A GIS-AIDED MONITORING SYSTEM OF GROUNDWATER LEVEL IN WIDE LAND SUBSIDENCE AREA

MURAKAMI, S., YASUHARA, K. and MOCHIZUKI, N.
Department of Urban and Civil Engineering, Ibaraki University, Ibaraki, Japan

www.civil.ibaraki.ac.jp
murakami@civil.ibaraki.ac.jp
Objective Land Subsidence area in the Northern Kanto Plain, Japan
72 locations where variations of settlement and GWL over time have been observed
Land Subsidence Features in the Northern Kanto Plain, Japan
Damage due to Land Subsidence

- Direct damage
  - Structures
  - Roads
  - Lifelines, etc.....
Damage due to Land Subsidence

- Potential damage
  - Earthquake
  - River Flooding
  - Heavy Rain, etc.....
Infrastructures in wide land subsidence area

• Maintenance plan with consideration of damage due to land subsidence
  – Forecasting land subsidence
  – Regulating land subsidence
A new system for regulating land subsidence for the infrastructure maintenance

• Features
  – To use the previously observed settlements and GWL records for predicting future settlements
  – To use Geographical Information System for systematically monitoring and transmitting from time to time
Observational Prediction of Land Subsidence with Consideration of GWL fluctuation
A Simplified Prediction Model of Land Subsidence (Murakami et al., 1998, 2000)

- Features
  - In the case of the constant range of GWL fluctuation
  - On the basis of 1D consolidation theory
  - Using previously observed settlement records

\[
\delta S_i = S_p \left( 1 - \exp \left(- C_R \cdot t_i \right) \right)
\]
A Prediction Model with Consideration of GWL Fluctuation

• Settlement-Time Relationships
  – Type I
  \[ S_i^A = S_{p0}^A \left\{ 1 - \exp(-C_R \cdot t_i) \right\} \]
  – Type II
  \[ S_i^B = S_{p0}^B \left\{ 1 - \exp(-C_R \cdot t_i) \right\} \]
  \[ S_{p0} = A_w \cdot \Delta h + B_w \]
A Prediction Model with Consideration of GWL Fluctuation

\[ \delta S_{n+1} = A \cdot \Delta h - B \cdot S_n + C \]

\[ A = A_w \cdot \{1 - \exp(-C_R)\} \]

\[ B = 1 - \exp(-C_R) \]

\[ C = B_w \cdot \{1 - \exp(-C_R)\} \]
Determination of Range in GWL Fluctuation using Time Series Analysis

[Graph showing groundwater level fluctuations over years with measured values and presumed values indicated.]
Application of the Proposed Method to Land Subsidence Prediction
Application to the representative 6 locations

- Koshigaya
- Tatebayashi
- Tokorozawa
- Washinomiya
- Sowa
- Nogi

**Graph:**
- X-axis: Year
- Y-axis: Settlement (mm)

**Table:**

<table>
<thead>
<tr>
<th>Location</th>
<th>$A_v$</th>
<th>$B_v$</th>
<th>$C_R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>88.197</td>
<td>61.748</td>
<td>0.111</td>
</tr>
<tr>
<td>2</td>
<td>82.342</td>
<td>-257.852</td>
<td>0.142</td>
</tr>
<tr>
<td>3</td>
<td>5.107</td>
<td>-113.809</td>
<td>-0.0295</td>
</tr>
<tr>
<td>4</td>
<td>860.836</td>
<td>595.542</td>
<td>0.0295</td>
</tr>
<tr>
<td>5</td>
<td>52.804</td>
<td>140.625</td>
<td>0.0415</td>
</tr>
<tr>
<td>6</td>
<td>38.563</td>
<td>158.601</td>
<td>0.153</td>
</tr>
</tbody>
</table>

Curves: Calculated results
Plots: Observed results
Application to all the Locations (72 locations)

The multi-correlation coefficients are detected from calculated and observed settlement for 3 years from 1992 to 1994.
GWL fluctuation for regulating land subsidence

- Proposed Land Subsidence Prediction Model

\[ \delta S_{n+1} = A \cdot \Delta h - B \cdot S_n + C \]

- Permissible range of GWL fluctuation for regulating land subsidence

\[ \Delta h = \frac{1}{A} \left( \delta S_n + B \cdot S_{n-1} - C \right) \]
A GIS-aided
GWL Monitoring System
for Regulating Land Subsidence
GWL Fluctuation Map for Regulating settlement

Map showing fluctuations in groundwater levels (GWL) in different regions, with color coding indicating the extent of fluctuation in millimeters (mm): 20mm, 10mm, and 0mm.
GWL Monitoring System

Realtime monitoring for GWL

Network for monitoring GWL

Distribution maps of GWL fluctuation such as shown in Fig.10

Warning

Caution
CONCLUSIONS

• An observational prediction method of land subsidence with consideration of GWL fluctuation by using previously observed settlements and GWL records is proposed.

• A GIS-aided monitoring system of GWL in wide land subsidence area is proposed.