Nuverra
Environmental Solutions™

April 14, 2015

Ms. Karlene Fine
North Dakota Industrial Commission
ATTN: Oil and Gas Research Program
State Capitol – 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: Nuverra Proposal Entitled "Recycled Drill Cuttings Beneficial Reuse Demonstration Projects" for a North Dakota Industrial Commission Oil and Gas Research Program Special Session Funding Request

Nuverra Environmental Solutions (Nuverra) is proposing demonstration projects designed to encourage and promote the use of new technologies to beneficially reuse drill cuttings. The conversion of drilling waste into value-added beneficial reuse products will have a positive economic and environmental impact on oil and gas exploration and production in North Dakota.

Enclosed please find an original and one copy of the subject proposal along with a check for the $100 application fee.

This transmittal letter represents a binding commitment by Nuverra to complete the projects described in this proposal. If you have any questions, please contact me by telephone at (701) 580-5494 or by e-mail at david.johnson@nuverra.com.

Sincerely,

David L. Johnson
Director

14264 N. Scottsdale Road, Suite 300, Scottsdale, AZ 85264
www.nuverra.com

Oil and Gas Research Program

North Dakota

Industrial Commission

Application

Project Title: Recycled Drill Cuttings Beneficial Reuse Demonstration Projects

Applicant: Nuverra Environmental Solutions

Principal Investigator: David Johnson

Date of Application: 4/15/15

Amount of Request: $759,860

Total Amount of Proposed Project: $1,523,384

Duration of Project: 1 Year

Point of Contact (POC): David Johnson

POC Telephone: (701) 580 - 5494

POC E-Mail Address:

david.johnson@nuverra.com

POC Address:

3711 4th Ave. NE
Watford City, ND 58854

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ABSTRACT

Objective: The key objective of the proposed project is to demonstrate, evaluate, and quantify the geotechnical and environmental performance of drill cuttings treated by Nuverra Environmental Solutions' (Nuverra's) Terrafficient℠ process. The treated cuttings from Nuverra's process will be used in three field-scale demonstrations, including 1) a gravel road-surfacing demonstration project in conjunction with McKenzie County; 2) a road construction project where Nuverra has been contracted by Knife River Corporation to provide fill material for the road subbase; and 3) a landfill daily cover demonstration project at the McKenzie County Landfill. This quantitative assessment will allow Nuverra and its project partners to determine the technical, economic, and environmental feasibility of using treated drill cuttings for these applications with the goal of working with the North Dakota Department of Health to obtain regulatory approval.

Expected Results: This project is expected to demonstrate that treated cuttings can be successfully utilized as beneficial reuse products while providing similar or improved technical performance over the native materials currently used with no adverse environmental impacts.

Duration: The duration of the proposed project will be 12 months (May 1, 2015, to April 30, 2016).

Total Project Cost: The total cost of the project is $1,523,384. The amount requested from the Oil and Gas Research Council is $759,860. In-kind cofunding will be provided by Nuverra and McKenzie County totaling $342,529, and cash cofunding in the amount of $420,995 by Nuverra.

Participants: Participants include Nuverra, the Energy & Environmental Research Center, the Civil Engineering Department at the University of North Dakota, and the Upper Great Plains Transportation Institute of North Dakota State University. McKenzie County and the Knife River Corporation will partner with these organizations on selected demonstration tests by providing the field support for material preparation and installation.

PROJECT DESCRIPTION

Objectives:

The goal of this test program is to document, quantify, and mechanistically describe the geotechnical and environmental performance of cuttings-based beneficial reuse products applied in three field-scale demonstrations, including 1) a road-surfacing demonstration project in McKenzie County to evaluate the performance of road surface materials comprising Class 13 aggregate blended with treated drill cuttings; 2) a road fill demonstration project near the Nuverra Environmental Treatment Center consisting of a blend of the treated drill cuttings and standard fill material used by the Knife River Corporation; and 3) a landfill daily cover demonstration project at the McKenzie County Landfill. This quantitative understanding will allow the Nuverra technical team to predict any potential environmental impacts for future commercial applications of these beneficial use strategies for the purpose of working with the North Dakota Department of Health (NDDH) to obtain regulatory approval.

Methodology:

Nuverra's Terrafficient℠ process removes and recovers residual hydrocarbons from drill cuttings while reducing the naturally occurring salt content of the cuttings, resulting in a material that has many potential beneficial reuse applications. This project proposes to demonstrate the beneficial reuse of Nuverra's cuttings through three field-scale projects, the performance of which will be evaluated using an integrated combination of laboratory characterization, bench-scale studies, and field-scale demonstration tests. Additional details on the project methodology can be found in Appendix D.

Task 1: Laboratory Characterization. Task 1 will be overseen by the Energy & Environmental Research Center (EERC) with the goal of determining the chemical and geotechnical properties of several materials to support the final design of the proposed field-scale demonstration tests. Multiple samples of treated cuttings and produced water samples (to be used as a dust suppressant for the road-surfacing project) will be collected and analyzed to determine the variability in these materials. Geotechnical characterization will be conducted at the University of North Dakota (UND) Civil Engineering Department to determine the optimal blends of materials for the road-surfacing and road fill demonstrations. Testing will include

gradation and plasticity index (PI) testing and determination of moisture–density relationships.

Task 2: Bench-Scale Studies. Bench-scale tests will be conducted to simulate the effects of rainfall events (and subsequent surface runoff/infiltration) on the fate and transport of various constituents of interest (COIs) within the reuse application scenarios. A list of COIs to be evaluated in the water samples for these tests and subsequent field tests will be submitted to NDDH for review within the environmental sampling and monitoring plan (Appendix D). These bench-scale tests will be constructed to mimic the physical systems of the demonstration tests, e.g., compaction and slope, using a commercially available rainfall simulator. Evaluations of the treated cuttings will support all three demonstrations, while additional studies will be demonstration-specific.

Task 3: Field-Scale Demonstration Tests. The demonstration projects will be located near Nuverra's Environmental Treatment Center south of Arnegard, North Dakota (Appendix A). The road-surfacing demonstration project will be conducted using test sections to evaluate performance and potential environmental impacts of a road that has been surfaced using blends of aggregate and treated drill cuttings with and without dust suppressants. Two test sections made up of standard aggregate with and without dust control methods will serve as controls. Evaluation of the road performance will include routine visual inspections of the road surface for corrugation and rutting. The potential for air quality and surface water impacts will be assessed with respect to each test section. Dust emissions will be collected on a monthly basis. Stormwater runoff will be collected and analyzed predemonstration and from up to three storm events following placement. The layout of the test sections are depicted in Figure 1.

A second demonstration project will use a blend of treated drill cuttings and native fill as a subbase for a road to be reconstructed near Nuverra's Environmental Treatment Center. The goal of the project is to determine an optimal environmentally acceptable blend for use as fill material and to assess the environmental performance of the material through water sampling and analysis from a ditch adjacent to the road construction site. The subgrade, subbase, and base course will be covered with a relatively impermeable pavement surface course. The water quality data from this effort will be evaluated based on a comparison with the quality of the water in this wet area prior to the construction of the road.

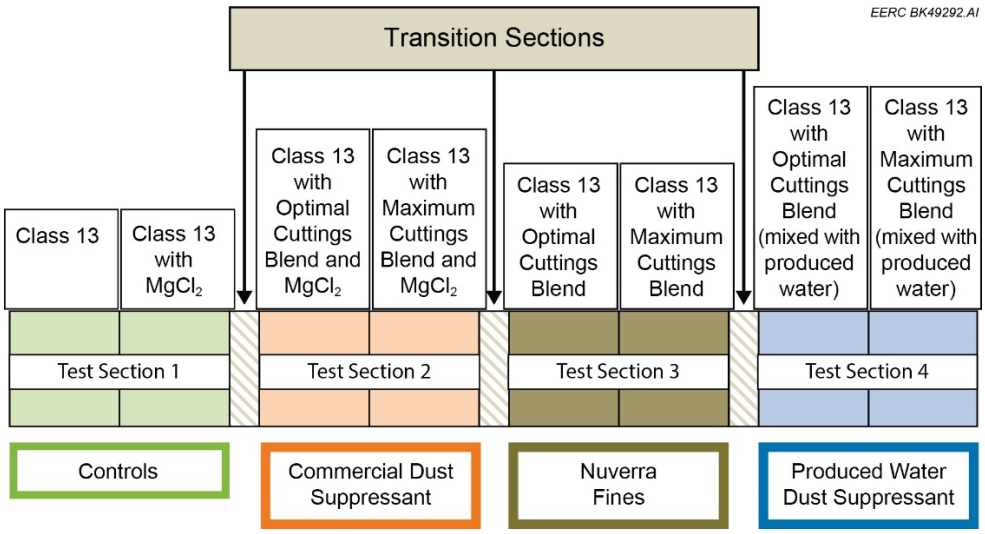


Figure 1. Layout of test sections and surface material blends for the road-surfacing demonstration.

The third demonstration project will investigate the use of Nuverra's treated drill cuttings as an alternative daily landfill cover for the McKenzie County Landfill. This beneficial reuse is of interest given the geotechnical suitability of the material for use as a daily landfill cover and the close proximity of Nuverra's treatment facility to the landfill. Field measurements will be made during the demonstration project to evaluate the potential impacts to the landfill leachate quality associated with this beneficial reuse strategy. These field measurements will focus on the characterization of the rainfall runoff from the compacted landfill daily cover of the test cell and the landfill leachate that is collected from this test cell.

Anticipated Results:

It is anticipated that these demonstrations will show that treated drill cuttings can be beneficially reused in applications that typically require native resources. The anticipated benefits of adding treated drill cuttings to the road surface aggregate currently used in McKenzie County include improved safety through reduced dust and traffic risks, improved gravel surface skid resistance, and reduced corrugation; decreased surface permeability, resulting in fewer roadway shutdown days; resource conservation with reduced application frequency and associated cost for gravel resurfacing projects; and improved long-term performance. The use of treated drill cuttings as part of a subbase road fill represents a beneficial reuse strategy that will substantially reduce the quantity of native fill material that is required for road

construction projects, thereby helping to conserve North Dakota's natural resources. Landfill daily cover materials reduce the release of odors from the landfill and provide a firm surface on which vehicles can operate. Currently, the daily cover material that is used for the McKenzie County Landfill is a resource that could otherwise be used for construction-related activities; it is also costly to transport to the landfill. Use of treated drill cuttings as daily cover will minimize the use of the current cover materials, thereby making them available for other uses while reducing truck traffic and attendant transportation cost for the cover materials and the unnecessary nonbeneficial disposal of the treated drill cuttings.

Facilities:

The processed drill cuttings for bench-scale testing and field-scale implementation will be generated at Nuverra's Environmental Treatment Center. This facility has the current capacity to process and treat over 150 tons/day with a projected future capacity to process 600 tons/day. The facility is currently equipped with storage space for 300 tons of processed material, with additional storage being built.

Laboratory characterization and bench- and field-scale testing will be conducted by the EERC and by the Civil Engineering Department at UND. The EERC houses several laboratories that have the capabilities to characterize the inorganic and organic content of solid and aqueous samples. These laboratories have decades of experience and have been instrumental in conducting a broad range of research, including research to support previous Nuverra research activities and the evaluation of beneficial reuse options for fly ash. (See Appendix B for detailed description of relevant EERC capabilities.) The UND Civil Engineering Laboratory is fully equipped to evaluate almost all materials and testing parameters used in civil engineering. To accomplish the goals of this project, its geotechnical characterization capabilities will be utilized to perform sieve analyses, PI determination, and compactions characterization (moisture/density relationship) of the cuttings. Additional details on the capabilities of the Civil Engineering Laboratory are provided in Appendix B.

Resources:

The proposed project will be overseen and managed by Nuverra and will include a technical team consisting of Nuverra, the EERC, the Civil Engineering Department at UND, and the Upper Great Plains

Transportation Institute (UGPTI) of North Dakota State University (NDSU). McKenzie County and the Knife River Corporation will partner with these organizations on selected demonstration tests by providing the field support for material preparation and installation. In-kind cost share will be provided by Nuverra and McKenzie County. The project team will work closely together with the Oil & Gas Research Council (OGRC) through project meetings and reporting to ensure project quality and timeliness. The project team will also continue to work with NDDH by providing project-specific information to gain acceptance on the beneficial reuse of oilfield wastes in the state of North Dakota. The educational contribution of the project will be fulfilled by public reporting to OGRC and presentation of the project approach and findings at a minimum of one major regional conference or symposium, such as the Williston Basin Petroleum Conference or a Society of Professional Engineers (SPE) meeting.

Techniques to Be Used, Their Availability and Capability:

Laboratory characterization and bench-scale testing will be conducted on representative samples of the materials to be used in the field-scale demonstrations. The treated drill cuttings will be generated through the Terrafficient process at Nuverra's Environmental Treatment Center. Bench-scale testing will be performed at the EERC using a rainfall simulator that will be purchased from Conservation Demonstrations. The EERC will also perform the chemical characterization, and analyses from the bench- and field-scale tests will be conducted using x-ray fluorescence, x-ray diffraction, gas chromatography, inductively coupled plasma (ICP)–mass spectroscopy, ICP–atomic emission spectrometry, and ion chromatography. Total petroleum hydrocarbon analyses on aqueous samples will be submitted by the EERC to the commercial laboratory Energy Laboratories, Inc. The geotechnical characterization activities of gradation, PI testing, and moisture–density relationships as well as the dust collection testing will be performed using standard ASTM International methods with equipment currently available in the UND Civil Engineering Department Laboratory.

The materials, water, and dust suppressants for the road-surfacing demonstrations will be placed with equipment currently available to Nuverra and McKenzie County. The road fill will be placed with equipment currently available to Nuverra and Knife River Corporation. Treated drill cuttings for use as

landfill daily cover will be transported by Nuverra and applied by the McKenzie County Landfill using currently available equipment. Supplies for stormwater runoff collection will be purchased.

Environmental and Economic Impacts While Project Is Under Way:

No significant environmental or economic impacts are anticipated during the period of performance of the project. Previous material characterization and leaching tests conducted by the EERC suggest that the use of treated drill cuttings in the targeted applications will have no significant environmental impact.

Ultimate Technological and Economic Impacts:

Ultimately, the beneficial use of treated cuttings, and the recovery and reuse of diesel within the cuttings, creates the following technological and economic impacts: prolongs the natural resources of the state by supplementing aggregate and fill materials; creates a cost saving for local governments by reducing the amount of native resources purchased; reduces the long-term environmental and associated economic liability for producers by eliminating the need for on-site cuttings pits which could fail or be breached in the future; prolongs the lifetime of special waste landfills by reducing the disposed volume of drilling waste; and creates a cost saving to industry through recycling and reuse of diesel fuel as a drilling mud component.

Why the Project Is Needed:

Given the magnitude and long-term outlook of oil and gas development in the Williston Basin, environmentally friendly options for recycling and reuse of drilling waste are needed to reduce the environmental footprint of drilling activities. Based on previous work conducted by Nuverra and the EERC, on average, drilling a typical Bakken well produces waste containing 600 tons of cuttings (dry equivalent) and 10,000–12,000 gallons of diesel. Currently this waste material is buried on-site in cuttings pits, or transported to special waste landfills. Nuverra's process results in a material that is geotechnically and environmentally suitable for beneficial reuse, while recovering and recycling the diesel fuel that is present in the drilling waste. Widespread recycling and reuse of drilling waste would substantially reduce the environmental footprint of oil and gas drilling activities. This project is needed to demonstrate and evaluate the effectiveness of the treated cuttings in various field-scale beneficial reuse applications and to obtain approval from NDDH for future beneficial reuse of this material in those applications.

STANDARDS OF SUCCESS

Success will be measured according to the timely execution of the three demonstration projects encompassed within this effort, and through documentation of their performance. By removing and recovering the hydrocarbons that are mixed with the cuttings (via the drilling mud or from crude oil from the target reservoir) and by reducing the salt content of the material, Nuverra's Terrafficient process provides the following value to North Dakota: a reduction in on-site cuttings pits or decreased disposal of waste in special waste landfills reduces the environmental footprint of oil and gas development; substitution of a portion of native aggregate and fill material used for road construction or as daily landfill cover helps to conserve the natural resources of the state; recovery and reuse of the diesel from the cuttings helps reduce the need for fresh diesel used in drilling mud, while eliminating the unnecessary disposal or on-site burial of this reusable resource; and the development of environmental performance measures in conjunction with NDDH will help pave the way for other drill cuttings recycling and reuse technologies and applications within the state.

While other commercial entities have indicated interest in beneficial reuse of drill cuttings, there has yet to be a vigorous scientific characterization of the materials and subsequent field-scale demonstration and evaluation of the geotechnical and environmental performance of various beneficial reuse applications. Performing these demonstration projects and working with NDDH to obtain regulatory approval will provide a pathway by which other commercial entities can work toward obtaining approval to implement other beneficial reuse applications. Pending NDDH approval, commercial application of Nuverra's beneficial reuse products is highly likely given that McKenzie County is a vested partner in this project and very interested in reducing its aggregate and fill costs for road-surfacing and landfill daily cover. In addition, Knife River Corporation is supportive of the use of treated cuttings as road subbase.

In terms of job creation, demonstration of these beneficial reuse applications and ultimate approval by NDDH will not only help immediately support 15–20 permanent jobs and an anticipated 100 or more jobs supporting Nuverra's Environmental Treatment Center, but it will, at its full planned capacity, pave the way for other commercial drilling waste recycling operations to become active in North Dakota, creating

additional job opportunities.

This project will illustrate the commitment of the state of North Dakota and industry toward reducing the environmental impacts of oil and gas development and toward the responsible use of North Dakota resources. Through a rigorous scientific assessment of these reuse applications, this project will provide robust data and information about the geochemical and geotechnical nature of drill cuttings and their environmental suitability for reuse.

The benefits described above help to accomplish many of OGRC's goals, including promoting the environmentally sound development of North Dakota's oil and gas resources; encouraging the use of new technologies and ideas that will have a positive economic and environmental impact on oil and gas development in North Dakota; maximizing the market potential for oil, natural gas, and the associated by-products produced therewith; improving the overall suitability of the oil and gas energy industry in North Dakota through the development of new environmental practices that will help to reduce the footprint of oil and gas activities; and developing baseline information that will lead to other projects, processes, ideas, and activities.

The success of the project will be described through the development of a comprehensive final report and summary presentation(s) for download to the OGRC Web site, in addition to presentations and/or papers prepared for at least one major regional conference, such as the Williston Basin Petroleum Conference or a regional SPE meeting.

BACKGROUND/QUALIFICATIONS

Personnel:

David Johnson, Director of Nuverra Environmental Solutions, will serve as program manager and lead principal investigator. Three additional principal investigators will coordinate the research activities. John Harju, EERC Associate Director for Research, and Bethany Kurz, EERC Senior Research Manager, will lead the technical research activities to be performed by all parties, including the test components to be performed at the EERC. Dr. Daba Gadafa will coordinate the geotechnical and field testing components to be conducted by UND Civil Engineering. Dale Heglund, North Dakota Local Technical Assistance

Program Director, NDSU's UGPTI, will serve as a project advisor on the road demonstration projects. Additional key research staff will include Loreal Heebink, EERC Research Chemist, and Bruce Dockter, UND Civil Engineering Senior Lecturer. Resumes of key personnel are provided in Appendix C.

Experience:

Nuverra is one of the largest environmental solutions companies in the United States, with more than 2,000 employees and operations in more than 39 locations across 10 states. Nuverra is dedicated to the removal, treatment, recycling, transportation, and disposal of restricted solids, fluids, and hydrocarbons for major exploration and production companies operating in the oil and gas basins. The Nuverra Environmental Treatment Center is a new, technically advanced, state-approved facility in the heart of the Bakken that accepts solid waste from oilfield exploration and production activities in the area. Nuverra coordinates all solid waste disposal needs for its Bakken customers, including on-site collection, transportation, and disposal of accepted materials.

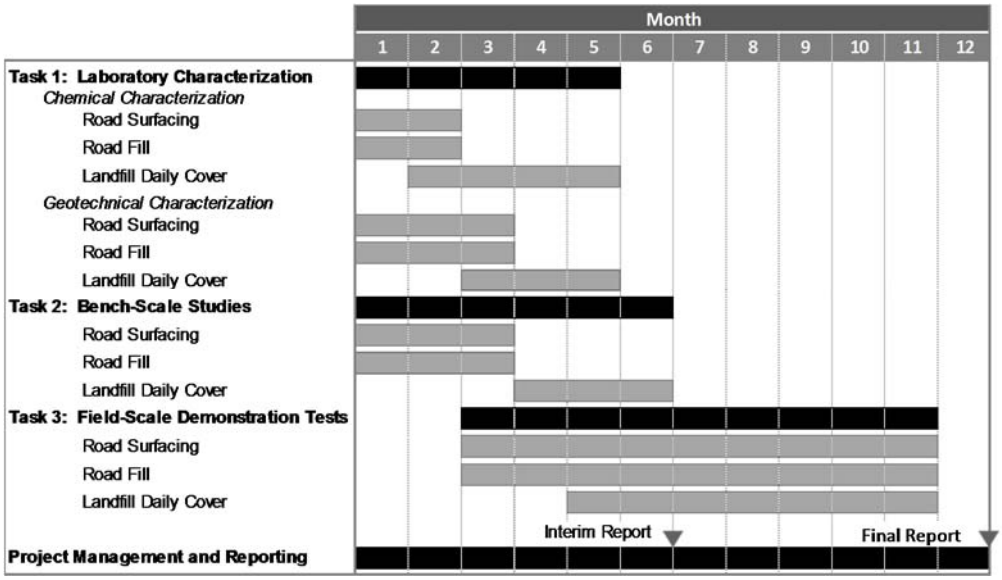
The EERC is a nonprofit contract research center at UND. The EERC has been actively engaged in assessing practical, economical, and environmentally friendly solutions to optimize surface operations in the Bakken, including options for dealing with oilfield waste, through the Bakken Production Optimization Program. This program is funded by OGRC with matching funds provided by several industrial partners. In conjunction with Nuverra, the EERC has been actively engaged in characterizing the physical, geochemical, and geotechnical properties of cuttings generated from the drilling of Bakken wells to identify various beneficial reuse options. The EERC also has past experience evaluating beneficial reuse options for fly ash and working with NDDH to obtain regulatory approval for those uses.

The staff at UND's Department of Civil Engineering conduct research in the areas of pavement and materials, and environmental, geotechnical, and water resources engineering. The professors involved in this effort recently completed a project sponsored by the North Dakota Association of Oil and Gas Producing Counties to evaluate dust generation and daily traffic from five counties in North Dakota: three western counties and two eastern counties. Their research experience also includes the evaluation of beneficial reuse options for fly ash, including the use of fly ash in concrete and as road material.

MANAGEMENT

Nuverra will oversee the proposed efforts to ensure that all planned activities are being performed according to the scope of work and time line established. The EERC will assist Nuverra in tracking progress, milestones, and deliverables, given its past experience in managing large, multicomponent research projects. Best practices and dedicated professional staff are provided to EERC project managers and clients in providing up to date budget and expense status, and contract services. The EERC's project managers and principal investigators will ensure that spending is occurring according to the planned budget and that project milestones and deliverables are completed according to the planned scope of work, which is summarized in the timetable. Project deliverables will include an interim progress report, a final report, and a summary presentation.

TIMETABLE



BUDGET

Project Associated Expense	NDIC's Share	Nuverra's Share (In-Kind and Cash)	McKenzie County's Share (In-Kind)	Total Project
Project Administration	$130,000	-	-	$130,000
Equipment Use and Operating Fees	$154,183	-	$16,600	$170,783
Material Costs	-	$158,496	$167,433	$325,929
Subcontract to UND	$475,677	$420,995	-	$896,672
Total:	**$759,860**	**$579,491**	**$184,033**	**$1,523,384**

The total cost of the project is $1,523,384. The amount requested from the OGRC is $759,860. Cofunding will be provided by Nuverra in the form of in-kind support for provision of the treated cuttings, as well as a cash contribution totaling $420,995 which has been provided to the EERC for cuttings characterization efforts to support the proposed demonstration projects (see confirmation letter in Appendix E). Of the total amount requested from OGRC, Nuverra's costs total $284,183. These costs include those for general project coordination and administration, as well as the labor, material, and trucking costs needed to supply the cuttings to the demonstration sites. The remaining amount requested, $475,677, will be subcontracted to UND. A letter of commitment from UND can be found in Appendix F. This subcontract includes all of the materials characterization, bench- and field-scale testing and associated analytical work to be conducted at the EERC and UND Civil Engineering. In addition to the cost share being provided by Nuverra, McKenzie County has agreed to provide an estimated $184,033 in the form of in-kind support for the road surface demonstration project. A letter of commitment from McKenzie County can be found in Appendix F. This support includes provision of all of the commercially available materials (i.e., aggregate and magnesium chloride dust suppressants) and equipment needed for emplacement of the road test sections, as well as associated labor costs to run the equipment.

If less funding is available, the project scope of work could be reduced accordingly, such as the demonstration of only one or two of the three proposed field tests.

CONFIDENTIAL INFORMATION

There is no confidential information disclosed in this funding request.

PATENTS/RIGHTS TO TECHNICAL DATA

Patents or rights do not apply to this proposal.

STATUS OF ONGOING PROJECTS (IF ANY)

Nuverra has not previously received funding from OGRC.

AFFIDAVIT OF TAX LIABILITY

See Appendix G.

APPENDIX A

DEMONSTRATION LOCATIONS

Figure A-1. The locations of the proposed demonstration projects.

APPENDIX B

CAPABILITIES

RELEVANT EERC LABORATORY CAPABILITIES

Natural Materials Analytical Research Laboratory

- 4200-square-foot laboratory facility
- JEOL 5800 scanning electron microscope with NORAN instruments energy-dispersive spectrometer (EDS) detector system, GW Electronics enhanced backscatter detector, and NORAN instruments microanalysis system
- JEOL 5800 LV with Princeton Gamma-Tech Spirit Instruments EDS and microanalysis system and a HKL Technology electron backscatter diffraction system.
- Rigaku ZSK Primus II x-ray fluorescence system
- Bruker AXS D8 ADVANCE x-ray diffraction system

Analytical Research Laboratory

- 4200-square-foot, fully equipped, exceedingly clean laboratory with seven fume hoods
- VG PQ ExCell inductively coupled plasma–mass spectrometer (ICP–MS) with collision cell technology
- Perkin Elmer Optima 2100 ICP–AES
- CETAC M6000A cold-vapor atomic absorption spectrometer (CVAAS) mercury analyzer
- PS Analytical Millennium Merlin cold-vapor atomic fluorescence spectrometer (CVAFS)
- PS Analytical Millennium Excalibur hydride generation atomic fluorescence spectrometer (HGAFS)
- Varian Spectra AA-880Z graphite furnace atomic absorption spectrometer (GFAAS)
- Mitsubishi TOX-100 chlorine analyzer with oxidative hydrolysis microcoulometry
- Dionex ISC3000 ion chromatograph (IC) with conductivity detection
- Dionex 2020i IC with UV–VIS, conductivity, and electrochemical detection
- CEM MDS 2100 microwave with temperature and pressure control
- Shimadzu Total Organic Carbon Analyzer TOC-L

Environmental Chemistry Laboratory

- Several Hewlett-Packard 5890 capillary gas chromatographs equipped with both on-column and split/splitless injection ports and a variety of detectors (flame ionization detector [FID], electron capture detector [ECD], and atomic emission detector [AED])
- High-pressure liquid chromatography (HPLC) with UV and a refractometric detector
- Three Hewlett-Packard gas chromatography-mass spectrometry (GC–MS) systems (a 5972 and two 5973s) with electron impact or chemical ionization mode
- Supercritical fluid chromatography (SFC)-MS
- Supercritical fluid extraction (SFE)
- ISCO (100D and 260D) pumping systems
- Several EERC-constructed laboratory-scale systems and one pilot-scale (8-L) unit to perform subcritical water extractions and reactions
- Solid-phase microextraction (SPME)

UNIVERSITY OF NORTH DAKOTA
CIVIL ENGINEERING DEPARTMENT
LABORATORY CAPABILITIES

The UND Civil Engineering Laboratory is fully equipped to evaluate for almost all materials testing parameters used in civil engineering. These materials include concrete, cement, aggregates, soils, and asphalt oils.

Some of the specific procedures include:

- Testing for compressive strength of hydraulic cement mortars, ASTM C 109
- Determination of time of setting of hydraulic cement by Vicat needle, ASTM C 186 and by Gilmore needles, ASTM C 266
- Fineness by air permeability, ASTM C 204
- Fly ash and other pozzolans for use with lime, ASTM C 593
  - Compressive strength
  - Vacuum saturation test
- ASTM C666: Resistance of concrete specimens to rapid freezing and thawing in water, Procedure A
- ASTM C 215: Test for fundamental transverse frequency of concrete specimens
- ASTM C 469: Static modulus of elasticity of concrete in compression, 6- × 12-inch and 4- × 8-inch cylinders
- Bituminous (asphalt concrete) testing
  - Marshall hot-mix design by ASTM D 1559
  - Extraction, Rice voids analysis by ASTM D 2172
- Permeability testing
  - Concrete cylinders (6 × 12 in.)
  - Soil and other materials
  - ASTM D2343: Membrane-type permeameter (triaxial apparatus)
  - Bureau of Reclamation: Falling and constant head methods
- ASTM C 192: Laboratory batching and testing of portland cement concrete
- ASTM C 136: Test Method for Sieve Analysis of Fine and Coarse Aggregates
- ASTM D 4318: Test Method for Liquid Limit, Plastic Limit , and Plasticity Index of Soils
- ASTM D 698: Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,000 ft-blf/ft^3)
- ASTM D 5821: Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
- ASTM D 2419: Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate

UGPTI ADVISORY CAPABILITIES

The Upper Great Plains Transportation Institute (UGPTI) is a research, education, and outreach center at North Dakota State University which is guided, in part, by an advisory council composed of representatives of various organizations, industries, and agencies affecting or affected by transportation.

MISSION:

Providing innovative transportation research, education, and outreach that promote the safe and efficient movement of people and goods.

- Research — Conducting applied and advanced research in highway, transit, rail, air, and waterway transportation that addresses the critical issues of the state, region, and nation.

- Education — Educating the transportation workforce of tomorrow through multidisciplinary curricula that focus on transportation economics, management, infrastructure planning, mobility, and supply chain logistics.

- Outreach — Improving the skills and knowledge of the existing workforce through training, technical assistance, and the transfer of research results to practitioners.

APPENDIX C

RESUMES OF KEY PERSONNEL

David L. Johnson, PE

Nuverra Environmental Solutions, Inc.
Director of Total Environmental Management Systems

Mr. Johnson serves as Director of Total Environmental Management Systems for Nuverra Environmental Solutions, Inc., one of the largest U.S. companies dedicated to providing comprehensive and full-cycle solutions to customers in the energy end-market. Mr. Johnson joined Nuverra in May 2013 and oversees the Company's solid waste and pipeline solutions projects.

During his tenure with Nuverra, Mr. Johnson has completed permitting and opened a special waste landfill in Western North Dakota's Bakken Shale region; led research and development efforts for Terrafficient^{SM}, the Company's innovative solution for drilling waste, and developed a pipeline system for major customer that will become the foundation for water pipeline infrastructure in the Company's Rocky Mountain Division.

Before joining Nuverra, Mr. Johnson was Operations Manager for AE2S, a North Dakota-based provider of civil/environmental engineering services. He was instrumental in the development of the Western Area Water Supply project and managed staff for several infrastructure projects in Willison and Watford City, North Dakota.

Prior to AE2S, Mr. Johnson worked eight years as District Engineer for the Garrison Diversion Conservancy District. He was the state representative on the Interdisciplinary Team that conducted the Red River Valley Water Supply environmental impact statement and led the team to complete the design of the water transfer project. He also managed the operation and maintenance of the principal supply works for the district.

Mr. Johnson spent 15 years serving as the Watford City, North Dakota, City Engineer/City Administrator, where he managed all city infrastructure, including water and waste water treatment collection and distribution. He also led the effort to permit and construct the McKenzie County landfill and closed the Watford City Landfill. Mr. Johnson served as Chairman of the McKenzie County Water Resource Board when the rural water system in McKenzie was started.

Mr. Johnson is a North Dakota native and Registered Professional Engineer, with a Bachelor of Science degree in Mechanical Engineering from North Dakota State University.

JOHN A. HARJU
Associate Director for Research
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5157, Fax: (701) 777-5181, E-Mail: jharju@undeerc.org

Principal Areas of Expertise

Mr. Harju's principal areas of interest and expertise include carbon sequestration, enhanced oil recovery, waste management, geochemistry, technology development, hydrology, and analytical chemistry, especially as applied to the upstream oil and gas industry.

Qualifications

B.S., Geology, University of North Dakota, 1986.

Postgraduate course work in Management, Economics, Marketing, Education, Climatology, Weathering and Soils, Geochemistry, Geochemical Modeling, Hydrogeochemistry, Hydrogeology, Contaminant Hydrogeology, Advanced Physical Hydrogeology, and Geostatistics.

Professional Experience

2002–Present: EERC, UND, Grand Forks, North Dakota.

2011–Present: Associate Director for Research. Mr. Harju oversees the activities of a team of scientists and engineers focused on research, development, demonstration, and commercialization of energy and environmental technologies. Strategic energy and environmental issues include zero-emission coal utilization; CO_2 capture and sequestration; energy and water sustainability; hydrogen and fuel cells; advanced air emission control technologies, emphasizing SO_x, NO_x, air toxics, fine particulate, and mercury control; renewable energy; wind energy; water management; flood prevention; global climate change; waste utilization; energy efficiency; and contaminant cleanup.

2003–2011: Associate Director for Research. Mr. Harju's responsibilities included developing and administering programs involving petroleum technology, natural resource evaluations, water management and contamination cleanup and building industry–government–academic teams to carry out research, development, demonstration, and commercialization of energy and environmental products and technologies.

2002–2003: Senior Research Advisor. Mr. Harju's responsibilities included development, marketing, management, and dissemination of market-oriented research; development of programs focused on the environmental and health effects of power and natural resource production, contaminant cleanup, water management, and analytical techniques; publication and presentation of results; client interactions; and advisor to internal staff.

1999–2002: Vice President, Crystal Solutions, LLC, Laramie, Wyoming. Mr. Harju's firm was involved in commercial E&P produced water management, regulatory permitting and compliance, and environmental impact monitoring and analysis.

1997–2002: Gas Research Institute (GRI) (now Gas Technology Institute [GTI]), Chicago, Illinois.

2000–2002: Principal Scientist, Produced Water Management. Mr. Harju's responsibilities included development and deployment of produced water management technologies and methodologies for cost-effective and environmentally responsible management of oil and gas produced water.

1998–2000: Program Team Leader, Soil, Water, and Waste. Mr. Harju's responsibilities included project and program management related to the development of environmental technologies and informational products related to the North American oil and gas industry; formulation of RFPs, proposal review, and contract formulation; technology transfer activities; and staff and contractor supervision. Mr. Harju served as Manager of the Environmentally Acceptable Endpoints project, a multiyear, $8MM effort focused on a rigorous determination of appropriate cleanup levels for hydrocarbons and other energy-derived contaminants in soils. He also led GRI/GTI involvement with numerous industry environmental consortia and organizations, including PERF, SPE, AGA, IPEC, and API.

1997–1998: Principal Technology Manager, Soil and Water Quality.
1997: Associate Technology Manager, Soil and Water Quality.

1988–1996: EERC, UND, Grand Forks, North Dakota.
1994–1996: Senior Research Manager, Oil and Gas Group. Mr. Harju's responsibilities included the following:

- Program Manager for program to assess the environmental transport and fate of oil- and gas-derived contaminants, focused on mercury and sweetening and dehydration processes.
- Project Manager for field demonstration of innovative produced water treatment technology using freeze crystallization and evaporation at oil and gas industry site.
- Program Manager for environmental transport and fate assessment of MEA and its degradation compounds at Canadian sour gas-processing site.
- Program Manager for demonstration of unique design for oil and gas surface impoundments.
- Director, National Mine Land Reclamation Center for Western Region.
- Co-Principal Investigator on project exploring feasibility of underground coal gasification in southern Thailand.
- Consultant to International Atomic Energy Agency for program entitled "Solid Wastes and Disposal Methods Associated with Electricity Generation Fuel Chains."

1994: Research Manager.
1990–1994: Hydrogeologist.
1989–1990: Research Specialist.
1988–1989: Laboratory Technician.

Synergistic Activities

Member, National Petroleum Council
Outgoing Chairman, Interstate Oil & Gas Compact Commission, Chairman, Energy Resources, Research and Technology Committee
Member, U.S. Department of Energy Unconventional Resources Technology Advisory Committee
Member, Rocky Mountain Association of Geologists

Publications and Presentations

Has authored and coauthored numerous publications.

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Principal Areas of Expertise

Ms. Kurz's principal areas of interest and expertise include the evaluation of water and waste management strategies for the oil and gas industry, assessment of the fate and transport of chemical constituents in surface water and groundwater, and the geochemical and geological characterization of reservoirs for CO_2-based enhanced oil recovery and/or carbon storage.

Qualifications

M.S. (Summa Cum Laude), Geology, University of North Dakota, Grand Forks, ND, 1998.
B.S. (Summa Cum Laude), Geochemistry, Bridgewater State University, Bridgewater, MA, 1995.

Professional Experience

2011–Present: Senior Research Manager, Oil and Gas Research Program, EERC, UND. Ms. Kurz's activities include the management of research efforts focused on produced water and drilling waste management and beneficial reuse, characterization of geologic media for enhanced oil recovery and carbon storage, characterization of unconventional resources and the development and testing of proppants for use in hydraulic fracturing. Ms. Kurz oversees several of the EERC's analytical research laboratories that focus on petrochemical and geomechanical evaluation of rocks and soils; mineralogical assessment of natural materials using optical microscopy, x-ray fluorescence, x-ray diffraction, and scanning electron microscopy; and classical and advanced wet-chemistry analyses..

2002–2011: Senior Research Manager, Water Management and Flood Mitigation Strategies, EERC, UND. Ms. Kurz's activities included the evaluation of nontraditional water supply sources for use in municipal and industrial applications, development of strategies to address future water shortages, flood and drought mitigation, water quality modeling to evaluate efficacy of best management practices (BMPs) to reduce soil and nutrient runoff, and public education and outreach on various water and energy issues.

1998–2002: Research Scientist, Subsurface Remediation Research, EERC, UND. Ms. Kurz's activities included management and implementation of projects to remediate hydrocarbon contaminated groundwater and soils, evaluation of mercury and heavy metals contamination in organic-rich sediments, groundwater sampling and analysis, technical report writing, and proposal research and preparation.

1997–1998: Research Assistant, Water Quality Laboratory, Department of Geology and Geological Engineering, UND. Ms. Kurz's duties included the operation and maintenance of a water quality laboratory containing several analytical instruments, including an ion chromatograph, inductively coupled plasma emission spectrometer, total organic carbon analyzer, and several ion selective electrodes.

Publications and Presentations

Publications available upon request.

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(a) Professional Preparation

Addis Ababa University, Addis Ababa, Ethiopia, Civil Engineering, B.S., 2001
Indian Institute of Technology Bombay, Mumbai, India, Civil Engineering, M.Tech., 2005
Kansas State University, Manhattan, KS, Civil Engineering, Ph.D., 2008
Kansas State University, Manhattan, KS, Pavement and Materials Eng., Post-doc, 12/08-08/09

(b) Appointments

Assistant Professor, Civil Engineering Department, College of Engineering and Mines, University of North Dakota, Grand Forks, ND Aug. 2011 – present
Assistant Professor in Residence, Civil & Environmental Engineering Department, School of Engineering, University of Connecticut, Storrs, CT Aug. 2009-2011
Post-doctoral Research Associate, Civil Engineering Department, College of Engineering, Kansas State University, Manhattan, KS Dec. 2008-Aug. 2009
Graduate Research Assistant, Civil Engineering Department, College of Engineering, Kansas State University, Manhattan, KS Aug. 2005-Nov. 2008
Assistant Lecturer, Civil Engineering Department, School of Engineering, Arbaminch University, Arbaminch, Ethiopia Sep. 2002-Jul. 2003
Office Engineer, Alemayehu Ketema General Contractor, Addis Ababa, Ethiopia Oct. 2001-Oct. 2002

(c) Products

i. Five Products Most Closely Related

1. **Gedafa, D.S.**, Gullicks, H., and Page, J. (2014). *Measuring Dust from Unpaved Roads and Its Impact on Crops and Livestock,* Report submitted to North Dakota Association of Oil and Gas Producing Counties.
2. **Gedafa, D.S**., Hossain, M., Siddique, Z.Q., Fredrichs, K., and Meggers, D. (2012). "Curling of new concrete pavement and long-term performance." *Journal of Civil Engineering and Architecture,* 6(2): 121-131.
3. **Gedafa, D.S.**, Khanum, T., Hossain, M., and Schieber, G. (2011). "Effect of construction environment on JPCP performance." *Proceedings of 1st Transportation and Development Institute of the American Society of Civil Engineers Congress*, **Chicago, IL, 2:** 834-843**.**
4. Khanum, T., Hossain, M., Gisi, A., and **Gedafa, D.S.** (2008). "15-Year performance of SPS-2 in Kansas." *Proceedings of 9th International Conference on Concrete Pavements: The Golden Gate to Tomorrow's Concrete Pavements*, International Society of Concrete Pavements, San Francisco, CA, 2: 976-994.
5. **Gedafa, D.S.**, Hossain, M., Ingram,L.S., R. Kreider, R. (2011). "Performance-related specification for superpave pavements in Kansas." *Transportation Research Record: Journal of the Transportation Research Board,* 2228: 78-86.

(ii) Five Other Significant Products

1. **Gedafa,D.S**., Hossain, M., Romanoschi, S. A., and Gisi, A. J. (2010). "Comparison of moduli of Kansas superpave asphalt mixes." *Transportation Research Record: Journal of the Transportation Research Board*, 2154:114-123.
2. **Gedafa,D.S**., Hossain, M., Romanoschi, S. A., and Gisi, A. J. (2010). "Field verification of superpave dynamic modulus." *ASCE Journal of Materials in Civil Engineering*, 22(5): 485-494.
3. **Gedafa, D.S**., Uppu, K.K., Hossain,M., Ingram, L.S., and Kreider, R. (2013). "Verification of

performance-related specifications for superpave pavements." *Transportation Research Board 92nd Annual Meeting Compendium of Papers USB (amonline.trb.org)*, Transportation Research Board of the National Academies, Washington, D.C.
4. **Gedafa, D.S**., Hossain, M., Ingram, L.S., and Kreider, R. (2010). "Composite pay index for superpave pavements in Kansas." *Proceedings of 11th International Conference on Asphalt Pavement*, Nagoya, Japan, 1:709-718.
5. Romanoschi,S., Onyango, M., **Gedafa, D**.S. (2010). "Accelerated pavement testing validation of the response and distress models for new flexible pavements in the mechanistic -empirical design guide." *Proceedings of 11th International Conference on Asphalt Pavement*, Nagoya, Japan, 1: 532-541.

(d) Synergistic Activities

Broadening Participation of Native Americans in STEM

Participate in Sunday Academy and Summer Camp to attract and retain Native Americans in STEM fields

Journal Peer-reviewer

ASCE Journal of Materials in Civil Engineering, ASCE Journal of Transportation Engineering, Journal of Civil Engineering and Architecture, Transportation Research Record: Journal of Transportation Research Board, Transportation Research Policy Part C, and International Journal of Pavement Research & Technology

Scientific Committee Member and Co-chair for International Conferences

ASCE Pavement Conference 2015, Scientific committee member for International Conference on Asphalt Pavement 2014 and co-chair for Geo Congress in 2013

Membership and service in professional organizations

American Society of Civil Engineers (Geo-institure committee), Transportation Research Board (AFD40, AFD50, and AFD60 committee member), American Society for Testing and Materials (Committee C09 on Concrete and Concrete Aggregates, Committee D04 on Road and Paving Materials, and Committee E17 on Vehicle - Pavement Systems), International Society for Concrete Pavements, International Society for Asphalt Pavements

Session Chair at International Conference

Served as presiding officer for two sessions at Transportation Research Board 92nd Annual Meeting in 2013

(e) Collaborators & Other Affiliations

- **Collaborators:** Mike **Ayers,** Global Pavement Consultants; Dr. Harvey **Gullicks**, University of North Dakota; Dr. Surojit **Gupta**, University of North Dakota; Dr. Mustaque **Hossain**, Kansas State University; Dr. Zhong **Hu**, South Dakota State University; Dr. Eric **Jackson**, University of Connecticut; Dr. Andrei **Kirilenko**, University of North Dakota; Dr. Howe **Lim**, University of North Dakota; Dr. Iraj **Mamaghani**, University of North Dakota; Dr. Mbakisya **Onyango**, University of Tennessee- Chattanooga; Dr. Stefan **Romanoschi,** University of Texas at Arlington; Dr. Wayne **Seams**, University of North Dakota; Dr. Nabil **Suleiman**, University of North Dakota; Dr. Mijia **Yang**, North Dakota State University; Dr. Habtamu **Zelelew**, Federal Highway Administration; Dr. Julia **Zhao**, University of North Dakota
- **Graduate Advisors and Postdoctoral Sponsors:** Dr. K.V. Krishna **Rao**, Indian Institute of Technology Bombay, India (M.Tech.); Dr. Mustaque **Hossain**, Kansas State University (Ph.D. and Post-doctoral)
- **Thesis Advisor and Postgraduate-Scholar Sponsor:** Daniel **Landrus** (M.S. Advisor), University of North Dakota; Spencer **Tolliver** (M.S. Advisor), University of North Dakota; Bishal **Karki** (M.S. Advisor), University of North Dakota

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Dale's past 35 years have been a blend of growth opportunities: starting out on his family's Northern Minnesota dirt construction business, learning how to produce with a shovel and a backhoe; moving onto college studies, learning engineering fundamentals; accepting challenges of project oversight and engineering design for the NDDOT across much of North Dakota, learning material properties, teamwork and project management; volunteering on professional associations, learning how to give back; selling precast concrete products for Cretex, learning how to help others; and in 2014 accepting the opportunity to join the talented and energetic NDLTAP team, helping North Dakota's transportation system leaders grow.

Employment

- 2014 – Present, NDLTAP Director, Upper Great Plains Transportation Institute
- 2000 - 2014, North Dakota Sales Engineer, Cretex Concrete Products
- 1995 – 2000, Dickinson Assistant District Engineer, North Dakota Department of Transportation
- 1985 – 1995, Transportation Engineer, North Dakota Department of Transportation

Education

- Graduate of Bismarck-Mandan Chamber of Commerce Leadership Development
- Registered North Dakota Professional Engineer and Professional Land Surveyor
- B.S.C.E., Civil Engineering, University of North Dakota, 1985

Professional Memberships/Affiliations

- Order of the Engineer
- NDSPE, Past President
- NDAPWA, Past President
- NDSPLS, Past Continuing Education Committee Member
- ASHE, Central Dacotah Section Charter Member
- NDSPE, Ch 3 Bruce Nelson Award Recipient

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Principal Areas of Expertise

Ms. Heebink's principal areas of interest and expertise include assisting in the planning, development, and management of projects related to core assessment and CO_2 sequestration, beneficial use of wastes, and data management. She is responsible for progress reporting under the U.S. Department of Energy's Plains CO_2 Reduction (PCOR) Partnership. Her recent research has included data management and interpretation, Karl Fischer titration, Dean–Stark extraction, and data sheet generation and reporting in several core assessment projects. Ms. Heebink has experience in evaluating environmental impacts of oilfield waste and coal combustion product (CCP) use and disposal, CCP chemistry, leaching procedures, mercury analyses, sample management, and data management and interpretation. Ms. Heebink developed and maintains project-specific sample analysis-tracking spreadsheets and an internal EERC database containing chemical characterization, leaching, and other laboratory data on CCPs.

Qualifications

B.S., Chemistry, Magna Cum Laude, University of North Dakota, 2000.
A.S., Chemistry, Summa Cum Laude, Minot State University–Bottineau, Bottineau, North Dakota, 1997.

Professional Experience

2012–Present: Research Chemist, Oil and Gas Research Program, EERC, UND. Ms. Heebink's responsibilities are focused on assisting in the workflow management of the Applied Geology Laboratory, technical report writing, data management and interpretation, and data sheet generation. Additional activities include database development and maintenance, beneficial use evaluations, Karl Fischer titrations, helium porosimetry, 3-D scanning for bulk volume, Dean–Stark and Soxhlet extraction techniques, and investigation of carbon dioxide mineralization materials. Beginning in 2015, she is responsible for progress reporting under the U.S. Department of Energy's PCOR Partnership.

2000–2012: Research Chemist, Coal Combustion Product Research, EERC, UND. Ms. Heebink's responsibilities included research focused primarily on the environmental impacts of CCP use and disposal, ultratrace mercury analysis, data interpretation and management, and sample inventory management. She managed the research efforts of the Coal Ash Resources Research Consortium® (CARRC®) from 2010–2012 and other CCP research at the EERC. She also managed several research projects concurrently and was responsible for the technical oversight and fund management of these projects. Areas of interest and expertise included ash chemistry, leaching procedures, ultratrace mercury analysis with a double-gold amalgamation atomic fluorescence apparatus, and database development and maintenance.

1997–1999: Stockroom Assistant, Department of Chemistry, UND. Ms. Heebink's responsibilities included preparing solutions weekly for classroom laboratories, assisting students and instructors with chemicals, and organization of the stockroom.

Professional Memberships
American Chemical Society
North Dakota Academy of Science
Sigma Xi

Publications and Presentations
Has authored or coauthored several publications and presentations.

BRUCE A. DOCKTER
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Principal Areas of Expertise
Principal areas of interest and expertise include physical and chemical analysis of fly ash for utilization in high- and low-volume applications. Extensive work in the field of high-temperature research on the physical and chemical properties of coal ashes, slags and refractory materials.

Qualifications
Registered Professional Engineer, 1993.
M.E., Civil Engineering, University of North Dakota, 1991.
B.S., Civil Engineering, University of North Dakota, 1983.

Professional Experience
2014-Present: Senior Lecturer/Laboratory Manager, Department of Civil Engineering, UND. Responsibilities include teaching undergraduate courses, research activities, service activities and laboratory management.

1991–2014: Research Engineer/Manager, Fuels and Materials Research Laboratory, Energy & Environmental Research Center (EERC), UND. Responsibilities include supervisory and management of laboratory projects and testing procedures and coordination of research efforts between laboratory facilities and EERC project managers for evaluating coal by-products for utilization options. Tasks also include methodology evaluations, proposal writing, and paper publications and presentations.

1985–1991: Chemist II/Manager, Coal By-Products Utilization Laboratory, EERC, UND. Responsibilities included daily operation of laboratory emphasizing setting daily work objectives, supervision of full-time and student employees, and general lab maintenance. Additional responsibilities included training new employees, conducting seminars, keeping test result books, and writing final report papers.

1983–1985: Chemist I, Fine Coal Cleaning Project, Grand Forks Energy Research Center. Responsibilities included data interpretation for methods including oil agglomeration and froth flotation. In addition responsibilities also included performing washability and other beneficiation tests for the physical separation of mineral-rich materials from coal samples.

Professional Memberships
American Society for Testing and Materials
National Society of Professional Engineers
Transportation Research Board

Publications and Presentations
Has authored or coauthored over 100 publications.

APPENDIX D

ENVIRONMENTAL SAMPLING AND MONITORING PLAN

ENVIRONMENTAL SAMPLING AND MONITORING PLAN

FIELD-SCALE DEMONSTRATION PROJECTS USING RECYCLED DRILL CUTTINGS FROM NUVERRA'S TERRAFICIENT PROCESS

BACKGROUND

Nuverra Environmental Solutions (Nuverra) is proposing to perform three beneficial use field-scale demonstration projects that utilize treated drill cuttings from Nuverra's Terrafficient℠ process. These field-scale demonstration projects include:

1. A road-surfacing demonstration project in McKenzie County to evaluate the performance of road surface materials comprised of Class 13 aggregate blended with treated drill cuttings.

2. A road fill demonstration project near the Nuverra environmental treatment center using 10,000 cubic yards of fill consisting of a blend of the treated drill cuttings and standard fill material used by the Knife River Corporation.

3. A landfill daily cover demonstration project at the McKenzie County Landfill.

These demonstration projects will be located near Nuverra's Environmental Treatment Center (Figure 1) and will be performed by a technical team consisting of Nuverra, the Energy & Environmental Research Center (EERC), the Civil Engineering Department at the University of North Dakota (UND), and the Upper Great Plains Transportation Institute (UGPTI) of North Dakota State University (NDSU). McKenzie County and the Knife River Corporation will partner with these organizations on selected demonstration tests by providing the field support for material preparation and installation. The complementary laboratory and bench-scale studies and the field-scale monitoring components of the proposed efforts will be led by the EERC under direction from Nuverra.

Road-Surfacing Field-Scale Demonstration Project

The road-surfacing field-scale demonstration project in McKenzie County will evaluate the performance of road surface materials comprised of Class 13 aggregate blended with treated drill cuttings from Nuverra's environmental treatment process. The high fines content (silt- and clay-sized fractions) and plasticity index (PI) of the treated drill cuttings are expected to enhance the McKenzie County aggregate, which tends to be devoid of fines and has a low PI. Fines are important in road surface aggregate, providing particle cohesion that helps reduce the loss of surface aggregate, allowing for compaction of the road surface material, and limiting infiltration of water into the roadbed. The anticipated benefits of adding treated drill cuttings to the road surface aggregate currently used in McKenzie County include the following:

- Improved safety
  - Reduced dust and traffic risks
  - Improved gravel surface skid resistance

Figure 1. The locations of the proposed demonstration projects.

  - Reduced corrugation (washboarding or the occurrence of periodic, transverse ripples in the surface of gravel and dirt roads)

- Decreased surface permeability
  - Improved rainfall runoff, resulting in fewer roadway shutdown days

- Resource conservation
  - Reduced application frequency and associated cost for gravel resurfacing projects

- Improved long-term gravel performance

McKenzie County has agreed to partner with Nuverra's technical team on this effort and has offered significant assistance by providing a road test site and agreeing to install the road test sections for the demonstration test. Given that McKenzie County's 2015 budget includes $17 million for the purchase of gravel, the county recognizes that the value-added properties inherent to the treated drill cuttings of Nuverra may provide an opportunity to produce an improved road surface material while, at the same time, reducing the costs for aggregate purchases as well as the long-term road maintenance needs.

Road Fill Field-Scale Demonstration Project

A second demonstration project will examine the use of a blend of treated drill cuttings and native fill material as road fill. Nuverra has been contracted by Knife River Corporation to provide 10,000 cubic yards of fill material for use beneath a road that is being constructed near the Nuverra treatment center in McKenzie County. The goals of the project are to evaluate the engineering performance of a road subbase

consisting of an optimal blend of the treated drill cuttings and native fill and to monitor any potential environmental impacts.

The use of treated drill cuttings as part of a subbase road fill represents a beneficial reuse strategy that will substantially reduce the quantity of native fill material that is required for road construction projects. A reduction in native fill quantities will not only conserve the natural resources of the State of North Dakota but will also eliminate any environmental impacts that may be associated with the extraction of these resources.

Landfill Daily Cover Field-Scale Demonstration Project

Representatives of McKenzie County are interested in using treated drill cuttings from the Nuverra treatment center as an alternative daily landfill cover for the McKenzie County Landfill. This interest is based on the geotechnical suitability of the treated cuttings for this beneficial reuse and the close proximity of the treatment facility to the landfill.

Landfill daily cover materials reduce the release of odors from the landfill and provide a firm surface on which vehicles can operate. Currently, the daily cover material used for the McKenzie County Landfill is a resource that could otherwise be used for construction-related activities; it is also costly to transport to the landfill. Use of treated drill cuttings for this purpose will minimize the use of the current cover materials, thereby making them available for other, more productive uses while reducing the transportation cost for the cover materials and the unnecessary nonbeneficial disposal of the treated drill cuttings.

Sampling and Monitoring Plans

The sampling and monitoring plans for each of the above demonstration projects are provided in this document along with the complementary laboratory characterization and bench-scale studies that are required for finalizing the design of the demonstration projects and assisting in the interpretation of the field monitoring data, respectively.

EVALUATION FRAMEWORK

The beneficial reuse of treated drill cuttings as part of a road surface material, a road fill, and a landfill daily cover is being evaluated using an integrated, weight-of-evidence framework which includes a combination of laboratory characterization studies, bench-scale studies, and field-scale demonstration tests. The laboratory characterization studies, consisting of both chemical and geotechnical testing, are being conducted to finalize the test parameters of the bench-scale and field demonstration tests, e.g., mix ratios, lists of monitoring analytes, etc. The bench-scale and field demonstration tests will then be conducted in parallel with the goal of developing an understanding of the fate and transport of the chemicals of interest (COIs) during the commercial implementation of these beneficial reuse strategies. The bench-scale tests will generate surface/subsurface migration data under controlled conditions, permitting the development of models (either conceptual or quantitative) to describe the transport of COIs during each beneficial use application. The field demonstration test monitoring data will provide measurements which can be used to confirm and/or calibrate the bench-scale models with “real-world” data collected at a more appropriate scale of operation and frequency.

The ultimate goal of this test program is to document, quantify, and mechanistically describe the potential movement of the COIs from the treated drill cuttings into the surrounding environmental media during these beneficial use demonstration tests. This quantitative understanding will then allow the Nuverra technical team to predict any potential environmental impacts at future commercial applications

of these beneficial use strategies for the purpose of assessing the potential risks to human health and the environment.

LABORATORY CHARACTERIZATION STUDIES

The chemical and geotechnical properties of several materials will be determined to support the final design of the proposed field-scale demonstration tests. The specific materials of interest for each demonstration test are listed in Table 1 along with the nature of the testing that is planned, i.e., chemical, geotechnical, and/or simulated rainfall runoff and infiltration). Groundwater sampling is not part of the proposed plan due to the lack of shallow groundwater resources beneath each of the demonstration test sites (Croft, 1985). However, by monitoring surface water quality, information will be obtained regarding the potential movement of the COIs from the treated drill cuttings to groundwater for use in future applications where groundwater resources may be present. If the conceptual site model for a site-specific commercial deployment of these beneficial reuse strategies suggests the presence of a potentially vulnerable groundwater source, a groundwater monitoring plan could be implemented that includes both a baseline monitoring of the groundwater quality as well as routine monitoring following implementation of the strategy.

In addition, predemonstration, site-specific, baseline samples of surface water, stormwater runoff, and landfill leachate will be characterized to aid in the evaluation and analysis of the field-scale monitoring data. These predemonstration measurements will serve as the baseline data against which the subsequent field-scale monitoring data will be compared. A description of the chemical and geotechnical characterization studies that will be conducted on the test materials listed in Table 1 are provided in the remainder of this section.

Table 1. Chemical/Geotechnical Characterization Test Matrix for Demonstration Test Materials.

	Demonstration Test		
Test Material	Road-Surfacing Demonstration	Road-Fill Demonstration	Landfill Daily Cover Demonstration
Treated drill cuttings	C / G / SR	C / G / SR	C / G / SR
Class 13 aggregate	G	NA	NA
Blends of treated drill cuttings and Class 13 aggregate	G / SR	NA	NA
Produced water	C	NA	NA
Native road fill	NA	G	NA
Blends of treated drill cuttings and native fill	NA	G / SR	NA
Predemonstration landfill leachate	NA	NA	C
Predemonstration surface water	NA	C	NA
Predemonstration stormwater runoff	C	NA	NA

NA – Not applicable
C – Chemical characterization
G – Geotechnical characterization (In some cases this may include only gradation testing.)
SR – Simulated rainfall runoff and infiltration tests

Test Materials

Treated drill cuttings will be used in all three of the field-scale demonstration tests. Samples of these materials, representing different batches of treated drill cuttings, will be obtained from the Nuverra environmental treatment facility. Local Class 13 aggregate that is typically used for road surface material will be obtained from the McKenzie County highway department stockpile in Watford City. Samples of produced water will be collected from nearby oil fields and chemically characterized. Similar to the treated drill cuttings, multiple produced water samples will be characterized to determine the variability in their chemistry.

Baseline conditions will be established for all of the demonstration tests by conducting predemonstration characterization tests on site-specific samples of the environmental media that will be monitored during the demonstrations. These media include stormwater runoff prior to the road-surfacing demonstration, surface water samples in the proximity of the road fill demonstration test, and the landfill leachate of the landfill daily cover demonstration test. At least one more baseline sampling of these surface waters will be conducted prior to the demonstration test.

The chemical testing of these materials will be performed by the EERC and an external laboratory for total petroleum hydrocarbons (TPH); the geotechnical testing will be performed by the Civil Engineering Department of UND. Brief summaries of the chemical characterization and geotechnical testing are provided below.

Chemical Characterization

X-ray fluorescence (XRF) and x-ray diffraction (XRD) will be used to measure the bulk elemental composition and bulk mineralogical composition of the treated drill cuttings, respectively. The residual hydrocarbon content of the treated cuttings will also be quantified using solvent extraction followed by gas chromatography (GC) analysis (U.S. Environmental Protection Agency [EPA] Method 8260). Multiple samples of treated cuttings will be characterized to determine the variability in chemistry of these materials.

The various water samples will be characterized using inductively coupled plasma–atomic emission spectrometry (ICP–AES), inductively coupled plasma-mass spectroscopy (ICP-MS), and ion chromatography (IC) to measure their trace, minor, and major elemental content. A list of target COIs for the water samples is provided in Table 2. Preliminary chemical characterization data of this type were previously generated on composite samples of drill cuttings that were obtained from different stratigraphic zones from four different wells and then subjected to laboratory treatment similar to that of the Nuverra treatment facility. Specifically, the bulk elemental data for these samples were quantified using XRF. The samples were also subjected to the synthetic precipitation leaching procedure (SPLP) of the EPA (EPA Method SW-846 Method 1312). These preliminary data were used to develop a preliminary set of COIs for the demonstration test monitoring plan as presented in this document. In addition to these specific elements, other general water quality parameters indicative of hydrocarbon and salt impacts have also been included in the preliminary list of COIs in this monitoring plan. These include TPH, total dissolved solids (TDS), electrical conductivity, pH, total alkalinity, and bicarbonate (HCO_3^-). Based on these results, the preliminary set of COIs and general parameters identified in this monitoring plan will be reviewed and, if necessary, modified to establish a final set of COIs for use during the implementation of the bench-scale and field-scale demonstration tests.

Table 2. Suggested COIs to Be Measured in Water Samples

Type of Water Sample	Major and Minor Elements	Trace Elements	Other Parameters
Produced water, surface water, landfill leachate, and cuttings simulated rainfall runoff	Ca, Mg, Na, K, Cl, SO_4^-, P, Al, Fe, Ba, Mn	As, B, Cr, Cu, Li, Mo, Ni, Pb, Se, Tl, V, Zn	TPH,* conductivity, pH, HCO_3^-, total alkalinity, TDS**
Simulated rainfall runoff and infiltrate, stormwater runoff	Ca, Mg, Na, K, Cl, SO_4^-, P, Al, Fe, Ba, Mn	As, Mo, Se, and up to two additional elements	TPH, conductivity, pH, HCO_3^-, total alkalinity, TDS

* Total petroleum hydrocarbons.
** Total dissolved solids.

Geotechnical Characterization

Geotechnical considerations of appropriate blending ratios of treated drill cuttings and aggregate for the road-surfacing demonstration test will be determined through laboratory-scale testing. Initially, gradation and PI tests will be performed on the treated cuttings and on the Class 13 aggregate[1]. These laboratory test data will be used to create three to five blends of aggregate and treated drill cuttings for additional gradation and PI testing as well as the determination of a moisture-density relationship. The optimal blend of treated drill cuttings and aggregate for the road surfacing demonstration test will be selected based on a comparison of these laboratory test results to the field criteria that must be met for these parameters by the demonstration test road surface after it is placed and compacted at the demonstration test site. In addition to identifying this optimal blend for field-scale testing, additional geotechnical laboratory tests will be performed to determine the maximum proportion of treated drill cuttings that can be blended with aggregate while still meeting the field criteria for gradation, PI, and moisture–density relationship required for an acceptable road surface. This maximum blend of treated drill cuttings and aggregate will also be incorporated into the field-scale demonstration test with the goal of maximizing the potential quantity of treated drill cuttings than can be utilized as part of this beneficial reuse strategy.

An optimal blend of treated cuttings and native fill will be determined through laboratory-scale testing based on specifications to be supplied for the road fill demonstration test. The native fill and treated cuttings will be tested for gradation at minimum to determine the optimal blend, which will then be tested to verify the blend is within specifications.

The geotechnical characteristics of the treated cuttings, alone, will also be compared to the requirements of the landfill daily cover material to ensure that this material is geotechnically suitable for this beneficial reuse.

BENCH-SCALE STUDIES

Concurrent with the demonstration tests, bench-scale tests will also be conducted to simulate the rainfall and surface runoff/infiltration that takes place in these larger-scale systems. These bench-scale tests will be constructed to mimic the physical systems of the demonstration tests and will provide a

[1] Preliminary gradation, PI, and moisture–density data for samples of treated drill cuttings are appended to this sampling and monitoring plan as Attachment A.

significantly more controlled environment for the investigation of the fate and transport of the COIs of the treated drill cuttings. These bench-scale data will support the development of fate and transport models for the COIs, which will aid in the interpretation of the demonstration test results. Furthermore, the demonstration test monitoring data will be used to validate the bench-scale models, ultimately providing the capability to predict the potential movement of the COI at future commercial applications of these beneficial use strategies.

Road-Surfacing Demonstration Bench-Scale Tests – Simulated Rainfall and Surface Runoff/Infiltration Testing

The potential leaching of COIs from the road surface materials following placement in the field-scale demonstration test will be examined at the bench-scale by simulating rainfall events on the road material blends scheduled for field testing, as well as the individual components of the blends. The specific materials that will be investigated at the bench-scale are listed below:

- Compacted treated drill cuttings.
- Optimal and maximum blends of Class 13 aggregate and treated drill cuttings.
- Optimal and maximum blends of Class 13 aggregate and treated drill cuttings following the application of produced water.

The bench-scale test will subject the test materials, which will be sloped to mimic the road surface, to two simulated rainfall events. The surface runoff and road bed infiltrate will be captured and chemically characterized. The COIs for these tests will be determined by conducting an initial test on loose treated drill cuttings, which represents a worst-case scenario for impacting both the runoff and infiltrate because the material will have a greater hydraulic conductivity which will result in more infiltration and greater contact between water and the treated drill cuttings. These initial samples will be analyzed for the same parameters as were previously listed for the produced water characterization study in Table 2. Based on the previous analytical and leach tests performed on the treated drill cuttings , it is anticipated that most of these trace elements will be absent or present at very low levels in the leachate of the these cuttings, when compared to existing irrigation standards. As such, it is anticipated that this bench-scale test program will focus on the analysis of As, Mo, Se, and, possibly, an additional two trace elements in the blended road materials as shown in Table 2. However, if the runoff and infiltration testing of the loose treated drill cuttings reveal the presence of unanticipated trace elements in significant quantities, these additional elements will be included in the bench-scale stormwater runoff/infiltration testing of the blended road materials.

Prior to the bench-scale testing of the road surface blends of treated drill cuttings and Class 13 aggregate, these blends will be compacted to the required density for road surfaces. This compaction will increase the amount of surface runoff and decrease the amount of infiltration. In addition, it will limit the extent of contact of the simulated rainfall with the treated drill cuttings and likely result in significantly less leaching of the COIs. Two artificial rainfall events representative of the climatic conditions in western North Dakota will be used to generate runoff from these compacted, blended materials and capture any rainfall infiltration.

Road Fill Demonstration Bench-Scale Tests – Simulated Runoff and Infiltration Testing

The leaching of COIs from the blend of treated drill cuttings and native fill material that will be used in the road fill demonstration test should be minimal given the construction profile of the road, i.e., the blend of fill and treated drill cuttings will form a subbase that is overlain by a base course and surface

course. In addition, the surface course will be a relatively impervious paved material. Nevertheless, bench-scale testing will be conducted to evaluate the potential leaching of COIs from this profile of materials that may result from the infiltration of rainfall. To perform this test, the road profile will be simulated in the bench-scale test using representative materials of construction and a subbase consisting of a blend of treated drill cuttings and native fill. These materials will be placed in accordance with standard road construction specifications, i.e., slopes and compaction requirements. Two artificial rainfall events will be conducted to generate runoff from, and infiltration into, the road, both of which will be captured and analyzed for the same COIs listed in Table 2 for the road-surfacing bench-scale test.

Landfill Daily Cover Demonstration Bench-Scale Tests – Simulated Runoff and Infiltration Testing

Bench-scale tests will be conducted to investigate the potential effects of using the treated drill cuttings as landfill daily cover material. Of particular interest is the effect of the treated drill cuttings on salinity levels in the leachate collection system of the McKenzie County Landfill and, ultimately, on the Watford City wastewater treatment plant (WWTP)[2].

As part of the bench-scale tests, treated drill cuttings will be compacted to meet the specifications of the McKenzie County Landfill and will subsequently be exposed to leachate acquired from the landfill. This leachate will be characterized for the COIs previously identified in Table 2. The landfill leachate will be used for the infiltration testing to simulate the potential impacts of the treated drill cuttings once within the landfill cell covered with refuse on the chemistry of the leachate. Exposure of the compacted cuttings to fresh water will be investigated to simulate the impacts of the compacted drill cuttings on the quality of surface runoff. Both the infiltrate/leachate and surface runoff generated from these tests will be analyzed for the COIs listed in Table 2.

While this testing assumes that there will be some infiltration and leaching into the treated drill cuttings, it is likely that such leaching will be quite slow given the reduced permeability of the material after compaction. In addition, the reduced permeability of the compacted, treated drill cuttings will also significantly reduce the amount of contact that occurs between them and any rainwater, which should also minimize leaching of the COIs into the surface runoff from the landfill daily cover.

FIELD-SCALE DEMONSTRATION TESTS

Road-Surfacing Field-Scale Demonstration

The goal of this demonstration test is to evaluate performance and the potential environmental impacts of a road that has been surfaced using a mixture of aggregate and Nuverra's treated drill cuttings. In this context, road performance will be evaluated based on visual inspections of the road surface for corrugation (washboarding) and rutting while the potential for environmental impacts to air quality and surface water will be assessed.

[2] The concentrations of the chemical constituents in the leachate will be used to estimate the potential impacts to the Watford City WWTP. The leachate is discharged periodically (i.e., on the order of once every other year) to the WWTP and represents only 0.1% of its daily treatment volume per event.

Demonstration Test Design

This demonstration test will be conducted using "test sections" of road routinely surfaced with Class 13 aggregate near Arnegard, North Dakota, north of the Nuverra treatment facility (see Figure 1). As shown in Figure 2, this demonstration will consist of four discrete test sections, each separated by a transition section. Each of the test sections will be partitioned into two parts. A brief description of each test section is as follows:

Test Section 1: This consists of two control sections of road, one which uses only Class 13 aggregate as the road surface, and one which uses Class 13 aggregate to which has been added a commercial-grade magnesium chloride dust suppressant.

Test Section 2: This consists of two test sections, both of which consist of a blend of Class 13 aggregate and treated drill cuttings to which has been added a commercial-grade magnesium chloride dust suppressant. However, one section contains an optimal blend of the aggregate and treated drill cuttings while the other contains a maximum blend of these materials, each of which will be determined based on geotechnical performance in the laboratory.

Test Section 3: This consists of two test sections, both of which consist of a blend of Class 13 aggregate and treated drill cuttings to which no commercial-grade magnesium chloride dust suppressant has been added. Similar to Test Section 2, one section contains an optimal blend of the aggregate and treated drill cuttings while the other contains a maximum blend of these materials.

Test Section 4: This consists of two test sections, both of which consist of a blend of Class 13 aggregate and treated drill cuttings to which produced water has been added as a dust suppressant. Again similar to Test Section 2 and 3, one section contains an optimal blend of the aggregate and treated drill cuttings while the other contains a maximum blend of these materials.

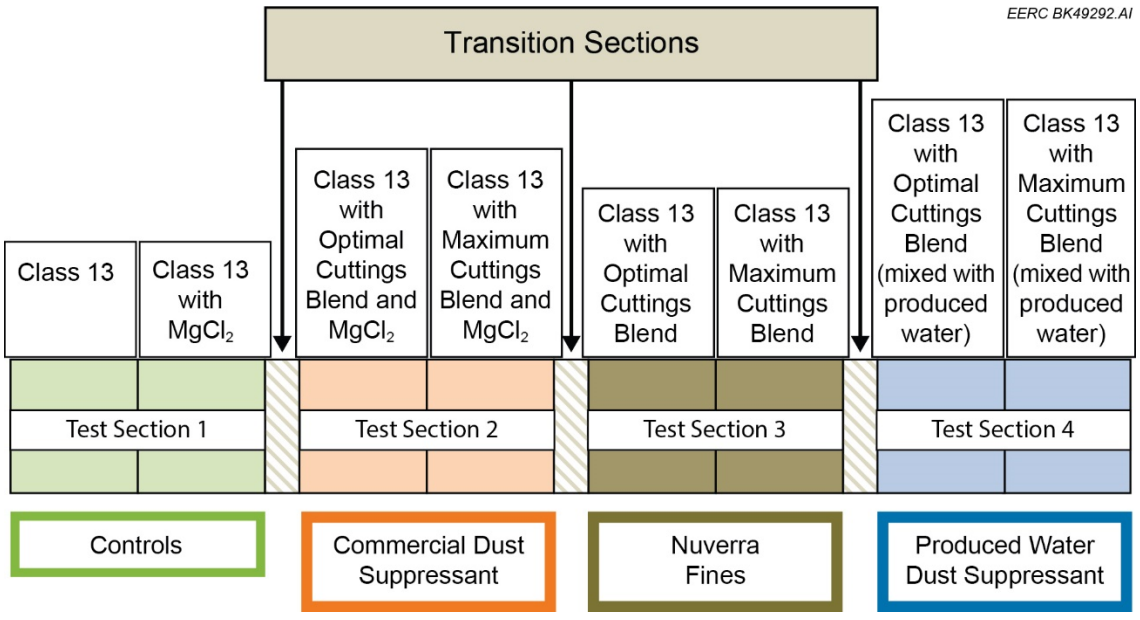


Figure 2. Layout of the various road test sections and associated surface material blends to be tested in the road-surfacing demonstration test.

Using the monitoring results from Test Sections 1 through 4, it will be possible to evaluate the road performance and potential environmental impacts of: (1) blending treated cuttings with Class 13 aggregate (Test Section 3 compared to Test Section 1 control (Class 13 aggregate only)); (2) blending treated cuttings with Class 13 aggregate to which a commercial-grade magnesium chloride has been added (Test Section 2 compared to Test Section 1 control (Class 13 aggregate to which commercial-grade magnesium chloride has been added)); and (3) using produced water as a dust suppressant in lieu of commercial-grade magnesium chloride with blended treated cuttings and Class 13 aggregate (Test Section 4 compared to Test Section 2).

Demonstration Test Implementation

The demonstration test system will consist of a test road that is constructed as shown in Figure 3, with the surface course constructed of the different blends described in Figure 2. During the test, various construction and environmental media will be targeted for monitoring during specific events. The specific components of the demonstration test are described in the remainder of this section.

Placement of Test Site Material

The Nuverra technical team (i.e., Nuverra, EERC, and UGPTI) will work closely with the McKenzie County Engineer and Road Superintendent to resurface the test road section for the road-surfacing demonstration test. McKenzie County will provide all of the materials that would normally be needed to resurface a gravel road, including Class 13 aggregate from a typical local source and commercial-grade magnesium chloride dust suppressant. Nuverra will provide any additional materials needed for the test sections, including sufficient volumes of dry treated drill cuttings and produced water. Blending of the cuttings with the aggregate will be performed on-site. The aggregate and treated drill cuttings will be transported and placed via belly dump truck to minimize dust. Sprayer trucks will be used to add the appropriate volume of water and dust suppressants (either commercial-grade magnesium chloride or produced water) during the on-site blending process.

Demonstration Test Monitoring

Several field measurements will be made during the conduct of the demonstration project to evaluate the road performance and the potential environmental impacts associated with this beneficial reuse strategy.

Road Performance. Visual inspection of the road test sections will be performed at least once a month, at which time the condition of each test section of the road will be documented. Any performance issues, such as corrugation and rutting, will be noted and photographed using a digital camera. These digital photos will be included in the reporting of the demonstration test results. To account for traffic volume and speed, a traffic counter capable of monitoring traffic in both directions, will be used. The traffic count data will also be collected on a monthly basis. Weather data such as wind speed and direction, precipitation, humidity, air temperature, and dew point temperature will also be gathered from the NDAWN weather station located near Watford City.

Potential Environmental Impacts. Potential environmental impacts include dust emissions and leaching of COIs from the drill cuttings to surface water and/or groundwater. Dust emissions and stormwater runoff will be monitored during the road surfacing demonstration test to characterize these potential impacts. These monitoring efforts were developed based on the conceptual model shown in Figure 3.

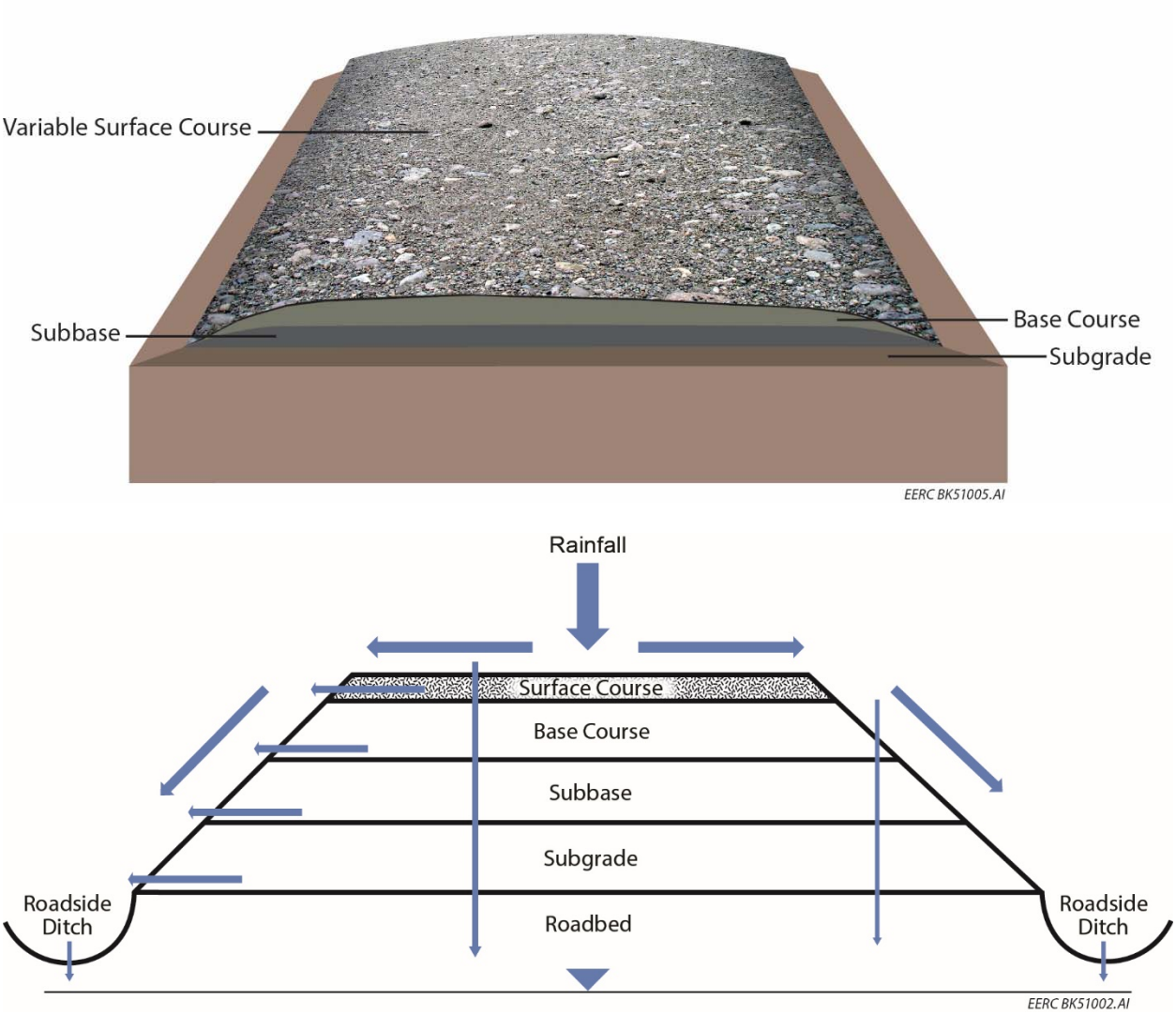


Figure 3. Construction profile and cross section for road surfacing demonstration test road. The surface course will be constructed of various test materials as shown in Figure 2; the remainder of the road exists previously. The arrows describe the flow of rainfall that impacts the road surface, which is distributed between surface runoff that is collected in a roadside ditch, and infiltration into the road bed.

It is anticipated that dust from the road surface will be entrained, resulting in additional airborne particulates entering the atmosphere. Of particular importance to this demonstration test is the impact of introducing treated drill cuttings to the road surface aggregate has on the generation rate of these particulate emissions.

Also of interest is the leaching of COI from the treated drill cuttings in the blended road surface course (see Figure 3) into both surface water and near-surface groundwater. The source of water to the road surface is rainfall. Since the road surface material will be compacted, the majority of the rainfall will become stormwater runoff. To the extent that this rainfall comes into contact with treated drill cuttings that are part of the road surface, COIs may be leached and carried away from the road by the stormwater and into the adjacent road ditch. Because of the compaction of the road surface course, very little, if any, of the rainfall is likely to infiltrate the road surface and transport any leached contaminants from this

surface course into the geologic subsurface. The movement of this leachate will initially be downward but may move laterally at the interface of the various layers of the road bed, depending upon the relative permeability of the different layers. This lateral movement could result in additional leachate making its way into the roadside ditches, with only a minor amount continuing downward, further into the subsurface. As a result of this process repeating itself through the multiple layers of the roadbed, it is not anticipated that a significant flow of leachate will make its way into the earthen foundation and eventually, into the groundwater. However, over time, because of cracking of the compacted road surface resulting from road use and weather-related factors (e.g., freeze–thaw and temperature cycles), the infiltration rate of the rainfall into the surface course may increase with time. This increased infiltration rate would increase the volume of water that infiltrates and leaches the blended aggregate surface course and subsequently migrates into the roadside ditches via the various layers of the road bed or into the groundwater.

Dust Emissions. The research team from the Civil Engineering Department at UND will collect dust from the test sections of the road using an ASTM method (ASTM International D1739-98). These samples will be collected at each side of the road to account for variations in wind direction. The sampling locations will be approximately 30 ft from the center of the road. At the same time that these samples are collected, the weather data described above (i.e., wind speed and direction, precipitation, humidity, air temperature, and dew point temperature) will also be recorded to permit the interpretation of these monitoring results. At each sampling location, jars will be placed at heights of 2, 3, and 4 ft from the surface to determine the effect of height on the monitoring results.

It is currently envisioned that the jars will be collected on a monthly basis during the period from August through October 2015. Following collection, the jars will be replaced with new ones, and the existing jars will be taken to UND's Civil Engineering laboratory for analysis. The research team will analyze and compare dust from the different test sections, while taking into account the monthly traffic counts and speed, material properties, and weather conditions.

Stormwater Runoff Sampling. Samples of the stormwater runoff in the roadside ditch will be collected during the road surfacing demonstration test. Precipitation events permitting, samples will be collected from a single location during at least one storm event prior to construction of the test road as well as from each of the control and road test sections of Figure 2 during three storm events following placement of the blended road surface materials. For each control and road test section, two samples will be taken, one adjacent to the road as well as one from the center of the ditch. The collection of samples from these two different locations will provide data specific to each road section to better estimate which constituents may runoff into the ditch. Sample collection systems will be set up to prevent cross-contamination between adjacent test sections of the road. V-shaped runoff diversion systems will be placed adjacent to each of the eight test segments (two from each test section) and the segment-specific surface runoff will be collected in pre-placed sample containers with bulb-type stoppers. Within 24 hours of a storm event, a sampling crew will retrieve the pre-placed sample containers and collect grab samples of runoff within the center of the ditch. Separate samples will be preserved appropriately for the COIs and sent to the EERC and an outside laboratory as appropriate based on the sampling protocols provided by the EERC.

Based on the previous laboratory examination of the leaching of the drill cuttings (see Laboratory Characterization Studies), the stormwater runoff samples will be analyzed for the constituents listed in Table 2. This same list of constituents is targeted for analysis during the concurrent bench-scale studies that have been planned (see Bench-Scale Characterization Studies).

Road Fill Field-Scale Demonstration

A second demonstration project will use a blend of treated drill cuttings and native fill as a subbase for a road. Nuverra has been contracted by Knife River Corporation to provide 10,000 cubic yards of fill material for this use beneath a road that is being constructed near Nuverra's treatment center. The location of the road is shown in Figure 1. The goal of the project is to determine an optimal environmentally-acceptable blend of treated cuttings with native local material for use as a subbase fill material and to assess the environmental performance of the material through water sampling and analysis from a ditch adjacent to the road construction site.

Demonstration Test Design

This demonstration test will be conducted on a section of road that will be constructed as shown in the cross section in Figure 4. This demonstration differs from the road surfacing demonstration test since it demonstrates a blend of native fill and treated drill cuttings as the subbase with a relatively impermeable pavement surface course rather than the treated cuttings as part of an aggregate surface course. The cuttings may also be used as a fill material beneath aggregate or soil in the shoulders of the approaches included in the road construction project.

Demonstration Test Monitoring

Field measurements will be made during the conduct of the demonstration project to evaluate the potential environmental impacts associated with this beneficial reuse strategy.

Stormwater Runoff Sampling and Analysis

Given this construction profile, it is anticipated that the majority of the rainfall will not infiltrate the road surface but will instead be diverted into a roadside ditch. Due the nature of the paved surface course, very little infiltration of the rainwater is expected to enter the base course and migrate into the subbase consisting of the treated drill cuttings/native fill blend. While this rate of infiltration may increase over time as cracks in the pavement develop as a result of road use and weather effects such as freeze–thaw cycles, the downward migration of the rainwater and potential mobilization of the COIs from the subbase into the geologic subsurface environment is not expected to be significant due to the relatively small hydraulic head and the relative permeabilities of the multiple layers of the compacted road construction materials. In addition, the leachate generated from the cuttings that extend to the roadside slope will represent a very small volume when compared to the volume of runoff from other areas of the road and ditch. Thus, the potential impact of leachate from the cuttings to the overall volume of groundwater recharge will be very small. For this reason, the sampling efforts of this demonstration test will focus on the chemical characterization of the water that accumulates in the roadside ditch/wet area that lies adjacent to the constructed road. If the cuttings are used as additional fill material beneath aggregate or soil on the shoulders of the approaches, water samples will be collected in the ditches adjacent to these areas if possible. All surface water samples will be analyzed for the list of COIs previously identified for the bench-scale tests that are being conducted to support this demonstration test (Table 2).

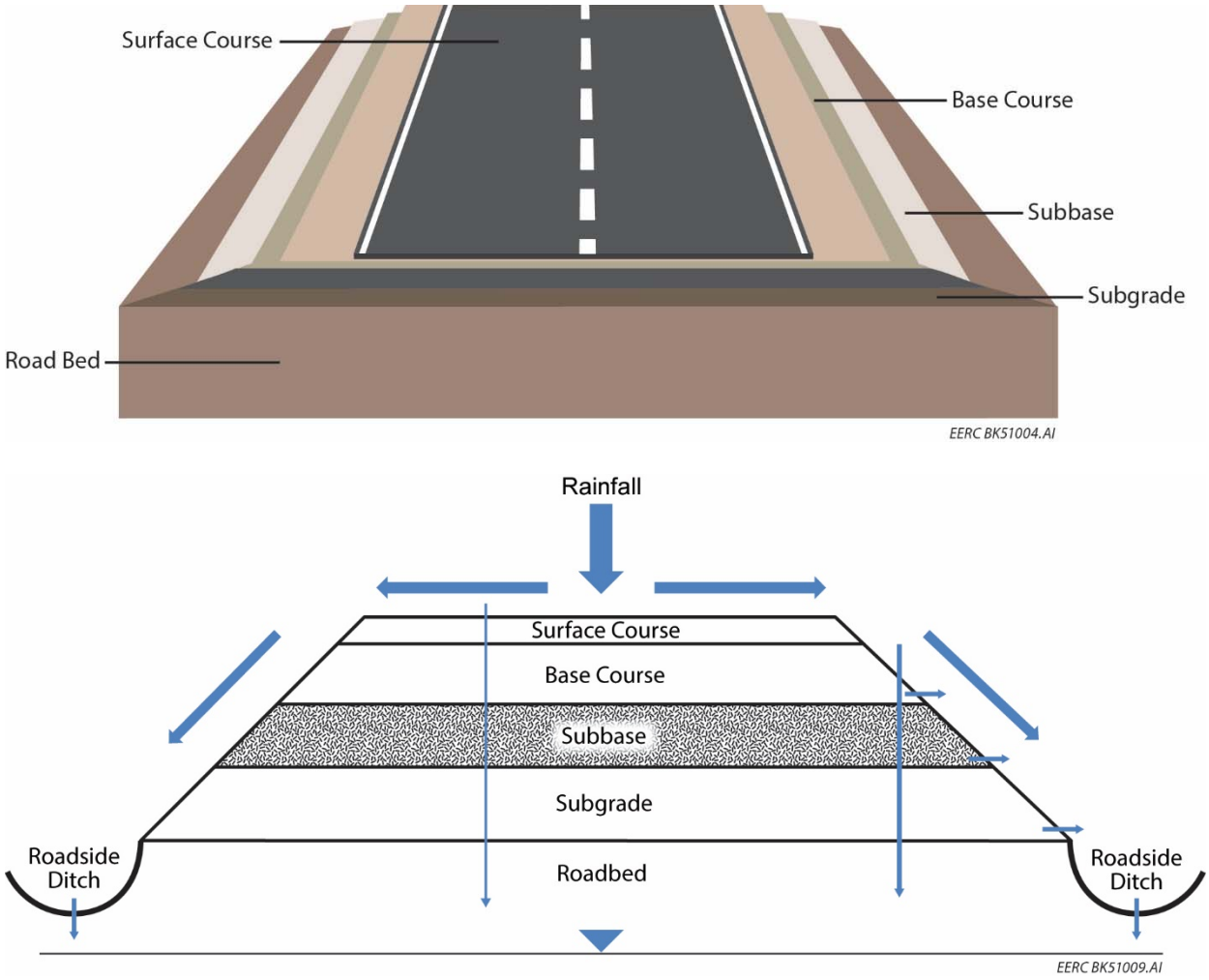


Figure 4. Construction profile and cross section for road fill demonstration test. All but the subbase will be constructed using standard construction materials, including a paved surface course; the subbase will consist of a blend of treated drill cuttings and native fill. The arrows describe the flow of rainfall that impacts the road surface, which is distributed between surface runoff that is collected in a roadside ditch, and infiltration into the road bed.

The surface water in the roadside ditch may also contain small contributions of flow from each of the road bed construction layers as there is a potential for the lateral movement of any rainwater infiltration that enters these layers. Again, the contribution of any COIs into the surface water of the roadside ditch from this potential flow path is not expected to be large and will be captured as part of the surface water characterization effort. The water quality data from this effort will be evaluated based on a comparison with the quality of the water in this wet area prior to the construction of the road.

Landfill Daily Cover Field-Scale Demonstration

The third demonstration project will investigate with the use of Nuverra's treated drill cuttings as an alternative daily landfill cover for the McKenzie County Landfill. This beneficial reuse of the treated drill cuttings is of interest given the geotechnical suitability of the material for use as a daily landfill cover and the close proximity of Nuverra's treatment facility to the county landfill.

Demonstration Test Design

This demonstration test will be constructed by placing compacted cover on the existing McKenzie County Landfill (see Figure 1). A schematic and a cross section of the landfill daily cover demonstration test cell are shown in Figure 5. As shown in Figure 5, all of the rainfall that impacts the test cell, except that which is retained in the refuse, will be collected in the leachate collection system, either as runoff from the surface cover or through lateral movement within each refuse layer. The recovered leachate is sent to a leachate evaporation pond, from which there are only rare, periodic releases (approximately once every other year) to WWTP. These releases occur when the evaporators are not properly functioning. During those events, the leachate is hauled to the WWTP. The leachate volume transferred to the WWTP is typically about 30,000 gallons per event, which is less than 0.1% of the volume of water treated by the WWTP.

Demonstration Test Monitoring

Field measurements will be made during the conduct of the demonstration project to evaluate the potential impacts to the landfill leachate quality associated with this beneficial reuse strategy. These field measurements will focus on the characterization of the rainfall runoff from the compacted landfill daily cover of the test cell and the landfill leachate that is collected from this test cell.

Both the surface runoff and landfill leachate will be analyzed for COIs identified previously for the supporting laboratory and bench-scale studies. Impacts to the landfill leachate quality that result from the use of the treated drill cuttings as the landfill daily cover will be evaluated by comparing the field monitoring data with the baseline, predemonstration leachate quality data. Potential impacts to the WWTP permitted values resulting from the periodic discharge of this leachate will also be evaluated.

REFERENCES

Croft, M.G. 1985. Ground Water Resources of McKenzie County, North Dakota. County Ground Water Studies 37 – Part III. North Dakota State Water Commission. Located at: http://www.swc.state.nd.us/4dlink9/4dcgi/GetSubContentPDF/PB-289/McKenzie_Part_3.pdf (accessed March 2015).

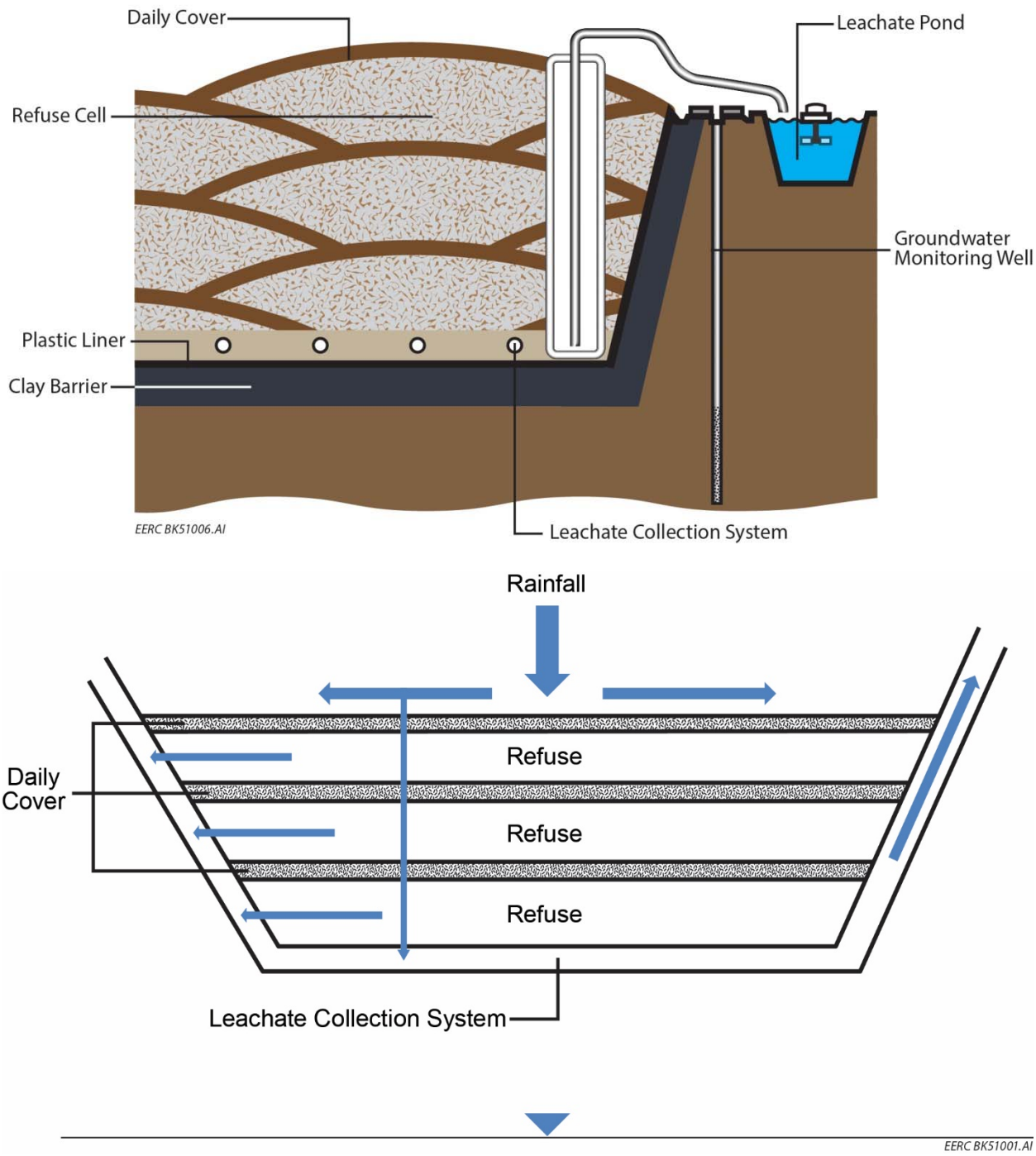


Figure 5. Cell profile and cross section of landfill daily cover demonstration test. The daily cover of this test cell will consist of compacted treated drill cuttings. The arrows describe the flow of rainfall that impacts the landfill daily cover, all of which is collected in the leachate collection system.

ATTACHMENT A
PRELIMINARY GEOTECHNICAL DATA

Pit Name: Nuverra Drill Cuttings QC Tech: KRC-TM Prospect Date: Unknown

Prospector: Samples provided by Nuverra Legal Descrip: Unknown

Nuverra - Drill Cutting Materials

Date>	8/8/14	8/8/14	8/8/14	8/8/14	8/8/14												
Sample #>	#1	#2	#3	#4	#5												
Sieve																AVG	Sieve
3"																	3"
2"																	2"
1.5"																	1.5"
1"																	1"
3/4"																	3/4"
5/8"																	5/8"
1/2"																	1/2"
3/8"	100	100	100	100	100											100.0	3/8"
#4	99.6	99.6	98.1	99.2	99.8											99.3	#4
#8	98.6	89.0	92.1	94.1	96.8											94.1	#8
#16	96.6	69.0	82.9	82.8	88.1											83.9	#16
#30	93.5	57.3	76.5	75.1	80.5											76.6	#30
#50	88.4	51.1	73.0	70.0	75.3											71.6	#50
#100	74.0	47.2	70.6	63.4	70.8											65.2	#100
#200	66.8	44.0	67.4	58.7	66.0											60.6	#200
+4 Shale																	+4 Shale
-4 Shale																	-4 Shale
Ttl Shale	1.0	10.6	0.7	3.7	1.3											3.5	Ttl Shale
PI				12.0	8.0											10.0	PI
SE																	SE
Fracture																	Fracture
Plate																	Plate
LAR																	LAR
SS																	SS
OB Depth:																	OB Depth:
Grvl Depth:																	Grvl Depth:

Notes: Sample #1 is surface zone, #2 is Carbonate zone, #3 is Shale zone, #4 is Composite drill cuttings sample, #5 is Mixed zone

FORSGREN Associates Inc.

Project Number : 12-14-0107
Project Name : Watford City QC
Report Number : 6
Report to : Knife River
Copies to :

MATERIALS LABORATORY REPORT

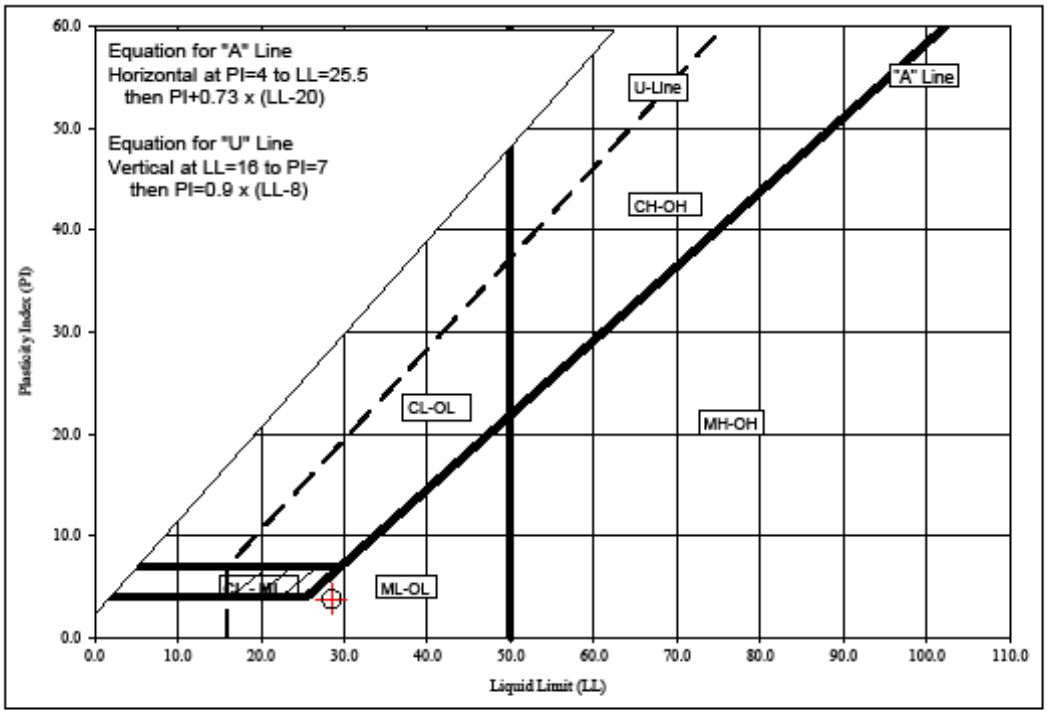
Atterberg Limits Determination

D 4318

Sample Location: New Verra Drillings
Material Source: Supplied by Client
Sample ID #: 6
Date Obtained: 3/18/2015
Date Tested: 3/21/2015
Tested By: ASE

Liquid Limit: 28.5
Plastic Limit: 24.8

Plasicity Index: 3.7
Soil Classification: ML



Reviewed By:

Aaron Ekstrom

Manager: Materials Laboratory

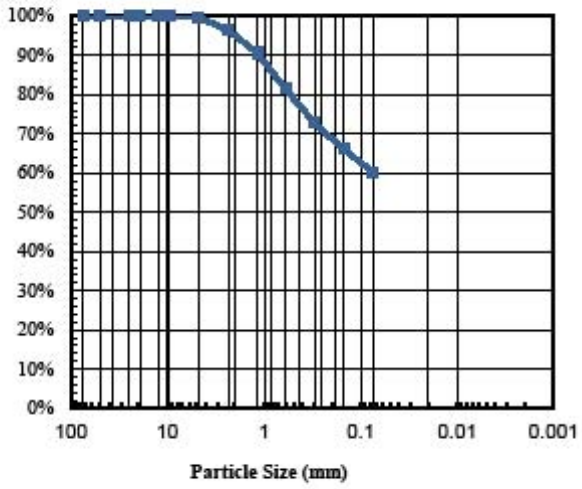
C:\Users\FA-ND-02\Dropbox\Forsgren Work\2015\Knife River\[12-14-0107 Atterberg (#6) 3-21-2015.xls]PI Report Sheet

Project Number : 12-14-0107
Report Number: 6

FORSGREN Associates Inc.

Client:	Knife River
Project:	Watford City Batch Plant QC
Job No.:	12-14-0107
Lab No.:	6
Received:	March 18, 2015
Reported:	March 21, 2015

Material Description: New Verra Drillings
Sample Location: Supplied by Client
USCS Soils Class: ML



Sieve Analysis ASTM C136

SIZE	PASSING	SPECIFICATION Low	SPECIFICATION High
3"	100%		
2"	100%		
1"	100%		
3/4"	100%		
1/2"	100%		
3/8"	100%		
No. 4	100%		
No. 8	96%		
No. 16	91%		
No. 30	81%		
No. 50	73%		
No. 100	66%		
No. 200	60.3%		

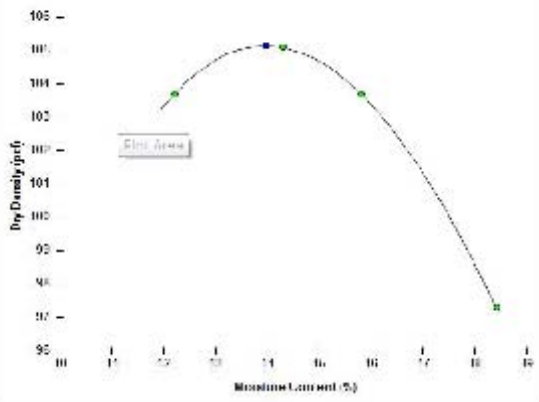
Moisture Content As Received ASTM D2216

1.4%

Corrected Density & Moisture Content ASTM D4718

Maximum Density	**105 pcf**
Optimum Moisture	**14.0%**

Moisture Density Relationship of Soils ASTM D698



Reviewed By:
Aaron Ekstrom
Materials Testing Manager

305 S Main Street
Watford City, ND 58854
701-842-2120

APPENDIX E

LETTER OF CONFIRMATION

EERC
Energy & Environmental Research Center®
Putting Research into Practice

University of North Dakota
15 North 23rd Street, Stop 9018 • Grand Forks, ND 58202-9018 • P. 701.777.5000 • F. 701.777.5181
www.undeerc.org

April 7, 2015

Oil and Gas Research Council
North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Council Members:

This letter is to confirm that Nuverra has provided $420,995 in cash to the EERC to conduct a detailed evaluation of potential beneficial reuse options for the treated cuttings produced through Nuverra's Terraficient process. The work performed by the EERC to date includes the following:

- Evaluation of Nuverra's treatment process and confirmation of the hydrocarbon removal efficiency from the processed cuttings,
- Detailed characterization of the geochemical properties of drill cuttings representing the various geologic formations encountered throughout the entire length of a Bakken/Three Forks well,
- Determination of the geotechnical suitability of the processed cuttings for various beneficial reuse applications,
- Coordination with the North Dakota Department of Health to determine the chemical testing criteria desired by the department to evaluate the suitability of the processed drill cuttings for various reuse applications,
- Completion of leaching tests performed on processed cuttings samples from different formations and evaluation of the environmental suitability of different beneficial reuse options.

The data generated from these efforts were necessary to properly design and formulate the currently proposed demonstration projects, and are critical to the expeditious implementation of the demonstrations project.

Sincerely,

John A. Harju
Associate Director for Research

APPENDIX F

LETTERS OF SUPPORT

EERC
Energy & Environmental Research Center®
Putting Research into Practice

University of North Dakota
15 North 23rd Street, Stop 9018 • Grand Forks, ND 58202-9018 • P. 701.777.5000 • F. 701.777.5181
www.undeerc.org

April 10, 2015

Mr. David Johnson
Nuverra Environmental Solutions
3711 4th Avenue Northeast
Watford City, ND 58854

Dear Mr. Johnson:

Subject: EERC Proposal 2015-0187 Entitled "Recycled Drill Cuttings Beneficial Reuse Demonstration Projects"

This letter is to confirm that the Energy & Environmental Research Center (EERC) and the Civil Engineering Department at the University of North Dakota are committed to working with Nuverra on the effort being proposed to the North Dakota Industrial Commission Oil and Gas Research Council entitled "Recycled Drill Cuttings Beneficial Reuse Demonstration Projects." As described in the proposal, the EERC and Civil Engineering Department will perform the laboratory characterization of the various materials; bench-scale testing to simulate rainfall leaching and runoff associated with each application; and field testing, verification and monitoring of the demonstration projects. The total cost to perform this work is $475,677. A breakdown of this cost is attached.

Sincerely,

John A. Harju
Associate Director for Research

Approved by:

Thomas A. Erickson, Director
Energy & Environmental Research Center

JAH/sah

Attachment

RECYCLED DRILL CUTTINGS BENEFICIAL REUSE
DEMONSTRATION PROJECTS
NUVERRA ENVIRONMENTAL SOLUTIONS
EERC PROPOSAL# 2015-0187
PROPOSED PROJECT START DATE: 5/1/15

BUDGET

CATEGORY	TOTAL
Labor	$ 292,999
Travel	$ 16,213
Supplies	$ 12,935
Other*	$ 1,807
Laboratory Fees & Services	
Natural Materials Analytical Research Lab	$ 8,371
Fuels & Materials Research Lab	$ 918
Analytical Research Lab	$ 127,395
GC/MS Lab	$ 930
Graphics Service	$ 1,163
Shop & Operations Fee	$ 1,997
Outside Lab	$ 10,949
Total Project Costs – U.S. Dollars	$ 475,677

Labor Categories	Labor Hours Total per Category
Research Scientists/Engineers	2,502
Research Technicians	317
Senior Management	69
Technical Support Services	46
Total	**2,934**

*May include costs such as food, printing, communications, or other miscellaneous expenses.

April 14, 2015

Nuverra Environmental Solutions
3711 4th Ave. NE
Watford City, ND 58854

Dear Mr. Johnson:

This letter is to confirm that McKenzie County supports Nuverra's proposed field demonstration projects using treated drill cuttings for beneficial reuse as road construction materials and as daily landfill cover.

To demonstrate their support, the McKenzie County Commission has agreed to provide in-kind support for the road surfacing project through selection of an appropriate road test site, provision of road surface aggregate, equipment and labor needed for road emplacement, and supply and application of magnesium chloride where designated in the test plan. The County will also be performing routine maintenance of the road test site. The estimated value of this support is $184,033.

The County will also help demonstrate the use of Nuverra's treated product as a daily landfill cover by applying it at the McKenzie County Landfill. The use of Nuverra's product as a supplement to the aggregate and fill commonly used for road construction and daily landfill cover would not only help prolong the supply of native aggregate resources, but it would also provide a cost savings for the County.

Sincerely,

Suhail Kanwar

Suhail Kanwar, Public Works Administrator
McKenzie County, ND

APPENDIX G

AFFIDAVIT OF TAX LIABILITY

STATE OF NORTH DAKOTA)
) ss
COUNTY OF MCKENZIE)

AFFIDAVIT OF TAX LIABILITY

DAVID JOHNSON, being first duly sworn, states:

1. That he is the Director of Nuverra Environmental Solutions' Total Environmental Management Systems, who is duly authorized to make this affidavit on behalf of Nuverra Environmental Solutions.

2. That Nuverra Environmental Solutions does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

Dated this 15th day of April, 2015.

David Johnson, Director

SUBSCRIBED AND SWORN TO before me this 15th day of April, 2015.

DEELYNN HEISLER
NOTARY PUBLIC
STATE OF NORTH DAKOTA
My Commission Expires DECEMBER 26, 2019

Notary Public