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PipelineOptimizer® Use Case

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Overview

PipelineOptimizer is a state-of-the-art engineering and operations tool for simulating liquid pipeline hydraulics that will help minimize operating costs. This is done by determining the best pumping schedule and DRA usage to meet the demands of the operating schedule. A great deal of knowledge about the system can be learned through the modeling of pipelines in PipelineOptimizer.

This document walks through a use case for PipelineOptimizer. The inputs for the configuration are described, and then the simulation results are given for the available optimization modes.

Inputs

Schematic

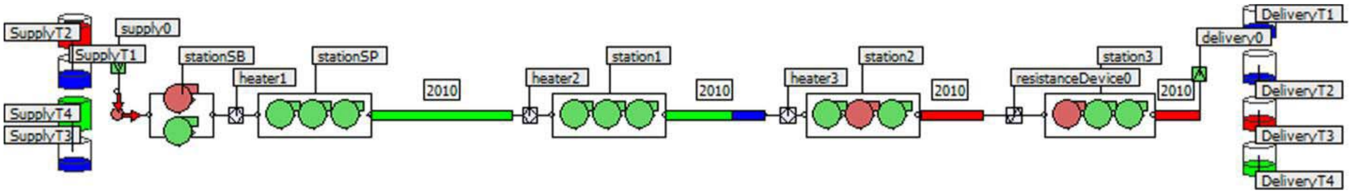

Figure 1. Case Study Schematic

EMERSON

The pipeline described in this use case is configured in PipelineOptimizer as seen in the above screenshot. The configuration includes four supply and four delivery tanks; supply and delivery locations, including the supply boosters and pumps; the three pumping stations with their respective pumps; three heaters; one resistance device; and the pipelines between stations. The two sets of pumps in the supply station have been modeled as two separate stations in order to model the heater in between.

Elevation Profile

	Name	Milepost (miles)	Elevation (ft)
1	Survey_1	0.162	672.570
2	Survey_1	0.385	643.043
3	Survey_1	0.466	623.358
4	Survey_1	0.777	639.762
5	Survey_1	0.851	616.796
6	Survey_1	1.081	902.228
7	Survey_1	1.386	1167.975
8	Survey_1	1.696	1292.647
9	Survey_1	2.007	1604.326
10	Survey_1	2.312	2011.149
11	Survey_1	2.616	1843.826
12	Survey_1	2.920	1735.559
13	Survey_1	3.231	1656.819
14	Survey_1	3.536	1489.497
15	Survey_1	3.679	1463.250
16	Survey_1	3.846	1699.470
17	Survey_1	4.151	1574.798
18	Survey_1	4.461	1220.469
19	Survey_1	4.642	1089.235
20	Survey_1	4.766	1220.469
21	Survey_1	5.070	1085.955
22	Survey_1	5.375	1089.235
23	Survey_1	5.605	1115.482
24	Survey_1	5.686	1082.674
25	Survey_1	5.996	1249.996
26	Survey_1	6.089	1059.708
27	Survey_1	6.307	1082.674

Figure 2. Elevation Profile

The elevation profile is entered into the configuration into the Survey table.

Pipes

	Pipe Name	Inlet Node	Outlet Node	Number of Parallel Pipes	Pipe Profile	Survey Name	Survey Start MP (miles)	Survey End MP (miles)	Average Ground Temperature (degF)
1	pipe1	node0	node1	1	pipe1	Survey_1	0.162	25.725	78.00000
2	pipe2	node2	node14	1	pipe2	Survey_1	25.725	44.938	78.00000
3	pipe3	node4	node13	1	pipe3	Survey_1	44.938	57.502	78.00000
4	pipe4	node6	node7	1	pipe4	Survey_1	57.502	67.636	78.00000

Figure 3. Pipe Table

Pipe data is entered into the Pipe Types Table, Pipe Profile Table, and the Pipes Table.

Fluids

	Fluid Name	Description	Linefill Color	Specific Gravity (sp grav)	Viscosity 1 (cSt)	Temperature 1 (degF)	Viscosity 2 (cSt)	Temperature 2 (degF)	Specific Heat (BTU/lbm/F)	NGL Composition	Vapor Pressure (psi)
1	HC1	HC1		0.7266	0.60000	86.00000	0.49000	104.00000	0.45		10.00000
2	HC2	HC2		0.7809	1.20000	86.00000	0.97000	104.00000	0.45		10.00000
3	HC3	HC3		0.8452	4.60000	86.00000	3.70000	104.00000	0.45		10.00000

Figure 4. Fluids Table

The three fluids are configured with the corresponding specific gravity, viscosity, specific heat, and vapor pressure for each fluid in the Fluids table.

Stations and Station Set Points

	Station	Suction Node	Discharge Node	Suction Pressure (psi)	Discharge Pressure (psi)	Bypassed	Power Contract	On-Peak KW Limit (kW)	Off-Peak KW Limit (kW)	Peak Period	Baseline Power Usage (kW)
1	stationSB	node11	node9	50.00000	5000.00000	No	Contract_A			PeriodA	
2	stationSP	node3	node0	50.00000	5000.00000	No	Contract_A			PeriodA	
3	station1	node12	node2	350.00000	1900.00000	No	Contract_A			PeriodA	
4	station2	node15	node4	550.00000	2000.00000	No	Contract_A			PeriodA	
5	station3	node10	node6	150.00000	1400.00000	No	Contract_A			PeriodA	

Figure 5. Stations Table

The stations and their corresponding set points are included in the Stations table. Since there are no set points for the “stations” in the Supply Station, the values entered are chosen as to not restrict the flow at those locations.

Supplies/Deliveries

	Supply Name / Delivery Name	Function	Inlet Node	Boundary Pressure (psi)	Boundary Flow (bbl/hr)	Symbol	Temperature (degF)	Boundary Type	Terminal Name
1	supply0	Supply	node8	190.00000		Triangle	78.00000	Pressure	Supply_Terminal
2	delivery0	Delivery	node7	100.00000		Triangle	78.00000	Pressure	Delivery_Terminal

Figure 6. Supplies/Deliveries Table

The boundary pressures for the supply and delivery are entered in the Supplies/Deliveries table. The upstream boundary pressure for the supply was chosen to be 190 psi.

Pumps/Pump Curves

	Pump Name	Station	Pump Position	Pump String Position	Pump Curve	View Curve	Pump Driver	VFD Option	Design Speed (RPM)	Minimum Speed (RPM)	Maximum Speed (RPM)	Fixed Speed (RPM)	Pump Flow Multiplier	Pump Head Multi
1	PumpB1	stationSB	0	0	Curve_Booster	Curve_Booster	Booster_Driver		1800.00000	500.00000	1800.00000	1800.00000	1.00	
2	PumpB2	stationSB	0	0	Curve_Booster	Curve_Booster	Booster_Driver		1800.00000	500.00000	1800.00000	1800.00000	1.00	
3	PumpSb1	stationSP	2	0	Curve_X	Curve_X	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
4	PumpSb2	stationSP	1	0	Curve_Y	Curve_Y	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
5	PumpSb3	stationSP	0	0	Curve_Beta	Curve_Beta	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
6	Pump1b1	station1	0	0	Curve_Z	Curve_Z	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
7	Pump1b2	station1	1	0	Curve_Z	Curve_Z	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
8	Pump1b3	station1	2	0	Curve_X	Curve_X	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
9	Pump2b1	station2	0	0	Curve_Y	Curve_Y	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
10	Pump2b2	station2	1	0	Curve_Z	Curve_Z	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
11	Pump2b3	station2	2	0	Curve_X	Curve_X	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
12	Pump3b1	station3	0	0	Curve_Z	Curve_Z	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
13	Pump3b2	station3	1	0	Curve_Y	Curve_Y	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	
14	Pump3b3	station3	2	0	Curve_X	Curve_X	Driver		3560.00000	2200.00000	3560.00000	3560.00000	1.00	

Figure 7. Pumps Table

	Pump Head Multiplier	Motor Coupling Efficiency	Motor Gear Ratio	VFD Coupling Efficiency	VFD Gear Ratio	Design Impeller Size (inches)	Design # Stages	Actual Impeller Size (inches)	Actual # Stages	Inlet Resistance (psi/(bbl/hr)^2)	Outlet Resistance (psi/(bbl/hr)^2)
1.00	1.00	1.00	1.00	1.00	1.0000	12.0000	1	12.0000	1		
.00	1.00	1.00	1.00	1.00	1.0000	12.0000	1	12.0000	1		
1.00	1.00	1.00	1.00	1.00	1.0000	12.6300	4	12.6300	4		
1.00	1.00	1.00	1.00	1.00	1.0000	11.9400	4	11.9400	4		
1.00	1.00	1.00	1.00	1.00	1.0000	12.0000	1	12.0000	1		
1.00	1.00	1.00	1.00	1.00	1.0000	12.6300	1	12.6300	1		
1.00	1.00	1.00	1.00	1.00	1.0000	12.6300	1	12.6300	1		
1.00	1.00	1.00	1.00	1.00	1.0000	12.6300	4	12.6300	4		
1.00	1.00	1.00	1.00	1.00	1.0000	11.9400	4	11.9400	4		
1.00	1.00	1.00	1.00	1.00	1.0000	12.6300	1	12.6300	1		
1.00	1.00	1.00	1.00	1.00	1.0000	12.6300	4	12.6300	4		
1.00	1.00	1.00	1.00	1.00	1.0000	12.6300	1	12.6300	1		
1.00	1.00	1.00	1.00	1.00	1.0000	11.9400	4	11.9400	4		
1.00	1.00	1.00	1.00	1.00	1.0000	12.6300	4	12.6300	4		

Pumps Table, Continued

The pump information is entered into the Pumps table. This table describes the location, speed, impeller size, and design stages of each pump. Each pump is also paired with its corresponding pump curve. The pump curves are entered through the Pump Curve table, and can be viewed through a pop-up screen by clicking on the corresponding button on the Pumps screen.

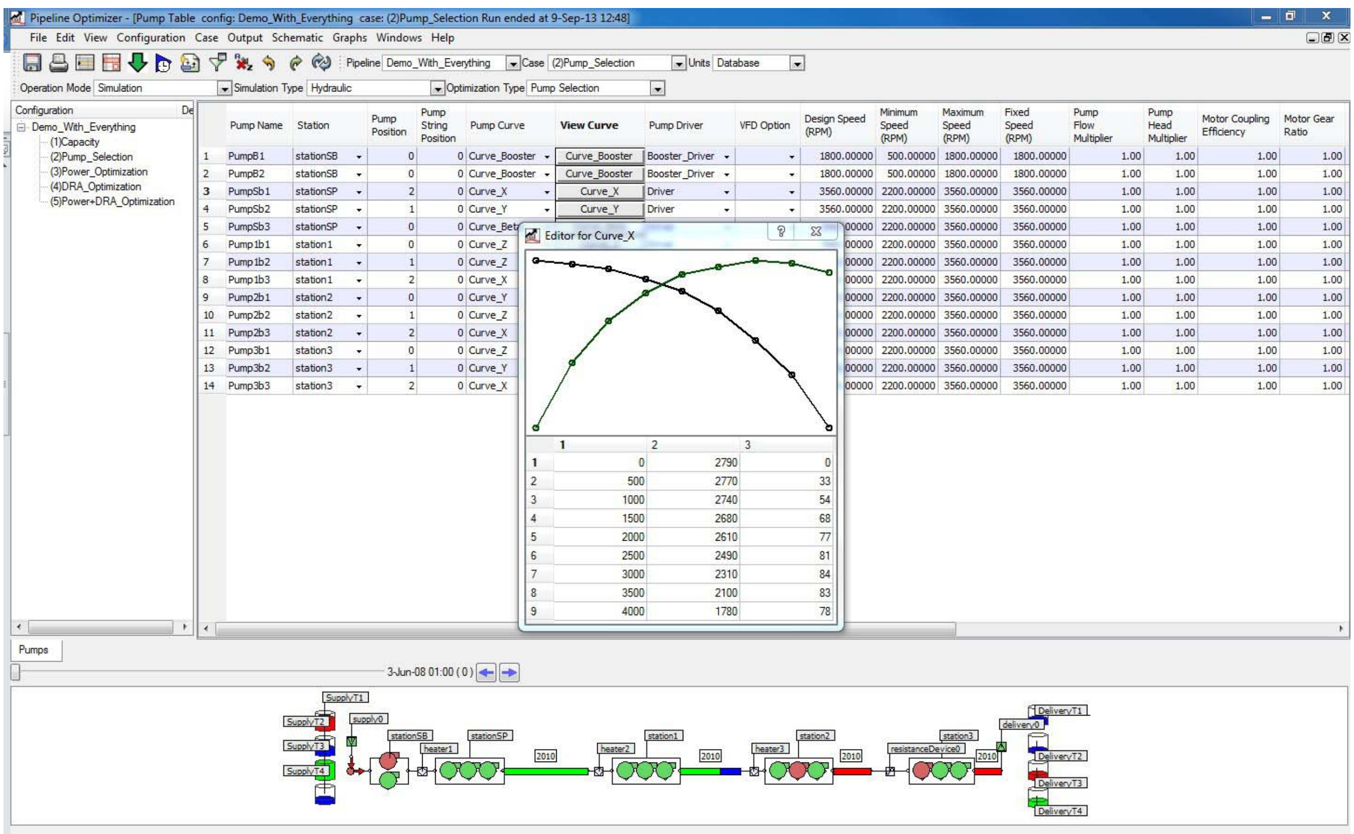

Figure 8. Pumps Table, Pump Curve X

Batch Plan

	Batch ID	Product	Activity	Activity Volume (bbls)	Location	Tank Name	Rate (bbl/hr)	Maximum Volume (bbls)	Synchronized Batch ID	Initial Linefill Only
1	BAT_A_INIT	HC1	P	13309.00000	supply0	SupplyT1		0.00000		Yes
2	BAT_A_INIT	HC1	FLA	13309.00000	delivery0	DeliveryT3		0.00000		Yes
3	BAT_B_INIT	HC2	P	3803.00000	supply0	SupplyT2		0.00000		Yes
4	BAT_B_INIT	HC2	FLA	3803.00000	delivery0	DeliveryT1		0.00000		Yes
5	BAT_C_INIT	HC3	P	20915.00000	supply0	SupplyT3		0.00000		Yes
6	BAT_C_INIT	HC3	FLA	20915.00000	delivery0	DeliveryT4		0.00000		Yes
7	BAT_A	HC1	P	50000.00000	supply0	SupplyT1		0.00000		No
8	BAT_A	HC1	FLA	50000.00000	delivery0	DeliveryT3		0.00000		No
9	BAT_B	HC2	P	1200.00000	supply0	SupplyT2		0.00000		No
10	BAT_B	HC2	FLA	1200.00000	delivery0	DeliveryT1		0.00000		No
11	BAT_C	HC3	P	60000.00000	supply0	SupplyT3		0.00000		No
12	BAT_C	HC3	FLA	60000.00000	delivery0	DeliveryT4		0.00000		No

Figure 9. Batch Plan Table

The batch plan, including the initial linefill, is entered in the Batch Plan table. Under the Activity column, P stands for pumping activity, while FLA stands for full-line all activity.

DRA Usage

DRA has been added to the configuration in the following manner:

	DRA Degradation Factor	Degradation Location
1	0.05000	All Pipes
2	1.00000	All Stations

Figure 10. DRA Degradation Table

The DRA degradation factors are entered into the DRA Degradation Table.

	DRA Name	Product	Equation Type	Coefficient A	Coefficient B	Specific Gravity	Reduction
1	DRA1	HC1	Baker_Hughes	3.00	6.00	0.80	Fraction
2	DRA1	HC2	Baker_Hughes	3.00	6.00	0.80	Fraction
3	DRA1	HC3	Baker_Hughes	3.00	6.00	0.80	Fraction

Figure 11. DRA Types Table

The DRA equation types and coefficients are set through the DRA Types Table.

	Station Name	Product	Batch	Rule Status	DRA Type	Injection Fraction (ppm)	Minimum Fraction (ppm)	Price ($/gal)
1	station1	All Fluid		Enable	DRA1	20.00	0.00	8.00
2	station2	All Fluid		Enable	DRA1	20.00	0.00	8.00

Figure 12. DRA Injection Rules Table

Finally, the DRA injection rules are entered in the DRA Injection Rules Table. For a baseline, DRA will be injected continuously at 20 ppm at Station 1 and Station 2 at a cost of $8/gallon.

Power Contract

The power contracts have been set up in the following manner:

	Period Name	On-Peak Start (time)	On-Peak Stop (time)	Applies to Day of Week	Override for Date (md)	Description
1	PeriodA	8:00	16:00	All Days		

Figure 13. Peak Periods Table

The peak period has been chosen to be from 08:00 until 16:00, every day of the week.

	Contract Name	On Peak Demand Price ($/kW)	On Peak Energy Price ($/kW-hour)	Off Peak Demand Price ($/kW)	Off Peak Energy Price ($/kW-hour)
1	Contract_A	5.7500	0.1200	4.0000	0.0900

Figure 14. Power Contracts Table

The on- and off-peak demand and energy cost rates are shown in the above table.

Simulations

Capacity Calculation

In capacity mode, PipelineOptimizer computes the maximum possible throughput, running all of the pump units to generate maximum head. This mode will also show the user the current bottlenecks of the system.

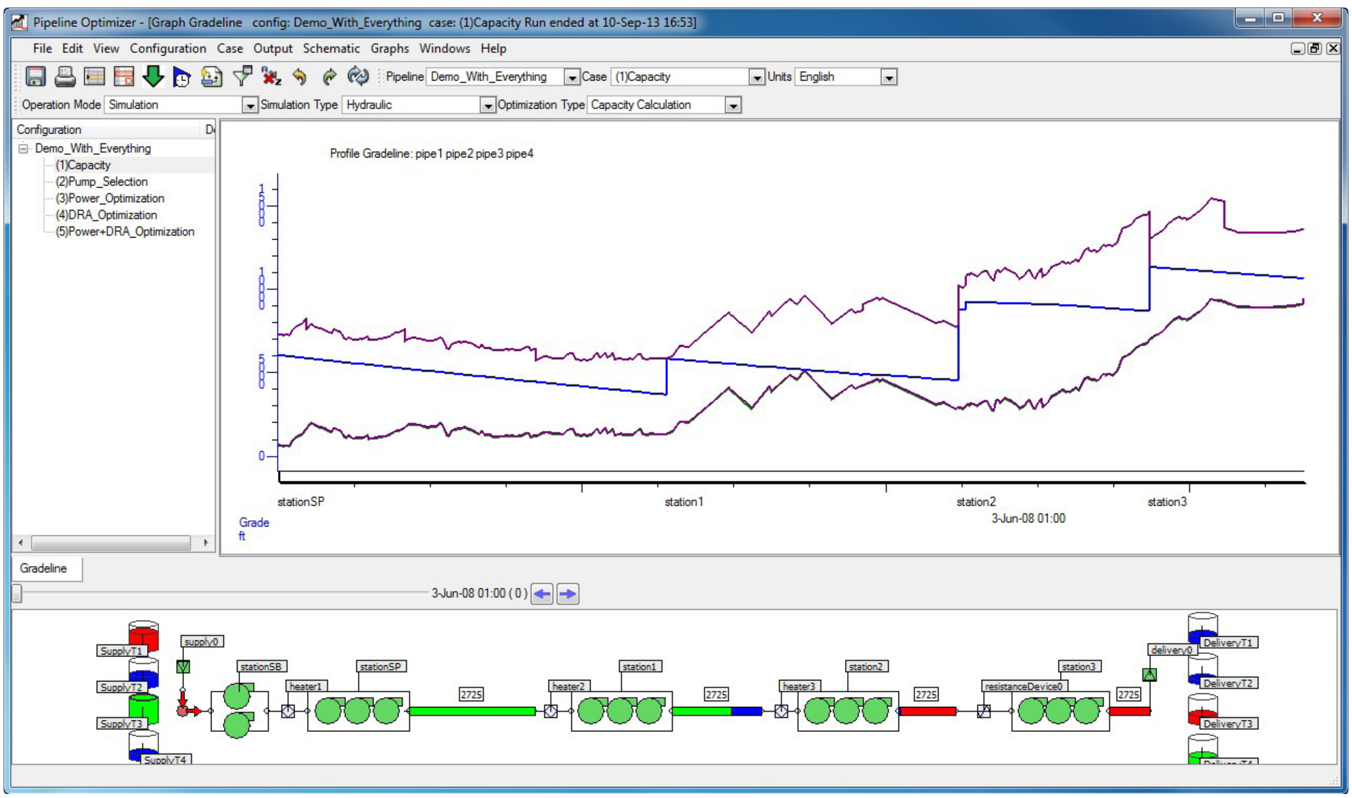

Figure 15. Gradeline for Capacity Simulation

One interesting graph to look at is the gradeline plot, which shows the pumps pushing as hard as possible to get maximum flow through the system. The time bar on the left can be dragged to see the gradeline at different points in time.

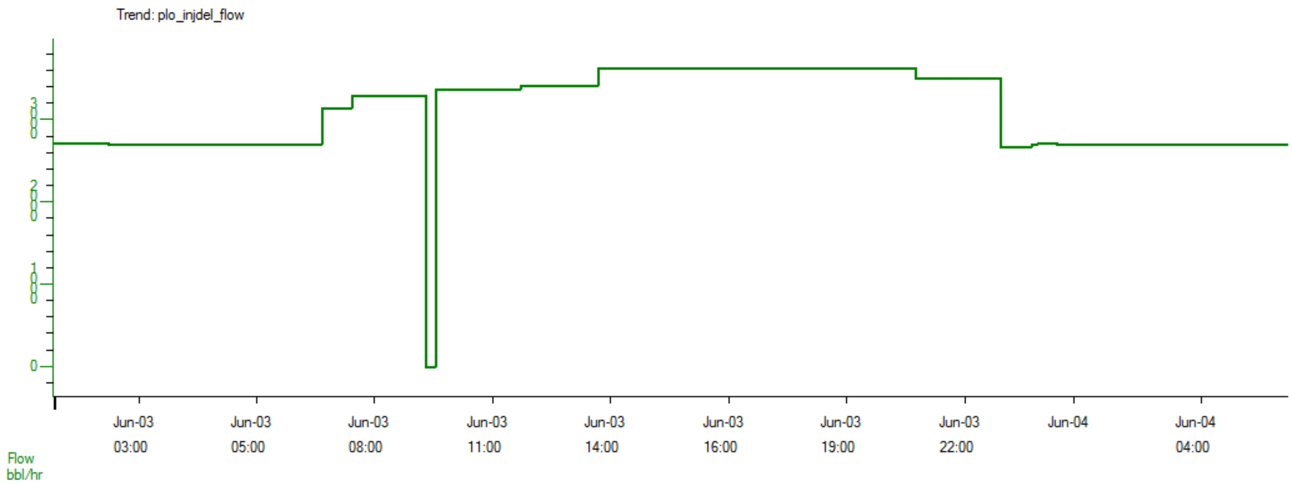

Figure 15. Flow Plot for Capacity Simulation

The Flow plots show how the flow rate changes over time as different fluids enter and leave the system. The short period where the flow rate is zero bbl/hr is a simulated shutdown in the system for 15 minutes.

The bottleneck reporting capability in PLO can provide the user great detail on the location and type of bottlenecks in a given pipeline.

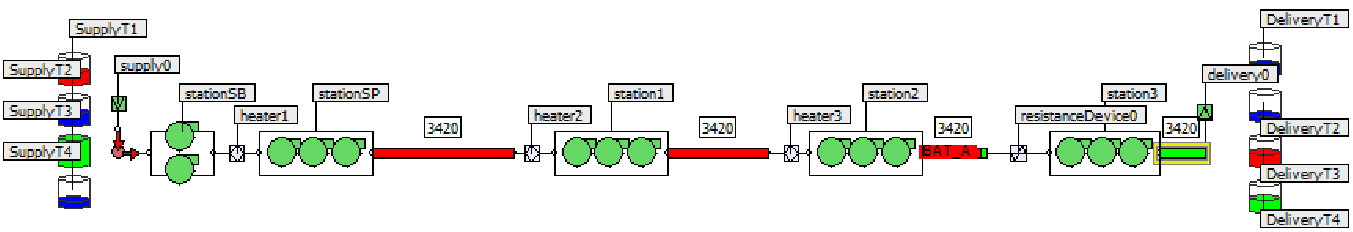

Figure 16. Schematic with Bottleneck Location

Bottleneck locations are shown by yellow boxes around elements in the pipeline configuration schematic.

	Active Time (hours)	Bottleneck Type	Active Fraction	Bottleneck Location	Show Details
1	2.20611	Pipe pressure limit	0.20	pipe4_0000	pipe4_0000

Figure 17. Bottleneck Report

The bottleneck report can give more specific detail on the bottlenecks as well. In this instance, there is a pipe pressure limit on Pipe 4 that is active for 20% of the simulation runtime.

Pump Selection

Capacity mode does not necessarily produce an accurate picture of power consumption in the line. Pipelines are typically run near capacity, but without every single pump turned on. To this point, we use Pump Selection mode, which optimizes pump selection while meeting a target throughput at all points in time. To begin, we enter a target throughput in the Model Options.

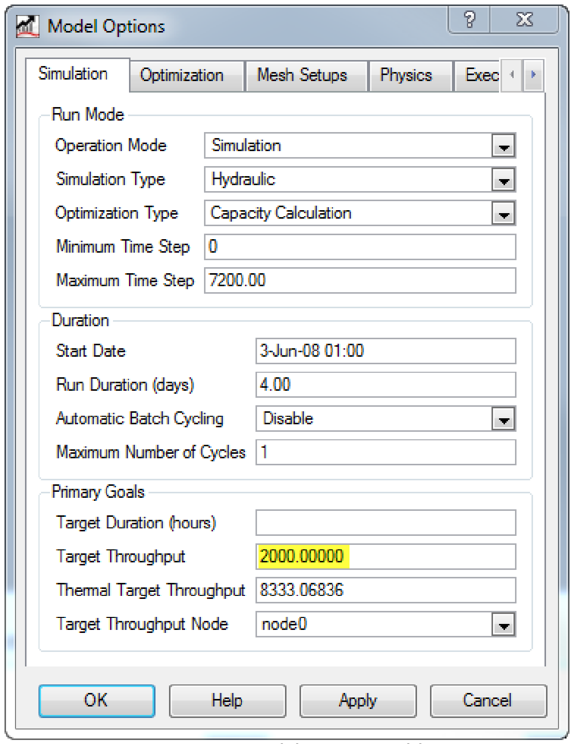

Figure 18. Model Options Table

In this case, we have chosen a target throughput of 2000 bbl/hr.

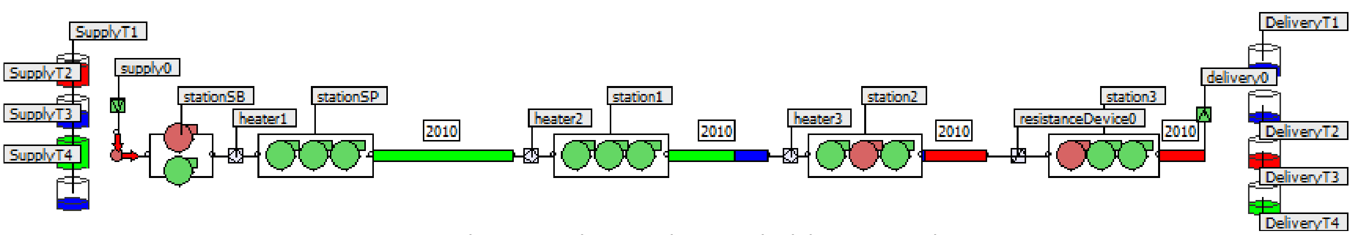

Figure 19. Schematic with Optimal Pump Schedule in Pump Selection

After running Pump Selection, we can immediately see a difference in the pumps selected in a given time step. At many points in the simulation, pumps in Station 2 and Station 3 are turned off because they are not needed to achieve the target throughput. A booster pump in the Supply station remains off for the entire simulation as it is also unnecessary for meeting the target throughput.

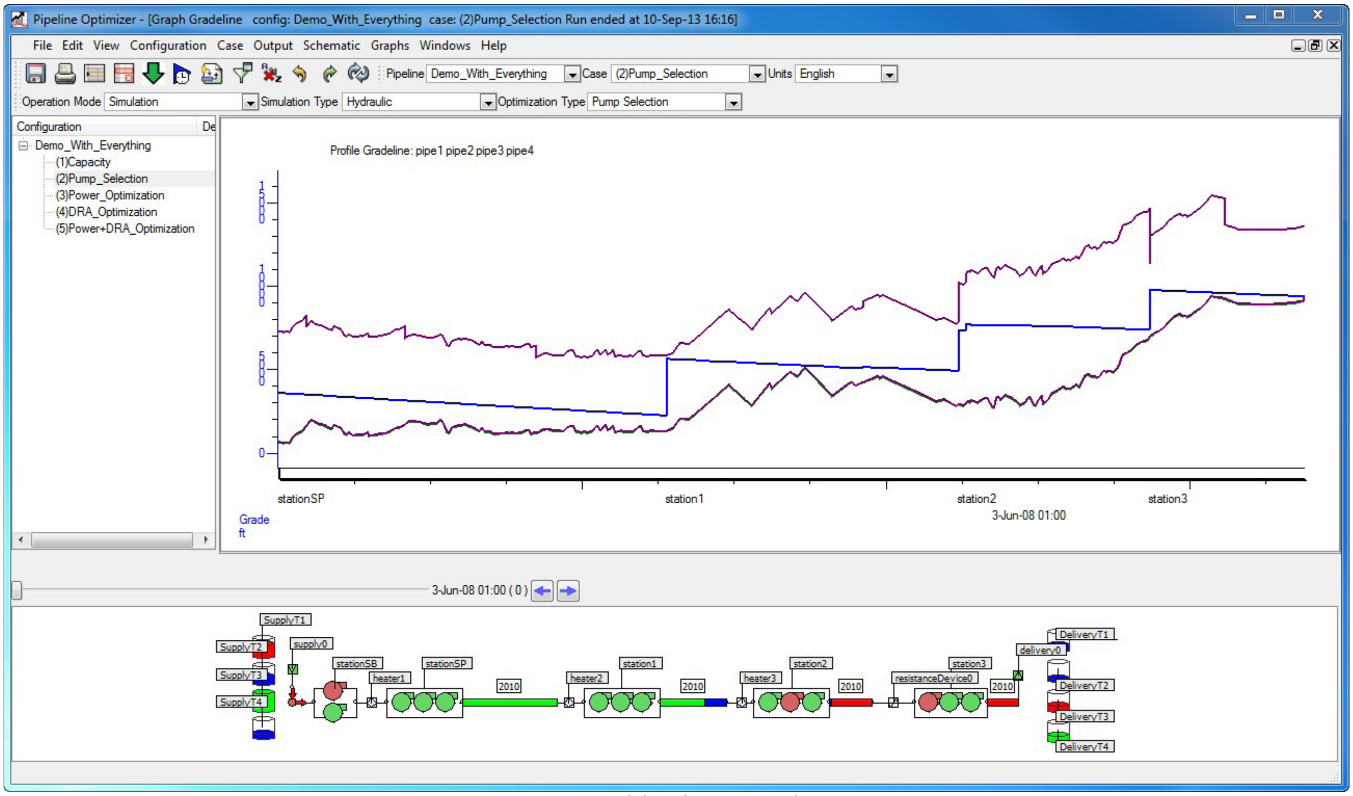

Figure 20. Gradeline for Pump Selection

There is also a difference in the gradeline for the Pump Selection simulation. It is easy to see that the pumps do not need to run at full capacity to comply with the given set points of the system. A look at the flow plot for the simulation shows that, while less interesting than the Capacity flow plot, the target throughput has been met for all points in time, the only exception being during the planned shutdown.

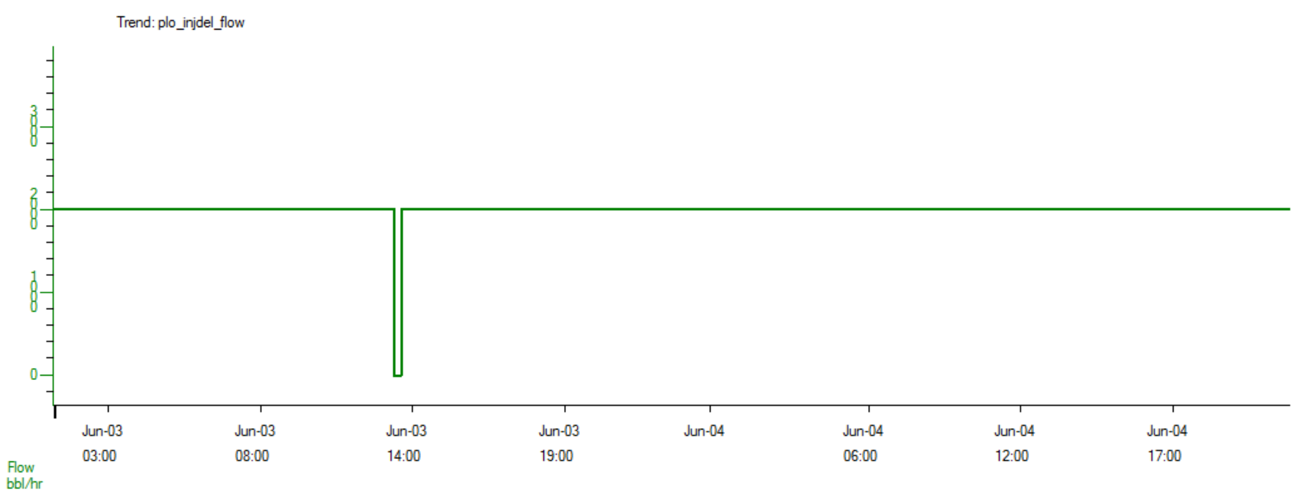

Figure 21. Flow Plot for Pump Selection

Another interesting graph to view is the Pressure Solutions Space (PSS) Chart.

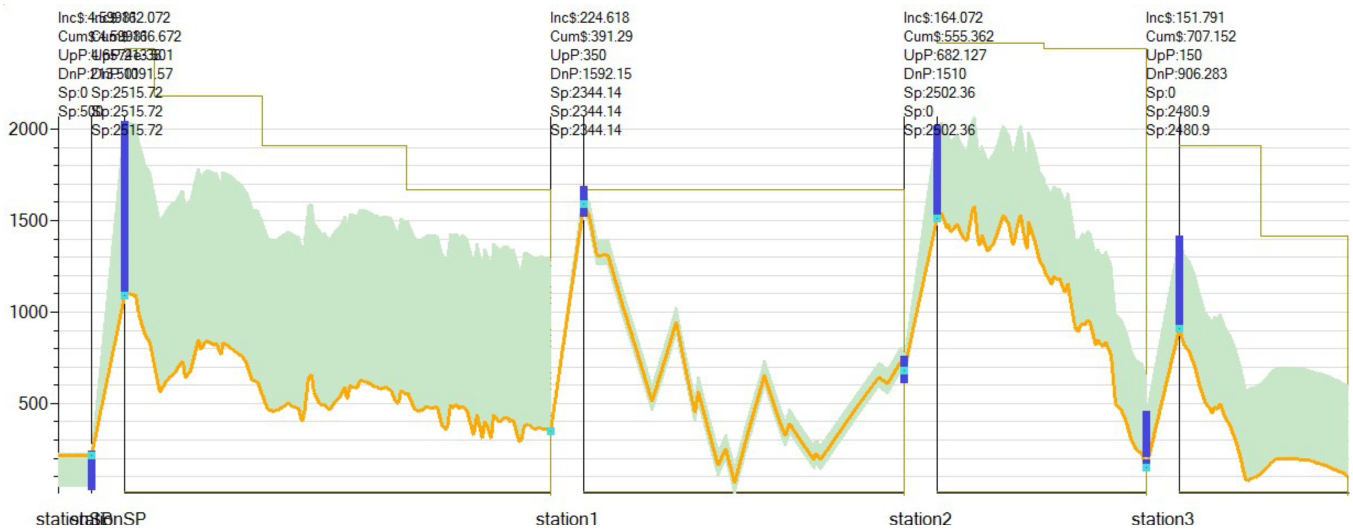

Figure 22. Pressure Solutions Space Chart

The PSS Chart gives a visual explanation of the different possible solutions the optimizer has traveled to achieve lowest cost. In this example, there were many possibilities for travel between Station SP and Station 1, but very few hydraulic possibilities between Station 1 and Station 2 due to the constraints in the system.

Adding up the off- and on-peak energy cost, demand cost, and DRA cost yields a total cost of $58,946.67 for the given setup for a single batch cycle.

Power Optimization

The Power Optimization mode finds the least costly method to run the batch schedule while minimizing power usage. In this mode, the flow rate is allowed to vary in time, while still meeting the target throughput as an average in time.

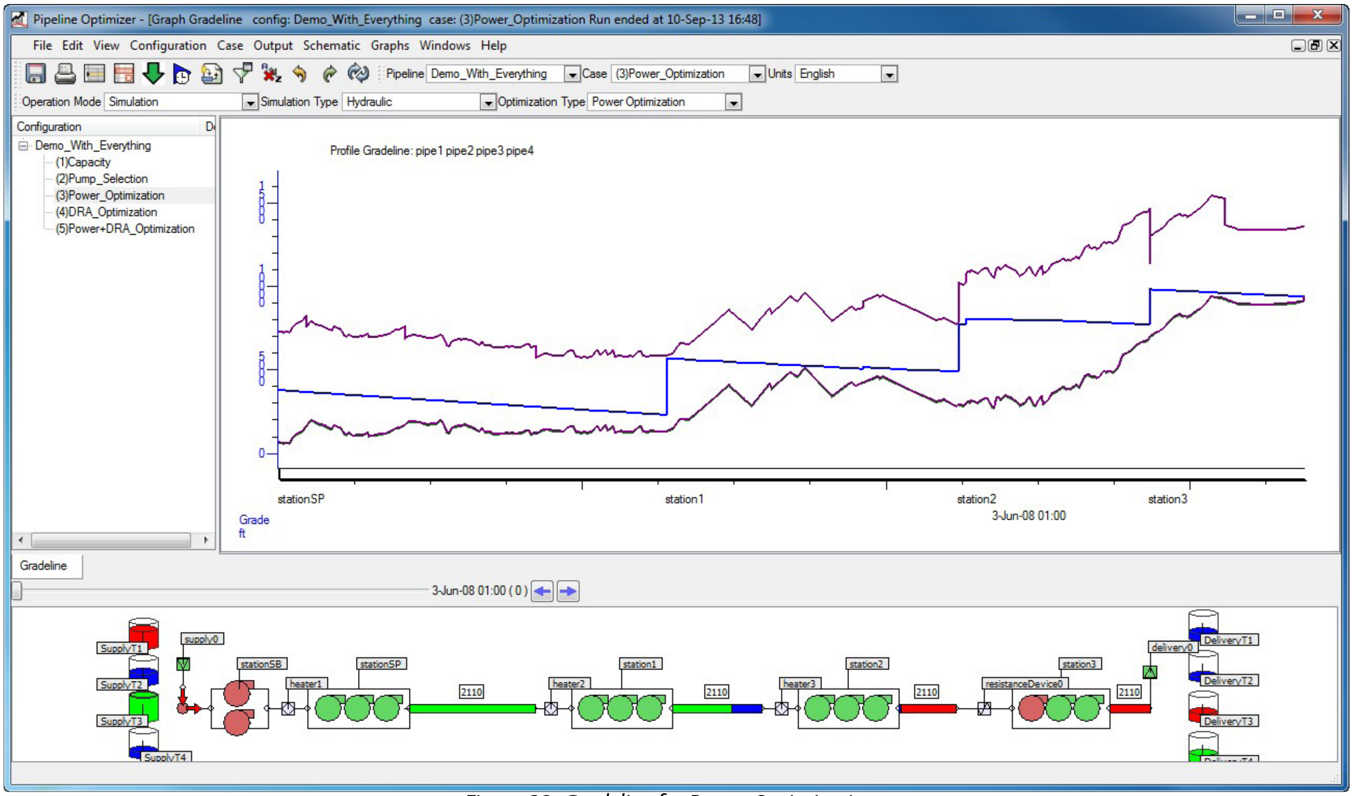

Figure 23. Gradeline for Power Optimization

The gradeline for the Power Optimization is similar to that of Pump Selection; however, there is a significant difference in the power used to reach the same target throughput. We can see in the flow plot the varying flow rates over time, while the target flow rate is still met on average.

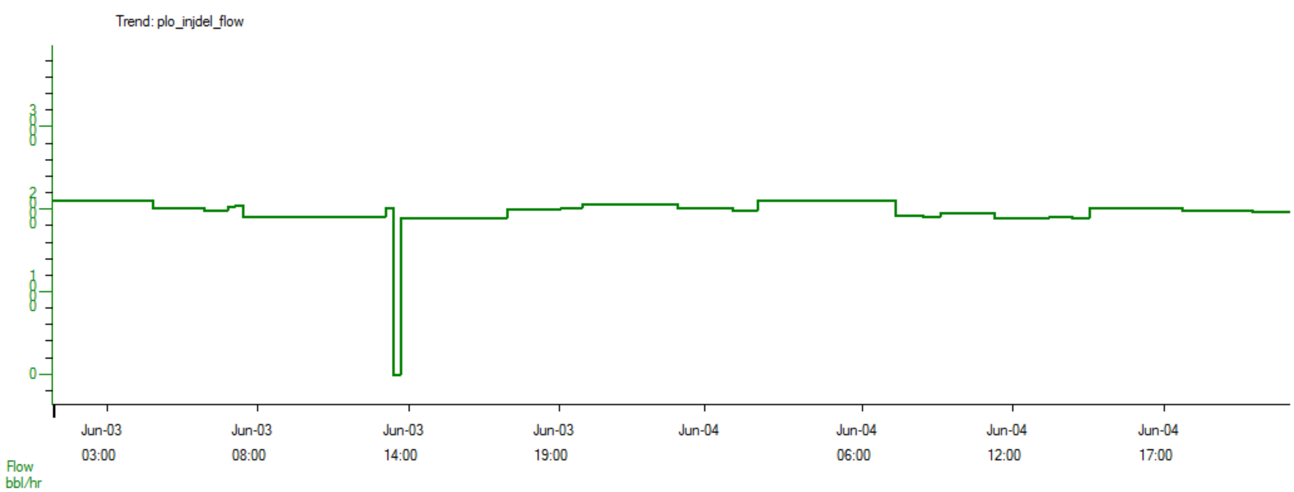

Figure 24. Flow Plot for Power Optimization

DRA Optimization

DRA Optimization mode optimizes the DRA injection rates based on the target flow rate of 2000 bbl/hr.

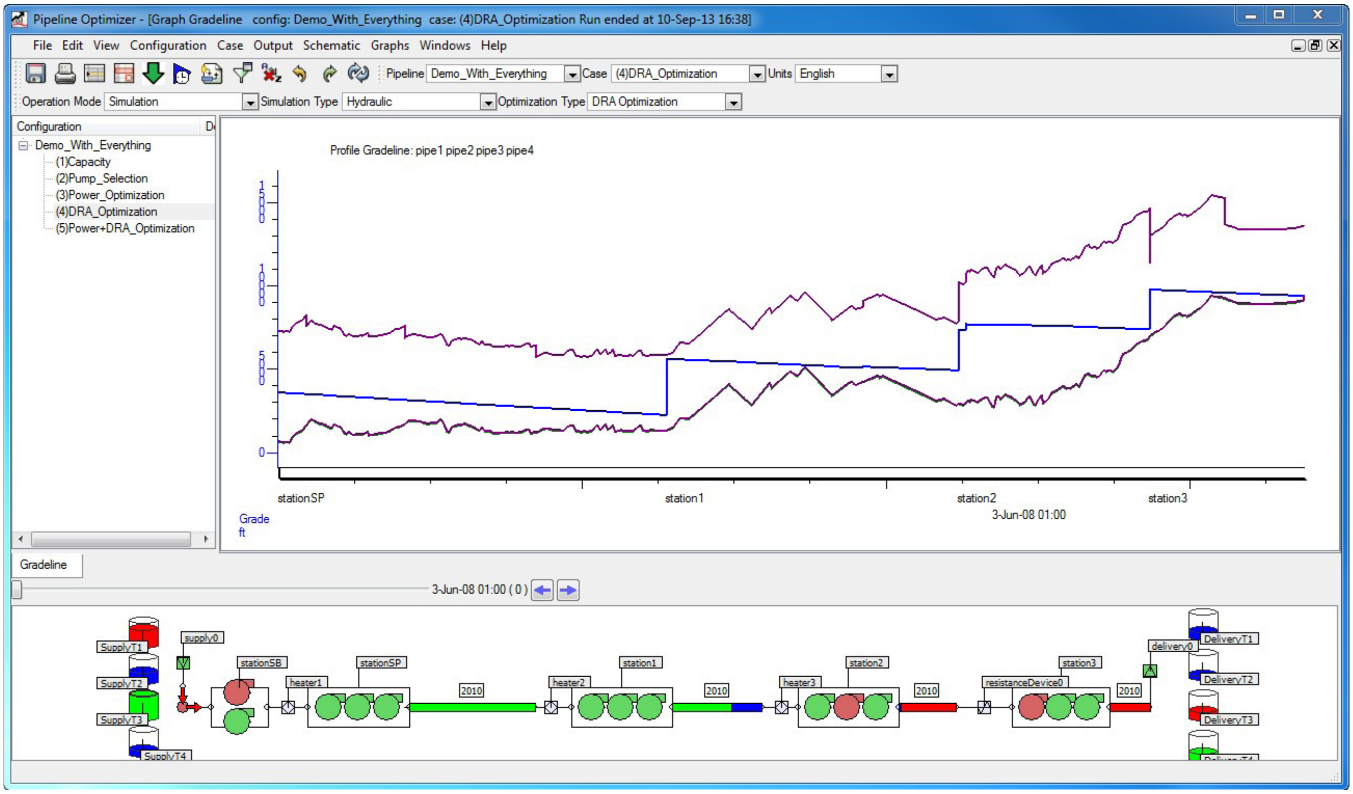

Figure 25. Gradeline for DRA Optimization

The gradeline for the DRA optimization is similar to that of Pump Selection and Power Optimization. In this case, the total cost to run one batch plan, which includes off- and on-peak energy costs, demand costs, and DRA cost, was $57,511.55, compared to the Pump Selection cost of $58,946.67, a savings of 2.4%.

	Station	Batch	Fluid	DRA Type	Injection Mode	Suggested Injection PPM (ppm)	Suggested Injection Rate (gal/day)
1	station1		All Fluid	DRA1	PPM	2.22774	0.00000
2	station2		All Fluid	DRA1	PPM	2.01703	0.00000

Figure 26. DRA Optimized Injection Rules Table

The suggested DRA rules are given in the DRA Optimized Injection Rules table. In this case, the suggested DRA rate for Station 1 is 2.23 ppm and 2.02 ppm for Station 2.

Power Optimization with Suggested DRA Injection Rates

Now that we know the suggested DRA injection rates, we can enforce these rates in a Power Optimization simulation to achieve the lowest cost of the pipeline system.

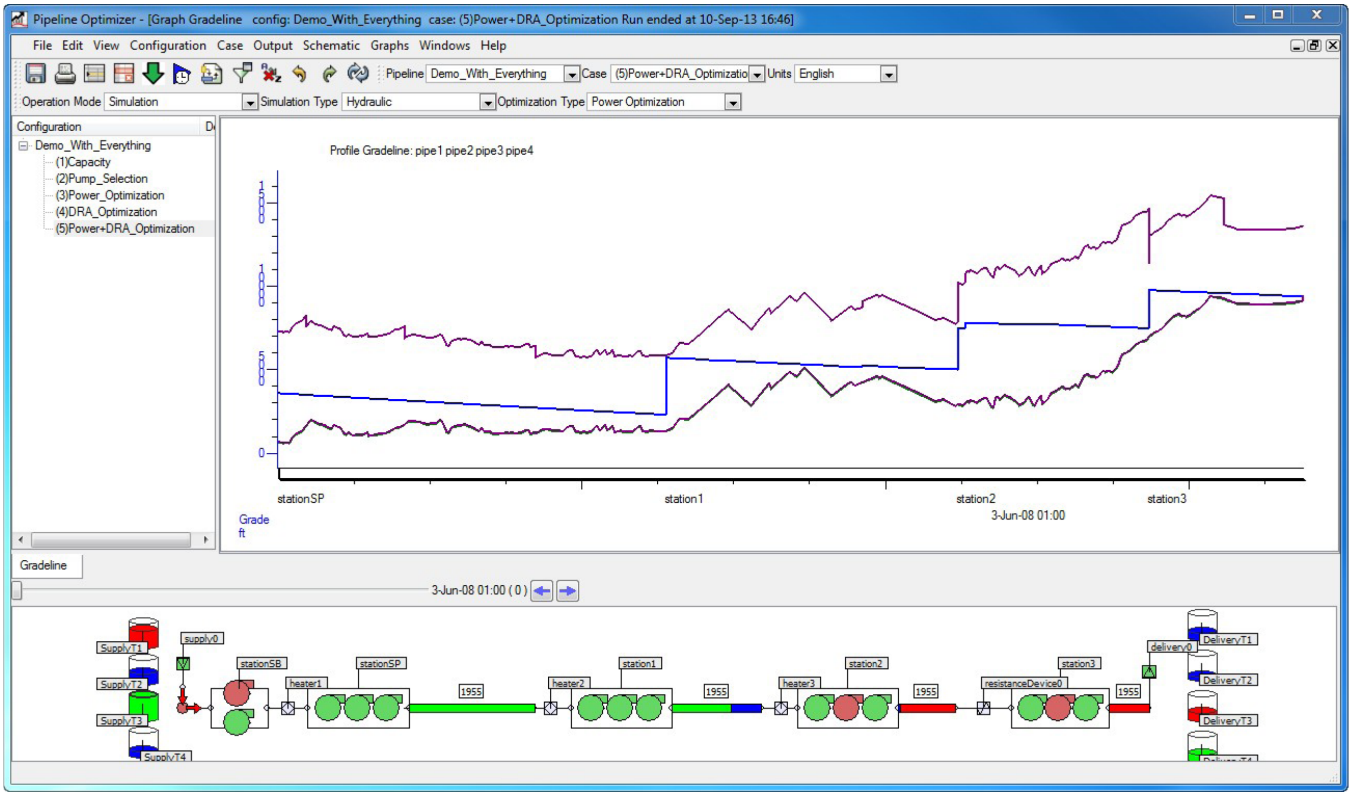

Figure 27. Gradeline for Power Optimization with Suggested DRA Injection Rates

The gradeline is similar again to preview optimization simulations. The flow plot shows a change in the flow pattern for the simulation.

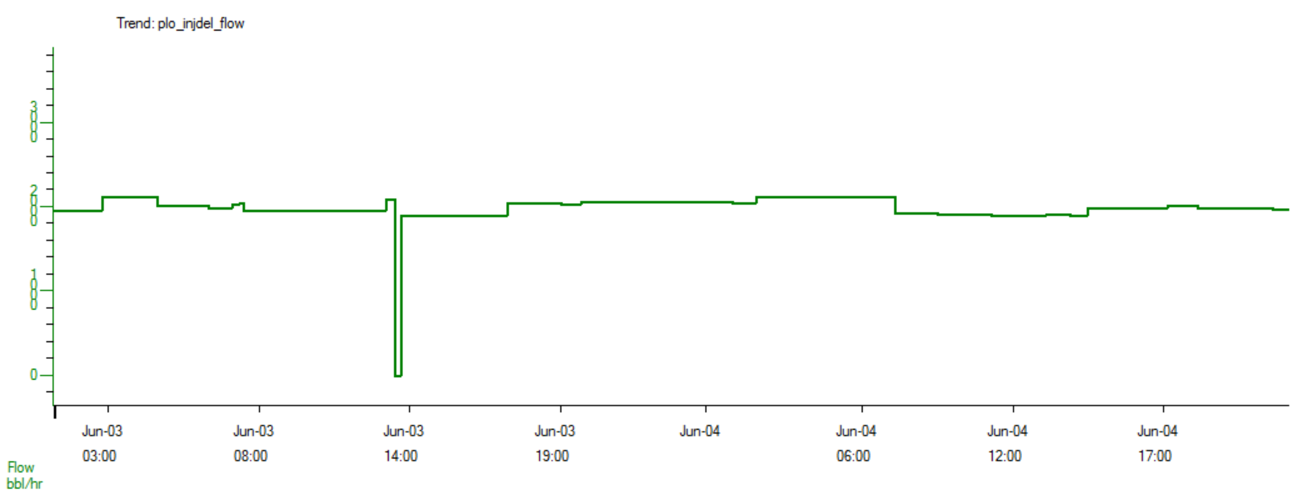

Figure 28. Flow Plot for Power Optimization with Suggested DRA Injection Rates

The gradeline is similar again to preview optimization simulations. The flow plot shows a change in the flow pattern for the simulation.

Simulation	Station Cost	DRA Cost	Total Cost	Savings
Pump Selection	$57,733.24	$1,213.43	$58,946.67	-
Power Optimization	$56,501.18	$1,213.43	$57,714.61	2.1%
DRA Optimization	$57,382.78	$128.77	$57,511.55	2.4%
Power Optimization with Suggested DRA Injection Rates	$57,295.94	$128.77	$57,424.71	2.6%

Table 1. Simulation Cost Results

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