SPR834: Determining Landslide Drain Lifecycle for Development of Maintenance and Operation Manuals

Background: Horizontal drain systems, in combination with other mechanical reinforcing elements, are one of the most effective means of mitigating movements of deep-seated landslides that creep under elevated groundwater conditions. However, the design and implementation of horizontal drain systems is often qualitative and there is limited information regarding their long-term performance. Frequently, drain systems are installed with limited means of estimating or measuring how long they will effectively function. Maintenance of horizontal drains is critical for maintaining the integrity of these landslide mitigation systems. Without maintenance, these systems may cease to function, and excessive slope movement will resume. To ensure long-term slope stability and driver safety on ODOT right-of-way, development of drain design criteria to help inform maintenance operations and projected design life is of high importance.

Study Outline: To meet the research need, numerical models are proposed to evaluate the (1) mechanisms and transient drawdown from horizontal drains for a wide range of geometric conditions using simplified design charts, (2) siltation mechanisms and timing for various drain geometries and grain sizes as a means of determining “time until failure” using simplified design charts (Figure 1), (3) hydrologic data from the HWY20 Pioneer Mountain-Eddyville (PME) realignment, which was used to develop simple observation-based criteria for evaluating horizontal drain performance at a systems level, explored through proposed hazard matrices that guide actions regarding inspection and intervention (Figure 2). Further, a simple machine learning model is implemented as a GIS toolbox to evaluate transient lowering of groundwater for evaluation of horizontal drain feasibility. Lastly, in collaboration with the OSU OpenS lab, we propose a low-cost, open-source flowmeter system, designed and developed as a future means of monitoring discharge from horizontal drain systems along with design specifications.

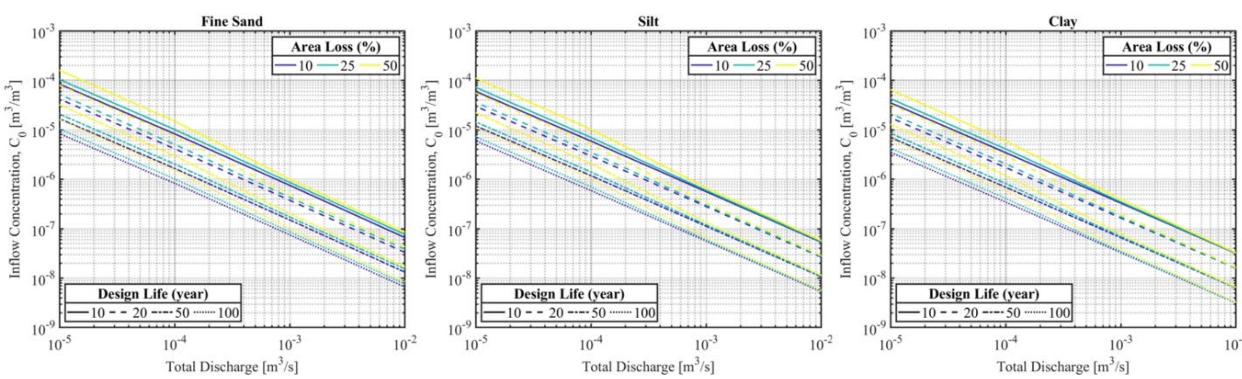

Figure 1: Design charts for service life of horizontal drain systems as a function of sedimentation. This lifecycle is a function of flow rate, sediment size and concentration, and area loss of pipe.

Observations and Implementation: In general, it is apparent that horizontal drains are an effective means of lowering groundwater in the long-term (steady-state conditions from recharge) and are effective in preventing groundwater storage from infiltration in the short-term. These influences result in more stable slope conditions. However, these systems require strategic and systematic inspection and in the case of poor performance, intervention and repair. Select observations and tools include:

- Observations from the Highway 20 Pioneer Mountain-Eddyville realignment suggest that when functioning appropriately, horizontal drains (1) reduce steady-state groundwater levels, including in winter months, (2) decrease the magnitude and flashiness of groundwater rise after storm events, and (3) decrease the storage of infiltrating water during storm events. These observations can be corroborated on a site-specific basis using simple piezometric data.
- Generally, comparative, observational data focused on drain discharge and groundwater levels serve as a comparative means of evaluating the frequency of inspection and decision-making strategies regarding maintenance and repair. Simple hazard matrices are proposed to allow a professional to comparatively evaluate drain performance and implement strategic, data-driven decisions regarding maintenance.
- Numerical models are developed to quantify the mechanisms by which groundwater drawdown occurs following drain installation. These models provide a simple means of estimating the magnitude by which slopes can be stabilized following drain installation. It is observed that there are several phases of groundwater lowering, the timing of which scales with drawdown. For implementation, a series of design charts and a simple GIS toolbox are proposed to allow users to estimate groundwater drawdown.
- Siltation of horizontal drains may occur from the accretion of sediment within the pipe annulus. We propose a series of design charts that enables designers to characterize "time until clogging" based on observed effluent sediment size and flow rates. This enables first-order estimates of drain lifecycles as it relates to the parent landslide materials that are being stabilized with horizontal drains.

These tools and findings all support implementation of improved maintenance and function of ODOT geotechnical assets.

Groundwater Level Change Pre-Drain Conditions

	Significantly Decreased Groundwater Levels	*Decreased Groundwater Levels*	*Similar Groundwater Levels*
Higher Intensity	A3: Significant increase in drain efficacy (Less frequent monitoring, no repair or added mitigation required)	A3: Increasing drain efficacy (Less frequent monitoring, no repair or added mitigation required)	A2: Stable drain function (Yearly monitoring, no repair or added mitigation required)
Similar Intensity	A3: Increasing drain efficacy (Less frequent monitoring, no repair or added mitigation required)	A2: Stable drain function (Yearly monitoring, no repair or added mitigation required)	A1: Decreasing drain efficacy (More frequent monitoring, consider repair or added mitigation)
Lower Intensity	A2: Stable drain function (Yearly monitoring, no repair or added mitigation required)	A1: Decreasing drain efficacy (More frequent monitoring, consider repair or added mitigation)	A1: Severe decrease in drain efficacy. (Monitor continuously, repair or added mitigation required)

Groundwater Level Change Post-Drain Conditions

	Decreased Groundwater Levels	*Similar Groundwater Levels*	*Increased Groundwater Levels*
Higher Intensity	B3: Significant increase in drain efficacy (Less frequent monitoring, no maintenance required)	B3: Increasing drain efficacy (Less frequent monitoring, no maintenance required)	B2: Stable drain function (Yearly monitoring, no maintenance required)
Similar Intensity	B3: Increasing drain efficacy (Less frequent monitoring, no maintenance required)	B2: Stable drain function (Yearly monitoring, no maintenance)	B1: Decreasing drain efficacy (More frequent monitoring, consider maintenance)
Lower Intensity	B2: Stable drain function (Yearly monitoring, no maintenance required)	B1: Decreasing drain efficacy (More frequent monitoring, consider maintenance)	B1: Severe decrease in drain efficacy. (Monitor

Figure 2: Example hazard matrices with inspection and maintenance strategies for evaluating horizontal drain performance in comparison to pre-drain installation (left) and post-drain installation conditions.