# Katz (Strawn) Field CO2 Project

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KINDER MORGAN

Presented at the 15th Annual $CO_2$ Flooding Conference

December 10-11, 2009

Midland, Texas

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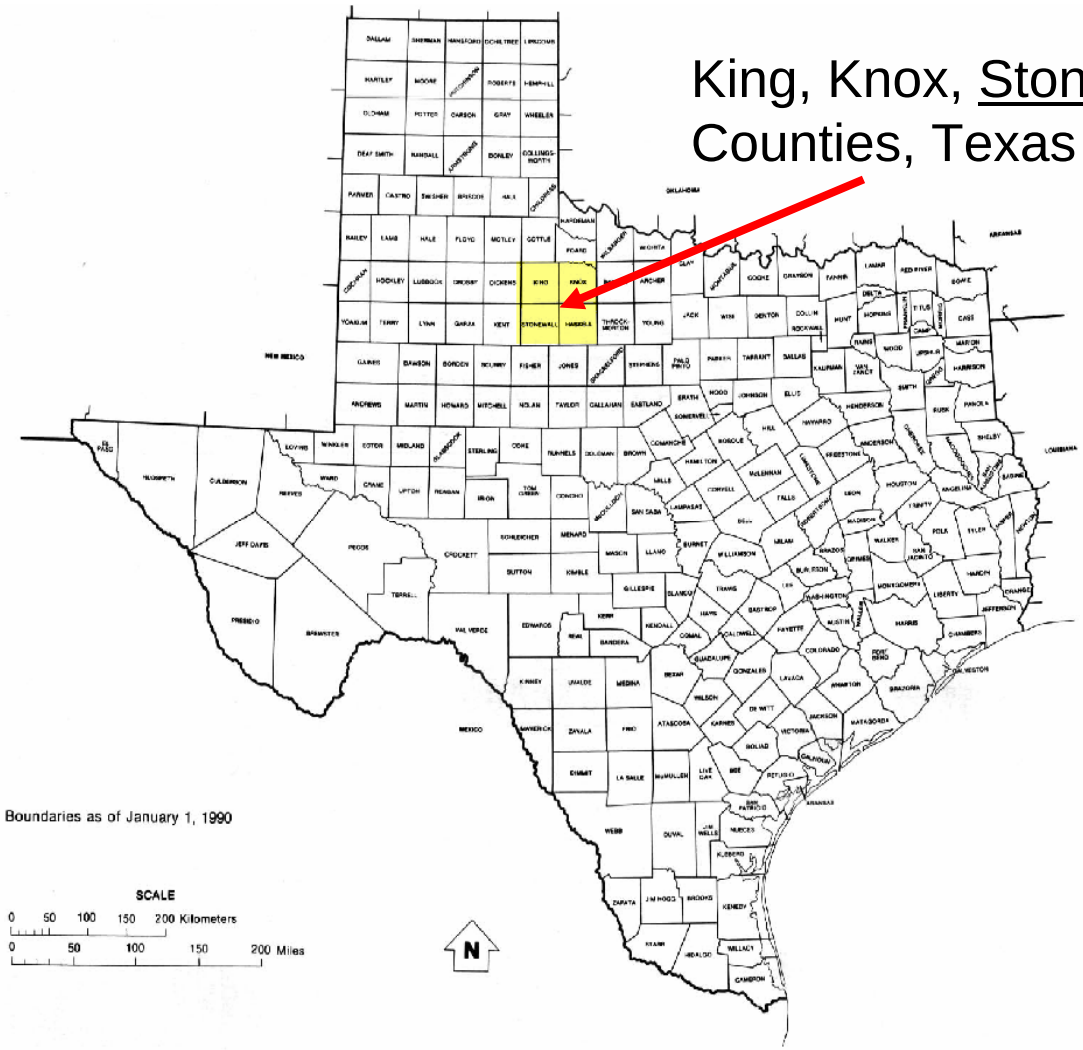
# Outline

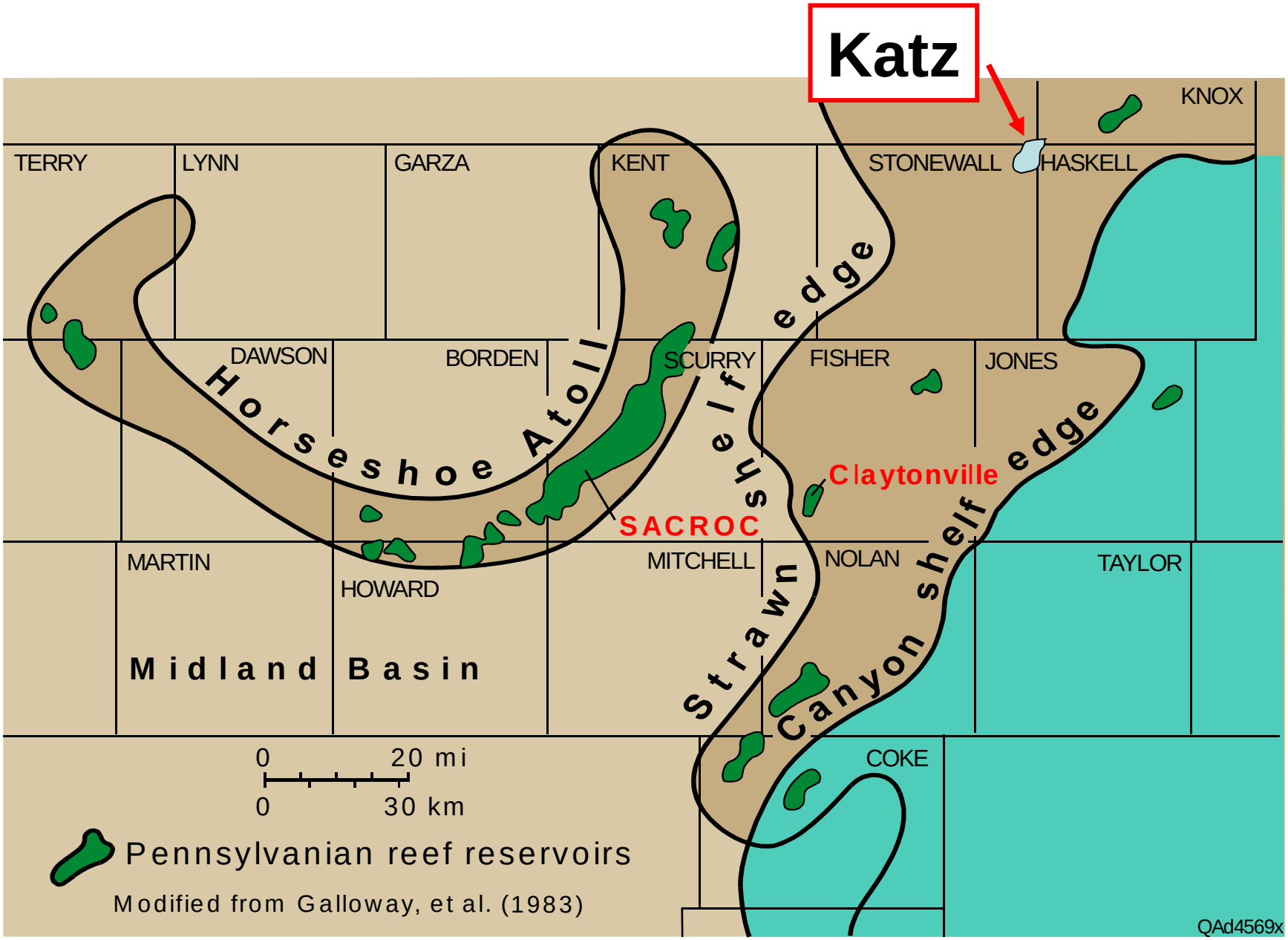
- Field Overview
- Reservoir Data
- CO2 Project – Design and Implementation
- Facilities – Compression / Pipeline

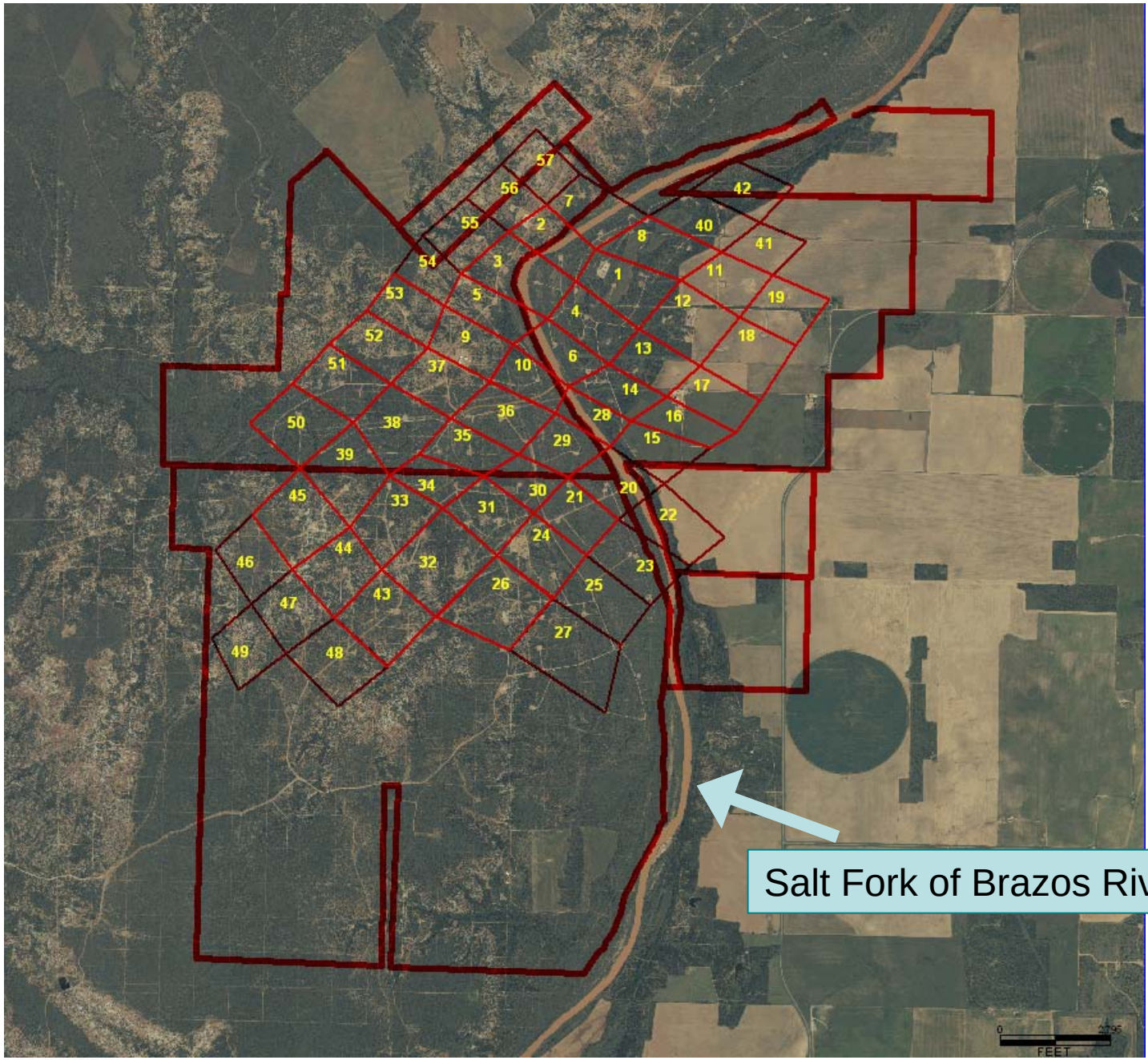
# Katz (Strawn) Field

King, Knox, Stonewall, Haskell Counties, Texas

80 miles north of Abilene, TX




Katz
KNOX
TERRY
LYNN
GARZA
KENT
STONEWALL
HASKELL
DAWSON
BORDEN
SCURRY
FISHER
JONES
Horseshoe Atoll
shelf edge
Claytonville
SACROC
MARTIN
HOWARD
MITCHELL
NOLAN
TAYLOR
Midland Basin
Strawn Canyon shelf edge
COKE
0 20 mi
0 30 km
Pennsylvanian reef reservoirs
Modified from Galloway, et al. (1983)
QAd4569x

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# Katz Type Log

25 Square Miles of 3D data

Specialty Processing

Relative Acoustic Impedance

**1St Strawn (4,800' Sand)**

- Average Porosity – 16%
- Average Permeability – 53 md

**2nd Strawn (4,900' Sand)**

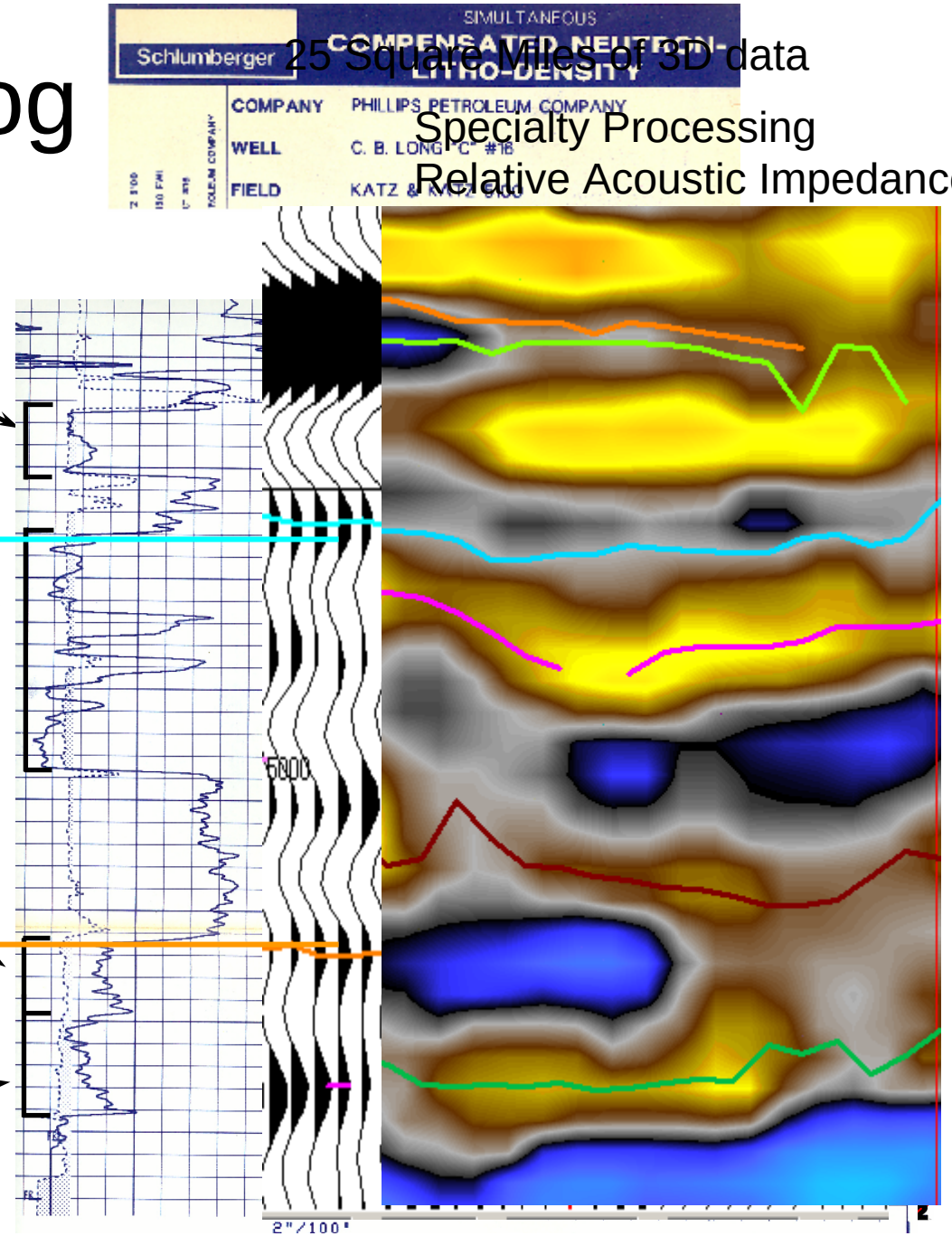
- Average Porosity – 17%
- Average Permeability – 124 md

**Dirty 3rd Strawn (5,100' Sand)**

- Average Porosity – 16%
- Average Permeability – 3.2 md

**Clean 3rd Strawn (5,100' Sand)**

- Average Porosity – 16%
- Average Permeability – 55 md

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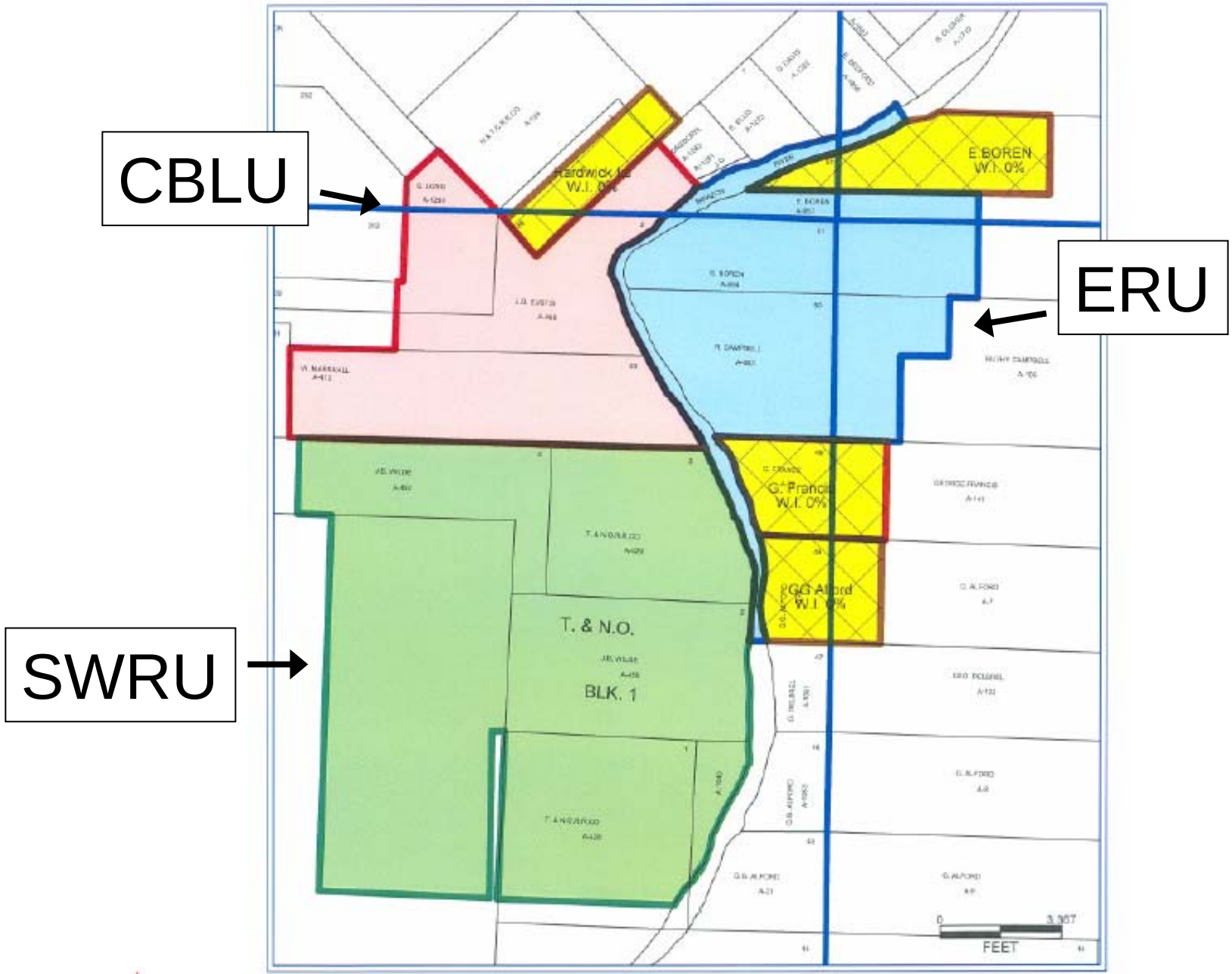
# Katz Field History

| | |
|---|---|
| Jan. 1951 | Katz Field discovered by Katz Oil Co, H.D. Dozier No. 1 (current well name, ERU No.59). |
| Mar. 1951 | Katz (5100) Field discovered by T.D. Humphrey, Mattie Davis No. 1 (located on the Orsborn Unit). |
| Jul. 1983 | Katz (Day) Field discovered by Getty Oil Co, Roy Day No. 4 (current well name, SWRU No.35). |
| Oct. 1984 | Orsborn Unit waterflood began into the Katz and Katz (5100) Fields (Conoco, operator). |
| Oct. 1987 | ERU unitized in the Katz and Katz (5100) Fields (Standard Oil Production Co, operator). |
| Nov. 1989 | SWRU unitized in the Katz, Katz (Day), Katz (5100) Fields (BP Exploration, operator). |
| Nov. 1989 | CBLU unitized in the Katz and Katz (5100) Fields (Phillips Pet. Co, operator). |
| May 2006 | Kinder Morgan Production Co. became operator of ERU, CBLU, and SWRU. |
| Nov 2009 | Consolidated 3 fields into the Katz (Strawn) Field. |

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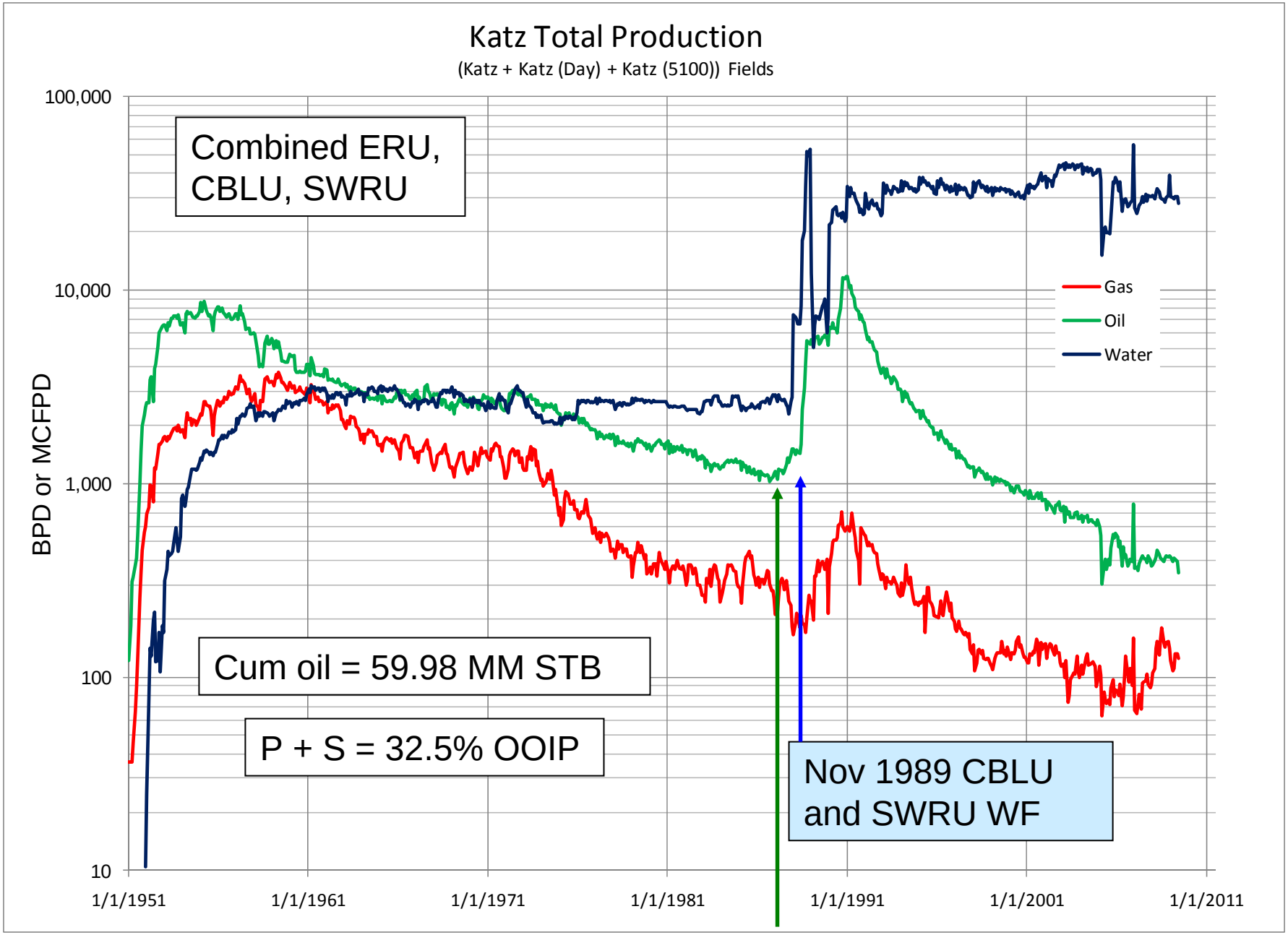


Oct 1987 ERU WF

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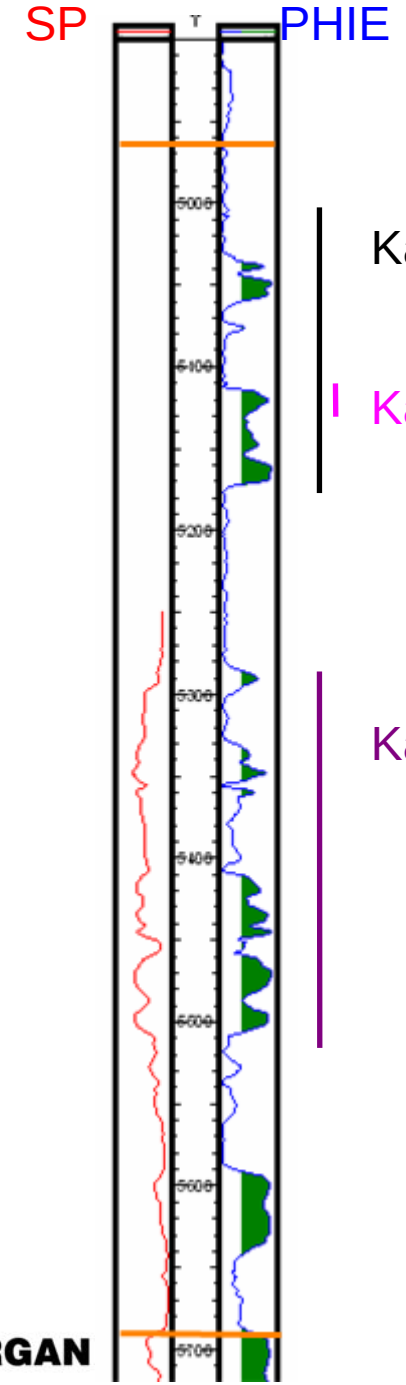



Sid Katz

H. T. Lorentzen "C"

Well No. 11,
Stonewall County, TX

Katz Field

Katz (Day) Field

The Katz (Day) Field is not located in this well, but would be found at this relative depth in portion of reservoir where it exists.

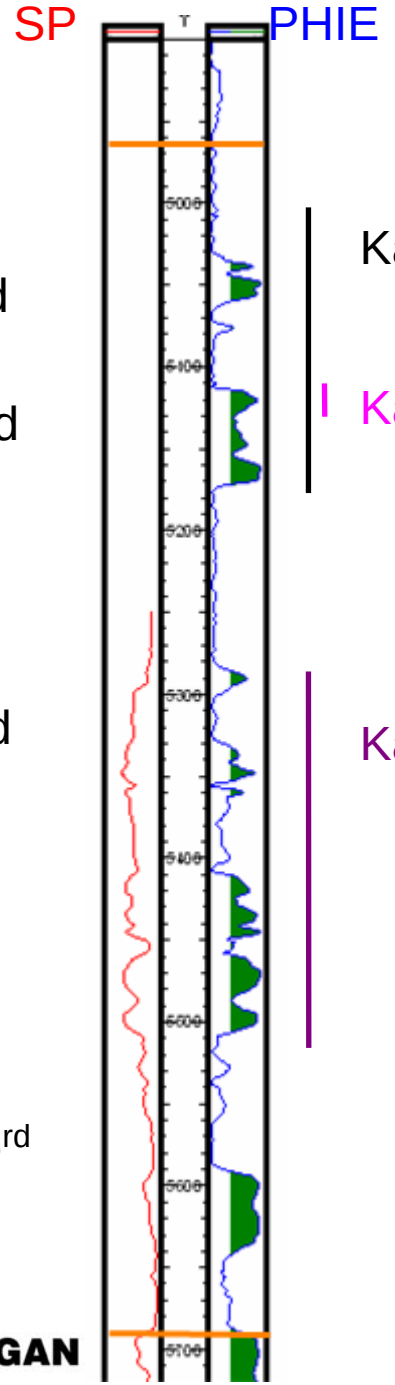
Katz (5100) Field

Historically Katz was comprised of 3 fields.

Sid Katz

H. T. Lorentzen “C”

Well No. 11,
Stonewall County, TX




1st Sand

2nd Sand

3rd Sand

Lower 3rd Sand

Katz Field

Katz (Day) Field

Katz (5100) Field

Orientation of the 3 sands to the 3 fields

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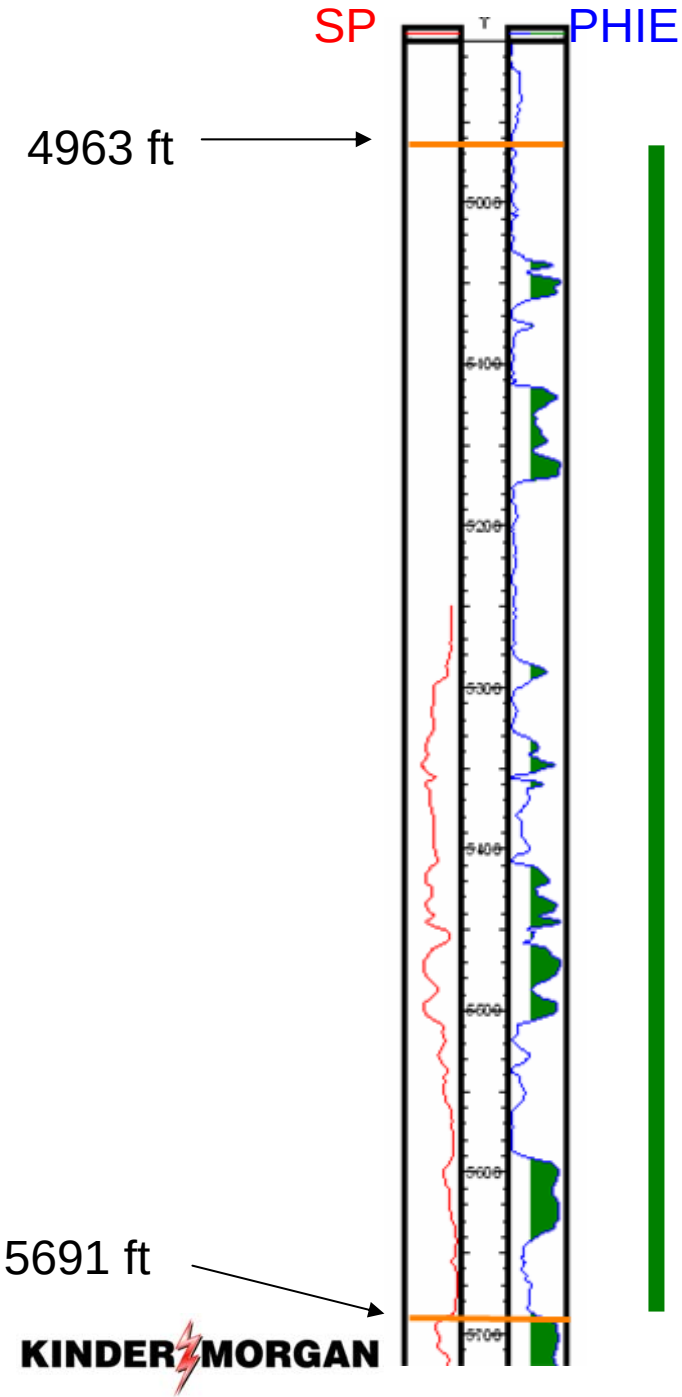


Sid Katz

H. T. Lorentzen "C"

Well No. 11,
Stonewall County, TX

Katz (Strawn) Field

Consolidation into 1 field was approved by TRRC November 4, 2009

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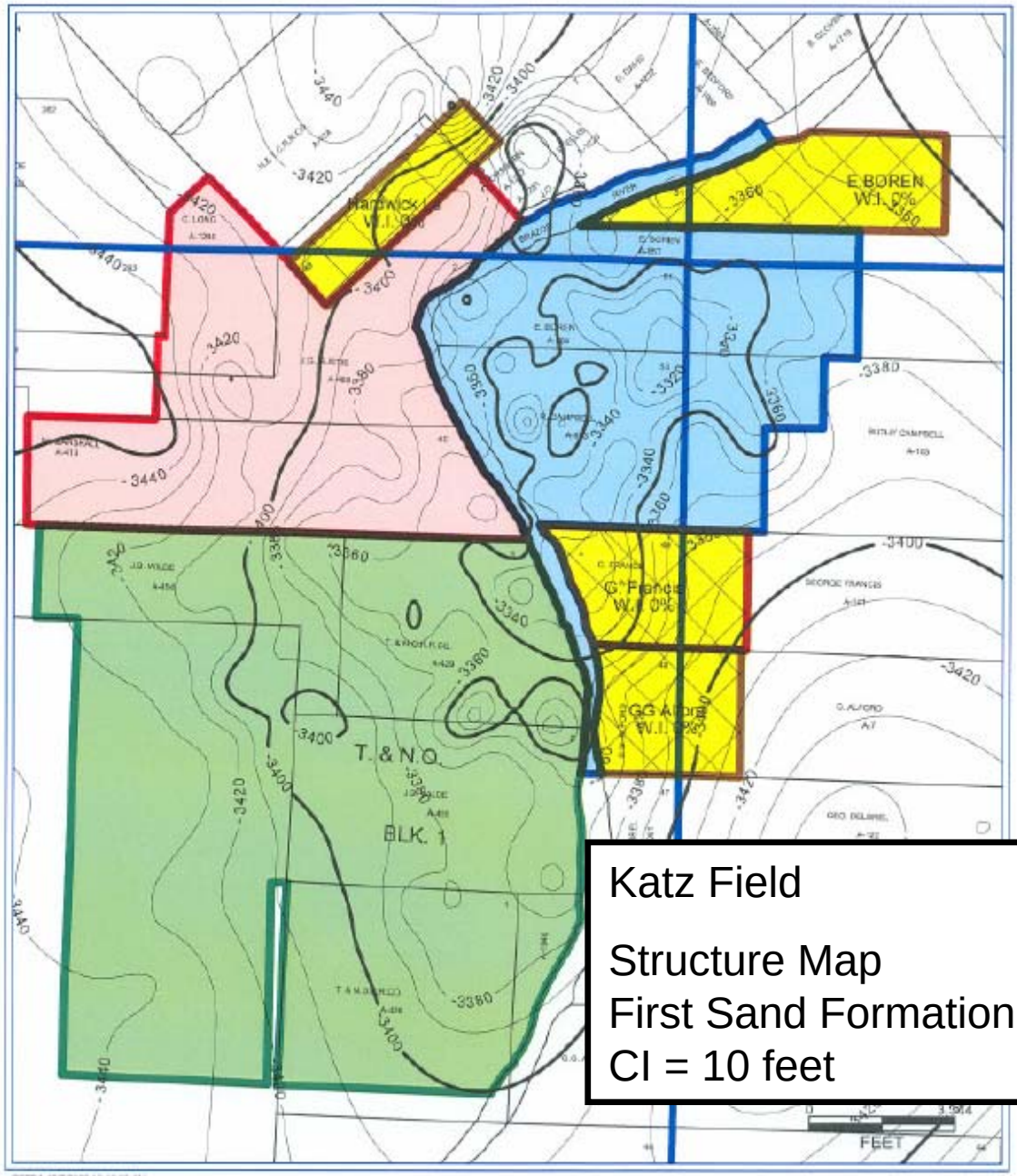
# Reservoir Data

| | |
|---|---|
| Lithology | Strawn Sandstone |
| Producing Interval | 4800’ – 5400’ |
| Reservoir Dip | 3 degrees (to SW) |
| Net Pay | 45’ * 3 sands = 135’ |
| Porosity | 12 – 22% |
| Perm | 2 – 3700 mD |
| Initial Water Saturation | 28% |
| 1st and 2nd Sand WOC | TZ begins -3503’ thru -3438’ |
| 3rd Sand WOC | -3660’ |
| Water Salinity | 120,000 ppm Cl,<br>TDS = 185,000 ppm |
| Reservoir Temperature | 116 deg F (orig. 119 deg F) |
| Reservoir Pressure | 1600 psig (orig. 2200 psig) |




Katz Field

Structure Map
First Sand Formation Top
CI = 10 feet

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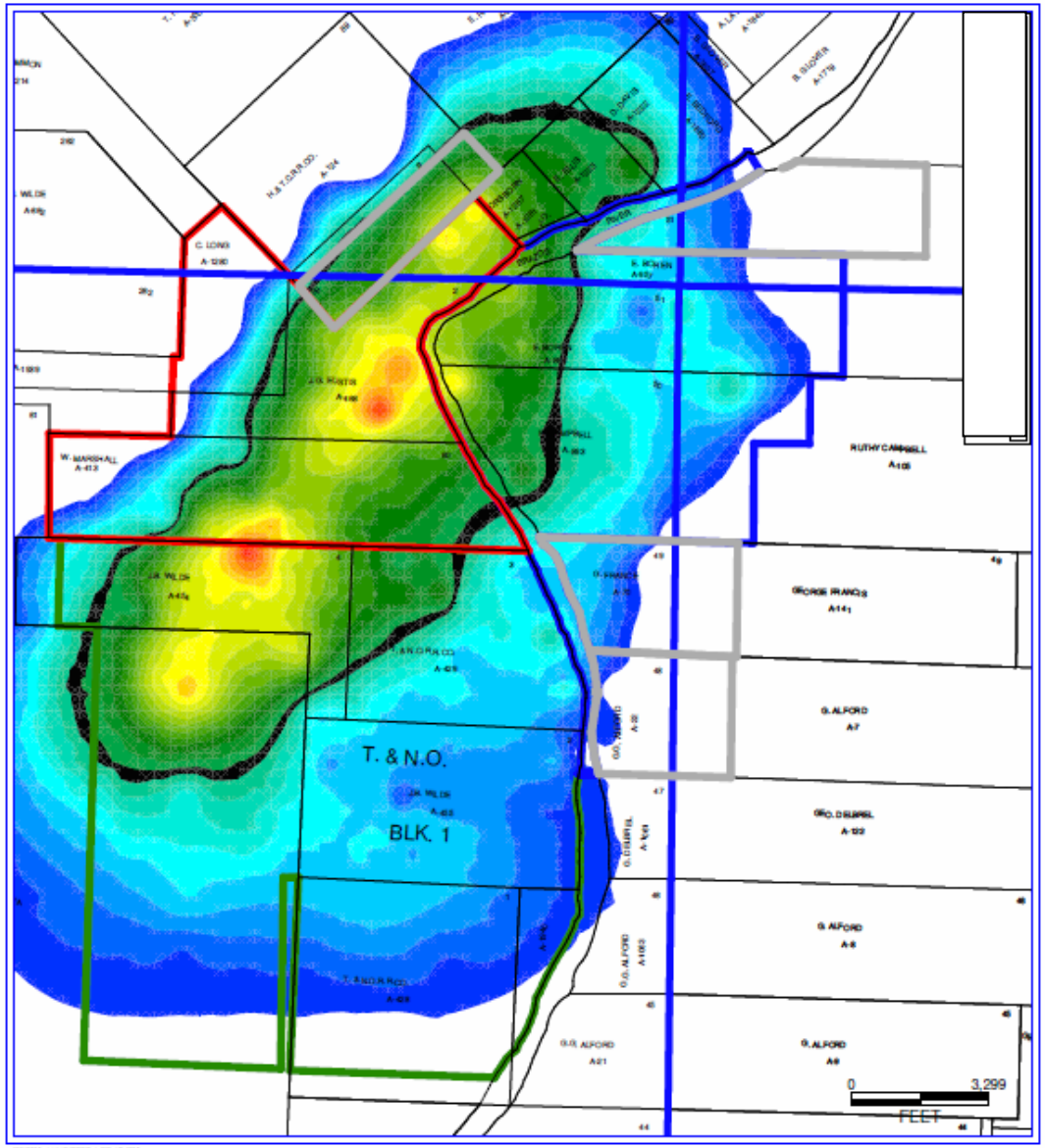
# 1st Sand - HCFT

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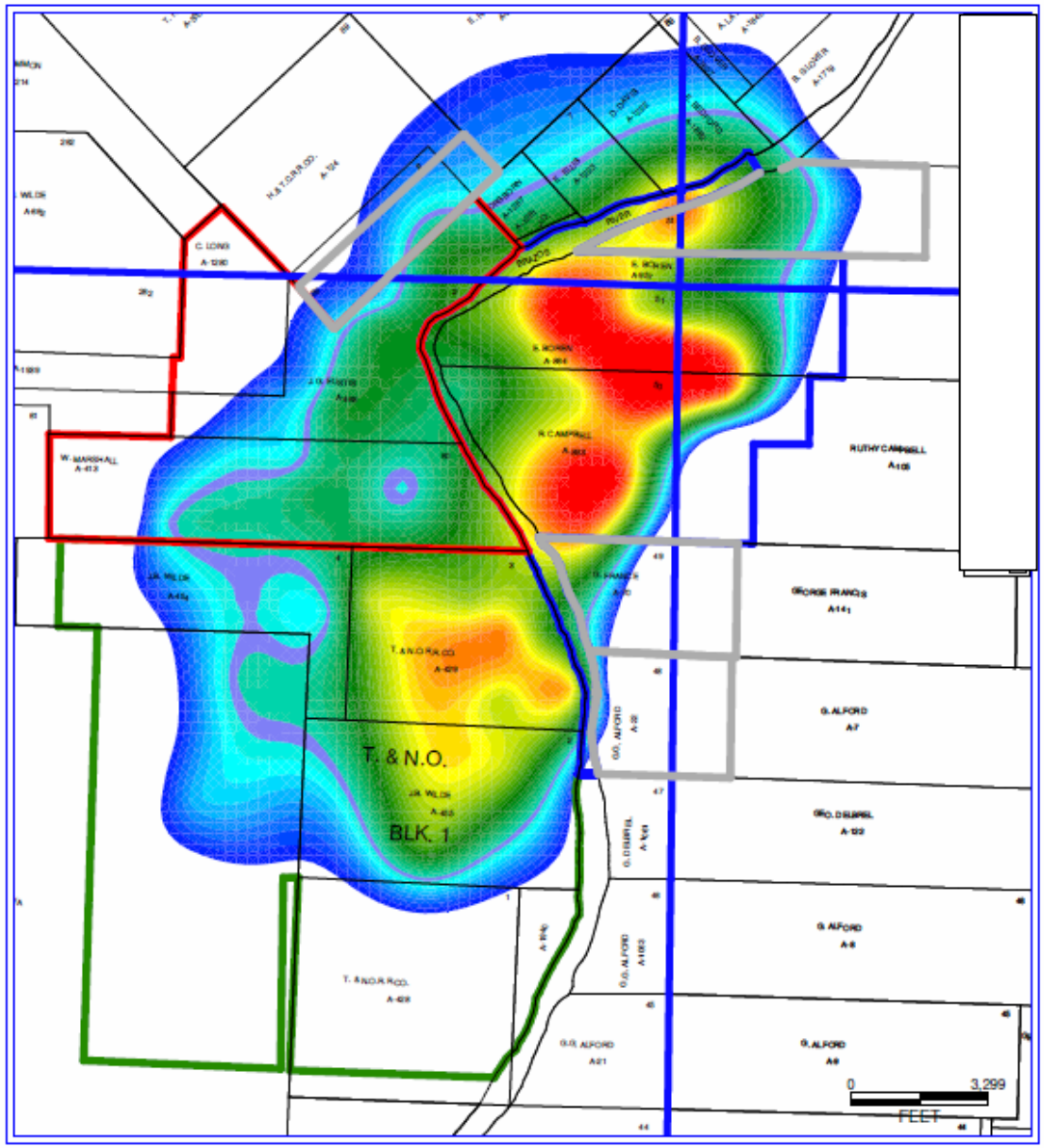
# 2nd Sand - HCFT

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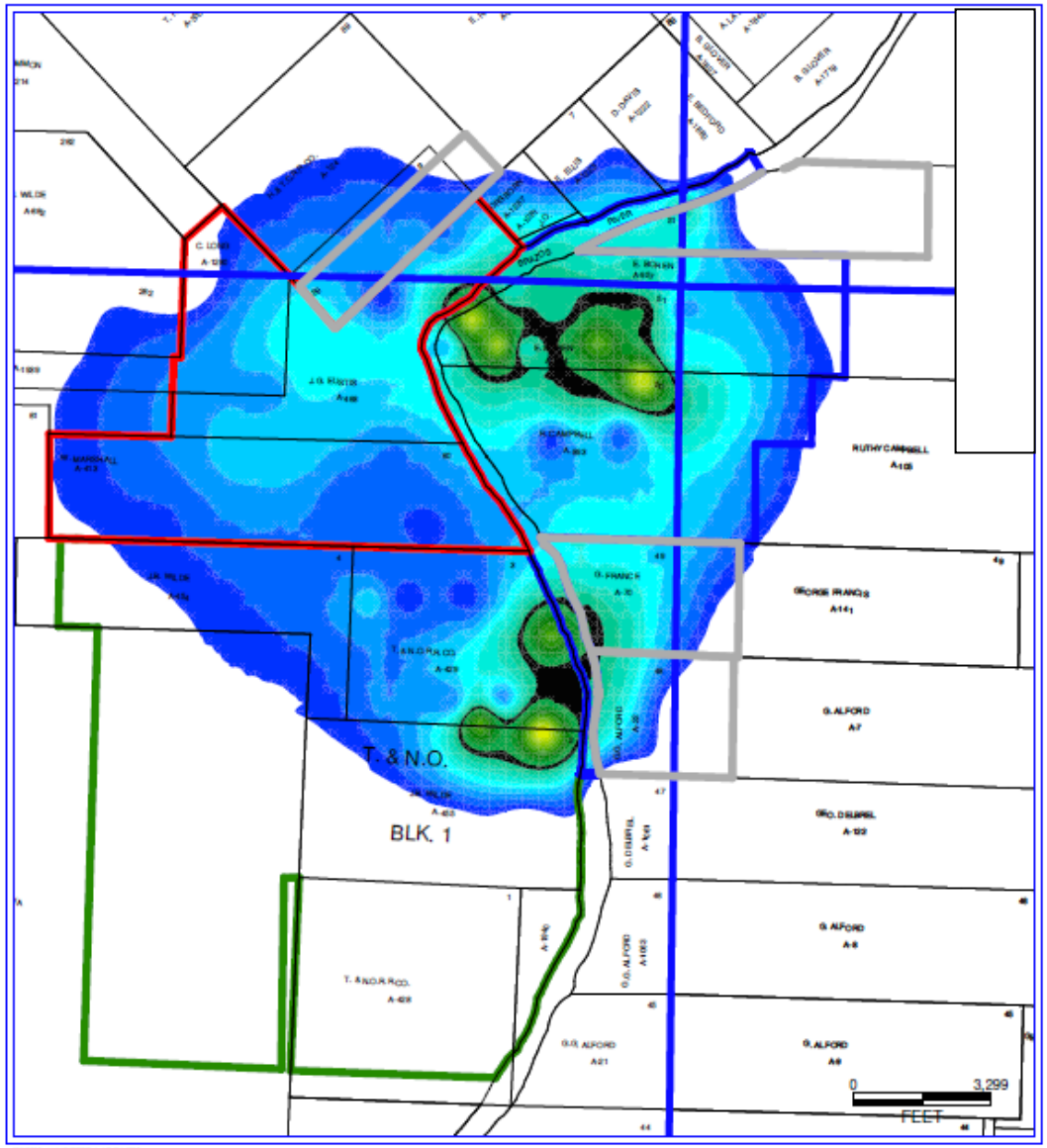
# 3rd Sand - HCFT

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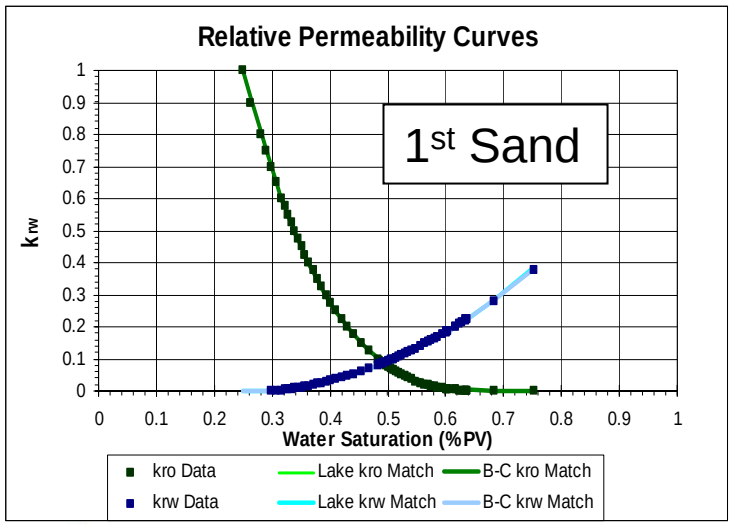
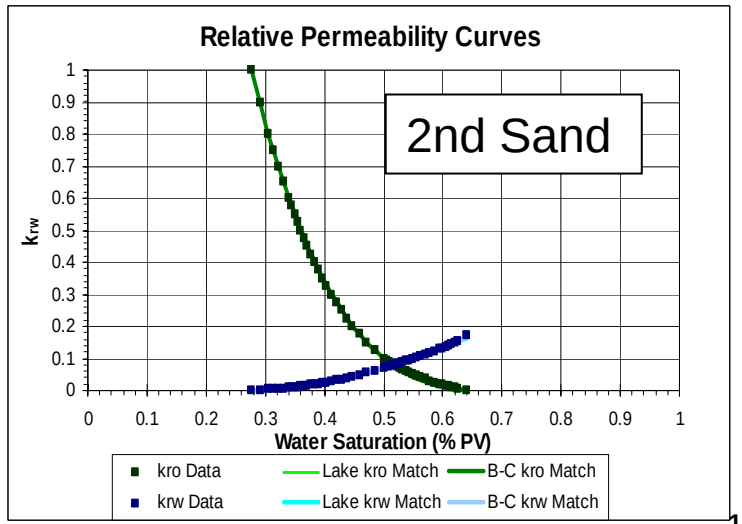
# Key Reservoir Engineering Data

| | Core | ϕ-k Transform | Dykstra-Parsons | Relative Perm End Points | | Wettability |
|---|---|---|---|---|---|---|
| | Avg | Average | | Swi | Sorw | |
| 1st | 53 md | 47.7 md | 0.82 | 0.248 | 0.753 | Water-Wet |
| 2nd | 124 md | 263.2 md | 0.67 | 0.278 | 0.641 | Strongly WW |
| Dirty 3rd | 3 md | 3 md | 0.70 | 0.39 | 0.639 | Strongly WW |
| Clean 3rd | 55 md | 50 md | 0.64 | 0.347 | 0.694 | Moderately WW |

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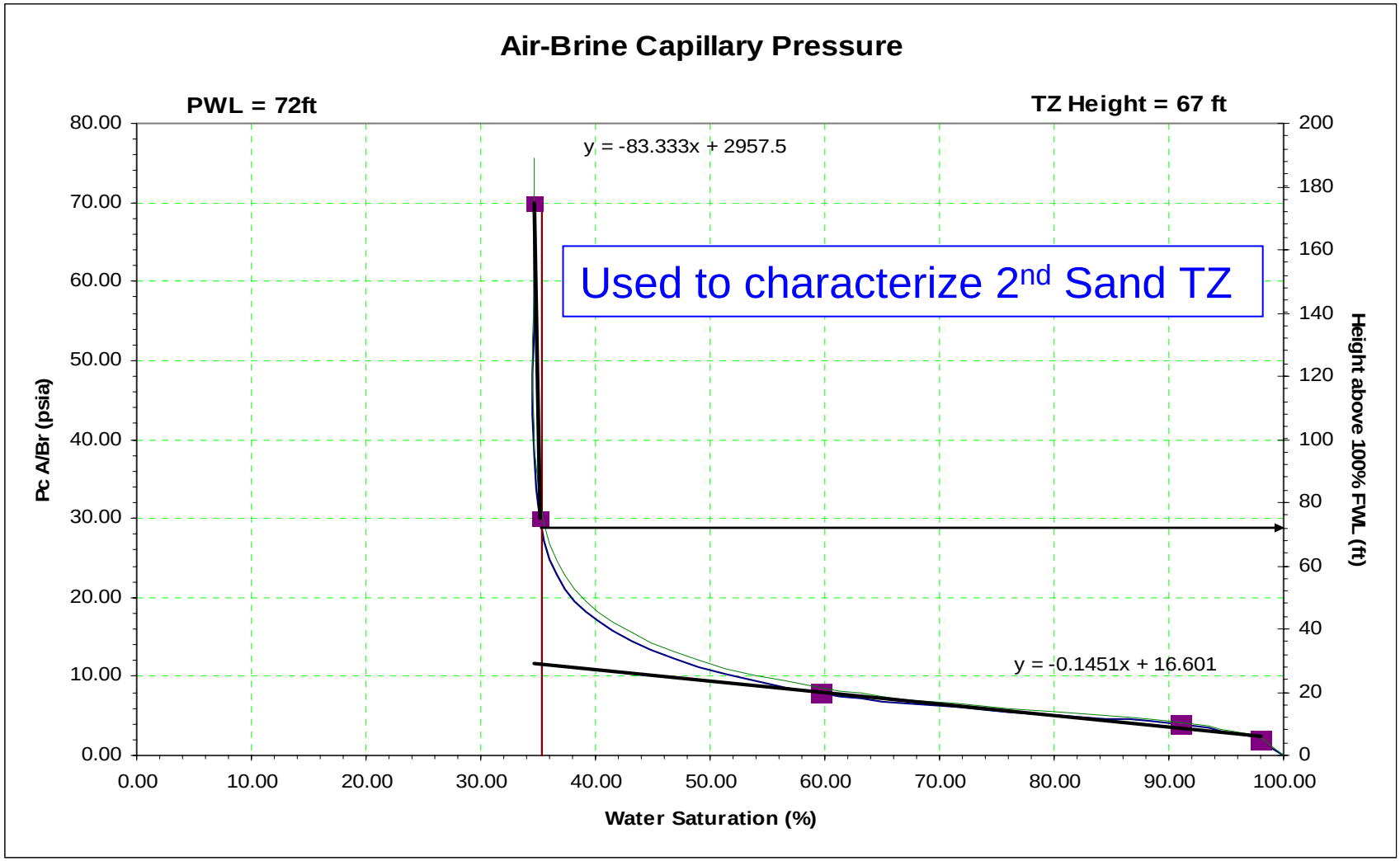
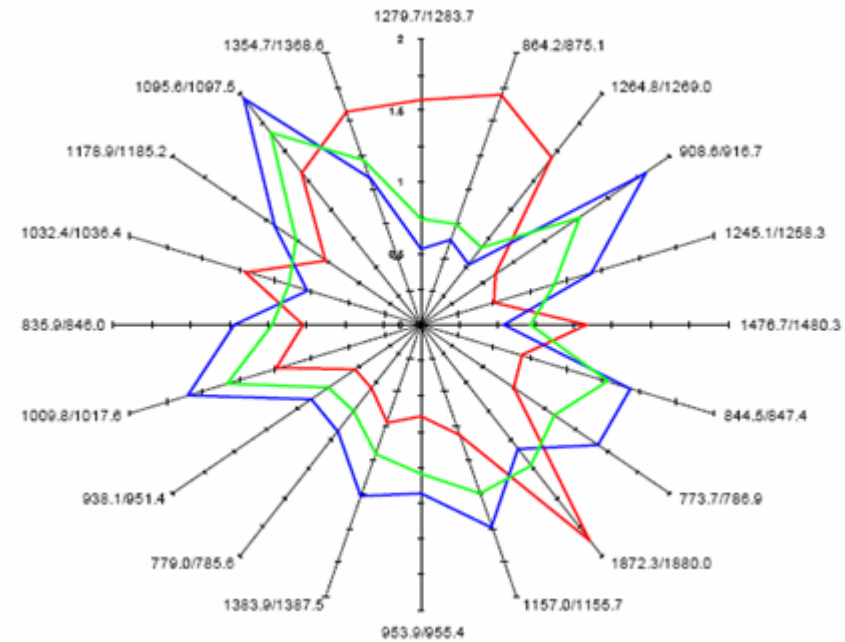
# Capillary Pressure



# PVT Data

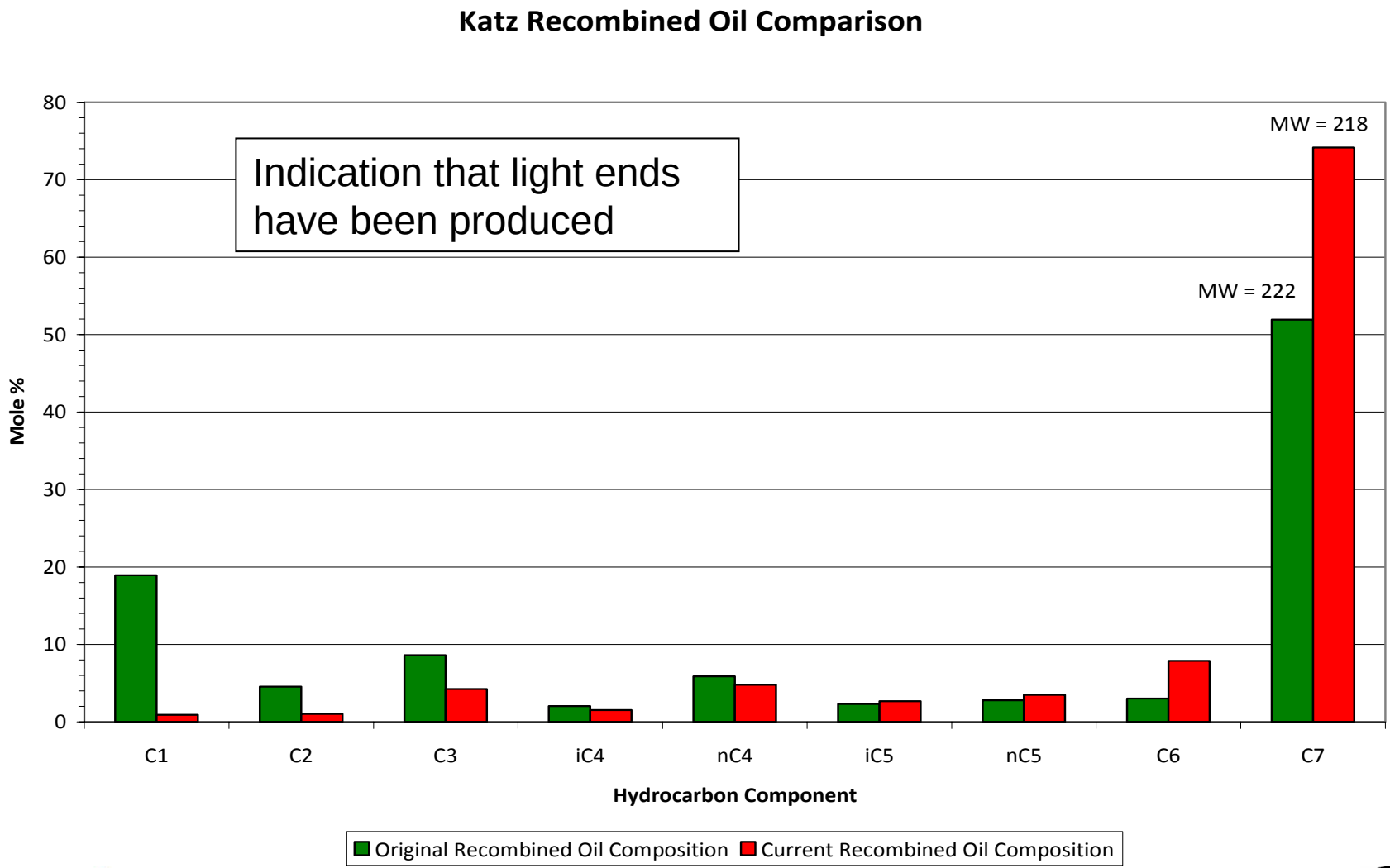
- Discovery Pressure – 2200 psia
- API Gravity – 38.6º
- Oil Viscosity – 2.151 cP
- Current GOR - < 100 scf/bbl
  - Original Solution GOR – 250 scf/bbl
- Current Bubblepoint – 138 psia
  - Original Bubblepoint – 1130 psia
- Oil Formation Volume Factor – 1.183 rvb/stb

# PVT Data (cont)




- Oil Fingerprint Analysis
  - All three sands have same source
    - Biomarkers indicate Late Paleozoic
      - Barnett Shale
  - Marine Depositional Environment
    - Marine algal-bacterial organic matter
    - Low terrigenous organic material

# Original vs. Current Oil Recombination

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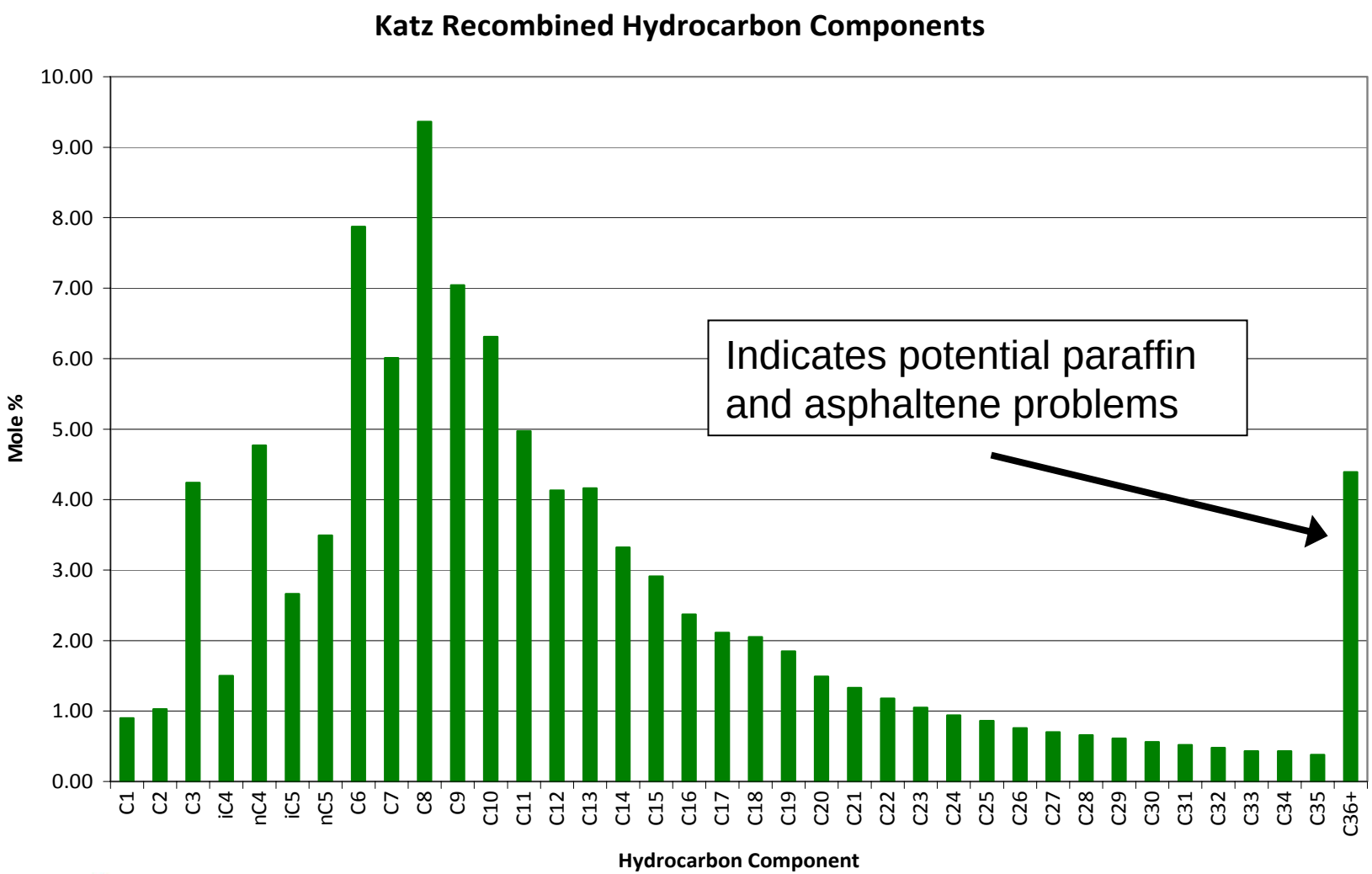
# Recombined Hydrocarbon Components



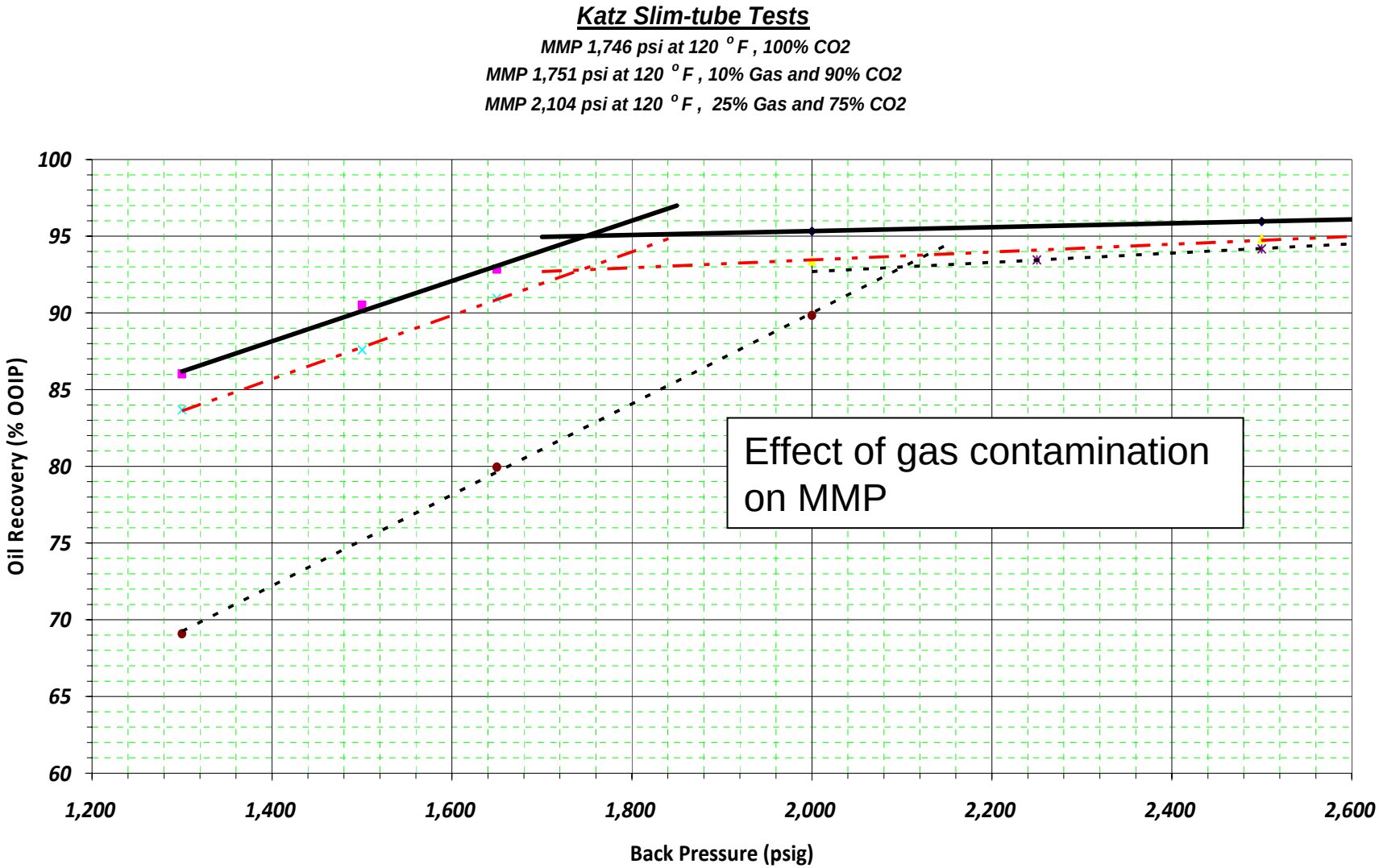
# CO2 Project Hurdles

- No allocated production/injection data
- Limited and missing well test data
- Old neglected wellbores
- No physical core samples
- No CO2 Pipeline
  - Long PL for smaller target
- Multiple Zones
- Brazos River
- Outdated / limited log data

# CO2 PVT

- MMP – 1746 psia @ 100% CO2
  - 1751 psia @ 90% CO2 – 10% Produced Gas
  - 2104 psia @ 75% CO2 – 25% Produced Gas
- CO2 FVF – 1.83 mcf/rvb
- CO2-Water Solubility – 83 scf/bbl

# Katz Slim-tube Tests

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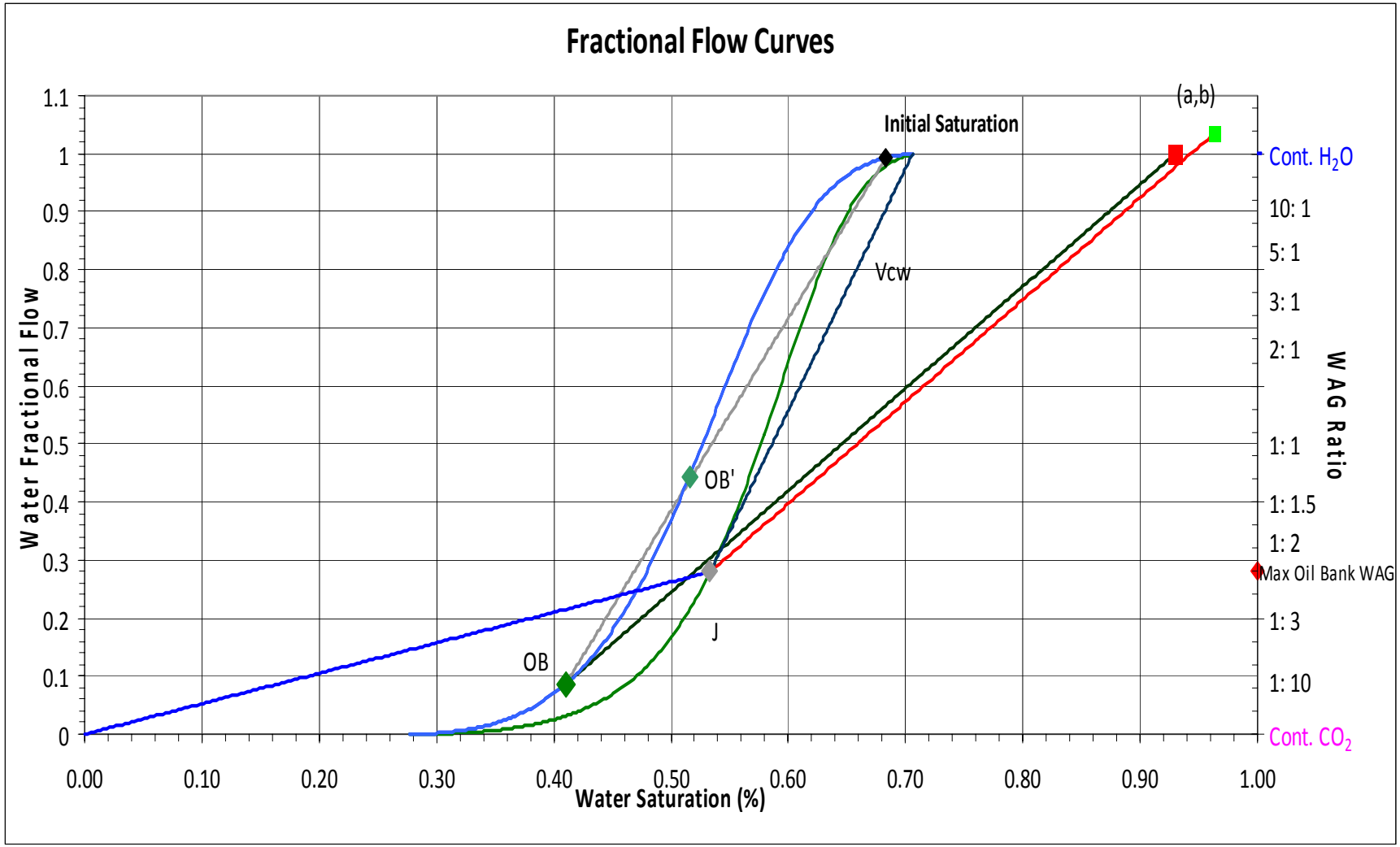
# Analytical Model

- Generates Ideal WAG Ratio and Slug Sizes, Total Recovery, Production Forecast
  - Good for limited datasets
  - Quick
- Requires Water-Oil Rel Perm Curves and Basic PVT Properties

# Analytical Model

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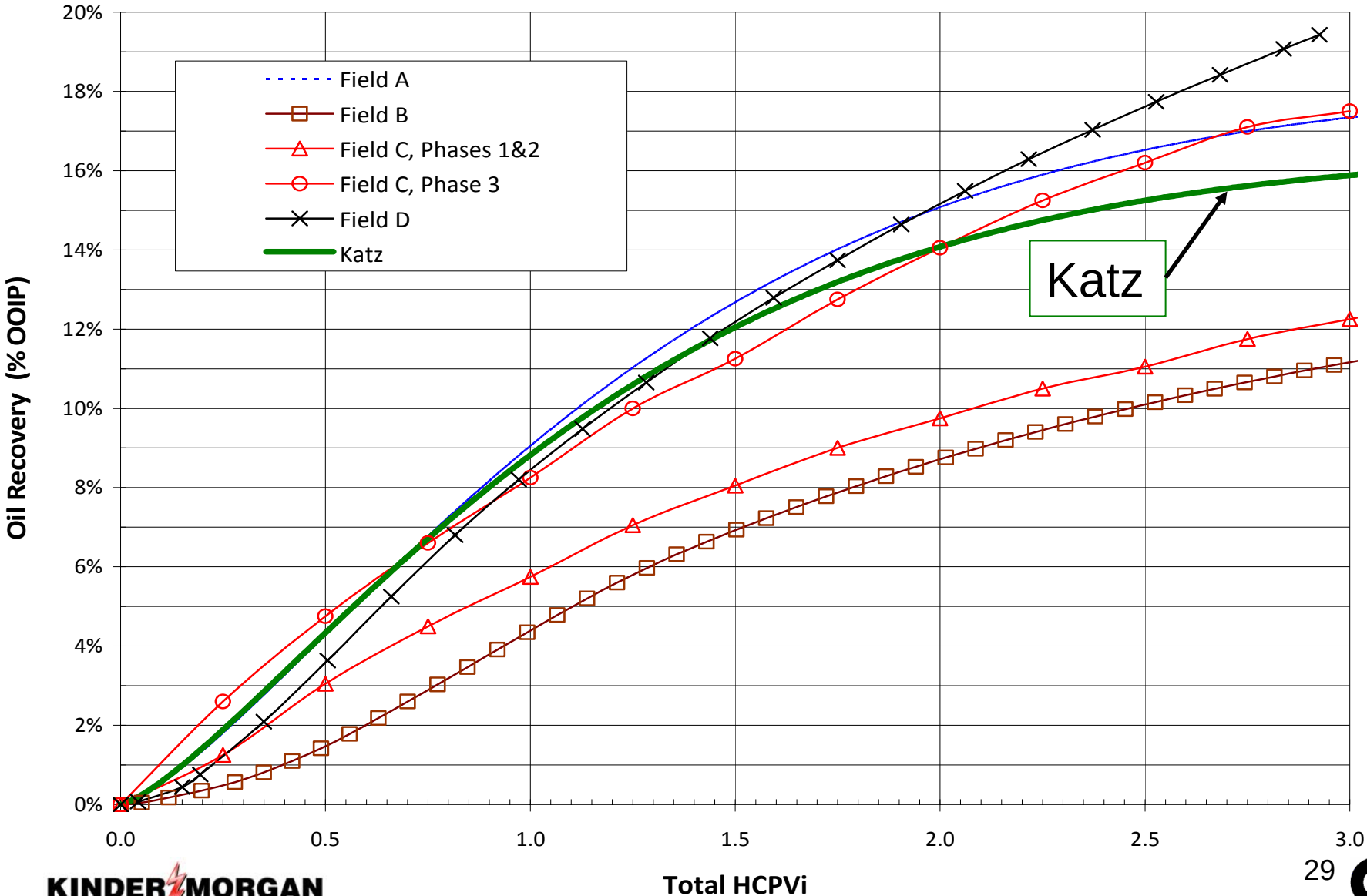
# Dim Rec Curves w/ Katz Overlay for SS Reservoirs

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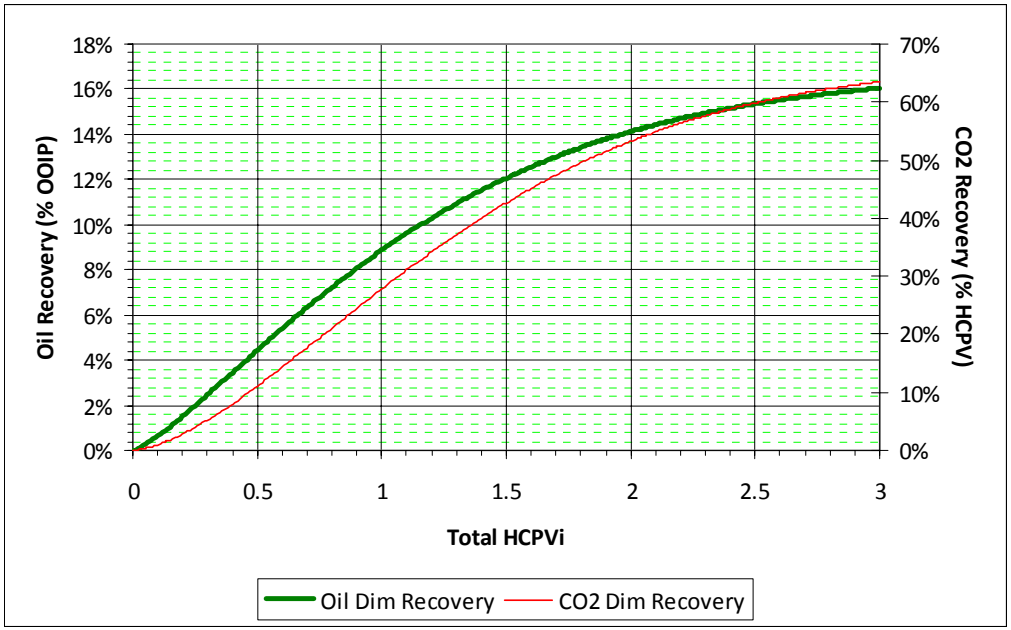
# Project Forecast




- 150.8 MMSTBO CO2 Target
- Economic Recovery – 15.8%
- Purchase CO2 Vol. – 220 BCF
- Net – 9 Mcf/bbl
- Gross – 19 Mcf/bbl
- Total Recovery – 23.8 MMSTBO

- Dimensionless Curve Construction
  - Combination of Reservoir Simulation, Analogies, Analytical Models, and Engineering Experience

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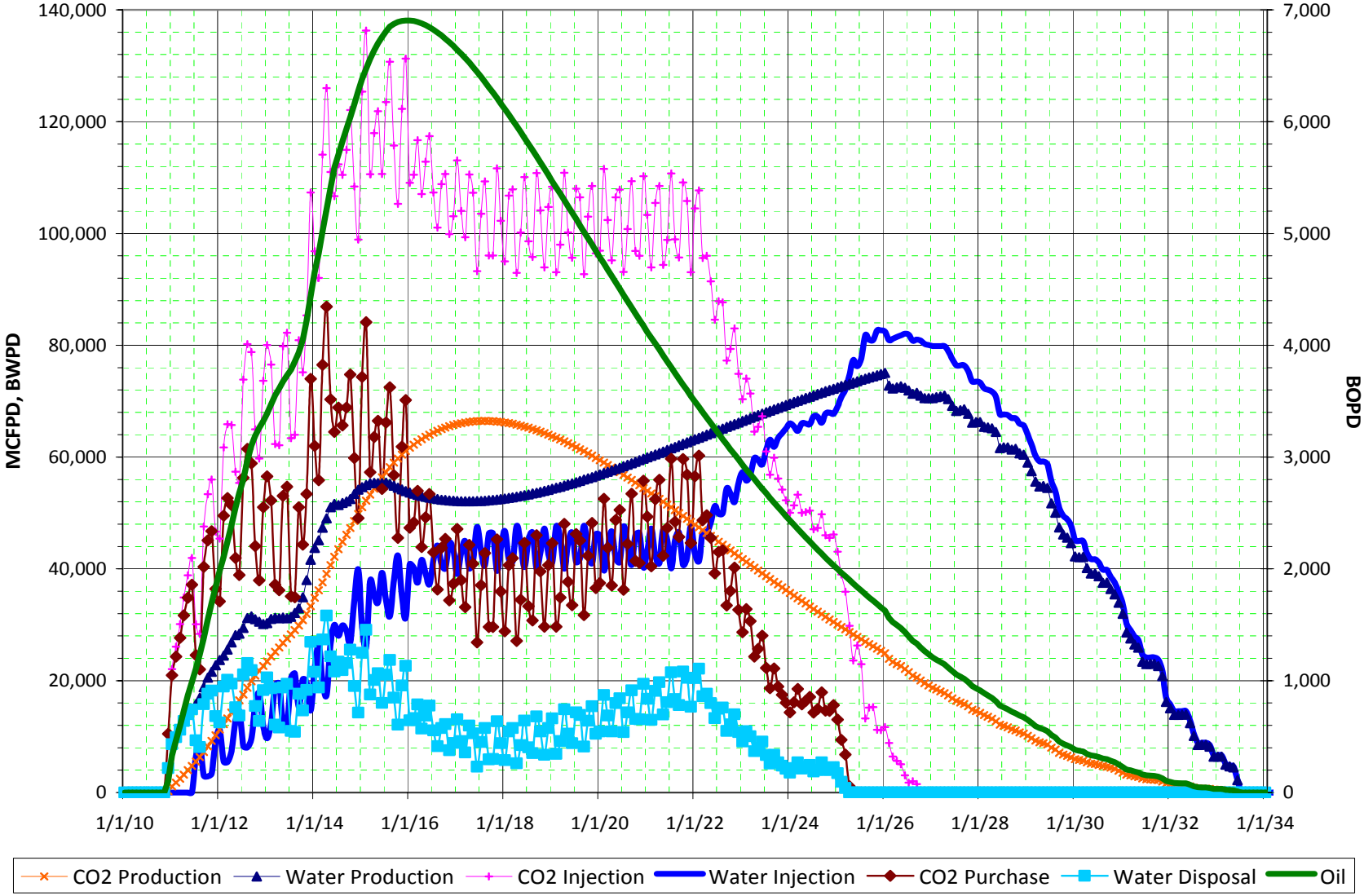
# Katz CO2 Project Forecast

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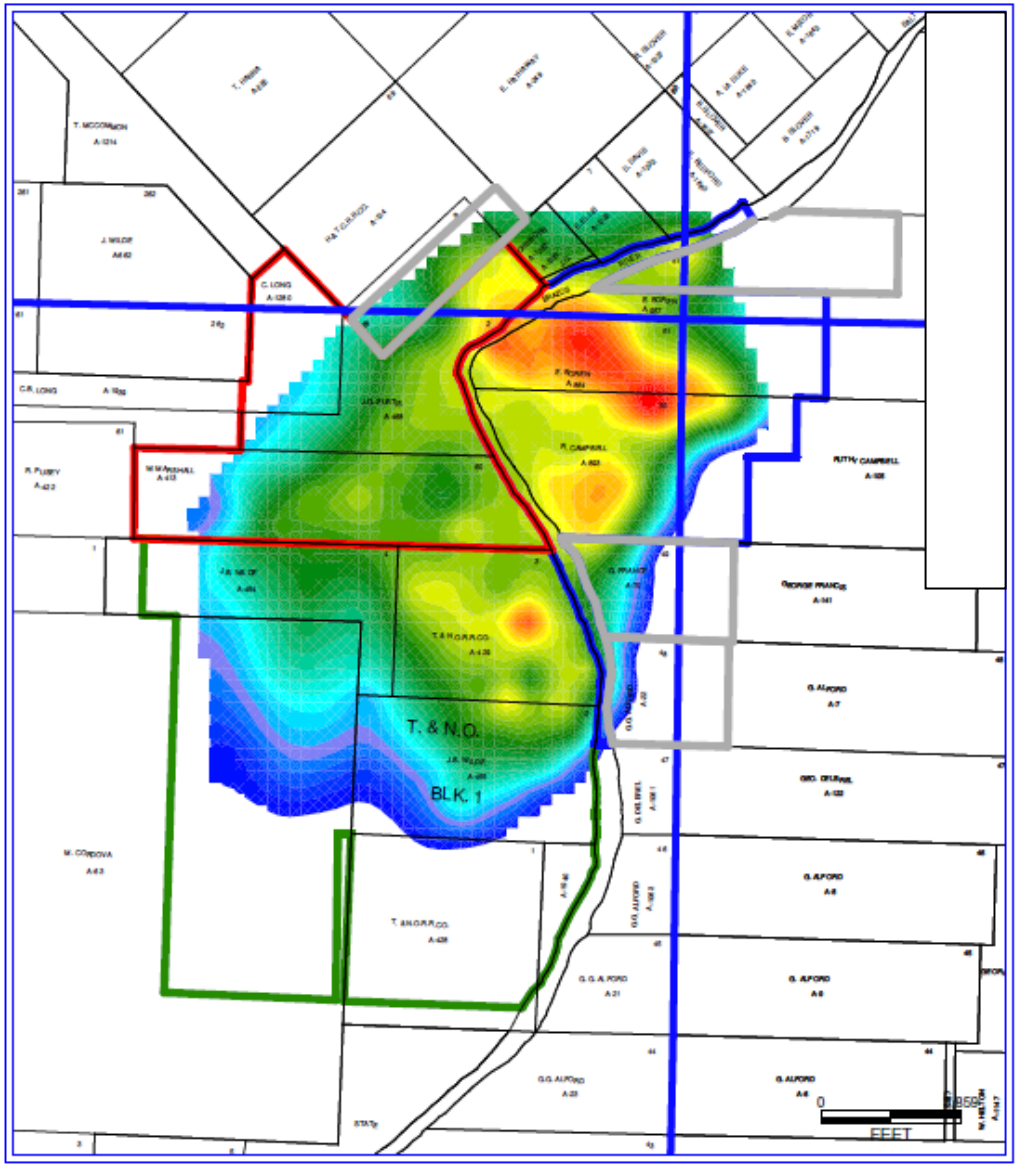
# Combined 3 Sands - HCFT

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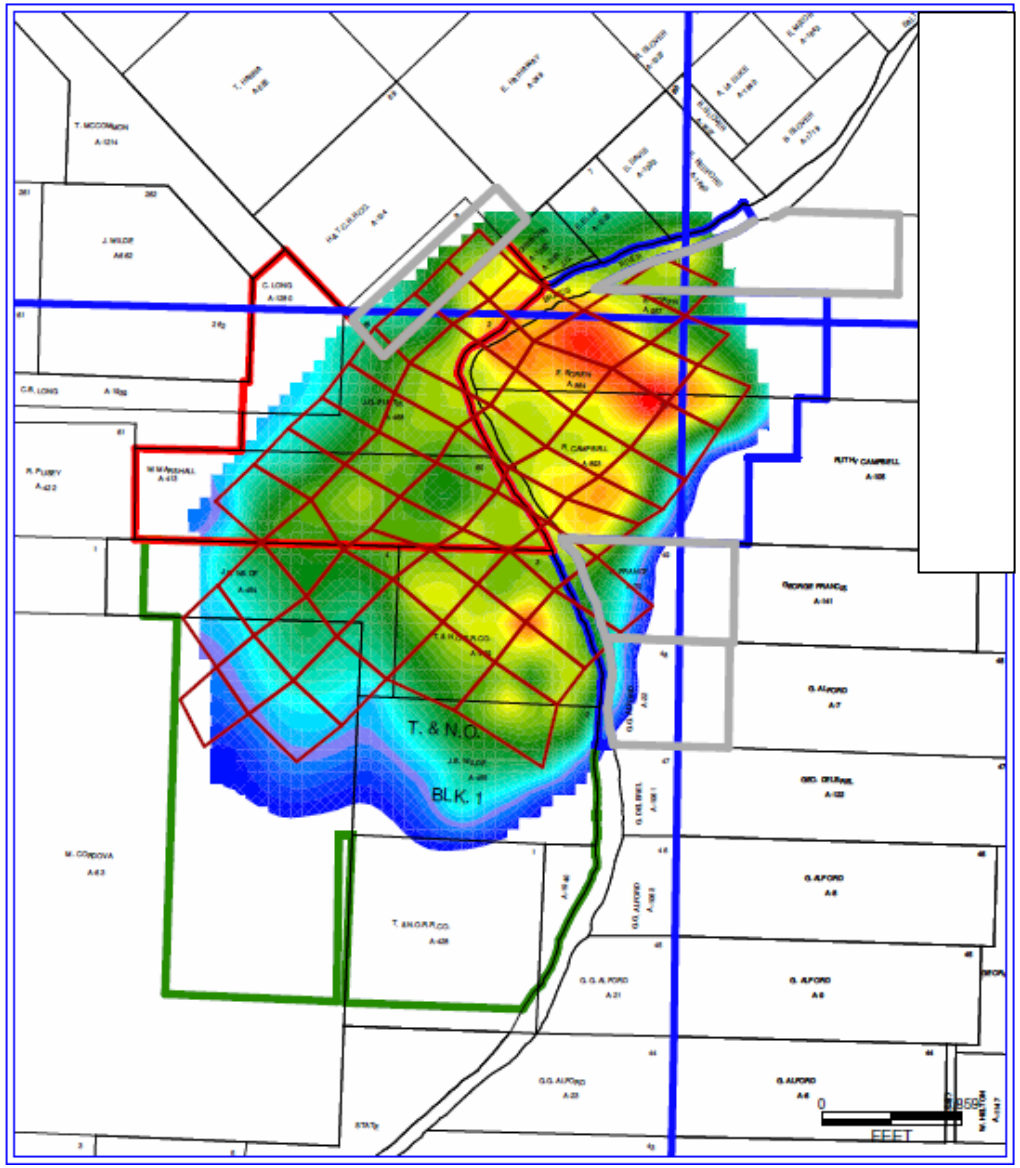
# 3 Sands – HCFT (w/ patterns)

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# CO2 Project Design

- 57 WAG Injectors
- 74 Producers
- 84 New Drills
- 47 Workovers
- 76 P&A's
- 4 Water Curtains
- 5 Observation Wells
- 3 Disposal Wells

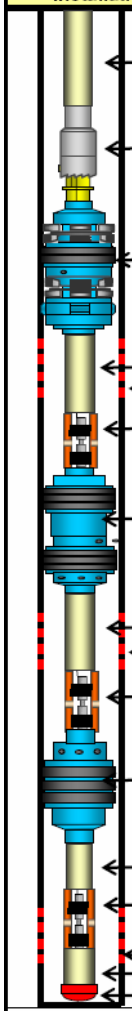
# CO2 Project Design

- Injection Rates
  - 18% HCPV/yr
- Injection Pressure
  - Fracture Gradient of 0.72 psi/ft
  - CO2
    - Surface – 1650 psig
    - BH - 3375 psia
  - Water
    - Surface 1400 psig
    - BH – 3380 psig

# Katz Injection Wells

- Down hole isolation assembly used on $CO_2$ WAG injectors:
  - Control $CO_2$ injection side when high GOR seen at producer.
  - One method of zonal conformance:
    *cheaper than some polymer jobs or expandable liner systems.
  - Can function individual zone sleeves from surface via slick line, no rig necessary.
  - Can limit individual zone rate based on orifice size.

# Downhole Isolation Assembly



| Installation | Description | OD | ID |
|---|---|---|---|
| | **Proposed Packer Installation** | | |
| | 2 7/8" EUE 8RD Tubing String With Poly Liner | 2.875 | 1.901 |
| | 5 1/2" Box X 2 3/8" Pin On-Off Tool With Profile | 4.50 | 1.875 |
| | Approx depth 4,750'<br>5 1/2" x 2 3/8" Double Grip Mechanical Set Right Hand 1/4" Turn Release 1/4" Right Hand Turn To Release | 4.750 | 1.901 |
| | 2 7/8" EUE 8RD Tubing String With Poly Liner | 2.875 | 1.901 |
| | Perforations | | |
| | 2 7/8" X 1.812" Segregation Valve With Isolation Sleeve in Place to Allow Setting Of Isolation Packers | 3.668 | 1.812 |
| | Approx depth 4,850'<br>5 1/2" X 2 3/8" Double Element Hydro 1V Hydraulic Set Packer<br>Packer Shear Release | 4.750 | 1.901 |
| | 2 7/8" EUE 8RD Tubing String With Poly Liner | 2.875 | 1.901 |
| | Perforations | | |
| | 2 7/8" X 1.612" Segregation Valve With Isolation Sleeve in Place to Allow Setting Of Isolation Packers | 3.668 | 1.612 |
| | Approx Depth 5,050'<br>5 1/2" X 2 3/8" Double Element Hydro 1V Hydraulic Set Packer<br>Packer Shear Release | 4.750 | 1.901 |
| | 2 7/8" EUE 8RD Tubing String With Poly Liner | 2.875 | 1.901 |
| | 2 7/8" X 1.50" Segregation Valve With Isolation Sleeve in Place to Allow Setting Of Isolation Packers | 3.668 | 1.500 |
| | Perforations | | |
| | 2 7/8" EUE 8RD Tubing String With Poly Liner | 2.875 | 1.901 |
| | Bull Plug | | |

KMKatz ERU#2

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# Segregation valve Assembly

# Producing Wells – ESP's

- 1100 – 1500 psig intake pressure
  - ~3000' FL
  - CO2 in dense phase
  - No Gas Separator
  - Mixed Flow Stages
- All equipped w/ VSD's and BH Sensors
- Continuous and Batch Corrosion Treatments
  - Mitigate predicted low pH reservoir fluids
    - pH ~ 3.5
  - High Cl
- ~ 400 psig Wellhead Pressure
  - Can produce at high GOR's without freezing
  - Reduces need for inlet compression

# Compression Overview

- Two Stage Compression – Gas Fired
  - Stage 1
    - Suction – 300 psia
    - Discharge – 700 to 800 psia
      - 10º Approach Chiller
        - » Drop out any liquids
  - Stage 2
    - Suction – 700 psia
    - Discharge – 2200 psia
      - 10º Approach Chiller
  - Cooling Tower
  - 1800 psia supply to the field at 95ºF
- No Hydrocarbon Recovery

# Katz SWIF and Production Satellites

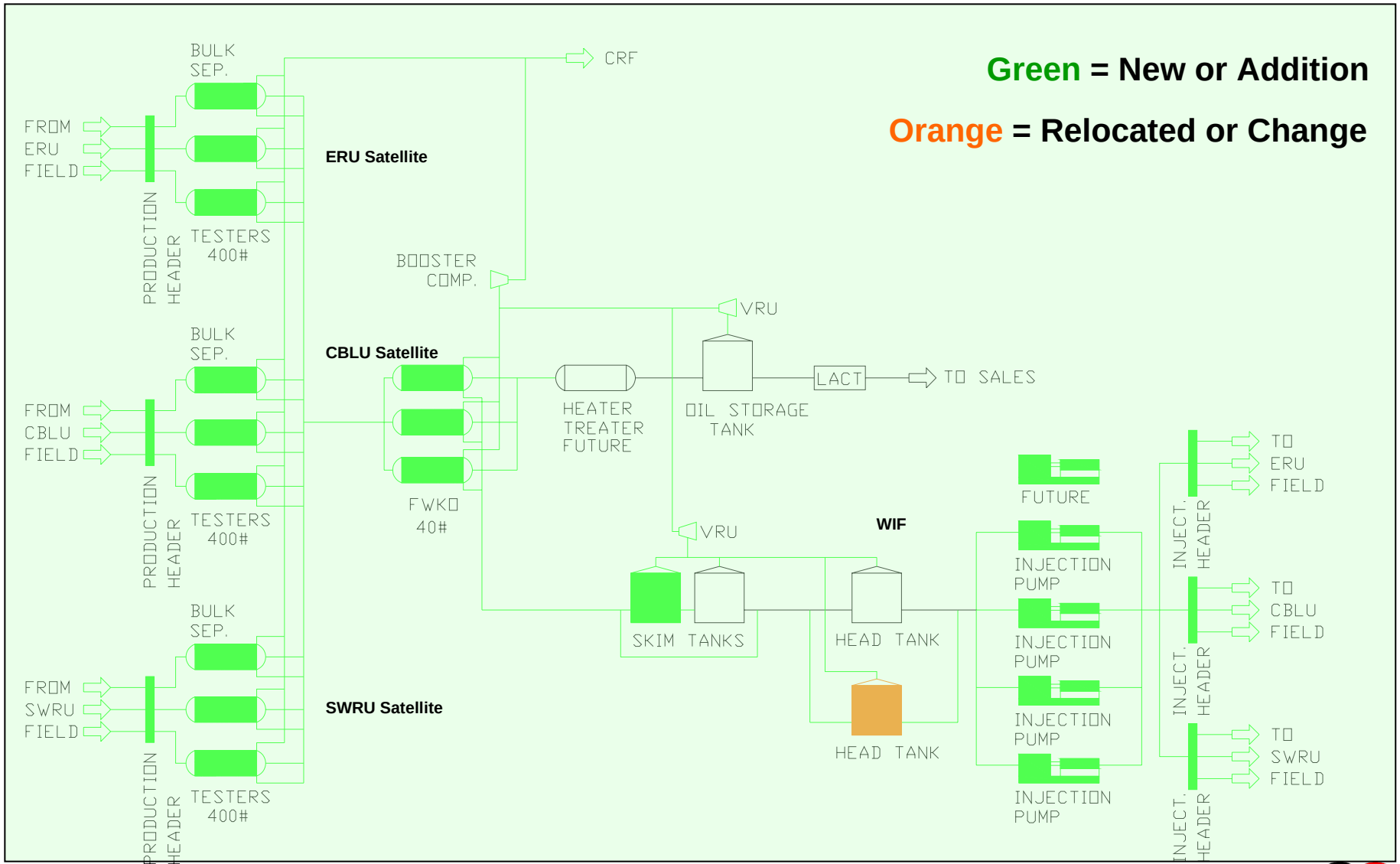


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Exhibit 11

SUMMARY

| FID | id | layer | description | diameter | length_ft |
|---|---|---|---|---|---|
| 0 | 0 | Flowline | Baseline | 3 | 1482.28 |
| 1 | 0 | Flowline | Baseline | 3 | 2586.3101 |
| 2 | 0 | Flowline | Hydrotest | 12 | 4861.4286 |
| 3 | 0 | Flowline | Baseline | 3 | 2484.83 |
| 4 | 0 | Flowline | Baseline | 3 | 1127.42 |
| 5 | 0 | Flowline | Baseline | 3 | 1127.42 |
| 6 | 0 | Flowline | Baseline | 3 | 1101.08861 |
| 7 | 0 | Flowline | Baseline | 3 | 2170.8756 |
| 8 | 0 | Flowline | Baseline | 3 | 1277.28 |
| 9 | 0 | Flowline | Baseline | 3 | 1277.28 |
| 10 | 0 | Flowline | Baseline | 3 | 1487.38 |
| 11 | 0 | Flowline | Hydrotest | 12 | 1878 |
| 12 | 0 | Flowline | Baseline | 3 | 1208.11 |
| 13 | 0 | Flowline | Baseline | 3 | 2180.3101 |
| 14 | 0 | Flowline | Baseline | 3 | 2180.3101 |
| 15 | 0 | Flowline | Baseline | 3 | 1482.28 |
| 16 | 0 | Flowline | Baseline | 3 | 1209.3008 |
| 17 | 0 | Flowline | Baseline | 3 | 1211.28 |
| 18 | 0 | Flowline | Baseline | 3 | 1211.28 |
| 19 | 0 | Flowline | Hydrotest | 12 | 2788.83 |
| 20 | 0 | Flowline | Baseline | 3 | 3482.1988 |
| 21 | 0 | Flowline | Baseline | 3 | 2487.78 |
| 22 | 0 | Flowline | Baseline | 3 | 1482.01 |
| 23 | 0 | Flowline | Baseline | 3 | 2414.1988 |
| 24 | 0 | Flowline | Baseline | 3 | 1482.28 |
| 25 | 0 | Flowline | Baseline | 3 | 2010.3001 |
| 26 | 0 | Flowline | Baseline | 3 | 2010.3001 |
| 27 | 0 | Flowline | Baseline | 3 | 1011.428 |
| 28 | 0 | Flowline | Baseline | 3 | 4020.3001 |
| 29 | 0 | Flowline | Baseline | 3 | 2030.3001 |
| 30 | 0 | Flowline | Baseline | 3 | 1209.28 |
| 31 | 0 | Flowline | Hydrotest | 12 | 4848.3108 |
| 32 | 0 | Flowline | Baseline | 3 | 2883.88 |
| 33 | 0 | Flowline | Baseline | 3 | 1009.28 |
| 34 | 0 | Flowline | Baseline | 3 | 2010.3001 |
| 35 | 0 | Flowline | Baseline | 3 | 2010.3001 |
| 36 | 0 | Flowline | Baseline | 3 | 1701.28 |
| 37 | 0 | Flowline | Baseline | 3 | 1210.28 |
| 38 | 0 | Flowline | Baseline | 3 | 1708.88 |
| 39 | 0 | Flowline | Baseline | 3 | 1884.3101 |
| 40 | 0 | Flowline | Baseline | 3 | 1884.3101 |
| 41 | 0 | Flowline | Baseline | 3 | 1708.88 |
| 42 | 0 | Flowline | Baseline | 3 | 1884.3101 |
| 43 | 0 | Flowline | Baseline | 3 | 1011.428 |
| 44 | 0 | Flowline | Baseline | 3 | 4020.3001 |
| 45 | 0 | Flowline | Baseline | 3 | 2030.3001 |
| 46 | 0 | Flowline | Baseline | 3 | 1209.28 |
| 47 | 0 | Flowline | Baseline | 3 | 1025.28 |
| 48 | 0 | Flowline | Baseline | 3 | 2884.3108 |
| 49 | 0 | Flowline | Baseline | 3 | 1013.28883 |
| 50 | 0 | Flowline | Baseline | 3 | 2883.88 |
| 51 | 0 | Flowline | Hydrotest | 12 | 2832.18 |
| 52 | 0 | Flowline | Baseline | 3 | 1884.3101 |
| 53 | 0 | Flowline | Baseline | 3 | 1884.1 |
| 54 | 0 | Flowline | Baseline | 3 | 2883.88 |
| 55 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 56 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 57 | 0 | Flowline | Baseline | 3 | 2884.3101 |
| 58 | 0 | Flowline | Baseline | 3 | 2884.3101 |
| 59 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 60 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 61 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 62 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 63 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 64 | 0 | Flowline | Baseline | 3 | 1884.1 |
| 65 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 66 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 67 | 0 | Flowline | Baseline | 3 | 2884.3101 |
| 68 | 0 | Flowline | Baseline | 3 | 2011.3101 |
| 69 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 70 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 71 | 0 | Flowline | Baseline | 3 | 1011.428 |
| 72 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 73 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 74 | 0 | Flowline | Baseline | 3 | 1884.28 |
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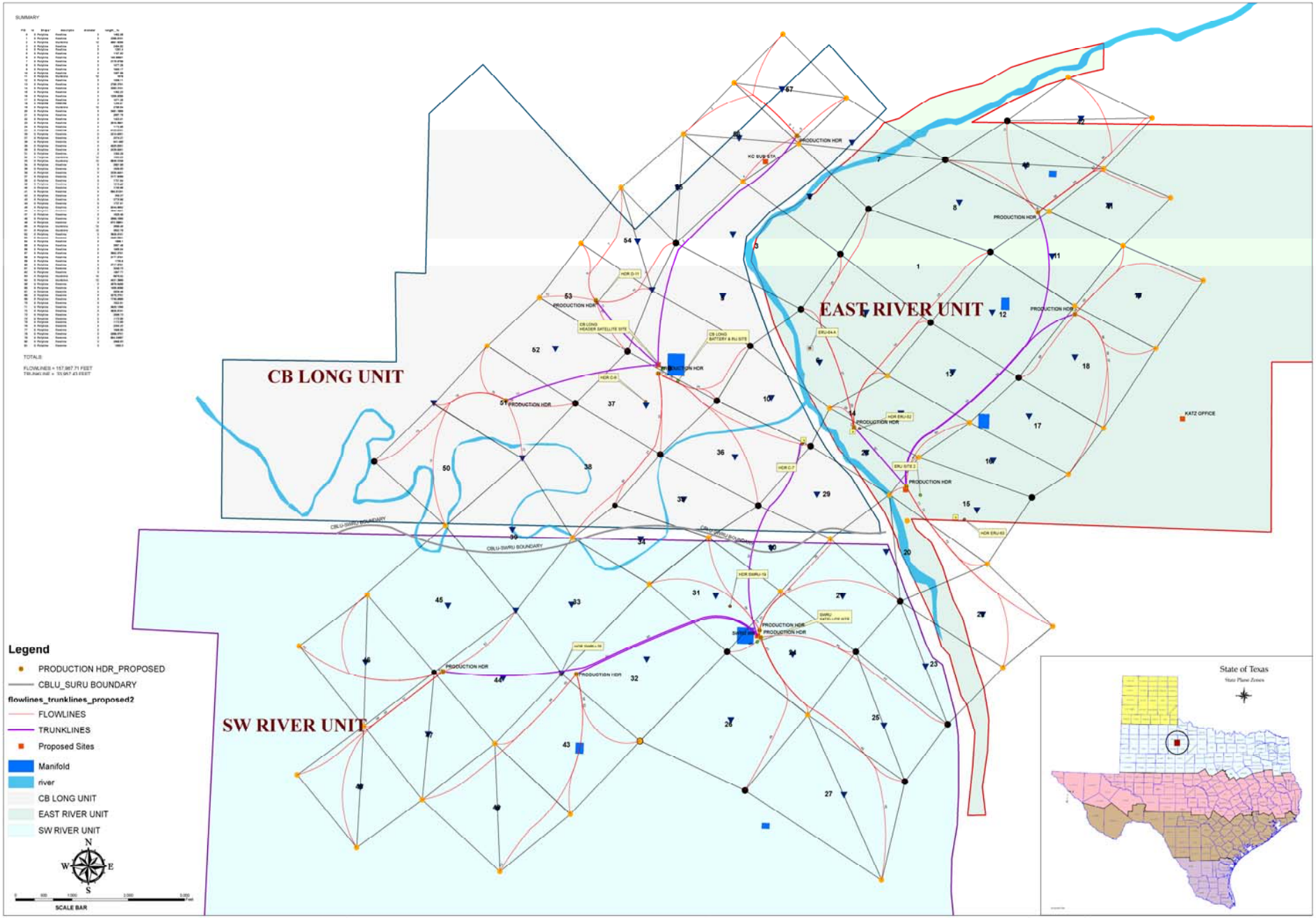
| 158 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 159 | 0 | Flowline | Baseline | 3 | 1884.28 |
| 160 | 0 | Flowline | Baseline | 3 | 1884.28 |

TOTALS:

FLOWLINES = 157,987.71 FEET
TRUNKLINE = 15,987.43 FEET




**KINDER MORGAN**
**Knox County**
**CO2 COMPANY, L.P.**

SACROC STANDARD MAPPING PROJECTION
GEOGRAPHICAL COORDINATE SYSTEM
WORLD GEODETIC SYSTEM 1984 (WGS84)

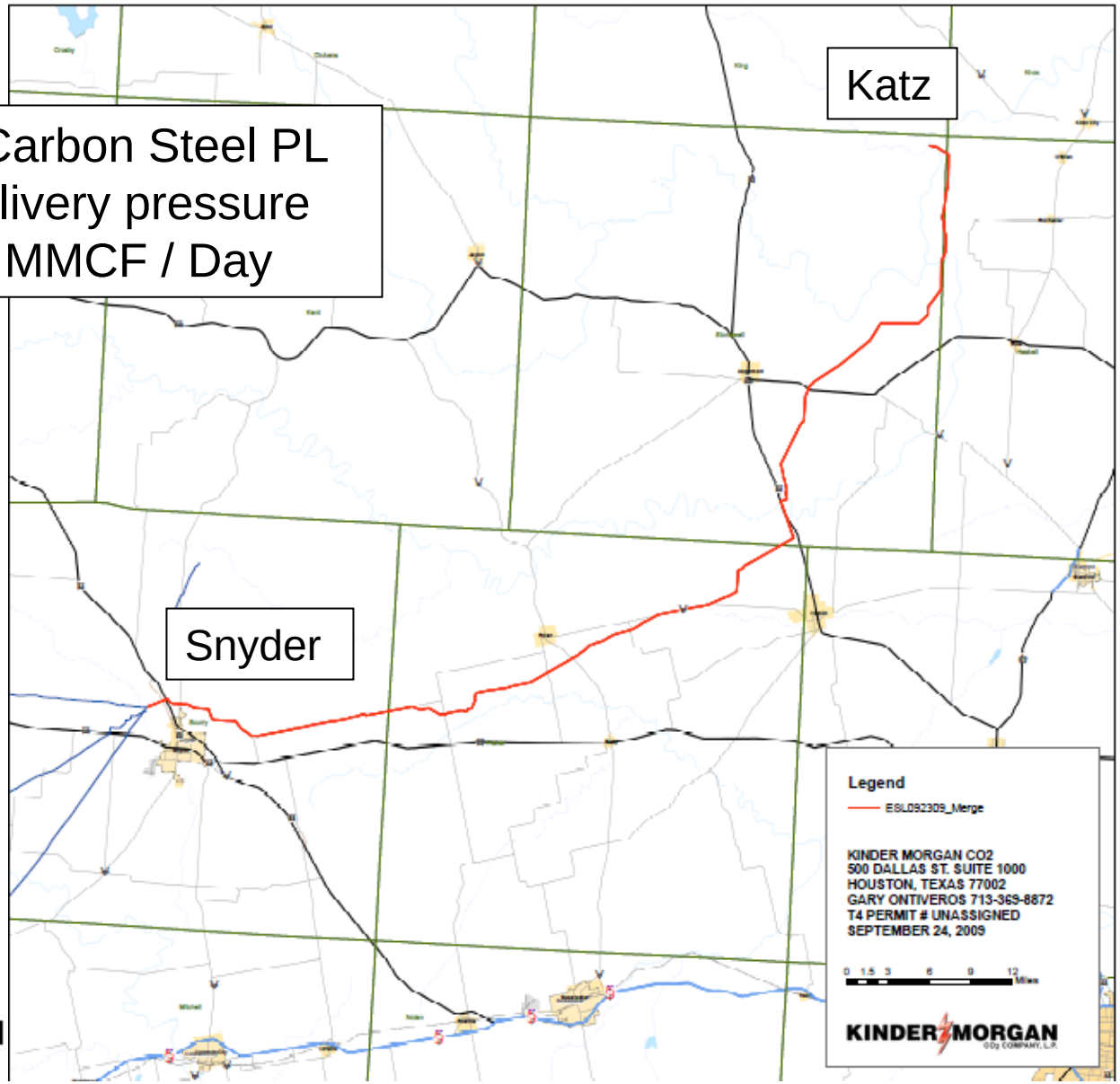
# EASTERN SHELF
## *(KATZ OILFIELD)*

## GENERAL FIELD MAP

| DATE | REVISION | DRW |
|---|---|---|
| 08-19-09 | INITIAL ISSUE FOR REVIEW | NAD |
| 09/09/09 | UPDATED LEASE ROADS | NAD |
| 09/09/09 | UPDATED WITH PROPOSED FACILITY LOCATIONS | NAD |
| 09/23/09 | ADDED PROPOSED INJ. HDRS | NAD |

# Eastern Shelf Pipeline

10” 91-mile Carbon Steel PL
1700 psig delivery pressure
Capacity  65 MMCF / Day




KINDER MORGAN

# Thank You

- Questions?