Using the Power of Nature to Prevent Pollution

Opportunities for nature-based solutions in the automotive industry

WHC
WILDLIFE HABITAT COUNCIL

SUPPLIERS PARTNERSHIP FOR THE ENVIRONMENT

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Contents

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Introduction

In order to understand the capabilities of automotive companies to implement nature-based solutions (NbS) to support their pollution prevention goals, it is necessary to examine the existing research and information regarding the use of NbS. The benchmarking research conducted for this report was supported by a two-year grant from the U.S. Environmental Protection Agency (EPA) to identify, develop and advance nature-based solutions as effective tools to reduce air and water pollution at source and improve community resilience and sustainability.

Throughout this project, WHC (Wildlife Habitat Council) worked alongside the Suppliers Partnership for the Environment (SP). As WHC and SP's members span the automotive supply chain from extraction to energy to waste, this partnership ensured connections, feedback and dissemination to an audience of auto manufacturers and their suppliers across the U.S. As per the grant, research and implementation focused on manufacturers and suppliers within EPA's region 4 (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee and six indigenous tribes), a region that also plays host to many automotive manufacturers and suppliers.

When discussing NbS, WHC uses the definition developed by the International Union for Conservation for Nature (IUCN) stating that NbS are "…actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human wellbeing and biodiversity benefits." NbS represent an ideal opportunity for the auto industry not only because of the source-level pollution reduction benefits that can support companies in meeting regulatory requirements, but also via the numerous co-benefits of NbS that can allow the auto industry to go above and beyond regulations to support biodiversity and local communities.

Findings & Opportunities

In addition to the benchmarking research that formed the basis for this report, WHC conducted an analysis of pertinent data related to NbS from WHC-Certified projects. WHC Certification is a third-party certification program that provides objective evaluation of corporate conservation programs that manage wildlife, manage habitat, provide conservation education or result in a combination of all three areas.

The findings from WHC Certification data showed that 25 projects — which were carried out specifically by auto manufacturers, suppliers and/or SP members — mentioned keywords related to NbS, such as swales, pollution, etc. Additionally, 10-15 projects mentioned stormwater directly. A review of data collected from a random selection of these projects showed that largely, the co-benefits of these interventions were not calculated or measured but were characterized in the application information as co-benefits. This illustrates a constraint of the data itself, as the WHC Certification application does not specifically ask for measurements related to co-benefits, which also represents a potential opportunity to focus more on this area in the future.

To gain further insight from industry professionals, in April 2022, WHC and SP convened a workshop with representatives from various automotive manufacturing and supply companies. Companies in attendance included Battery Solutions, DENSO Manufacturing Tennessee, ERA Environmental Management Solutions, geff LP, General Motors, GZA, SP, Stellantis, Tetra Tech, Toyota North America and Mazda Toyota. During this workshop, attendees learned about NbS as tools for pollution prevention and explored a suite of available and measurable NbS interventions. They then participated in a breakout activity that required them to generate NbS opportunities based on different example sites and scenarios. Based on the conditions of their particular examples, participants identified existing ecological features, such as streams, as potential opportunities for rehabilitation, as well as engineered solutions like bioswales, stormwater collection and blue roofs.

A follow-up breakout activity then had participants conduct a risk analysis on their theoretical NbS plan and report the risks and challenges they identified to the larger group. Among the risks identified with implementing NbS were costs, regulatory and permitting concerns, disruption to operations and long-term maintenance. Through these two activities, participants explored the pollution-prevention opportunities presented by NbS while also thinking critically about how to mitigate the potential risks involved in implementation.

Informed by benchmarking research, WHC Certification data and stakeholder input via workshop sessions, the following report outlines 17 NbS identified as potential pollution prevention opportunities for the auto sector. Details provided for each solution include the estimated costs; the pollutants targeted; the co-benefits to biodiversity, climate change mitigation and communities; the business benefits; and the risks or challenges associated with implementation. This information is followed by a decision tree to guide automotive companies in determining which solutions best fit their site, pollution prevention needs, budget, operational phase and other factors.

WETLAND REHABILITATION

Wetlands are one of the earth's most threatened ecosystems, with a 35% global loss since 1970. Rehabilitating or restoring a wetland involves returning a degraded wetland's physical, chemical and biological characteristics to a functioning ecological system. Building partnerships and using mechanisms such as incentives, purchases of land title or easements can protect wetlands from further degradation. The type of wetland (estuary, marsh, bog, etc.) can vary based on location, vegetation and other factors.

Before beginning a wetland rehabilitation project, defining terms such as "restoration," "management" and "success" is vital. Having clear and consistent definitions ensures that the appropriate restoration and management techniques are utilized throughout the life of the project. Long-term commitment and planning are crucial to the overall success of a wetland rehabilitation project, regardless of the scale.

COST

- Varies depending on techniques used — can range from $300/acre to $300,000/acre.

POLLUTANTS TARGETED

- Sediment.
- Urban runoff (such as nitrogen and phosphorus).

CO-BENEFITS

- Reduces intensity and frequency of flooding by creating natural storm buffers.
- Controls erosion.
- Bio-remediates pollution.
- Creates wildlife corridors and critical habitat for amphibians, as well as breeding and stopover sites for migratory and resident birds.

BUSINESS BENEFITS

- Flood attenuation benefits provided by wetlands are between $166-$3,256/acre per year.
- Creates recreational opportunities.
- Supports fishing economies and eco-tourism.

RISKS AND CHALLENGES

- Maximizing one function of a wetland typically means minimizing another.
- Costs vary widely.
- Lack of monitoring post-implementation has led to the failure of many wetland restoration projects, so long-term planning has proven essential.

TO DECISION TREE

STREAM REHABILITATION

Streams represent an integral part of the natural landscape. They carry water and sediment from higher elevations to downstream lakes, estuaries and oceans, while also providing the vital resource of water to a variety of ecosystems, including wetlands, bogs, ponds, forests and floodplains.

Similar to wetland rehabilitation, the overall goal of stream rehabilitation is to restore the natural functions of a stream ecosystem. Nitrogen, phosphorus and other contaminants from urban runoff are the main sources of urban stream pollution, while fertilizers and erosion of stream banks affect streams as well, so NbS that target these pollutants are critical to supporting stream health as well as the health of downstream ecosystems.

COST

- Typically costly — ranging from $500-1,200/ft.

POLLUTANTS TARGETED

- Sediment.
- Urban runoff (including nitrogen and phosphorus).
- Agricultural runoff (including fertilizers).

CO-BENEFITS

- Provides wildlife habitat.
- Improves water quality.
- Provides recreational opportunities.
- Mitigates negative effects of climate change.

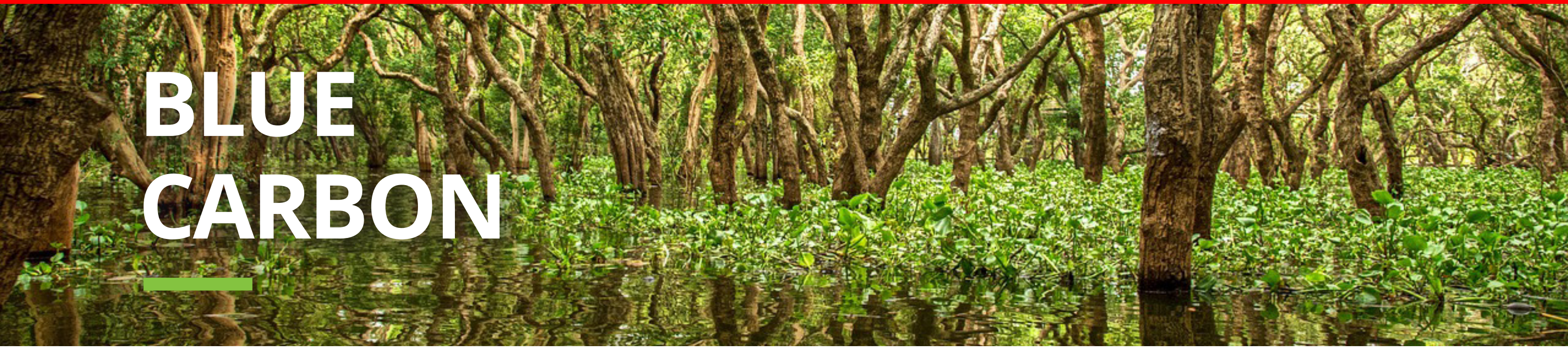
BUSINESS BENEFITS

- The value of recreational and aesthetic benefits can outweigh initial costs.
- Restoring streams can support fishing economies/revenue and eco-tourism.

RISKS AND CHALLENGES

- Stream rehabilitation covers a large footprint and can be costly.
- Expertise is needed to adhere to mitigation regulations, as well as for design and implementation.

TO DECISION TREE



BLUE CARBON

Blue carbon refers to the carbon sequestration capacity of marine ecosystems such as mangrove forests, seagrass meadows and tidal marshes. As these afore-mentioned ecosystems exist on every continent except Antarctica, they represent a wide NbS opportunity for the auto industry to explore. Mangrove restoration is the most widely recognized form of blue carbon sequestration, but awareness is growing globally for other blue carbon ecosystems.

Engineering solutions — such as modification of hydrodynamics to restore historical tidal exchange — and native planting solutions exist for restoring blue carbon ecosystems. There are many crossovers between blue carbon interventions and other NbS, including wetlands and naturalized shorelines, making it a valuable part of a suite of solutions.

COST

- There is a lack of research on scale and cost of blue carbon solutions, but some estimates suggest restoration can cost as little as $10–100 per ton of CO_2.

POLLUTANTS TARGETED

- Greenhouse gases (CO_2).

CO-BENEFITS

- Rapidly sequesters carbon.
- Is gaining international recognition to meet climate change mitigation and adaptation targets.

BUSINESS BENEFITS

- Supports coastal livelihoods via fishing and eco-tourism.
- Protects infrastructure by stabilizing shorelines and preventing coastal erosion.

RISKS AND CHALLENGES

- Blue carbon ecosystems can go from a carbon sink to a carbon source if damaged, degraded or destroyed; therefore, continuous monitoring and management of the ecosystem is essential.
- As an emerging NbS, new research has shown that, even without damage, some blue carbon ecosystems may emit more carbon than they absorb.
- There is currently a limited amount of research on scale and cost.

TO DECISION TREE

GRASSLAND RESTORATION

Grasslands, often referred to as prairies or conservation prairies, provide a variety of ecosystem services including food production, nutrient cycling, carbon sequestration and prevention of soil erosion. These vital services mean that protecting and restoring grasslands leads to a multitude of benefits for wildlife, biodiversity, human wellness and the economy.

It is important to note that native grasslands can be complex to establish, especially in a changing climate, and the implementation of a grassland restoration process has a long timeframe and requires continued maintenance. Therefore, this NbS is best suited for a long-term, well-resourced and partnered effort.

COST

- Estimated cost of restoring a degraded grassland is approximately $2,173/acre.

POLLUTANTS TARGETED

- CO_2.
- Sediment.

CO-BENEFITS

- Improves water quality.
- Stabilizes soil.
- Provides habitat for wildlife.
- Supports threatened or endangered species that rely on grasslands.
- Promotes pollinators.
- Supports soil carbon storage and sequestration.
- Increases water storage and stormwater retention.
- Controls erosion.
- Supports production of food and raw materials through improved soil quality.
- Supports firebreak potential.
- Provides aesthetic and recreational purposes.

BUSINESS BENEFITS

- Economic benefits associated with agricultural use of grasslands.
- Prevents flood damage to infrastructure.
- Supports pollinators, which in turn supports the economy.

RISKS AND CHALLENGES

- Grasslands are not well-suited for human action such as commercial uses or recreational activities.
- Limiting investments in grassland establishment, such as trying to save costs by reducing the number of species or frequency of weed control, can ultimately reduce the grassland's effectiveness. Investing in native plant diversity and weed control can help save on long-term costs.
- Native grasslands are disturbance dependent, meaning best management practices require implementing prescribed fire and/or mowing regimes that mimic natural disturbance cycles.

TO DECISION TREE

PHYTOREMEDIATION

The process of using plants to clean up contaminated environments is known as phytoremediation. It is considered the most sustainable of the existing physical, chemical and biological remediation techniques, and it is also cost-effective and relatively non-invasive. This solution complements other NbS; for example, constructed wetlands can be used as a type of phytoremediation.

Phytoremediation includes many methods, such as phytoextraction (using plants to remove contaminants from soils), phytodegradation (using plants to break down organic contaminants) and phytovolatilization (using plants to convert contaminants into a gaseous state). Phytoremediation is most effective when contaminant levels are low, and one single method is generally not sufficient to remediate heavily polluted soils, so a combination of approaches is recommended. Public acceptance of phytoremediation strategies is growing, with the U.S. among the countries leading phytoremediation research.

COST

- Most of the costs are associated with infrastructure and fertilizer — estimated at $37.70/m^3.

POLLUTANTS TARGETED

- Heavy metal toxins.
- Pesticides.
- Explosives.
- Oil.
- Common chemicals (such as trichloroethylene, benzene or chloroform).

CO-BENEFITS

- Reclaims polluted soil.
- Stabilizes and improves soil fertility.
- Reduces risk of spreading contaminants.
- Reduces risk of secondary air or water pollution from remediation techniques.
- Reduces likelihood of metals entering the food chain.
- Supports the creation of threatened habitats, such as wetland construction and native grasslands.

BUSINESS BENEFITS

- Low cost of installation and maintenance.
- Improves site aesthetics.
- Reduces noise when trees and plants are used.
- Controls soil erosion.
- Recovers and uses metals from plants.

RISKS AND CHALLENGES

- Although low risk with little disruption to the community, phytoremediation is a time-consuming process.
- Barriers or fences should be installed to prevent wildlife or humans from consuming intoxicated plants.

TO DECISION TREE

REFORESTATION

One of the most well-practiced environmental conservation methods, reforestation involves replanting a forest area that has been affected by both natural disturbances — such as wildfires, drought and disease — as well as unnatural impacts like logging, mining or development.

The scope and methods of reforestation projects vary greatly depending on goals, and an assessment of the land's current condition is necessary to develop a reforestation plan. This type of assessment ensures the appropriate local species are used, that the nursery infrastructure exists to support the necessary production of seedlings and that local staff and volunteers are involved before, during and after planting.

COST

- Varies depending on the size of trees and scope of the project — tree seedlings can range from $5-$20 each, with large trees costing $1200-$1900 each.
- Annual maintenance, such as pruning and treating, can cost approximately $100-$1000.

POLLUTANTS TARGETED

- Greenhouse gases (CO_2).
- Air pollutants.

CO-BENEFITS

- Sequesters carbon.
- Creates wildlife habitat, particularly for threatened woodland-dependent species.
- Stabilizes soil and prevents erosion.
- Attenuates flooding and filters water.
- Reduces ambient air temperature by up to 8° C.
- Provides recreational opportunities such as areas for hiking, walking and biking.

BUSINESS BENEFITS

- Increases aesthetic value of facility grounds.
- Reduces energy costs (can cool buildings via shade and serve as a windbreak during winter).
- Provides recreational and provisional value such as firewood, food, timber, etc.

RISKS AND CHALLENGES

- The scale of reforestation must be defined.
- Soil disturbances during the initial forest establishment can lead to carbon loss caused by factors like erosion, oxidation, decomposition and leaching.

TO DECISION TREE

URBAN FORESTRY

Urban forestry meets needs expressed by community members while building resilience and mitigating the urban effects of climate change. This broad solution encompasses many methods, from creating an urban park to lining a city street or riverwalk with trees to encouraging private landowners to plant trees in their yards.

Community involvement and capacity assessment is vital for urban forestry success. Many local municipalities have planning departments with the technical expertise to implement an urban forestry plan, but it is important to understand the community's capacity (in time, resources, skills and knowledge). Involvement, feedback and buy-in from the local community can foster a sense of ownership of and support for urban forestry projects.

COST

- Trees can cost anywhere from $5-$1000+ depending on their size.
- The value added to a city outweighs the initial planting costs.

POLLUTANTS TARGETED

- CO_2.
- Urban runoff (such as nitrogen, phosphorus and heavy metals).

CO-BENEFITS

- Reduces both air and water pollution.
- Supports wildlife habitat.
- Mitigates the urban heat island effect.
- Improves public safety by reducing stormwater runoff and mitigating storm effects.
- Provides healthy venues for recreation and improves psychological well-being.

BUSINESS BENEFITS

- Economic benefits increase over time, and maintenance needs decrease as trees mature.
- Return on investment outweighs the costs of installation and maintenance.

RISKS AND CHALLENGES

- Capital is often dedicated to urban forest creation with few resources earmarked for maintenance.
- Planting rules and regulations vary and depend on culture, city rules, etc.

TO DECISION TREE

MICROFORESTS

This afforestation method, pioneered by Japanese botanist Akira Miyawaki, relies on the creation of small, rapidly developed, densely packed forests that grow through intense competition for resources. Microforests can range in size from multiple hectares to a tiny backyard. The Miyawaki process advocates for the use of native trees planted very densely along with layers of vegetation to reproduce the composition and succession of natural forests. Collecting seeds from a variety of native trees helps to ensure that the microforest is representative of indigenous forests and local genetics.

Prior to microforest planting, a soil survey should be conducted to determine the type of mulch and soil amendments that will be required. A mulch composed of local materials provides protection and moisture for the newly planted seedlings, which must only be weeded and watered for the first two years of the microforest's life.

COST

- Can range from $21,400-$23,500 for larger projects or $3,000 for a smaller, backyard forest.
- Organizations and municipalities typically split the costs of planting and training.

POLLUTANTS TARGETED

- CO_2.
- Runoff.

CO-BENEFITS

- Provides habitat for wildlife.
- Reduces urban heat island effect.
- Buffers against flooding and erosion.
- Sequesters carbon.
- Creates opportunities for people living in urban areas to connect with nature close to home.

BUSINESS BENEFITS

- Improves aesthetics.
- Buffers sites from extreme weather events like tsunamis or hurricanes.

RISKS AND CHALLENGES

- Creates an even-aged habitat of trees; however, a variety in native species chosen means there is still an abundance of biodiversity supported.
- More expensive method of planting because it requires more seedlings to cover a certain area.

TO DECISION TREE

VEGETATIVE BUFFERS

Vegetative buffers are composed of natural, existing or established vegetation that protect the water quality of neighboring waterbodies. These types of buffers vary from strips of grass and shrubs to riparian forests that border streams, lakes or wetlands. Vegetative buffers are fairly ubiquitous throughout the United States, particularly in the Chesapeake Bay watershed.

The pollution prevention capabilities of vegetative buffers are high, as they remove almost any pollutants that would flow into a waterbody. Factors to consider when designing a vegetative buffer are the width, structure, species composition and vegetation management, with buffer width widely considered one of the most critical aspects. Buffers ranging from 5 – 300 meters wide will filter up to 95% of sediments and nutrients.

COST

- Can be relatively low, provided that resulting land management costs are low.
- Riparian buffer mitigation credit through NEEP is currently $1.16/$ft^2$, which translates to $50,530/acre.

POLLUTANTS TARGETED

- Sediment.
- Nutrients (such as nitrogen, phosphorus, calcium, sulfur and magnesium).
- Pathogens and toxins.
- Agricultural runoff.
- CO_2.

CO-BENEFITS

- Improves water quality by reducing pollution that would flow into a stream or wetland.
- Provides recreational and habitat value.
- Has immediate pollution reduction benefits as well as long-term flood reduction benefits.

BUSINESS BENEFITS

- Prevents future flood damage.
- Increases access to recreational fishing.
- Reduces costs associated with dredging due to sedimentation.

RISKS AND CHALLENGES

- A buffer's ability to absorb sediment and nutrients decreases over time if it is not maintained properly.
- Social barriers exist when attempting to use private land for vegetative buffers.
- Economic barriers include the cost of implementation, especially without government funding.

TO DECISION TREE

RAIN GARDENS

Originally developed at commercial sites and public spaces where space is limited, this NbS is particularly well-suited for small sites in urban settings. Rain gardens utilize native plants to collect and absorb runoff from pervious surfaces such as parking lots or roofs. Through bioretention, a water quality practice where plants and soils naturally remove pollutants from stormwater, a rain garden's deep-rooted, wet-tolerant plants capture and filter stormwater runoff.

The location of a rain garden is of utmost importance to ensure it receives runoff, is located far enough from buildings to avoid damage and that underground utilities are not impacted. It is recommended that rain gardens be located at least 10 feet from a building in a low spot that collects rain.

COST

- Dependent on size, site characteristics and types of plants — estimated costs vary between $3-$40/ft^2, with annual maintenance costs around $10-$100+.

POLLUTANTS TARGETED

- Stormwater and roof runoff (including suspended solids, phosphorous, nitrogen, lead and zinc).

CO-BENEFITS

- Reduces stormwater pollution.
- Provides food and habitat for wildlife.
- Recharges groundwater.
- Provides water for plants.
- Reduces erosion.
- Reduces flooding.
- Increases aesthetics.
- Moderates air temperature.

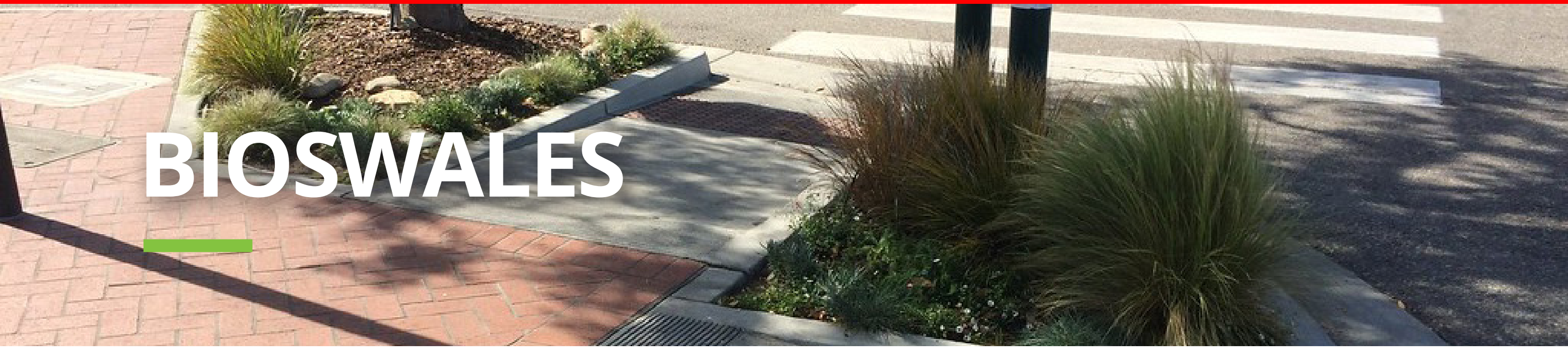
BUSINESS BENEFITS

- Reduces runoff in a cost-effective manner.
- Improves property aesthetics, thereby increasing property value.
- Prevents breeding of mosquitoes.
- Reduces landscape maintenance costs.
- Reduces stormwater utility fees.

RISKS AND CHALLENGES

- There is a lack of research on the business, environmental or social risks associated with rain gardens.
- Usually not suitable for steeply sloped landscapes.

TO DECISION TREE



BIOSWALES

Much like rain gardens, bioswales also collect and filter runoff, but instead of using native plants alone, bioswales channel stormwater into a trough filled with multiple layers of vegetation, compost, mulch or rubble. They are often located near roads or parking lots to capture the associated runoff. Bioswales have been found to reduce surface runoff by almost 99% and are relatively inexpensive and easy to implement.

There are various types of bioswales determined by the type of vegetation used: Grassed bioswales are planted with turfgrass, while vegetated bioswales can be planted with ornamental grasses, shrubs or perennials. Xeriscape, or low-water use, bioswales are well-suited for areas with hot summers or dry conditions, and wet bioswales function much like stormwater wetlands.

COST

- \$58/linear foot and \$20-\$30/ft^{2}.
- Annual maintenance costs range from \$10-\$100 for removing weeds, etc.

POLLUTANTS TARGETED

- Urban runoff.
- Nitrogen.
- Phosphorus.
- Organic carbon.
- Pathogens.
- Motor oils.

CO-BENEFITS

- Reduces stormwater runoff.
- Provides habitat for pollinators and other small animals.
- Aesthetically pleasing.

BUSINESS BENEFITS

- Reduces infrastructure costs.
- Cheaper than other grey infrastructure methods.
- Can help prevent future flood damage.
- Supports United Nations Sustainable Development Goals (SDGs) 6 and 15.

RISKS AND CHALLENGES

- Maintenance is required each growing season.
- Can be overwhelmed by large storms.
- Soil can be eroded in high-velocity and steeply sloped areas.

TO DECISION TREE

WET DETENTION SYSTEMS

Wet detention systems include both detention and retention ponds, which collect and filter stormwater. Detention ponds hold water for a temporary period, after which the water is slowly released, while retention ponds contain a permanent pool of water throughout the year. Both solutions are suited for nearly any geography, and both require large land area and tend to have limited applicability in highly urbanized settings and arid climates.

Design and implementation of detention and retention ponds are site-specific and depend on site solids, utility conflicts, property ownership, space constraints and drainage area. Once implemented, regular inspections and routine maintenance are required. Proper design can mitigate the risks associated with wet detention systems such as standing water and impact on local water systems.

COST

- Depends on site conditions but typically ranges from \$17.50-\$35.00/m^3.

POLLUTANTS TARGETED

- Stormwater pollutants.
- Copper.
- Zinc.
- Nitrogen.
- Nitrate.
- Phosphorus.
- E. coli and other pathogens.
- Total suspended solids.

CO-BENEFITS

- Attenuates flooding.
- Reduces erosion.
- Protects stream channels.
- Recharges groundwater.
- Provides water and habitat for wildlife.
- Provides space for recreation.

BUSINESS BENEFITS

- Saves on stormwater cost repairs.
- Project has a long lifespan.

RISKS AND CHALLENGES

- Water quality can be at risk if ponds are not adequately designed.
- Mosquito proliferation can occur, which can be mitigated by addressing standing water in the design.
- Location-specific risks (barriers may be needed if there are steep slopes to protect pedestrians; urban environments may have limited space at the end of storm drain systems).

TO DECISION TREE

GREYWATER SYSTEMS

Greywater refers to wastewater generated in domestic or commercial settings, excluding wastewater from toilets. Traditional greywater recycling involves capturing, treating and recirculating greywater, but greywater reuse can also be combined with other NbS to provide further benefits.

Options for nature-based greywater treatment that support its reuse for irrigation and toilet flushing include constructed wetlands, integrated technologies such as green roofs or living walls and new approaches like treatment wetlands comprised of willow trees. Constructed wetlands, green roofs and living walls have high removal performances, with constructed wetlands representing one of the most widely used greywater systems today.

COST

- Depends on the solution used to treat greywater.
- Use of constructed wetlands to treat greywater are viewed as low-cost and low maintenance.

POLLUTANTS TARGETED

- Solids.
- Organic material.
- Nutrients from wastewater.
- Greenhouse gases (when integrated with other NbS).

CO-BENEFITS

- Reduces pollution in freshwater.
- Mitigates global warming.
- Decreases the potential of eutrophication.
- Reduces carcinogenic potential in freshwater.
- Lowers environmental costs associated with wastewater management, such as the energy use in its transportation and movement.

BUSINESS BENEFITS

- Operational savings from reusing water for toilet flushing, irrigation, etc.
- Creates an additional source of water in times of drought or when irrigation restrictions exist.

RISKS AND CHALLENGES

- There have been concerns and opposition around greywater systems, especially as it gets closer to human contact, indicating a need for education and awareness to ensure success.

TO DECISION TREE

NATURALIZED SHORELINES

Naturalized shorelines are also referred to as living or softened shorelines. In contrast to hardened shorelines that consist of concrete or steel barriers, softened shorelines integrate natural elements such as terrestrial vegetation, aquatic plants, trees, woody debris, etc. to buffer the shoreline. This NbS can support a variety of different ecosystems, including coastal wetlands, blue carbon ecosystems and tidal marshes.

Bioengineering techniques —such as the addition of coir logs, live stakes and brush mattresses — can be used to create naturalized shorelines. Different methods of shoreline softening are appropriate for different needs; for example, vegetation-only shorelines break small waves and are therefore suitable for sites with low wave energy, while rock sills parallel to the shore with vegetation planted behind them make excellent barriers to higher energy waves.

COST

- Generally more affordable than hardened shorelines, with installation fees estimated at $1,000 to $5,000/linear foot and maintenance costs around $100/linear foot annually.

POLLUTANTS TARGETED

- CO_2.
- Chemical runoff.

CO-BENEFITS

- Resilient to storm damage.
- More cost effective (in both installation and maintenance) than hardened shorelines.
- Provides wildlife habitat.
- Reduces erosion.

BUSINESS BENEFITS

- Supports the life of existing infrastructure.
- Reduces maintenance needs and costs.
- Protects infrastructure from storms.

RISKS AND CHALLENGES

- Various considerations and methods depend on site-specific factors such as current and desired land use, soil type, availability of sunlight, etc.
- In many states, the permitting and regulatory environment is still not supportive of living shoreline projects.
- Many engineers and contractors do not have a lot of experience with designing or implementing living shorelines.

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PERMEABLE PAVEMENT

Traditional materials used at commercial sites such as asphalt or concrete are impermeable, leading to contaminated runoff, flooding, lack of groundwater recharge and increased temperatures. Permeable pavement is a constructed solution to this issue that allows water to infiltrate the ground. Open-cell concrete blocks, grass concrete pavers, gravel, open-pattern pavers and porous clinkers are all examples of permeable pavement.

Permeable pavement projects have been implemented worldwide and, if they have water quality and pollution reduction characteristics, can even earn credits under voluntary standards such as LEED and Green Globes. In the U.S., the design of permeable pavements must meet the Americans with Disabilities Act (ADA), with many options fulfilling this requirement.

COST

- Porous asphalt typically costs \$10-\$15/ft^2, porous concrete usually costs about \$4-\$18/ft^2 and permeable pavers cost \$5-\$40/ft^2.
- While permeable pavement has a higher design and installation cost than impermeable pavement, the benefits offset the initial costs.

POLLUTANTS TARGETED

- Sediments.
- Nitrogen.
- Phosphorus.
- Metals.
- Pathogens.

CO-BENEFITS

- Reduces stormwater runoff.
- Soaks up pollutants.
- Reduces water on surfaces, which prevents icing and hydroplaning.
- Reduces urban heat island effect.

BUSINESS BENEFITS

- Lower maintenance cost following higher cost of installation.
- Saves money on amount of water needed for irrigation.
- Reduces ice and snow buildup, decreasing the need for salting.
- Can have longer lifespan than traditional paving.

RISKS AND CHALLENGES

- Tradeoff between permeability and strength — the more permeable the material is, the weaker it is.
- Can become clogged.
- May not be suitable for colder climates.

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BLUE/GREEN ROOFS

Roof modifications provide opportunities to detain and filter runoff. Green roofs are spaces on top of buildings that are covered in vegetation growing from a substrate. Green roofs can be either intensive or extensive: Intensive green roofs have a thick layer of substrate and a more varied selection of vegetation, while extensive green roofs have a thinner substrate layer and include low-maintenance plants such as moss or sedum. Intensive roofs generally require more maintenance.

Blue roofs contain a system that temporarily detains stormwater using roof dams, roof checks or modular tray systems. Blue roofs are one of the least expensive means to store stormwater but do not remove pollutants, so a combination blue-green roof can remove contaminants while facilitating additional co-benefits such as habitat creation and improved air quality.

COST

- Costs of green roofs differ between intensive and extensive — estimated initial costs are between \$10-\$40/f^{t2} with annual maintenance costs being \$0.75-\$1.50/ft^{2}.
- Considered economically favorable to conventional roofs.

POLLUTANTS TARGETED

- Air pollution.
- Stormwater pollutants.

CO-BENEFITS

- Reduces air pollution.
- Reduces heat island effects.
- Filters and absorbs stormwater runoff.
- Increases flood resilience.
- Mitigates negative effects of climate change.

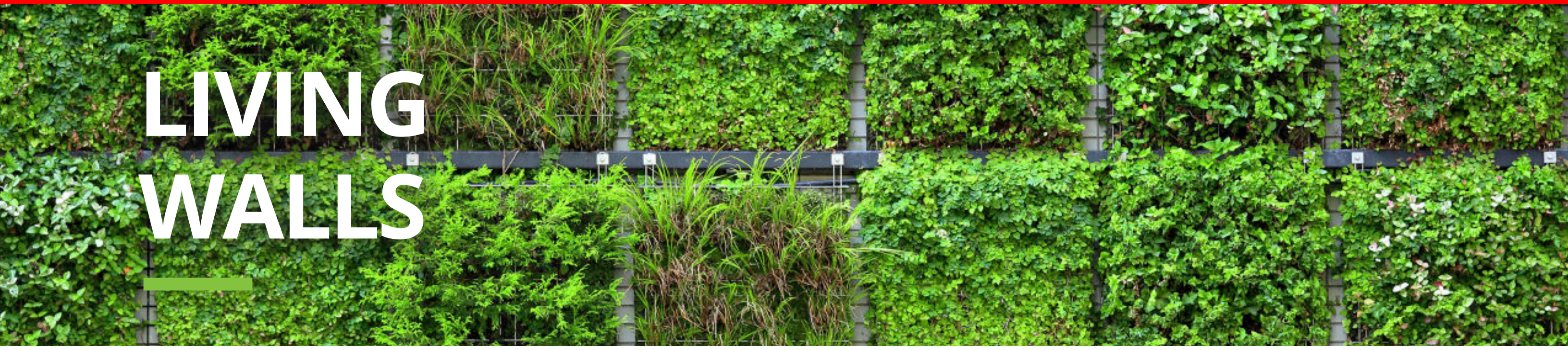
BUSINESS BENEFITS

- Easy to install.
- Least expensive means for storing stormwater.
- Improves energy efficiency by providing thermal insulation.

RISKS AND CHALLENGES

- Requires regular inspection and maintenance.
- Initial cost of a green roof is higher than conventional roofing, but costs are offset by long lifespan and energy savings.
- Structural limitations and risk of damage to the building – insurance is necessary.
- Considerations (types of plants, waterproofing, space, weight, etc.) must be taken into account to protect the roof and ensure success.

TO DECISION TREE



LIVING WALLS

Living walls, also sometimes called green walls, are fully or partially covered with vegetation. These solutions are very versatile and can vary in size, type and vegetation as needed. Living walls typically include planters fixed to the wall from which the plants grow vertically and usually include an automated drip-irrigation system and special substrates that help reduce the weight of the living wall.

Green façades, on the other hand, use climbing plants that are planted directly in the ground or planters on the ground and therefore need no constructed supports. These typically take about 5-20 years to cover a building's façade.

COST

- Varies depending on type — if no construction of a supporting frame is required, the only cost incurred is for the plants and planters. Professionally installed façades start at $400/m^2$.
- Substrate, plants and irrigation in planter boxes can run $100-$150 /m^2, and annual maintenance costs can be between $10-$100.

POLLUTANTS TARGETED

- CO_2.
- NO_2.
- SO_2.
- Particulate matter.

CO-BENEFITS

- Mitigates urban heat island effect.
- Improves thermal and sound insulation for buildings.
- Provides habitat for birds, reptiles and insects.

BUSINESS BENEFITS

- Improves aesthetics of the building, which in turn can influence the economic value of the neighborhood in which it is located.

RISKS AND CHALLENGES

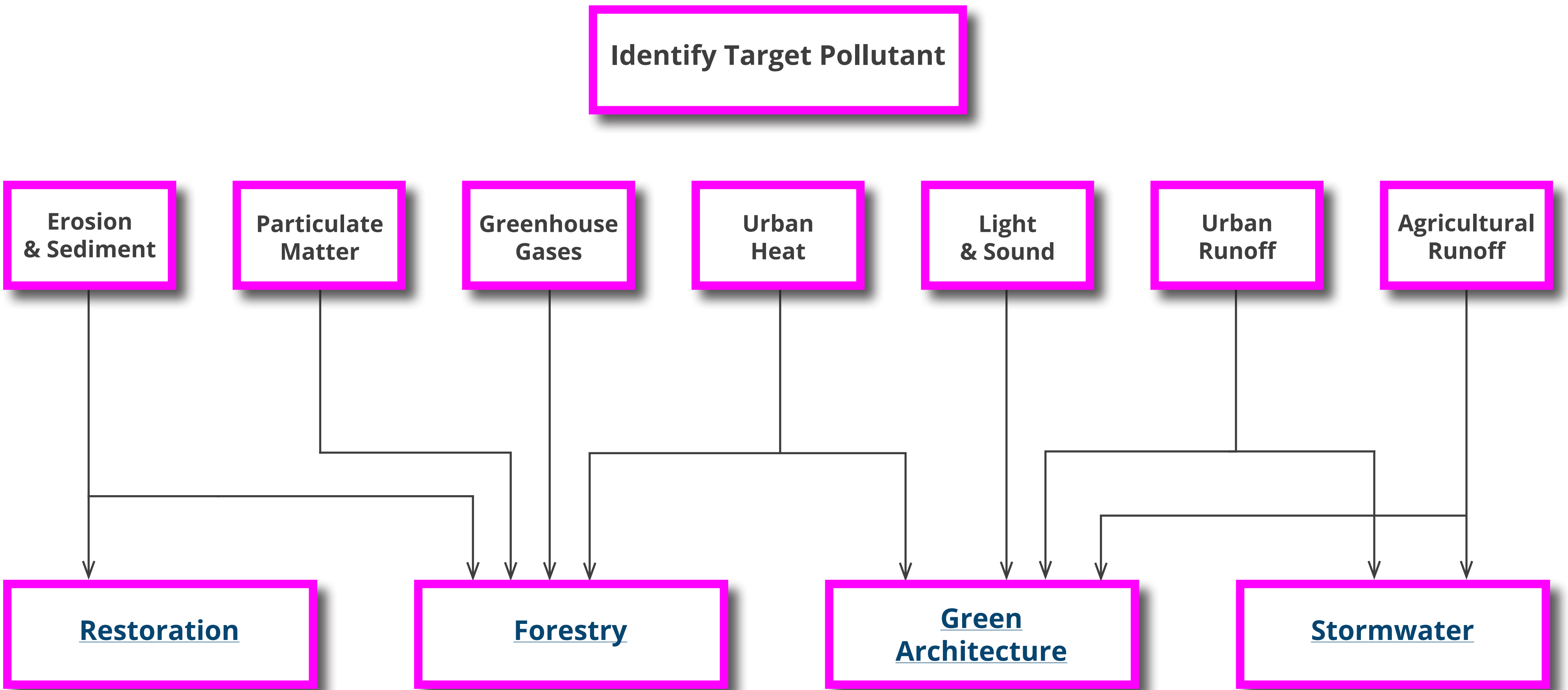
- Climbing plants can impact infrastructure of building.
- Irrigation may be needed if there is a drought. In addition, droughts can bring an increased risk of fire.
- Plants may need to be replaced every five to ten years.

TO DECISION TREE

Decision Tree

There is a lot of information to consider for automotive companies interested in taking a new tactic towards pollution prevention and looking to pursue NbS. A helpful starting point is identifying the target pollutant and then determining which corresponding NbS best fits company- and site-specific needs.

Using the decision tree below, first choose the target pollutant. Then click on the associated category (restoration, forestry, green architecture or stormwater) to learn more about the scoping, selection considerations and maintenance associated with each. Click on each NbS to refer to additional details about it.



Restoration

Project Scoping	Variable size Variable cost Flexible operational phase Long timeline Low risk	Widely varying cost and size Slow implementation Potential high impact High maintenance High risk Flexible operational phase	Size depends on contamination extent Reactive, not preventative Long-term project Expensive
NbS Selection	Grassland restoration Benefits: Habitat creation Stormwater mitigation Co-Benefits: Carbon sequestration Erosion control	Wetland/stream rehabilitation and blue carbon Benefits: Flood mitigation Habitat creation Co-Benefits: Erosion control Carbon sequestration	Phytoremediation Benefits: Improved soil health Erosion control Co-Benefits: Carbon sequestration Stormwater mitigation
Maintenance	Controlled burns Selective use of herbicide Cutting and removing trees and shrubs Removing overgrown grasses and weeds Fertilizing Watering	Cleaning and removing debris after major storm events (>2” rainfall) Harvesting vegetation when 50% reduction in original open water surface area occurs Repairing embankment and side slopes Repairing control structure	Irrigation, fertilization, pest control, pruning and thinning Harvesting and disposing of contaminated plant material Replacing plants lost to removal, disease or damage

Forestry

Project Scoping	Low land availability Short timelines Ideal for PR-related risks/low risks Easily retrofitted to existing operations	Requires significant land Long timeline to significant metric generation Large initial investment Can follow operations or run externally	Sequestration takes place over long time frame Varying land needs Engages many external stakeholders Cost per tree is high Can work in any operational phase	Variable size Flexible operations phase Slow implementation Low maintenance Low risk
NbS Selection	Microforestry Benefits: Urban heat reduction Stormwater mitigation Carbon sequestration Co-Benefits: Habitat creation Air quality increase	Reforestation Benefits: Carbon sequestration Habitat creation Co-Benefits: Erosion control	Urban forestry Benefits: Urban heat island reduction Stormwater mitigation Particulate matter reduction Co-Benefits: Carbon sequestration Community engagement Soil stabilization Erosion control	Vegetative buffers Benefits: Stormwater mitigation Habitat creation Co-Benefits: Air and water quality increase Carbon sequestration
Maintenance	Caretaking required for minimum of 2-3 years for successful establishment Mulching (initial + reapplication) Stake establishment/ replacement Replacing trees that die off Pruning/weeding Pest/disease control Watering	Caretaking required for minimum of 2-3 years for successful establishment Mulching (initial + reapplication) Stake establishment/ replacement Replacing trees that die off Pruning/weeding Pest/disease control Watering	Caretaking required for minimum of 2-3 years for successful establishment Mulching (initial + reapplication) Stake establishment/ replacement Replacing trees that die off Pruning/weeding Watering	Caretaking required for minimum of 2-3 years for successful establishment Mulching (initial + reapplication) Stake establishment/ replacement Replacing trees that die off Pruning/weeding Pest/disease control Watering

Green Architecture

Project Scoping	Variable size Relatively expensive Rapid implementation timeline Low risk Not constrained by operational phase, but best for construction	Variable size Low risk High/immediate impact for heat, low impact for runoff Not constrained by operational phase	Variable size Low risk High/immediate impact for heat, low impact for runoff Not constrained by operational phase	Variable size Flexible operations phase Slow implementation Low maintenance Low risk
NbS Selection	Eco building materials Permeable pavement/ bird-safe glass/ lighting changes Benefits: Cost-effective Energy use reduction Light/sound pollution reduction	Blue/green roof Benefits: Stormwater mitigation Heat island reduction Co-Benefits: Carbon sequestration Habitat creation	Living wall Benefits: Heat reduction/ energy saver Air quality increase Co-Benefits: Habitat creation Aesthetic increase Carbon sequestration	Vegetative buffers Benefits: Stormwater mitigation Habitat creation Co-Benefits: Air and water quality increase Carbon sequestration
Maintenance	Keep sediment or areas with bare soil from draining onto permeable pavement Inspect at least twice a year and remove trash and litter regularly Vacuum porous asphalt or permeable concrete at least twice a year with standard street-cleaning equipment Replace stone between pavers as needed Vacuum pavement for ponding water after rain Glass cleaning/repairs Lighting upkeep/repairs	Watering (frequently during first year) Weeding/pruning Replacing plant loss Fertilizing Structural repairs/ replacements Trash/sediment accumulation removal Remove debris from drainage outlets and outlet screens to prevent clogging Remove debris from secondary drainage Remove excessive buildup of sediment around outlet controls/within storage cells Inspect/repair for leaks	Watering/irrigation (frequently during first year) Pruning/replacing plants Fertilizing Soil fertilization/ replacement Pest/disease prevention Structural repairs/ replacements Lighting upkeep/ replacements	Caretaking required for minimum of 2-3 years for successful establishment Mulching (initial + reapplication) Stake establishment/ replacement Replacing trees that die off Pruning/weeding Pest/disease control Watering

Stormwater

Project Scoping	Variable size Flexible operations phase Slow implementation Low maintenance Low risk	Variable size and cost Can produce immediate impact Either retrofitted or preinstalled	Lower cost and size Faster implementation Smaller impact Low risk Flexible operational phase	Inexpensive Easy to implement Low maintenance Moderate risk (overrun by stormwater)	Typically smaller in size and lower in cost Easy to implement Low maintenance Needs to be in low area	Require larger land area Typically not suitable for urban settings Flexible operational phase Needs drainage
NbS Selection	Vegetative buffers Benefits: Stormwater mitigation Habitat creation Co-Benefits: Air and water quality increase Carbon sequestration	Greywater systems Benefits: Cost-effective Quicker implementation Co-Benefits: Energy use reduction	Naturalized shorelines Benefits: Habitat creation Stormwater mitigation Co-Benefits: Carbon sequestration	Bioswales Benefits: Stormwater management Co-Benefits: Carbon sequestration Particulate matter reduction	Rain gardens Benefits: Rainwater management Co-Benefits: Carbon sequestration Community beautification Pollinator habitat	Wet detention systems Benefits: Stormwater mitigation Co-Benefits: Habitat creation
Maintenance	Caretaking required for minimum of 2-3 years for successful establishment Mulching (initial + reapplication) Stake establishment/ replacement Replacing trees that die off Pruning/weeding Pest/disease control Watering	Pump requires occasional inspection to ensure it is working and there are no blockages Filter cleaning/ replacement Periodically inspect irrigation system and flushing dripline for leaks Recover exposed dripline with mulch Conduct soil and plant health inspections	Mowing Watering (frequently during first year) Fertilizing Debris removal Replanting vegetation Additional sand fill Structural repairs/ replacements	Weeding Watering (frequently during first year) Remove accumulated sediment from inlets, outlets and basin bottom Debris removal Mulching Inspect filter strip/grass channel for erosion and sod as needed Remove road sand buildup	Watering (frequently during first year) Weeding Mulching (initial + reapplication) Replacing/removing dead plant material Pruning	Sediment accumulation inspection/removal Inlet/outlet pipe inspection Debris removal Removal/replacement of dead plant material Bank/bottom erosion inspection and repair Weeding Mowing Watering (frequently during first year)

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EPA

SUPPLIERS PARTNERSHIP FOR THE ENVIRONMENT

WHC can help support a wide spectrum of conservation activities from the design and planning, to the implementation and management of a program. We do so through a framework that connects business drivers, stakeholder and community relations, and ROI to positive environmental and conservation education outcomes. For more information, please contact us at whcconsulting@wildlifehc.org.

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