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environmental management, inc.

**From:** Deni Chambers
Derrick Willis
Ted Splitter

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**To:** Shannon Harbour, P.E.
Nevada Division of Environmental Protection

**RE:** Engineering Evaluation of Slope Stability GW-11 and WC Pond Embankments
*Phase B Soil Remediation of RZ-D,* Tronox LLC, Henderson, Nevada

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**COMMENTS:**

Northgate Environmental Management, Inc. (Northgate) submits this memorandum presenting the results of Northgate's engineering evaluation of the slope stability of the GW-11 and WC Pond embankments for the *Phase B Soil Remediation of RZ-D* on behalf of Tronox LLC (see Figure 1, Site Location Map).

## Available Geotechnical Data

A significant number of laboratory data reports are available for the Site soils. Tests performed include grain size analyses, specific gravity, porosity, bulk density, hydraulic conductivity, and permeability. The grain size analyses indicate that the Site soils are primarily granular in nature and would generally be characterized as sand and gravel mixtures with traces of silt and clay. One sample of the soil was found to be fine sand and one sample was classified as silt.

Based on this information, Northgate characterized the soil strength for the embankments which were built from on-Site soils as granular soil with an internal angle of friction of 30 degrees. This strength was used in Northgate's analyses of the embankment stability.

## Stability Analyses

Two locations were selected as representative of the steeper portions of the GW-11 Pond and WC Ponds. These locations are shown on Figure 2, the Site Plan. Cross-sections were drawn through these locations and were used to model the Site surface and subsurface conditions in the slope stability analyses. STABL software was utilized for the analyses. STABL uses the PCSTABL slope stability analysis program from Purdue University. It allows calculations using Bishop's Simplified Method, as well as other methods.

Eight cases were selected for analysis. The cases are as follows:

1. GW-11 pond configuration with the top of the 10-foot excavation cut slope 40 feet from the toe of the embankment.

2. GW-11 pond configuration with the top of the 10-foot excavation cut slope 40 feet from the toe of the embankment including using a pseudo-static coefficient of 0.15g.

3. WC pond configuration with the top of the 10-foot excavation cut slope 40 feet from the toe of the embankment.

4. WC pond configuration with the top of the 10-foot excavation cut slope 40 feet from the toe of the embankment including using a pseudo-static coefficient of 0.15g.

5. GW-11 pond configuration with the top of the 15-foot excavation cut slope 35 feet from the toe of the embankment.

6. GW-11 pond configuration with the top of the 15-foot excavation cut slope 35 feet from the toe of the embankment including using a pseudo-static coefficient of 0.15g.

7. WC pond configuration with the top of the 15-foot excavation cut slope 35 feet from the toe of the embankment.

8. WC pond configuration with the top of the 15-foot excavation cut slope 35 feet from the toe of the embankment including using a pseudo-static coefficient of 0.15g.

In all the analyses Northgate assumed that the ponds were full of water. The water was modeled to reflect its weight only. The soils were assumed to be moist but not saturated. These conditions would be typical for watertight lined ponds such as the GW-11 and WC ponds.

| Pond | Height of Cut Slope, Feet | Minimum Factor of Safety Static Case | Minimum Factor of Safety Seismic Case |
|---|---|---|---|
| GW-11 | 10 | 3.04 | 1.54 |
| WC | 10 | 2.92 | 1.51 |
| GW-11 | 15 | 2.33 | 1.33 |
| WC | 15 | 2.45 | 1.37 |

The selection of acceptable factors of safety depends on the level of risk that Tronox is willing to accept and, in some cases, what the state agencies set as a minimum. The acceptable factors of safety are also selected based on the consequences of failure (loss of life, property damage, and loss of facility use). Another consideration which is applicable to these pond embankments is the confidence in the quality of construction and the associated selected strength value used in the analysis. Acceptable factors of safety for static conditions can range from 1.4 minimum to 3 or more. The values obtained in our analysis, about 2.5 to 3, are considered adequate and would be acceptable to the state agency. Acceptable factors of safety for seismic conditions are lower than static conditions and can typically range from 1.1 to 1.5. In the case of the GW-11 and WC Ponds, a slightly higher seismic factor of safety is desirable due to the unknowns such as lack of site specific strength data and lack of records documenting the construction methods and quality control.

Based on the above results, we conclude that the embankment slopes are stable under both static and seismic loading conditions. In addition, the factors of safety appear in the acceptable range for the proposed setback of 35 to 40 feet from the toe of the embankment slope to the top of the cut slope depending on the slope height. Northgate recommends that the buffer strip be designed and constructed based on these setback distances.


Theodore Splitter, P.E., 020615