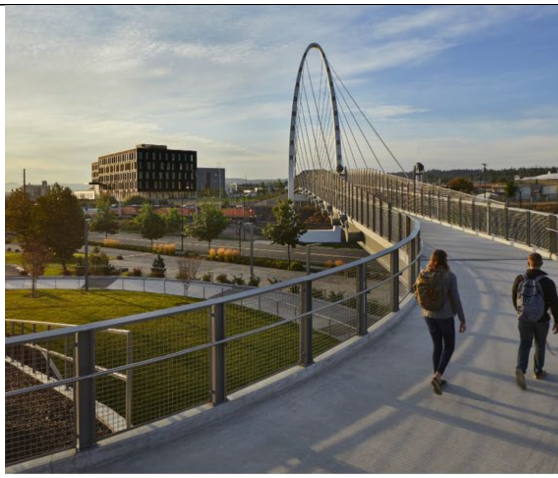
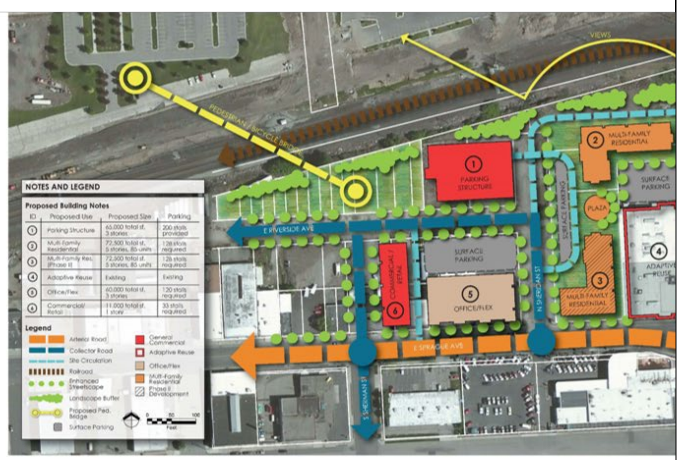
University District Ecological Assets and Performance Standards





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Ecological Assets and Performance Standards Study

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February 2024

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Executive Summary

"What if every single act of design and construction made the world a better place?" This foundational question informed the District Ecological Asset and Performance Standard Study. Commissioned by the University District Public Development Authority (UDPDA), the goal of the study was to create standards for an urban ecological design framework that led to the development of performance and design guidelines that sustain and improve the University District's (UD) baseline ecological assets.

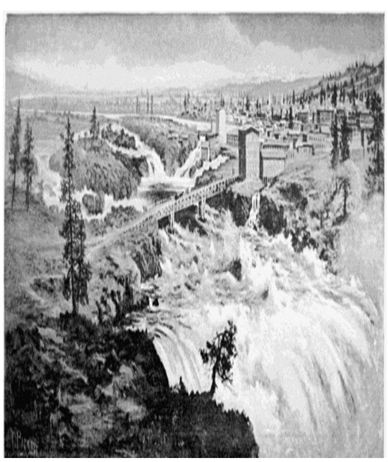
Utilizing regenerative design principles and biomimicry, Greene Economics assembled a team of economists, ecologists, biologists, urban planners, and landscape architects to support the project.

> *From a regenerative design perspective…. "buildings can serve as carbon sequestration sites. They can generate and store energy on site for surrounding communities, can use the site to clean stormwater runoff, and can even have skins that 'scrub' the air… this idea of not just using fewer resources, but of replenishing and bettering our environment"*
>
> *HMC Architects*

A regenerative design approach moves beyond "net zero" and "reduce-reuse-recycle," embracing a "net positive" outcome. It applies a whole systems approach to understanding the natural and built environments and the relationships between system health and human health and well-being. Regenerative design is place-based, utilizing place-specific ecosystem characteristics and performance measures to inform design standards. The regenerative approach is also community-driven, using, and integrating community priorities and needs into neighborhood and building design.

Developing a Sense of Place Then and Now

The process starts by developing an understanding of historical geographies as well as ecological and biological conditions. As outlined in Chapter 1, the team interviewed key stakeholders in the UD and the community and reviewed a number of written sources to develop an understanding and establish a baseline for historical conditions in the area.



HISTORICAL CONDITIONS

- Ponderosa pines and grass savannas
- Frequent fires (low intensity)
- Riparian corridor-priority habitat for many species
- Cultural connection to the river
- Clean river and salmon
- Floodplains and vegetation provided water management and purification

Figure ES-1. Historical Conditions

The team also identified a set of twelve core ecosystem services that were present in the historical environment. These included air filtration, biodiversity, carbon sequestration, energy provision, fire adaptation, nutrient cycling, pollination, stormwater management, temperature regulation, waste management, water cycling, and human health and wellbeing.

The team also evaluated the existing environment and developed a profile of the current situation. Current conditions include too much concrete- not enough pervious surfaces, few trees, and not enough native trees), degraded or non–native soils, increased levels of air and water pollution, a general disconnect from the river, a lack of public gathering spaces, and the presence of heat island effects.

Establishing the Possible

For the next step in the process, the team used historical information to develop a set of performance targets for each of the twelve ecosystem services. These targets are summarized below and are discussed in detail in Chapter 3.

Table ES 1. Ecosystem Services and Performance Targets

Ecosystem Service	Performance Target
Air Filtration	• Shade should approach **that** provided by ponderosa pine savanna
Biodiversity	• Manage waste in a closed loop (meaning all waste is decomposed or recycled back into the ecosystem)
Carbon Sequestration	• Water withdrawals will not exceed historical aquifer recharge rates
Energy Provision	• Preserve the “winter camp” status of the area as a meeting place where people come to share knowledge food and culture
Fire Adaptation	• Emulate low-fuel load savanna grasses and fire-retardant outer materials approximating ponderosa bark
Nutrient Cycling	• Open space areas should have the same ratio of trees to shrubs and grass as the ponderosa pine savanna ecosystem
Pollination	• Vegetation should mimic native perennial grasslands by including plant species known to host native pollinator communities represented in ponderosa pine savanna.
Stormwater Management	• Zero percent impervious services or equivalent
Temperature Regulation	• Shade should approach that provided by ponderosa pine savanna
Waste Generation & Management	• Manage waste in a closed loop (meaning all waste is decomposed or recycled back into the ecosystem)
Water Cycling	• Water withdrawals will not exceed historical aquifer recharge rates
Human Health & Wellbeing	• Preserve the “winter camp” status of the area as a meeting place where people come to share knowledge, food, and culture

Enabling Success

The final step in the process was the development of a set of design considerations that can be used to inform a master plan for the area as well as design standards for specific structures and areas within the community. For this phase of the work, the team established three design realms: the built environment, the public realm, and the riparian realm. The built environment included both new construction and retrofitting of existing structures. The public realm focused primarily on public spaces, both open spaces and rights of way that support movement between and within the UD. The final realm focused on the Spokane River and a 200-foot buffer zone. For each of the three realms, the twelve ecosystem services were evaluated, and design considerations were established to improve and enhance ecosystem service provision and achieve performance targets. Table ES 2 presents an example of this. A detailed explanation is provided in Chapter 4.

Table ES 2. Design Standard Considerations for Select Ecosystem Services

	Riparian		Public Realm		Built Environment	
Ecosystem Service/ Design Consideration	River/ Nearshore	Buffer Area	Right of Way	Parks	New Construction	Retrofitting
Air Filtration						
Urban Canopy	●	●	●	●	●	●
Green Walls		●	●		●	●
Emission Reduction		●	●			
Energy Conservation					●	●
Biodiversity						
Landscape Design		●	●	●	●	
Wildlife Connectivity	●	●	●	●		
Carbon Sequestration						
Carbon Specific Planting	●	●	●	●	●	
Green Spaces		●		●	●	
Building Materials				●	●	●
Energy Provision						
Promote Alternative Energy Sourcing	●		●	●	●	●
Smart Building Design				●	●	●
Reduce Heat Island	●	●	●	●	●	●

In the final component of the work, potential metrics that could be used to track progress toward achieving the established targets were identified. The details of the design standards and the data collection and analysis needs of specific projects will determine the final choice of metrics.

As part of the project, the team interviewed a range of stakeholders and reviewed several reports and resources. Appendix A and B provide this information and an annotated bibliography.

1. Introduction

1.1. Overview and Purpose

The University District Public Development Administration (UDPDA) is a key partner in developing an innovative life sciences and energy district in Spokane. As such, the UDPDA seeks to develop design standards that sustain and improve the District's baseline ecological assets, improve the entire ecosystem's long-term health, and support future development as a “living lab” for the institutions that will call the University District (UD) home. In support of this vision, the UDPDA retained Greene Economics in 2023 to investigate, model, prioritize, and quantify nature-informed best practices to support the development of design standards around an urban ecological framework, leading to performance standards that will enable the District to sustain, improve, and restore the District’s baseline ecological assets.

1.1.1. Study Framework

The work began with a kickoff meeting held in May 2023. Greene Economics team members traveled to Spokane and participated in a site tour and a daylong meeting with key stakeholders and representatives from the six Universities with a physical presence in the UD. A complete list of participants and stakeholders who were interviewed can be found in Appendix A.

In the context of this study, features of the landscape (e.g., trees) are referred to as ecosystem assets, which means they are a feature that can produce ecosystem services. Ecosystem services are the benefits to communities that are derived from an ecosystem asset. For example, the ecosystem asset of trees produces ecosystem services such as carbon sequestration, heat reduction, mental wellbeing, community connection, habitat for biodiversity. For this effort, both ecosystem assets and services will be identified because both represent value, and both may be used to measure and monitor the natural system.

Following the kickoff, the team reviewed over fifty resources and planning documents as well as documentation related to ongoing development activities in order to develop a comprehensive understanding of work performed to date in support of the vision for the District and to begin to develop a more complete understanding of the geography and ecology of the area (Task 2). A comprehensive bibliography of those resources is provided in Appendix B.

Using the inputs from stakeholder interviews as well as the background research, the team compiled a list of community priorities and identified candidate ecosystem assets and services.

Once assets were identified and priorities established, the team completed an exercise to align those assets with community priorities (Task 3). These results were presented to the UD Development Committee in a technical memorandum. Task 4 involved a further definition of the historical environment and further refinement of ecosystem assets and services to establish performance targets and support the development of design standards for future District projects. These targets were presented to the UD Development Committee as a technical memorandum and a slide presentation (Task 5).

The team drew heavily on principles of biomimicry and regenerative design to complete the remainder of the work. Task 6 focused on developing draft design standards and creating a performance evaluation framework that can be used in the future. In addition to the narrative presented in this report, the team made several presentations (Tasks 5, 7, and 8) to the UD Development Committee and to the UD Board of Directors. These presentations have been synthesized into a single presentation, which is provided in Appendix C.

The remainder of this report details the findings and recommendations from this work. An introduction and overview of biomimicry concepts and regenerative design principles are presented in Chapter 2. Chapter 3 provides a historical biodiversity profile of the District, identifying ecosystem services and assets that were likely present as a result of the conditions of the natural environment. Chapter 3 also provides an overview of ecosystem service provision's current status and establishes future performance targets. Using these performance targets, in Chapter 4, design concepts that will help the District reach the ecosystem-based regenerative development goals and targets are developed, as well as a design matrix that highlights which design considerations are best suited to the general geographies of the District. Chapter 5 outlines recommendations and next steps and provides an overview of the types of funding sources that may be available to support the implementation of projects using the recommended design standards.

1.1.2. The University District Today

The City of Spokane and the UD have been actively engaged in strategic planning and community visioning for a number of years, as illustrated in Figure 1 below. [1]

[1] Adapted from: Makers, and City of Spokane. 2020. South University District Subarea Plan (Draft). February. Pg 6&7. Available at:

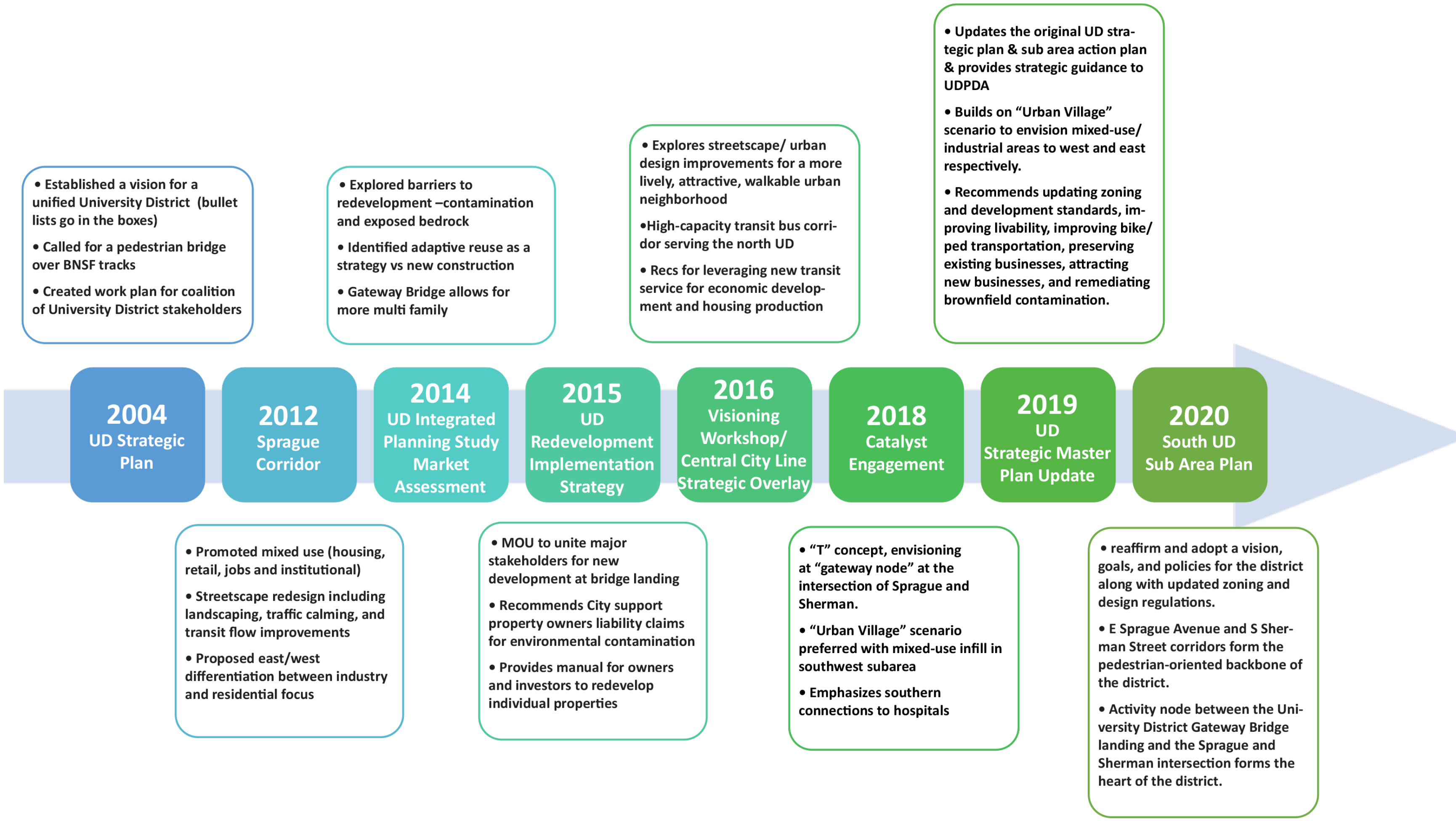


Figure 1. UD Planning Process Trajectory

As noted in the introduction, the team reviewed many of these documents and engaged key stakeholders to better understand community priorities. From these reviews and interviews, the team identified and categorized those common community goals and attributes across multiple planning efforts. The list of identified community priorities is presented in Table 1.

Table 1. Community Priorities from UD Planning Documents

Community Priority	Definition/Elements	Source
Strong District "heart"	a "destination" or "focal point" highly interconnected within and between other parts of the city, which creates a sense of place and inclusivity, fostering friendlier streets.	TOD Public Draft, Sub Area Action Plan-2020, Urban Amenities, Master Plan Update, New Economy, Policy Options
Flexibility-multiple uses for open space.	Space design that is intended for multiple uses such as recreation, public gatherings, walkability, bikeability, benches, playgrounds, performance stages, etc.	Main Avenue, TOD EIS, Urban Amenities
Community Connectivity-cohesive streetscapes, gathering spaces in relation to structures	Space design that invites multiple uses, front-facing building design, indoor/outdoor connectivity, and includes amenities that encourage engagement.	Sub Area Action Plan 2019, Design Standards
Improved Mental/Physical Health	Outcome of increased connection to community and nature improved health due to increased walkability	Spokane Action Plan
Transportation Connectivity - walking, biking, parking management	Mid-block crossings, pay-by-plate parking, rapid transit, connectivity between car/bike/walking pathways, traffic control, and traffic calming.	Main Avenue, TOD Framework, Trail, Bicycle, Pedestrian, Urban Amenities
Parks & Open Space	Accessible mixed-use green space with native plants, connected corridors for wildlife, and designated areas with nodes for human gathering.	South Logan TOD, TOD EIS, TOD Public Draft, Main Ave, Sub Area Action Plan 2019 & 2020, Urban Amenities, Master Plan Update
Street Trees	Number of trees, diversity of species, density of planting, canopy.	Main Ave, Spokane Action Plan, Trail, Bike, Pedestrian
Habitat Preservation/Restoration-including support for natives	Use of native species, water management, corridors, and connectivity, support for species diversity, and reintroduction of native plant and animal species.	Spokane Action Plan

Community Priority	Definition/Elements	Source
River Connectivity	River as a central gathering space, reconnection to the river, colocation of gathering and community spaces with river, increased river access	River Vision, Sub Area Action Plan, Master Plan Update
Cultural Heritage	Recognition of cultural and historical antecedents and first economic, nature, habitat, customs, and culture, not limited to River connectivity, but specifically referenced here.	River Vision
Stormwater/Water Management	Managed runoff, stormwater ponds, wetlands, swales, and other stormwater management strategies.	Design Standards, Spokane Action Plan, Water Quality, Water Conservation, Master Plan Update
Transit Oriented Development	Development with transit route as core with a mix of housing, commercial businesses, schools, jobs, and services concentrated along walkable, bikeable streets within ¼ mile of transit routes.	South Logan TOD, TOD EIS, TOD Public Draft, TOD Framework
High Density		South Logan TOD, Urban Amenities
Mixed/multiple uses for buildings		Main Ave, TOD Framework
Diversity and range of housing, space for “makers” & small business,		TOD Framework, Urban Amenities, Master Plan Update
Adaptive Re-Use	Repurposing structures for uses other than their original intent (e.g., converting a warehouse to loft apartments).	Master Plan Update
Energy Efficiency- net zero, green design	Reductions in emissions, energy conservation.	Spokane Action Plan, Sub Area Action Plan-2019, Urbanova Energy
Economic Vitality/Viability	Capitalizing on economic development potential, range of living wage/high wage jobs, vibrant local business options	Spokane Action Plan

The foundational approach that guides all of the visioning and planning efforts is "Transit Oriented Development (TOD)." As defined by the Institute of Transit Oriented Development, this urban planning approach offers a "hybrid of regional planning, city revitalization, and urban renewal, resulting in compact walkable pedestrian-oriented mixed-use communities centered around high-quality transit systems."[2]

Characterizing the UD as a focal point, or "heart," of a thriving, vibrant community, is a consistent theme throughout the various planning documents. The concepts of flexibility, accessibility, inclusion, and connectivity all contribute to realizing this vision. These characteristics or outcomes can be considered benefits (or ecosystem services) that will arise as a result of a set of actions, design standards, or policies that will support and encourage the adoption or utilization of particular practices. Specific priorities related to native species use, tree canopy cover, and permeable surfaces, for example, focus more on ecosystem assets- those "stocks" that will contribute to the flow of "heart."

A few priorities are specifically identified only in UD planning documents but are consistent with concepts articulated in general community documents. In particular, the concept of adaptive reuse is specifically introduced as part of the work in which Macy and Cascadia Partners[3] examined several similar districts in other parts of the country. In this context, adaptive reuse refers to the process of re-using or repurposing buildings for something other than what they were originally intended—for example, turning a warehouse into loft apartments. While Macy et al. were uncertain as to the potential for adaptive reuse in their analysis, the concept is one that, if effectively utilized, could result in multiple benefits, both for the environment and the economy. Macy et al. also introduce the concept of a "strong district heart"[4] in their work, identifying it as an "ingredient for success" observed in all five of the reference districts. The concept refers to creating a "central" destination space: one or two blocks that include festival space, interactive art space, and concentrated activity connected and integrated with the surrounding area.[5]

These community priorities helped inform the remainder of the work, serving as a foundation for identifying and prioritizing ecosystems assets and services that can be supported through regenerative design principles and standards.

[2] http://www.tod.org/

[3] Walker Macy, and Cascadia Partners. 2023. Spokane University District Urban Amenities Research and Analysis for the South UD. March. Available at:. Pg. 32

[4] Ibid Pg. 16

[5] Ibid Pg. 52

2. Principles of Biomimicry and Regenerative Design

2.1. Regenerative Design

Regenerative design goes beyond the idea of net- zero, or "do no harm," to focus on actively working to not only restore what has been lost but also to look towards having a positive impact on people and communities. Regenerative design results in buildings that give back, not only recycling carbon and waste produced by those in the building but actively working to improve air or water quality or reduce heat stress in areas where the buildings are located. Regenerative design is a holistic approach that focuses on working in harmony with the natural environment, tailoring designs to specific locations- taking into consideration climate, topography, and culture. A focus on long-term sustainability, natural materials, and products that serve multiple functions and have multiple uses is also central to the approach. Regenerative design considers not only the structures themselves but also the values and needs of the communities where the buildings will be located, including human health and resilience. [6]

2.2. What is Biomimicry

Within the regenerative design paradigm, biomimicry centers on taking inspiration from and mimicking individual elements or systems in nature. According to the Biomimicry Institute, biomimicry differs from other bio-inspired design processes in "the emphasis on learning from and emulating the regenerative solutions living systems have for specific functional challenges."[7]

Biomimicry can involve the emulation of:

1. An organism mimicking the form and function of an organism. This is called *ad hoc* biomimicry and can include the development of a structure or material.
    a. Example: Olympic swimmer bathing suit material mimicking the jagged skin of sharks to reduce drag in the water.
2. Behavior: mimicking interactions between an organism and its environment.
    a. Example: The Beijing National Stadium is designed to function like a bird's nest to take advantage of natural light and maximize its weight load.
3. An ecosystem: mimicking natural systems.
    a. Lavasa City in India was designed to mimic the vertical layers of vegetation in the surrounding tropical forest ecosystem.

The prevailing ethos across multiple institutions for biomimicry in urban design (that is, designing entire communities rather than a single structure) is to analyze the existing ecosystem that is present or was present and the site of construction and take design inspiration from the systems by which the ecosystem responded to specific environmental factors at the site.

[6] Chetty, Zahara. Designing for the Future: 9 Principles of Regenerative Design. Available here.

[7] Benyus, Janine. "What Is Biomimicry?" *Biomimicry Institute*, 21 Feb. 2023. Available here.

2.3. Implementing Regenerative Design and Biomimicry in Urban Design

Planning to bring ecosystem services back to an urban area starts with an ecosystem service analysis. This process is outlined in Figure 2 below. Essentially, the process requires one to take stock of what ecosystem services used to exist on the site in question, what services are provided now, and what/how different actions and designs could improve upon the ecosystem services currently provided to better match historical services.

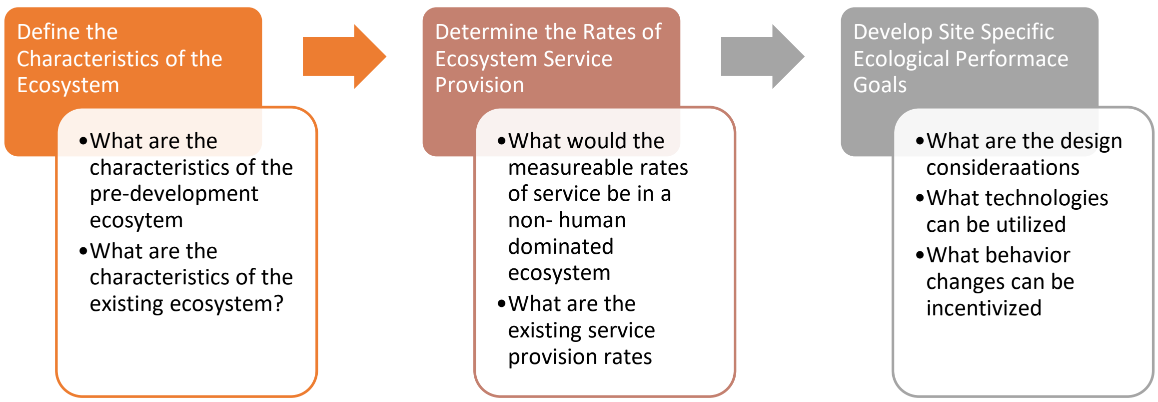


Figure 2. Process for Ecosystem Services Analysis[8]

Based on this analysis, measurable goals for urban regenerative designs are created based on the site-specific information gathered. “Regenerative design seeks to address the continued degradation of ecosystems by developing the built environment to restore the capacity of ecosystems to function at optimal health for the mutual benefit of both human and non-human lives.” [9] Regenerative design typically focuses on seven ecosystem services: food, fuel/energy, fresh water, climate regulations, air purification, nutrient cycling, and habitat provisions. Other ecosystem services can be incorporated as well, though they may be more challenging or less conducive to regenerative design.

[8] Adapted from [8] Zari, M. P. 2015. Ecosystem Services Analysis: Mimicking Ecosystem Services for Regenerative Urban Design. February. International Journal of Sustainable Built Environment, 4:145-157.
[9] Ibid.

3. Ecosystems of the Okanogan Region

An ecosystem service approach to regenerative urban design is closely related to its physical site in terms of ecology, climate, and culture. In order to develop an understanding of the ecosystem services that might be enhanced or restored through the built environment, the team first characterized the pre-development ecosystems present in the region and then compared them to what the region currently provides. This section provides a historical overview of the UD and briefly examines what is present in the area today.

The UD is an approximately 770-acre area in Spokane located just east of downtown in the East Central and Logan neighborhoods. The UD is made up of a northern portion, including the Gonzaga campus, WSU Health Sciences Spokane Whitworth UW/GU Health Partnership campus, and the Spokane River, and a southern portion south of the train tracks, including Eastern Washington University, which is almost entirely industrial. The UD's population is expanding: since 2004, population and employment in the UD have grown at a faster rate than Spokane or Spokane County overall, with a 2.1 percent annual growth rate. Though the population today includes only 5,500 people, the population is projected to reach 8,000 people by 2035. Most of these residents are students attending one of the universities in the district. Housing units consist primarily of single-family residents on small plots of land, though off and on-campus apartment-style units are also present. Over half of the UD is covered by impervious surfaces (64 percent), although the district still has 350 acres of planted and open unplanted space.

Ecologically, the region is a transition area between the channeled Scablands and Spokane Valley Outwash Plains. It is an area where shrub-steppe and grasslands meet coniferous forests, made up of ponderosa (Pinus ponderosa) and lodgepole (Pinus contorta) pines predominantly to the east and prairies to the south. The Spokane River was and continues to be a prominent feature running through the area, providing food, water, a means of transportation, and a meeting place for Indigenous people (Warren Seyler, personal communication, July 2023). Prescribed burning was a technique utilized by the Spokane Tribe, which likely limited understory growth. The first settlers arrived in 1810, but it was not until the late 1870s when a sawmill, gristmill, and railway led to an influx of people and Spokane became the gateway to the inland northwest. Many of the trees were cut down to serve the lumber industry, and the city continued to become more industrialized thanks to the power supplied by the Spokane Waterfall.

To determine how ecosystems used to function, we focused on the time before settlers arrived as a baseline for ecosystem services provided. Spokane County and the University District are part of the Okanagan ecoregion of the Columbia Plateau. An ecoregional map (Figure 3) generated using LandScope places nearly all of Spokane (including the extent of the UDPDA) in the southeastern lobe of the Okanogan ecoregion, near its boundaries with the Columbia Plateau ecoregion to the west and the Canadian Rocky Mountains ecoregion to the east.

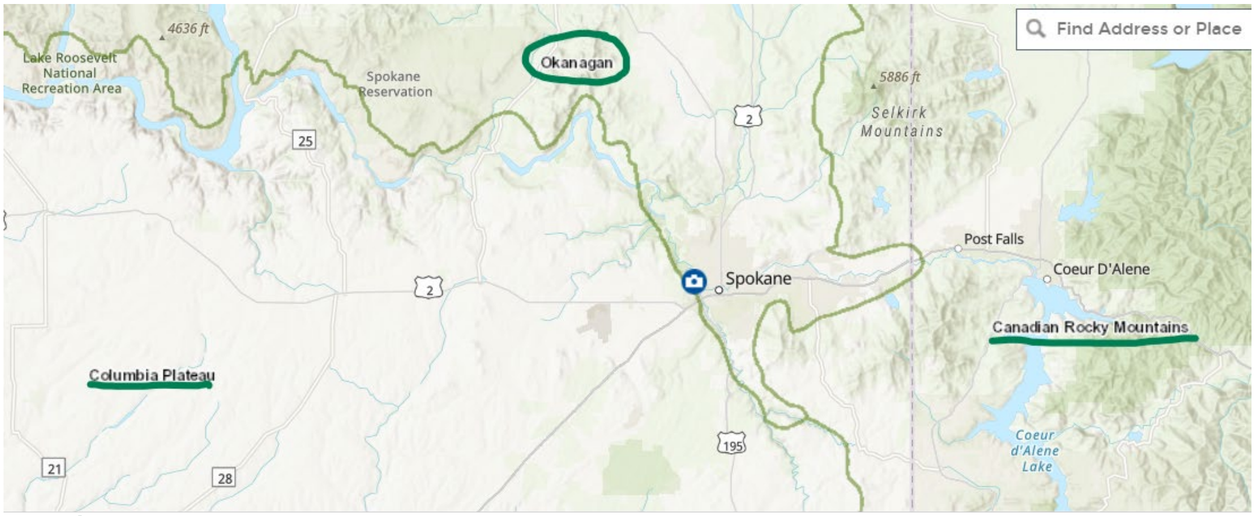


Figure 3. Ecoregional Map of the Columbia Plateau

The region is characterized as having hot, dry summers and cold, snowy winters. Plant communities and wildlife species vary with elevation. Prior to 1900, the area was described as "open and park-like" with few understory trees. Historically, four distinct ecosystems have been present in the area encompassed by what is now the UDPDA: grassland, pine/ponderosa savanna, riparian, and floodplain. Each of these systems possesses unique characteristics and provides specific functionalities that contribute to a balanced environment. Figure 4 provides a pictorial rendering of the historical conditions in the District.

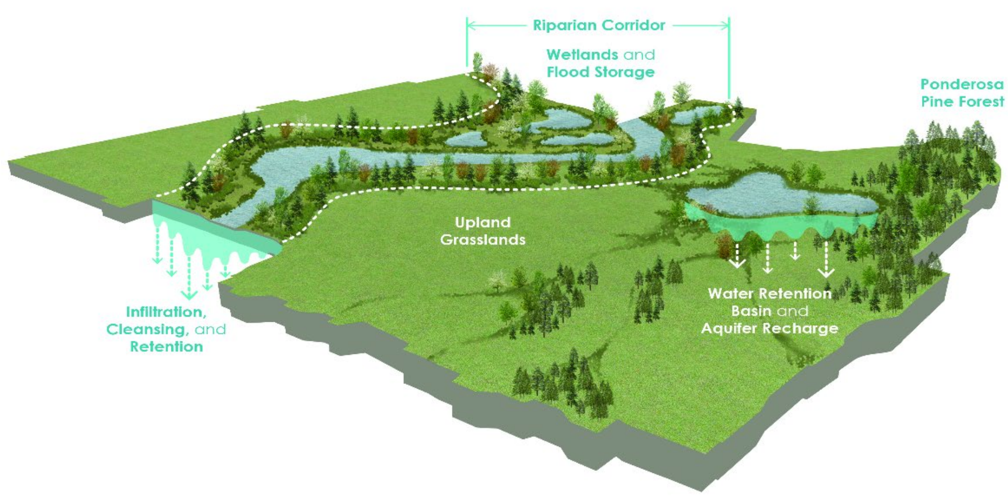


Figure 4. Historical Conditions in the University District[10]

[10] Cascara Designs

The goal of regenerative design is to replicate these characteristics and functionalities in the built environment to both restore and enhance ecosystem services for the benefit of humans and nature. The historical characteristics and functions of these four systems are detailed in the sections below.

3.1. Characteristics and Functions of Historical Ecosystems

3.1.1. Ponderosa (Pine) Savannah Ecosystem

Based on a review of ecosystem and ecoregion mapping resources and materials as well as through narrative photography conversations with Mr. Warren Seyler, Spokane Tribal Member, Spokane Tribe Natural Resource Department, the pre-colonization ecosystem in and near Spokane's UD was likely Northern Rocky Mountain Ponderosa Pine Woodland and Savannah system.[11]

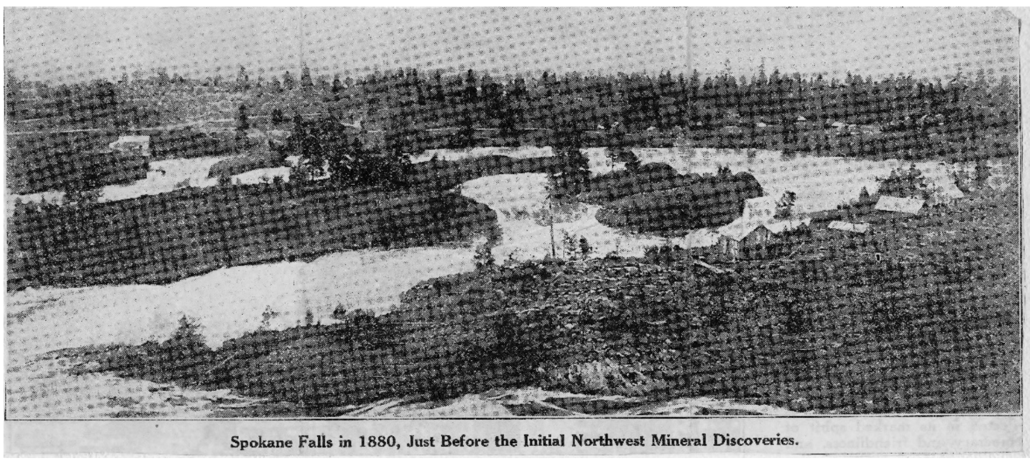


Photo 1. Northern Rocky Mountain Pine Ponderosa, photo courtesy of Mr. Warren Seyler[12]

This ecological system occurs at lower tree line elevations between grasslands or shrublands and is predominant at dry, low-level elevations. This system generally occurs on glacial till, glacio-fluvial sand and gravel, basaltic rubble, and other soil types that are slightly acidic in pH and feature good aeration and drainage. There are periods of drought during growing seasons. Typically, winter and spring rains result in spring "green-up" seasons. The system is characterized by grassy-floored open forests with ponderosa pine, Douglas-fir, western larch, western white pine, and quaking aspen.[13] The understory is primarily fire-resistant grasses and forbs that resprout following surface fires. Shrubs, understory trees, and downed logs are not common in this environment.[14]

Ponderosa pine has many characteristics that make it fire resistant, including deep roots, thick, relatively inflammable bark, thick scales that protect leaf and stem buds, high foliar moisture content, open branch crowns, and self-pruning lower branches.

[11] NatureServe Western Ecology Team. 2018. Northern Rocky Mountain Ponderosa Pine Woodland and Savanna. Available at:
[12] Photo from the personal collection of Mr. Warren Seyler, Spokane Tribe, Wellpinit, WA
[13] LandScope America. Okanogan Vegetation. Available at:
[14] Ibid. NatureServe Western Ecology Team 2018.

Fire is an essential aspect of the health of this ecosystem. According to the US Forest Service's Fire Effects Information System, *"The historical fire regime of ponderosa pine communities in the Northern Rocky Mountains was mostly frequent, low- to moderate-severity surface fires that burned in a mosaic pattern. Stand-replacement surface and crown fires were an infrequent but important part of the fire regime"*.[15] Fire intensity, size, and frequency decreased with elevation, soil moisture, and aspect. Studies suggest that the fire return interval ranged from 6-31 years, with low-severity fires more common at lower elevations.

Lightning and human intervention are the two most common sources of fire. The USDA Fire Regimes database notes that American Indians regularly and intentionally burned ponderosa pine sites in fall or early spring to improve forage, promote the production of berries and other food plants, and reduce the chances of crown fires.[16]

3.1.2. Shrub-steppe Ecosystems

As indicated in the previous section, the typical understory for a pine/ponderosa savanna ecosystem comprises fire-resistant grasses, shrubs with woody stems, and broad-leafed, non-woody herbaceous flowering plants (Forbs). South Okanagan grasslands can be divided into bunchgrass and shrub-steppe. Shrub-steppe ecosystems are arid grasslands that include sagebrush, rabbitbrush, bitterbrush, bunchgrass, and wildflowers.[17] Historically, shrub-steppe ecosystems have been home to greater sage-grouse, pygmy rabbit, sharp-tailed grouse, and pronghorn antelope, as well as burrowing owls.

More than 80 percent of the historical shrub-steppe has been lost or degraded.[18] While the shrub-steppe ecosystem is not currently present in the boundaries of the UDPDA, as noted in Figure 5 below, there is evidence to suggest that it may have been present in the past century.[19]

[15] Fryer, J. 2016. Fire Regimes of Northern Rocky Mountain Ponderosa Pine Communities. Produced by U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Available at:
[16] ibid
[17] Washington Department of Fish and Wildlife. 2020. Shrubsteppe Habitat. Available at:
[18] Washington Department of Fish and Wildlife. Shrubsteppe. Available at:
[19] Washington Department of Fish and Wildlife. 2020. Page. 4

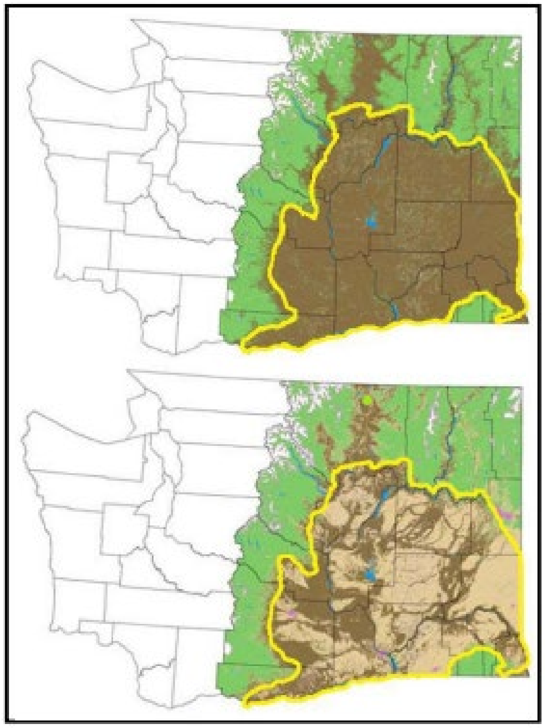


Figure 5. Historical and Current Shrub-steppe and Steppe Ecoregions in Washington

In addition to being high repositories of biodiversity, grassland ecosystems deliver multiple ecosystem services, including water retention and flow regulation, carbon sequestration, erosion control, and pollinator habitat. When managed, they also can serve as a forage source for livestock grazing and, in some cases, require interaction with grazing livestock to maintain ecological health.[20]

As with pine/ponderosa, savanna fire is a natural part of the grassland ecosystem and is important for clearing, warming the soil, and reducing leaf litter, which increases microbial activity and releases nutrients. Fire also controls woody shrubs and invasive species.[21]

3.1.3. Riparian Ecosystems

Riparian areas are the woodlands and shrublands associated with permanent, intermittent, and ephemeral streams at or below the tree line. Riparian areas are the transition zones at the margin between water and land-based ecosystems and usually have elements of both. The Washington Department of Fish and Wildlife (WDFW) has adopted the following definition for riparian ecosystems:

> "*Riparian areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly*

[20] J. Bengtsson, et al., Grasslands, More Important for Ecosystems Services Than You Might Think. ECOSPHERE, an ESA Open Access Journal. Available at:

[21] Schumann. 2023. Washington Department of Fish and Wildlife to Use Controlled Burns in Grasslands. June. Available at:

> *influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence)."*[22]

The WDFW definition comprises the active floodplain, including riverine wetlands and terraced and adjacent uplands.[23] Riparian ecosystems are considered priority habitats, and more than 85 percent of Washington's wildlife species utilize these zones. Because of the availability of water, soil fertility, and milder microclimates, these areas can support a diverse variety of plants and food sources. Riparian areas provide not only food and water to a variety of wildlife species but also ecosystem services that benefit humans, including regulating (and decreasing) flood flows, supporting nutrient cycling, filtering sediment and pollution and carbon sequestration.[24] Finally, there are often cultural, spiritual, and recreational services provided by riparian areas.

A complex relationship exists between riparian zone health, stream channel morphology, and groundwater recharge. Urbanization can alter riparian water availability by modifying stream flows and stream channel morphology. In cities, runoff from impervious surfaces tends to increase the volume and speed of water flow, causing stream channels to deepen and scour as more water moves through at a faster rate. This has been linked to lowered water tables and drier conditions in temperate urban riparian zones, leading to shifts in riparian nitrogen (N) cycling and vegetation communities.[25]

Some research has shown that in areas with distinct wet/dry seasons, the opposite may occur with changes in stream morphology, leading to increased flows at times when streambeds would otherwise be dry. In the context of the riparian zones of the Spokane River and the role of the Spokane-Valley-Rathdrum-Prairie-Aquifer as a drinking water source, this relationship between riparian zone health, flow rates and recharge is a significant ecosystem service.

3.1.4. River-floodplains and Groundwater Dependent Ecosystems

Using the definition provided above by WDFW, active floodplains are considered part of the riparian ecosystem. Floodplains provide ecosystem services similar to riparian ecosystems, including habitat for fish and wildlife, flood and erosion control, nutrient cycling, and water purification. They also provide water for consumption (both human and animal), irrigation, and energy production.

The Spokane Valley- Rathdrum Prairie Aquifer is the sole water source for Spokane County, Washington, and is one of only two "sole source aquifers" in the nation. The Spokane River is the surface outlet for this aquifer.[26] The role of riparian zones and the relationship between water flow, both in terms of quantity and timing, is a critical component of aquifer recharge.

The Spokane River, which runs through downtown Spokane, was once home to at least five species of anadromous fish, including summer Chinook; fall, winter, and spring steelhead; coho; and small silver fish and bull trout. These fish and the culture surrounding them are the lifeblood of the Spokane Tribe and represent a foundational cultural ecosystem service.

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[22] Quinn, T., Wilhere, G., and Krueger, K. 2020. Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications. Produced by Washington Department of Fish and Wildlife. Page 3. Available at:
[23] Ibid pg. 4.
[24] Ibid pg. 6.
[25] Solins, J., Cadenasso, M. 2022. Urban Runoff and Stream Channel Incision Interact to Influence Riparian soils and Understory Vegetation. Ecological Applications 32:4. Available at:
[26] Spokane County Public Works. Spokane Valley-Rathdrum Prairie Aquifer. Available at:

3.2. Historical Ecosystem Services and Current Status in the University District

Building on the characteristics and functions associated with the four ecosystems described in the previous section, the team identified twelve ecosystem services/assets that encompass the key goals and visions in place for the UD. The twelve ecosystem features are generally measurable and are also helpful in setting site-specific ecological targets for regenerative design. For each ecosystem feature, the report briefly describes the ecosystem features and services that were likely present at the pre-development UD site, what they are currently like in today's UD, and establishes a regenerative goal based on the pre-development site conditions and current conditions in the UD.

The following list of twelve ecosystem services has been selected as appropriate for ongoing attention in the UD, based on the review of literature, the review of planning documents, and the review of the historical ecology of the area. Due to the integrated nature of ecosystem elements, the target services are listed below and throughout the remainder of this document in alphabetical order. The twelfth service category, Human Health and Wellbeing, serves as a 'catch-all' for the direct benefits expected to accrue to people due to strengthening the other elements of the ecosystem.

- Air Filtration
- Biodiversity
- Carbon Sequestration
- Energy Provision
- Fire Adaptation
- Nutrient Cycling
- Pollination
- Stormwater Management
- Temperature Regulation
- Waste Generation and Management
- Water Cycling
- Human Health and Wellbeing

In this section, each of the ecosystem assets or services is explained with attention to the pre-development conditions so that targets for each in the District may be defined in terms of restoring the system to the natural balance that was originally in place and also in so that the original ecosystem can be used as a source of design inspiration in the UD.

3.2.1. Air Filtration

Trees and vegetation provide air filtration services by intercepting particulate matter (PM) on plant surfaces and absorbing gaseous pollutants through their leaves. Conifers are considered more effective at PM_{10} and $PM_{2.5}$ capture than broadleaved species. The coniferous trees that used to exist at the site would have been able to remove at least 20 micrograms of $PM_{2.5}$ per centimeter^2 from the atmosphere[27] though the only source of particulate matter would have been from fires. The trees would also have absorbed gas from the atmosphere. It is important to note that the barren landscape and predominant winds in the area would have promoted air filtration and movement.

Principle

Trees remove particulate matter and other pollutants from the air by depositing particles on the leaf surface.

[27] Chen, L., et al. 2017. Variation in Tree Species Ability to Capture and Retain Airborne Fine Particulate Matter (PM2.5). Science Reports 7:3206. Available at:

Status

Today, there are many more contributors to particulate matter in the air. Industrial processes, cars, trucks, power plants, construction, the tilling of fields, stone crushing, and forest fires all contribute particulate matter to the atmosphere. Industrial processes have also increased the amount of pollutant gases in the atmosphere, such as SO_2 and NO_2. Tall, crowded cities also limit airflow and slow air filtration rates. In the City of Spokane, the trees remove approximately 35,445 pounds of NO_2, 6,635 pounds of PM_{10}, 6,555 pounds of VOC, and 30,127 pounds of SO_2 annually.[28]

3.2.2. Biodiversity Support

The ecoregion is in a transition area between the channeled Scablands and Spokane Valley Outwash Plains, with the Spokane River running through it. Predevelopment, shrub-steppe, barren grasslands, and coniferous forests were the main ecosystems present in this region.[29] The Spokane River provided riparian habitat along its banks, aquatic habitat in the river itself, and wetland habitat along some stretches of the river. Ponderosa pines, lodgepole pines, western larch, quaking aspen, netleaf hackberry trees, water birch, and black cottonwood would have likely populated the region, though some, like the ponderosa pine, would have been more prevalent than others.[30] The understory consisted of native grasses, Idaho fescue, and antelope bitterbrush. Native shrubs, including rabbitbrush, sagebrush, wild tarragon, serviceberries, and elderberries, would have been found at the site as well.[31] These habitats and vegetation would have directly supported species such as coyote, deer, elk, a large variety of birds (raptors, turkey, quail, songbirds, etc.), small mammals, amphibians, reptiles, insects, and aquatic species like salmon. The entire site offered habitat, food, and shelter for the myriad of species that called it home. Though some larger species, including ungulates, would have traveled through the site, the majority of the species present would have been 100 percent supported by the ecosystems in the pre-development UD area.

Principle

This region's ponderosa pine woodland and savanna systems support 116 bird species, 70 mammals, and 17 species of reptiles and amphibians. Patches of shrub-steppe ecosystems host wildlife at risk.

Status

In the post-development UD, riparian habitat remains along the Spokane riverbanks, as well as the aquatic habitat of the river itself, though this has been degraded due to historical industrial practices and damming. A section of wetland remains on the northern bank of the Spokane River within the UD, Lake Arthur. The forests and grasslands have almost entirely been developed for university and residential structures. The only remaining large areas of open space are located within the university campuses, and these are closely managed by university staff and do not mimic the ecosystems that were once present in

[28] Davey Resource Group. 2013. Resource Analysis of Inventoried Street Trees. Prepared for the City of Spokane Parks and Recreation Department Urban Forestry Division. June. Available at:

[29] U.S. Environmental Protection Agency. 2016. Ecoregions of the Pacific Northwest (Idaho, Oregon, Washington). U.S. EPA, National Health and Ecological Effects Research Laboratory, Western Ecology Division, Corvallis, Oregon. Map scale 1:1,500,000. Available at:

[30] Bentler. Eastern Washington Native Trees. Available at:

[31] Bentler. Eastern Washington Native Shrubs. Available at:

the UD. Some native species are still present in the UD. They include Oregon grape, red-flower/golden currant, ponderosa pine (eighteen reported observations), black cottonwood, lodgepole pines, bulbous bluegrass, bluebunch wheatgrass, cheatgrass, staghorn Sumac, wild cherry, red osier dogwood, chokecherry, parsnip flower buckwheat, and quaking/shaking aspen.[32] Only 33 percent of the UD is currently considered plantable space.[33] The remaining area is covered with pervious surfaces, buildings, or water bodies that provide little to no support for native plant and animal species.

3.2.3. Carbon Storage and Sequestration

Carbon storage and sequestration removes carbon from the atmosphere and secures it in the form of organic material such as grassland soil or a tree trunk. As trees grow, they sequester carbon from the atmosphere and increase carbon storage. Coniferous trees would have historically provided the vast majority of the area's land-based carbon storage. Coniferous trees were most common at the UD site. These included ponderosa pines and lodgepole pines. Other native species included Rocky Mountain maples, serviceberries, western larches, black cottonwoods, and flowering crabapples, though these species would have made up a very small percentage of the total tree population. Coniferous forests may have covered approximately 40 percent of the UD prior to development, storing between 65 and 218 metric tons of carbon per acre C/Ha and sequestering between 212 and 261 metric tons of carbon per acre per year based on research on carbon partitioning in ponderosa pine plantations.[34]

Principle

Trees remove particulate matter and other pollutants from the air through the deposition of particles on the leaf surface.

Status

Today, there are just over 2,300 trees in the UD. They cover just under 30 acres of space. According to an estimate produced by i-Tree, the trees in the UD sequester approximately 32 tons of carbon per year and 118 tons of CO_2 equivalent per year.[35] Unlike the pre-development UD site, the current tree composition includes a mere 2.8 percent of native species. The most common trees are Norway maples, honey locusts, flowering pears, red maples, and red oaks, none of which are native to the area. The Ponderosa pines that used to rule the ecosystem now only account for 1.3 percent of all the trees in the UD.[36] Though the makeup of these trees is quite different than what might have been found in the UD historically, these trees still store carbon.

3.2.4. Energy Use

As primary producers, pine forest and grassland vegetation capture solar energy and convert it to chemical energy through photosynthesis that supports complex soil, terrestrial, and aquatic food webs. Thus, ALL the energy in this ecosystem was from the sun. This net primary productivity also resulted in substantial carbon sequestration in soils and vegetation (which underwent carbonification to become the fossil fuels

[32] iNaturalist. 2023. Observations in the UD. Available at:
[33] i-Tree Canopy. i-Tree Software Suite v5.x. (n.d.). Web. Accessed 21 July. 2023. Available at:
[34] Zhang, J., et al. 2021. Allometry of Tree Biomass and Carbon Partitioning in Ponderosa Pine Plantations Grown Under Diverse Conditions. Forest Ecology and Management 497. Available at:
[35] i-Tree Canopy. i-Tree Software Suite v5.x. (n.d.). Web. Accessed 21 July. 2023. Available at:
[36] Spokane Urban Forestry Department. 2023. Species Distribution: Spokane University District Tree Information. August.

we burn today). Cooling processes included evaporation from the surface of soil and transpiration from vegetation.

Principle

Pine forests and grassland vegetation capture solar energy and convert it to chemical energy.

Status

In 2017, Avista Utilities received a grant to support a shared energy economy model pilot project to demonstrate the integration of energy assets, including rooftop solar and battery storage and building energy management systems, that can be shared and used for numerous purposes. The model includes two 110kW rooftop PV systems, two battery storage systems, and flexible building loads that serve WSU.[37]

The Catalyst Building, a prominent feature in the UD, produces clean energy rather than relying on fossil fuels. It houses a central energy plant that powers the Catalyst Building itself and the nearby Scott Morris Center for Energy Innovation through a microgrid system.[38]

3.2.5. Fire Adaptation

Ponderosa Pine Woodland and Ponderosa Pine Savannah systems were maintained through frequent, low-intensity fires; high-intensity, catastrophic fires were infrequent. Mature ponderosa pine trees are resistant to low-intensity fires. Frequent, low-intensity fires served to reduce fuel load in the herbaceous understory, allowing trees to continue to grow and provide structural diversity. The understory's aboveground biomass of perennial grasses burned quickly and resprouted from root systems.

Principle

As long-term ecosystem residents, ponderosa pine are fire resistant thanks to their thick bark and self-pruning capabilities, while the short-term perennial grasses provide quick fuel that encourages fires to move quickly across the landscape. Together, these species protect the ecosystem from catastrophic fires.

Status

Spokane is one of many communities across Washington at extremely high risk of catastrophic fire because of development into natural or forested areas and climate change.[39]

Smoke from forest fires can contain pollutants that can attach to building materials and lead to staining and discoloration of susceptible surfaces. Smoke can cause damage to mechanical assemblies by acting as an abrasive between moving components. In addition, the particles borne in smoke can clog filters, thereby obstructing airflow and causing equipment to overheat.[40]

3.2.6. Nutrient Cycling and Soil Health

The predevelopment site contained both grass-dominated areas and ponderosa savanna that created a tight cycling of nutrients that reduced nutrient losses (in the absence of fire) through steady-state

[37] Wu, D., et al. 2022. Avista's Shared Energy Economy model Pilot: A Techno-economic Assessment. Prepared for the US Department of Energy. Available at:
[38] Avista Connections. Creating a Clean-Energy Future in Spokane, Washington. Available at:
[39] White, R. 2023. Citing Wildfire Risk, Spokane to Thin 1,000 Acres of Urban Forest. March. Available at:
[40] Smith, A. et al. 2023. The Impact of Forest Fire Smoke on Building Materials and Electronic Equipment. Available at:

decomposition and mineralization of above and below-ground organic matter. Nutrients released via mineralization would have mostly been absorbed by growing vegetation (or temporarily immobilized by soil microorganisms). Diffuse root systems of grasses concentrated in the upper soil horizon absorbed inorganic elements as they were mineralized (either through decomposition or fire), minimizing ecosystem losses of nutrients. Ultimately, the ecosystem maintained a loop in which nutrients were cycled and distributed throughout the UD site, maintaining healthy soil conditions for native plants. Though not specific to the UD or Spokane region, the diagram below illustrates the nutrient cycle process and the key forest elements that participate in this cycle.

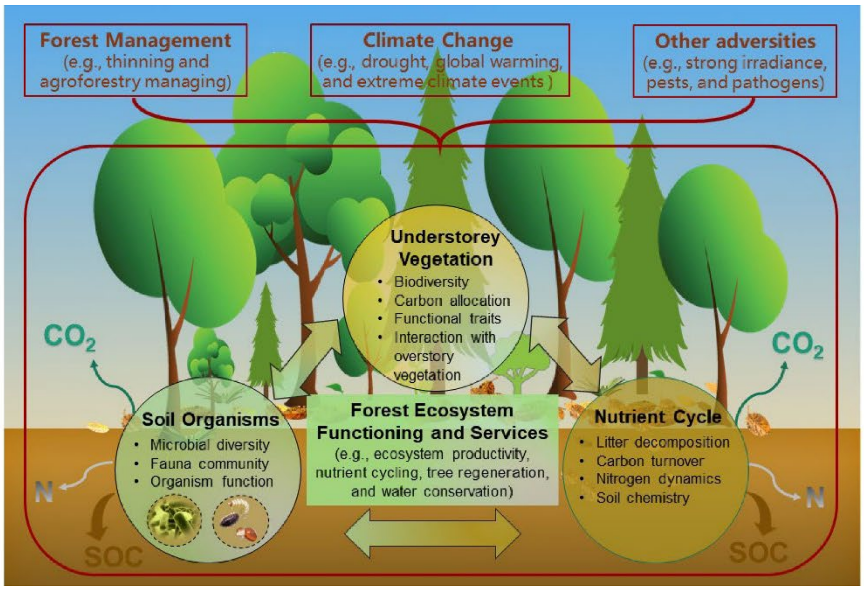


Figure 6. The Nutrient Cycle in Forest Ecosystems [41]

Principle

Ponderosa pine woodland and ponderosa pine savanna systems foster tight recycling of nutrients and reduced loss of nutrients from the system or nutrient export to other adjacent ecosystems, like water bodies.

Native perennial grasses in the understory of the ponderosa pine savanna protect the soil against loss through water and wind erosion and contribute to soil carbon sequestration. The carbon accumulation in soil supports diverse food webs essential to soil health and mitigates CO_2 emissions. Extensively distributed native perennial grasses stabilize and hold onto soil while the grass canopy protects the soil by providing physical cover, shade, and soil temperature regulation.

Status

Today, the soil in Spokane ranges from slightly alkaline to slightly basic, which favors hardy native plants. The soil is typically coarse-loamy or ashy loam, which are favorable conditions for rural home sites, grazeable woodland, livestock grazing, timber production, wildlife habitat, and some dryland cropland.[42]

[41] Deng, J., et al. 2023.Forest Understory Vegetation Study: Current Status and Future Trends. Forestry Research, 3:6. March. Available at:
[42] USDA. 2016. Spokane Soil Series. Available at:

The site's surface soils are generally variable imported materials and site-originated soils that have been relocated. Drilling records suggest that the top three feet of the site are probably underlain with a mixture of topsoil, granular material (sand, gravel), cinder, broken rock, and miscellaneous urban demolition material (mainly brick, concrete, and asphalt). Basalt rock underlies the site at varying depths, from exposed at the surface in some locations to below river level in other locations. In general, the western portion of the site contains only a thin veneer of surface soil over bedrock. The eastern portion of the site formerly contained some low areas which were filled during the railroad era. Basalt bedrock may be overlain in these locations with 15 or more feet of fill.[43]

Due to soil imports and the removal or change of vegetation and microorganisms, the soil in the UD cannot cycle and retain nutrients like it did pre-development. Also, the majority of the soil is covered by impervious surfaces, allowing nutrients to flow off the site into the Spokane River, leaving the soil nutrient-depleted and water bodies oversaturated with nutrients.

3.2.7. Pollination

Before development, this region was home to many flowering plant species that supported native pollinators, such as lupine, Oregon grape, red-flowering/golden currant, wild bergamot, pearly everlasting, kinnikinnick, big leaf maple, nodding onion, blue elderberry, common snowberry; mock orange; and penstemon.[44] These plants and habitats support a number of native pollinators, including multiple species of bumblebees that live belowground in preexisting cavities or under dense layers of vegetation; multiple species of honeybees that live in hives or human-provided bee boxes; mason bees that live in small cavities in wood; sweat bees that nest in the ground; multiple species of flies that nest in trees close to food sources; multiple species of butterflies and moths; hummingbirds (specifically the anna's hummingbird, rufous hummingbird, and calliope hummingbird) that nest in trees and bushes; and various other bees. Figure 5 illustrates the roles that forests and forest-adjacent ecosystems can play in supporting pollinator habitats.

[43] NBBJ, Transpo Group, Taylor Engineering. 2014. 2014-2024 Master Plan Update. Prepared for Washington State University Health Sciences Spokane. Available at:

[44] WSU Master Gardener Program. Native Plants for Spokane Area Gardens. Available at:

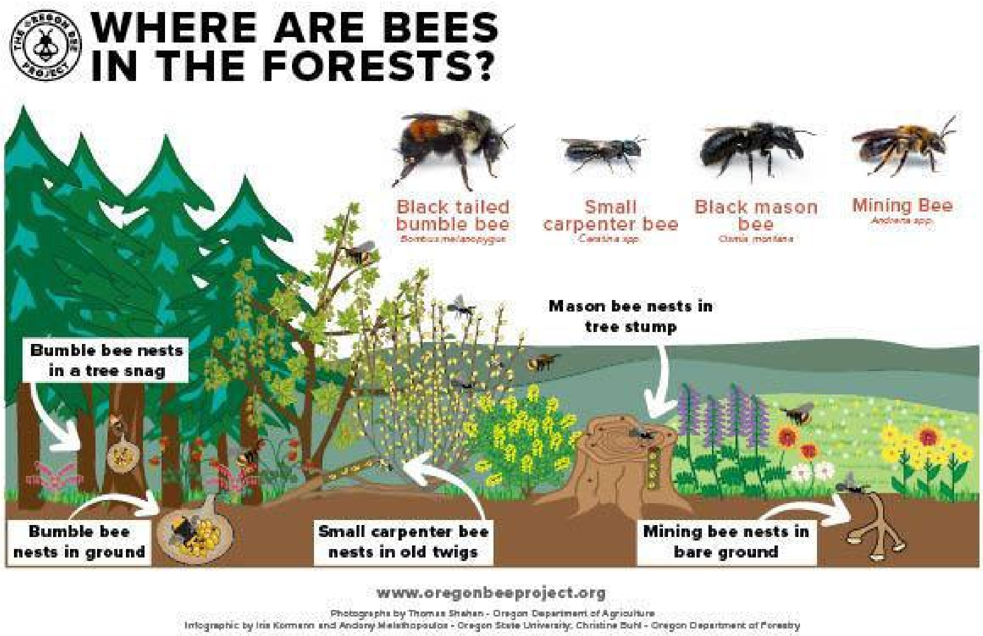


Figure 7. Ecosystem Support for Pollinator Habitat[45]

Principle

Flowering plants, grasses, and other attractants for pollinators support diverse pollinator and plant communities.

Status

During a recent survey in July, the following species were observed and reported within the bounds of the UD: a total of 131 bumblebees across 11 distinct bumblebee species; 37 total western honeybees; 21 woodcarver bees; 14 various other bee species; 94 individual butterflies; 8 individual moths; 40 individual flies; and four individual hummingbirds (3 rufous hummingbirds, one black-chinned hummingbird).[46] According to University of Gonzaga biology Professor Gary Change, at least 11 species of bumblebee and 20 species of butterfly are present in the UD. In terms of pollinator habitat, there are currently two university-owned bee boxes with active hives on the Gonzaga University campus.

3.2.8. Stormwater Management

The original ecoregion's vegetation (grasses and trees) would have slowed the rate at which precipitation hit the ground, giving the soil and roots more time to absorb stormwater. The pervious soil also would have helped absorb stormwater. Once absorbed, the microbiome and roots would have filtered the stormwater before it reached the Spokane River or aquifer. The floodplains/wetlands along the bank of the Spokane River also would have helped filter the stormwater and accommodated any overflow from the Spokane River. The ecosystem itself would have filtered and slowed the rate of any stormwater runoff, providing 100 percent of the area's stormwater management needs.

[45] Korman, I., et al. Resources for Building Bee Pollinator Habitat in Managed Forests. Available at:

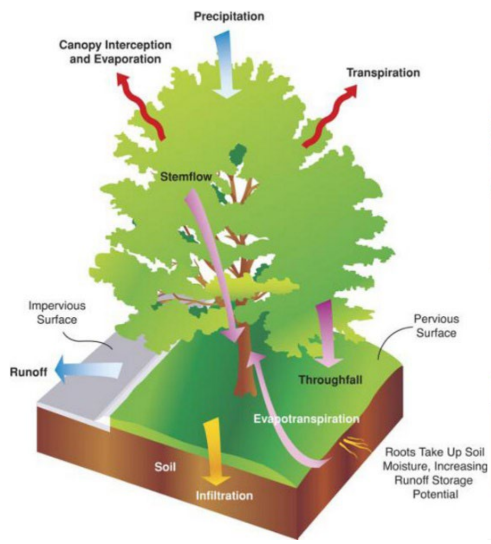
[46] iNaturalist. 2023. Observations in the UD. Available at:

Principle

Rather than absorb into the soil, stormwater runs off the impervious surfaces, picking up pollutants from the sidewalks and roads.

Status

Some pervious surface (exposed soil around urban vegetation, open spaces), urban vegetation (mostly campuses, riverbanks, and private yards), swales (near Gonzaga parking lot), aquifer, Spokane River, Lake Arthur (only classified wetlands in city limits) are found in the UD. However, 64 percent of the UD is now covered by impervious surfaces.[47] The UD has some swales, particularly near university campus parking lots, that provide filtration and stormwater management services like those offered pre-development. Arthur Lake, a two-acre lake near the Spokane River, also provides stormwater filtration and overflow services. It is the only classified wetland on the Spokane River within city limits.[48] Besides urban vegetation centered on the university campuses and riverbanks, the ecosystems provide a fraction of the stormwater management services they once provided. The lack of filtration is a particular concern because the porous soil above the aquifer allows 30 percent of pollutants to reach the aquifer, which supplies over 500,000 people, highlighting the importance of vegetation on pervious surfaces. Due to the basalt below SW UD and the aquifer in NE (10-17ft below the surface, covered by porous soil) in these areas, 30 percent of pollutants can reach the aquifer. The first diagram below demonstrates the importance of vegetation in slowing and filtering stormwater before it reaches the water table, while the second diagram highlights the need for pervious surfaces to ensure that stormwater may replenish the water table beneath the surface. Both diagrams illustrate the processes described but are not specific to the UD.



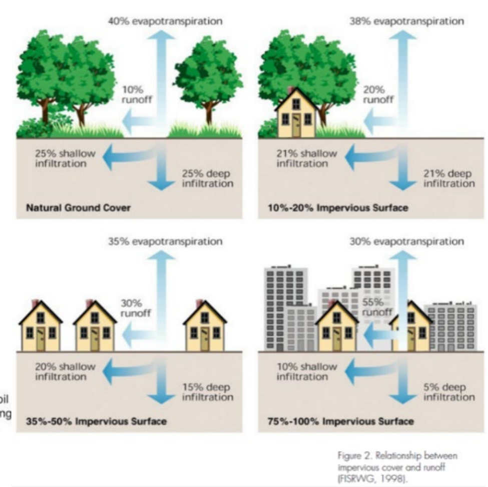


Figure 8. Ecosystem Functions and Stormwater Management [49] [50]

[47] i-Tree Canopy. i-Tree Software Suite v5.x. (n.d.). Web. Accessed 21 July. 2023. Available at:
[48] Bernardo, S. 2020. Life at Lake Arthur. September. Available at:
[49] Marritz, L. 2013. How Do You Calculate Stormwater Credits for Trees? Part 1: Why Tree-Based Credits are Hard to Quantify. March. Available at:
[50] Biomimicry Oregon. 2013. Genius of Place Process Report: Nature's Strategies for Managing Stormwater in the Willamette Valley. Page 14.

The following local regulation applies to all local projects unless specifically approved by local jurisdiction: the peak rate and volume of stormwater runoff from any proposed land development to any natural or constructed point of discharge downstream shall not exceed the pre-development peak rate or volume of runoff.[51]

3.2.9. Temperature Regulation

Tree canopies also help regulate air temperature. They increase evapotranspiration rates and provide shade, which in turn reduces the air temperature surrounding the tree. Depending on the time of day, trees can decrease surrounding air temperatures by 8 to 13 degrees Fahrenheit. Historically, the coniferous trees on the UD site would have covered approximately 230 to 310 acres, providing significant shade and cooling effects to the area.

Principle

Trees moderate air temperature by providing shade and through evapotranspiration. The tree canopy in the ponderosa pine savanna is highly variable but estimated as approximately 30 to 60 percent. Also, grasslands have high albedo (fraction of sunlight that is diffusely reflected by a body) that reduces ecosystem heat load.

Status

In the UD today, tree canopies cover just under 30 acres. Yet temperature regulation is more important than ever. Climate change has increased average annual temperatures and is contributing to the region's rising number of extreme heat events. Cities are at particular risk during these events due to the urban heat island effect in which the dark surfaces and limited airflow in the city increase the air temperature directly over the ground. Urban trees, like those in the UD, help mitigate this effect by reducing surrounding air temperatures by up to 13 degrees Fahrenheit.[52] The 76,500 trees in the greater Spokane area reduce annual electric energy consumption by 6,500 MWh and annual natural gas consumption by 224,00 therms.[53]

3.2.10. Waste/Recycling

The ecosystem assets and features of the pre-development UD site would have managed waste in a closed loop, meaning that all waste created would have been decomposed and recycled back into the ecosystem. The ecosystem itself would have provided 100 percent of the waste and recycling services needed to prevent waste from building up within the site.

Principle

To mimic the ponderosa pine savanna, 100 percent of the organic waste generated must be composted and applied to vegetation to add nutrients that would have otherwise been recycled within the system.

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[51] City of Spokane, Spokane County, City of Spokane Valley. 2008. Spokane Regional Stormwater Manual. April. Available at:

[52] Gonzaga Center for Climate, Society and the Environment. 2023. Spokane Beat the Heat. Available at:

[53] Davey Resource Group. 2013. Resource Analysis of Inventoried Street Trees. Prepared for the City of Spokane Parks and Recreation Department Urban Forestry Division. June. Available at:

Status

Today, the average Spokane County resident generates 1,000 to 1,750 lbs. of trash per year, of which only 45 percent is diverted through recycling or composting.[54] The city offers optional curbside pickup for yard waste and food scraps, along with educational information on home composting. Curbside recycling is also available every two weeks, or residents can drop their waste off at the Spokane Materials and Technology Center (SMaRT). The UD ecosystem provides but a minimal percentage of waste management services today through home composting and City composting efforts. Additional waste management services are provided by the built environment. The use of recycled or reclaimed materials like those used in the Catalyst building are an example of the built environment providing waste services and reducing waste generation.

3.2.11. Water Cycling and Resiliency

This region was historically, and still is today, relatively dry. Annual precipitation ranges from 15 to 20 inches, annual temperatures range from 0 to 90 degrees Fahrenheit, and the wet winter months tend to be more humid than the dry summer months.[55] Precipitation is but one key water source in the UD area. The northeastern section of the UD sits atop a large aquifer that covers 325 square miles and extends into Idaho. The soil above the aquifer was not thick or deep (10-17 feet) and allowed fluids to infiltrate into the porous sands and gravel that make up the aquifer material.[56] The pre-development UD site area was historically covered by pervious surfaces, aka soil. The soil at this site was likely covered by grasses and sparsely populated ponderosa pines. The roots of the vegetation would have slowed any surface water as it flowed along the ground and increased its absorption rate into the soil. Once in the soil, the microbiome and plants would have helped filter the water of pollutants before the water reached the aquifer. Any water that was not absorbed into the soil would have run into the Spokane River, a prominent water feature in the region. The floodplains along the river also would have provided filtration, flood protection, and absorption services.

Principle

Water filters into the aquifer and Spokane River, maintaining consistent ground and surface water levels year to year.

Status

Today, less water is seeping into the aquifer through the soil in the UD site area, and more water is directly flowing into the Spokane River when compared to historical conditions. Increased summer drought and urban water demand[57] are also putting pressure on aquifer recharge rates. The aquifer below the northeastern section of the UD is the only drinking source for more than 500,00 people across the Spokane region and north Idaho. The aquifer has a storage capacity of 10 trillion gallons. The average daily water withdrawal is 160 million gallons, with peak summer daily withdrawals reaching 450 million. Models

[54] City of Spokane. Reduce, Reuse, and Recycle. Available at:
[55] NBBJ, Transpo Group, Taylor Engineering. 2014. 2014-2024 Master Plan Update. Prepared for Washington State University Health Sciences Spokane. Available at:
[56] City of Spokane, Spokane County, City of Spokane Valley. 2008. Spokane Regional Stormwater Manual. April. Available at:
[57] Watering Rules and Drought Response Measures - City of Spokane, Washington (spokanecity.org)

suggest that during high-demand times, water is being pulled from its reserve capacity.[58] Due to limited pervious surfaces and water withdrawal from the aquifer, the ecosystems in Spokane perform less than half of the water cycling and resiliency services that they provided pre-development.

3.2.12. Improved Human Health and Community Well-Being

The pre-development UD was likely sparsely populated with ponderosa pines with short herbaceous plants growing below. The Spokane River was a focal point at the site and in the region. Both the river and the ponderosa forests would have provided hunting and foraging opportunities. The river namely provided a source of water for fish. The forest provided habitat for huntable species like deer, marmots, and squirrels, as well as nuts, seeds, berries, and herbs. The UD site itself would not have provided 100 percent of the food supply utilized by indigenous people, as this area was used as a winter campsite (Warren Seyler, personal communication[59]). However, the ample greenery and open space would have provided mental health benefits and allowed for ample recreational/physical activity. The site was, therefore, culturally important in that it served as a gathering place to share food, knowledge, and culture. The area also likely provided hunting and foraging opportunities, medicinal plants, and other aesthetic values that were culturally significant.

Principle

A broad number of Public Health and Community Well-Being outcomes are expected to flow from the principles and development targets identified above. These include:

- Mental health/emotional wellbeing
- Physical health
- Recreation
- Air Quality
- Green Jobs
- Accessibility and Social Justice
- Cultural Ecosystem Services
- Education, and
- Community-based Science

Status

Today, there are three community gardens run by Spokane Community Gardens in the middle of the UD. Gonzaga University also has a community garden open to students, staff, faculty, and the greater Spokane community.[60]

[58] United States Environmental Protection Agency, Idaho Department of Environmental Quality, Panhandle Health District, Kootenai County Planning Department (Idaho), Spokane County (Washington), United States Geologic Survey and Eastern Washington University. 2000. The Spokane Valley-Rathdrum Prairie Aquifer Atlas. Available at:

[59] Warren Seyler, Spokane Indian Tribe, personal communication, September 2023.

[60] Spokane Community Gardens. Gonzaga Campus Garden. Available at:

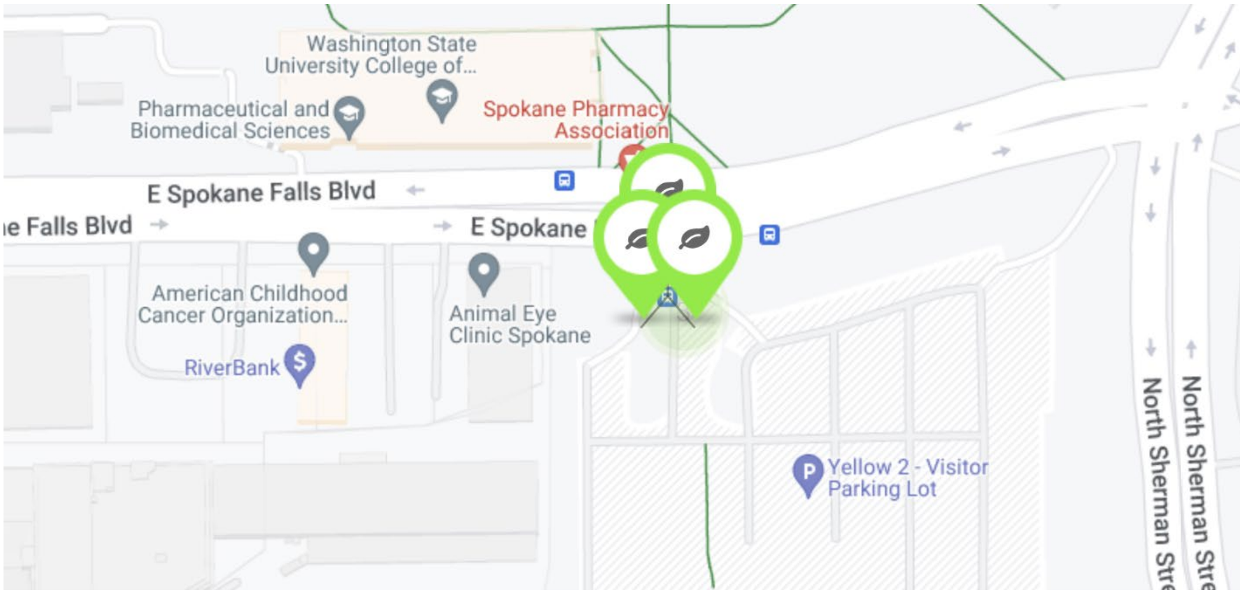

Figure 9. University District Community Gardens [61]

These are the only remaining local food sources provided by the UD site. The Centennial Trail runs along the riverbank through the UD, providing the community with a place to recreate and connect with nature. Besides the trail and riverfront, most of the open green space is contained within the university campuses. In the UD today, there is limited access to open green spaces and places to connect with nature. The commercial and industrial areas that now dominate the UD lack the greenery known to improve mental health, promote physical activity, and increase healing rates.

Currently, the UD has many programs in place to increase access to culture, traditional practices, and place-making opportunities. These include the Spokane Environmental Learning and Cultural Center (SELCC), UD Wayfinding and Culture Corridor, and a folk market/maker space. The SELCC is focused on restorative environmental education and culturally responsive community health and is led by community stakeholders. Their goal is to "cultivate cultural patterns that reconnect an individual's inner nature with the dynamic and living presence of great nature."[62] [63] The Wayfinding Program and Culture Corridor will positively impact local economic development by increasing signage, directions, and streetscaping amenities and adding cultural/interpretive signs.[64] The U Folk Market will also support local businesses by providing up to 20 market stall spaces. The marketplace is multi-cultural and led by local BIPOC and diverse, culture-led business support organizations.[65] Together, these programs, among others, provide similar services previously provided by the UD site pre-development. Though the area does not provide the same hunting/foraging services it once did, the UD still offers the same social and place-making opportunities it once did. There are also programs in place to reconnect the community with nature and

[61] Spokane Community Gardens. 2021. Community Gardens. Available at:
[62] SELCC. 2023. SELCC Spring 2023.
[63] U Mosaic. 2018. U Mosaic.
[64] Spokane Arts, other stakeholders. 2023. Investing in Downtown Economy Through Culture, Public Health, and Urban infrastructure: Downtown/University District Comprehensive Wayfinding Program and Cultural Corridor.
[65] University District. 2023. U Folk Market.

teach about traditional practices, strengthening the cultural relationship the people once had with this area.

3.3. Ecosystems Service Status and Targets

Once the characteristics and functions of the prehuman development ecosystem are understood, regenerative design principles can be used to set performance targets going forward. The table below summarizes the performance targets performance targets can be set.

Table 2. Ecosystem services and Targets

Ecosystem Service	Target
Air filtration	AQI $PM_{2.5}$ and PM_{10} in the urban core should not exceed that of native ponderosa pine savanna (in fire-free conditions).
Biodiversity	Environmental restoration activities will use species native to the ecosystem in appropriate locations in ratios similar to the original landscape.
Carbon Sequestration	CO_2 emissions from energy generated from fossil fuels and building construction should not exceed the net primary productivity (Mg C/ha/year) of the surrounding landscaping/vegetation, including any engineered sequestration that may become feasible and/or offset credits.
Energy Provision	Energy produced by rooftop solar and other distributed energy sources (geothermal and wind) should produce the equivalent net primary productivity of a mature ponderosa pine savannah.
Fire adaptation	Plant and maintain native fire-adapted vegetation that produces a fuel load similar to savanna grasses that burn quickly to reduce the incidence of and/or damage caused by catastrophic fire. Structures should have fire -retardant outer materials like the Ponderosa bark, and vegetation should emulate the quick-burning grasslands.
Nutrient Cycling	Open space areas should have the same ratio of trees to shrubs and grass as the ponderosa pine savanna ecosystem to enhance nutrient interception by roots and protect the system against nutrient losses. Artificial media in non-vegetated areas can also be used to absorb and retain nutrients.
Pollination	UD vegetation should mimic native perennial grasslands by including plant species known to host native pollinator communities represented in ponderosa pine savanna.
Stormwater Management	Zero percent impervious services or equivalent.
Temperature Regulation	The amount of shade in the developed urban ecosystem should be the same as what was provided by the ponderosa pine savanna. Shade targets could be met by

Ecosystem Service	Target
	both vegetation plantings and built structures. In addition, shade trees should be distributed equitably, as low-income areas tend to have fewer trees and arguably less income to pay for air cooling.
Waste Generation & Management	The ecosystem assets and features of the pre-development UD site would have managed waste in a closed loop, meaning that all waste created would have been decomposed and recycled back into the ecosystem.
Water Cycling	Water withdrawals should be calibrated to protect the aquifer and limit water withdrawal to support historical aquifer recharge rates.
Human Health & Wellbeing	The ongoing development theme is to preserve the “winter camp” status of the area, as it was a meeting place for indigenous people where people come to share knowledge, food, and culture.

4. Nature Informed Design Standards and Performance Metrics

Before humans drastically changed the form and landscape of the UD, there was a thriving ecosystem that kept the land and its resources balanced and healthy. This self-maintaining and sustainable ecosystem was lost through decades of planning, building, and increased human activity in the area.

Using the biomimicry approach, centering and taking inspiration from the systems or elements of systems that were once present as outlined in the previous chapter, can be a powerful tool to restore ecological health to the land, as well as to promote sustainability. Through biomimicry, nature-informed design standards and considerations can be created to address sustainability goals and fit site-specific needs.

As noted in Chapter 2, the prevailing ethos across multiple institutions for biomimicry in urban design (that is, designing entire communities rather than a single structure) is to analyze the existing ecosystem that is present or was present and take design inspiration from the systems that the local ecosystem adapted to respond to specific environmental factors at the site.

This chapter presents a design framework and identifies design considerations for each ecological service. These considerations are mostly nature-informed design, though some are intended to facilitate or create the opportunity for ecological services to thrive.

4.1. Design Framework

The research team developed a design framework to support the development of design considerations and recommendations for the District. The design framework for enhancing ecosystem services in the UD is built around three realms or "ecosystems": the riparian, the public realm, and the built environment. Each of these realms within the UD has unique functions, needs, and opportunities to welcome regenerative ecosystem services. This description of the design framework summarizes each of these realms, identifying the ecosystem service principles and associated design standards that could be applied. Each of these UD areas may have unique design interventions, though some may overlap with one or more of the other areas. Figure 10 below illustrates the three.

Figure 10. Ecosystems and Design Realms of the University District

For each of the twelve ecosystem services identified in Chapter 3, there are a number of design considerations that can enhance the provisioning capacity of an ecosystems service. The table below provides some examples of design considerations that could enhance each of the 12 ecosystem services that the design framework supports.

Table 3. Design Standard Considerations

Ecosystem Service	Target	Design Standards
Air Filtration	Shade should approach that provided by ponderosa pine savanna	• Increase urban canopy • Green Walls • Reduce vehicle emissions • Energy Conservation
Biodiversity	Manage waste in a closed loop (meaning all waste is decomposed or recycled back into the ecosystem)	• Landscape design • Wildlife connectivity
Carbon Sequestration	Water withdrawals will not exceed historical aquifer recharge rates	• Carbon specific planting • Increase green spaces • Building materials
Energy Provision	Preserve the "winter camp" status of the area as a meeting place where people come to share knowledge, food, and culture	• Promote alternative energy sourcing • Smart building design • Reduce heat islands
Fire Adaptation	Emulate low-fuel load savanna grasses and fire-retardant outer materials approximating ponderosa bark	• Protect buildings and envelope • Fire-resistant landscape design
Nutrient Cycling	Open space areas should have the same ratio of trees to shrubs and grass as the ponderosa pine savanna ecosystem	• Symbiotic planting • Replicate Pine Savanna
Pollination	Vegetation should mimic native perennial grasslands by including plant species known to host native pollinator communities represented in ponderosa pine savanna.	• Pollinator specific planting • Protected pollinator habitats
Stormwater Management	Zero percent impervious services or equivalent	• Green stormwater infrastructure • Reduction of impervious surfaces • Mimic historical runoff patterns • Increase infiltration
Temperature Regulation	Shade should approach that provided by ponderosa pine savanna	• Cool building design • Vertical planting

Ecosystem Service	Target	Design Standards
Waste Management	Manage waste in a closed loop (meaning all waste is decomposed or recycled back into the ecosystem)	• Community waste reduction • Waste to energy technology • Recycled building materials
Water Cycling	Water withdrawals will not exceed historical aquifer recharge rates	• Drought resistant landscaping • Rainwater harvesting and reuse • Aquifer protection
Human Health	Preserve the "winter camp" status of the area, as a meeting place where people come to share knowledge, food, and culture	• Edible landscapes/Urban food forests • Passive recreation • Culturally relevant design

The remaining sections of this chapter provide a more detailed description of each of the three realms and the associated ecosystem services and design standards.

4.1.1. Riparian Ecosystem

The riparian ecosystem captures the portion of the Spokane River that runs through the UD, the shore immediately adjacent to the waterway (about five feet), and the associated buffer (200 feet). The geography of this UD ecosystem and possible design standards are depicted in Figure 11. Historically, the river provided riparian habitats along its banks, and wetlands along specific stretches, creating an environmentally significant resource. Today, much of the area surrounding the river within its buffer has been built into the urban form, although there are some green spaces and riparian habitats that remain. Despite the differences in its current form today, the riparian area is an important part of the ecosystem of the UD. The design standards that will be selected for this area will prioritize replicating its original function and protecting it in its current form.

Figure 11 is a conceptual cross-section illustrating implementation of some of the design standard considerations in the riparian ecosystem, including:

- Aquatic habitat improvements with re-contouring of the existing steep riverbanks, native plant revegetation, and the implementation of in-water fish habitat structures
- Low-impact recreational trails and bike paths with improved riverfront access to protect these sensitive landscapes.
- Restoration of the floodplains, riparian forest, and upland ponderosa pine forest-grassland to enhance habitat and connectivity.

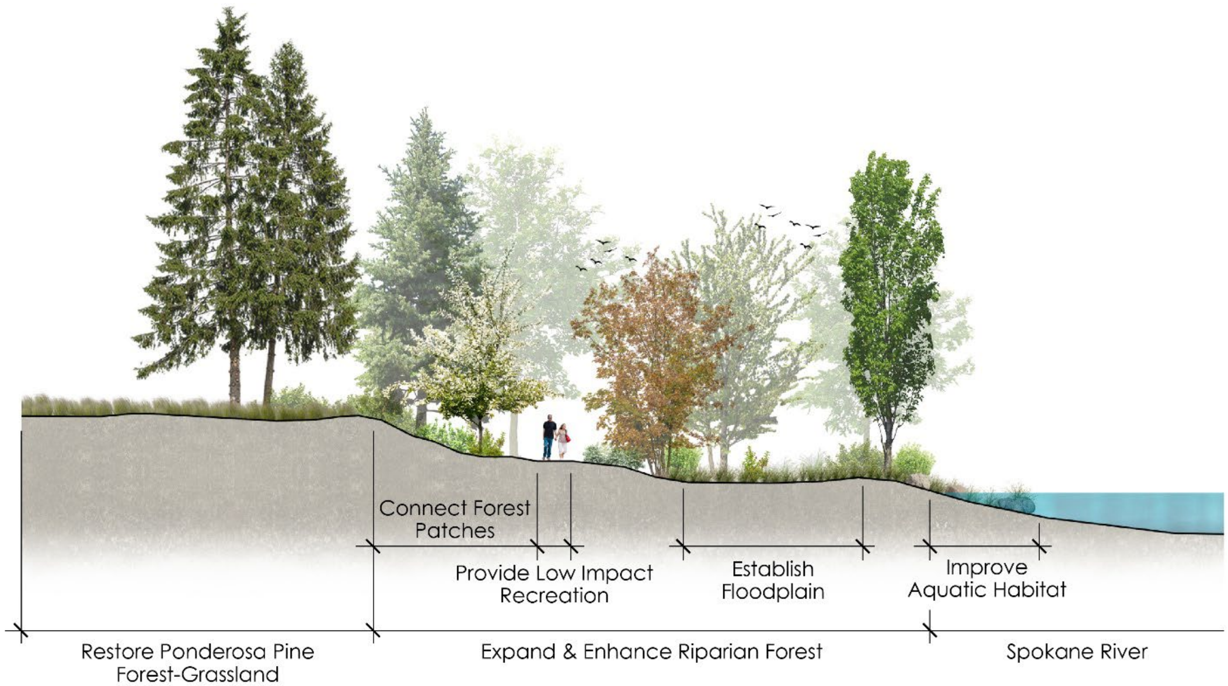

Figure 11. Riparian Ecosystem Conceptual Cross-Section[66]

4.1.2. Public Realm Ecosystem

The public realm is made up of public spaces such as street rights-of-way, bike lanes, sidewalks, parks and open spaces, and plazas. The geography of this UD ecosystem and possible design standards are depicted in Figure 12. The public realm is the foundation of the urban form of the district and the areas surrounding the various universities in the UD. There are currently no city-owned or operated parks in the UD, however, green spaces on both university campuses allow for access and recreation as well as along the bike trails along the Spokane River. Although Gonzaga University is private, it exists as an open, urban campus that is generally accessible to the public (though some portions are not accessible to all). The Washington State University Health Sciences campus also provides public spaces.

Figure 12 is a conceptual cross-section illustrating implementation of some of the design standard considerations in the riparian ecosystem, including:

- Green corridors integrated into the urban fabric such as ponderosa pine grasslands to encourage habitat connectivity.
- Increased urban canopy through the installation of drought-tolerant street trees on both sides of the street to improve air quality, reduce stormwater runoff, and provide shade.
- Street improvements with low-impact development (LID) vegetated stormwater facilities along both sides of the street to treat stormwater runoff.
- Dedicated bike lanes are incorporated on both sides of the street to reduce vehicular traffic.

[66] Source: Cascara Land Design

- New parks and open spaces with low-impact recreation, enhanced habitat, and potentially a regional vegetated stormwater facility to improve stormwater quality, mitigate existing developed areas, and provide for future development.

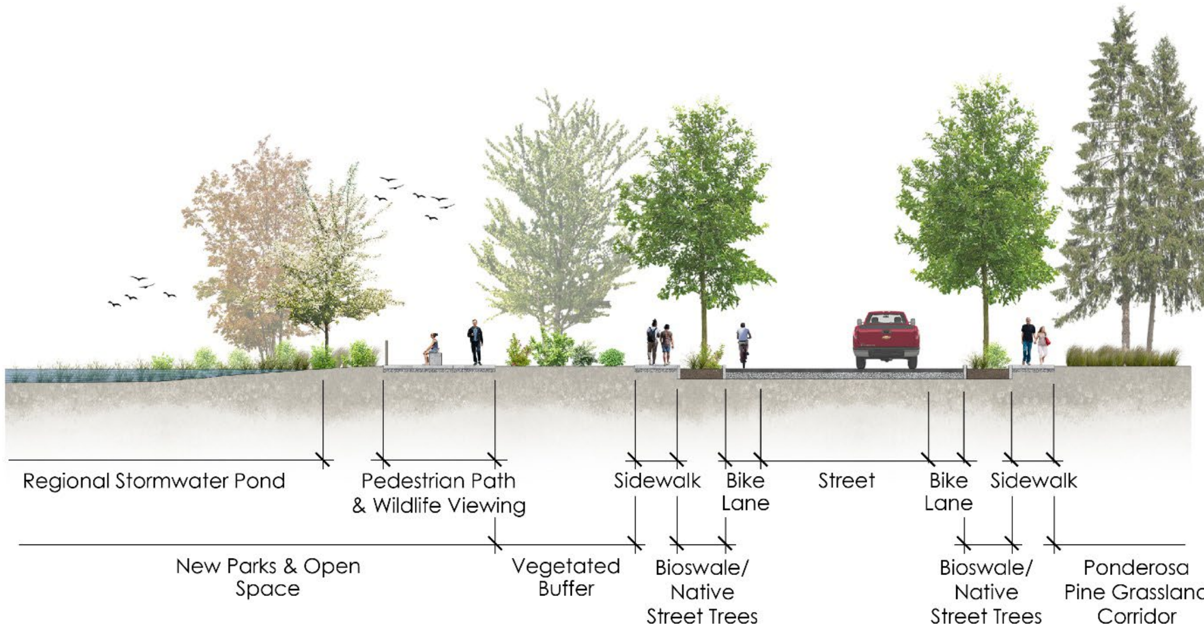

Figure 12. Public Realm Ecosystem Conceptual Cross-Section[67]

4.1.3. Built Environment Ecosystem

The built environment is defined by buildings and site development, specifically new construction, and retrofitting efforts; this applies to both public and private properties. The geography of this UD ecosystem and possible design standards are depicted in Figure 13. New construction is an important aspect of this area as it can incorporate sustainable design standards that impact the rest of the environment. Similarly, efforts to retrofit buildings can utilize these design standards while also preserving open space and land, which in turn can satisfy other goals.

Figure 13 is a conceptual cross-section illustrating implementation of some of the design standard considerations in the riparian ecosystem, including:

- Retrofitting existing buildings with LID strategies such as green roofs and vegetated stormwater facilities to treat and reduce stormwater runoff.
- Removal of existing impervious asphalt and replacement with permeable pavement such as permeable pavers or concrete.
- Enhanced landscapes and buffers with native drought-tolerant plant material between properties or where sites allow.
- New site development improvements with LID strategies, permeable pavement, native plant palettes, and electrical vehicle charging stations.

[67] Source: Cascara Land Design

- New buildings that meet third-party certification systems such as LEED (Leadership in Energy and Environmental Design) or the Living Building Challenge guidelines with the use of sustainable building materials, rainwater harvesting for irrigation and greywater, greywater reuse, green roofs, and vertical green walls.

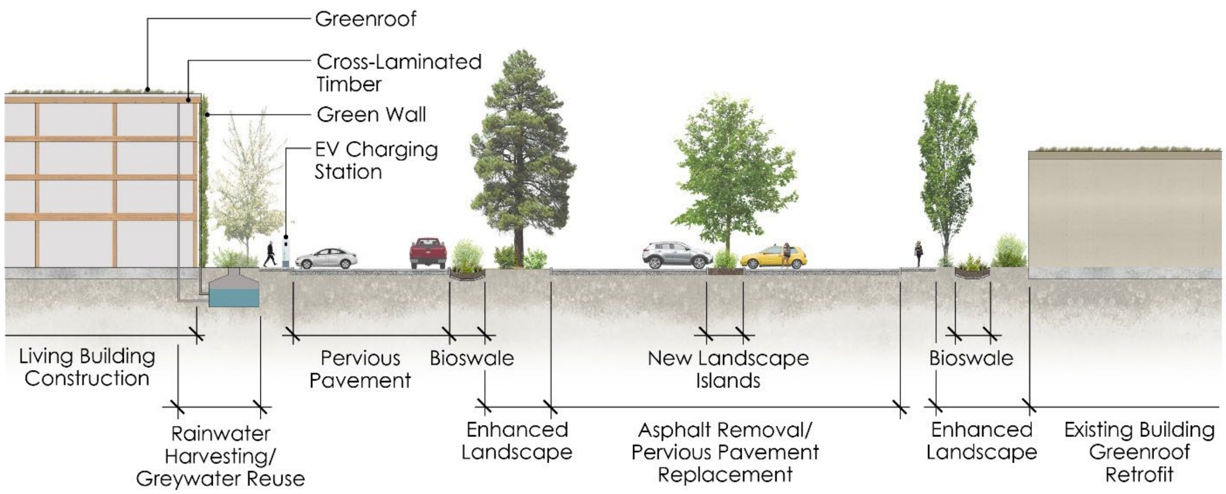

Figure 13. Built Environment Ecosystem Conceptual Cross-Section[68]

4.2. Integrating Design Considerations into Planning Design

Multiple design considerations and ecosystem services can be supported and integrated into each of the three realms. These relationships and synergies are presented in Table 4 below. This matrix can be used to quickly identify design standards that may be impactful across UD ecosystems. Each design standard consideration can be categorized under one or more of the twelve UD ecosystem services. The matrix serves as a visual guide that shows which recommended considerations are best suited to the principle/goals, depending on the area. The matrix highlights instances where the same design consideration, for example increasing urban canopy, can enhance ecosystem service provisioning capacity across all three of the ecosystem realms. For planning and prioritization purposes it will be important to identify these multiple benefit opportunities as places to start developing codes and regulations and offering incentives for adoption.

[68] Source: Cascara Land Design

Table 4. Design Standard Consideration Matrix

	Riparian		Public Realm		Built Environment	
Ecosystems Service/ Design Consideration	River/ Nearshore	Buffer Area	Right of Way	Parks	New Construction	Retrofitting
Air Filtration						
Urban Canopy	●	●	●	●	●	●
Green Walls		●	●		●	●
Emission Reduction		●	●			
Energy Conservation					●	●
Biodiversity						
Landscape Design		●	●	●	●	
Wildlife Connectivity	●	●	●	●		
Carbon Sequestration						
Carbon Specific Planting	●	●	●	●	●	
Green Spaces		●		●	●	
Building Materials				●	●	●
Guiding Matrix	●	●	●	●	●	
Energy Provision						
Promote Alternative Energy Sourcing	●		●	●	●	●
Smart Building Design				●	●	●
Reduce Heat Island	●	●	●	●	●	●
Energy Literacy					●	●
Fire Adaptation						
Protect Buildings and Envelope					●	●
Fire Resistant Landscape Design		●	●	●	●	●
Nutrient Cycling						
Symbiotic Planting		●	●	●	●	
Replicate Pine Savanna	●	●	●	●	●	
Pollination						
Pollinator Specific Planting		●	●	●	●	
Protected Pollinator Habitats		●		●	●	
Stormwater Management						
Green Stormwater Infrastructure		●	●	●	●	●
Geological Assessment		●	●	●	●	

	Riparian		Public Realm		Built Environment	
Ecosystems Service/ Design Consideration	River/ Nearshore	Buffer Area	Right of Way	Parks	New Construction	Retrofitting
Reduction of Impervious Surfaces		●	●	●	●	
Temperature Regulation						
Cool Building Design					●	●
Vertical Planting			●	●	●	●
Waste Generation and Management						
Community Waste Reduction				●	●	
Waste to Energy Technology					●	●
Building Materials				●	●	●
Water Cycling						
Develop Drought-Tolerant Landscapes		●	●	●	●	
Rainwater Harvesting and Reuse		●	●	●	●	●
Human Health and Wellbeing						
Edible Landscapes		●		●		
Passive Recreation	●	●		●		
Culturally Relevant Design	●	●		●	●	

4.3. Metrics to Measure Success

The primary goal of developing and applying ecosystem-based regenerative design standards in the UD is the preservation, restoration, and enhancement of ecosystem services so that human and natural area health and well-being are protected and improved. To gauge the effectiveness of design standards and measure progress towards meeting targets and/or improvements from baseline conditions as well as compare impacts of different projects and approaches there needs to be a common set of metrics that can be utilized across projects and initiatives. The team identified and reviewed a number of potential candidates for each of the ecosystem services that could be utilized to track progress. In making recommendations the team looked at a number of factors including ease of monitoring and data collection as well as cost-effectiveness. Given that six higher education institutions partner with the UD, the team was also mindful of the potential for engagement with students and academic researchers to collect and evaluate data. The recommendations presented in Table 5 below serve as a starting point for future development once design standards are finalized and prioritized.

Table 5. Metrics for Measuring Ecosystem Service Provision

Ecosystem Service	Target	Potential Metrics
Air Filtration	• Shade should approach **that** provided by ponderosa pine savanna	• Tons of gas are removed annually • Total savings in gas removal annually • Tons of $PM_{2.5 \text{ and } 10}$ are removed from the air annually • Total savings in PM removal annually
Biodiversity	• Manage waste in a closed loop (meaning all waste is decomposed or recycled back into the ecosystem)	• Species richness of indigenous vegetation or wildlife • Area of habitat type (wetland, riparian, etc.) in the UD • Abundance of native species in designated area • Abundance of invasive species in designated area
Carbon Sequestration	• Water withdrawals will not exceed historical aquifer recharge rates	• Tons of carbon sequestered by trees annually • Amount saved in reduction of atmospheric CO_2 annually
Energy Provision	• Preserve the “winter camp” status of the area, as a meeting place where people come to share knowledge, food, and culture	• kW energy produced through renewable energy sources annually
Fire Adaptation	• Emulate low-fuel load savanna grasses and fire-retardant outer materials approximating ponderosa bark	• Percent of structures in UD with fire-resistant outer materials • Acres or m^2 of fire-adapted vegetation
Nutrient Cycling	• Open space areas should have the same ratio of trees to shrubs and grass as the ponderosa pine savanna ecosystem	• Percentage of soil contaminants • Organic matter content • Area of plantable space • Soil pH
Pollination	• Vegetation should mimic native perennial grasslands by including plant species known to host native pollinator communities represented in ponderosa pine savanna.	• Pollinator density/abundance per area • Number of pollinator-friendly plants per area
Stormwater Management	• Zero percent impervious services or equivalent	• Reduced cost of sewer treatment by volume ($/$ft^3$) • Percent of area covered by pervious or impervious surface • Cubic feet of stormwater detention services provided by urban ecosystems • Percentage of water pollutants absorbed by urban vegetation • Stormwater management costs avoided annually

Ecosystem Service	Target	Potential Metrics
Temperature Regulation	• Shade should approach that provided by ponderosa pine savanna	• Percentage/acreage of tree canopy cover in UD • Energy costs avoided per capita annually
Waste Generation & Management	• Manage waste in a closed loop (meaning all waste is decomposed or recycled back into the ecosystem)	• Total waste recycled per capita annually • Total waste disposed of per capita annually • Total waste recycled per square foot annually (for industrial businesses)
Water Cycling	• Water withdrawals will not exceed historical aquifer recharge rates	• Percent of area covered by pervious or impervious surface • Depth of aquifer
Human Health & Wellbeing	• Preserve the "winter camp" status of the area, as a meeting place where people come to share knowledge and food, and culture	• Number of visitors to green spaces/trails

5. Conclusions, Recommendations, and Next Steps

This research has provided a snapshot of conditions in the region and the geographic boundaries of what is now the University District. While the characteristics of ponderosa pine and shrub step ecosystems in the Okanagan region are generally known and well documented, this analysis has gone a step further, identifying and describing the ecosystem services that were provided in the historical environment. In addition, the analysis looked at current conditions to establish whether, and to what degree, those ecosystems and services are present in the area today. Looking to the future, and to the potential for preservation, restoration, and enhancement of ecosystem services, it was important to identify and prioritize ecosystem services that would be most responsive to community priorities. Evaluating ecosystem services against the current planning documents and the stated goals for community development, twelve ecosystem services were identified. Service provision targets, based on historical conditions, have been established and design considerations have been identified to support the utilization of the built environment to maintain and grow ecosystem service provision. In addition, initial metrics have been identified to track progress and measure success.

This project represents the first step in the development of a design canon that can be used to support the economic revitalization of the 770 acres in the UD. An important next step will be to engage with planners. landscape designers, and architects to develop place and facility-specific design standards and performance measures that can be used to inform the development of plans for individual structures and/or a master plan for the whole District. A second critical next step will be to engage current UD partners and initiatives (like Urbanova), to identify existing data as well as resources for future data collection and management that can be utilized to track and monitor progress UD-wide towards meeting ecosystems service provision targets. A third opportunity area can be found in partnerships with academic departments and with faculty across the five universities that have a presence in the UD. Once design and performance standards are established there are likely to be numerous opportunities for experimentation and design innovation related to water and wastewater capture, storage and management, energy efficiency, fire resilience, and air quality – to name a few. In addition, there will be opportunities for student and community engagement in data collection and monitoring.

It is clear from this analysis that it is quite possible, and highly probable, that these frameworks can be used successfully to further the regenerative design goals that the District aspires to.

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Appendix A- List of Academic Stakeholders Interviewed

Name	Institution
Chuck Murphy, Chief Strategy Officer	Gonzaga University
Eric Smith, Director of Facilities and Capital Projects	Washington State University Health Sciences Spokane
Lori Hunt, Provost	Community Colleges of Spokane
Brooke Kiener, Dean of Continuing Studies and Graduate Admissions	Whitworth University
Grant Casady, PhD, Professor of Biology, Director of Environmental Studies	Whitworth University
Aaron Putzke, PhD, Professor and Chair of Biology	Whitworth University
Jim Simon, Director of Sustainability	Gonzaga University
Greg Gordon, PhD, Professor/Chair of Environmental Studies	Gonzaga University
Warren Seyler	Spokane Tribe of Indians

Appendix B- Annotated Resource Bibliography

Over fifty sources related to the University District (UD) and the Ecological Asset and Performance Standards Study (EAPS) were reviewed by the team and compiled in an Excel spreadsheet which is attached to this report. Each reference has been assigned a unique identifying number within the database, which corresponds to when the resource was received (Column B). Sources are further classified by bibliographic citation (Column D). Each source offers unique insights into one of the many facets of the study, and when reviewed collectively some larger themes began to emerge. The following core themes and subcategories have been used to categorize the references contained in the database:

- Spokane Planning, Management, and Vision
  - Transit-Oriented Development Plans
- Design Standards
  - Stormwater/Hydrology
- Ecosystems in Spokane
- Ecosystem Services and Metrics
  - Spokane specific Ecosystem Services and Metrics
- Nature-Based/Eco-Centric Designs and Landscaping

For easy visual reference, the team developed a color-coding system within the Resource Database to categorize the references under their respective themes. Cells in Column B of the database are color-coded according to the key below. Where more than one theme is present, the reference is coded to the primary theme.

(red)	Spokane Planning, Management, and Vision
(orange)	Transit-Oriented Development Plans
(yellow)	Design Standards
(light yellow)	Stormwater/Hydrology
(green)	Ecosystems in Spokane
(light blue)	Ecosystem services and Metrics
(blue)	Spokane Specific Ecosystem Services and Metrics
(purple)	Nature Based/Eco-Centric Designs and Landscaping

Spokane Planning, Management, and Vision

The team gathered and reviewed seventeen references regarding Spokane's, or specifically the UD's, vision for future development and management. Included in this list are the UD Strategic Master Plan Update (#4), Spokane Sustainability Action Plan (#7), South UD Subarea Plan (#8), and many other references guiding future development in the area.

Project Relevance

These plans directly informed the teams' work in Task 3: "Align Ecosystem Assets with Planning and Development." As the team proposed strategies for preserving and/or enhancing ecosystem services, they factored in their alignment with or potential conflict with features included in the various development plans. This allowed for the development of a list of recommendations and challenges for each strategy as they relate to future development plans.

Some of the planning documents also illustrate broader implications for the study. For example, the UD Strategic Master Plan Update (#4) emphasizes the area's need for affordable housing (pages 35-43), visions to incorporate green spaces (page 59), and highlights some environmental barriers like soil contamination along with zoning and marketing issues that could impact development. When suggesting ecosystem service enhancement strategies, the team considered how these might impact affordable housing efforts and how urban ecosystem expansion could work in tandem with development expansion to solve zoning and other environmental issues. The Master Plan also references the design and sustainability choices made on the Catalyst project, which influenced our design standard recommendations in later tasks.

Other planning documents like the Main Avenue Visioning Study (#6), Urban Amenities Study for the South UD (#9), Spokane Bicycle Master Plan (#49), and Spokane Pedestrian Master Plan (#50) have narrow implications for a specific aspect or area of future development. For example, proposed ecosystem preservation strategies work in tandem with pedestrian and bicycle trail expansion plans, and the street trees and proposed planters in the Main Avenue Visioning Study could be incorporated into the standard design recommendations.

Spokane's Sustainability Action Plan (#7) includes action goals across seven topics: buildings and energy, transportation and land use, waste diversion and material conservation, water resources, economic prosperity, natural environment, and health and well-being to help the city mitigate the impacts of climate change and become more resilient. Recommended strategies should align or not conflict with the proposed actions and goals in this highly pertinent planning document.

Transit-Oriented Development Plans

Included in the Spokane planning documents are four references specific to transit-oriented development (TOD) plans in the UD and surrounding area. The city is pushing for TOD, where land use and transportation are integrated with a transit route at its core with a mix of housing, commercial businesses, jobs, and services concentrated along walkable and bikeable streets within a quarter mile of the transit route. There are efforts to pursue TOD along the City Line Bus Rapid Transport in the South Logan neighborhood.

Project Relevance

It is important to understand Spokane's commitment to TOD and how this will affect future development if the TOD alternative is chosen among the South Logan TOD Draft EIS alternatives. The South Logan TOD Draft EIS (#2) also includes the environmental impact each development alternative will have on the existing ecosystems found in the study area, which could inform baseline ecosystem understanding and development of strategies to enhance/preserve ecosystem services around this development. The TOD plan will also inform potential zoning changes and the types of structures planned for the area.

Design Standards

The team gathered and reviewed seven references centered on design standards. Of particular note is the City of Spokane Design Standards document (#5). It was updated in 2021 and touches on stormwater management design, street lighting, roadside planting, parklets, low-impact development storm drains, bioretention facilities, permeable pavement, and planter box regulations. Additionally, many of the planning documents mentioned in the Spokane Planning, Management, and Vision theme include design suggestions for streetscapes, stormwater management, and other design choices that have created lively districts that serve their communities.

Project Relevance

While the City of Spokane Design Standards (#5) can serve as a reference for the basic requirements and guidance on the development topics included within, the guidance is clear in that it is not meant to limit innovative efforts that could result in higher quality and/or lower cost efforts. However, any proposed departure from these standards will be judged by the likelihood that such variance produces a comparable result, so our understanding of these standards and expected results will be essential when developing draft design standards under Task 7. The other, less strict guidance proposed in the Spokane planning documents should also inform our design standards and understanding of what types of development can be expected in the future.

Stormwater/Hydrology

Of the seven design standard documents reviewed, six refer specifically to stormwater and hydrology design standards from the federal to city level. Included in this list are the Water System Design Manual (#13), the WSDOT Design Manual (#11), and the Spokane Regional Stormwater Manual (#14).

Project Relevance

The capture, storage, and management of stormwater and stormwater runoff is important not only for overall water quality indicators and ecosystem health but also in terms of water management in the face of climate change. These technical references can inform our stormwater and hydrology-related draft design standards.

Ecosystems in Spokane

The team reviewed four references that allude to the ecosystems found in Spokane. The references are the Approved Street Tree List for Spokane (#41), the Native and Drought Tolerant Plant List (#43), Washington Bumble Bees in Home Yards and Gardens (#44), and Native Trees and Plants You Will See Everywhere in Spokane (#46). Each one touches on the wildlife and plant species native to the area.

Project Relevance

These references were essential for the identification and evaluation of opportunities to increase and preserve ecosystem services as they highlight what ecosystems and species are present in the city to begin with. From this, the team was able to determine the ecosystem services already provided in the UD and develop plans to preserve and enhance these services. The Approved Street Tree List (#41) and Native and Drought Tolerant Plant List (#43) impacted the species we recommend planting in design standard development. The Washington Bumble Bee reference (#44) also provides habitat recommendations for commonly found pollinators in the state. Pollination is a considerable ecosystem service, so incorporating bumble bee-friendly habitats in design standards and understanding what pollinators are critical to the region are important considerations for this project.

Ecosystem Services and Metrics

Nineteen references reviewed by the team centered on ecosystem services and metrics used to measure these services in cities around the world. Studies across the globe have created frameworks to identify, measure, and quantify ecosystem services in urban areas. The City Biodiversity Index (#30) is a handbook launched by Singapore to help profile a city's biodiversity and establish a baseline and metrics to measure future progress. Defining Key Concepts and Indicators to Measure Nature-based Solutions (#31) and the Urban Ecosystem Services Index for Sustainable Planning (#32) are other examples of international efforts to highlight and measure ecosystem benefits in urban settings. Other ecosystem service studies have been conducted within the United States, including the Urban Ecosystem Analysis conducted in Bellevue, WA (#25), the study on Urban Green Spaces and Fine Particulate Matter in Texas (#27), and Seattle's Forest Ecosystem Values report (#28). Each reference touches on urban ecosystem services, with some delving deeper into how to establish a baseline understanding of ecosystem services in an urban area, measure these services over time, and quantify ecosystem services.

Project Relevance

These references informed the creation of an initial list of potential Ecosystem Services as candidates for ongoing monitoring and metrics in the UD using the ecosystem services, as well as proposed metrics, monitoring techniques, and potential data sources supplied within these references. The ecosystem services referenced include everything from carbon sequestration to stormwater management to improved mental health to pollination and soil mineralization. The team also utilized suggested data sources, like iTree, iNaturalist, and eBird, to support monitoring and metrics designation.

Spokane Specific Ecosystem Services and Metrics

Five of the Ecosystem Services and Metrics references are specific to Spokane. Spokane Beat the Heat (#22), the SpoCanopy Planting Program (#38), and Resource Analysis of Inventoried Street Trees (#40) all reference work within Spokane to measure ecosystem benefits, or lack thereof, and bring these benefits to all areas of Spokane.

Project Relevance

The Resource Analysis of Inventoried Street Trees (#40) includes a list of the number of street trees, by health status and species, found in Spokane in 2012. The same report also quantifies the amount of money the trees save the city annually in reduced heating/cooling costs, carbon sequestration, air quality improvements, stormwater mitigation, and beautification. This source has established urban tree-related ecosystem benefit metrics and provides a baseline for the number of trees in the city and their composition. The Spokane Beat the Heat Project (#22) and the Urban Tree Analysis (#42) highlight how disproportionately ecosystem benefits are distributed across the city. Low-income and vulnerable communities reap far fewer benefits, like cooler temperatures during a heat event, because there are far fewer trees in these areas. The team used these resources to consider how to make the distribution of ecosystem benefits more equitable in future designs and potentially work in tandem with groups like SpoCanopy, who are working to ensure every person in every neighborhood in Spokane has access to trees and green space.

Nature-Based/Eco-centric Designs and Landscaping

The team reviewed three references focused on eco-centric, sustainability, or nature-based designs. The references under this theme include Stormwater Ponds: A Guide for Pond Owners (#17), Nature-Based Solutions Roadmap (#18), and Drought Tolerant Landscaping for Washington State (#45).

Project Relevance

These sources supported developing nature-informed design standards that prioritize sensitive landscapes and habitats within future development. The Stormwater Pond Guide (#17) includes stormwater pond requirements including the pond's required capacity, and structure. As a nature-based stormwater management tool, the team considered how stormwater ponds might fit within the UD. The Drought Tolerant Landscaping guide (#45) served a similar purpose in that it provided a reference with drought-tolerant species, preferred soils, irrigation systems, and appropriate planting sites in dry climates. Since Spokane receives only 20 inches of rain a year, drought-tolerant landscaping is necessary and will match the native ecosystems that already exist in the dry climate. The Nature-Based Solutions Roadmap (#18) includes principles to guide the design and implementation of nature-based solutions. Not only does it touch on design, but it also includes an extensive list of benefits provided by nature-based solutions, ways to streamline nature-based development permitting and incorporate nature-based solutions into city policies and programs, and a list of federal funding resources. Though bigger picture, some suggested solutions like green roofs, planting pollinator habitats, and increasing urban trees also acted as inspiration for the team's design standards.

Appendix C- Presentation