Natural Gas Reserve Estimate of Bangladesh

Zaved Choudhury
Manager (Reservoir Engineering)
Reservoir and Data Management Division
Petrobangla

Contents:

- Background
- Methodology
  - Material balance Estimate
  - Volumetric estimate
- Results
  - Titas Gas Field
  - Habiganj Gas Field
  - Meghna Gas Field

Background:

- Earlier Works:

  - In 1991 Welldrill Ltd. did a review on gas reserves of Bangladesh, included 17 gas fields, GIIP was 22.7 Tcf

  - IKM(Intercomp Kanata Management) completed a study of 8 gas fields during 1989-92, GIIP was 15.65 Tcf

- Latest Works:

  - Bangladesh Petroleum Potential and Resource Assessment 2001, included 22 gas fields, GIIP was 28.7 Tcf, Hydrocarbon Unit, EMRD

  - Bangladesh Gas Reserve Estimation 2003, it's an update to 2001 report, reassessed the GIIP to 28.4 Tcf.

Reports of Hydrocarbon Unit are in public domain by the address:
www.hcu.org.bd

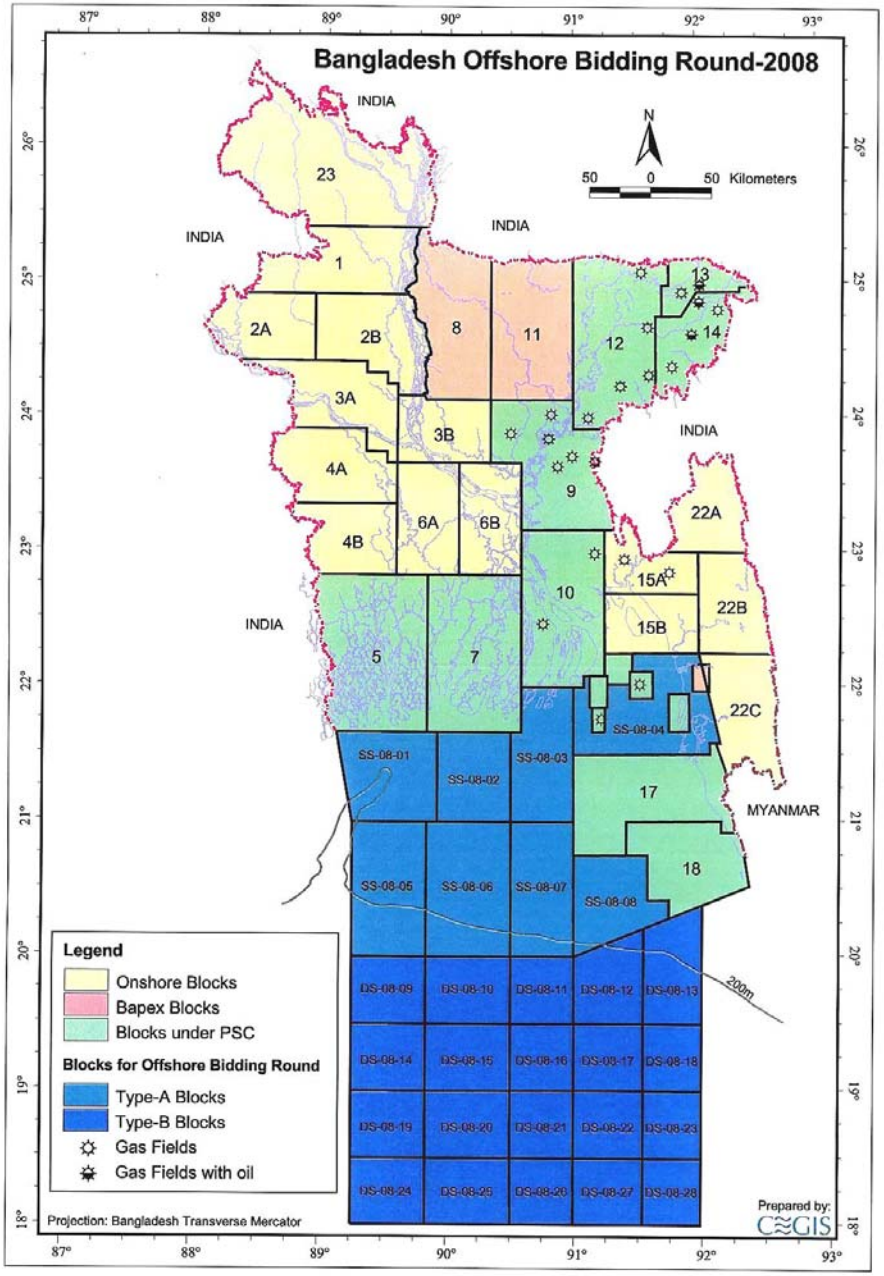
National Companies Producing The Gas Fields Are:

- Bangladesh Gas Fields Company Ltd. (BGFCL):

  Titas, Habiganj, Bakhrabad, Narshingdi, Meghna
- Sylhet Gas Fields Ltd. (SGFL):

  Sylhet, Kailashtilla, Rashidpur, Beanibazar
- Bangladesh Exploration and Production Company Ltd. (BAPEX):

  Fenchuganj and Salda Nadi.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Blocks for Offshore Bidding Round
Type-A Blocks
Type-B Blocks
Gas Fields
Gas Fields with oil
Projection: Bangladesh Transverse Mercator
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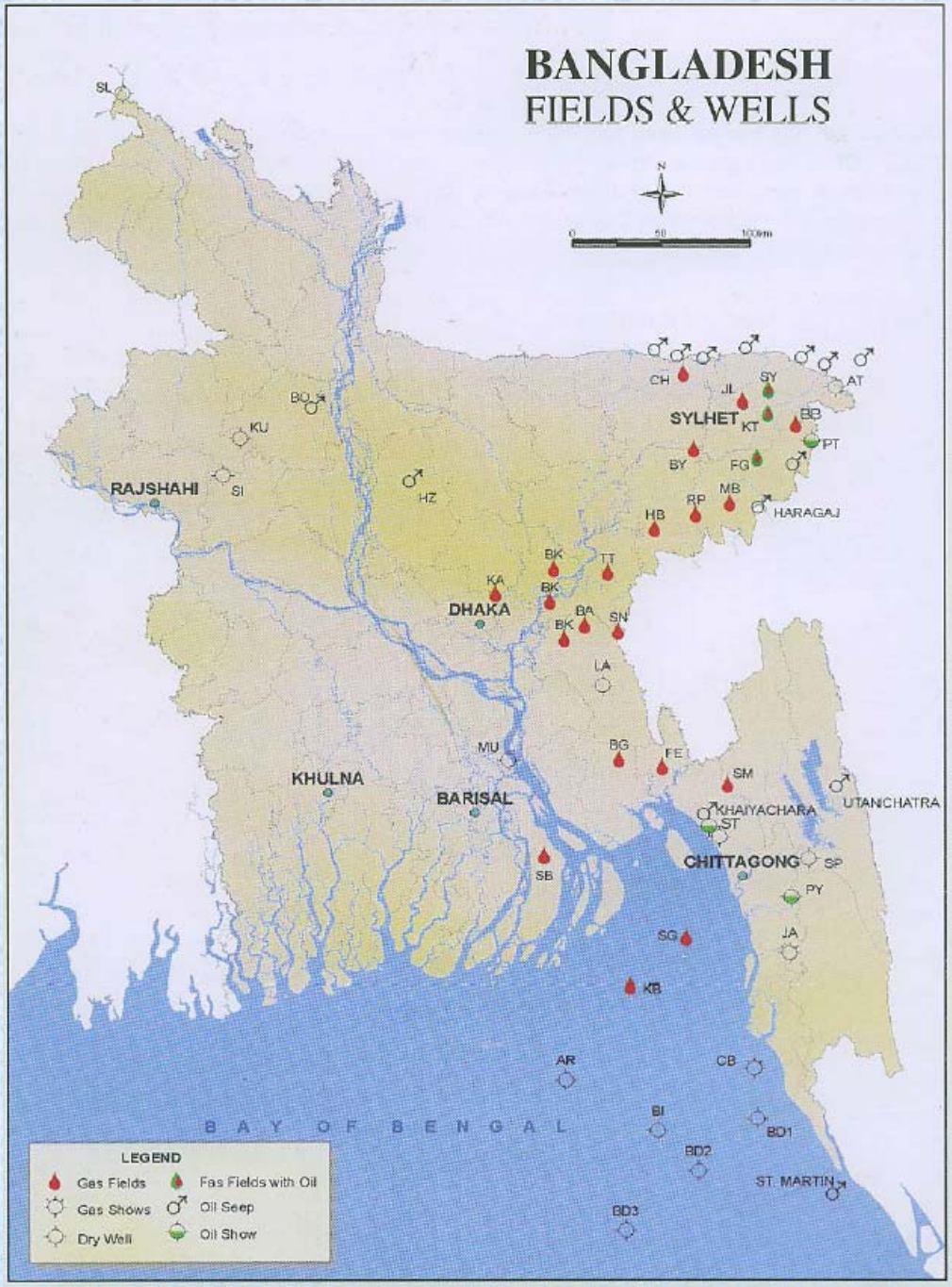
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LEGEND
Gas Fields
Gas Shows
Dry Well
Gas Fields with Oil
Oil Seep
Oil Show

Reserves Definition

- Reserves are those quantities of petroleum which are recoverable economically in the future using commercial methods and government regulations
- Reserves are estimates which are subject to revisions during the life of a field
- Reserve estimates can be made for varying recovery processes:

  -Primary recovery

  -Secondary recovery

  -Tertiary recovery

Reserve Estimates Involve some Degree of Uncertainties:

- Dependent upon reliability of the available data
- Interpretation of the data
- Techniques used

Producing Mechanism of Gas Reservoirs:

- ✓ Gas Expansion
- ✓ Aquifer Water Influx
- ✓ Combination Drives

Recovery Factor

- Recovery factor is the fraction of hydrocarbon that can be technically and economically extracted from hydrocarbons originally present in the reservoirs
- New information of the reservoir, new technology of extraction and the economy of the extraction may change this number from time to time
- Recovery factor depends mainly on the reservoir characteristics, drive mechanism and reservoir management practice
- Ultimate recoveries of 80%~ 90% are common in expansion drive gas reservoirs
- Typical recovery factor for water drive gas reservoirs can range from 50%~70% depending upon size of the reservoir.

Reserves Classification

1. Proved Reserves
2. Probable Reserves
3. Possible Reserves

1. Proved reserves are those quantities of petroleum, by analysis of geologic and engineering data, can be estimated with reasonable certainty to be commercially recoverable in the future from known reservoirs and under current economic conditions, operating methods and government regulations.

Probability of recovery should be at least 90% or more.

Reserves Classification

2. Probable reserves are those unproved reserves that geologic and engineering data suggest are likely than not to be recoverable

Probability of recovery should be at least 50% or more of the sum of the estimated proved plus probable reserves

3. Possible reserves are those unproved reserves that geologic and engineering data suggest are less likely to be recoverable than probable reserves

Probability of recovery should be at least 10% or more of the sum of the estimated proved plus probable plus possible reserves

Methodology

Different Approaches of Reserve Estimation:

- Volumetric Estimate
- Material Balance Estimate
- Decline Curve
- Reservoir Simulation

Volumetric Estimate

- Deterministic Approach

  Use Average Thickness, Porosity, Saturation, and Formation Volume Factors of all the Wells

- Probability Approach

  Use Range of Values for Each Variable, and a Statistical Model to Determine the Probability of Occurence

Data for Volumetric Estimate

Variables	Sources
▪ Area, thickness	▪ Structure, Isopach, Well Logs and Core Analysis
▪ Porosity, Saturation	▪ Logs and Core Analysis
▪ Formation Volume Factor	▪ PVT, Correlations

Gas Reservoir
Original Gas in Place

$$G = \frac{43{,}560 V \Phi (1 - S_{wi})}{B_g}$$

G	**in-place gas, standard cubic feet**
V	**(Axh) reservoir volume, acre-feet**
Φ	**reservoir porosity, fraction**
S_{wi}	**connate water saturation**
1-S_{wi}	**S_g= gas saturation**
B_g	**gas formation volume factor**
43,560	**cubic feet / acre-foot**

Material Balance Estimate

Assumptions:

- Homogeneous Tank (Same Rock and Fluid Properties)
- Fluid Production at a Single Point
- No Direction to Fluid Flow

Applications:

- Original Oil or Gas-In-Place
- Producing Mechanism
- Production Performance

General Form of Material Balance Equation

$$F = N(Eo + mEg + Efw) + We$$

F	= production of oil, water and gas, rb
N	= original oil-in-place,stb
Eo	= expansion of oil and original gas in solution,rb/stb
m	= initial gas cap volume, fraction of initial oil volume
Eg	= gas cap expansion, rb/stb
Efw	= connate water expansion and pore volume reduction due to production, rb/stb
We	= cumulative natural water influx, rb

Gas Material Balance Equation

$$F = Gp(Eg + Efw) + We$$

$$P/Z=(1-Gp/G\ )\ Pi\ /Zi$$

F	*= production of gas, and water, rb*
G	*= original gas in place,scf*
Eg	*= expansion of gas,rb/scf*
Efw	*= connate water expansion and pore volume reduction,rb/scf*
Et	*= Eg + Efw*
We	*= cumulative natural water influx,rb*
P	*= pressure,psia*
Pi	*= initial pressure,psia*
Gp	*= cumulative gas production,scf*
Z	*= compressibility at pressure*
Zi	*= compressibility at initial pressure*

Material Balance Estimate (contd.)

- Using the Software MBAL™
- Conventional Material Balance Approach
  [using SBHP (static bottom hole pressure); p/z vs cumulative production]
- FWHP(Flowing Wellhead Pressure) Approach
  (in the case of paucity of pressure survey data)

Data for Material Balance Study

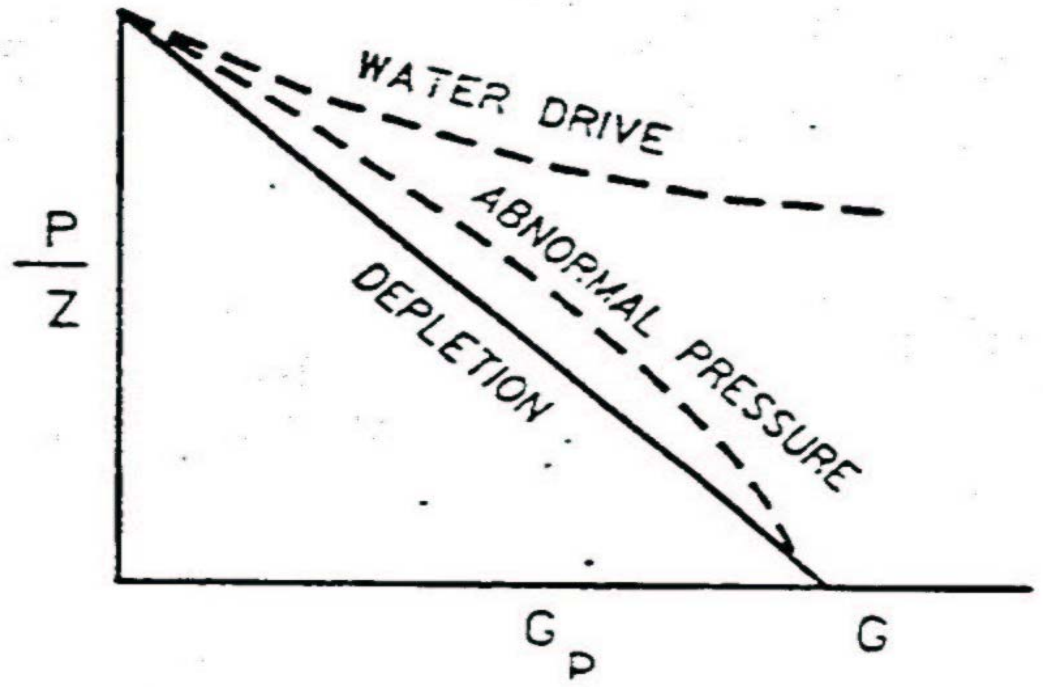
- Cumulative Gas, Condensate and Water Productions
- Average Reservoir Pressure
- PVT

1. P/Z Method
(any reservoirs)

$P/Z = (1 - G_p/G)\ P_i/Z_i$

Plot: P/Z vs G_p
G = X intercept

Plot is linear if $W_e = E_{fw} = 0$



Analysis of Titas Gas Field

Titas (contd.)

- Titas Gas Field is approximately 50 miles east of Dhaka City
- Titas Field was delineated in the early 1950s by Pakistan Petroleum Ltd.(PPL)
- Pakistan Shell Oil Company(PSOC) conducted seismic survey and confirmed an anticline structure (1960)
- The Field was discovered in 1962 by PSOC

Titas (contd.)

- The sands are classified into three groups A, B and C.
- Several estimates put GIIP as 2.25 to over 3.45 TCF (1962-1984)
- IKM conducted a comprehensive study under Gas Field Appraisal Project (1990) :

  Main features:

  GIIP of A Sands 9.58 TCF (MB); 3.17 TCF (Volumetric)

  GIIP of B and C Sands 745.8 BCF (MB); 970 BCF (Volumetric)
- Production from the A sand group began in 1968

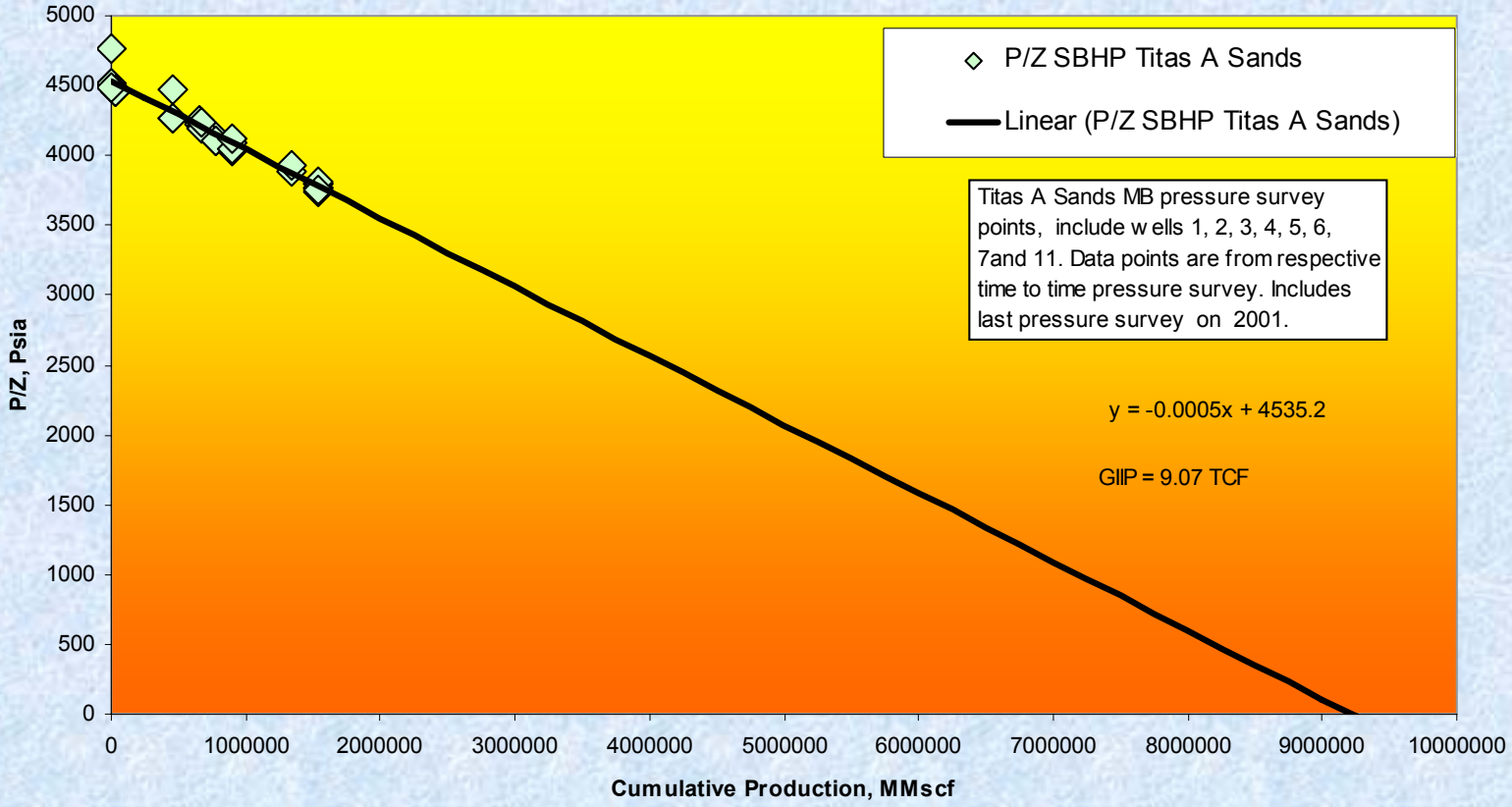
Material Balance Study

Conventional method

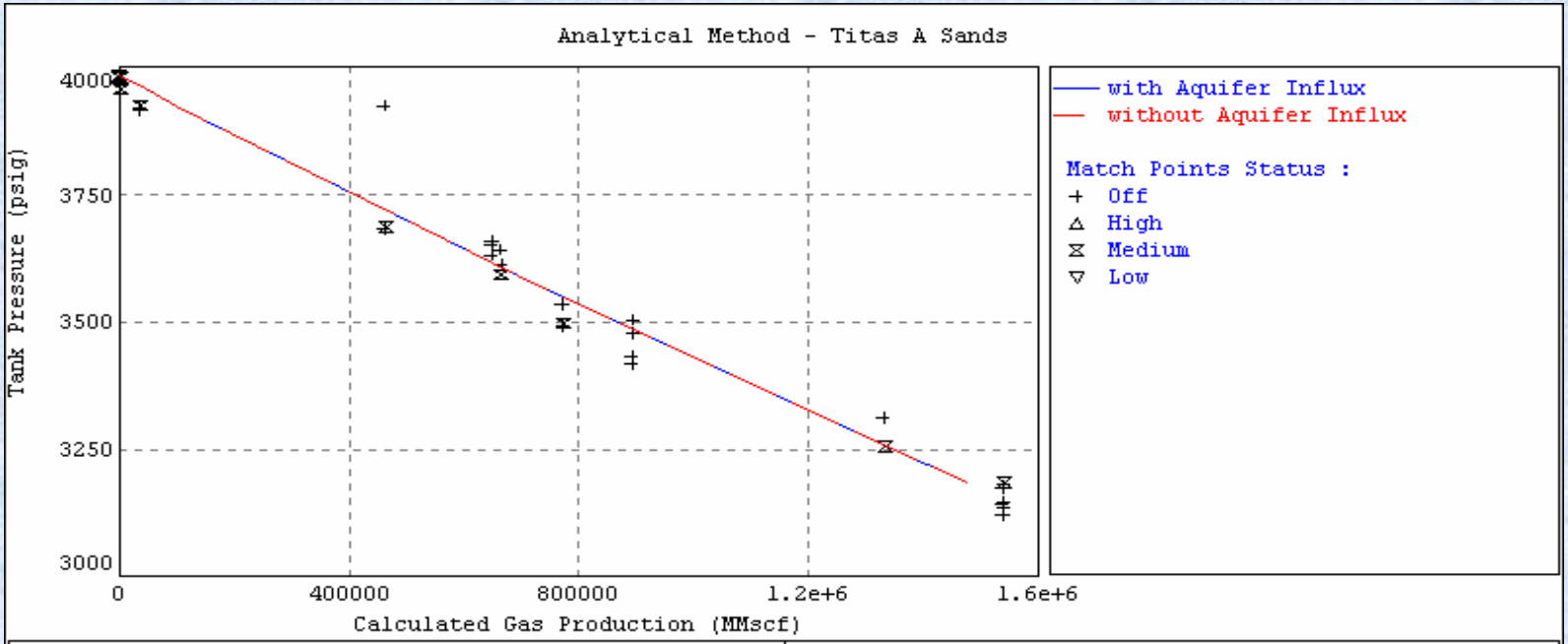
- p/z vs G_P plot

  p is static reservoir pressure
- using MBAL^{TM} software

MB using Pressure Survey Data of Titas A Sands



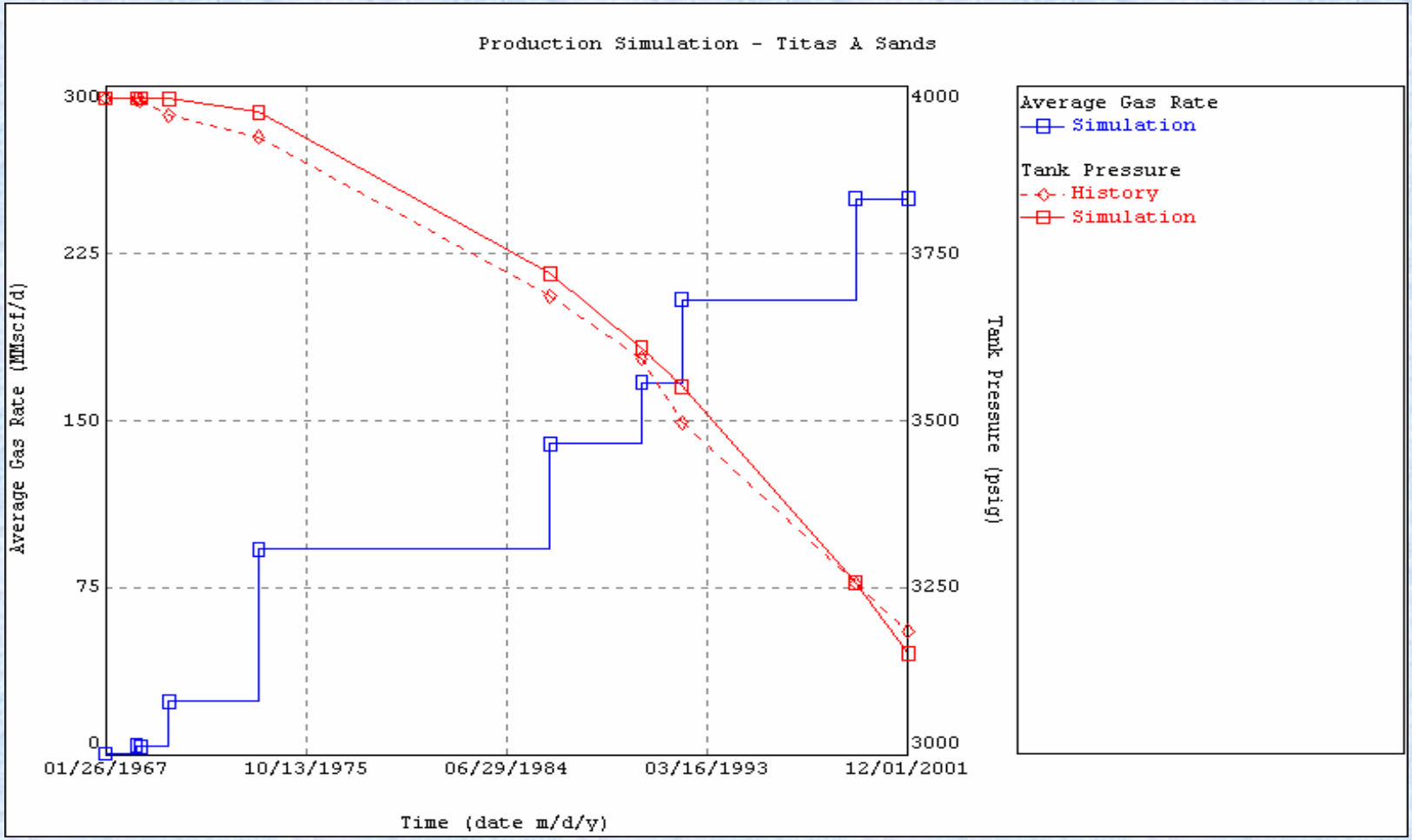
MBAL™ Analysis for Titas A Sands



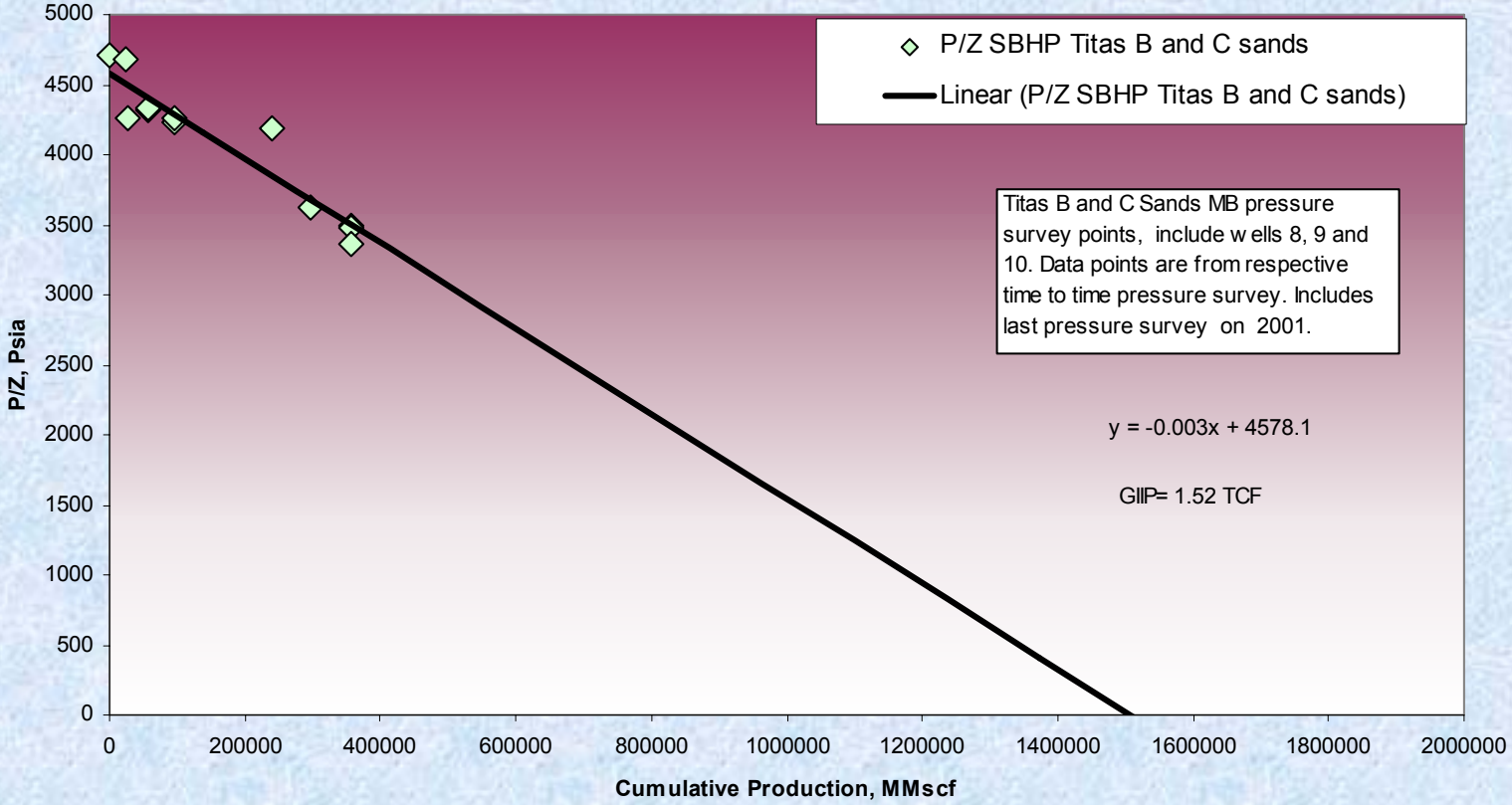
Tank Temperature	200	(degrees F)
Tank Pressure	3983	(psig)
Tank Porosity	0.2	(fraction)
Connate Water Saturation	0.2	(fraction)
Water Compressibility	Use Corr	(1/psi)
Formation Compressibility	3.49998e-6	(1/psi)
Gas in Place	8.53253e+6	(MMscf)
Production Start	01/26/1967	(date m/d/y)

Aquifer Model	Hurst-van Everdingen-Modified	
Aquifer System	Radial Aquifer	
Outer/Inner Radius	1.002	
Encroachment Angle	360	(degree)
Calc. Aquifer Volume	185.993	(MMft3)
Aquifer Permeability	50	(md)
Tank Thickness	228	(ft)
Tank Radius	22000	(ft)

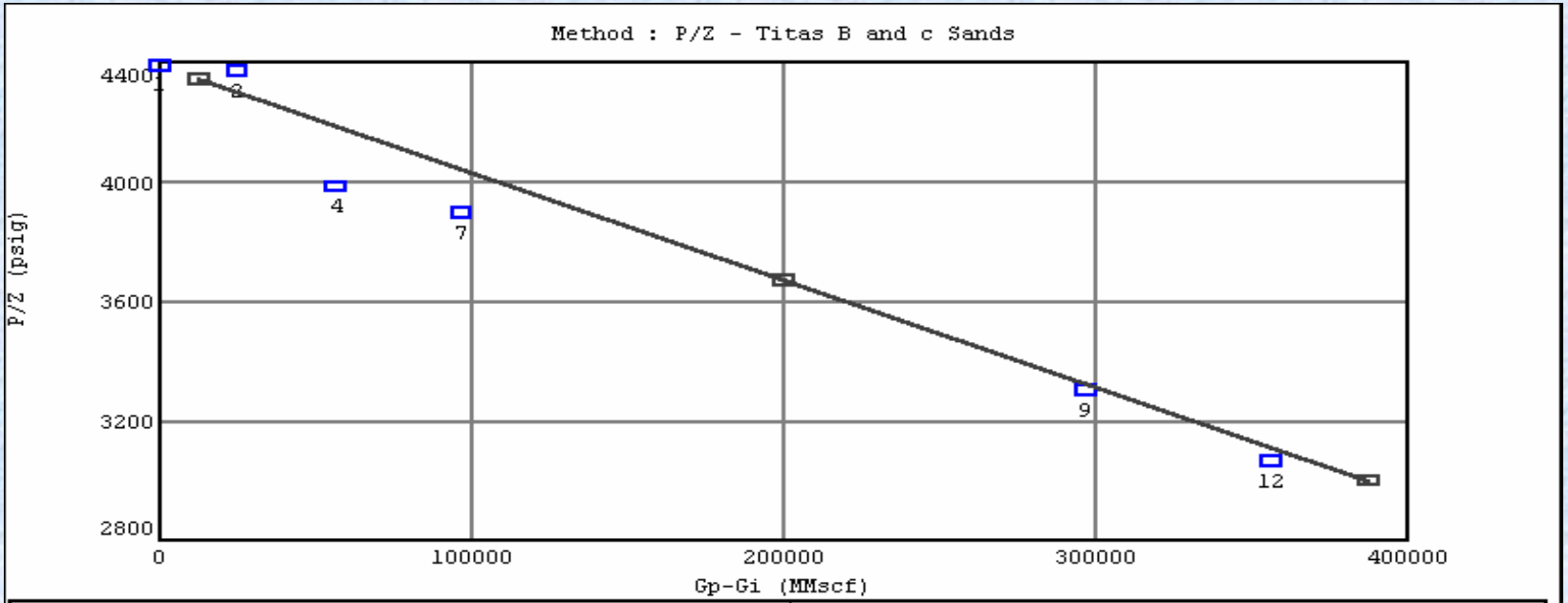
MBAL™ Analysis for Titas A Sands (cont.)
History Matching by MBAL™



MB using Pressure Survey Data of Titas B & C Sands



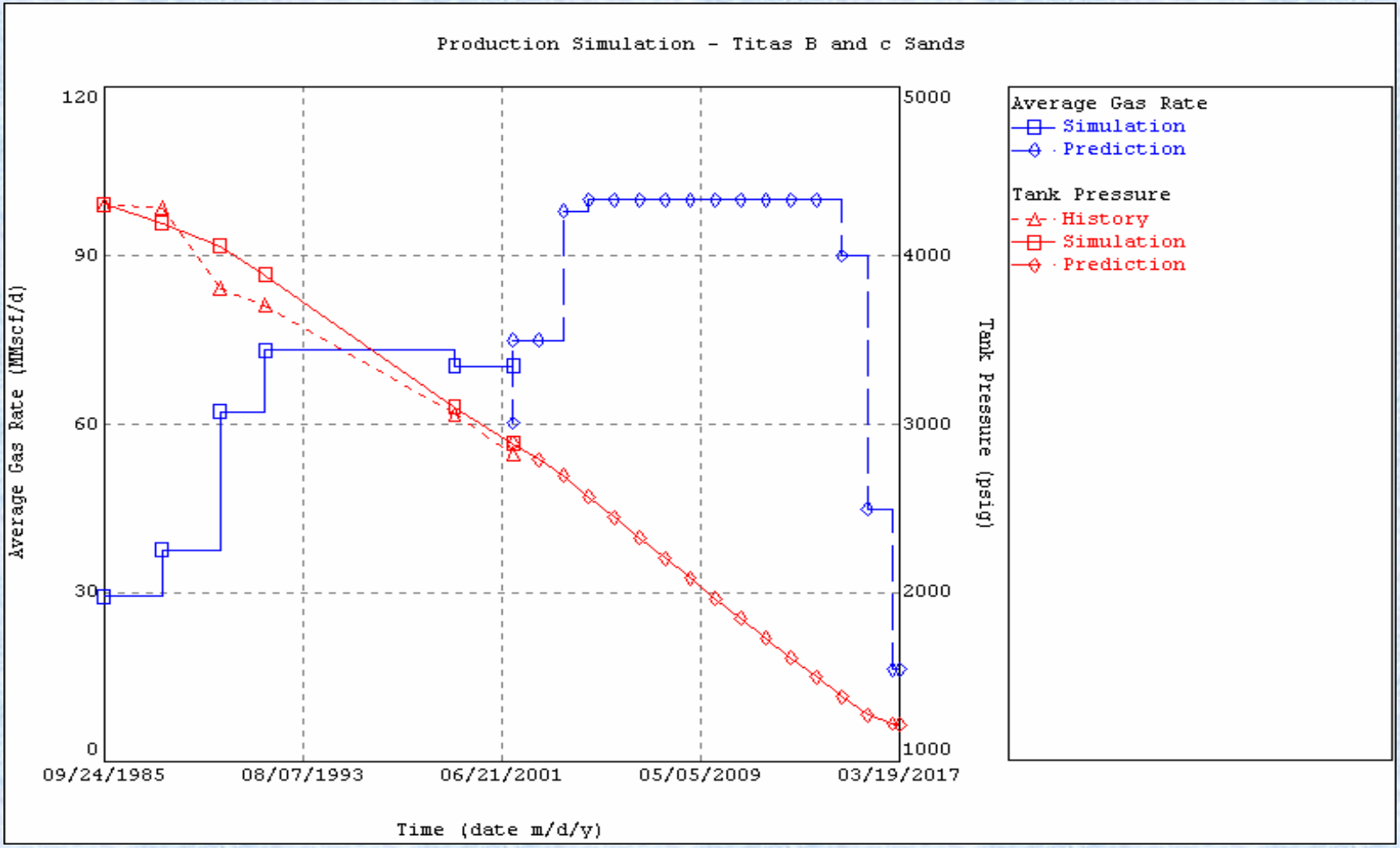
MBAL™ Analysis for Titas B and C Sands



Tank Temperature	200	(degrees F)
Tank Pressure	4306	(psig)
Tank Porosity	0.2	(fraction)
Connate Water Saturation	0.2	(fraction)
Water Compressibility	Use Corr	(1/psi)
Formation Compressibility	3.49998e-6	(1/psi)
Gas in Place	1.22497e+6	(MMscf)
Production Start	09/24/1985	(date m/d/y)

Aquifer Model	None
Aquifer System	Radial Aquifer

MBAL™ Analysis for Titas B and C Sands (cont.)
History Matching and Performance Prediction by MBAL™



Comparison of the P/Z (conventional), MBAL™ and Volumetric Estimates of Titas Sands

Sand	GIIP Tcf (P/Z) (conventional)	GIIP Tcf (MBAL™)	GIIP Tcf (Volumetric)
A Sands	9.07	8.5	6.1
B and C Sands	1.52	1.2	1.2
Total	10.59	9.7	7.3

The Discrepancy Between the Estimates is Probably due to the Fact:

The Field is Producing for the Last 40 Years

- With Insufficient Geophysical Data
- Limited Well Control

The Reality is, that the Field has not been Fully Appraised. These are the Limitations in the Volumetric Estimate.

Analysis of Habiganj Gas Field

Habiganj (contd.)

- Habiganj Gas Field is located approximately 75 miles north-east of Dhaka City
- Pakistan Shell Oil Company(PSOC) conducted seismic survey and confirmed an anticline structure (1962)
- The Field was discovered in 1963 by PSOC
- The Sands are :
  - Upper Gas Sand
  - Lower Gas Sand

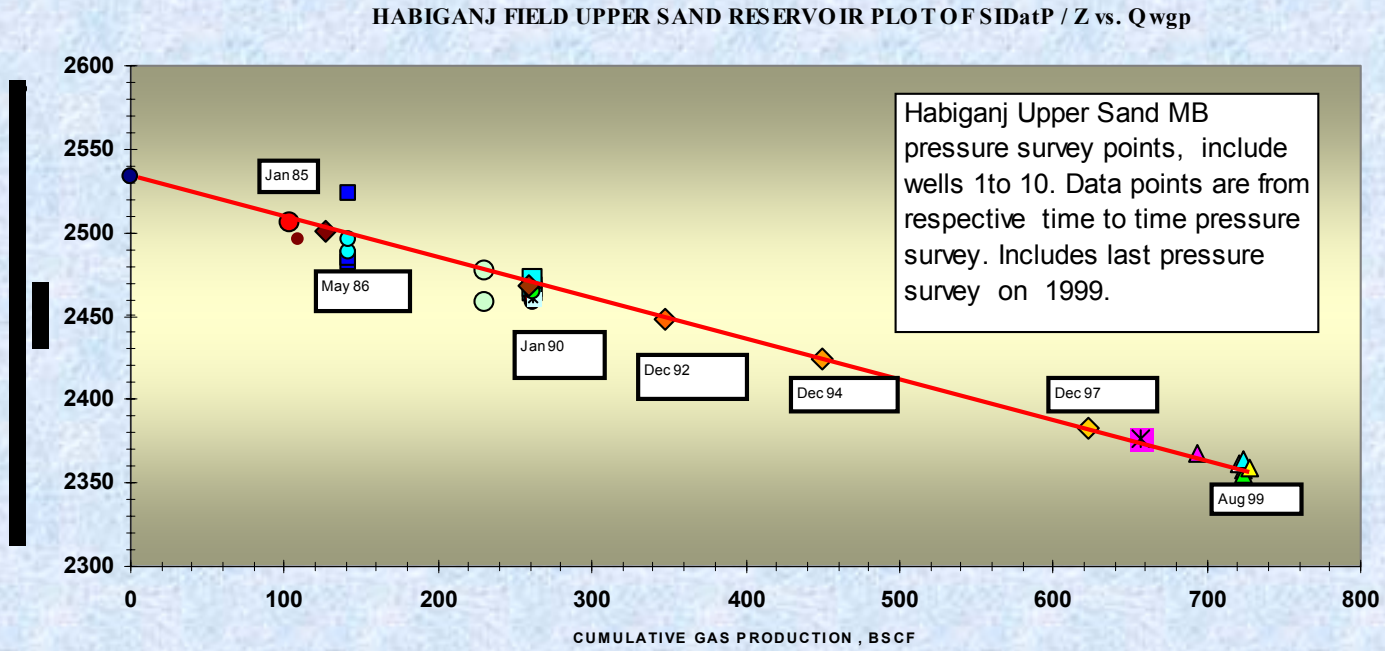
Habiganj (contd.)

- IKM study (1990)
  - Main features:

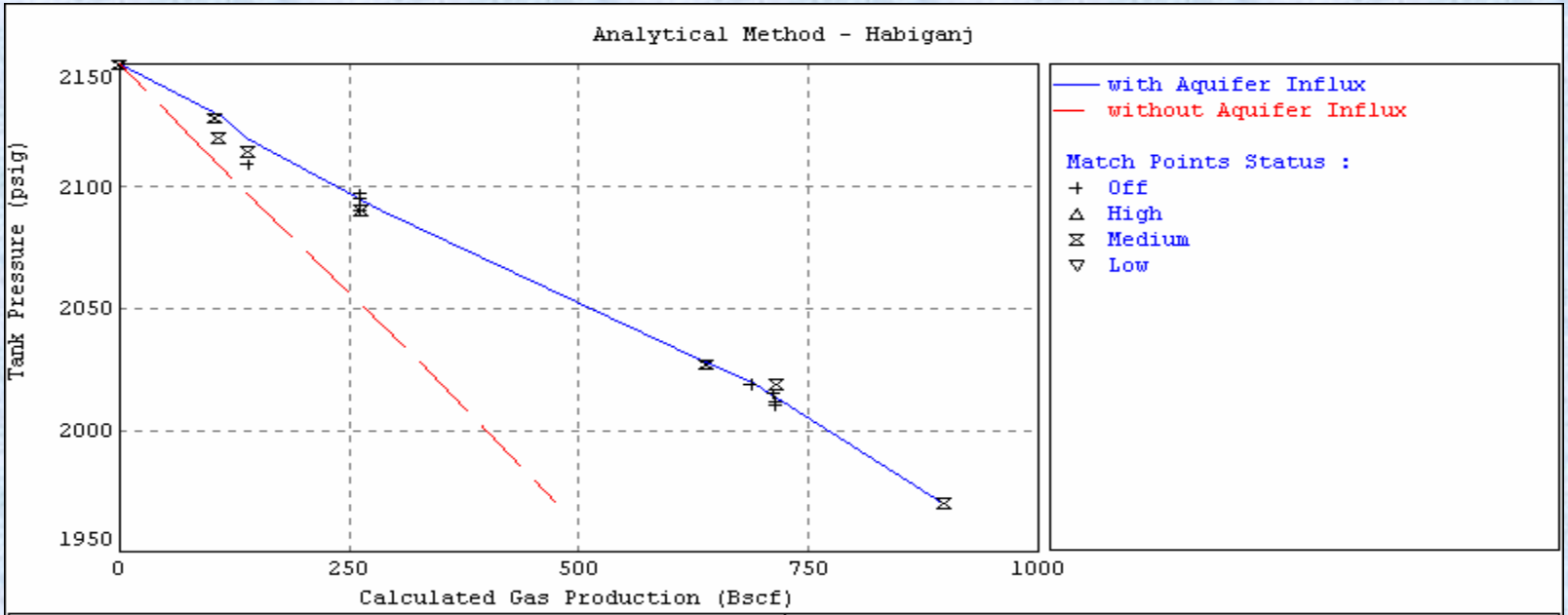
    Upper Sand 3630 BCF

    Lower Sand 38.6 BCF
- Production from Upper Sand began in 1968

MB using Pressure Survey Data of Habiganj Upper Sand



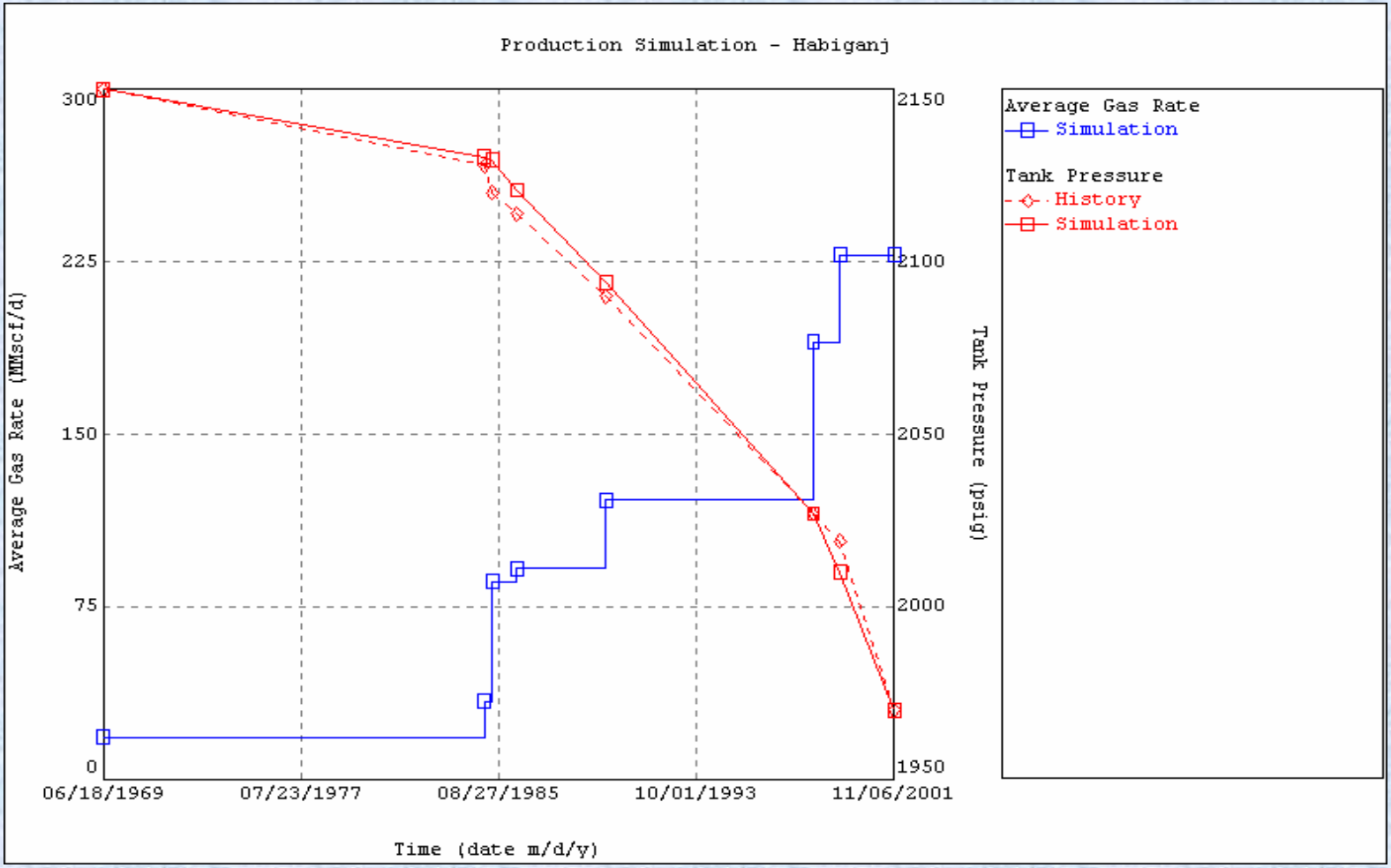
MBAL™ Analysis for Habiganj Upper Sand



Tank Temperature	115	(degrees F)
Tank Pressure	2150	(psig)
Tank Porosity	0.3	(fraction)
Connate Water Saturation	0.2	(fraction)
Water Compressibility	3e-6	(1/psi)
Formation Compressibility	4e-6	(1/psi)
Gas in Place	5104.95	(Bscf)
Production Start	06/18/1969	(date m/d/y)

Aquifer Model	Hurst-van Everdingen-Modified	
Aquifer System	Bottom Drive Aquifer	
Boundary Model	Sealed Boundary	
Aquifer Volume	55590.7	(Bft3)
Aquifer Permeability	54.3574	(md)
Tank Radius	8885.7	(ft)

MBAL™ Analysis for Habiganj Upper Sand (cont.)
History Matching by MBAL™



Comparison of the P/Z (conventional), MBAL™ and Volumetric Estimates of Habiganj Upper Sand

Sand	GIIP Tcf (P/Z) (without considering water drive)	GIIP Tcf (MBAL™)	GIIP Tcf (Volumetric)
Upper Sand	10	5.1	4.69

Results of Habiganj Gas Field Estimate

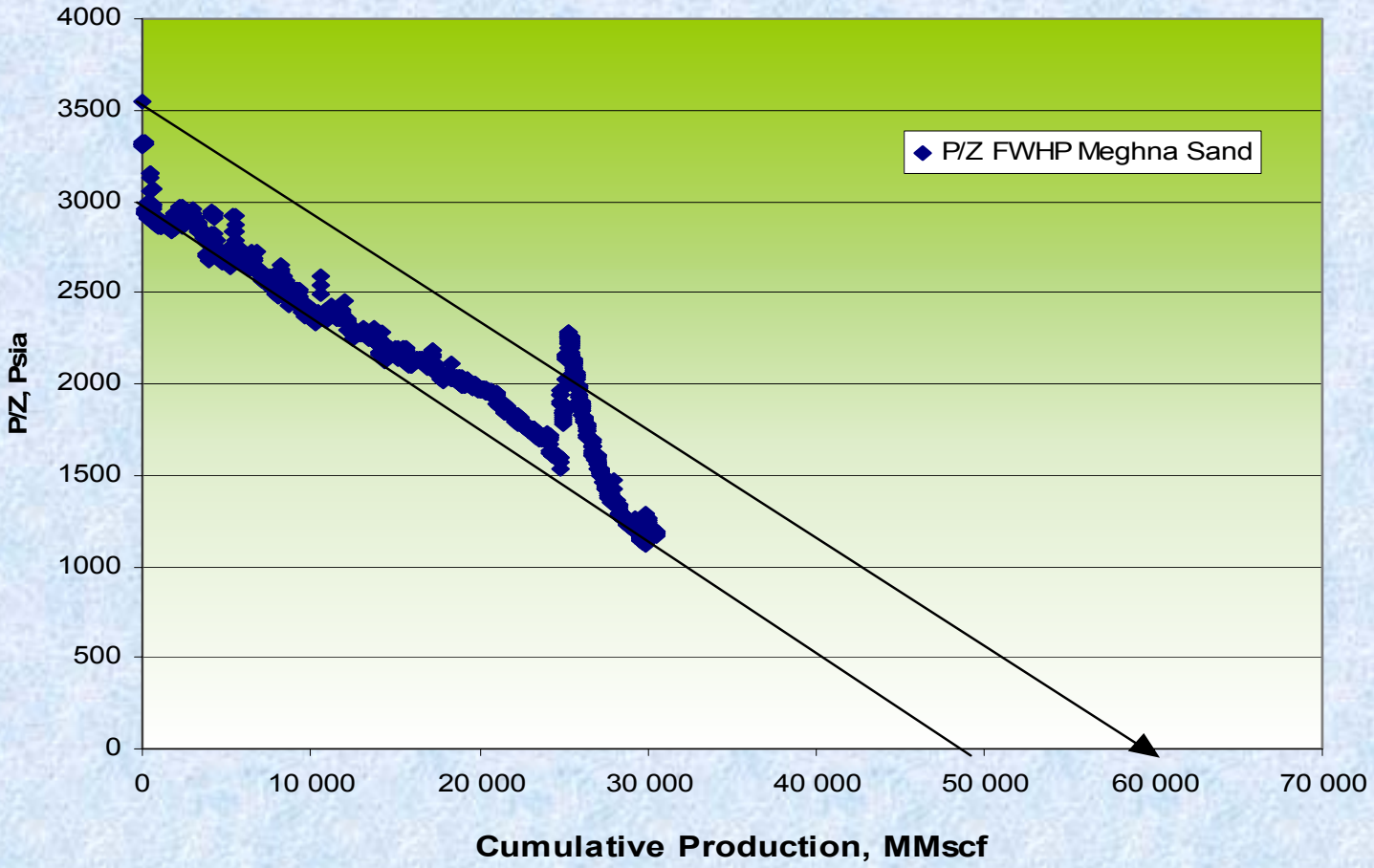
- Conventional method shows the trend with a higher GIIP value which is not supported by the volumetric analysis. Extrapolated straight line gives a value of 10Tcf which is almost double the volumetric figure.
- Analytical approach of MBAL™ software matches with the historical production, which depicts a strong water drive.
- Habiganj Field Upper Sand MBAL™ Estimate is very close to the Volumetric Estimate
- Habiganj Field GIIP:
  - Upper Sand GIIP 5.1 TCF
  - Lower Sand GIIP 39 BCF

Analysis of Meghna Gas Field

Meghna(contd.)

- Meghna Gas Field is approximately 35 miles east of Dhaka City
- The Field was delineated by PPL in 1953
- Petrobangla discovered the field in 1990
- The Field started production in 1997
- In the Reserve estimate of Meghna Gas Field Flowing Well Material Balance has been used, due to the paucity of pressure survey data

Material Balance for Meghna Field (C-sand) using FWHP Data



Comparison of Flowing Well Material Balance and Volumetric Estimates of Meghna C Sand

Sand	GIIP Bcf (FWHP Material Balance)	GIIP Bcf (Volumetric)
C Sand	60	74

For Meghna Gas Field Pressure Survey Data are not Available

Inconsistency Between the **Material Balance** and the **Volumetric** Estimates is due to Data Constraints

Constraints in Material balance and Volumetric Estimate :

- Material Balance Estimate
  - Amount of Production History
  - Inadequate Pressure Survey Data
  - Confidence Level of Data
    - -PVT Properties
    - -Rock Properties
    - -Production Data

- Volumetric Estimate
  - Seismic Coverage
  - Number of Wells
  - Confidence Level of Data
    - -PVT Properties
    - -Rock Properties

RESERVE OF NATURAL GAS IN BANGLADESH

Gas in BCF

Sl. No.	Fields	Year of Discovery	Operator	GIIP (Prvd.+ Prbl.)	Recov-erable (Prvd. +Prbl.)	Reco. Factor(%)	Cumu-lative Gas Produ-ction	Remai-ning Reserve
A.	Developed Reserve							
a.	Under Production							
1.	Bakhrabad	1969	BGFCL	1498.6	1049	70	660.6	381.4
2.	Beanibazar	1981	SGFCL	243.1	170.2	70	46.9	123.3
3.	Habiganj	1963	BGFCL	5139	3852.3	75	1453.4	2398.9
4.	Jalalabad	1989	CHEVRON	1195	836.5	70	398.9	437.6
5.	Kailastila	1962	SGFCL	2720.1	1903.3	70	394.6	1508.7
6	Meghna	1990	BGFCL	170.6	119.6	70	35.9	83.7
7.	Narsingdi	1990	BGFCL	307.2	215.1	70	74.2	140.9
8.	Rashidpur	1960	SGFCL	2002	1401.2	70	410.4	990.8
9.	Saldanadi	1996	BAPEX	165.8	116.1	70	51	65.1
10	Sangu	1996	CAIRN	1031	848.5	82	420.7	427.8
11.	Sylhet	1995	SGFCL	683.9	478.7	70	184.9	293.8
12.	Titas	1962	BGFCL	7325	5127.5	70	2705.2	2422.3
13.	Fenchuganj	1988	BAPEX	404	282.8	70	45.2	237.6
14	Moulovibazar	1997	CHEVRON	448.9	359.6	80	84.9	274.7
15.	Feni	1981	NIKO	185.2	129.6	70	59.5	70.1
16.	Bangura		TULLOW	*204	*122.4	60	22.6	99.8
17.	Bibiyana	1988	CHEVRON	3144.5	2400.8	76	0	2400.8
Sub-Total (a)				26867.9	19413.2	-	7055.9	12357.3

RESERVE OF NATURAL GAS IN BANGLADESH (Cont.)

Gas in BCF

Sl. No.	Fields	Year of Discovery	Operator	GIIP (Prvd.+ Prbl.)	Recov-erable (Prvd. +Prbl.)	Reco. Factor(%)	Cumu-lative Gas Produ-ction	Remai-ning Reserve
b.	Production Suspended							
18.	Chattak	1959	BGFCL	677	473.9	70	25.8	448.1
19.	Kamta	1981	SGFCL	71.8	50.3	70	21.1	29.2
Sub-Total (b)				748.8	524.2	-	46.9	477.3
Total Developed Reserve (a+b)				27616.7	19937.4	-	7102.8	12834.6
B.	Undeveloped Reserve							
	Not in Production							
20.	Begumganj	1977	BAPEX	46.7	32.7	70	0	32.7
21.	Kutubdia	1977	CAIRN	65	45.5	70	0	45.5
22.	Semutang	1969	BAPEX	227	150.3	66	0	150.3
23	Shahbazpur	1995	BAPEX	664.3	465.6	70	0	465.6
Total Undeveloped Reserve(c)				1003.0	694.1	-	0	694.1

Reserves & Production Based on HCU/NPD

As of June 2007

***Provisional Reserve figure of Bangura**

Last update : August 2007

-Production Data of Bibiyana not included

Source: www.petrobangla.org.bd

RESERVE OF IOC OPERATED FIELDS IN BANGLADESH

Gas in BCF

Sl. No.	Fields	Year of Discovery	Operator	GIIP (Prvd.+ Prbl.)	Recov-erable (Prvd. +Prbl.)	Reco. Factor(%)	Cumu-lative Gas Produ-ction	Remai-ning Reserve
A.	Developed Reserve							
a.	IOCs Under Production							
1.	Jalalabad	1989	CHEVRON	1195	836.5	70	398.9	437.6
2.	Sangu	1996	CAIRN	1031	848.5	82	420.7	427.8
3.	Moulovibazar	1997	CHEVRON	448.9	359.6	80	84.9	274.7
4.	Feni	1981	NIKO	185.2	129.6	70	59.5	70.1
5.	Bangura		TULLOW	*204	*122.4	60	22.6	99.8
6.	Bibiyana	1988	CHEVRON	3144.5	2400.8	76	0	2400.8
	Total			50578.7	4697.4	-	986.6	3710.8

*Provisional Reserve figure of Bangura

Last update : August 2007

Summary of Gas Reserve and Production

June 2007

Gas (Proven+Probable)	28,619.70 Bcf	28.62 Tcf
Recoverable	20,631.45 Bcf	20.63 Tcf
Cumulative Gas Production as June-07	7,102.91 Bcf	7.10 Tcf
Remaining Reserve	13,528.54 Bcf	13.53 Tcf
Gas Production in June-07	40.83 Bcf	0.04 Tcf

Includes provisional reserve figure of Bangura

Source: www.hcu.org.bd

Thanks for Your Patient Hearing