Production Data from the Cardium Formation Evaluated within a Geologic Framework to Identify Criteria Useful in Selecting Areas for Exploitation by Multi-stage Fracturing of Horizontal Wells*

L. Barry McNamara[1]

Search and Discovery Article #20158 (2012)**
Posted July 23, 2012

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Long Beach, California, USA, April 22-25, 2012

[1]Spartan Oil Corp, Calgary, AB, Canada (bmcnamara@spartanoil.ca)

Abstract

The Cardium Formation in Alberta, Canada, has produced more than 1.7 billion barrels of light oil since 1953. This zone has been revived as a drilling target since 2008 by application of multi-stage fracture stimulations to horizontal wells. As of November, 2011, 62,000 bopd is being produced from over 1100 horizontal wells. The oil rate in the 3rd month of production (IP3) is used here as a standard to correlate with geologic setting and reservoir properties. The objective is to develop methods to 1) identify where there are recoverable reserves remaining within the boundaries of established pools, including undeveloped tight sands, and 2) high-grade areas outside the known pool boundaries that will produce oil at economic rates from tight sands. The impact on IP3 of differing well-stimulation strategies was not part of this analysis.

The objectives were explored in 2 steps. First, based on where the wells were placed relative to producing areas, over 900 wells having IP3 values were assigned to the following categories: primary recovery area, waterflood area, extensions to known pools, or exploration area. The IP3 data were analyzed by these categories to identify trends and statistics. Observations included:

- average IP3 rates from new wells in and around known pools are higher than average IP3 rates in exploration areas;
- exploration wells accounted for a disproportionate share of poorly performing wells;
- higher gas-oil-ratio (GOR) is associated with lower IP3 rates in every field area.

To address the GOR issue, a screening tool was developed and applied regionally to identify areas where high GOR was expected in oil exploration targets.

Next, an area in Pembina, covering 5 townships, and containing a variety of prospect types was studied. Net pay, oil in-place, oil recovery factor (RF), GOR, and depletion, were quantified in each of 3 zones over the map area: lower sand, main sand and conglomerate. To address exploration risk (i.e., low IP3 rates in exploration wells), multiple regression was used to predict expected IP3 in the tighter halo surrounding the producing area. Net pay in the “main sand” was the most significant variable for prediction of expected IP3. In legacy producing areas,

RF varied from less than 4% to over 16%. A map of RF highlighted areas to be targeted by infill drilling. The approach used here should be applicable to the assessment of the Cardium Formation in other areas.

Production Data From The Cardium Formation Evaluated Within A Geologic Framework To Identify Criteria Useful In Selecting Areas For Exploitation By Multi-stage Fracturing Of Horizontal Wells

L BARRY MCNAMARA
SPARTAN OIL CORP

Tight Oil in the Cardium Formation

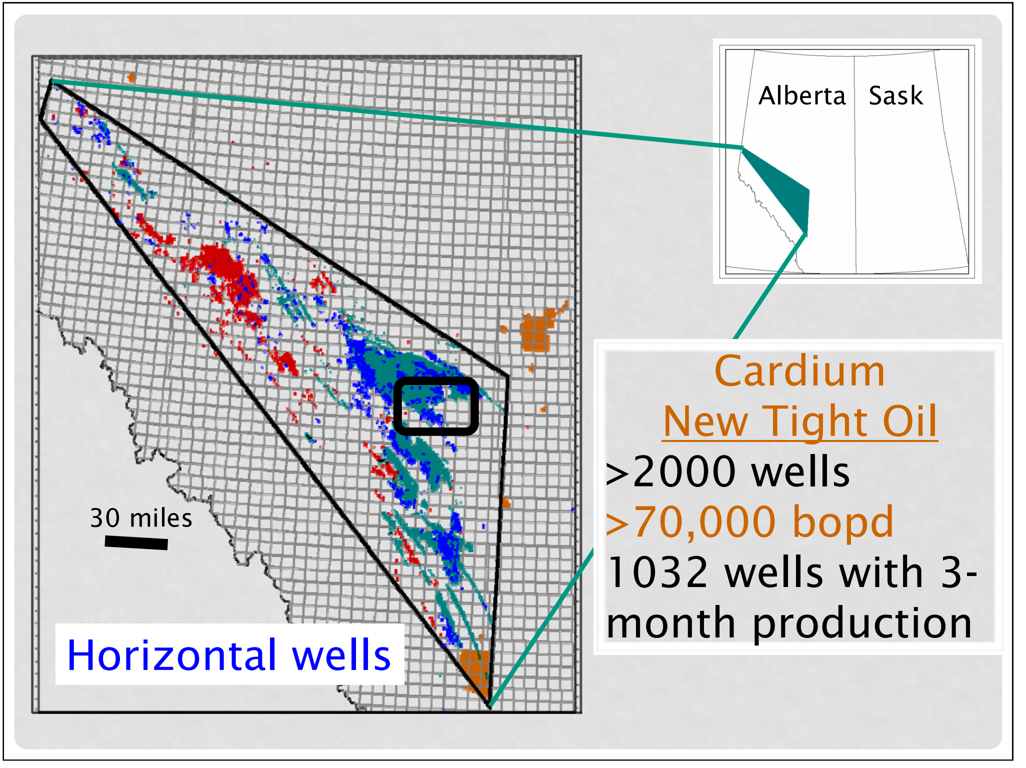
- Highest risk: extension and outpost drilling,
- Real differences in IP across the Cardium tight sand fairway
- Net pay definition: critical to success
- Oil production with high GOR is a significant risk in the Cardium (if you don’t screen for it)
- Relative importance of differing risk factors depends on exploration or development context

THE SUPPORTING STORY

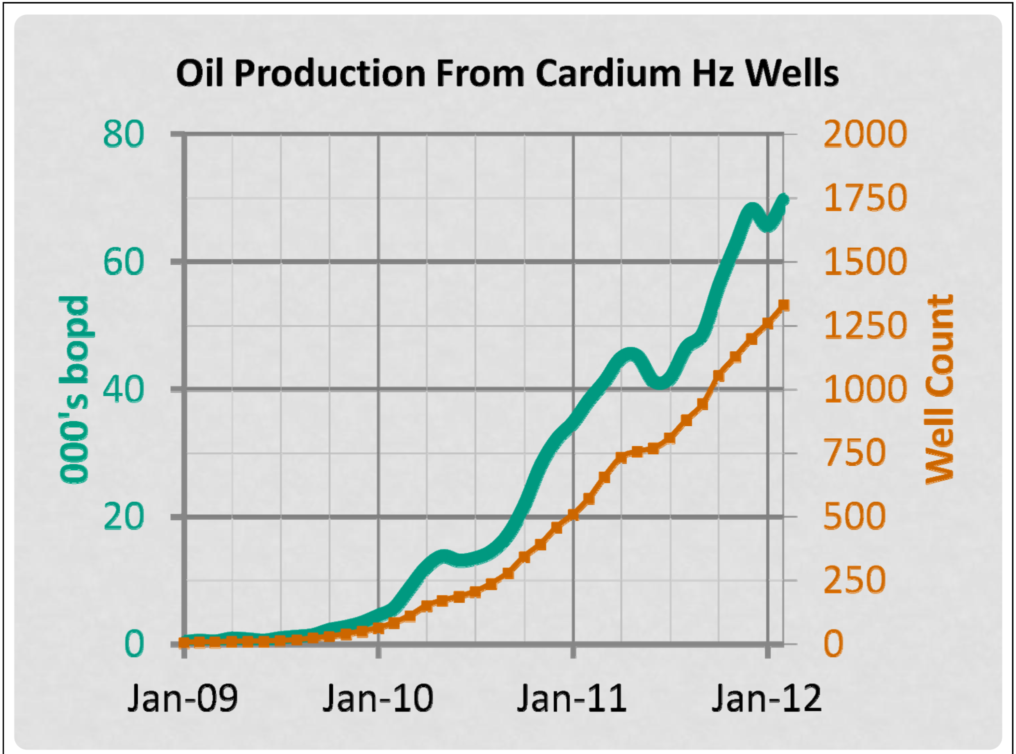
1. Breakdown of production data from horizontals:
   - By exploration and development wells
   - By drilling area
2. Net pay and cutoffs
3. GOR screening
4. Conclusions

Breakdown of Production Data

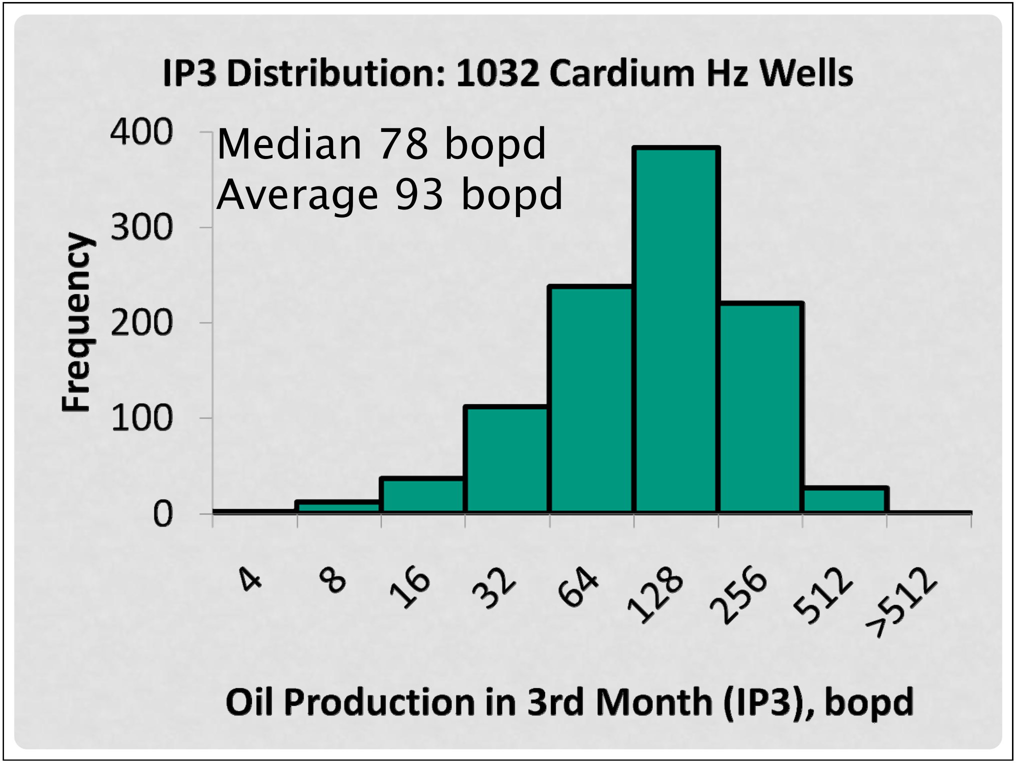
IP DATA FROM OVER 1000 WELLS



Presenter's notes: Since 2008, open-hole completions of horizontal wells have given way to cased hole, multi-stage fractured horizontal wells, with great success. Production levels are back up to 1979 levels (30 + years!)

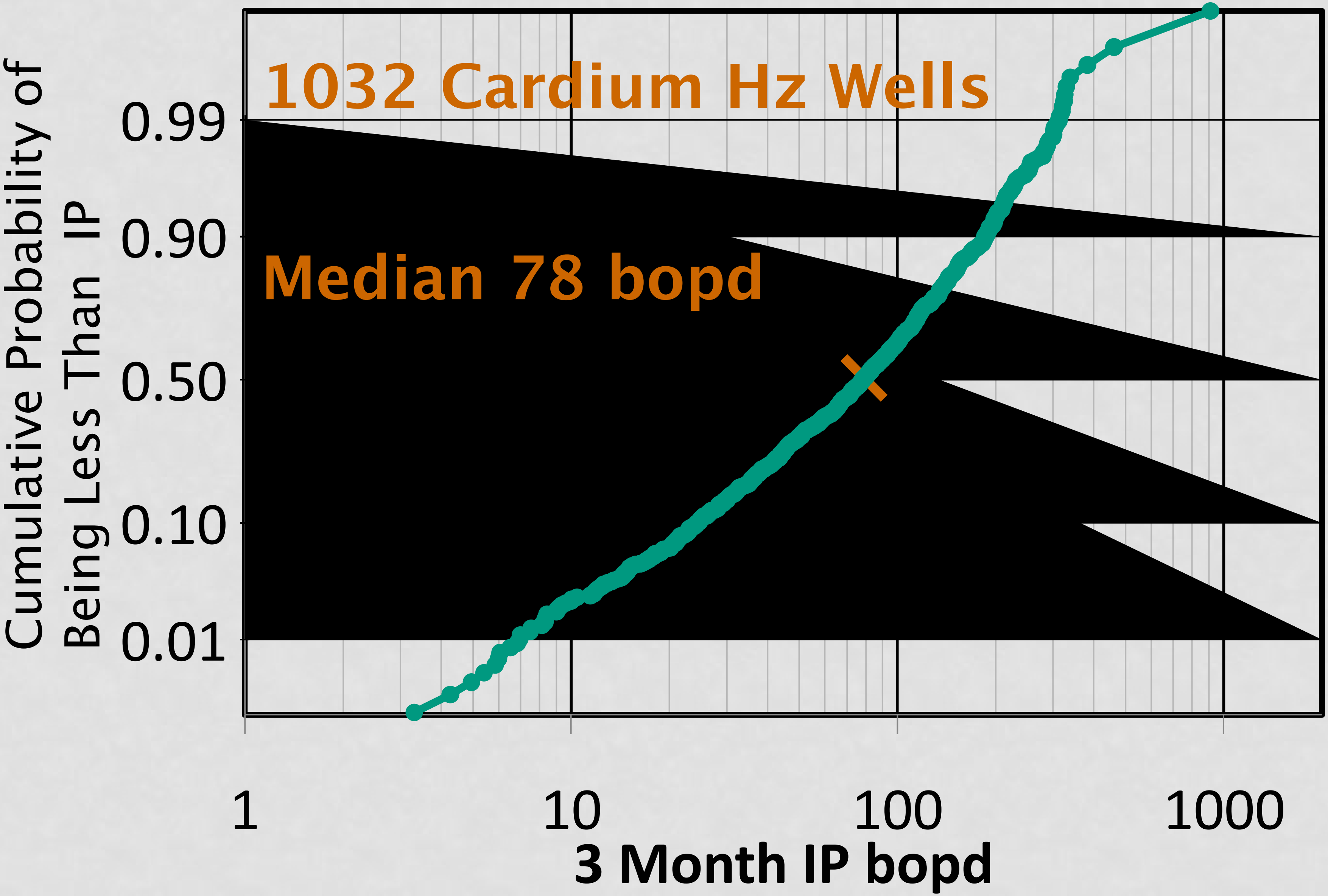


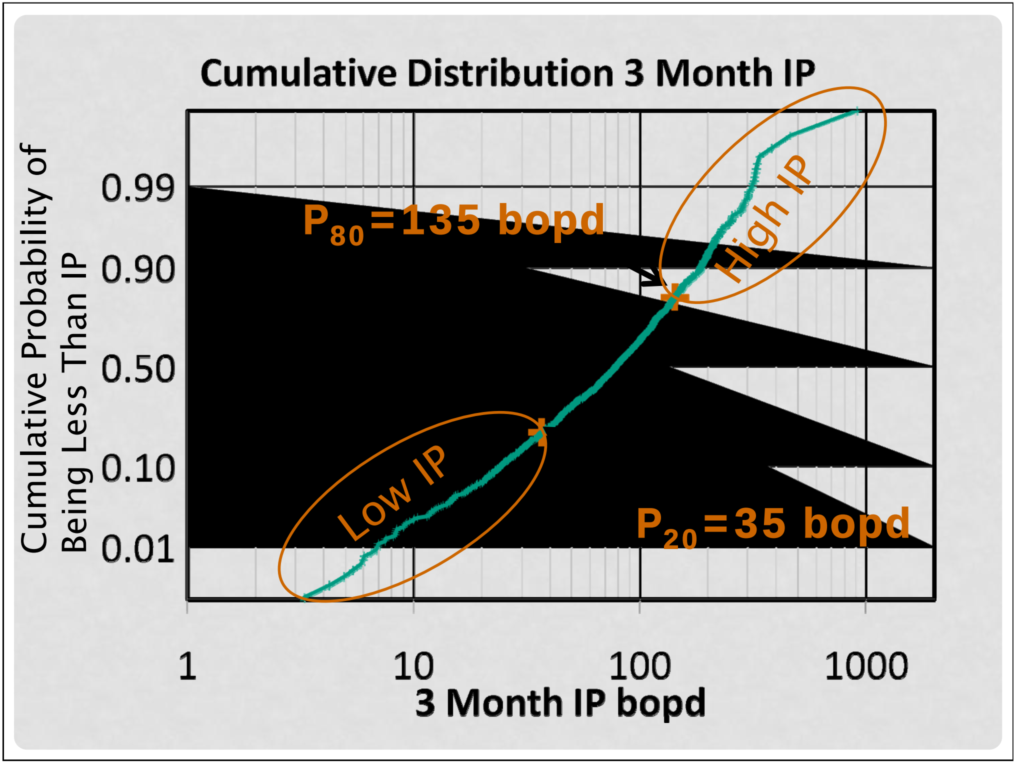
Presenter's notes: Production rise is poised to go ever steeper. We are awaiting production info on 700+ wells. There are less than 500 wells with 1 year of production.



Presenter’s notes: Histogram of IP 3 month. Lognormal distribution. This is for all IP 3-month data from 1032 wells.

Cumulative Distribution 3 Month IP





Presenter's notes: There are many reasons wells will have low IP: 1) knowingly drill marginal lands (farm-in to earn better lands, drilling on expiring lands, tax treatment for exploration wells, the only land we have on the play) 2) unknowingly drill marginal lands (confidence in high resource estimate misplaced due to anomalous value of key variable) 3) unknowingly drill where significant unknown variables had a negative impact. There are many reasons wells will have high IP: 1) knowingly drill superior wells (competitive advantage from technology or land position) 2) unknowingly drill superior lands (confidence in low resource estimate misplaced due to anomalous value of key variable) 3) unknowingly drill where significant unknown variables had a positive impact.

CLASSIFICATION OF HORIZONTALS (1032 WELLS ASSIGNED TO CATEGORIES)

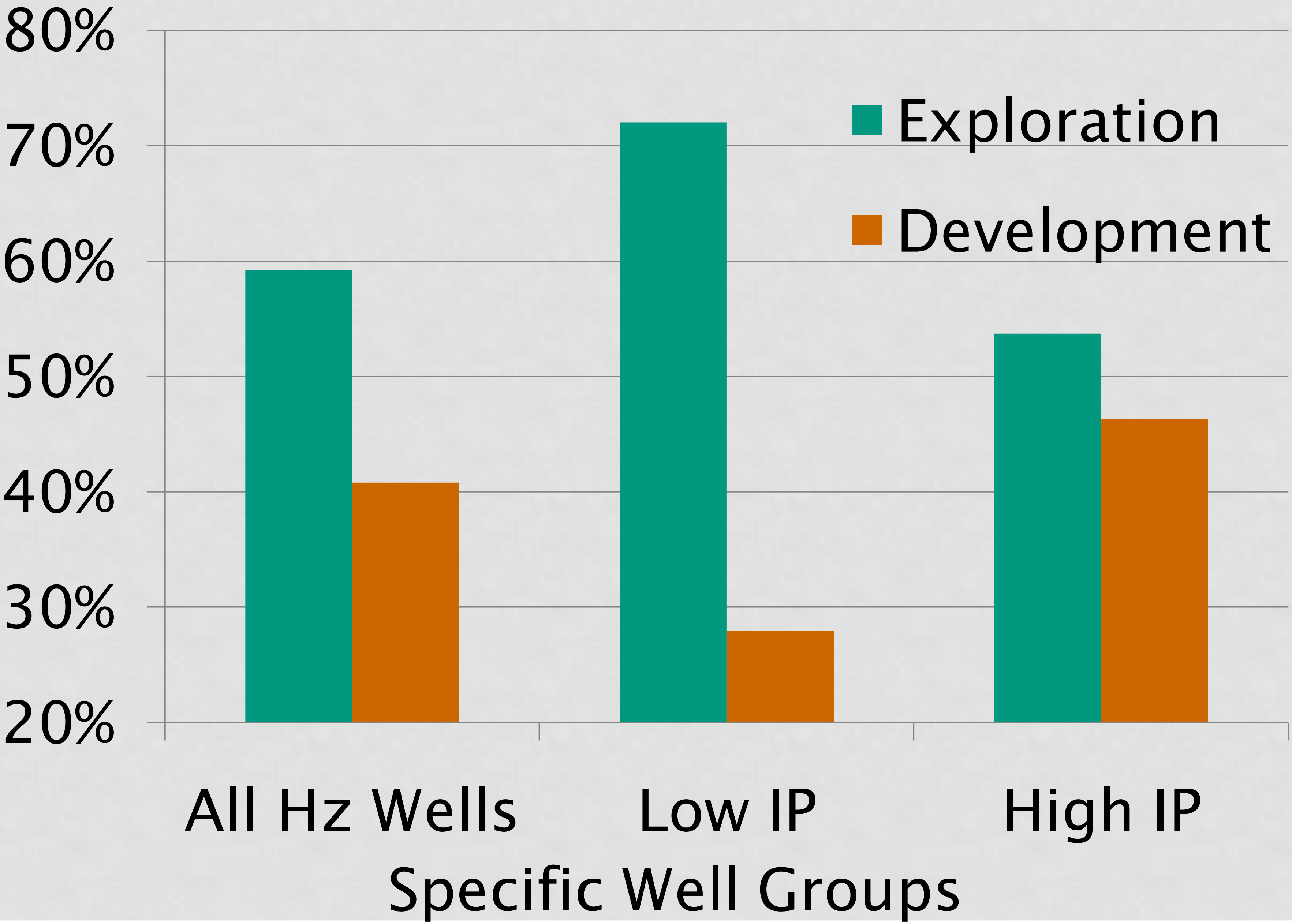
Development

- Drilled into primary area
- Drilled into waterflood area
- Drilled into known pool edge

Exploration

- Extension drill (0.5 to 1 mile from known edge)
- Outpost (more than 1 mile)

EXP and DEV Wells Within Groups

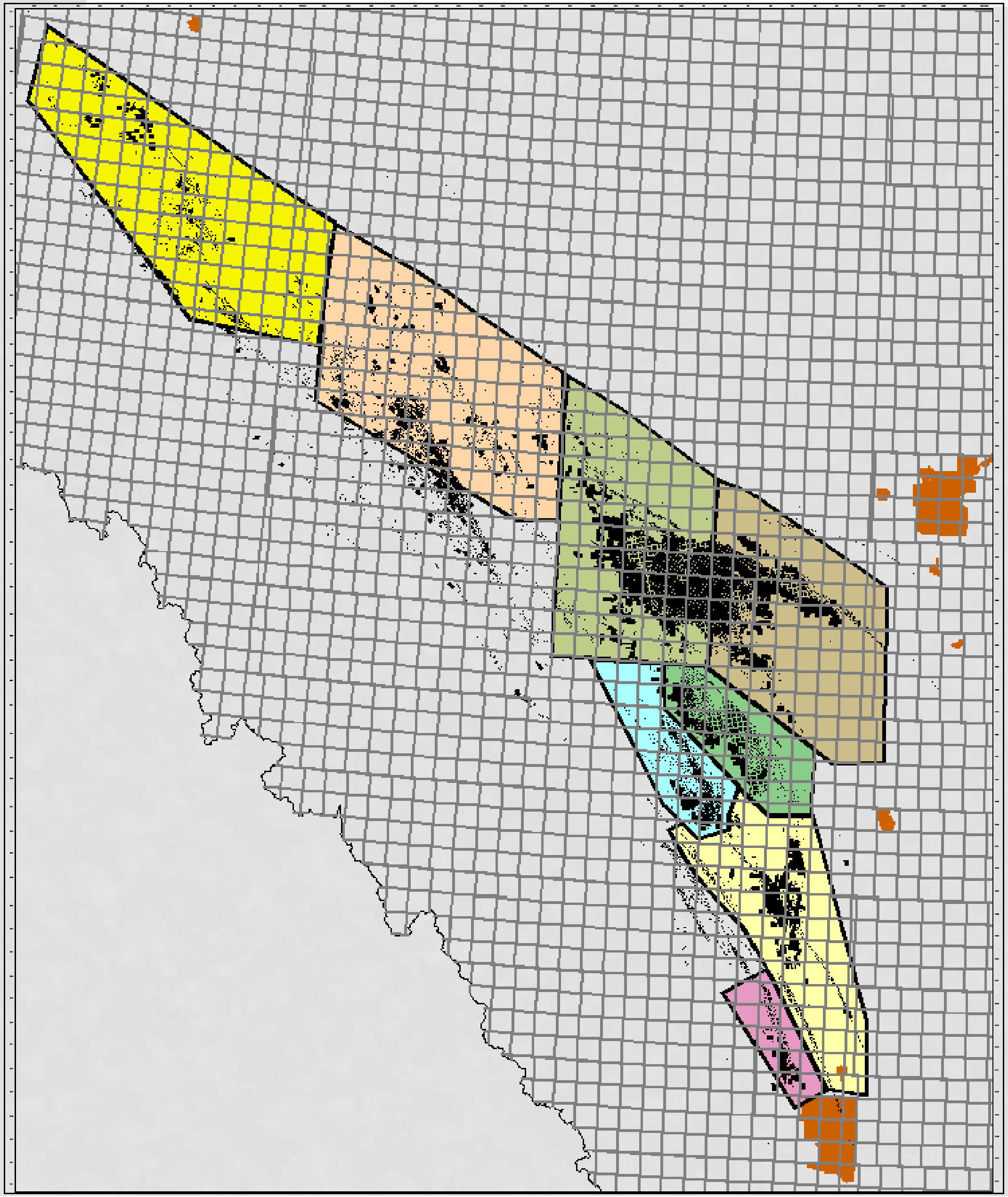


IP BY DEVELOPMENT OR EXPLORATION CATEGORY

Location	# wells	Avg IP3 bopd
Infill Primary	148	103
Infill Waterflood (same lsd as injector)	24	66
Infill Waterflood (adjacent lsd)	79	107
Edge	177	99
Extension	296	93
Outpost	308	85

Red = good, better than average Blue = bad, worse than average

Production By Area



Wapiti

Pine Creek

West Pembina

East Pembina

Willesden Green

Ferrier

Garrington

Lochend

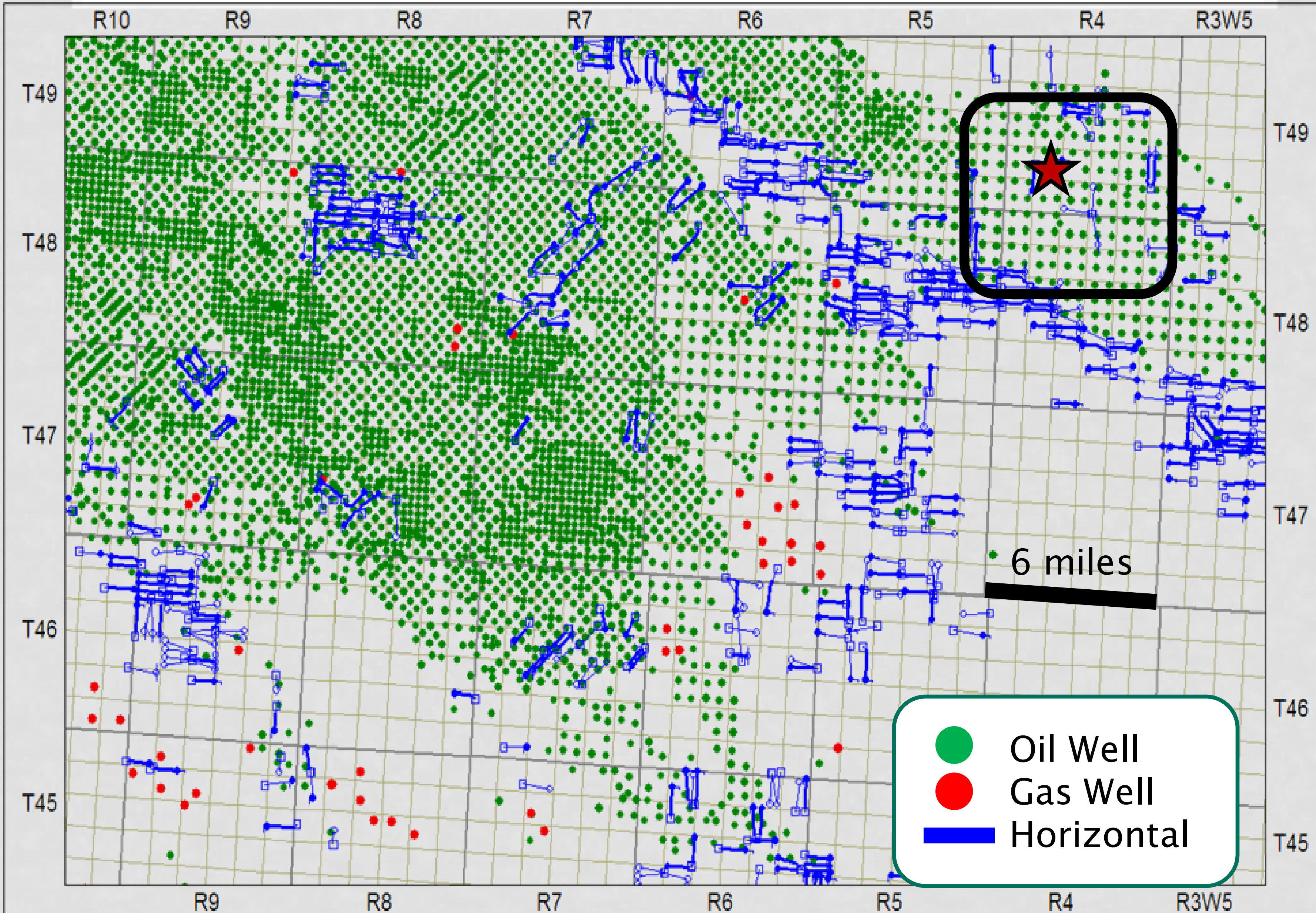
Area	Drills	Avg IP3 bopd	Avg GOR scf/bbl	% Low IP In Area	% High IP In Area
Lochend	34	**118.9**	1736	21%	**32%**
West Pembina	332	**114.8**	2513	**13%**	**33%**
Willesden Green	79	87.4	**7626**	**13%**	18%
East Pembina	325	85.6	2426	19%	18%
Garrington	176	81.3	1891	**13%**	**11%**
Ferrier	28	70.1	**18517**	**36%**	**7%**
Pine Creek	43	62.4	**11092**	**42%**	**12%**
Wapiti	15	37.9	**8411**	**53%**	**0%**

Red = good, better than average   Blue = bad, worse than average

NET PAY AND CUTOFFS

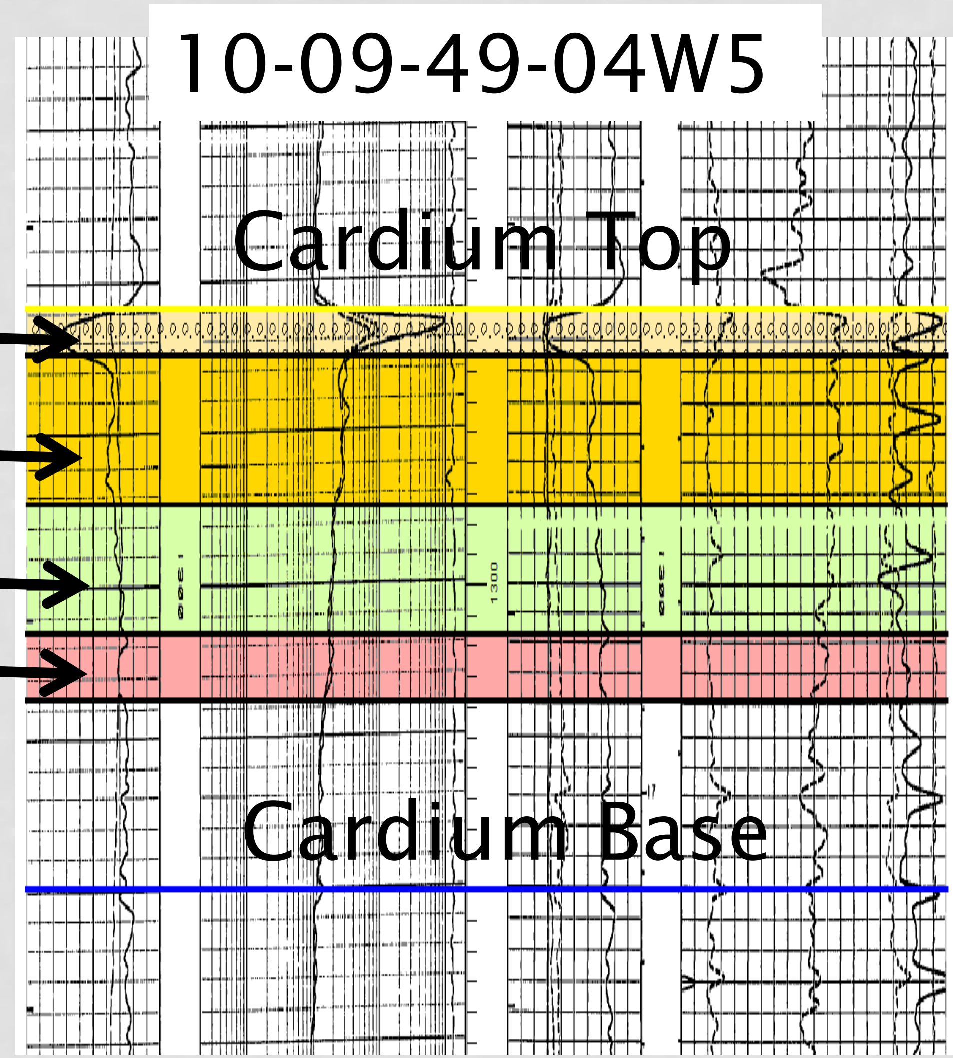
6% CUTOFF?

Net Pay Example: Keystone Area



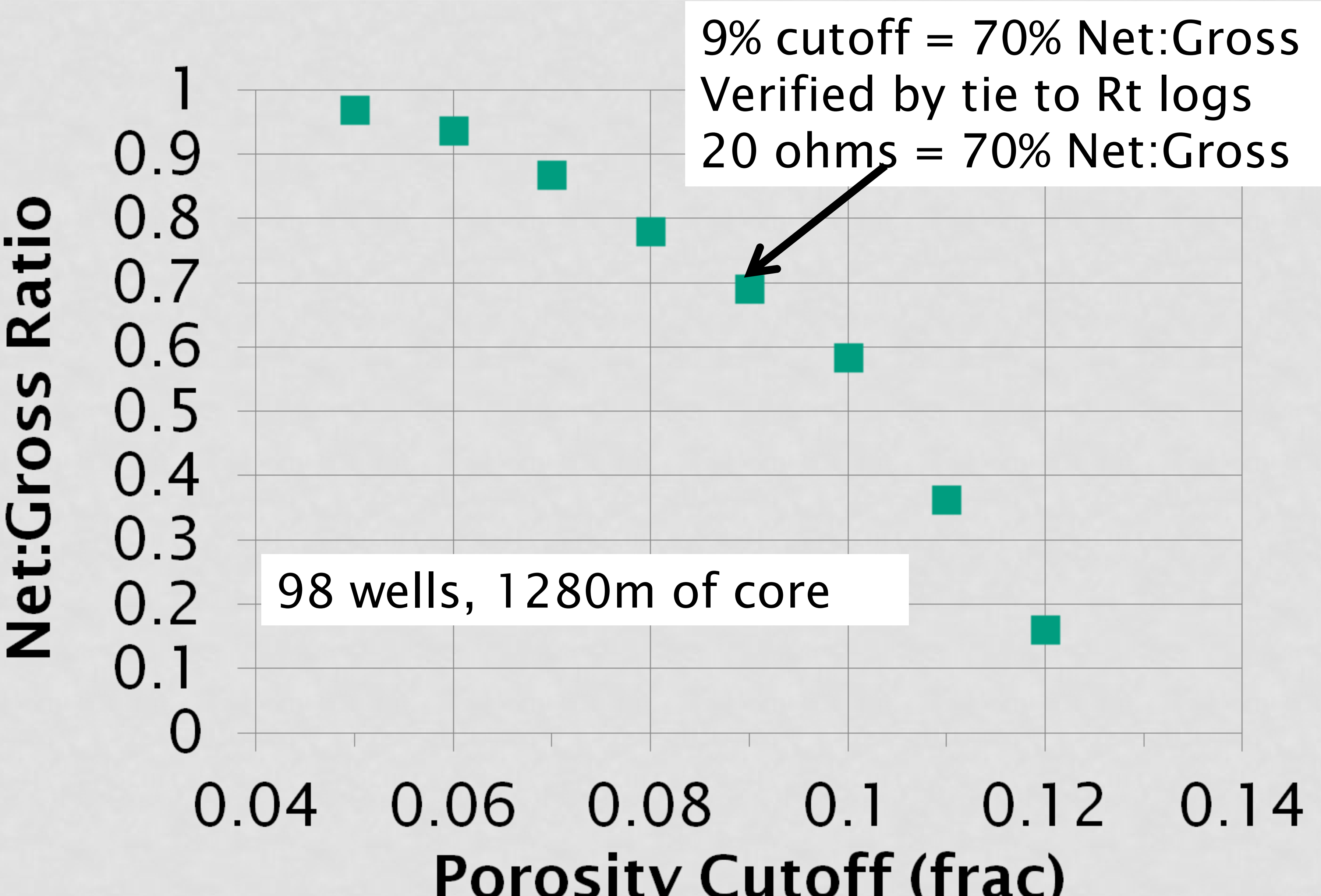
AVERAGE POR & PERM: 98 WELLS, KEYSTONE AREA

Zone	k_{max} (mD)	por (frac)
Zone 3	90.7	0.124
Zone 2	3.6	0.105
Zone 1	5.0	0.101
Zone 0	5.2	0.097



Net Pay Using:
6% por = 16.1m
20 ohm = 9.4m

Net:Gross Ratio by Porosity Cutoff



Application:

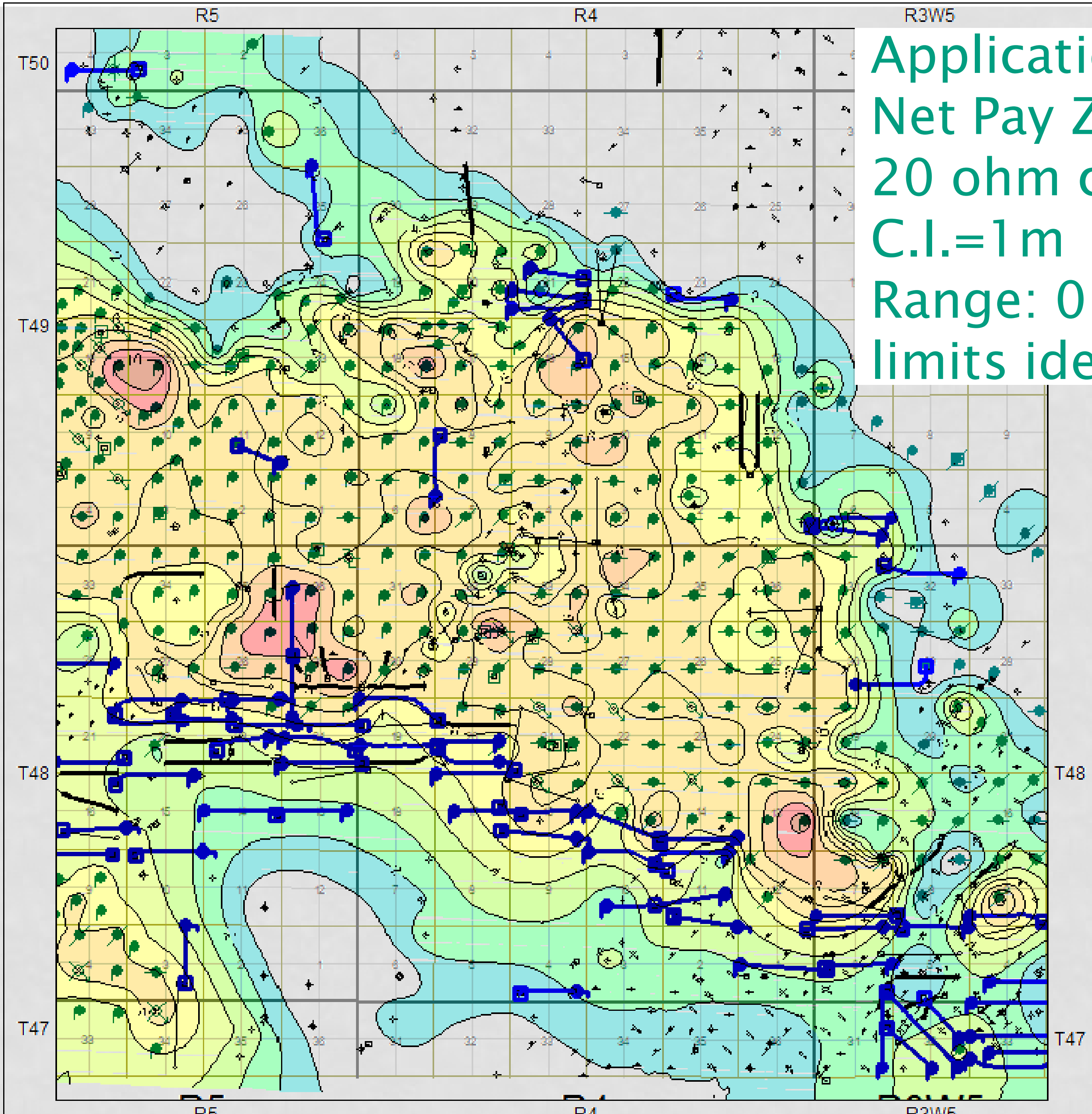
Net Pay Zone 2:

20 ohm cutoff

C.I.=1m

Range: 0 to 9m

limits identified



2 miles

TEST NET PAY CUTOFF AGAINST ACTUAL PRODUCTION FROM HZ WELLS

	Wells	Avg IP3	Low IP Wells	Risk of Low IP
Pay > 4m	25	98.6	1	4%
Pay < 4m	26	54.7	11	42%

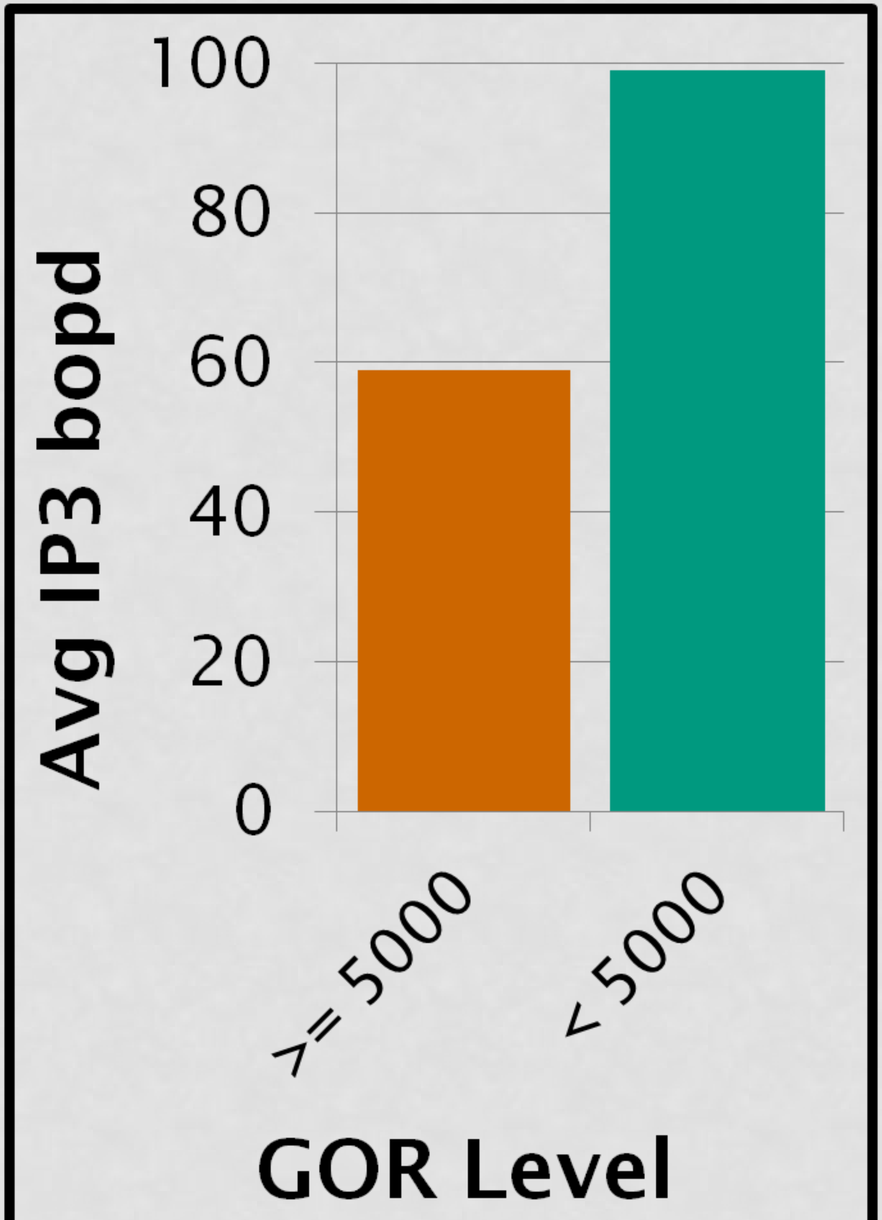
i) porosity cutoff of 9%
ii) net:gross = 70%
iii) Cutoff resistivity of 20 ohms

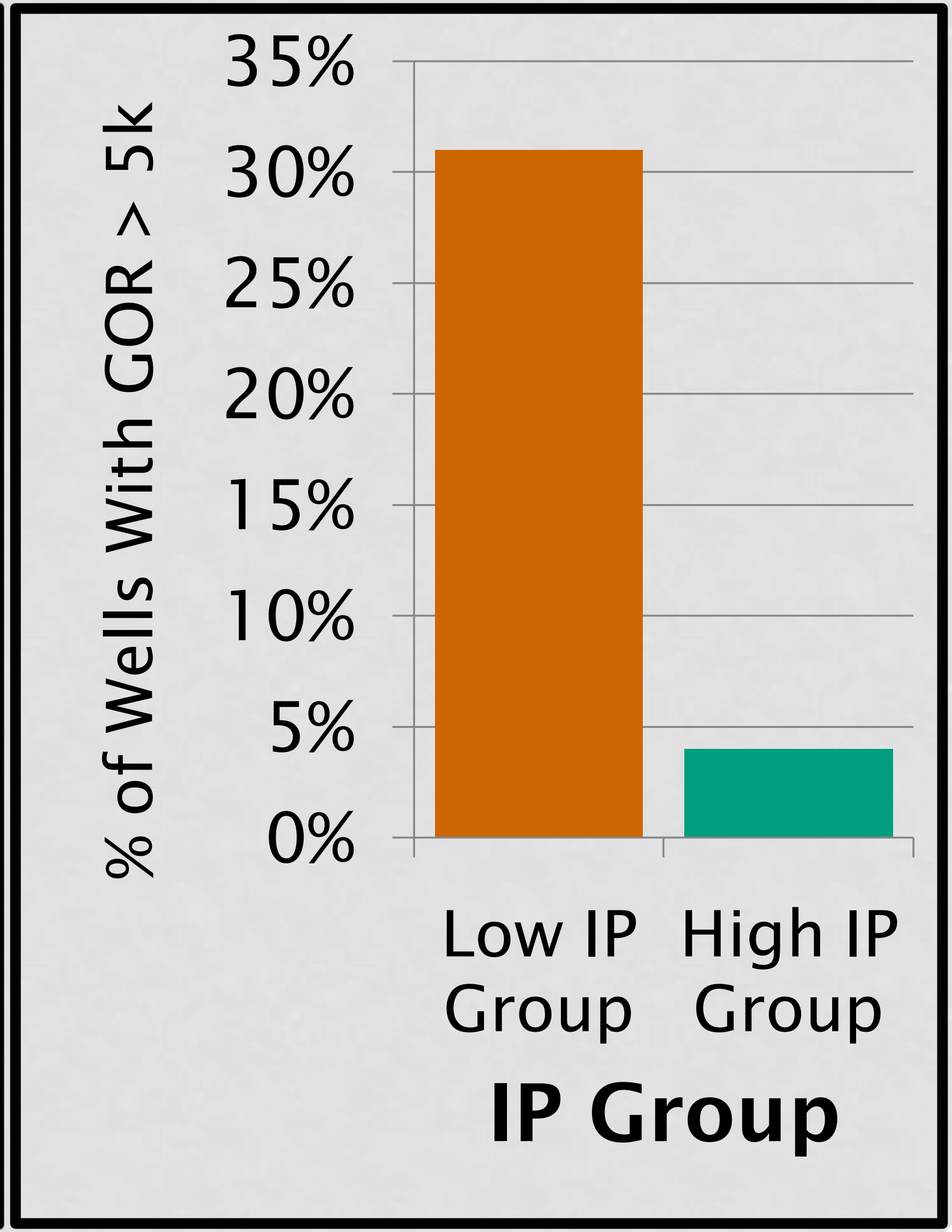
minimum pay of 4m at these cutoffs to meet drilling objectives

GOR Screening

MORE THAN JUST CUM GAS PRODUCTION!

GOR Impact on IP3 and Risk

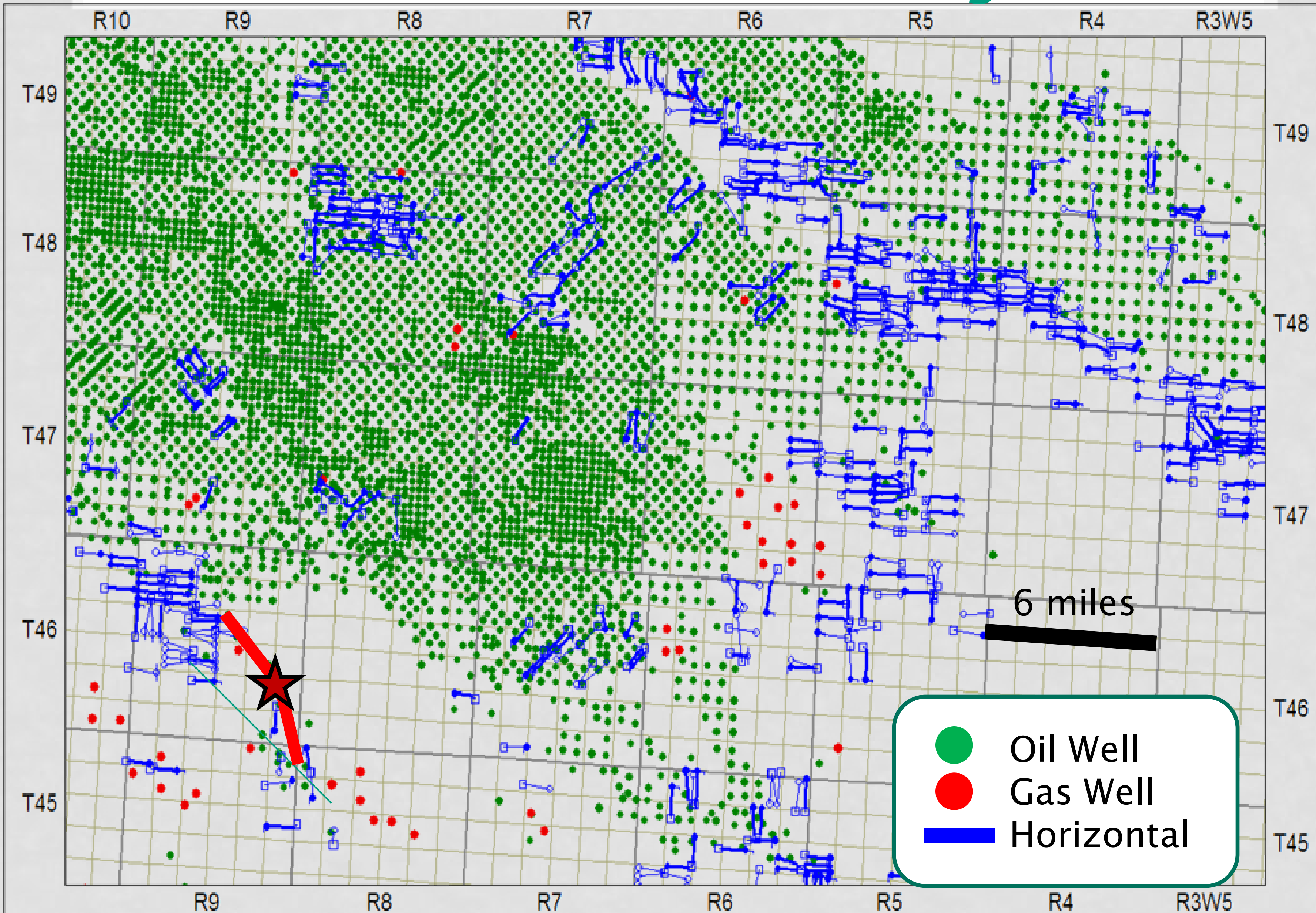




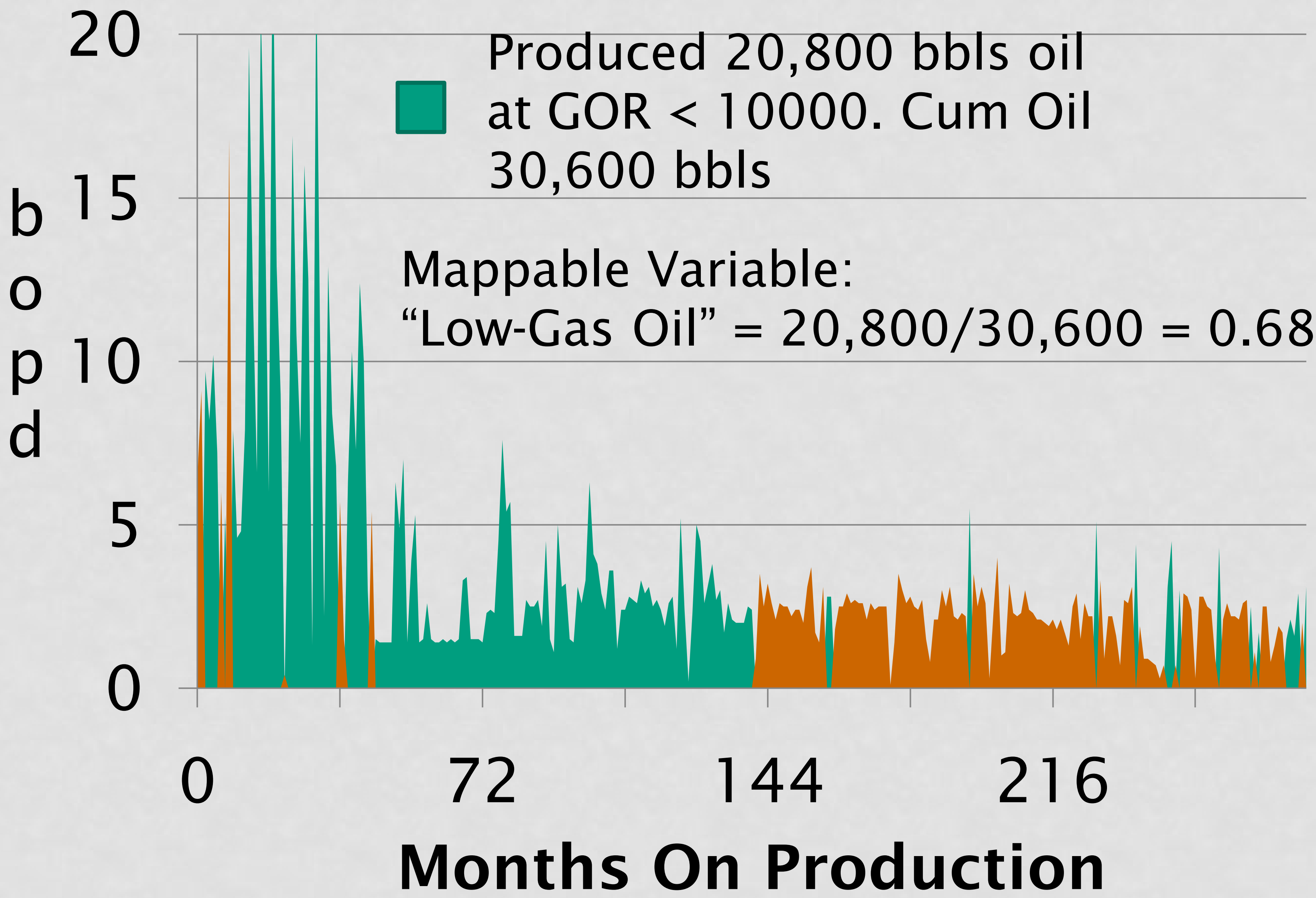
In General GOR is a Concern When…

	1st month	3rd month	12th month
GOR (scf/bbl)	> 2500	> 5000	> 7500

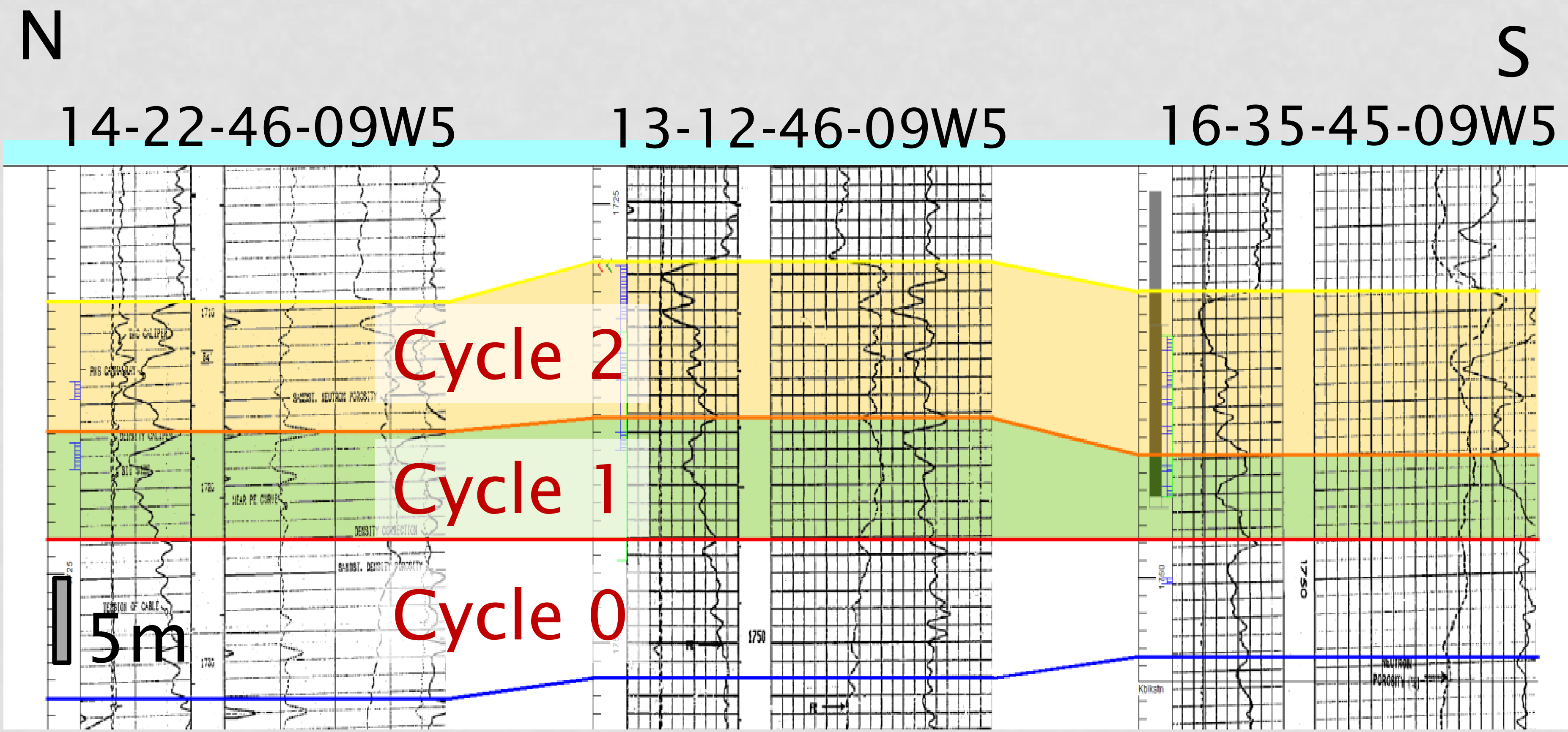
Create A Screen to Avoid High GOR



13-12-46-09W5 Oil Production

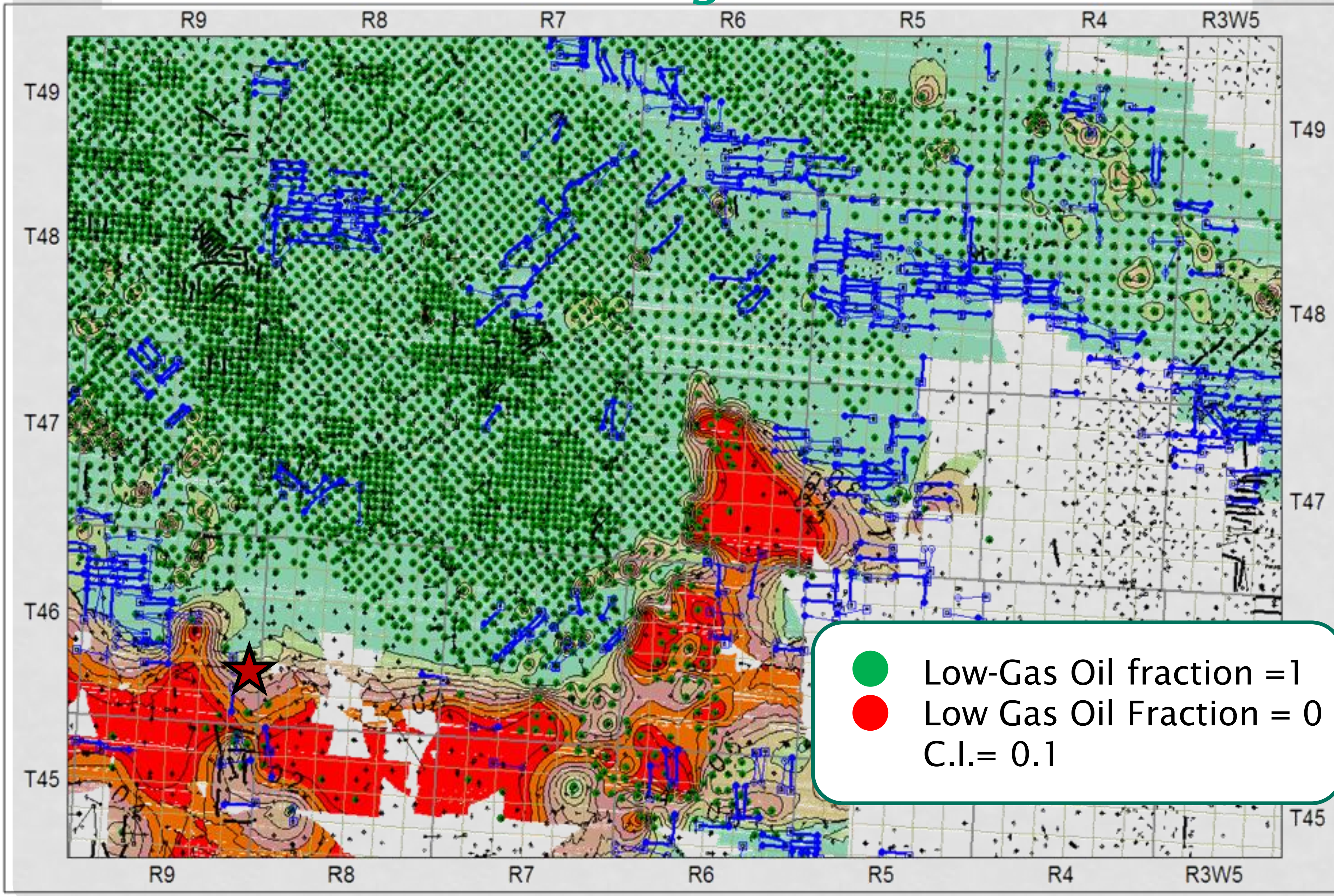


Low-Gas Oil Values in Local Area



Cum oil = 35,800 bbl	Cum oil = 30,600 bbl	Cum oil = 24,800 bbl
Low-Gas Oil = 1.0	Low-Gas Oil = 0.68	Low-Gas Oil = 0.0

GOR Screen Using "Low-Gas Oil"



Conclusion

Tight Oil in the Cardium Formation

- Definition of net pay in tight sands is a critical factor in drilling success; adapt with new info and technology
- Limits to productive tight sands can be mapped to set boundaries for activity
- Real differences in IP across the Cardium tight sand fairway
- Highest risk: exploration extension and outpost drilling
- Oil production with high GOR is a significant risk in the Cardium (if you don’t screen for it)
- Relative importance of differing risk factors depends on exploration or development context

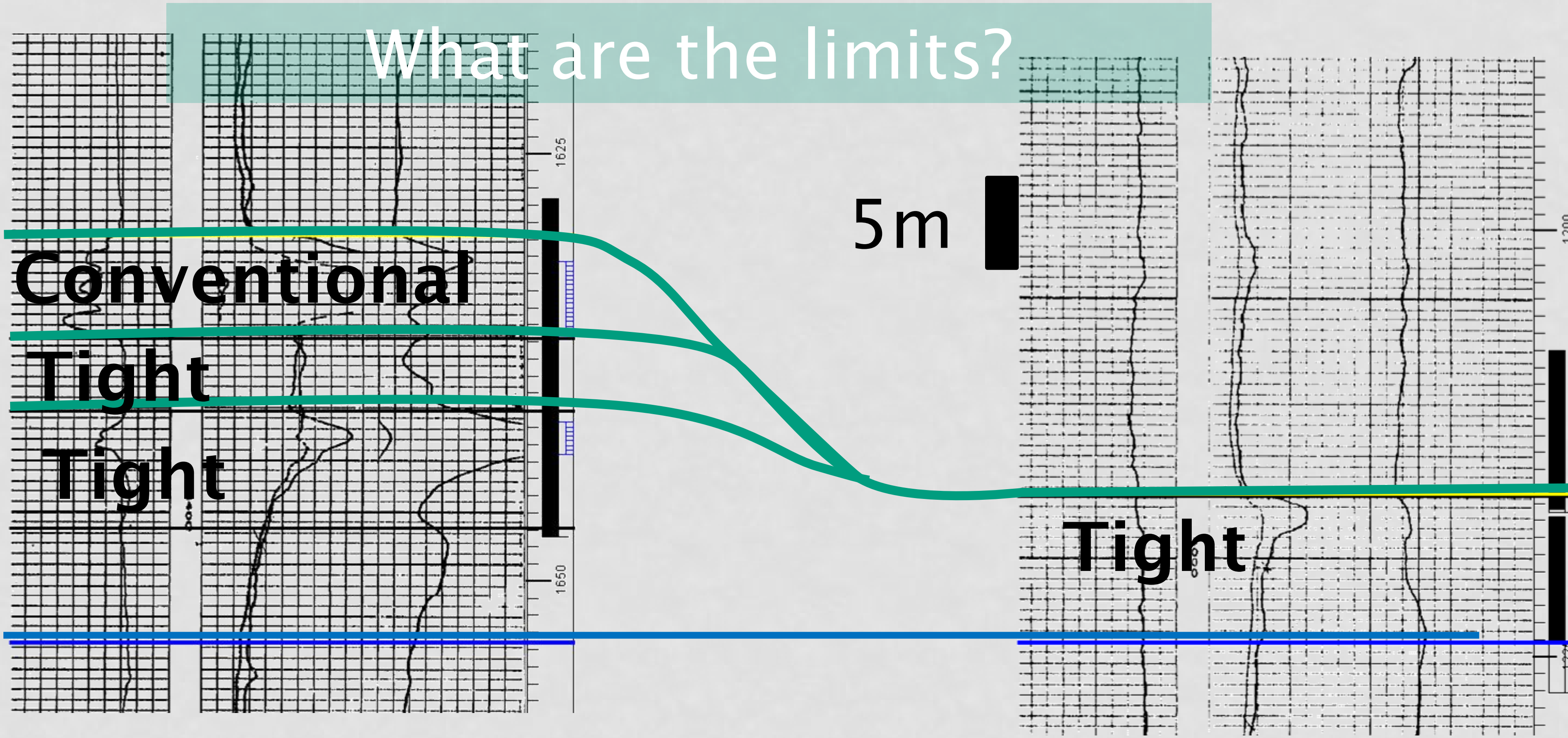
QUESTIONS

ADDENDUM

Limits of Hz Multi-Stage Completions

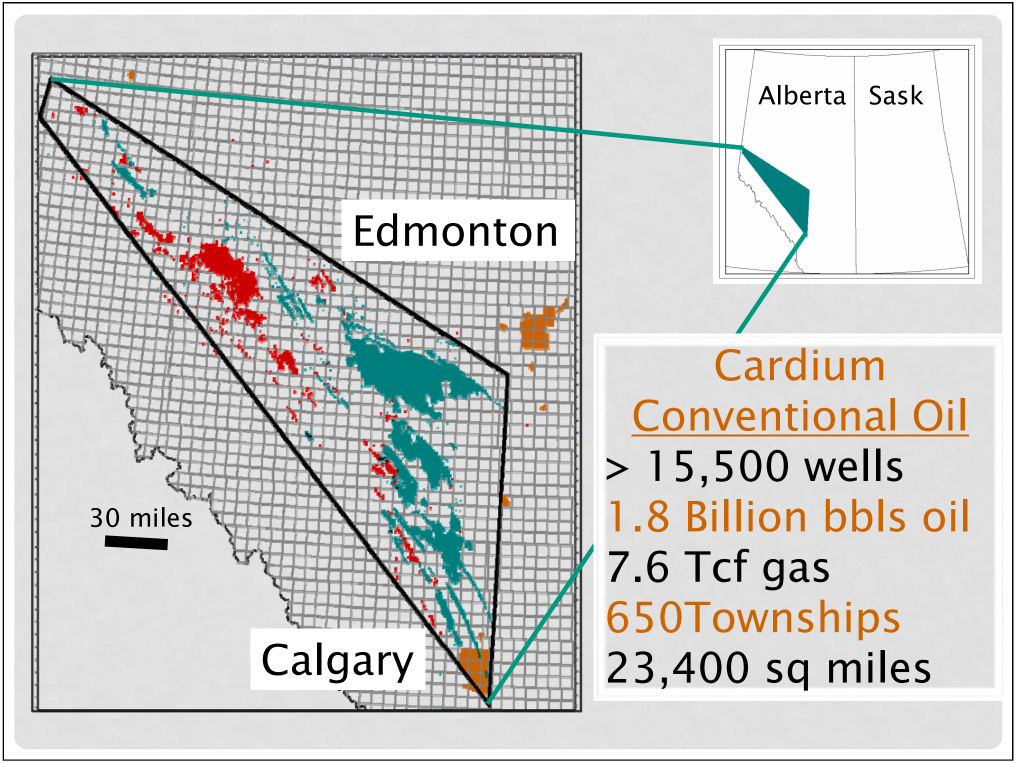
02-18-48-08W5

06-23-49-04W5



Over1MM bbls oil
New Hz Drill?

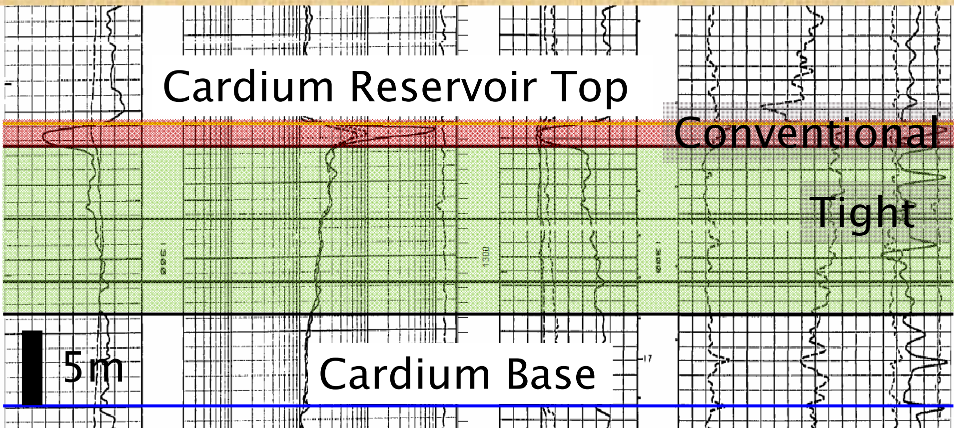
Vertical Dry Hole
New Hz Drill?



Presenter's notes: The Cardium is a "big deal" and has been for "going-on" 60 years.

TYPE WELL: KEYSTONE AREA

10-09-49-04W5



Presenter's notes: Conventional:10's to 100's mD, 12% porosity cutoff, sand and conglomerate. Tight: 0.1 to 1 mD,6% to 9% cutoff, vf sand, silty sand, shaly sand.