

Realistic Automated Scenario Drilling Through Implementation and Validation of Physical and Machine Learning Models Using a Real-Time Drilling Simulator

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Outline

- Background
- Research Objectives
- Methodology
- Simulation and Evaluation
- Conclusions and Future Work

Background: Challenges in Drilling

- High cost in drilling an oil, gas, or geothermal well
- High non productive time (NPT) drilling time efficiency in certain drilling operations
- Automated drilling simulation to optimize the drilling process

Background: Factors of Inefficiency in Drilling



(DrillSim:600)

- Natural factors
- Technical factors
- Human resources
- Equipment availability

Research Objectives

- Project: Optimization of geothermal drilling operations through real-time advance simulation
- Research purpose: Create realistic drilling environments to simulate and execute complex drilling processes in real-time
- Research scope: a certain section of a drilled well which is simulated in the advanced DrillSIM:600 Training Simulator

Methodology – Software Simulator at DSC

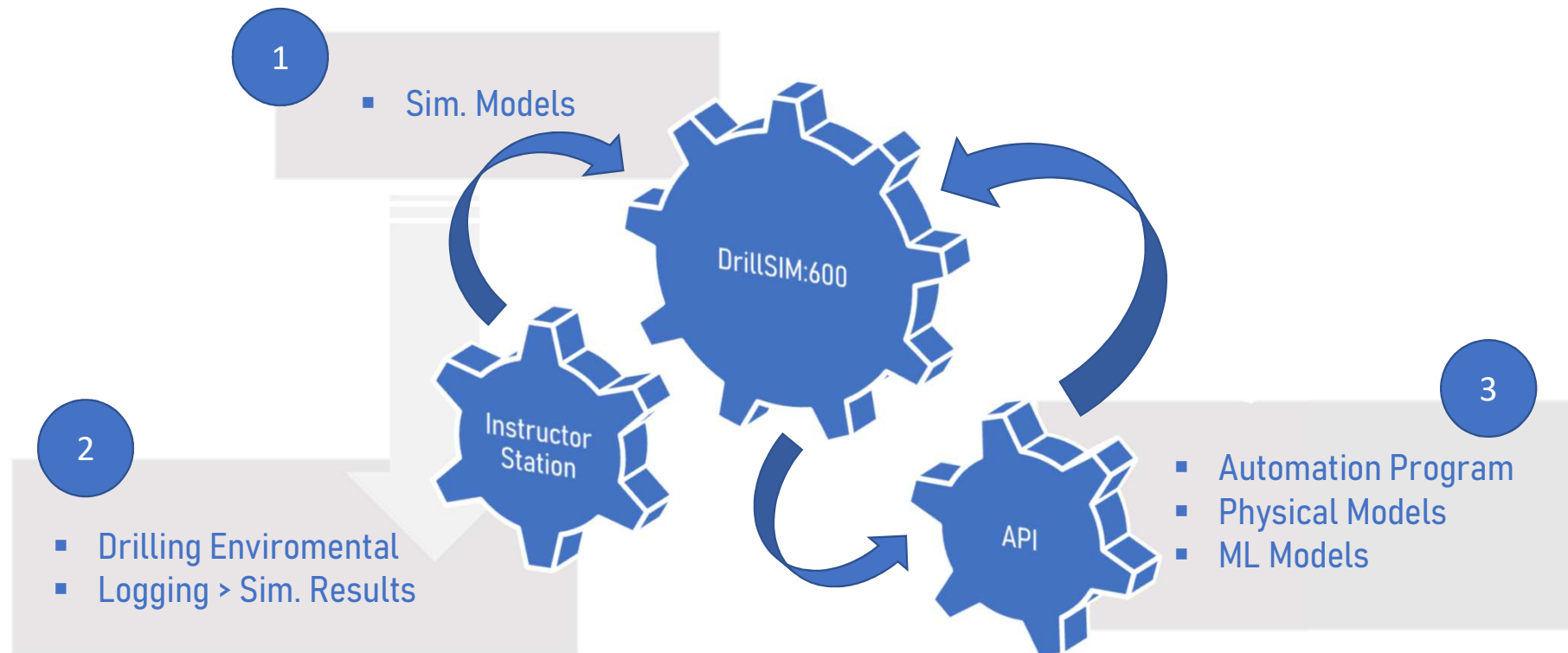


(Instructor Station)



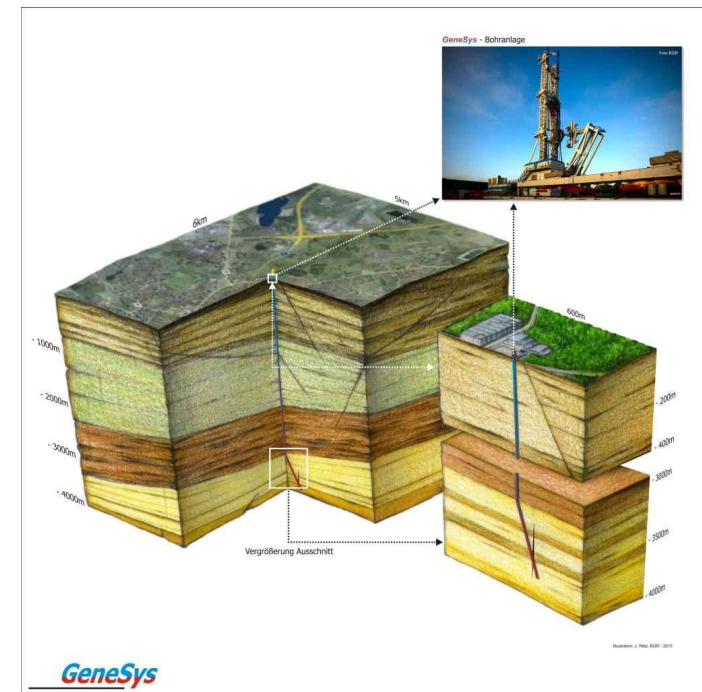
(Student/Drillers Chair)

Methodology - Workflow



Methodology – Well Information

- Wellbore Information: GeneSys
- Location: GEOZENTRUM Hannover
- Target Formation: Mittlerer Buntsandstein
- Type: Geothermal Well
- Depth: 3.901 m
- Simulated section: 1542 – 1562 m



(https://www.genesys-hannover.de/Genesys/DE/Home/genesys_node.html)

Methodology – Setting Simulation Environment

■ Formation

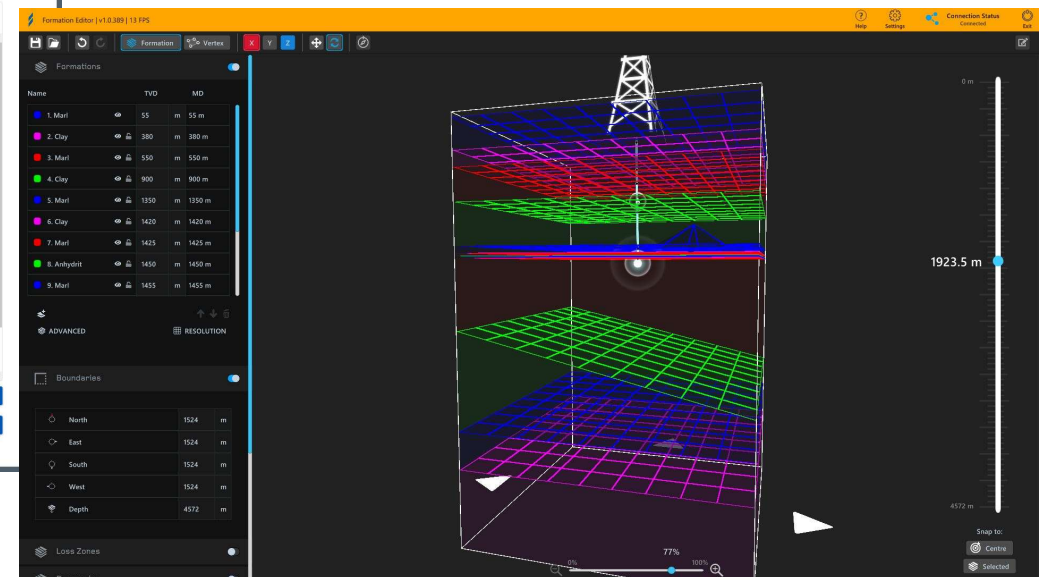
Formations

Loss Zones by Default

Rock Type	Zone Type	Zone ID	Status	Fluid Type	Depth (Top) (m)	Rock Strength (0-10)	Abrasion Factor (0-10)	Permeability (mD)	Pressure Gradient (Bar/m)	Pressure (bar)	Temp Gradient (°C/m)	Advanced Details
Marl	None	None	Inactive	None	55	2	2	0	1.03	57.67	0.02	
Clay	None	None	Inactive	None	380	3	1	0	1.03	391.4	0.02	
Marl	None	None	Inactive	None	550	3	2	0	1.03	566.5	0.02	
Clay	None	None	Inactive	None	900	3	1	0	1.03	927	0.02	
Marl	None	None	Inactive	None	1350	3	2	0	1.03	1390.5	0.02	
Clay	None	None	Inactive	None	1420	3	1	0	1.03	1462.6	0.02	
Marl	None	None	Inactive	None	1425	3	2	0	1.03	1467.76	0.02	
Anhydrit	None	None	Inactive	None	1450	3	2	0	1.03	1493.51	0.02	
Marl	None	None	Inactive	None	1455	3	2	0	1.03	1498.66	0.02	
Clay	None	None	Inactive	None	1470	3	1	0	1.03	1514.11	0.02	
Marl	None	None	Inactive	None	1475	3	2	0	1.03	1519.25	0.02	
Clay	None	None	Inactive	None	2579.74	4	1	0	1.03	2714.8	0.02	
Sandstone	None	None	Inactive	None	3305	4	3	0	1.03	3461.02	0.02	

Import Export Select All

(Instructor Station – Formation Editor)



(Instructor Station – Formation Editor)

Methodology – Setting Simulation Environment

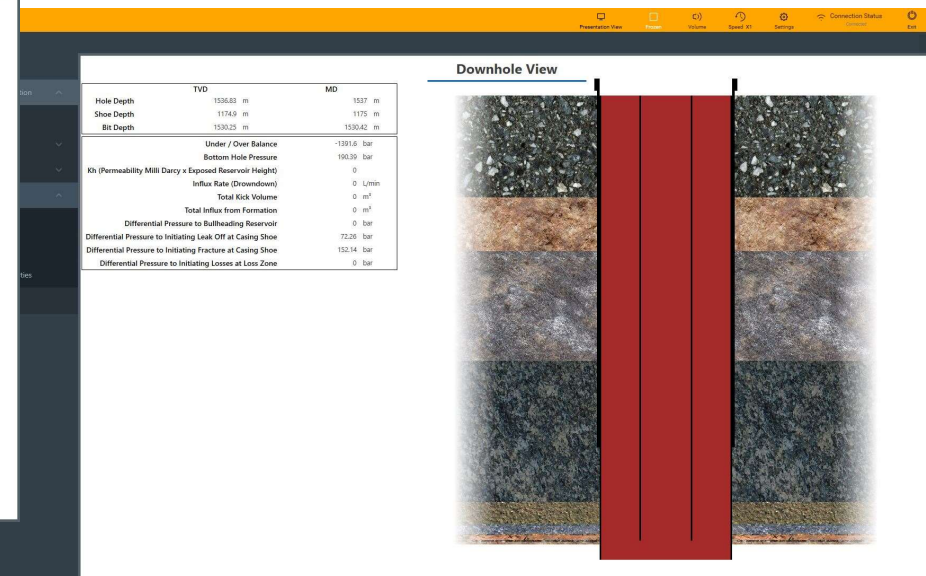
Well Designer & Downhole View

Main Well Path

Default Hole Size: 311 mm
RKB: 55 m

Measure Depth (m)	Inclination (°)	Azimuth (°)	Vertical Depth (m)	Northing (m)	Easting (m)	V-Section (m)	Dogleg (°/30m)	Turn Rate (°/30m)	Build Rate (°/30m)
0	0	0	0	0	0	0	0	0	0
55	0	0	55	0	0	0.94	0.38	271.04	0.38
345	0.37	262.01	345	-0.13	-0.93	0.18	4.38	-60.45	4.35
365	0.66	257.98	365	-0.16	-1.1	0.16	5.7	-10.2	-5.7
385	0.28	257.3	385	-0.2	-1.26	0.02	3.69	-726.5	-1.33
388.6	0.26	248.58	388.6	-0.2	-1.28	0.02	3.5	-726.5	-1.33
392.2	0.25	239.86	392.2	-0.21	-1.29	0.02	3.32	-726.5	-1.33
395.8	0.23	231.15	395.8	-0.22	-1.31	0.01	3.13	-726.5	-1.33
399.4	0.22	222.43	399.4	-0.23	-1.32	0.01	2.95	-726.5	-1.33
403	0.2	213.71	403	-0.24	-1.33	0.02	3.19	510.16	2.53
407.75	0.24	221.79	407.75	-0.25	-1.34	0.02	3.42	510.16	2.53
412.5	0.28	229.86	412.5	-0.27	-1.35	0.02	3.67	510.16	2.53
417.25	0.32	237.94	417.25	-0.28	-1.37	0.03	3.94	510.16	2.53
422	0.36	246.02	422	-0.29	-1.4	0.16	3.79	137.05	3.63
441	0.59	254.7	441	-0.34	-1.55	0.19	1.12	-80.37	-0.79
460	0.54	249.61	459.99	-0.4	-1.72	0.2	2.28	122.53	1.89

(Instructor Station – Wellbore Designer)



(Instructor Station – Downhole View)

Methodology – Setting Simulation Environment

- Fluid System
- BHA & Drillpipe

The screenshot displays two main windows from a drilling simulator. The left window, titled 'Bottom Hole Assembly', contains a table with the following data:

Component	Length (m)	Single Length (m)	Quantity	OD (mm)	ID (mm)	Weight (kg/m)	Tot. Weight (kg)	Yield Press. (bar)	Tensile Str. (kg)	Collapse Press. (bar)	Joint Length (cm)	Joint OD (mm)	Joint ID (mm)	Config	Move	Delete Row
HW Drill Pipe	186.4	9.32	20	127	76.2	31.82	5931.48	9999.99	999999	9999.99	0	0	0			
Cross Over	1.09	1.09	1	209.5	73.66	0	0	0	0	0	0	0	0			
Drill Collar	9.4	9.4	1	209.5	73.66	118.57	1114.59	9999.99	999999	9999.99	0	0	0			
Hydraulic Jar	7	7	1	203.2	73.66	0	0	0	0	0	0	0	0			
Drill Collar	65.17	9.31	7	209.5	73.66	118.57	7727.46	9999.99	999999	9999.99	0	0	0			
Float Sub	1.98	1.98	1	203.2	76.2	0	0	0	0	0	0	0	0			
Stabiliser	2.19	2.19	1	300	73.66	0	0	0	0	0	0	0	0			
Float Sub	1.58	1.58	1	209.5	132.1	0	0	0	0	0	0	0	0			
MWD	8.9	8.9	1	209.5	10	0	0	0	0	0	0	0	0			
Stabiliser	1.41	1.41	1	300	73.6	0	0	0	0	0	0	0	0			
PD Motor	10	10	1	203.2	10	0	0	0	0	0	0	0	0			
DrillBit PDC	0.37	0.37	1	311	10	0	0	0	0	0	0	0	0			
Total BHA Length	295.49						m									
Total BHA Weight							14773.53									
Total Drill String Length							1532.46									
Total Drill String Weight							74123.31									

The right window, titled 'Initial Mud Conditions', shows settings for the fluid system:

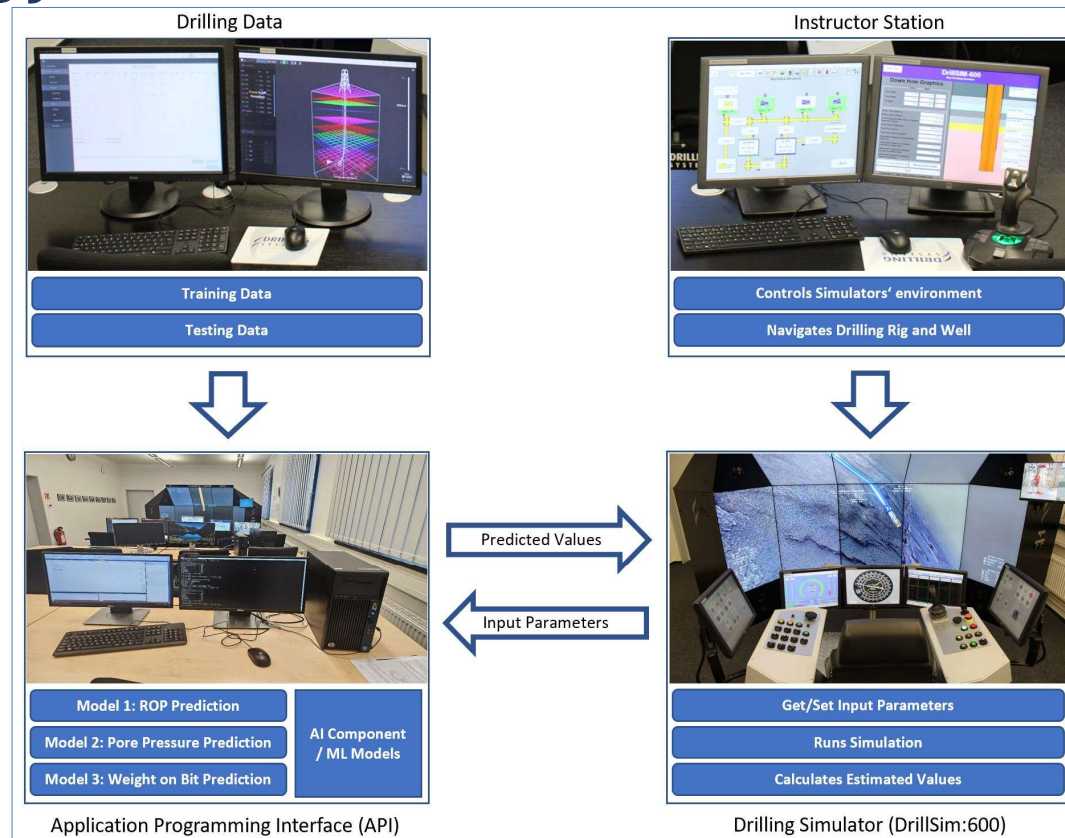
- Fluid System:** Water Based Fluid (checked), Oil Based Fluid (unchecked)
- Fluid Properties:** Fluid Type: Mud, Fluid Model: Newtonian, Fluid Density: 1.26 sg, Viscosity: 1 Pas
- RPM Effects to Fluid:** Active (unchecked), Turning Factor: 0

Buttons for 'Import', 'Export', and 'Select All' are visible at the bottom of the simulator interface.

(Instructor Station – Drillstring Designer)

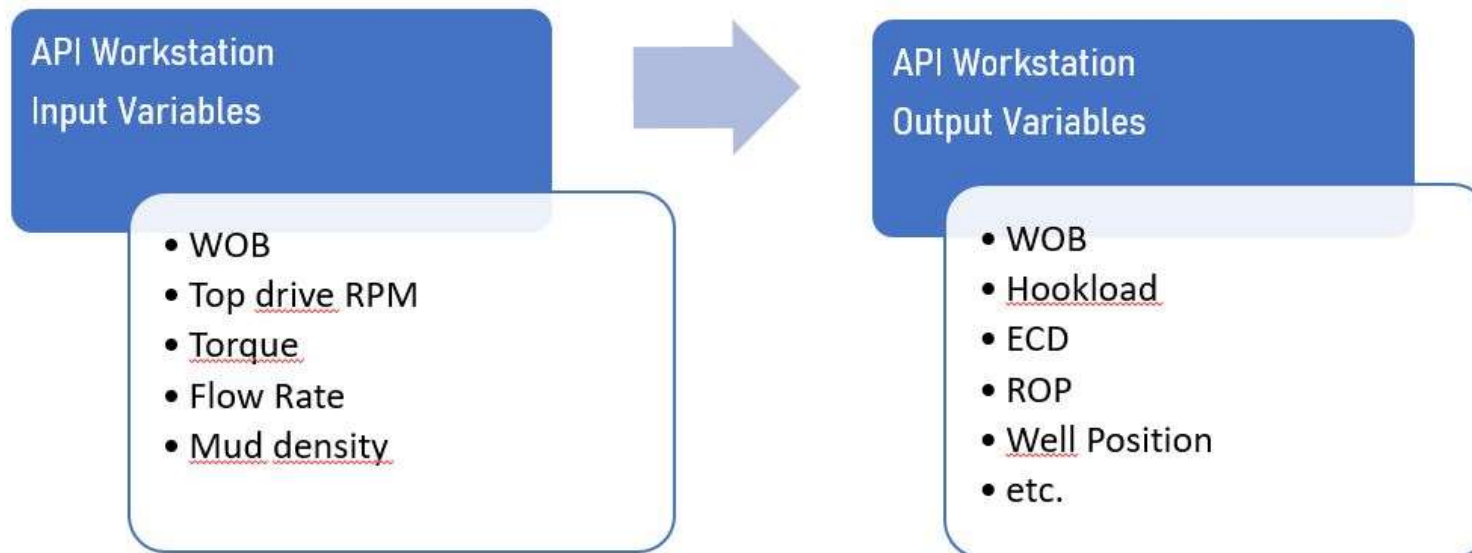
(Instructor Station – Fluid System Designer)

Methodology – API Workstation



(Workflow between API Workstation and Drillsim:600)

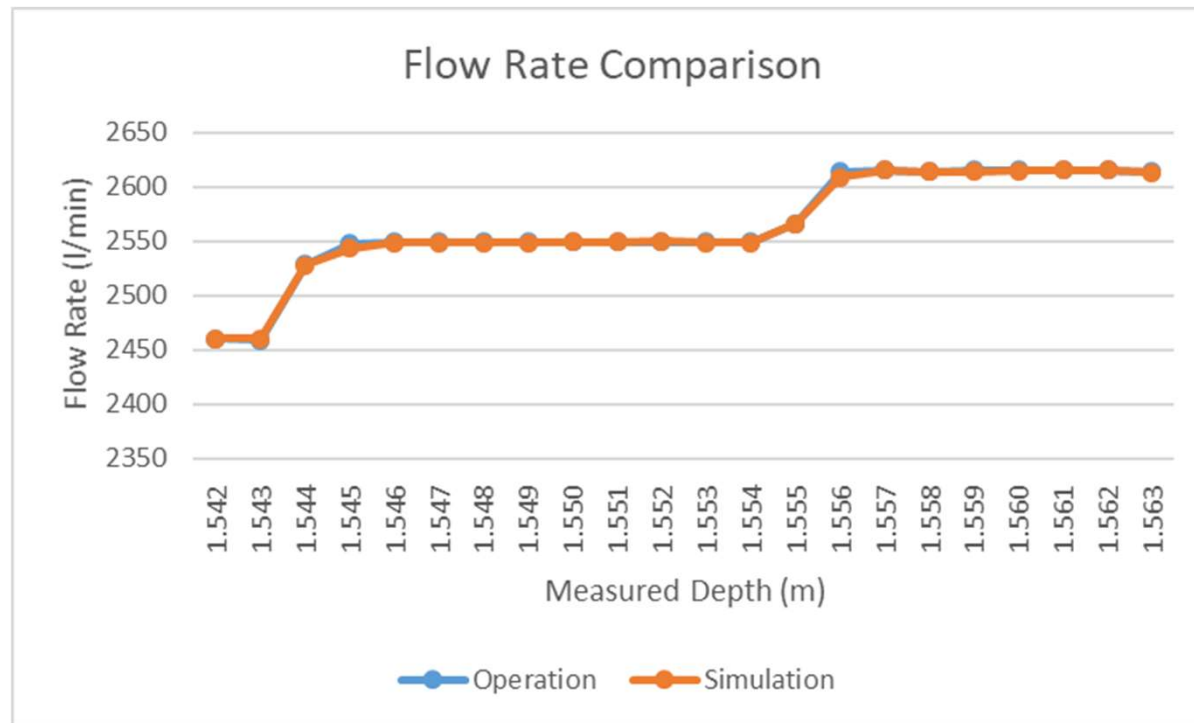
Methodology – Communication with Simulator



Simulation and Evaluation

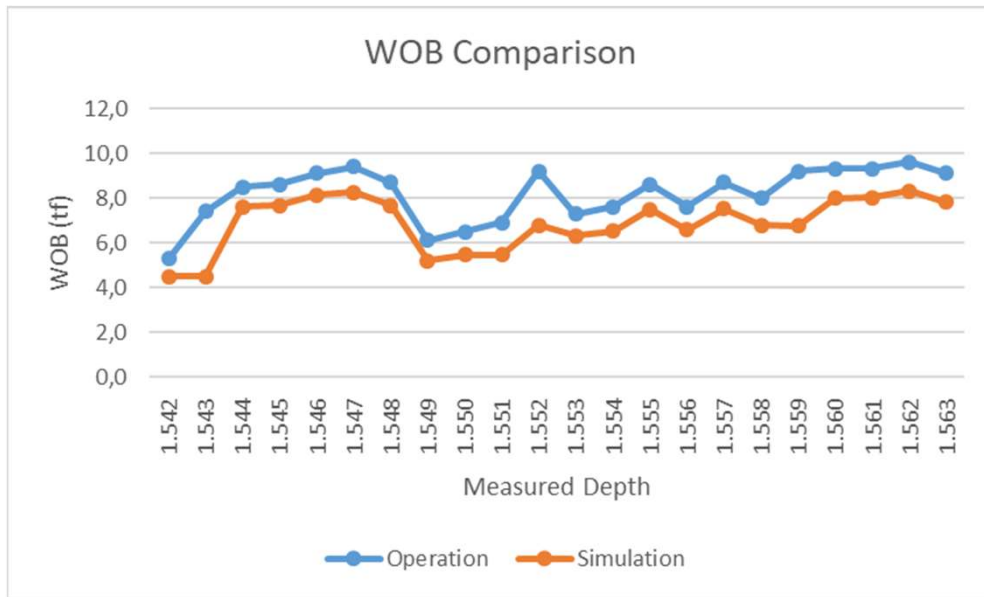
- Flow Rate
- Weight on bit
- Torque
- ROP

Flow rate

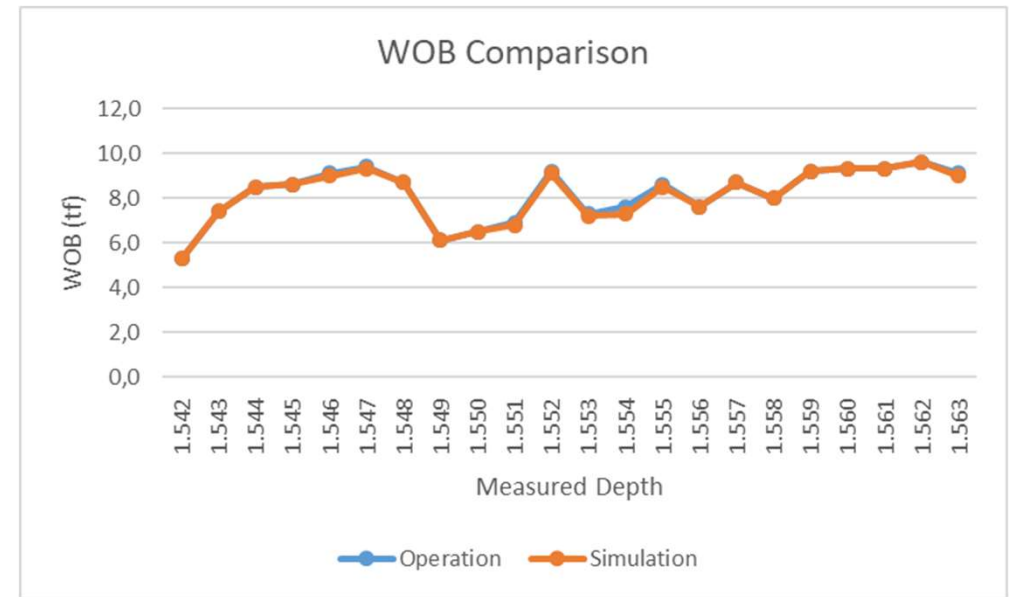


(Flow Rate comparison at parameter input depth)

Weight on bit

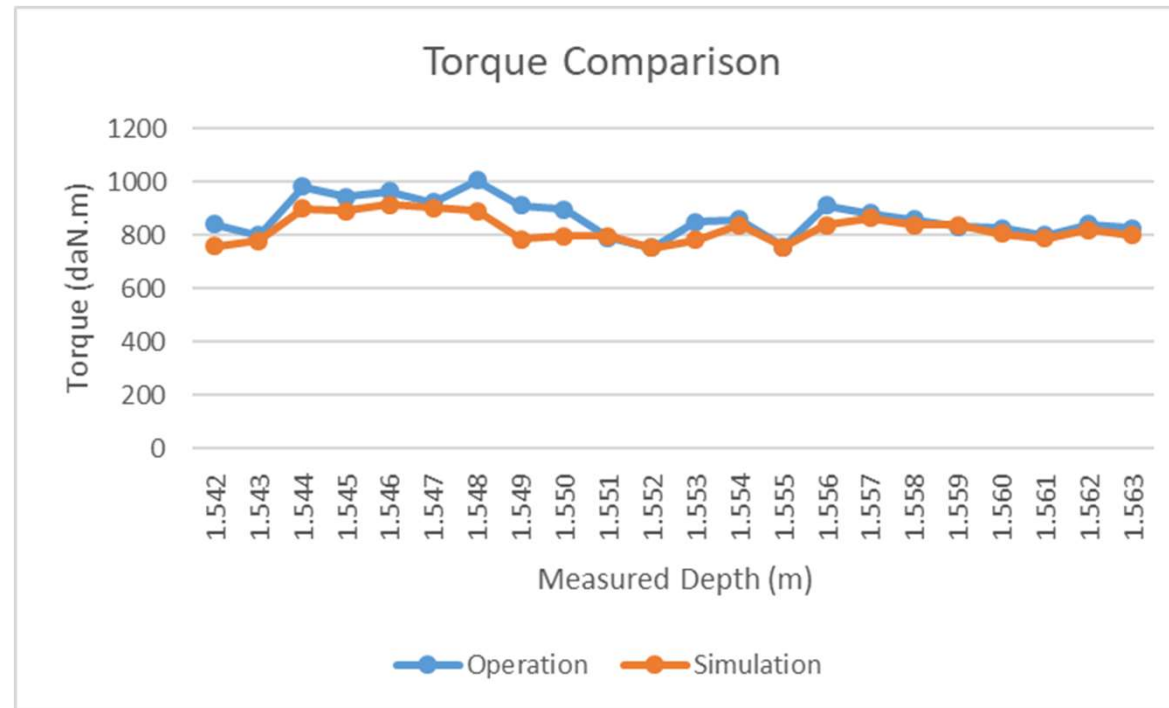


(WOB at parameter input depth)



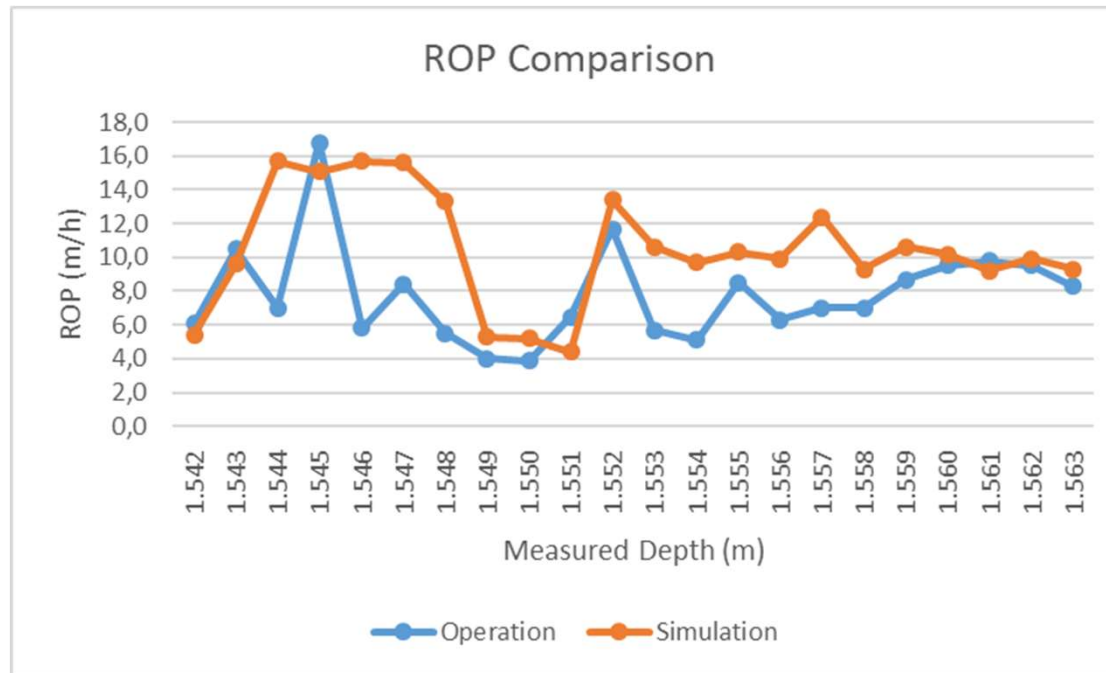
(WOB at parameter input depth with iteration time)

Torque



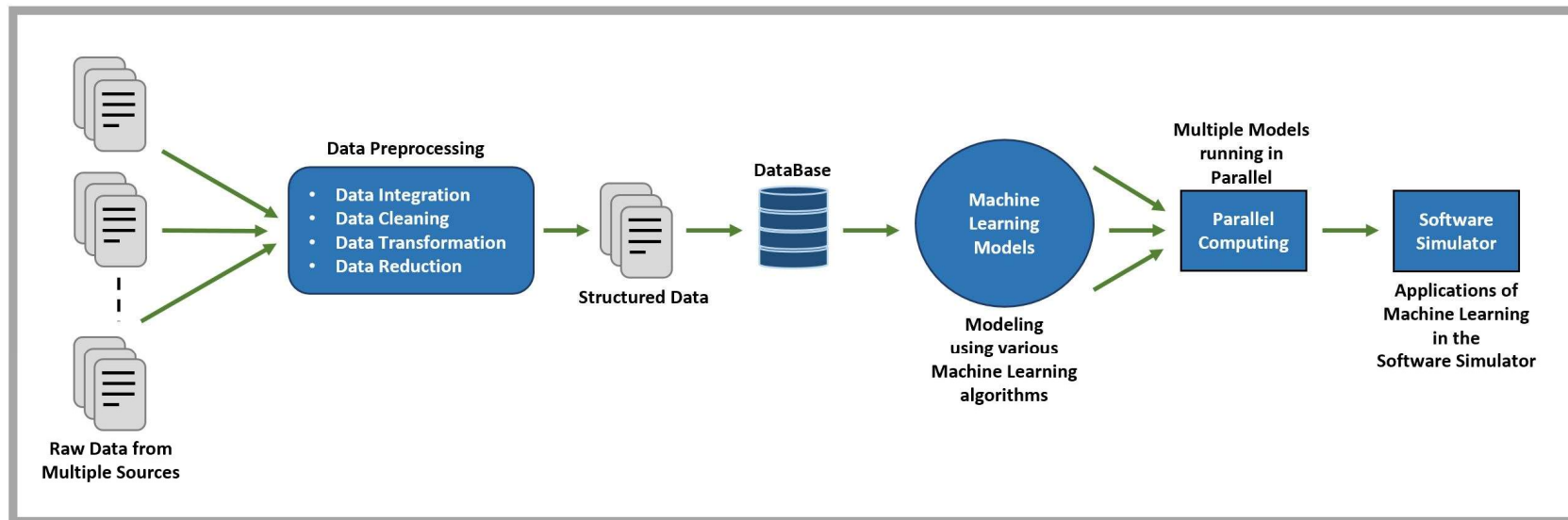
(Torque comparison at parameter input depth)

ROP



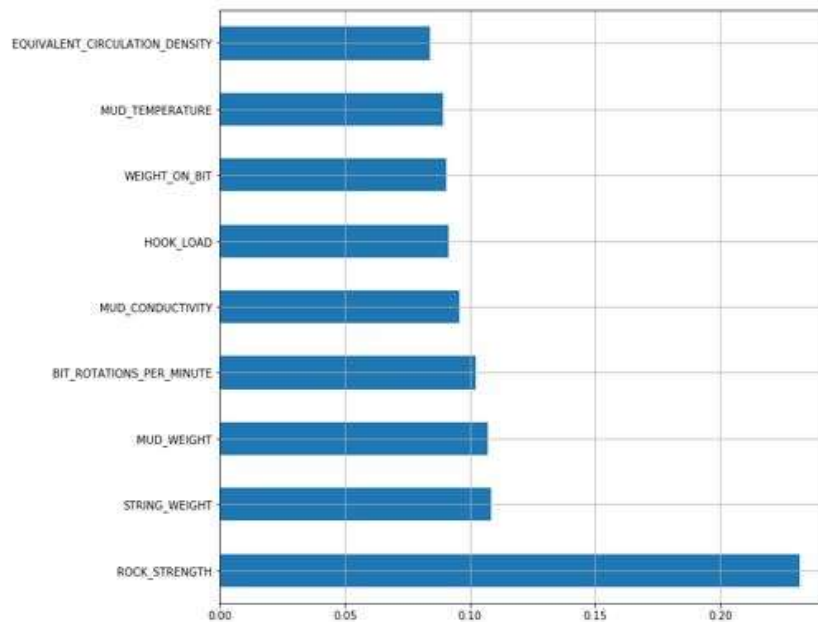
(ROP comparison at parameter input depth)

Machine Learning Application



(Machine Learning Application Workflow)

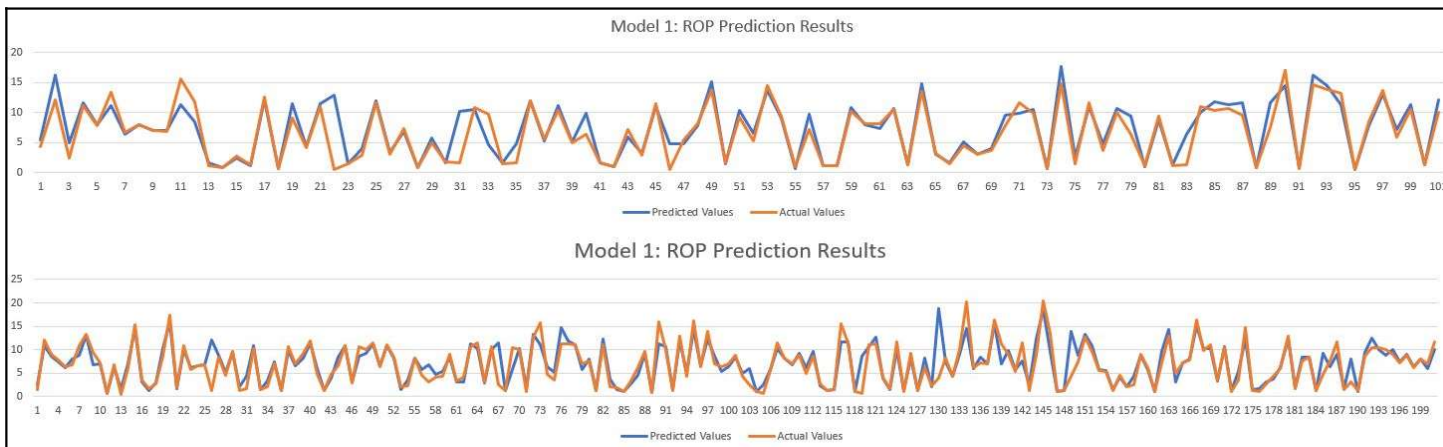
Machine Learning Model Application - ROP



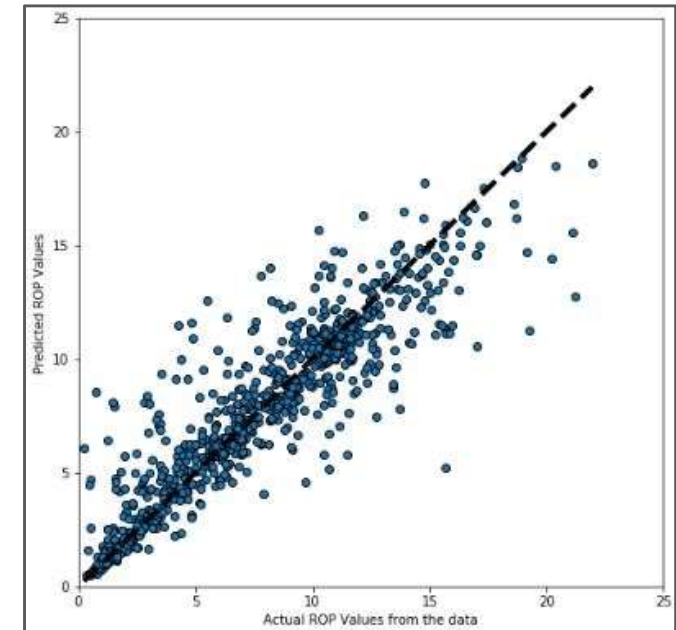
Features	Features Importance
EQUIVALENT_CIRCULATION_DENSITY	8.40 %
MUD_TEMPERATURE	8.90 %
WEIGHT_ON_BIT	9.04 %
HOOK_LOAD	9.12 %
MUD_CONDUCTIVITY	9.59 %
BIT_ROTATIONS_PER_MINUTE	10.25 %
MUD_WEIGHT	10.72 %
STRING_WEIGHT	10.82 %
ROCK_STRENGTH	23.17 %

(Machine Learning Model – Features Importance)

ROP – Machine Learning Model



(Results of ROP Machine Learning Model)



(Comparison between Predicted and Actual Values of ROP)

Conclusions and Future Work

- A wellbore was recreated and a section of the wellbore was successfully simulated
- An automated program was created to utilize the drilling parameters inputs from the original operation
- The scenario drilling simulation outputs were able to follow the same trends and patterns as the actual drilling operation
- Improve the automation program to simulate drilling a complete wellbore
- Improve simulation results by implementing more machine learning and physical models

Thank you