# APPENDIX E
# ATTACHMENT 1

## Site-Wide Soil Gas Human Health Risk Assessment

This attachment provides a comparison of American Standards Testing Method (ASTM) D4464 to method ASTM C117 and the hydrometer portion of method ASTM D422 for the determination of the particle size distribution for fine grains in soil[1]. Method ASTM D4464 was substituted for the latter methods, which had been specified in the Sampling and Analysis Plan (SAP) for the Tronox Phase B investigation. ASTM D4464 uses laser light scattering to analyze fine-grained sediments, whereas ASTM C117 and ASTM D422-hydrometer[2] use a wet sieve and hydrometer, respectively. The goal of this attachment is to establish the validity of fine particle size measurements obtained by laser light scattering. Additionally, this attachment compares the results from laser light scattering to results from the other analytical methods, focusing on the implications for vapor intrusion modeling. This comparison shows that ASTM D4464 generally measures a particle size distribution that is slightly shifted towards coarser grains as compared to the other methods, which leads to a more conservative model of vapor intrusion.

### Particle Size Distribution measured according to ASTM D442 and ASTM D4464

The particle size distributions (PSD) of soil samples from the Tronox Facility were measured according to ASTM D422-sieve[3] and ASTM D4464. Specifically, grains larger than 37 µm (No. 400 sieve) were measured according to ASTM D422 using a dry sieve and finer grains were measured according to ASTM D4464 using laser light scattering. The results were then combined to establish a PSD, which was used to determine soil type for the purpose of vapor intrusion modeling[4].

### ASTM D 4464 – Laser Light Scattering

Laser light scattering (or laser diffraction) is a relatively new method for analyzing PSD that is becoming increasingly common. According to the method, the material is

[1] This information was submitted to NDEP in draft form on March 1, 2010.
[2] The "-hydrometer" designation is used to differentiate the part of the ASTM D422 method which outlines the analysis of fine size fractions by hydrometer from the portion which outlines the analysis of coarse size fractions by sieve (ASTM D422-sieve).
[3] The use of method ASTM D422-sieve is consistent with the SAP for the Tronox Phase B investigation.
[4] For additional information, see the *Site-Specific Input Parameters for the Johnson & Ettinger Model* Memorandum re-submitted February 10, 2010.

dispersed in water or a compatible organic liquid and analyzed based on how the particles scatter a light beam (ASTM D4464-00).

The accuracy of particle size measurement by laser light scattering is periodically checked in the laboratory by the measurement of a standard material. PTS Laboratories, Inc., which performed the geotechnical analysis for this project, relies on control charting to ensure their instrument is providing accurate results. Their control protocol includes daily testing of an ASTM standard fine powder garnet with a traceable diameter. Reproducibility for the mean particle size from repeat measurements of the same sample is >99% (PTS, 1999).

Studies have confirmed that laser light scattering gives accurate and very reproducible results for fine-grain PSDs. One study measured a series of National Institute of Standards and Technology (NIST) standard materials and concluded that their instrument produced acceptable results for particle sizes between 0.33 µm and ~60 µm (McKay, 2009). Another study, which compared laser light scattering to classical particle size analysis methods, concluded that laser light scattering is a valid method for determining the PSD in soil (Eshel, 2004). The Southern California Coastal Water Research Project hosted a workshop to discuss analytical techniques used for grain size measurement with the objective of finding a consistent method. Overall, they determined that laser analysis was preferable to pipette or hydrometer analysis (PTS, 1999).

**Comparison of Laser Light Scattering to Classical Methods**

Multiple studies have attempted to quantify the comparability of results obtained by laser light scattering to results from classical methods. The classical methods of particular interest to this attachment are the use of a sieve (as in ASTM C117) and the use of a hydrometer (as in ASTM D422-hydrometer). All methods of particle size determination utilize differing physical principles and therefore contain varying sources of error (ASTM D4464-00). Because of this, the results from differing methods are not fully comparable (Eshel, 2004). However, as is explained below, the PSD measured by laser light scattering generally leads to more conservative inputs to the Johnson & Ettinger (J&E) model as compared to the other analytical methods.

ASTM C117 describes a method of washing a No. 200 sieve (also called wet sieve) to measure the percentage of fine grains[5]. A thorough comparison of the particle size

[5] According to the method, the reported result is the percentage of material finer than 75 µm (ASTM C 117-04). These data alone would not be of particular usefulness to vapor intrusion modeling, because the

measurements by laser light scattering and dry sieve was conducted by the Ashland Petroleum Company (Dishman, 1993). The conclusions from the dry sieve comparison are generally transferable to a wet sieve since these methods rely on the same physical principles for particle size measurement. This study measured the particles of cracking catalyst, which are primarily non-spherical. This non-sphericity is the main cause of the differing results between the sieve and laser light scattering methods. The laser light scattering information is typically analyzed assuming a spherical geometry, so calculated particle sizes are presented as equivalent spherical diameters [6]. In contrast, a sieve allows particles to pass through that can fit in any orientation, resulting in the assignment of a measured particle to a smaller size fraction than it actually belongs. This leads to the laser light scattering measurements giving a larger average particle diameter than the sieve when non-spherical particles are present[7] (Dishman, 1993). Therefore, a PSD measured according to laser light scattering will generally be shifted towards coarser grains compared to a PSD measured by a sieve. For the purposes of vapor intrusion modeling, this leads to the use of a more conservative soil type in the J&E model.

Fine grains can also be analyzed with the use of a hydrometer as outlined in ASTM D422-hydrometer. The study by Eshel et. al. (2004) cited above compared particle size results from laser light scattering to a pipette. A hydrometer uses the principles of settling to measure particle size, in the exact same way as the pipette method. The two techniques give similar results (Liu, 1966; Walter, 1978); therefore, conclusions about the comparability of the pipette method to laser light scattering also apply to the hydrometer method. The results of the study were that relative to laser light scattering, the pipette overestimated the fraction of clay, slightly underestimated silt, and was comparable for sand. A number of other studies have attempted to compare these methods with variable results depending on material type, but have generally shown that the pipette overestimates fines compared to laser light scattering (Eshel, 2004). This is likely because during settling, non-spherical particles will tend to travel with their maximum cross-sectional area perpendicular to the direction of motion (Krumbein, 1942). This increases drag and results in the overestimation of the percentage of fines (Matthews,

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soil type determination for the Johnson & Ettinger Model requires information on the fraction of sand, silt, and clay as defined by the USDA. The USDA defines silt as finer than 50 µm and clay as finer than 2µm. In general, wet sieves are not useful for analyzing particle fractions <50 µm (Eshel 2004).

[6] Additionally, the projected cross-sectional area of a non-spherical particle averaged over all possible orientations is larger than that of a sphere with the same volume (Jonasz, 1991). This can shift the PSD slightly towards the coarser grains. This produces a more conservative vapor intrusion model.

[7] The one exception to this general rule is disc shaped particles. In this case, the particle's actual average diameter would be less than the diameter measured by the sieve (Eshel 2004).

1991). Again, this means that for the purpose of vapor intrusion modeling, a PSD determined according to laser light scattering will generally be more conservative compared to measurement by a hydrometer.

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