THE VALUE OF ORGANIC AMENDMENTS FOR KING COUNTY & SEATTLE

2024 ECOSYSTEM SERVICES

King County
Department of
Natural Resources and Parks
Solid Waste Division

Seattle Public Utilities

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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the keystone concept
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INTRODUCTION & CONTEXT:

Overview and How to Use this Assessment

The "Ecosystem Services: The Value of Organic Amendments for King County and Seattle" report was developed by a collaboration of agency stakeholders and the project consulting team to inform policy-makers, decision-makers and staff about:

• The ecosystem service values of the current organic amendment programs (both food/ yard waste compost and biosolids)

• The potential future value and markets for the organic amendments, given potential investments in waste stream processing infrastructure

This report showcases the value of organic amendments in creating healthy soils, which in turn provide a foundation for a healthy economy by supporting the region's natural capital.

• Much like financial capital (e.g. bonds, stocks, savings accounts) and built capital (e.g. roads, bridges, houses), natural capital provides valuable goods and services

• Natural capital is the ecosystems, natural resources, and ecological processes that benefit society. Natural capital includes farms, gardens, rivers and lakes, air, water, habitat, minerals, plants, and animals

•Soil and working landscapes are an important subset of natural capital

Staff and leadership at King County and Seattle can use this report to:

• Inform and justify current and future investments in the region's organic amendments programs to ratepayers

• Improve efficiency and effectiveness of organic amendments programs through enhanced education, and therefore compliance and participation with organics recycling programs

RESOURCES GENERATED BY NATURAL CAPITAL

COMPOST + BIOSOILIDS
when applied to soils

=

healithier soils

cleaner water

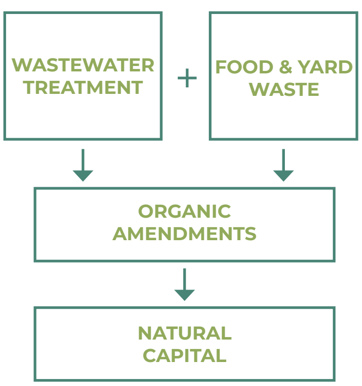
carbon mitigation

CREATING A SOURCE OF NATURAL CAPTIAL

Natural capital produces ecosystem services that contribute to the health, wellbeing, resilience, and prosperity of the region.

EXECUTIVE SUMMARY:

How Waste is Recycled Into Organic Amendments



The “Ecosystem Services: The Value of Organic Amendments for King County and Seattle” report evaluates the ecosystem service benefits of organic amendments application. Organic amendments are natural materials, such as manure, woodchips, biosolids, or food and yard waste compost, that can be added to soils to enhance soil health and productivity. In this report, **the term organic amendments refers to both biosolids and food and yard waste compost**.

Starting in January 2022 and concluding in April 2024, The Keystone Concept, Consor, and Equilibrium Economics project team partnered with staff at King County and Seattle Public Utilities to conduct an ecosystem services assessment. This report estimates the value of ecosystem services produced by organic amendments across King County, Washington.

Every year, Seattle and King County produce approximately 120,000 tons of biosolids and collect over 415,000 tons of food and yard waste

COMPOST GENERATES

\$18.7M TO \$35.8M

IN BENEFITS PER YEAR

BIOSOLIDS GENERATE

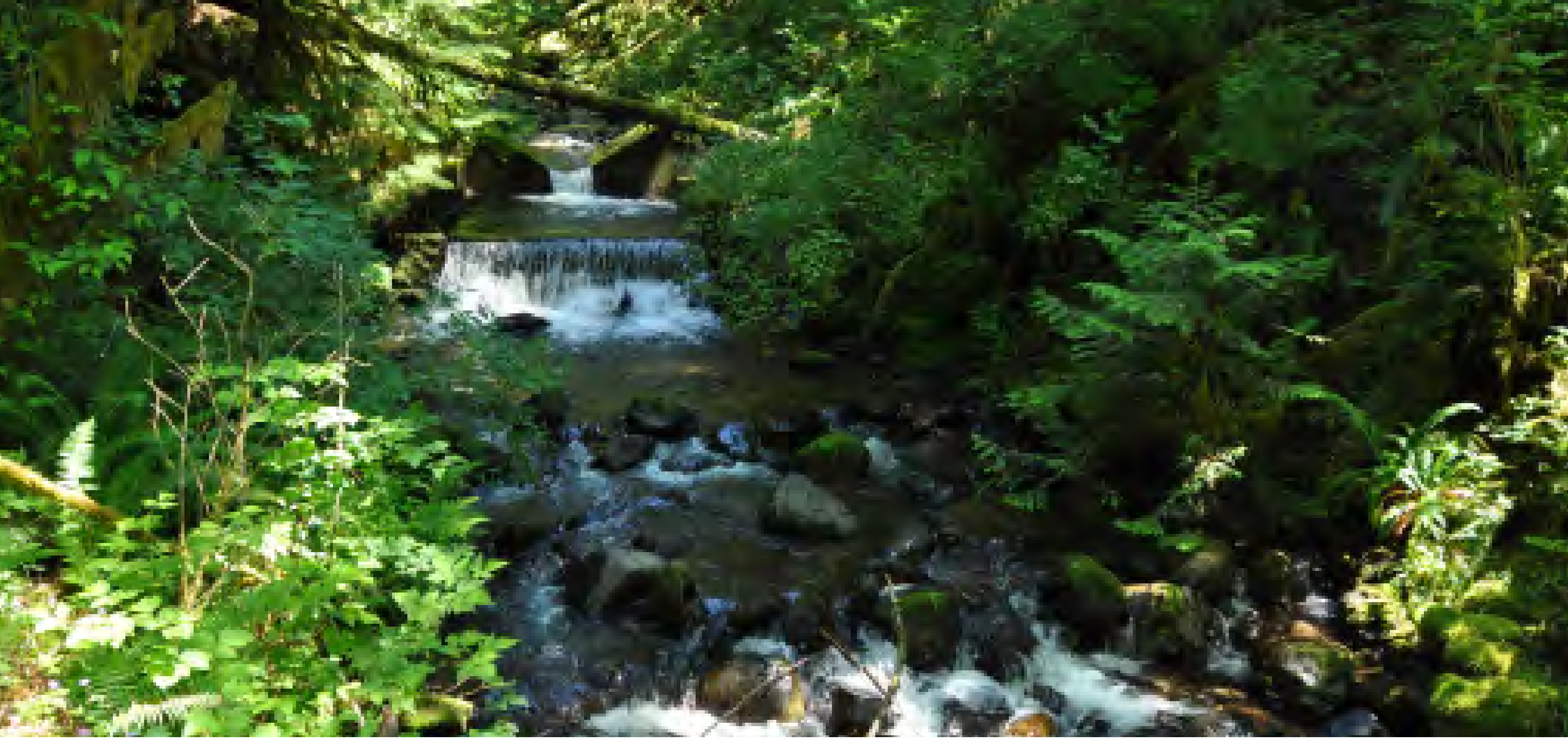
\$5.2M TO \$9.5M

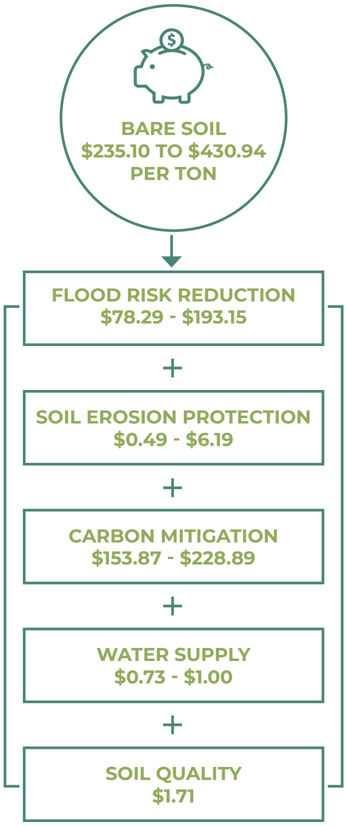
IN BENEFITS PER YEAR

When this organic waste is processed into compost, each ton provides not only the nutrients to grow local foods and support vegetation, but it also provides a suite of ecosystem services (air quality, water quality, carbon mitigation, etc.) when applied to the landscape.

- When applied to bare soil, the compost produced from food and yard waste in King County and Seattle generates between \$18.7 million and \$35.8 million in benefits every year.

- Likewise, every ton of biosolids produced from wastewater treatment also produces similar ecosystem services (restoring soils, sequestering carbon, improving water infiltration and soil water holding capacity). King County’s current biosolids program provides between \$5.2 million and \$9.5 million in ecosystem services benefits every year.





This ecosystem services report of organic amendments is a first of its kind assessment of the value of organic amendments to municipal and county programs. Over the course of this collaborative project we learned that the multiple variables in these programs are complex and the multiple benefits of varied applications of compost and biosolids are also complex; however, **the resulting benefits of diverting organics from the waste stream, and converting that material into soil amendments both to the environment and society are immense, ranging between $24 - $45 million in ecosystem benefits (clean water, healthy soil and carbon mitigation) every year**. This report explores the complexities behind King County and Seattle's organics programs, the myriad of ecosystem benefits provided by the current programs, and additional potential benefits that could be realized with improvements to existing programs. In addition, we explore the impacts these programs have on regional climate action and environmental justice initiatives.

Organic Amendment Ecosystem Service Values in Decision-Making

In addition to quantifying ecosystem services for the organics recycling programs in King County and Seattle, this report also evaluates the potential market opportunities for organic amendments given potential future investments in waste stream processing infrastructure. This report showcases the value that organic amendments provide for the region, which goes far beyond healthy soil conditions.

A Suite of Opportunities

This assessment aligns closely with a suite of King County and Seattle climate action, equity, and strategic planning policy directives, including: King County Re+ Strategic Plan, King County 2020 Strategic Climate Action Plan, King County Clean Water Healthy Habitat Strategic Plan, King County Comprehensive Solid Waste Management Plan, Seattle Climate Action Plan, 2022 Seattle Solid Waste Plan, King County Biosolids Program Strategic Plan, and others. **Through effective communication and collaboration, this assessment can inform and justify future investments in organics recycling programs that will result in more effective, efficient, and sustainable organics recovery programs that build health and climate resilience across King County and Seattle.**

Key strategic opportunities include:

- **Raise awareness about the value that current organic amendment programs within King County and Seattle provide. This will result in enhanced investment in these programs and improved soil amendment use across the region.**

When applied to bare soil, the compost produced from food and yard waste in King County and Seattle generates between $18.7 million and $35.8 million in benefits every year.

When applied to agricultural and forest lands, King County's biosolids program generates between $5.2 to $9.5 million in benefits every year.

- **Invest in the technology and equipment to process current biosolids into consumer products, such as biosolids compost.** This investment will expand opportunities for organic amendment applications for the King County Biosolids Program immensely, entering into the residential marketplace and other commercial applications beyond the current applications on westside forest properties and limited eastern washington dryland agricultural properties.

- **Build community partnerships to increase application of organic amendments in areas of King County with underserved or disproportionally at-risk communities.** Application of organic amendments on currently fallow or abandoned lands has the potential to support a drastic increase in the value of natural capital and improve the health, wellness, and resilience of these communities.

SECTION ONE:

Organic Amendments in King County and Seattle, and a Path Forward Toward Climate Action

Preventing or recovering waste can improve the use of land, water, energy, and other resources beneficial to communities and the economy. Estimates show that 30%-50% of food produced in the United States is lost or wasted (Muth et al., 2019). Recycling organic materials is one way to limit this waste going to a landfill while integrating those waste streams back into the production of food and raw materials. Production of food and raw materials requires many resources including healthy soils, water and/or irrigation, machinery, energy, fertilizers, pesticides, and labor. Recycling food scraps, yard waste, and biosolids into organic amendments can limit the need for fertilizer application, increase soil water retention, improve water quality, and reduce carbon emissions that arise from landfilling and incinerating organic materials.

King County and Seattle have implemented programs to recover organic waste and create valuable organic amendments that improve soil quality, reduce flood risk, lower greenhouse gas (GHG) emissions, and mitigate pollution from runoff using two different types of organic amendments.

- **COMPOST** made from collected yard debris and food waste:
  - Composting is the controlled aerobic decomposition of organic materials, turning materials such as food scraps, food-soiled paper, and yard waste into a nutrient-rich soil amendment.
  - In both King County and Seattle, yard waste, food waste, and approved compostable packaging are diverted from the garbage through a separate collection system, and recycled into compost.
- **BIOSOLIDS** made by treating wastewater solids:
  - In King County, wastewater solids are treated through mesophilic anaerobic digestion. In this process, the solids are separated from the liquids and broken down by beneficial microorganisms to reduce pathogens and create a nutrient-rich organic amendment.

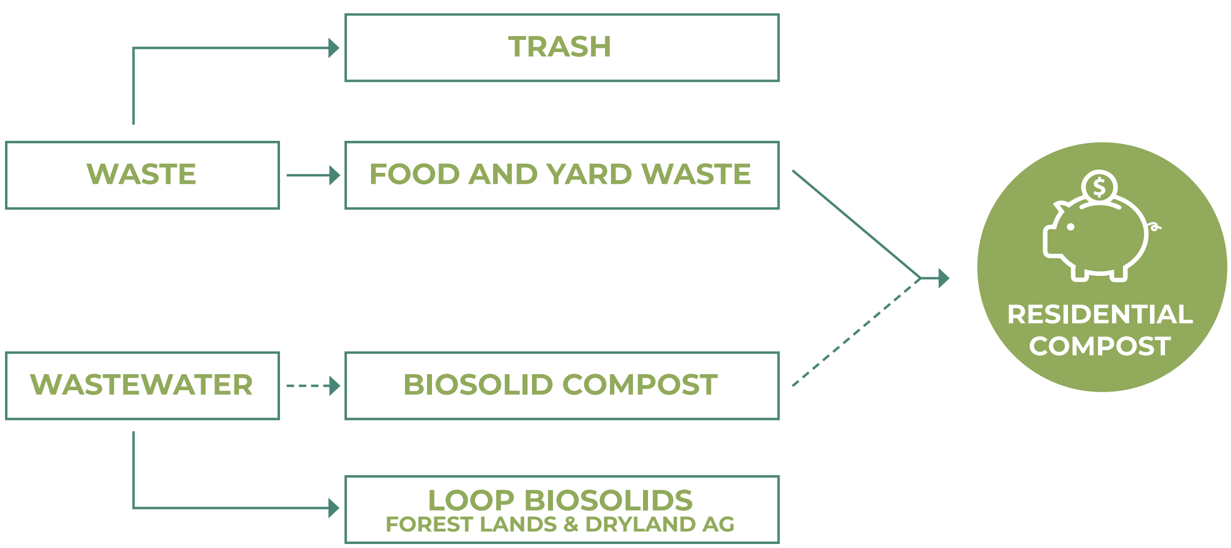
Stormwater runoff is reduced by increasing water infiltration and retention, therefore improving water quality and reducing flood risk.

The result of these organics recycling programs is a solid waste and wastewater management system that has shifted to greater recovery, reuse, and recycling. King County and Seattle have developed programs to facilitate the recycling of organic materials, from both solid waste and wastewater streams, to produce organic amendments that can be applied to forest land, agricultural land, landscapes, and/or residential properties to improve the health and resilience of the soil.

Organic amendments provide a range of benefits, including:

(1) **By increasing water infiltration and retention, stormwater runoff is reduced, therefore improving water quality and reducing flood-risk.** Studies on organic amendments show significant reduction in water runoff. Organic amendment application is an effective tool for reducing soil erosion and detrimental water quality impacts (Bell and Platt, 2014; Brown et al., 2011; Crohn et al., 2011; Faucette et al., 2005). Crohn (2011) found that organic amendment applications on fire- and construction-damaged soils reduced runoff volumes, on average, by 80 percent. Sediment and nutrients, that would otherwise be discharged into local waterways, can be retained using organic amendments. Improving soil quality provides other benefits on the landscape where organic amendments are applied.

(2) **Organic amendments applied to agricultural lands have been shown to increase soil organic carbon, total nitrogen content, and microbial biomass** (Bell and Platt, 2014; Brown et al., 2011; de Araújo et al., 2010). These are critical indicators of soil health and increases often lead to higher yields on farm products while reducing the need for fertilizers and other inorganic inputs, which increase the risk of pollution from stormwater runoff and/or leaching to groundwater. Reducing stormwater runoff, as mentioned above, can reduce the impacts of flooding, lower pollution into surface and groundwater sources, and lower water treatment costs. By applying organic amendments, farmers, foresters, landscape managers, and gardeners can have better success with fewer inorganic inputs that can pollute local surface and groundwater sources. This benefits the local jurisdictions where organic amendments are applied by reducing burdens on existing stormwater and water treatment systems. The increase in water retention has the added benefit of making soils more drought tolerant. As the US continues to be impacted by wildfires, droughts, and floods, organic amendments can be effective tools for curbing the impacts of these challenging issues.



**Solid line indicates current programs, dashed line indicates potential programs

History and Current Approaches for King County & Seattle Organics Recycling Programs

Organics recycling is the process of separating organic waste from conventional waste streams (i.e., disposal, burial, incineration, and/or landfill of garbage) and processing those materials into valuable compost products. Waste management companies and public utilities have increased efforts to properly recycle organic materials (food scraps, yard waste, food soiled paper, compostable food service ware, and other recoverable organic materials) to reduce the environmental impacts on landfilling these materials and create products that can be used as a soil amendment to improve soil and landscape health. King County and Seattle have increased composting efforts to reduce the amount of organic materials entering the landfill while creating valuable products that can be used by residents, businesses, developers, landscapers, farmers, foresters, and landscape managers.

This section provides an introduction into the current organics recycling systems at King County and Seattle with a historical context for how these programs evolved. At the conclusion of this section, we will understand:

(1) the robust and progressive programs that currently exist

(2) the opportunities to improve efficiency and enhance the current operations at both King County and Seattle

Enhanced programs will result in improved reduction of waste and more strategic use of organic amendments across the landscape to build soil health and the resulting natural capital of the region.

Solid Waste in Seattle

Seattle Public Utilities (SPU), a City of Seattle Department, provides essential drinking water, drainage and wastewater, and solid waste services to more than 1.5 million people in the greater Seattle area. About 1,400 SPU employees work with the community to provide affordable and equitable stewardship of the region's water and waste resources for future generations. Until 1988, Seattle prepared its solid waste plan as part of the King County plan. In 1989, Seattle started planning for its own solid waste management through regular planning efforts that informed program development and implementation for the next ten years. In 1998, Seattle's Solid Waste Management Plan, "On the Path to Sustainability", established a progressive path forward for the program. SPU is now working from the most recent "2022 Solid Waste Plan Update: Moving Upstream to Zero Waste."

While the City of Seattle develops an independent solid waste management plan, SPU collaborates with King County on several programs, including the LinkUp and CompostWise to support market and infrastructure development. In addition, SPU's wastewater system collects and conveys sewage and a portion of the City's stormwater to King County's regional wastewater treatment system. One major difference between King County and Seattle is Seattle Municipal Code (SMC) sections 21.36.082 and 21.36.083 prohibits residents and businesses from putting food scraps, compostable paper, yard waste, and recyclables in the garbage; these municipal codes ensure that no matter where someone is in the city (schools, homes, places of businesses, special events), they are required to sort waste properly into the recycling, compost, and garbage collection streams.

The SPU 2021-2026 Strategic Business Plan established a vision as a **Community Centered, One Water, Zero Waste utility.**

> **Community-centered** = SPU understands that improving current water and waste recycling requires active participation from residents and businesses. SPU strives to center community priorities and needs in service delivery and program development to support all recycling efforts; together, in a partnership with residents and businesses, SPU is focused on doing better to serve all of Seattle's neighborhoods, residences and businesses equitably
>
> **One water** = SPU seeks to manage water at all stages of the process through conservation, capture, restoration, and reuse. The goal is to ensure that water, both fresh and wastewater, are protected and managed in an integrated and sustainable way so that all people and species have access to healthy waters.
>
> **Zero waste** is the effort to protect human health and the environment by eliminating waste, preventing pollution, encouraging product durability and reusability, conserving natural resources, and ultimately building a circular and inclusive economy.

The 2022 Solid Waste Plan Update focuses on a zero-waste vision which prioritizes waste prevention, reducing impacts to human health and the environment, and a commitment to ensuring that resources with value stay out of the landfill: recommends 39 actions for innovation in solid waste management; increases emphasis on minimizing waste by considering life cycle of materials from natural resource extraction to final disposal.

Seattle Public Utilities (SPU) manages collection and processing of recycling, food and yard waste, and residential and commercial garbage: in 2020 SPU solid waste handled more than 700,000 tons of recycling, compost and garbage generated by residents and workers (SPU, 2022); construction and demo projects generated another 560,000 tons. Seattle currently: contracts with Waste Management and Recology for collection and hauling of garbage, recycling and organics; transports organic waste to Cedar Grove (processes approx. 30%) and Lenz Enterprises (approx. 70%) for composting contracts. Seattle owns and operates two transfer stations, two household hazardous waste collection facilities, a fleet of trucks and heavy equipment, and several closed landfills. Along with waste handling and disposal activities, Seattle engages its customers in environmental sustainability programs and policies that promote waste prevention, recycling, and composting. Seattle also works to keep the city clean by targeting illegal dumping, supporting community cleanups, and providing public litter and recycling cans across Seattle.

1989

Integrated Solid Waste Management Plan established the first separate solid waste management plan for Seattle

2007

Seattle Resolution 30990 – Zero Waste Resolution is adopted by Seattle Mayor and Council

2009

Seattle begins accepting all food waste with yard waste collection

2011

Seattle required food and yard waste collection services for multi-family and commercial customers in addition to single family

2015

Organics were banned from the garbage in Seattle

TODAY

Seattle / Seattle Public Utilities currently collects over 700,000 tons of waste per year, of which over half of all materials are recycled or composted

Solid Waste in King County

King County's solid waste programs are guided by a myriad of management plans, data collection, and survey reports. The current program includes 37 of 39 cities in the county (excluding the cities of Seattle and Milton) and the unincorporated areas of King County.

First published in 2001, the King County Comprehensive Solid Waste Management Plan provides a roadmap for solid waste management throughout the county and establishes the process for facilitating collection, disposal, and recycling of solid waste. In accordance with RCW 81.77.020 and RCW 36.58.040, the State of Washington and cities share the responsibility of regulating collection of solid waste and recyclables; counties are prohibited from providing curbside garbage collection services. Washington manages collection services through the Washington Utilities and Transportation Commission (UTC). The UTC establishes service areas and rates, requiring compliance with existing solid waste management plans. The State established a framework for solid waste planning, authorizing counties to prepare coordinated Comprehensive Solid Waste Management Plans in cooperation with the cities within their borders. All cities within King County, except for Seattle and Milton, have chosen to participate in the development of a single, coordinated regional plan for the incorporated and unincorporated areas of King County. These cities enter interlocal agreements (ILAs) with the county that established the Solid Waste Division (SWD) as the lead planning agency.

Within the King County service area, 4 private sector companies provide the majority of garbage, recyclables, and organics collection: Recology CleanScapes, Inc.; Republic Services, Inc. (formerly Allied Waste, Inc.); Waste Connections, Inc.; and Waste Management, Inc. 28 of the 37 municipalities within the King County service area contract directly with one or more of these companies. 2 cities – Enumclaw and Skykomish – provide municipal collection services within their own jurisdictions. Enumclaw collects garbage, recyclables, and organics; Skykomish collects only garbage. The remaining 7 cities that do not opt to manage a direct hauler contract or provide their own collection are serviced by haulers designated to their area by the UTC, along with unincorporated areas.

King County has a variety of programs, aligned under the umbrella of the county's Comprehensive Solid Waste Management Plan and the Re+ Strategic plan:

- King County's 2019 Comprehensive Solid Waste Management Plan sets out a goal to eliminate the disposal of materials with economic value by 2030 with an interim goal of 70% recycling through a combination of efforts, including waste prevention and reuse, product stewardship, recycling and composting, and beneficial use.

- The Re+ Strategic Plan, released in 2023, is a community-focused, systems-level approach to creating a more circular economy. This plan plays a key role in re-imaging King County's regional solid waste system from one that is disposal-based to one that is focused on reduction, recovery, recycling, and regeneration. The Re+ approach encompasses a series of actions that keep materials with economic value in use and out of the landfill, and creates an equitable system that centers on community needs. To achieve King County's goal of zero waste of resources by 2030 (KCC 10.14.020), the County will continue to participate in efforts to pass statewide policies that help keep organics out of the landfill as well as serve as a leader in the implementation of the Washington State 2022 Organics Management Law (HB 1799) and the 2024 Organics Management Law (HB 2301). The Organics Management Law has the potential to divert approximately 110,000 tons of organics per year away from the landfill within King County and its 2024 counterpart, which would result in a GHG emissions reduction of 67,500 MTCO2e (metric ton of CO2 equivalent) or the equivalent of removing 13,000 gas-powered cars from roads for a year.

- The King County LinkUp program seeks to expand markets for recyclable and reusable materials. LinkUp is dedicated to increasing demand for recycled and reuse materials, creating conditions for secondary material markets, incentivizing investment in additional infrastructure, and ensuring equitable distribution of services. The LinkUp program identifies focus materials and dedicates time to improving the collection and processing of those materials. Current focus materials include paper, plastics, and organics. While paper and plastics are critical aspects of the LinkUp program, this Organic Amendments Report focuses strictly on the organics component. Organic materials make up more than 35% of disposed material at the Cedar Hill Regional Landfill. Increasing capacity and participation in composting can reduce the amount being disposed of in the landfill and support a regional circular economy through the identification of regional markets for compost (King County Organics Market Development Plan, 2019).

- CompostWise is King County's educational program that informs procurement and application of compost for regional public agencies. The program includes a detailed guide on the common uses and benefits of compost, compost and topsoil product selection, how to calculate compost or soil mix need, the contracting process for purchasing and applying compost, and how application can help public entities meet environmental goals.

1989

King County Solid Waste Code (KCC 10.18.010)

2001

King County Solid Waste Division (SWD) begins working with cities and waste collection companies to implement curbside collection of food scraps and food-soiled paper

2007

King County Code 10.14.20 for Zero Waste of Resources (KCC 10.14.20)

2017

King County SWD accepts solid waste for disposal at County Facilities - Waste Acceptance Rule

2019

Cascadia Consulting Group conducts Regional Organic Materials Management Assessment

Biosolids in King County

King County's Biosolids Program (Loop) plays a key role in the County's future sustainability and its progress toward reducing carbon emissions. Loop is a nutrient-rich organic fertilizer alternative and natural soil builder produced from King County's wastewater treatment process. King County's program is the longest running biosolids program in the state of Washington. King County manages this product from the wastewater treatment plants to the farmland and forest floors where Loop is applied. The product is actively managed to ensure beneficial use. While the product is currently only available for agriculture and forestry purposes, changes to the existing program could expand the uses available for the product and ensure greater adoption from other potential users. To this end, in 2012, the King County Biosolids Program developed a four-year biosolids plan to expand its existing customer base and guide the county's Wastewater Treatment Division (WTD) through changes in the soil amendment industry. In the 2012 to 2016 plan, WTD committed to continue using 100 percent of its Loop biosolids as an organic amendment, expanding its marketing and customer base, and supporting ongoing biosolids research. Although WTD consistently uses 100 percent of its Loop biosolids and supports biosolids research, expanding its customer base remains a challenge. In the WTD's 2018 to 2037 Biosolids Program Strategic Plan, WTD is committed to producing a King County-owned biosolids compost by 2024 and expanding the market for its Biosolids Program. This would diversify the market and increase WTD's adaptive capacity to use 100 percent of its biosolids consistently and beneficially.

1958
Voters created Metro – The Wastewater Treatment Utility

1972
The Clean Water Act was passed

1973
First land application of biosolids on forest lands

1978
King County began partnership with GroCo Inc. to create GroCo Compost made with biosolids and sawdust from local mills

1984
First full year of 100% beneficial use of biosolids county-wide

1987
Began application of biosolids on the Weyerhaeuser Tree Farm in Snoqualmie, WA

1991
Public-private partnership with Boulder Park, Inc was established

1992
Washington State Legislature established the state's biosolids program, designating biosolids as a "beneficial commodity" and requiring its beneficial use

1992
US Environmental Protection Agency (EPA) finalized Title 40 of the Code of Federal Regulations, Part 503 "The Standard for Use or Disposal of Sewage Sludge" to regulate biosolids application

1999
King County Council adopts Regional Wastewater Services Plan and biosolids beneficial use policies

2005
First of many Class A Technology Assessments conducted

2011
King County Biosolids are branded as Loop®

2018
Developed 2018-2037 Biosolids Strategic Plan

2020
Long-time private sector compost partner, GroCo Inc. closed their business and operations ceased.

Challenges to organic waste management

While the organic waste management programs in King County and Seattle are nationally recognized as some of the most effective and successful programs in the United States, staff recognize there are still challenges to reach maximum effective utilization of organic amendments in the region. We have identified three major challenges to organic waste management in King County and Seattle. Addressing these challenges will greatly improve organic waste management in King County and Seattle.

1) Organic Waste Recovery & Contamination – Not all organic waste generated in the region is recovered for processing. Currently over 50% of food waste generated by residents and businesses throughout Seattle are disposed of in the landfill and of the food and yard waste that is recovered for composting, contamination with plastics and non-compostable items continues to be an issue.

2) Limited Processing Capacity – King County and Seattle currently contract with private sector companies to process collected organics into compost. Currently, there are a limited number of facilities and limited capacity to support complete utilization of organic waste. Even if all the organic materials generated were recovered for processing, the current capacity may not be adequate (Cascadia Consulting Group, 2020). To effectively scale-up recovery and processing, processing capacity will need to be further investigated for the region.

3) Limitations for Biosolids Application – King County currently applies biosolids to large-scale commercial applications in forestlands of western Washington and dryland agricultural lands in eastern Washington. If King County was able to produce a biosolid compost, it would expand opportunities for application in multiple markets including residential application.

Organic Waste Recovery & Contamination

Organic waste recovery and contamination are significant challenges to more effective processing of the waste stream. In 2019, the King County SWD contracted with Cascadia Consulting Group to produce a report, "King County LinkUp: Organic Materials Management in King County." This report provides an assessment of regional and county-specific data and markets for disposal and recovery of organic materials. It includes data by sector, the organics disposal and recovery analysis methodology, and compost use best practices literature. This assessment outlines the generation and recovery of organic materials as well as the challenges of dealing with contamination in the waste stream (a significant concern impacting compost markets). Cascadia Consulting Group found that organics contamination was nearly 5 percent of the organics waste stream. Composters reported that the most common, problematic, and persistent types of contaminants are plastic film (non-compostable), rigid plastics (non-compostable), and glass (ibid). This can lead to inefficiencies, reduced processing capacity, limitations on available markets for the finished product, and a portion of this contamination ends up on the landscape as litter. Developing a high-quality finished product is critical to meeting market demand for compost. Reducing and targeting the major contaminants would improve the current system. King County's "2022 Waste Characterization and Customer Survey Report" found that 26% of the county's overall garbage stream is compostable organic waste. In addition to King County's many programs encouraging organic waste reduction and management, King County SWD continues to explore additional programs and policies to further divert compostable materials from the landfill.

Seattle's "2021-2022 Residential and Commercial Organics Composition Study" reported an average contamination concentration of 2.1%, with top contaminants being: potentially compostable paper, other nonrecoverable waste, pet waste, non-compostable film, recyclable plastic containers and polycoated paper. While Seattle contamination rate is lower than that reported for King County, contamination is the prominent problem for the composters processing Seattle's collected organics. The 2020 Residential Garbage and Recycling Stream Composition Study found that on average 30% of the garbage stream is compostable waste. Despite a ban prohibiting organics from the garbage, a significant portion of the food waste generated from Seattle residents is still going to the garbage for landfilling

Limited Processing Capacity

The 2019 King County Link-Up: Organic Materials Management in King County report conducted by Cascadia Consulting Group identified the composition of materials disposed of at the Cedar Hills Landfill and highlighted the amount that could be recovered through organic amendment processing programs. It has been identified that with increased collection of organic materials for recovery, the region already utilizes 85% of capacity as of 2019 (Cascadia Consulting Group, 2019), meaning that increased development of processing facilities and expanding current capacity would be required to meet the existing supply of organic materials. It's important to note that organic amendment processing facilities have added 75,000 tons of capacity to the region since the 2019 study was conducted. King County continues to investigate the region's processing capacity as collection of organic material increases in the coming years due to statewide organics legislation.

Limitations for Biosolids Application

For King County, Loop is certified as Class B biosolids. Biosolids are classified as Class A or Class B based on the level of pathogen reduction. Class A biosolids are treated to eliminate pathogens completely and can be used in landscaping and home gardens. Class B biosolids are treated to significantly reduce, but not eliminate, pathogens. Therefore, use of Class B biosolids requires application site permits which include public access and crop harvest restrictions to allow for die-off of pathogens to non-detectable levels after application.

All of Loop is land applied every year on forestlands and agricultural lands within the state. While these applications on a commercial scale are a quality use of the material, they are limited to commercial consumers as a Class B product. Appendix E of this report evaluates the substantial increase in market opportunities that could be realized, if King County invested in the technology and processes to create a Class A product, such as biosolids compost, resulting in expanded opportunities into the residential marketplace.

Best Practices in Organic Amendment Programs

There are several jurisdictions in the Pacific Northwest and along the West Coast which have enhanced collection, capture, and recovery of reusable and recyclable materials. These programs provide lessons learned and examples of potential enhancements that could be made to King County and Seattle programs to improve the resilience of their current programs.

1) The City of Tacoma, WA maintains their TAGRO ("Tacoma Grow") product, Class A biosolids processed into soil blends for residential and commercial use. The biosolids are processed via a dual digestion process at the Central Wastewater Treatment Plant which serves the City of Tacoma and roughly 20,000 customers in Fife, Fircrest, and unincorporated Pierce County. The city produces three products: a TAGRO Mix containing 50% biosolids, 25% screened sand, and 25% sawdust; TAGRO Topsoil containing equal parts biosolids, sawdust, screened sand, and bark; and TAGRO Potting Soil composed of 20% biosolids, 20% sawdust, and 60% screened bark. Tacoma has provided TAGRO Mix since 1991, and 100% of all biosolids produced from the treatment plant are recycled and turned into TAGRO gardening products. Tacoma has won awards from the EPA for the best biosolids recycling program in the country.

2) San Francisco, CA, was the first city in the US to establish a citywide food waste composting program in 1996. Since 2012, the city has captured and processed 80% of its solid waste through compost and recycling efforts. Recology, the city's refuse hauler, collects and recycles yard trimmings and food scraps through processing facilities in Vacaville and Vernalis, CA. Recology produces compost, soil blends, and a variety of mulches serving farms, construction companies, and residents throughout the state. The compost is certified by the Organic Materials Review Institute for use in organic operations and the Seal of Testing Assurance Program through the US Composting Council. Similarly, Portland composts roughly 70% of its green waste. Starting in 2005, the City of Portland, OR, developed the Portland Composts! Program which requires all garbage and recycling companies to offer compost collection to businesses that request the service. These organic materials are processed at Recology Organics in Washington County and Republic Services near Corvallis.

3) City of Seattle, WA established programs to teach and promote composting in 1985, initially with onsite/backyard composting. Soon thereafter, in 1989, the city banned yard waste from the garbage and began a curbside collection for both recycling and yard waste composting. In 2005 the city expanded the curbside collection of organics to include both food and yard waste, and eventually banned the disposal of food waste in the garbage in 2015. Through these and other related programs and policies, the city has been able to capture and process over 50% of its waste through recycling and composting. The City's 2018 Home Organics Waste Management Survey Report indicated that 91% of respondents are composting their food waste and over 98% of respondents are composting their yard waste either on site or through curbside collection. Despite high participation rates and a ban on organics from entering the garbage, the City still finds significant amounts of food waste and recyclables in the garbage (2020 Residential Garbage and Recycling Stream Composition Study). Seattle is now striving for zero waste by expanding the traditional emphasis on recycling and composting and looking upstream to reduce and prevent waste from happening in the first place. As part of the emphasis on waste prevention, Seattle is working to address the root causes of waste, including food waste, to reduce impacts on environmental and human health . Seattle is also working to build and support existing compost markets to ensure a circular organics economy.

Looking Ahead – Improvements to Solid Waste Management = Strategic Climate Action

The solid waste management plans developed by both King County and Seattle align with current and future climate action planning and strategic business goals across jurisdictions. Efforts to reduce waste and increase the production of organic amendments can reduce economic, social, and environmental costs across the region. **By aligning solid waste management goals with climate and business objectives, the agencies can better collaborate with residents, businesses and stakeholders to ensure a more sustainable and resilient economy.**

The King County 2020 Strategic Climate Action Plan (SCAP) sets out three focus areas: (1) Reduce Greenhouse Gas (GHG) emissions; Build and support sustainable and resilient frontline communities; (3) Prepare for climate change. The zero waste strategies implemented by King County and Seattle address these three focus areas, which all represent important progress toward mitigating the impacts of climate change. The following strategic goals and performance measures can all be supported through improved organics management, including:

- Strategy GHG 5.1 specifically targets waste prevention, including food waste prevention throughout King County cities and other stakeholders. Strategies 5.3.1 and 5.3.2 set out a goal to reach a 70% recycling rate for materials collected in its solid waste service area and for the Solid Waste Management Advisory Committee to partner with cities to focus on waste prevention and reuse, extended producer responsibility, recycling, and composting, and beneficial use of solid waste. Performance Measure GHG 26 maintains a target of Zero Waste of Resources (KCC 10.14.020) that has economic value for reuse or recycling.

- 72% of materials disposed of at the Cedar Hills Regional Landfill in 2019 were readily recyclable or reusable. By reaching the 2030 zero waste target, it is estimated that King County would reduce emissions by approximately 946,000 MTCO2e annually. Performance measure GHG 27 sets a target of zero food waste disposed of in the Cedar Hills Landfill.

- In 2019, residents, businesses, and institutions in King County threw away over 136,000 tons of food waste. While this represents a 20% reduction in food waste since 2015, composting this food waste would result in GHG emissions reduction of 97,000 MTCO2e. The benefits of compost use can be quantified to further justify compost procurement by public and private sector stakeholders. King County already uses a lens of climate change as a way to show the benefits of using Loop biosolids, estimating that they offset the majority of GHG emissions from WTD operations.

- Silver et al. (2018) produced a report for California's Fourth Climate Change Assessment showing that compost amendments had a noticeable effect on soil carbon stocks after a single growing season. Compost application resulted in net GHG emissions reduction compared to landfilling, anaerobic digestion, or incineration for energy. Showing the link between organic amendment production and current climate action goals can further incentivize the necessary investment in collection and processing to make a significant impact in GHG reduction goals.

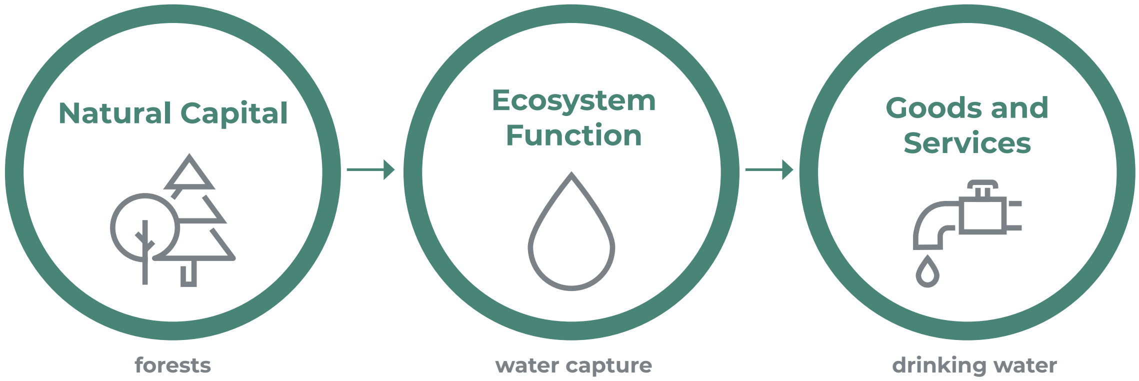
- Strategies 6.2 - 6.5 communicate the value of organic amendments for sustainable agriculture and forestry practices on lands across the county. By exploring enhancements to the composting programs and implementing these enhancements, the county will provide leadership and education to assist residents and farmers across the county to implement these practices.

SECTION TWO:

Ecosystem Goods and Services Framework

Ecosystem services are the benefits that people derive from nature. Healthy soil and landscapes provide a foundation for a healthy economy. Natural capital and the ecosystem goods and services they produce are essential to economic development and quality of life. Ecosystem goods and services (referred to henceforth as ecosystem services) provided by healthy soils are diverse and valuable, and amending soils in developed and disturbed landscapes can help soils recover those benefits. The use of organic amendments is a key tool to restoring once healthy soils, allowing them to support vegetation and healthy landscapes.

Soil is essential to all landscapes, for agriculture, wildlife, carbon sequestration, disaster risk reduction, stormwater management, and more. The analysis throughout this report provides useful concepts for understanding the benefits of expanding organic amendment programs. It is in everyone's interest to improve soil fertility, soil carbon content, and soil health. These improve natural, urban, and agricultural landscapes and the value they produce. Below is a simplified illustration of how forests (natural capital) produces an ecosystem function (water capture) which in-turn produces goods and services (drinking water).



The ecosystem service framework is recognized in federal policy. The US Federal Emergency Management Agency (FEMA), among other U.S. federal agencies, has incorporated these values into disaster risk planning and mitigation efforts with a series of policies (FEMA, 2020a, 2016, 2013). Having found the inclusion of ecosystem services highly effective for saving taxpayer money and reducing the cost of repetitive disasters, FEMA created ecosystem services measuring policies to flood, hurricane protection, fire, drought, and landslide mitigation (FEMA, 2016).

Often underappreciated or aggregated into larger system evaluations, measuring ecosystem service benefits of soils can help land managers, policy makers, and the public understand the opportunities to improve soil health, which in-turn supports vegetation that cleans the air and water, produces shade (reducing urban heat), and improves wildlife habitat and overall quality of life in urban areas. This section outlines a structure under which the ecosystem services can be identified and measured.

Exploring Ecosystem Services

Clean air, clean water, healthy soils, healthy food, flood risk reduction, timber, and a stable climate are all examples of ecosystem services. Without natural capital (forests, wetlands, rangelands, farmlands, and the soils that support them), we would not have the benefit of nature's goods and services which are the basis of economic activity. Forests, agricultural lands, and rangelands are critical natural capital that can produce goods and services into the indefinite future and are worth the investment of proper management and stewardship.

Soil directly provides the nutrients and foundation for all plant growth, controls nutrients and water cycles, and holds substantial amounts of carbon, is capable of degrading waste and detoxifying compounds, and provides habitat for diverse microorganisms and fauna. Healthy soil is the underpinning of robust benefits provided by numerous ecosystems services. In depleted soil, organic amendments like compost and biosolids help restore soil to provide these myriad of benefits once again.

In 2012, a Soil Science Society of America (SSSA) task force convened to define and value ecosystem services derived from soil for the benefit of scientists, elected officials, and practitioners with the hope that a better understanding of soil ecosystem services will result in informed decisions in the use of soils (Comerford et al. 2013). Much of the literature on ecosystem service benefits of natural systems focuses on above-ground vegetation, such as wetlands, forests, and grasslands. Soil ecosystems are often secondary to the vegetation it supports (ibid). **This Report focuses on the benefits provided by healthy soil, specifically the benefits provided by application of organic amendments to improve soil quality. By adapting the SSSA task force ecosystem service framework, this report classifies ecosystem services into four broad categories according to how they benefit humans:**

- **Provisioning goods** provide physical materials and energy for society from natural systems. Soil is used in construction, real estate development, landscaping, product development, fuel, industrial processes, and growing food and medicinal products.
- **Regulating services** are benefits obtained from the natural control of ecosystem processes. Intact ecosystems keep disease organisms in check, improve water quality, control soil erosion reduce disaster damage, and regulate climate.
- **Supporting services** include primary productivity (natural plant growth) and nutrient cycling (e.g., nitrogen, phosphorus, and carbon cycles). These services are the basis of the vast majority of food webs and life on the planet.
- **Information services** are functions that allow humans to interact meaningfully with nature. These services include providing spiritually significant species and natural areas, natural places for recreation, and opportunities for scientific research and education.

Each category above can be defined by several ecosystem services, and contributions that soil ecosystems make to human well-being. Table 1 identifies the ecosystem services valued using this approach.

Table 1: **bolded indicates this service was analyzed in the report

Service	Ecosystem Service Description for Healthy Soils
Provisioning	
Energy and Raw Materials	Extracting and amending for use in development, product processing and production, etc.
Food	Supporting crops and other vegetation for food
Medicinal Resources	Supporting crops, vegetation, and soil organisms for use and extraction
Ornamental Resources	Providing resources for clothing, jewelry, handicraft, worship, and decoration
****Water Storage**	**Providing long-term reserves of usable water**
Regulating	
Air Quality	Providing clean, breathable air via dust and erosion mitigation
Biological Control	Providing pest, weed, and disease control
****Carbon Sequestration & Stock**	**Supporting a stable climate at global and local levels through carbon sequestration.**
****Disaster Risk Reduction**	**Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts.**
Pollination & Seed Dispersal	Pollinating wild and domestic plant species via wind, insects, birds, or other animals
***Soil Quality and Formation**	**Maintaining soil fertility and capacity to process waste inputs (bioremediation)**
****Soil Erosion Protection**	**Retaining arable land, slope stability, and coastal integrity.**
****Water Quality**	**Removing water pollutants via soil filtration and transformation by vegetation and microbial communities.**
Temperature Regulation	Supporting vegetation by providing shade that can reduce local temperatures and provide energy savings
Supporting	
Habitat	Providing shelter, promoting growth of species, and maintaining biological diversity.
Nutrient Cycling	Movement of nutrients through an ecosystem by biotic and abiotic processes. Supports retention in the biosphere and the soil organic layer
Information	
Aesthetic Value	Enjoying and appreciating the scenery, sounds, and smells of nature.
Cultural Value	Providing opportunities for communities to use lands with spiritual, religious, and historic importance
Science & Education	Using natural systems for education and scientific research
Recreation & Tourism	Experiencing the natural world and enjoying outdoor activities.
Artistic Inspiration	Using nature as motifs in art, film, folklore, books, cultural symbols, architecture, and media

Measuring the Benefits provided by Soil Ecosystems

The benefits of ecosystem services can be valued using multiple techniques. In this study, a combination of two approaches is used: (1) Benefit Transfer Methodology (BTM); and (2) Function Transfer Methodology (FTM).

1. Like house or business appraisals, BTM calculates the economic value of ecological goods and services by using economic data and transferring quantitative estimates, like monetary values, from the existing literature (often referred to as the study site or sites) to the area currently being examined or area of interest (often referred to as the policy site). Economists often refer to the degree of similarity between the study site and policy site as correspondence. The greater the degree of correspondence, the lower uncertainty and error in transfer of economic values. As in a house or business appraisal, BTM accounts for the value of various attributes (number of rooms in a house, or different assets in a business) and establishes the value based on closely related comparable valuations. BTM is only implemented in the ROI model for Class A biosolids investment, discussed in more detail below.

2. FTM uses a value function estimated for an individual study site (e.g., existing literature) in conjunction with information on policy site (e.g., area of interest) characteristics to calculate the unit value of an ecosystem service at the policy site. Value function is a set of parameters that defines a biophysical condition (I.e., carbon biomass of compost) where, when combined with economic data, renders the value of a physical process (I.e., carbon sequestration). This approach can provide a more accurate estimate of value for the policy site with the availability of on-the-ground data, particularly if limited studies exist which meet the criteria for a valid BTM. FTM is the primary method used in this report, with data gaps identified for specific ecosystem services. nitrogen, phosphorus, and carbon cycles). These services are the basis of the vast majority of food webs and life on the planet.

All valuation appraisals include a degree of uncertainty. A house appraisal will have several "comparables" that range in value, though a single value is often chosen. The greater the similarities are between the study site and the policy site, the lower the error is when transferring values between sites. Appendix C of this report provides more detail on the study limitations of this approach.

Using the Ecosystem Services Framework for Organic Amendments

Not all ecosystem services presented in Table 1 above are included in the scope of this study. Some are extremely difficult or even impossible to measure monetarily, particularly cultural value or the value to science and education. Others are commonly measured but doing so is dependent on data availability, particularly using data local to the study area. Table 2 identifies each ecosystem service measured and monetized in this report, and whether local data was available for use.

Table 2:

Ecosystem Service	Local Data or BTM	
	Compost & Class A Biosolids	Class B Biosolids
Carbon Sequestration & Stock	FTM	Local Data, FTM
Soil Erosion	FTM	Not measured
Soil Quality	FTM	Local Data, FTM
Flood Risk Reduction	FTM	Not measured
Water Quality	Not measured	Not measured
Water Supply	FTM	FTM
Other Analyses		
Ecosystem Service Value of Avoided Landfill Costs	FTM	N/A
Organics Market Analysis (Appendix E)	Local Data	Local Data
ROI of Biosolids (Appendix E)	N/A	Local Data
Spatial Prioritization	Local Data	Local Data

The items in “Other Analyses” in the table above are not included in the body of this report and are detailed in the appendices. The remaining sections of this report focus on organic amendment applications in the King County and Seattle service areas. Each section provides an overview of data and research used to measure and calculate ecosystem services provided by either product.

SECTION THREE:

Ecosystem Service Benefits of Organic Amendments

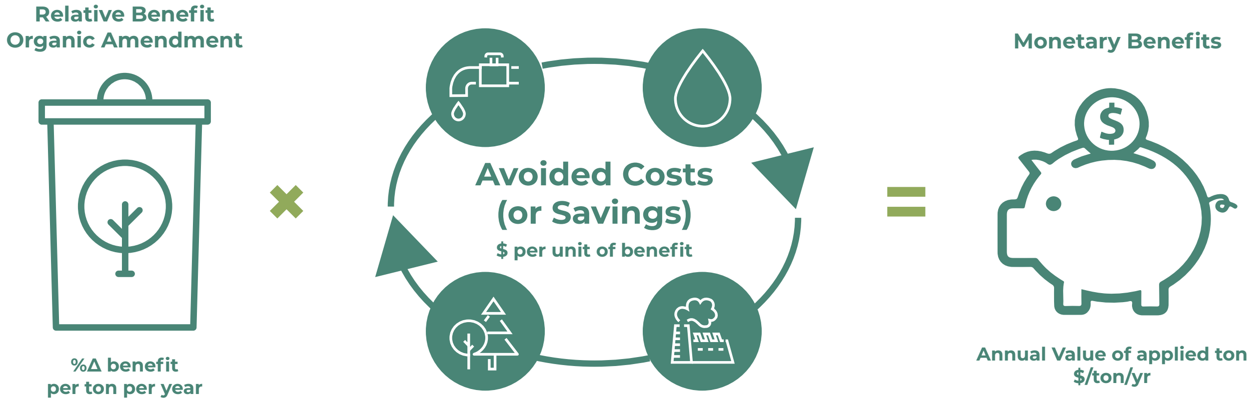
Soil is valuable. Application of organic amendments provides extensive soil benefits, improving the efficient use of land, water, energy, and other resources beneficial to communities and the economy. The economic value of these benefits is rarely recognized as a cost-effective strategy to reduce waste and improve soil quality. Measuring the value of these benefits can help local governments, non-profit organizations, and for-profit companies justify investment in infrastructure to produce this material and make it available to the community.

This section first outlines the cumulative economic value of food and yard waste compost and Class A biosolids for six ecosystem services: flood risk reduction; soil erosion; carbon sequestration and storage; water supply; and soil quality and yield. Then we calculate the annual cumulative ecosystem service benefits for five separate land uses: bare soil; post-wildfire; and in 3 separate agricultural land uses (dryland wheat, grapes, and vegetables). Lastly, this section includes the economic value of biosolids application in working forests and dryland wheat. Biosolids application benefits did not include flood risk reduction or soil erosion due to data limitations and lack of relevant literature, although these benefits would likely be similar to those seen with compost application.

Ecosystem Service Benefits of Compost and Class A Biosolids

In this report, six ecosystem services were included in scope for measuring economic benefits of compost and Class A biosolids application: flood risk reduction, erosion control, carbon storage, water supply, soil quality, and crop yields. All research benefits estimations below are primarily citing food and yard waste compost benefits. This research is used as a proxy for estimates of benefits related to biosolids compost. Appendix D discusses the literature cited in more detail. **For the remainder of this subsection, we will refer to the benefits of food and yard waste compost and biosolids compost simply as "compost."**

For each ecosystem service discussed, benefits were measured relative to some land use or on-the-ground condition. A brief summary of the methods used for the valuation of each ecosystem service is described below. Detailed explanations of each method are described futher in Appendices D and E. Figure 3 outlines how monetary benefits are measured by combining relative benefits of organic material application, such as compost application, with avoided costs associated with mitigative activities like soil erosion and flood risk reduction. Unit avoided costs is one example of the use of function transfer methodology described in more detail in Appendix B. Each ecosystem service was valued using the method outlined in Figure 3, with more detail below.



Flood risk-reduction

Compost application can help increase the porosity of soil, increasing soil infiltration and water holding capacity, and thereby reduce flood risk. Every gallon of flood water that is captured in healthy soils reduces the cost to downstream communities from flooding. Based on existing literature, compost application reduces downstream costs for flood mitigation infrastructure. Similar benefits are shown in agriculture, post-fire landscapes, and post-construction bare soil. The avoided cost of flood mitigation infrastructure is used to estimate the benefit of compost application for flood risk reduction.

Soil erosion

Compost application can reduce the damages from soil erosion. For example, applying one inch or more of compost can mitigate over 90% of soil erosion on post-construction bare soil. Soil erosion can damage drainage systems as well as irrigation ditches and canals. In this case, the cost of soil erosion includes both the impacts to road drainage and the clogging of irrigation ditches and canals. By mitigating these impacts, compost application helps avoid these downstream costs. This is referred to as the avoided cost, or benefit of compost application. Similar methods have been identified for each ecosystem service.

Carbon mitigation and methane avoidance

Soil can act as a major carbon sink and healthy soils with growing vegetation can actively sequester carbon. In addition, application of compost reduces the need for synthetic fertilizers which are dependent on fossil fuel production and carbon emissions for their production. Organic waste that is sent to the landfill also produces methane, which can be mitigated through composting. Through storing carbon in the soil via compost application, reducing reliance on fossil fuel-based fertilizers, and mitigating methane emissions, compost can be a net positive when measuring carbon sequestration and storage. These benefits, measured in tons of carbon, are combined with existing estimates of the social cost of carbon (SCC) to estimate the benefits of carbon sequestration and storage from compost application.

Water supply (water conservation)

As stated above for flood risk reduction, compost increases the porosity and decrease the bulk density of the soil. This leads to greater water holding capacity within the soil. This can reduce irrigation needs in both urban landscaping and agricultural operations. The economic analysis conducted in this report shows how unit costs of irrigation and structural water storage are used to estimate the water supply benefits of compost. Particularly in agricultural systems, large amounts of water are supplied to crops during dry summer conditions often requiring on-site storage and privately managed water distribution infrastructure. Utilizing the unit cost of irrigation infrastructure provides a marginal estimated benefit, or the benefit per cubic foot of water.

Soil quality and crop yields

Compost application can improve both soil quality and crop yields. Due to the overlap between soil quality and crop yields, the analyses for these ecosystem services are combined. The economic analysis of soil quality in this report is scoped narrowly to value the avoided cost of fertilizer following application of compost and, where available, the crop yield benefits from application. Annual application of fertilizers rich in nitrogen (N), phosphorus (P), or potassium (K), among other plant nutrients, vary by crop and existing soil quality. In addition, the analysis uses the scope of literature reported by Hills et al. (2019) and recent commodity prices to estimate the economic value of yield increases. Compost can be used as a supplement or replacement for fertilizer use, reducing annual costs and improving yields.

Economic Impact of Compost Application

The next section summarizes the ecosystem service value of compost application on different land use types. As mentioned above, this report treats estimates for compost application as a proxy for the benefits of Class A biosolids application.

Appendix D provides details of the data used to calculate ecosystem service benefits from compost application and the literature used in the methodology. Research literature and local data were combined to estimate annual benefits per ton of compost application, as well as the benefits of each ton of food waste diverted from the landfill. The economic analysis was conducted for each ecosystem service by land conditions (bare soil/construction, post-fire, agricultural) where applicable each land use type is defined in Appendix D. Results are grouped below by ecosystem services.

This portion of Section 3 concludes with an estimation of the total economic benefits associated with compost application. Results below combine the six ecosystem service benefits of compost application for which data allowed the estimate of an economic benefit across different land use types. The land use types considered in this report were based on what data and information was available from the literature review for this report. Key datasets and reports provide ample information on bare soil conditions. Post-wildfire conditions were well published for specific ecosystem services, with the literature excluding some services such as water supply, leading to an underestimate relative to the other land use types considered. Specific agricultural land use types were included based on what data was available, sampling wheat, grapes, and a mixed vegetable rotation. Appendix D provides more detail on all utilized research.

Results show that, for each land use type considered in this report, the ecosystem service value of one ton of compost application is as follows:

	Bare Soil	Post-Wildfire	Ag: Wheat	Ag: Grapes	Ag: Vegetable Rotation
FLOOD RISK REDUCTION	$78.29 - $193.15	$71.42 TO $195.30	$71.42 TO $182.42	$45.33 TO $128.77	$71.42 TO $182.42
SOIL EROSION PROTECTION	$0.49 - $6.19	$0.20 TO $0.43	$0.22 TO $0.87	$0.21 TO $0.88	$0.22 TO $0.87
CARBON MITIGATION	$153.87 - $228.89	$153.87 TO $228.89	$186.83 TO $190.18	$194.09 TO $194.09	$158.60 TO $176.37
WATER SUPPLY	$0.73 - $1.00		$0.13 TO $0.74	$0.13 TO $1.14	$0.35 TO $0.73
SOIL QUALITY	$1.71		$19.04 TO $28.10	$1.71 TO 102.58	$13.03 TO $26.04
=	$235.10 TO $430.94 PER TON	$225.49 TO $424.62 PER TON	$277.64 TO $402.32 PER TON	$241.47 TO $427.45 PER TON	$243.62 TO $386.43 PER TON

Sum Year 1 Ecosystem Service Benefit of 1 Ton of Compost Application

If compost was applied each year over multiple years, the benefits are greatest with the first applications, particularly in poor soil conditions. The figure above shows the one-time benefit of each ton of compost applied in each of the five scenarios. Table 3 below calculates the total benefits of compost applications over 5, 10, and 50 years of application. When estimating benefits and costs over different time horizons, economists use a discount rate. Discount rates are adjustments placed on future streams of income/benefits to consider how people value benefits in the future and the fact that money not spent in the present can be invested to generate money into the future. To estimate value over time, future years are discounted to account for the time value of money. Below is a graph showing how $100 in annual benefits accumulates over 50 years under three discount rates (0%, 2.25%, and 7%). Further discussion is provided on asset value in Appendix B.

The numbers below can be seen as the value of annual application at 5, 10, and 50 years of the program (present value). These benefits can be multiplied by the total tons of compost produced to estimate the value of the program over different time horizons. Appendix B provides more information on how the value was calculated over time.

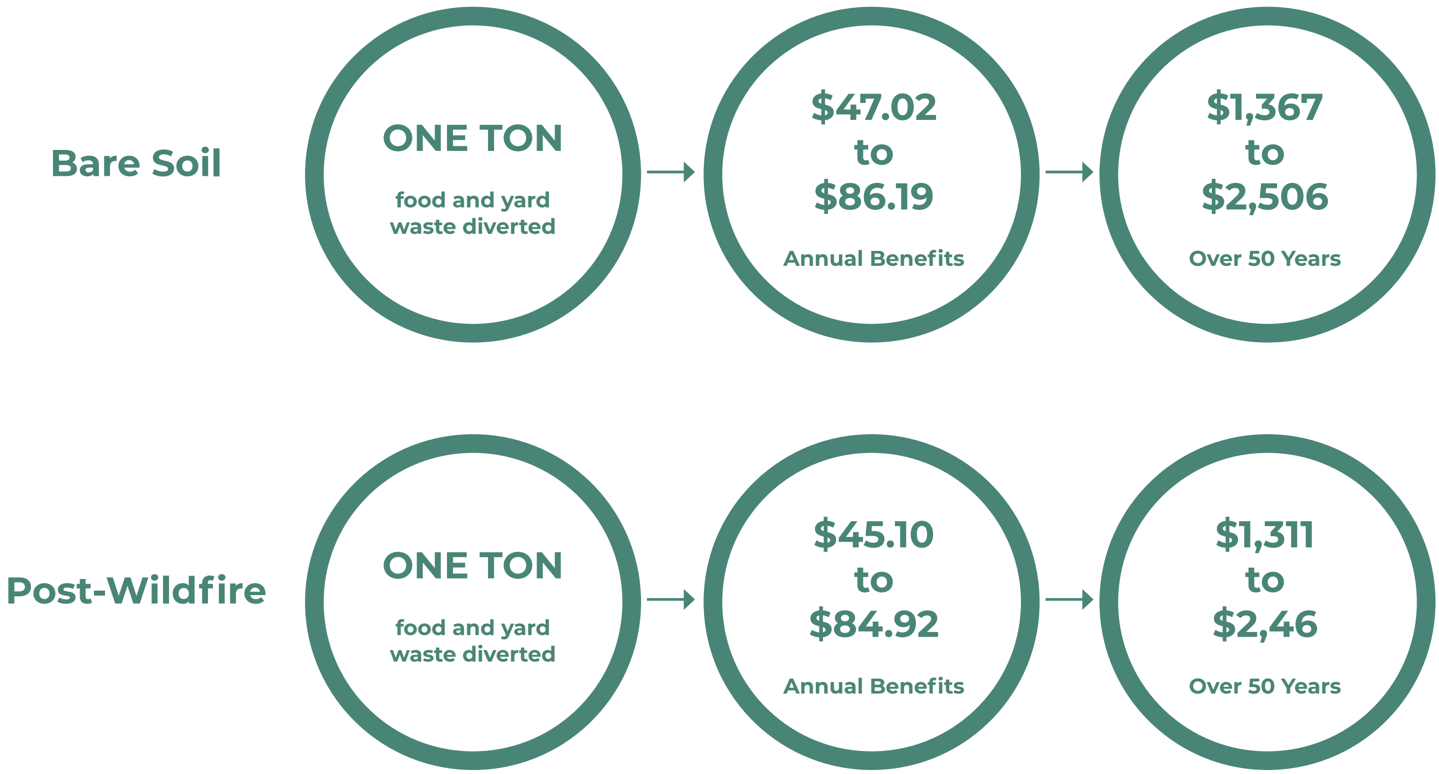
Table 3:

Present Value of Annual Applications Over Time for All Land Use Categories

	Bare Soil	Post-Wildfire	Ag: Wheat
	RANGE OF VALUES	RANGE OF VALUES	RANGE OF VALUES
5 - YEAR	$1,120 TO $2,052	$1,074 TO $2,022	$1,322 TO $1,915
10 - YEAR	$1,120 TO $2,052	$2,023 TO $3,809	$2,491 TO $3,609

	Ag: Grapes	Ag: Vegetable Rotation
	RANGE OF VALUES	RANGE OF VALUES
5 - YEAR	$1,150 TO $2,036	$1,160 TO $1,840
10 - YEAR	$2,166 TO $3,835	$2,185 TO $3,467

According to Sally Brown in “Carbon Accounting for Food Scrap Composting in King County, WA,” approximately one wet ton of food and yard waste translates to as estimated 0.2 tons of compost. The author suggests this estimate is for purposes of simplicity. Using this ratio, it follows that for every ton of food and yard waste diverted from the landfill used to make compost and applied to bare soil conditions, approximately $50.87 to $86.19 are realized in just the first year. Figure 5 summarizes this compost impact by land use.



*the annual benefit stated here is not the benefit of annual re-applications

Figure 5. Impact of Food and Yard Waste Diversion by Land Use Summary.

These per-ton benefits can be used to estimate the total benefit of the King County and Seattle organic waste collection programs. From 2018-2022, King County and Seattle collected an average of 415,000 tons of organic waste. This is based on data provided by King County SWD through email correspondence and Seattle Public Utilities’ online MSW Tonnage Quarterly Reports. The table below summarizes the organic waste collected (in tons) from 2018-2022 and the 5-year average across both programs.

Table 4. Organic waste collected in King County and Seattle.

Table 4:

Organic Waste Collected (tons)		
YEAR	King County	Seattle
2022	243,216	151,185
2021	253,811	147,414
2020	279,817	162,311
2019	241,352	182,320
2018	233,076	181,230
5-year average	250,254	164,892
Combined organic waste collected		415,146

Using the assumption that 5 tons of organic waste is processed into 1 ton of compost, this is the equivalent of roughly 83,000 tons of compost. Using the range of benefits shown above, this results in a minimum of $18.7 million in ecosystem services and as much as $35.8 million in ecosystem services benefits. Table 5 summarizes this benefit calculation.

Table 5. Annual benefit of King County and Seattle organic waste collection programs.

2022	Organic waste collected (1)	Compost produced (2)	Benefit, low (2)	Benefit, high (3)	Compost Benefit, Low, Annual	Compost Benefit, High, Annual
Compost	415,146	83,029	$225	$431	$18.7 million	$35.8 million

1. Organic waste collected is based on a 5-year average of both King County and Seattle organic waste collection programs.
2. Based on the assumption that 5 tons of organic waste is processed into 1 ton of compost.
3. The low and high values are based on the range of estimates provided for compost benefits in all contexts, rounded to the nearest dollar. The low estimate is the minimum benefit from post-fire application. The high estimate is the maximum bare soil value.

Economic Impact of Class B Biosolids Application in King County

The following provides results of the ecosystem service benefits provided by application of Class B biosolids. Due to limitations in published research, the ecosystem services studied in this section were limited to agricultural wheat and working forests land use contexts, and limited to three ecosystem services: Carbon sequestration, water supply, and soil quality. Results below combine the three ecosystem service benefits of Class B biosolids application for which data allowed the estimate of an economic benefit. Appendix D provides detail on the literature cited, data used, and calculations made to produce the results below. Results show that, for both land use type currently receiving Class B biosolids, the ecosystem service value of one ton of biosolids application is as follows:

Total Class B Value – Working Forest

CARBON MITIGATION
$16.31 TO $391.92

→

INCREASED YIELD
$165.01

→

$181.34 TO $556.92 PER TON

Total Class B Value - Wheat

CARBON MITIGATION
$120.09

→

WATER SUPPLY
$0.61 TO $16.49

→

SOIL QUALITY AND YIELD
$47.80

→

$168.50 TO $184.38 PER TON

Similar to the benefit of the organic waste collection programs, an annual benefit can be estimated for the current biosolids program. King County produces roughly 120,000 tons of biosolids every year. Using the per ton benefits of biosolids application, it can be shown that the King County biosolids program generates between $5.2 million and $9.5 million in ecosystem services every year. Table 6 shows the calculation.

Biosolids produced[1] (wet tons)	Biosolids produced (dry tons)[2]	Application context	Biosolids Applied[3]	Benefit, Low	Benefit, High	Biosolids Benefit, Low	Biosolids Benefit, High
123,502	30,361	Agriculture	19,735	$169	$184	$3.3 million	$3.6 million
		Forestry	10,626	$181	$557	$1.9 million	$5.9 million
					Total	$5.2 million	$9.5 million

1. Biosolids produced based on 2022 estimate provided by King County WTD via email correspondence.
2. Based on the assumption that 120,000 wet tons of biosolids is roughly equivalent to 29,500 dry tons. Biosolids have a high water content. Dry tons are the amount of biosolids with the water weight removed.
3. Amount of biosolids distributed to each category, agriculture and forestry application, is based on estimates in dry tons provided by King County WTD via email correspondence.

SECTION FOUR:

Case Study Prioritizing Application of Organic Amendments across King County

King County and Seattle's compost and biosolids programs are public resources that can reduce food waste, yard debris, and resources recovered from wastewater from going to the landfill, cut GHG emissions, and promote better stewardship of our community and natural assets.

This case study uses geospatial data to inform where the application of compost and Class A biosolids products could be regionally prioritized. This data includes underserved and disproportionally at-risk communities layered with active and non-active farmland in King County. Each GIS dataset is discussed below in its relevance and use in the final prioritization.

Vulnerable and Disproportionally At-Risk Communities

For many in our region, King County is a great place to live, learn, work and play. Yet the region experiences racial and income inequities. In many neighborhoods, these inequities have grown worse, particularly after the Covid-19 pandemic. Urban low-income residents suffer disproportionately from environmental hazards such as poor air quality and adverse health outcomes, as well as having less of the infrastructure needed to combat this.

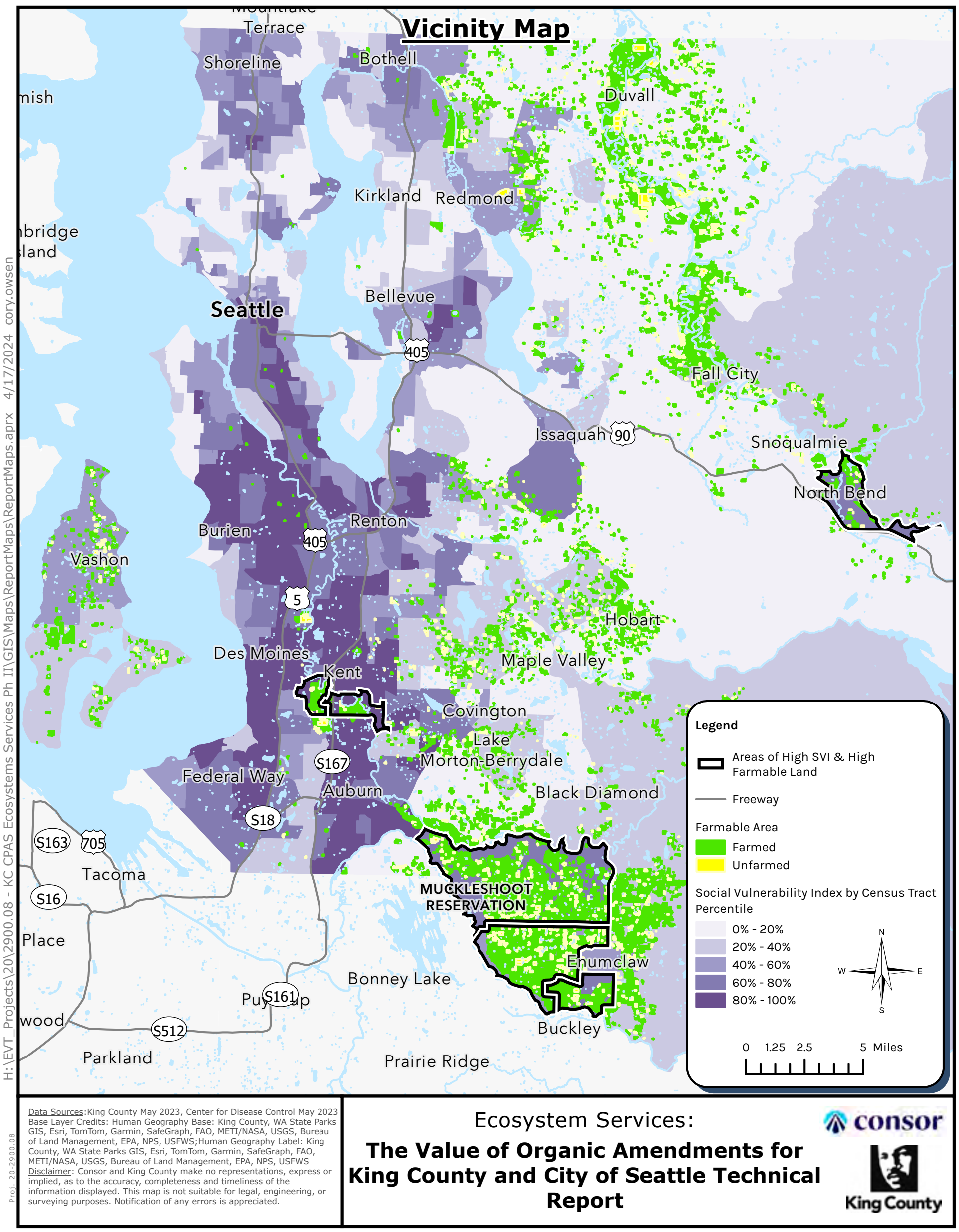
The Center for Disease Control (CDC) created the Social Vulnerability Index (SVI) as a measure of the degree to which a community is experiencing social conditions that may "affect that community's ability to prevent human suffering and financial loss in the event of a disaster" (CDC 2020). The SVI uses sixteen variables, including, but not limited to poverty, unemployment, racial diversity, and crowding. Communities that have high SVI scores often lack the conditions for a fair and just society as defined as "determinants of equity" in King County Code 26.12.003.

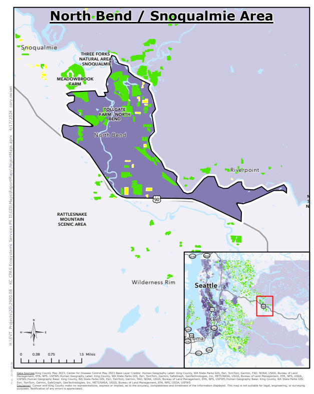
Healthy soil offers various benefits to communities. As discussed above, organic amendments enhance soil quality, water-holding capacity, and nutrient content, helping revitalize degraded lands and promote healthy plant growth. This supports local food production, community gardens, and urban agriculture initiatives, enabling residents to grow their own nutritious food. By diverting organic waste from landfills, creating organic amendments reduces climate pollution and other environmental impacts associated with landfilling organic materials. Additionally, organic amendment programs can engage communities in sustainable practices, promoting environmental awareness and empowerment.

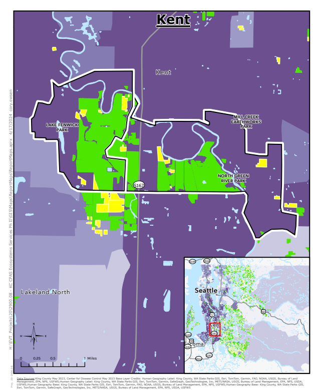
Maximizing the Benefits of Organic Amendments in King County

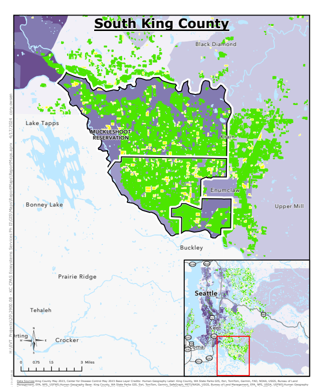
In order to prioritize organic amendment application, we layered an agricultural land use map over the results from the SVI. The land use data show both farmed and farmable, but unfarmed land. This exercise is not meant to identify specific parcels, but to demonstrate areas, particularly in South King County, home to vulnerable communities and with enough farming activity to benefit significantly from local organic amendments.

These geographic regions within the county represent strategic locations for application of compost in partnership with local communities and neighborhoods. By working together with local partners, the county could develop small-scale farming efforts that would help the county meet its goals for climate mitigation and building healthy, resilient and equitable communities.









Appendix A: Acronyms and Glossary

Acronyms

DNRP: Department of Natural Resources and Parks

ECY: Department of Ecology

SPU: Seattle Public Utilities

SWD: Solid Waste Division

WTD: Wastewater Treatment Division

Glossary

Benefit Transfer Methodology (BTM) – BTM is an ecosystem service valuation method that uses values derived from published studies for application in similar ecosystems. It resembles a house or business appraisal that is based on comparable characteristics of similar houses or businesses.

Class A Biosolid – solid organic matter recovered from a sewage treatment process that meets US EPA guidelines for land application with no restrictions.

Class B Biosolid – solid organic matter recovered from a sewage treatment process that meets US EPA guidelines for land application with some restrictions. These restrictions make Class B Biosolids unfeasible for applications where small quantities would be used, such as landscaping or residential gardens.

Ecosystem – An interacting system of living organisms, soil, and climatic factors. Forests, wetlands, watersheds, ponds, prairies, and communities are ecosystems.

Ecosystem Services – Benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, air, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling.

Ecosystem Services Valuation (ESV) – the quantification of the benefits that people derive from ecosystems, generally expressed as non-market values or market value equivalents.

Ecosystem Service Value – Measure of the benefit provided by an ecosystem using market proxies to infer a dollar value equivalent.

Isopluvial – Of, relating to, or showing a line on a map connecting places registering the same amount of precipitation or rainfall.

Natural Capital – The interconnected network of natural resources (also called green infrastructure) that produces a variety of natural capital assets. These natural capital assets provide people with a wide range of ecosystem services, which contribute to the local economy, society, and environmental health.

Stormwater runoff – rain and snowmelt that flows over land or impervious surfaces, such as paved streets, parking lots, and building rooftops, and does not soak into the ground.

Valuation of Ecosystem Goods and Services Database (VEGS) – The VEGS is a computational engine and database developed and maintained by Equilibrium Economics for the application of "benefit transfer methodology" in "ecosystem service valuation". It houses the world's largest library of ecosystem goods and services valuation studies.

Appendix B: Ecosystem Goods and Services Economic Methods

Benefit Transfer Methodology Detail and Limitations

Benefit transfer is a widely accepted valuation method that has been used for many decades in the ecosystem service valuation field. Authors such as Freeman (1984) have been conducting benefit transfer since the 1980s, and in the early 1990s benefit transfer was broadly recognized as a distinct area of research (Rosenberger and Loomis, 2001). Currently, benefit transfer values are used by several federal agencies. The EPA utilizes benefit transfer in benefit-cost analyses related to proposed air and water quality regulations and specifically discusses it in the EPA's Guidelines for Preparing Economic Analyses (EPA, 2014). The U.S. Forest Service and U.S. Army Corps of Engineers both utilize benefit transfer for estimating the economic value of recreation related to project activities and impacts (Johnston et al., 2015). FEMA allows the use of benefit transfer values in their Hazard Mitigation Assistance Program and all other mitigation projects (FEMA, 2016).

The benefit transfer method allows for the estimation of ecosystem service values at large scales when analysis of primary data is unavailable. This is achieved by transferring values estimated in a previous study (i.e., study or source site) in a different location, to the area of interest, or target location (i.e., policy or target site). There are two primary forms of benefit transfer: unit value transfers and function transfers.

Unit value transfer offers several approaches that transfer a single value per unit (e.g., per acre, per trip) from the study site to the policy site. One approach can be to directly transfer the value obtained from a single study site and apply it to the policy site. Function transfer uses a value function estimated for an individual study site in conjunction with information on policy site characteristics to calculate the unit value of an ecosystem service at the policy site. The latter may provide a more accurate estimate of value for the policy site with the availability of on-the-ground data and particularly if limited studies exist which meet the criteria for a valid value for transfer. In few cases, a third technique can be used which involves the use of administratively approved values in government jurisdictions. Some examples of administratively approved values include the U.S. Forest Service Resources Planning Act for recreation and other ecosystem services and the U.S. Water Resources Council's values for recreation (Richardson et al., 2015; Rosenberger et al., 2017).

Currently, multiple academic articles and federal agencies publish criteria and best practices to ensure valid benefit transfer. Criteria were first recommended by Boyle and Bergstrom (1992), which states that, under ideal conditions, the study and policy sites, populations, and welfare measures are matched as closely as possible. Since then, guidelines have been proposed to ensure appropriate value transfer when variation in study and policy site is present. Rolfe et al. (2015) summarize the set of criteria suggested by Bennett (2006) under five requirements:

1. Condition: The biophysical conditions in the source case must be similar to those in the target case;
2. Scale: The scale of environmental change considered in the source must approximate the target;

3. Socioeconomics: The socioeconomic characteristics of the population impacted by the change investigated in the source must approach those of the target population;
4. Framing: The frame or setting in which the valuation was made at the source must be close to that of the target;
5. Rigor: The source study has to have been conducted in a technically satisfactory fashion.

BTM was used in limited cases in this report and, where it is used, meet all requirements listed above.

Details on ESV of Remediated Surface Mines

The major objectives of soil remediation on surface mine sites are in part to reestablish, on a perpetual basis, vegetative cover, soil stability, and water conditions. One approach is the application of compost or similar products to reintroduce nutrients and organic matter into the soil. What follows is the replanting or re-establishment of native vegetation. For the purposes of this report, we assumed all native plant re-establishment was native forest types, either coniferous or deciduous.

With limited research on the recovery rates of native vegetation following surface mine remediation in the Pacific Northwest (PNW), multiple proxies were used to estimate these rates: afforestation and severe wildfire. Following severe wildfire, soil can be burned as far down as 20cm or further (Martínez-Aznar et al., 2016). While wildfire is historically naturally occurring and even necessary in some landscapes, severe fires scorch the ground leaving the area uninhabitable in the short term without intervention. Severe conditions were found to be comparable in many ways to surface mines with poor quality topsoil.

Recovery from wildfire varies drastically based on fire intensity and severity, tree species, and existing conditions. Even if the bark is considerably scorched, the cambium can remain undamaged (Moench, 2002). Their roots run deep thus providing further protection where other species may be more susceptible to slow, hot fires. As a result, this study focuses solely on high-severity fires that threaten all forest types, leaving the landscape barren in the aftermath.

The following research demonstrates the immediate impact of severe wildfire to the ecosystem services of focus for this portion of the report. It also demonstrates how ecosystems recover following restoration efforts.

- Carbon Sequestration: Following high-severity fires, all above ground biomass is assumed burned, providing no carbon sequestration. Smith et al. (2006) provides ample data on recovery rates of five different PNW forest types following clearcutting. Data can be extracted for each species in 10-year increments. Recovery to mature growth takes approximately 55 to 110 years depending on the species.
- Flood Risk Reduction: A study of the 2000 Valley Complex wildfire included a rainfall simulation in burned and non-burned areas (Robichaud et al., 2016). After the fire, burned area water runoff yields increased by 10-20% in the first two years compared to non-burned areas. By the fifth year, water yields were similar between both sites. All results were statistically significant. A comparison study from Santa Barbara, CA, found that estimated flood discharge associated with the FEMA 100-year storm is four to 20 times more likely one year after high severity fire (Abramson et al., 2009). In “small” fire conditions, flood discharge with the same storm increased by only 25%.

- Water Quality: A study of the 2000 Valley Complex wildfire included a rainfall simulation in burned and non-burned areas (Robichaud et al., 2016). Water quality treatment (nitrates and sedimentation abatement) downstream increased by more than tenfold directly after one year, with rates increasing in the second year and full recovery by the fifth year. All results were statistically significant.

Other ecosystem services were not included in this report but are certainly impacted by degraded soils and provide value when restored.

Asset Value

When the value of natural capital is brought to light, it shows that investments in restoration and remediation have the capacity to provide good rates of return. Benefit/cost analysis and rate of return calculations were initiated after the 1940s to examine investments in built capital assets which were expected to be productive for a few decades until they required replacement. Built capital does fall apart and depreciate without maintenance.

Natural capital does not depreciate or fall apart like built capital assets. In fact, natural capital can even appreciate in value over time, being composed of living and growing organisms. Of course, natural capital is only renewable if it is protected against degradation, development, unsustainable extraction, and other impacts. As long as the natural capital is not degraded or depleted below its ability to renew itself, this flow of value will continue into the future.

Discounting can be adjusted for different types of assets and is designed to reflect the following:

- **Time preference of money.** This is the value that people put on something for use now, as opposed to the value they assign for that use at a later date.
- **Opportunity cost of investment.** A dollar in one year's time has a present value of less than a dollar today, because a dollar today can be invested for a positive return in one year.
- **Depreciation.** Built assets such as roads, bridges, and levees deteriorate and lose value due to wear and tear. Eventually, they must be replaced or removed.

Discounting has limitations that may result in under- or overestimates when applied to natural capital. Using a discount rate assumes that the benefits humans reap in the present are more valuable than the benefits provided to future generations, or even to this generation in just a few years into the future. Natural capital assets should be treated with lower discount rates than built capital assets because they tend to appreciate over time, rather than depreciate.

The US Army Corps of Engineers recognizes this and provides a lower discount rate for natural capital and long-lived built water infrastructure capital assets such as dams and levees.

Unlike a factory that is 50 years old, a protected and/or restored forest will appreciate in value if it remains mostly intact and experiences an increase in demand for its services. Additionally, most of the benefits that a natural asset, such as a forest, provides reside in the distant future, whereas most of the benefits of built capital reside in the near-term, with few or no benefits provided into the distant future when the asset has deteriorated. Both built and natural assets are important to maintain a high quality of life, but each operates on a different time scale. It would be unwise to treat human time preference for a forest like it were a building, or that of a building as if it were a disposable coffee cup. Thus, a low discount rate better reflects the asset value of organic amendment applications.

The net present value of the state's forest ecosystem services was calculated using one primary discount rate over 50 years: 2.5 percent (used by the U.S. Army Corps of Engineers). A secondary discount rate was considered in some cases at 0 percent. The discount rate of 0 percent reflects the fact that human population and future development will degrade ecosystems and reduce their ability to provide ecosystem services if they are not adequately protected. This process is analogous to depreciation of a built capital asset. Federal agencies like the Army Corps of Engineers historically have used a 3.5% percent discount rate for water resource projects (USACE, 2022).

The cut-off date is arbitrary. Clearly, far greater value yet resides for the many generations who should benefit from the watershed well beyond 50 or 100 years, assuming the watershed is adequately protected. Currently, the value of economic assets is generally not considered beyond 50 years. This study follows that standard. With no cut-off date for value, any renewable resource would register an infinite net present value. However, the value of watersheds does extend far beyond 50 years, and better tools for capturing that value are being developed by economists.

Appendix C: Study Assumptions and Limitations

Existing Conditions Before Compost Application – Construction Fill and Bare Soil

A low percentage of the literature cited in this report on compost or biosolids application provides information on soil quality. As a result, our analysis assumes that application of compost and biosolids products are done in soil conditions that need nutrients and organic matter. This doesn't necessarily suggest soil conditions are assumed to be poor.

Fill dirt used in construction and development is generally made of rocky subsoil which typically has as little organic material present and is thus deemed "poor quality." The lack of organic matter is a benefit to construction because organic matter makes soil less stable, however, soil remediation is often needed to support vegetation growth and prevent soil erosion. Seattle Department of Construction and Inspections requires that a "minimum 8-inch depth of compost amended soil or imported topsoil shall be placed in all areas of the project site that have been disturbed during construction," (SDCI, 2009).

Class A and Class B Biosolids Application Rate Assumptions

As referenced in soil quality sections above, there is what is described as a "threshold" effect for biosolids application and resulting yields. This indicates a diminishing marginal benefit of biosolids application, relative to fertilizer, in resulting yields. This analysis assumes that biosolids are applied at the most efficient rate consistent with ideal/peak performance when measuring benefits of biosolids.

Recent efforts have been made by King County WTD to explore expanding current operations to include a Class A biosolids project. Given the potential for using composting processes to develop a Class A biosolids product, compost literature review values were used as a proxy to estimate Class A application benefits. These are different values than what is used for Class B application benefits estimations.

Class B wet tons to dry tons conversion

The weight of organic amendments is provided in either wet or dry weights. Conversion of Class B wet tons to dry tons conversion factor of 4:1. In other words, the dry weight of biosolids is roughly 25% of the wet weight.

Compost Application Rate Assumptions

Compost application rates vary across studies. To account for the variation in application rates, a conversion was made to estimate the economic impacts by assuming 2-inch compost depth applications. The 2-inch compost application depth was selected because most studies used in this analysis used a 2-inch compost application depth among other treatment options, if any. To convert this depth to an application rate, we used assumptions from Sally Brown (2021), *Carbon Accounting for Food Scrap Composting in King County, WA*. In the carbon accounting analysis, Sally Brown provides an example from a research project on Vashon Island which had an application rate of 104 cubic yards per acre. When converting the volumetric rate into weight-based application rate (e.g. Mg per hectare), she assumes "a dry weight equivalent to a [cubic] yard of compost at 500 pounds or 0.25 tons. This is based on a wet weight per yard of 0.5 tons and a moisture content of 50%. This results in a compost application rate of 26 tons per acre or 58 Mg per hectare." Using the assumption that 104 cubic yards per acre is equivalent to 26 tons per acre or 58 Mg per hectare (1 megagram (Mg) = 1 metric ton, and 1 megagram = 1.10231 US tons), we can show that a 1-inch compost blanket is equivalent to roughly 75 Mg per hectare. We can demonstrate this with the conventional conversions below:

- 1 acre-inch (i.e., 1-inch depth over an acre) is equivalent to 134.44444581331 cubic yards
- This means 104 cubic yards is equivalent to 0.7735537… acre-inches (104/134.44…)
- Under our assumption, 104 cubic yards per acre is equivalent to 26 tons (US) per acre or 58 Mg per hectare.

Convert 1-acre inch (134.444yd^3) into Mg per hectare:

$$\left(\frac{134.444yd3}{104yd3}\right) * 58\frac{Mg}{hectare} = 74.97863 \ldots \frac{Mg}{hectare}$$

Multiply this by two to obtain the approximate value of 2-acre-inches, or 150 Mg per hectare (149.957… Mg/ha) or 67 US tons per acre (66.9 tons/acre). This is the standard application rate assumed for benefits estimated in this report. This study is interested in the extent to which one US ton of organic amendments is applied to the landscape to be consistent with this application rate. Dividing the square meters within an acre (4,046.9 m^2) by the application rate in tons per acre (67), the estimated area that a single ton is applied (using the application rate of 67 US tons/acre) is 60.5m^2. Table 8 below shows the steps completed to estimate the area covered by one ton of compost at a depth of 2 inches.

Table 8. Application Rate Conversions and Assumptions.

Category	Value	Notes/Source
Application Depth	2 inches	Most studies included a 2-inch application depth
Equivalency	1-inch application equivalent to 75 Mg/ha	Brown 2021; See Appendix C: Study Assumptions and Limitations for details
Application Rate (mg/ha)	150.0 Mg/ha	2-inch application rate at 75 Mg/ha per inch
Conversion	1 US Ton = .9072 Mg 1 acre = .4046 ha	Standard conversion (rounded units)
Application Rate (tons/acre)	66.9 tons/acre	Conversion from Mg/ha to t/acre
Conversion	1 acre = 4046.87261 m^2	Standard conversion (rounded units) square meters/acre divided by tons/acre = square meters/ton

Area covered by one ton of compost at a depth of 2 in.	60.50 square meters per ton of compost	Average extent per ton of compost applied. *That is to say: to apply roughly 2 inches of materials on an area of land is roughly equivalent to one ton of compost applied to every 60.50 square meters.*

It is important to note that data was provided by Lenz Compost to compare this assumption with local data on compost. The difference between the two measures of volume to weight (Sally Brown 2021 and Lenz Compost) was only 2 Mg per hectare of compost material (75 Mg/ha compared to 77 Mg/ha). This is a less than 3% difference in the estimate of the ratio between weight and volume. Because of this similarity, the analysis uses the assumption provided in Brown (2021).

Estimating the Value of Organic Amendments on the Landscape

One primary limitation of this study is the effect of organic amendments on the landscape in specific contexts. This study attempts to estimate the ecosystem goods and services value associated with each ton of organic amendments produced. While the benefits of organic amendments on different land cover categories are explored (agriculture, bare soil, post-fire, etc.), it is not always clear how these benefits change over time with continued application. Some landscapes can see immediate benefits from organic amendment application (bare soil and the reduction in stormwater or agriculture for increases in yields), but the marginal benefits may change over time. It is more likely that once the benefits are seen, some level of organic amendments application will be necessary to maintain those benefits. Carbon storage is one example where this can be seen. Carbon storage in the soils is measured as the Mg of CO2e per Mg of amendment applied. Continuous application of amendments to the same landscape will have diminishing returns on the carbon stored in the soil. Leonard et al. (2021) discuss this as a state of “carbon equilibrium”. Once the soil has reached a level of carbon equilibrium, additional applications of organic amendments may not have a significant effect on carbon storage in the soils. The benefits measured in this report are generally assumed to be the benefits of new applications or the maintenance of existing benefits from past applications.

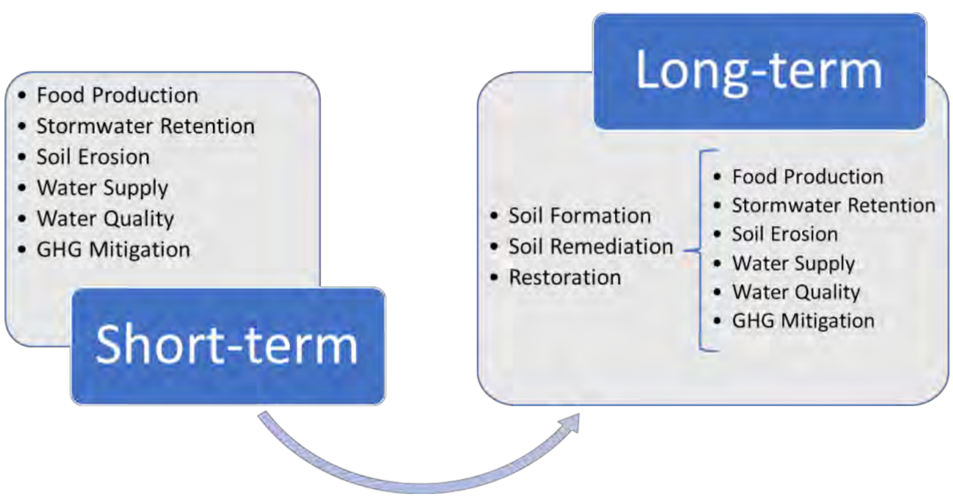
Another limitation of this study is the ability to account for varying application rates and associated impacts across the literature cited. Not all application rates are consistent across studies. To account for differences in application rates and associated impacts, where data is available, the literature cited can be used to adjust the percentage reduction in runoff by comparing results across different application rates. For example, Crohn et al. (2011) uses both a 1-inch and 2-inch application rate in their study of organic amendment application. This is a useful relationship to examine the variation in impacts between 1- and 2-inch application rates. In addition, the University of New South Wales Recycled Organics Unit (2006) compiled a comprehensive literature review of organic amendment application studies and their impacts including reduction in fertilizer applications, water use, and soil erosion and increase in yields, among other effects. The literature review for varying impacts also included, where possible, the relationship between application rate and associated impacts. This allowed for adjustments to be made in impacts when application rates were not consistent. These "Adjusted Benefits" are shown in Appendix D Measuring Benefits of Compost and Biosolids Details. The impacts from organic amendment application were adjusted to all be consistent to 2-inch application, 150 Mg/ha, or tons/acre, the equivalent of 1 US ton applied over 60.5 m^2.

Estimating Short- and Long-Term Ecosystem Service Benefits

Organic amendment application has both short-term and long-term benefits. Understanding the timing and magnitude of these benefits and how subsequent applications affect those benefits is not always clear. In some cases, a single, large application can have sustained benefits, such as on bare soil, turf, or post-construction application. Other instances, such as agriculture, consistent, repeated applications are necessary to maintain the nutrient balance in the soils and maintain benefits to soil quality and yields. Understanding these differences was beyond the ability of this report, although the results do speak to the magnitude of benefits and the potential for long-term returns in the public and private benefits provided by organic amendment application.

The application of organic amendments has immediate short-term benefits. For example, when applied in landscaping and remediation projects, organic amendments provide immediate water supply benefits by retaining water that may otherwise convert to runoff. Soil composition and the soil's ability to provision ecosystem services over the long-term improve with one or more applications. For example, organic amendments improve depleted soils, building healthy soils and providing enhanced benefits to the vegetation it supports. Figure 2 below shows which short and long-term ecosystem services are in scope for this project. While these benefits are considered, it is difficult to disentangle the short-term and long-term benefits.

Figure 2. Short- and Long-Term Ecosystem Service Value



Another important distinction is the difference between "final" versus "intermediate" ecosystem services. Ecosystems depend on, and perform a wide variety of, intermediate processes and functions, which contribute to final ecosystem services (FES). For simplicity, "intermediate" ecosystem services can be considered as input-output relationships. For example, plant transpiration can be represented as a process through which plants use soil moisture as an input and release water to the atmosphere as an output. While many input-output processes like these are ultimately important to humans, their outputs do not always flow directly to humans. In contrast, FES are outputs from nature that flow directly to and are directly used or appreciated by humans in diverse ways. As it relates to compost and biosolids applications, this distinction is clearest with the ecosystem service soil formation. Healthy soils are formed by cyclical nutrient cycles and regular inputs such as vegetation decay, fauna fecal deposits, and sedimentation. The benefits provided by soil formation are the suite of services that result, such as robust crop yields, water storage, filtration and drainage, and the benefits provided by the vegetation the soil supports. Results in Section 4 are presented as FES and are defined narrowly where necessary to make this distinction.

Comparing Class A biosolids and Compost benefits with Class B biosolids

It is important to note here that comparison between Class A biosolids and compost with Class B biosolids using the results from this report is not recommended. The context in which these organic amendments are applied is vastly different, which causes significant differences in the benefits identified in the literature and the economic benefits estimated. Class A biosolids and compost are different from Class B biosolids both in where and how much can be applied to the landscape.

Class B biosolids application is heavily regulated and currently is only used in commercial agricultural and forestry operations. In addition, application rates are very different. Class B biosolids application in most cases is only 3 to 4.5 dry tons per acre. Compost and Class A biosolids are assumed to have an application rate of 67 tons per acre based on the literature cited and application rates used in those studies. As described above, this is roughly 1 ton of organic amendment applied to just 60.5 square meters of land, compared to Class B biosolids application rates (which are regulated and enforced by the state) are equivalent to approximately 1 ton of Class B biosolids applied to 900 square meters. If the benefits are similar in magnitude, but application rates are lower for Class B biosolids, then the benefit per ton may appear much larger for Class B biosolids application.

Many ecosystem goods and services are evaluated based on the extent of land area (e.g. $/acre). Because of this difference in application rates and the landscape-dependent benefits related to ecosystem goods and services, these significant differences in the landscapes where organic amendments are applied and the amount applied lead to much different benefits. For example, the water supply value for wheat is significantly different due to this difference in application rates. While both organic amendments may increase water holding capacity by as much as 35%, the application rate for compost is assumed to be much higher, and thus the per ton benefit is much lower for compost than Class B application. This is a significant limitation on the current study. Future research should address these differences to better compare Class B biosolids directly with Class A biosolids and compost application.

Appendix D: Measuring Benefits of Compost and Biosolids Details

Compost

The following provides a literature review of the measured benefits of compost application, with benefits identified by individual ecosystem service in each subsection below. All data referenced below meet criteria for being used in this economic analysis. For example, benefits provided by applications of compost are measured against some on-the-ground conditions, such as bare soil or developed land cleared of vegetation. These criteria are outlined in the following:

1. **Compost product**: Literature describes compost "recipe" in varying ways. For this report, compost recipe references the food waste, yard debris, and compostable products inputs as well as wastewater which is developed into biosolids.
2. **Baseline condition**: The literature review conducted for this report was found to compare the benefits of compost application to some existing condition. A majority of referenced conditions were "bare soil" often alluding to post-construction, cleared, or fallow conditions. Both post-fire and agricultural land conditions will also be considered alongside bare soil. *The economic analysis only used studies that referenced these conditions.* Other assumptions related to bare soil condition are discussed further in the study limitations in Appendix C.
3. **Application rates**: The literature referenced below includes a number of different compost application measurements, including a depth of 1.5 inches, with other cases applying as little as 0.5 inches and as much as 10 inches of compost. The most common cases cite application by volume or weight, including tons or cubic yards, applied. As a result of this variation in the literature, studies referenced below only included those that identify application amount. The economic analysis conducted in this report converted compost application rates to the same units.

Flood Protection

Representing a literature review of the flood risk reduction benefits of compost application, Table 9 shows the list of studies considered or directly used to measure benefits in this economic analysis. Each value has a corresponding timeframe under which benefits were measured also shown in the table below. The next section shows how these data were converted to an economic value in the overall assessment. The differences between estimates in this study are used to adjust impacts.

Table 9. Compost Application Flood Risk Reduction Benefits Literature Review Data

Flood Risk Reduction Benefit (Avg)	Application Rate	Land Use	Timeframe	Source Reference	Adjusted Benefit
55% reduction in runoff	1.5-inch	Construction sites	Immediate, 3 month, 1-year	Faucette et al., 2005	57%

52% to 91% (74%) reduction in runoff	2-inch	Fire-damaged sites	Immediate, 1 month	Crohn et al., 2011	52%-91%
68% to 82% reduction in runoff	1-inch	Construction sites	Immediate, 1 month	Crohn et al., 2011	71%-86%
85% reduction in runoff acceleration	2-inch	Simulated construction, lawn	3.5 years (41 months	Logsdon et al., 2017	85%
90% reduction cumulative runoff	2- to 4-inch	New construction, roadway embankments	1-year	Glanville et al., 2001	90%

This section outlines how *unit* costs of built infrastructure to abate stormwater are used to estimate the flood risk reduction benefits of compost. Figure 8 at the bottom of this subsection provides an overview example of the data used to calculate total annual stormwater benefits of compost, specifically for bare soil conditions, using built infrastructure cost estimates. The following outlines why and what data went into the final benefit estimate.

Stormwater infrastructure is not one size fits all. Depending on the type of infrastructure selected, the per unit cost of stormwater mitigated varies. For example, a stormwater detention basin requires limited construction versus more advanced assets like a bioretention system. Both structures may provide similar storage capacity but are designed for much different purposes and at different costs. Table 10 provides a wide sampling of stormwater infrastructure projects from a single study, showing a range of costs per cubic foot and water storage capacities (Ballestero et al., 2005). The study discussed how more expensive projects targeted water quality performance goals in addition to providing some quantity of stormwater storage.

Table 10. Unit Cost of Stormwater Infrastructure

Infrastructure Type	Unit Cost ($/cf)	Study
Retention Basin (Low)	$0.86	USEPA, 2009
Retention Basin (High)	$1.71	USEPA, 2009
Wet Pond - Medium Density Residential	$0.95	King County, 2012
Wet Pond - Low Density Residential	$1.17	King County, 2012
Detention Basin (High)	$1.25	CNT, 2009
Detention Basin (Low)	$0.80	CNT, 2009
Large Detention Basin	$2.63	Barr 2011
Bioretention System	$7.29	Ballestero et al., 2005

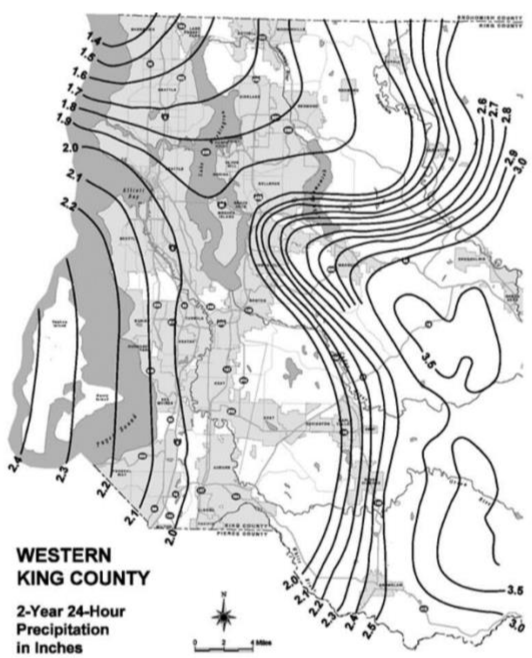
Surface Sand Filter	$13.41	Ballestero et al., 2005

Each value in the table above was amortized, meaning the cost of the capital infrastructure project was spread out over an estimated 30-year lifespan, discounted at 5%. Additionally, dollar values were converted to 2022 dollars.

For this study, the detention basin infrastructure type was selected to estimate the avoided infrastructure costs of using compost. The authors felt selecting this unit cost was a conservative approach to ensure benefits measured to were not overestimated. Using this value can be interpreted as follows: for every cubic foot (cf) of stormwater mitigated from use of compost, $1.28 to $2.00 in benefits are realized from the avoided costs of building an on-site or downstream detention basin. At this point, water flow and volume have not been estimated to realize the total benefit of compost application, which is done in the remainder of this section.

Compost reduces peak flows and stores water in all types of storms through the year. This analysis will limit the scope of annual estimated rainfall to modeling a 2-year, 24-hour storm. Updated approximately every 10 years, the King County Surface Water Design Manual (King County, 2021a) models 2-year 24-hour isopluvials (see glossary) throughout the County. Figure 7 below shows a snapshot of each isopluvial in western King County, with each band representing an estimated amount of rainfall in inches under the 2-year 24-hour storm. With a wide range of rainfall, the most frequently occurring isopluvial at 2.0 inches was selected for use in this study. This suggests that, to estimate the flood risk reduction benefits of the 2-year 24-hour storm, an estimated 2 inches of precipitation was used for the single storm.

Figure 7. 2-Year 24-Hour Isopluvial Map Western King County



To estimate water volume, we take the assumed extent of one ton of compost applied at 2-inch depth which Appendix D shows is approximately 60.5m^2. The calculation follows that an estimated 2 inches of precipitation falls on one ton of compost if applied at 2-inch depth. Finally, referencing the literature cited in the section above, we know that compost stores approximately 57% to 90% of precipitation, compared to bare soil. Using this final factor, the final calculated benefit provided by compost is $78.29 to $193.15 per ton applied. Figure 8 shows cubic feet of water storage capacity combined with water volume estimates from modeled precipitation events used to calculate compost (including Class A biosolid) application.

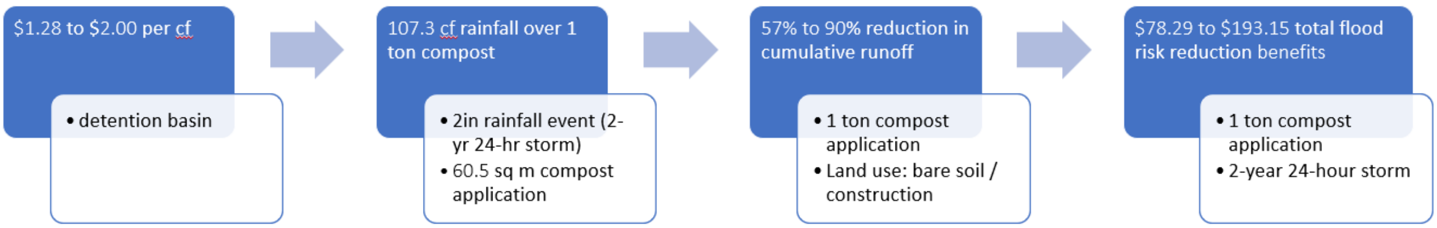


Figure 8. Overview Stormwater Benefits of Compost – Land Use Bare Soil Example

Economic Calculations

Generally, in vegetated undeveloped conditions, most rain that falls infiltrates into the ground and evapotranspires from plants and soil surfaces. Yet, on developed sites, as much as 95% of total rainfall converts to surface runoff (PA DEP, 2006). Multiple studies have shown that for every 1% increase in organic matter in the soil, an increase in water-holding capacity follows by 16,500 to 27,000 gallons of water per acre, depending on soil type and other rainfall parameters (USDA NRCS, 2013).

Following one or more applications of compost to poor soils, the percentage of organic matter increases over time. This in turn improves soil infiltration (Scott et al., 1986) and bulk density (Minnesota Pollution Control Agency, 2022), increasing the capacity of the soil to hold and drain stormwater. One study demonstrated after a year of applying municipal solid waste compost, cumulative peak runoff rates improved by 60% and total runoff volume improved by nearly 50% relative to bare soil conditions (ibid).

The economic analysis conducted in this study estimates the value of flood protection from the application of compost. In the absence of vegetation, flood water is mitigated with built infrastructure, sometimes temporarily storing water but often conveying it as well. Similarly, compost is used in construction, transportation, and other civil projects to, among other things, manage flood waters. This use of compost mitigates the need for infrastructure that would slow down and store water in order to reduce the risk of flooding and washouts. Utilizing the unit cost of built stormwater infrastructure provides a marginal estimated benefit, or the benefit per cubic foot of water.

When applied on bare soil, the estimated value of flood risk reduction from compost application: $78.29 to $193.15 per year per ton.

Soil Erosion

Representing a literature review of the erosion control benefits of compost application, Table 11 shows the list of studies considered or directly used to calculate benefits in this economic analysis. Each value has a corresponding timeframe under which benefits were measured (also shown in the table below). The next section shows how these data were converted to an economic value in the overall assessment.

Table 11. Compost Application Soil Erosion Benefits Literature Review Data

Soil Erosion Benefit (average)	Compost Amount	Land Use	Timeframe	Source Reference	Adjusted Benefit
88% to 99% (94%) reduction in sediment	2-inch	Fire-damaged sites,	Immediate, 1-month	Crohn et al., 2011	88%-99% (94%)
79% to 98% reduction in sediments	1- to 2-inch	Post-construction	Long term (2-3.5 years)	Eck et al., 2010, Logsdon et al., 2017	79%-98%
98% reduction in soil loss	4-inch	Agriculture (grape)	Short term	ROU, 2006	94%
99.98% reduction in interrill erosion	2-inch	Highway construction site bare soil	First 30min heavy rain event (3.7in/hr)	Glanville et al., 2003	99.98%
80% reduction in slope erodibility	2-inch	Highway construction site bare soil	Construction period (variable over 3-6 months)	Glanville et al., 2003	80%

Figure 9 at the bottom of this subsection provides an example of the data used to calculate total annual soil erosion benefits of compost application, specifically for bare soil conditions, using costs associated with sediment replacement and cleanup. This section outlines why and what data went into the final benefit estimate.

The USDA Economic Research Service has developed national measures for estimating the economic benefits of soil conservation (Hansen and Ribaudo, 2008). There are fourteen categories included in the report. Of those, reduced costs of sediment removal from irrigation channels ($1.75/ton of sediment) and avoided costs from damage to and flooding of roads ($0.34/ton of sediment) are considered in this analysis ($2.10/ton of sediment, Figure 9). For agricultural lands, soil productivity can also be considered ($0.69/ton of sediment). The example below shows the benefit per ton of compost produced for construction site application.

Soil erosion rates vary across land use and can vary greatly depending on the soil type, slope, and local precipitation, among other factors. Construction sites can yield sediment loads between 20 and 200 tons per acre per year (Table 12) and can often be higher where no erosion control measures are placed

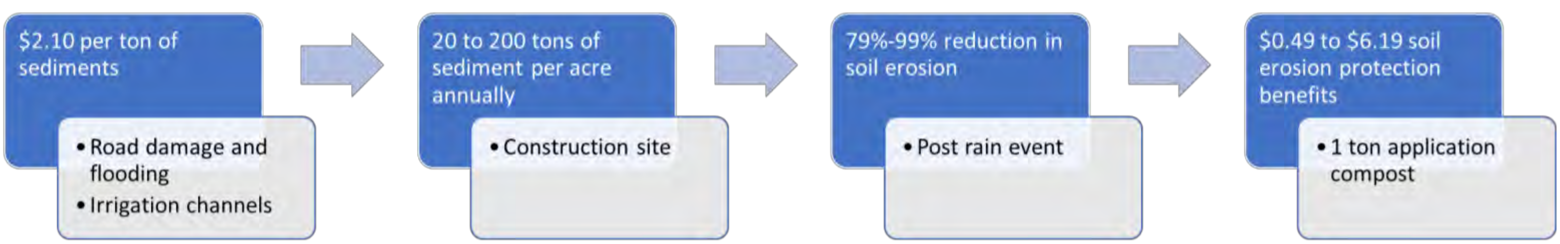
(Broz et al., 2017; Morrow et al., 2017; Pudasaini et al., 2004). Table 12 shows a literature review of soil erosion rates for bare soil, construction sites, post-fire, and agriculture. These rates are used to estimate the soil erosion benefits for each land-use category.

Table 12. Soil Erosion Rates

Land Use Category	Value, low	Value, high	Reference
Bare Soil	0.07 tons/acre	5.17 tons/acre	Crohn et al., 2011
Construction	20 tons/acre	200 tons/acre	Broz et al., 2017; Morrow et al., 2017; Pudasaini et al., 2004
Post-Fire	7.1 tons/acre	13.8 tons/acre	Robichaud et al., 2006
Agriculture	5 tons/acre	20 tons/acre	USDA, 1978

The estimate of soil erosion benefits shown in Figure 9 is the value per ton of compost produced and applied to construction sites. We take the assumed extent of one ton of compost applied at 5cm depth which in Appendix C shows is approximately 60m^2. The literature shows a 79%-99% reduction in soil erosion due to a 5cm compost application, resulting in a range of \$0.49 to \$6.19 in soil erosion protection benefits per ton of compost applied on construction sites.

Figure 9. Overview Soil Erosion Benefits of Compost – Bare Soil Example



Economic Calculation

According to the U.S. Department of Agriculture, the United States loses more than 2 billion tons of topsoil each year to erosion (Bills and Heimlich, 1984). Erosion removes fertile soil rich in nutrients and organic matter, which reduces the ability of plants to establish, grow and remain healthy in the soil. Using compost in highly erosive areas can decrease erosion and allow quicker establishment of vegetation. One study conducted showed compost application reduced soil loss by 86 percent compared to bare soils (Demars et al., 2000).

Application of compost blankets and compost filter berms both provide soil erosion protection and have advantages depending on site conditions. The scope of this research is narrowed to only include compost blankets on bare soil conditions as well as other application techniques commonly used in agricultural contexts. The efficacy of filter berms is application- and site-specific, with techniques recommended based on the gradient of the landscape.

The economic benefits of compost application were calculated using literature referenced in this section combined with unit costs of soil erosion restoration and cleanup. Heavy rain events erode soils and deposit sediment downstream, creating significant water quality issues, often requiring expenses related to restocking soil or removing it from unintended places. Construction projects can lose soil needed for bank or foundation stabilization while leaving trills on embankments and sending sediment over roadways and into water navigation infrastructure. Erosion control can have many downstream benefits including reduced sediments in reservoirs, irrigation channels, and local water ways, improved stormwater drainage, increased soil productivity, among many other benefits (Hansen and Ribaudo, 2008). As shown above, compost can be an effective tool at retaining soil during heavy precipitation, helping stabilize embankments and protect roadways.

When applied on bare soil (construction), the estimated value of soil erosion protection from compost application: $0.49 to $6.19 per year per ton.

Carbon Sequestration and Storage

Representing a literature review of the carbon-related benefits of compost application, Table 13 shows the list of studies considered or directly used to calculate benefits in this economic analysis. Each value has a corresponding timeframe under which benefits were measured also shown in the table below. The next section shows how these data were converted to an economic value in the overall assessment.

Table 13. Compost Application Carbon Ecosystem Service Literature Review Data

Carbon Benefit	Compost Amount	Land Use	Timeframe	Source Reference
Methane landfill diversion: Avoided .35 Mg CO2e	1 Mg food scrap (0.2 tons dry compost)	All	1 year	Brown, 2021
Transport emissions: Avoided .005 to .09 Mg CO2	1 Mg	All	1 year	Brown, 2021
Fertilizer production: Avoided 22kg	1 ton wet compost	All	1 year	Brown, 2021
.21 Mg CO2e per Mg compost	150 Mg/ha*	Reclaimed (bare soil)	1 year	Brown et al., 2011
.22 Mg CO2e per Mg amendment	149 Mg/ha*	Turf/fescue	8 years	Brown et al., 2011,

.44 Mg CO2e per Mg amendment	84 Mg/ha*	Agricultural (Pear)	4 years, annual application	Brown et al., 2011
.88 Mg CO2e per Mg amendment	140 Mg/ha*	Agricultural (Hops)	5 years, annual application	Brown et al., 2011,
0.47 Mg CO2e per Mg amendment	91 Mg/ha*	Agricultural (Grapes)	6 years, annual application	Brown et al., 2011
1.98 Mg CO2e per Mg amendment	134 Mg/ha*	Agricultural (orchard)	Long term, 25 years	Brown et al., 2011
.62 Mg CO2e per Mg amendment	153 Mg/ha*	Agricultural (vegetable rotation)	5 years, multiple applications	Brown et al., 2011
0.64 Mg CO2e per Mg amendment	50 Mg/ha*	Agricultural (wheat)	16 years	Brown et al., 2011; Reeve et al., 2012
*Cumulative amendment loading				

The methodological detail provided below estimates the value of carbon sequestration and offsets that occur due to the processing and application of compost. Compost production offsets greenhouse gases (GHGs) that would otherwise be emitted through landfilling food and yard waste. In addition, reduction in fertilizer application also offsets carbon emissions of fertilizer production associated with the synthesis of atmospheric nitrogen or the mining of phosphorus from rock. Finally, carbon is stored in the soil directly through compost application and the improvement in soil quality enhances the soil's ability to sequester carbon by increasing net primary productivity. All these benefits can be estimated to calculate the economic value of compost for reducing carbon emissions. Figure 10 at the end of this subsection provides an overview the calculated total value of carbon reduction and offsets provided through compost production and application, with benefits calculated using the social cost of carbon described further in the following section.

There are two primary means of measuring the economic value of carbon emissions. This can be done through **voluntary and involuntary markets**, where dozens of carbon values exist today in US markets alone. For example, as of mid-2022, the California Carbon Auctions market is trading at $29.15 per metric ton of carbon (California Air Resources Board, 2022). The other method of valuing carbon is through non-market valuation. Carbon emissions carry many social costs, often aggregated, and described as the **Social Cost of Carbon** (SCC, or SC-CO2). The SCC estimates the monetized value of damages caused by CO2 emissions. This can be used to inform climate policy. The most recent study on the subject (Rennert et al., 2022) estimates the SCC at $185 per metric ton. This is over 3.5 times the current U.S. federal interim estimate of $51 per metric ton based on findings from the Interagency Working Group (IWG) published in February 2021 (IWGSCGG, 2021). Locally, Washington State established a range of social cost of carbon values to comply with the package of clean energy legislation signed into law in 2019, then adopted by King County for use in capital projects (WA UTC, 2022). Selecting from the array of values, a SCC of $76.10 per metric ton attributed to emissions in 2022 was selected for use in this report.

The economic benefit of carbon offsets and sequestration are estimated using the data summarized above. Carbon offsets and sequestration range between 2.06 and 3.08 metric tons of CO2 per ton of compost applied. Based on the SCC of $76.10 per metric ton of CO2 (described above), the economic value of the carbon benefits is between $156.77 (2.06 tons CO2e, SCC price) to $234.39 (3.08 tons CO2e, SCC price) per ton of compost produced and applied.

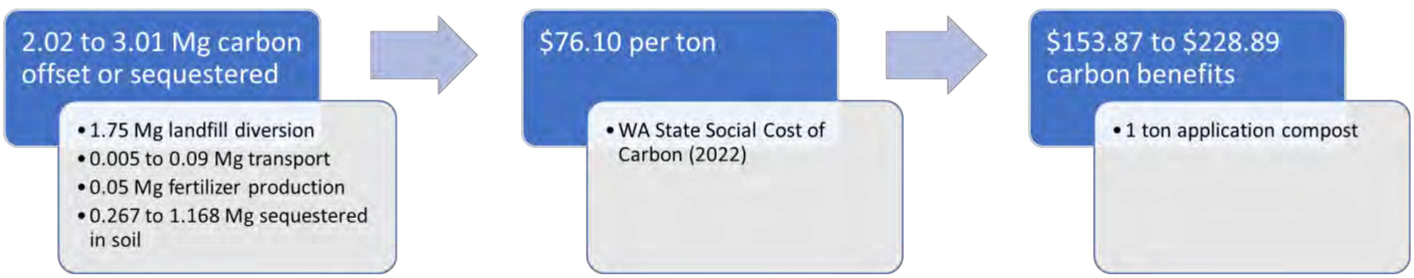


Figure 10. Overview Carbon Benefits Social Cost of Carbon Value of Compost – Bare Soil Example

Economic Calculation

Compost application can be an effective measure to increase carbon sequestration and storage. Diversion of organic waste from the landfill avoids the production of methane gas during breakdown, contributing to avoided GHG emissions. Adding compost to the soil improves the plant productivity of that site where carbon is removed from the atmosphere via greater photosynthetic activity. Finally, established vegetation then adds more carbon to the soil via roots and leaf litter, with a portion of the carbon from the original compost application remaining in the soil for a long period of time (Bloemsma et al., 2020; Kareiva, 2020). These processes are far more beneficial compared to the alternatives of landfilling or incineration of the compost which often lead to greater emissions (Nordahl et al., 2020). Tiefenbacher et al. (2021) provide a synthesis of agricultural management practices for improving carbon sequestration and found the average carbon sequestration potential of compost application was at least 310 kg Carbon per hectare per year depending on the application rate.

The immediate benefits of compost application for carbon sequestration and storage are largely due to the direct application of carbon to the soil and the improvements in net primary productivity. Expanding use of organic amendments can help in the effort to reduce GHG emissions. Compost application increases soil organic carbon which can also enhance soil physical, chemical, and biological processes and properties (Blanco-Canqui et al., 2013). Brown et al. (2011) found that application rate and time both influence soil carbon concentration. The economic analysis conducted in this study estimates the value of carbon storage and offsets that occur due to the processing and application of compost.

When applied on bare soil, the estimated value of carbon sequestration and storage from compost application: $153.87 to $228.89 per ton.

Water Supply

Representing a literature review of the water supply benefits of compost application, Table 14 shows the list of studies considered or directly used to calculate benefits in this economic analysis. Each value has a corresponding timeframe under which benefits were measured also shown in the table below. The next section below shows how these data were converted to an economic value in the overall assessment.

Table 14. Compost Application Water Supply Ecosystem Service Literature Review Data

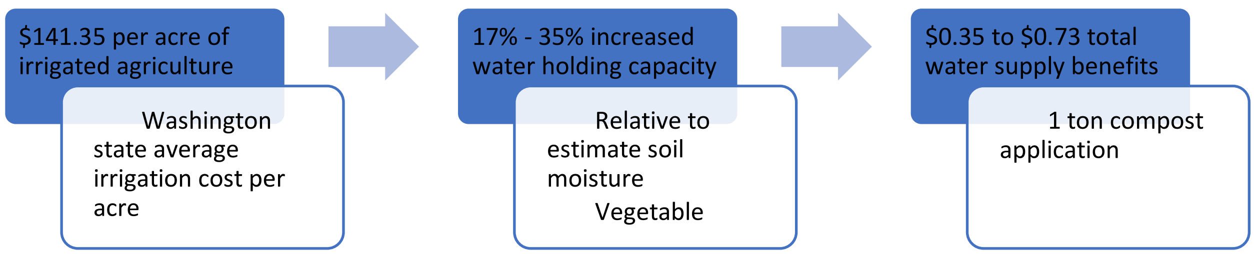
Water Supply Benefit	Compost Amount	Land Use	Timeframe	Source Reference	Adjusted Benefit
48% increased water holding capacity	224 Mg/ha*	Landscape (mixed shrub)	7 years	Brown et al., 2011	35%-48%
11% to 17% increase in water holding capacity	68 – 153 Mg/ha*	Agricultural (vegetable rotation)	5 years	Brown et al., 2011	17%-35%[1]
50% to 61.5% increased water holding capacity	105 Mg/ha*	Agricultural (cherry)	6 years	Brown et al., 2011	68%-83%
54% increased water holding capacity	140 Mg/ha*	Agricultural (hops)	5 years	Brown et al., 2011	54%
1.7% to 4.4% increase plant-available water content	16.5 – 66 tons/ha	Agriculture (Irrigated Wheat)	2 years	Sabrah et al., 1995, cited by ROU, 2006	4%-10.5%
1.75% to 3.75% increase plant-available water	5-15 cm	Agricultural (grape vineyard)	Year 1	ROU, 2006	1.75%-2.3%
6.1% to 11.6% increase soil moisture	5-15 cm	Agricultural (grape vineyard)	Year 1	ROU, 2006	6.1%-7.1%
*Cumulative amendment loading					

[1] The study compared compost (treatment) to chicken manure (control) application. It is likely that the water supply benefit would be higher if the compost application was compared to only fertilizer application. To account for this potential change, the study incorporates the low-end of the landscape (mixed shrub) value to estimate the benefit.

Figure 11 at the end of this subsection provides an overview of the data used to calculate total annual water supply benefits of compost using built infrastructure cost estimates and water rates. The figure shows the average per acre cost of irrigating mixed vegetables in western Washington. The following outlines why and what data went into the final benefit estimate.

The USDA publishes, as part of the Census of Agriculture, the Irrigation and Water Management Survey. The latest survey was in 2018 (USDA, 2019). This survey reports on irrigation and water use on farms throughout the United States. The survey reports on average per acre irrigation costs from off-farm sources, approximately $141.35 (in 2022 USD). The per acre value is converted to a unit cost over 60m^2, the assumed extent of application for one ton of compost presented above. This data was combined with the literature review provided in the beginning of this section (Table 14) showing compost application in mixed vegetable farming in Washington state rendering a 17% - 35% increased water holding capacity.

Figure 11. Overview Water Supply Benefits of Compost – Vegetable Rotation



Economic Calculation

Incorporation of compost into soil improves the soil's physical properties, increasing aggregate stability, water holding capacity, hydraulic conductivity, and plant available water (Brown et al., 2011; State of California, n.d.). Compost can save water by increasing infiltration rates and soil water-holding capacity, and when used as a mulch can save water by moderating soil temperature and reducing evaporation (ibid). One study estimated that every one percent organic matter in the top six inches of soil holds about 27,000 gallons of water per acre (ibid). Plant available water capacity (AWC) of soil primarily depends on soil texture and soil organic matter content. For example, loamy soils have the highest AWC while coarse sand and gravel have the lowest.

Remediation of poor or construction base soils improves AWC. If not infiltrated and stored, water becomes surface runoff and lost. Faucette et al. (2005) show how rainfall converts to runoff by different treatment levels of compost application at multiple time spans.

The economic analysis conducted in this report shows how unit costs of irrigation and structural water storage are used below to estimate the water supply benefits of compost. Particularly in agricultural systems, large amounts of water are supplied to vegetation during dry summer conditions often requiring on-site storage and private managed water distribution infrastructure. As discussed, compost can alleviate some irrigation costs by holding and retaining water made available to soil and plants. Utilizing the unit cost of irrigation infrastructure provides a marginal estimated benefit, or the benefit per cubic foot of water.

When applied in agricultural contexts, the estimated average value of water supply from compost application: $0.35 to $0.73 per ton per year.[2]

Soil Quality and Yield

Representing a literature review of the soil quality and yield benefits of compost application, Table 15 shows the list of studies considered or directly used to calculate benefits in this economic analysis. Each value has a corresponding timeframe under which benefits were measured also shown in the table below. The next section shows how these data were converted to an economic value in the overall assessment.

Table 15. Compost Application Soil Quality and Yield

Soil Quality/Yield Benefit	Compost Amount	Land Use	Timeframe	Source Reference
10% increase in yield	20 Mg/acre	Agriculture (wheat)	Year 1	Hills et al., 2019; WSU Snohomish County Extension 2013
20% increase in yield	20 Mg/acre	Agriculture (vegetable rotation)	Year 1	Collins et al., 2015; Hills et al., 2019
20.5% increase	4-inch	Agriculture (grape vineyard)	Unclear	Buckerfield 1998 (adapted from ROU, 2006)
7%-30% increase in yield	30 Mg/ha	Agriculture (grape vineyard)	Year 1	Aguilar et al., 1997
27-40kg reduction in fertilizer needs (N) 45-68kg reduction in fertilizer needs (P)	80-120 Mg/ha	Agricultural (grape vineyard)	Year 1	ROU, 2006

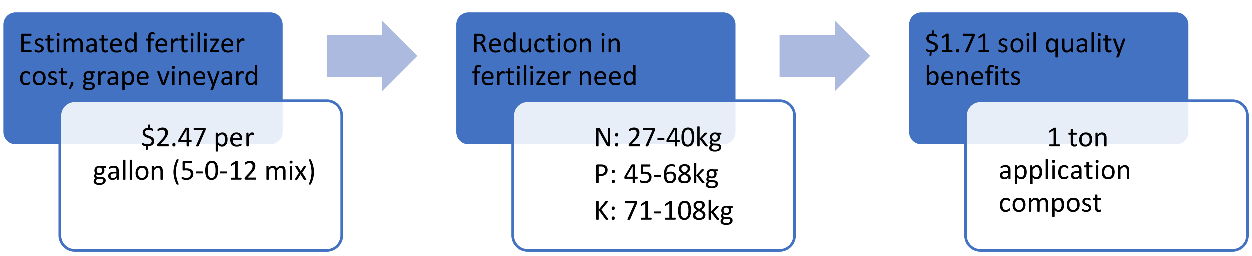
[2] The agricultural products considered in this analysis include two eastern Washington crops, wheat and grapes (vineyards), and one western Washington crop category, mixed vegetables. The method for economic benefit is the same across all crops. The range arises from the difference in impacts identified in the literature for compost application. Water supply benefits from one ton of compost was estimated at $0.13 to $0.74 for wheat and $0.13 to $1.14 for grapes.

71-108kg reduction in fertilizer needs (k)				
72-108kg reduction in fertilizer need (N) 120-180kg reduction in fertilizer needs (P) 90-135kg reduction in fertilizer needs (k)	80-120 Mg/ha	Agricultural (grape vineyard)	3-5 years	ROU, 2006

Figure 12 below provides an overview of the data used to calculate total annual soil quality benefits of compost using unit fertilizer cost estimates. The figure shows per gallon cost estimate of fertilizer (example: Grape vineyards) combined with estimates of reduced fertilizer need due to compost application, used to calculate benefits of compost application.

Restoration and soil quality benefits: Not included above are the soil quality benefits compost provides in soil remediation, landscaping, or other restorative projects. Reclamation efforts such as the Vashon Island Borrow Pit project demonstrate how organic amendments renourish soils that formerly had little organic material (Brown, n.d.). Later versions of this report will include recommendations on further understanding these benefits.

Figure 12. Overview Soil Quality Benefits of Compost – Grape Vineyard



Economic Calculation

Soil quality is a broad concept defined by multiple qualities, including bulk density, nutrient composition and concentration, water holding capacity, living organisms, and other health and function indicators. Soil quality, or health, has been defined as the “capacity of a living soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health,” (Doran, 2002; Vidal Legaz et al., 2017). Major soil properties include physical (bulk density, water holding capacity, aggregate stability, infiltration rate), chemical (soil organic matter, nutrient concentration, pH, salinity), and biological (microbial biomass and diversity, earthworms/invertebrates, respiration) (Soil Life, n.d.). Soil quality and yield are combined in this analysis because of the overlap between fertilizer application and yields. Studies have shown that compost can adequately replace fertilizer while maintaining or increasing yields (Collins et al., 2015; Hills et al., 2019; WSU Snohomish County Extension, 2013).

Soil microorganisms are essential for productive soils and healthy plants. Their activity is largely based on the presence of organic matter. Soil microorganisms include bacteria, protozoa, and fungi. These microorganisms play an important role in organic matter decomposition, which leads to humus formation and nutrient availability. Some microorganisms also promote root activity; specific fungi work symbiotically with plant roots, assisting them in extracting nutrients from the soils. Compost can help improve soil quality in ways that conventional fertilizers cannot. The primary purpose of fertilizer is to provide nutrients to plants. Compost can be used to enrich the soil with organic matter necessary for productive soils.

As discussed, soil quality is a broad concept defined by multiple qualities, including bulk density, nutrient composition and concentration, water holding capacity, living organisms, and other health and function indicators. The economic analysis of soil quality in this report is scoped narrowly to valuing the avoided cost of fertilizer following application of compost. Annual application of fertilizers rich in nitrogen (N), phosphorus (P), or potassium (K), among other plant nutrients, vary by crop and existing soil quality. In addition, the analysis uses the scope of literature reported by Hills et al. (2019) and recent commodity prices to estimate the economic value of yield increases. Compost can be used to supplement or replace fertilizer use, reducing annual costs and improving yields.

When applied in agricultural contexts, the estimated average value of soil quality and yield enhancements from compost application: $1.71 to $102.58 per year per ton.[3]

Water Quality

Representing a literature review of the water quality benefits of compost application, Table 16 shows the list of studies considered or directly used to calculate benefits in this economic analysis. Each value has a corresponding timeframe under which benefits were measured (also shown in the table below). Results show that compost application on post-construction sites can have varying net water quality impacts. Of note is the potential increase of ortho-phosphorous. Due to the uncertainty of the net water quality impact and data limitations of unit water quality costs associated with many compounds referenced in Table 16 below, water quality benefits from compost application were excluded from the scope of this analysis. The next section below discusses the economic data limitations and shows how data taken from the literature were converted to an economic value in the overall assessment.

Table 16. Compost Application Water Quality Benefits Literature Review Data

Water Quality Benefit	**Compost Amount**	**Land Use**	**Timeframe**	**Source Reference**
72%-96% reduction in turbidity (NTU) 73%-91% reduction in TDS 88%-99% reduction in TSS	5 cm*	Fire-damaged sites	Immediate, one-month	Crohn et al., 2011

[3] The agricultural products considered in this analysis include two eastern Washington crops, wheat and grapes (vineyards), and one western Washington crop category, mixed vegetables. The method for economic benefit is the same across all crops. The significant range, relative to other benefit categories, is due to grape production, which has significantly higher prices than other crops considered.

56%-88% reduction in total phosphorus 6% *increase* to 89% reduction in ortho-P 57%-91% reduction in nitrate 46%-95% reduction in ammonium-N				
48%-84% reduction in turbidity (NTU) 23% increase to 57% reduction in TDS 88%-93% reduction in TSS 4%-344% *increase* in total phosphorus 15%-485% *increase* ortho-P 70%-98% reduction in nitrate 41%-85% reduction in ammonium-N	2.5 cm*	Post-construction	Immediate, one-month	Crohn et al., 2011
86% reduction in ortho-P	126 tons/acre or 10 cm*	Post-construction	2 – 3.5 years	Eck et al., 2010, Logsdon et al., 2017

Compost application improves water quality in multiple ways, including improving infiltration, reducing nitrogen leaching, breaking down compounds like oils and pesticides, and adsorbing copper and other compounds (US Composting Council, 2008), and tire dust pollutants such as 6PPD-quinone (WA ECY, 2022). Research has shown that turf grown in areas improved with compost required up to 30 percent less water, fertilizer, and pesticides than turf treated conventionally (EPA, 1997). Treatments to bare soil conditions have been shown to reduce nutrient loads, though in some cases, concentrations of nitrate and dissolved P from compost treated plots were higher (Eck et al., 2010).

Over time, prior application of compost provides a considerable variety of macro- and micronutrients essential for plant growth. Since compost contains relatively stable sources of organic matter, these nutrients are supplied in a slow-release form.

Water quality benefits of compost application were monetized for only post-fire land conditions due to data limitations. Bare soil construction conditions and agricultural land uses were found to have limited information available to derive a unit cost for all water quality compounds. This subsection describes these data limitations and explores the known water quality impacts of compost application, despite the inability of this analysis to derive an economic value.

For some water quality compounds, such as phosphorous, nitrogen, and total suspended solids, there are standardized estimates for developing economically feasible management plans to reduce nutrient loadings (EPA, 2016). Such tools often focus on stormwater and agricultural runoff and do not associate an individual marginal cost with a wide array of water quality compounds, particularly specific to compost application. Table 16 provides a list of water quality impacts of compost application, including nitrate, ammonium-N, and turbidity, all of which do not have easily measurable unit costs for treatment from available tools. Table 16 also shows the positive and negative impacts associated with application of compost in bare soil conditions, of which ortho-phosphorous was found to have a potential 89% increase after application.

Despite the unavailability of detailed impact estimates, the water quality benefits of compost application are well understood. Composting is recognized as a Best Management Practice by the EPA's Non-Point Source Program (ROU, 2006). In one case, a study showed that annual applications of ¾-1" of compost per acre would result in increased soil moisture and reduced water seepage below the root zone of pollution-prone areas, thus reducing the potential for nitrogen and atrazine (herbicide) to leach into nearby water sources (Savabi et al., 2005).

One third of the pollution in Washington state's water is from stormwater runoff (King County Natural Resources and Parks, n.d.). In the absence of natural capital, polluted stormwater is sometimes treated in stormwater systems or is left to circulate and create impacts downstream. Functioning like a filtration system, compost-amended soils are consistently used to capture stormwater and filter many compounds from the water before its released. This use of compost helps mitigate the impact of pollutants and can potentially be used to supplement existing infrastructure.

Class B Biosolids

This section provides a literature review of the measured benefits of Class B biosolids application, with benefits identified by individual ecosystem service in each subsection below. Similar to compost, all data referenced below meets a set of criteria for being used in this economic analysis. These include the following:

1. **Biosolids recipe**: Unlike compost, creation of a biosolids-based product is consistent in accordance with federal regulation 40 CFR Part 503 (US EPA, 2020). Even considering the alternative use options of waste processing, including alkaline stabilizers or thermal drying, this analysis will treat the end product as essentially the same for simplicity.
2. **Baseline condition**: Like compost, literature on biosolids applications compares the benefits of to some existing condition, with a majority of referenced conditions being agricultural. As eluded to above, other applications were more common with Class A biosolids, such as use in gardens. Post-fire conditions are not a common application of biosolids like compost and will not be included in this analysis. Other assumptions related to application conditions are discussed further in the study limitations in Appendix C.
3. **Application rates**: The literature sampled below includes varying rates of biosolids application. The most common cases site application by volume or weight, including tons or cubic yards applied. As a result of this variation in the literature, studies referenced below only included those that identify application rates. The economic analysis conducted later in this report converted biosolids applications to the same unit (tons per acre).

It is important to reiterate here that comparison of Class A biosolids and compost with Class B biosolids based on the results of this study is not recommended. Application rates for Class B biosolids are much lower (3-4.5 tons per acre) compared to the literature cited for application rates of compost and Class A biosolids (as much as 67 tons per acre). Ecosystem services benefits are often reported per acre, and so per ton benefits of Class B biosolids will appear much higher because there is less being applied to the landscape even though similar benefits are often provided. For this reason, comparisons are not advised.

Carbon Sequestration

Representing a literature review of the carbon benefits of biosolids application, Table 17 shows the list of studies considered or directly used to measure benefits in this economic analysis. Each value has a corresponding timeframe under which benefits were measured also shown in the table below. The next section shows how these data were converted to an economic value in the overall assessment.

Table 17. Biosolids Application Carbon Ecosystem Service Literature Review Data

Carbon Benefit	Biosolids Amount	Land Use	Application Rate	Source Reference
0.43 Mg C per Mg amendment	18* Mg/ha	Agriculture (Wheat-fallow rotation)	Every 4 years (1994 – 2006)	Brown et al. 2011
7.4 g/kg C	7 Mg/ha	Agriculture (Wheat-fallow rotation)	4 times over 16 years	Cogger et al. 2013
2.75 g/kg C	50 Mg/ha	Turf	Single	Brown et al. 2011
0.47 Mg C per Mg amendment	147* Mg/ha	Roadside	Long term, annual application	Brown et al. 2011
King County Data				
5.15 Mg CO2 per Mg amendment	4.5 dry tons per acre	Working forest	Every 4 years	WTD_ForestsSoilData; Leonard et al., 2021
*Cumulative amendment loading				

Economic Calculation

Biosolids application is an effective measure to increase carbon sequestration and storage. The two components of carbon accounting from biosolids application are the diversion of human waste from the waste stream and the beneficial impacts of biosolids application on soil function. Soil carbon content increases due to the direct application of additional carbon through the biosolids medium. Multiple studies have shown that biosolids application is an effective way to increase soil carbon reserves (Antonelli et al., 2018; Miller, 2004). Increasing organic carbon concentrations in agricultural and rangeland soils help restore degraded soils to productivity or return agricultural soils to native ecosystems, both of which have been proposed as a means to sequester carbon and increase the reserves (Antonelli et al., 2018).

The short-term benefits of biosolids application for carbon sequestration and storage are largely due to the direct application of carbon to the soil and the improvements in net primary productivity. One study demonstrated positive rates of carbon storage in multiple Washington state locations in multiple contexts, including agriculture (wheat and grass/fescue), roadside projects, and turf (Brown et al., 2011). Another Puget Sound study examined the effects of different treatments on the restoration of a borrow pit, acting as a proxy for degraded soils such as in construction, urbanization, or roadside development. The study measured positive soil carbon storage in all treatments that used biosolids in remediation.

The economic analysis of Class B biosolids used social cost of carbon ($76.10 per metric ton) and carbon storage data (Table 17) to estimate ecosystem service value, like compost benefits calculated in Section 4. The carbon benefit (0.43 per Mg of organic amendment applied) was multiplied by 3.67 to convert carbon to carbon dioxide equivalents (CO2e). Carbon stored from Class B biosolids application results in reduced carbon emissions and increased carbon storage.

When applied in agricultural contexts, the estimated average value of carbon storage and mitigation from Class B biosolids application is $120.09 per ton.

Water Supply

Table 14 below shows a list of studies that evaluated the water supply benefits of biosolids application. These studies will be used to measure the benefits associated with biosolids application for improving water holding capacity and plant available water in soil. The studies generally cover specific land use and duration. The following section will demonstrate how the literature shown here can be used to estimate economic value of water supply benefits due to biosolid application. Due to data and literature limitations, forests benefits related to increased water supply were not included in the results.

Table 18. Biosolids Application Water Supply Ecosystem Service Literature Review Data

Water Supply Benefit	Application Rate (tons/acre)	Land Use	Timeframe	Source
46% to 90% Reduced runoff volume	5 cm	Fire-damaged soils	Short term, after first rain event and the following month	Crohn 2011
12% increase in water holding capacity	45 tons/ha	Agriculture, orchard	2 applications over 7 years	Neilsen et al. 2002
King County Data				
35% increase in available water holding capacity	3-4.5 tons/acre	Agriculture, Dryland wheat	Long term (27 years), Application every four years	LaHue 2021; WTD_2021BiosolidsSoilHealth Overview

Economic Calculation

Biosolids application can improve the water supply of soils through several mechanisms. The water supply of soil, or water holding capacity, is influenced by the texture (i.e., sandy, silt, clay, loamy), organic matter content (primarily carbon and other organic components), and bulk density of the soil. Biosolids applications have been shown to increase organic matter content and reduce bulk density (Brown et al., 2011; Neilsen et al., 2003). Both increase the water holding capacity of the soil.

In vegetated conditions, most rain that falls infiltrates into the ground and evapotranspires from plants and soil surfaces. Following one or more applications of biosolids to poor soils, the percentage of organic matter increases and bulk density decreases, increasing water holding capacity. Available water holding capacity in the soil is crucial. This is especially true in the low rainfall region of eastern Washington with dryland (non-irrigated) agriculture. In a study from Eastern Washington, annual biosolids applications of 3 to 4.5 dry tons per acre increased available water holding capacity by approximately 35% (LaHue, 2021). The experimental plots have been evaluated for over 27 years.

To estimate the economic benefit of Class B biosolids, unit costs of irrigation and structural water storage were used ($141.35 per acre of irrigated agriculture). As discussed with compost, biosolids can also alleviate some irrigation costs by improving soil's water holding capacity made available to plants. The unit cost ($141.35) was divided by three (the minimum biosolids application to observe the 35% increase), and multiplied by the percentage increase in water holding capacity to estimate the potential savings from water conservation ($16.49). To account for the duration of the study, the benefit is escalated linearly for the period of the study (27 years). Minimum initial benefits from Class B biosolids are $0.61 per ton and escalate to as much as $16.49 per ton.

When applied in agricultural contexts, the estimated average value of water supply from Class B biosolids application: $0.61 to $16.49 per year per ton.[4]

Soil Quality

Table 19 shows the relevant literature regarding biosolids application and soil quality and yield benefits.

Table 19. Biosolids Application Soil Quality Ecosystem Service Literature Review Data

Soil Benefit	Application Rate	Land Use	Timeframe	Source
10% - 14% increased grain yield	24 – 45* Mg/ha	Agriculture, wheat fallow	Application every 4 years (1994-2010)	Cogger et al. 2013
Up to 22% increased grain protein	24 – 45* Mg/ha	Agriculture, wheat fallow	Application every 4 years (1994-2010)	Cogger et al. 2013
8% - 31% increased N uptake	24 – 45* Mg/ha	Roadside	Application every 4 years (1994-2010)	Brown et al. 2011

[4] As described in Appendix C: Study Assumptions and Limitations, the application rates for compost and biosolids are significantly different while the ecosystem goods and services evaluated are based on the extent of application (area per ton applied). Due to the low application rate of Class B biosolids, per ton benefits of Class B biosolids may appear larger because a single ton is applied to a larger area and may have similar benefits. This speaks to the challenges in both the timing/duration of applications and potential "threshold effects", meaning that compost application rate assumptions may not be necessary to observe similar benefits as those to Class B biosolids.

10% - 20% increased yield	50 Mg/ha	Dryland wheat	Cumulative loading	Brown et al. 2011
38% - 63% increased nitrogen	18 – 40* Mg/ha	Agriculture, wheat fallow	Application every 4 years (1994-2006), results sampled in 2008	Brown et al. 2011
614% - 969% increased phosphorus	18 – 40* Mg/ha	Agriculture, wheat fallow	Application every 4 years (1994-2006), results sampled in 2008	Brown et al. 2011
4% increased nitrogen	74 Mg/ha	Turf	Long term, 8 years	Brown et al. 2011
44% increased phosphorus	74 Mg/ha	Turf	Long term, 8 years	Brown et al. 2011
7% - 23% increased dry matter yield	13.4 – 20.2 Mg/ha	Tall Fescue	One year	Cogger et al. 2001
3% - 7% increased dry matter yield	13.4 Mg/ha	Tall Fescue	Long Term, average across 7 years	Cogger et al. 2001
12% - 18% increased dry matter yield	20.2 Mg/ha	Tall Fescue	Long Term, average across 7 years	Cogger et al. 2001
King County Data				
166 kg increase	4.5 tons/acre	Working forest	Multiple	King County Data: WTD_TreeGrowth Measurements
Reduction in fertilizer application, 67 lbs/acre	3 tons/acre	Agriculture, wheat	Short and Long Term	WSU Dryland Wheat Nitrogen Fertilizer Calculator, King County Data: WTD_AgricltursalSoilSamplingData
16% increase in wheat yield compared to fertilizer	3 tons/acre	Agriculture, wheat	Short and Long Term	King County Data: GP-17Yield1996-2020 13nov20
*Cumulative loading rate				

Economic Calculation

Soil quality is a broad concept defined by multiple qualities, including form, bulk density, nutrient composition and concentration, water holding capacity, living organisms, and other health and function indicators. Soil quality, or health, has been defined as the “capacity of a living soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health,” (Doran, 2002; Vidal Legaz et al., 2017). Major soil properties include physical (bulk density, water holding capacity, aggregate stability, infiltration rate), chemical (soil organic matter, nutrient concentration, pH, salinity), and biological (microbial biomass and diversity, earthworms/invertebrates, respiration) (Soil Life, n.d.).

Class B biosolids application have been shown to improve soil quality and reduce the strain on soils used in agriculture and forest production. Biosolids applications also improve yields for both agricultural and forestry related production. Several studies have examined biosolids application impacts on the yields of wheat (both dryland and fallow), grasses (tall fescue), and trees (both for timber and orchards).

As with the compost analysis, the economic analysis of soil quality benefits from Class B biosolids was limited to the reduction of synthetic fertilizers. The economic benefit does include the potential benefits of increased yields. Due to data limitations, only wheat was considered for biosolids application. The economic benefit from fertilizer reduction was estimated using the Washington State University (WSU) Dryland Wheat Nitrogen Fertilizer Calculator and fertilizer prices (WSU, n.d.). The inputs for the fertilizer calculator were based on data[5] provided by King County. The nitrogen recommendation was 67 pounds per acre. King County data compared Class B biosolids with Anhydrous Ammonia (AA), and so the estimates used AA prices from the U.S. Department of Agriculture Economic Research Service Monthly average fertilizer prices from 2021, inflated to 2022 dollars ($1,846 per ton), or $0.92 per pound, or $61.84 per acre. This per acre value was divided by three ($20.61) to account for the fact that three dry tons of Class B biosolids could replace the use of 67 pounds of nitrogen. This is a conservative estimate since nitrogen is only a portion of the total weight of AA. The application of three dry tons of Class B biosolids not only supplemented the use of nitrogen, but also increased yields where applied. Data provided by King County showed that, when compared to AA, Class B biosolids increased yields by 413 pounds per acre. Using current market prices, that increase in yields is an additional $81.55 per acre. Dividing that total by three ($27.19) provides a per ton estimate. Combined, the economic benefit from reduced fertilizer application and increased yields is $47.80 per ton of Class B biosolids.

When applied in agricultural contexts, the estimated average value of soil quality and yield enhancements from Class B biosolids application: $47.80 per year per ton.

[5] The data provided by King County can be found in “GP-17 yield 1996-2020 12nov20”. Average values were used as inputs to the calculator.

Appendix E: Class A Biosolids Capital Investment in King County

In this section, the benefits of Class A biosolids are understood through the lens of a King County capital investment in Class A infrastructure, shifting part of the County's Class B biosolids production into Class A production. The following outlines the capital and operations and maintenance (O&M) costs associated with the investment, with subsequent subsections exploring the implications on wider market product availability, revenues, and environmental benefits related to the application of Class A biosolids.

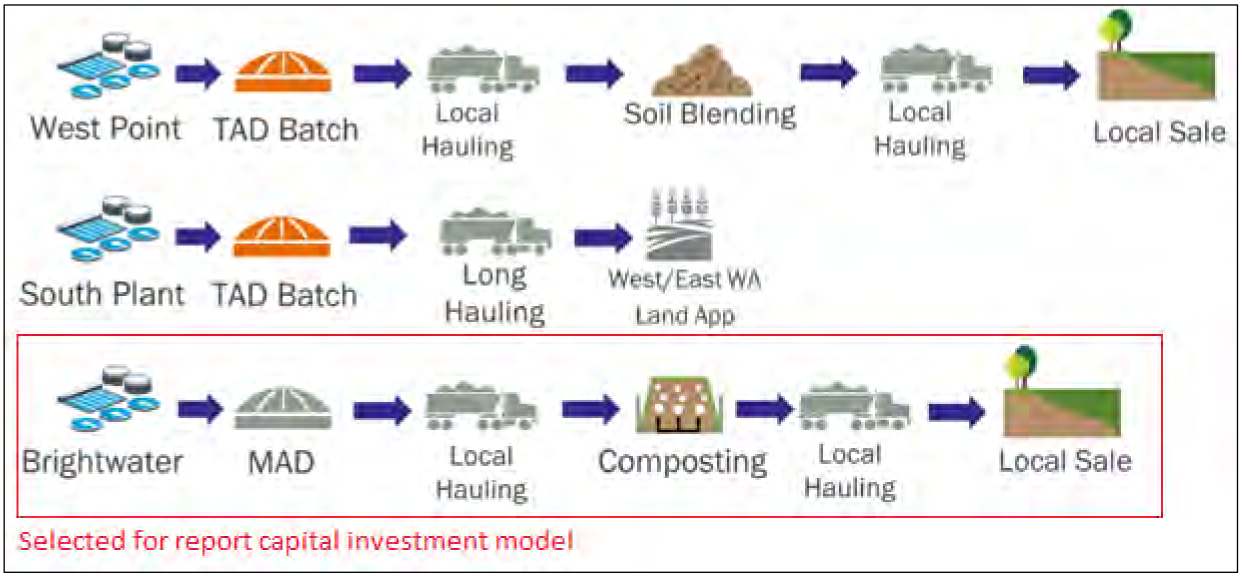
As discussed in the body of this report, limited storage space for Class B biosolids and the risk of product delivery failure makes it worth considering investment in capital infrastructure that would allow for the creation of a Class A biosolids product. Multiple municipalities have cited cost savings and increased revenue following a transition from Class B to Class A, particularly when market analysis confirmed demand for the product (Creech, 2021; Trojak, 2016). The remainder of this section is dedicated to evaluating the benefits of biosolids application under King County's current Class B program and exploring the opportunities for Class A investment.

In April 2020, King County commissioned a technical report on Class A biosolids technology evaluation to assist the County in preparing their response to Council Proviso 2019-0148. The proviso calls for the identification of Class A alternatives to the current Class B biosolids application in forest and farm environments in an effort to diversify the biosolids products and increase resiliency. The report (referred to hereon as Technical Report) produced a comprehensive list of relevant Class A technologies with screening criteria to narrow selection of Class A technologies to those potentially suitable for King County biosolids management (Brown and Caldwell, 2020).

For this report, King County WTD selected a single scenario from the Technical Report referenced above called Optimized Class A biosolids (referred to hereon as Scenario 4). While this scenario is comprised of three options for producing Class A; this report is modeling a partial implementation of Scenario 4, the implementation of a composting program using 20% of the biosolids production. Figure 13 below outlines this process upgrade, showing the process of creating each biosolids product and its intended market entry point. A summary description of the plant upgrade includes the following:

- Utilization of existing mesophilic digestion at Brightwater Treatment Plant (Brightwater) with Class B biosolids hauled to an off-site Class A composting facility and local sales
- Thermophilic anaerobic digestion (TAD) with batch tanks at South Plant with Class A land application in western and eastern Washington (40 percent/60 percent)
- TAD with batch tanks at West Point and off-site soil blending with local sales

Figure 13. Scenario 4 Investment Option



With the partial modeling of Brightwater plant from Scenario 4, only 20% of existing Class B feedstock will be dedicated to Class A biosolids product creation, retaining approximately 80% of the Class B product model. This assumption models a stepwise adoption of Scenario 4 and is used to model cost and benefit analyses in the following sections. This partial implementation of Scenario 4 will be referred to in the remainder of this report as King County's Class A investment. Using this Class A investment as the baseline investment cost for King County to transition from a Class B to a Class A product, the next section discusses other costs and benefits associated with the creation of both products.

Overview of Class A Biosolids Investment

Table 20 below outlines the investment, O&M, and other cost considerations for the Class A investment. Revenue and increased market access/demand are not included and are considered in the subsequent section.

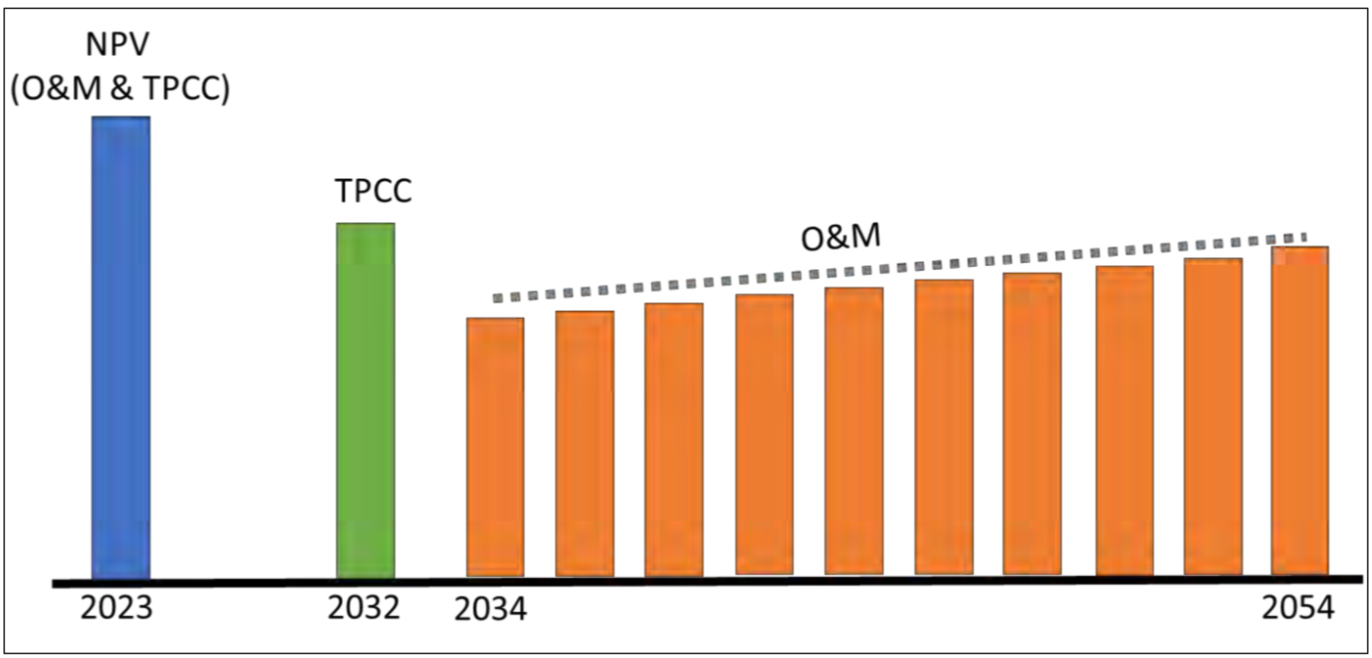
Table 20. Overview cost considerations for Class A Investment

Category	Class B (Business as Usual)	Impact to Class A (Scenario 4)
O&M	Hauling (Fuel, truck rental, insurance)	Reduced average cost overall per wet ton delivered across all markets
O&M	Supplies, Equipment, and repairs	Reduced average cost overall per wet ton delivered across all markets
O&M	Truck Shop Maintenance and Rental	Same
O&M	Everett pad lease	Same
O&M	Fleet payments	Increased with new composting equipment

O&M	Standby hourly rate	Reduced average cost overall per wet ton delivered across all markets
Admin	Program Operations	Increased
Fleet capital	Equipment	Increased in new markets, reduced in existing markets
Fleet capital	Trucks	Increased in new markets, reduced in existing markets
Labor	Labor	Increased in new markets, reduced in existing markets
Risk	Risk	Reduced in existing markets
Regulatory	Permit time	Reduced overall

To project costs into the future, a simplified 20-year net present value (NPV) was taken from the Technical Report. This NPV model helps account for both the total escalated project capital cost (TPCC) and the O&M costs. Later in this report, the NPV model is compared to the current BAU Class B program currently implemented by King County. The NPV is intended to be used only as comparative costs between alternatives.

Figure 14. Class A Capital and O&M Costs (Conceptual Model)



Capital Investment Cost Summary

Table 21 below itemizes construction and non-construction costs associated with the Class A investment for Brightwater. We assume that construction would begin in 2028 and be completed in 2032. All construction costs were inflated to December 2022 costs using the producer price index (PPI) industry data for new industrial building construction (series id PCU236211236211).

Table 21. Capital Investment Itemized Construction and Non-Construction Costs

Category	Item Description	Item Cost (Thousands $)
Construction Costs	Primary Composting	$9,646
Construction Costs	Secondary Composting	$12,218
Construction Costs	Process/Maintenance Buildings	$7,097
Construction Costs	Office/Administration Building	$1,571
Construction Costs	Admin Parking, Roads, Truck Access, Maintenance Yard, Curing and Storage, Screening	$1,990
Construction Costs	Dry Wood Storage	$943
Construction Costs	Ponds and Collection System	$3,112
Construction Costs	Equipment Purchases (ECS)	$2,731
Construction Costs	Install Equipment Purchases (ECS)	$1,711
Construction Costs	Site Preparation / Demolition	$1,303
Construction Costs	Site Mass Grading (whole site using avg. of 2.5' of cut to fill)	$366
Construction Costs	Water / Sewer / Electrical Services to Site	$437
Construction Costs	Site Perimeter - Chain Link Fencing	$187
Construction Costs	Site Perimeter - New Landscape	$1,995
Construction Costs	Construction Cost Markup	$13,819
Construction Costs	Allowance for Indeterminates (Design Allowance)	$15,768
Construction Costs	Construction Change Order Allowance	$7,884
Construction Costs	Construction Sales Tax	$8,361
Construction Costs	Owner Furnished Equipment	$3,946
Construction Costs	Misc. Capital Costs	$173
Non-Construction Costs	Design and Construction Consulting	$19,874
Non-Construction Costs	Permitting & Other Agency Support	$434
Non-Construction Costs	Misc. Service & Materials	$1,561
Non-Construction Costs	Non-WTD Support	$737
Non-Construction Costs	WTD Staff Labor	$9,696
Non-Construction Costs	Project Contingency	$38,388

Non-Construction Costs	Initiatives	$1,536

Once the inflated to 2022 USD, we use the same method applied in the technical memorandum to estimate the present value of construction costs. The project costs are increased based on a 3% escalation rate to the midpoint of construction in 2030. This provides the escalated total project capital costs (EPCC). This value is then discounted using a 5.25% discount rate to estimate the NPV of the EPCC.

O&M and Recurring Cost Summary

Table 22 below summarizes O&M costs associated with the Class A investment. All O&M costs were escalated to 2034 USD (and each year thereafter until 2054) for the overall model, but values below are inflated to 2022 USD. Multiple assumptions were used to estimate annual costs, including NPV calculations of O&M costs, which are outlined in the "Net Present Value Calculations" subsection below.

Table 22. Summary O&M Annual Costs in USD 2022 in Thousands

Category	**Annual Cost**
Hauling	$445
Fuel	$307
Equipment	$562
Program operation	$651
Labor	$2,991
Total	**$4,958**

Risk Cost Model Summary

As discussed in Section 1, expanding King County's Class B biosolids customer base is a growing challenge. Given the reduction in forestry application and the stoppage in compost production from the County's prior compost partner, the program has become reliant on farmers in Douglas County to purchase and utilize approximately 90 percent of WTD biosolids production since 2018. Having only one reliable biosolids management approach leaves WTD vulnerable and with few options when highway passes close, fields are inaccessible, biosolids production increases, or farming practices change.

The challenges described here are risks to the fiscal sustainability of the overall biosolids program. The hypothetical loss of one or more farms as customer in Douglas County would entail some portion of unused Class B biosolid product, requiring it to be landfilled at a high cost. The risk described here is one (of many) driver in the argument for a Class A biosolids program investment. A full or partial Class A biosolids program would mitigate these risks by broadening the customer base for the product and limiting (or eliminating) regulatory requirements for biosolids application and storage.

To date, these risks have been identified in WTD strategic documents, guiding the development of Class A investment scenarios including the Class A Investment considered in this report. One factor limiting decision making is how the risks discussed above are incorporated in current budget planning. While included in strategic discussions, the risks are only subjective and are not reflected directly in scenario analysis or budget decision-making to date. In this subsection, an initial attempt will be made to quantify and monetize this risk for the first time.

To begin measuring risk, Table 23 lists all known risks deemed materially relevant to the current BAU Class B program. This list was created by subject matter expert staff in King County's WTD. The team prioritized the largest risks to the program and attributed a probability of the outcome of each event. The total cost of this outcome was estimated using best available information, including budgetary data.

Table 23. Summary Risk Costs Associated with BAU Class B Program

Risk Category	Probability	Total Cost of Event
Application sites are not accessible due to weather	5% per year	$413,625
Customer loss (Boulder Park)	20% (over the next five years)	$29.3M
Customer loss (Campbell Global, DNR, NSF)	6% per year	$10M
Truck Accident	2 in past 5 years	$150,000
Chemical of Emerging Concern (CEC) concentration limit that we already meet with Class B 90% of the time	25% over 5 years	$2.9M
CEC concentration limit that requires dilution to meet (composting or soil blending)	40% over 5 years	$29M
CEC regulations that result in land application ban	25% over 5 years	$1.1B

Principles from asset management can be used to derive a final calculation of risk cost associated with the Class B program. Asset management involves the balancing of costs, opportunities, and risks against the desired performance of assets, enabling an organization to examine budget scenarios with these concepts embedded in budget decisions (IAM, 2023). This asset management principle shows that risk cost is equal to the product of the likelihood of a risk event and the cost associated with that event (likelihood x risk cost). This methodology was the basis for collecting the information provided in the table above. The result of the risk cost of each scenario identified above is presented in Table 24. The column "Class A Investment Risk Mitigation" represents the reduced risk from the proposed investment in Class A biosolids. In other words, with 20% of Class B biosolids converted to Class A biosolids, 20% of the risk associated with Class B is mitigated.

Table 24. Annualized Risk Mitigation from Class A Investment

Risk Category	Annualized Risk Impact	Class A Investment Risk Mitigation

Application sites are not accessible due to weather	$20,681	$4,136
Customer loss (Boulder Park)	$5.80M	$1.17M
Customer loss (Campbell Global, DNR, NSF)	$600,000	$120,000
Truck Accident	$150,000	$1,500
CEC Class B 90%	$725,000	$145,000
CEC concentration dilution	$11.6M + $40M	$2.32M + $8M
CEC regulations application ban	$27.5M	$5.5M

Permit Time Savings

Product production under the Class A investment would result in a significant reduction in the compliance costs associated with the planning, hauling, and application of materials. There are different regulatory requirements for Class A and Class B biosolids production. Class B biosolids production is regulated under WAC 173-308. This code sets out requirements including general and site-specific land application plans, recordkeeping, and documentation of all materials transported and applied. There are limits to where, how, and when Class B biosolids can be applied to surfaces, among many other requirements. The content required for site-specific land application plans is similar to the process of producing an environmental impact statement for each site where Class B biosolids are produced, and also includes related spill response plans and recordkeeping required for hauling materials. Class A biosolids are exempt from several procedures including site management and access restrictions, portions of recordkeeping and certification requirements, and land application plans.

The Class A investment will have a significant impact on the administrative cost that King County incurs under its BAU Class B program. According to King County internal data, approximately 696 hours, or 34% of an FTE, is allocated toward permit planning and writing for the BAU Class B program. Additionally, the salary associated with the classification that completes this work, a Wastewater Capital Manager III, is approximately $110,508 to $140,076 per year depending on the salary schedule step. Taking the middle step, the assumed salary is $124,413 per year. The table below summarizes the associated time savings and related FTE costs associated with the Class A investment.

Table 25. Summary Permit Time Savings

% FTE Work on Class B Permitting	Average Wage of Associated Classification	Annual Time Savings from Class A Investment*
34%	$124,412	$8,460

**Class A Investment entails a 20% reduction in permitting time.*

NPV Summary of Class B and Class A Investments

The cost summaries above represent the full cost of the Class A investment as defined above. This suggests that both Class B and Class A products will be active biosolids production systems with their own O&M cost streams, revenues, and avoided costs. In later sections of this report, estimates for costs and revenues of both products were used to estimate a ROI of the Class A investment compared to today's BAU Class B program.

Section 4 outlines all assumptions that were used to estimate the full suite of costs for both scenarios in the ROI exercise defined above. Table 26 below summarizes the NPV of the costs and benefits from 2023-2060.

Table 26. Summary of Class B BAU and Class A Investment (Class B 80% Class A 20%)

Timeframe	BAU	Class A Investment			
	O&M	Cap	O&M	Risk Avoided	Permit Time Avoided
NPV	$303.4M	$145.3M	$314.4M	$309.5M	$151,711

Expanded Market with Class A Investment

This subsection explores the information available to understand access to new markets from converting Class B biosolids to Class A biosolids under the Class A investment discussed above. In general, the use of Class A biosolids products avoid many requirements of the land application plan, hauling-related spill response plan, and other application restriction requirements. Class A products are available to a broader market without restriction as well, including direct sale to residential customers, and use in all government development projects that do not require stormwater mitigation plans.

Limited information is available providing insight into market demand and sales for Class A products locally. However, the County's Class A product market access and demand can be modeled after research on compost, namely because the Class A investment product is a compost blend. As the Technical Report outlines, Class B biosolids undergo a composting treatment process to create a Class A biosolid-based compost. This understanding allows the use of compost-related market research to shed light on market demand for the Class A product.

In 2017, the Washington State Organics Contamination Reduction Workgroup (WSOCRW) reported that, on average, commercial composters sell their products to customers within a 50-mile radius of where it is made (OCRW, 2017). In 2015, the King County Recycling Market Assessment interviewed compost processors, summarizing that residential demand ranged from 15 to 50 percent of their compost sales, and agriculture ranged from five to 10 percent with the remaining product used by government agencies or landscapers (King County SWD, 2015). This customer breakdown is utilized in modeling a hypothetical expanded market in further analysis below.

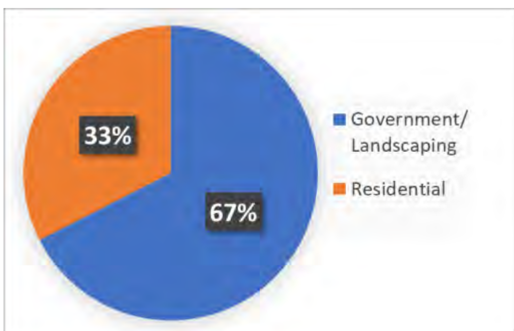
Uncertainties in the market demand for compost create room for errors in assumptions made of demand in future years, particularly when the Class A investment capital project is projected to be complete. While the likelihood of consistent and/or increased demand for compost products is uncertain, recent County policy may, at the least, create demand for compost products in local government capital projects such as development or roadside projects. In King County Code Title 10.14, the County sets a goal to "achieve zero waste of resources by 2030 through maximum feasible and cost-effective prevention, reuse and reduction of solid wastes going into its landfills and other processing facilities." This in turn requires all local government projects to use organic amendment products, such as compost, everywhere applicable. This report does not attempt to quantify demand for future projects but provides some assurance that demand for future Class A products can be sustained by local government projects.

The next subsection uses the market survey research cited above for compost sales to estimate the volume of compost sold to different sectors, using markets prices to estimate revenue from the Class A investment program.

Class A Biosolids Revenue Model with Expanded Market

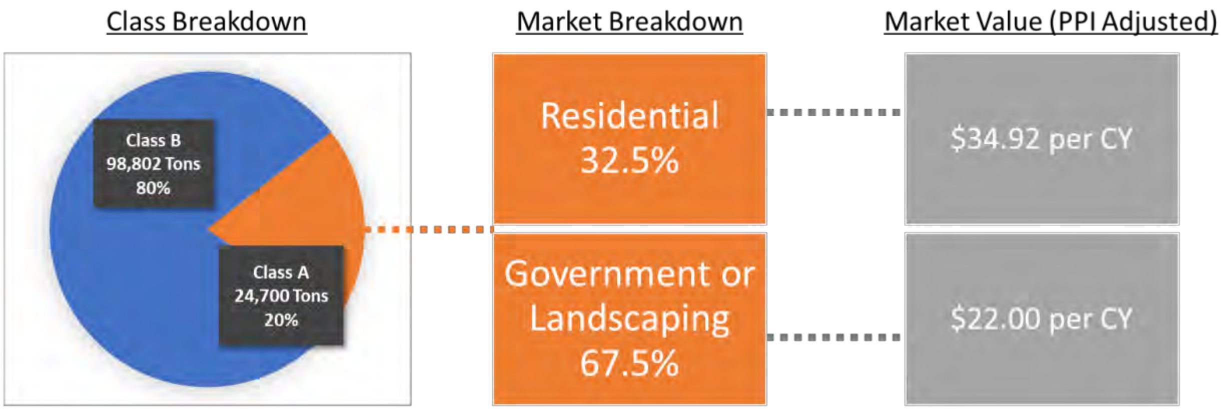
Using the King County Recycling Market Assessment on compost sales, Figure 15 below shows breakdown of potential sales by residential and government/landscaping categories. These values were derived using an average of each range provided by the market assessment data referenced above.

Figure 15. Expanded Hypothetical Market for Class A Biosolids



In 2019, a total of 124,958 wet tons of Class B biosolids were produced at all three of King County's wastewater treatment plants. It follows from the section above that 20% of future Class B wet tons produced will be allocated to Class A product processing, suggesting 24,992 wet tons of Class B biosolids will be used to create Class A product. Given the availability of Class B biosolids in King County, agricultural demand would likely only be for Class B products. Therefore, the survey category for agricultural reflected in Figure 15 above was lumped into the "government/landscaping" category for the purposes of this report. Figure 16 below summarizes the resulting market availability of Class A product based on the market breakdown presented above.

Figure 16. Class A Market Breakdown and Value Summary



The data from Figure 16 is used to calculate the revenue associated with the modeled Class A investment scenario, which is outlined in subsequent subsections below. Not included in the figure above are assumptions and calculations used to derive the final revenue figure, including the conversion of wet tons of Class B product to dry tons of Class A product, as well as the final sales minus cost of operations. Details on all conversions are provided in Appendix C.

Using an Ecosystem Service Framework to Measure Return on Investment of Class A Investment

This section first outlined the benefits associated with Class B biosolids application, then mapped out multiple costs and benefits associated with the Class A investment. The remainder of this section brings together all benefits associated with a Class A investment and compares this hypothetical program to today's BAU Class B program. First, the ecosystem service benefits of Class A are discussed under different scenarios and long-term outlooks. Then all costs and benefits of both programs are brought together to understand an estimated ROI of converting 20% of the BAU Class B program with a Class A investment.

As mentioned above, the product created from the Class A investment is effectively compost. This allows for the use of research outlined in Section 4 to identify and estimate the ecosystems services benefits of Class A product application in different land uses. Unlike compost made from food scraps and yard clippings (discussed in Section 4), the Class A product is created from Class B biosolids, a wastewater feedstock product.

In Section 4, Year 1 benefits of applying one ton of compost is $235 to $431 in bare soil conditions. The same application renders $225 to $425 in post-fire conditions, $278 to $402 in wheat, $241 to $427 in grapevines, and $244 to $386 in specialty crops in western Washington. Reapplication of compost year after year provides similar and, in some cases, diminishing benefits over time. Appendix D discusses where marginal benefits over time change with each year.

In the prior subsection on increased market demand of Class A, Figure 16 shows compost demand breakdown by sector with associated market rates. Using the sector sales breakdown from Figure 16 and the associated Class A application, Table 27 outlines the ecosystem service value of Class A product application using compost benefit estimates.

Table 27. Summary Annual Ecosystem Service Value from Compost Application by Sale Category

Category	Dry Tons	Ecosystem Service				
		Flood Risk Reduction	Soil Erosion Protection	Carbon Sequestration	Water Supply	Soil Quality
Residential	1973.5	\$155,000 to \$381,000	\$1,000 to \$12,000	\$304,000 to \$452,000	\$1,400 to \$2,000	\$3,400
Government / Landscaping	4098.7	\$400,000 to \$792,000	\$2,000 to \$25,000	\$631,000 to \$938,000	\$3,000 to \$4,000	\$7,000

The values in the table above are annual and calculated in 2022 dollars. Compost values from Section 4 corresponding to bare soil land use type were used for both residential and government/landscaping categories above.

As discussed in the results of Section 4, annual application of compost produces similar benefits year after year, where in some cases ecosystem service value diminishes over time. Discussion of asset value methodology can be found in Appendix B.

King County Use of Class A Biosolids for Mine Remediation and Restoration

King County has a large number of sites with degraded soil. These include borrow pits, gravel pits, and soils degraded through different types of construction, urbanization, and road building. Many of these sites are surface mines leased by the County to private businesses. King County is responsible for reclamation of many surface mine sites per the conditions of the purchase and sale agreements. In these agreements, the County assumed the responsibility for complying with all permit requirements for implementing surface mine reclamation.

Reclamation is defined as rehabilitation for the appropriate future use of disturbed areas resulting from surface mining activities. The major objectives are to prevent or mitigate future environmental degradation and reestablish, on a perpetual basis, vegetative cover, soil stability, and water conditions to accommodate and sustain the approved subsequent use. This reclamation is intended to restore native vegetation, often forests, and their associated ecosystem services. This section explores the resulting ecosystem service benefits of forest restoration from surface mine remediation activities.

The Washington State Department of Natural Resources (DNR) publishes a directory of State surface mining reclamation sites, the most recent from 2010 (WADNR, 2010). King County staff determined that surface mines in the County categorized as “Commodity Type: Sand & gravel” were, overall, more likely candidates suitable for remediation using compost application. As referenced earlier in this report, compost application was shown to be effective at restoring surface mines to some vegetative state. Restoration of the former mine entailed revegetation of shrubs and trees once structures were removed (King County Parks, n.d.). According to the DNR surface mine directory, there are approximately 5,164 acres of sand and gravel surface mines in the County.

The remainder of this subsection models using compost created from the Class A investment for sand and gravel surface mine remediation.

Ecosystem Service Benefits of Surface Mine Remediation: In order to estimate the environmental benefits of remediated surface mines, the same ecosystem service framework introduced in Section 1 will be used to estimate ecosystem service value. Multiple efforts to estimate the ecosystem service value of forests have been conducted in King County. For example, forests ecosystems services, including flood risk reduction and carbon sequestration, were estimated in Snoqualmie, Washington, demonstrating the value of these services to the regional economy (Christin et al., 2020). However, little research has been done on the ecosystem service impact of restoration of surface mines in the region.

To retain a simplified model, the ecosystem service value from the Snoqualmie report referenced above was used to measure ecosystem service value of forests in this report. Additional research was used to adjust this value to reflect restorative forest vegetation over time. Table 28 shows the annual ecosystems service values from the Snoqualmie Report, converted to 2022 dollars. Appendix C references all information used to calculate final values presented below.

Table 28. Total Annual Forest Value by Ecosystem Service Value from Snoqualmie Report

Ecosystem Service	**Annual per Acre Value**	
	Low	High
Flood Risk Reduction	$5,149	$6,328
Carbon Sequestration	$196	$248
Water Quality	$58	$149

As mentioned above, the remediation and restoration activities modeled here are based on compost application from the Class A investment program. This suggests a fixed compost application rate starting once the program is assumed to be in place in 2032. The annual rate of compost available to use in remediation is based on compost not sold residentially, or that allocated to the “government / landscaping” category from Figure 16 above. This suggests that 67.5% of all annual Class A compost created, or approximately 16,870 tons of compost, would be available for remediation projects assuming 100% of this category was allocated for this purpose. With the assumptions presented in Section 4 and Appendix D on tonnage to acre application, it follows that 252 acres of sand and gravel surface mines would be remediated each year, accounting for approximately 21 years of remediation to target all surface mines.

The total ecosystem service value from surface mine remediation starting in 2032 through the 20-year Class A investment timeline is summarized in Table 29 and incorporated in the results in the following section. Research on recovery rates and ecosystem services is referenced in Appendix C and reflected in the results below. Restoration following compost application is assumed to be all western native forest types planted as saplings left to mature over the 20-period, depending on when they were hypothetically planted.

Table 29. Summary of Forest Ecosystem Service Value Following Surface Mine Remediation (Compost Value + Vegetation Restoration 3 Ecosystem Service Value)

Total Compost Application Benefit		Flood Risk Reduction		Carbon Sequestration		Water Quality	
Low	High	Low	High	Low	High	Low	High
$70,337,000	$128,930,000	$10,551,000	$12,967,000	$44,000	$56,000	$119,000	$305,000

Total Return on Investment of Class A Investment

Table 30 shows the present value of costs and benefits for both Class B BAU program and Class A Investment program. Calculations began in 2023, operating through the year 2060. The Class A Investment program started in the year 2032 after a 2028 capital investment implementation period, also ending in 2060. Both avoided regulatory costs and risk reduction were counted as benefits to the Class A Investment program.

Table 30. Summary Benefits, Costs, and ROI of Class B and Class A Investment Program

	Class B BAU	Class A Investment	
Category	**Value**	**Value, Low**	**Value, High**
Capital Costs	0	$145,331,000	$145,331,000
O&M	$303,386,000	$314,351,000	$314,351,000
Total Cost	***$303,386,000***	***$459,682,000***	***$459,682,000***
Revenue	$26,452,000	$71,715,000	$71,715,000
Avoided Regulatory Cost		$152,000	$152,000
Risk Reduction		$309,548,000	$309,548,000
ESV Benefits	$227,342,000	$237,943,000	$276,545,000
Remediation Scenario		$555,044,000	$690,493,000
Total Benefits	***$253,794,000***	***$1,174,402,000***	***$1,348,453,000***
Return on Investment	***0.8***	***2.6***	***2.9***

Net Present Value Calculations

As in the asset value discussion above, calculating the net present value of an asset implies the use of a discount rate. The range of values used as discount rates varies greatly across federal agencies and applications. There is no standard across the board. The current rate for federal water projects is 2.5% (USACE, 2022). This rate was chosen and used for this analysis based on federal acceptance for water projects.

Total project capital cost (TPCC) was escalated to 2032 and discounted back to 2023. The O&M cost assumed operation from 2034 to 2060 and was escalated based on solids growth projections and then discounted back to 2023 for an NPV. For both capital and O&M costs, the calculations were performed using an escalation rate of 3 percent and a discount rate of 2.5 percent. The escalated TPCC is a better reflection of the costs that may impact budget, sewer rates, and other planning impacts. However, future evaluations with more detailed costing will be needed to provide the classification accuracy ranges needed to understand impacts to the program.

Salvage and replacement costs were not included in the analysis, particularly because all Class B infrastructure is maintained in the Class A investment scenario.

Cost estimates for hauling, fuel, and equipment related to Class B operations were used as a proxy to estimate Class A O&M costs in these categories. Namely, 20% of 2018 values in each category for Class B biosolids was the Class A proxy estimate. For other Class A O&M cost categories, such as program operations, labor, and fleet capital costs, King County staff provided estimates. Details for the cost estimations are shown in the table below.

Biosolids Risk Cost Estimation Detail

Risk Category	Probability	Cost	Risk Cost	Comment
Application sites are not accessible due to weather	5% per year	$413,625 Everett loads: 1) Cost for Skagit to haul to Everett $60/ton (100 loads a year) 2) Cost for BPI to reload and haul to Boulder Park at $62.77/wt 3) Tony (or Jake) to maintain loads and communications w/ Everett & haulers ($2500-$3000/year) 4) Sawdust for odor control ($2600/year) 5) Front loader and fuel ($3300/month, for six months) 6) Annual Lease Agreement fee for use of Everett storage pad ($1200-$1500/year)	$20,681.25	Reasons preventing access to application sites include 1) mountain pass closures, 2) heavy snow/blizzard conditions at sites, 3) seasonal wildfire activity that closes a large area.
Customer loss (Boulder Park)	20% (over the next five years)	$29.3 M/year	$5.8 M	More demand than product, but owners are in their 80s and succession is not clear. Program could not make up for loss of Boulder Park.
Customer loss (Campbell Global, DNR, NSF)	6% (this has sort of happened 2 times in the last 25 years during land sales)	$10 M/year	$600,000	Boulder Park could absorb biosolids from any of these customers
Truck Accident	2 in past 5 years	$150,000	$1,500	This is approximately 0.01% of trips, but we make a LOT of trips

Chemical of Emerging Concern (CEC) concentration limit that we already meet with Class B 90% of the time.	25%	$2.9 M/y	$725,000	Cost = $300 ($200 tipping, and $100 trucking) for 10% of B produced
CEC concentration limit that requires dilution to meet (composting or soil blending)	40%	$29 M/y + $100 M	$11.6 M/y + $40M	Landfill until we are able to build larger compost facility
CEC regulations that result in land application ban	25%	$1.1 B	27.5 M	Assume that WTD will build a thermal system of some kind

Appendix F: References

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