Assessing land-drainage performance

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Mole drainage is used in fine, poorly-permeable soils, in conjunction with a network of shallow field drains, to improve hydraulic conductivity, thereby, increasing infiltration of rainwater to the field-drainage system.

In such soils, the installation of field drains alone does not offer sufficient discharge capacity. Mole drainage relies on a network of closely-spaced channels and subsoil cracks, formed during installation, to rapidly discharge excess soil water during rainfall events (Tuohy *et al*, 2016). Stable mole channels can only be formed in clay-textured, stone-free soil layers and their performance and lifespan will be largely dictated by soil type and installation conditions (particularly soil-moisture content during installation). Their lifespan can vary from one to five years.

Monitoring system performance

The performance of a mole drainage system, installed in Doonbeg, Co Clare, is being monitored as part of the Teagasc Heavy Soils Programme. Soil physical and modelled hydraulic parameters for the site are presented in Table 1. In June 2013, a series of field drains were installed at a depth of 0.9m and spacing of 15m, comprising of 110mm corrugated pipe and stone aggregate (10-50mm grade) backfilled to within 0.2m of the soil surface. Mole drains were installed perpendicular to these drains at a depth of 0.6m and spacing of 1.4m.

End-of-pipe flow-meters record water-flow rates, while a number of in-field wells (2m deep) with water level sensors record water-table fluctuations. There is also a weather station on the farm.

Table 1. Soil physical and hydraulic parameters. θ_r = residual water content, θ_s = saturated water content, ks = saturated hydraulic conductivity.

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Dry density (g/cm³)	Bulk density (g/cm3)	θ_r ($cm^3\ cm^{-3}$)	θ_s ($cm^3\ cm^{-3}$)	k_s (m/s)
0-26	21	45	34	1.11	1.61	0.078	0.390	3.52E-07
26-47	13	49	38	1.23	1.73	0.077	0.370	1.75E-07
47-75*	12	59	29	1.65	2.04	0.053	0.288	6.73E-08
75-140	23	50	27	-	-	0.078	0.441	1.47E-06

**Mole drain channels installed in this layer.*

Simulation models

Using modelling software, it is possible to create a simulation of the drainage system installed. This simulation can then be manipulated to estimate the performance of the installed system (or alternative system designs) in a range of hypothetical short and long-term weather events. The key input parameters for the modelling software include soil physical characteristics, drainage design and weather conditions. The SEEP/W software package developed by GEO-SLOPE (2012) was used in this study.

The project had three objectives: i) to model the performance of a combined field/mole drainage system during a short-term, high-intensity rainfall event using SEEP/W software; ii) to validate the model and assess its reliability relative to measured discharge collected over a three-month period; and iii) to model the installed system and a range of alternative systems under a range of rainfall scenarios to assess their performance.

Model calibration and validation

The model was calibrated by simulating an actual rainfall event (Event A), which occurred over a five-day period spanning September 10-15, 2015. During this period, 156.4mm of rainfall was recorded on the farm. The material properties of soils below the mole channels were defined using data from the site-soil survey and hydraulic properties derived from them (Table 1). Above the mole channels, soil properties could be varied to model improved hydraulic properties brought about by mole drainage. The field drain was assigned a high-saturated hydraulic conductivity (k_s = 10m/s), while mole drains were assigned a k_s of 0.001m/s. Analyses were run with a range of values assigned for k_s above the mole channel until the drain discharge results in the model output were comparable to the field results observed. The resulting modelled drainage system is referred to as System 1 with soil k_s above the mole channel of 5.50cm/hr. A dataset spanning a three-month period from October 1 to December 31, 2015 (Event B) was used to validate the model formulated. The modelling software provided reliable predictions of drain discharge of a combined field/mole drainage system compared with actual values (Figure 1).

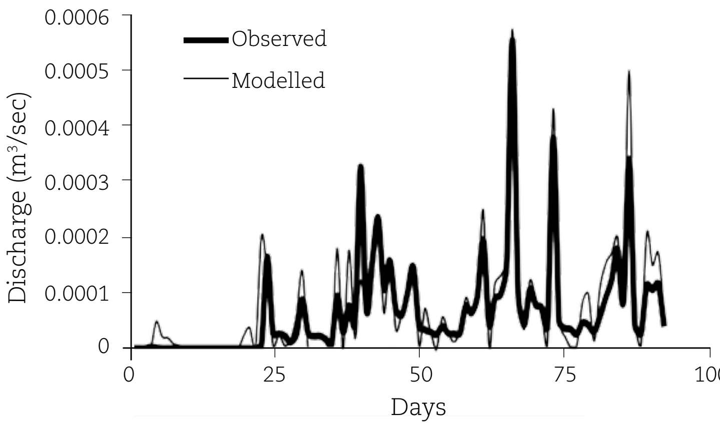

Figure 1. Comparison of daily field drain discharge from modelled analysis and observed field measurements of installed drainage system (System 1) during Event B.

Modelled alternative systems

Three alternative drainage systems were evaluated under the conditions of both rainfall events, i.e., the calibration event (Event A: September 10-15, 2015) and the validation event (Event B: October 1- December 31, 2015). System 2 consisted of field drains only with no mole drains. System 3 and 4 are similar to System 1 except soil k_s above the mole channel has been set at 0.55cm/hr and 55.00cm/hr, respectively, equivalent to the calibrated k_s in System 1 divided or multiplied by a factor of 10 to mimic either a reduction or improvement in mole-channel integrity. Furthermore, simulations were carried out for two hypothetical rainfall scenarios. In Event C, a rainfall rate of 2mm/h was applied to all systems for 50 hours. In Event D, the 30-year average daily values were applied to all systems.

Assessing system performance

Systems 1 and 4 consistently outperformed Systems 2 and 3 in terms of average and peak discharge and water-table control capacity. Across rainfall events, System 2 (without mole drains) was the least effective, and reduced drain discharge (Figure 2) and average water-table depth when compared with Systems 1 and 4. The performance of combined field/mole drainage systems reflected the variations in k_s of that material above the mole channels. The greater the improvement in soil k_s brought about during mole channel installation, the better the system performance will be.

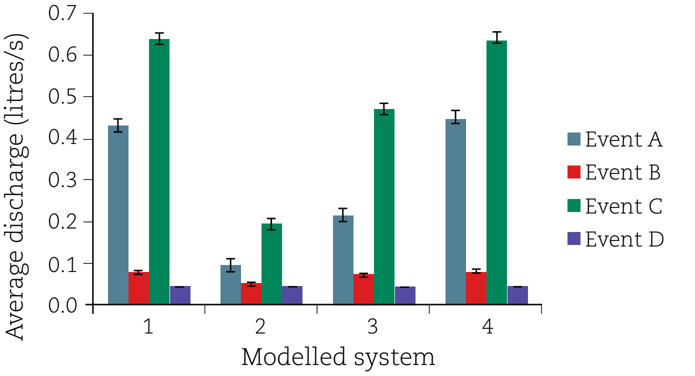

Figure 2. Comparison of mean field-drain discharge from modelled drainage systems; (1) Installed system (field drains with mole drains), (2) Field drains only, (3) Installed system with deteriorated mole drains, (4) Installed system with improved mole drains.

References

GEO-SLOPE (2012). SEEP/W, Version 8.0.10.6504. Calgary, Canada: GEO-SLOPE

Tuohy, P., Humphreys, J., Holden, N.M. and Fenton, O. (2016). 'Runoff and subsurface drain response from mole and gravel mole drainage across episodic rainfall events'. *Agricultural Water Management*, 169: 129-139.