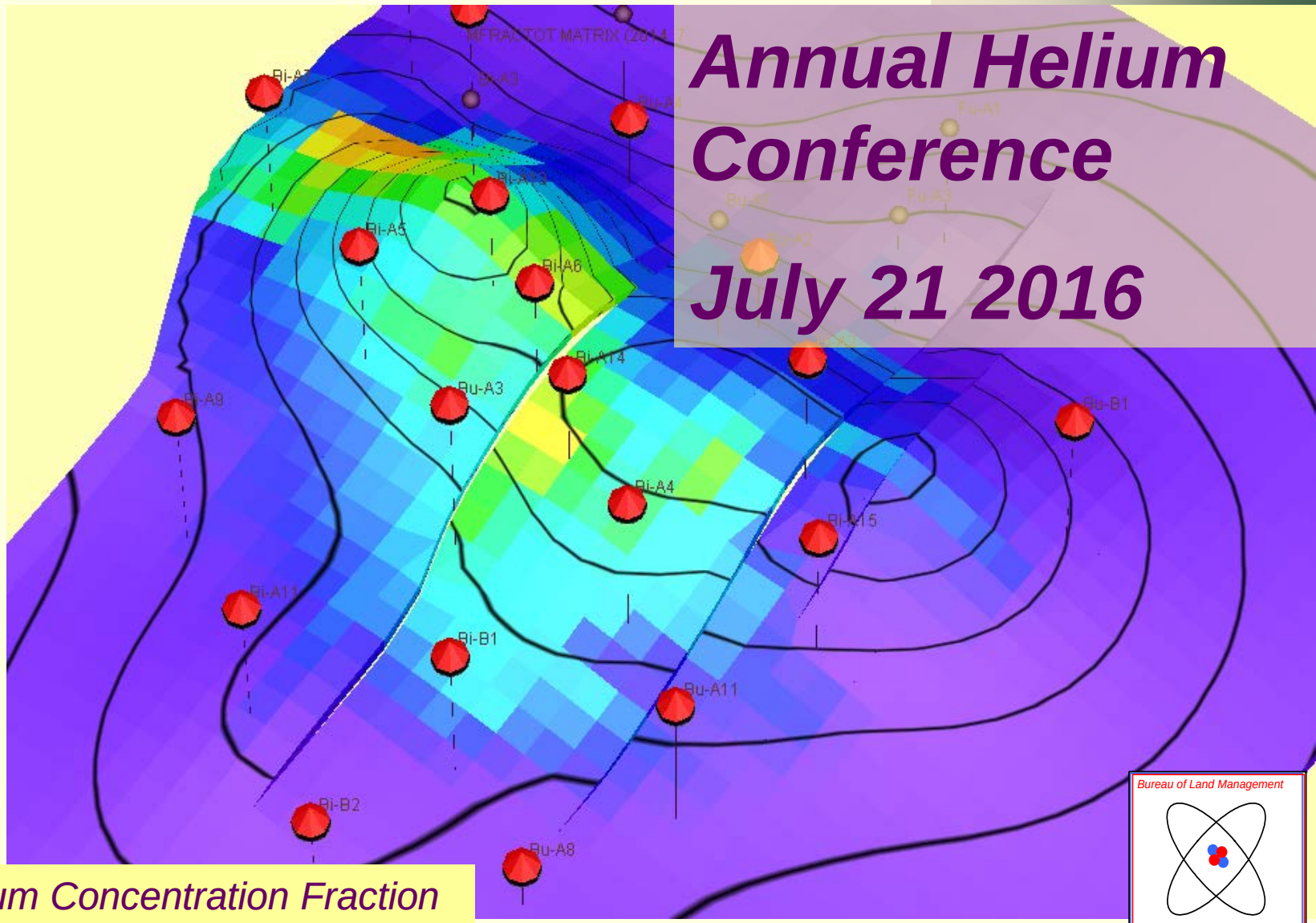
Bush Dome Helium Reservoir



Helium Concentration Fraction
June 30 2015

Bureau of Land Management
Helium Operations

Outline

- Reservoir Status (Operations: 2015-2016)
- Simulation Model Status
- Predictions
- Conclusions

Reservoir Status 2016

- Field & Bi-A6 Operations Summary:
  - July 2015 – 2016
  - Comparison to prior years
- Production Analysis
- Helium concentration maps
- Flowing WHP

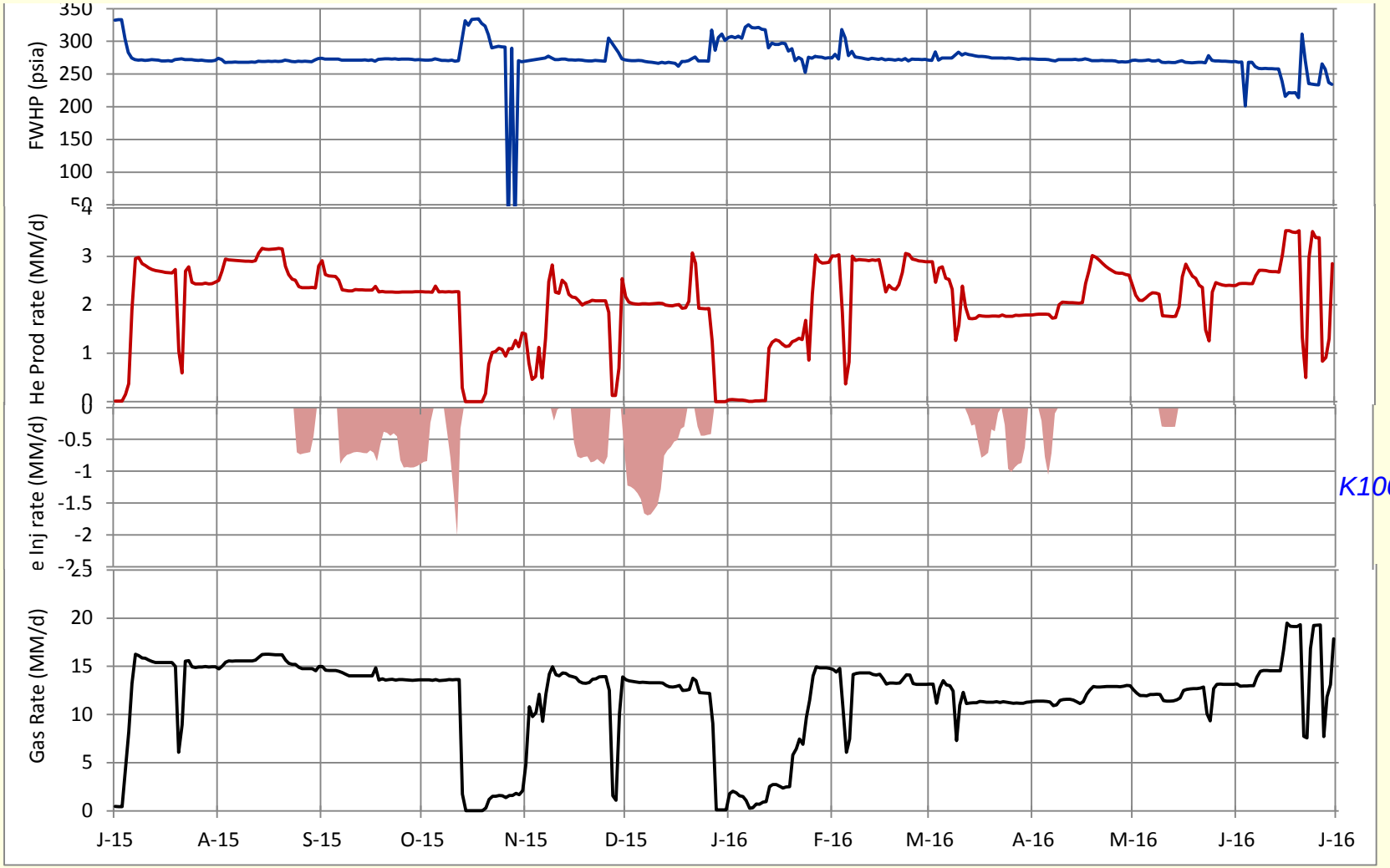
Reservoir Status 2016

Summary – 2015-16 Operations

- **Field/HEU at or close to minimum suction pressure and minimum flow July 2015 – Apr 2016**
  - At or near minimum total gas input most of the year
  - Total gas rate declines from ~16 to ~13 MM/d (Jul-Jan)
  - Most wells are flowing at pressure limit ~265-270 psia
  - HEU shutdown – 4 major events, a few partial day glitches
  - Well compressors removed (Fall 2015)
  - Central Compression installed, not up and running
- **HEU facility operating limits improved**
  - Successful ~10 MM/d low flow test (Apr 2016)
  - K-100 successfully modified, new Pmin = 200 psia

Reservoir Status 2016

- **Summary – 2015-16 Operations**



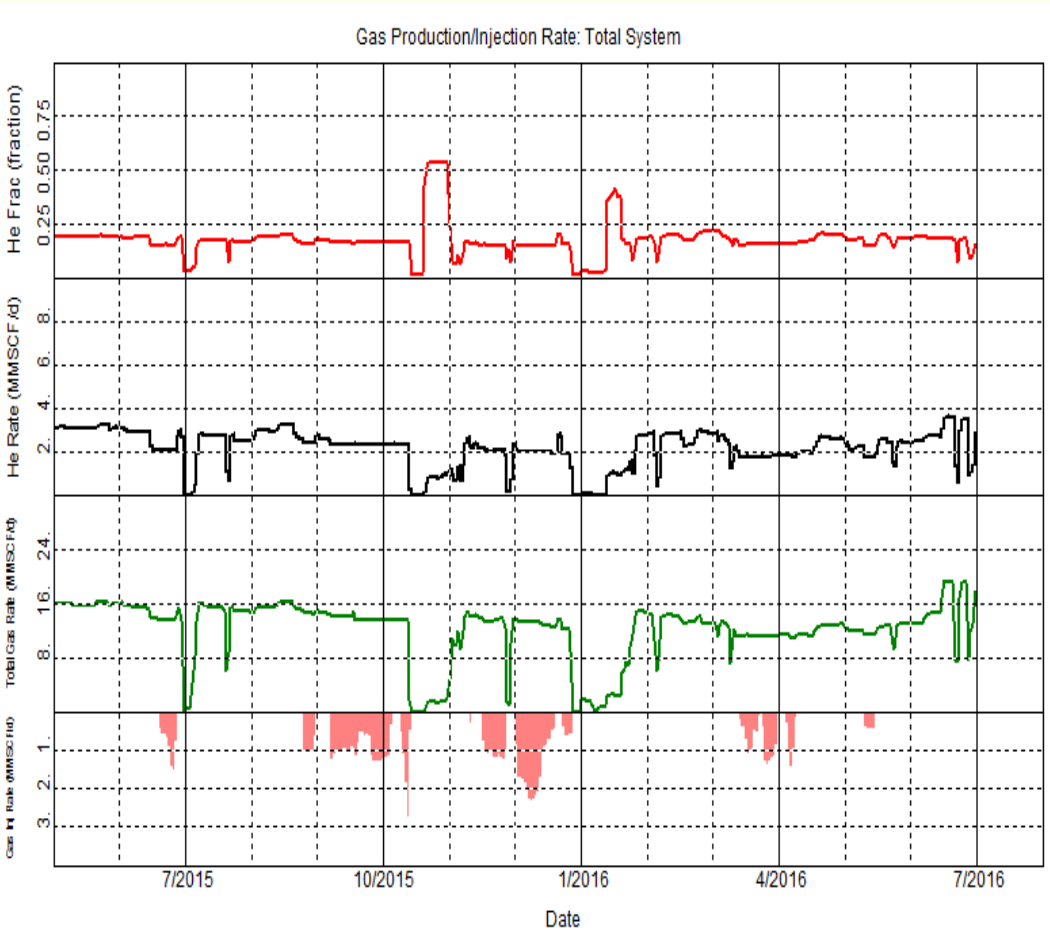
Reservoir Status 2016

Summary – 2015-16 Operations

- **Reduced He demand July 2015 – July 2016**
  - He production demand was low most of the year
  - Helium injection periods: Aug-Dec, Mar-May (8 months)
  - He produced ~750 MM
    He Injected ~74 MM,
    Net He delivered ~676 MM
  - Max. He injection rate, 2,010 Mcf/d
    Total He production rate, 2,272 Mcf/d
    Net He delivered (10/15/15), 262 Mcf/d
  - 5 wells produced 74% of helium, ~555 MM (Bi-A6 19%)
  - Before K100 modification, max He rate ~2.9 MM/d (3/2/2016)
  - After K100 modification, max He rate ~3.5 MM/d (6/16/2016)

Reservoir Status 2016

Field & HEU Summary	July-July 2015-16	
HEU Operating	306	days
HEU Down	58	days
He rate < 1MM/d	45	days
He rate > 6.25mm/d	0	days
Beg. Avg Flowing Press	255.0	psia
End Avg Flowing Press	201.0	psia
Change in Flowing Press	-54.0	psi
Total Gas Produced	4.272	BCF
Total Gas Injected	-0.100	BCF
Net Gas	4.172	BCF
He Produced	0.751	BCF
He Injected	-0.074	BCF
He Net	0.677	BCF

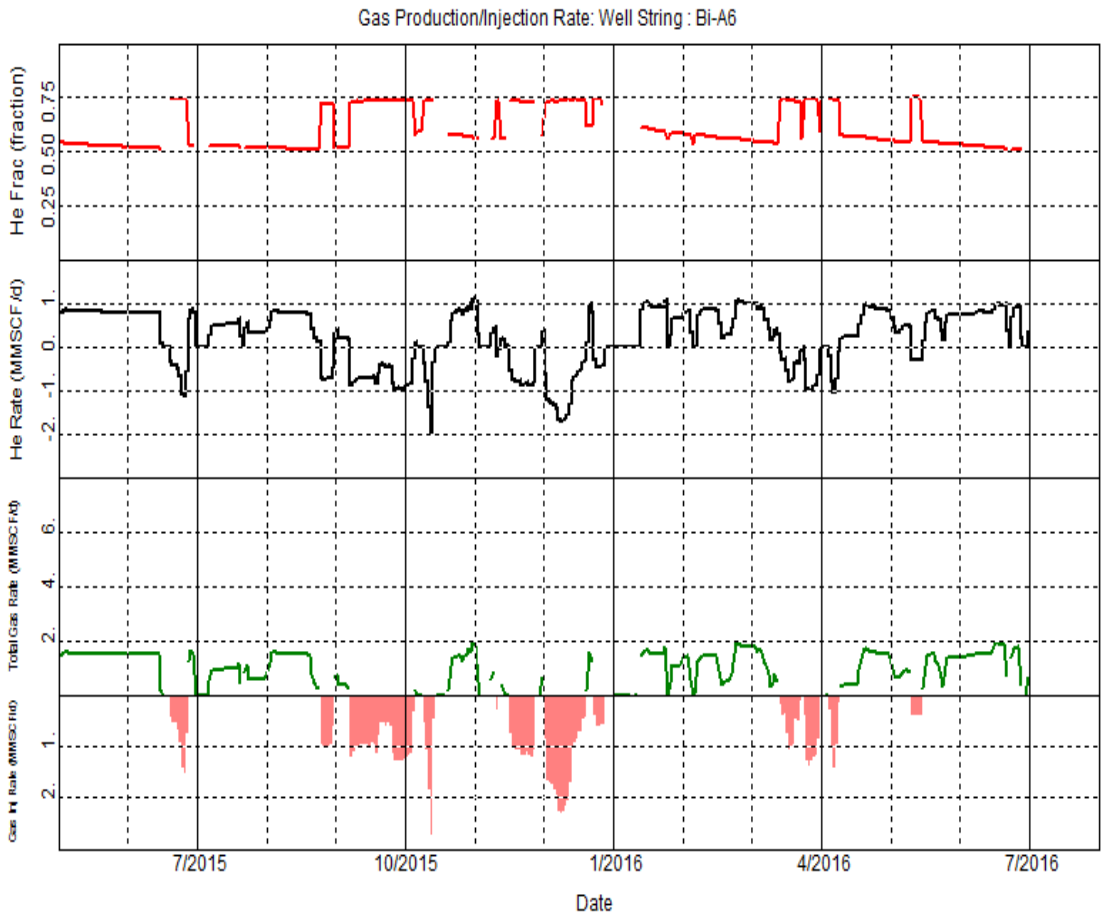


Reservoir Status 2016

Summary – 2015-16 Operations

- **Bi-A6 Performance**
  - Injected crHe during 8 months
  - Until K-100 modification, Bi-A6 flow was pressure limited ~1500 MSCF/d Total Gas, ~750-800 MSCF/d He
  - Without injection enrichment, Bi-A6 He concentration started ~51% (July 2015) and ends ~48% (Jun 2016)

Reservoir Status 2016



Bi-A6 Summary	July-July 2015-16	
Producing	217	days
Injecting	105	days
No Flow	42	days
Total Gas Produced	243.55	MM
Total Gas Injected	-100.6	MM
Net Gas	143.0	MM
He produced	143.96	MM
He injected	-74.4	MM
Net He	69.6	MM
Beginning He %	69.40%	
Ending He%	48.60%	
Change in He%	-20.80%	
Bi-A6 produced 19% of 2015-2016 Helium		
Bi-A6 He % range 48.3% - 75.6%		

Reservoir Status 2016

Field & HEU Summary	July-July 2015-16	
HEU Operating	306	days
HEU Down	58	days
He rate < 1MM/d	45	days
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Bi-A6 He % range 48.3% - 75.6%		

Reservoir Status 2016

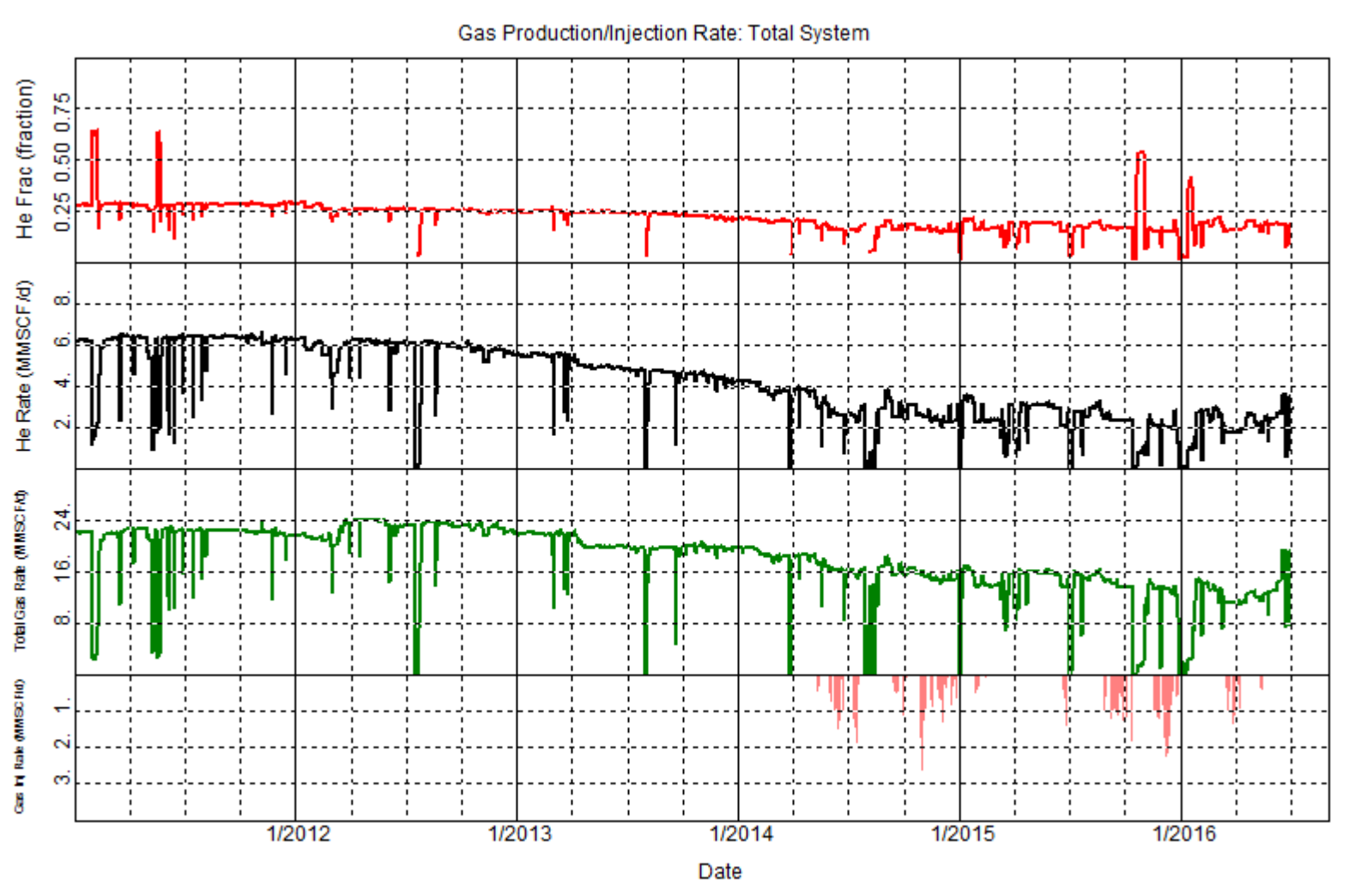
Field Production: 2011- 2016

Field & HEU Summary								
beginning	July	2011	2012	2013	2014	2015	5 Year	2004-16
ending	July	2012	2013	2014	2015	2016	Totals	Totals
HEU Operating	days	355	361	359	355	307	1737	3814
HEU Down	days	0	4	6	10	58	78	192
He rate < 1MM/d	days	0	4	11	29	45	89	127
He rate > 6.25mm/d	days	242	3	0	0	0	245	839
Beginning Pressure	psia	310**	278**	287**	277**	255**	310**	626
Ending Pressure	psia	278**	251**	277**	255**	201**	201**	201**
Change	psi	-32	-27	-10	-22	-54	-109	-425
Total Gas Produced	BCF	8.154	7.797	6.669	5.322	4.272	32.214	73.840
Total Gas Injected	BCF	0.000	0.000	-0.021	-0.080	-0.100	-0.201	-0.754
Net Gas	BCF	8.154	7.797	6.648	5.242	4.172	32.013	73.085
He Produced	BCF	2.263	1.970	1.428	0.916	0.751	7.327	18.712
He Injected	BCF	0.000	0.000	-0.015	-0.060	-0.074	-0.149	-0.583
He Net	BCF	2.263	1.970	1.412	0.856	0.677	7.179	18.130

**Flowing Pressures K100 Modified

Reservoir Status 2016

Field Production: 2011 - 2016



Reservoir Status 2016

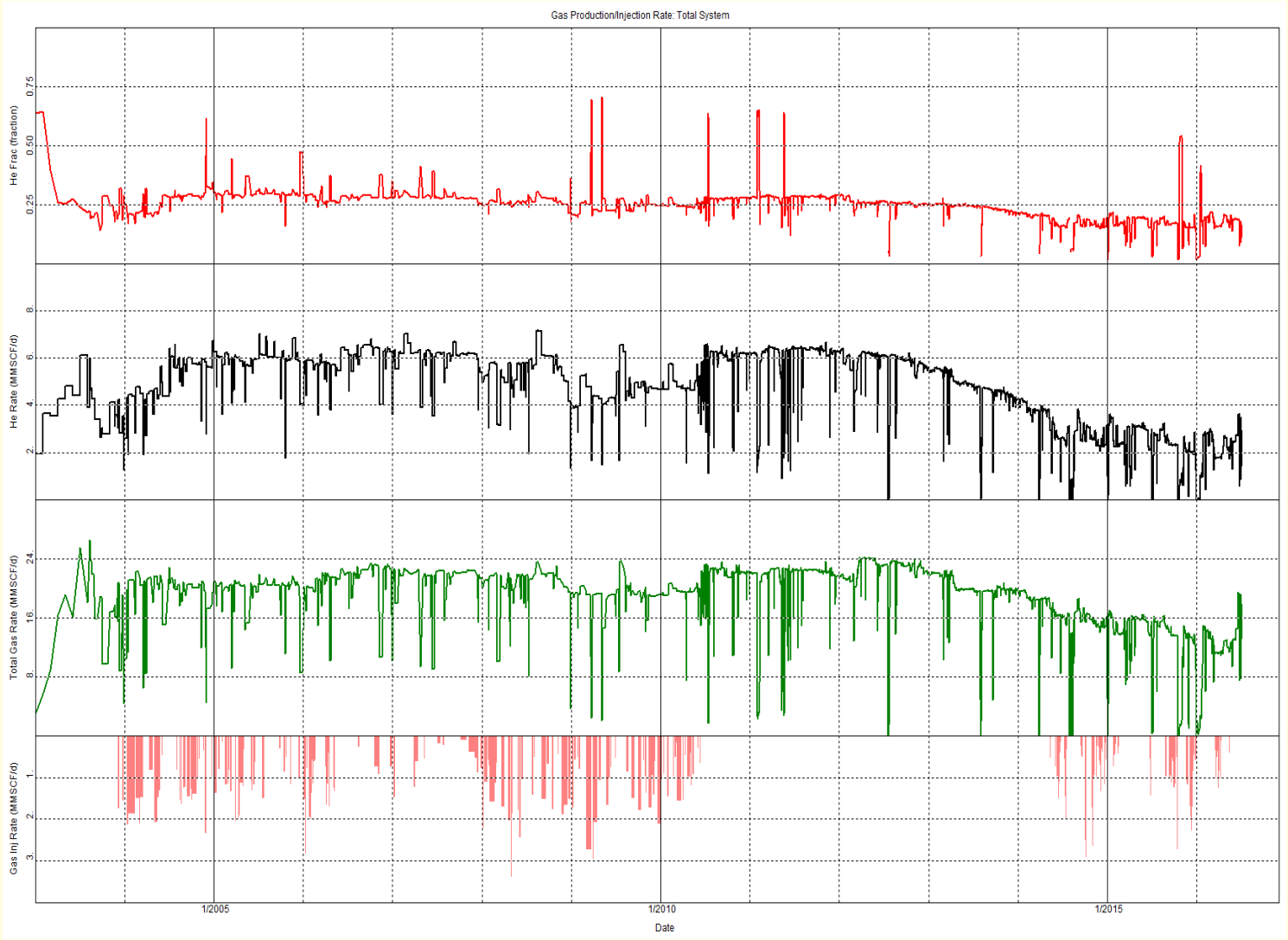
Field Production: 2004 - 2016

Field & HEU Summary														
beginning	July	2004	2005	2006	2007	2009	2010	2011	2012	2013	2014	2015	5 Year	2004-16
ending	July	2005	2006	2007	2008	2010	2011	2012	2013	2014	2015	2016	Totals	Totals
HEU Operating	days	332	348	334	351	361	351	355	361	359	355	307	1737	3814
HEU Down	days	33	17	31	15	4	14	0	4	6	10	58	78	192
He rate < 1MM/d	days	35	0	0	1	0	2	0	4	11	29	45	89	127
He rate > 6.25mm/d	days	30	82	189	43	28	222	242	3	0	0	0	245	839
Beginning Pressure	psia	626	601	575	548	362**	334**	310**	278**	287**	277**	255**	310**	626
Ending Pressure	psia	601	575	548	523	334**	303**	278**	251**	277**	255**	201**	201**	201**
Change	psi	-25	-26	-27	-25	-28	-31	-32	-27	-10	-22	-54	-109	-425
Total Gas Produced	BCF	5.026	7.226	7.509	7.431	7.155	7.279	8.154	7.797	6.669	5.322	4.272	32.214	73.840
Total Gas Injected	BCF	-0.060	-0.041	-0.060	-0.183	-0.209	0.000	0.000	0.000	-0.021	-0.080	-0.100	-0.201	-0.754
Net Gas	BCF	4.966	7.185	7.449	7.248	6.946	7.279	8.154	7.797	6.648	5.242	4.172	32.013	73.085
He Produced	BCF	1.262	2.077	2.176	1.930	1.817	2.123	2.263	1.970	1.428	0.916	0.751	7.327	18.712
He Injected	BCF	-0.047	-0.033	-0.048	-0.144	-0.163	0.000	0.000	0.000	-0.015	-0.060	-0.074	-0.149	-0.583
He Net	BCF	1.215	2.045	2.128	1.786	1.654	2.123	2.263	1.970	1.412	0.856	0.677	7.179	18.130

**Flowing Pressures K100 Modified

Reservoir Status 2016

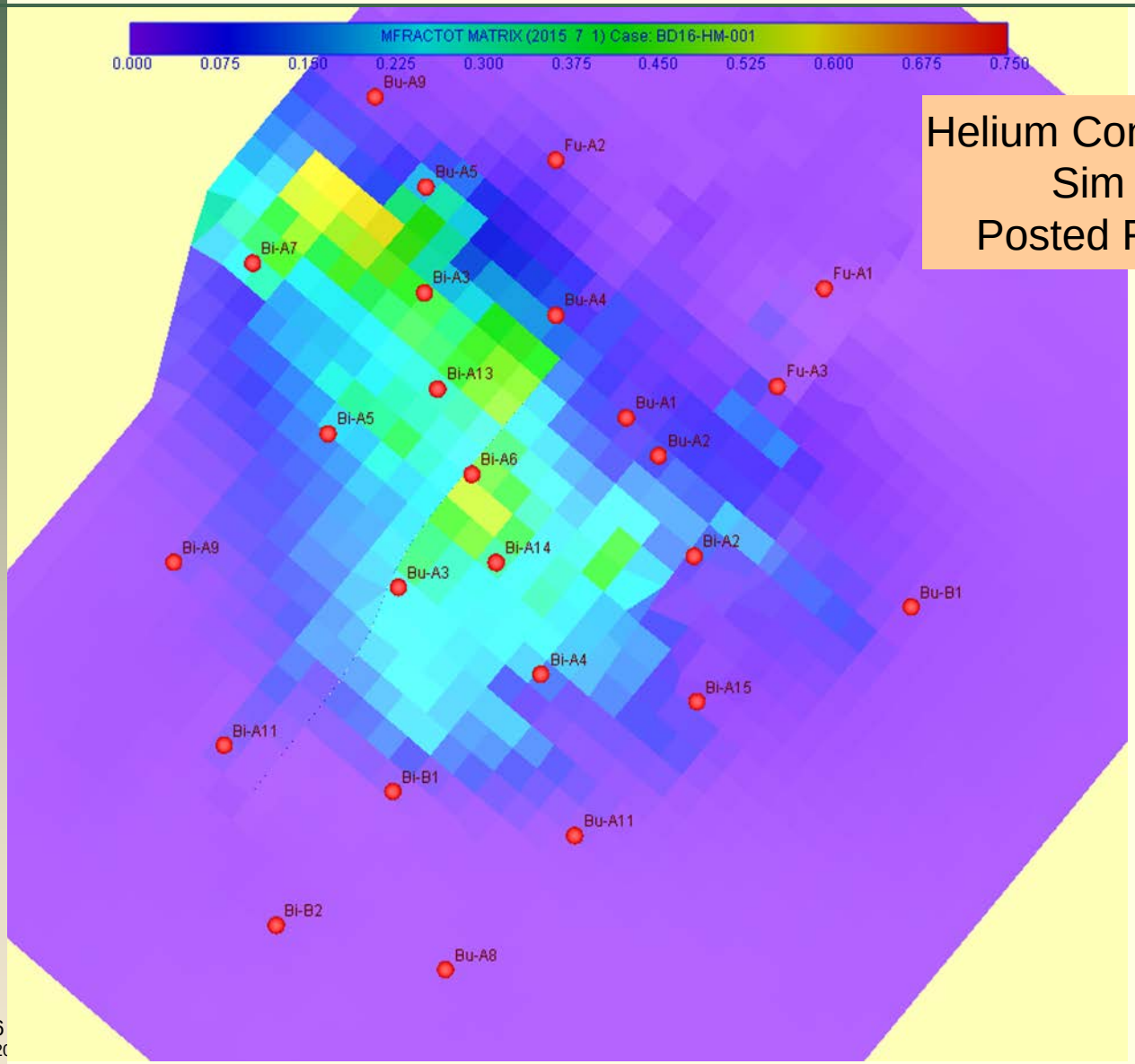
Field Production: 2003 - 2016



Reservoir Status 2016

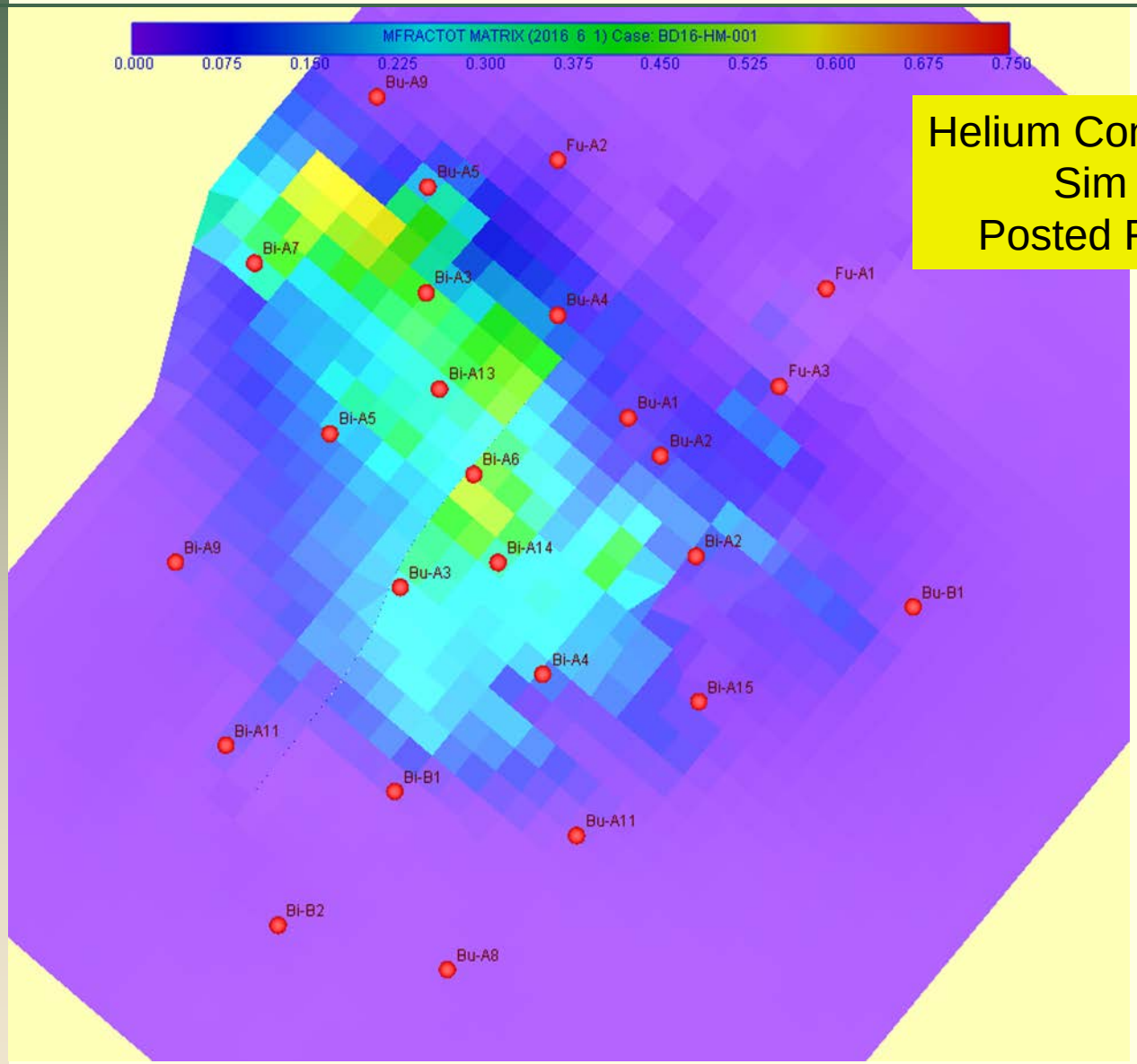
- Helium concentration maps
  - July 1 2015
  - June 1 2016
  - Change in He %
- Flowing WHP – June 1 2016

Reservoir Status 2016



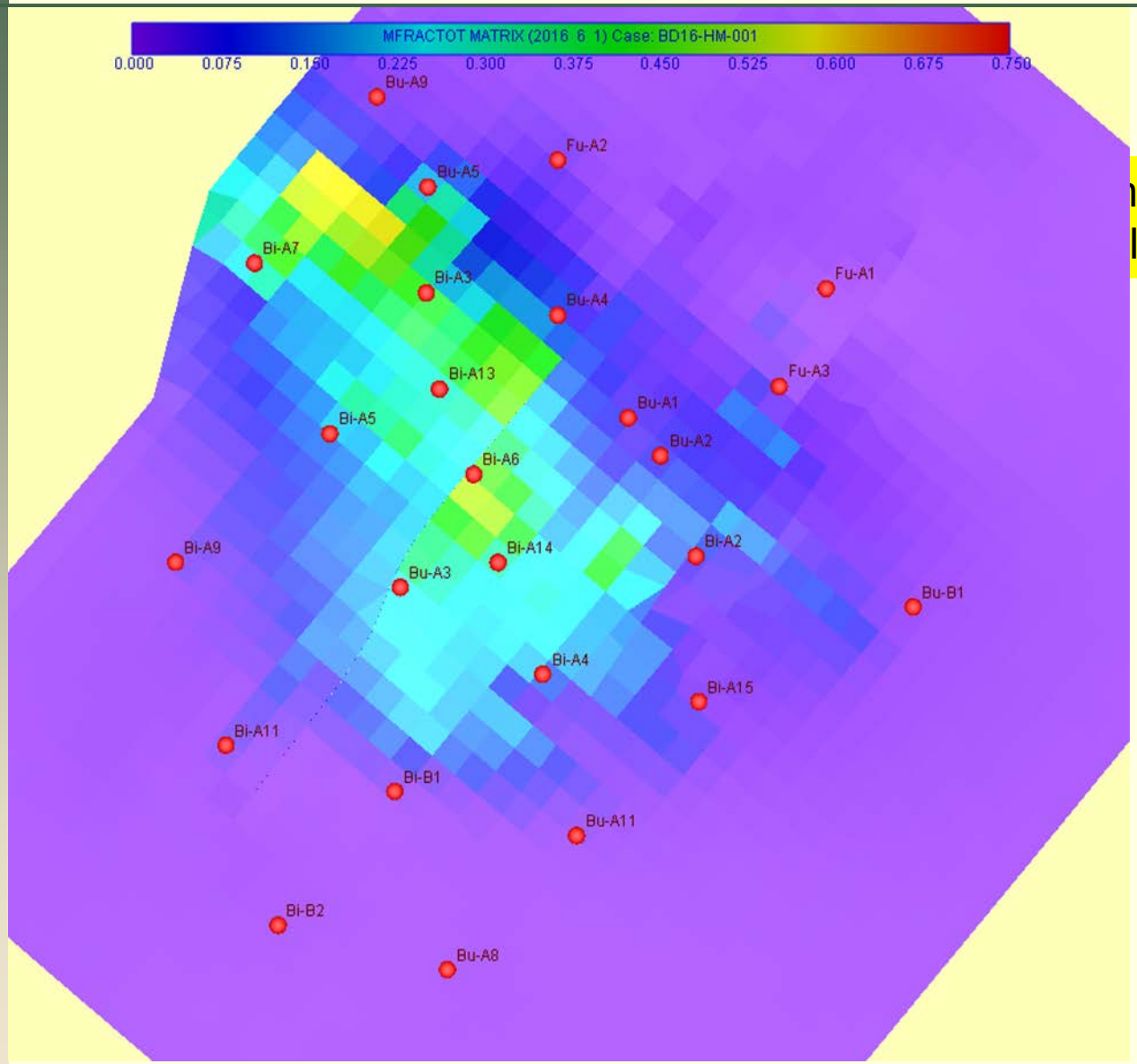
Helium Concentration – **Jun 2015**
Sim Model – Layer 7
Posted Field Produced HE%

Reservoir Status 2016



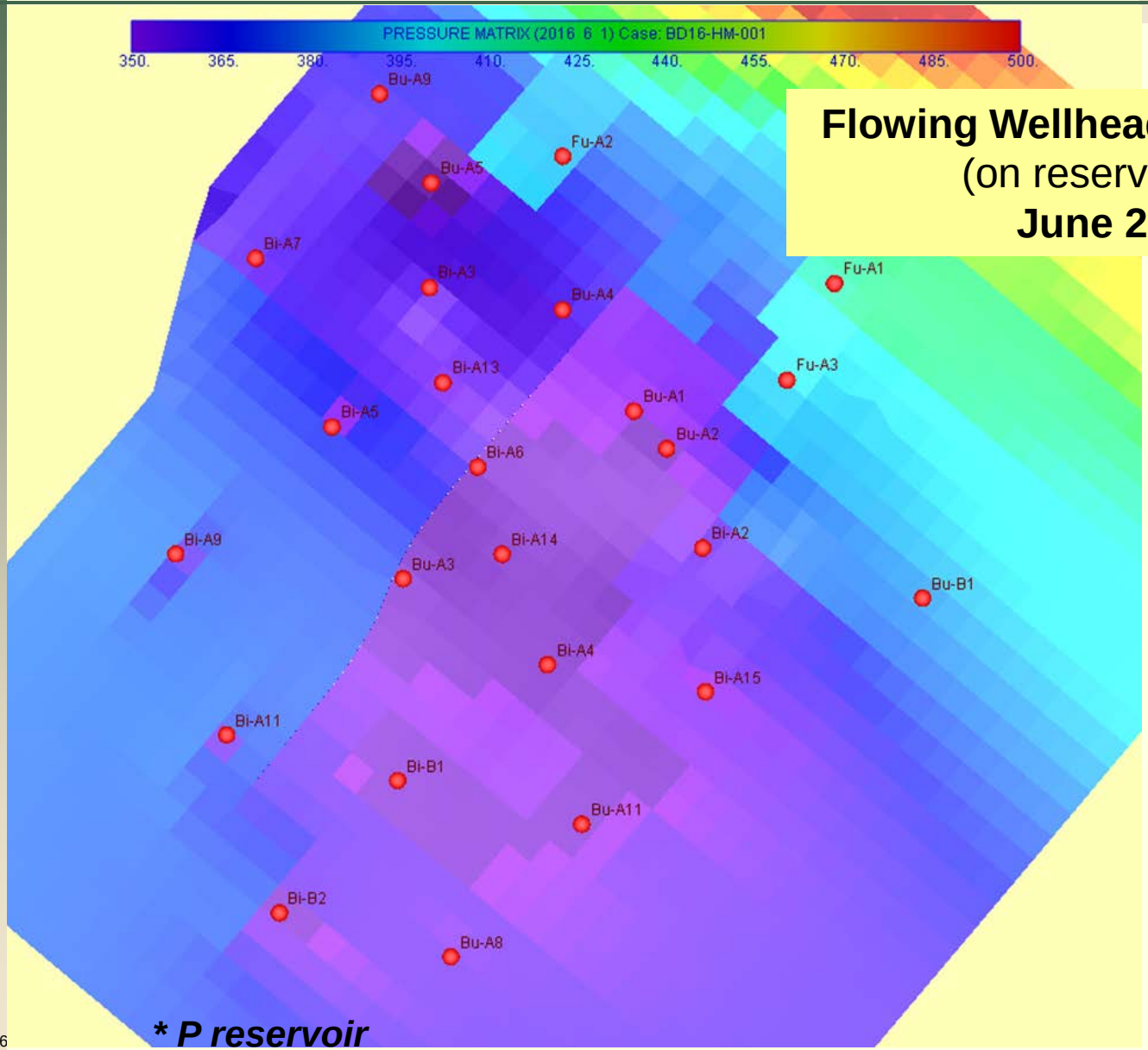
Helium Concentration – **Jun 2016**
Sim Model – Layer 7
Posted Field Produced HE%

Reservoir Status 2016



ge in He Concentration
ly 2015 to June 2016

Reservoir Status 2016



Flowing Wellhead Pressure (FWHP)
(on reservoir pressure)
June 2016, psig

**** P reservoir***

Reservoir Status 2016

- **Conclusions**
  - **Low helium demand most of the year**
    - HEU able to operate between 16 to 10 MM/d, but not operating at the max He rate possible which impacts maximizing total He production by 2021
  - **Wells are FWHP limited until central cmpr online**
  - **He concentration below 50% for all wells**
  - **He injection temporarily enriches Bi-A6**
  - **Water encroachment impacts edge wells**

Outline

- *Reservoir Status (Operations: 2015-2016)*
- *Reservoir History & Life Cycle (Depletion)*
- *Simulation Model Status*
- *Predictions*
- *Conclusions*

Simulation Model Status- 2016

- No changes to model in 2015-16 update
- Updated rates and pressures for 2015-16:
  - Helium match:
    - Field Level: 99.85% of 2015-16 He produced
      Annual volume: 0.675 vs. 0.676 Bcf (model vs. measured)
    - Most wells (20 of 22) within +/- 3% (very good+)
    - A few wells show increase mismatch on He%, but total He production balanced by other wells.
  - Pressure match:
    - Very good to excellent reservoir pressure match

Simulation Model Status- 2016

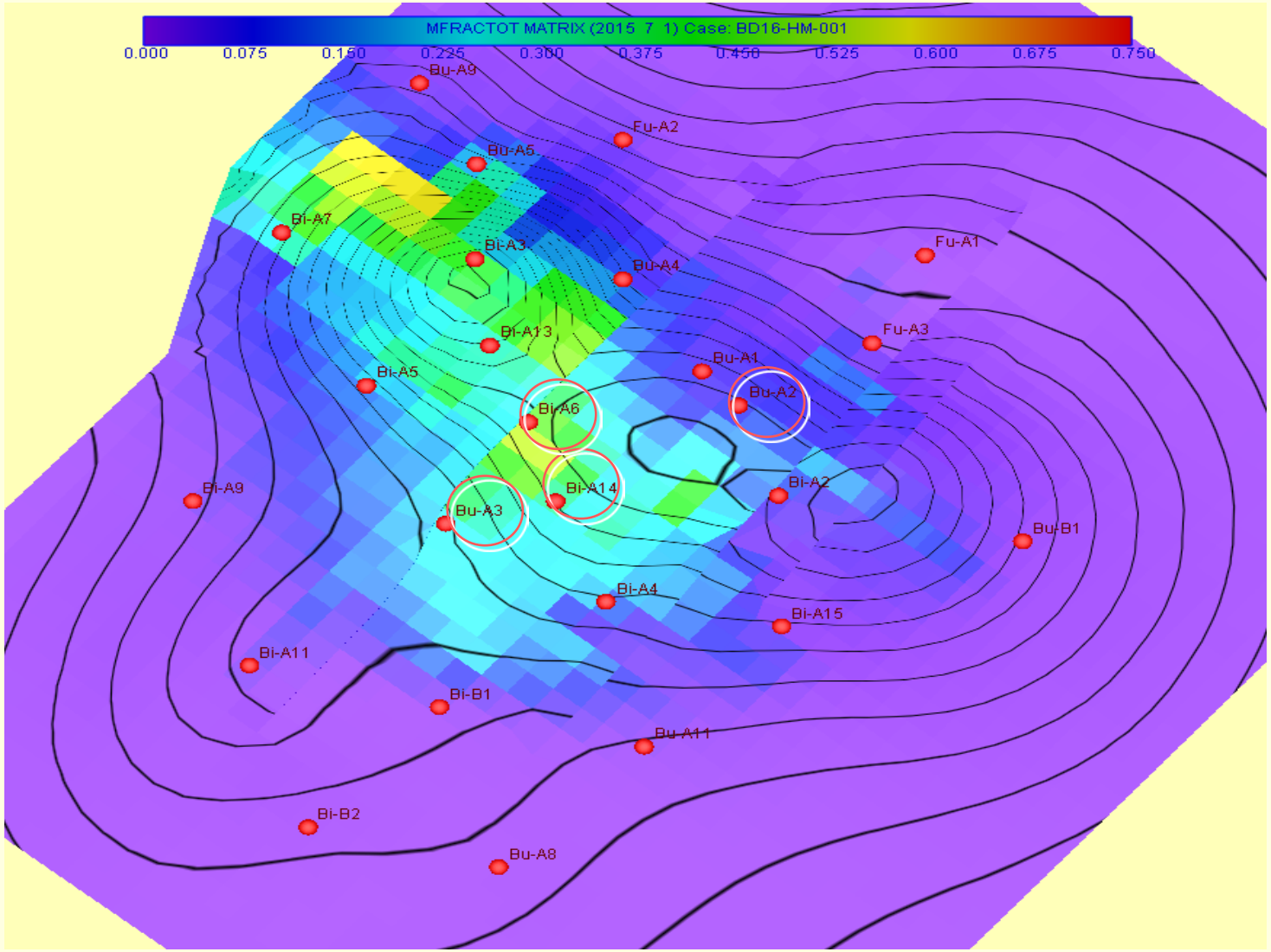
- Q: How accurate is the simulation model ?
  - Field Level – most important for He forecast
    - Very good history match on pressure and He Prod
    - Previous predictions track well with historical trends
    - Predictions should be within +/- 5%, for next few years
  - Well Level – key wells very important
    - Very good match on pressure and He Prod, but more variability
    - Decline trend match for He is also very good
    - 2 important wells have weaker He match
    - Mismatches are balanced between wells (Field match)
  - Examples

Simulation Model Status- 2016

- Examples – History Match Graphs
  - South Wells
    - Bi-A6 – Best producing well, He Injection
    - Bi-A14 – 2nd best producing
    - Bu-A2 – Shows significant methane invasion
    - Bu-A3 – weaker match on He concentration (-7%)

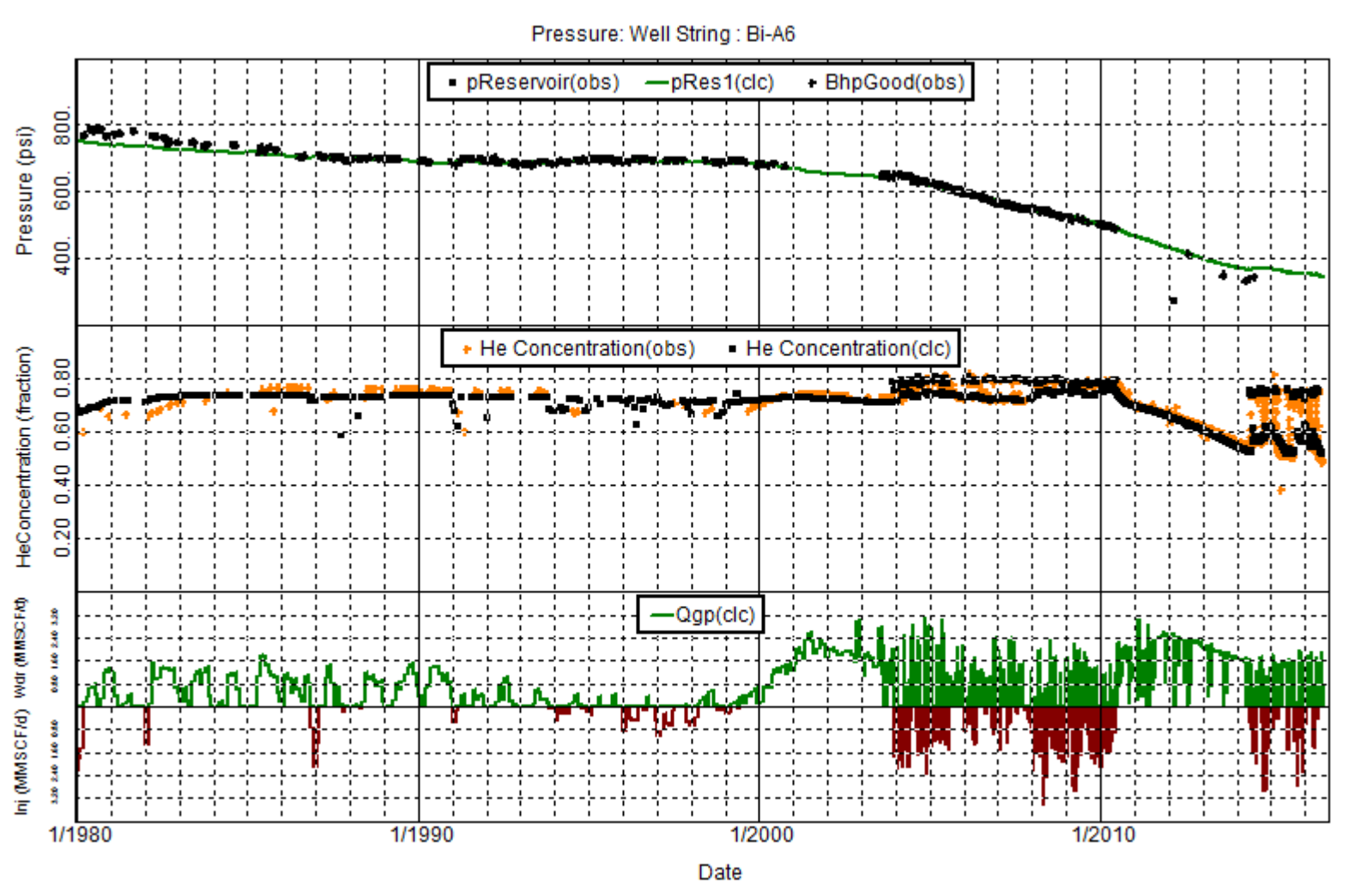
Simulation Model Status - 2016

- South Wells



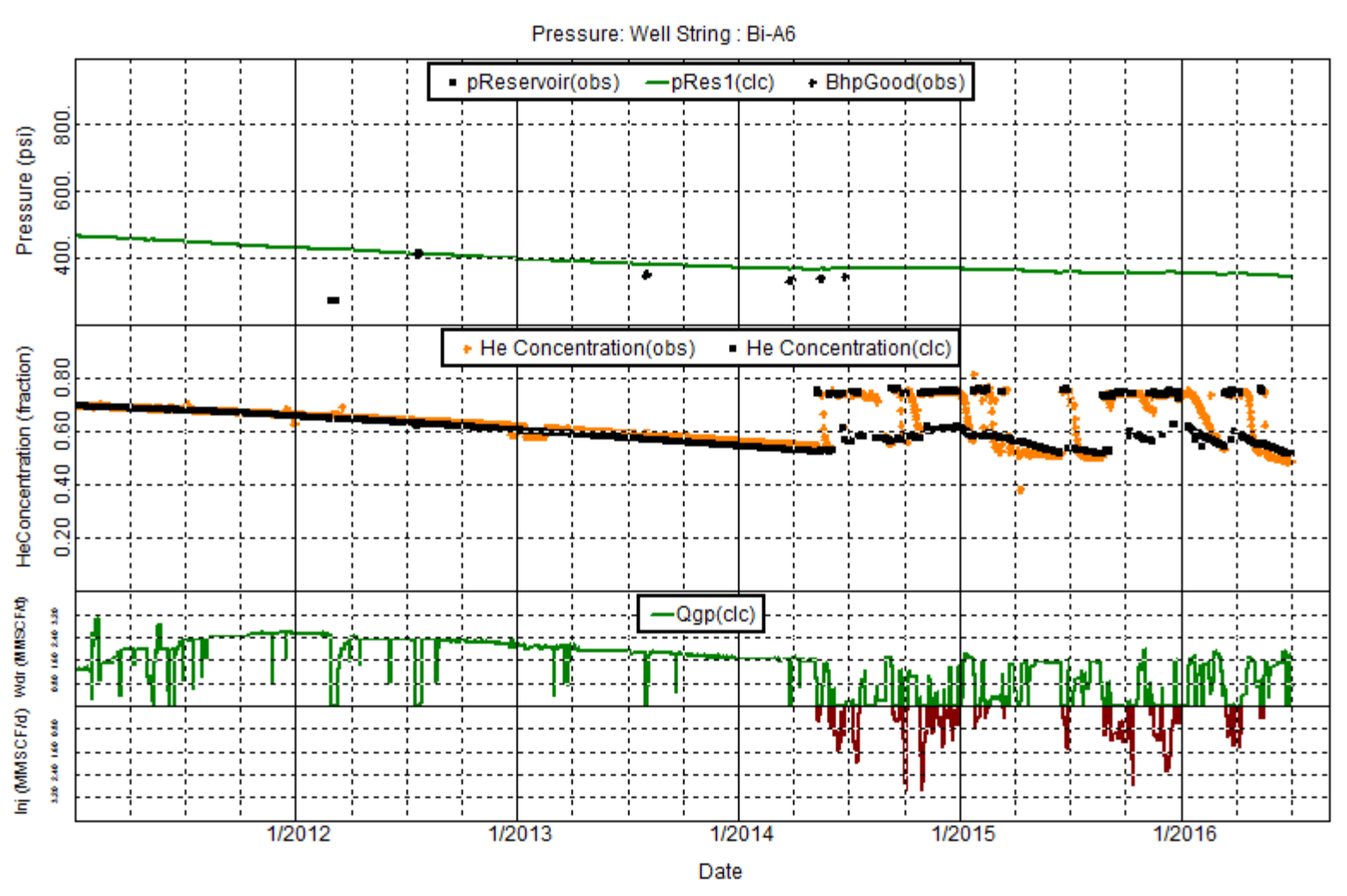
Simulation Model Status - 2016

- HM Plot – Bi-A6 (South Well)



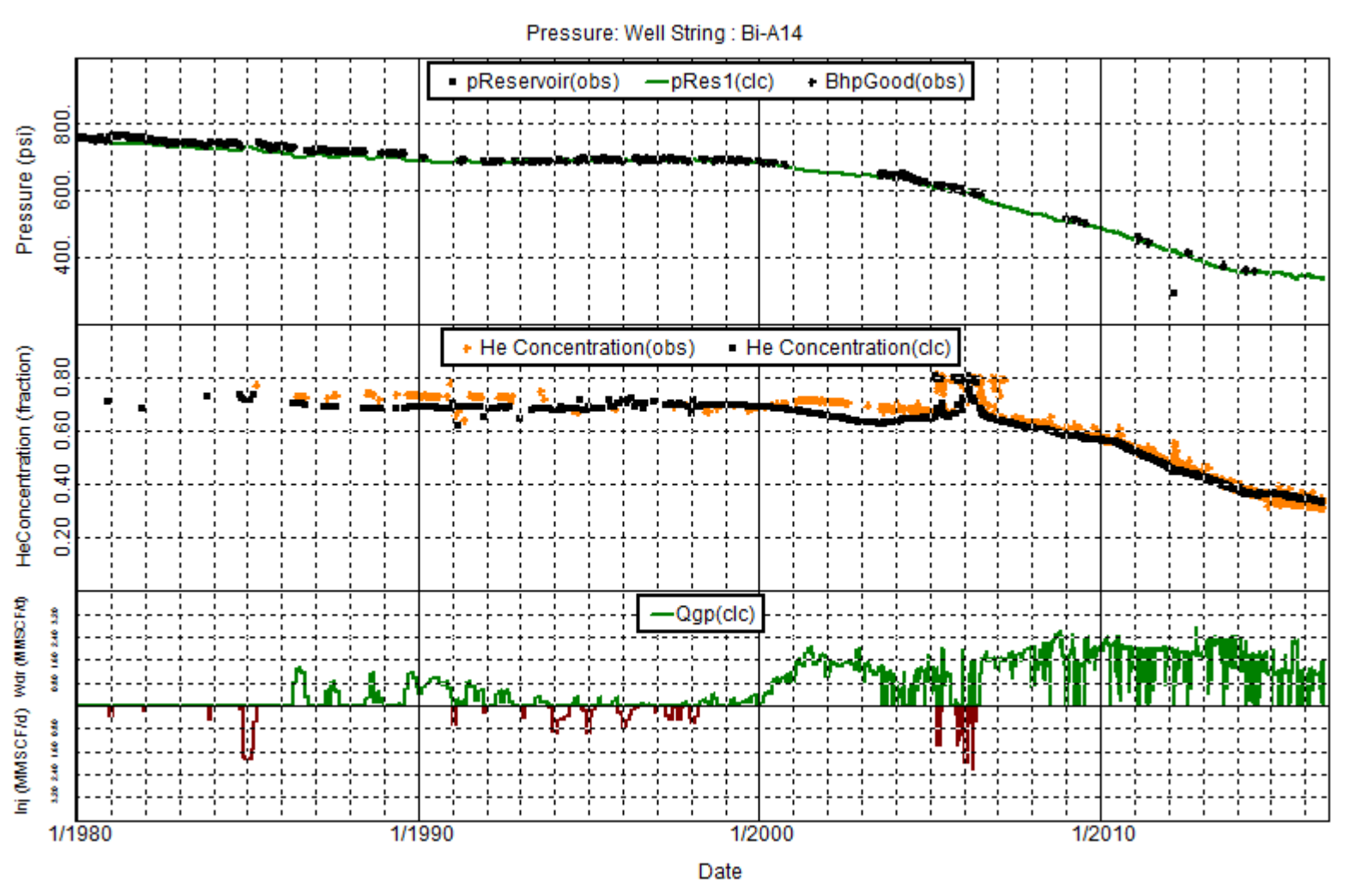
Simulation Model Status - 2016

- HM Plot – Bi-A6 (South Well)



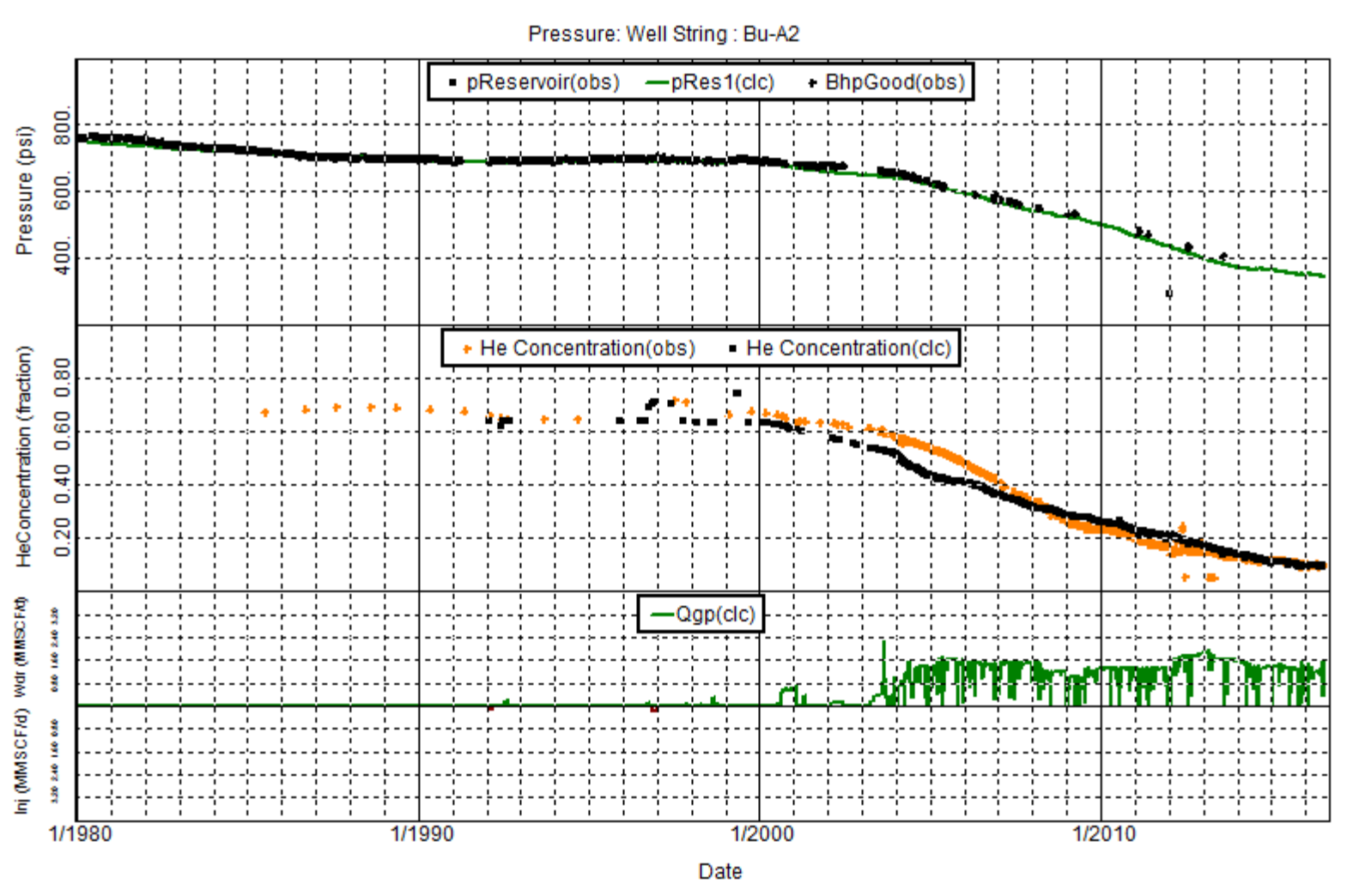
Simulation Model Status - 2016

- HM Plot – Bi-A14 (South Well)



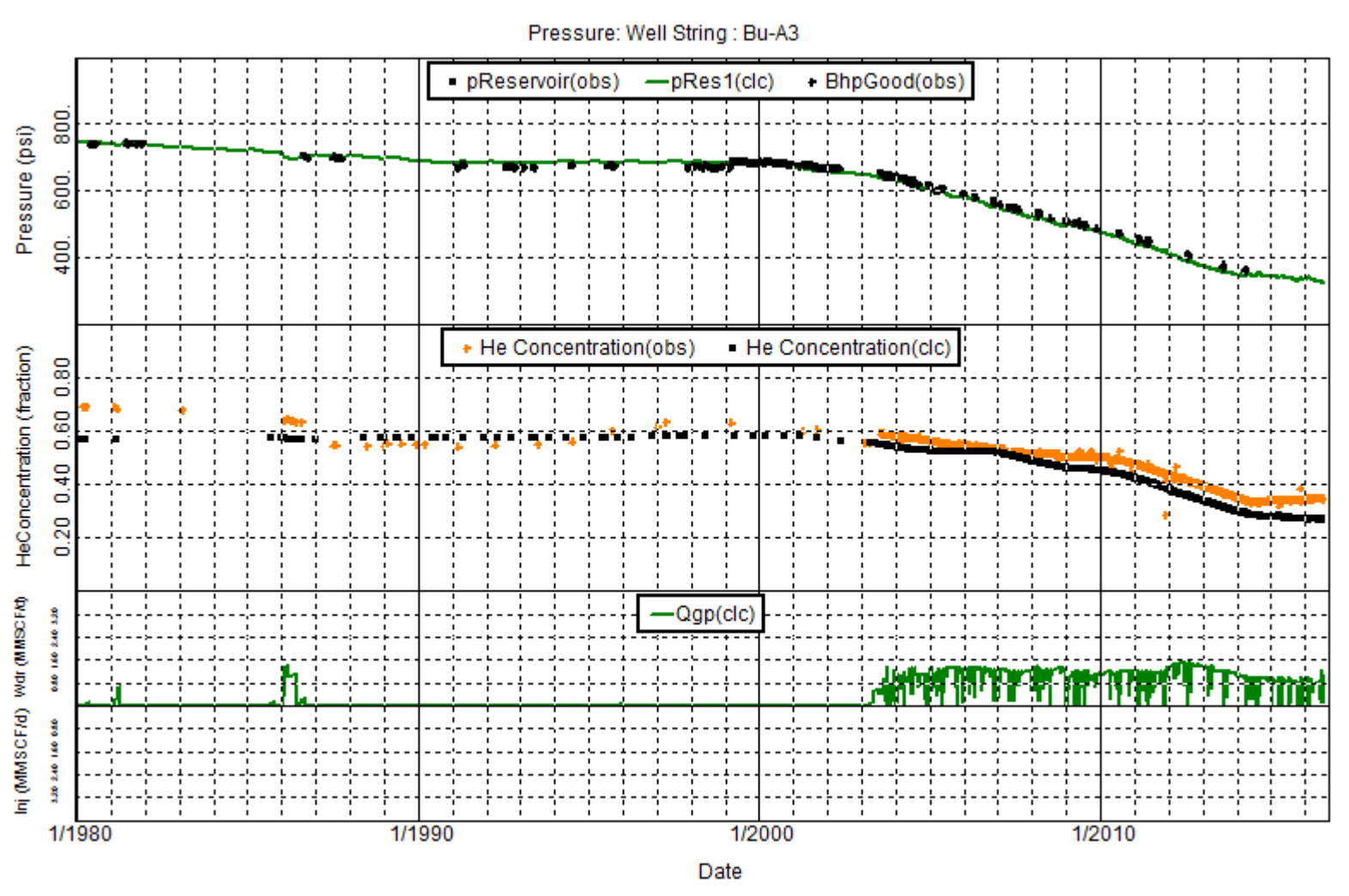
Simulation Model Status - 2016

- HM Plot – Bu-A2 (South Well)



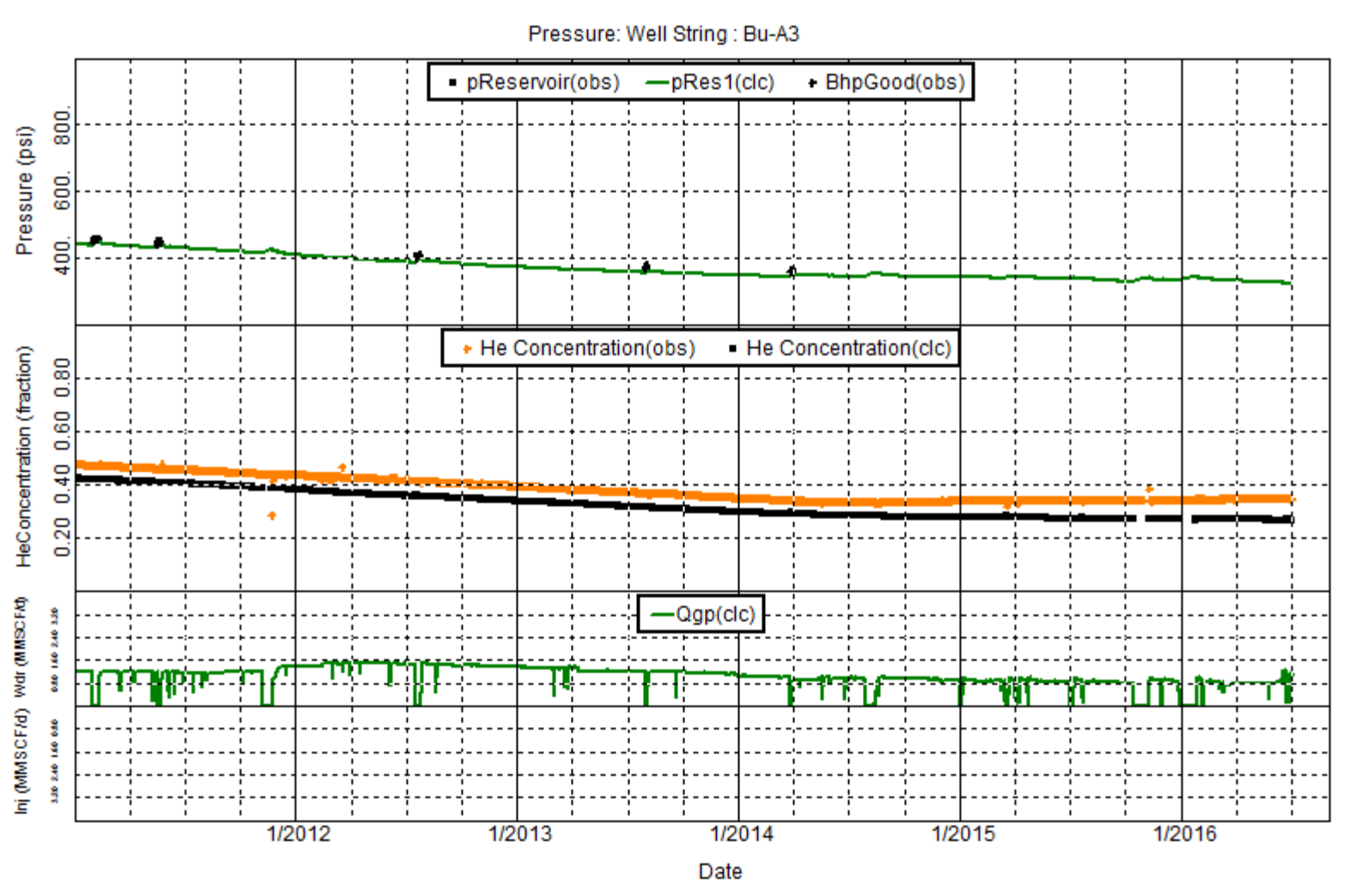
Simulation Model Status - 2016

- HM Plot – Bu-A3 (South Well)



Simulation Model Status - 2016

- HM Plot – Bu-A3 (South Well)

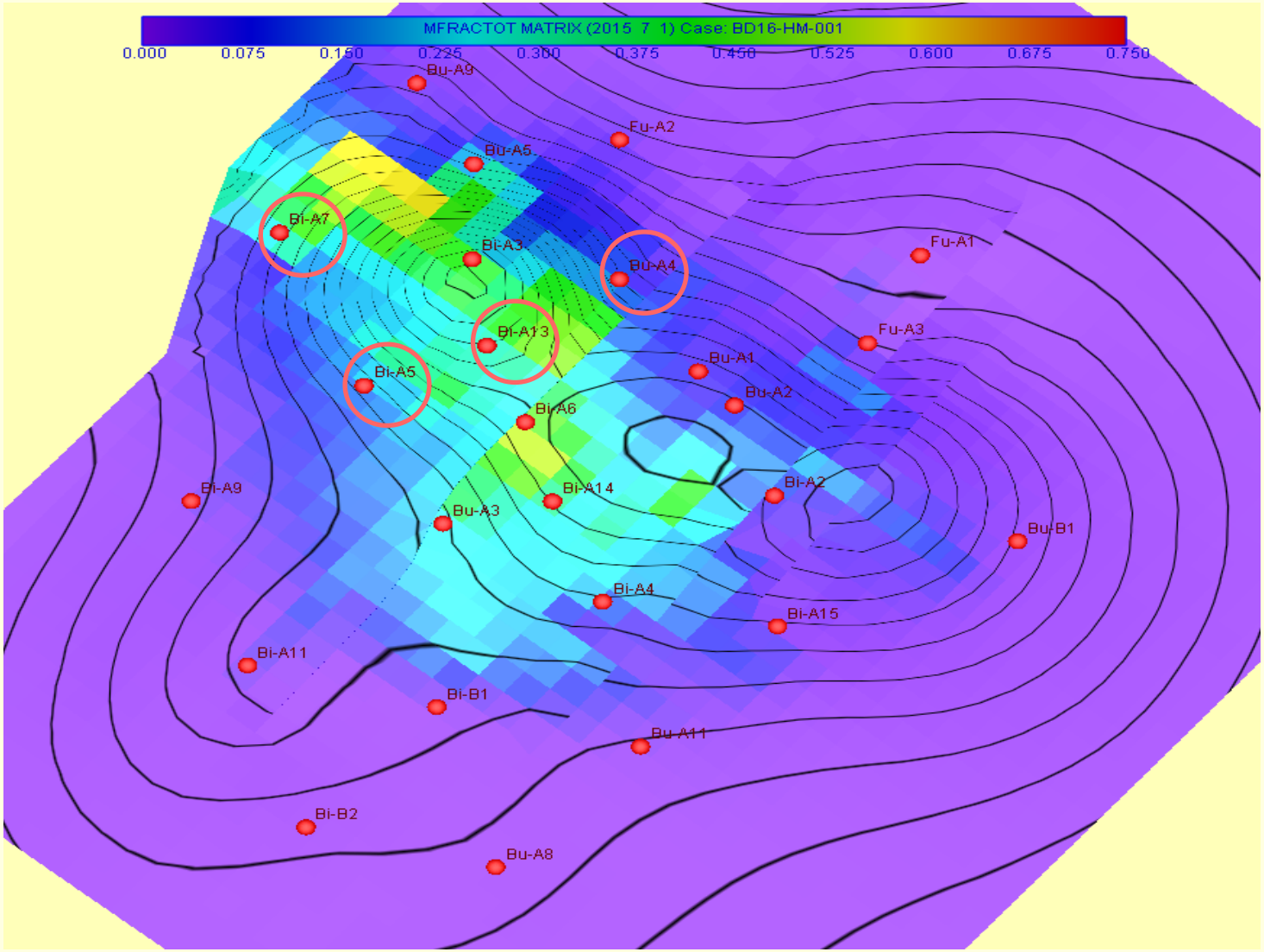


Simulation Model Status- 2016

- Examples – History Match Graphs
  - North Wells
    - Bi-A13 – Best producing well in north area
    - Bi-A7 – Good He concentration
    - Bu-A4 – weaker match on He concentration (+7%)
    - Bi-A5 – weaker match on He concentration (-3%)

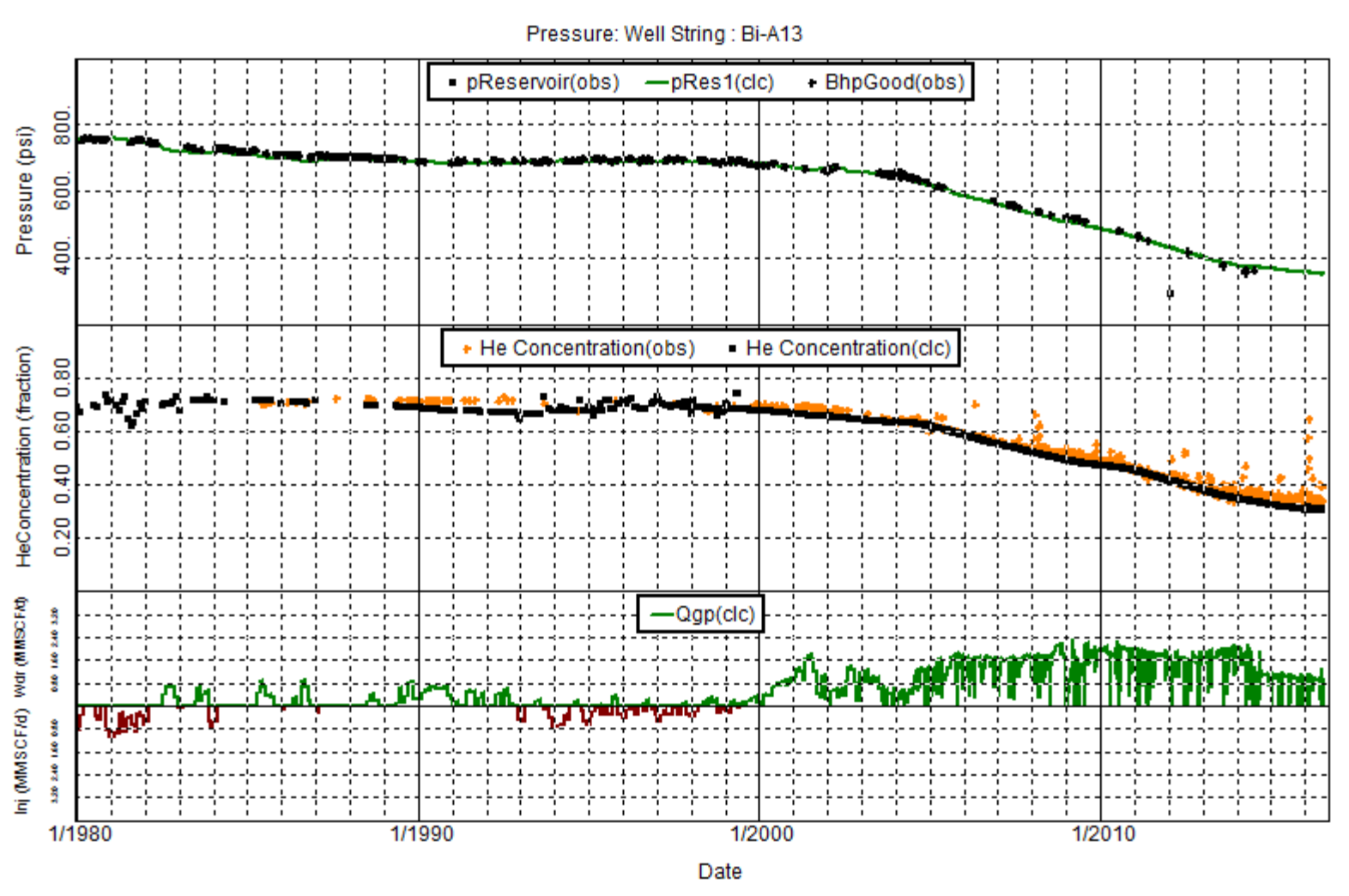
Simulation Model Status - 2016

- North Wells



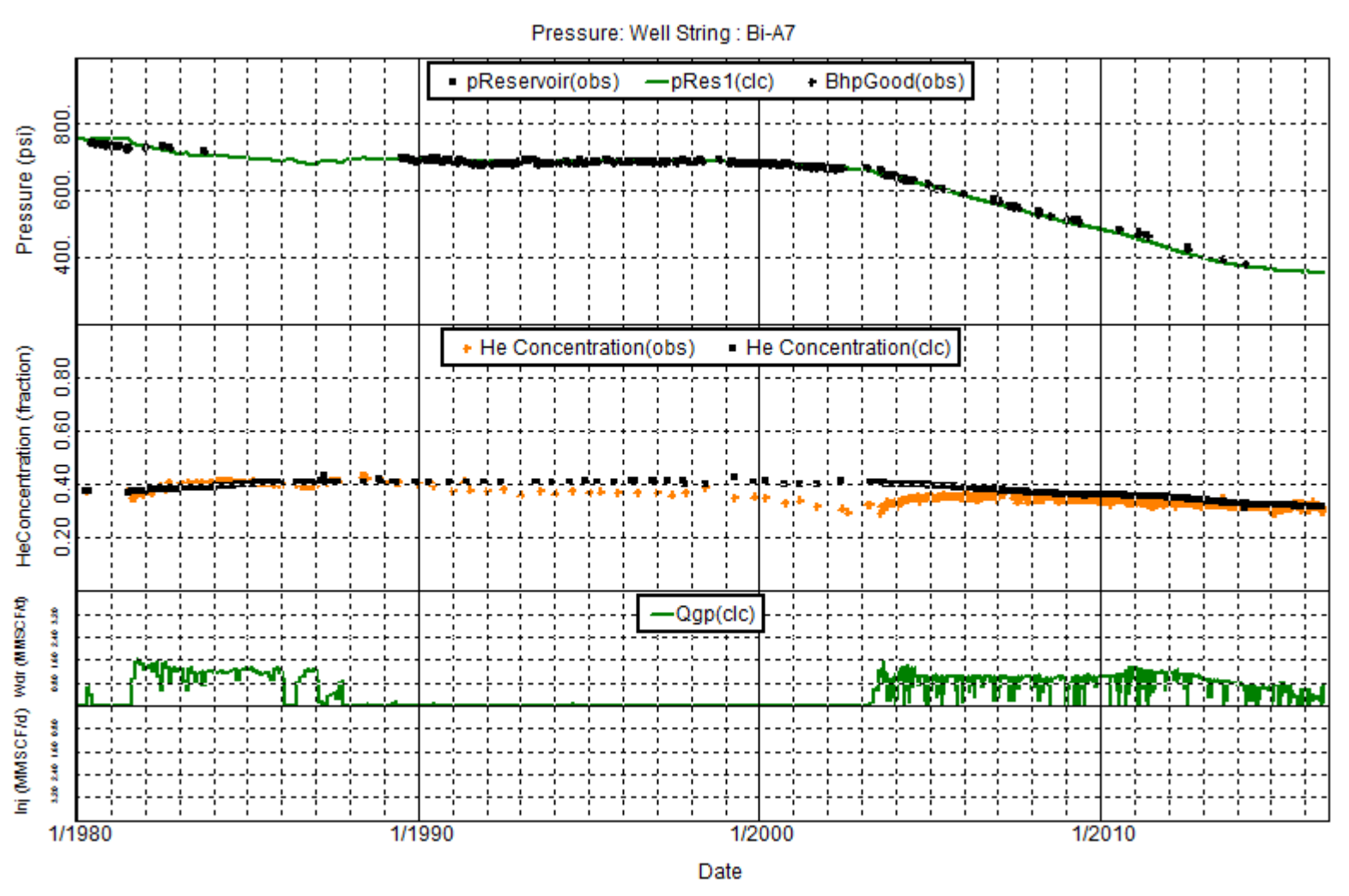
Simulation Model Status - 2016

- HM Plot – Bi-A13 (North Well)



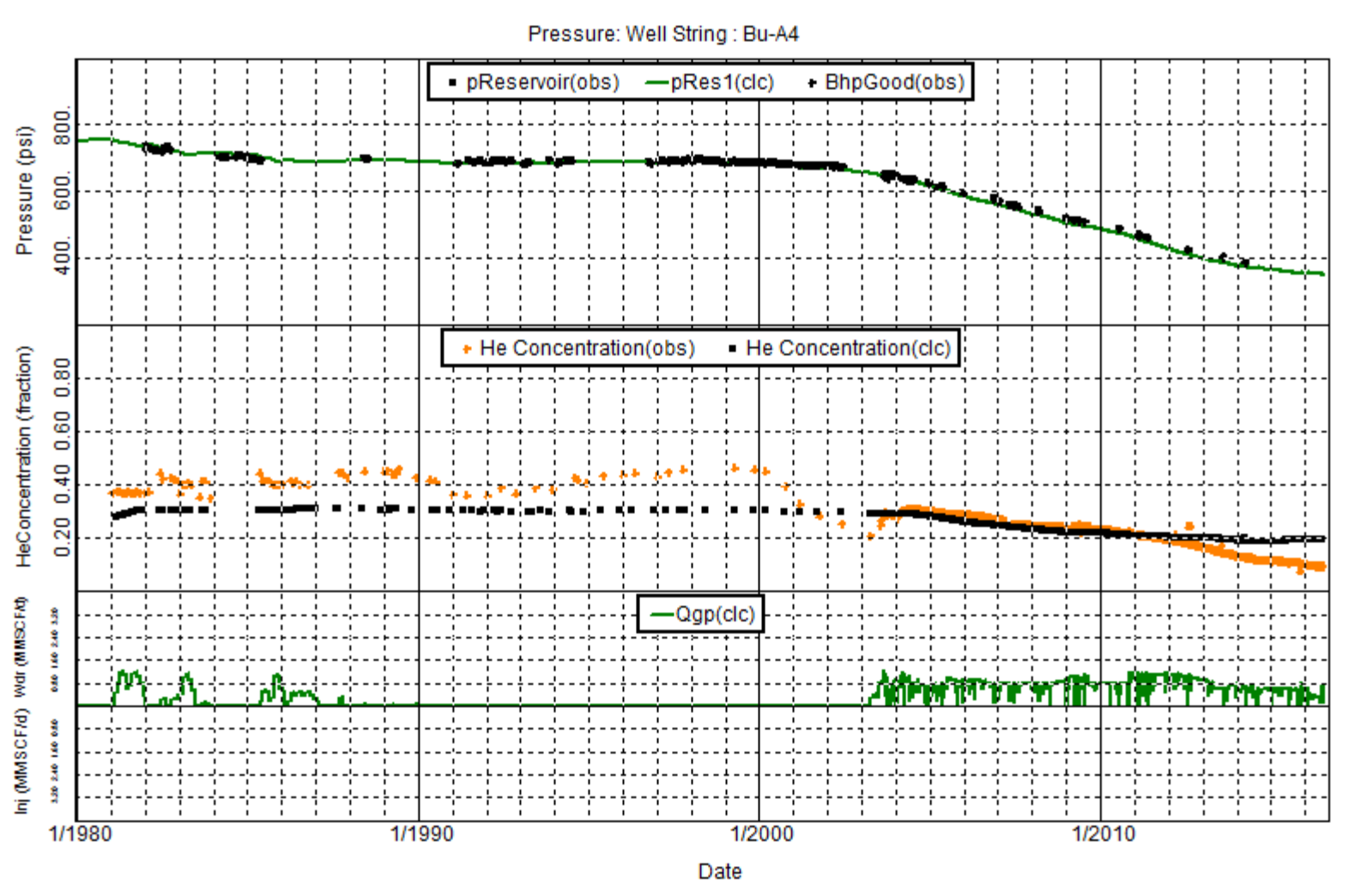
Simulation Model Status - 2016

- HM Plot – Bi-A7 (North Well)



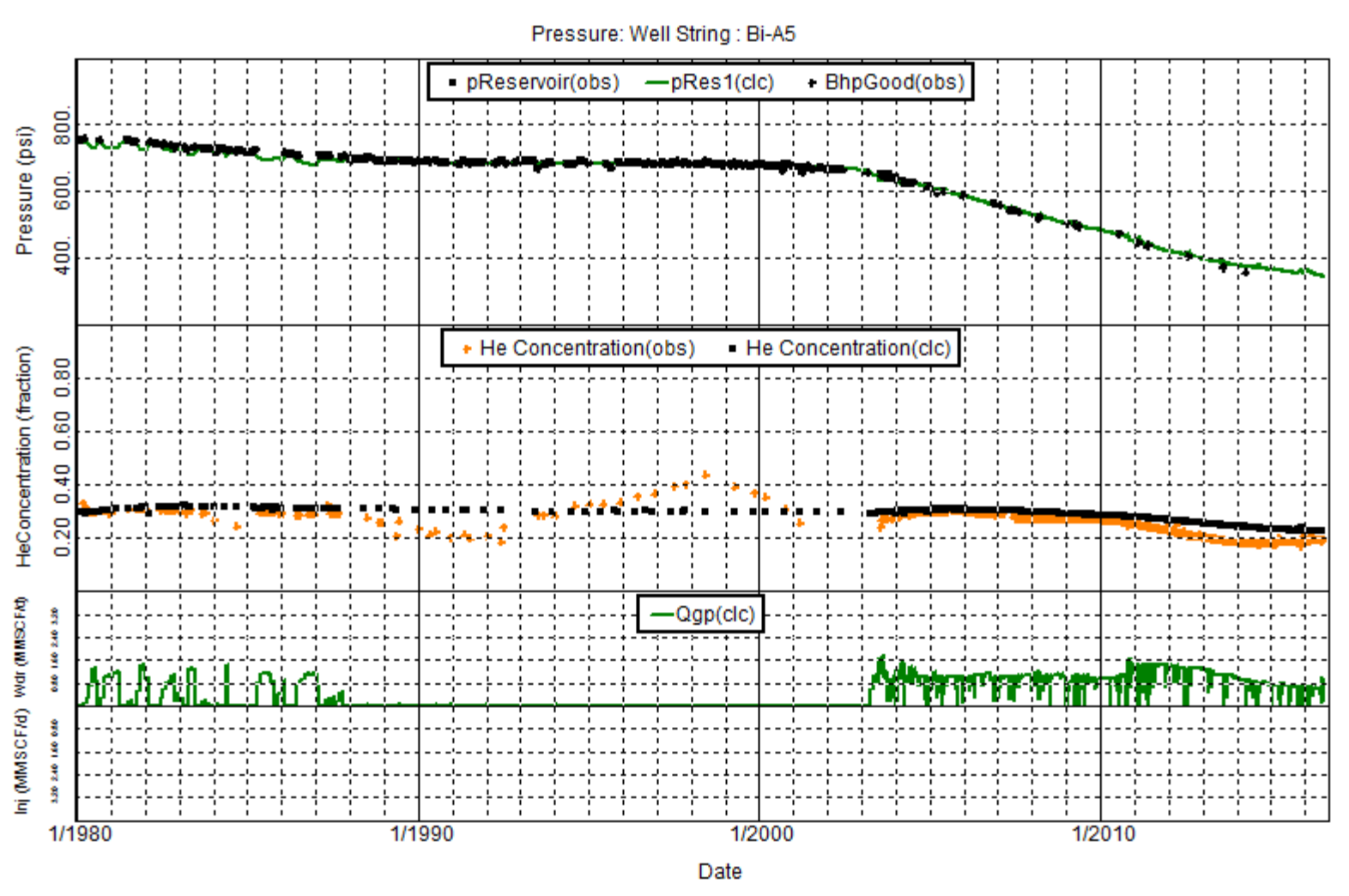
Simulation Model Status - 2016

- HM Plot – Bu-A4 (North Well)



Simulation Model Status - 2016

- HM Plot – Bi-A5 (North Well)



Simulation Model Status - 2016

- Conclusions
  - Model shows very good-excellent match at field level for helium rate, concentrations and pressure
  - Individual well match on helium rate / fraction shows wider variations, but averages out at field level
  - No significant changes in measured water production. Model is OK-good water match
    - Outer edge wells on east produce more water in the model than measured.
    - Other wells show good water match
  - Discussion with BLM on need to improve the history match for wells with divergent He match and to improve water encroachment match.

Implications on Predictions - 2016

- Helium Rate / Fraction
  - Expect model will continue with same level of accuracy VG-Excellent at Field level (Total Gas and He Rate)
- Water Encroachment
  - Provides indications of effects of water encroachment.
  - At this time the model may not accurately predict which wells could be shut-in due to water encroachment and low flow rates.
  - The model can not predict the sudden water breakthroughs due to unidentified fracture connections.

Outline

- *Reservoir Status (Operations: 2015-2016)*
- *Reservoir History & Life Cycle (Depletion)*
- *Simulation Model Status*
- *Predictions*
- *Conclusions*

Estes Park, Rocky Mtn National Park - 2015

Prediction Cases 2016

- Prediction cases
  - 2 Cases: Maximum Rate & Maximum He
    - Case 1
      Current Conditions (K100 modification)
    - Case 2
      Central compression on-line Jan 1 2017

Prediction Cases 2016

- Prediction cases
  - K100 modification, FWHP limit 200 psia
  - All wells producing at FWHP limit
  - Central compression (Jan 2017), FWHP limit 70 psia

  - Case 1 optimize for minimum total gas rate of 9 MM/d

Prediction Cases 2016

- Prediction objective:
  - Determine maximum possible annual helium production from July 1,2016 – Sep 30 2021

Prediction Cases 2016

- Prediction cases
  - **Case 1: Current operations**
    - Pmin for all wells = 200 psia
    - Maximum well rates (max He rate)
  - **Case 1- 9MM**
    - Maintain at least 9 MM/d total gas rate until 9/30/2021
  - **Case 2: Central compression online Jan 1 2017**
    - Pmin = 70 psia
    - Maximum well rates (max He rate)

Prediction Cases 2016

- Results
  - *Preliminary results to assist with future planning. Prediction results will be reviewed with BLM.*
  - *Final annual sales volumes will be determined by BLM based on the predicted production volumes with consideration of other relevant factors.*
  - *Note: all results are simulation model estimates, indicating the future trends. These predictions do not take into account production changes or future operational issues that can occur in any gas production field – such as (but not limited to)*
    - *Changes in He demand*
    - *Well damage/flow issues, water encroachment*
    - *Surface facility issues, upgrades, repairs….*

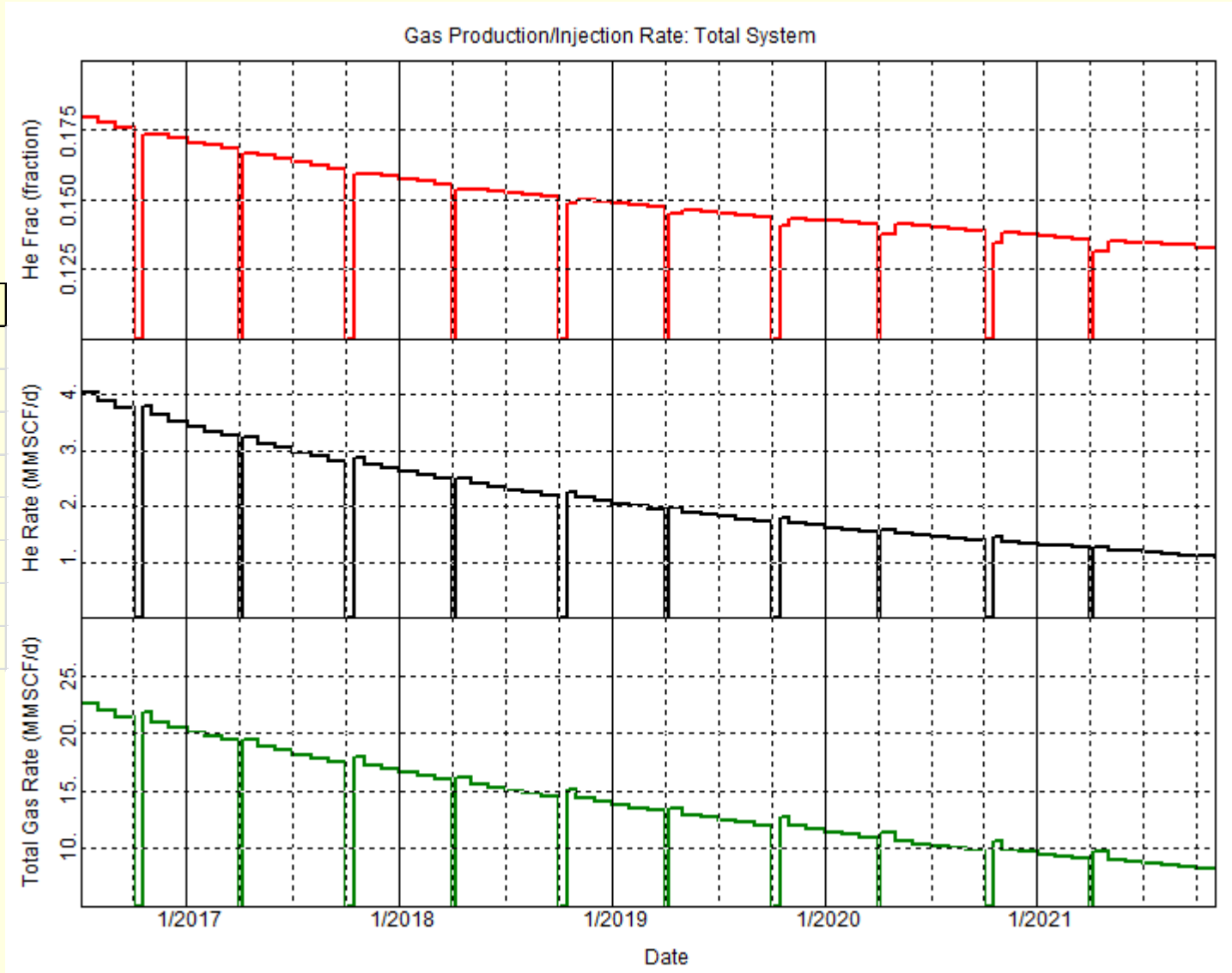
Prediction Cases 2016

- Results
  - Case comparisons
    - Graphs with rates and cumulative volumes
    - Tables with rates and cumulative volumes

Prediction Cases 2016

- Case 1 K-100

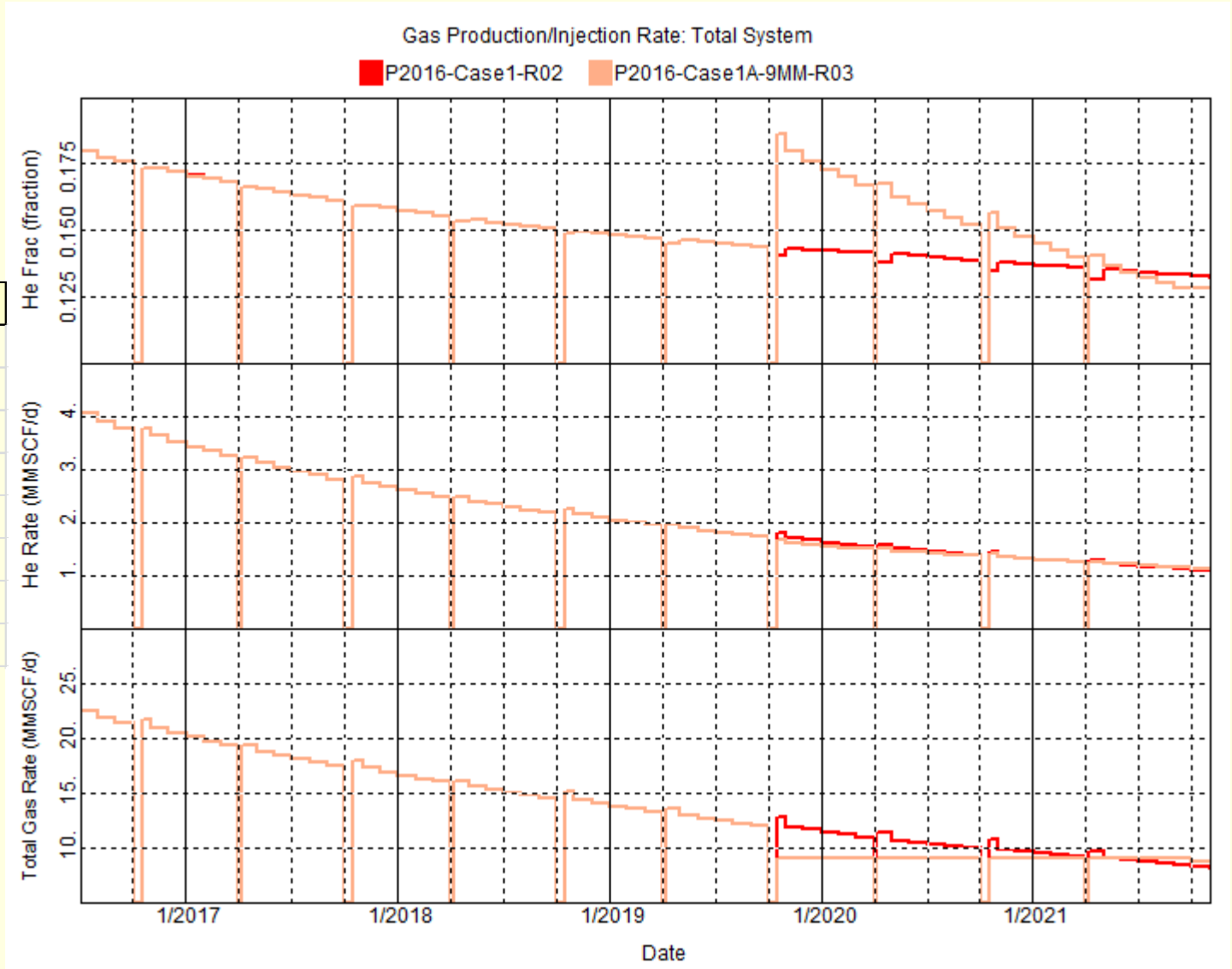
Annual Helium Vol (BCF)	
FY	Case 1
2016	0.339
2017	1.059
2018	0.812
2019	0.638
2020	0.509
2021	0.410
Total	3.767



Prediction Cases 2016

- Case 1 K-100 – 9MM

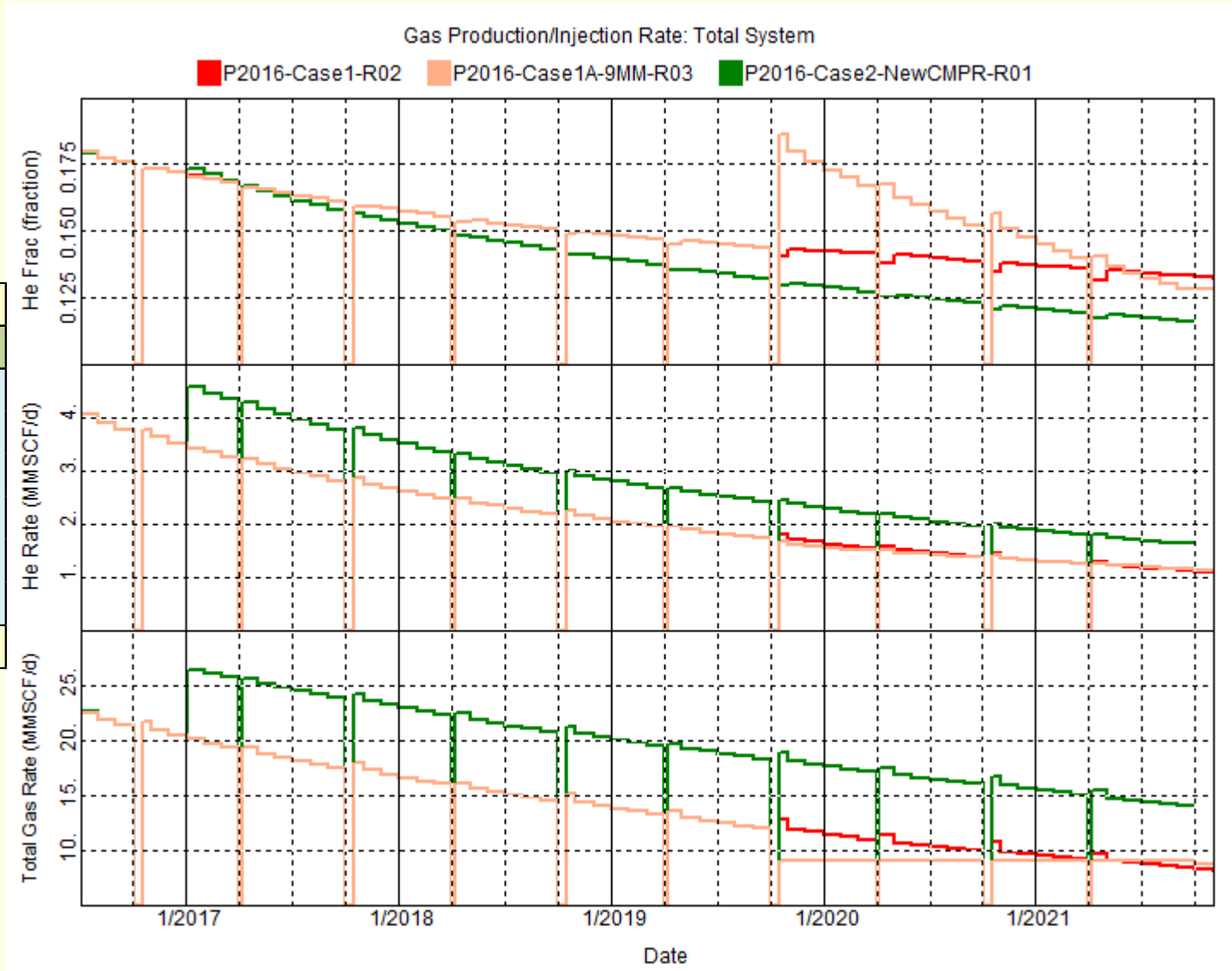
Annual Helium Vol (BCF)		
FY	Case 1	Case1-9
2016	0.339	0.339
2017	1.059	1.059
2018	0.812	0.811
2019	0.638	0.638
2020	0.509	0.493
2021	0.410	0.412
Total	3.767	3.752



Prediction Cases 2016

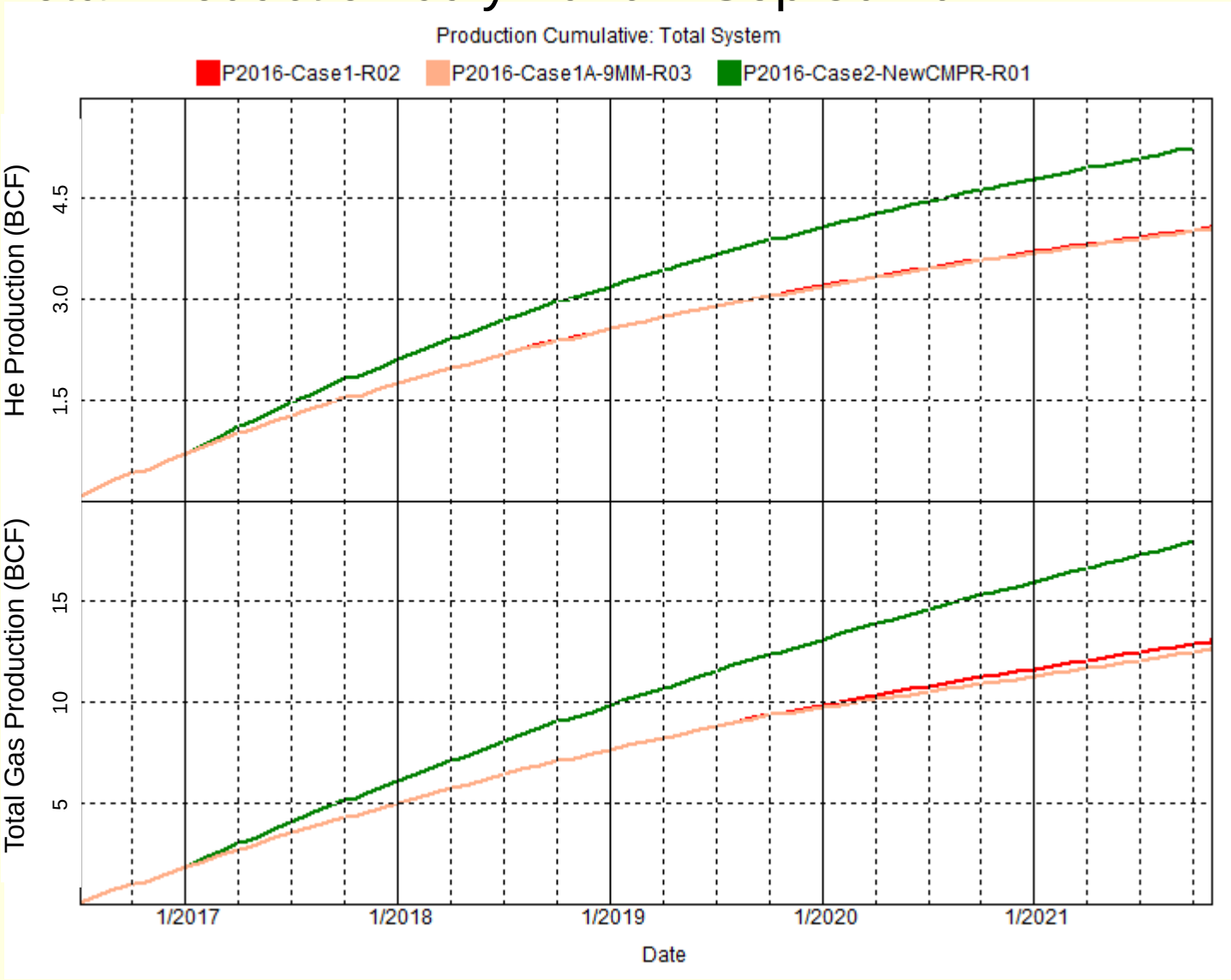
- Case 2 C-100

Annual Helium Vol (BCF)			
FY	Case 1	Case1-9	Case 2
2016	0.339	0.339	0.339
2017	1.059	1.059	1.325
2018	0.812	0.811	1.092
2019	0.638	0.638	0.876
2020	0.509	0.493	0.716
2021	0.410	0.412	0.586
Total	3.767	3.752	4.934



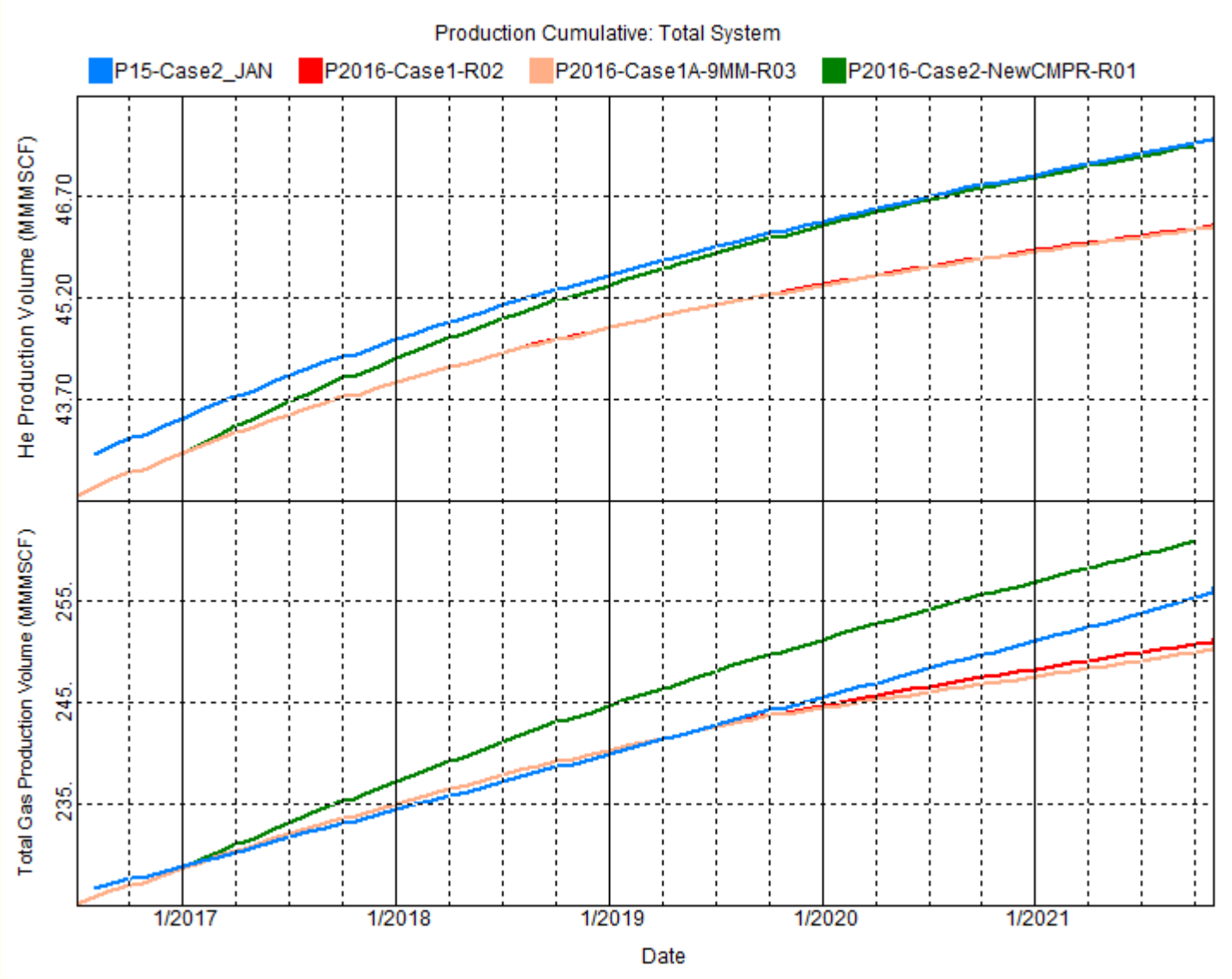
Prediction Cases 2016

- Total Production July 2016 – Sep 30 2021



Prediction Cases 2016

- Total Prod. July 2016 – Sep 30 2021 vs 2015 Case 2



Prediction Cases 2016

2016 Prediction Case Results			
Annual Production - 95%			
	Helium Produced Since July 1 2016		
(1st of mth)	Case 1 K100 (Bcf)	Case 1-9MM K100-9MM (Bcf)	Case 2 CC 1/2017 (Bcf)
Oct-2016	0.339	0.339	0.339
Oct-2017	1.059	1.059	1.325
Oct-2018	0.812	0.811	1.092
Oct-2019	0.638	0.638	0.876
Oct-2020	0.509	0.493	0.716
Oct-2021	**0.410**	**0.412**	**0.586**

Cumulative Production - 95%			
	Helium Produced Since July 1 2016		
(1st of mth)	Case 1 K100 (Bcf)	Case 1-9MM K100-9MM (Bcf)	Case 2 CC 1/2017 (Bcf)
Oct-2016	0.339	0.339	0.339
Oct-2017	1.398	1.398	1.664
Oct-2018	2.210	2.210	2.756
Oct-2019	2.848	2.848	3.632
Oct-2020	3.357	3.340	4.348
Oct-2021	**3.767**	**3.752**	**4.934**
Difference between cases		***-0.015***	***1.182***

Outline

- *Reservoir Status (Operations: 2015-2016)*
- *Reservoir History & Life Cycle (Depletion)*
- *Simulation Model Status*
- *Predictions*
- *Conclusions*

Conclusions

Conclusions

- Producing with only the K100 modification will reduce the total He produced by 9/30/2021 by -1.228 BCF when compared to central compression online by Jan 2017 *(Case1)*
- In order to keep the HEU running until 9/30/2021 with only the K100 modification, the total gas rate must be reduced to 9 MM/d on 10/1/2019. This will further reduce the total He produced by -15 MM *(Case1-9MM)*
- Having central compression online by Jan 1 2017, will increase the total gas rate and He rate for 45 months. *(Case2)*
- Additional He produced under this case is 4.934 BCF (July 2017 – Sep 30 2021) *(Case2)*

Conclusions

- **Conclusions**
  - Predicted annual He volumes are the sum of the daily production rate, which is on *a constant decline* from the first day of the FY to the last day of the FY.
  - Predicted production volumes represent the maximum volume of helium that *could be* delivered from the HEU;

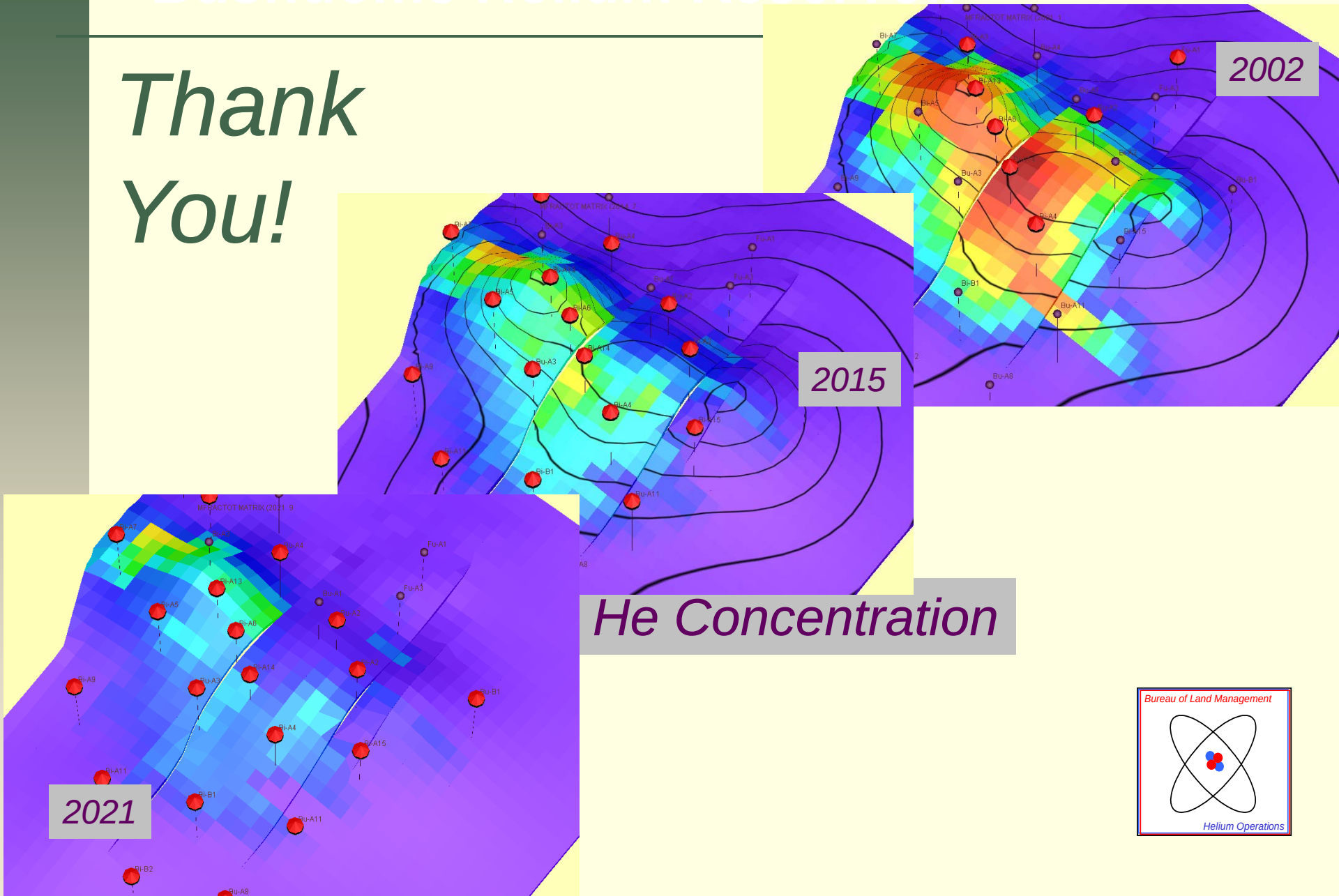
    It does not necessary equate to future helium sales (determined by BLM)
    or actual production volume (determined by demand)
  - The *declining rates* will impact the volume per month of private industry helium as the helium production available for private industry will be the helium, production volume less Federal requirements.

Discussion

- Questions, comments, concerns ?

Bushdome Helium Reservoir

Thank You!



Bureau of Land Management

Helium Operations