OPERATIONS REPORT ON MSEEL PROJECT

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Objective

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term collaborative field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development.

Through implementation of this project it is expected to demonstrate the best practices to drill, complete and produce a new horizontal well in shale which minimizes the environmental/societal costs while maximizes economic productivity.

This report summarizes the drilling, completion and production activities at the MSEEL field site operated by Northeast Natural Energy (NNE).

Introduction

MSEEL Project

Marcellus Shale Energy and Environment Laboratory aims at achieving a better understanding of the unconventional shale resources through application of advanced technology in drilling, completion, reservoir characterization, production and monitoring of horizontal wells. This research also focuses on societal and environmental impacts of shale gas development.

In order to reach these goals through this project the following actions are implemented.

- Monitoring and documenting shale gas production impacts in a controlled environment
  - ✓ greenhouse gas emissions
  - ✓ local air pollution
  - ✓ water supply and quality
  - ✓ noise and activity
  - ✓ societal impacts
- Employing new technologies
  - ✓ microseismic monitoring
  - ✓ advanced logging
  - ✓ production monitoring
  - ✓ simulation
- Developing new scientific and engineering approaches to apply to multi-disciplinary and multi-institutional natural resource studies

Site selection

The Morgantown Industrial Park (MIP) site was selected to drill Marcellus shale production wells. This site offers a convenient location for researchers to collect the required data and conduct their studies in multiple areas.

Well History

The MSEEL site is operated by Northeast Natural Energy (NNE). Two NNE wells (MIP-4H and MIP-6H) were drilled in 2011 at the MIP site and that data made available as part of the MSEEL project. For the purpose of the MSEEL project two new horizontal wells were drilled from the existing pad (MIP-3H and MIP-5H). The MIP-3H also includes a vertical pilot hole that was cored and logged. The MSEEL project also includes a vertical well scientific observation well (MIP-SW) drilled approximately one half mile to the northwest between the two new horizontal wells for additional subsurface data and microseismic monitoring. The locations of the existing and newly drilled wells are depicted in Figure 1.

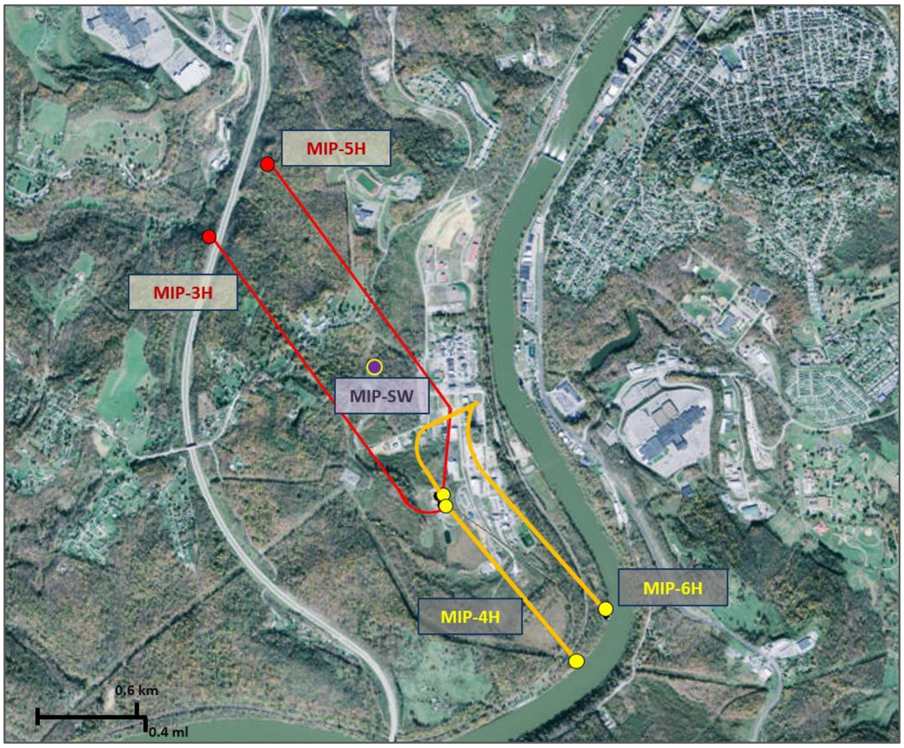


Figure 1. Location of all wells located at MIP site

The detailed description of the drilling, completion and production of each of these wells are presented in the following sections.

1. Drilling

- *Northeast Natural Energy MIP-4H (API 47-061-01622) and MIP-6H (API 47-061-01624)*

NNE MIP-4H was drilled and completed in July 2011. This well is located at the latitude of 39.602285 and longitude of -79.976411. MIP-6H was drilled at latitude of 39.602285 and longitude of -79.976411 and completed in August 2011.

The detailed drilling information is not available for these wells.

- *Northeast Natural Energy MIP 3H (API 47-061-01699)*

The NNE MIP-3H well is located at the latitude of 39.601783 and longitude of -79.976335. Rig up process for drilling started on July 6th 2015. Drilling of the vertical section of the well was accomplished on July 15th at a measured depth of 6,923 feet.

Drilling was resumed on September 18th with drilling the curve section of the well. Drilling the lateral section began on September 19th and completed in two days. The 5.5 inch casing with fiber optic line was run and completed on September 29th. The well was cemented on September 30th and the cement temperature was monitored by Schlumberger. The well measured depth was reported as 13,874 feet. Rig down process started at the end of September.

Different sizes of casing set along the MIP-3H well and their corresponding setting depths are presented in the following table.

Table 1. Casing setting in MIP-3H

Casing	Hole Size (in)	Casing Size (in)	Setting Depth (ft)
Conductor	24	20	50
Surface	17-1/2	13-3/8	507
Intermediate	12-1/4	9-5/8	1,803
Production	8-3/4	5-1/2	13,869

The deviation data from the Kick off Point (KOP) for the well MIP-3H is tabulated in Table 2 and the lateral trajectory is depicted in Figure 2.

Table 2. Deviation from KOP for MIP-3H

Location	MD (ft)	TVD (ft)
KOP*	6,212	6,211
10°	6,450	6,447
20°	6,733	6,716
30°	7,017	6,973
40°	7,302	7,209
50°	7,396	7,276
60°	7,586	7,385
70°	7,776	7,461
80°	7,871	7,479
LP*	8,061	7,483
TD*	13,874	7,413

In Table 2 and Table 3, the starred abbreviation definitions are given below:

- KOP: Kick Off Point
- LP: Landing Point
- TD: Total Depth

Precise wellbore placement during directional drilling was performed utilizing rotary steerable directional drilling tool, in combination with azimuthal gamma tool.

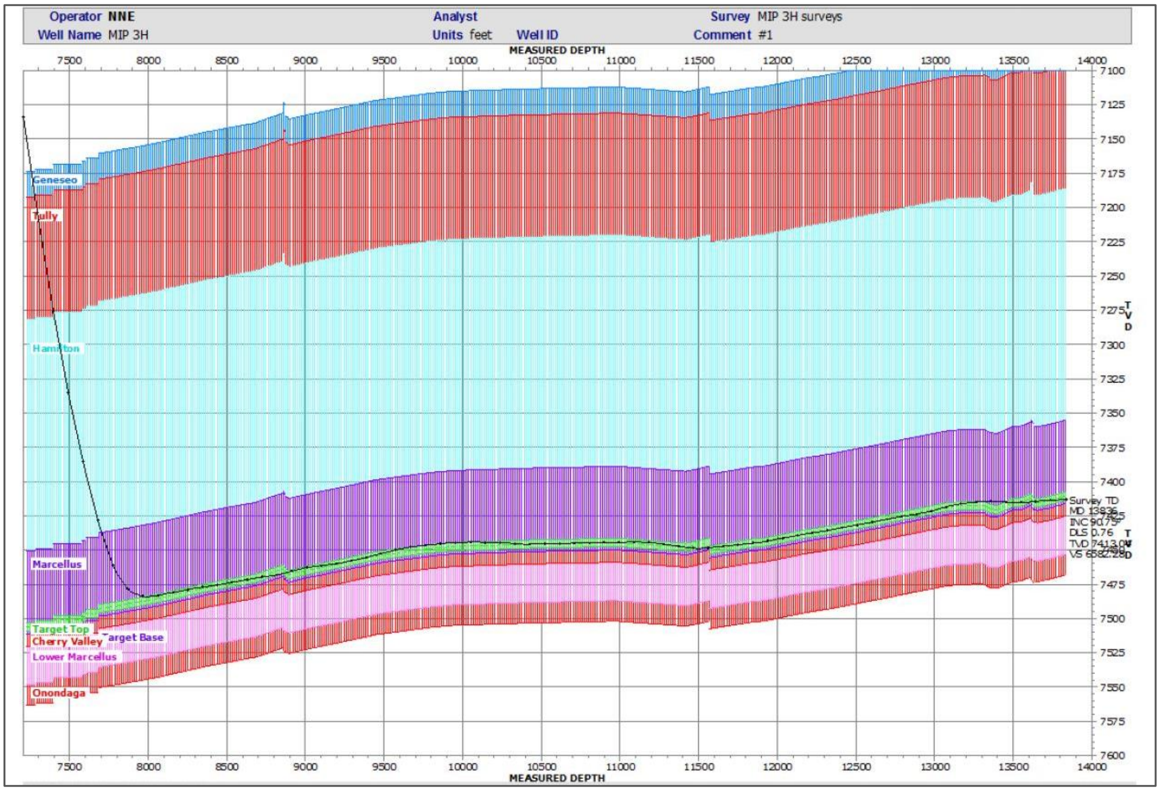


Figure 2. MIP-3H lateral trajectory

- *Northeast Natural Energy MIP 5H (API 47-061-01707)*

Well NNE MIP-5H is located at the latitude of 39.601833 and longitude of -79.976152. The rig up started on June 26th and drilling started on June 28th 2015. The vertical section of the well was drilled to the depth of 6500 feet by July 5th. Then the rig moved to MIP-3H.

The drilling process of this well was resumed on September 10th when drilling initiated on the curve section of the well. The lateral section drilling started on September 11th and completed in two days. The final cementing job was performed on September 16th. The measured depth of this well is reported as 14,455 feet.

In Table 3 the details regarding the casing sizes and their corresponding setting depths are presented.

Table 3. Casing setting in MIP-5H

Casing	Hole Size (in)	Casing Size (in)	Setting Depth (ft)
Conductor	24	20	50
Surface	17-1/2	13-3/8	493
Intermediate	12-1/4	9-5/8	1,781
Production	8-3/4	5-1/2	14,438

The wellbore geometry data of the well MIP-5H from its KOP to the target is presented in the table below and the trajectory is demonstrated in Figure 3.

Table 4. Deviation from KOP for MIP-5H

Location	MD (ft)	TVD (ft)
KOP*	6,472	6,472
10°	6,602	6,600
20°	6,750	6,740
30°	6,900	6,875
40°	7,000	6,955
50°	7,100	7,025
60°	7,250	7,100
70°	7,400	7,170
80°	8,550	7,485
LP*	8,963	7,530
TD*	14,454	7,530

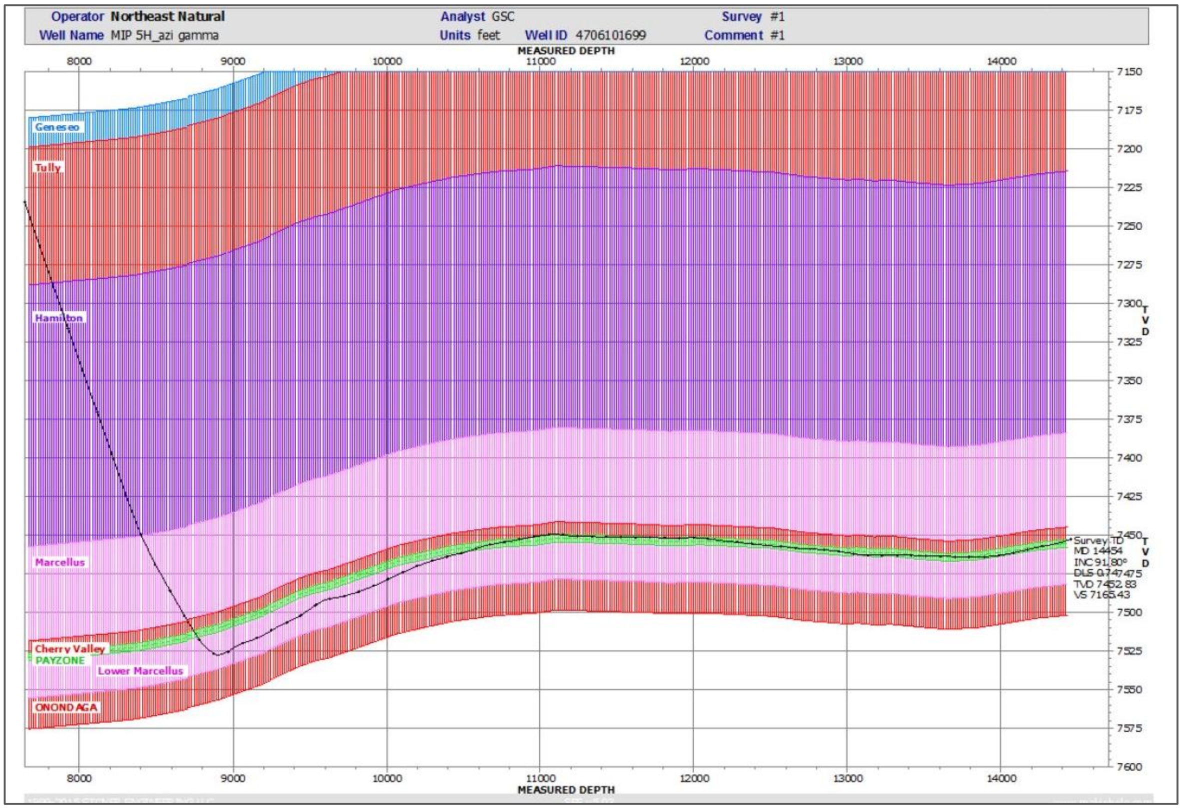


Figure 3. MIP-5H lateral trajectory

- *Well-MIP SW*

This well is a vertical well located at the latitude of 39.608876 and longitude of -79.979920 which was drilled in between the two laterals of MIP-3H and MIP-5H.

The rig up process started on the well location on September 8th 2015. Drilling started on September 13th. At a depth of 530 feet a wireline log was run which was repeated when the hole reached to the depth of 1,845 feet and at the end of drilling at the depth of 7,672 feet. The final depth was reached by September 24th. At the depth of 7,530 sidewall core recovery was started through which 40 cores was recovered in 2 runs. The production casing was run on September 27th which was followed by the final cementing job. The casing setting along this well is presented in Table 5.

Table 5. Casing setting in MIP-SW

Casing	Hole Size (in)	Casing Size (in)	Setting Depth (ft)
Conductor	28	24	50
Surface	17-1/2	13-3/8	500
Intermediate	8-5/8	7	1,800
Production	6-1/2	4-1/2	7,650

The science well was equipped with borehole microseismic. The gathered data is used to assist with the lateral well placement and optimizing hydraulic fracturing design during well stimulation.

2. Coring

- *MIP 3H*

The objective was to collect several cores through Marcellus and Onondaga formations using a conventional coring system. The operational and coring parameters were tailored to maximize coring performance. Coring job was performed on the 3H pilot hole from August 25 to September 1, 2015. During this job a total of 111 feet of core with 4-inch diameter was recovered from a borehole size of 8 3/4” and at the depth of 7445 feet through 7556 feet in the Marcellus Formation. In addition, more than 50 1.5-inch sidewall cores were obtained from this well.

- *Well-MIP SW*

A total of 150 Sidewall 1-inch core samples were collected from different formations along this well. The sampled formations are: Genesseo Shale, Tully Limestone, Mahantango Shale SW, Upper Organic-rich Tongue Marcellus Shale, Lime, Middle Organic-rich Tongue Marcellus Shale, Cherry Valley Limestone, Lower Organic-rich Tongue Marcellus Shale, and Onondaga Limestone.

3. Completion and Stimulation

- *MIP 4H*

Stimulation

Fracturing stimulation on this well started on September 30, and accomplished by November 15, 2011. During the stimulation job a total of 11 stages of hydraulic fracturing were implemented along the horizontal section of the well. Stimulation was performed based on predetermined constant parameters for all stages which are presented in Table 6.

Table 6. Stimulation parameter for MIP-4H

Fluid	Slick Water
Clusters per Stage	5
Shot Density (s/ft)	5
Shots per Cluster	10
Stage Length (ft)	350

- *MIP 6H*

Stimulation

Fracturing stimulation on this well started on October 1, 2011. The stimulation of the last stage (stage 8) was accomplished by October 11, 2011. The stimulation parameters which are presented in Table 7 are kept constant in different stages of stimulation process.

Table 7. Stimulation parameter for MIP-6H

Fluid	Slick Water
Clusters per Stage	5
Shot Density (s/ft)	6
Shots per Cluster	10
Stage Length (ft)	300

- *MIP 3H*

Well Preparation and Logging

Wireline Perforating Platform (WPP) was set up and a wire line log was run on MIP-3H on October 11, 2015. An Ultra Sonic Cement Bond log was run along the well. On October 13, pressure test was performed by increasing the pressure up to 9500 psi to ensure the casing integrity. Rig up process for coiled tubing unit was completed on October 15, 2015 and cleanup process was performed subsequently.

Perforation and Stimulation

On November 6, the frac and flowback iron was set up at the well site. A pressure test followed by DFIT (Diagnostic Fracture Injection Test) was performed on this well. Subsequently, perforation and hydraulic fracturing was implemented at the designated positions for stage 1 through stage 28. During this process each stage is perforated, fracked and plugged in order to be isolated and then the same procedure is repeated for the next stage. The stimulation job was accomplished for MIP-3H on November 16, 2015.

Engineered completion and stimulation design was implemented on this well, with variable cluster design for 28 stages. High resolution data received from the advanced measurement tools (fiber optic and microseismic data) were utilized for hydraulic fracturing design of this well.
The main challenge in this process is to ensure optimal lateral coverage while improving efficiency and EUR and the goal is to predict and optimize cluster efficiency through performance monitoring. In order to reach this goal the stage placement were performed based on rock properties.

Completion parameters for each stages of this well based on engineered design is summarized in Table 8. In section D, slickwater & Viscoelastic Stimulation Fluids (Sapphire VF®) was used for the purpose of improving well performance while reducing water usage. This method provides better proppant transport and fracture cleanup compared to fracturing stimulations in which conventional linear gel or slickwater formulations are used.

Table 8. Completion and stimulation parameters for MIP-3H

Section		Stage	Cluster Count	Average Mid-perforation Depth (ft)	Total Shot Count	Shot Density (shot/ft)	Stage Length (ft)	Pump schedule
E	Best Practice Applied	28	4	7,828	40	6	191	A
		27	4	8,017	40	6	184	A
		26	5	8,220	40	6	225	A
		25	5	8,449	32	6	231	A
		24	5	8,678	30	6	222	A
		23	5	8,911	40	6	237	C
		22	5	9,138	40	6	220	C
D	Saphire VEF	21	5	9,363	40	5	218	D
		20	5	9,596	40	5	240	D
C	SLB Engineered Completion	19	4	9,802	32	6	180	C
		18	4	9,981	32	8	180	C
		17	4	10,115	32	6	181	C
		16	4	10,343	26	6	178	C
		15	4	10,526	26	6	186	C
		14	5	10,731	30	6	228	A
		13	5	10,956	30	6	230	A
B	NNE 75% 100-Mesh	12	5	11,186	50	5	231	B
		11	5	11,416	50	5	232	B
		10	5	11,648	50	5	227	B
		9	5	11,878	50	5	237	B
		8	5	12,103	50	5	222	B
		7	5	12,328	50	5	224	B
A	NNE Standard 35% 100-Mesh	6	5	12,557	50	5	245	A
		5	5	12,792	50	5	234	A
		4	5	13,025	50	5	230	A
		3	5	13,259	50	5	238	A
		2	5	13,489	50	5	223	A
		1	5	13,720	50	5	233	A

As presented in the table above for different stages of this well four pump schedules, three shot densities and two cluster configurations have been designed. Furthermore, the shot orientation is also varying within different clusters and different stages.

For different stages of this well the fracture gradient were recorded which in general has the following basic statistics.

- Average: 1.25 (psi/ft)
- Min: 1.2 (psi/ft)
- Max: 1.3 (psi/ft)

- *MIP 5H*

Well Preparation and Logging

A Cement Bond Log was run to verify the marker joint at the depth of 6508 feet and down to the depth of 7250 feet (67 degrees) on October 10, 2015. Casing pressure test was performed on October 15 increasing the pressure up to 9500 psi and subsequently the borehole clean-up process was completed.

Perforation and Stimulation

On October 29 the frac and flow back equipment were set up and the required pressure tests were implemented. The first perforation was performed for stage 1, followed by fracture stimulation. Then this section was plugged and the same process was repeated until stage 30 was completed. Fracture stimulation operations were completed on November 6th for MIP-5H.

Despite the varying stimulation parameter selection for well MIP-3H, these parameters do not vary within different stages in MIP-5H and instead the constant values presented in Table 9 were applied to perform the stimulation job in this well.

Table 9. Stimulation parameter for MIP-5H

Pump Schedule	A
Fluid	Slick Water
Clusters per Stage	5
Cluster Spacing	40'
Shot Density (s/ft)	6
Shots per Cluster	8

The average mid-perforation depth and stage length for different stages of this well are reported in Table 10.

Table 10. Perforation and stimulation parameters for MIP-5H

Stage	Average Mid-perforation Depth (ft)	Calculated Stage Length (ft)
30	8522.6	198
29	8722.2	198
28	8919.6	198
27	9117	196
26	9315.2	198
25	9514.2	206
24	9713.8	198
23	9910.6	198
22	10109.2	198
21	10305.8	200
20	10503.6	198
19	10702.2	198
18	10900.2	198
17	11096.4	198
16	11296.2	198
15	11494.2	198
14	11692.2	198
13	11890.2	198
12	12088.2	198
11	12286.2	198
10	12484.2	198
9	12682.2	198
8	12881	198
7	13078.2	198
6	13277.2	203
5	13475	193
4	13672.2	198
3	13870.2	198
2	14068.2	228
1	14207	191

The fracture gradient were recorded for different stages of this well which in general has the following basic statistics and does not have a notable variation from those of MIP-3H.

- Average: 1.24 (psi/ft)
- Min: 1.14 (psi/ft)
- Max: 1.36 (psi/ft)

Fracture Stimulation Summary for MIP-4H, MIP-6H, MIP-3H and MIP-5H

In Table 11 some of the stimulation parameters are compared for the four MIP wells.

Table 11. Summary of stimulation data for MIP wells

Stimulation parameters	MIP-4H	MIP-6H	MIP-3H	MIP-5H
Total Stage	11	8	28	30
Average Fluid (Bbls/Stage)	9,099	9,108	9,054	7,906
Total Proppant Placed (lbs)	4,453,920	3,222,295	11,257,640	11,088,100
Total Completed Interval (ft)	3,782	2,342	6,058	5,784
Total Average Proppant (lbs/ft)	1,178	1,376	1,858	1,917
Total Average Proppant (lbs/stg)	404,902	402,787	402,059	369,603

Special Operation and Measurement Tools

1. Microseismic

Objective

The main objectives of running microseismic can be mentioned as follows:

- understanding the complexity of the stimulation
- estimating the stimulated reservoir volume
- obtaining information regarding the vertical and horizontal progression of the frac as it advances
- avoiding over stimulation or under stimulation of the well by maintaining the stimulation within zone
- having a better understanding of the stages, stage sizes and well interaction

Operation Detail

The seismic array was installed along the Science Well (MIP-SW) which is located between the two laterals of MIP-3H and MIP-5H and it was used to record the microseismic events during well stimulation. The Hydraulic Fracturing Monitoring (HFM) through microseismic was started on October 27th 2015 at the beginning of stage 1 of MIP-5H through stage 30 of this well. Then it was resumed at the beginning of stage 7 of well MIP-3H and ended when stage 28 of this well was completed on November 16, 2015. During this operation a total of 52 out of 58 stimulation stages were monitored and evaluated.

Figure 4 demonstrates the location of the stimulated laterals as well as the monitoring well (MIP-SW) where the geophones were located to record the microseismic events.

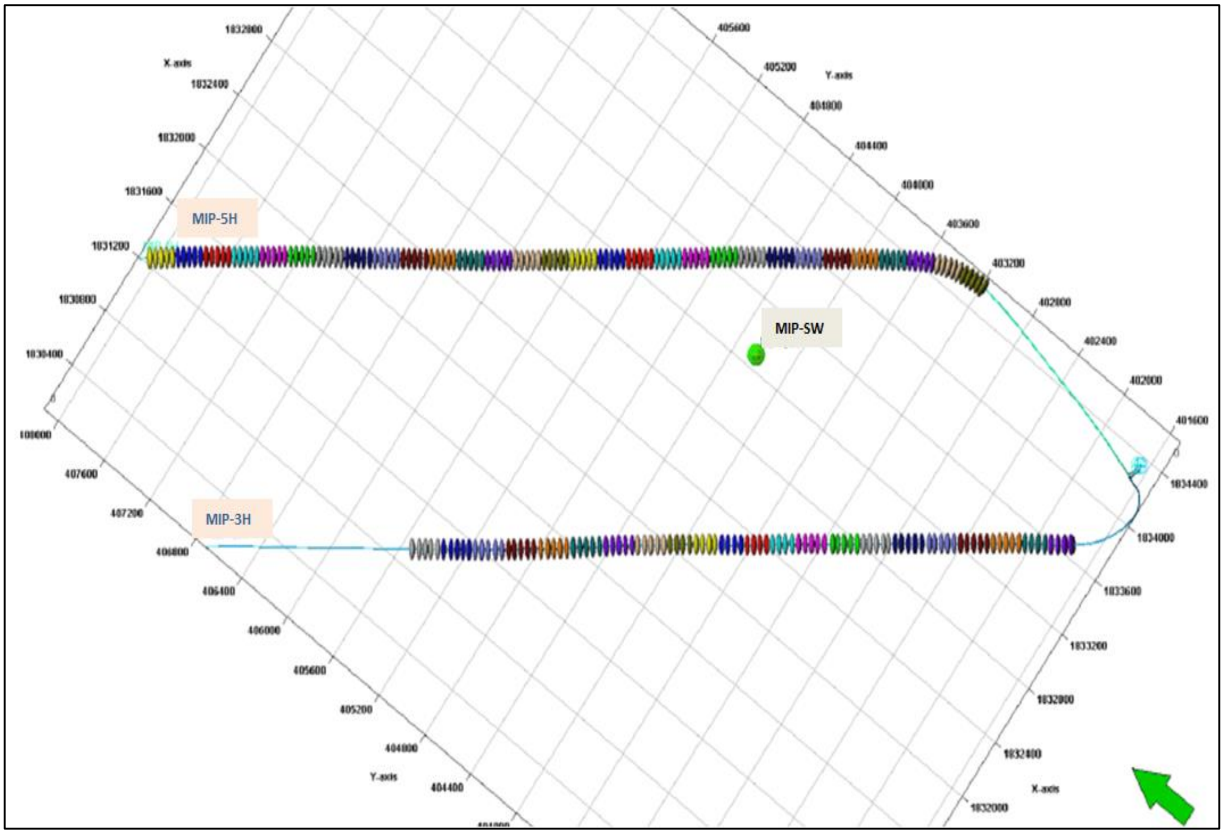
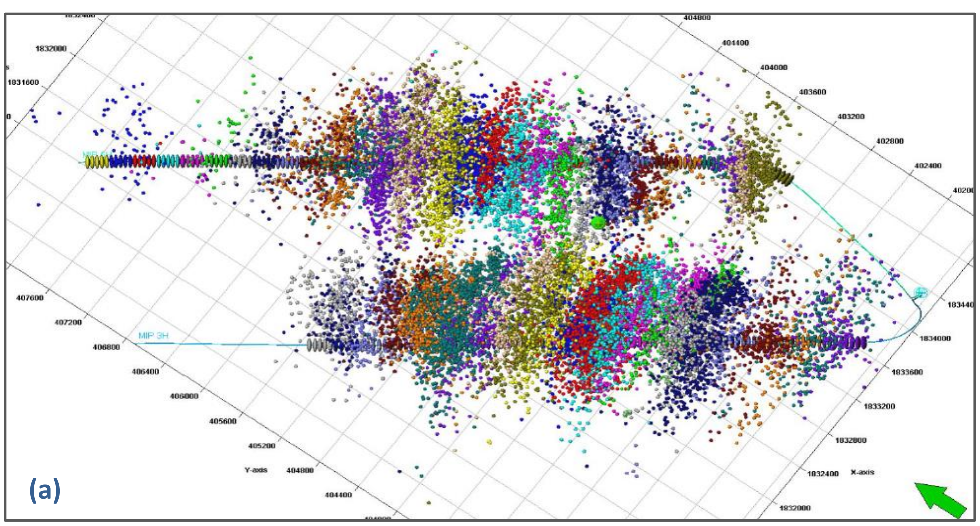


Figure 4. Location of the stimulated wells and the monitoring well (Ref. Schlumberger StimMAP Evaluation Report)

To acquire the microseismic data, 12 VSI (Versatile Seismic Imager) geophones were installed along the science well at the depth of 6310 feet (MD) to the depth of 7110 feet with 100 foot spacing.

The following figure depicts the recorded microseismic events after the stimulation operation was competed.



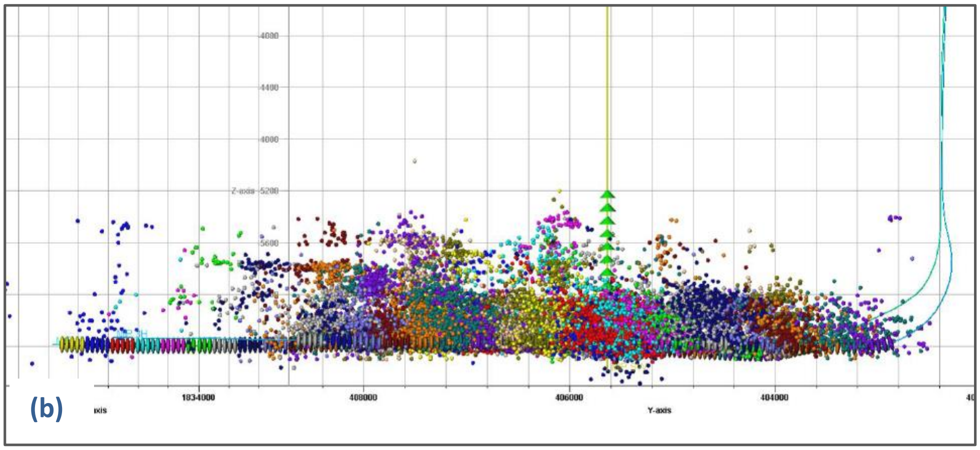


Figure 5. Recorded microseismic events at the stimulated location, (a) top view, (b) side view (Ref. Schlumberger StimMAP Evaluation Report)

Evaluation

For each stage, microseismic dimensions (length, height and width) and azimuth were calculated. Length and azimuth are based on the longest horizontal dimension within the generated cloud; height and width are oriented with respect to the length. The microseismic volume was calculated based on the event density.

Result and Conclusion

The followings were observed and concluded through the microseismic event study:

- Overall fracture geometries do not vary significantly.
- More microseismic events were recorded for MIP-3H compared to those of the MIP-5H. The reason is that the stimulation of MIP-5H was performed first and therefore the stress region was intact. However, when stimulation started on MIP-3H the fracturing job on MIP-5H has already altered the stress region which caused an increase in the microseismic activity of MIP-3H.
- All stages appear to have entered the formation based on the planned perforation interval for both laterals.
- Overall event complexity indicates higher stress anisotropy when compared to other unconventional plays.
- Higher amounts of 40/70 sand resulted in larger fracture geometries.
- Higher viscosity fracturing fluid leads smaller fracture height growth, although it delivered better proppant transport properties.
- The large fracture height growth is an indication of low stress barriers.
- Microseismic, lateral logs, and pumping data were used to create a calibrated DFN model with synthetic microseismic.

The final stages in two laterals of MIP-3H and MIP-5H and the way they have penetrated the shale formation is depicted in Figure 6.

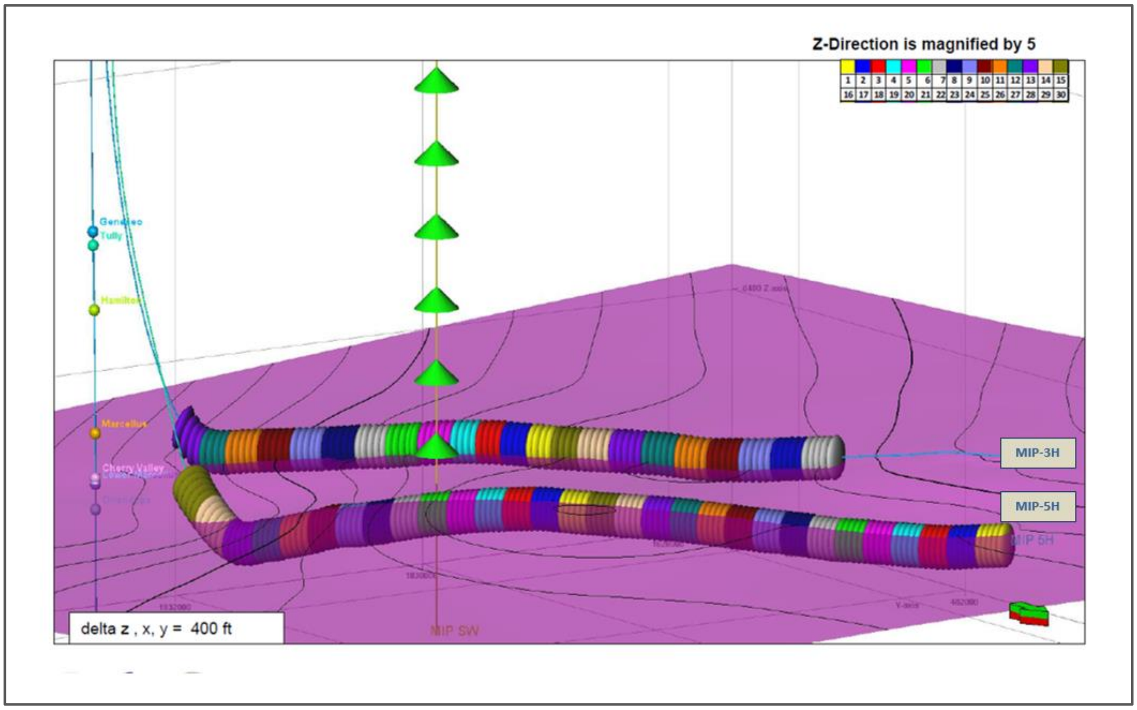


Figure 6. Final hydraulic fracturing stages of MIP-3H and MIP-5H and their extension into the shale formation (Ref. Schlumberger stimulation evaluation Presentation)

The average parameters of fracture geometry for the two laterals were estimated through microseismic interpretation. Theses parameters are presented in Table 12.

Table 12. Fracture parameters estimated through microseismic interpretation for MIP-3H and MIP-5H

Stimulation parameters	MIP-3H	MIP-5H
Average Half Length (ft)	784	618
Average Height (ft)	496	540
Average Azimuths	N76E	N63E

2. Fiber Optic

A permanent Neon Fiber Optic cable was installed in well MIP-3H. Distributed Acoustic Sensing (DAS) and Distributed Temperature Sensing (DTS) fiber optic device measures and records high resolution energy band amplitude and temperature data along the well, which can be considerably valuable for the purpose of well surveillance and long term performance monitoring of the well bore as well as the reservoir.

Overview

Application of this technology in multi-stage hydraulically fractured wells during stimulation and production has increased in recent years. Multiple different deployment options is available for this technology. Some of them can be used for temporary monitoring and decision making of re-fracking a well or as an onsite confirmation of stimulation which can be used with PLT or coiled tubing. Others can be used permanently for long term monitoring which are deployed behind the casing.

The resolution of the data collected through distributed measurement tools depends on two parameters of gauge length and spatial sampling distance and therefore these are two essential characteristics of the fiber optic tool.

Objective

Employing fiber optic distributed measurements can be significantly beneficial in multiple stages of well completion, post completion and production of a well. The main application of fiber optics at each of these stages are listed below.

- Completion and stimulation phase
  - ✓ fracturing monitoring (fracture height and position)
  - ✓ optimization of spacing
  - ✓ stage confirmation
  - ✓ monitoring breakout during fracture stimulation
- Post completion/clean up phase
  - ✓ monitoring kick-off post fracture stimulation
  - ✓ monitoring deployment of any subsequent stimulation fluids (acids, diverters, etc.)
- Production phase
  - ✓ identifying best producing zones
  - ✓ monitoring fluid changes and reservoir depletion over time
  - ✓ optimizing completion design and drainage strategy

Operation Details

The DTS/DAS hardware consists of hDVS (Distributed Vibration Sensing) system which provides options for energy band amplitudes as well as seismic and microseismic options, a DTS system and a standalone solar powered box for remote applications and wireless data transfer.

Since hDVS and DTS have a time lag with respect to the fracture stimulation data, a time shift is implemented to align the data. The following figure demonstrates the operation log aligned with the data recorded by distributed sensing system during hydraulic fracturing event of stage 21 of MIP-3H.

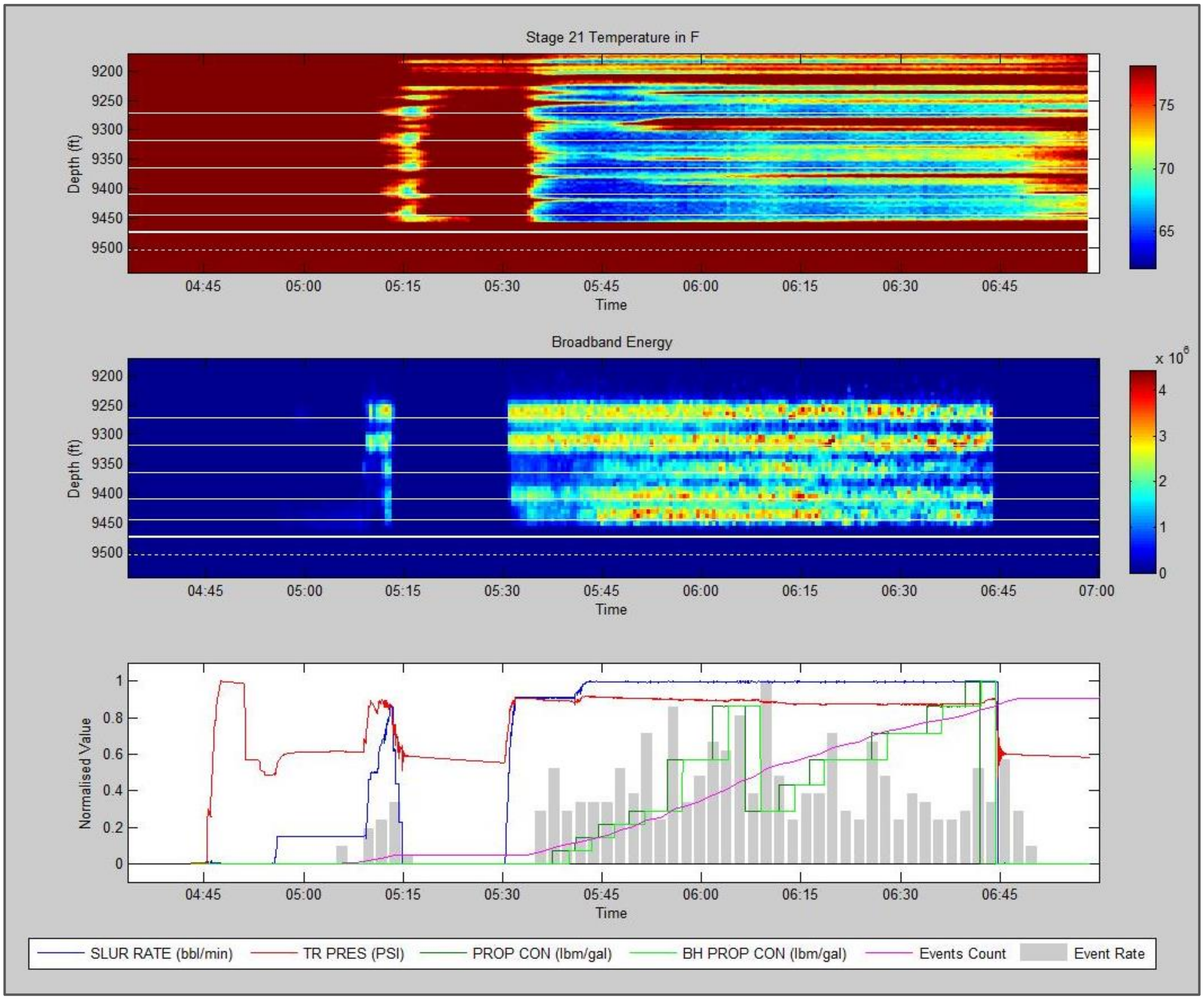


Figure 7. Time aligned plot of operation log and distributed sensing data (temperature and energy) during a fracking job

In order to apply all available data in optimized hydraulic fracturing design, it should be noted that many parameters affect the fracture initiation. These parameters are generally categorized as formation properties and design parameters. Some of the parameters under each category can be named as follows.

- Formation properties
  - ✓ physical properties: such as porosity, permeability and TOC
  - ✓ geomechanical properties: such as Young's modulus, Poisson's ratio, tensile strength, compressive strength and In-situ stress
- Design parameters
  - ✓ Well bore configuration: such as hole diameter, deviation and azimuth
  - ✓ Perforation design: such as phasing, length, shot count
  - ✓ Stimulation parameters: pump rate, treating pressure, fluid volume and amount of proppant

Distributed sensing system plays and important role in monitoring and evaluation of the perforation performance. During the hydraulic fracturing process of all stages of MIP-3H the perforation injection was observed in real-time which illustrates how clusters are becoming active, inactive and in some occasions they become reactivated as other stages are progressed.

In order to design the stimulation parameters for MIP-3H the horizontal section of this well was divided into 5 sections (A to E as presented in Table 8). Identification of these sections was based on the log data evaluation of this section as shown in Figure 8.

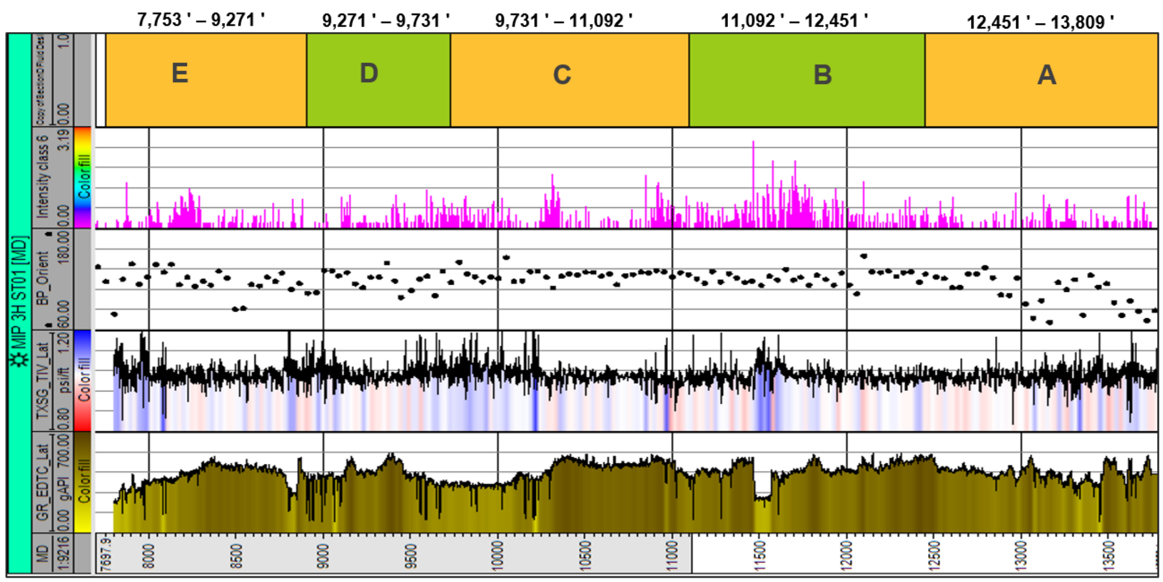


Figure 8. MIP-3H log data evaluation and section identification for stimulation (Ref. Schlumberger presentation on fiber optic analysis)

The first section of the lateral (stages 1 through 6) was stimulated based on a predetermined schedule with constant parameters such as 5 clusters per stage and shot density of 10 shots per foot. The second section (stages 7 through 12) was also stimulated applying similar constant perforation parameters and a different pump schedule. Observing all the data collected during the stimulation process of these two sections through distributed sensing system as well as other sources, engineered design was implemented for stimulation of other sections (C, D, and E).

The engineered stages which have less than 5 clusters, or a shot density less than 10 (shot/foot) are called "Limited Entry" design which are implemented based on estimated break down pressure.

Result and Conclusion

From analysis of different stimulation design and the outcome of the stimulation job on different stages of MIP-3H the following can be concluded.

- Fiber optics DTS and hDVS plays an important role in monitoring and evaluation of perforation performance.

- The average match between the predicted and actual perforation efficiency is about 75%. The stages with limited entry have a higher match percentage.
- Limited entry designs show more uniform activity distribution across the treatment stage (such as more equal distribution of slurry) compared to geometric design.

Well Event Timeline

The timeline in Figure 9 demonstrates different operations performed on MIP-3H, MIP-5H and MIP-SW from the beginning of drilling to production.

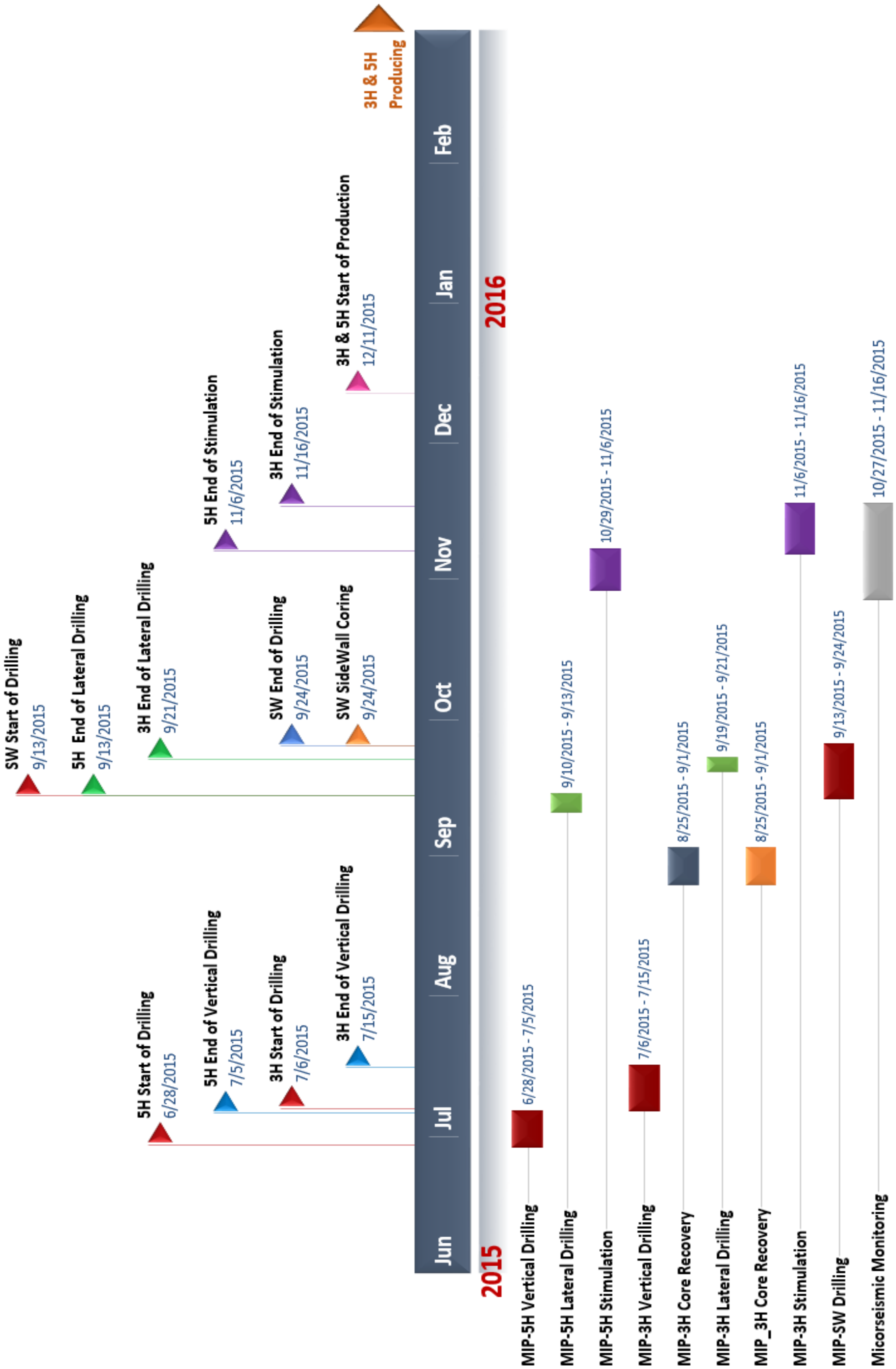


Figure 9. Well event timeline for MIP-3H and MIP-5H

Production

Production Operation and Monitoring

The produced gas from the well pad is conducted to the Gas Production Unit where water is separated from the stream and the produced gas passes through a metering system and is sent to the sales pipeline. The produced water is stored in tanks on the well site.

All facilities are installed according to industry standards with appropriate safety system. Well pressure and flow rates are constantly recorded and monitored in order to ensure proper facility operation.

Production Rates

On December 11, 2015 production started from the MIP-3H and MIP-5H.The following plots shows the production and cumulative production of the two laterals from the start of production till end of May 2016. Production is constrained by the maximum consumption of the City of Morgantown.

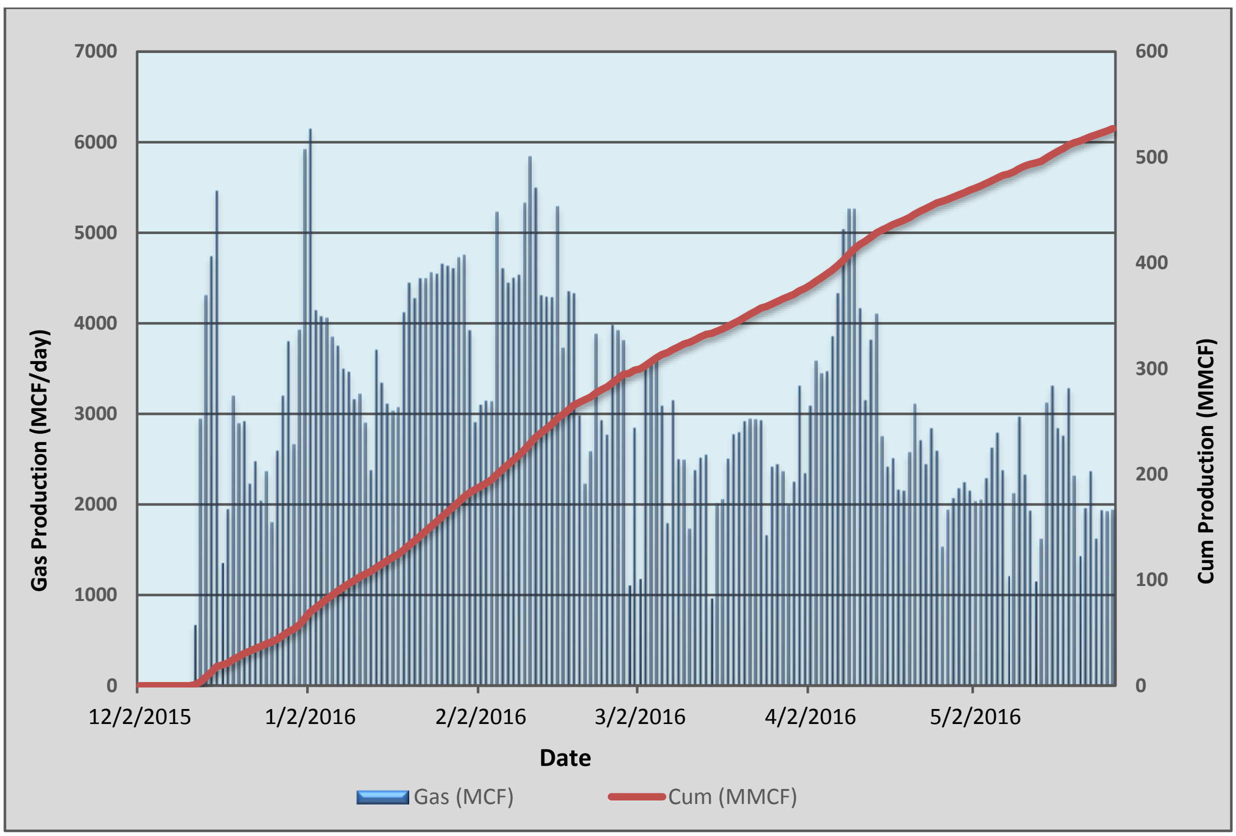


Figure 10. Gas rate and cum gas production of MIP-3H

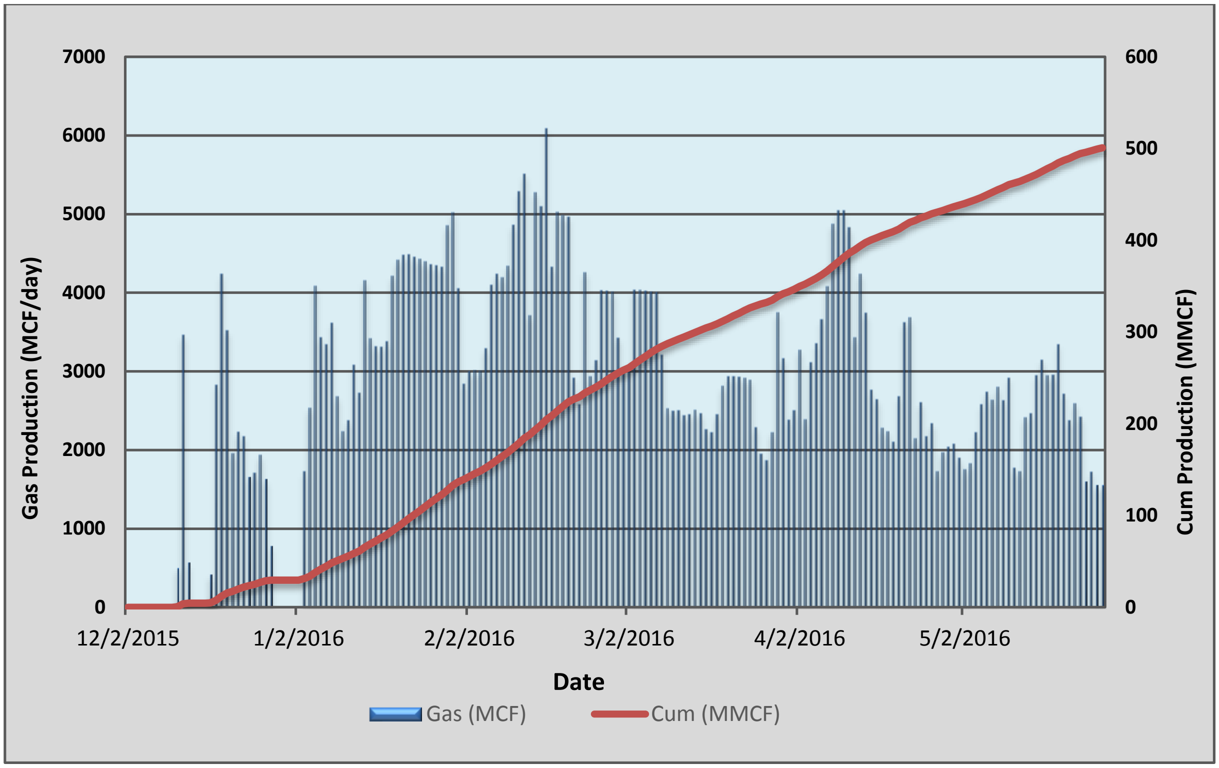


Figure 11. Gas rate and cum gas production of MIP-5H

The following plot compares the two laterals' production from December 2015 to the end of May 2016.

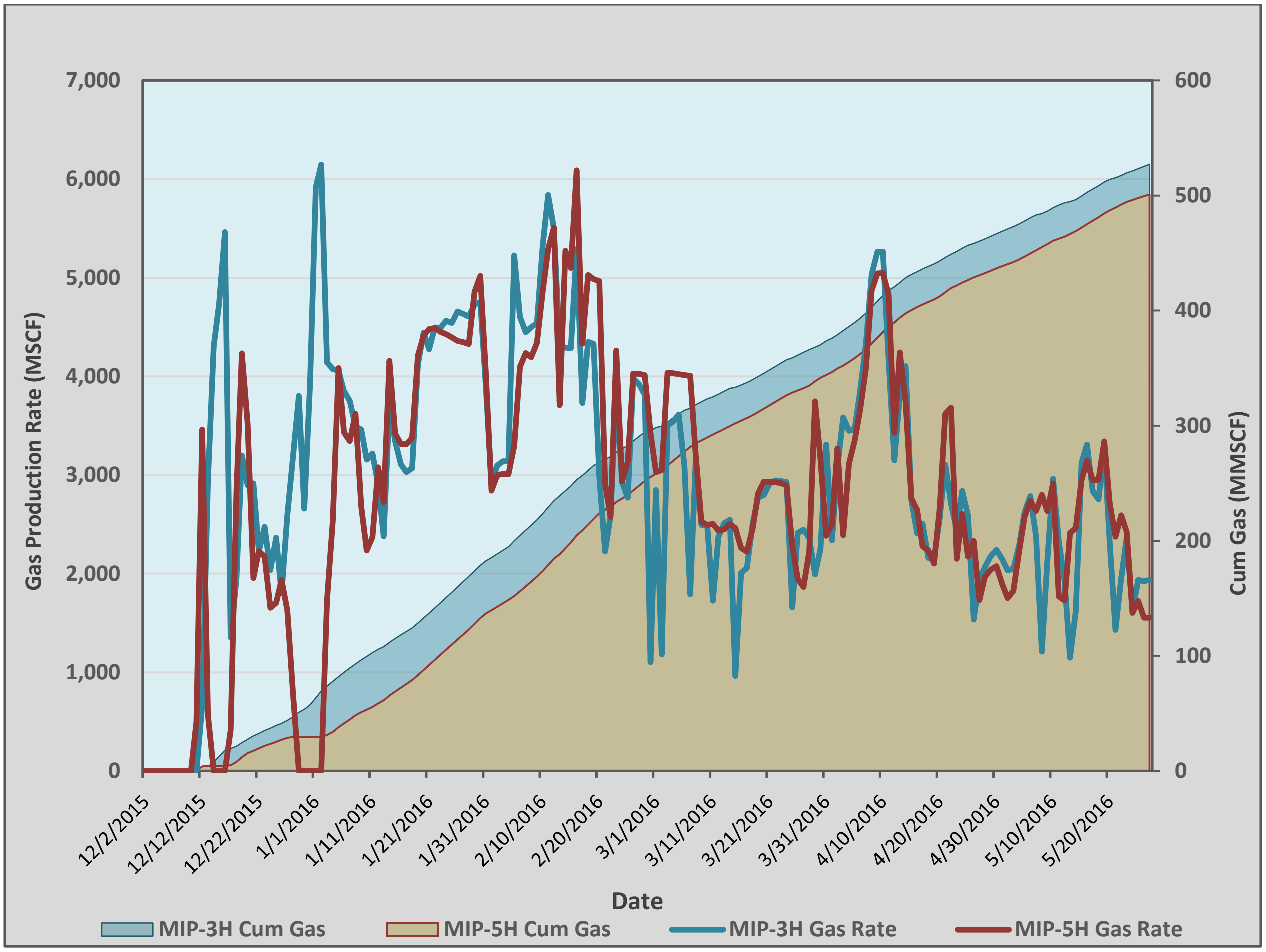


Figure 12. Gas rate and cum gas production of MIP-3H and MIP-5H

Flowback or Produced Water

In unconventional gas development water treatment and disposal is a significantly important issue from environmental point of view. Due to the characteristics of shale formation economic gas production necessitates implementation of hydraulic fracturing stimulation of the formation. During this process a considerable amount of liquid is pumped underground to generate fractures in shale formation. The hydraulic fracturing fluid contains the following:

- Makeup water: is taken from the impoundments or tanks on the well site and consists of fresh water and recycled flowback water.
- Mixture of chemicals: is added in very small amount (around 0.5% of the total fluid) and the composition varies based on the operator special formula.
- Proppant: a solid material such as sand which helps keeping the fractures open after they are generated.

The water sources for hydraulic fracturing process at the MIP site was obtained by temporary pipeline from the nearby Monongahela River.

After hydraulic fracturing stimulation, once the well is put on production some of the pumped fluid is produced which is called "flowback produced water" and is usually about 10% to 30% of the total injected water. Therefore 70% to 90% of the injected water remains in the formation and is not produced. The flowback produced water is used as makeup fluid after going through some treatments.

The amount of water produced from MIP-3H and 5H for the first 60 days of production is demonstrated in Figure 13.

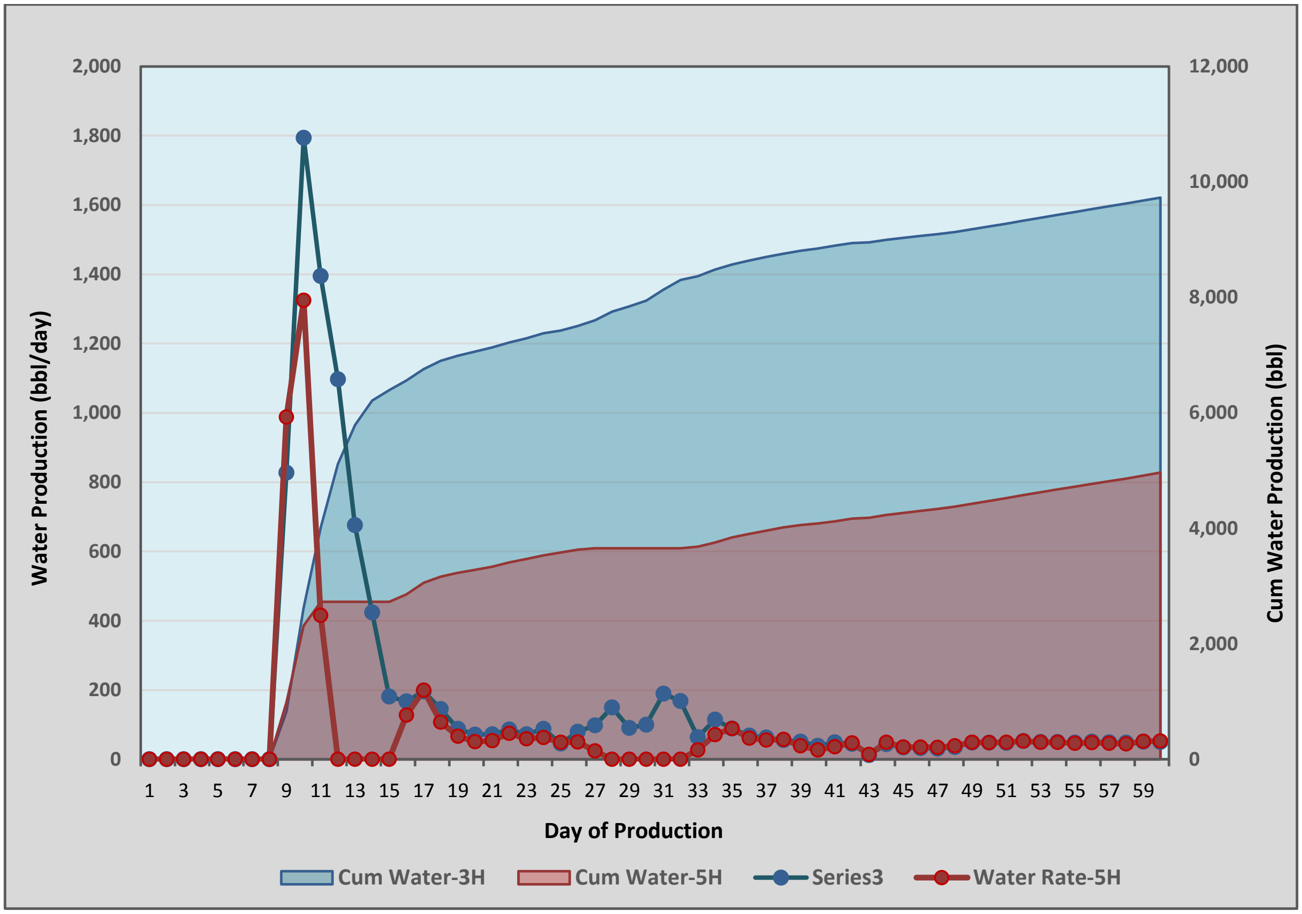


Figure 13. Produced water from MIP-3H and MIP-5H during the first 60 days of production

Generally, total water production is calculated based on the changes in tank level and then it is back allocated to each well based on the gas production volume.

The water production rate for MIP-3H and MIP-5H from the start of production till end of May, 2016 is shown in Figure 14.

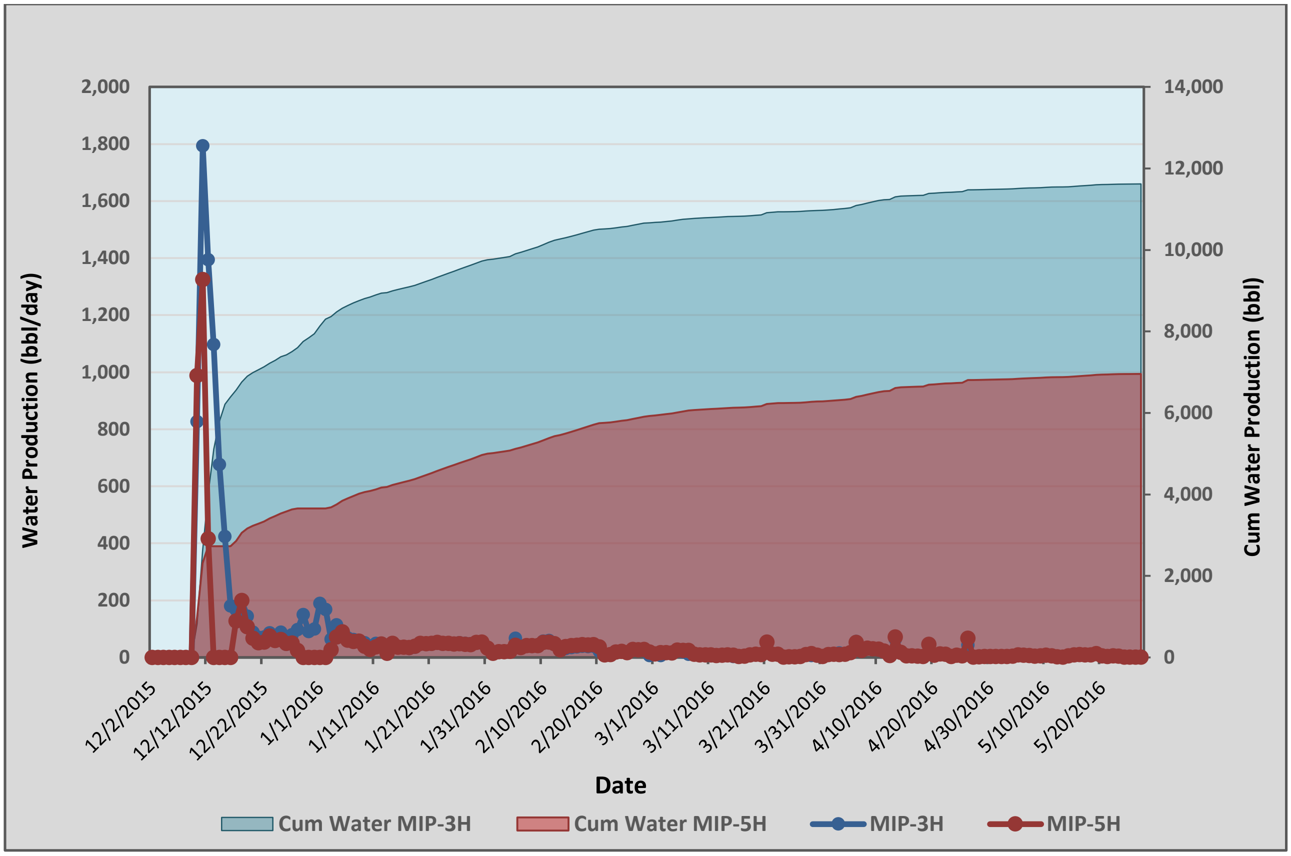


Figure 14. Water production for MIP-3H and MIP-5H

As depicted in the two above figures, the difference between water production from MIP-3H and MIP-5H is much more prominent during the first month of production and as time passes the two laterals produce almost equal amount of water.

Figure 15 shows the water production rate in logarithmic scale in which the amount of water production from each lateral can be more clearly observed.

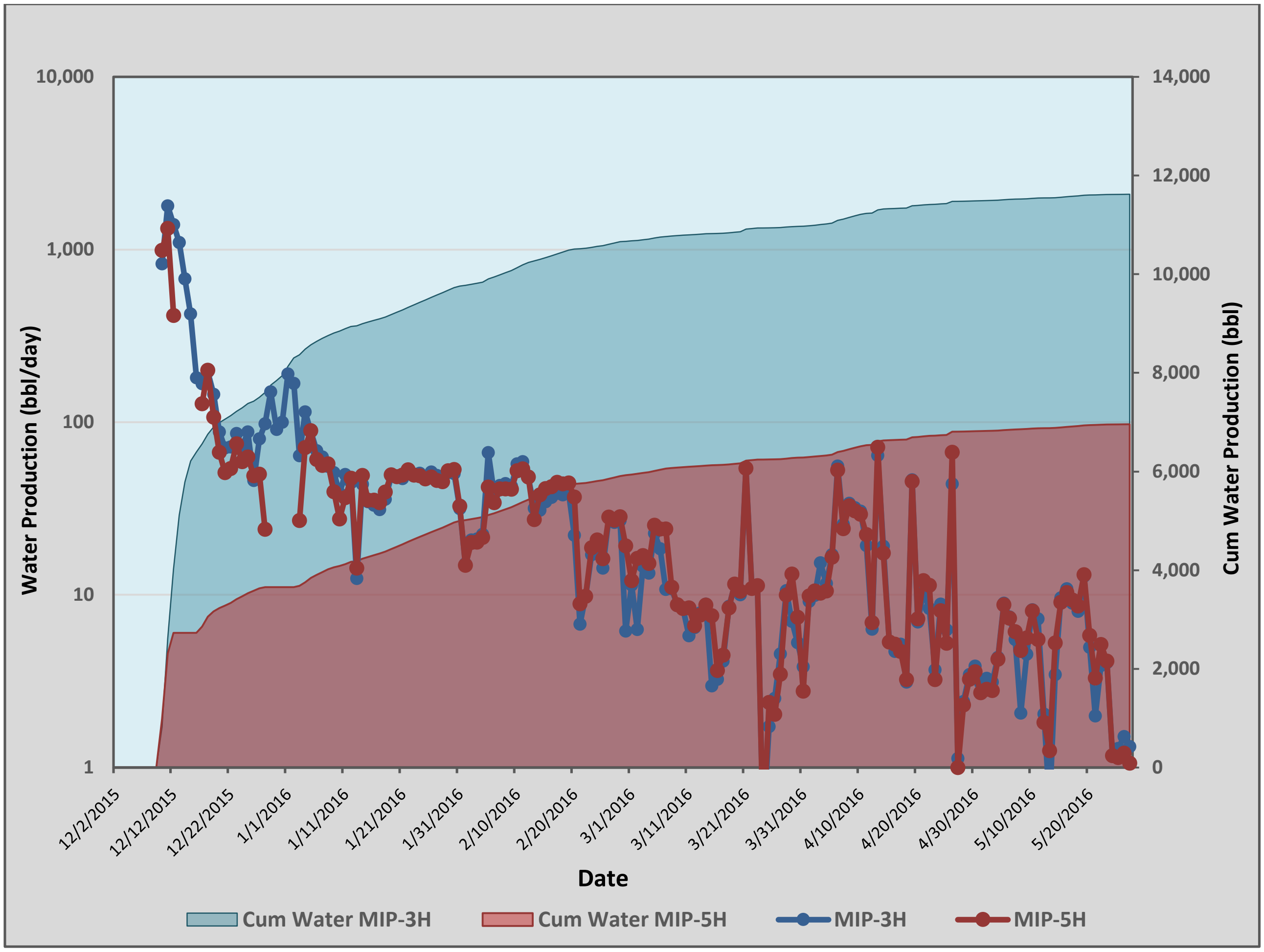


Figure 15. Water production for MIP-3H and MIP-5H in logarithmic scale