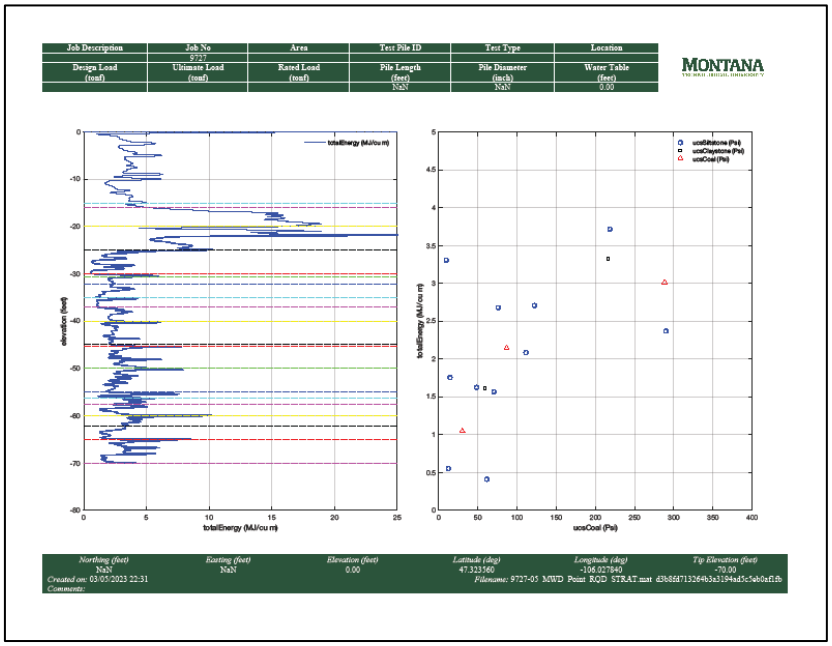
# Organization and Analysis of Measurement While Drilling (MWD) Data

*Presented at Project Annual Meeting*
*September 4, 2024*

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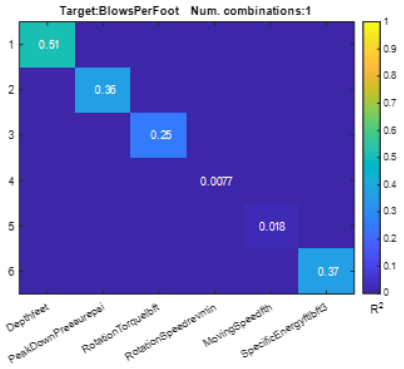
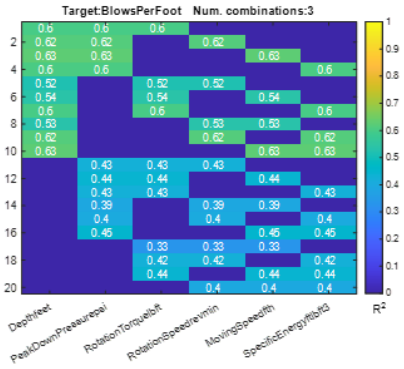
# Phase 1 Summary – Single Parameter/linear correlations

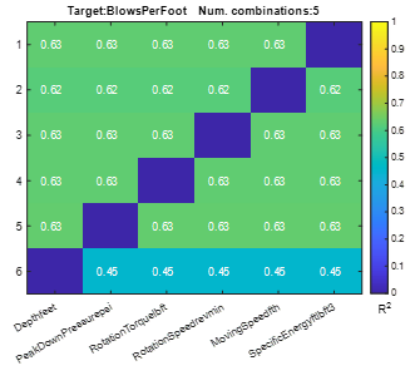
| | SPT N (n = 64) | | UCS (psi) (n = 117) | | Unit weight (pcf) (n = 117) | |
|---|---|---|---|---|---|---|
| **MWD input** | *Linear $R^2$* | *Exponential $R^2$* | *Linear $R^2$* | *Exponential $R^2$* | *Linear $R^2$* | *Exponential $R^2$* |
| *Down pressure* | 0.36 | 0.34 | 0.00 | 0.00 | 0.05 | 0.05 |
| *Rotation torque* | 0.25 | 0.24 | 0.13 | 0.17 | 0.03 | 0.02 |
| *Rotation speed* | 0.01 | 0.01 | 0.10 | 0.11 | 0.01 | 0.01 |
| *Rate of advance* | 0.02 | 0.02 | 0.05 | 0.06 | 0.00 | 0.00 |
| *Specific energy* | 0.37 | 0.34 | 0.08 | 0.09 | 0.12 | 0.11 |

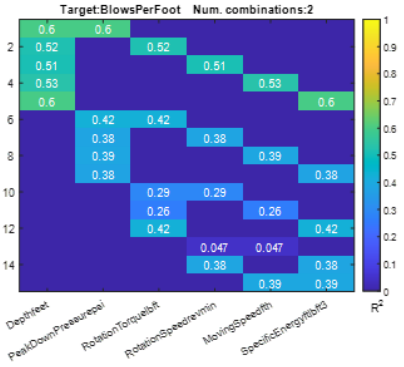
- Low correlation coefficients
- Poor predictive capability

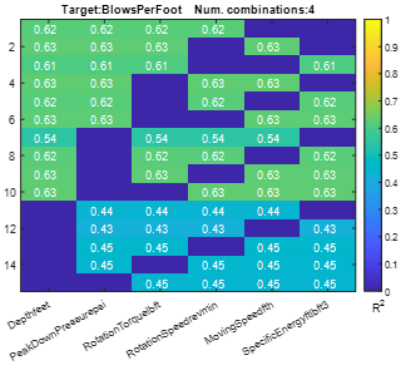
# Phase 2 Summary – Multiple Parameter/linear correlations (MLR): SPT

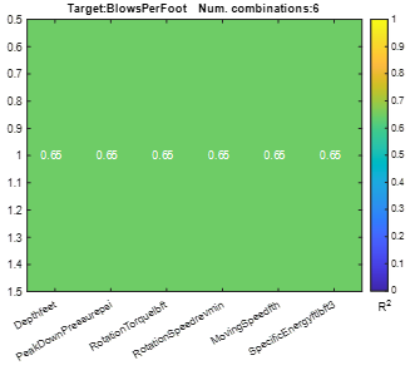


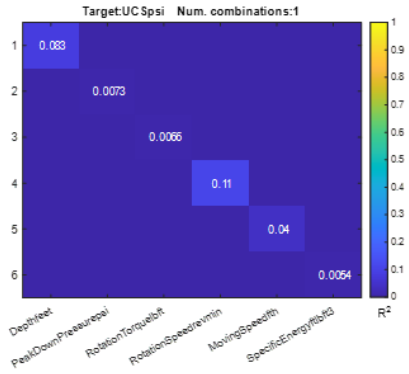



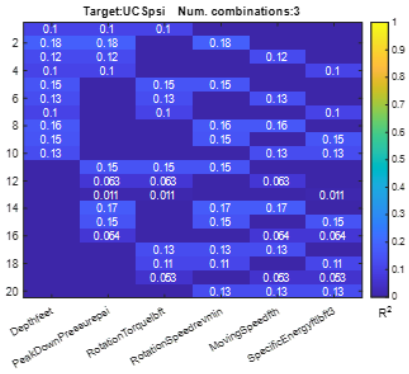



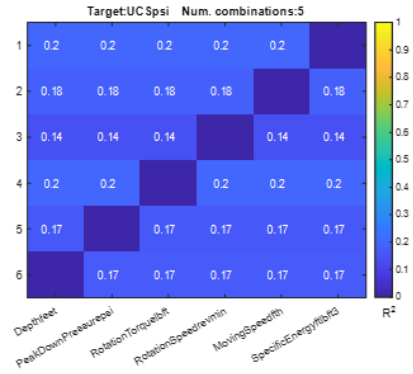



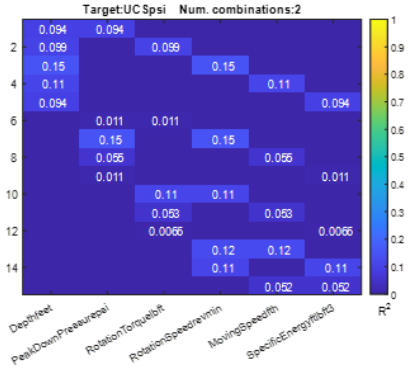

- SPT correlation coefficients significantly improved to approximately 0.6 range (light green)
- Improved predictive capability

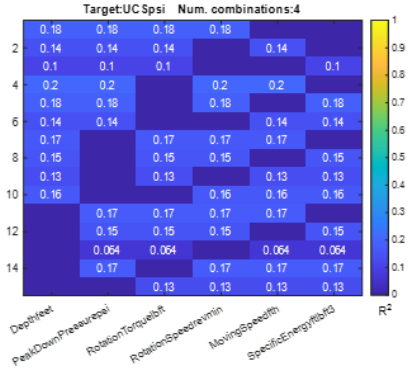
# Phase 2 Summary – Multiple Parameter/linear correlations (MLR): UCS

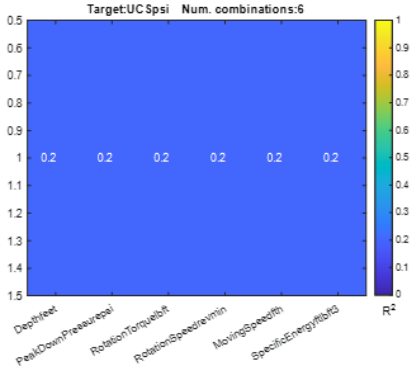


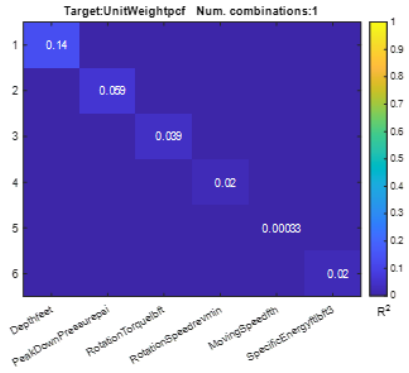



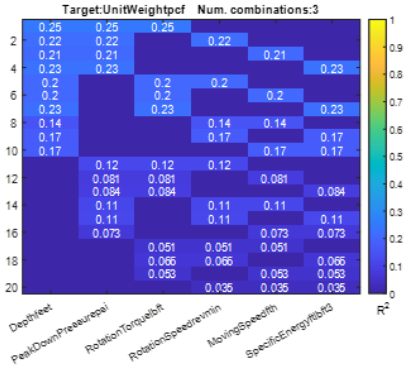



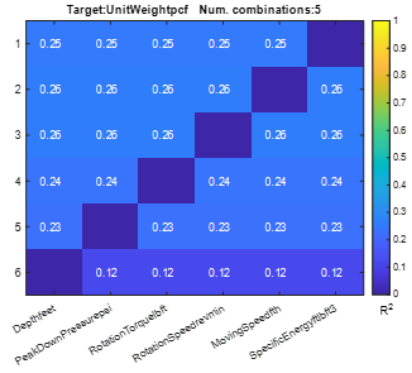



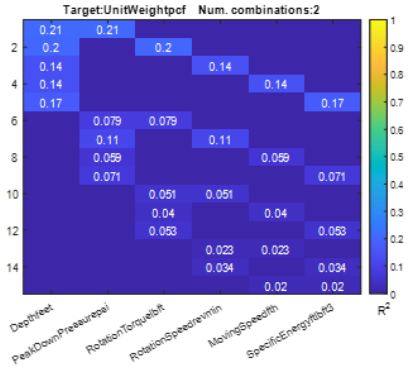

- UCS correlation coefficients slightly improved to approximately 0.2 range (light blue)
- Little improvement in predictive capability

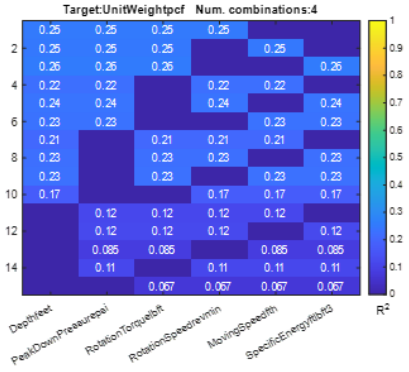
# Phase 2 Summary – Multiple Parameter/linear correlations (MLR): Unit Weight

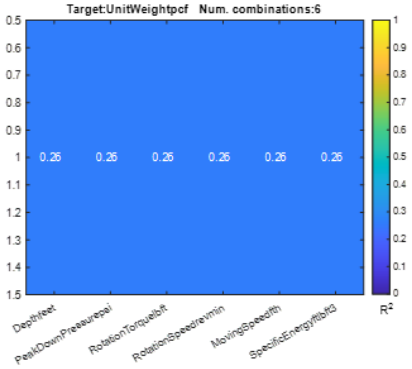



- Unit weight correlation coefficients slightly improved to approximately 0.25 range (light blue)
- Not much improvement in predictive capability

# Phase 3 Summary – Multiple Parameter/nonlinear correlations (NN)

4 inputs:

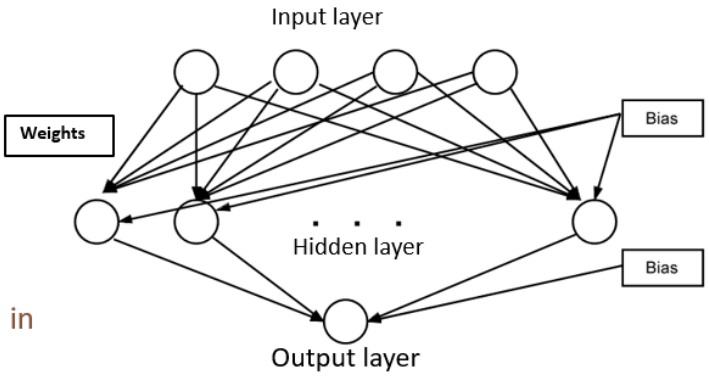
- Peak down pressure (psi)
- Rotation torque (lb-ft)
- Rotation speed (rev/min)
- Moving speed (ft/h)

1 hidden layer:

- Vary number of neurons in hidden layer:
  - 2 3 5 7 9 10 11 15 20 25 30

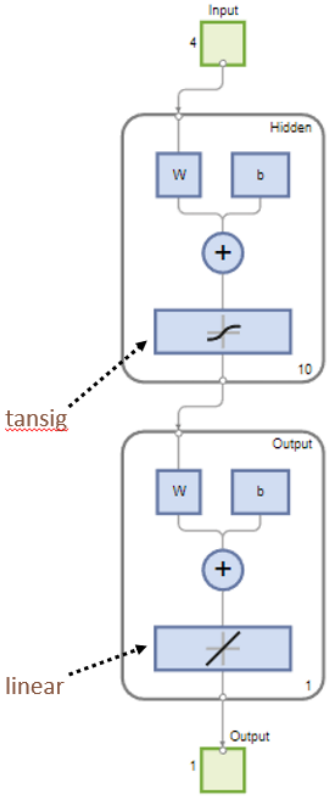
1 output layer:

- Single neuron




Stochastic/iterative process:

- Each NN model initializes with random weights and biases
- Each NN model uses a random partitioning of data inputs into training, validation and testing subsets



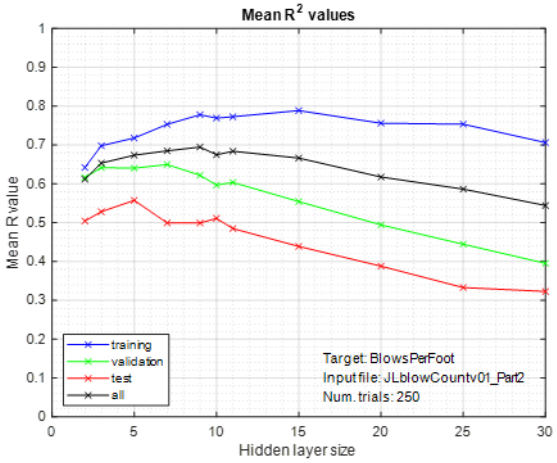
# Phase 3 Summary – Multiple Parameter/nonlinear correlations (NN): SPT

- Training subset – 70%
- Validation subset – 15%
- Testing subset – 15%
- All – 100%

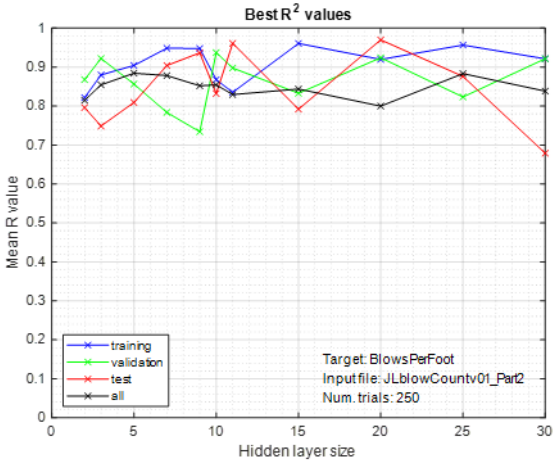
- Training inputs:
  - PeakDownPressurepsi
  - RotationTorquelbft
  - RotationSpeedrevmin
  - MovingSpeedfth

- Training target:
  - BlowsPerFoot
  - Number of blow count values = 64

Mean $R^2$ regression results over 250 trials




Best $R^2$ regression results over 250 trials



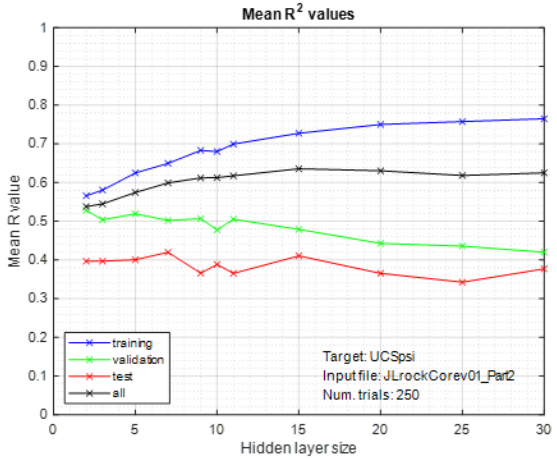
# Phase 3 Summary – Multiple Parameter/nonlinear correlations (NN): UCS

- Training subset – 70%
- Validation subset – 15%
- Testing subset – 15%
- All – 100%

- Training inputs:
  - PeakDownPressurepsi
  - RotationTorquelbft
  - RotationSpeedrevmin
  - MovingSpeedfth

- Training target:
  - UCSpsi
  - Number of UCS values = 117

Mean $R^2$ regression results over 250 trials




Best $R^2$ regression results over 250 trials

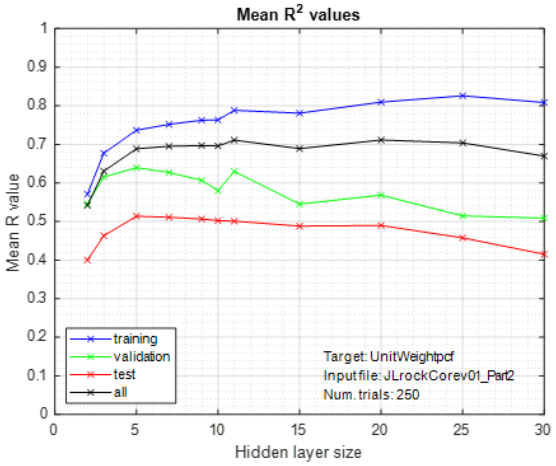
# Phase 3 Summary – Multiple Parameter/nonlinear correlations (NN): Unit Weight

- Training subset – 70%
- Validation subset – 15%
- Testing subset – 15%
- All – 100%

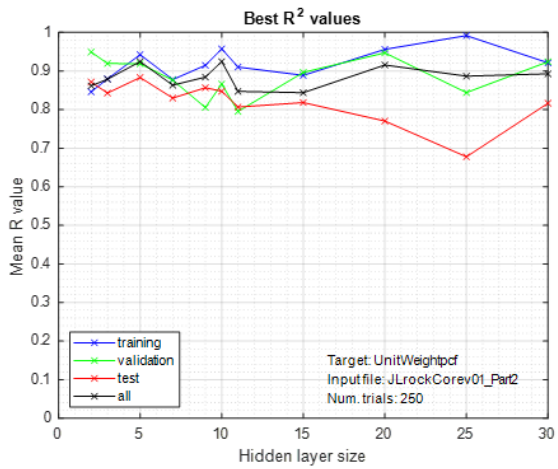
- Training inputs:
  - PeakDownPressurepsi
  - RotationTorquelbft
  - RotationSpeedrevmin
  - MovingSpeedfth

- Training target:
  - Unitweightpcf
  - Number of unit weight values = 117

Mean $R^2$ regression results over 250 trials




Best $R^2$ regression results over 250 trials



# Conclusions and Takeaways

- Problem appears to be nonlinear; at least for Montana IGMs
- Single and multiple parameter linear correlations give poor results
- Using a compound parameter (a function of 4 individual MWD parameters i.e. specific energy), gives slightly better linear correlations
- For MLR correlations, depth is an important predictive parameter
- A nonlinear approach (ANN) using 4 and 5 individual parameters as inputs gives much improved prediction capability
- Ranked best predictive results:
  1. SPT blow counts
  2. Unit weight
  3. UCS