

SHIFTING SANDS

REVOLUTIONIZING SOIL LIQUEFACTION ASSESSMENT
THROUGH MACHINE LEARNING MODELS

LEARNING TEAM 1

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THE EMPIRICAL METHOD

IDRISS AND BOULANGER (2010)

$$FS = \frac{CRR}{CSR}$$

THE EMPIRICAL METHOD

IDRISS AND BOULANGER (2010)

$$CSR = 0.65 \frac{\sigma_v}{\sigma_v'} \frac{a_{max}}{g} r_d$$

$$C_\sigma = \frac{1}{18.9 - 2.55 \sqrt{(N_1)_{60cs}}} \leq 0.3$$

$$r_d = e^{[\alpha(z) + \beta(z)M]}$$

$$FS = \frac{CRR}{CSR}$$

$$K_\sigma = 1 - C_\sigma \ln \left(\frac{\sigma_v'}{P_a} \right) \leq 1.1$$

$$\alpha(z) = -1.012 - 1.126 \sin \left(\frac{z}{11.73} + 5.133 \right)$$

$$N_{1-60cs} = N_{1-60} + e^{\left(1.63 + \frac{9.7}{FC+0.01} - \frac{15.7}{FC+0.01}^2 \right)}$$

$$\beta(z) = 0.106 + 0.118 \sin \left(\frac{z}{11.28} + 5.142 \right)$$

$$CRR = e^{\left(\frac{N_{1-60cs}}{14.1} + \frac{N_{1-60cs}}{126}^2 - \frac{N_{1-60cs}}{23.6}^3 + \frac{N_{1-60cs}}{25.4}^4 - 2.8 \right)}$$

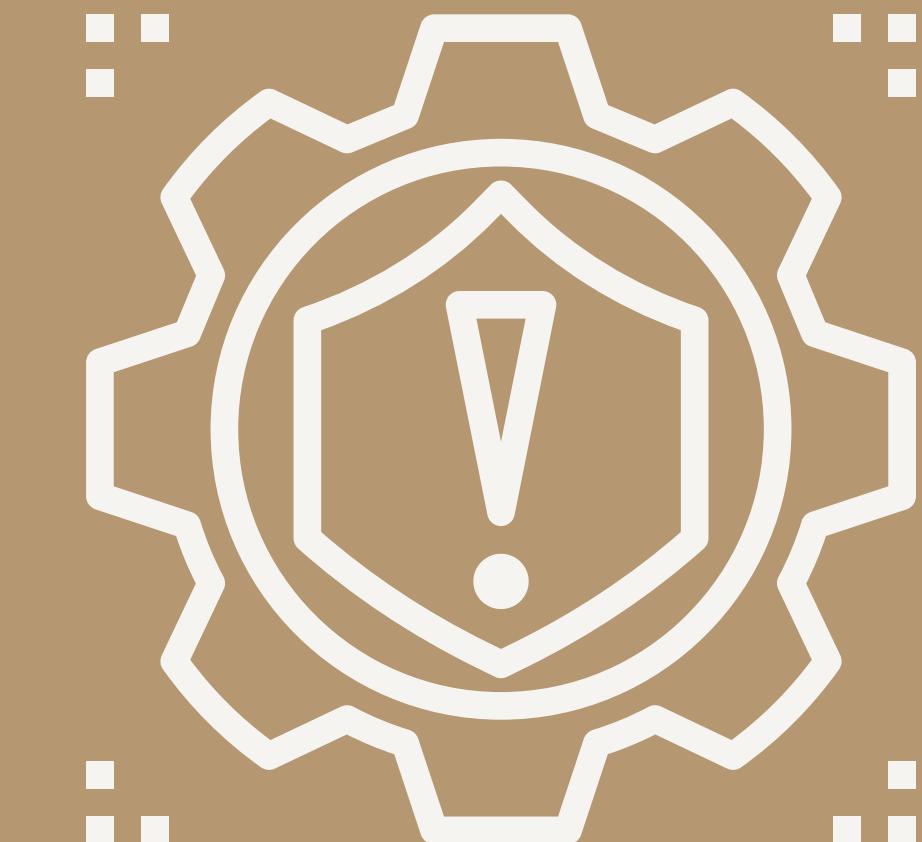
$$MSF = 6.9e^{\frac{-M}{4}} - 0.058 \leq 1.8$$

OBJECTIVE

MACHINE LEARNING MODEL



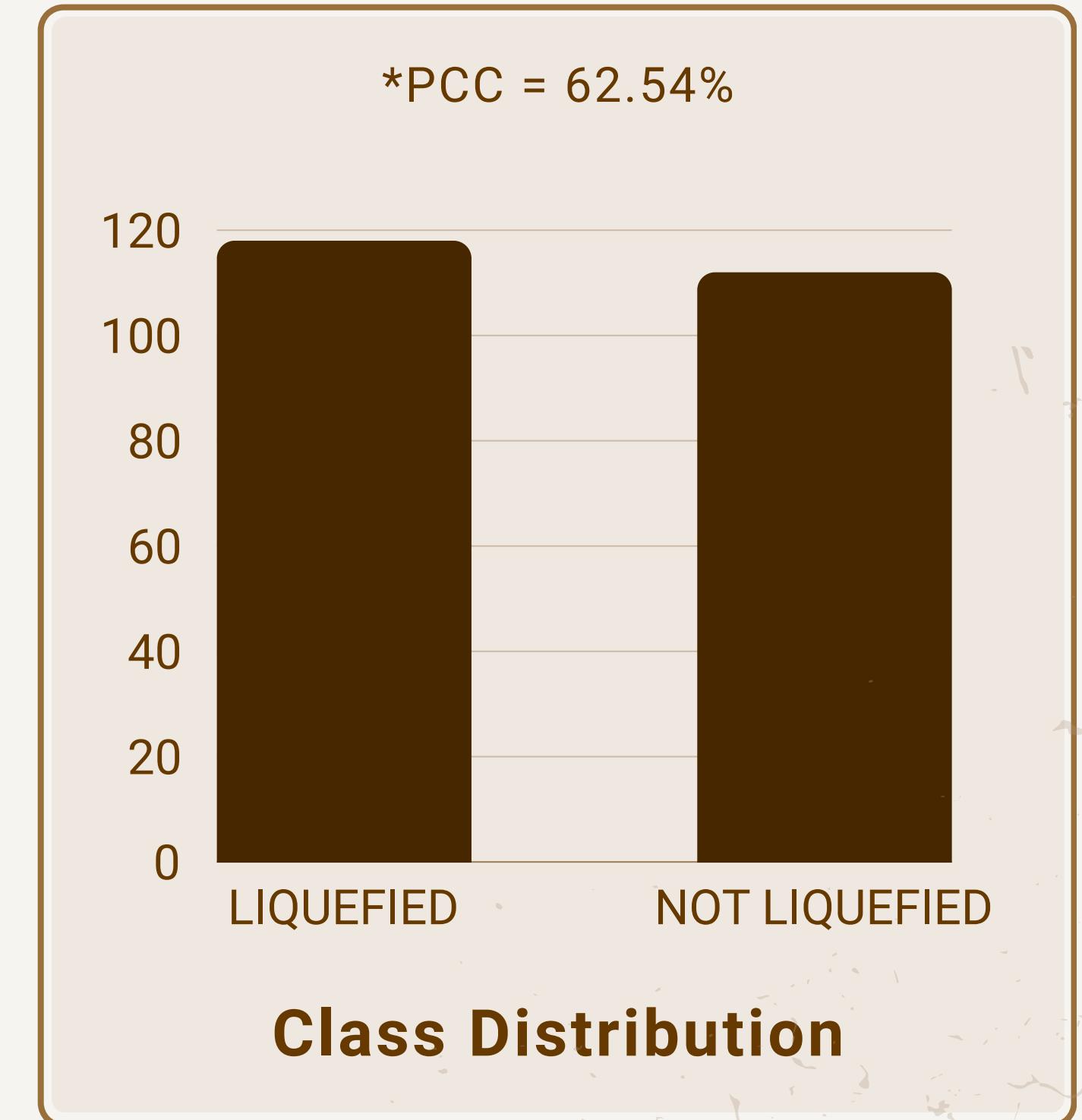
PREDICT



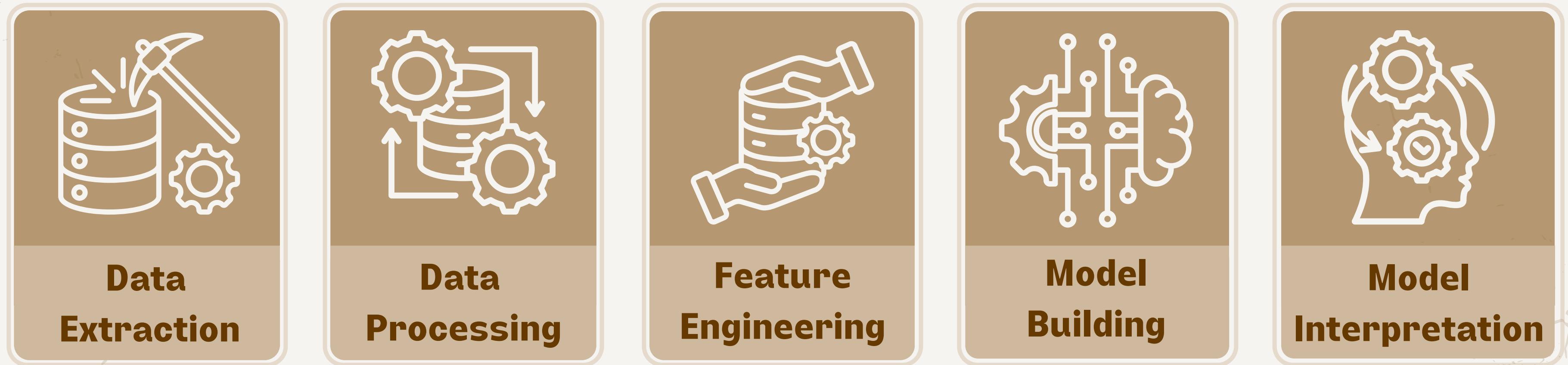
MITIGATE

DATASET

- 254 Data Points (Case Histories)
- Identified Critical Layers
- Features:
 - Magnitude
 - Peak Ground Acceleration
 - Average Depth
 - Ground Water Depth
 - Porewater Pressure
 - SPT N-Value (N_{1-60})
 - %Fines Content
 - Total Vertical Stress
 - Effective Vertical Stress
 - K_σ
 - Magnitude Scaling Factor
 - Cyclic Stress Ratio
 - Cyclic Resistance Ratio
 - Shear Stress Reduction Factor



METHODOLOGY



KNN, Logistic Regression, SVC, Decision Tree, Random Forest, GBM, XGBoost

MODEL PERFORMANCE

XGBoost Classifier Accuracy

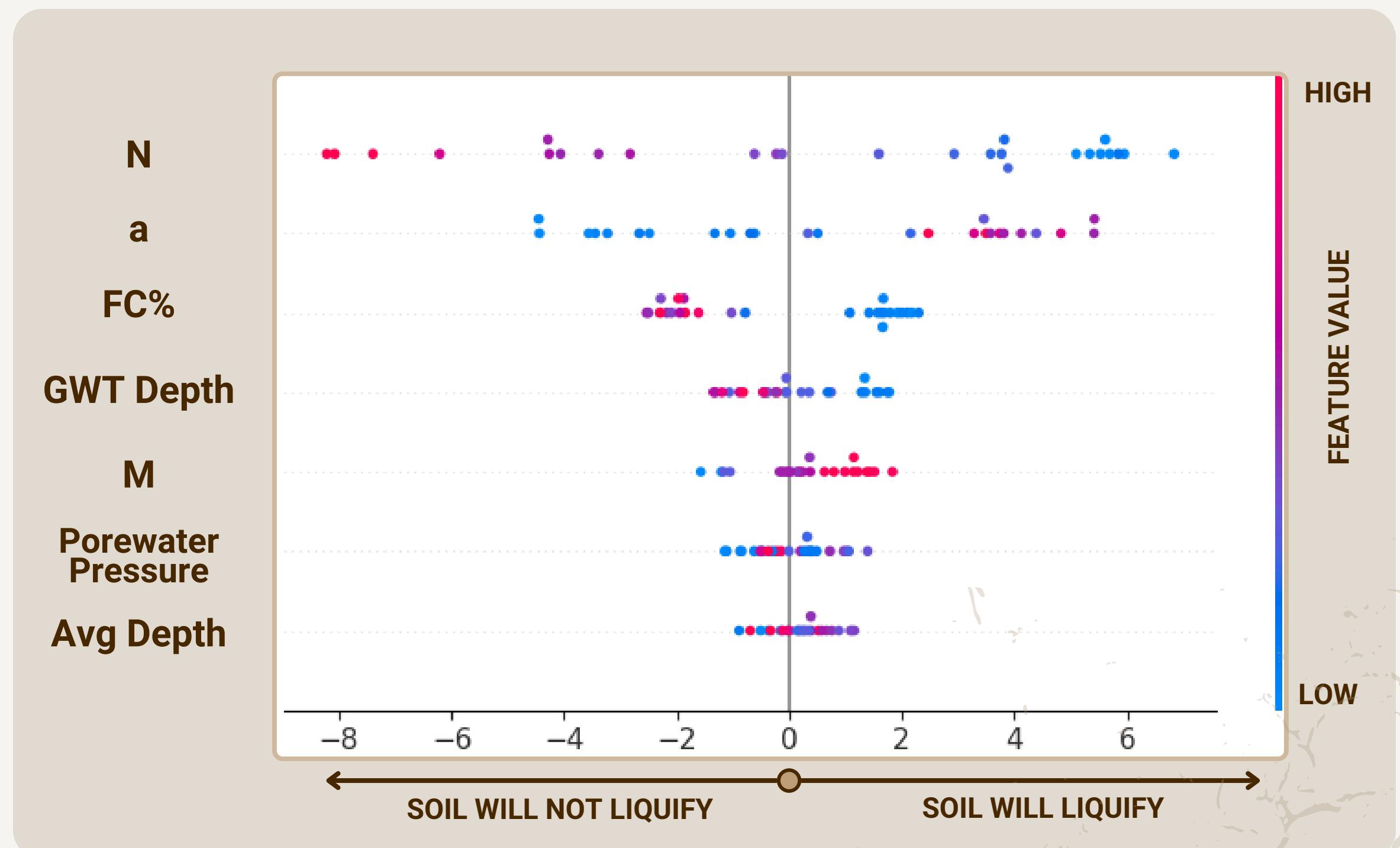
TRAIN **99.95%**

TEST **84.69%**

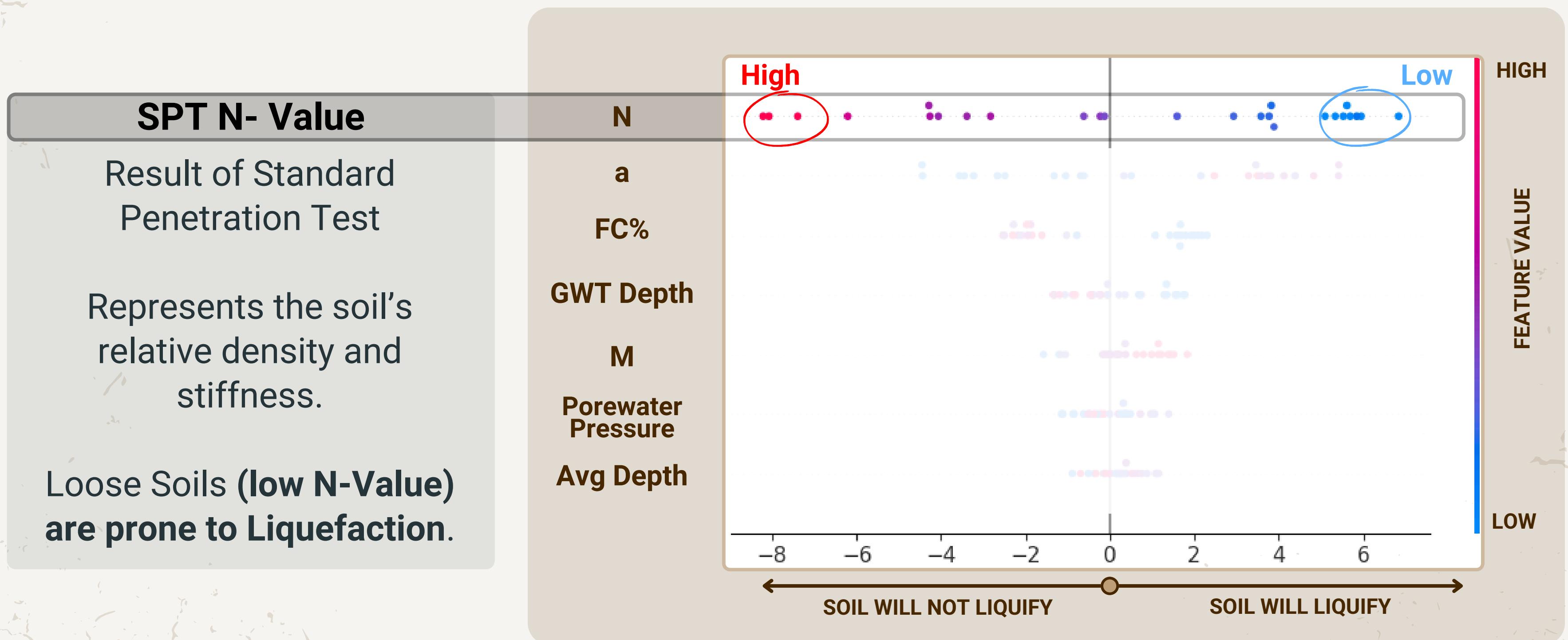
Empirical Method Accuracy

TEST **83.00%**

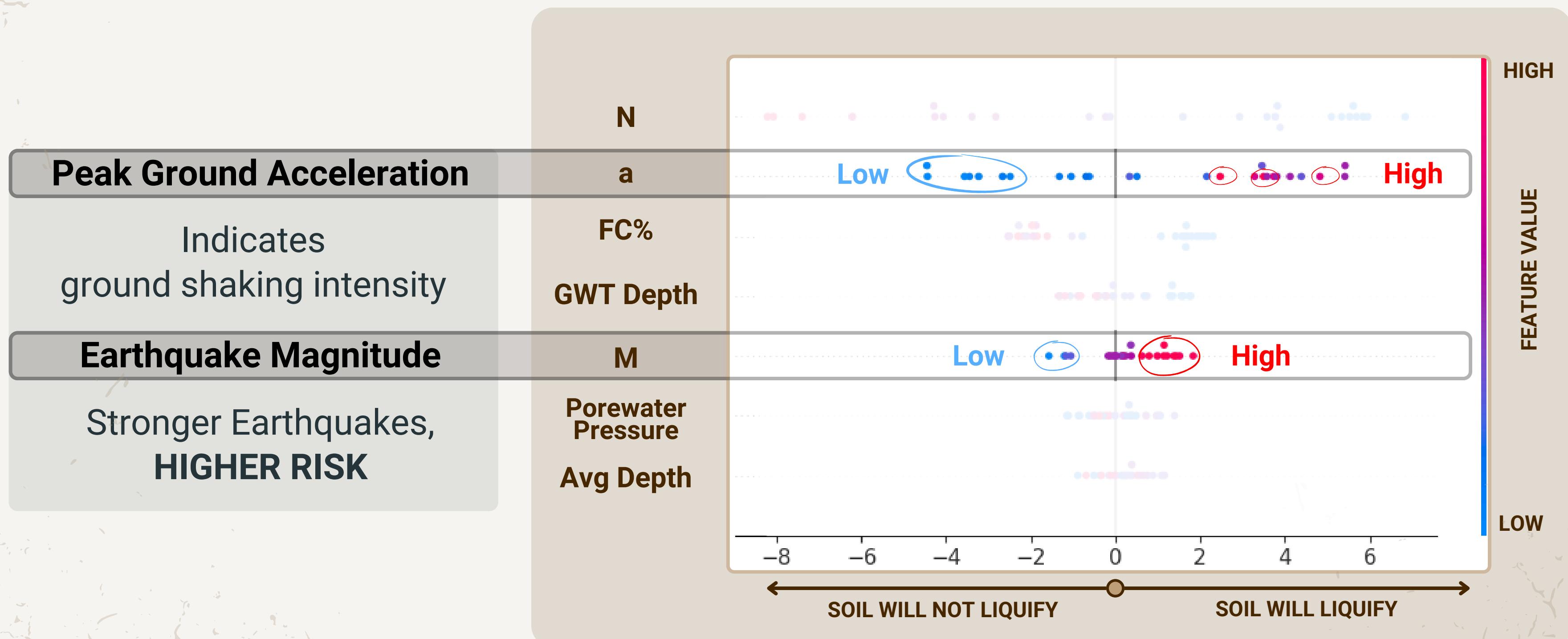
DOES THE MODEL MAKE SENSE?



MODEL INTERPRETATION



MODEL INTERPRETATION



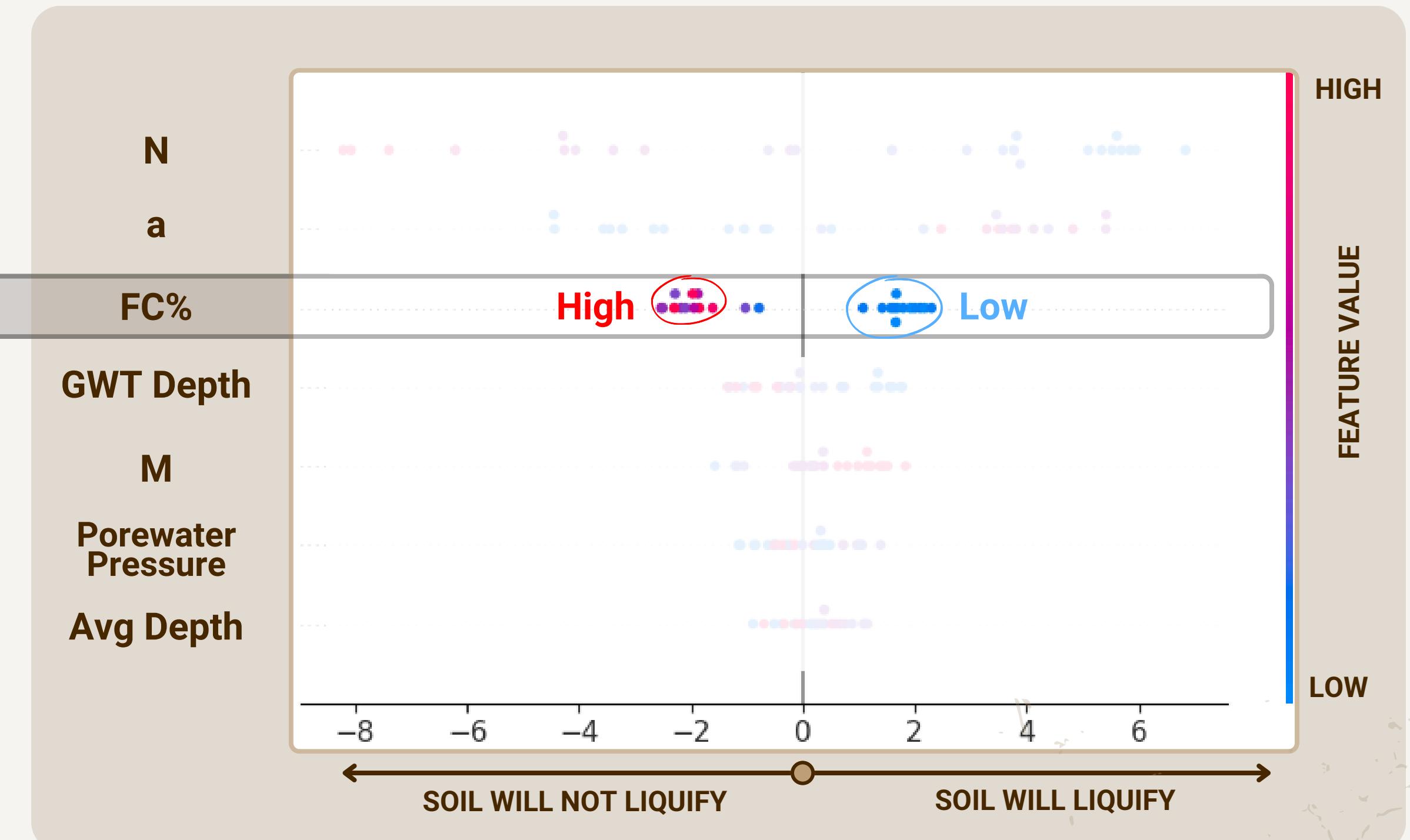
MODEL INTERPRETATION

HIGH FC% - more silt and clay

Percentage of Fines Content

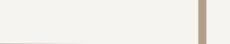
Clay provides **COHESION**.

**COHESION RESISTS
LIQUEFACTION**



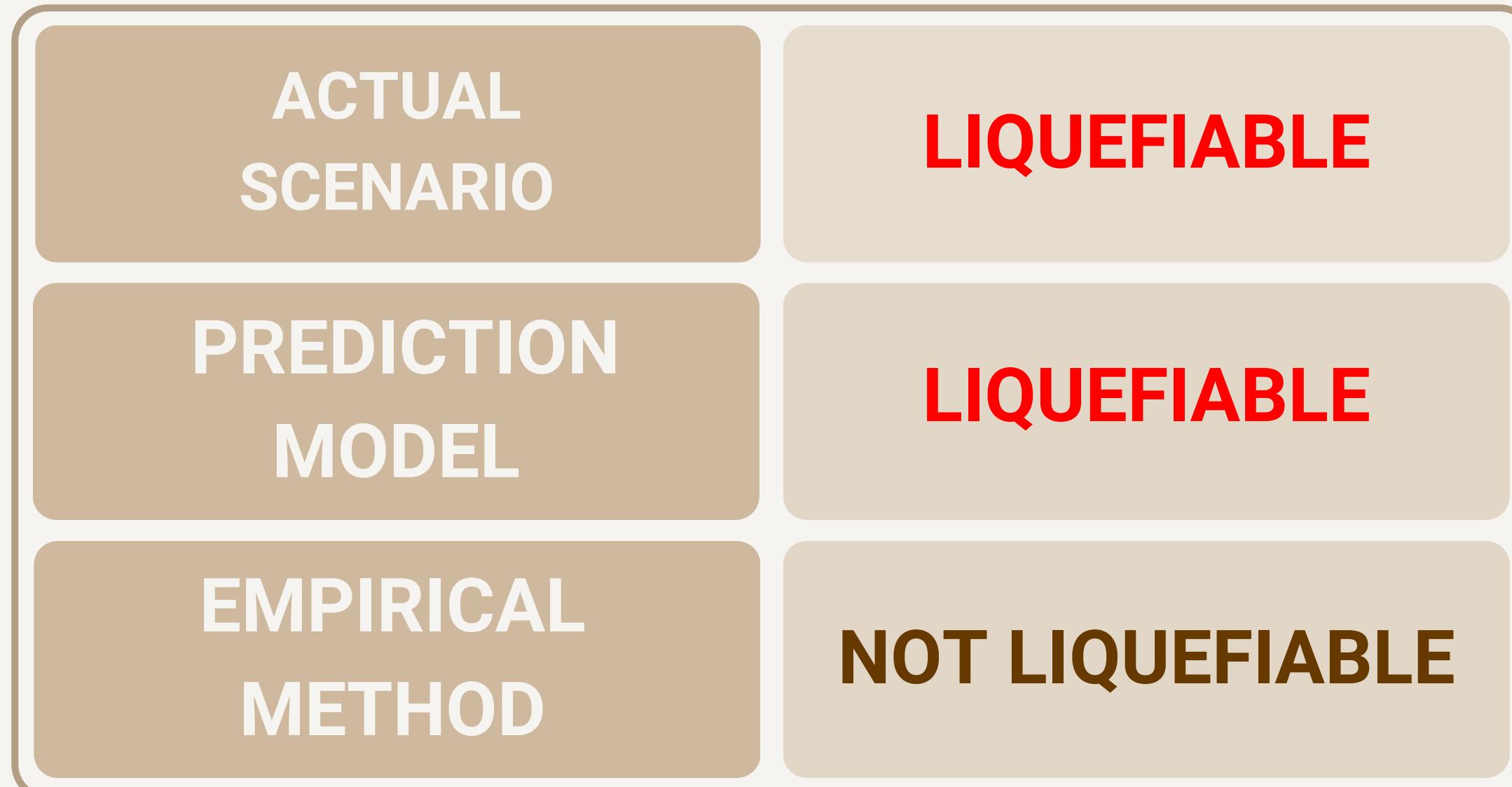
IMPLEMENTATION

IMPLEMENTATION

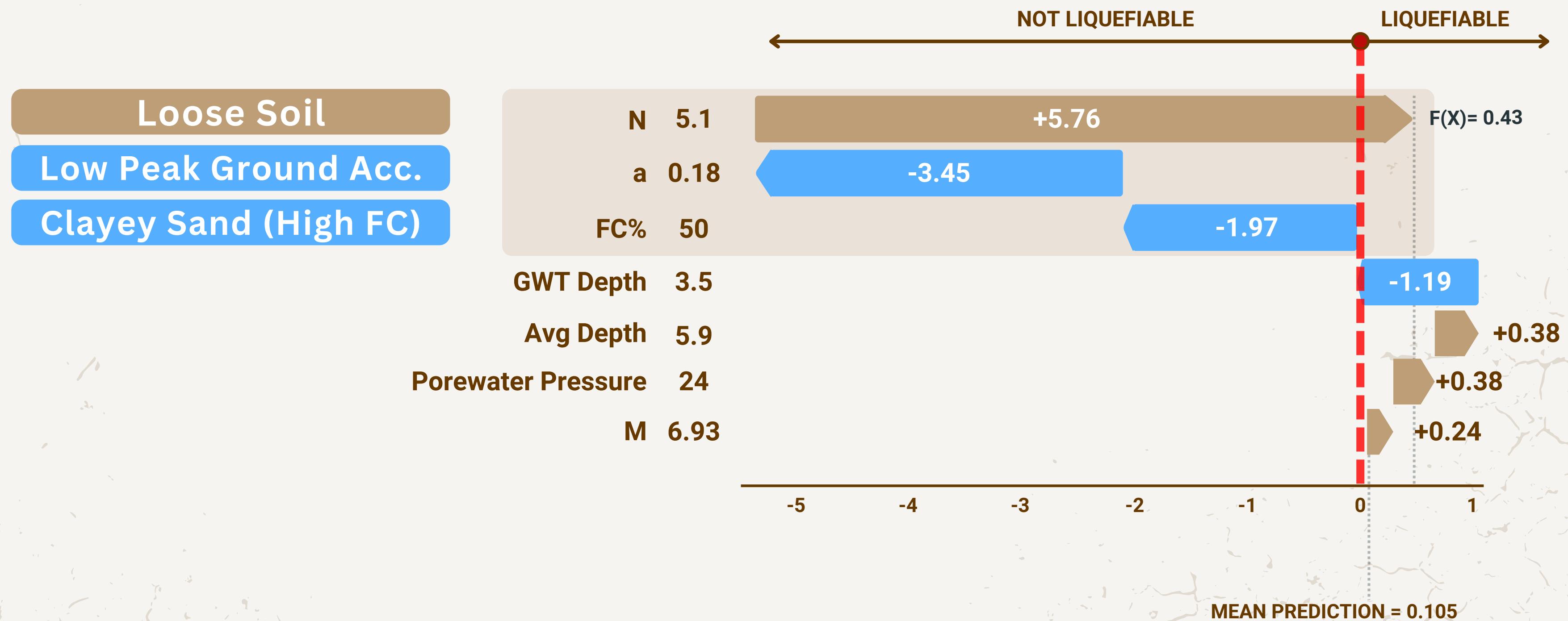
| | | | |
|--------------------|------|---|----------------------------------|
| N | 5.1 |  | <i>stiffness of soil</i> |
| a | 0.18 |  | <i>ground shaking intensity</i> |
| M | 6.93 |  | |
| FC% | 50 |  | <i>presence of silt and clay</i> |
| GWT Depth | 3.5 | | |
| Avg Depth | 5.9 | | |
| Porewater Pressure | 24 | | |

CASE HISTORY

| | |
|-------------|------|
| N | 5.1 |
| a | 0.18 |
| FC% | 50 |
| GWT Depth | 3.5 |
| Avg Depth | 5.9 |
| Stress Diff | 24 |
| M | 6.93 |



PREDICTION EXPLANATION



COUNTERFACTUALS

| | | | |
|--------------------|------|---|-----------------|
| N | 5.1 | → | 13.3 |
| a | 0.18 | → | 0.18 |
| FC% | 50 | → | 50 |
| GWT Depth | 3.5 | → | 3.5 |
| Avg Depth | 5.9 | → | 5.9 |
| Porewater Pressure | 24 | → | 24 |
| M | 6.93 | → | 6.93 |
| LIQUEFIABLE | | → | NOT LIQUEFIABLE |

INCREASE SOIL
STIFFNESS

COUNTERFACTUALS

| | | | |
|--------------------|------|---|-----------------|
| N | 5.1 | → | 13.3 |
| a | 0.18 | → | 0.18 |
| FC% | 50 | → | 50 |
| GWT Depth | 3.5 | → | 3.5 |
| Avg Depth | 5.9 | → | 5.9 |
| Porewater Pressure | 24 | → | 24 |
| M | 6.93 | → | 6.93 |
| LIQUEFIABLE | | → | NOT LIQUEFIABLE |

