The Multiple Roles of Environmental Data in the SGMA

Thursday, May 4, 2017

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The Big Takeaways

• It’s all in the empirical data
• The Best Management Practice elements for groundwater monitoring include effective and efficient data collection
Overarching Premise

• Under the SGMA, physically / process based models will often be used to predict what may happen under changes in conditions to support resource management decisions

• Empirical data:
  • Provides important foundation for such models
  • Calibrate the models to provide assurance they reflect reality
  • Used to infer what *actually* occurred after-the-fact
  • The ultimate arbiter of how *good* any model is
Primary vs Secondary: Common Definitions

- Primary data – collected by the investigator first-hand, or collected for a purpose directly relevant to the study. Often are “raw”.
- Secondary – collected by others, collected for another purpose, or representing statistical or other summaries rather than direct quantities. Often are “syntheses”
  - Example would be lithologic data on well logs as raw data
  - Reduction to percentage of a particular vertical interval for sediment type is a type of secondary data
Groundwater Levels (i.e. hydraulic head pressures)

- Fundamental data type
- Obtained as “primary” data for limited range of purposes:
  - Assessing mechanical lift for an extraction well
  - Constructing iso-contour maps of hydraulic head
- Utilized as “secondary” data for a far wider range of applications:
  - Time-series analyses
  - Model development (e.g., specifying boundary conditions)
  - Numerical model calibration
  - Inferring interactions between surface- and groundwater
• Not so!

• Many of the “best-practice” elements presented here are derived from the more detailed publications and guidance regarding water quality

• A well-designed water level monitoring program of relevance to the SGMA requires thoughtful and sophisticated analysis
Monitoring Groundwater Levels

- Commonly driven by legal requirement and not desire for better management decision-making:
  - Leads to sub-optimal datasets
- In the ideal case you assess and quantify what is required for compliance and improved decision making:
  - Saves money to identify these requirements and goals in advance
  - Design program specifically to obtain it
- Establish clear relationship between the information to be produced and its use within the management agency's decision-making process
Factors to Consider for Monitoring in General

• Hard to quantify whether a certain monitoring network design will provide the desired information
  • Often don’t find out until analysis and reporting stages if adequate
  • Start out with a denser coverage, and then reduce locations and frequency
    • In other words you need more data, to show which data are essential and which data are not
    • Monitor those locations and with a strategy for analysis, decision-making, storage, reporting, etc.
Wheel and Axle Monitoring Strategy

• Presents a method and monitoring planning approach
  • to develop and formalize connections between various monitoring efforts
    • that occur on different spatial and temporal domains
Wheel and Axle Monitoring Strategy

Monitoring is disconnected and inconsistent

Monitoring is connected and consistent

Not integrated!

Special studies are not normally "connected" to fixed-station, longer-term trend monitoring

Existing, fixed-station trend monitoring system (dotted line indicates lack of documented operation)

"Special studies" are now planned to mesh with fixed-station, longer-term trend monitoring

Subset of total monitoring program devoted to fixed-station, trend monitoring (solid line indicates documented operation)

Initiation of Total, Documented Monitoring System
“Vital Signs” Concept as the Axle?

- National Park Service monitoring program is available as a case study for the SGMA - [https://science.nature.nps.gov/im/monitor/](https://science.nature.nps.gov/im/monitor/)

- “Vital signs monitoring” tracks a subset of data types selected to represent the overall health or condition of resources

- Analysis to determine the status and trends in the selected indicators of the resource conditions:
  - Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
  - Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
  - Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
  - Provide a means of measuring progress towards performance goals.
Major Factors to Consider: Groundwater Levels

• Location:
  • Geographic
  • Vertical

• Frequency:
  • Occasional (wheel)
  • Frequent (axle)

• Methods:
  • Manual
  • Automated

• Data Reduction, QA, Storage, Uses, Access, Reporting
Monitoring Program of Key Wells 200-300’ Deep

Legend
- < 100’ Screen
- 100’ to 250’ Screen
- > 250’ Screen
- Group 1 200’ to 300’ midscreen USGS

Groundwater Levels: Frequency – Quarterly?
Groundwater Levels: Location as $X, Y, Z_1, Z_2, Z_3$
Groundwater Levels: Location as X, Y, Z₁, Z₂, Z₃
Tools for Improved Monitoring Program Design

- Principal Components Analysis
  - Identify Well Response Groups or Clusters via Correlation Analysis
  - Correlate Responses to Temporal Factors (e.g. extraction) and Common Factors (e.g. hydrostratigraphic units or HSUs)
- Using mixed Universal Kriging create isocontour maps of hydraulic heads
- Assess what the groups represent for HSU and which groups are important
- Evaluate key data locations to define the system condition(s)
- Design monitoring network
- Document it and plan on updating it as you learn more from the data
Multi-Component Responses in Groundwater Levels

Precip. contribution

Basin contribution

Pumping contribution
Hierarchical Cluster Analysis: Overview

- Hard clustering: *membership solely to one group*
- Fuzzy clustering: *membership divided between clusters (i.e., fractional membership)*
- Ordering arbitrary or based on a-priori distance or time functions
- Patterns visually evident
- Subject clusters to further analysis
Clustering via Pattern Recognition for Monitoring

- Membership shown at left
- Tightly-spaced cluster near basins irrespective of well depth
- Common and strong recharge response
- Monitor fewer of these
### Superposition in Data Analysis

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<thead>
<tr>
<th>Linear trend (Event 1)</th>
<th>Well trend (Event 1)</th>
<th>Superposed trend (Event 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grad = 0.0010</td>
<td>T = 300, Q = (10, -10)</td>
<td>T = 300, Grad = 0.0010, Q = (10, -10)</td>
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<table>
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<tr>
<th>Linear trend (Event 2)</th>
<th>Well trend (Event 2)</th>
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<thead>
<tr>
<th>Linear trend (Event 3)</th>
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<tbody>
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<td>Grad = 0.0005</td>
<td>T = 300, Q = (15, -15)</td>
<td>T = 300, Grad = 0.0005, Q = (15, -15)</td>
</tr>
</tbody>
</table>

**Distance along transect**
Superposition in Data Analysis

• Superposition enables kriging with a combination of analytic drift terms:

\[ h(x,y) = a + bx + cy + d \sum_{1}^{m} Q(ri) + e \sum_{1}^{n} L(ri) + f \sum_{1}^{o} P(ri) + \ldots + e(x,y) \]

• Terms can be grouped, enabling testing of a Hydrogeologic Conceptual Model

• For example incorporating separate terms for two line sinks believed to exhibit different exchange rates with the groundwater system enables hypothesis testing without additional data
Multi-Event Universal Kriging: MEUK

- MEUK looks at a multitude of temporal or spatial datasets simultaneously
- Models the system without guessing at parameters
- Mapping events independently using Universal Kriging implies that:
  - Coefficients for each event are unrelated
  - There are sufficient data each event to estimate coefficients
- MEUK enables coefficients to be conditioned on a subset or all of a multi-event dataset
Monitoring Programs for Correlated MEUK Maps

- Membership shown at left for municipal extraction response
- More dispersed cluster across HSU boundary but more tightly clustered vertically
- Diminished recharge signal but present
- Monitor fewer for condition assessment
With MEUK:
- Test the foundations of the HCM
- Regionally
- Locally
- Because it is essentially grid-free

*while producing maps*
Central Valley of California

Mapped elevations:
- How representative are they?
- Are they suitable for decisions?
- Or for initial conditions?

What about:
- Pumping?
- Irrigation returns?

Data galore
- Basin-wide and sub-basin scale interests?
- Regional subsurface structure?
- Bedrock sub-crop?

Tools for Developing a GSP
GRA SGMA Conference Modesto, California
• Empirical data define the system state – “patient health”

• By applying existing methods of “vital signs” monitoring to groundwater levels one can reduce the number of locations and periods of monitoring and know more

• Multi-event kriging with local and global variable enables data derived identification of HSUs

• Further analysis of the data can establish the key monitoring points and timing to define HSU “health”
Summary BMP for Monitoring Program Design

1. Define information needs of management
2. Define information that can be produced by monitoring
3. Design monitoring network to collect the data to address the information needs
4. Generate and document data collection procedures
5. Document the analysis to be performed and the temporal need for more exhaustive analysis (e.g. Annual reporting vs. 5-year sustainability path assessment for management decisions and actions)
6. Document to a GSP or a GSP monitoring plan the information generating and reporting procedures
SELECT REFERENCES
Select References


