SOX EROSION

ENVIRONMENTAL BENEFITS VERSUS GEOTUBES

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December 5, 2022

1 INTRODUCTION

We have prepared this alternatives analysis document to assess the environmental benefits that may result from the use of installation of the SOX Erosion DredgeSOX/ShoreSOX®[1] Erosion Control product. The product, which is used as a shoreline stabilization measure (Exhibit 1), has been successfully deployed to prevent soil erosion in such settings. The purpose of this assessment is to determine how its use in a hypothetical application compares with other alternatives with respect to efficacy and derived primary and secondary environmental benefits. For the purposes of this analysis, we have compared a DredgeSOX/ShoreSOX installation with a Geotube® alternative (Exhibit 2) as well as a "do-nothing" alternative.

EXHIBIT 1: Typical DredgeSOX/ShoreSOX Installation (Source: SOXErosion)

The DredgeSOX/ShoreSOX Erosion Control product (DredgeSOX/ShoreSOX) is a patented high-density polyethylene (HDPE) geotextile-based system with a unique anchoring array used to stabilize shorelines, hillsides, and other earthen environments. The DredgeSOX/ShoreSOX product consists of a double layer of knitted HDPE technical mesh; the knitted structure minimizes potential structural undermining/unraveling, which is often experienced by woven and non-woven geotextiles. Additionally, the knitted structure allows DredgeSOX/ShoreSOX product to be cut or torn without significantly compromising its strength. Competing alternative woven products like Geotubes are susceptible to tears that may compromise their structural integrity and ability to maintain erosion and/or slope control.

[1] DredgeSOX/ShoreSOX® Registration Number 5237519

The DredgeSOX/ShoreSOX technical mesh is designed with apparent opening size (AOS) technology to promote root infiltration and growth, protecting the root systems in perpetuity, and allowing successful infiltration and water flow. When installed, the technical mesh is filled with suitable organic materials, often obtained from dredging shallow sediment, blown-in compost mix, or other situationally appropriate fill material. Recycled materials may also be used, provided it has been tested and determined to be free of contaminants that could be released into the environment.

To stabilize a shoreline or hillside, DredgeSOX/ShoreSOX can be deployed as a single unit or may be stacked in lifts. Typically, the individual stabilized shoreline height can range from as little as 1 foot to as much as 6 feet per lift[2]. In addition to reclaiming a variable slope height, the DredgeSOX/ShoreSOX system will typically reclaim between 2 and 9 feet of top-of-slope property (land lost to erosion).

Once installed, the DredgeSOX/ShoreSOX can be covered with a layer of vegetation. This may include turf grass or native plants, such as grasses, broadleaf cover plants, or shrubs. Additionally, the SOX system can accept cast seed and vegetate from the inside out. The DredgeSOX/ShoreSOX technical mesh allows for penetration of the root systems of plants without damage to the plant roots or to the technical mesh. As a result, plants are able to root, further stabilizing the protected shore against erosion, and thrive through the uptake of stabilized nutrients.

2 CONCEPTUAL PROJECT DESCRIPTION

To assess the efficacy of the DredgeSOX/ShoreSOX product, we have developed a hypothetical stabilization application. For comparison, we have assumed the stabilization of a creek or canal bank, approximately 6 feet in height. We have assumed a do-nothing alternative, which assumes no construction or other stabilization effort, but would result in bank erosion and/or failure. The alternatives include the following.

- Alternative 1 – No Bank Improvements

- Alternative 2 – Geotube GT1000M retained slope (filled with on-site dredged material)
  - 6-foot height, consisting of multiple lifts; 4 tubes required for 6-foot-high slope
    - Each tube has circumference of 14 feet; 56 square feet of Geotube per linear foot parallel to bank
    - Unit weight = 3.67 ounces (0.229 pounds) per square foot = 12.83 pounds per linear foot for four Geotubes parallel to bank.
  - Turfgrass vegetated layer
    - 15-foot tributary width per linear foot parallel to bank

- Alternative 3 – DredgeSOX/ShoreSOX retained slope; vegetated slope face
  - One lift of DredgeSOX/ShoreSOX filled with adjacent dredged spoils or adjacent excavated soil
    - Lift = 6 feet in height
    - Lift uses 12 square feet of DredgeSOX/ShoreSOX per linear foot parallel to bank
    - Unit weight = 1.07 ounces (0.067 pounds) per square foot = 0.8 pounds per 12-foot section per linear foot parallel to bank

[2] The lift system can exceed 6 feet to achieve larger protected environments in a single lift.

- Turfgrass vegetated layer
  - 15-foot tributary width per linear foot parallel to bank
  - 6-foot slope face

EXHIBIT 2: Geotubes (Source: SOX Erosion Control)

3 GEOTUBES FOR SLOPE FACES

Geotubes are a common tool used to armor slope faces. It is an appropriate option, provided its use is supported by proper engineering design.

The use of Geotubes is cumulatively expensive, often consisting of frequent routine maintenance and relatively expensive dredging operations (commonly under time-prohibitive permitting) for the Geotubes. Geotube locations must often be invasively graded to prepare the slope embankment for installation. Additional measures include lining the area to be improved with additional empty "sacrificial" Geotubes. While the erosion control method can be effective, Geotubes do not encourage or facilitate overlying vegetative growth, which lessens the potential to create aesthetically pleasing or functional green spaces at the slope face.

Geotubes are made of woven polypropylene (PP), which is susceptible to tearing. DredgeSOX/ShoreSOX is constructed of knitted HDPE, utilizing a design that eliminates the structural undermining of the geotextile. This innovation allows DredgeSOX/ShoreSOX to be cut to accept native plants, wrap around root systems that need to be stabilized, or handle unwanted burrowing animals without compromising the erosion control.

4 ALTERNATIVES ANALYSIS

To perform an alternatives analysis, we have assumed the dimensions as indicated above in the conceptual project description section, and we have assumed a 25-year design life for both constructed alternatives. We have assumed that the identical delivery routes for materials in each constructed scenario. Although DredgeSOX/ShoreSOX requires less site preparation resulting from its conformance with existing topography and undulations of slope/surface soil facing, as a measure of conservatism, we have assumed the same grading volumes and effort for both constructed scenarios. As a result, specific to our analysis, there is no net benefit between the constructed scenarios for materials procurement or grading work for the carbon calculations presented below, although it must be explicitly acknowledged that DredgeSOX/ShoreSOX usually requires less grading activity.

5 PREVENTION OF SOIL EROSION/RUNOFF FLOW VELOCITY

The purpose of the project contemplated by this alternatives analysis is to stabilize a shore bank; i.e., a lake bank or a creek bank. Of primary importance is the ability of the project alternatives to prevent bank slope or top-of-bank soil erosion.

Under a do-nothing alternative (Alternative 1), no improvement would be made to the shore bank. As a result, no additional protection would be provided to the bank slope or top-of-bank, and mass wasting processes from erosion would occur. As a result, the bank would be susceptible to failure from long-term chronic processes or from infrequent but high-impact flow events.

Both the Geotubes (Alternative 2) and DredgeSOX/ShoreSOX (Alternative 3) provide sufficient erosion protection. Both have been assumed to have an intended service life of 25 years, and assuming appropriate inspection and as-needed maintenance, both can be expected to minimize the potential for soil erosion and/or bank failure. Geotubes will slow parallel flow velocity into the water course. The DredgeSOX/ShoreSOX alternative also provides reduced surface water flow velocity. As a result, while both Alternative 2 and 3 provide erosion protection, Alternative 3 (DredgeSOX/ShoreSOX) may be considered a slightly better alternative for reducing surface-flow velocity and reducing the potential for related deleterious effects. As a do-nothing alternative, Alternative 1 offers no additional protection with respect to soil erosion.

6 REDUCTION IN SURFACE FLOW CONTAMINANT AND NUTRIENT LOADING

In addition to affecting the velocity of surface flow, the slope facing and top-of-slope ground covering can affect the water quality of surface flow that flow over these surfaces. Surface runoff can be contaminated with a variety of pollutants. Flows emanating from agricultural, residential, or recreational areas (e.g., parks or golf courses), surface runoff may have been impacted with herbicides, pesticides, fertilizers, or sediments from bare-earthen areas. In urban settings, surface runoff may be impacted with petroleum hydrocarbons, volatile organic compounds (VOCs), or heavy metals.

The Geotubes associated with Alternative 2 would likely affect surface runoff quality. While turfgrass or other vegetation (explained in detail below) can be cultivated inward from top of bank, Geotubes discourage potential rooting/fixation of overlying vegetation, which results in Geotubes exposed at the slope face. Dusts and contaminants that accumulate on these surfaces during dry periods would become mobilized into surface runoff flowing over these surfaces. As a result, surface flows contacting the Geotubes of Alternative 2 would likely be negatively affected, leading to deleterious effects on receiving water quality. Therefore, we have assumed water quality benefits derived from the inward turfgrass area would be negated by slope face condition of the Geotubes.

In the do-nothing approach of Alternative 1, the natural soil of the slope bank would allow for infiltration of surface flow, which could lead to a reduction of select contaminants in the surface flow. However, the exposed soil of the bank would be subjected to the erosive effects of the surface flow, which could mobilize soil and negatively affect the flow and the quality of the receiving water. Ultimately, water flow into an unmanaged, unstable slope condition could result in slope failure.

In the case of Alternative 3, the use of turfgrass or similar vegetation on the slope face (at the DredgeSOX/ShoreSOX interface) and at the top of the slope act as a vegetative filter strip (VFS), a useful best management practice (BMP) commonly implemented for stormwater runoff treatment. A VFS is an area of vegetation designed to remove sediment and other pollutants from surface water runoff through filtration, deposition, infiltration, adsorption, absorption, decomposition, and/or volatilization (Smyth et al., 2018). The United States Environmental Protection Agency (EPA) encourages use of engineered VFSs to reduce nonpoint source (NPS) pollution (USEPA, 2002).

Three distinct layers are present within the VFS – the surface vegetation, the root zone, and the subsoil horizon (Grismer and O'Geen, 2006). The vegetation and its ability to slow surface flow velocity increases the residence time over the turf surface, allowing sediments and contaminants to settle. Additionally, the permeable surface and presence of organic matter allows surface flow to infiltrate into the root zone. Within the root zone, some of the water flow continues to infiltrate into the underlying soil horizon, while some continues as lateral "interflow" within the root zone (Grismer and O'Geen, 2006). For nutrients, the most important VFS capture mechanism is infiltration. Nitrogen is primarily removed via uptake by the vegetation or resident microbial activity, while phosphorus and heavy metals are captured via adsorption to soil particles (Grismer and O'Geen, 2006).

As a result, during the use of DredgeSOX/ShoreSOX (Alternative 3), surface water quality is improved due to the removal of sediments, contaminants, and nutrients from the flow, resulting in a beneficial effect on the quality of the receiving water. Recent research has indicated that the vegetated feature is effective in reducing sediment, contaminant, and nutrient loads in surface runoff, including total suspended solids (TSS), select nutrients, and select heavy metals (Water Research Foundation, 2020). Although the degree of contaminant removal is highly dependent on vegetation type, soil conditions, VFS dimensions, slope angle, and climate conditions, VFS systems such as those simulated by the use of Alternative 3 can be very efficient at contaminant removal. Field studies indicate that VFSs can successfully remove more than 90 percent of sediments, 50 to 80 percent of nutrients (Smyth et al., 2018), and over 60 percent of certain pathogens (Grismer and O'Geen, 2006). Empirical studies of prairie filter strip use adjacent to agricultural fields have demonstrated reduced nitrate-nitrogen (NO_3-N), total nitrogen (TN), and total phosphorus (TP) concentrations by 35 percent, 73 percent, and 82 percent, respectively (Zhou et al., 2014).

Contaminant and nutrient removal continue over the life span of the VFS feature, provided basic maintenance activities are performed. To maintain optimal pollutant removal efficiency, permanent vegetative plants should be harvested properly to encourage dense growth and removal of sediment, nutrients, and other pollutants trapped in the plant tissue (Smyth et al., 2018). Other straightforward maintenance practices include activities at the surface to maintain uniform sheet flow across the vegetation, removal of excessive sediment accumulation, repair of bare spots or distressed vegetation, and limitations of foot or vehicular traffic across the vegetated surface (Grismer and O'Geen, 2006).

7 EMBODIED CARBON AND CARBON SEQUESTRATION

A third dimension considered in this alternatives analysis is the carbon footprint of the project alternatives. In considering the overall carbon footprint, we have considered both the construction carbon footprint, as well as the operational carbon footprint.

The construction carbon footprint considers the net of carbon sources (emissions) and sinks associated with the manufacture, delivery, and installation of the project. The operational carbon footprint considers the net of carbon emissions or sequestration that occur during the presence, operation, and maintenance of the alternative. As discussed in Section 5, we have assumed that the fabrication and the installation, including earthwork and grading activities, are neutral with respect to Alternatives 2 and 3.

As a do-nothing alternative, Alternative 1 is assumed to be carbon neutral for this analysis, although it is likely that slope erosion or failure would require future slope rebuilding and/or dredging. This would result in measure carbon emissions and eliminate the carbon neutrality assumption for Alternative 1.

In considering operational carbon for Alternatives 2 and 3, the inclusion of turfgrass on the slope facing (only for Alternative 3) and at the top of slope provides a means to sequester carbon. During photosynthesis, plants take in carbon as carbon dioxide and fix the carbon into their structural (leaves, stems, roots, etc.) and non-structural (sugars and other metabolites) components (Putnam, 2016). In perennial grass ecosystems, a large portion of that carbon ends up in the soil organic matter because of their large fibrous root systems (Putnam, 2016). Further, as turfgrass roots die, they decompose into soil organic matter, fixing carbon in the soil, allowing turf areas to act as a carbon sink for greenhouse gases (Leslie, 2021).

Of course, ongoing maintenance activities and the use of power equipment can result in generation of carbon emissions. Further, a limit is reached as to the carbon sequestering capacity of grasses, such that over a long period of time, ongoing carbon emitting activities can result in a turf installation to go from a net carbon sink (sequestration) to a net carbon source. However, carbon-positive (sequestration) system has been estimated to range between 66 and 199 years in U.S. home lawns, with an average of 184 years (Selhorst and Lal, 2013). Our estimate of a 25-year design life is well within the sequestration timeframe. Additionally, because more efficient and reduction of carbon-intensive maintenance practices could increase the overall sequestration longevity of home lawns and improve their climate change mitigation potential (Selhorst and Lal, 2013), these time ranges of sequestration may be conservative, as they may be vegetated and subsequently subjected to little to no ongoing maintenance. Further, similar sequestration performance could be expected in native grasses/plants are used in place of turfgrass (Qian and Follett, 2002).

To determine the carbon sequestration potential of the turfgrass, we assumed a sequestration rate of 100 grams of carbon per square meter per year, or 0.0205 pounds of carbon per square foot per year. This is at the lower end of a range estimate of 25.4 to 204.3 grams of carbon per square meter per year to account for maintenance emissions generation and lower growth rates (and CO_2 utilization) that may occur in colder or drier climates (Zirkle et al., 2011).

In calculating the embodied carbon for Alternative 2, carbon is generated during refining of petroleum-based raw materials and the manufacture of the Geotube product. To determine these emissions, we classified the product as a PP-based geotextile. For our calculations, we estimated an embodied carbon unit value of 3.43 kg (or lb.) of CO_2 emissions per kg (or lb.) of PP (Hammond and Jones, 2011, Raja et al., 2015). We have incorporated a unit weight of 3.67 ounces (0.229 pound) per square foot of Geotube GT 1000M (Layfield Group. 2022). As each Geotube can be used for 1.5 feet of slope, four tubes would be needed for a 6-foot slope. As each tube has a circumference of 14 feet, the combined weight of four Geotube GT 1000M segments would be 12.83 pounds per linear foot of slope. Applying the embodied carbon unit value for PP geotextile, we estimate 44.02 pounds of CO_2 emissions per linear foot of Geotube GT 1000M slope.

In considering operational carbon, we assume 15 square feet of turfgrass per linear foot of slope, which results in 0.31 pounds of sequestered carbon per year per linear foot of slope, or 7.69 pounds of sequestered carbon per linear foot of slope over a 25-year design life. When compared to the embodied carbon of the manufacture of the Geotube GT 1000M product, its use in the conceptual project results in net negative carbon emissions, or positive carbon sequestration, over the design life of the installation.

- Alternative 2 – Geotubes retained slope with turfgrass vegetated layer
    - Embodied Carbon – 44.02 pounds of CO_2 emissions per linear foot of slope
    - Operational Carbon – -7.69 pounds of CO_2 emissions per linear foot of slope
    - TOTAL: 36.33 pounds of CO_2 emissions per linear foot of slope

For Alternative 3, carbon is generated during refining of petroleum-based raw materials and the manufacture of the DredgeSOX/ShoreSOX product. To determine these emissions, we classified the product as a HDPE-based geotextile. For our calculations, we estimated an embodied carbon unit value of 1.93 kg (or lb.) of CO_2 emissions per kg (or lb.) of HDPE (Hammond and Jones, 2011, Raja et al., 2015). As noted, we have assumed a unit weight of 1.07 ounces (0.067 pound) per square foot of DredgeSOX/ShoreSOX. Assuming a 12-foot-long section per lift, this results in a DredgeSOX/ShoreSOX weight of 0.8 pounds per linear foot of slope. Applying the embodied carbon unit value for HDPE geotextile, we estimate 1.54 pounds of CO_2 emissions per linear foot of DredgeSOX/ShoreSOX slope.

Assuming 21 square feet of turfgrass per linear foot of slope (including 6 feet of vegetated slope face), this results in 0.43 pounds of sequestered carbon per year per linear foot of slope, or 10.76 pounds of sequestered carbon per linear foot of slope over a 25-year design life. When compared to the embodied carbon of the manufacture of the DredgeSOX/ShoreSOX product, its use in the conceptual project results in net negative carbon emissions, or positive carbon sequestration, over the design life of the installation.

- Alternative 3 – DredgeSOX/ShoreSOX retained slope with turfgrass vegetated layer
    - Embodied Carbon – 1.54 pounds of CO_2 emissions per linear foot of slope
    - Operational Carbon – -10.76 pounds of CO_2 emissions per linear foot of slope
    - TOTAL: -9.22 pounds of CO_2 emissions per linear foot of slope

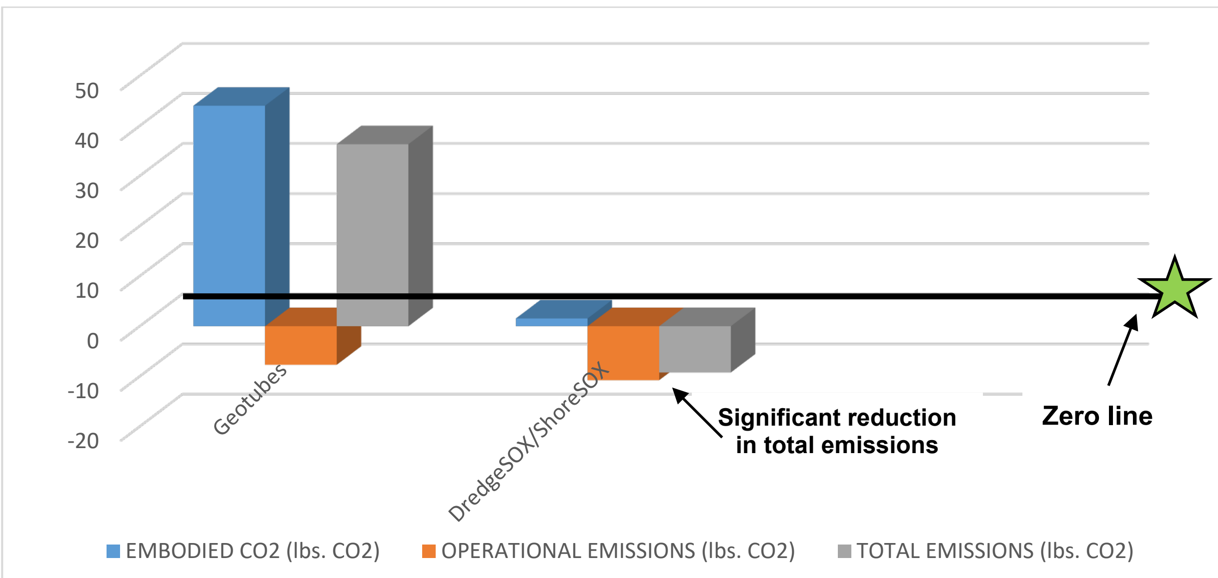
8 DISCUSSION

Across the assessed environmental dimensions, the DredgeSOX/ShoreSOX product presents a superior alternative to the use of the Geotube alternative, while both offer a range of advantages over a “do-nothing” alternative (Table 1). The following table provides a summary of the performance of the considered alternative across the assessed dimensions. Of course, the do-nothing alternative could likely result in project failure.

TABLE 1: Summary of Alternatives Analysis

DIMENSION	ALTERNATIVE 1: DO NOTHING	ALTERNATIVE 2: GEOTUBES	ALTERNATIVE 3: DREDGESOX/SHORESOX® AND TURF
Reduction of Runoff Velocity/Erosion	—	+	+
Reduction of Contaminant Loading	—	—	+
Embodied Carbon/Sequestration	—	—	+

EXHIBIT 3: Summary of Carbon Emissions per Linear Foot of Slope for Alternatives 2 and 3



With respect control of velocity of surface runoff flow, the incorporation of the DredgeSOX/ShoreSOX alternative with turfgrass results in a rougher surface, which reduces flow velocity and potential deleterious erosive effects, an advantage also offered by the use of Geotubes. The inclusion of turfgrass also allows the DredgeSOX/ShoreSOX alternative to reduce loading of several contaminants before runoff reaches the protected water body, thereby improving water quality as compared to the Geotube alternative. Finally, the Geotube alternative results in an installation with higher embodied carbon, while the manufacture of DredgeSOX/ShoreSOX results in relatively low carbon emissions, and the more extensive use of turfgrass (or other grasses/native vegetation), which can be directly supported on the slope face, results in a ***carbon neutral or net carbon sink*** alternative for shoreline protection (Exhibit 3). As a result, in addition to providing an easy-to-install, technically effective, and cost-effective alternative, DredgeSOX/ShoreSOX offers an environmentally protective and sustainable shoreline protection solution.

9 REFERENCES

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