Engineering Review of McPhail Associates October 26, 2010 Slope Stability Analyses of Concept C at the Crow Lane Landfill, Newburyport MA

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McPhail Associates prepared the Report "Crow Lane Landfill Corrective Action Design; Newburyport, Massachusetts, Slope Stability Analysis Performed for Concept C Proposed Berm" dated October 26, 2010. The report was prepared in response to a meeting held at MassDEP's, Northeastern Regional Offices (NERO) on October 14, 2010 and the summary email provided by MassDEP on Tuesday, October 19, 2010. Shaw Environmental Inc. (Shaw) has reviewed the report and has prepared this summary of findings. In general, the report addresses the issues raised at the meeting. In particular, the report provided a rationale for material strength selection used in the analyses. However; the report concludes that the Factor of Safety against slope failure may be greater than we believe can be reasonably justified. This increase in FS is based largely on the incorporation of 3D effects.

Based upon the stability analyses provided, there is some risk to global landfill stability. We believe that the computed existing and proposed Factor of Safety (FS) against failure is most likely between 1.2 and 1.3. While the near future risk of constructing the Concept C berm is similar to existing conditions, the most critical time for potential failure existed several years ago when the existing berm was constructed. In addition, the FS for the landfill should improve with time due to consolidation of the underlying clay layer, and gradual lowering of the leachate mound in the waste. Considering the marginal FS, the stability monitoring program is appropriate and it should be strictly adhered to during and immediately after construction of the new berm slope. This is also true for the organics area in the berm. Should there be a worsening of the groundwater conditions in and under the landfill, slope instability would rapidly become a significant concern, however the mechanism for such a change is currently not identifiable.

Shaw's comments below identify some differences in opinion we have with McPhail's report that identify a possibly lower FS exists that they predict. Given the urgent need to complete closure of the landfill and achieve the environmental benefits associated with closure, and the fact that stability conditions should improve with time, Shaw concurs that construction should proceed even though there is a lower than ideal FS for the landfill's stability.

<u>Soil Properties for the Slope Stability Analysis</u>

McPhail Assoc. revised its stability analysis to include factors which Shaw thought were important. These factors included an explanation of soil property selection including details on SHANSEP correlations, issues with the testing data, a discussion of the water table profile, and a discussion of 3D effects if they are considered in the analyses. These changes reduced the existing FS from previous analyses, except for the 3-D effects, but in our opinion provide a clearer definition of potential stability issues and a more accurate stability assessment, which is necessary for everyone to fully understand the site conditions and the need to address potential contingencies.

A new SHANSEP analysis was performed for the Newbury Boston Blue Clay (NBBC) rather than just the Boston Blue Clay (BBC) in order to calculate the clay's strength values. This resulted in a reduced FS by 0.1 when compared with the BBC FS. The SHANSEP equation used for the NBBC was derived by Poirier and based upon its similarity to BBC, whereas the FWHA report provided a SHANSEP equation for NBBC that yields even lower clay strengths under the landfill that would reduce the FS further. McPhail's use of Poirier's SHANSEP equation, rather than the FWHA equation, should not be considered as the lower bound for the clay strength, and instead as the appropriate strength to use in the stability calculations. Therefore Shaw considers the starting FS, prior to adjustment upward to be 1.1 for the most critical location at Cross Section AA based upon the NBBC values.

Another revision to the analysis is the change in water table height. This also appears to have reduced the FS by 0.1 from the previous stability analysis. The condition is realistic under the berm, but to assume that it des not continue to some higher elevation behind the berm is not conservative. A higher water table behind the berm would tend to further reduce the FS.

McPhail modified the solid waste strength slightly to include cohesion. This is reasonable. We also recognize that the overall waste strength used is relatively conservative, but is appropriate for this analysis.

McPhail did not use one of the four consolidation tests due to sample disturbance. This was appropriate since that data could have resulted in an underestimate of the over consolidation ratio (OCR) and undrained shear strength (S_u) of the deeper clay (Layer C). The use of that data would have resulted in an underestimate to the FS.

3-Dimensional Effects

New to the analysis was consideration of 3-D effects. Based upon a formula contained in a paper by Azzouz, there is a 30% gain in the FS due to edge effects. We agree that there are benefits to the FS by accounting for edge support; however the gain in FS exceeds the FS for the adjacent cross sections which are providing the additional support for stability. Considering the limitations of the adjacent areas to support Cross Section AA, a more appropriate assessment would average the FS of all the sections and used the average for Section AA. The average FS for Sections AA, BB, CC, and DD is 1.2, or 9% higher than for just Section AA, so this would be the maximum adjustment upward. The Azzouz paper indicated that the minimum FS increase is 7% and the maximum is 30%. Based upon the low FS for the other cross sections which are still a greater distance each side of Section AA than that assumed in the McPhail's computation, 9% would seem to be a more logical increase since stability FS is low at the edges.

The method used to account for 3-D effects does not consider the convex curvature shape of the landfill. Since average length of buttressing material is longer than the average length of the driving area, this could be viewed as a benefit where the sum of the driving loads relative to the sum of the resisting loads is reduced when compared to the 2-D cross sections. However, this aspect could also reduce the benefits of end edge effects.

Parametric Study and Wedge Failure Analysis

The Parametric Study examines uniform clay strengths since it is quite possible that full consolidation has not been achieved under the landfill yet. Where the clay strength is 900 psf, the FS is 1.0. The average strength of the lowest clay layer is 922 psf, so that if consolidation has not progressed as much as has been assumed, the FS should still be better than 1.0.

Since there appeared to be a layer of lower clay strength at Layer B, a wedge failure analysis was also performed using a clay strength of 900 psf. This resulted in an FS of 1.0. Since the average clay strength for Layer B is 860 psf, this implies an FS of less than 1.0 is possible. In this case, the stability calculations must rely on the unknown degree of consolidation in the clay to assure stability.

Monitoring Program

McPhail's Preliminary Slope Monitoring Plan is adequate. We suggest the monitoring points on the top of the landfill be 50 feet within the projected radius of failure, incase the radius is smaller than modeled. We also suggest that monitoring occur daily in the vicinity of the active construction.

Shaw's Conclusions

McPhail has projected that the overall FS ranges from 1.4 to 1.6. This exceeds the 1.3 minimum requirement established by MassDEP. There is reason to believe that the FS could be less based upon the discussions above. While the existing and proposed stability conditions maybe less than desirable; conditions should improve with time due to the increase in clay strength. In the unlikely event that a sudden slope failure occurs, there are no immediate human health hazards except potentially to the workers in the failure zone. At all times the workers should remain vigilant to any unusual noises or slope and toe of slope cracks or surface deformations that could indicate initiation of a failure. Where construction is occurring, daily survey monitoring should be considered as good practice. Due to potential landfill gas releases associated with a failure, the contractor should be prepared to immediately acquire tarps to cover and contain such emissions. A complete final slope monitoring plan is still required. A final design for the north buttress is still required.