Appendix E

Liner Stability in Grass Swales

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On-Site Biofilter Swales

The following is a description of the analysis results for the small biofiltration swales on the individual sites. The drainage design assumptions were the 25 yr storm for a typical 2 acre industrial site, with C soils (compacted). The resulting CN was 91. The peak flow from each 2 acre site was estimated to be about 16 cfs. For a 2 yr storm, the peak flow would be about 60% of this flow value.

The grass-lined swales are 10 ft wide at the bottom with 3H 1V side slopes. Assuming sheet flow conditions, the Manning's n is about 0.24. The on-site slopes are expected to range from 1 to 6.5%. The following summarize the results for several slope categories in this range for the 25-year storm:

1% slopes: 5.4 inches deep flow, max shear stress 0.28 lb/ft^2 and 3.1 ft/sec velocity
3% slopes: 3.6 inches deep flow, max shear stress 0.56 lb/ft^2 and 4.8 ft/sec velocity
5% slopes: 3.2 inches deep flow, max shear stress 0.84 lb/ft^2 and 5.5 ft/sec velocity
6.5% slopes: 2.8 inches deep flow, max shear stress 0.93 lb/ft^2 and 6.4 ft/sec velocity

A seed bed of silt loam soil has a maximum permissible shear stress of about 0.05 lb/ft^2, which would be greatly exceeded for all of these conditions (and also for the 2 year storm). Therefore, a simple erosion control mat is needed in the channel to protect the seeds before they become stabilized grass, or sod can be used. As an example, a North America Green S75 mat would be suitable (permissible shear stress of 1.55 lb/ft^2). The S75 has an expected life of about 12 months, allowing the grass (assuming Bermudagrass) to become well established. When established, the Bermudagrass can withstand a maximum velocity of about 6 ft/sec in sandy silt soil and up to 5% slopes. Therefore, if the slopes are greater than about 5%, the velocities may exceed these values, and rock check dams should be used. They are not needed (except at the end of the swale to act as a level spreader, to be described below), for lesser slopes.

The check dams should be a maximum of 2 ft high in the 3 ft deep swales (leaving at least 1 ft overflow in the center of the dam). The check dams should be spaced so that the top of the down gradient dam is at the same elevation as the toe of the upgradient dam. In other words, if in a swale of 5% slope and the dams are 2 ft tall, they need to be spaced about every 40 ft. If in a swale having 6.5% slopes, 2 foot check dams need to be spaced every 30 ft. If shorter, they need to be closer together. According to the *Alabama Erosion Control Manual*, the riprap in the check dams should be AL DOT #1 riprap. This has a d50 of 50 lbs (about 9.6 inches in diameter), a d100 of 100 lb (about 13.2 in diameter) and a d10 of 10 lb. The Manning's n for channels lined with this stone is dependent on the channel slope: if 1%, n = 0.033; if 3%; n = 0.039; if 5%, n = 0.042; and if 6.5%, n = 0.044. The flow through these check dams using this stone in these swales (assuming 2 ft height, 8 ft base) is about 5 ft^3/sec. This would leave about 11 ft^3/sec to overflow the check dam during the 25 year event. There should be adequate capacity for this overflow in these channels if at least 1 ft overflow is allowed, even if partially clogged.

The level spreader at the end of the on-site biofilter channels as they discharge the water at the edge of the site boundary would be one of these check dams, followed by a rock pad. This pad should taper out and be about 50 ft long and be about 50 ft wide at the widest. The rock should be #1 AL DOT riprap (about 9.6 inches in diameter) and the pad should be about 12 inches thick, according to the *Alabama Erosion Control Manual*.

Large Drainage Swales

The estimated flow depth in the large drainage swales during the 25-year storm is expected to be 1 to 2 ft, with velocities of several ft/sec. The average slope between contours 823 and 850 is about 2.7%, so the maximum shear stress may be about 1.5 to 3 lb/ft^2. Since the existing grass cover won't be disturbed, this should be acceptable. Any areas of disturbance will have to be stabilized as soon as possible. It is likely that NAG P300 reinforcing mat may be needed in disturbed areas, as sod may not be adequate. With mature vegetation (as in the natural condition), some vegetation blow out during rare events may occur, but they should be minimal. Since there is an elevation drop of about 27 feet in this reach from the upper location where site runoff enters the pond, up to 10 check dams 3 ft high would theoretically be needed. However, this is not reasonable, as we want the check dams for alkalinity increases, and not to slow the water. It is recommend that about 5 check dams be used, located about every 5 ft contour difference, at about the 830, 825, 840, 845, and 850 ft contours. These would be 100 to 150 feet apart. The face of the check dams need to be 4H to 1V, or flatter, and have at least 1 ft (preferably more for these channels) overflow. They need to extend completely across the channels, dipping down in the center for the maximum overflow. The drainage area is way too large for conventional check dams, so the stone should probably be larger than the AL DOT #1 riprap typically used. A d50 of about 12 to 18 inches (AL DOT #2 or 3 riprap) may be more suitable, if available. The stone should be limestone to provide the alkalinity increase in the flowing water.