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104B Soil Moisture Study/Phase 2 – Results By Soil Type

Background

In 2018 BES constructed 53 green street facilities in the Argay Terrace neighborhood as part of the Slough 104B Green Streets project (BES Project E10638). The facilities were built to treat runoff draining to the Columbia Slough. All of the facilities are vegetated biofilters with underdrains, and about half are fully lined to protect groundwater along the busier streets. The project allowed for an experimental trial to test facility design modifications with potential to improve summer soil moisture conditions and plant health in fully-lined biofilters. Fully-lined systems have been a particular maintenance concern for BES: staff have observed higher plant mortality rates in systems with liners where plant roots don't have access to the native soil. The experimental design allowed comparison of moisture results in lined facilities with a short underdrain vs. lined facilities with a full underdrain, and comparison of results in lined facilities with a trial soil blend vs. lined facilities with the city's 2008 standard soil blend.

The results for Phase 2 of the soil moisture study, which are the subject of this report, compare soil moisture by soil type using data obtained during summer 2022. The results for Phase I are presented in a separate report which compares moisture by underdrain type using data from summer 2021. A separate report concerning plant health monitoring results for the Slough 104B project summarizes both plant health results and soil moisture data.

Study Design

The central aim of the study was to compare the impact of two different soil types on soil moisture levels. BES staff installed Stevens Water Hydra Probe continuous soil moisture loggers in six fully-lined green street facilities constructed as part of the Slough 104B Green Streets project. Each logger was connected to three soil moisture sensors, placed at the same depth below the surface (7-8"), and evenly distributed across the facility. Staff positioned three loggers in facilities with the standard soil blend and the remaining three in facilities containing the high-fines soil blend. To eliminate underdrain type as a variable in the comparison, all six facilities are configured with the Washington (short) underdrain. Staff assessed the sun exposure of each facility and concluded that they were all in medium to high sun exposure areas.

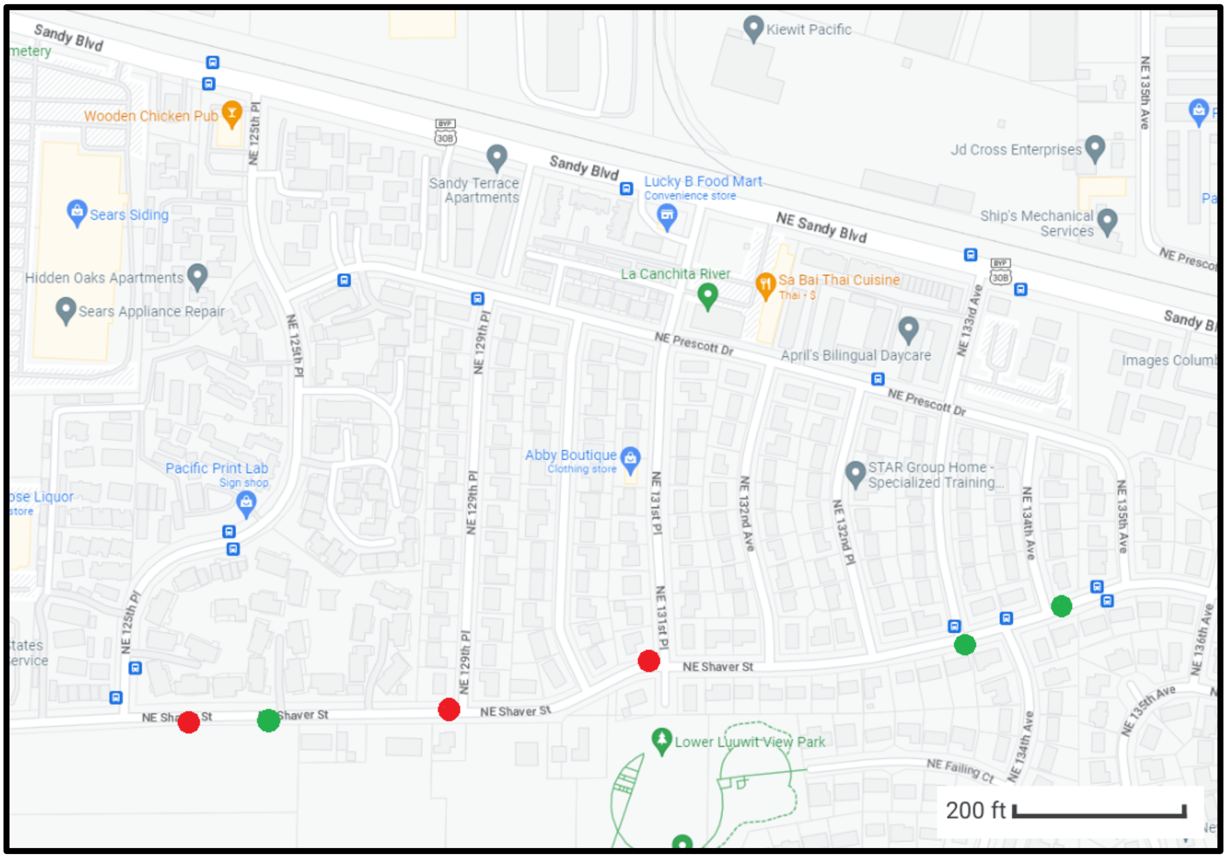

Figure 1. Soil moisture monitoring locations. Red dots are facilities with standard soil and green dots are facilities with high-fines soil.

Analysis

To investigate how differences in soil type affects soil moisture, staff analyzed the data collected from the three sensors in each facility at 15-minute intervals, and calculated facility averages. Drying events were then identified in the facility average for each data logger, which was defined as the period between field capacity and the next occurrence of saturation. Field capacity was defined as the data point 24 hours after a peak in soil moisture values.

Across all six facilities where data loggers were deployed, a total of 180 drying events were identified. Drying events caused by irrigation or rainfall were both included. Figure 2 illustrates the distribution of drying event lengths; as only a few drying events lasted longer than 14 days, staff limited the comparison analysis to events shorter than 14 days. All drying curves included in the analysis are displayed in Figure 3, with soil type indicated by color.

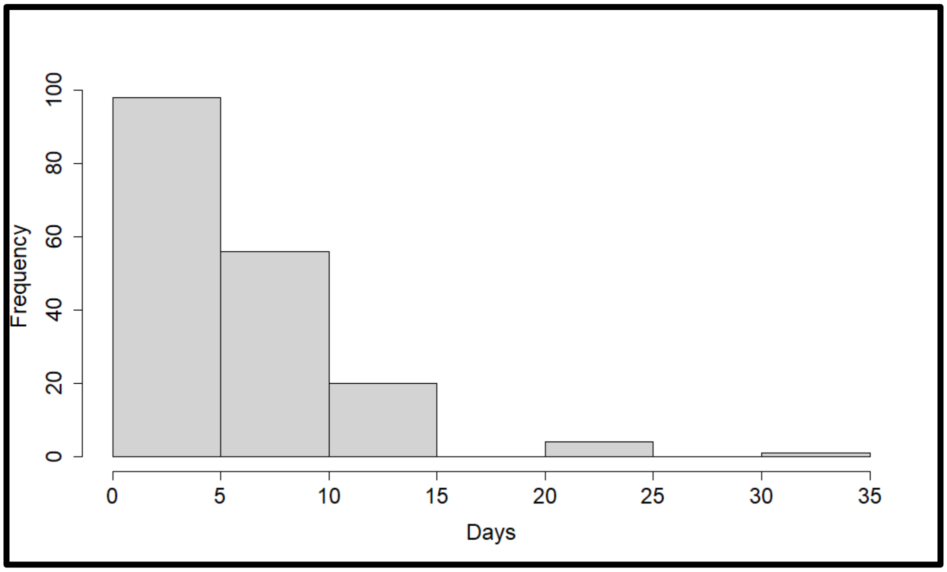

Figure 2. Distribution of drying event lengths.

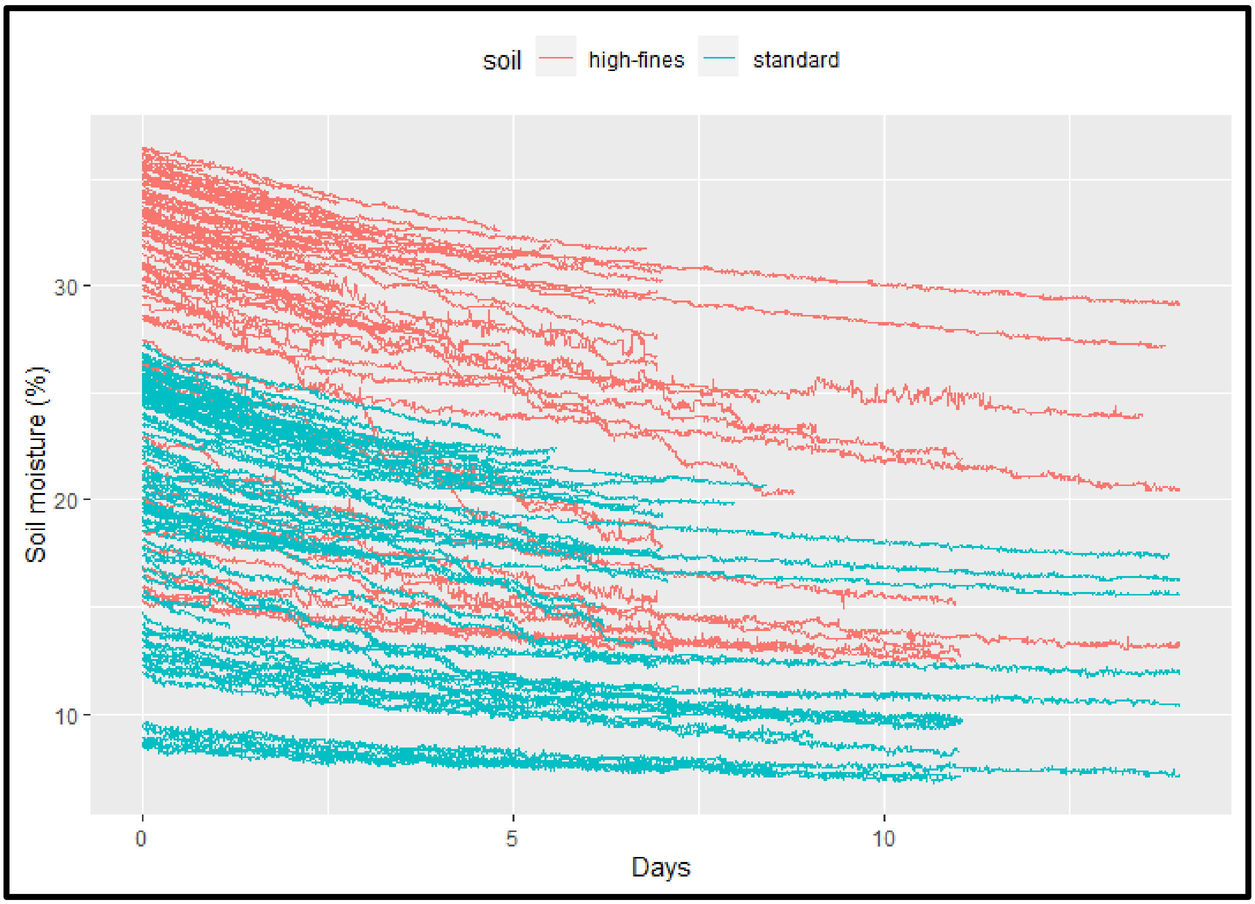

Figure 3. Drying events across six facilities. Red lines denote facilities with the high-fines soil and blue lines denote facilities with the standard soil.

The statistical analysis for this study was based on previous work by BES employees Peter Bryant and Jason Law in a similar comparison of 104B moisture results by underdrain type. Generalized Additive Models (GAM) were applied to the drying events, including an intercept and smooth term for each soil type. The intercept term represented the starting point for each soil type, while the smooth term indicated the drying rate, similar to the slope term in a linear regression. Additionally, the model allowed for different intercepts for each event to account for varying soil moisture conditions at the beginning of each drying event. The model was used to generate predictions over a 14 day period. An ANOVA test was performed for the two soil types which showed that the high-fines soil type is significantly different ($p < 0.001$) than the standard soil type for both the intercept and smooth terms. The model estimated that facilities with the high-fines soil had 9.5% higher soil moisture at field capacity, when compared to facilities with the standard soil (Figure 4).

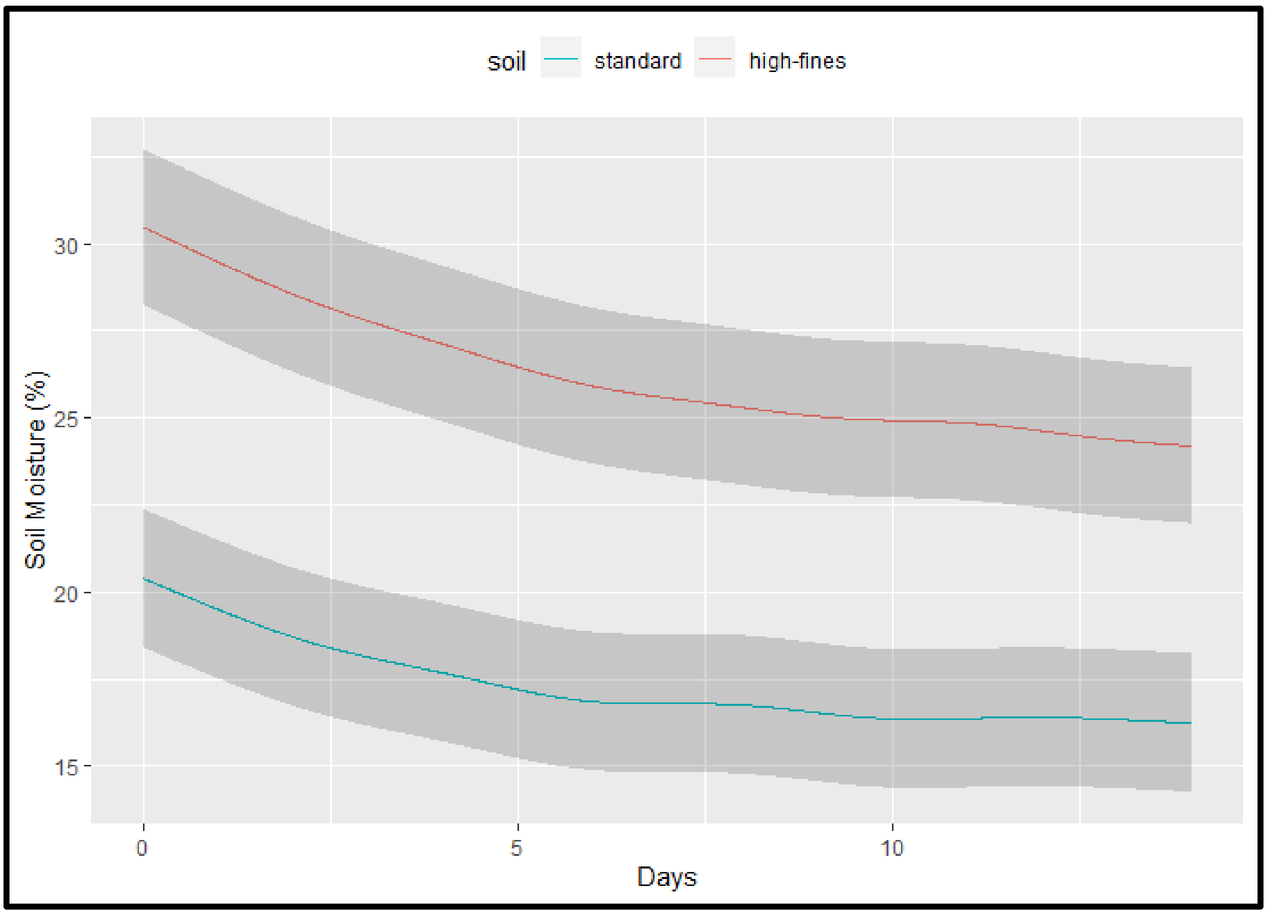

Figure 4. Predicted soil moisture drying curves with 95% confidence intervals for facilities with standard and high-fines soils.

GAM models were also applied to the same dataset with storm events separated by seasonality (Figure 5 & 6). Wet and dry seasons were determined by precipitation data gathered at the Parkrose High School rain gauge (HYDRA 235). The dry season contained all drying events between 5/28/2022 – 10/21/2022. The wet season contained all drying events in 2022 before 5/28/2022 and after 10/21/2022.

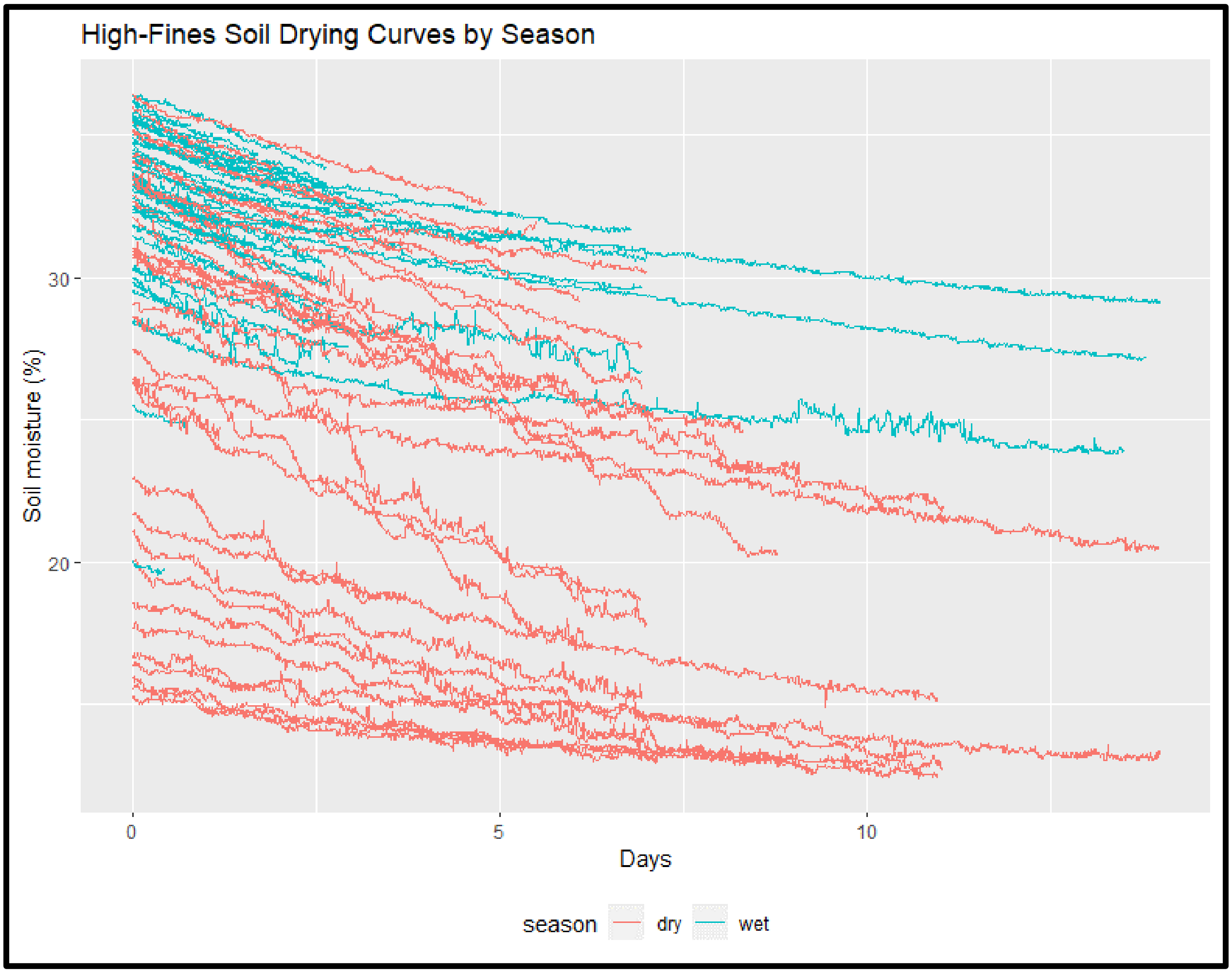

Figure 5. Drying events across three facilities with the high-fines soil. Red lines denote drying events during the dry season and blue lines denote drying events during the wet season.

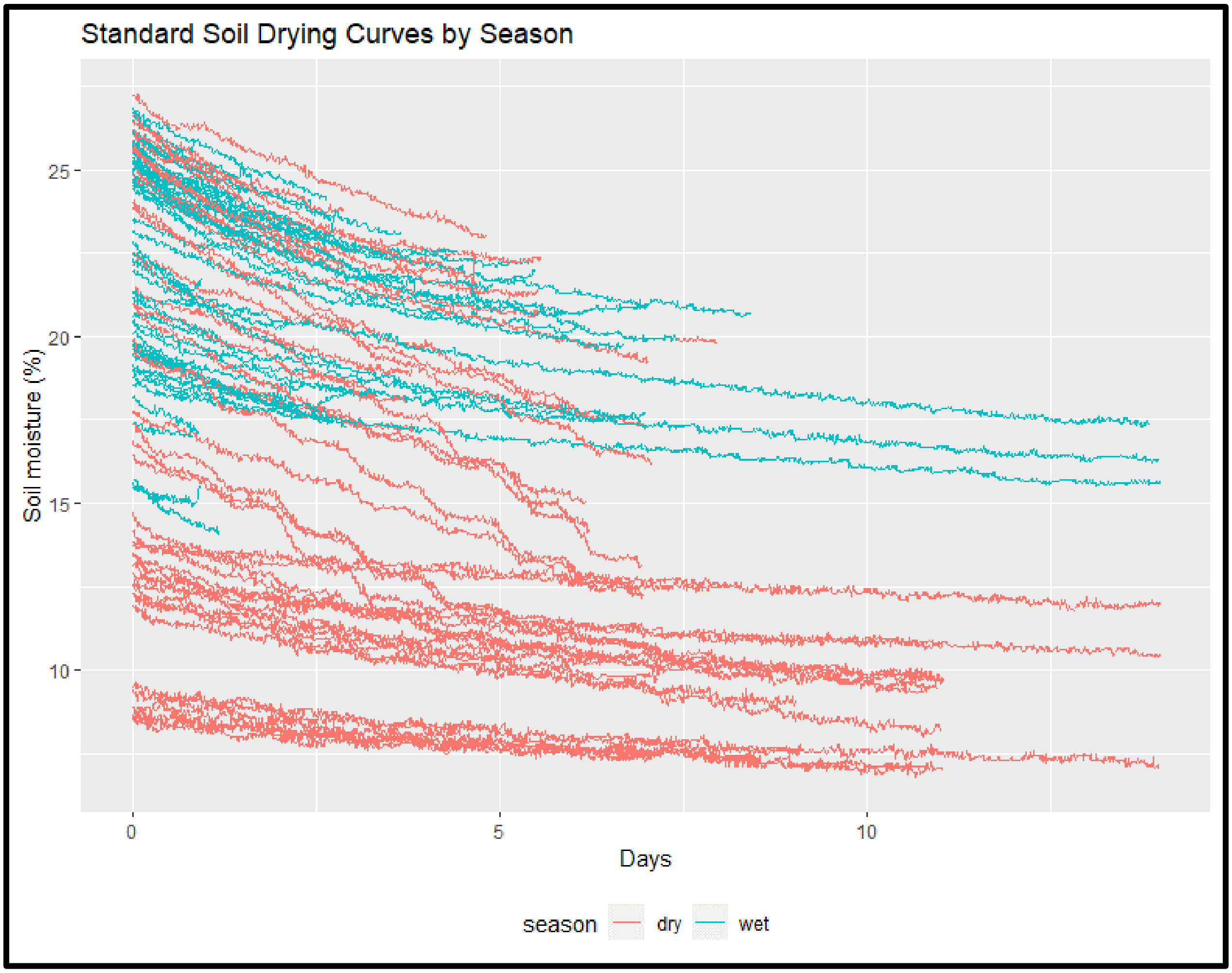

Figure 6. Drying events across three facilities with standard soil. Red lines denote drying events during the dry season and blue lines denote drying events during the wet season.

An ANOVA test was performed on each model and showed the smooth terms for all factors were significantly different ($p < 0.001$). However, the intercept terms were not significantly different due to high levels of variance. Despite the lack of significance, staff observed that the field capacity of standard soil in wet and dry seasons is approximately 20% (Figure 8). A second observation was that the field capacity of the high-fines soil during the wet season is approximately 5% higher than high-fines soil during the dry season (Figure 7). The overall trend of the high-fines soil having a higher field capacity than standard soil was also observed in these models (Figure 7 & 8).

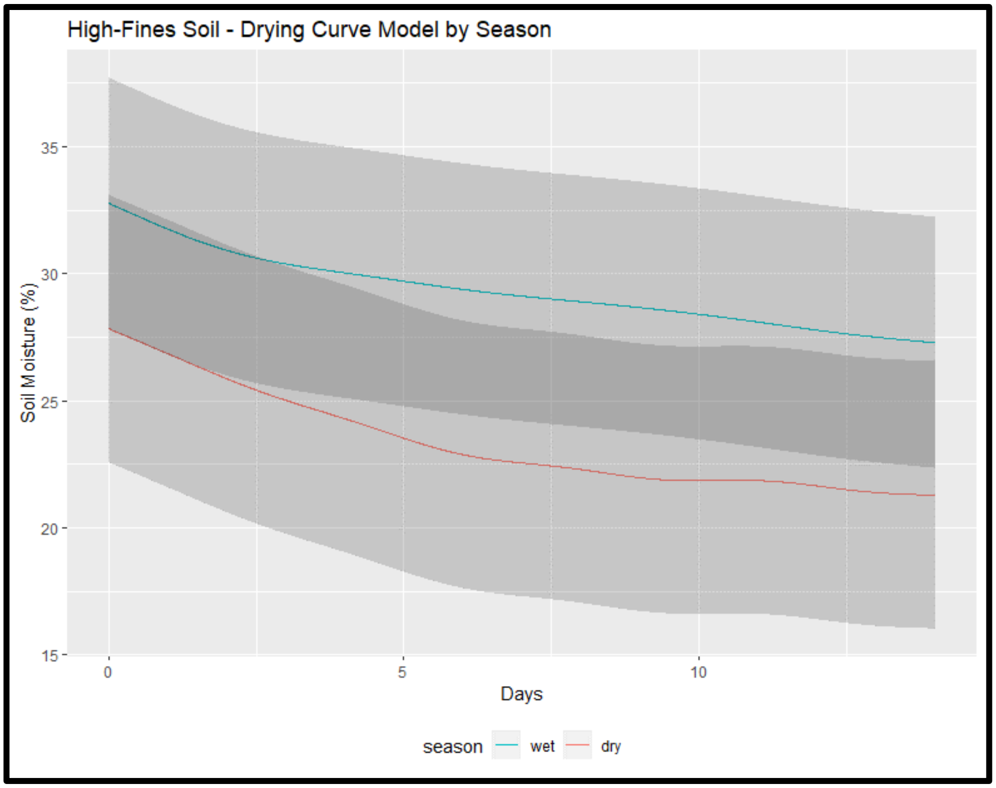

Figure 7. Predicted soil moisture drying curves by season for facilities with high-fines soil.

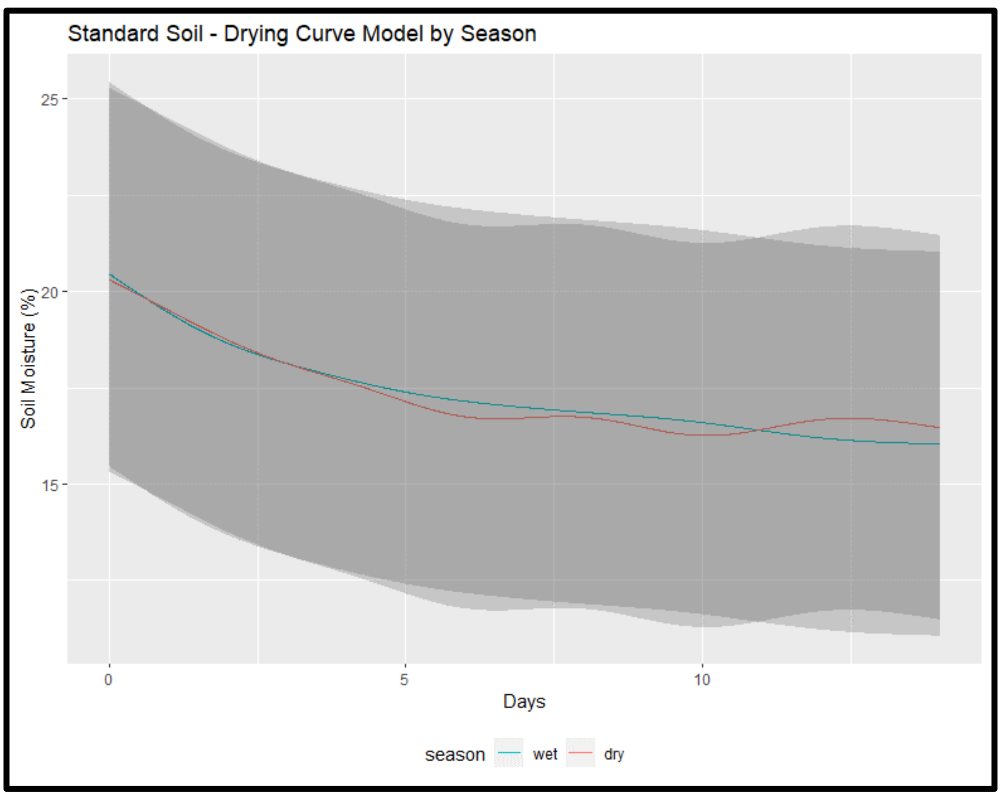

Figure 8. Predicted soil moisture drying curves by season for facilities with standard soil.

Conclusion

The purpose of this study was to determine if there was any observable difference in soil moisture drying trends between vegetated stormwater facilities with high-fines and standard soil blends. We utilized GAM models and ANOVA tests to statistically analyze differences in drying trends between soil types. Based on the model outputs, there was a significant difference in drying trends between soil types.

When comparing drying trends between soil types, facilities with high-fines soil had approximately 9.5% higher soil moisture at field capacity. When seasonality was added as a factor, the differences in soil moisture at field capacity were not statistically significant due to high levels of variance. Despite this it was observed that the field capacity of the standard soil in wet and dry seasons is approximately 20% and the field capacity of high-fines soil during the wet season is approximately 5% higher than the high-fines soil during the dry season.