



# **Research on Gas Injection Rate Transient Analysis**

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# Background

RIPED-Langfang

Dagang UGS plays an vital role in ensuring a secure and stable gas supply in Beijing

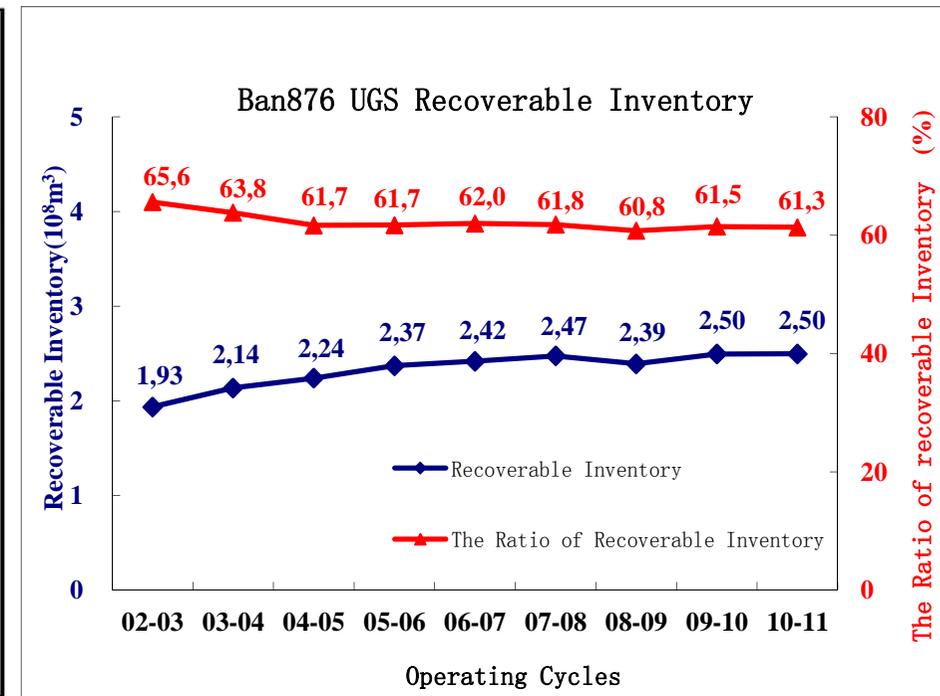
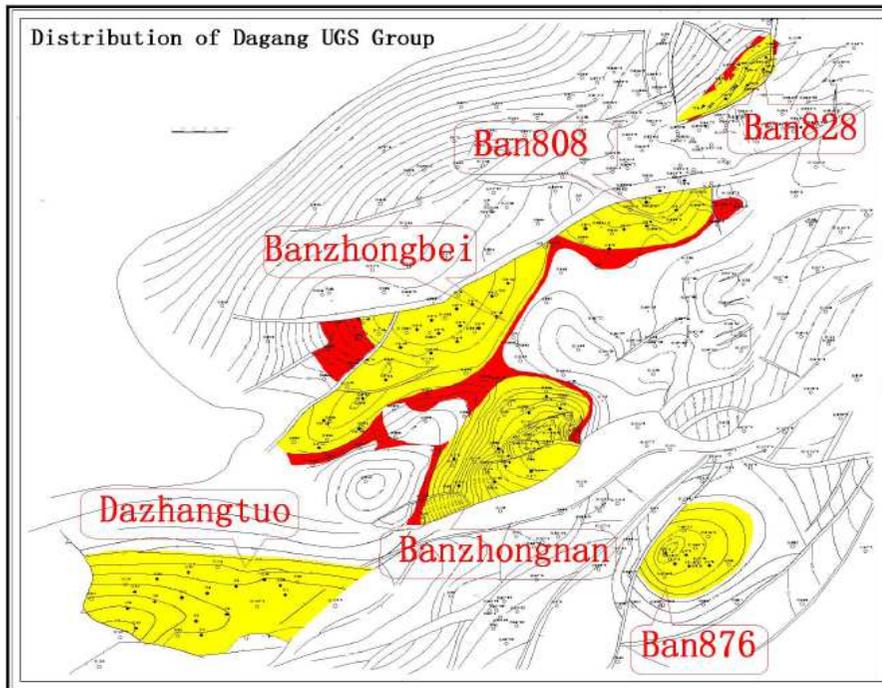




# Background

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Not all of the inventory is recoverable at present well pattern



Ban876, total capacity designed  $400 \times 10^6 \text{m}^3$ , current inventory to use ratio 61%

**How to optimize current well pattern?**

Only daily rate & pressure datas available

**Solving the problem with the help of daily injection data**



# Background

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No commercial software has the feature to analyze gas injection process at present!



RTA from Fekete



Topaze from Kappa

**Why?**

No mathematical model for gas injection has been published yet



# OUTLINE

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**Description**

2

Verification

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Conclusion



# 1. Description

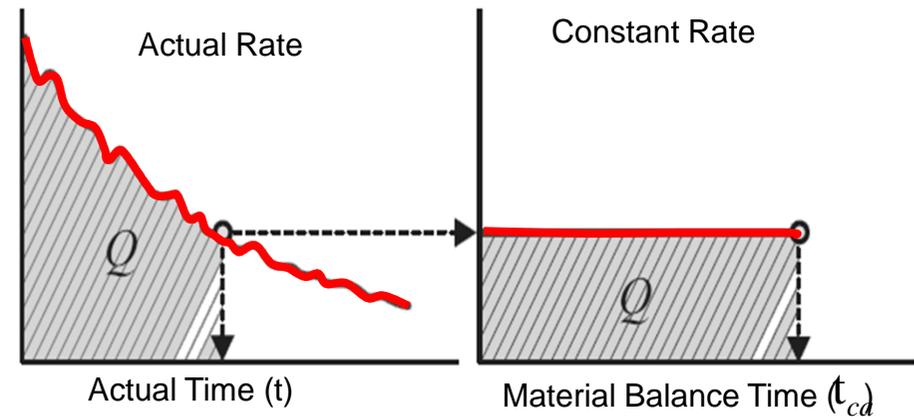
RIPED-Langfang

## 1). Definitions

$$P_{pi} = \frac{\mu_{gi} z_i}{p_i} \int_0^{P_i} \frac{p}{\mu_g Z} dp$$

Equation for **liquid** flow in reservoir  
Into  
Equation for **gas** flow in reservoir

$$t_{ca} = \frac{\mu_{gi} c_{ti}}{q_g} \int_0^t \frac{q_g}{\mu_g(p) c_t(p)} dt$$





# 1. Description

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## 2). Derivation

$$\frac{p_{wfi} - \bar{p}_p}{q_g} = 141.2 \frac{\mu_{gi} B_{gi}}{k_g h} \left[ \frac{1}{2} \ln \left( \frac{4A}{e^r C_A r_w'^2} \right) \right]$$

Pseudo-steady state flow equation



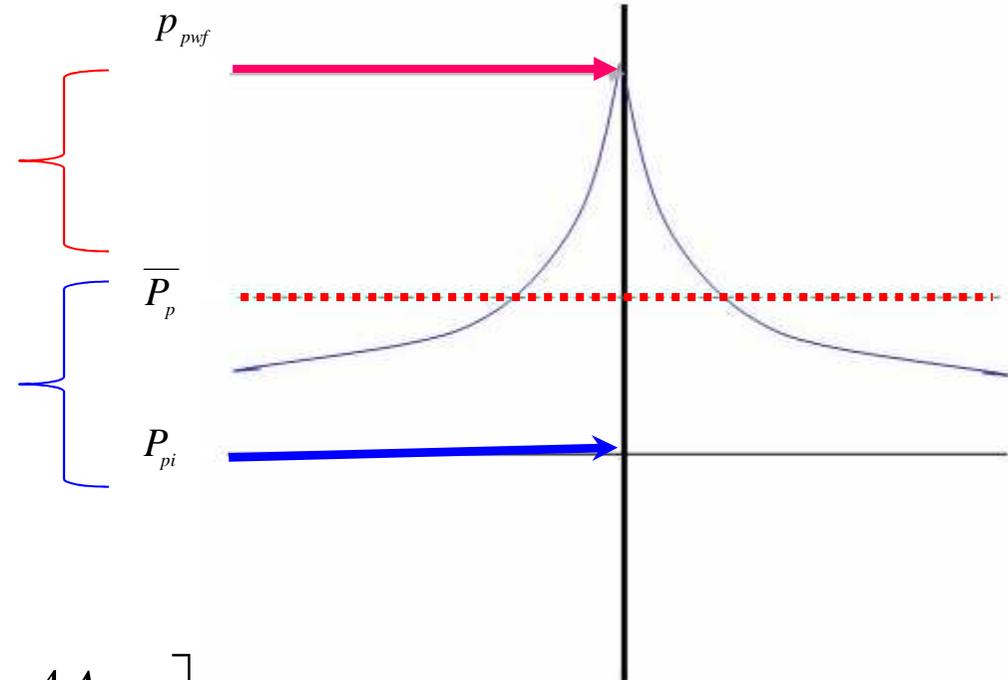
$$\frac{\bar{p}_p - p_{pi}}{q_g} = \frac{1}{Gc_t} t_{ca}$$

Material balance equation



$$\frac{p_{pwf} - p_{pi}}{q_g} = \frac{1}{Gc_t} t_{ca} + 141.2 \frac{\mu_{gi} B_{gi}}{k_g h} \left[ \frac{1}{2} \ln \left( \frac{4A}{e^r C_A r_w'^2} \right) \right]$$

Gas flowing equation for variable rate post transient flow



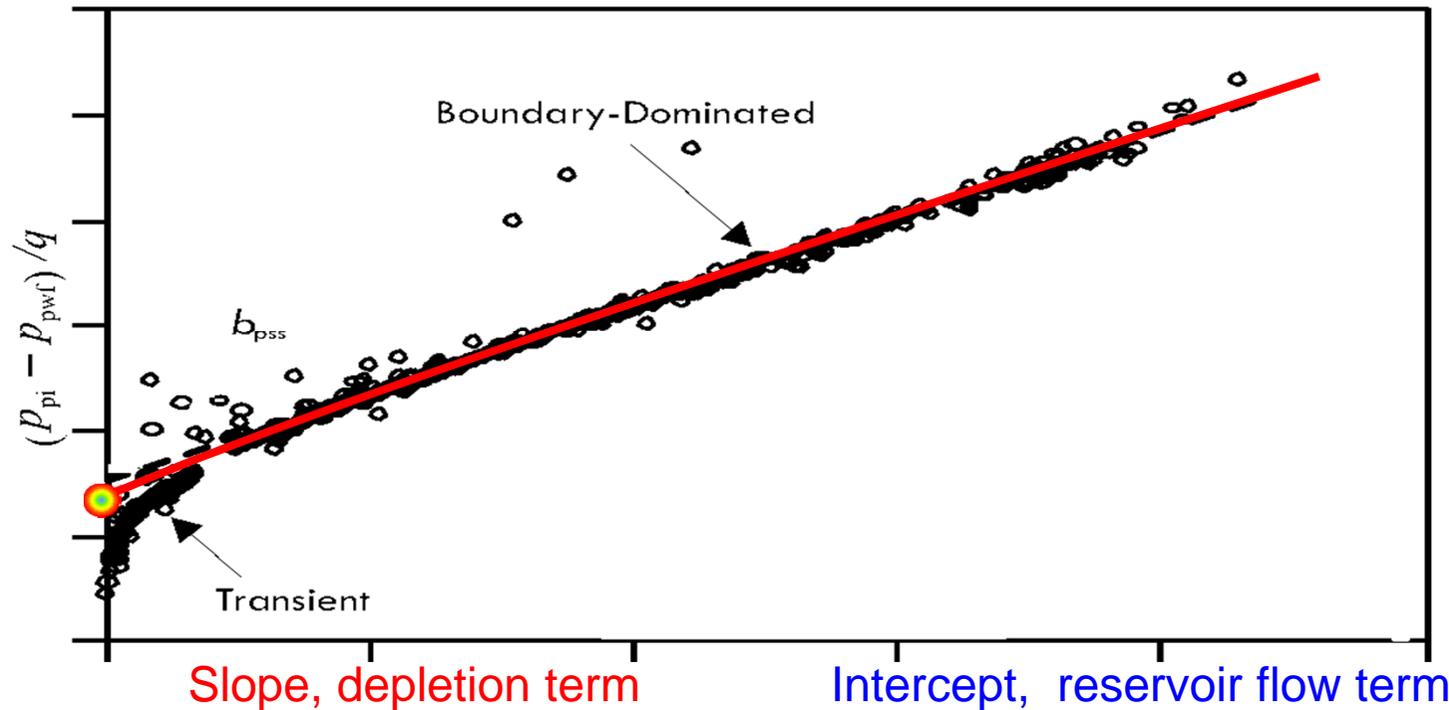
Knowing pressure & rate, inventory and Kg can be estimated



# 1. Description

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## 3). Algorithm



$$\frac{P_{pi} - P_{pwf}}{q_g} = \frac{1}{Gc_t} t_{ca} + 141.2 \frac{\mu_{gi} B_{gi}}{k_g h} \left[ \frac{1}{2} \ln\left(\frac{4A}{e^r C_A r_w'^2}\right) \right]$$

$$G = \frac{1}{slope \cdot c_t} \rightarrow A = \frac{GB_{gi}}{h\phi S_g} \rightarrow k_g = \text{intercept} \cdot \left( 141.2 \frac{\mu_{gi} B_{gi}}{h} \left[ \frac{1}{2} \ln\left(\frac{4A}{e^r C_A r_w'^2}\right) \right] \right)^{-1}$$



# OUTLINE

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# 2. Verification

## 1). Programming in Matlab

$$G = \frac{1}{\text{slope} \cdot c_t} \Rightarrow A = \frac{GB_{gi}}{h\phi S_g} \Rightarrow k_g = \text{intercept} \cdot \left( 141.2 \frac{\mu_{gi} B_{gi}}{h} \left[ \frac{1}{2} \ln\left(\frac{4A}{e^r C_A r_w'^2}\right) \right] \right)^{-1}$$

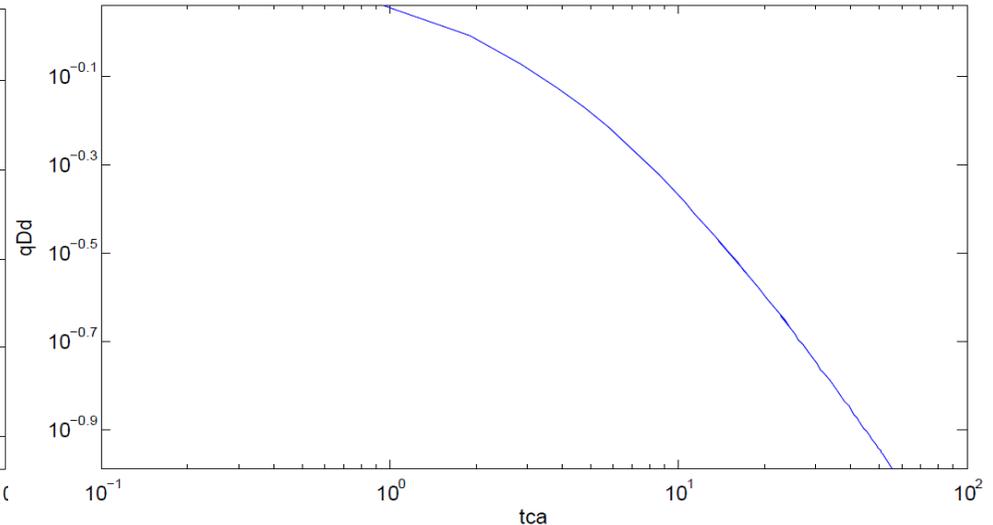
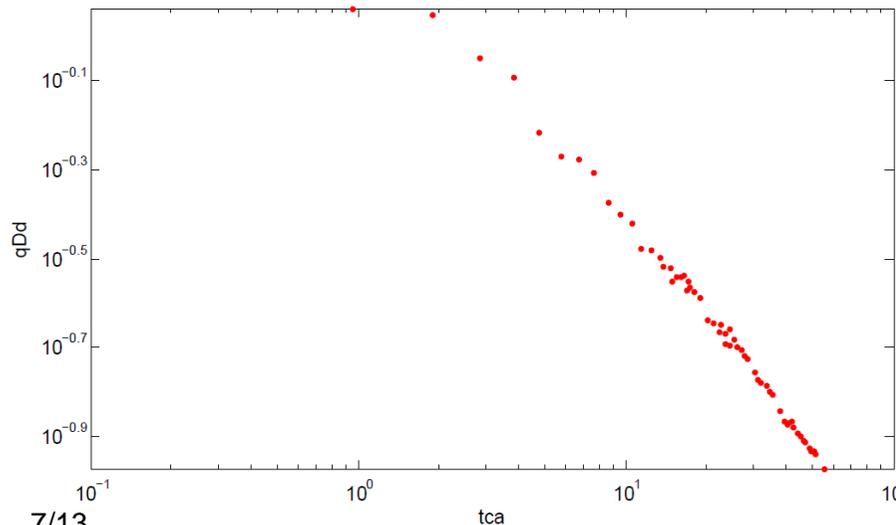
$$q_{Dd} = 141.2 \frac{\mu_{gi} B_{gi}}{k_g h} \frac{q_g}{p_{wfi} - p_{pi}} \left[ \ln\left(\frac{r_e}{r_w'}\right) - \frac{1}{2} \right]$$

Actual data : dimensionless injection

$$\tilde{q}_{dD}(s) = \frac{\beta_1 \alpha_1}{\sqrt{s}} \frac{K_1(\alpha_1 \sqrt{s}) - I_1(\alpha_1 \sqrt{s}) \frac{K_1(\alpha_1 r_{eD} \sqrt{s})}{I_1(\alpha_1 r_{eD} \sqrt{s})}}{K_0(\alpha_1 \sqrt{s}) + I_0(\alpha_1 \sqrt{s}) \frac{K_1(\alpha_1 r_{eD} \sqrt{s})}{I_1(\alpha_1 r_{eD} \sqrt{s})}}$$

Theory data: **Stehfest** numerical inversion

↓ plot qDd vs tca curves for **actual** and **theory model** respectively ↓

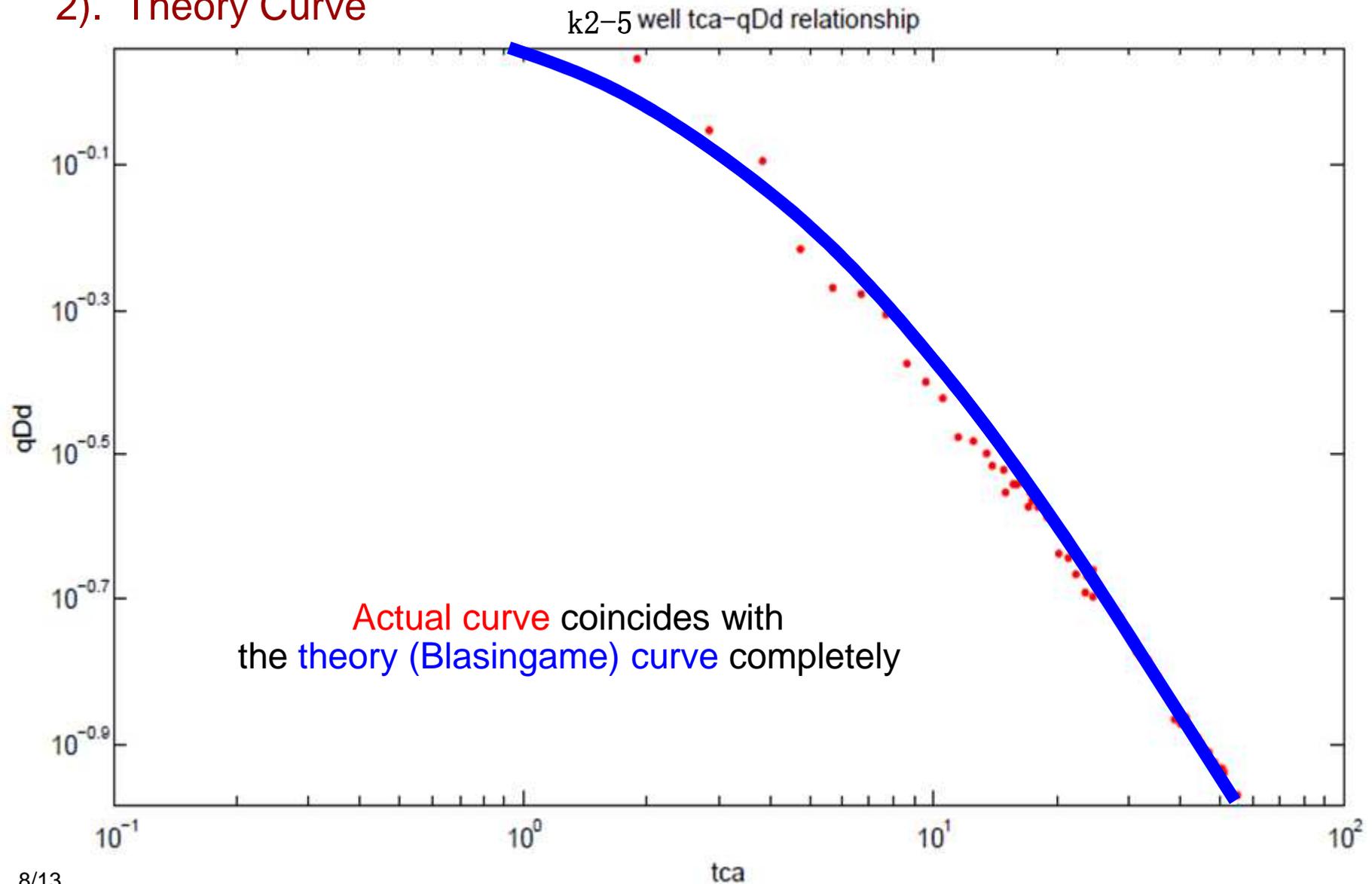




## 2. Verification

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### 2). Theory Curve

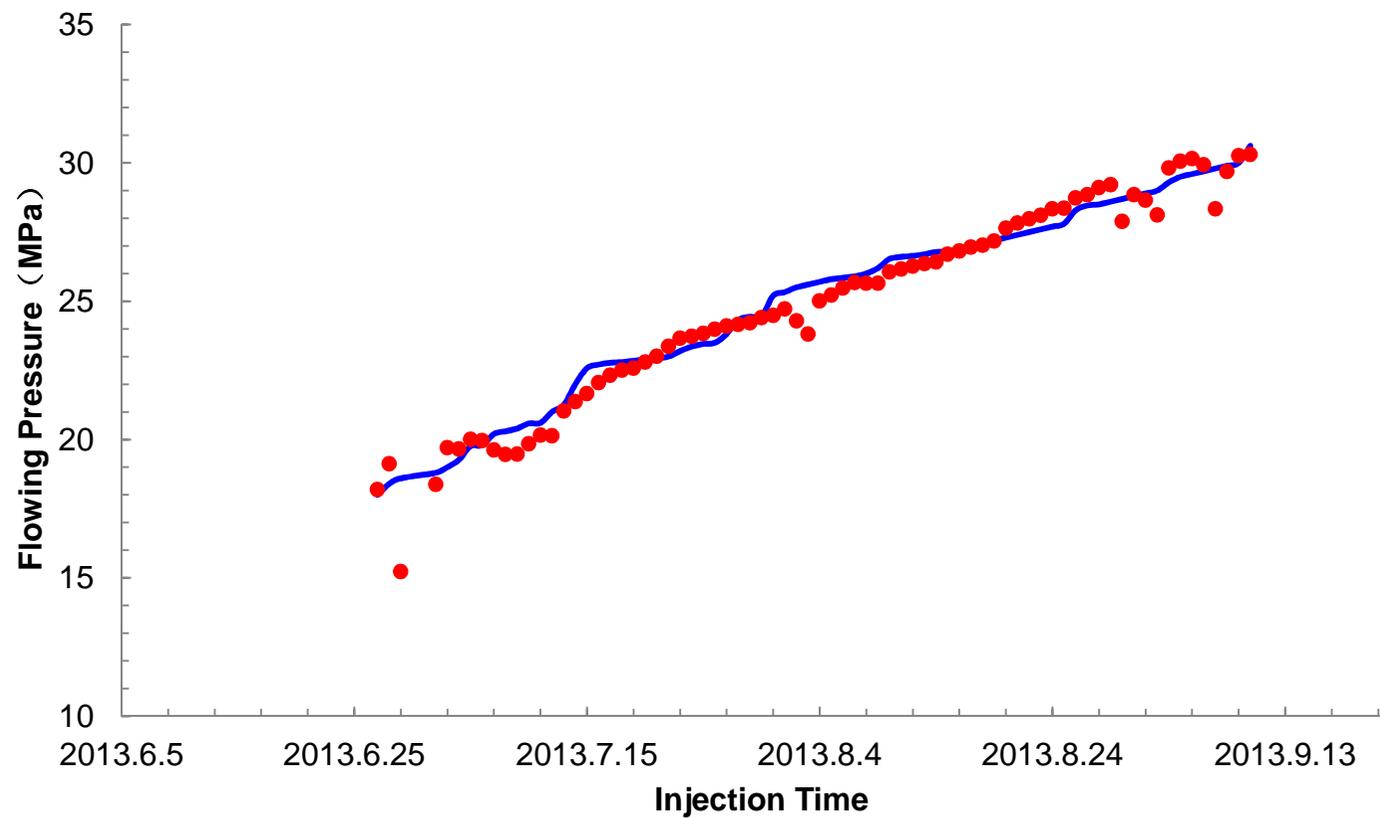




## 2. Verification

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### 3). History Matching



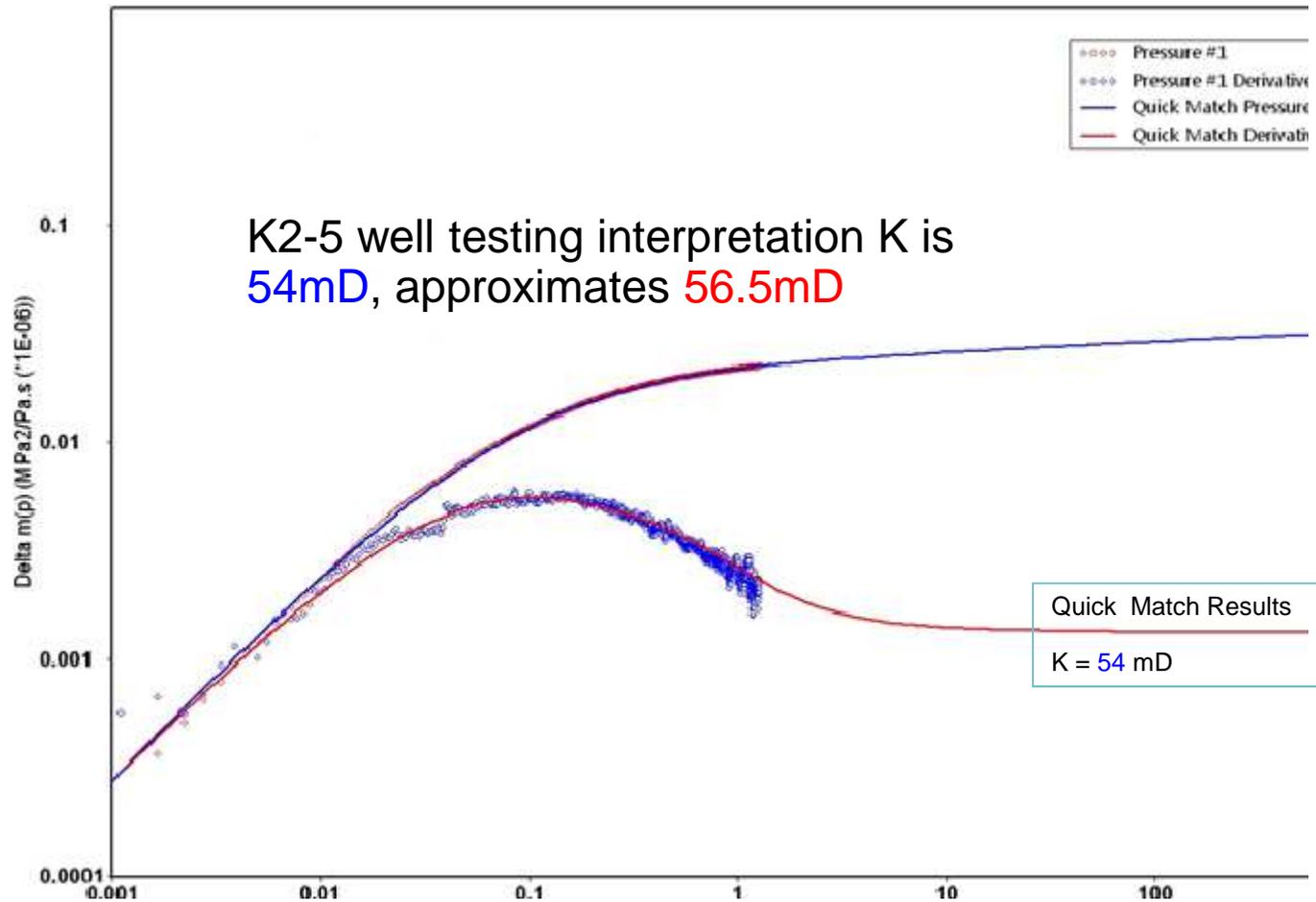
Theory model matches actual injection performance



## 2. Verification

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### 4). Well Testing



Increasing confidence with the results from the new method



# OUTLINE

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**Discussion**



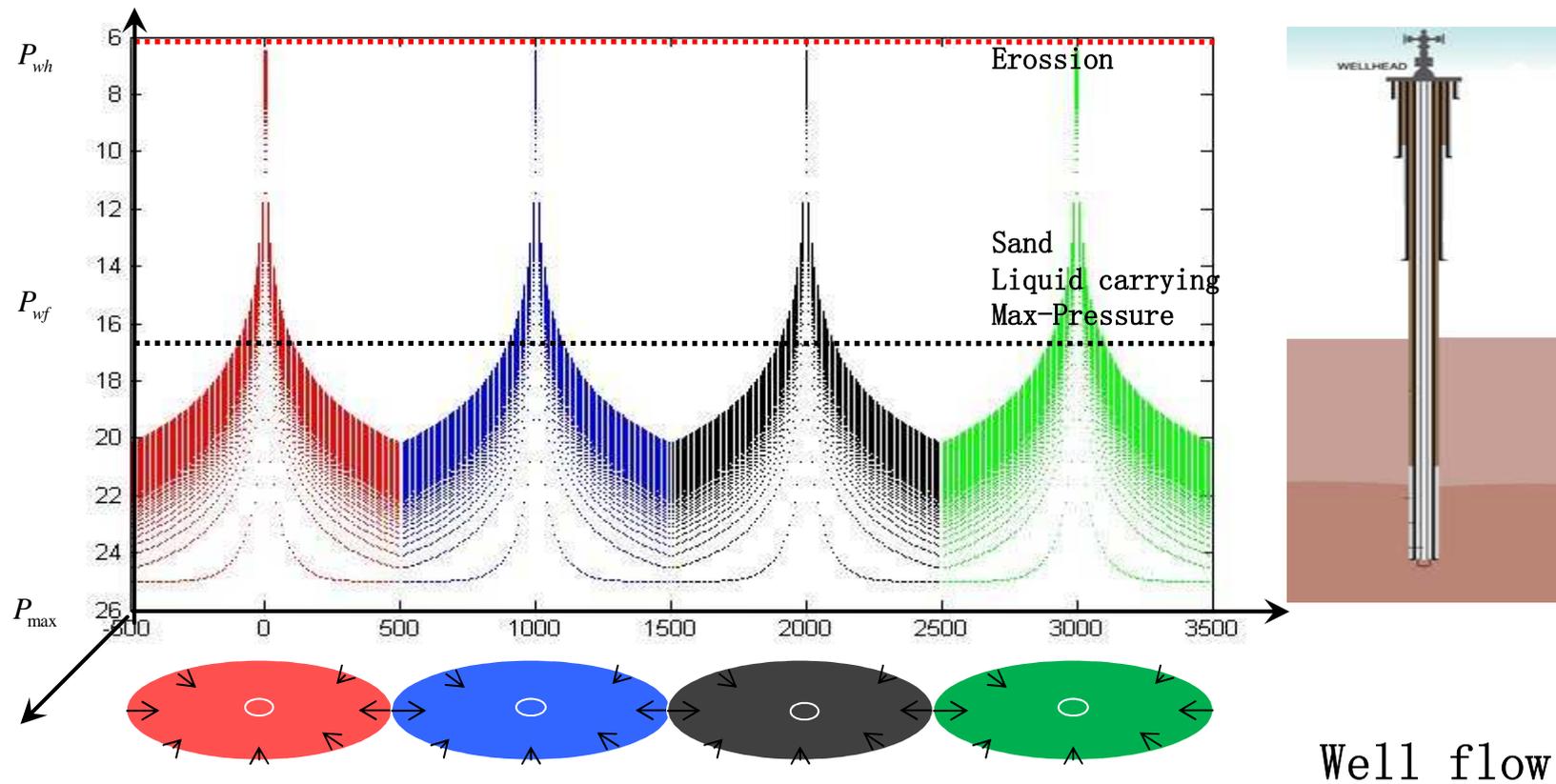
Conclusion



# 3. Discussion

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1). Result is a simply flow model with known drainage area and K s ...

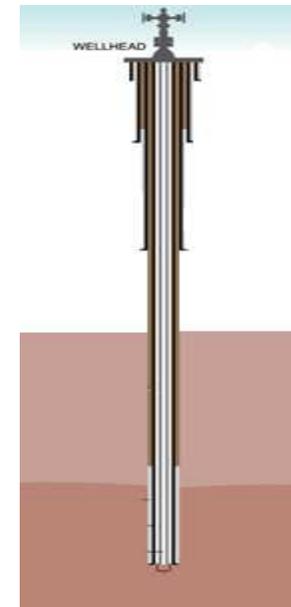
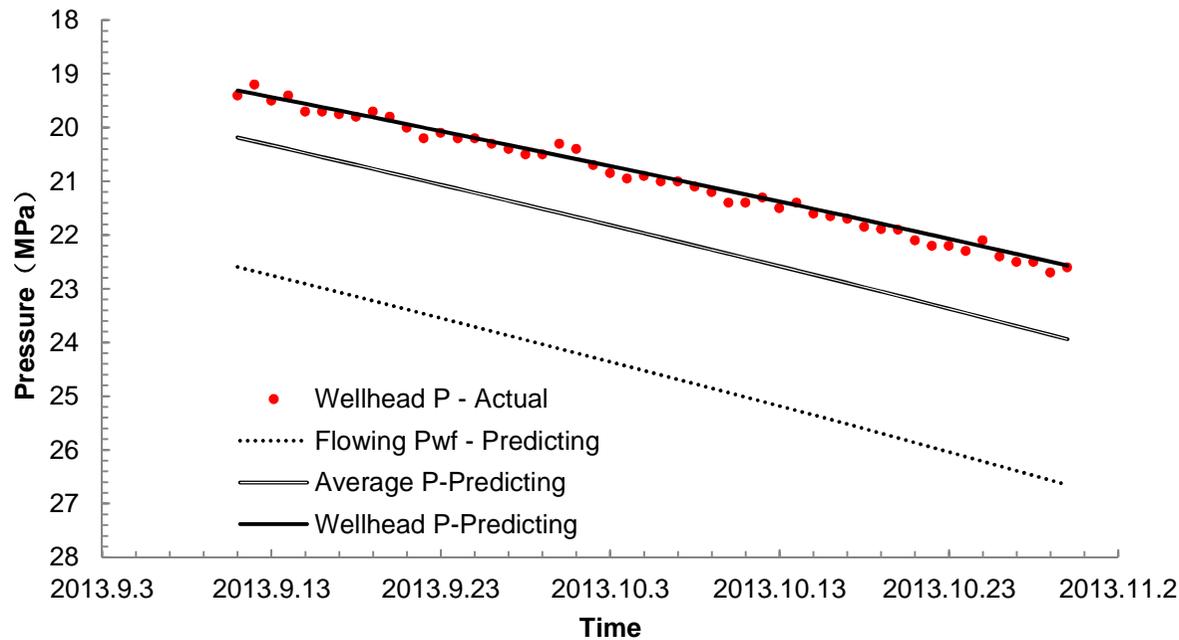




# 3. Discussion



## 2). Predicting well injection performance



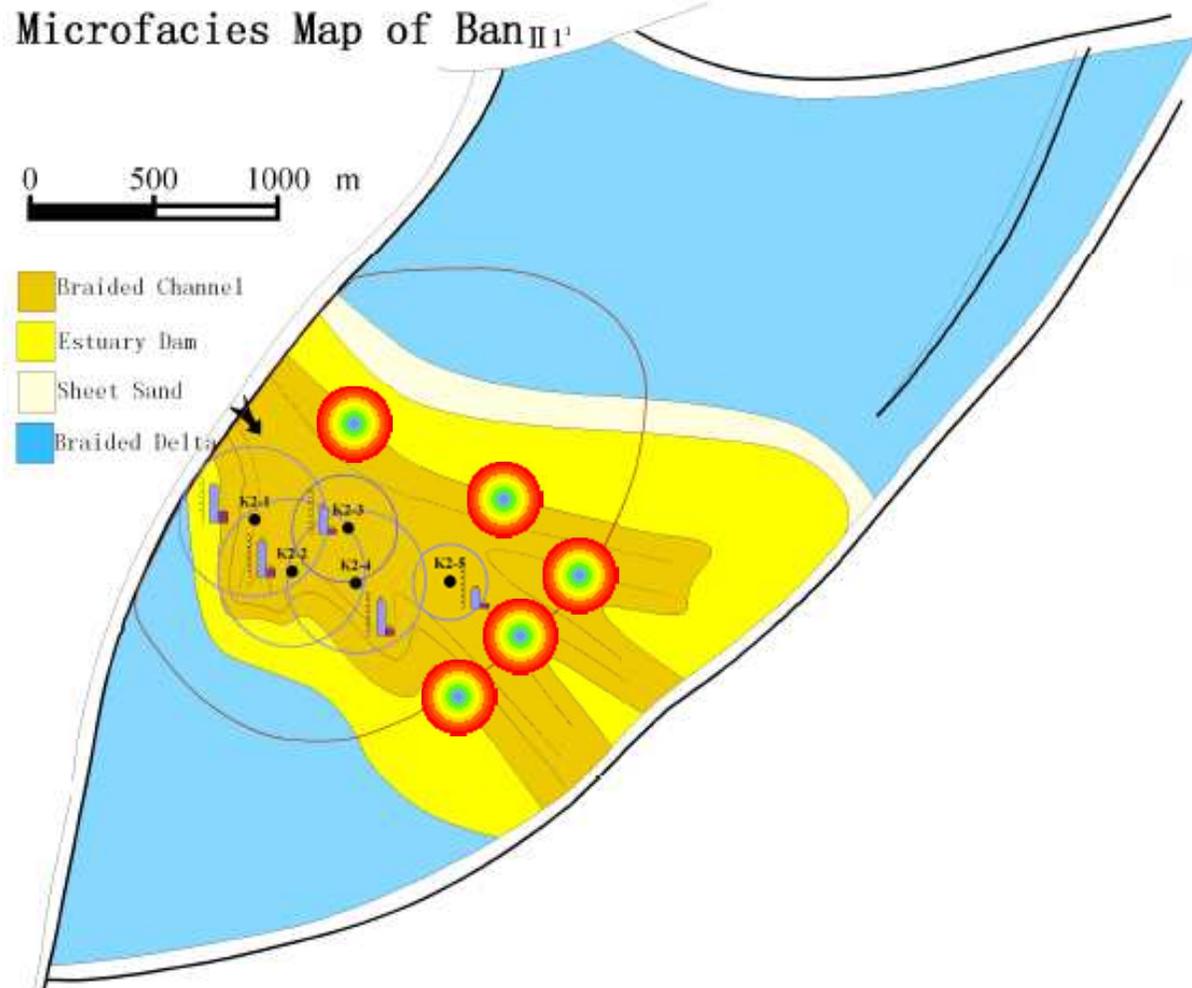
Well flow

an meaningful tool to estimate **injection performance**  
and **average-P** without down-hole test during injection



# 3. Discussion

## 3). Well pattern infill



5 wells propose: K2-6, k2-7, k2-8 ,k2-9,k2-10, increase working gas  $0.4 \times 10^8 \text{m}^3$



# OUTLINE

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Description



Verification



Discussion



**Conclusion**



## 4. Conclusion

- A meaningful tool for gas injection analysis & prediction
- A supplement to commercial software being good at gas production

**Thank You!**

