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# Predictive Models to identify High-Pressure, High-Temperature Zones in the Gulf of Mexico

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# PROJECT SPONSOR

The study was conducted under a contract funded by The Bureau of Safety and Environmental Enforcement (BSEE) of the U.S. Department of Interior (DoI)

# PURPOSE OF THE STUDY

- Develop predictive models to estimate bottom hole pressures (BHP)in the GOM at water depths:
  - <1,000 ft - Shallow water
  - ≥1,000 ft - Deep water
- Develop predictive models to estimate bottom hole temperatures (BHT) in the GOM at water depths :
  - 0 – 500 ft
  - 500 – 1,000 ft
  - 1,000 – 2,000 ft
  - 2,000 – 3,000 ft
  - 3,000 – 4,000 ft
  - ≥ 4,000 ft

# WHY MODELS FOR DIFFERENT WATER DEPTHS

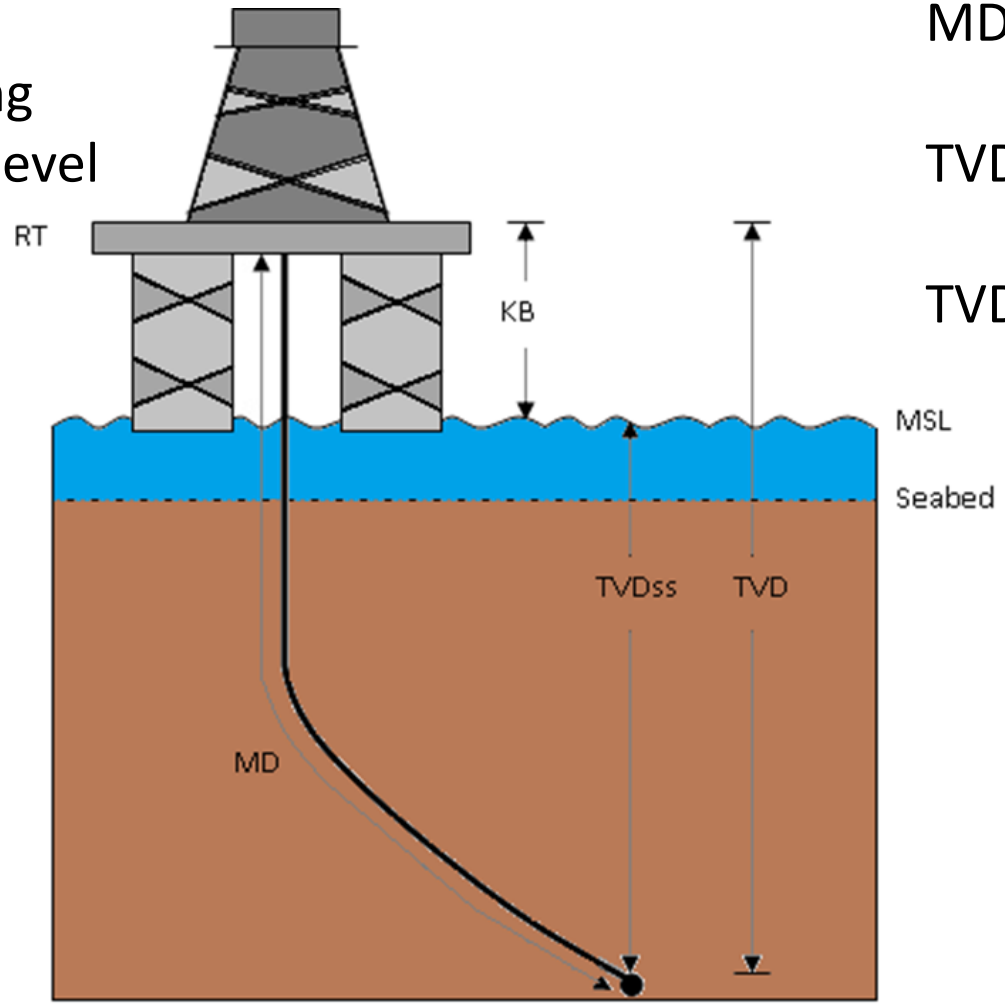
- Pressure increases with water depth at a rate similar to formation depth (0.44 psi/ft and 0.46 psi/ft, respectively) but they are not the same. Therefore, 2 water depths were selected for predicting bottom hole pressures.
- Temperature decreases with water depth, but it increases with formation depth – an inverse relationship. Therefore, several bands of water depths were selected for predicting bottom hole temperatures.

# DEFINITIONS

- High Pressure: Pressure rating >15,000 psig.
- High Temperature: Temperature rating >350F$^{o}$.
- BSEE defines deep water as water depth ≥1,000 ft.
- $R^2$: Statistical measure of how close the actual data is to the regression line.

# DEFINITIONS

RT – Rotary Table
KB – Kelly Brushing
MSL – Mean-sea level




MD – Measured depth
TVD – True vertical depth
TVDss – True vertical depth subsea

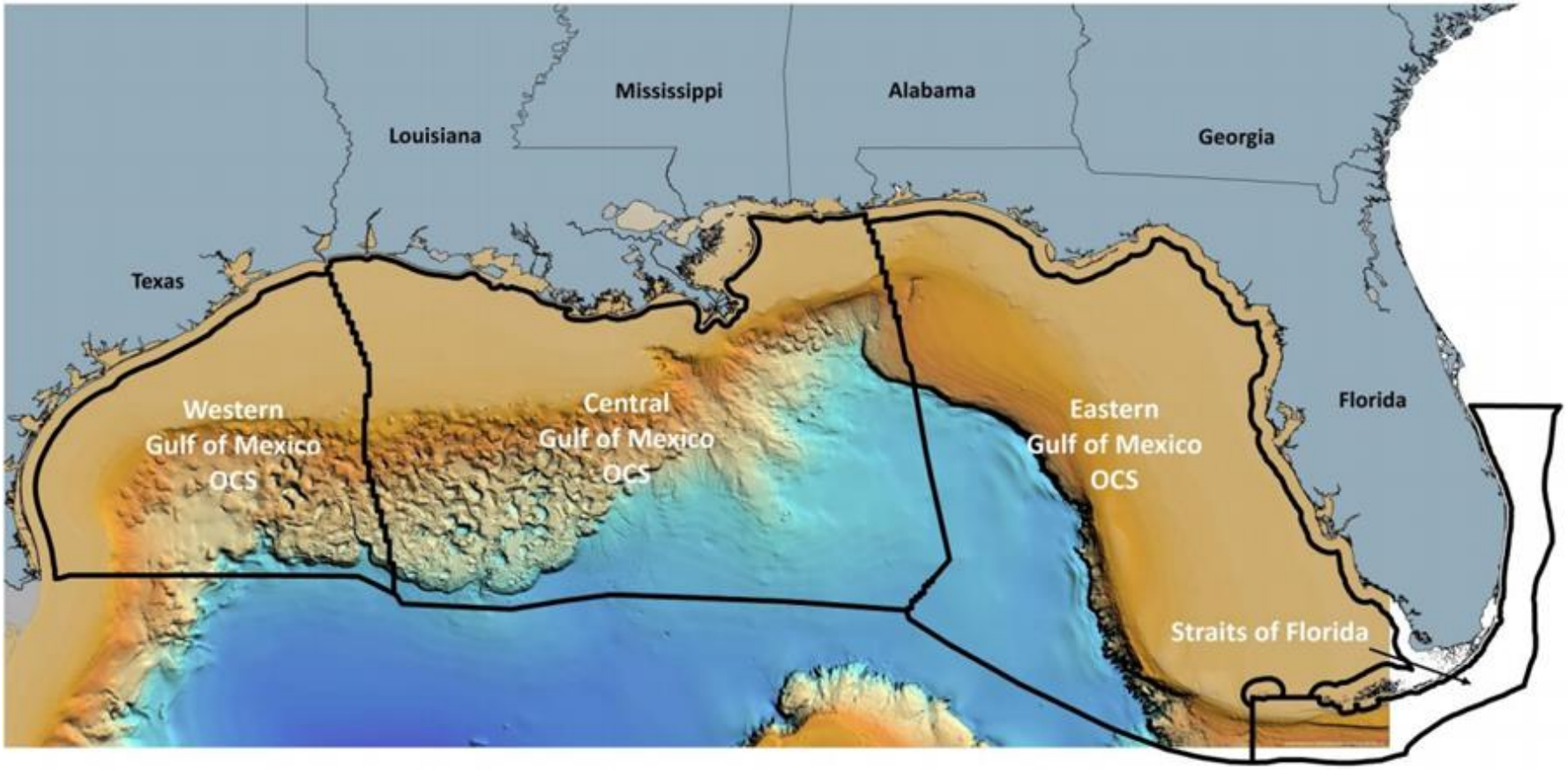
# WHY PREDICT HPHT?

- HPHT zones are becoming common due to deep drilling.
- HPHT information necessary for well planning, casing design, mud program, well control, and health and safety.
- HPHT data can assist in determining reservoir connectivity, fluid contacts, and lateral and vertical seals.

# DATA SOURCE

- Data provided by BSEE for Outer Continental Shelf
- Data consisted of:
  - Old data set (2000 – 2006) and
  - New data set (2006 – 2016)

# DATA COVERAGE




**Gulf of Mexico Outer Continental Shelf**

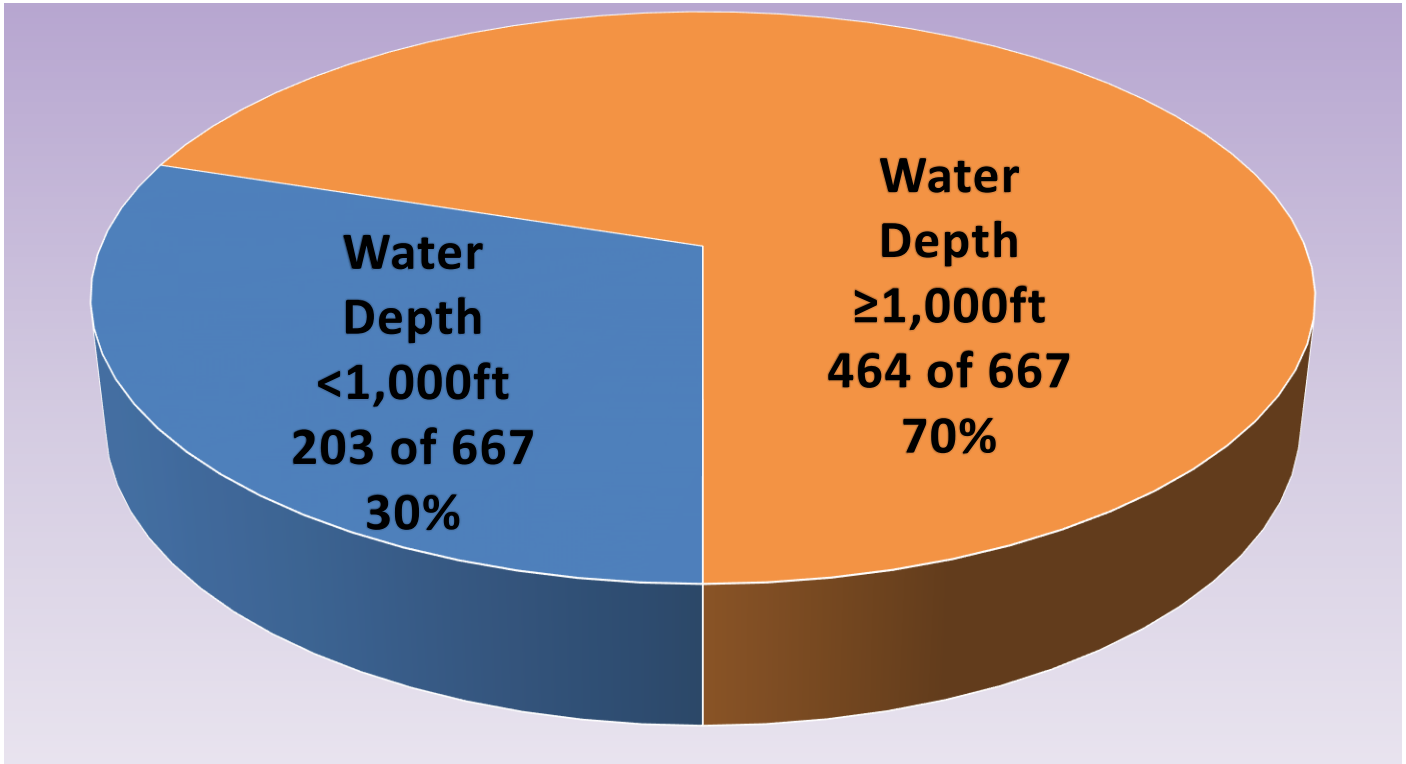
# PRESSURE AND TEMPERATURE DATA

BHP calculated from mud weight data: BHP = 0.052 x TVDss x Mud Weight (lbs/gal)

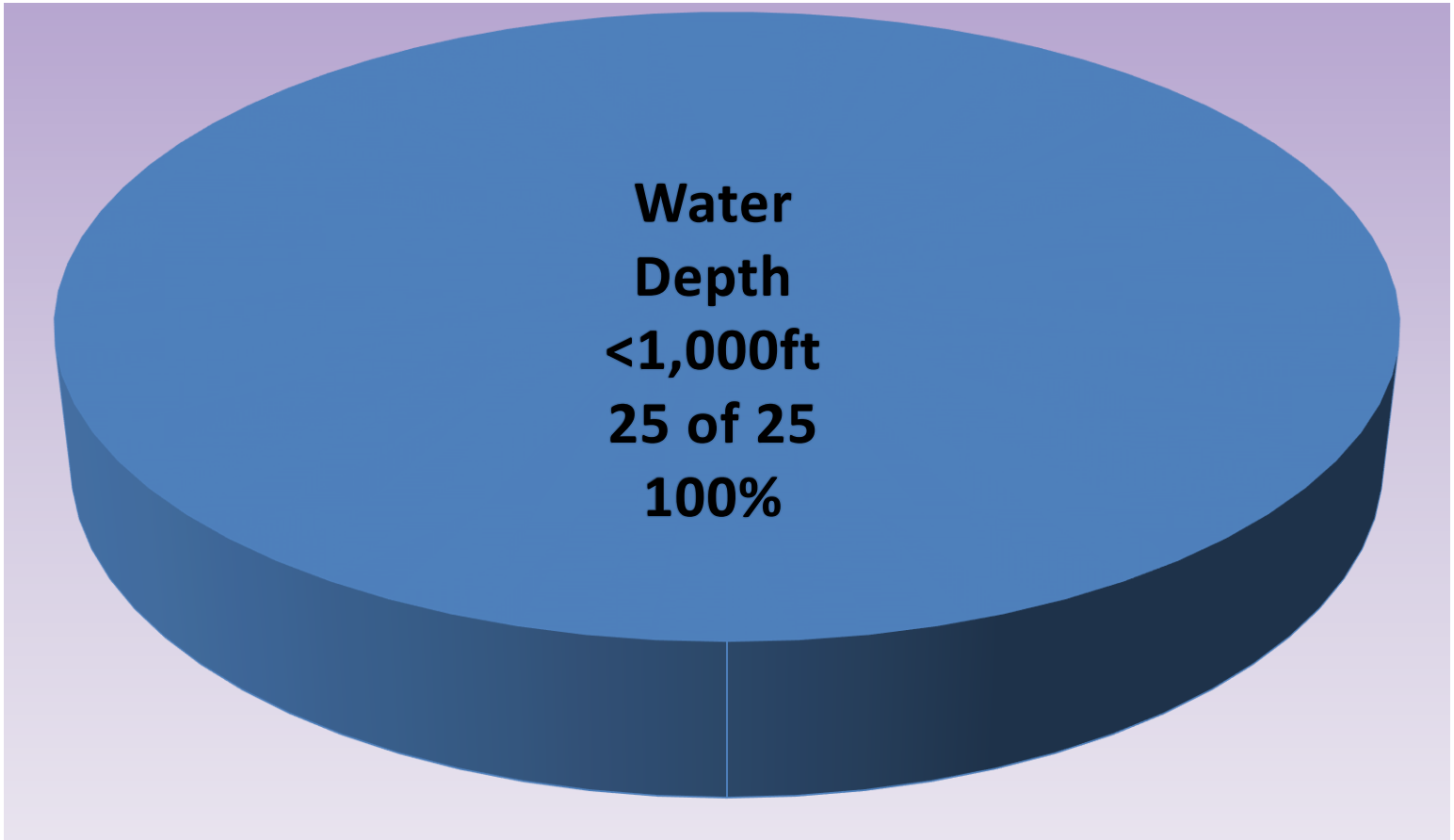
BHT = Measured at the bottom hole

| | Water Depth <1000 ft | Water Depth ≥1000 ft |
|---|---|---|
| **BHP** | 3,818 | 1,457 |
| **BHT ≥100°F** | 2,040 | 857 |

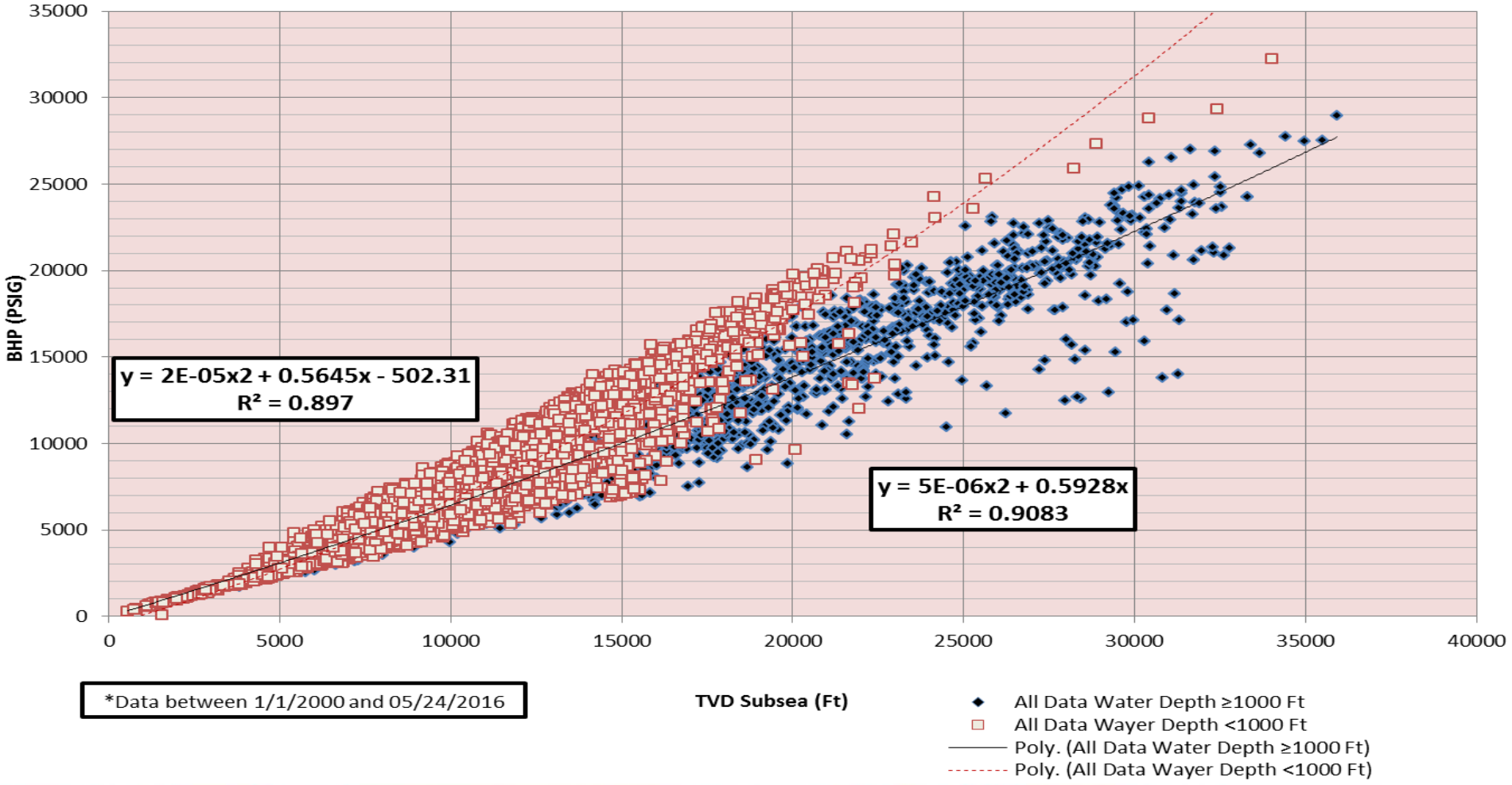
# HIGH PRESSURE DATA COUNT



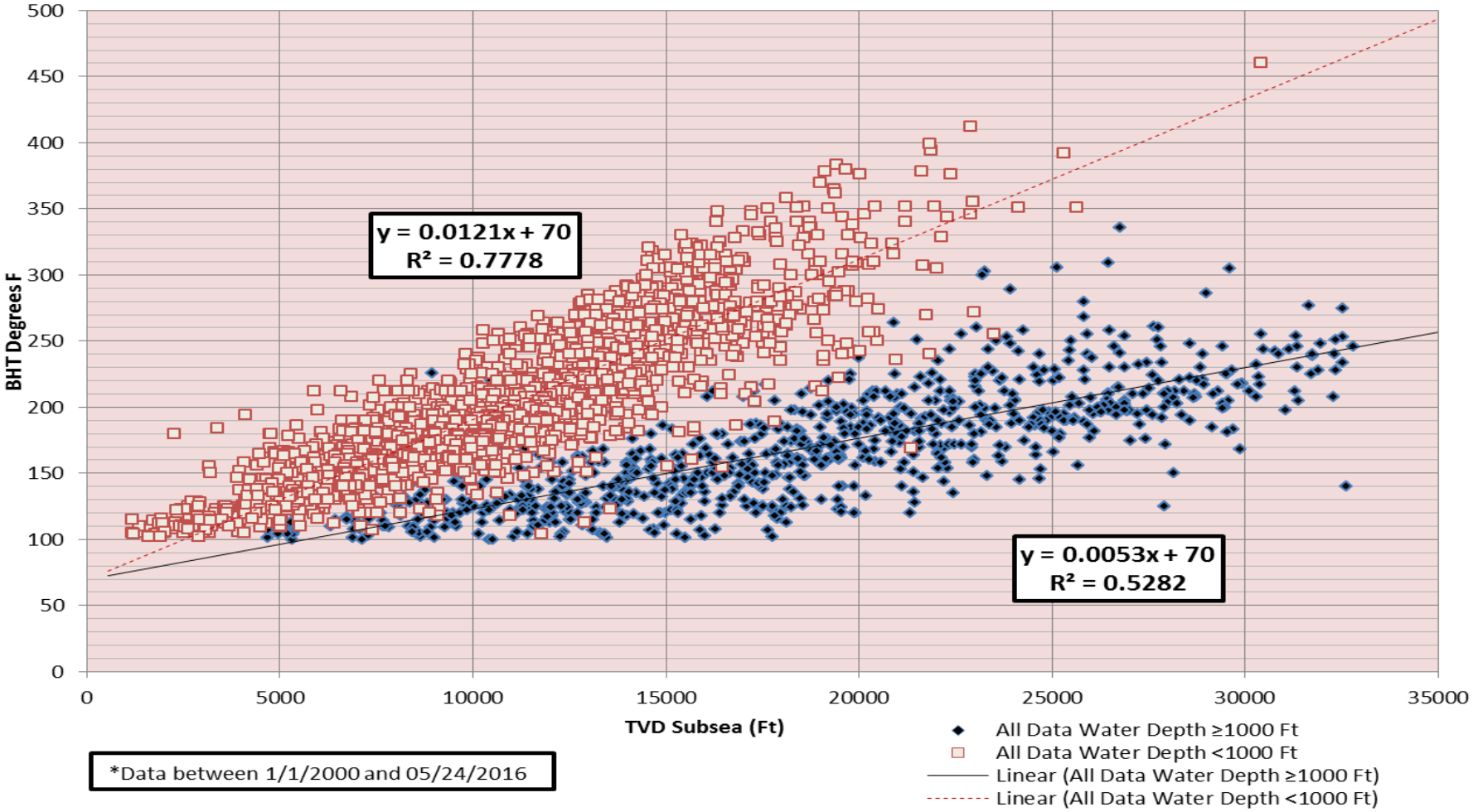
# HIGH TEMPERATURE DATA COUNT



# BHP vs TVDss (Water Depths ≥1000 ft and <1000 ft)

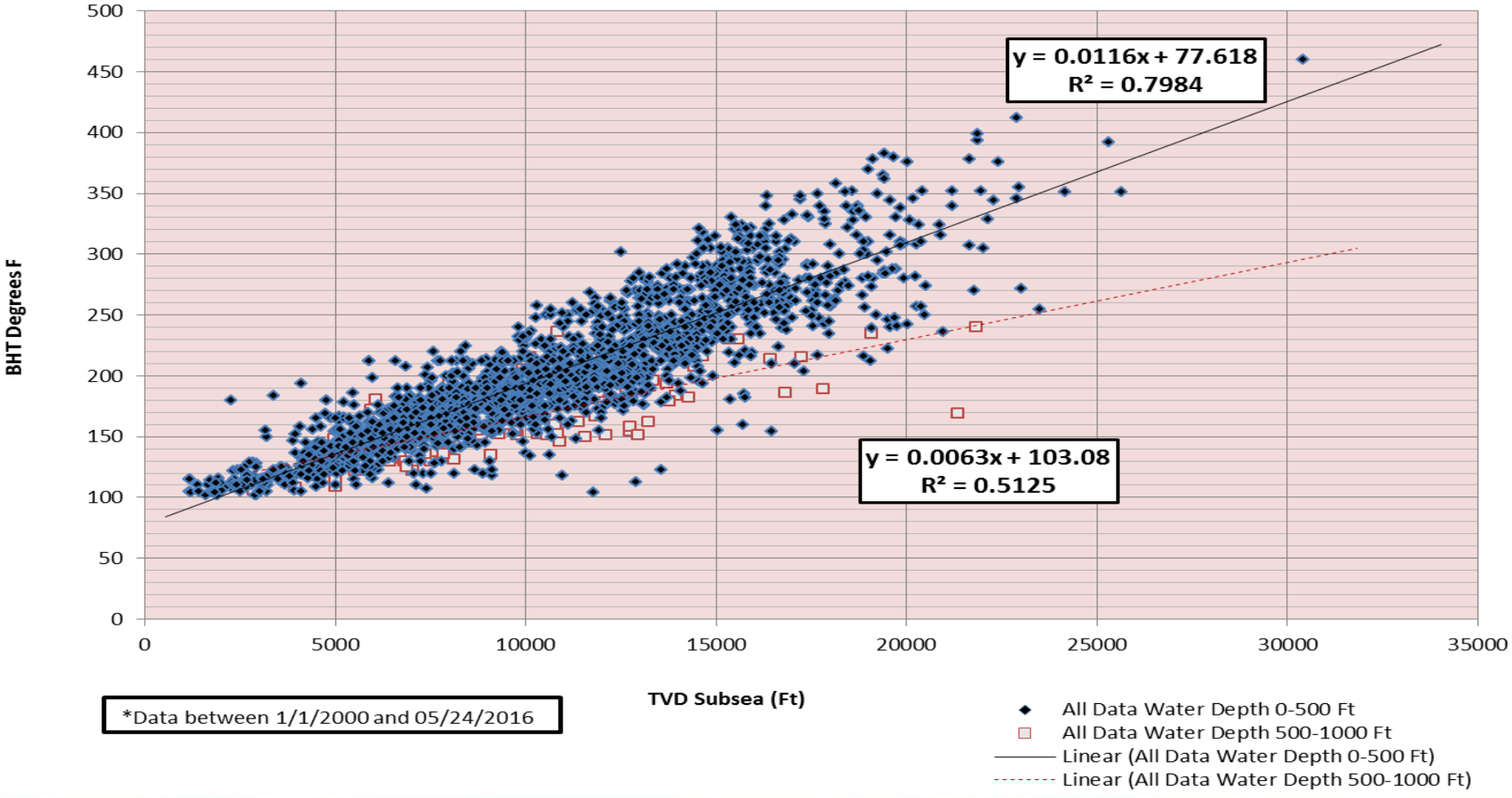


# BHT vs TVDss (Water Depths ≥1000 ft and <1000 ft)



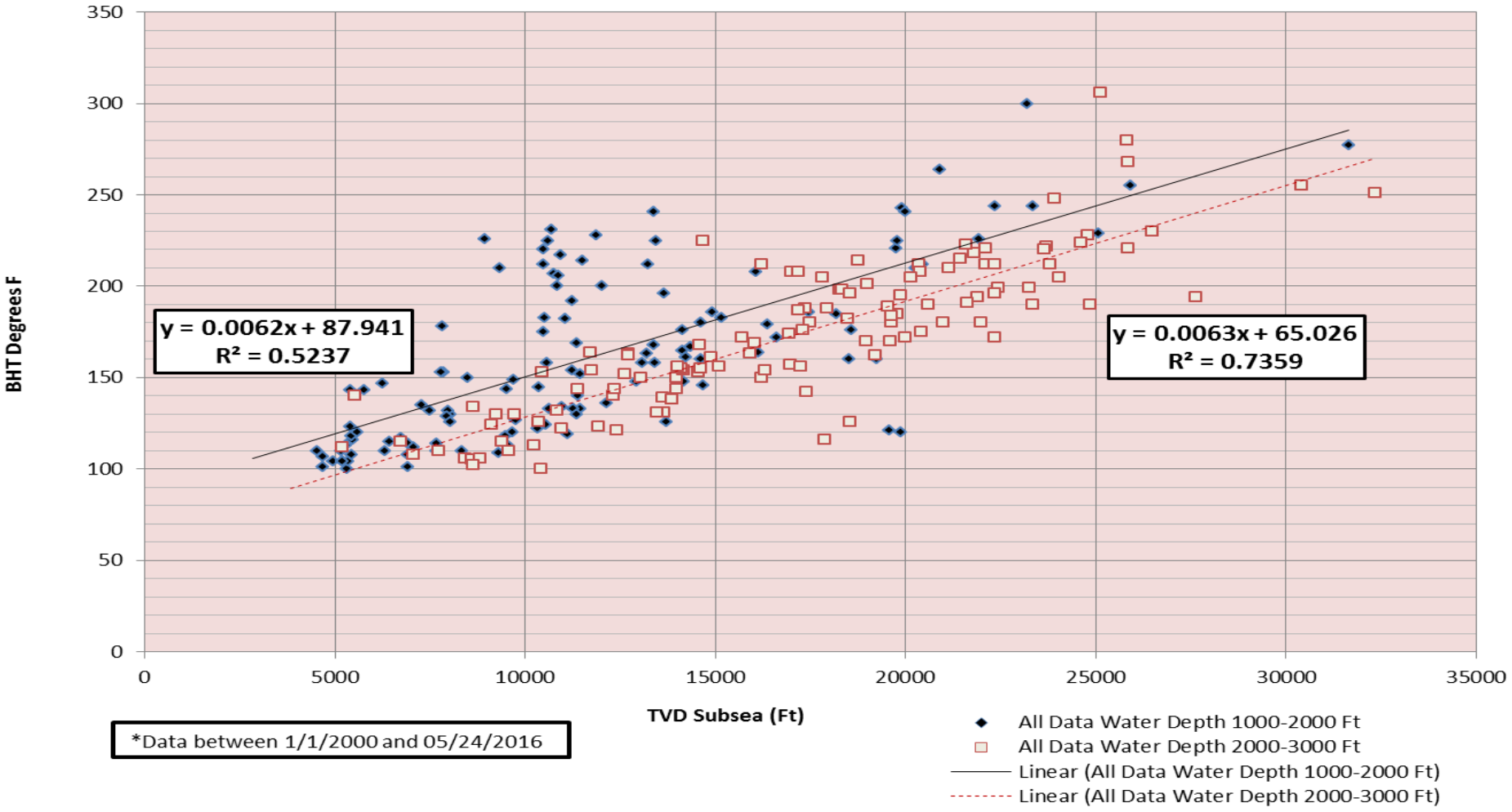

*Data between 1/1/2000 and 05/24/2016

# BHT vs TVDss (Water Depths 0-500 ft and 500-1000 ft)

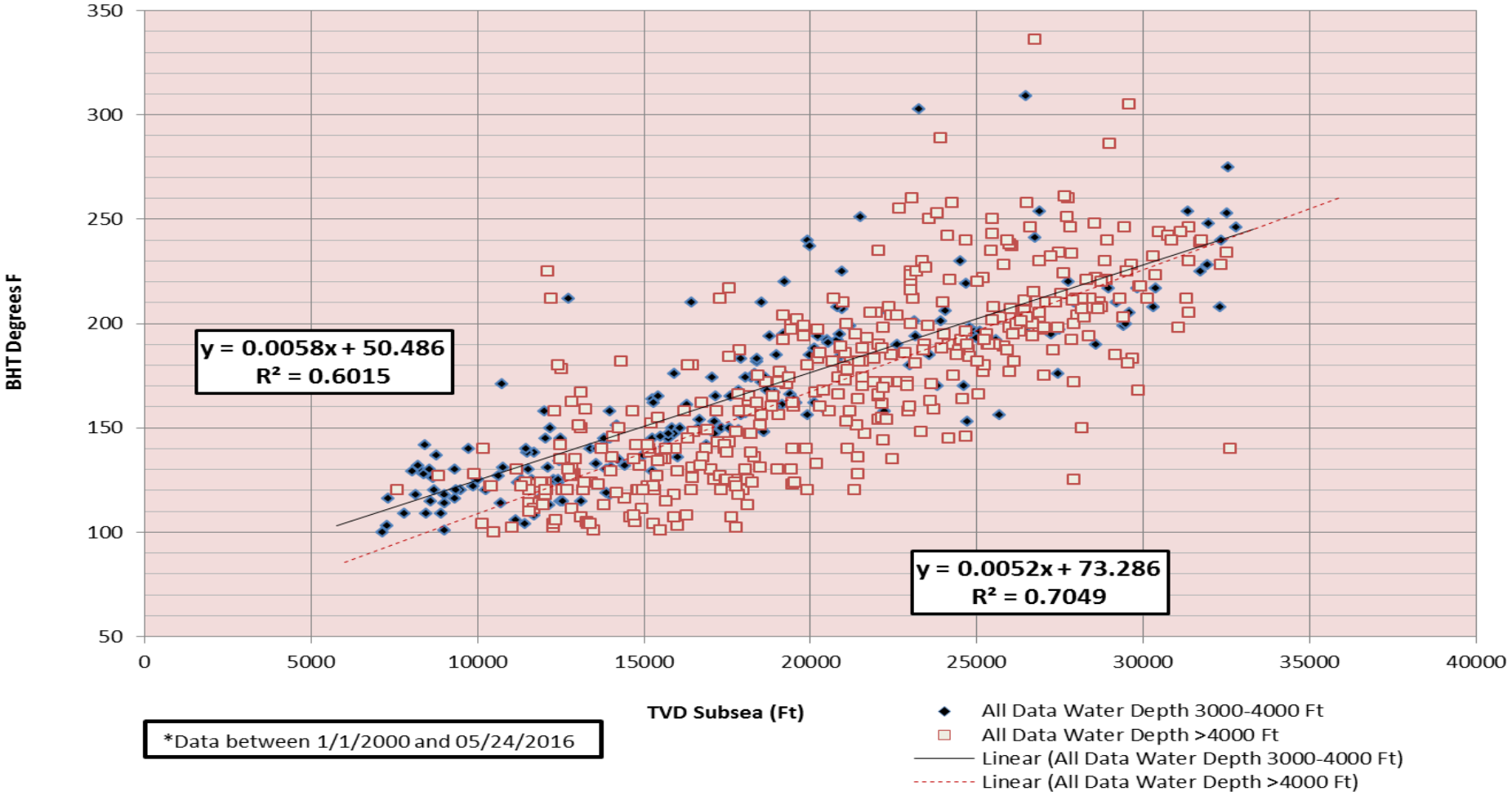



*Data between 1/1/2000 and 05/24/2016

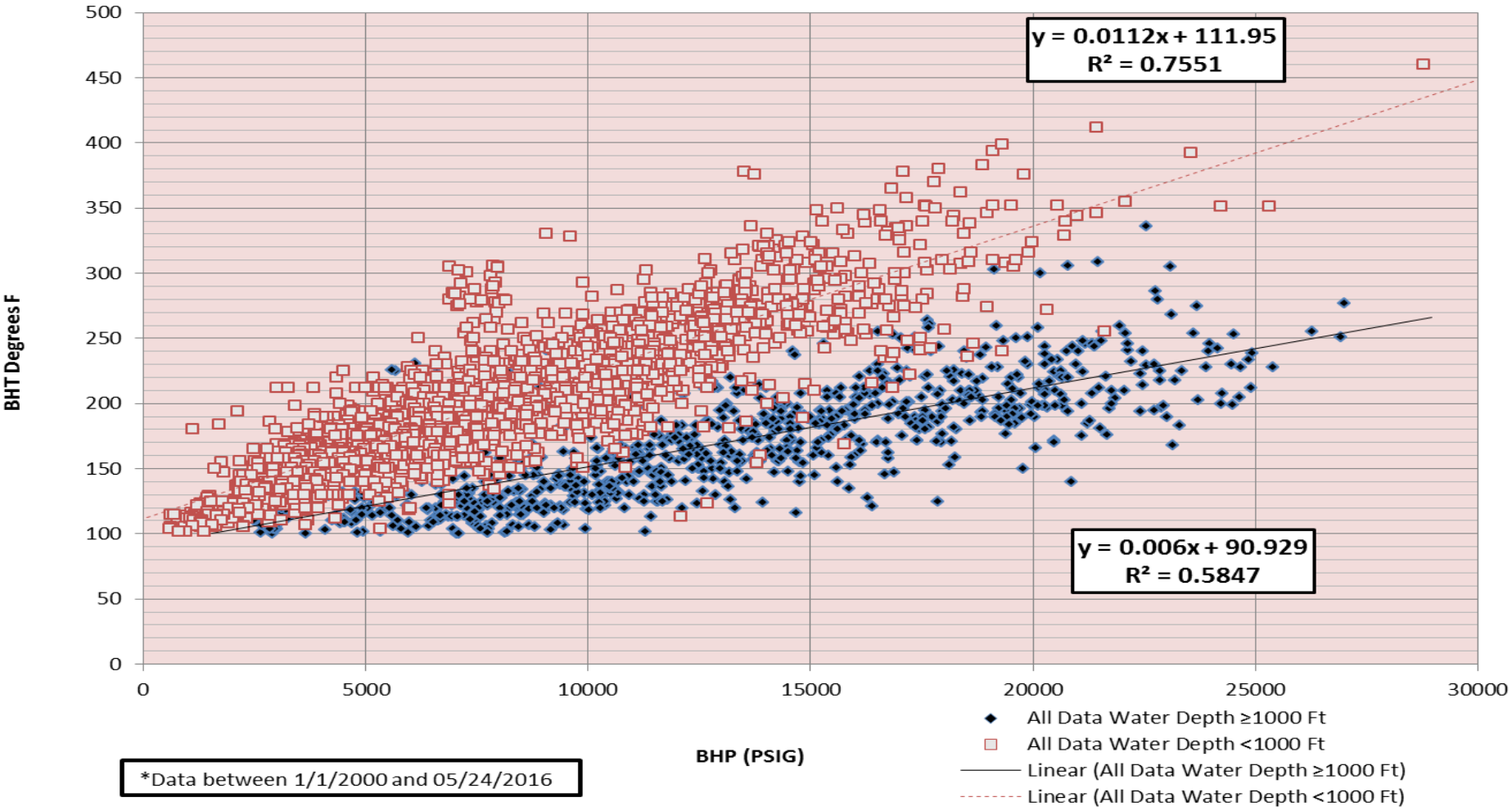
# BHT vs TVDss (Water Depths 1000-2000 ft and 2000-3000 ft)



# BHT vs TVDss (Water Depths 3000-4000 ft and >4000 ft)



# BHT vs BHP




*Data between 1/1/2000 and 05/24/2016

# CONCLUSIONS

| Plot | Water Depth | Regression Equation | $R^2$ Value |
|---|---|---|---|
| **BHP v TVDss** | <1,000 ft | $Y=2E\text{-}05x^2+0.5645x-502.31$ | 0.8970 |
| **BHP v TVDss** | ≥1,000 ft | $Y=5E\text{-}06x^2+05928x$ | 0.9083 |
| **BHT v TVDss** | <1,000 ft | $Y=0.0121x+70$ | 0.7778 |
| **BHT v TVDss** | ≥1,000 ft | $Y=0.0053x+70$ | 0.5282 |
| **BHT v TVDss** | 0 - 500 ft | $Y=0.0116x+77.618$ | 0.7984 |
| **BHT v TVDss** | 500 - 1,000 ft | $Y=0.0063x+103.08$ | 0.5125 |
| **BHT v TVDss** | 1,000 - 2,000 ft | $Y=0.0062x+87.941$ | 0.5237 |
| **BHT v TVDss** | 2,000 - 3,000 ft | $Y=0.0063x+65.026$ | 0.7359 |
| **BHT v TVDss** | 3,000 - 4,000 ft | $Y=0.0052x+73.286$ | 0.7049 |
| **BHT v TVDss** | ≥4,000 ft | $Y=0.0058x+50.486$ | 0.6015 |
| **BHT v BHP** | <1,000 ft | $Y=0.0112x+111.95$ | 0.7551 |
| **BHT v BHP** | ≥1,000 ft | $Y=0.006x+90.929$ | 0.5847 |

x = TVDss

# CONCLUSIONS

- $R^2$ values, in some cases, are small as only one independent variable (depth) is used in the model.
- Other variables, such as geological and geochemical abnormalities, may also affect the dependent variables (pressure and temperature).
- If mudline were used as the datum for measuring depth, $R^2$ could be higher as it would eliminate the effect of water depth on bottom hole pressure and temperature.
- Mudline for different wells are at different depths introducing the challenge of dealing with different baselines for measuring depths, unlike MSL which is constant from which TVDss is measured.

# CONCLUSIONS

- Hydrostatic pressure gradient at GOM is 0.465 psi/ft.
- Overpressure zones are identified with hydrostatic pressure gradients greater than 0.465 psi/ft.
- BSEE data can further be utilized to develop maps showing areas and zones that have high-pressure gradients that are a risk to health and safety, and to the environment.