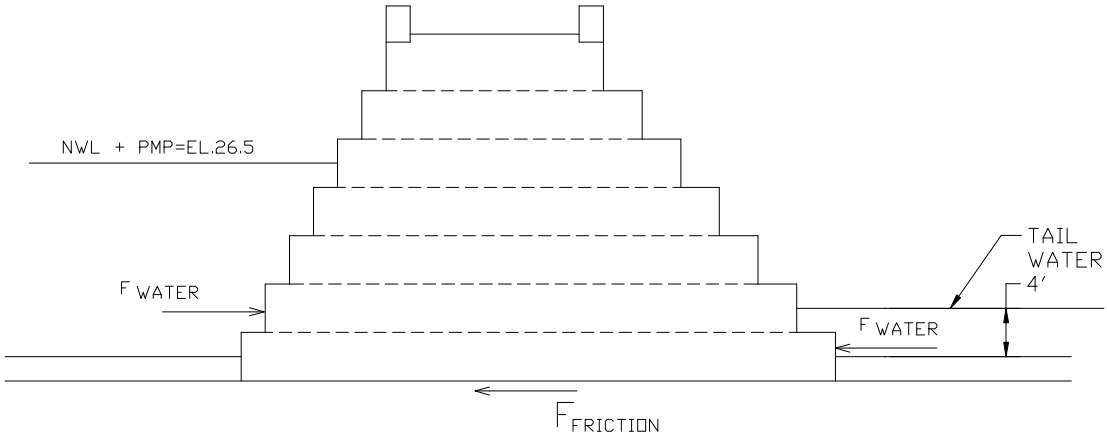
$$\sum M_{TOE} = (312)(42.2) + (811.2)(44.2) + (1310.4)(46.2) + (1809.6)(48.2) + (828)(20.2) + (828)(36.2)$$
$$+ (11230)(28.2) + (12806)(27.6) + (15677)(27) + (18547)(26.4) + (21418)(25.8) + (24288)(25.2)$$
$$+ (27158)(24.6) + 0.5(62.4)(2)^2(4/3) - 0.5(62.4)(16.5)^2(5.5) - 0.5(62.4)(49.2)(14-4)(32.8) - 0.5(62.4)(49.2)(4)(49.2/2)$$
$$= 2{,}958{,}877 \text{ lb} - \text{ft}$$

$$\sum V = W_{14} + W_{13} + W_{12} + W_{11} + W_{10} + W_9 + W_8 + W_7 + W_6 + W_5 + W_4 + W_3 + W_2 + W_1 - U_1 - U_2$$
$$= 399.4 + 312 + 811.2 + 1310.4 + 1809.6 + 828 + 828 + 11230 + 12806 + 15677 + 18547 + 21418 + 24288 + 27158 - 15350 - 6140$$
$$= 115{,}933 \text{ lb}$$

$$\text{Resultant Location} = \frac{\sum M}{\sum V}$$
$$= \frac{2958877}{115933}$$
$$= 25.52 \text{ ft}$$

Requiremnt for Extreme Load Condition: Resultant must be within base
Therefore, resultant location meets requirement

1.2.2 Sliding



$$
\begin{aligned}
F.S. &= \frac{T_F}{T} \\
&= \frac{\mu W_{TOTAL}}{F_{WATER}} \\
&= \frac{\mu W_T}{\gamma_W d_1^2 - \gamma_W d_2^2} \\
&= \frac{(0.7)(115933)}{0.5(62.4)(16.5)^2 - 0.5(62.4)(2)^2} \\
&= 9.70
\end{aligned}
$$

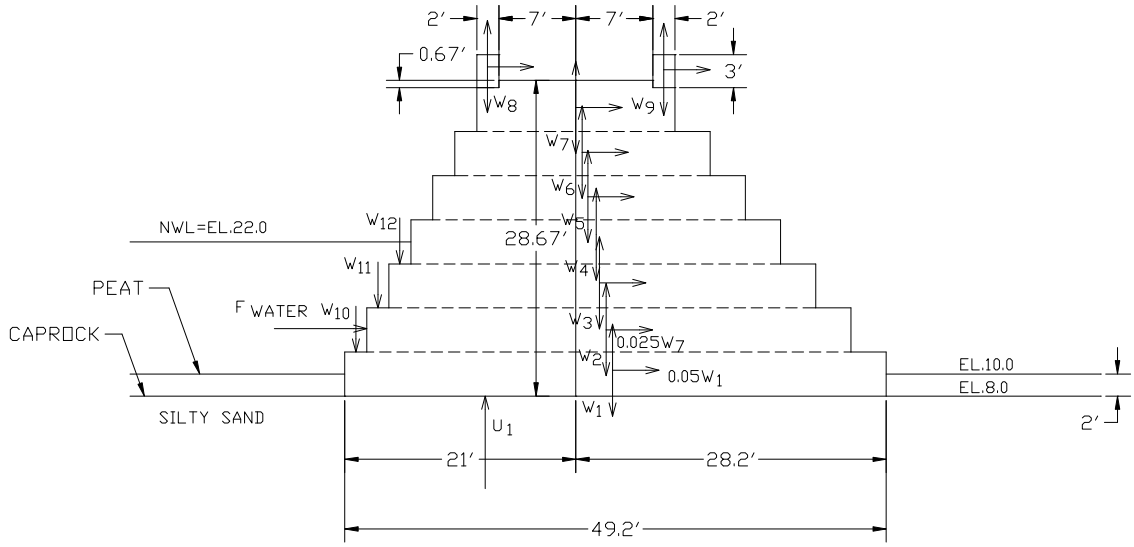
Design requirement for extreme load condition: factor of safety > 1.3

9.70 > 1.3

Therefore, requirement is met.

1.3 Seismic Conditions – Normal water level, maximum credible earthquake, no tail water

1.3.1 Overturning



EMBANKMENT ALTERNATIVE NO. 5
ROLLER COMPACTED CONCRETE-RCC

RCC Stability Analysis Embankment Alternative 5

$$\sum M_{TOE} = W_{12}d_{x12} + W_{11}d_{x11} + W_{10}d_{x10} + W_9d_{x9} + W_8d_{x8} + W_7d_{x7} + W_6d_{x6} + W_5d_{x5} + W_4d_{x4} + W_3d_{x3} + W_2d_{x2} + W_1d_{x1}$$
$$+ 0.05W_9d_{y9} + 0.05W_8d_{y8} + 0.05W_7d_{y7} + 0.05W_6d_{y6} + 0.05W_5d_{y5} + 0.05W_4d_{y4} + 0.05W_3d_{y3} + 0.05W_2d_{y2}$$
$$+ 0.05W_1d_{y1} + 0.025W_9d_{x9} + 0.025W_8d_{x8} + 0.025W_7d_{x7} + 0.025W_6d_{x6} + 0.025W_5d_{x5} + 0.025W_4d_{x4} + 0.025W_3d_{x3}$$
$$+ 0.025W_2d_{x2} + 0.025W_1d_{x1} - 0.5\gamma d^2 d_y - 0.5\gamma d_{total} x_{base} d_{toe}$$

$W = V\rho$

Ex : $W_7 = (4')(49.2')(1')(138\,{}^{lb}\!/_{ft^3}) = 27{,}158$ lb

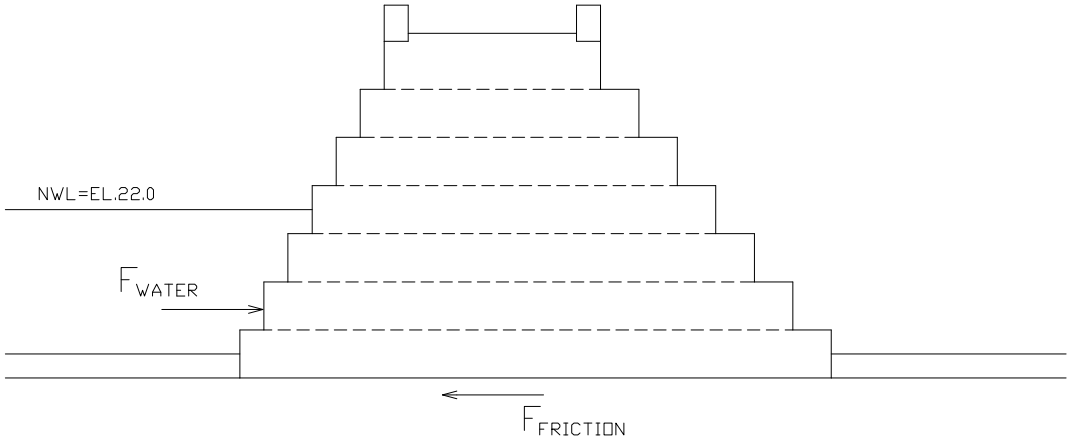
$$\sum M_{TOE} = (249.6)(44.2) + (748.8)(46.2) + (1248)(48.2) + (828)(20.2) + (828)(36.2) + (11230)(28.2) + (12806)(27.6)$$
$$+ (15677)(27) + (18547)(26.4) + (21418)(25.8) + (24288)(25.2) + (27158)(24.6) - 0.05(27158)(2) - 0.05(24288)(6)$$
$$- 0.05(21418)(10) - 0.05(18547)(14) - 0.05(15677)(18) - 0.05(12806)(22) - 0.05(11230)(26) - 2[0.05(828)(29.5)]$$
$$- 0.025(828)(20.2) - 0.025(828)(36.2) - 0.025(11230)(28.2) - 0.025(12806)(27.6) - 0.025(15677)(27)$$
$$- 0.025(18547)(26.4) - 0.025(21418)(25.8) - 0.025(24288)(25.2) - 0.025(27158)(24.6) - 0.5(62.4)(12)^2(6)$$
$$- 0.5(62.4)(14)(49.2)(32.8)$$
$$= 2{,}670{,}919 \text{ lb} - \text{ft}$$

$$\sum V = W_{12} + W_{11} + W_{10} + W_9 + W_8 + W_7 + W_6 + W_5 + W_4 + W_3 + W_2 + W_1 - 0.025W_9 - 0.025W_8 - 0.025W_7 - U_1$$
$$- 0.025W_6 - 0.025W_5 - 0.025W_4 - 0.025W_3 - 0.025W_2 - 0.025W_1$$
$$= 249.6 + 748.8 + 1248 + 828 + 828 + 11230 + 12806 + 15677 + 18547 + 21418 + 24288 + 27158 - 20.7 - 20.7 - 280.8$$
$$- 320.2 - 391.9 - 463.7 - 535.5 - 607.2 - 679.0 - 21490.6$$
$$= 110{,}216 \text{ lb}$$

$$\text{Resultant Location} = \frac{\sum M}{\sum V}$$
$$= \frac{2670919}{110216}$$
$$= 24.23 \text{ ft}$$

Design requirement for Extreme Load Condition: Resultant location within base
Therefore, design requirement is met.

1.3.2 Sliding



$$
\begin{aligned}
F.S. &= \frac{T_F}{T} \\
&= \frac{\mu W_{TOTAL}}{F_{WATER}} \\
&= \frac{\mu W_T}{\gamma_W d^2} \\
&= \frac{(0.7)(110216)}{0.5(62.4)(12)^2} \\
&= 17.17
\end{aligned}
$$

Design requirement for extreme load condition: Factor of safety > 1.3

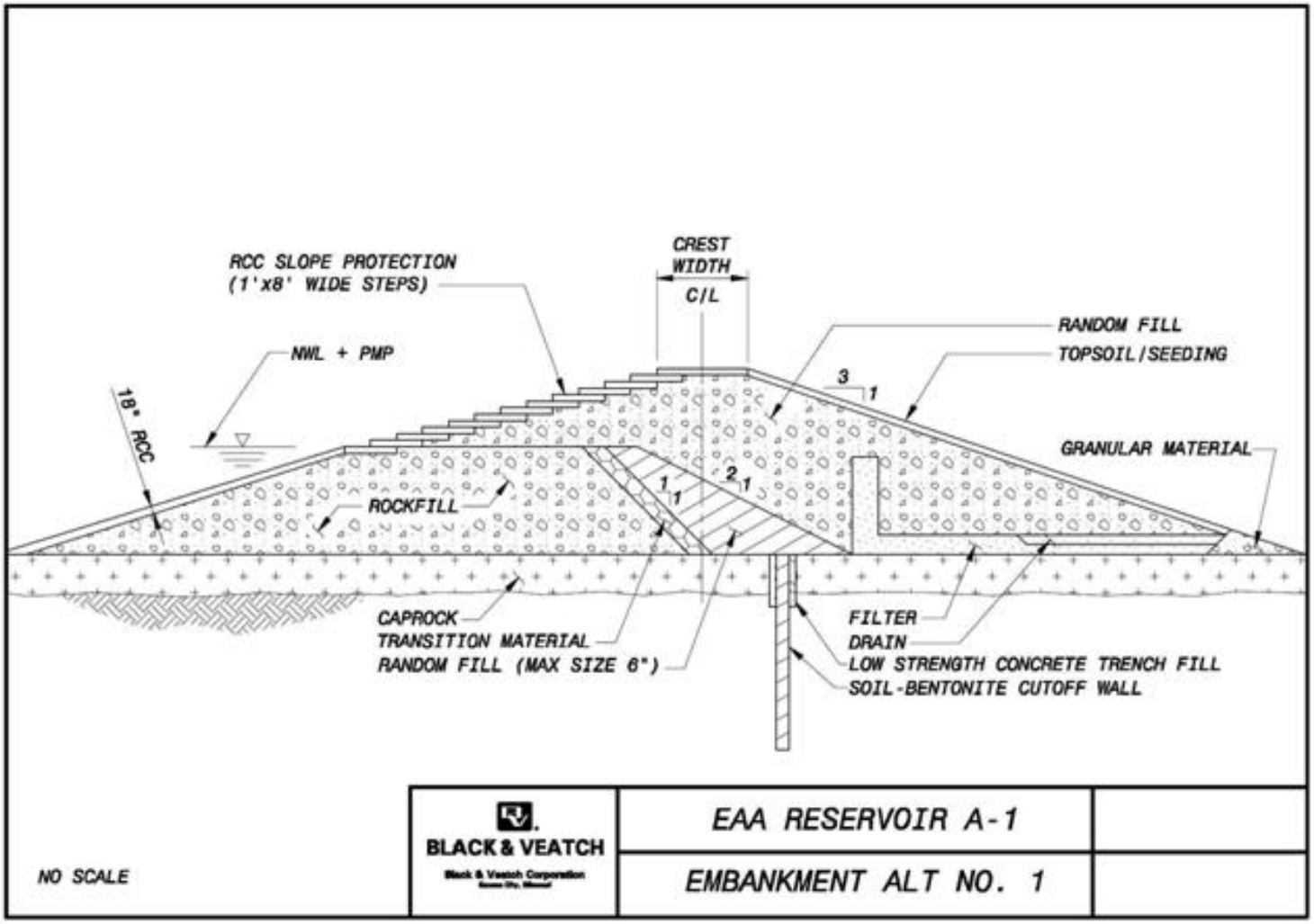
17.17 > 1.3

Therefore, design requirement is met.

RCC Stability Analysis Embankment Alternative 5

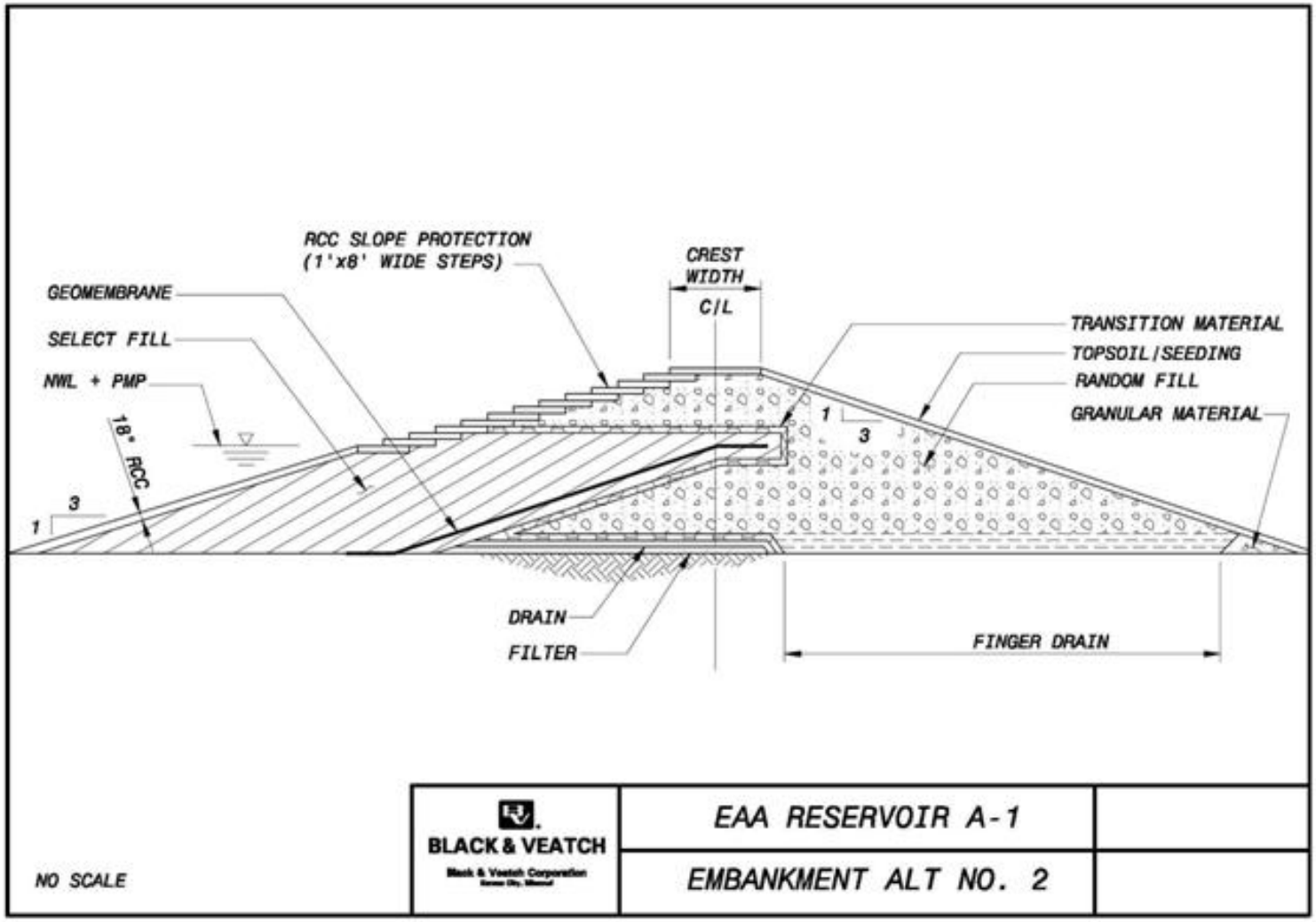
FIGURES

Figure 1 Embankment Alternative 1



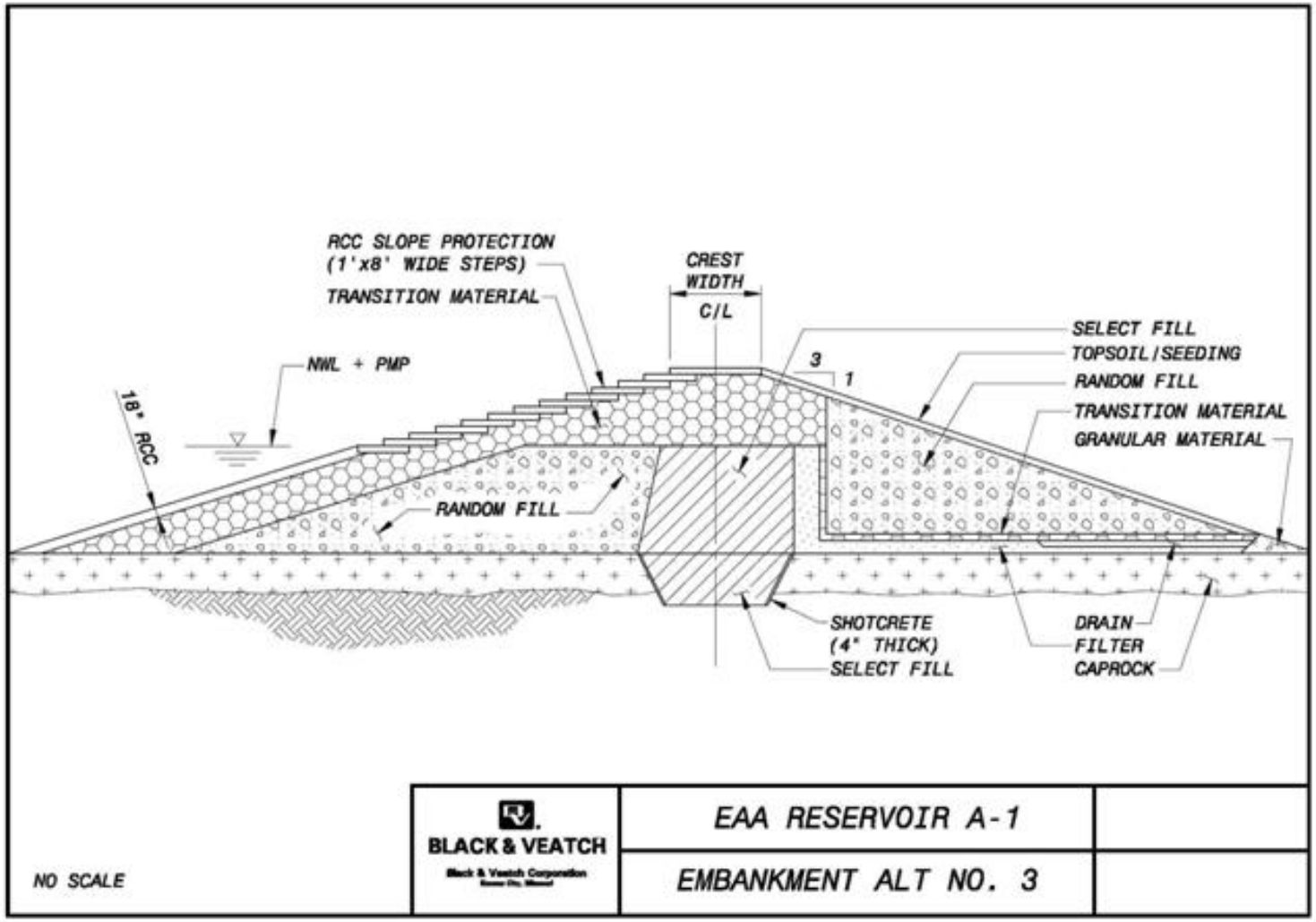
RCC Stability Analysis Embankment Alternative 5

Figure 2 Embankment Alternative 2



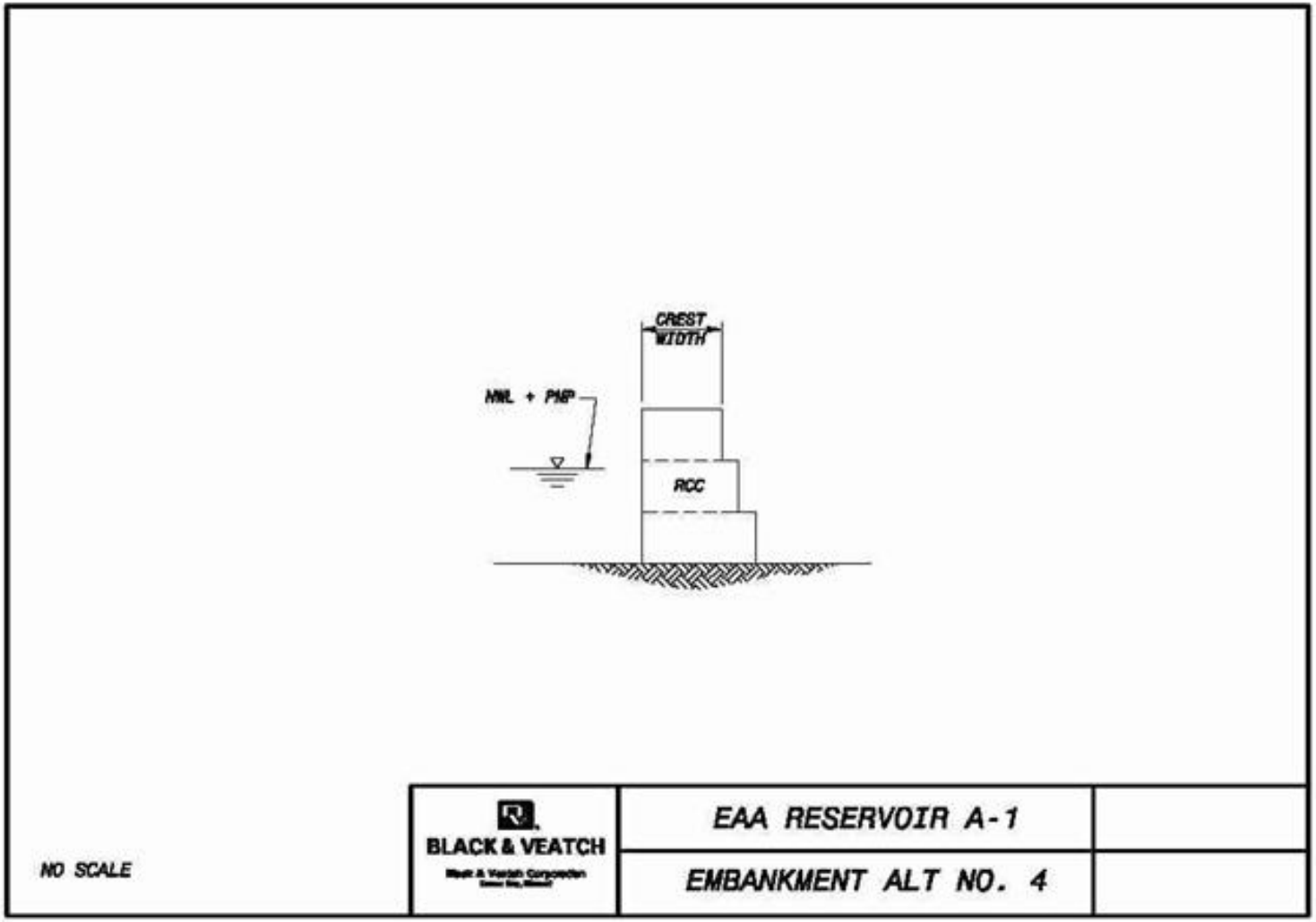
RCC Stability Analysis Embankment Alternative 5

Figure 3 Embankment Alternative 3



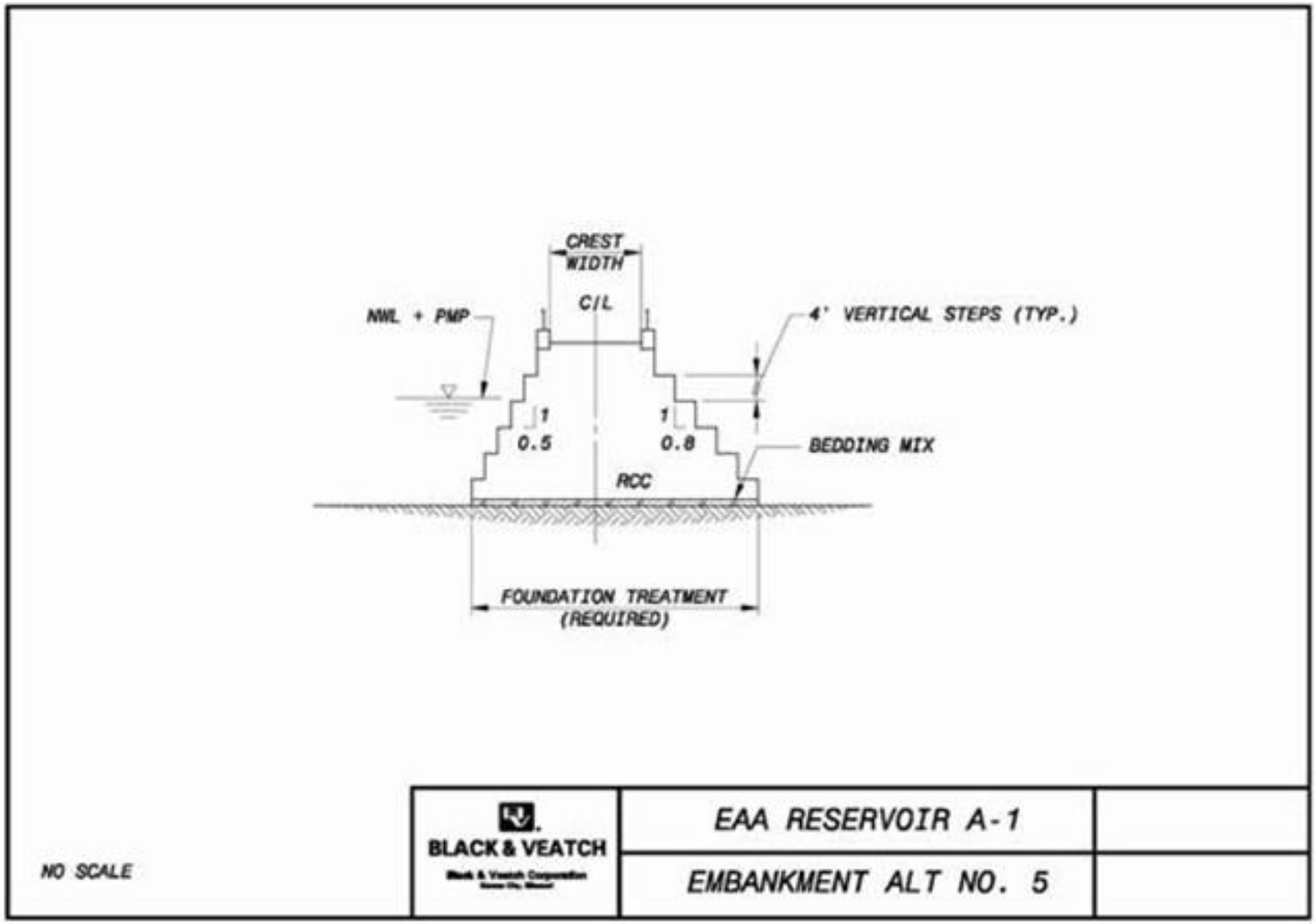
RCC Stability Analysis Embankment Alternative 5

Figure 4 Embankment Alternative 4



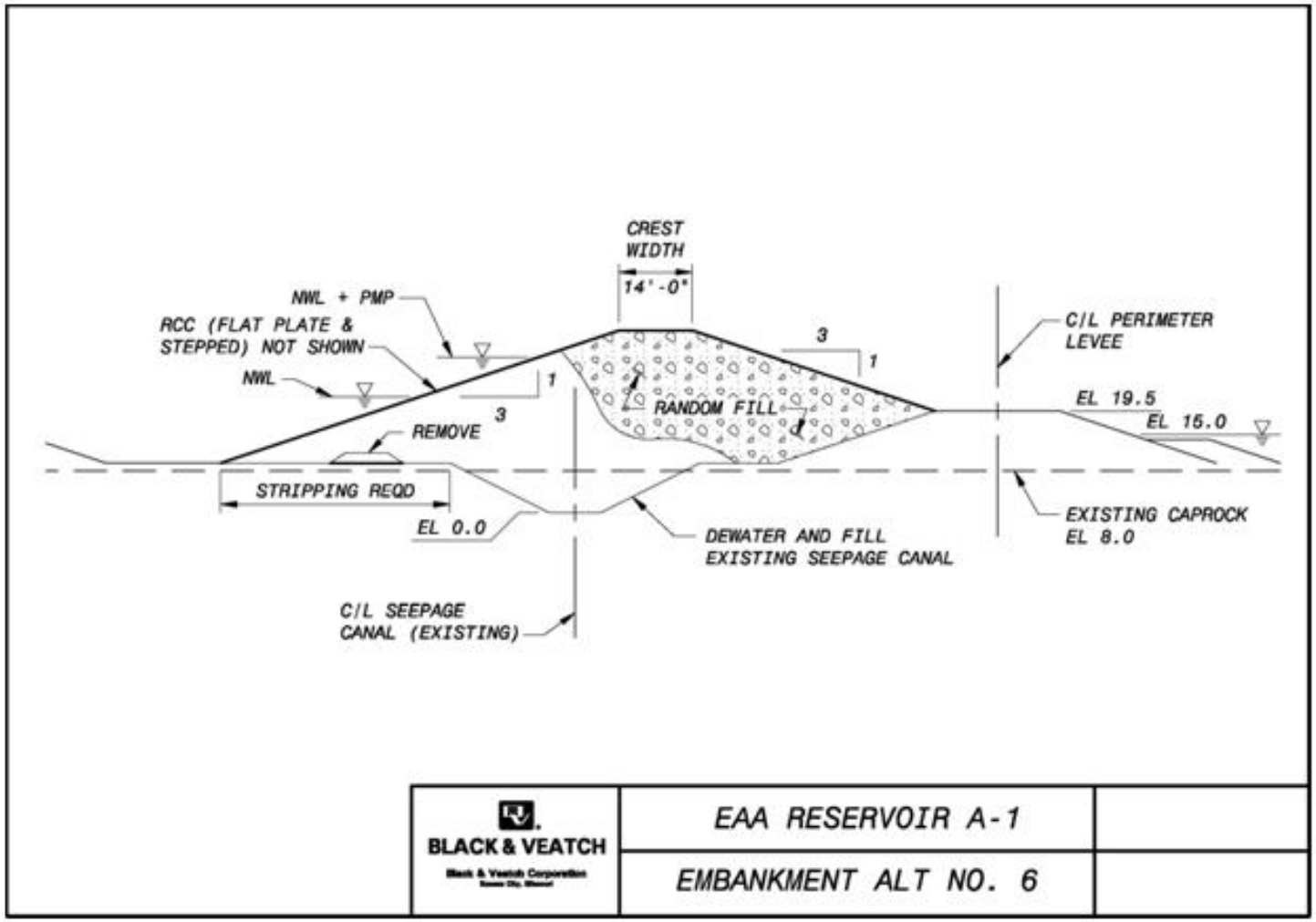
RCC Stability Analysis Embankment Alternative 5

Figure 5 Embankment Alternative 5



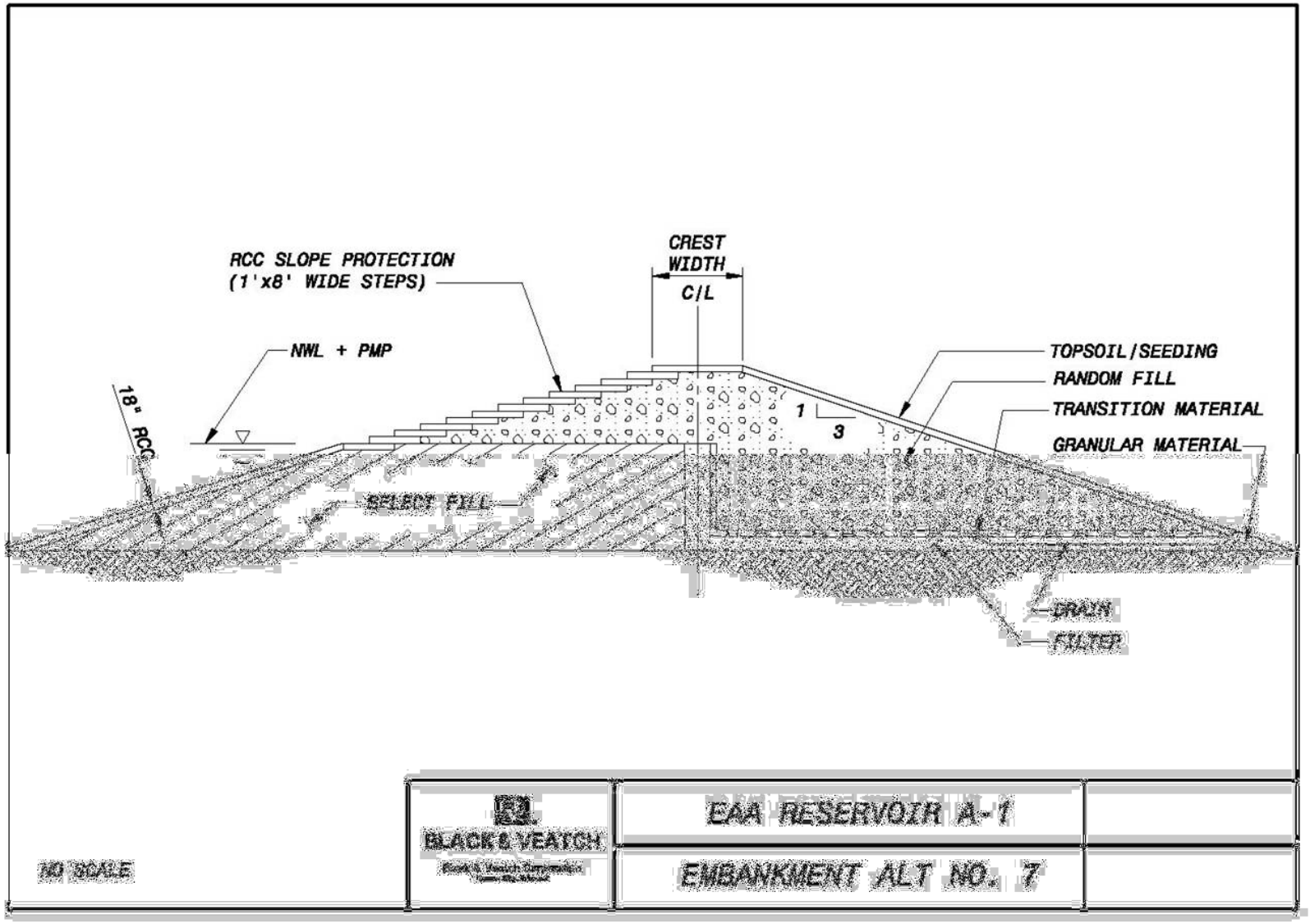
RCC Stability Analysis Embankment Alternative 5

Figure 6 Embankment Alternative 6



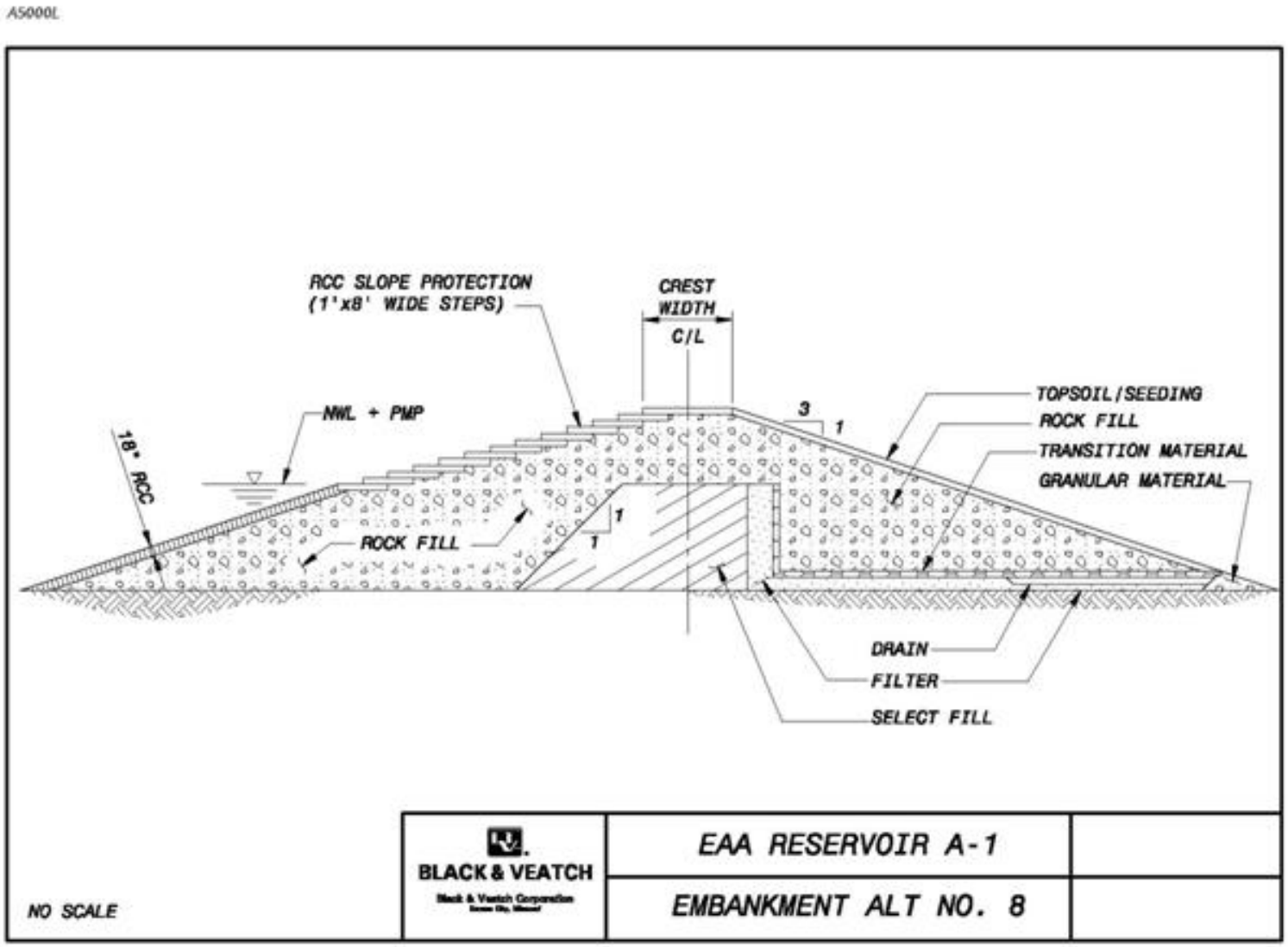
RCC Stability Analysis Embankment Alternative 5

Figure 7Embankment Alternative 7



RCC Stability Analysis Embankment Alternative 5

Figure 8 Embankment Alternative 8



RCC Stability Analysis Embankment Alternative 5

Figure 9 Embankment Alternative 9

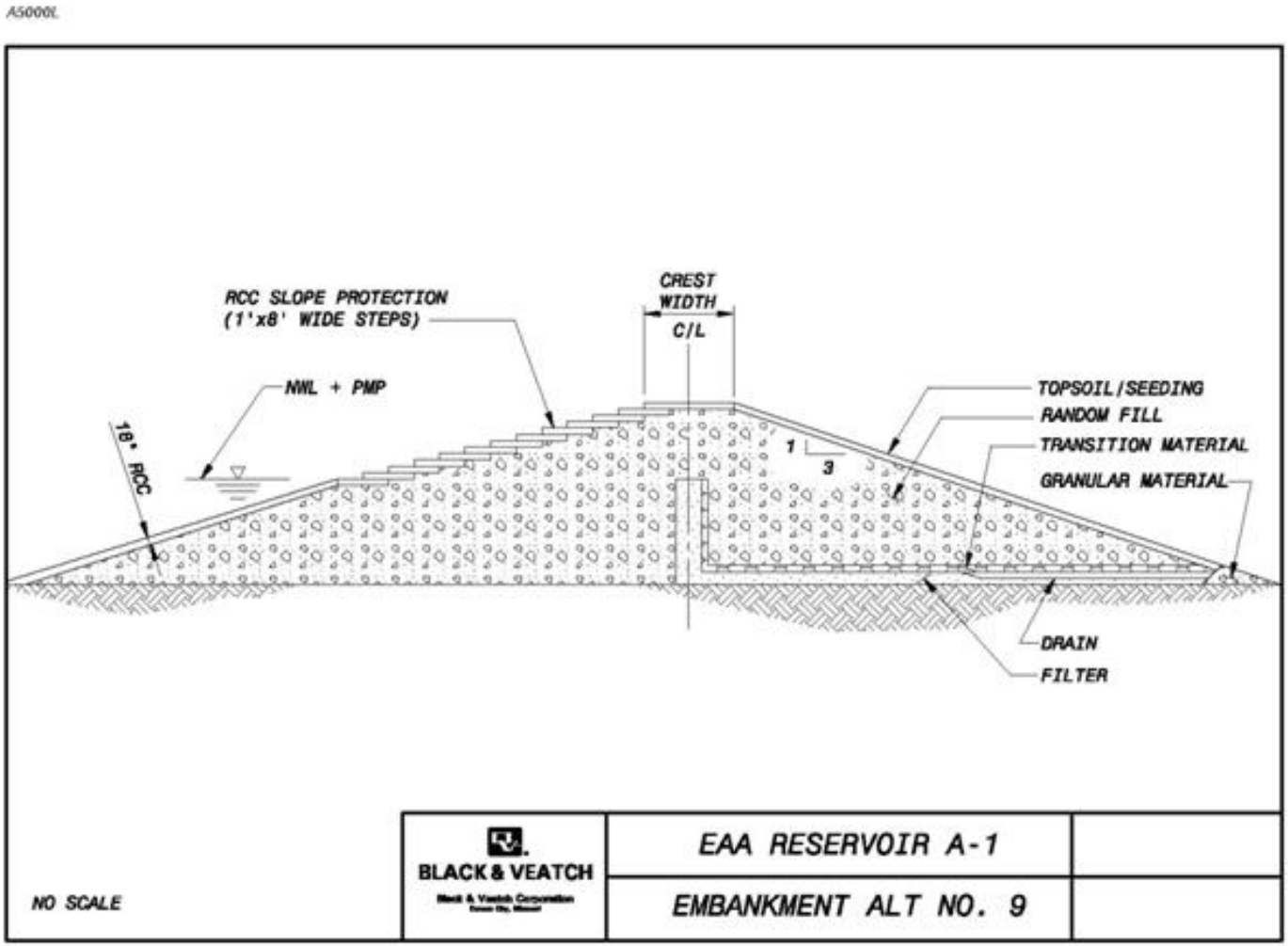
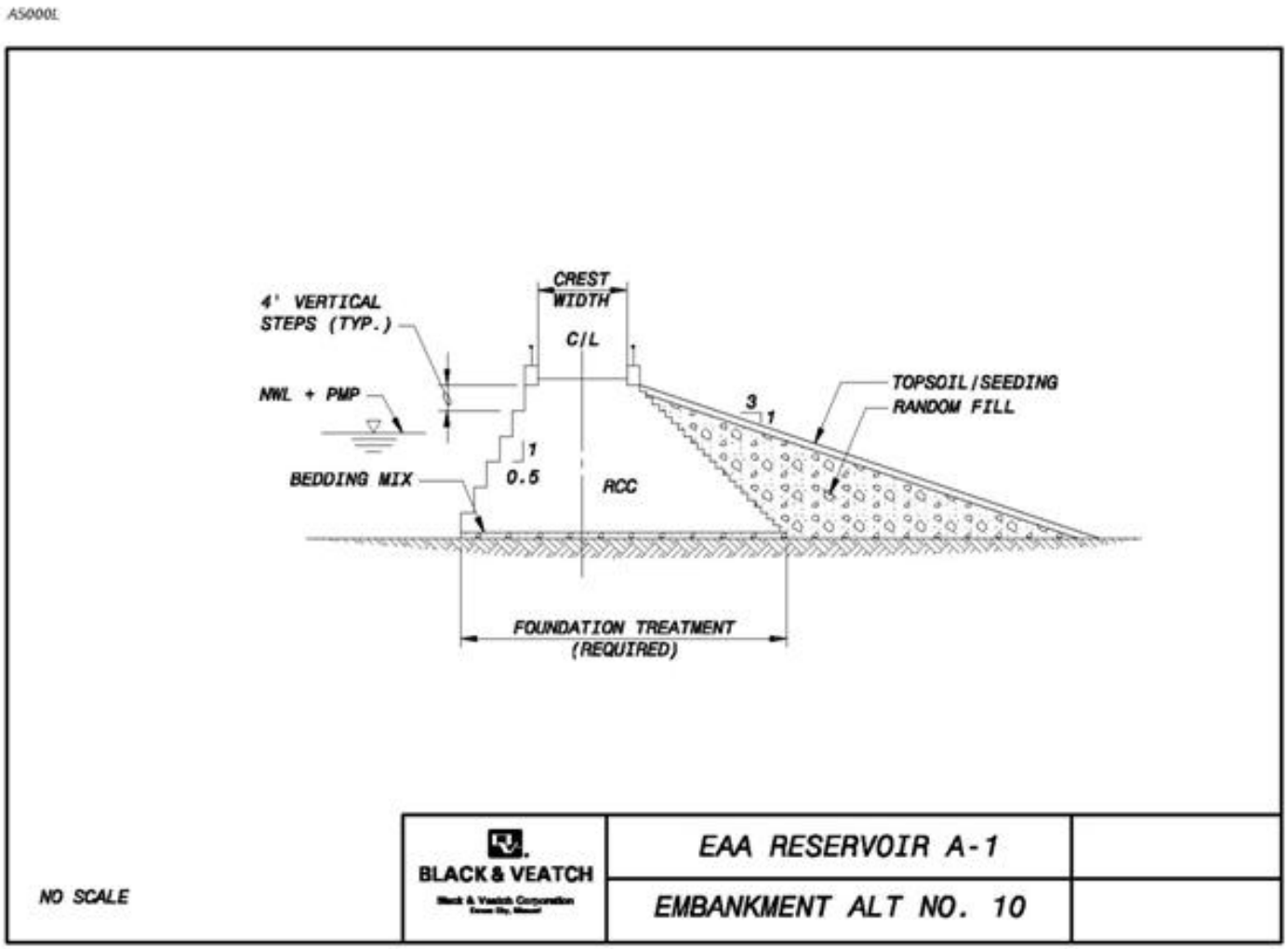



Figure 10 Embankment Alternative 10