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WIND TUNNEL TESTS OF BIODEGRADABLE
FUGITIVE DUST SUPPRESSANTS BEING CONSIDERED
TO REDUCE SOIL EROSION BY WIND AT
RADIOACTIVE WASTE CONSTRUCTION SITES

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SUMMARY

Wind tunnel tests were performed of three fugitive dust control agents derived from potato and sugar beet products. These materials are being considered for use as dust suppressants to reduce the potential for transport of radioactive materials by wind from radioactive waste construction and remediation sites. Soil and dust control agent type, solution concentrations, application quantities, aging (or drying) conditions, surface disturbance, and wind and saltating sand eolian erosive stresses were selected and controlled to simulate application and exposure of excavated soil surfaces in the field. A description of the tests, results, conclusions, and recommendations are presented in this report.

The dust control agents included powdered potato starch, XDCA (a liquid mixture of water, sugar beet extract sugars, and organic and inorganic additives), and FPW (a fermented potato waste sludge containing starch and sugars converted by fermentation to ammonium lactate). The materials were mixed with water and spray-applied to uncompacted bare soil surfaces. The two types of soils tested were a loamy soil from Idaho National Engineering Laboratory (INEL) and a sandy soil from the Hanford Site. The surfaces were aged under controlled conditions and then exposed to increasing wind and saltating erosive stresses. Following initial tests the surfaces were disturbed, or broken, and the tests were continued to provide additional information. Data were compared to control surfaces that were subjected to similar tests. Aging conditions included a standard diurnal cycle and ultra violet- and moisture-cycling to represent possible field conditions.

The wind tunnel tests provided data for comparing the effectiveness of three fugitive dust suppressant agents. Soil type had a large impact on the effectiveness of the dust control agents. Potato starch (PS) solutions, especially the high starch, low water mixtures, such as 2.5% starch applied at 1 L/m², provided the best protection of loamy Idaho soil surfaces. Erosion rates from Idaho soil surfaces protected by potato starch were only 0 to 14% of those from control surfaces. The XDCA did not protect the Idaho soil with the marginal exception of the 33% solution applied at 9.2 L/m². FPW provided intermediate results. In contrast, XDCA provided nearly ideal protection of the sandy Hanford soil surfaces and potato starch did not. Again, FPW provided intermediate results. Erosion rates of XDCA-protected Hanford soil surfaces never exceeded and were generally much less than 5% of those from corresponding controls.

Tests of aging processes performed using Idaho soil showed that added moisture the erosion control effectiveness of potato starch and FPW. The XDCA-protected surfaces were not significantly impacted. The uv-cycling did not appear to impact any of the agents. The impact of biological activity was not tested.

The results of this study indicate that all three dust control agents can protect exposed soil surfaces from extreme eolian stresses. It is also clear that the interaction and performance of each agent with various soil types may differ dramatically. Thus, soils similar to that received from INEL should be best protected by high concentration (~ 2.5%) solutions of potato starch at low water application levels (~ 1 to 2 L/m²). Because the effectiveness of PS on this soil type is degraded after a moderate amount of simulated rainfall, other options or additives should be considered if surfaces are to be protected for long intervals or during periods of intermittent rainfall and hot, windy conditions. On the other hand, XDCA should be considered when excavating sandy soils. It should be noted, however, that because the Hanford soil test results are based on a small number of tests, it would be prudent to perform additional tests prior to selecting a fugitive dust control agent for use at the Hanford Site. While fermented potato waste was not the best fixative used on either soil, it did perform reasonably well on both soil types (better than XDCA on Idaho soil and better than PS on Hanford soil). Additional development work, perhaps including additives, could produce an improved product.

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1.0 INTRODUCTION

Effective, inexpensive, environmentally safe methods are being sought to control wind transport of contaminated soil from excavation related to clean up of radioactive waste sites. Initial work has focused on agricultural waste or related products containing natural polysaccharides such as starch and pectin. In support of this work, the Pacific Northwest Laboratory (PNL)^(a) contracted with Westinghouse Hanford Company (WHC) to perform wind tunnel tests of the relative effectiveness of two dust suppressant agents to protect bare soil surfaces. Tests of an additional dust control agent were supported by PNL and are included in this report. The WHC project, "Contaminant Migration Control: Fixation of Soil Surface Contamination Using Natural Polysaccharides" was created to support a U.S. Department of Energy Integrated Field Demonstration Project at the Idaho National Engineering Laboratory (INEL).

Staff at the PNL Aerosol Wind Tunnel Research Facility performed 69 tests of three dust control agents derived from potato and sugar beet products. Soil and dust control agent type, solution concentrations, application quantities, aging (or drying) conditions, and wind and saltating sand eolian erosive stresses were selected and controlled to simulate application and exposure of excavated soil surfaces in the field. All surfaces were dried under diurnal conditions prior to testing. Surface treatments that survived a series of four wind tunnel tests of incrementally increasing wind and saltating sand erosive intensity were then disturbed in a uniform, repeatable manner, and the four tests were repeated to provide information on the ability of the dust control agents to continue to protect the surface after being broken. Data were compared to dry and wet control surfaces that were subjected to similar tests. Solution concentrations (percentage of agent mixed with water) and application quantities (volume of total solution applied per surface area) were tested over ranges under consideration for use in the field. Aging conditions included a standard diurnal cycle and ultraviolet- (uv) and moisture-cycling to represent possible actual field conditions.

This report includes a description of the tests, a discussion of results, and a statement of conclusions and recommendations. Actual test data and summaries grouped by test parameters are provided in the appendices. This project was performed to test the effectiveness of agents to control fugitive dust emissions only; no cost comparisons or other field-scale logistical issues were considered.

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2.0 BACKGROUND

Construction activities associated with reclamation of radioactive waste sites have the potential for creating fugitive dust sources. Surface fixatives are needed to prevent contamination from leaving the site. Copious amounts of water, such as supplied by in-place irrigation systems, might not provide the best solution because any drainage could increase the transfer of radioactive materials into the groundwater at waste sites. Therefore, the use of natural, biodegradable fugitive dust suppressant agents (surface fixatives) could provide the best solution for mitigating risks associated with fugitive dust emissions from clean-up sites.

The stability of soil surfaces subject to erosive stresses in an arid environment depends on their protection by non-erodible elements or crusts. Surfaces that are armored by crusts or gravel or protected by vegetation have greater resistance to eolian erosion. In addition, the formation of soil aggregates also aid surface stability. In contrast, sand-sized materials in the surface layer can act as an abrasive agent and reduce its resistance to eolian stresses. Freshly disturbed surfaces are the most susceptible to transport offsite by wind. Surface crusts, whether formed by water or applied fixatives improve the resistance of surfaces to eolian stresses. Water crusts form as soluble materials in the soil are dissolved and concentrate at the surface. They are often brittle and provide only brief protection. Surface fixatives are designed to provide additional protection by containing dissolved, particulate, or fibrous elements that, upon drying, enhance the natural water crust.

After drying, erosive processes begin to act to degrade protective crusts. Wind gusts provide the driving force for erosion of exposed soil surfaces and their subsequent transport away from a site. Wind also acts to transport sand, where present on the surface or mixed in native soils, across the surface in abrasive saltation that results in the reduction of natural or applied surface protection. At arid sites, surface and climatic conditions combine to produce low-moisture soils that are especially susceptible to erosion when disturbed. Mechanisms of eolian erosion include surface creep, saltation, and suspension. Surface creep is the wind-driven sliding and rolling of sand and soil particle aggregates along the surface. Saltation is the transport mechanism of sand-sized particles and consists of vertical leaps followed by low-angle returns to the surface. Suspension is the long-distance transport of soil particles away from exposed surfaces. Saltation, and to a lesser extent creep, are often the primary causative mechanisms of soil erosion in arid lands; the kinetic energy of windborne or rolling grains is imparted to dry surfaces on impact and causes crust abrasion, soil particle suspension, and surface deflation.

3.0 MATERIALS AND METHODS

Solutions of three candidate fugitive dust suppressant agents were prepared, applied to flat unpacked soil surfaces, and exposed to ranges of wind and saltating sand erosive stresses under controlled conditions in a wind tunnel. The tests were performed in a wind tunnel to allow known surface treatments to be compared by exposure to controlled and similar erosive stresses. Erosive stresses were selected to represent extreme conditions anticipated in the field. Materials, the preparation and handling of test surfaces, procedures, and test data were documented and are reported in this section.

3.1 WIND TUNNEL TEST FACILITY

Tests were conducted at the PNL Aerosol Wind Tunnel Research Facility. The facility, shown in Figure 3.1, is located on the Hanford Site in southeastern Washington. The facility's environmental wind tunnel is equipped to control wind speed, temperature, humidity, and lighting. Heat generated during high-speed tests is dissipated using an integrated air conditioning system. Wind speed profiles and boundary layers are uniform and controlled within the 0.61-m square by 6.1-m long test section that was used for the wind erosion tests. The maximum attainable wind speed in the test section is 36 m/s (80 mph). Greater wind speeds may be achieved by reducing the cross-sectional area of the test section. Wind speed and other environmental data are recorded using a computerized data acquisition system. Two exhaust systems that use filters and scrubbers maintain the wind tunnel at slightly reduced air pressure during tests to contain dust, chemicals, or other test materials.

3.2 WIND AND SALTATING SAND STRESSES

Comparison of fugitive dust suppressant agents requires that realistic maximum stresses be applied to test surfaces. These must be repeatable to ensure that test-to-test variations are limited to parameters of interest such as fixative type, concentration, application rate, weathering, etc. Wind and saltating sand grains were applied to test surfaces to simulate worst-case natural conditions and identify which surface application methods provided the best surface protection.

Wind and saltating sand erosive stresses were applied based on previously completed work supporting the development of a gravel admixture in silt-loam soil to reduce rates of erosion by wind (Ligotke 1993). Peak wind gust data at Hanford and wind tunnel air-flow boundary layer conditions were considered to determine wind tunnel air velocities needed for the tests. The peak wind gust (PG) return period (RP) for the Hanford Site Meteorological Station, based on Stone et

FIGURE 3.1. Orthographic Projection of the PNL Aerosol Wind Tunnel Research Facility

al. (1983) and excluding data having return periods of less than 2 years, was found to be represented by:

$$PG = 26.05 + 2.348 \cdot \ln(RP) \quad R^2 = 0.965 \quad (3.1)$$

Thus, peak gusts of 31.5 and 37 m/s (70 and 82 mph) may be expected to have return periods of 10 and 100 years, respectively. Based on this information, and the determination by Ligothke and Klopfer (1990) that the ratio of wind speed at 2 m to that at 15 m was approximately 1.5 ± 0.2 , the corresponding peak gusts at the lower height would be 21 ± 3 and 25 ± 4 m/s, respectively.

Ligothke (1993) provided an evaluation of surface shear stresses produced in a wind tunnel compared to those produced in the field at Hanford. Because of thicker air-flow boundary layers present in the field, comparable shear stresses are produced at lower wind speeds in a wind tunnel. This does not reduce the validity of wind tunnel data, but rather, underlines the importance of using surface shear stress (or friction velocity) rather than wind speed when comparing wind tunnel data with actual field conditions.

Eolian erosive forces are created by the flow of air over surfaces and may be modeled physically in wind tunnels. Rather than measuring it mechanically, the shear stress may be calculated from measurements of the change in wind speed with elevation near to the surface. Therefore, by measuring the air-flow boundary layer over the surface it is possible to determine surface shear stress. Two parameters that are useful in the determination of surface shear stress are roughness height (z_0) and friction velocity (u^*). Friction velocity is an erosion parameter that is related to surface shear stress by:

$$u^* = (\tau_s/\rho_0)^{1/2} \quad (3.2)$$

where τ_s is the surface shear stress (force/area) and ρ_0 is the density of air (mass/volume). Solving the equation results in units of length/time for u^* , and hence, the name "friction velocity." At constant temperature, u^* increases as the square root of increasing τ_s . Another erosion parameter influencing the interaction between wind and surface is the roughness height. The parameter z_0 is a measure of the aerodynamic roughness of a particular surface, and thus, its capacity to impart aerodynamic drag on air flowing over it. It is influenced by, but not equal to, the average or maximum height of surface roughness elements such as gravel, tilled ridges, or vegetation. Roughness heights are also measured as a function of the air-flow boundary layer, and are often between 1/10 and 1/30 of the apparent average height of surface relief.

Calculating z_0 and u^* from measured air-flow boundary layers provides a quantitative method of comparing different surfaces and surfaces shear stresses, respectively. Vertical air-flow boundary layers over rough surfaces take the form

$$\Delta u = (u^*/k) \ln(z_1/z_2) \quad (3.3)$$

where u is mean air velocity, z is elevation, and k is the Von Karmon constant (0.40). In the equation, u and z are measured at two elevations, 1 and 2, above the surface, and $\Delta u = u_1 - u_2$. By plotting measured boundary layers as the local mean wind speed versus the natural log of dimensionless elevation, both aerodynamic surface roughness z_0 and friction velocity u^* can be determined. Such plots are reduced linearly over the elevation range of the air-flow boundary layers and take the linear form

$$\ln(z_d) = b + M(u_z) \quad (3.4)$$

where z_d = the dimensionless elevation
 u_z = the local velocity at elevation z
 b = the elevation axis intercept
 M = the slope of the curve fit ($M = \Delta z/\Delta u$).

Both surface shear stress parameters can be determined using Equations (3.3) and (3.4).

The parameter z_0 is defined using Equation (3.4) as the elevation above the surface at which the mean air velocity is zero. Rather than being a quiescent region, however, the z_0 elevation is a region where air velocities occur but fluctuate in direction and average zero. Therefore, z_0 occurs at the extrapolated elevation axis intercept. For example, an intercept of -3.00 corresponds to a z_0 of 0.050 cm. The parameter u^* is determined from Equation (3.3) as

$$u^* = k\Delta u / \ln(z_1/z_2) = kM^{-1} \quad (3.5)$$

where M equals $\ln(z_1/z_2)/\Delta u$ and u^* has units of u . For an air-flow boundary layer having $M = 0.30$, the corresponding u^* is 1.33 m/s. At wind speeds less than those that modify or smooth a surface (as a strong wind smoothes a grassy field), z_0 is constant, and u^* increases linearly with wind speed.

The range of wind speeds selected for the current project was based on those used in a previous study. Because of uncertainties associated with the determination of stresses present in the field, it is likely that the selected wind speeds are representative of many arid locations in the west. The comparison of field and wind tunnel stresses indicated that 25 m/s is a reasonable upper limit on wind speed in wind tunnel tests (Ligotke 1993). Resulting friction velocities at wind tunnel wind speeds of 20 and 25 m/s were estimated to be roughly 1.5 and 2 m/s, respectively, over flat surfaces.

Having selected the range of wind speeds for wind tunnel tests, the range of erosive stress caused by saltating sand particles was assigned to be equal to and less than the quantity of dune sand that could be carried by the test wind speeds. Sand was moved by wind from deposits placed on top of boundary layer surfaces 0.5 to 1.5 m upwind of the test surfaces. Sand particles passed across the test surfaces in saltation and creep. The intensities of sand storms simulated in the wind tunnel, based in part on the Hanford Site sand transport potentials described by Glantz et al. (1990), were 170 and 250 g/(m²-s) for the 20 and 25 m/s wind speeds.

3.3 MATERIALS AND TEST SURFACES

Test materials included soils, sand, water and dust suppressant agents. Two types of soils were received, a loamy soil from Idaho National Engineering Laboratory (INEL) and a sandy soil from Hanford. A few control tests were performed using McGee Ranch silt-loam soil from the batch tested by Ligotke (1993). Three batches of the Idaho soil were used. Sand was taken from an active dune on the Hanford Site. Water was mixed with dust control agents to aid application to test surfaces. Three dust control agents were used, powdered potato starch (PS), XDCA, and

fermented potato waste (FPW). The PS was commercial grade powder obtained from WHC. The XDCA, a liquid mixture of water, sugar beet extract sugars, and organic and inorganic additives, was obtained by WHC from Syntech Products Corporation. The Syntech product was formerly known as Dust Suppressant (CMS). PNL supplied three different batches of the FPW. The FPW was prepared by fermenting potato sludge derived from off-specification product and filter belt slurry from a commercial processing plant. The material contained starch and sugars converted by fermentation to ammonium lactate. Each batch of FPW was slightly different in appearance, with the third batch seeming to be more watery with less particulate matter.

Materials were used in bulk or were sieved to obtain needed particle size distributions. Sieve numbers herein refer to U.S. Alternate classifications. The soil was stored in barrels until just prior to use. The Idaho soil was screened using 0.25- to 0.38-in. mesh sizes, and larger unbreakable material and clods were removed. Hanford and McGee Ranch soils were used as collected. Soil moisture content tests were not required because initial moisture content was small, and moisture levels during tests (after aging in a growth chamber) were even less and did not contribute to surface mass loss during the wind tunnel tests. Idaho soil was loamy with small particles and hard clods ranging from about 1/16 to < 3/8 in. (after sieving). Hanford soil was a uniform sandy silt with easily breakable clods. McGee Ranch silt loam was fine and powdery when dry with medium to hard clods. The three batches of the Idaho loamy soil appeared grossly similar; however, comparison tests were performed between Batches 1 and 2 to determine their similarity with regard to erosion.

Dune sand was collected from the Hanford Site during both dry and moist periods. Moisture was removed when necessary using a drying oven or a growth chamber. The dry sand was sifted through a No. 18 sieve and stored in a sealed barrel. The grain size distribution of sand was measured using Method D422-63 (ASTM 1984), modified by the use of additional intermediate sieves to provide finer particle size gradation. The mass median grain size was 0.020 cm. The geometric standard deviation of the distribution was 1.65. Sand grains well represented the range susceptible to transport by saltation, with 90% of the sand mass consisting of grains having diameters between 0.010 and 0.038 cm.

Test surfaces were prepared by placing soil into stainless steel trays, leveling and smoothing the surface, and applying a surface agent. Control surfaces were prepared and left dry (dry controls) or sprayed with tap water (wet controls). The trays were square, having 50.5 cm wide sides, a surface area of 0.255 m², and depth of 1.9 cm. Soil surfaces were prepared to a total height of 3.2 cm--1.3 cm above the rim of the tray. A few early tests, identified in Section 4.0, were performed with total surface heights of 2.9 cm. Trays were prepared with 9300 g of Idaho

s soil or 9500 g of Hanford soil in an attempt to maintain uniform densities for all surfaces of each
t type. After placing the soil and smoothing the surface, all four edges were packed back at an angle
c of roughly 45° to prevent sloughing losses. Tray masses, less tare weights, were recorded.

Guidance was provided by WHC, PNL, and Syntech regarding the concentrations and
a application quantities to be applied for each dust control agent. The test matrix for each agent was
r modified slightly based on the results of early tests to ensure that an appropriate range of
c conditions was tested. These mid-project decisions were made based on performance and not cost-
b benefit considerations. The PS was prepared by mixing 1.0 and 2.5% solutions and applying a
r nominal solution volume of 0.25 to 1.0 L to test surfaces. The solutions were prepared as mass
l per volume, with a 1.0% solution consisting of 1.00 g of PS per 100 mL of water. Because PS
c did not readily mix with water, a blender was used at high and low speed for several minutes. The
r resulting solution was fairly stable over a period exceeding 10 min, with only a small quantity of
l PS settling to the bottom of a container. Spray applications of PS provided both the liquid and
s suspended solids constituents of the solution to test surfaces. The XDCA was easily mixed with
t water and was spray-applied to surfaces. Liquid XDCA had an undiluted density of 1.26 g/cm³
and was mixed with water volumetrically at 1:2 and 1:1 concentrations (see Section 4.1). The
l FPW was shaken vigorously and mixed volumetrically at 1:1 through 1:9 (see Section 4.1) with
water and applied using a "watering can" method. This method was used because the size of
solids in the solution precluded use of the spray nozzle. The method consisted of shaking the
FPW solutions in an inverted container having an array of twelve 0.16 cm holes drilled into its lid.
While the solids in the FPW solutions plugged the fine nozzles needed for the small areas tested in
the wind tunnel, it is expected that these solids will not cause difficulties in the field because of
greater volumetric application rates.

The amount of water or agent solution applied to each surface was tracked using either
gravimetric or volumetric methods, or both. In all cases, surfaces were also weighed before and
after application. Differences between the amounts measured to have been added to the surfaces
and those applied were caused primarily by loss of small amounts around the tray edges and to a
lesser extent by evaporation. The actual quantity applied was determined from the mass change of
the surface. Except for applications of less than 0.5 L, two half applications were made to each
tray to ensure complete and uniform coverage. Application quantities generally refer to nominal
values. Applications were made uniformly over the surfaces with the exception that perhaps twice
the nominal application rate was applied to an approximately 2 cm wide perimeter edge of the
surface. This was done to reduce the susceptibility of the edge regions to erosion.

Surfaces were aged following application of fugitive dust control agents to allow the added moisture to dry. This was done to represent actual field conditions and to remove the varying levels of moisture from the test surfaces. Moisture added ranged from 0.25 to 2.34 L per tray. An aging period of 4 days generally reduced the moisture to standard levels (determined by gross tray mass). An alternate drying period of 5 days was used for surfaces having the 2.34 L application (this application was only performed for XDCA). All aging took place in a plant growth chamber having a diurnal cycle of 40°C during 12-h days, and 20 °C during 10-h nights. Two 1-h transition periods of light and temperature (dawn and dusk) also occurred each day. Selected surfaces were exposed to uv radiation during the daylight cycles of the 4 days between preparation and testing. Four Sylvania 350 Blacklight 20-W lamps were suspended 44 cm above the surfaces to provide the uv source. Other selected surfaces were exposed to simulated rain three times during an extended drying period. After three days of normal aging, these surfaces were sprayed lightly with a total of 0.5 L of water per tray for each of the next three days. The surfaces were then allowed to dry normally for four days after the third application of water.

3.4 TEST PROCEDURES AND MEASUREMENTS

Tests were conducted between March and August 1993. Test procedures were modifications based on those reported by Ligothke and Klopfer (1990) and Ligothke (1993). Surfaces were exposed to known wind-caused surface shear stresses through a series of up to eight subtests. Surface masses (surface and tray masses) were recorded before each test and between subtests, and mass changes were used to determine deflation rates. Surfaces were tested undisturbed then disturbed until the subtest series was complete or failure criteria were met. Observed test conditions were recorded on the back of data sheets. Because several seconds were required to attain the target wind speed at the beginning of each subtest, the wind tunnel fan controller was engaged approximately 8 s prior to the planned start of each subtest. The impact of this uncertainty on the duration of subtests was about 6 s (about 5% of a 2-min subtest).

The test section of the wind tunnel was configured to provide steady air-flow boundary layers to test surfaces. Three boundary layer surfaces, extending over a length of 152 cm, were positioned upwind of one test tray. The boundary layer surfaces consisted of weathered 0.67-cm pea gravel admixtures surfaces that modified air-flow boundary layers by providing frictional drag. The surfaces were prevented from eroding by the protection of a thin layer of water-soluble polyvinyl alcohol that was sprayed on wet and allowed to dry. Aluminum angle studded with pea gravel was placed to the sides of the boundary layer and test surfaces to extend the width of the rough surface and reduce preferential scouring along the edges of test surfaces. The elevation of the test surface was maintained near that of the boundary layer surfaces using shims. The wind

tunnel was operated with dust-stop filters placed in the 4.5-m² cross-section return loop to trap suspended soil. An air conditioner removed heat generated when operating the wind tunnel at high speed for extended periods.

Surfaces were exposed to as many as eight subtests. Subtests 1 through 4 proceeded from target wind speeds of 20 m/s, 25 m/s, 20 m/s plus 10 kg of sand, and 25 m/s plus 15 kg of sand. After Subtest 4, surfaces that had not failed (see below) were disturbed to break up the crust. Effort was made to break the surface crusts in a similar fashion from test to test. A regular grid of square-edged indentations were pressed into the surfaces using a plexiglass tool having an array of teeth 1.2 cm square and 0.7 cm deep. These indentations were separated by a distance of 2.5 cm. The tool was used to press a single row of 19 indentations into each surface near its leading edge, and then lifted above the surface and moved to make a total of 19 rows of indentations transverse to the direction of wind. After disturbing the surface, a new mass was recorded, and Subtests 5 through 8 were performed. This second series of subtests repeated the conditions of Subtests 1 through 4. Tests were performed for a duration of 2 min, with a few exceptions. Dry control surfaces were exposed to 10 and 15 m/s for durations of 5 minutes, followed by the normal test process until failure. Wet control surfaces were subjected to the same test series as were agent-coated surfaces.

Surface crusts either survived the entire eight-part test or failed during the process. Because of an inability to match the test surface to the boundary layer surface after all material above the test tray rim had been eroded, tests were considered to be complete, or the surfaces to have failed, after a portion of the tray rim became exposed. Failure often occurred at the back rim because of the greater influence of creep and saltation on the downwind portions of the test surface. At other times, surfaces failed when a large fraction of the surface crust had been removed, leaving unprotected material exposed to wind. The mass of the test trays were measured before and after each subtest by removing the trays from the wind tunnel and placing them on a mass balance. Test surfaces having an accumulated mass loss of about 2000 g were also considered to have failed. Replicate tests were performed on all fixative application rates with the exception of two FPW tests that did not perform well. Subtests completed after failure criteria were met were not included in the final analysis of data. Subtests completed on replicate trays after another replicate surface failed were not included either.

Measurements were required during each test to characterize surface characteristics, environmental conditions, erosive stresses, and surface deflation mass losses. Measurement devices were compared to laboratory standards when needed. Others were based on standard

quality assurance certifications. In addition, photographs were taken to document changing surface conditions during selected tests.

Trays were weighed every day after preparation to note mass changes. By the fourth day, most added moisture was depleted. Trays were removed from the growth chamber and allowed to come to room temperature before testing. Mass was recorded just prior to beginning each test. Changes in mass of test surfaces exposed to wind and sand erosive stresses were monitored by removing the surfaces after each subtest and measuring their mass using a Sartorius Model 3807 high-capacity mass balance. The device was readable and accurate to ± 1 g. Other uses of the Sartorius balance included weighing solutions and surfaces during application of dust control agents and preparing 10 and 15 kg quantities of sand for the saltation tests. A Mettler PE 163 mass balance with an accuracy better than ± 0.01 g was also used in the preparation of solutions. Mass balances were calibrated routinely by the Hanford Westinghouse Standards Laboratory.

Mean wind speed, temperature, and relative humidity were measured routinely using the facility's computer data acquisition system. Temperature and relative humidity were measured using a General Eastern Model 1500 hygrometer. The device was supplied by the manufacturer with a calibration certificate and checked using a constant-draft psychrometer prior to being used to monitor wind tunnel conditions. Mean wind speed was measured using a pitot-static probe located at the center of the test section and oriented within less than 5° of the mean wind direction. The probe was located in a region of uniform flow well away from the influence of air-flow boundary layers. The pitot-static probe provided dynamic and static pressures to a Model 398 MKS Baratron differential pressure transducer connected to a Model 270B controller and the facility computer system. The MKS system measured the pressure difference between the static and dynamic pressures in the wind tunnel test section. The computer system was used to convert these data to wind speed and store the information. Mean wind speed, u in m/s, was determined by measuring the pressure differential, Δp in in.-H₂O, and the air temperature and pressure, T and P in $^\circ\text{K}$ and in.-Hg, respectively. Wind speed was calculated using the Bernoulli equation reduced to the form

$$u = 6.496(T/P)^{1/2}(\Delta p)^{1/2} \quad (3.6)$$

Wind speed calibrations were performed by comparing the output of the MKS system to a Dwyer Model 1430 micromanometer with a certified micrometer. No adjustments to the factory calibration of the MKS system were required as both it and the Dwyer generally agreed within about 1%. The standard deviations of the typically five measurements made during each subtest were generally less than 1% of the mean wind speeds. Erosive stresses provided by wind to the test surfaces were based on boundary layer measurements made previously (Ligotke 1993).

3.5 DATA ANALYSIS PROCESS

Test data were analyzed to determine surface deflation rates and effectiveness of applied dust control agents. The information was used to compile a set of data for future reference and to form correlations and make conclusions. Data included soil type, agent, agent concentration, quantity of agent applied, aging conditions, temperature, relative humidity, wind speed, surface mass history, and observations. All data for each test were recorded on two data sheets. The average, standard deviation, and number of wind speed measurements were calculated on test data sheets, and the mean wind speeds were entered directly into deflation rate data worksheets. Worksheets were used to calculate surface deflation rates from mass change, subtest duration, and surface area information. Deflation rate (D_r), in grams per square meter per second ($g/(m^2-s)$), were calculated from subtest data as:

$$D_r = \Delta M / (A_s \Delta t) \quad (3.7)$$

where ΔM is the loss in mass of the test surface in g, A_s is the surface area of the test surface in m^2 , and Δt is the duration in seconds of the subtest. These data were summarized in other worksheets by subtest, agent and soil type, agent concentration, application quantity, and aging conditions. Comparisons were made of the various test parameters. Because of the range-finding nature of this study and the variability associated with the Idaho soil wet controls, results of each set of parameters were compared to others using average deflation rates and considering uncertainty to equal the standard deviation of typically two replicate tests. Significant differences between two sets of parameters were considered to have occurred when no overlap occurred in the deflation rates and their uncertainties.

4.0 RESULTS AND DISCUSSION

This section, Appendix A, and Appendix B present the results of wind erosion tests performed between March and August 1993, including a list of tests and surface configurations, descriptions of applied eolian erosive stresses, and actual deflation rate results compared with test parameters. Data generated provide information regarding the influence on deflation rate (fugitive dust control) of wind speed and sand particle saltation for a range of applications of three dust control agents on two soil types.

4.1 TESTS AND SURFACE CONFIGURATIONS

A list of tests completed in the present study is shown in Table 4.1. As described in Section 3.0, the fugitive dust control agents were potato starch (PS), XDCA, and fermented potato waste (FPW). The PS solution concentrations refer to percentage by mass in water, k:l, where k grams of PS powder were mixed in each 100 mL of water. The 1.0% PS solution is listed as 1.0:100, and the 2.5% solution as 2.5:100. The XDCA and FPW concentrations, m:n, refer to m parts concentrate plus n parts water. Tests 1 through 6 were performed with an initial surface elevation 0.3 cm lower than all subsequent tests. Pre-spray surface densities were calculated using a correction for material removed during preparation of the 45° sloped tray rim to top surface transitions. Pre-spray surface densities were 1.14 ± 0.01 , 1.15 ± 0.03 , and 1.10 ± 0.03 g/cm³ for Idaho, Hanford, and McGee Ranch soils, respectively. All batches of Idaho soil were similar in density within ± 0.01 g/cm³.

4.2 APPLIED EOLIAN EROSIVE STRESSES

The primary emphasis of wind tunnel tests of fugitive dust suppressant agents was to provide data for side-by-side comparisons of various treatment levels and conditions. Thus, it was important to reproduce from test to test the preparation of surfaces, application of agents, aging, and wind and sand conditions during the tests. Specific procedures were followed in preparing the surfaces to minimize uncertainty. Wind velocities were measured and found to typically range within $\pm 1\%$ of the target speeds. Wind erosion parameters were determined. Sand flow rates and the kinetic energy of sand grains were likewise well controlled.

The erosion parameters friction velocity, u^* , and roughness height, z_0 , were measured previously (Ligotke 1993 and Ligotke and Klopfer 1990) for surfaces similar to the undisturbed surfaces in the present study. The u^* was found to be a linear function of mean wind speed and to increase from about 0.8 to 1.6 m/s over boundary layer surfaces used in the present study. Over soil (smooth) and pea gravel admixture surfaces, u^* was found to increase from 0.6 to 1.1 m/s and

TABLE 4.1. Fugitive Dust Control Surface Fixative Agent Tests Performed in a Wind Tunnel Between March and August 1993

Test No.	Date	Soil Type	Pre-Spray Density (g/cm ³)	Dust Control Agent	Solution Concentration	Application Quantity (L/m ²)	Surface Aging Conditions
1-trial	3/22/93	Hanford	1.06	PS	(a)	(a)	Standard
2-trial	3/25/93	Hanford	~1.03	Wet Control	n/a	1.4	Standard
3	3/30/93	Idaho	1.03	PS	1.0:100	1.0	Standard
4	3/30/93	Idaho	1.11	PS	2.5:100	4.0	Standard
5	4/02/93	Idaho	1.08	Dry Control	n/a	0.0	Standard
6	4/02/93	Idaho	1.08	Wet Control	n/a	2.0	Standard
7	4/05/93	Idaho	1.14	PS	1.0:100	2.0	Standard
8	4/05/93	Idaho	1.13	PS	2.5:100	1.0	Standard
9	4/06/93	Idaho	1.12	PS	1.0:100	1.0	Standard
10	4/06/93	Idaho	1.14	PS	2.5:100	4.0	Standard
11	4/09/93	Idaho	1.12	Dry Control	n/a	0.0	Standard
12	4/09/93	Idaho	1.16	Wet Control	n/a	2.0	Standard
13	4/12/93	Idaho	1.14	PS	1.0:100	2.0	Standard
14	4/12/93	Idaho	1.17	PS	1.0:100	2.0	uv-cycle
15	4/13/93	Idaho	1.14	PS	2.5:100	2.0	Standard
16	4/13/93	Idaho	1.14	PS	1.0:100	2.0	uv-cycle
17	4/19/93	Idaho	1.14	PS	2.5:100	1.0	Standard
18	4/19/93	Idaho	1.14	PS	2.5:100	2.0	Standard
19	4/21/93	Idaho	1.14	PS	1.0:100	2.0	Moisture-cycle
20	4/21/93	Idaho	1.14	PS	1.0:100	2.0	Moisture-cycle
21	4/22/93	Idaho	1.14	Dry Control	n/a	0.0	Standard
22	4/22/93	Idaho	1.15	Wet Control	n/a	2.0	Standard
23	4/27/93	Idaho	1.14	PS	0.7:100	1.0	Standard
24	6/07/93	Idaho(2)	1.14	XDCA	1:2	4.5	Standard
25	6/07/93	Idaho(2)	1.14	XDCA	1:2	1.1	Standard
26	6/11/93	Idaho(2)	1.14	Dry Control	n/a	0.0	Standard
27	6/11/93	Idaho(2)	1.15	Wet Control	n/a	2.0	Standard
28	6/11/93	Idaho(2)	1.14	PS	1.0:100	2.0	Standard
29	6/11/93	Idaho(2)	1.14	PS	1.0:100	2.0	Standard
30	6/18/93	Idaho(2)	1.14	XDCA	1:2	4.5	Standard
31	6/18/93	Idaho(2)	1.13	XDCA	1:1	4.5	Standard
32	6/22/93	Idaho(2)	1.15	XDCA	1:2	1.1	Standard
33	6/22/93	Idaho(2)	1.15	XDCA	1:1	4.5	Standard
34	6/22/93	Idaho(2)	1.14	XDCA	1:2	4.5	uv-cycle
35	6/22/93	Idaho(2)	1.14	XDCA	1:2	4.5	uv-cycle
36	6/28/93	Idaho(2)	1.16	Dry Control	n/a	0.0	Standard
37	6/28/93	Idaho(2)	1.16	Wet Control	n/a	2.0	Standard
38	6/28/93	Idaho(2)	1.16	PS	1.0:100	4.0	Standard
39	6/28/93	Idaho(2)	1.16	PS	1.0:100	4.0	Standard
40	7/03/93	Idaho(2)	1.15	XDCA	1:2	2.3	Standard
41	7/03/93	Idaho(2)	1.14	XDCA	1:2	2.3	Standard
42	7/07/93	Idaho(2)	1.15	FPW	1:4	2.0	Standard
43	7/07/93	Idaho(2)	1.15	FPW	1:4	4.0	Standard
44	7/08/93	Idaho(2)	1.14	XDCA	1:2	4.5	Moisture-cycle
45	7/08/93	Idaho(2)	1.15	XDCA	1:2	4.5	Moisture-cycle
46	7/12/93	Hanford	1.20	Wet Control	n/a	2.0	Standard
47	7/12/93	Hanford	1.14	Wet Control	n/a	2.0	Standard
48	7/12/93	Idaho(2)	1.14	FPW	1:4	4.0	Standard
49	7/12/93	Idaho(2)	1.15	FPW	1:1	4.0	Standard
50	7/13/93	Hanford	1.11	PS	1.0:100	2.0	Standard

TABLE 4.1. (contd.)

Test No.	Date	Soil Type	Pre-Spray Density (g/cm ³)	Dust Control Agent	Solution Concentration	Application Quantity (L/m ²)	Surface Aging Conditions
51	7/13/93	Hanford	1.11	PS	1.0:100	2.0	Standard
52	7/16/93	McGee Ranch	1.09	Wet Control	n/a	2.0	Standard
53	7/16/93	McGee Ranch	1.13	Wet Control	n/a	2.0	Standard
54	7/16/93	Idaho(2)	1.15	FPW	1:2	4.0	Standard
55	7/16/93	Idaho(3)	1.13	FPW	1:9	4.0	Standard
56	7/20/93	Hanford	1.15	FPW	1:4	4.0	Standard
57	7/20/93	Hanford	1.15	FPW	1:4	4.0	Standard
58	7/20/93	Idaho(3)	1.14	FPW	1:4	4.0	uv-cycle
59	7/20/93	Idaho(3)	1.14	FPW	1:4	4.0	uv-cycle
60	7/22/93	Hanford	1.16	Dry Control	n/a	0.0	Standard
61	7/22/93	Hanford	1.17	Dry Control	n/a	0.0	Standard
62	7/22/93	Idaho(3)	1.16	FPW	1:4	4.0	Moisture-cycle
63	7/22/93	Idaho(3)	1.13	FPW	1:4	4.0	Moisture-cycle
64	7/24/93	Hanford	1.17	XDCA	1:2	4.5	Standard
65	7/24/93	Hanford	1.16	XDCA	1:2	4.5	Standard
65a	7/26/93	Hanford	1.16	XDCA	1:2	4.5	Standard
65b	8/03/93	Hanford	1.16	XDCA	1:2	4.5	Standard
66	7/24/93	McGee Ranch	1.07	Dry Control	n/a	0.0	Standard
67	7/24/93	McGee Ranch	1.11	Dry Control	n/a	0.0	Standard
68	7/26/93	Idaho(3)	1.16	FPW	1:9	4.0	Standard
69	7/26/93	Idaho(3)	1.15	FPW	1:4	2.0	Standard

(a) The surface prepared for Test 1 was sprayed with two PS treatment levels, 1.0:100 and 1.0 L/m² on the north half, and 2.5:100 and 4.0 L/m² on the south.

0.8 to about 1.7 m/s, respectively for wind speeds of 10 and 20 m/s. Because the undisturbed surfaces in the present study were similar to the soil (smooth) surfaces tested previously, u^* was known to be about 1.1 and 1.4 m/s at wind tunnel wind speeds of 20 and 25 m/s, respectively. For such surfaces, z_0 was found previously to be about 0.003 to 0.004 cm.

The disturbed surfaces in the present study formed rough ridges and furrows that caused greater erosive stresses than over the smooth, undisturbed surfaces. Measurements of the air-flow boundary layer were made over the disturbed surface from Test 65 at 10 and 20 m/s to provide an indication of the erosive stresses over all disturbed surfaces. The surface appeared to represent an average of the disturbed surfaces. The u^* increased from 0.85 to 1.67 m/s, at 10 and 20 m/s, respectively, and z_0 was 0.052 cm. Because u^* varies linearly with wind speed, u^* at 25 m/s was estimated to be 2.1 m/s.

Based on the u^* and z_0 parameters, the surface shear stress, τ_s , caused by wind on the undisturbed test surfaces in the present study was estimated [Equation (3.2)] to be approximately 1.5 and 2.4 N/m² at wind speeds of 20 and 25 m/s, respectively. In a similar fashion, τ_s on the

disturbed surfaces was 3.4 and ~ 5.3 N/m² at 20 and 25 m/s, respectively. The mass flow rates, or intensities, of saltating sand in the present study were 170 and 250 g/(m²-s) for 20 and 25 m/s wind speeds, respectively.

4.3 SURFACE DEFLATION RATE RESULTS

Wind tunnel test data were analyzed to provide information on the influence of fugitive dust suppressants on two soil types exposed to eolian stresses. The agents were applied using a range of solution concentrations and application quantities, and were aged by exposure to standard, uv-cycle, and moisture-cycle conditions before testing. A list of all tests including measured subtest duration, wind speed, and mass change, as well as calculated deflation rate, are shown in Appendix A. Appendix B shows this information grouped by test parameter. The control tests of McGee Ranch soil were supported by another study but were included in the data sets because of their applicability. The performance under conditions of eolian stress of the control surfaces are described as are the performance of PS, XDCA, and FPW. The majority of the tests were performed using Idaho loamy soil; however, the few tests performed using a Hanford sandy soil provided an indication of the importance of soil type on the performance of dust control agents and are described. Summary information is presented in this section. Additional results are listed in Appendix A and summarized in groups in Appendix B. Figures presented in this section show all data prior to surface failure; for cases that failed after a given subtest, subsequent subtests were excluded from the figures. In other cases, surface failure is noted on the figures.

Comparisons of the various dust control agents by test parameters and subtest are listed in tables in the following sections. The following description refers to those tables. The comparisons shown in the tables were made by considering the ratio of the agent-protected surface to the corresponding wet control deflation rates. A significant difference was judged to have occurred if the ratio of deflation rates from the agent-protected to the wet control surfaces was always less than unity for the range of uncertainties associated with the data. A significant difference, for ranges of ratios less than unity, indicates that the dust control agent provided protection superior to the water crust of the wet control. The smaller the maximum ratio of deflation rates, the better the protection provided by the dust control agent. For example, if the deflation rate from an agent-protected surface is 0.11 ± 0.067 g/(m²-s) and that from the corresponding wet control is 1.2 ± 0.54 g/(m²-s), then the range of possible deflation rate ratios is 2.5 to 27%, and the difference is significant because the range does not span unity (100%). This conservative approach was selected based on the small number of replicate tests and the wide variation in the Idaho soil wet control results. Smaller variation in the wet controls was expected and would have provided more easily interpreted results. All surfaces were protected from

deflation during Subtests 1 and 2 and the surfaces were disturbed as described in Section 3.4 between Subtests 4 and 5.

4.3.1 Dry and Wet Control Surfaces (Not Treated)

Dry and wet control surfaces were prepared from both Idaho and Hanford soils and tested to provide a baseline of deflation rates from untreated surfaces. As described above, similar tests of McGee Ranch silt-loam are also reported. The dry controls differed from treated surfaces by having no additional water spray added. The wet controls received 2.0 L/m² of water spray. It should be noted that the wet controls were allowed to dry prior to testing. This is in contrast to normal field applications of water where the surface is kept wet by repeated applications. As expected, the dry controls produced the greatest deflation rates. The cohesiveness of the soils and their resistance to wind erosion varied greatly and was apparently related to sand content. Figure 4.1 shows the influence of wind speed on deflation rate from the dry controls for each soil type. With the greatest sand content, Hanford soil deflated at rates decreasing from about 50- to about 3-fold greater as wind speed increased from 10 to 20 m/s. No uncertainty limits were available for the Hanford soil case because the tests were performed at different wind speeds to cover the range of 10 to 20 m/s without depleting the test surfaces. At a wind tunnel wind speed of 20 m/s, deflation rates averaged 0.14 ± 0.10 , 6.4, and 0.45 ± 0.28 g/(m²-s) for both Idaho soils, Hanford soil, and McGee Ranch soil, respectively. The rate of increase in deflation rate with wind speed was proportional to $\exp bu$, where $b = 0.18 \pm 0.02$, and u = mean wind speed. These measured deflation rates represent soil mass loss from freshly exposed dry soil surfaces. A comparison of the undisturbed test cases for all soil types is shown in Figure 4.2.

The water-sprayed wet controls formed crusts of soluble materials on the soil surfaces that provided protection from eolian stresses. In the case of the Idaho loamy soil (Batches 1 and 2 were tested), the water crust provided good protection of the undisturbed surfaces but was subject to failure at high wind speed after the surfaces were disturbed. In contrast, undisturbed Hanford sandy soil failed on exposure to saltating sand stress at 20 m/s. McGee Ranch soil provided an intermediate case as it also failed before being disturbed, but did not fail until saltating sand stress was applied at 25 m/s. The degree of protection provided by the crust formed after water was sprayed on the surfaces was apparently related to the sand content of the soils. The more sand present, the less well the water crust protected the surfaces. The soluble materials content of the soils was not known, but also likely affected the durability of the crusts. Figure 4.3 shows a comparison of all soil types in the undisturbed condition. Figure 4.4 shows both dry and wet control Idaho soils in the undisturbed condition. Figure 4.5 shows wet control Idaho soils in both the undisturbed and disturbed conditions. The figures compare Idaho soil Batches 1 and 2.

FIGURE 4.1 Deflation Rate from Dry Control Soil Surfaces Versus Mean Wind Speed

FIGURE 4.2 Deflation Rate From Undisturbed Dry Control Soil Surfaces

FIGURE 4.3 Deflation Rate from Undisturbed Wet Control Soil Surfaces

FIGURE 4.4 Deflation Rate from Undisturbed Idaho Soil Wet Control Surfaces

FIGURE 4.5 Deflation Rate from Disturbed Idaho Soil Wet Control Surfaces

Results of the Idaho soil wet controls from Batch 1 were used as a baseline for comparison with the fugitive dust control agent results in the figures in the following sections; measured deflation rates were 0.54 ± 0.50 , 1.3 ± 0.48 , 1.1 ± 1.1 , and 27 ± 37 g/(m²-s) during Subtests 3, 4, 5, and 6, respectively. Results of the Idaho soil wet controls from Batches 1 and 2 were used as a baseline for comparison with the fugitive dust control agent results; measured deflation rates were 1.2 ± 0.95 , 1.2 ± 0.54 , 1.1 ± 0.86 , and 29 ± 31 g/(m²-s) during Subtests 3, 4, 5, and 6, respectively. Similar results for Hanford soil wet controls were 230 ± 71 g/(m²-s) for Subtest 3; the Hanford soil wet controls failed at the end of Subtest 3.

The most significant difficulty in comparing wet controls with agent-protected surfaces is the large uncertainty in the Idaho soil wet control test results. Based on past results of tests with McGee Ranch silt-loam soils, we had anticipated better test-to-test repeatability. The presence of a greater fraction of loam in the Idaho soil might have caused the poorer repeatability in the present study. However, comparison with agent-protected surfaces were made and did indicate the more obvious agent treatments. It should be noted that the Hanford sandy soil would be expected to result in better test-to-test repeatability because of its high sand content, low loam content, and uniformity.

4.3.2 Potato Starch Surface Crusts

Results discussed in this section refer to Idaho soil surfaces. Hanford soil surfaces protected by potato starch solutions are discussed in Section 4.3.5. The PS surface crusts were prepared using two solution concentrations (1.0 and 2.5%) and three application quantities (1, 2, and 4 L/m²). Tests were performed of all combinations of the two parameters. Based on early results, the "standard" case was selected to be 1.0% at 2 L/m². This case was used to test the impact of surface aging conditions (uv-cycle and moisture-cycle).

In general, application of PS to Idaho soil improved resistance to wind erosion, although the degree of improvement at the least application (1.0% and 1 L/m²) was not significant based on the limited number of replicate tests performed. Rather than being a function of starch mass applied per area of surface, the results indicated that the 2.5% solution provided the best surface protection even when applied at 1 L/m². It is possible this result occurred because the 1.0% solution washed the starch further into the surface and reduced its effectiveness. Figures 4.6 and 4.7 show the results of all tests compared to the wet control surfaces. Negative deflation rate results indicate that the rough surfaces actually gained mass from depositing sand particles during Subtests 3, 4, 7, and 8 (saltating sand subtests). This was most pronounced for the disturbed surfaces, which were broken into rough ridges and furrows. Sand was trapped in the furrows. From the figures, it is clear that all PS applications, with the possible exception of 1.0% at 1 L/m², improved resistance to wind erosion. It is clear (Figure 4.7) that the high concentration, low water PS solution (2.5% PS at 1 L/m²) provided the best protection. Results of Subtest 6 (disturbed surface, 25 m/s, no sand) indicated that even increasing the starch content on the surface 4-fold, the 2.5% at 4 L/m² case, did not perform as well. This supports the conclusion that water tends to dilute the effect of the PS.

Figures 4.8 and 4.9 show the impact of surface aging condition on PS crusts. Although uv-cycling did not seem to impact PS crusts, tests of the disturbed surfaces indicated that moisture-cycling eliminated the benefit of applying PS to Idaho soil surfaces.

Table 4.2 shows a comparison of PS-treated to wet control Idaho soil surfaces by PS solution concentration and quantity applied. A general description of the table is provided in Section 4.3. The PS formed a superior surface crust in all cases; however, because of uncertainties in the wet controls, significant differences were not measured in all cases. As described above, it can be seen in the table that the 2.5% PS solution at application quantities of 1 and 2 L/m² provided the best overall surface protection with average deflation rates between 0 and 14% of those from the wet control surfaces.

FIGURE 4.6 Deflation Rate from Undisturbed Idaho Soil Protected by Potato Starch

FIGURE 4.7 Deflation Rate from Disturbed Idaho Soil Protected by Potato Starch

FIGURE 4.8 Influence of Aging Conditions on Undisturbed Potato Starch Crusts

FIGURE 4.9 Influence of Aging Conditions on Disturbed Potato Starch Crusts

TABLE 4.2. Ratio of Deflation Rates--Potato Starch Agent-Protected to Wet Control Surfaces, Idaho soil only. Data are listed as average, less than a maximum value, or average (range).

Subtest No.	Case	1 L/m ²	Significant Difference	2 L/m ²	Significant Difference	4 L/m ²	Significant Difference
1.0% PS Solution/Undisturbed							
3	20 m/s + sand	~0	yes	~0	yes	~0	yes
4	25 m/s + sand	0.43 (0-2)	no	~0	yes	~0	yes
1.0% PS Solution/Disturbed							
5	20 m/s	0.57 (0.03-5)	no	0.53 (0.07-4)	no	0.72 (0.3-4)	no
6	25 m/s	0.31 (0->1)	no	0.14 (0.05->1)	no	0.23 (0.1->1)	no
7	20 m/s + sand	~0	yes	~0	yes	~0	yes
8	25 m/s + sand	<0.30	yes	<0.088	yes	<0.066	yes
2.5% PS Solution/Undisturbed							
3	20 m/s + sand	~0	yes	~0	yes	~0	yes
4	25 m/s + sand	~0	yes	~0	yes	~0	yes
2.5% PS Solution/Disturbed							
5	20 m/s	0.10 (0.4-0.6)	yes	0.14 (0.07-0.7)	yes	0.44 (0.2-2.5)	no
6	25 m/s	0.045 (0.02->1)	no	0.055 (0.01->1)	no	0.12 (0.05->1)	no
7	20 m/s + sand	~0	yes	~0	yes	~0	yes
8	25 m/s + sand	<0.027	yes	~0	yes	~0	yes

4.3.3 XDCA Sugar Beet Extract Surface Crusts

Results discussed in this section refer to Idaho soil surfaces. Hanford soil surfaces protected by XDCA solutions are discussed in Section 4.3.5. The XDCA surface crusts were prepared using two solution concentrations (1:2 and 1:1) and three application quantities (1.1, 4.5, and 9.2 L/m²). Solutions were prepared volumetrically as described in Section 3.3 and 4.1. Solution concentrations 1:2 and 1:1 represent 33 and 50% XDCA in water, respectively. Tests were performed of the 1:1 at 4.5 L/m² and all 1:2 cases. Based on early results, the "standard" case was selected to be 1:2 at 4.5 L/m², and was used to test the impact of surface aging conditions (uv- and moisture-cycling).

The XDCA application quantity tests, performed at a solution concentration of 1:2 are shown in Figures 4.10 and 4.11. The crusts performed similar to the wet control with the exception of the 1:2 at 1.1 L/m² case, which provided less protection than the wet control case. The XDCA solution concentration tests, performed at an application rate of 4.5 L/m² are shown in Figures 4.12 and 4.13. Neither test case resulted in a surface crust providing a significant difference from the wet control. Figures 4.14 and 4.15 show the impact of aging conditions on XDCA surface crusts. Both uv-cycling and moisture-cycling may have reduced the effectiveness

FIGURE 4.10 Undisturbed Idaho Soil Protected by XDCA - Application Quantity Tests

FIGURE 4.11 Disturbed Idaho Soil Protected by XDCA - Application Quantity Tests

FIGURE 4.12 Undisturbed Idaho Soil Protected by XDCA - Solution Concentration Tests

FIGURE 4.13 Disturbed Idaho Soil Protected by XDCA - Solution Concentration Tests

FIGURE 4.14 Influence of Aging Conditions on Undisturbed XDCA Crusts

FIGURE 4.15 Influence of Aging Conditions on Disturbed XDCA Crusts

of the undisturbed crusts; however, the results were not significantly different from the standard case. The disturbed crusts eroded similarly in all aging cases.

Table 4.3 shows a comparison of XDCA-treated to wet control Idaho soil surfaces by XDCA solution concentration and quantity applied. A general description of the table is provided in Section 4.3. The XDCA formed a superior surface crust only at a solution concentration of 1:2 and the highest application quantity of 9.2 L/m². Results of the other cases indicate that the water crust provided better protection. In particular, the 1:2 concentration, 1.1 L/m² case seemed to cause an increase in deflation rate.

4.3.4 Fermented Potato Waste Surface Crusts

Results discussed in this section refer to Idaho soil surfaces. Hanford soil surfaces protected by FPW solutions are discussed in Section 4.3.5. FPW surface crusts were prepared using four solution concentrations (1:9, 1:4, 1:2, and 1:1) and two application quantities (2 and 4 L/m²). Solutions were prepared volumetrically as described in Section 3.3 and 4.1. Solution

TABLE 4.3. Ratio of Deflation Rates--XDCA Agent-Protected to Wet Control Surfaces, Idaho Soil Only. Data are listed as average, less than a maximum value, or average (range).

Subtest No.	Case	1.1 L/m ²	Significant Difference	4.5 L/m ²	Significant Difference	9.2 L/m ²	Significant Difference
<u>1:2 XDCA Solution/Undisturbed</u>							
3	20 m/s + sand	19 (10-95)	(a)	0.83 (0.3-6)	no	0.11 (0-1.4)	no
4	25 m/s + sand	33 (21-62)	(a)	0.72 (0.2-2)	no	0.013 (0-0.13)	yes
<u>1:2 XDCA Solution/Disturbed</u>							
5	20 m/s	>1	(a)	3.0 (1-20)	no	1.4 (0.5-8)	no
6	25 m/s	>1	(a)	1.9 (0.9->1)	no	0.97 (0.4->1)	no
7	20 m/s + sand	~1	no	~1	no	n/a	
8	25 m/s + sand	~1	no	~1	no	<0.10	yes
<u>1:1 XDCA Solution/Undisturbed</u>							
3	20 m/s + sand	n/a		0.81 (0-8)	no	n/a	
4	25 m/s + sand	n/a		1.0 (0-4)	no	n/a	
<u>1:1 XDCA Solution/Disturbed</u>							
5	20 m/s	n/a		2.2 (0.7 - 14)	no	n/a	
6	25 m/s	n/a		1.5 (0.5->1)	no	n/a	
7	20 m/s + sand	n/a		~0	yes	n/a	
8	25 m/s + sand	n/a		<0.22	yes	n/a	

(a) Significant difference, XDCA-coated surfaces less protected than wet control surfaces.

concentrations 1:9, 1:4, 1:2, and 1:1 represent 10, 20, 33, and 50% FPW in water, respectively. Tests were performed of the 1:4 at 2 L/m² and all 4 L/m² cases. Based on early results, the "standard" case was selected to be 1:4 at 4 L/m². This case was used to test the impact of surface aging conditions (uv-cycle and moisture-cycle). Solution concentrations of 1:1, and to a lesser extent 1:2, formed heavily cracked surfaces similar to a dried lake bottom. While the other dust control agents also formed lightly cracked surfaces, these cases were the only ones that formed crusts so heavy that the crust plates curled up at the edges. One result of this was a susceptibility to erosion as wind was able to apply force to the exposed edges. It is possible that a modified solution would prevent this occurrence.

The FPW provided protection of undisturbed surfaces for certain combinations of solution concentration and application quantity. Disturbed surfaces were not significantly protected. Application of FPW at 4 L/m² performed better than that of 2 L/m² for the single solution concentration tested (1:4) and undisturbed surfaces. However, both application quantities performed similarly to the wet controls after the surfaces were disturbed. These results are shown in Figures 4.16 and 4.17. Applications of low and medium solution concentrations of FPW performed better than the highest concentration, as shown in Figure 4.18, simply because the heavily cracked surface resulting from the 1:1 application was susceptible to losing crust plates. As shown in Figure 4.19, FPW did not significantly protect the disturbed surfaces regardless of solution concentration. Figures 4.20 and 4.21 show the impact of surface aging on surface protection by FPW. As with the PS fixative, surface protection was lost with exposure to moisture-cycling, but exposure to uv-cycling did not significantly degrade surface protection.

Table 4.4 shows a comparison of FPW-treated to wet control Idaho soil surfaces by FPW solution concentration and quantity applied. A general description of the table is provided in Section 4.3. The 1:2 and 1:1 solution concentration cases were not included in the table because no replicate tests were performed. The FPW generally provided better surface protection; however, because of uncertainties in the wet controls, significant differences were not measured in some cases.

4.3.5 Impact of Soil Type on Surface Protection

Although a majority of tests were performed using Idaho soil, it was recognized that the much different structure of the Hanford soil could impact the suitability of dust control agents. This presumption was based on the potential for different wettability and penetrability of the agents into the different soil surfaces. The Idaho soil appeared to contain more loam and the Hanford soil clearly contained more sand and was more coarsely grained. Two replicate tests were therefore

FIGURE 4.16 Undisturbed Idaho Soil Protected by FPW - Application Quantity Tests

FIGURE 4.17 Disturbed Idaho Soil Protected by FPW - Application Quantity Tests

FIGURE 4.18 Undisturbed Idaho Soil Protected by FPW - Solution Concentration Tests

FIGURE 4.19 Disturbed Idaho Soil Protected by FPW - Solution Concentration Tests

FIGURE 4.20 Influence of Aging Conditions on Undisturbed FPW Crusts

FIGURE 4.21 Influence of Aging Conditions on Disturbed FPW Crusts

TABLE 4.4. Ratio of Deflation Rates--FPW Agent-Protected to Wet Control Surfaces. Idaho soil only. Data are listed as average, less than a maximum value, or average (range).

Subtest No.	Case	1 L/m ²	Significant Difference	2 L/m ²	Significant Difference	4 L/m ²	Significant Difference
<u>1:9 FPW Solution/Undisturbed</u>							
3	20 m/s + sand	n/a		n/a		0.13 (1-1.2)	~no
4	25 m/s + sand	n/a		n/a		0.48 (0.3-0.97)	~yes
<u>1:9 FPW Solution/Disturbed</u>							
5	20 m/s	n/a		n/a		1.0 (0.05-9)	no
6	25 m/s	n/a		n/a		1.6 (0->1)	no
7	20 m/s + sand	n/a		n/a		~1	no
8	25 m/s + sand	n/a		n/a		~1	no
<u>1:4 FPW Solution/Undisturbed</u>							
3	20 m/s + sand	n/a		0.092 (0-2)	no	~0	yes
4	25 m/s + sand	n/a		0.58 (0.2-1.7)	no	0.092 (0.02-0.3)	yes
<u>1:4 FPW Solution/Disturbed</u>							
5	20 m/s	n/a		0.71 (0.4-3)	no	1.4 (0.7-7)	no
6	25 m/s	n/a		1.2 (0.5->1)	no	1.2 (0.4->1)	no
7	20 m/s + sand	n/a		~0	yes	~1	no
8	25 m/s + sand	n/a		<0.24	yes	~1	no

performed on Hanford soil using the standard application rate for each of the three dust control agents. Tests of dry and wet controls were also performed for comparison. As shown in Section 4.3.1, unprotected dry and wet control Hanford soil surfaces were significantly more susceptible to erosion by wind than were the other two soil types (dry and wet controls of McGee Ranch silt-loam were also tested). Based on the 20 m/s + 10 kg sand case (Subtest 3), erosion by wind of wet control Hanford soil was about 14-fold greater than that of McGee Ranch soil and about 170-fold greater than Idaho soil. Tests were performed using dry controls, wet controls (2 L/m² water), PS (1% solution at 2 L/m²), XDCA (1:2 solution at 4.5 L/m²), and FPW (1:4 solution at 4 L/m²). Only Batch 1, wet Idaho soil controls, was considered.

Results of these single-treatment tests clearly indicate that the differences between the two soils did indeed significantly alter the protection provided by the dust control agents. Figures 4.22 through 4.24 show measured surface deflation rates for both soil types and each dust control agent. The PS provided protection of both undisturbed and disturbed Idaho soil surfaces. In the figures, deflation rates equal to or exceeding 100 g/(m²-s) indicate that surface protection failed at that condition. The XDCA did not protect Idaho soil surfaces. The FPW protected only undisturbed Idaho soil surfaces. However, an entirely different result occurred for the highly

FIGURE 4.22 Surface Deflation Rates Measured from Undisturbed (Wind and Saltating Sand) Idaho and Hanford Soils Protected by PS, XDCA, and FPW Dust Control Agents. Wet controls provided for information, rates ≥ 100 g/(m²-s) indicate failure of surface protection.

FIGURE 4.23 Surface Deflation Rates Measured from Disturbed (Wind Only) Idaho and Hanford Soils Protected by PS, XDCA, and FPW Dust Control Agents. Wet controls provided for information, rates ≥ 100 g/(m²-s) indicate failure of surface protection.

FIGURE 4.24 Surface Deflation Rates Measured from Disturbed (Wind and Saltating Sand) Idaho and Hanford Soils Protected by PS, XDCA, and FPW Dust Control Agents. Wet controls provided for information, rates ≥ 100 $g/(m^2 \cdot s)$ indicate failure of surface protection.

erodible Hanford soil. The PS provided limited protection of undisturbed and disturbed Hanford soil surfaces. The XDCA clearly provided nearly ideal protection of the sandy Hanford soil. This protection was less than perfect only during the disturbed surface, 25 m/s, no-sand case (Subtest 6). However, after stabilizing during that subtest, XDCA-protected Hanford soil surfaces again became nearly perfectly resistant to erosion during subsequent disturbed surface tests with saltating sand stresses. *Additionally, in extended tests performed using one disturbed surface (Test 65a), the XDCA-protected Hanford soil remained intact even after several days additional aging under laboratory conditions. After additional post-test moisture-cycling of this twice-tested and disturbed case (Test 65b), the surface continued to perform very well, although some minor deflation losses did finally occur during subtests 5 and 8.* FPW provided an intermediate level of protection of both undisturbed and disturbed Hanford soil surfaces. In all undisturbed surface cases, PS was better than FPW. In all disturbed surface cases, FPW was better than PS.

Table 4.5 compares of the various dust control agents by soil type and subtest. A general description of the table is provided in Section 4.3. Idaho soil surfaces were protected by PS other than during Subtests 5 and 6, were not protected by XDCA, and were protected by FPW only during Subtests 3 and 4. In contrast, Hanford soil surfaces were protected through Subtest 6 by PS and through all subtests by XDCA and FPW. Noting the ratio of deflation rates shown in the table, it is clear that XDCA provides the best protection of Hanford soil surfaces; deflation rates from the XDCA-protected surfaces never exceeded, and were generally much less than 5% of those from the wet control, while the rates from the FPW-protected surface less than 3, 5, 13, and 82% of the wet control for the disturbed surface case (Subtests 5, 6, 7, and 8, respectively).

TABLE 4.5. Ratio of Deflation Rates --Agent-Protected to Wet Control Surfaces.
Comparison of soil types. Data are listed as average, less than a maximum
value, or average (range).

Subtest No.	Case	PS	Significant Difference	XDCA	Significant Difference	EPW	Significant Difference
<u>Idaho Soil/Undisturbed</u>							
3	20 m/s + sand	~0	yes	0.83 (0.3-6)	no	~0	yes
4	25 m/s + sand	~0	yes	0.72 (0.2-2)	no	0.092 (0.02-0.3)	yes
<u>Idaho Soil/Disturbed</u>							
5	20 m/s	0.53 (0.07-4)	no	3.0 (1-20)	no	1.4 (0.7-7)	no
6	25 m/s	0.14 (0.05->1)	no	1.9 (0.9->1)	no	1.2 (0.4->1)	no
7	20 m/s + sand	~0	yes	~1	no	~1	no
8	25 m/s + sand	<0.08	yes	~1	no	~1	no
<u>Hanford Soil/Undisturbed</u>							
3	20 m/s + sand	~0	yes	~0	yes	<0.005	yes
4	25 m/s + sand	<0.003	yes	~0	yes	<0.03	yes
<u>Hanford Soil/Disturbed</u>							
5	20 m/s	<0.16	yes	<0.001	yes	<0.03	yes
6	25 m/s	<0.37	yes	<0.05	yes	<0.05	yes
7	20 m/s + sand	~1	no	~0	yes	<0.13	yes
8	25 m/s + sand	~1	no	~0	yes	<0.82	yes

5.0 CONCLUSIONS AND RECOMMENDATIONS

A series of 69 wind tunnel tests were performed and provided data for comparing the effectiveness of three fugitive dust suppressant agents to protect a loamy Idaho soil subjected to eolian stresses. A small number of tests were also performed that permitted comparison of these products on a sandy Hanford soil. Test parameters included soil and dust control agent type, solution concentrations, application quantities, aging (or drying) conditions, surface disturbance, and wind and saltating sand eolian erosive stresses that were selected and controlled to simulate application and exposure of excavated soil surfaces in the field. Test procedures were modifications of those described by Ligothke (1993). It should be noted that the deflation rates reported were averaged over the durations of the subtests (generally 2.0 min). Because the rate of loss typically decreased with time as erodible elements were removed, these results represent initial, or worst-case, conditions. In the field, actual deflation rates would be expected to decrease with time until the crusts fail, after which rates would increase and eventually return to those typical of unprotected surfaces.

Quantification of surface shear stresses applied to the surfaces were based on the previous work and on measurements performed during the present study. Friction velocities applied to the undisturbed surfaces were about 1.1 and 1.4 m/s at wind tunnel wind speeds of 20 and 25 m/s, respectively. Friction velocities applied to the disturbed surfaces were 1.76 and 2.1 m/s at wind tunnel wind speeds of 20 and 25 m/s, respectively. The mass flow rates of saltating sand in the present study were 170 and 250 g/(m²-s) at 20 and 25 m/s wind speeds, respectively.

Deflation rates from dry and wet controls (water applied at 2 L/m²) averaged 0.14 ± 0.10 , 6.4, and 0.45 ± 0.28 g/(m²-s) at 20 m/s for the Idaho, Hanford, and McGee Ranch soils, respectively. (Only control cases were tested using the McGee Ranch silt-loam.) The water-sprayed wet controls formed crusts of soluble materials on the soil surfaces that provided protection from eolian stresses. Measured deflation rates from Idaho soil wet controls from Batches 1 and 2 were 1.2 ± 0.95 , 1.2 ± 0.54 , 1.1 ± 0.86 , and 29 ± 31 g/(m²-s) during Subtests 3, 4, 5, and 6, respectively. Similar results for Hanford soil wet controls were 230 ± 71 g/(m²-s) for Subtest 3; the Hanford soil wet controls failed at the end of Subtest 3. Smaller variation in the Idaho soil wet controls was expected and would have aided more clear interpretation of the results.

Application of PS to Idaho soil improved resistance to wind erosion, although the degree of improvement at the least application (1.0% and 1 L/m²) was not significant. Surface protection was not a simple function of starch application rate. The best surface protection was favored by high PS concentration (2.5%) and low water application (1 L/m²). Even increasing the starch

content on the surface 4-fold, the 2.5% at 4 L/m² case, did not perform as well. It is possible that greater water applications washed the starch further into the surface and reduced the integrity of the surface crust. Average surface deflation rates from the best PS-protected surfaces ranged between 0 and 10% of those from corresponding wet control surfaces.

Tests of XDCA on Idaho soil indicated that the material does not protect that soil from eolian stresses except for undisturbed surfaces treated with a solution concentration of 1:2 at an application rate of 9.2 L/m². The XDCA crusts generally performed similar to the wet control with the exception of the 1:2 at 1.1 L/m² case, which provided less protection than the wet control case. Also note the result of XDCA applications on sandy Hanford soil below.

The FPW provided protection of undisturbed Idaho soil surfaces for certain combinations of solution concentration and application quantity. Disturbed surfaces were not significantly protected. Application of FPW at 4 L/m² performed better than that of 2 L/m² for the single common solution concentration tested (1:4) and undisturbed surfaces. However, both application quantities performed similarly to the wet controls after the surfaces were disturbed. Applications of 1:1 and 1:2 solution concentrations resulted in thick, heavily cracked and curled surfaces that were unsteady in their susceptibility to erosion.

The aging process impacted surface crust effectiveness. Tests were performed using Idaho soil. Exposure to uv-cycling did not seem to impact any of the three dust control agents. Moisture-cycling eliminated the effectiveness of PS and FPW crusts but did not seem to significantly impact XDCA crusts.

Soil type, Idaho loamy soil or Hanford sandy soil, had a large impact on the effectiveness of the dust control agents. Idaho soil surfaces were protected by PS other than during Subtests 5 and 6, were not protected by XDCA, and were protected by FPW only during Subtests 3 and 4. In contrast, Hanford soil surfaces were protected through Subtest 6 by PS and through all subtests by XDCA and FPW. The XDCA clearly provided the best protection of Hanford soil surfaces; deflation rates from the XDCA-protected surfaces never exceeded and were generally much less than 5% of those from corresponding wet controls. Deflation rates from the FPW-protected Hanford soil surfaces were also small at less than 3, 5, 13, and 82% of the wet control for the disturbed surface case (Subtests 5, 6, 7, and 8, respectively).

The results of this study indicate that all three dust control agents can protect exposed soil surfaces from extreme eolian stresses. It is also clear that the interaction and performance of each agent with various soil types may differ dramatically. Thus, soils similar to that received from INEL should be best protected by high concentration (approximately 2.5%) solutions of potato

starch at low water application levels (approximately 1 to 2 L/m²). Because the effectiveness of PS on this soil type is degraded after a moderate amount of simulated rainfall, other options or additives should be considered if surfaces are to be protected for weeks during periods of intermittent rainfall and hot and windy conditions. In addition, PS applied to wet surfaces might provide reduced surface protection; all tests were performed by spray-coating dry soil surfaces. In contrast to its performance on the Idaho soil, the effectiveness of XDCA on the sandy Hanford soil was near ideal, even during extended wind tunnel testing. The XDCA should be considered when sandy soils are excavated. While fermented potato waste was not the best fixative on either soil, it did perform reasonably well on both soil types (better than XDCA on Idaho soil and better than PS on Hanford soil). Additional development work, perhaps including additives, could produce an improved product.

Although the test surfaces were aged under uv- and moisture-cycling conditions, no attempt was made to determine if insect or microbial activity could degrade (or enhance) the performance of these products. It is recommended that field or laboratory trials include these biological aging parameters. Also regarding possible future tests, the Hanford soil made a better test substrate because it was less cohesive, and replicate tests produced a greater degree of agreement. Because Hanford soil results are based on the results of a small number of tests, it would be prudent to perform additional tests prior to selecting a fugitive dust control agent for use at the Hanford Site.

6.0 REFERENCES

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APPENDIX A

WIND EROSION TEST DATA AND DEFLATION RATE RESULTS

Special Notes: Tests 1 and 2 were trial tests not included in the general data analysis. Tests 1 through 6 were performed using an initial surface elevation 0.3 cm lower than all subsequent tests. Idaho soil from Batch 1 was used through Test 23, Batch 2 was then used through Test 54, and subsequent tests used Batch 3.

Test No.	Wind Speed (m/s)	Δt (min)	ΔM Admix* (g)	Total Deflation (g/m ² -s)	Wind Speed Category (m/s)
1-1	9.97	15.0	-3	-1.3E-02	10.00
1-2	14.90	15.0	-1	-4.4E-03	15.00
1-3	19.86	15.0	-2	-8.7E-03	20.00
1-4	24.77	15.0	-1	-4.4E-03	25.00
1-5	19.50	4.0	0		20.00
1-6	25.05	2.0	11	3.6E-01	25.00
1-7	19.71	2.0	69	2.3E+00	20.00
1-8	25.07	2.0	128	4.2E+00	25.00
1-9	19.94	1.5	775	3.4E+01	20.00
1-10	24.96	1.5	2606	1.1E+02	25.00
2-1	15.16	15.0	1	4.4E-03	15.00
2-2	19.91	15.0	2	8.7E-03	20.00
2-3	25.11	15.0	12	5.2E-02	25.00
2-4	19.63	1.25	3973	2.1E+02	20.00
3-1	19.89	15.0	0		20.00
3-2	24.96	15.0	0		25.00
3-3	19.72	1.5	-43	-1.9E+00	20.00
3-4	25.08	1.5	-7	-3.1E-01	25.00
3-5	20.10	2.0	11	3.6E-01	20.00
3-6	25.09	2.0	107	3.5E+00	25.00
3-7	20.09	2.0	-185	-6.0E+00	20.00
3-8	24.98	2.0	666	2.2E+01	25.00
4-1	19.99	2.0	1	3.3E-02	20.00
4-2	25.00	2.0	0		25.00
4-3	20.03	2.0	-22	-7.2E-01	20.00
4-4	25.04	2.0	-13	-4.2E-01	25.00
4-5	20.26	2.0	12	3.9E-01	20.00
4-6	25.28	2.0	102	3.3E+00	25.00
4-7	20.10	2.0	-288	-9.4E+00	20.00
4-8	25.24	2.0	-67	-2.2E+00	25.00
5-1	9.75	5.0	0		10.00
5-2	14.91	5.0	54	7.1E-01	15.00
5-3	20.05	2.0	450	1.5E+01	20.00
5-4	24.88	2.0	402	1.3E+01	25.00
5-5	19.82	2.0	345	1.1E+01	20.00
5-6	19.91	2.0	10	3.3E-01	20.00
6-1	20.14	2.0	0		20.00
6-2	25.02	2.0	0		25.00
6-3	19.94	2.0	0		20.00
6-4	24.99	2.0	45	1.5E+00	25.00
6-5	20.08	2.0	24	7.8E-01	20.00
6-6	24.94	2.0	169	5.5E+00	25.00
6-7	20. *	2.0	-22	-7.2E-01	
6-8	25. *	2.0	969	3.2E+01	
7-1	20.31	2.0	-1	-3.3E-02	20.00
7-2	25.30	2.0	-1	-3.3E-02	25.00
7-3	20.05	2.0	-17	-5.6E-01	20.00
7-4	25.16	2.0	-5	-1.6E-01	25.00
7-5	20.21	2.0	34	1.1E+00	20.00
7-6	25.06	2.0	146	4.8E+00	25.00
7-7	20.00	2.0	-169	-5.5E+00	20.00
7-8	24.91	2.0	141	4.6E+00	25.00
8-1	19.81	2.0	0		20.00
8-2	24.83	2.0	-1	-3.3E-02	25.00
8-3	19.86	2.0	-23	-7.5E-01	20.00
8-4	24.89	2.0	-5	-1.6E-01	25.00
8-5	20.10	2.0	4	1.3E-01	20.00
8-6	25.04	2.0	35	1.1E+00	25.00
8-7	20.13	2.0	-264	-8.6E+00	20.00
8-8	25.04	2.0	-39	-1.3E+00	25.00
9-1	20.12	2.0	0		20.00
9-2	25.90	2.0	1	3.3E-02	25.00
9-3	19.89	2.0	5	1.6E-01	20.00
9-4	24.82	2.0	56	1.8E+00	25.00
9-5	20.33	2.0	41	1.3E+00	20.00
9-6	25.06	2.0	646	2.1E+01	25.00
9-7	19.97	2.0	-64	-2.1E+00	20.00
9-8	24.83	2.0	869	2.8E+01	25.00
10-1	19.88	2.0	0		20.00
10-2	24.95	2.0	0		25.00
10-3	19.88	2.0	-22	-7.2E-01	20.00
10-4	24.99	2.0	-17	-5.6E-01	25.00
10-5	20.13	2.0	17	5.6E-01	20.00
10-6	25.16	2.0	119	3.9E+00	25.00
10-7	20.13	2.0	-219	-7.2E+00	20.00
10-8	25.07	2.0	-67	-2.2E+00	25.00
11-1	9.87	5.0	16	2.1E-01	10.00
11-2	14.99	5.0	99	1.3E+00	15.00
11-3	19.77	2.0	274	9.0E+00	20.00
11-4	24.74	2.0	566	1.8E+01	25.00
11-5	19.98	2.0	279	9.1E+00	20.00
11-6	24.83	2.0	825	2.7E+01	25.00
12-1	19.95	2.0	1	3.3E-02	20.00
12-2	25.12	2.0	1	3.3E-02	25.00
12-3	19.99	2.0	30	9.8E-01	20.00
12-4	24.88	2.0	53	1.7E+00	25.00
12-5	19.98	2.0	70	2.3E+00	20.00
12-6	24.78	2.0	2155	7.0E+01	25.00
13-1	20.01	2.0	0		20.00
13-2	25.12	2.0	0		25.00
13-3	20.05	2.0	-7	-2.3E-01	20.00
13-4	25.02	2.0	-5	-1.6E-01	25.00
13-5	20.13	2.0	24	7.8E-01	20.00
13-6	25.11	2.0	167	5.5E+00	25.00
13-7	20.03	2.0	-174	-5.7E+00	20.00
13-8	24.89	2.0	296	9.7E+00	25.00
14-1	19.81	2.0	0		20.00
14-2	24.82	2.0	0		25.00
14-3	19.89	2.0	-8	-2.6E-01	20.00
14-4	24.83	2.0	-4	-1.3E-01	25.00
14-5	20.30	2.0	13	4.2E-01	20.00
14-6	25.11	2.0	104	3.4E+00	25.00
14-7	19.85	2.0	-178	-5.8E+00	20.00
14-8	24.86	2.0	181	5.9E+00	25.00
15-1	19.76	2.0	1	3.3E-02	20.00
15-2	24.74	2.0	0		25.00
15-3	19.71	2.0	-10	-3.3E-01	20.00
15-4	24.88	2.0	-4	-1.3E-01	25.00
15-5	20.10	2.0	4	1.3E-01	20.00
15-6	25.05	2.0	67	2.2E+00	25.00
15-7	19.90	2.0	-272	-8.9E+00	20.00
15-8	24.91	2.0	-2	-6.5E-02	25.00

* Mass gains from exposure to saltating sand reported as negative (-) mass losses.

Test No.	Wind Speed (m/s)	Δt (min)	ΔM Admix* (g)	Total Deflation (g/m ² -s)	Wind Speed Category (m/s)
16-1	19.79	2.0	0		20.00
16-2	24.76	2.0	0		25.00
16-3	19.80	2.0	-5	-1.6E-01	20.00
16-4	24.87	2.0	-1	-3.3E-02	25.00
16-5	19.80	2.0	4	1.3E-01	20.00
16-6	24.99	2.0	40	1.3E+00	25.00
16-7	19.92	2.0	-263	-8.6E+00	20.00
16-8	24.95	2.0	92	3.0E+00	25.00
17-1	20.57	2.0	0		20.00
17-2	25.37	2.0	0		25.00
17-3	20.28	2.0	-12	-3.9E-01	20.00
17-4	25.16	2.0	-4	-1.3E-01	25.00
17-5	20.34	2.0	3	9.8E-02	20.00
17-6	25.12	2.0	45	1.5E+00	25.00
17-7	20.01	2.0	-295	-9.6E+00	20.00
17-8	24.93	2.0	62	2.0E+00	25.00
18-1	20.02	2.0	0		20.00
18-2	24.77	2.0	0		25.00
18-3	19.90	2.0	-22	-7.2E-01	20.00
18-4	24.98	2.0	-15	-4.9E-01	25.00
18-5	20.27	2.0	5	1.6E-01	20.00
18-6	25.22	2.0	31	1.0E+00	25.00
18-7	20.16	2.0	-252	-8.2E+00	20.00
18-8	25.12	2.0	-71	-2.3E+00	25.00
19-1	19.93	2.0	0		20.00
19-2	25.02	2.0	0		25.00
19-3	20.09	2.0	-4	-1.3E-01	20.00
19-4	25.04	2.0	-3	-9.8E-02	25.00
19-5	20.13	2.0	31	1.0E+00	20.00
19-6	24.97	2.0	888	2.9E+01	25.00
19-7	19.97	2.0	14	4.6E-01	20.00
19-8	24.74	2.0	1279	4.2E+01	25.00
20-1	19.88	2.0	1	3.3E-02	20.00
20-2	24.91	2.0	1	3.3E-02	25.00
20-3	19.97	2.0	-3	-9.8E-02	20.00
20-4	24.90	2.0	1	3.3E-02	25.00
20-5	20.04	2.0	26	8.5E-01	20.00
20-6	25.20	2.0	992	3.2E+01	25.00
20-7	19.98	2.0	4	1.3E-01	20.00
20-8	24.87	2.0	998	3.3E+01	25.00
21-1	9.85	5.0	0		10.00
21-2	14.96	5.0	26	3.4E-01	15.00
21-3	19.81	2.0	123	4.0E+00	20.00
21-4	24.71	2.0	586	1.9E+01	25.00
21-5	19.75	2.0	35	1.1E+00	20.00
21-6	24.77	2.0	539	1.8E+01	25.00
22-1	19.97	2.0	0		20.00
22-2	25.03	2.0	0		25.00
22-3	19.98	2.0	20	6.5E-01	20.00
22-4	24.80	2.0	24	7.8E-01	25.00
22-5	20.11	2.0	6	2.0E-01	20.00
22-6	25.16	2.0	177	5.8E+00	25.00
22-7	19.92	2.0	-123	-4.0E+00	20.00
22-8	24.87	2.0	429	1.4E+01	25.00
23-1	19.98	2.0	1	3.3E-02	20.00
23-2	25.03	2.0	0		25.00
23-3	19.82	2.0	-11	-3.6E-01	20.00
23-4	25.11	2.0	2	6.5E-02	25.00
23-5	20.03	2.0	7	2.3E-01	20.00
23-6	24.14	2.0	63	2.1E+00	25.00
23-7	19.90	2.0	-170	-5.6E+00	20.00
23-8	24.99	2.0	187	6.1E+00	25.00
24-1	19.83	2.0	0		20.00
24-2	24.81	2.0	0		25.00
24-3	19.82	2.0	39	1.3E+00	20.00
24-4	24.82	2.0	36	1.2E+00	25.00
24-5	19.94	2.0	133	4.3E+00	20.00
24-6a	24.95	1.0	1491	9.7E+01	25.00
24-6b	24.85	1.0	175	1.1E+01	25.00
25-1	20.00	2.0	3	9.8E-02	20.00
25-2	24.93	2.0	14	4.6E-01	25.00
25-3	19.92	2.0	711	2.3E+01	20.00
25-4	24.89	2.0	1222	4.0E+01	25.00
26-1	9.95	5.0	10	1.3E-01	10.00
26-2	14.97	5.0	86	1.1E+00	15.00
26-3	20.17	2.0	298	9.7E+00	20.00
26-4	25.08	2.0	1407	4.6E+01	25.00
27-1	20.00	2.0	0		20.00
27-2	24.92	2.0	0		25.00
27-3	19.92	2.0	61	2.0E+00	20.00
27-4	24.90	2.0	48	1.6E+00	25.00
27-5	20.11	2.0	18	5.9E-01	20.00
27-6	24.95	2.0	265	8.7E+00	25.00
27-7	19.95	2.0	-15	-4.9E-01	20.00
27-8	24.84	2.0	914	3.0E+01	25.00
28-1	19.91	2.0	-1	-3.3E-02	20.00
28-2	24.86	2.0	0		25.00
28-3	19.90	2.0	-4	-1.3E-01	20.00
28-4	24.79	2.0	-3	-9.8E-02	25.00
28-5	20.14	2.0	11	3.6E-01	20.00
28-6	25.08	2.0	114	3.7E+00	25.00
28-7	19.83	2.0	-176	-5.8E+00	20.00
28-8	24.87	2.0	200	6.5E+00	25.00
29-5	20.14	2.0	3	9.8E-02	20.00
29-6	24.84	2.0	76	2.5E+00	25.00
29-7	19.97	2.0	-192	-6.3E+00	20.00
29-8	25.01	2.0	167	5.5E+00	25.00
30-1	20.29	2.0	0		20.00
30-2	25.05	2.0	1	3.3E-02	25.00
30-3	20.14	2.0	23	7.5E-01	20.00
30-4	25.03	2.0	16	5.2E-01	25.00
30-5	20.05	2.0	70	2.3E+00	20.00
30-6	25.00	2.0	1784	5.8E+01	25.00
31-1	19.91	2.0	0		20.00
31-2	25.01	2.0	0		25.00
31-3	19.90	2.0	7	2.3E-01	20.00
31-4	24.84	2.0	4	1.3E-01	25.00
31-5	20.02	2.0	52	1.7E+00	20.00
31-6	24.87	2.0	966	3.2E+01	25.00
31-7	20.37	2.0	-12	-3.9E-01	20.00
31-8	24.83	2.0	450	1.5E+01	25.00

* Mass gains from exposure to saltating sand reported as negative (-) mass losses.

Test No.	Wind Speed (m/s)	Δt (min)	ΔM Admix* (g)	Total Deflation (g/m ² -s)	Wind Speed Category (m/s)
32-1	20.03	2.0	1	3.3E-02	20.00
32-2	24.89	2.0	6	2.0E-01	25.00
32-3	20.10	2.0	686	2.2E+01	20.00
32-4	25.13	2.0	1139	3.7E+01	25.00
33-1	19.99	2.0	0		20.00
33-2	25.04	2.0	2	6.5E-02	25.00
33-3	20.04	2.0	51	1.7E+00	20.00
33-4	24.89	2.0	67	2.2E+00	25.00
33-5	20.05	2.0	95	3.1E+00	20.00
33-6	24.77	2.0	1556	5.1E+01	25.00
33-7	19.77	2.0	-7	-2.3E-01	20.00
33-8	25.00	2.0	635	2.1E+01	25.00
34-1	19.87	2.0	0		20.00
34-2	24.94	2.0	3	9.8E-02	25.00
34-3	19.92	2.0	157	5.1E+00	20.00
34-4	25.02	2.0	288	9.4E+00	25.00
34-5	19.87	2.0	48	1.6E+00	20.00
34-6	24.89	2.0	1119	3.7E+01	25.00
35-1	19.98	2.0	0		20.00
35-2	24.98	2.0	2	6.5E-02	25.00
35-3	19.93	2.0	101	3.3E+00	20.00
35-4	25.11	2.0	178	5.8E+00	25.00
35-5	19.95	2.0	29	9.5E-01	20.00
35-6	24.98	2.0	1265	4.1E+01	25.00
36-1	9.96	5.0	21	2.7E-01	10.00
36-2	14.90	5.0	141	1.8E+00	15.00
36-3	19.88	2.0	568	1.9E+01	20.00
36-4	24.64	2.0	3358	1.1E+02	25.00
37-1	19.90	2.0	-1	-3.3E-02	20.00
37-2	25.03	2.0	1	3.3E-02	25.00
37-3	19.99	2.0	71	2.3E+00	20.00
37-4	25.16	2.0	99	3.2E+00	25.00
37-5	19.92	2.0	51	1.7E+00	20.00
37-6	24.92	2.0	1719	5.6E+01	25.00
38-1	19.94	2.0	0		20.00
38-2	24.94	2.0	-1	-3.3E-02	25.00
38-3	19.94	2.0	-2	-6.5E-02	20.00
38-4	24.79	2.0	-3	-9.8E-02	25.00
38-5	20.15	2.0	29	9.5E-01	20.00
38-6	24.88	2.0	203	6.6E+00	25.00
38-7	19.93	2.0	-75	-2.5E+00	20.00
38-8	24.94	2.0	181	5.9E+00	25.00
39-1	19.68	2.0	0		20.00
39-2	24.76	2.0	0		25.00
39-3	19.81	2.0	-3	-9.8E-02	20.00
39-4	24.92	2.0	-3	-9.8E-02	25.00
39-5	20.16	2.0	19	6.2E-01	20.00
39-6	25.13	2.0	207	6.8E+00	25.00
39-7	20.06	2.0	-109	-3.6E+00	20.00
39-8	25.00	2.0	195	6.4E+00	25.00
40-1	20.09	2.0	2	6.5E-02	20.00
40-2	24.68	2.0	0		25.00
40-3	20.09	2.0	9	2.9E-01	20.00
40-4	25.12	2.0	-1	-3.3E-02	25.00
40-5	20.19	2.0	54	1.8E+00	20.00
40-6	25.16	2.0	784	2.6E+01	25.00
40-8	25.13	2.0	199	6.5E+00	25.00
40-9	25.01	2.0	182	5.9E+00	25.00
41-1	19.89	2.0	0		20.00
41-2	24.84	2.0	2	6.5E-02	25.00
41-3	19.76	2.0	-1	-3.3E-02	20.00
41-4	24.90	2.0	2	6.5E-02	25.00
41-5	20.18	2.0	33	1.1E+00	20.00
41-6	24.82	2.0	927	3.0E+01	25.00
41-7	20.01	2.0	-4	-1.3E-01	20.00
41-8	25.03	2.0	287	9.4E+00	25.00
42-1	19.99	2.0	-2	-6.5E-02	20.00
42-2	25.12	2.0	0		25.00
42-3	20.07	2.0	13	4.2E-01	20.00
42-4	25.15	2.0	30	9.8E-01	25.00
42-5	20.08	2.0	24	7.8E-01	20.00
42-6	24.80	2.0	1084	3.5E+01	25.00
42-7	19.83	2.0	-34	-1.1E+00	20.00
42-8	24.72	2.0	742	2.4E+01	25.00
43-1	20.06	2.0	-2	-6.5E-02	20.00
43-2	25.01	2.0	0		25.00
43-3	19.95	2.0	-4	-1.3E-01	20.00
43-4	25.02	2.0	5	1.6E-01	25.00
43-5	20.03	2.0	41	1.3E+00	20.00
43-6	24.87	2.0	1290	4.2E+01	25.00
44-1	20.20	2.0	1	3.3E-02	20.00
44-2	25.02	2.0	4	1.3E-01	25.00
44-3	19.98	2.0	50	1.6E+00	20.00
44-4	25.05	2.0	150	4.9E+00	25.00
44-5	19.97	2.0	125	4.1E+00	20.00
44-6	24.85	2.0	1425	4.7E+01	25.00
45-1	19.89	2.0	0		20.00
45-2	24.98	2.0	1	3.3E-02	25.00
45-3	19.97	2.0	33	1.1E+00	20.00
45-4	25.03	2.0	61	2.0E+00	25.00
45-5	20.04	2.0	102	3.3E+00	20.00
45-6	24.90	2.0	1617	5.3E+01	25.00
46-1	20.38	2.0	41	1.3E+00	20.00
46-2	25.07	2.0	49	1.6E+00	25.00
46-3	19.93	2.0	6938	2.3E+02	20.00
47-1	20.25	2.0	50	1.6E+00	20.00
47-2	24.95	2.0	78	2.5E+00	25.00
47-3a	19.89	1.0	4136	2.9E+02	20.00
47-3b	19.90	1.0	2227	1.5E+02	20.00
48-1	20.24	2.0	-2	-6.5E-02	20.00
48-2	24.82	2.0	0		25.00
48-3	20.16	2.0	-6	-2.0E-01	20.00
48-4	25.06	2.0	2	6.5E-02	25.00
48-5	20.15	2.0	48	1.6E+00	20.00
48-6	25.12	2.0	841	2.7E+01	25.00
48-7	19.96	2.0	-71	-2.3E+00	20.00
48-8	24.95	2.0	1260	4.1E+01	25.00

* Mass gains from exposure to saltating sand reported as negative (-) mass losses.

Test No.	Wind Speed (m/s)	Δt (min)	ΔM Admix* (g)	Total Deflation (g/m ² -s)	Wind Speed Category (m/s)	Test No.	Wind Speed (m/s)	Δt (min)	ΔM Admix* (g)	Total Deflation (g/m ² -s)	Wind Speed Category (m/s)
49-1	20.15	2.0	-3	-9.8E-02	20.00	57-1	19.82	2.0	0		20.00
49-2	25.00	2.0	41	1.3E+00	25.00	57-2	24.98	2.0	0		25.00
49-3	20.06	2.0	-111	-3.6E+00	20.00	57-3	19.99	2.0	34	1.1E+00	20.00
49-4	24.95	2.0	-16	-5.2E-01	25.00	57-4	24.99	2.0	90	2.9E+00	25.00
49-5	19.97	2.0	183	6.0E+00	20.00	57-5	19.99	2.0	90	2.9E+00	20.00
49-6	24.98	2.0	884	2.9E+01	25.00	57-6	24.93	2.0	134	4.4E+00	25.00
49-7	20.10	2.0	-89	-2.9E+00	20.00	57-7	19.99	2.0	369	1.2E+01	20.00
49-8	24.83	2.0	802	2.6E+01	25.00	57-8	24.75	2.0	2280	7.5E+01	25.00
50-1	19.98	2.0	-1	-3.3E-02	20.00	58-1	19.87	2.0	0		20.00
50-2	24.75	2.0	-1	-3.3E-02	25.00	58-2	24.95	2.0	0		25.00
50-3	20.04	2.0	0		20.00	58-3	20.19	2.0	-1	-3.3E-02	20.00
50-4	24.96	2.0	8	2.6E-01	25.00	58-4	25.10	2.0	7	2.3E-01	25.00
50-5	19.87	2.0	156	5.1E+00	20.00	58-5	20.15	2.0	29	9.5E-01	20.00
50-6	24.78	2.0	922	3.0E+01	25.00	58-6	24.90	2.0	545	1.8E+01	25.00
50-7	19.90	2.0	2844	9.3E+01	20.00	58-7	19.93	2.0	-80	-2.6E+00	20.00
51-1	20.06	2.0	0		20.00	58-8	24.85	2.0	889	2.9E+01	25.00
51-2	24.94	2.0	0		25.00	59-1	19.98	2.0	0		20.00
51-3	20.15	2.0	0		20.00	59-2	25.07	2.0	0		25.00
51-4	24.98	2.0	3	9.8E-02	25.00	59-3	20.04	2.0	-1	-3.3E-02	20.00
51-5	20.04	2.0	421	1.4E+01	20.00	59-4	24.95	2.0	3	9.8E-02	25.00
51-6	24.60	2.0	1071	3.5E+01	25.00	59-5	20.05	2.0	27	8.8E-01	20.00
51-7	19.70	2.0	3296	1.1E+02	20.00	59-6	24.95	2.0	472	1.5E+01	25.00
52-1	20.05	2.0	4	1.3E-01	20.00	59-7	19.97	2.0	-92	-3.0E+00	20.00
52-2	24.80	2.0	9	2.9E-01	25.00	59-8	24.93	2.0	681	2.2E+01	25.00
52-3	19.96	2.0	532	1.7E+01	20.00	60-1	9.86	5.0	489	6.4E+00	10.00
52-4	24.78	2.0	1739	5.7E+01	25.00	60-2	14.78	5.0	2903	3.8E+01	15.00
53-1	19.97	2.0	2	6.5E-02	20.00	60-3	20.00	1.0	2174	1.4E+02	20.00
53-2	25.01	2.0	6	2.0E-01	25.00	61-1	20.04	1.0	4276	2.8E+02	20.00
53-3	19.98	2.0	532	1.7E+01	20.00	62-1	20.32	2.0	-2	-6.5E-02	20.00
53-4	25.02	2.0	1410	4.6E+01	25.00	62-2	23.92	2.0	50	1.6E+00	25.00
53-5	20.06	2.0	232	7.6E+00	20.00	62-3	19.90	2.0	-36	-1.2E+00	20.00
53-6	24.88	2.0	2043	6.7E+01	25.00	62-4	24.89	2.0	34	1.1E+00	25.00
54-1	20.00	2.0	0		20.00	62-5	20.00	2.0	131	4.3E+00	20.00
54-2	25.14	2.0	0		25.00	62-6	24.89	2.0	2016	6.6E+01	25.00
54-3	20.25	2.0	-59	-1.9E+00	20.00	62-7	19.96	2.0	-11	-3.6E-01	20.00
54-4	24.92	2.0	3	9.8E-02	25.00	62-8	24.90	2.0	611	2.0E+01	25.00
54-5	20.12	2.0	104	3.4E+00	20.00	63-1	19.95	2.0	-1	-3.3E-02	20.00
54-6	24.81	2.0	1124	3.7E+01	25.00	63-2	25.22	2.0	97	3.2E+00	25.00
54-7	19.99	2.0	-98	-3.2E+00	20.00	63-3	20.02	2.0	-59	-1.9E+00	20.00
54-8	24.81	2.0	1283	4.2E+01	25.00	63-4	24.94	2.0	66	2.2E+00	25.00
55-1	19.97	2.0	0		20.00	63-5	19.98	2.0	164	5.4E+00	20.00
55-2	25.06	2.0	0		25.00	63-6	24.80	2.0	2275	7.4E+01	25.00
55-3	20.10	2.0	1	3.3E-02	20.00	63-7	20.00	2.0	-26	-8.5E-01	20.00
55-4	25.00	2.0	16	5.2E-01	25.00	63-8	25.00	2.0	841	2.7E+01	25.00
55-5	20.00	2.0	54	1.8E+00	20.00	64-1	20.06	2.0	0		20.00
55-6	24.91	2.0	2663	8.7E+01	25.00	64-2	24.21	2.0	0		25.00
56-1	20.04	2.0	0		20.00	64-3	20.10	2.0	0		20.00
56-2	24.33	2.0	0		25.00	64-4	25.13	2.0	-1	-3.3E-02	25.00
56-3	20.21	2.0	30	9.8E-01	20.00	64-5	20.00	2.0	4	1.3E-01	20.00
56-4	25.39	2.0	85	2.8E+00	25.00	64-6	25.16	2.0	147	4.8E+00	25.00
56-5	20.05	2.0	74	2.4E+00	20.00	64-7	20.01	2.0	-61	-2.0E+00	20.00
56-6	25.06	2.0	157	5.1E+00	25.00	64-8	25.09	2.0	-9	-2.9E-01	25.00
56-7	20.08	2.0	347	1.1E+01	20.00						
56-8	24.90	2.0	1408	4.6E+01	25.00						

* Mass gains from exposure to saltating sand reported as negative (-) mass losses.

Test No.	Wind Speed (m/s)	Δt (min)	ΔM Admix* (g)	Total Deflation (g/m ² -s)	Wind Speed Category (m/s)
65-1	19.90	2.0	0		20.00
65-2	25.05	2.0	0		25.00
65-3	20.06	2.0	0		20.00
65-4	24.99	2.0	-1	-3.3E-02	25.00
65-5	20.01	2.0	3	9.8E-02	20.00
65-6	25.04	2.0	7	2.3E-01	25.00
65-7	20.04	2.0	-83	-2.7E+00	20.00
65-8	25.03	2.0	-27	-8.8E-01	25.00
65a-5	19.88	2.0	4	1.3E-01	20.00
65a-6	24.96	2.0	10	3.3E-01	25.00
65a-7	20.19	2.0	-30	-9.8E-01	20.00
65a-8	24.95	2.0	4	1.3E-01	25.00
65b-1	19.74	2.0	-1	-3.3E-02	20.00
65b-2	23.97	2.0	-1	-3.3E-02	25.00
65b-3	20.09	2.0	-1	-3.3E-02	20.00
65b-4	24.97	2.0	0		25.00
65b-5	20.15	2.0	61	2.0E+00	20.00
65b-6	25.13	2.0	133	4.3E+00	25.00
65b-7	19.98	2.0	-87	-2.8E+00	20.00
65b-8	24.93	2.0	62	2.0E+00	25.00
66-1	9.94	5.0	36	4.7E-01	10.00
66-2	14.96	5.0	559	7.3E+00	15.00
66-3	19.98	2.0	1022	3.3E+01	20.00
66-4	24.85	2.0	1899	6.2E+01	25.00
67-1	9.98	5.0	33	4.3E-01	10.00
67-2	14.97	5.0	712	9.3E+00	15.00
67-3	19.97	2.0	1257	4.1E+01	20.00
67-4	25.05	2.0	2124	6.9E+01	25.00
68-1	19.68	2.0	-1	-3.3E-02	20.00
68-2	25.03	2.0	-1	-3.3E-02	25.00
68-3	20.00	2.0	8	2.6E-01	20.00
68-4	24.95	2.0	19	6.2E-01	25.00
68-5	19.95	2.0	10	3.3E-01	20.00
68-6	24.96	2.0	224	7.3E+00	25.00
68-7	19.99	2.0	-83	-2.7E+00	20.00
68-8	24.89	2.0	358	1.2E+01	25.00
69-1	19.84	2.0	-2	-6.5E-02	20.00
69-2	24.81	2.0	-1	-3.3E-02	25.00
69-3	20.06	2.0	-6	-2.0E-01	20.00
69-4	24.94	2.0	12	3.9E-01	25.00
69-5	20.02	2.0	24	7.8E-01	20.00
69-6	24.91	2.0	976	3.2E+01	25.00
69-7	19.96	2.0	-82	-2.7E+00	20.00
69-8	24.99	2.0	688	2.2E+01	25.00

* Mass gains from exposure to saltating sand reported as negative (-) mass losses.

APPENDIX B

WIND EROSION TEST DATA GROUPED BY TEST PARAMETER

Fix DRcontrol 7/93

Surface Deflation (g/(m²-s)) and Cumulative Mass Loss (g) Data Summary:

(Untreated Controls, Page 1 of 2)

Category	Test	Subtest 1	Subtest 2	Subtest 3	Subtest 4	Subtest 5	Subtest 6	Subtest 7	Subtest 8
<u>Idaho Soil</u>									
Dry Control (Batch 1)	5	1.5E+01	1.3E+01	1.1E+01	3.3E-01				
	11	9.0E+00	1.8E+01	9.1E+00	2.7E+01				
	21	4.0E+00	1.9E+01	1.1E+00	1.8E+01				
	Average:	9.3E+00	1.7E+01	7.1E+00	1.5E+01				
	Standard Deviation:	5.5E+00	3.2E+00	5.3E+00	1.4E+01				
	Avg Σ Mass Change (g):	-2.9E+02	-8.0E+02	-1.0E+03	-1.5E+03				
Dry Control (Batch 2)	26	9.7E+00	4.6E+01						
	36	1.9E+01	1.1E+02						
	Average:	1.4E+01	7.8E+01						
	Standard Deviation:	6.6E+00	4.5E+01						
	Avg Σ Mass Change (g):	-4.4E+02	-2.8E+03						
Wet Control (Batch 1)	6	0.0E+00	0.0E+00	0.0E+00	1.5E+00	7.8E-01	5.5E+00	-7.2E-01	3.2E+01
	12	3.3E-02	3.3E-02	9.8E-01	1.7E+00	2.3E+00	7.0E+01		
	22	0.0E+00	0.0E+00	6.5E-01	7.8E-01	2.0E-01	5.8E+00	-4.0E+00	1.4E+01
	Average:	1.1E-02	1.1E-02	5.4E-01	1.3E+00	1.1E+00	2.7E+01	-2.4E+00	2.3E+01
	Standard Deviation:	1.9E-02	1.9E-02	5.0E-01	4.8E-01	1.1E+00	3.7E+01	2.3E+00	1.3E+01
	Avg Σ Mass Change (g):	-3.4E-01	-6.7E-01	-1.7E+01	-5.8E+01	-3.3E+01	-8.6E+02	-7.9E+02	-1.5E+03
Wet Control (Batch 2)	27	0.0E+00	0.0E+00	2.0E+00	1.6E+00	5.9E-01	8.7E+00	-4.9E-01	3.0E+01
	37	-3.3E-02	3.3E-02	2.3E+00	3.2E+00	1.7E+00	5.6E+01		
	Average:	-1.7E-02	1.7E-02	2.2E+00	2.4E+00	1.1E+00	3.2E+01	-4.9E-01	3.0E+01
	Standard Deviation:	2.3E-02	2.3E-02	2.1E-01	1.1E+00	7.8E-01	3.3E+01	-	-
	Avg Σ Mass Change (g):	5.0E-01	0.0E+00	-6.6E+01	-1.4E+02	-3.5E+01	-1.0E+03	-1.0E+03	-1.9E+03
<u>Hanford Soil</u>									
Dry Control (1 min test)	60								
	61	2.8E+02							
	Average:	2.8E+02							
	Standard Deviation:	-							
	Avg Σ Mass Change (g):	-4.3E+03							
Wet Control	46	1.3E+00	1.6E+00	2.3E+02					
	47	1.6E+00	2.5E+00	2.2E+02					
	Average:	1.5E+00	2.1E+00	2.3E+02					
	Standard Deviation:	2.1E-01	6.4E-01	7.1E+00					
	Avg Σ Mass Change (g):	-4.4E+01	-1.1E+02	-7.0E+03					

Surface Deflation (g/(m²-s) and Cumulative Mass Loss (g) Data Summary:

(Untreated Controls, Page 2 of 2)

Category	Test	Subtest 1	Subtest 2	Subtest 3	Subtest 4	Subtest 5	Subtest 6	Subtest 7	Subtest 8
<u>McGee Ranch Soil</u>									
Dry Control	66	3.3E+01	6.2E+01						
	67	4.1E+01	6.9E+01						
	Average:	3.7E+01	6.6E+01						
	Standard Deviation:	5.7E+00	4.9E+00						
	Avg Σ Mass Change (g):	-1.1E+03	-3.1E+03						
Wet Control	52	1.3E-01	2.9E-01	1.7E+01	5.7E+01				
	53	6.5E-02	2.0E-01	1.7E+01	4.6E+01	7.6E+00	6.7E+01		
	Average:	9.8E-02	2.5E-01	1.7E+01	5.2E+01	7.6E+00	6.7E+01		
	Standard Deviation:	4.6E-02	6.4E-02	0.0E+00	7.8E+00	-	-		
	Avg Σ Mass Change (g):	-3.0E+00	-1.0E+01	-5.3E+02	-2.1E+03	-2.3E+02	-2.3E+03		

Surface Deflation ($\text{g}/(\text{m}^2\cdot\text{s})$) and Cumulative Mass Loss (g) Data Summary:

(Potato Starch, Page 1 of 2)

Category	Test	Subtest 1	Subtest 2	Subtest 3	Subtest 4	Subtest 5	Subtest 6	Subtest 7	Subtest 8
Idaho Soil / Potato Starch									
P.S. 1% @ 1 L/m ²	3	0.0E+00	0.0E+00	-1.9E+00	-3.1E-01	3.6E-01	3.5E+00	-6.0E+00	2.2E+01
	9	0.0E+00	3.3E-02	1.6E-01	1.8E+00	1.3E+00	2.1E+01	-2.1E+01	2.8E+01
	23	3.3E-02	0.0E+00	-3.6E-01	6.5E-02	2.3E-01	2.1E+00	-5.6E+00	6.1E+00
Average:		1.1E-02	1.1E-02	-7.0E-01	5.2E-01	6.3E-01	8.9E+00	-1.1E+01	1.9E+01
Standard Deviation:		1.9E-02	1.9E-02	1.1E+00	1.1E+00	5.8E-01	1.1E+01	8.8E+00	1.1E+01
Avg Σ Mass Change (g):		-3.4E-01	-6.7E-01	2.1E+01	4.9E+00	-1.9E+01	-2.9E+02	4.2E+01	-5.3E+02
P.S. 1% @ 2 L/m ²	7	-3.3E-02	-3.3E-02	-5.6E-01	-1.6E-01	1.1E+00	4.8E+00	-5.5E+00	4.6E+00
	13	0.0E+00	0.0E+00	-2.3E-01	-1.6E-01	7.8E-01	5.5E+00	-5.7E+00	9.7E+00
	28	-3.3E-02	0.0E+00	-1.3E-01	-9.8E-02	3.6E-01	3.7E+00	-5.8E+00	6.5E+00
" (Soil Batch 2)	29	nd	nd	nd	nd	9.8E-02	2.5E+00	-6.3E+00	5.5E+00
Average:		-2.2E-02	-1.1E-02	-3.1E-01	-1.4E-01	5.8E-01	4.1E+00	-5.8E+00	6.6E+00
Standard Deviation:		1.9E-02	1.9E-02	2.3E-01	3.6E-02	4.4E-01	1.3E+00	3.4E-01	2.2E+00
Avg Σ Mass Change (g):		6.7E-01	1.0E+00	1.0E+01	1.5E+01	-1.8E+01	-1.4E+02	3.4E+01	-1.7E+02
P.S. 1% @ 4 L/m ²	38	0.0E+00	-3.3E-02	-6.5E-02	-9.8E-02	9.5E-01	6.6E+00	-2.5E+00	5.9E+00
	39	0.0E+00	0.0E+00	-9.8E-02	-9.8E-02	6.2E-01	6.8E+00	-3.6E+00	6.4E+00
Average:		0.0E+00	-1.7E-02	-8.2E-02	-9.8E-02	7.9E-01	6.7E+00	-3.1E+00	6.2E+00
Standard Deviation:		0.0E+00	2.3E-02	2.3E-02	0.0E+00	2.3E-01	1.4E-01	7.8E-01	3.5E-01
Avg Σ Mass Change (g):		0.0E+00	5.0E-01	3.0E+00	6.0E+00	-2.4E+01	-2.3E+02	-1.4E+02	-3.2E+02
P.S. 2.5% @ 1 L/m ²	8	0.0E+00	-3.3E-02	-7.5E-01	-1.6E-01	1.3E-01	1.1E+00	-8.6E+00	-1.3E+00
	17	0.0E+00	0.0E+00	-3.9E-01	-1.3E-01	9.8E-02	1.5E+00	-9.6E+00	2.0E+00
Average:		0.0E+00	-1.7E-02	-5.7E-01	-1.5E-01	1.1E-01	1.3E+00	-9.1E+00	3.5E-01
Standard Deviation:		0.0E+00	2.3E-02	2.5E-01	2.1E-02	2.3E-02	2.8E-01	7.1E-01	2.3E+00
Avg Σ Mass Change (g):		0.0E+00	5.0E-01	1.8E+01	2.2E+01	-3.5E+00	-4.3E+01	2.4E+02	2.2E+02
P.S. 2.5% @ 2 L/m ²	15	3.3E-02	0.0E+00	-3.3E-01	-1.3E-01	1.3E-01	2.2E+00	-8.9E+00	-6.5E-02
	18	0.0E+00	0.0E+00	-7.2E-01	-4.9E-01	1.6E-01	1.0E+00	-8.2E+00	-2.3E+00
Average:		1.7E-02	0.0E+00	-5.3E-01	-3.1E-01	1.5E-01	1.6E+00	-8.6E+00	-1.2E+00
Standard Deviation:		2.3E-02	0.0E+00	2.8E-01	2.5E-01	2.1E-02	8.5E-01	4.9E-01	1.6E+00
Avg Σ Mass Change (g):		-5.0E-01	-5.0E-01	1.6E+01	2.5E+01	-4.4E+00	-5.3E+01	2.1E+02	2.4E+02
P.S. 2.5% @ 4 L/m ²	4	3.3E-02	0.0E+00	-7.2E-01	-4.2E-01	3.9E-01	3.3E+00	-9.4E+00	-2.2E+00
	10	0.0E+00	0.0E+00	-7.2E-01	-5.6E-01	5.6E-01	3.9E+00	-7.2E+00	-2.2E+00
Average:		1.7E-02	0.0E+00	-7.2E-01	-4.9E-01	4.8E-01	3.6E+00	-8.3E+00	-2.2E+00
Standard Deviation:		2.3E-02	0.0E+00	0.0E+00	9.9E-02	1.2E-01	4.2E-01	1.6E+00	0.0E+00
Avg Σ Mass Change (g):		-5.0E-01	-5.0E-01	2.2E+01	3.7E+01	-1.5E+01	-1.2E+02	1.3E+02	2.0E+02
P.S. 1% @ 2 L/m ² (uv-cycling tests)	14	0.0E+00	0.0E+00	-2.6E-01	-1.3E-01	4.2E-01	3.4E+00	-5.8E+00	5.9E+00
	16	0.0E+00	0.0E+00	-1.6E-01	-3.3E-02	1.3E-01	1.3E+00	-8.6E+00	3.0E+00
Average:		0.0E+00	0.0E+00	-2.1E-01	-8.2E-02	2.8E-01	2.4E+00	-7.2E+00	4.5E+00
Standard Deviation:		0.0E+00	0.0E+00	7.1E-02	6.9E-02	2.1E-01	1.5E+00	2.0E+00	2.1E+00
Avg Σ Mass Change (g):		0.0E+00	0.0E+00	6.4E+00	8.9E+00	-8.4E+00	-8.0E+01	1.4E+02	3.8E+00

Surface Deflation ($\text{g}/(\text{m}^2 \cdot \text{s})$) and Cumulative Mass Loss (g) Data Summary:

(Potato Starch, Page 2 of 2)

Category	Test	Subtest 1	Subtest 2	Subtest 3	Subtest 4	Subtest 5	Subtest 6	Subtest 7	Subtest 8
P.S. 1% @ 2 L/m ² (Moisture-cycling tests)	19	0.0E+00	0.0E+00	-1.3E-01	-9.8E-02	1.0E+00	2.9E+01	4.6E+01	4.2E+01
	20	3.3E-02	3.3E-02	-9.8E-02	3.3E-02	8.5E-01	3.2E+01	1.3E+01	3.3E+01
Average:		1.7E-02	1.7E-02	-1.1E-01	-3.3E-02	9.3E-01	3.1E+01	3.0E+01	3.8E+01
Standard Deviation:		2.3E-02	2.3E-02	2.3E-02	9.3E-02	1.1E-01	2.1E+00	2.3E-01	6.4E+00
Avg Σ Mass Change (g):		-5.0E-01	-1.0E+00	2.5E+00	3.5E+00	-2.8E+01	-9.6E+02	-9.7E+02	-2.1E+03
<u>Hanford Sandy Soil/Potato Starch</u>									
P.S. 1% @ 2 L/m ²	50	-3.3E-02	-3.3E-02	0.0E+00	2.6E-01	5.1E+00	3.0E+01	9.3E+01	
	51	0.0E+00	0.0E+00	0.0E+00	9.8E-02	1.4E+01	3.5E+01	1.1E+02	
Average:		-1.7E-02	-1.7E-02	0.0E+00	1.8E-01	9.6E+00	3.3E+01	1.0E+02	
Standard Deviation:		2.3E-02	2.3E-02	0.0E+00	1.1E-01	6.3E+00	3.5E+00	1.2E+01	
Avg Σ Mass Change (g):		5.0E-01	1.0E+00	1.0E+00	-4.5E+00	-2.9E+02	-1.3E+03	-4.4E+03	

Surface Deflation (g/(m²-s)) and Cumulative Mass Loss (g) Data Summary:

(XDCA, Page 1 of 1)

Category	Test	Subtest 1	Subtest 2	Subtest 3	Subtest 4	Subtest 5	Subtest 6	Subtest 7	Subtest 8
<u>Idaho Soil/XDCA</u>									
1:1 @ 4.5 L/m ²	31	0.0E+00	0.0E+00	2.3E-01	1.3E-01	1.7E+00	3.2E+01	-3.9E-01	1.5E+01
	33	0.0E+00	6.5E-02	1.7E+00	2.2E+00	3.1E+00	5.1E+01	-2.3E-01	2.1E+01
	Average:	0.0E+00	3.3E-02	9.7E-01	1.2E+00	2.4E+00	4.2E+01	-3.1E-01	1.8E+01
	Standard Deviation:	0.0E+00	4.6E-02	1.0E+00	1.5E+00	9.9E-01	1.3E+01	1.1E-01	4.2E+00
	Avg Σ Mass Change (g):	0.0E+00	-9.9E-01	-3.1E+01	-6.6E+01	-7.3E+01	-1.3E+03	-1.3E+03	-1.9E+03
1:2 @ 1.1 L/m ²	25	9.8E-02	4.6E-01	2.3E+01	4.0E+01				
	32	3.3E-02	2.0E-01	2.2E+01	3.7E+01				
	Average:	6.6E-02	3.3E-01	2.3E+01	3.9E+01				
	Standard Deviation:	4.6E-02	1.8E-01	7.1E-01	2.1E+00				
	Avg Σ Mass Change (g):	-2.0E+00	-1.2E+01	-7.0E+02	-1.9E+03				
1:2 @ 4.5 L/m ²	24	0.0E+00	0.0E+00	1.3E+00	1.2E+00	4.3E+00	5.4E+01		
	30	0.0E+00	3.3E-02	7.5E-01	5.2E-01	2.3E+00	5.8E+01		
	Average:	0.0E+00	1.7E-02	1.0E+00	8.6E-01	3.3E+00	5.6E+01		
	Standard Deviation:	0.0E+00	2.3E-02	3.9E-01	4.8E-01	1.4E+00	2.8E+00		
	Avg Σ Mass Change (g):	0.0E+00	-5.0E-01	-3.2E+01	-5.8E+01	-1.0E+02	-1.8E+03		
1:2 @ 9.2 L/m ²	40	6.5E-02	0.0E+00	2.9E-01	-3.3E-02	1.8E+00	2.6E+01		6.5E+00
	41	0.0E+00	6.5E-02	-3.3E-02	6.5E-02	1.1E+00	3.0E+01	-1.3E-01	9.4E+00
	Average:	3.3E-02	3.3E-02	1.3E-01	1.6E-02	1.5E+00	2.8E+01	-1.3E-01	8.0E+00
	Standard Deviation:	4.6E-02	4.6E-02	2.3E-01	6.9E-02	4.9E-01	2.8E+00		2.1E+00
	Avg Σ Mass Change (g):	-9.9E-01	-2.0E+00	-5.9E+00	-6.4E+00	-4.4E+01	-9.0E+02	-9.0E+02	-1.1E+03
1:2 @ 4.5 L/m ² (uv-cycling tests)	34	0.0E+00	9.8E-02	5.1E+00	9.4E+00	1.6E+00	3.7E+01		
	35	0.0E+00	6.5E-02	3.3E+00	5.8E+00	9.5E-01	4.1E+01		
	Average:	0.0E+00	8.2E-02	4.2E+00	7.6E+00	1.3E+00	3.9E+01		
	Standard Deviation:	0.0E+00	2.3E-02	1.3E+00	2.5E+00	4.6E-01	2.8E+00		
	Avg Σ Mass Change (g):	0.0E+00	-2.5E+00	-1.3E+02	-3.6E+02	-3.9E+01	-1.2E+03		
1:2 @ 4.5 L/m ² (Moisture-cycling tests)	44	3.3E-02	1.3E-01	1.6E+00	4.9E+00	4.1E+00	4.7E+01		
	45	0.0E+00	3.3E-02	1.1E+00	2.0E+00	3.3E+00	5.3E+01		
	Average:	1.7E-02	8.2E-02	1.4E+00	3.5E+00	3.7E+00	5.0E+01		
	Standard Deviation:	2.3E-02	6.9E-02	3.5E-01	2.1E+00	5.7E-01	4.2E+00		
	Avg Σ Mass Change (g):	-5.0E-01	-3.0E+00	-4.4E+01	-1.5E+02	-1.1E+02	-1.6E+03		
<u>Hanford Soil/XDCA</u>									
1:2 @ 4.5 L/m ²	64	0.0E+00	0.0E+00	0.0E+00	-3.3E-02	1.3E-01	4.8E+00	-2.0E+00	-2.9E-01
	65	0.0E+00	0.0E+00	0.0E+00	-3.3E-02	9.8E-02	2.3E-01	-2.7E+00	-8.8E-01
(not included in avg...)	65a	nd	nd	nd	nd	1.3E-01	3.3E-01	-9.8E-01	1.3E-01
(not included in avg...)	65b	-3.3E-02	-3.3E-02	-3.3E-02	0.0E+00	2.0E+00	4.3E+00	-2.8E+00	2.0E+00
	Average:	0.0E+00	0.0E+00	0.0E+00	-3.3E-02	1.1E-01	2.5E+00	-2.4E+00	-5.9E-01
	Standard Deviation:	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E-02	3.2E+00	4.9E-01	4.2E-01
	Avg Σ Mass Change (g):	0.0E+00	0.0E+00	0.0E+00	1.0E+00	-3.5E+00	-8.0E+01	-8.5E+00	9.4E+00

Surface Deflation (g/(m²·s)) and Cumulative Mass Loss (g) Data Summary:

(Fermented Potato Waste, Page 1 of 1)

Category	Test	Subtest 1	Subtest 2	Subtest 3	Subtest 4	Subtest 5	Subtest 6	Subtest 7	Subtest 8
<u>Idaho Soil/FPW</u>									
1:1 @ 4 L/m ²	49	-9.8E-02	1.3E+00	-3.6E+00	-5.2E-01	6.0E+00	2.9E+01	-2.9E+00	2.6E+01
	Average:	-9.8E-02	1.3E+00	-3.6E+00	-5.2E-01	6.0E+00	2.9E+01	-2.9E+00	2.6E+01
	Standard Deviation:	-	-	-	-	-	-	-	-
	Avg Σ Mass Change (g):	3.0E+00	-3.7E+01	7.3E+01	8.9E+01	-1.8E+02	-1.1E+03	-9.8E+02	-1.8E+03
1:2 @ 4 L/m ²	54	0.0E+00	0.0E+00	-1.9E+00	9.8E-02	3.4E+00	3.7E+01	-3.2E+00	4.2E+01
	Average:	0.0E+00	0.0E+00	-1.9E+00	9.8E-02	3.4E+00	3.7E+01	-3.2E+00	4.2E+01
	Standard Deviation:	-	-	-	-	-	-	-	-
	Avg Σ Mass Change (g):	0.0E+00	0.0E+00	5.8E+01	5.5E+01	-1.0E+02	-1.2E+03	-1.1E+03	-2.4E+03
1:4 @ 2 L/m ²	42	-6.5E-02	0.0E+00	4.2E-01	9.8E-01	7.8E-01	3.5E+01	-1.1E+00	2.4E+01
	69	-6.5E-02	-3.3E-02	-2.0E-01	3.9E-01	7.8E-01	3.2E+01	-2.7E+00	2.2E+01
	Average:	-6.5E-02	-1.7E-02	1.1E-01	6.9E-01	7.8E-01	3.4E+01	-1.9E+00	2.3E+01
	Standard Deviation:	0.0E+00	2.3E-02	4.4E-01	4.2E-01	0.0E+00	2.1E+00	1.1E+00	1.4E+00
	Avg Σ Mass Change (g):	2.0E+00	2.5E+00	-8.7E-01	-2.2E+01	-2.4E+01	-1.0E+03	-9.9E+02	-1.7E+03
1:4 @ 4 L/m ²	43	-6.5E-02	0.0E+00	-1.3E-01	1.6E-01	1.3E+00	4.2E+01	-	-
	48	-6.5E-02	0.0E+00	-2.0E-01	6.5E-02	1.6E+00	2.7E+01	-2.3E+00	4.1E+01
	Average:	-6.5E-02	0.0E+00	-1.7E-01	1.1E-01	1.5E+00	3.5E+01	-2.3E+00	4.1E+01
	Standard Deviation:	0.0E+00	0.0E+00	4.9E-02	6.7E-02	2.1E-01	1.1E+01	-	-
	Avg Σ Mass Change (g):	2.0E+00	2.0E+00	7.0E+00	3.6E+00	-4.4E+01	-1.1E+03	-1.0E+03	-2.3E+03
1:9 @ 4 L/m ²	55	0.0E+00	0.0E+00	3.3E-02	5.2E-01	1.8E+00	8.7E+01	-	-
	68	-3.3E-02	-3.3E-02	2.6E-01	6.2E-01	3.3E-01	7.3E+00	-2.7E+00	1.2E+01
	Average:	-1.7E-02	-1.7E-02	1.5E-01	5.7E-01	1.1E+00	4.7E+01	-2.7E+00	1.2E+01
	Standard Deviation:	2.3E-02	2.3E-02	1.6E-01	7.1E-02	1.0E+00	5.6E+01	-	-
	Avg Σ Mass Change (g):	5.0E-01	1.0E+00	-3.5E+00	-2.1E+01	-3.3E+01	-1.5E+03	-1.4E+03	-1.8E+03
1:4 @ 4 L/m ²	58	0.0E+00	0.0E+00	-3.3E-02	2.3E-01	9.5E-01	1.8E+01	-2.6E+00	2.9E+01
(uv-cycling tests)	59	0.0E+00	0.0E+00	-3.3E-02	9.8E-02	8.8E-01	1.5E+01	-3.0E+00	2.2E+01
	Average:	0.0E+00	0.0E+00	-3.3E-02	1.6E-01	9.2E-01	1.7E+01	-2.8E+00	2.6E+01
	Standard Deviation:	0.0E+00	0.0E+00	0.0E+00	9.3E-02	4.9E-02	2.1E+00	2.8E-01	4.9E+00
	Avg Σ Mass Change (g):	0.0E+00	0.0E+00	1.0E+00	-4.0E+00	-2.8E+01	-5.3E+02	-4.5E+02	-1.2E+03
1:4 @ 4 L/m ²	62	-6.5E-02	1.6E+00	-1.2E+00	1.1E+00	4.3E+00	6.6E+01	-3.6E-01	2.0E+01
(Moisture-cycling tests)	63	-3.3E-02	3.2E+00	-1.9E+00	2.2E+00	5.4E+00	7.4E+01	-8.5E-01	2.7E+01
	Average:	-4.9E-02	2.4E+00	-1.6E+00	1.7E+00	4.9E+00	7.0E+01	-6.1E-01	2.4E+01
	Standard Deviation:	2.3E-02	1.1E+00	4.9E-01	7.8E-01	7.8E-01	5.7E+00	3.5E-01	4.9E+00
	Avg Σ Mass Change (g):	1.5E+00	-7.2E+01	-2.5E+01	-7.5E+01	-1.5E+02	-2.3E+03	-2.3E+03	-3.0E+03
<u>Hanford Soil/FPW</u>									
1:4 @ 4 L/m ²	56	0.0E+00	0.0E+00	9.8E-01	2.8E+00	2.4E+00	5.1E+00	1.1E+01	4.6E+01
	57	0.0E+00	0.0E+00	1.1E+00	2.9E+00	2.9E+00	4.4E+00	1.2E+01	7.5E+01
	Average:	0.0E+00	0.0E+00	1.0E+00	2.9E+00	2.7E+00	4.8E+00	1.2E+01	6.1E+01
	Standard Deviation:	0.0E+00	0.0E+00	8.5E-02	7.1E-02	3.5E-01	4.9E-01	7.1E-01	2.1E+01
	Avg Σ Mass Change (g):	0.0E+00	0.0E+00	-3.2E+01	-1.2E+02	-8.1E+01	-2.3E+02	-5.8E+02	-2.4E+03

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