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Survey of Soil Health Characteristics Necessary to Support Native Plant Species at the Santa Susana Field Site

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Abstract

We report here the methods and results of laboratory tests conducted on soil samples collected from two sampling locations at the Santa Susanna Field Laboratory (SSFL) site as well as the on the backfill soil from Grimes Rock (Simi Valley, CA) identified as suitable for an Administrative Order on Consent (AOC) for Remedial Action. In this report the two samples from the SSFL site are denoted Ash Pile-Sewage Treatment Plant (AP-STP) Area, and skyline, and the backfill soil as grimes. The physical characteristics of the soils determined by laboratory testing and measurement are limited to textural class determined by particle size analysis, saturated hydraulic conductivity by the falling-head permeameter method, and soil moisture retention characteristic curves by pressure plate/membrane extractor and the hanging column methods. All soil samples were determined to be of the same textural class, namely sandy loam, with the AP-STP soil sample having the highest sand fraction and hydraulic conductivity. The backfill soil (grimes) was found to have the lowest hydraulic conductivity. This soil property regulates infiltration into as soil and potential run-off generation. The implication of the results reported herein is that infiltration rates at the site would be expected to decrease and the potential for run-off generation to increase following replacement of site soils with the suggested backfill soil. Soil moisture retention data and the model fits to these data are included in the report and are used to qualitatively compare the water holding capacities of the three soils. The data indicate only slight differences among the three soil samples, but suggest slightly higher average water holding capacities for the SSFL site soils than for the replacement material, which may be attributable to the higher organic matter content of the SSFL site soils (see below) and greater aggregation. This result is not sufficiently statistically significant to allow one to make predictions about moisture holding capacities under field conditions. Soil chemistry data suggests that all three soils have nutrient deficiencies. In addition to compost to increase soil organic matter, some acidification, due to elevated soil pH, and fertilizer would be needed to

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ameliorate nutrient deficiencies in the backfill material. For fertilizer, recommended amendments for the backfill material, based on bentgrass, include 140 lb/acre of nitrogen, 130 lb/acre of phosphorous (as P_2O_5), and 180 lb/acre of potassium (as K_2O). Additional amendments are required for elemental sulfur and other micro-nutrients. The results of the germination and growth experiments support the conclusion that the nutrient levels in the backfill material would not yield sustained growth of native species.

1 Introduction

The Santa Susana Field Laboratory (SSFL) site is located near Chatsworth, California on 2,850 acres in the Simi Hills, nearly thirty miles northwest of downtown Los Angeles, in southeastern Ventura County. The SSFL opened in 1948 and it became a center for the development and testing of rocket engines for defense and exploration purposes. It was also a test site for advanced energy research programs. SSFL is divided into four “Administrative Areas” and additional undeveloped areas of land to the north and south. Areas I, III, and IV and the undeveloped areas are owned and operated by the Boeing Company. NASA is responsible for Area II, consisting of 409.5 acres, along with 41.7 acres in Area I. The U.S. Department of Energy (DOE) has long held a lease on land in Area IV.

All research and testing activities at SSFL were discontinued by 2005 and environmental cleanup activities are now underway to remove chemicals in the environment that remain from past operations. NASA, Boeing and DOE are each responsible for cleanup in areas in which they operated. California’s Department of Toxic Substances Control (DTSC) is overseeing the cleanup. NASA’s overarching goal in its cleanup efforts at SSFL is to protect human health and safety and the environment, as well as the cultural legacy of the site. In August 2007, NASA, Boeing and DOE, and the Department of Toxic Substances Control (DTSC) signed a Consent Order for Corrective Action that addressed the cleanup of soils and groundwater at SSFL. Subsequently, in December 2010, NASA and DTSC executed an Administrative Order on Consent for Remedial Action (referred to as “2010 AOC”) with specific requirements to complete the characterization and cleanup of soils in NASA-administered areas. The AOC will require that NASA remove large volumes of soil from SSFL.

To restore the site, NASA plans on using replacement soils that can meet the strict look-up table (LUT) values in the AOC. There is some concern that AOC compliant replacement soils, while chemically acceptable, may not be able to sustain restoration as the replacement soils are virtually devoid of essential nutrients and soil microbes. One of the key activities at SSFL to be compliant with the AOC will be the restoration of the ecosystem. NASA aims to study the ecology of site soils with a view to understanding the unique site microbiome and the vital role this complex soil ecosystem plays in supporting native vegetation species. The Scope of Work proposed by NASA for the SSFL Replacement Soil Testing is as follows:

1. Conduct comparative analysis of reference soils from native southern California plant communities (oak woodland, chaparral, coastal sage scrub) at SSFL and the proposed fill material from Grimes Rock to assess the chemical and nutrient profiles and the microbial communities present in terms of its taxonomic and functional diversity.
2. Using established native plant nutrient requirements and propagation techniques, determine the suitability of the replacement soils for the germination and initial growth of various native plant species common to the plant communities of the SSFL. Seed germination and growth rates for native plant species in the replacement soils will be compared to a control group of the same species germinated in a standard greenhouse substrate.
3. Using the results of Objective 2, evaluate the type and quantity of soil amendments required to modify the proposed replacement soil into a soil of equivalent fertility and tilth to the native soil. Prepare a chemical analysis of the modified soil and compare it to the AOC

Look-up Table chemical values and identify areas where addition of soil amendments could cause a violation of the AOC Look-up Table chemical values.

4. Production of a Technical Report detailing all aspects of the laboratory and greenhouse trials. Report to include a complete discussion and recommendation on the suitability of the replacement soils to support the restoration of native ecosystems. The Technical Report should detail the methods used in the laboratory and greenhouse trials and the results of all data collected. Additionally the Technical Report should include a discussion of the results and recommendations as to the suitability or unsuitability of the replacement soil to meet the ultimate goal of restoration of native ecosystem functions. If the replacement soil is found to be unsuitable, recommendation for potential soil amendments will be provided. The Technical Report should summarize the type and quantity of soil amendments required to modify the proposed replacement soil into a soil of equivalent fertility and tilth to the native soil; provide a comparative chemical analysis of the amended soil and the AOC Look-up Table chemical values to identify areas where addition of soil amendments could cause a violation of the AOC Look-up Table chemical values.

In 2018 NASA contracted with the California Polytechnic State University (Cal Poly) to address this scope of work, through field sampling and laboratory testing of site soils with a view to establishing the baseline measures of soil health necessary to support native plant species at the SSFL site. Specific objectives of the study were to

1. Measure and contrast site soil physical characteristics
2. Measure representative soil nutrient profile from those of the control fill material, specifically NH_4^+ , NO_3^- , K^+ , PO_4^{3-} , Total C, Total N, Organic C, Organic N, as well as the CEC, pH, salinity profile;
3. Determine the profile of the microbial communities prevalent at the site by analysis of bacterial biomass, fungal biomass, and microbial activity, and contrast these with those present in the fill material;
4. Perform greenhouse trials to determine germination and growth rates in site soils and fill material, and;
5. Analysis of irrigation/water requirements for establishment of the native vegetation.

In this report, we outline the methods used to address the objectives enumerated above, the results, and recommendations of the work.

2 Materials and Methods

2.1 Soil Samples

Two homogenized samples of site soils were collected from two locations, which are referred to herein as *AP-STP* (or simply Ash-pile in figures) and *Skyline* soils. The samples were collected from the top 12 inches using a clean spade and placed in 5-gallon clean buckets that were sealed and transported to Cal Poly. They were air-dried at 85 °C for 24 hours then sieved with a 2-millimeter (2-mm or No. 10) sieve to removed rock fragments and gravels. An additional 5-gallon bucket of the backfill soil that has been identified as suitable for an AOC-based soil remediation, referred to hereafter as the *grimes backfill* or simply the *grimes* soil or material was provided to the Principal Investigator (PI) by NASA.

2.2 Soil Physical & Chemical Properties

The soil physical properties measured included soil texture, saturated hydraulic conductivity, and soil moisture retention. Soil texture was determined by sedimentation (Bouyoucos, 1962) and sieving. The sedimentation method was used to determine the clay and silt fractions. It was

performed on 50 gram (g) samples of the three soils that were first chemically dispersed by soaking them for 24 hours in 10 milli-liters (mL) of 5% Sodium Hexametaphosphate ($\text{Na}_6(\text{PO}_3)_6$) solution. They were then further dispersed by mechanical agitation before being transferred to a standard 1130 mL sedimentation cylinder. Reading of suspension were taken with the standard ASTM 152h hydrometer at time intervals of 40 minutes, 2 hours, and 7 hours. Readings were also taken in a blank solution comprising 100 mL $\text{Na}_6(\text{PO}_3)_6$ solution and 880 mL of DI water in a 1130 mL sedimentation cylinder. Temperature corrected reading were then used to determine the clay and silt fractions. The sediment suspension was decanted through 53 μm sieve (No. 270), thoroughly washed, oven-dried, then sieved with a stack of 1, 0.5, 0.25, and 0.1 mm sieves to separate the sand fractions.

Saturated hydraulic conductivity was measured using a falling-head permeameter. Soil samples were tightly packed into 2.5-inch diameter permeameters, saturated with a degassed 0.005 M calcium chloride (CaCl_2) solution, then subjected to initial pressure heads of 15 cm, which allowed the dilute CaCl_2 solution to drain through the samples. The temporal pressure head decay was monitored with 2-psig pressure transmitters attached to a CR300 Campbell Scientific data-logger and set to a log data every second during the tests. For each soil sample, three trials of falling-head permeameter tests were performed.

Soil moisture retention measurements were conducted using a hanging-column sandbox at low pressures ($P_c < 0.01$ MPa), a pressure plate extractor for the intermediate pressure range ($P_c \in [0.01, 0.4]$ MPa), and a pressure membrane extractor at the dry-end ($P_c \geq 0.4$ MPa). Three replicate samples were prepared for each suction pressure by saturating them with a dilute (0.005 M) CaCl_2 solution. Samples were then placed in the respective measurement instrument and a predetermined pressure applied to allow drainage of water until static equilibrium was established between sample matric potential and the applied pressure. Equilibrium was determined to have been established upon sample cessation of drainage. The drained (or equilibrated) samples were then weighed to determine the wet mass, placed in a drying oven at 105 °C, and weighed again to determine the oven-dry sample mass. This yielded the gravimetric moisture retained in the sample at equilibrium at the applied pressure.

The chemical properties of the soils were primarily measured by A & L Western Agricultural Laboratories. The measure characteristics include soil pH, base cation saturation, organic matter, as well as nitrogen, phosphorous and total heavy/trace metals. Secondary measurements were performed at the California Polytechnic State University's analytical soil and water chemistry laboratory using a portable X-ray Fluorescence Spectrometer (pXRF). The instrument is capable of measuring concentrations of 38 elements (with detection limits generally less than 10 ppm except for Magnesium = 2500 ppm) in the field (*in situ*) or in the lab directly on soil, rock, plant, and some water samples. pXRF measurements were conducted on dry samples of the three soils.

2.3 Plant Germination and Growth Trial

The greenhouse and growth experiment was carried out to assess the germination and growth of four plant species native to the Santa Susana area, in the grimes backfill replacement soil material and two reference soils collected at the SSFL (AP-STP and Skyline). The four plant species were *Eriogonum fasciculatum fasciculatum* (California buckwheat), *Penstemon spectabilis* (showy penstemon), *Eschscholzia californica* (California poppies), and *Stipa pulchra* (purple needle grass), all of which are native to the general area with which the study area is situated. Plant species were selected using the online tool www.calflora.org and sourced from a specialized vendor (<http://www.ssseeds.com>).

Seeds were germinated in three 72-plug germination trays, one per soil, with leachate traps at the base. Each plant species was seeded in ten plugs in each of the three trays, with 5 seeds per plug. Seeds were watered daily, and the germination percentage was assessed two weeks after seeding. Seedlings were subsequently thinned to one per plug and allowed to grow for an additional 5 weeks. The general procedure for the germination and growth experiment can be summarized as follows:

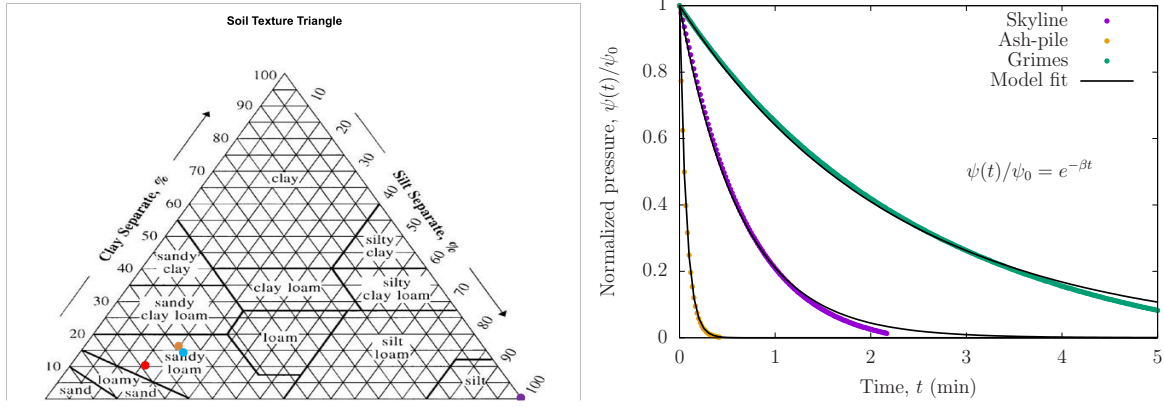


Figure 1: (a) The textural class data of the three soil samples, with AP-STP in red, Skyline in brown, and grimes (backfill) in blue/cyan, and (b) falling-head permeameter data showing normalized pressure head decay with time.

1. Place soil type in plots (one soil type per tray);
2. Water soil before placing the seeds;
3. Place 5 seeds on the surface of the soil using randomized placement;
4. Water to wet seeds and allow them to settle down into the soil;
5. Place a tray underneath the soil receptacles filled with water to ensure the soil is kept moist;
6. Rotate and turn the trays every day, and water each plot with the same amount;
7. Count the number of seeds germinated for each treatment;
8. Weed down each plot to one plant after they have germinated to provide best results for biomass measurements (minimizes competition among plants within plots);
9. Continue watering plants daily for an addition 5 weeks, and;
10. Harvest plant biomass, weigh, oven-dry, and weigh again.

On July 8th 2019, seedlings were harvested by clipping at the base of the shoot. The mass of the freshly harvested biomass was recorded and then they were oven-dried at 60 °C for three days until constant mass was attained, allowing for a dry-biomass determination.

3 Results

The two soil samples material from the site and the backfill (grimes) were all determined to be of the *sandy loam* textural class. The backfill material and Skyline soil were determined to be 64% sand, with 14% and 16% clay, respectively. The AP-STP sample had the highest sand and lowest clay content at 74% and 10%, respectively. These texture data are also broadly reflected in the results of the saturated hydraulic conductivity (K_{sat}) measurements on packed permeameter samples of the three soils. The AP-STP sample, which has the highest sand and lowest clay fractions also has the highest measured value of $K_{\text{sat}} = 1.20 \times 10^{-3}$ m/s (104 m/d) with the Skyline sample yielding a value of $K_{\text{sat}} = 1.33 \times 10^{-4}$ m/s (12 m/d). The backfill material is the least permeable of the three soils tested with a measured value of $K_{\text{sat}} = 3.68 \times 10^{-5}$ m/s (3.2 m/d). Soil texture and falling-head permeameter data are shown in Figure 1. Falling-head permeameter data clearly show that the AP-STP soil is associated with the most rapid decay of the initial head, an indication of high permeability, with the backfill material exhibiting the slowest decay to static equilibrium.

Another physical property of vital importance is the soil moisture retention or characteristic curve, which is an empirical relation between soil moisture content, θ , and the soil water potential, ψ . Soil water potential provides a measure of how strongly bound the moisture is to the soil matrix, which reflects the work or energy expended by plants to extricate the moisture from the soil. The empirical soil moisture retention curves for the two site soils and the backfill material are shown in Figure 2. The three soils exhibit very similar behavior with only slight and inconsistent

differences among them: the AP-STP sample has the highest saturated moisture content, and the grimes (backfill) material the least. The differences among the three soils are only evident close to saturation. The curves appear to be convergent in the intermediate pressure range and at the residual end. The results suggest that the three soils have comparable soil moisture holding capacities. Two theoretical models for describing soil moisture retention as a function of the soil water potential were used to analyze the data, namely the van Genuchten (1980) and Kosugi (1996) models. The former assumes a β -distribution for particle size, and the latter a log-normal distribution. Both models are widely used in the soil science literature, and are characterized by an air-entry potential, ψ_E , particle-size distribution mean and variance, and the saturated ($\theta_{g,s}$) and residual ($\theta_{g,r}$) moisture. The two models are used here for completeness of the comparison and yield comparable values for the parameters ψ_E , $\theta_{g,s}$, and $\theta_{g,r}$. The moisture holding capacity of a soil is proportional to $\theta_g(\psi_E) - \theta_{g,r}$.

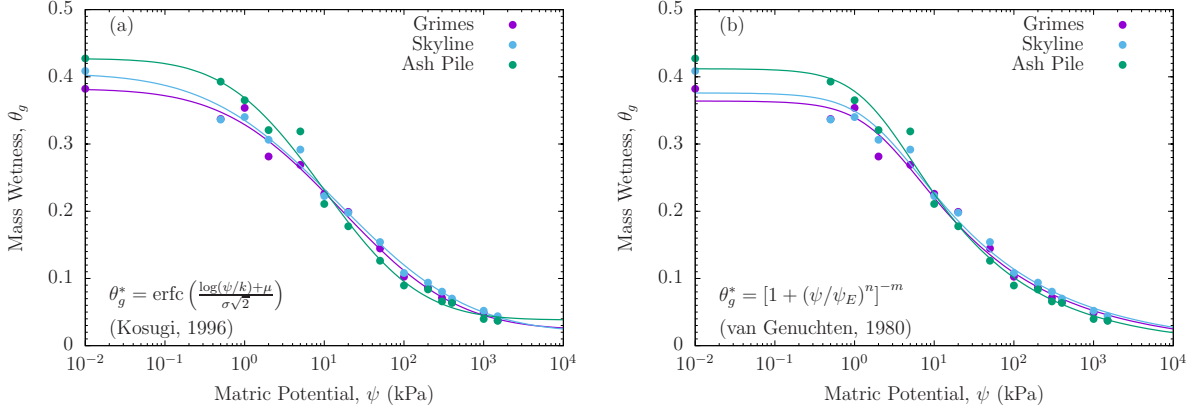


Figure 2: Soil moisture retention data for SSFL site and replacement soil samples analyzed with models of (a) Kosugi (1996) and Malama and Kuhlman (2015), and (b) van Genuchten (1980).

A review of the soil chemistry data from a fertility standpoint indicate that there are no hazards due to salinity (chloride) or high sodium (Na) in all samples tested. The pH is slightly acidic to neutral (pH = 6.1–6.6) in the two SSFL site samples and moderately alkaline (pH = 8) in the replacement material. The cation exchange capacities of the soils are similarly low with an average of 10 ± 1 cmolc/kg. The three samples have comparable base cation saturation with an average of $93 \pm 7\%$ and the most dominant cation on the cation exchange sites is calcium. All soils are low in organic matter and plant primary *macronutrients*, Nitrogen (N), Phosphorous (P), and Potassium (K). The average organic matter content for the two SSFL site samples $2.2 \pm 0.1\%$ is significantly higher than in the replacement material (OM = 0.6%). A summary of the nutrients (NPK), organic matter, and base cation saturation measured for the three soils is shown in Figure 3. The grimes backfill replacement material has the least of potassium, and organic matter, but shows marginally higher (statistically insignificant) nitrogen (measured as nitrate, NO_3^-) and phosphorous than the Skyline sample. It has, marginally, the least of the base cations K^+ and Mg^{2+} , but the highest of Ca^{2+} . As mentioned already and reemphasized here, all three soils have base cation saturation values that would largely be considered low to medium.

The concentrations of *micronutrients* and other trace metals (arsenic, chromium, copper, lead, manganese, molybdenum, nickel, niobium, rubidium, strontium, thorium, zinc, zircon, and yttrium) naturally extant in soils, as measured with the pXRF, are shown in Figure 4. The data in the figure are surface soil concentration for each of the metals (Kabata-Pendias, 2011). *Micronutrients* are essential nutrients that are taken up by plants only in minute amounts. The results from measurements on site soil samples and backfill material are compared to global averages as reported in Kabata-Pendias (2011). A review of total trace metal content of both on- and off-site soil was conducted utilizing the pXRF. These data were also compared to reported mean world surface soil concentrations (Kabata-Pendias, 2011). There are no data available in the soil science literature for soils of California or more specifically, the soils of the Southern California coastal mountain ranges

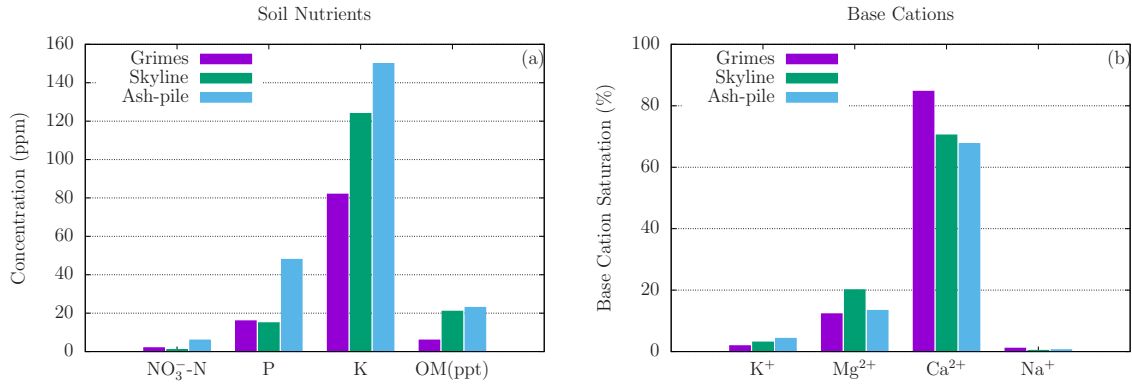


Figure 3: Measured soil (a) macro-nutrient concentrations and organic matter content (in parts per thousand, ppt), and (b) base cation saturation of the three soils (from A & L laboratories).

that would allow an assessment at a more local and regional scale. However, it should be noted that trace metal content of coastal California soils are controlled by parent materials derived from old ocean rocks and sediment that are rich in mafic minerals (of oceanic crust origin) and inherently have elevated trace heavy metal content. The results suggest that, whereas amendments may be required for the macro-nutrients (N, P, K) there may not be, in general, a need for amendments to boost the backfill material micro-nutrient concentrations to levels above the global averages, given that the observed levels are above or close to those required for optimal plant growth, particularly, native coastal California plant species.

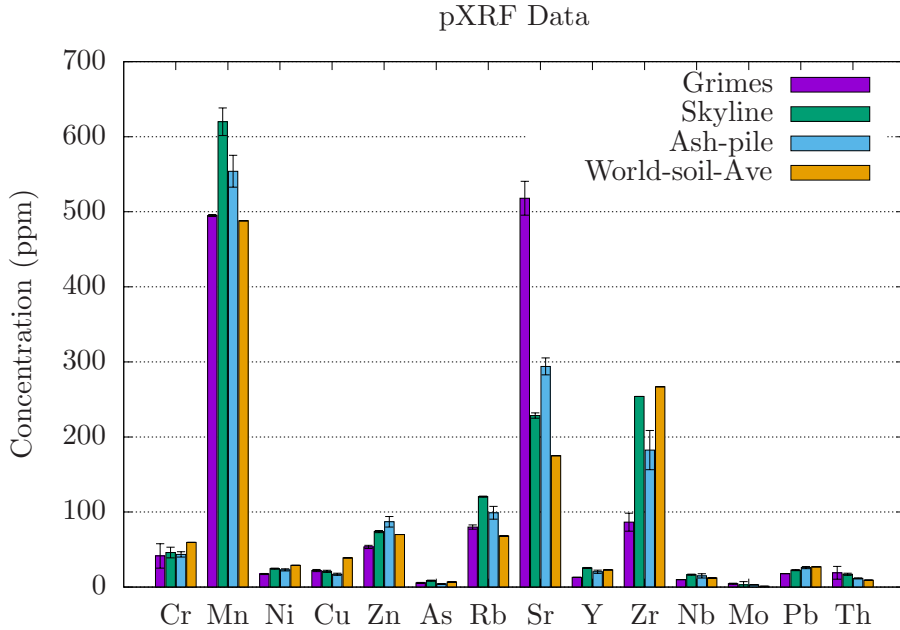


Figure 4: Micronutrient and other trace metal concentrations measured on dry soil samples using the pXRF. World average concentrations from Kabata-Pendias (2011) are included for comparison.

Results of the germination and growth experiments are shown in Figure 5. In the Figure California poppies are labeled as EC, California buckwheat as EF, showy penstemon as PS, and purple needle grass as SP. The results clearly indicate statistically significant differences among the plants and among the three soils. Pictures of germination are in Figure 7 in the Appendix. For California poppies and showy penstemon, the three soils are ranked in the order Skyline (1), AP-STP (2), and grimes (3) on the basis of the percentage of germinated seedlings. For California buckwheat, the ranking is AP-STP (1), grimes (2), and Skyline (3), while for purple needle grass the ranking

is grimes (1), Skyline (2), and AP-STP (3). For the four plant species, the ranking is showy penstemon (1), California poppies (2), with California buckwheat and purple needle grass (3) showing statistically similar germination.

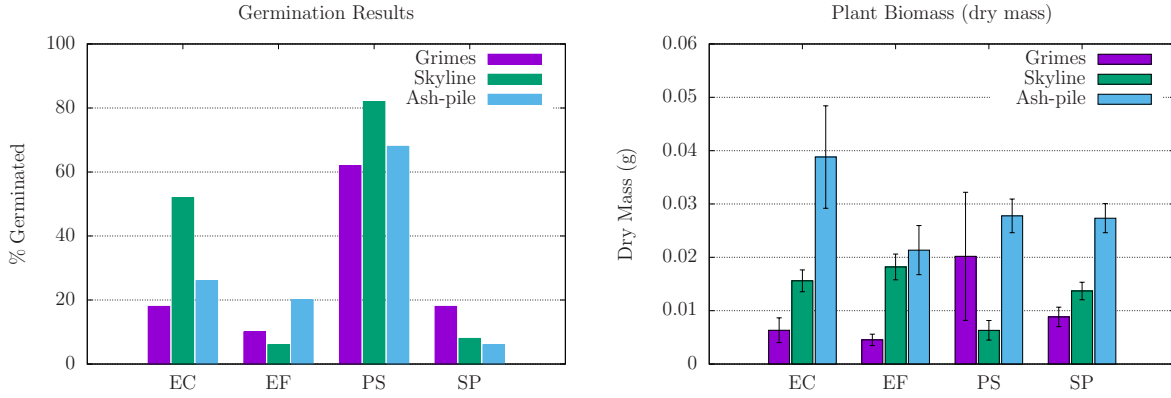


Figure 5: Results of the (a) germination and (b) growth experiment of four plants species in the three soils, with California poppies labeled as EC, California buckwheat as EF, showy penstemon as PS, and purple needle grass as SP.

The results of the growth phase of the experiment are shown in Figure 5(b). The four plant species showed statistically similar growth at harvest ($p = 0.711$), whereas the three soils analyzed showed statistically different results in plant growth ($p = 0.0002$) with the grimes replacement soil material resulting in the lowest average plant growth of all the three soils. When compared within each plant type, the soil collected at the AP-STP reference site consistently produced the highest plant growth, whereas the grimes backfill material resulted in the lowest growth and the Skyline reference soil resulted in intermediate growth. Only in the case of Penstemon spectabilis or showy penstemon (PS in chart) did the grimes replacement material, on average, outperform the other two soils. It should be noted however that variability in plant biomass, as reflected in the overlap of the error bars, suggests that the difference in the observed average biomass may not be sufficiently statistically different among the three soils.

4 Discussion and Recommendations

Measurement of soil physical parameters indicates that all three soils are of the sandy loam textural class with the replacement backfill soil having the lowest saturated hydraulic conductivity. The three soils have comparable water holding capacities, which were determined from soil moisture retention characteristics measurements and modeling. Saturated hydraulic conductivity is a pertinent parameter for water infiltration into a soil. The results obtained in this study, using the falling-head permeameter setup, suggest that the infiltrability of the replacement material is substantially lower than that of the country (or extant) soils. The lower permeability of the replacement material may be attributed to limited structure and aggregation. It should be noted that of the three soils considered, the backfill replacement soil had the highest (28 ppm) albeit low sodium (Na) saturation (1.1%) and lowest organic matter content (0.6%), which suggests it is the most dispersed and unstructured of the three materials. To improve soil structure and water infiltrability of the replacement material, it is recommended to increase its organic matter content by amending it with compost. The results also suggest that in addition to compost, some acidification and fertilizer (NPK) would be needed to ameliorate nutrient deficiencies in the replacement material. Fertilizer recommendations for the three soils are summarized in Figure 6 for bentgrass *Agrostis capillaris* nutrient requirements. They are scalable and proportional to requirements for the four native plant species considered in this study. On average, nitrogen and potassium requirements are highest for the replacement material. Phosphorous amendment is also recommended albeit at a rate that is marginally lower than would be required for the country soil at the Skyline sampling

location. Additionally, A & L Laboratories suggest amending the backfill material with elemental sulfur (1200 lb/acre), zinc (5 lb/acre), manganese (10 lb/acre), iron (10 lb/acre) and boron (2 lb/acre). Care should be taken however, in implementing these suggested amendments because of the possibility of violating the stipulations of the AOC for the backfill material by elevating elemental concentrations.

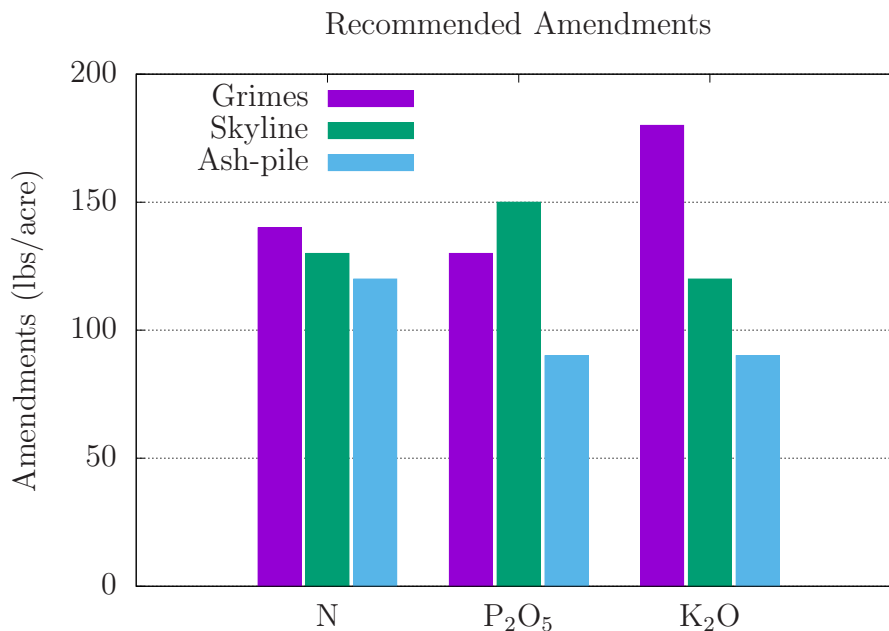


Figure 6: Recommended amendments for the three soils to improve soil fertility based on bentgrass *Agrostis capillaris*.

The germination and growth experimental results are reflective of the nutrient profiles of the three soils. The soils exhibited variable germination rates depending on the plant species. On average, the backfill soil lagged the two site soils for California poppies and showy penstemon, but exhibited similar or better germination rates for California buckwheat and purple needle grass. This variability in germination may be attributed to variability in seed quality and not to soil health parameters. Germination rate is typically a strong function of nutrient reserves within the seeds with soil moisture being the only limiting soil property. Soil chemical and health properties (*micro*- and *macro*-nutrients, microbial health, etc.) are typically most impactful post-germination during the growth phase as the seedlings deplete the seed nutrient supply and become dependent on soil nutrients after the roots are established. The results of the growth phase, on a dry plant biomass basis, clearly indicate that the plants in the replacement backfill soil, on average, lagged behind those in the site soils for three of the plant species considered. Harvested dry plant biomass of these species were statistically higher for the two site soils. For the species (showy penstemon) where those planted in the replacement soil appear on average to compare to or outperform those in the two site soils, the variability among the replicates and trials (see error bars) indicate that the three soils yield comparable results. In general, it is to be expected from these results that native species may show inhibited growth in the backfill material. This has implications for the potential of opportunistic invasive species to out-compete native species at the site if extant soils are replaced by the backfill material. Additional research is needed to definitively make such a determination.

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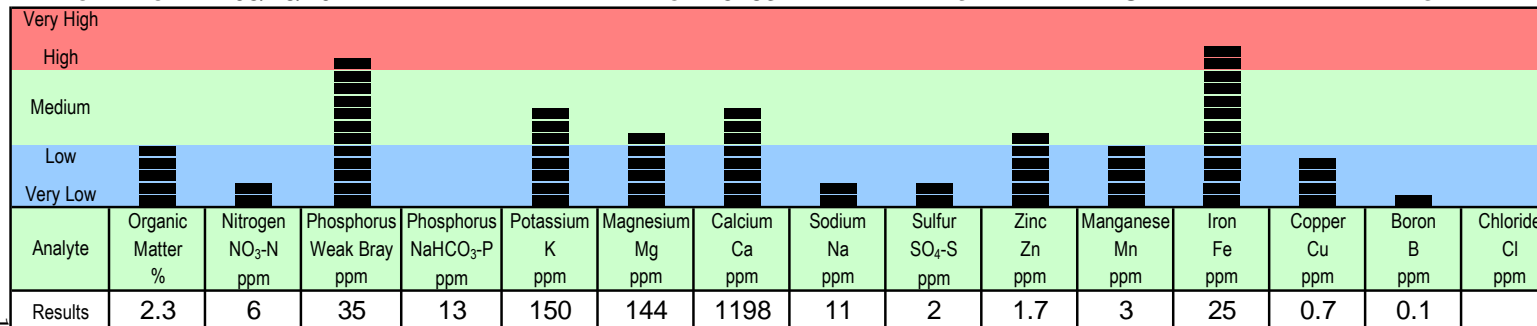
Graphical Soil Analysis Report

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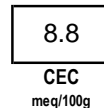
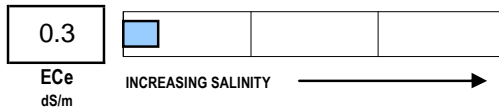
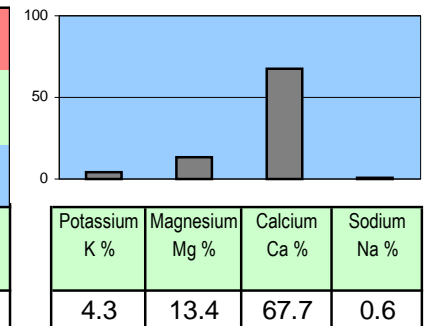
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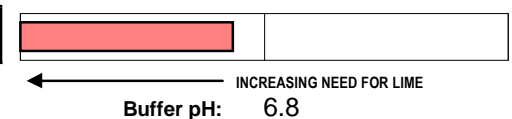
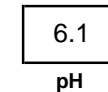


Percent Cation Saturation (computed)



L

Ex. Lime



NaHCO₃-P unreliable at this soil pH

Soil Fertility Guidelines

CROP: BENTGRASS

RATE: lb/acre

NOTES:

Dolomite (70 score)	Lime (70 score)	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P ₂ O ₅	Potash K ₂ O	Magnesium Mg	Sulfur SO ₄ -S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	
2000				120	90	90		30	5				2.0	

C ORGANIC MATTER: Low levels may restrict beneficial microbial activity and lead to soil compaction and erosion. Consider raising levels if a concern or practical.

O

M LIME REQUIREMENT: Liming may be necessary if buffer index is less than 6.9. Guidelines are based upon common agricultural lime (70-score) per six-inch depth to raise SOIL pH to about 6.5.

M

E ACIDIFICATION of high pH soils could improve soil environment. Compare different sources of acidifying materials, but be aware that sulfate-sulfur (as shown on report) has NO acidifying power.

N

T NITROGEN: Recommendation is only a guideline. Use local conditions and plant N for the right rate and

S time of application. Allow also for nitrate in your water (ppm NO₃ X 0.61= lb N/ac-ft water).

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Rogell Rogers

Rogell Rogers, CCA, PCA

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REPORT NUMBER: 19-133-063

CLIENT NO: 1120

SEND TO: CAL POLY - SLO
CROP SCIENCE DEPT.
SAN LUIS OBISPO, CA 93407-

GROWER: PO#F0027727

SUBMITTED BY: CHIP APPEL

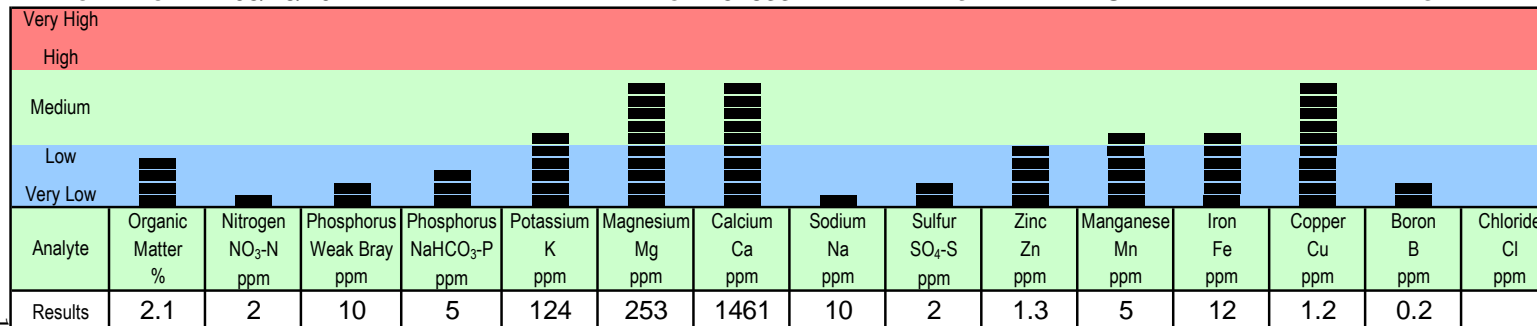
Graphical Soil Analysis Report

DATE OF REPORT: 05/16/19

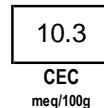
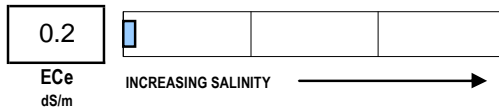
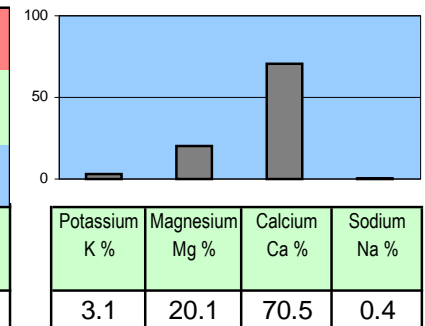
LAB NO: 54833

SAMPLE ID: SKYLN

PAGE: 2

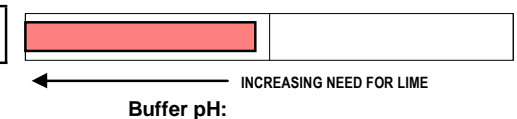
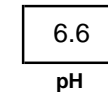


Percent Cation Saturation (computed)



L

Ex. Lime



Soil Fertility Guidelines

CROP: BENTGRASS

RATE: lb/acre

NOTES:

Dolomite (70 score)	Lime (70 score)	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P ₂ O ₅	Potash K ₂ O	Magnesium Mg	Sulfur SO ₄ -S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	
				130	150	120		30	5		10		2.0	

C CONSIDER applying controlled release fertilizers once any severe nutrient deficiencies have been
O addressed. Some brands may release over several months. Seek further advise from your supplier.
M EXCESSIVE NITROGEN hastens thatch build-up and increases disease susceptibility. Apply with caution if
M not a slow release source, and protect ground water by not over-fertilizing.
E ZINC: Maintain soil levels above 2.0 ppm to ensure an adequate zinc supply. A tissue analysis at the
N appropriate time will determine more accurately, availability to the plant.
T MANGANESE: Soil levels below 2 ppm may respond to applications of manganese. But, first check on tissue
S levels to confirm any likely deficiencies. Follow label instructions if required.

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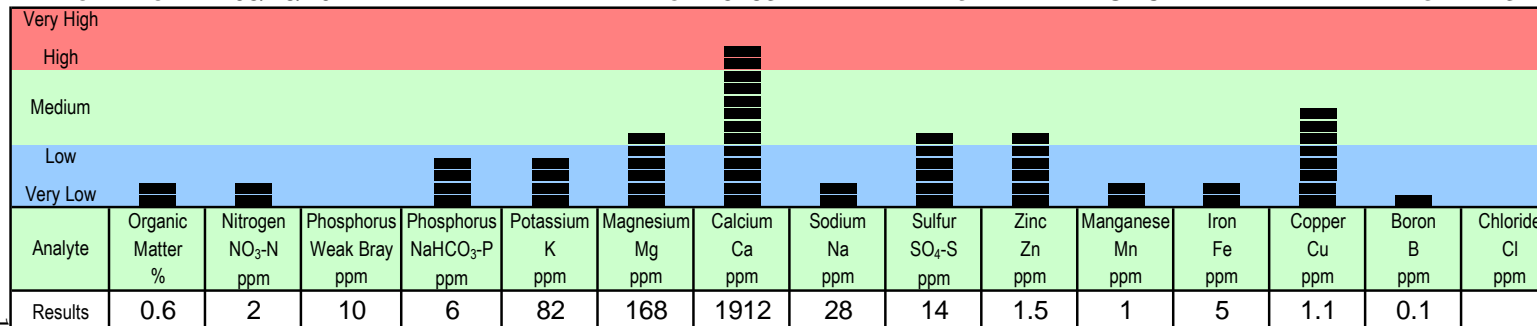
Graphical Soil Analysis Report

DATE OF REPORT: 05/16/19

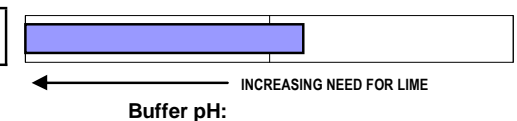
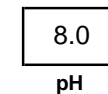
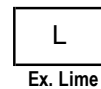
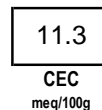
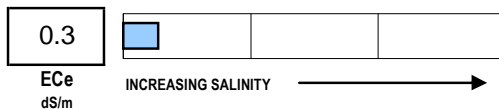
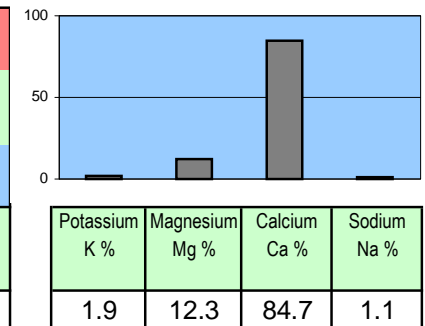
LAB NO: 54834

SAMPLE ID: GRCAN

PAGE: 3



Percent Cation Saturation (computed)



Weak Bray P unreliable at M or H excess lime or pH > 7.5

Soil Fertility Guidelines

CROP: BENTGRASS

RATE: lb/acre

NOTES:

Dolomite (70 score)	Lime (70 score)	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P ₂ O ₅	Potash K ₂ O	Magnesium Mg	Sulfur SO ₄ -S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	
			1200	140	130	180			5	10	10		2.0	

C BORON: Aim for soil levels above 0.5 ppm to avoid a deficiency. A tissue analysis at the appropriate
O time will determine more accurately, plant availability. ADD BORON WITH CAUTION.
M IRON: Existing conditions may induce a deficiency. Watch carefully and if required, follow label
M instructions. Normally a problem in high pH or cold wet soils, so treat accordingly.
E PLEASE NOTE THAT THE PREVIOUS COMMENTS WHERE APPLICABLE, APPLY TO THE ENTIRE REPORT. THANK YOU.
N
T
S

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S&S Seeds Inc

PO Box 1275
Carpinteria, CA 93014-1275 - USA
phone: 805/684-0436
fax: 805/684-2798

INVOICE

Date: 06-May-19
Invc #: OP-66118-19
Acct #: MiscCA
Ship Acct#:

Page 1

SOLD TO: Miscellaneous - CA
., CA

SHIPPED TO: *** DROP SHIP ***
Cal Poly * Cristina Lazcano
Natural Res. Mgt-Env'tl Sci.
One Grand Avenue
San Luis Obispo, CA 93407
(805) 534-4174

Sale #	OP-66118-19	Ordered:	06-May-19	Terms:	Prepaid
Sold By:	Web	Shipped:	06-May-19	Due:	07-May-19
Cust PO #:	Lazcano Larkin	Via:	UPS	FOB:	Point of Origin
DESCRIPTION LOT CODE		QUANTITY		NET PRICE	EXTENSION Taxes

A finance charge of 1.5% per month will be charged for accounts not paid within terms.

1	Eriogonum fasciculatum fasciculatum P3310	SHIP	1.000 lbs	\$10.00000 /lb	\$10.00
2	Penstemon spectabilis N5133	SHIP	1.000 lbs	\$120.00000 /lb	\$120.00
3	Eschscholzia californica Q3483	SHIP	1.000 lbs	\$36.00000 /lb	\$36.00
4	Stipa pulchra M8717	SHIP	1.000 lbs	\$54.00000 /lb	\$54.00
5	Freight	SHIP	0.000	\$29.95 /	\$29.95

Total Lines: \$249.95
Taxes: \$15.96

Unmixed Seed * Prepaid: Credit Card
Bill: Maria Cristina Lazcano Larkin
837 Murray Ave, Apt C * San Luis Obispo CA 93405
Email: lazcano@calpoly.edu

Invoice Total: \$265.91

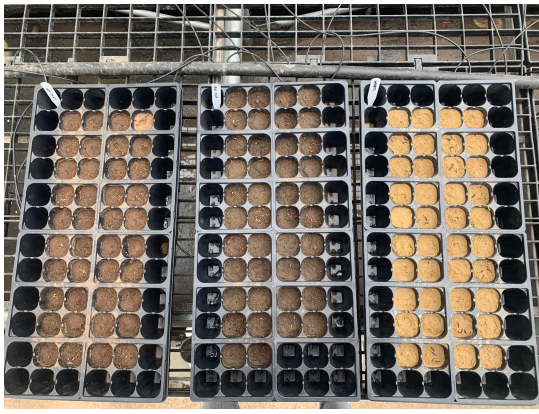
PAID

SALE
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06/06/19
ANS: 777 WATH
Trans ID: 469126369390384
0934:59
APPR CODE: 07177D
VISA
*****4457
Manual CP
/
AMOUNT \$265.91
APPROVED
THANK YOU
CUSTOMER COPY

S&S Seeds Inc
6155 Carpinteria Ave
Carpinteria, CA 93013
805-684-0436
543684555391931

Review Comments

1. General note: The 'final' audience will likely include members of the public, whom may not be as well versed as Dr. KT, or Jacobs' staff. In the main report, it will help to have some "why" clarification statements. For example, the ES states that Grimes soil needs to be amended..., but a couple short statements on how or why will help. This report will likely supplement data in an Environmental Impact Statement, which the target audience is the general public/middle-school reading level. Don't over-do it, but some short statements on "why does it matter parameter X is higher/lower in the backfill soil option" would help.
2. Please insert an explanation of the background and reason for contracting with Cal Poly for this work. An example of the language might read, "The National Aeronautics and Space Administration (NASA) is currently undertaking ongoing environmental clean-up activities on areas of land they control at the Santa Susana Field Laboratory (SSFL) in Ventura County, California. These clean-up activities include the removal of a various chemical contaminants that remain in the soil from past operations at the SSFL. the purpose of this report is to...."
3. use "backfill soil identified as suitable for an AOC-based soil remediation."
4. Is there any data available for other soils typical in Southern California coastal mountains that would allow a comparative assessment of the SSFL samples?
5. next paragraph states the germination study is complete, but this paragraph is still written in the future tense.
6. Final report, would be good to have a comparison graph in the main body of the A&L data. Could be redametary, no need to regurgitate all the info, but visually show the delta in 1 easy-to-digest graph. At least the OM and N-P-K, as these general nutrients associated with fertilizer as understood by a wide audience.



(a)



(b)



(c)



(d)



(e)



(f)



(g)



(h)

Figure 7: Germination experiment showing (a) Experimental plot setup, (b) Purple needle grass growing in Skyline soil, (c) Purple needle grass growing in Skyline soil, (d) CA poppy growing in AP-STP soil, (e) Purple needle grass growing in AP-STP soil, (f) Purple needle grass growing in AP-STP soil, (g) Purple needle grass growing in Grimes Canyon soil, and (h) Purple needle grass growing in Grimes Canyon soil.