CONTAM 01 Multi-Scale Soil Sensor Network in Support of Groundwater Quality Protection

CONTAM 01.1 People

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CONTAM 01.2 Overview

The capacity to adaptively manage irrigation and associated contaminant transport is desirable from the perspectives of water conservation, groundwater quality protection, and other concerns. In the previous annual report, we introduced the application of a feedback-control strategy known as Receding Horizon Control (RHC) to the problem of irrigation management. The RHC method incorporates sensor measurements, predictive models, and optimization algorithms to maintain soil moisture at certain levels or prevent contaminant propagation beyond desirable thresholds. With last year’s development of a closed-loop soil pylon sensor system for controlling contaminant transport in soils, emphasis this year turned to pilot-testing the system at the Palmdale field site. Key tasks included installation of long-term sensor system at the Palmdale site and execution of an intensive field campaign aimed at testing the closed-loop system. The long-term sensor system was installed and has been successfully monitoring conditions at Palmdale since July 2008, and the closed-loop system was successfully demonstrated at the Palmdale site.

CONTAM 01.3 Approach

In a campaign-style deployment at Palmdale, CENS researcher installed a network of soil moisture and temperature pylons at Palmdale for the purpose of testing the RHC algorithm under real field conditions. All sensors were removed from the system following this campaign. In a separate effort (Figure 1), a robust sensor system was deployed at the Palmdale site including three sensor pylons, a meteorological station and a cellular modem to transmit the data back to SensorBase.

CONTAM 01.4 Systems/Experiments

To test the RHC under real conditions, a field site was identified in Palmdale, California (longitude 118° W, latitude 34° N) in the Mojave Desert area. Reclaimed water is being used for agricultural irrigation there with application by a center-pivot irrigation system equipped with a 200 m (≈ 650 ft) pivot arm rotating over an area of 12.67 ha (≈ 31.3 acres). Given the current system, it was impossible to manage the pivot flow rate precisely, and instead applications were regulated by the application duration (based on the

Figure 1 - CENS researchers completing the trenching during the installation of the long-term soil monitoring pylons at the Palmdale experimental site.
rotational speed of the pivot arm) with a fixed application rate (0.5mm/min). For simplicity, three speeds--low (8 min duration with 4mm of water), medium (6 min; 3 mm), and high (4 min; 2mm)--were employed. The field test was performed at a single location in the southeast quadrant of the Palmdale pivot circle, where fine sandy loam is the main soil type.

The objective of the field test was to prevent the moisture content at a depth of 5cm from surpassing a threshold value of 0.22 [cm³/cm³]. This depth was selected to enable the application rates to impact the sensors within the timeframe of the experiment (12 h). However, additional sensors were deployed in order to capture data for future offline algorithm testing. Soil moisture sensors (S-SMC-M005, Onset Computer Corporation, Bourne, MA) were installed at 5cm, 10cm, 20cm, 40cm, and 60cm. Temperature sensors (S-TMB-M002, Onset) were installed at 5cm, 10cm, 20cm, and 40cm. Data loggers (H21-001 logger with C-002 radio modem, Onset) were used to collect and wirelessly transmit soil moisture, temperature, and meteorological data, including air temperature and relative humidity (S-SMA-M002, Onset), and wind speed and direction (S-WCA-M003, Onset). Atmospheric pressure and solar radiation data were downloaded from CIMIS website (California Irrigation Management Information System, www.cimis.water.ca.gov).

The results from the RHC field test are presented in Figure 2. Initially, the moisture content at 5cm was less than the threshold value, thus the RHC’s initial updates called for slowing the pivot speed (increasing the duration), enabling more water to be applied to the profile. As the estimated 5cm moisture content approaches the threshold value, the RHC called for increased pivot speeds in an attempt to stay near the threshold value. During the field test, we inadvertently executed the wrong speed at management time step 3, and a 4 min duration (high speed) was applied instead of the prescribed 8 min duration (low speed). However, RHC scheme adapted to this unexpected change and again prescribed an 8 min duration for the subsequent management time step to compensate for the inadequate water application during the previous step.

To establish a long-term observation system at Palmdale, three soil pylons were installed in July 2009. The gateway note in this setup was equipped with a cellular modem which transfers sensor data to SensorBase. Moisture, temperature and soil conductivity (salinity) data for one of these pylons is shown in Figure 3. This system continues to operate and has required no maintenance to date.

**CONTAM 01.5 Accomplishments**

There were two main accomplishments in 2008-09. First, real-time soil moisture control was successfully demonstrated for the center-pivot system in Palmdale. Real-time soil moisture, temperature, and meteorological data were streamed wirelessly to a field computer to enable autonomous execution of the RHC algorithm. The RHC scheme is demonstrated to be a viable strategy for achieving water reuse and agricultural objectives while minimizing negative impacts on environmental quality.
Second, a long-term observational system has been established at Palmdale and it has been operating continuously without significant maintenance efforts since installation in late July 2008.

**CONTAM 01.6 Future Directions**

Many groundwater degradation and agricultural sustainability problems occur slowly over long periods of time. The RHC schemes developed here will be implemented over longer term operational horizons (months, years, decades) in Palmdale, CA where reclaimed water is used for agricultural irrigation for decades. Wireless sensor data (soil moisture, temperature, and EC) will be used to update the status in Palmdale and incorporated in the RHC scheme.

**CONTAM 01.7 External Research Partnerships**

*Agriculturalists for Scientific Environmental Research (AFSER)*

This partnership, starting in March 2007, will fund one UC Merced graduate student and supplies for test deployments of 3 to 4 soil pylons at local dairy operations. The goal of the project is to assess the utility of the pylons for monitoring nitrogen releases (via waste streams) to the subsurface, and create a plan for comparing these releases at dairies under a range of conditions (underlying soil types, dairy management practices, etc.).

Figure 3. Long-term soil temperature (top), moisture content (middle) and conductivity (bottom) data from one of the three Palmdale soil pylons.