Surface Water Transport and Groundwater Infiltration

Comparing Characteristics of Post Reclamation Channels with Preexisting Channels

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June 5, 2013
Surface Water Conveyance and Groundwater Infiltration
La Plata Reclaimed Mine

- Open Pit Coal Mine ~ 20 years
- Geomorphic Land Reclamation initiated in 2003
- 560 Hectares Fully Reclaimed by 2009
Tension Infiltrometer

- 3 Infiltration Locations in Reclaimed Channel
- 2 Infiltration Testing Locations in Native Channel

- In-situ soil hydraulic properties
- Estimate Hydraulic Conductivity in the field
- Remove the effect of preferential pathways
Single-Disc Radius with Multiple Tensions

10-cm Radius Porous Membrane Disc (r)

Tension Settings (h)
- 10 cm tension
- 5 cm tension

Steady State Infiltration Rate (Q(h))
- 350 seconds in Reclaimed Channel @ -5 cm
- 2,450 seconds in Native Channel @ -10 cm

\[ Q(h_1) = \pi r^2 \left[ 1 + \frac{4}{\pi r \alpha} \right] K_{sat} \exp(\alpha h_1) \]

\[ Q(h_2) = \pi r^2 \left[ 1 + \frac{4}{\pi r \alpha} \right] K_{sat} \exp(\alpha h_2) \]

\[ \alpha = \frac{\ln \left( \frac{Q(h_2)}{Q(h_1)} \right)}{h_2 - h_1} \]
### Reclaimed Channel Hydraulic Conductivity Results

(average = 7.96E-04 cm/sec)

<table>
<thead>
<tr>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h_2$</td>
<td>$h_2$</td>
<td>$h_2$</td>
</tr>
<tr>
<td>-10 cm</td>
<td>-10 cm</td>
<td>-8.34 cm</td>
</tr>
<tr>
<td>$Q(h_2)$</td>
<td>$Q(h_2)$</td>
<td>$Q(h_2)$</td>
</tr>
<tr>
<td>0.2006 cm³/sec</td>
<td>0.1306 cm³/sec</td>
<td>0.4355 cm³/sec</td>
</tr>
<tr>
<td>$h_1$</td>
<td>$h_1$</td>
<td>$h_1$</td>
</tr>
<tr>
<td>-5 cm</td>
<td>-5 cm</td>
<td>-5 cm</td>
</tr>
<tr>
<td>$Q(h_1)$</td>
<td>$Q(h_1)$</td>
<td>$Q(h_1)$</td>
</tr>
<tr>
<td>0.4122 cm³/sec</td>
<td>0.1882 cm³/sec</td>
<td>0.5210 cm³/sec</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>$\alpha$</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>0.1440 cm⁻¹</td>
<td>0.0730 cm⁻¹</td>
<td>0.0537 cm⁻¹</td>
</tr>
<tr>
<td>$K_{sat}$</td>
<td>$K_{sat}$</td>
<td>$K_{sat}$</td>
</tr>
<tr>
<td>1.43E-03 cm/sec</td>
<td>3.14E-04 cm/sec</td>
<td>6.43E-04 cm/sec</td>
</tr>
</tbody>
</table>

### Native Channel Hydraulic Conductivity Results

(average = 7.60E-04 cm/sec)

<table>
<thead>
<tr>
<th>Test 1</th>
<th>Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h_2$</td>
<td>$h_2$</td>
</tr>
<tr>
<td>-10 cm</td>
<td>-10 cm</td>
</tr>
<tr>
<td>$Q(h_2)$</td>
<td>$Q(h_2)$</td>
</tr>
<tr>
<td>0.1011 cm³/sec</td>
<td>0.0498 cm³/sec</td>
</tr>
<tr>
<td>$h_1$</td>
<td>$h_1$</td>
</tr>
<tr>
<td>-5 cm</td>
<td>-5 cm</td>
</tr>
<tr>
<td>$Q(h_1)$</td>
<td>$Q(h_1)$</td>
</tr>
<tr>
<td>0.2380 cm³/sec</td>
<td>0.1166 cm³/sec</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>0.1712 cm⁻¹</td>
<td>0.1704 cm⁻¹</td>
</tr>
<tr>
<td>$K_{sat}$</td>
<td>$K_{sat}$</td>
</tr>
<tr>
<td>1.02E-03 cm/sec</td>
<td>4.98E-04 cm/sec</td>
</tr>
</tbody>
</table>
Geospatial Hydrologic Modeling Extension

- HEC-GeoHMS to HEC-HMS
  - Surface Water Runoff
  - Flow through Outlet

- HEC-GeoRAS to HEC-RAS
  - Channel Flow
  - Depth of Flow through Cross Section
HEC-GeoHMS

Reclaimed Sub Basin

Native Sub Basin
• Area = 60 Hectacres
• Longest Flow Path = 1,500 m.
• Average Basin Slope = 10 %
• Curve Number = 87
• Land Use = Forest & Agricultural
• Soil Type D = FA (NM618)
Native Watershed

- Area = 8 Hectacres
- Longest Flow Path = 625 m.
- Average Basin Slope = 9.5 %
- Curve Number = 83
- Land Use = Agricultural
- Soil Type D = FA (NM618) and BT
HEC-HMS

Loss Method: SCS Curve Number
Transform Method: SCS Unit Hydrograph
Routing Method: Kinematic Wave
2 minute increments

Precipitation

26 cm Precipitation in 2010
Flow through Outlet in Reclaimed Channel

Max Flow on July 23, 2010
2.2 m³/sec
Flow through Outlet in Native Channel

Max Flow on July 23, 2010
0.3 m³/sec
HEC-GeoRAS

Manning’s $n = 0.025$
TIN Created from 1.5 meter
Topographic Lines
HEC-RAS
Reclaimed Channel

Cross Section @ 36 m from DS
Channel Slope 0.02
Steady Flow profiles w/ Mixed Flow
US Boundary = Critical Depth
DS Boundary = Normal Depth
HEC-RAS
Native Channel

Cross Section @ 12 m from DS
Channel Slope 0.03
Steady Flow profiles w/ Mixed Flow
US Boundary = Critical Depth
DS Boundary = Normal Depth
HEC-RAS

**Reclaimed Rating Curve**

\[ y = 29.214x^{0.3885} \]

\[ R^2 = 0.9998 \]

**Native Rating Curve**

\[ y = 45.555x^{0.3903} \]

\[ R^2 = 0.9988 \]
Groundwater Modeling

- Average Monthly Pan Evaporation
- Linearly interpolated water content from surface to bottom boundary (5% to 25%)
- van Genuchten parameters based on saturated hydraulic conductivity values

Hydrus 2D/3D,
Version 2.x
Hydrus 2D Cross Section

Channel Cross Section during Evaporation
Thank You