HYDROGEOLOGICAL ASSESSMENT OF THE THAR LIGNITE PROSPECT

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Paper is concerned with
• Geological and hydro-geological studies of Thar coal field
• Bara formation-depth 130-250m
• In a mining prospect of 40 Km²
  Total reserves 9 billion Tonnes.
  Recoverable 3 billion Tonnes
• Thickness of lignite – 50-60m
• Lignite contains- 42-49% moisture

Paper Presents
• Results of pumping out tests
• Ground water model to simulate de-pressuring of aquifers
• Results show that 22 pumping out wells are required
  • Period of 10 years
  • Overall pumping rate of 53 L/sec

Problems of lignite mining
1. Lignite deposits are under-laid and overlaid by aquifers presenting problems:
  • Inflow of water causing safety
  • Operational and environmental problems.
2. Confined aquifers below the deposit cause:
  • In-pit flooding,
  • Erosion of toe of high-wall,
  • High-wall instability.

Background
The paper presents:
• Hydrogeological appraisal of proposed mining operations in Thar Lignite prospect, Sindh, Pakistan
• Thar coalfield -9000 km²,
• Estimated reserves: 192 Bt lignite;
  • Depth of seams- 130 to 250m,
  • Seam thickness- between 7.5m to 36m,
  • Maximum thickness of individual seam 23m,
  • Eight blocks have been explored which have;
    • 9 Bt proved reserves,
    • Coal seams surrounded by three aquifers.

Main Approach
In brief, the paper addresses two questions:
1. Dewatering Schemes for top, intermediate and bottom aquifers,
2. Estimation of inflow quantities from each aquifer using;
  (a) Equivalent well approach
  (b) SEEP/W Finite Element Software Package
Thar Lignite Field, Sindh, Pakistan

- 7th largest in the world discovered in 1994.
- 400 Km. East of Karachi.
- Total area of 9000 km²
- Estimated resources of 193 Bt.
- Mining Area 40 km²
- 9 Bt reserves

Average Composition of Lignite

- Moisture: 46.77%
- Fixed carbon: 16.66%
- Volatile matter: 23.46%
- Ash: 6.24%
- Sulphur: 1.16%
- Heating value: 10,898 Btu/lbs

Thar prospects

- Eight areas being prospected.
- Proven coal reserves in 2005 were over 9 Bt in eight Prospects.
- Total lignite resources in whole coalfield - 193 Bt.

Geology of the Thar prospect

- Dune Sand 48m
- Sub Recent-77m
- Bara formation
- Base Aquifer 50-60m thick
- Granite basement

Hydrogeology

1. Top aquifer
   - At the base of dune sand
   - Permeability x10⁻⁷ m/s
   - Water column up to 5m thick
   - Water table 10-12m, above mean sea level

2. Intermediate aquifer
   - Scattered lenses of sand
   - Permeability 10⁻⁴ to 10⁻³ m/s

3. Bottom aquifer
   - Beneath the coal formation down to the granite base
   - Fine to coarse sand grains, non-homogeneous permeability
   - 50-60m thick aquifer
   - Piezometric surface 25m above mean sea level
   - Aquifer covers an area of 15000 Km²

Evaluation of Pumping Test

- Q=14 L/s
- Δs=1.35m (draw down in one log cycle)

Pumping out well RE51; Observation well RE12P
Recovery test on RE 51 and Observation well RE-12

\[ Q = 13 \text{L/s} \]
\[ \Delta s = 1.38 \text{m in 1 log cycle} \]

Pumping out test on RE-52 & Observation well RE 22

Piezometer distance = 30m;
\[ \Delta = \text{Draw down in one log cycle} = 0.3 \text{ m} \]
\[ T = \frac{2.3 \times 0.013}{4 \times 3.14 \times 0.3} = 7.9 \times 10^{-3} \text{ m}^2/\text{s} \]

\[
\begin{array}{|c|c|}
\hline
\text{PUMPING OUT TESTS} & \text{Results} \\
\hline
1. \text{RE51-RE12P} & k = 6.3 \times 10^{-5} \text{ m/s} \\
\Delta s = 1.35\text{m}; Q = 0.013 \text{ m}^3/\text{s} & S = 2.0 \times 10^{-4} \\
t_0 = 43s; r = 25m & \\
2. \text{RE51-RE12P} & k = 8.0 \times 10^{-5} \text{ m/s} \\
\Delta s = 1.38; Q = 0.014 \text{ m}^3/\text{s} & S = 8.0 \times 10^{-4} \\
3. \text{RE52-RE22} & k = 2.63 \times 10^{-4} \text{ m/s} \\
\Delta s = 0.3m; Q = 0.013\text{m3/s} & S = 2.7 \times 10^{-3} \\
\hline
\end{array}
\]

FE Model of Pumping out test

258 nodes, 50 elements in single 30m layer, model length -2000m; 8-noded elements

FE model of well RE-51 intersecting the Bottom aquifer

1. No flow U & L Boundaries.
2. Head Boundary on RHS
3. LHS FLUX Boundary
4. \( k = 7.3 \times 10^{-5} \text{ m/s} \)
5. \( S = 2.9 \times 10^{-4} \)
6. Initial Head = 160m
7. Hydraulic head vs. draw down of RE-51 well at different radial distances for 24 time steps Transient flow condition

Comparison of field and predicted results RE51 test

Residual draw down RE12P vs. time

Close agreement
Factors affecting inflow to the Bottom Aquifer

FE Model of pumping well in the base aquifer
100m head
k = 8.0 x 10^-5 m/s
S = 2.7 x 10^-3
Q = 0.014 m^3/s
Distance from the pumping well

Factors affecting pumping out tests

Hydraulic head vs. time for various permeabilities

Hydraulic head vs. elapsed time intervals for various rates of pumping

Hydrology

Main rainfall is in July or August when it rains 100 mm/h and it may stop working of two coal benches in the open cut mine for two days.

Mithi district after rain
After Rain – Mithi District

After Rain, Thar Desert, Sindh

Total water inflow due to rainfall

\[ Q = 2.78 \times A \times I \]
\[ = 2.78 \times 463.77 \times 0.58 \times 100 \]
\[ = 7.5 \times 10^4 \text{ litres/s} \]

Where,
- \( Q \): Peak flow in litres/s
- \( A \): Catchment area in hectares = 463.77 hectares
- \( K \): run-off co-efficient in decimal = 0.58
- \( I \): rainfall intensity = 100 mm/h

Aquifers Dewatering in The Thar Prospect

Dewatering First Aquifer

Aquifer Characteristics
- Thickness of aquifer \( L = 5 \) m
- Drawdown required \( D = 20 \) m
- Radius at which draw down required \( = 2100 \) m
- Radius of influence, \( R = 3000 \) m
- \( k = 3 \times 10^{-7} \) m/s = 0.0259 m/d
- \( T = \) transmissivity
  \[ = 0.0259 \times 5 = 0.13 \text{ m/d} \]
- \( n = 12 \) m
- \( H = 20 \) m

Pumping Calculations
Unconfined steady state linear aquifer
Modified Dupuit (1865) Equation:
\[ Q = \pi \times \left[ \ln \left( \frac{R}{d} \right) - 1.44 \times 0.0259 \times \frac{20^2 - 12^2}{1000} \right] \]
\[ = 58 \text{ m}^3/\text{d} \]

Dewatering Second Aquifer

Aquifer Characteristics
- Scattered lenses
- Thickness of aquifer \( L = 10 \) m
- Drawdown required \( = 89 + 20 = 100 \) m
- Radius at draw down \( = 1050 \) m
- Radius of influence \( A = 2500 \) m
- \( k = 10^{-6} \) m/s = 0.086 m/d
- \( n = 0.5 \)

Pumping Calculations
Peterson (1865) Equation:
\[ Q = 2 \pi \times \frac{k \times L D}{\ln \left( \frac{R}{d} \right) - \frac{2\pi}{2\pi} \times 0.96 \times 100 \times 1000} \]
\[ = 14.69 \text{ m}^3/\text{d} \]
**Dewatering Base Aquifer**

**Aquifer Characteristics**
- Thickness of aquifer $L = 55m$
- Drawdown required $= 150 + 25 = 175m$
- Radius at draw down $= 750m$
- Radius of influence $R = 2050m$
- $k = 1.3 \times 10^{-4} m/s = 11.23 m/d$
- $n = 0.5$

**Pumping Calculations**

Peterson equation:

$$Q = \frac{2\pi k L D}{\ln \left( \frac{R}{r} \right)}$$

$$= \frac{2 \times 3.14 \times 10^{-4} \times 55 \times 175}{\ln \left( \frac{2050}{750} \right)}$$

$$= \frac{42777.95}{1805} = 23.72 m^2/d$$

Results: Pumping 3.5 m$^3$/s for two years

Rheinbraun Consultants estimated that 22 pumping out wells are required:
- Period of 10 years
- Overall pumping rate of 53 l/sec

**Simulation of inflow by top aquifer**

Hydraulic head vs Distance for various time periods

**Simulation from intermediate aquifer**

FE inflow simulation from the base aquifer

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**Steady state flow in top unconfined aquifer**

Constant Head=20m  
RADIAL DISTANCE= 1300m  
r=1100m  
K=3.0 x 10^-3 m/s  
Nodes =112000m,  
110 Elements,  
10 Layers of 3m thick  

Inflow k to fully penetrating top aquifer is 112 m3/d

**Intermediate Confined aquifer**

55 Elements, 116 nodes in single layer 10m thick and 1450m long  
Aquifer thickness= 10m  
K= 1.0 x 10^-6 m/s  
D=100m  
Inflow quantity= 141 m3/d

**Finite Element grid, velocity vectors and water table of the top unconfined aquifer**

**Comparison of analytical and numerical Inflow Results**

<table>
<thead>
<tr>
<th>Inflow Rate (m³/d)</th>
<th>Analytical solution (m³/d)</th>
<th>Numerical solution (m³/d)</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Unconfined Aquifer</td>
<td>Modified Dupuit Eq. Q=116 m³/d</td>
<td>112 m³/d</td>
<td>3.4%</td>
</tr>
<tr>
<td>Intermediate Con. Aquifer</td>
<td>Peterson EQ. Q=147 m³/d</td>
<td>141 m³/d</td>
<td>4.1%</td>
</tr>
<tr>
<td>Base Aquifer Confined</td>
<td>k=2.19 x 10^-3 m/s k= 1.3 x 10^-4 m/s D=260m r= 750m radius of influence =2050m</td>
<td>Q = 2.25 x 10² m³/d</td>
<td>2.34 x 10³ m³/d</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

- The paper uses the SEEP/W software to analyse pumping out data in RE-51 and RE-52 wells in an infinite confined aquifer in the Thar Lignite prospect.
- The pumping test simulation results were close to the analytical results and field data.

**Conclusions (Continued)**

- A model simulation of a hypothetical pumping out well carried out a sensitivity analysis of various factors affecting ground water inflow.
- It was indicated that the model is sensitive to permeability of the aquifer as an input data.
Conclusions (Cont.)

• The model was then used to predict ground water inflow
  - during the open cut mine advancement at various time periods and
  - inflow into fully penetrating pit into the three aquifers using the steady state flow condition.

The results of inflow provide significant information for the design of an effective dewatering system for all stages of mining.