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SUBJECT: REVIEW OF EQUIPMENT USED TO SAMPLE SOIL FOR DETERMINATION OF BULK DENSITY

I. SUMMARY

This review was undertaken to compare the handling and accuracy of the modified Madera, Eijkelkamp, and Drive Cylinder soil samplers and to select the most effective one for determining soil bulk density. The Environmental Monitoring Branch's (EMB's) Groundwater Program concluded that the Eijkelkamp soil sampler was the most effective at collecting a complete, undisturbed soil sample required for bulk density determination. EMB will update the current bulk density standard operating procedure (SOP) to reflect the preferred use and soil core collection procedure of the Eijkelkamp sampler.

II. BACKGROUND

During a previous study, EMB staff observed discrepancies in soil sampling data that were later associated with potential design issues with the modified Madera sampler. The modified Madera sampler is the equipment specified for use in EMB's current SOP FSSO001.00 for bulk density determination (Garretson, 1999). In addition to the modified Madera sampler, EMB staff also has the option to use the Eijkelkamp and the Drive Cylinder samplers to obtain soil samples for bulk density determination. The different sampler designs require unique methods to be used to obtain complete, undisturbed soil samples required for bulk density determination.

III. MATERIALS / METHODS

For this review, which was conducted in 2012, we evaluated the functionality of the three soil samplers in a coarse-textured soil in Fresno County. Each sampler was used to sample 3 cores of

soil at 6-inch increments to a depth of 24 inches. The Eijkelkamp and Madera samplers used a metal sleeve forced into the ground at each incremental depth to enclose the soil sample prior to its extraction. The Drive Cylinder sampler used a 1-meter long transparent plastic sampling tube encased in a metal sleeve that was forced into the ground to enclose the full soil core prior to extraction. The soil core was later removed from the plastic sleeve and divided into the 6-inch incremental soil samples. Bulk density for the collected soil samples was determined according to SOP FSSO001.00 (Garretson, 1999).

IV. RESULTS

The bulk density of the soil samples collected with the Eijkelkamp and modified Madera equipment were similar except for Madera sample MR3 12" (Table 1). This sample was compromised in the field and shows a lower than expected bulk density.

Table 1. Bulk density of soil samples collected by the modified Madera, Eijkelkamp and Drive Cylinder samplers in 2012.

Sample #	Bulk Density
Madera	
MR1 6"	1.710
MR1 12"	1.648
MR1 18"	1.657
MR1 24"	1.726
MR2 6"	1.709
MR2 12"	1.705
MR2 18"	1.669
MR2 24"	1.724
MR3 6"	1.678
MR3 12"	1.429
MR3 18"	1.721
MR3 24"	1.748

Sample #	Bulk Density
Eijkelkamp	
AR1 6"	1.885
AR1 12"	1.699
AR1 18"	1.780
AR1 24"	1.785
AR2 6"	1.700
AR2 12"	1.697
AR2 18"	1.713
AR2 24"	1.767
AR3 6"	1.813
AR3 12"	1.690
AR3 18"	1.596
AR3 24"	1.809

Sample #	Bulk Density
Drive Cylinder	
FR1 6"	1.329
FR1 12"	1.499
FR1 18"	1.466
FR1 24"	1.437
FR2 6"	1.395
FR2 12"	1.482
FR2 18"	1.384
FR2 24"	1.437
FR3 6"	1.474
FR3 12"	1.398
FR3 18"	1.419
FR3 24"	1.329

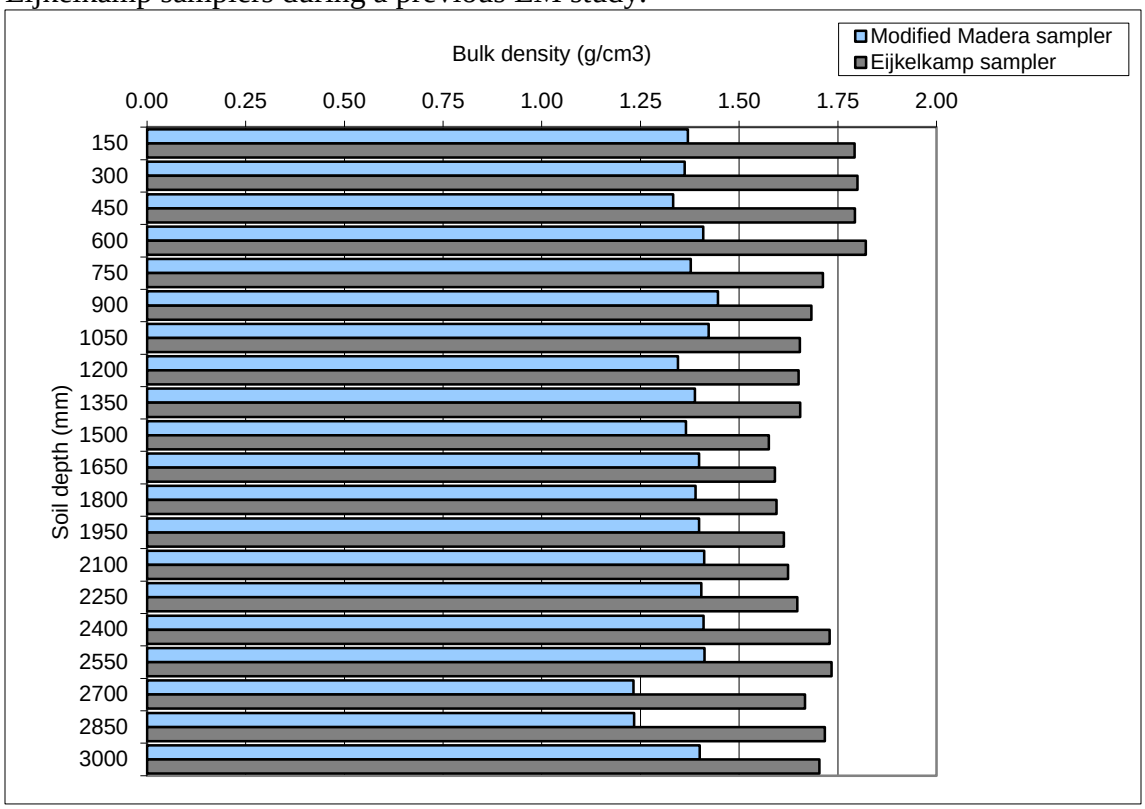
The bulk density of the soil samples collected with the Drive Cylinder sampler were consistently lower than those collected with the Eijkelkamp and modified Madera samplers and were generally lower than what would be expected from a coarse-textured soil. The low bulk density values associated with the Drive Cylinder sampler were due to difficulties related to removing and maintaining the integrity of a precise volume of soil for each incremental depth from the 1-meter long plastic sampling tube.

V. DISCUSSION

Modified Madera Sampler

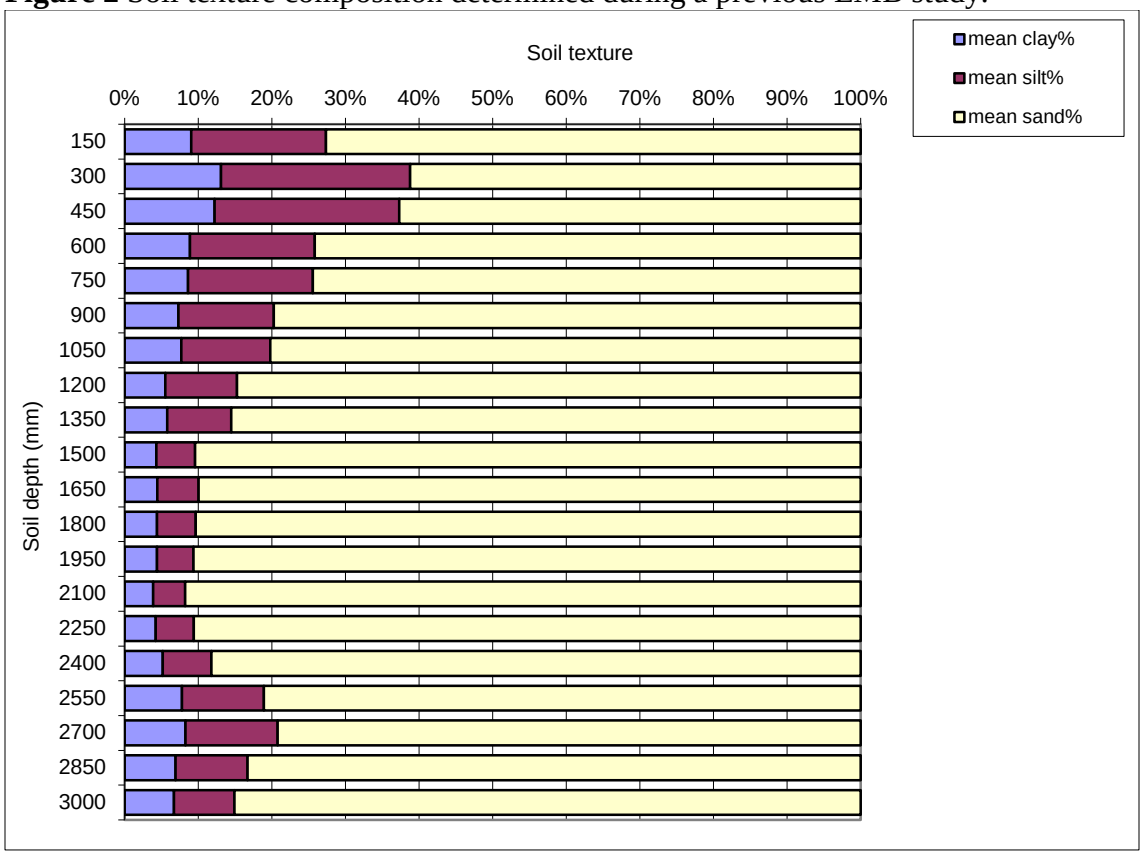
Soil bulk density data from a previous EMB study using the modified Madera sampler indicated that soil sample collection was problematic. Subsequent bulk density measurements taken from the original sampling location using the Eijkelkamp sampler revealed that soil bulk density from cores collected by the modified Madera sampler were underestimated (Figure 1). The likely cause of this underestimation was incomplete filling of the modified Madera sampling cylinder with soil during sampling.

Figure 1. Soil bulk density determined from sample collections by the modified Madera and Eijkelkamp samplers during a previous EM study.



A textural analysis of the soil in this same EMB study (Figure 2) indicated a relationship between soil texture and bulk density from samples collected with the Eijkelkamp sampler with higher clay and silt content [Figure 2] equating to higher bulk density [Figure 1]. No such relationship was evident with bulk density data determined from samples collected with the modified Madera sampler.

Figure 2 Soil texture composition determined during a previous EMB study.



The modified Madera sampler's design requires that the cylinder be completely filled with soil during sampling. This would normally be determined when resistance to its insertion into the ground is encountered as the top of the soil sample reaches the upper end of the closed sample cylinder. Because the upper end of the sampling cylinder is closed, the operator cannot accurately determine whether the cylinder is properly filled. As was observed in the previous EMB study, bulk density was underestimated and it was assumed to be due to incomplete filling of the sampling cylinder. Although not observed in this current study, bulk density could be overestimated if the sample is compacted due to excessive force during insertion of the sampling cylinder into the ground. The similarity in bulk density values between soil collected by the modified Madera and the Eijkelkamp samplers (Table 1) was most likely attributable to the

careful sampling technique used by the operator during this study. Thus, EMB's modified Madera sampler requires precise use of force during insertion into the ground and the tolerances for this force are largely unknown and are certainly dependent on the soil type and operator technique.

Advantages:
- The coupling union on the sampler is compatible with EMB's bucket auger extensions which allows for extended sampling depths without specialized equipment.
- An experienced, careful operator can obtain acceptable results.

Disadvantages:
- The sampling cylinder is not open-ended and prevents the operator from inspecting the upper end of the soil sample prior to its extraction from the sampling cylinder.
- The design increases the potential for over- or under-filling the cylinder which would result in an over- or underestimation of soil bulk density.
- The custom design and manufacture would make it difficult to replace if lost or damaged.
- The accuracy and predictability of the results is highly dependent on the operator's skills and the soil type and conditions.

Drive Cylinder Sampler
The Drive Cylinder sampler has an open-ended sample collection cylinder. This allows the soil sample to be inspected after its extraction from the ground. The Drive Cylinder sampler allows for a single, contiguous volume of soil to be collected to the full sampling depth. This single, contiguous core would likely provide a more representative assessment of overall soil bulk density of the full coring depth compared to the modified Madera and Eijkelkamp samplers. These latter two devices sample soil in noncontiguous increments relying on representative soil cores to characterize the full coring depth. However, in this current study difficulties were encountered with removing the soil sample from the Drive Cylinder collection tube and accurately dividing the sample into 6-inch-depth increments. Soil cohesion was poor and maintaining the integrity of the 6-inch-depth soil sections during their extraction from the sampling tube was not possible. Consequently, errors in measuring soil volume of the Drive Cylinder samples resulted in underestimations of soil bulk density (Table 1).

Advantages:
- It is convenient for collecting a large, single soil core.
- The soil sampling cylinder is of an open-end design reducing the potential for soil compaction during sampling.
- The soil sample can be inspected prior to its removal from the sampling cylinder.
- It is commercially available with readily available replacement parts.

Disadvantages:
- It is difficult to accurately subdivide a large, single core into smaller depth-specific cores for soil bulk density analysis, particularly if the soil has poor cohesion as what might be expected dry, coarse-textured soils.

Eijkelkamp Sampler
The Eijkelkamp soil sampler has an open-ended sampling cylinder. This provides for less risk of soil compaction during sampling and for inspection of the soil core for completeness prior to its extraction from the sampling cylinder. The sampler uses interchangeable stainless steel cylinders that can be sealed with a cap for safe containment of the soil sample during transportation and storage prior to analysis for bulk density.

Advantages:
- Easiest to use to obtain an accurate sample
- It is convenient for collecting soil samples at specific depths.
- The soil sampling cylinder is of an open-end design reducing potential for soil compaction during sampling.
- The soil sample can be inspected prior to its removal from the sampling cylinder.
- It is commercially available with readily available replacement parts.

Disadvantages:
- Extensions for deep soil coring required pipe-thread coupling unions that are not compatible with standard U.S. pipe-thread sizes. This would require ordering of sampler-specific extensions or custom fabrication of specialized parts.

VI. CONCLUSION

Based on trial use of the modified Madera, Drive Cylinder and Eijkelkamp samplers we have concluded that there is potential for substantial variation or error in bulk density determination resulting from the use of the modified Madera and Drive Cylinder Samplers.

The sampling cylinder of EMB's modified Madera sampler is not open-ended and has the potential for compaction of the soil specimen during sampling. This deficiency also obscures inspection of the sample upon its extraction from the ground potentially resulting in incomplete capture of soil sample. We recommend discontinuing use of this device to sample soil for bulk density determination.

The Drive Cylinder sampler would be suitable for sampling soil for bulk density determination in situations that call for large, contiguous volumes of soil to be analyzed as one sample. This

device was found to be problematic when subdividing a single, long, coarse-textured soil core into depth-specific segments of precise volume.

The Eijkelkamp sampler was efficient and accurate in obtaining depth-specific soil cores of precise volume, necessary for the accurate determination of soil bulk density at various depths.

We therefore conclude that EMB's SOP FSSO001.00 for bulk density determination be updated to adopt the Eijkelkamp sampler as the primary sampler for obtaining soil cores for determining bulk density with the Drive Cylinder described as an appropriate substitute under specific, limited circumstances. Due to the high potential for generating variable and inaccurate results, we conclude that the use of the modified Madera sampler for soil bulk density determination be discontinued.

VII. REFERENCE

Garretson, C. 1999. FSSO001.00 - Soil Bulk Density Determination. Available at: <http://www.cdpr.ca.gov/docs/emon/pubs/sops/fsso001.pdf>.