LEARNING OUTCOMES

• Identify the components of complex pier scour (A and B)

• Apply the HEC-18 equation for complex pier foundations (B only)
COMPLEX PIER FOUNDATIONS

• Pier stem
• Pile cap
• Pile groups
• Any/all may produce scour
SCOUR COMPONENTS

\[ y_s = y_{s\text{ pier}} + y_{s\text{ pc}} + y_{s\text{ pg}} \]
“SUPERPOSITION OF THE SCOUR COMPONENTS” METHOD

- Determine components exposed to flow
- Determine scour for each component
- Add scour components for total scour
\[ \frac{y_{spier}}{y_1} = K_{hpier} \left[ 2.0K_1K_2K_3K_4 \left( \frac{a_{pier}}{y_1} \right)^{0.65} \left( \frac{V_1}{\sqrt{gy_1}} \right)^{0.43} \right] \]
SUSPENDED PIER SCOUR RATIO

\[ K_{h\text{pier}} = (0.4075 - 0.0669f/a_{\text{pier}}) - (0.4271 - 0.0778f/a_{\text{pier}})h_1/a_{\text{pier}} \]
\[ + (0.1615 - 0.0455f/a_{\text{pier}})(h_1/a_{\text{pier}})^2 - (0.0269 - 0.012f/a_{\text{pier}})(h_1/a_{\text{pier}})^3 \]
Case 1 – Bottom of the pile cap is above the bed (by design or as a result of scour)

Case 2 – Bottom of pile cap is on or below the bed
CASE 1 – BOTTOM ABOVE THE BED

- Reduce the pile cap width, $a_{pc}$, to an equivalent full depth solid pier, $a^*_{pc}$

- The equivalent pier width, an adjusted flow depth, $y_2$, and an adjusted flow velocity, $V_2$, used to estimate the scour component
\[ \frac{y_{spc}}{y_2} = 2.0K_1K_2K_3K_4K_w \left( \frac{a^*_{pc}}{y_2} \right)^{0.65} \left( \frac{V_2}{\sqrt{gy_2}} \right)^{0.43} \]
CASE 1 – PILE CAP (FOOTING) EQUIVALENT WIDTH

\[
a^{\ast}_{pc}/a_{pc} = \exp\{-2.705 + 0.51 \ln(T/y_2) - 2.783(h_2/y_2)^3 + 1.751/\exp(h_2/y_2)\}
\]

where: max value of \( y_2 = 3.5a_{pc} \)
CASE 2 – BOTTOM ON OR BELOW THE BED

- Use full pile cap width, \( a_{pc} \)
- Use exposed footing height, \( y_f \)
- Use velocity at exposed footing, \( v_f \)
CASE 2 – PILE CAP (FOOTING) SCOUR COMPONENT

\[
\frac{y_{spc}}{y_f} = 2.0K_1K_2K_3K_4K_w \left( \frac{a_{pc}}{y_f} \right)^{0.65} \left( \frac{V_f}{\sqrt{gy_f}} \right)^{0.43}
\]
AVERAGE VELOCITY, $V_f$

\[
\frac{V_f}{V_2} = \frac{\ln \left( 10.93 \frac{y_f}{K_s} + 1 \right)}{\ln \left( 10.93 \frac{y_2}{K_s} + 1 \right)}
\]
VELOCITY AND DEPTH ON EXPOSED FOOTING

**Graph:**
- **X-axis:** Velocity Ratio
- **Y-axis:** Depth Ratio
- **Legend:**
  - Average Velocity, \( V_2 \)
  - Average Velocity on footing, \( V_f \)
  - Pier
  - Footing

**Equations:**
- \( y_f \)
- \( y_2 \)
CASE 2 – TOTAL SCOUR

\[ y_s = y_{s\text{ pier}} + y_{s\text{ pc}} \]
PILE GROUP SCOUR COMPONENT

- Determine projected width of piles
- Determine the effective width
- Adjust the flow depth, velocity and exposed height of the pile group
- Determine pile group height factor
- Compute scour component
PROJECTED WIDTH FOR ALIGNED FLOW
EFFECTIVE WIDTH OF AN EQUIVALENT FULL DEPTH PIER

\[ a^*_{pg} = a_{proj} K_{sp} K_m \]
PILE SPACING FACTOR

\[ K_{SP} = 1 - \frac{4}{3} \left[ 1 - \frac{1}{(a_{proj}/a)} \right] \left[ 1 - (S/a)^{-0.6} \right] \]
ADJUSTMENT FACTOR FOR NUMBER OF ALIGNED ROWS

\[ K_m = 0.9 + 0.10m - 0.0714(m - 1)(2.4 - 1.1\frac{S}{a} + 0.1\left(\frac{S}{a}\right)^2) \]
PROJECTED WIDTH FOR SKEWED FLOW

Project two Rows and one Column onto the Plane of Projection

\[ a^*_pg = K_{SP} \times + + + \]

Row m
Col. n
Col. 1
Row 1

Flow

Plane of Projection

\[ s \]

\[ a \]

\[ s_R \]
SCOUR EQUATION FOR PILE GROUP

\[
y_{spg} = K_{hpg} \left[ 2.0K_1K_3K_4 \left( \frac{a^*_{pg}}{y_3} \right)^{0.65} \left( \frac{V_3}{\sqrt{gy_3}} \right)^{0.43} \right]
\]
PILE GROUP HEIGHT ADJUSTMENT FACTOR

\[ K_{h,pg} = \left\{ 3.08\left(\frac{h_3}{y_3}\right) - 5.23\left(\frac{h_3}{y_3}\right)^2 + 5.25\left(\frac{h_3}{y_3}\right)^3 - 2.10\left(\frac{h_3}{y_3}\right)^4 \right\}^{1/0.65} \]

where: \( y_{3 \text{ max}} = 3.5a^*_{pg} \)
COMPLEX PIER TOTAL SCOUR

\[ y_s = y_{s\text{ pier}} + y_{s\text{ pc}} + y_{s\text{ pg}} \]
COMPLEX PIER VELOCITY AND DEPTH

\[ y_{s\,pier} \text{ from } V_1, y_1, h_1 \]
\[ y_{s\,pc} \text{ from } V_2, y_2, h_2 \text{ (or } V_f, y_f) \]
\[ y_{s\,pg} \text{ from } V_3, y_3, h_3 \]
$y_s = y_{s\,\text{pier}} + y_{s\,\text{pc}} + y_{s\,\text{pg}}$
COMPLEX PIER VELOCITY AND DEPTH

\[ y_2 = y_1 + y_{s \text{ pier}} / 2 \]
\[ h_2 = h_0 + y_{s \text{ pier}} / 2 \]

\[ y_3 = y_2 + y_{s \text{ pc}} / 2 \]
\[ h_3 = h_2 + y_{s \text{ pc}} / 2 \]

\[ V_1 y_1 = V_2 y_2 = V_3 y_3 \]
MULTIPLE COLUMNS SKEWED TO THE FLOW

- Use the CSU equation with $K_1 = 1.0$
- Spacing < 5a, use equivalent pier
- Spacing > than 5a, use single column and $K_2 = 1.2$
- Consider debris
MULTIPLE COLUMNS SKEWED TO THE FLOW

MULTIPLE COLUMNS

FLOW

2 m

10 m

10 m

FLOW

6 m

2 m

L/a = 3

EQUIVALENT PIER
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