Geosynthetic barriers to prevent poisoning of waterfowl

Barrières géosynthétiques pour éviter l'empoisonnement d'oiseaux palmipèdes

Karen S. Henry & Jeffrey A. Stark – *US Army Cold Regions Research and Engineering Laboratory, Hanover, N.H., USA*

SYNOPSIS: The feasibility of using geosynthetics to cover contaminated pond sediments and prevent waterfowl access to them was studied. Geosynthetic barriers were placed in ponds, the water above them was vigorously stirred, and the barriers were loaded by dropping a mass onto them to determine their ability to retain sediment below them and withstand damage. The barriers reduced the amount of sediment resuspended during stir and loading tests by at least 30%, and sustained no damage. Thus, they can probably prevent waterfowl from accessing and eating toxic particles contained in the sediment below them.

1.0 INTRODUCTION

Shallow, permanent ponds in a salt marsh, Eagle River Flats (ERF), located on Ft. Richardson, Anchorage, Alaska, are extensively contaminated with white phosphorus (WP) particles (Fig. 1). It is an artillery range used by the U.S. Army, and the WP was deposited by smoke-producing incendiary rounds. Ingestion of the white phosphorus causes approximately 1,000 to 2,000 waterfowl deaths annually; species that circulate sediment through their bills, retaining food-sized particles for ingestion (e.g., dabbling ducks), are most susceptible. This area is now used only when there is an ice cover, and only for artillery rounds that do not contain WP.

Remediation of ERF is being planned, and this report describes the feasibility study of one technique, placing geosynthetic barriers on pond bottoms to prevent waterfowl from eating WP. Geosynthetics are candidates for barriers because waterfowl cannot put their bills through them and they resist damage caused by large mammal traffic.

2.0 BACKGROUND

2.1 Nature and extent of contamination

Eagle River Flats contains 200 to 300 ponds that are used by waterfowl; slightly less than half of them are contaminated with significant amounts of WP (Racine and Walsh 1994). The WP particles found range in size from less than 0.1 to 3.5 mm in diameter (Racine et al. 1993b). The average diameter of food particles ingested by dabbling ducks is about 2 mm—a WP particle of this size is lethal for a small duck (Racine et al. 1993a). For this study, it was assumed that particles that are 0.1 mm in diameter and larger pose a risk to dabbling species. Lawson and Brockett (1993) determined that particles of this size make up 3% or less (by mass) of ERF pond sediment. Thus, a very small portion of the pond sediment is in the size range selected by feeding waterfowl.

White phosphorus particles in ERF pond sediments are not likely to become suspended in overlying water because of minor disturbances such as waterfowl swimming (Racine et al. 1993a, Henry et al. 1995). However, vigorous disturbances of water above the sediment were not studied. Pochop et al. (1994) found that an 8-cm-thick bentonite–gravel layer overlying WP-contaminated sediment prevented ducks from becoming poisoned (the bentonite–gravel layer is thicker than the length of the ducks' bills). Thus, keeping them from inserting their bills into contaminated sediment will prevent poisoning. However, the barrier used should also prevent underlying contaminated soil from intermixing with the sediment above it in the presence of "strong" water currents or when large mammals walk through the ponds (e.g., the moose that frequent the ERF).

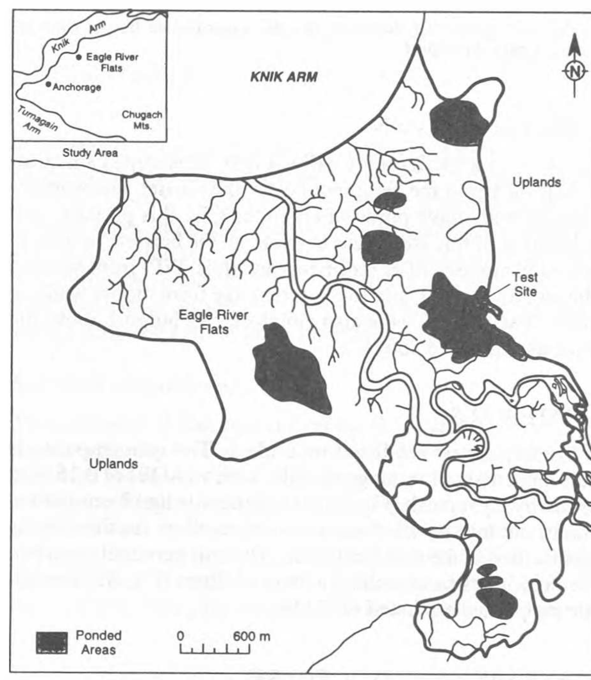

Figure 1. Location of Eagle River Flats and the test site.

2.2 Geosynthetic barriers in Eagle River Flats

In initial tests of geosynthetic barriers in ERF, portions of geotextiles placed on pond bottoms in ERF bulged above the water surface within a month of placement. Further study revealed that gas bubbles, limited by the size of the geotextile pores, could not develop enough buoyancy to overcome the downward force of gas–water interfacial tension exerted around the circumference of the pore (Henry et al. 1995). The gas coalesced into a large bubble and "floated" a portion of the material to the surface. It was estimated that a minimum 3.4-mm pore radius is needed to avoid this problem, which led to the development of a geocomposite barrier containing larger holes to permit gas to escape (Henry 1994).

Table 1. Barriers tested for sediment retention in ERF.

Test circle	Barrier
A	Geocomposite covered with 8 cm bentonite
B	Coir geotextile
C	Geocomposite
D	Geocomposite covered with 10 cm gravel
Control	No treatment

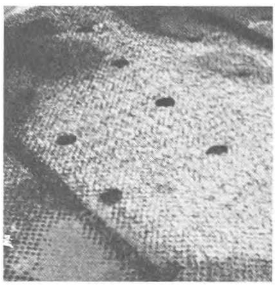

Figure 2. Geocomposite used in the field study.

[1]Property of a geotextile that indicates the approximate largest particle that would pass through it.

2.3 Objective of the study

If the pores of a barrier are small enough, waterfowl cannot insert their bills into the sediment below the barrier. Geosynthetics in this study have pores small enough for this purpose, and the objective of this study was to evaluate the barriers' ability to prevent the movement of sediment (and thus, WP) from beneath the barrier to above it, and to resist damage from moose walking on them. The barriers were also monitored for bulging above the surface as described above.

3.0 MATERIALS

The barriers tested are listed in Table 1. The geocomposite is needle-punched polyester geotextile, with an AOS[1] of 0.15 mm, overlain by a geomesh (Fig. 2). The geotextile had 8-cm-diameter holes cut into it, 0.305 m on center, to allow for the venting of gas formed in the pond sediment. The coir geotextile was two woven coir mats sandwiching a layer of fibers (Fig. 3). Geosynthetic properties are listed in Table 2.

4.0 TEST AREA AND PROCEDURE

A brief summary of experimental procedures is described herein; Henry (1995) contains complete details. In July of 1994, five 2.4-m-diameter test circles were constructed in a pond and surrounded by lateral barricades of clear plastic to contain any sediment suspended during testing. Figure 4 shows the test area with the five test circles (Fig. 1 shows location). The average pond depth during testing was 24 cm.

Two means were used to induce sediment to move through the barriers from below—stirring the water above the barrier and dropping a mass onto it (to simulate a walking moose). Responses measured were 1) total amount of sediment resuspended, and 2) percentage of the resuspended sediment particles that were larger than 0.15-mm diameter and 0.25-mm diameter. In addition, damage to the barrier caused by the loading was noted, and the barriers were observed for bulges above the water surface.

For the stirring tests, the water was vigorously stirred with a wooden paddle within 1 cm of the pond bottom for ten 0.75-m-diameter revolutions (Fig. 5). During stirring, a 250- to 400-mL water sample was taken, and then later analyzed for total suspended solids (TSS). Plates (26 cm diameter) were placed around the edges of the 'stirring circles' prior to the stirring tests, and the sediment was later collected from them and analyzed for percentages retained on the 0.25-mm and 0.15-mm sieves. Three stirring tests were conducted for each test circle.

Table 2. Physical and mechanical properties of geotextile and geomesh used in the geocomposite and the coir geotextile as provided by the manufacturers.

Product	Thickness (mm)	Mass per unit area (g/m²)	Tensile strength (kN/m)[1]
Geotextile	N.A.	542	MD: 36.0 XD: 28.8
Geomesh	16.8	380	MD: 2.51 XD: 1.42
Coir geotextile	12.7	740	MD: 32 XD: 22

notes: N.A. = not available
MD = machine direction, XD = cross direction
[1] ASTM D4595 (1994) Tensile properties of geotextiles by the wide width strip method, ASTM, W. Conshocken, PA.

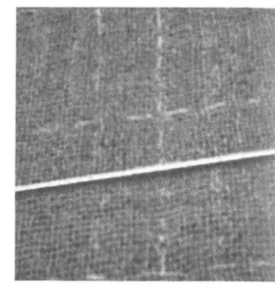

Figure 3. Coir geotextile used in the field study.

The barriers were loaded by dropping a cylindrical, 2.5-cm-diameter, 22.7-kg mass from a height of 10 cm above the pond bottom five times. The size and mass were selected to give an equivalent contact pressure of the a moose standing on three legs. The test was calibrated by finding fresh moose tracks and experimenting with drop heights to achieve the same depth of track. This procedure was accompanied by the same observations, sampling procedures and analyses as for the stirring test.

Prior to barrier placement, grab sediment samples were taken from the top 10 cm of sediment in each of the test circles, and the percentages (by mass) of sediment retained on 0.25- and 0.15-mm-apertures sieves were established. In addition, the percentages (by mass) of sediment retained on 0.25- and 0.15-mm-aperture sieves for sediment resuspended by stirring were determined.

5.0 RESULTS

5.1 TSS measurements from stirring and loading tests

Figure 6 shows the total suspended solids for water sampled during stir and loading tests. The reduction in TSS was about 30% for each barrier in the stir test, and 50% for each barrier in the loading test, except test circle A, which had more TSS for both procedures because bentonite is easily resuspended.

5.2 Large particles

Table 3 summarizes the percentages of particles that had diame-

Figure 4. Test area showing the five test circles.

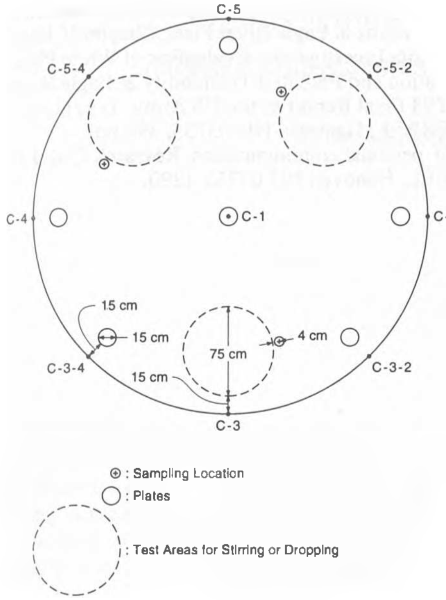

Figure 5. Locations of plates for measuring sediment depth, dimensions of stirring tests and locations of loading tests within each circle. Circle C is used as an example.

ters larger than 0.15 and 0.25 mm in the collected sediment. Only trace amounts of sediment were found on the plates after the tests, with the exception of the control section in the stir test, in which a 4.4-mm-thick layer had accumulated. Thus, we have less confidence about the values for samples listed in Table 3 than the others. Nonetheless, the measurements do not indicate differences from the percentages retained on the 0.15- and 0.25-mm sieves for the grab samples collected before testing.

5.3 Formation of bulges in geotextile and damage caused by dropping the mass onto the barriers

We observed no problems with gas formation pushing these products to the surface as of May 1996, almost two years after placement (Walsh, personal communication, 1996). There was no noticeable damage to the barriers as a result of the loading tests.

Table 3. Summary of percentage of sediment (by weight) retained on the 0.25- and 0.15-mm mesh sieves for pond sediment collected before, during and after stir and loading tests of barriers in ERF.

Sample	Treatment circle	% retained, 0.25-mm sieve (Std. dev.)	% retained 0.15-mm sieve (Std. dev.)
Grab sample before barrier placement	A, B, C and D (20 samples)	0.7 (0.5)	1.2 (0.5)
Stir tests before barrier placement	A, B, C and D (12 samples)	0.3 (0.2)	1.2 (0.8)
Stir test plates (six plates)	A	0.2	1.0
	B	2.0	2.0
	C	0.3	0.7
	D	1.9	2.7
	Control	0.2	0.9
Loading test plates (six plates)	A	0.2	0.5
	B	0.3	1.9
	C	0.1	0.5
	D	0.3	1.5
	Control	0.1	0.6

6.0 DISCUSSION

6.1 Overview

It is already assumed that the barriers will stop waterfowl from dabbling in the sediment below them. In light of this, the negligible amounts of sediment on the plates after the control tests show that the amount of sediment resuspended by vigorous stirring and loading was so small that the chance of resuspending any significant quantity of WP particles is also negligible. Thus, the second most important function of a barrier is to prevent soil intermixing because of large mammal traffic.

6.2 Grain size analyses

Measurement of soil retained on the 0.15- and 0.25-mm sieves agrees with the findings of Lawson and Brockett (1993). Furthermore, based on these tests, there is no reason to think that these percentages are significantly different when pond sediment becomes resuspended and moves through the barrier.

The gravel used to cover the barrier in test circle D contained fines. These fines were suspended during testing instead of the fine soil from beneath the geocomposite. Thus, it is likely that

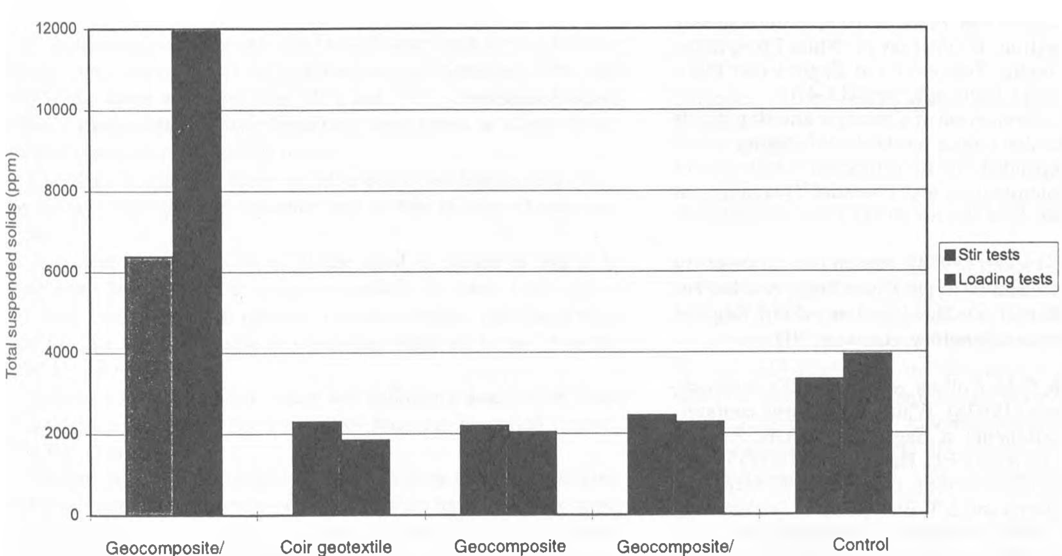

Figure 6. Total suspended solids measured in stirring and loading tests of geosynthetic barriers in Eagle River Flats, Alaska.

the geocomposite covered with gravel was even more effective at reducing the amount of sediment from below it being resuspended than indicated.

6.3 Survivability of the barriers

Since no damage to the barriers was incurred when the mass was dropped onto them, it is likely that they can survive a moose walking over them and continue to function as intended. However, it would be wise to conduct similar tests on products that have been in place for a year or more. Consideration should also be given to potential damage by artillery impacts during thin ice cover.

6.4 Formation of bulges in the geocomposite.

Even though there were no observed problems with gas formation pushing these products to the surface as of May 1996, the gas production of the sediment in the pond tested is unknown. Thus, this performance should be verified.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of field tests conducted in Eagle River Flats in the summer of 1994, the following conclusions and recommendations are made:

1. It is highly likely that barriers described herein could stop waterfowl from eating the sediment below them and thus prevent mortality. In addition, the barriers reduced the amount of sediment below them from being resuspended during stir and loading tests by 30% or more. Thus, they will be effective at keeping WP below them. The geocomposite barrier covered with 10 cm of gravel was probably more effective than indicated because the gravel itself contained significant amounts of fines.

2. The barriers tested were not damaged by loading that simulated a moose walking on them. However, for long-term use, the effects of aging on performance should be determined. Potential damage by artillery impact during thin ice cover might be tested as well.

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