2020 UDOT RESEARCH PROBLEM STATEMENT

Problem Statement deadline is March 16, 2020. Submit statements to UTRAC@utah.gov

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Title: Expected Infiltration Rates for UDOT Longterm Stormwater BMPs Within Roadway Environment

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Written By: Katherine Colburn, J. Erdman **Organization:** UDOT **Email:** kcolburn@utah.gov **Phone:** 385-626-2198

Submitted By UDOT Employee: Katherine Colburn, J. Erdman **Email:** jerdman@utah.gov **Phone:** 801-648-6253

UDOT Champion (if different): Rhonda Thiele **Email:** rhondathiele@utah.gov **Phone:** 801-965-4196

Select ONE Subject Group
☐ Materials/Pavements ☒ Maintenance ☐ Traffic Mgmt/Safety ☐ Structures/Geotech
☐ Planning ☐ Aeronautics ☐ Public Transportation ☐ Other

1. Write a brief research project objective:

Determine design parameters for the use of low impact development (LID) stormwater best management practices (BMPs) in Utah, baseline expected infiltration rates for roadway embankment and standard soil/vegetation conditions encountered in the ROW (i.e., quantifying the use of vegetation as a minimum control measure), and use these results to determine guidelines for infeasibility when evaluating long term stormwater control solutions to satisfy UDOT's Municipal Separate Storm Sewer System (MS4) permit.

2. Explain the problem and why this research is important: (*Importance reflects 50% of the statement score*)

The Environmental Protection Agency (EPA) and the Utah Department of Environmental Quality (UDEQ) have been updating stormwater regulations to minimize and prevent adverse stormwater runoff impacts. The EPA and UDEQ require long-term stormwater controls and emphasize low impact development (LID) principles as a preferred solution. These recommendations are to infiltrate, evaporate, or harvest the post-development stormwater runoff in order to mirror pre-development runoff conditions. UDOT has chosen to use LID volume reduction best management practices (BMPs) that infiltrate stormwater to meet its MS4 permit requirements. Utilizing the existing roadway prism without acquiring additional right of way is preferred.

Site conditions must be able to accommodate stormwater that is to be contained and treated in order for this requirement to be met. Many parameters impact the design of BMPs. The rate of infiltration into soils, a key value for designing successful BMPs, is highly variable based on soil properties, site characteristics, and seasonal or climatic variations.

Existing guidance in the UDOT Stormwater Quality Design Manual recommends using USDA Natural Resources Conservation Service (NRCS) Soil Survey data for preliminary values of infiltration rates and later using field testing to confirm these properties. NRCS soil data often significantly overestimates the infiltration capacity of compacted soils and is applicable only to surface soils in an uncompacted condition. While these values are useful for characterizing the predevelopment site hydrology, using these estimates in design without fully understanding the effects of compaction can lead to failing BMPs. Additionally, requiring preconstruction field testing for LID measures may be cost-prohibitive, overly stringent, or irrelevant for BMPs that do not concentrate stormwater runoff. While field testing can characterize a spot location, there is no guarantee that tests are representative of an expected range or that incidental compaction from the activity of construction equipment will not invalidate the test results. The resulting uncertainty in measuring site conditions is a unique challenge in developing quantitative measures to evaluate the success, risks of failure, or even expected operational capacity of infiltration BMPs.

The proposed research seeks to study the vegetated and non-vegetated conditions in typical UDOT roadway embankments with varying degrees of compaction through laboratory and field testing. The goal of the project is to eliminate costly field testing where appropriate and to establish design values for LID infiltration BMPs given a typical UDOT roadway embankment and level of compaction remediation.

This research will provide a valuable opportunity to consider establishing vegetation as both an erosion/sediment control measure and a stormwater infiltration BMP with additional benefits in pretreatment, sediment and salt load reduction, and pollutant removal. If this first stage of research is successful, additional studies using the built laboratory model could also be conducted to further quantify these benefits in the roadway embankment as part of a robust system of minimum control measures post-construction and long-term stormwater controls in the built environment.

Additional Literature Review

Existing guidance on sizing and selecting longterm stormwater control measures and LID BMPs is concentrated in national-level reports NCHRP 802 and 922. NCHRP 802 and 922 outline principles, tools, and practices that should be adopted by State DOTs to achieve successful stormwater management programs, but the guidance is not specific to any one State.

There is a broad consensus in the existing literature that compacted soils lose the majority of their infiltrative capacity and must be remediated in some fashion (i.e., through tillage, application of engineered soil amendments), regardless of their uncompacted properties. Existing UDOT erosion-control guidelines and standard practices for the establishment of vegetation with drill-seeding may already be sufficient to restore a useful fraction of soil permeability, but the extent of this remediation is currently unknown.

The accurate determination of saturated hydraulic conductivity (Ksat), a significant parameter used in the design of BMPs, has been the focus of much interdisciplinary research. A recent study conducted by WSDOT (Allen, 2017) determined that the harmonic mean of Ksat was the most accurate and developed guidance for using a modified Slichter equation to predict infiltration rates in compacted and uncompacted highway embankments. This study focused primarily on soil properties rather than vegetation. Interestingly, a different agricultural soil science study by Papanicolaou et. al. (2015) also found that the harmonic mean is the most representative of Ksat and that "soil texture dominated the infiltration process in soils with a higher sand content (> 15%), whereas bulk density dominated the infiltration process in soils experiencing the effects of compaction due to agricultural activity." While Papanicolaou's work is concentrated in a field unrelated to roadways and transportation, it is encouraging to note that this work further confirms Allen's observations and analysis through different methods of research and in a completely different environment and climate (Iowa rather than Washington State).

As a previous North Carolina DOT study by Brown et al. found in 2011, "Surprisingly, the infiltration rate on the compacted sandy soil [...] was very low, less than 0.2 inch/ hr. After tilling the rate increased one hundred times, the same sand soil infiltrated over 20 in/hr." This variability in infiltration due to compaction is highly significant to the design, construction, and performance of vegetated long-term stormwater control measures and to infiltration BMPs, in general. The North Carolina results were confirmed with additional studies in 2013 and 2016 which found that tillage to a depth of at least 6 inches was effective in quickly establishing vigorous vegetation which was also key to restoring compacted soil permeability.

Works Cited

Allen, T., 2017. Stormwater infiltration in highway embankments – saturated hydraulic conductivity estimation for uncompacted and compacted soils. WA-RD 872.1.

Brown, V., McCaleb, M., McLaughlin, R., 2011. Vegetation establishment and infiltration rates improved with soil tillage. Sediments. Vol. 18 No 2, 1-3.

Papanicolaou, A.N., Elhakeem, M., Wilson, C.G., Burras, C.L., West, L.T., Lin, H., Clark, B., Oneal, B.E., 2015. Spatial variability of saturated hydraulic conductivity at the hillslope scale: understanding the role of land management and erosional effect. Geoderma 243–244, 58–68.

3. Describe how the research results will be implemented and benefit Utah: (*Implementation reflects 50% of the statement score*)

This research will significantly improve UDOT's Stormwater Quality Design Manual and increase the validity and specificity of UDOT's design process. Being able to recommend conservative design values of the rate of infiltration under controlled conditions in the UDOT right of way will increase the overall context specificity in guidance for implementing infiltration BMPs and provide a useful range of expected values for engineers to use based on State-specific measurements. These design values will provide engineers and other stakeholders with key decision-making tools in determining whether or not proposed LID BMPs are infeasible for a site, measurable risks of failure for designed BMPs, and what kind of site testing should be used to support the use of a particular designed BMP.

This research will also be applicable to local government entities in Utah and possibly other state DOTs. The Utah City Engineers Association is interested in the potential of this research to improve the ability of Utah municipalities to recommend and require or select methods of field testing, as well as understanding the effects of vegetation on infiltration in compacted and uncompacted soils near city roadways and other facilities.

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4. List the major research tasks:

Model UDOT roadway embankments with material typically used in construction throughout the state and measure rates of infiltration in a controlled laboratory environment. Grow vegetation utilizing UDOT seed mixes. Develop infiltration testing protocols. Conduct randomized field testing. Analyze the results, generate a comprehensive report, and disseminate conclusions through presentations. Develop tables or other similar Utah-specific design tools or recommended values similar to those suggested by and used in NCHRP 922: Stormwater Infiltration in the Highway Environment Guidance Manual.

5. List the expected research deliverables (reports, manual, specification, design method, training, video, etc.):

Design parameters for infiltration BMPs, guidance on when and where field testing is appropriate, protocols for field testing, and a comprehensive report on the method that uses the developed design parameters and field protocols.

6. Requested from UDOT: $100,000 **Other/Matching Funds:** $0 **Total Cost:** $100,000

Briefly explain funding sources: UTRAC research funding.

7. Outline the proposed schedule, including start and major event dates:

June 5, 2020 – Start.

Simultaneous tasks:
(1-2 months): Grow vegetation for use in model.
(6 months – goal, multiple-season testing, until December 2020 and possibly ongoing): Laboratory testing and data collection, including building and verifying the model roadway embankment and establishing non-vegetated condition baselines. Later testing of vegetation will occur after the plants have reached maturity and can be incorporated into the functioning base soil model.

January–March (2021) – Develop protocol for field testing based on laboratory measurements. Evaluate initial laboratory results for vegetation and analyze impact of vegetated vs. non-vegetated embankments. (Option: Partner with consultant for evaluation of initial results and/or to supplement field testing. Seek additional funding from UTRAC to enhance understanding of vegetation impact, if found to be significant and warranting additional quantification of benefits (i.e., on pretreatment, sediment filtration, salt tolerance, etc.)).

April – June (2021) – Validate laboratory model with field data using the developed testing protocol.

July (2021) – Synthesize data from laboratory model testing and field testing. Produce reports and deliverables based on new understanding of action of vegetation in embankments. Potentially partner with consultant for analysis and production of deliverables.

November (2021) – Present results at UDOT annual conference.