

**LINKING GREEN INFRASTRUCTURE WITH TRANSIT-ORIENTED DEVELOPMENT
(TOD) TO CREATE SUSTAINABLE COMMUNITIES**

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Abstract

Community development has yet to adopt integrated design features from green infrastructure and transit oriented development. This link between the two strategies will be examined through literature review, case studies, and site visits; in attempt to gain a greater understanding of each, so we can begin to understand the possible coupling affects for communities of greater sustainability. Which, if current population trends continue, will be imperative in order to help preserve land, reduce automobile usage, and conserve our natural resources. The results intends to provide a starting point in the discussion for a linkage between green infrastructure and transit oriented development. The results will include, not only this research paper, but also a modeled development representing possible applications.

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Introduction

Increasing populations have resulted in many consequences throughout the world, and the United States. As a result, the rate of energy and resource consumption has drastically increased – leading to a loss of native land, wildlife species extinctions, increasing “natural disasters,” and much more. As the rate of the global population continues to rise, many cities have chosen to expand their boundaries, rather than increasing the densities within their existing boundaries. This has resulted in the development trend known as sprawl, which describes the outward expansion of cities away from their center core, into low density suburbs. Because these suburban neighborhoods generally consist of large lot single family housing, separated from commercial areas, they become greatly dependent on personal automobile transportation. Some environmental effects of sprawl often include the consumption of agricultural or wildlife lands, increased water run-off pollution, air pollution through increase automobile usage, and a general increase in energy consumption (Squires, 2002). From an economic stand point, suburban areas are much more expensive to develop. Often times, new infrastructure needs to be provided, such as water, sewer, power, roads, etc. Not to mention of the indirect costs of increasing garbage routes, mail routes, school bus stops, etc. Socially, sprawl has increases the probability of the loss a community feel or cohesion, increases economic class segregation, and lessens community involvement and interaction.

From a city planning perspective, sprawl also creates numerous problems. Planners face the task of determining how to deliver goods and services for a larger area, but for fewer people. Some of these services include schools, libraries, or childcare. Although sprawl leads to many problems,

the issues of increased automobile dependence and the consumption of agricultural or wildlife lands, are the main reasons for the development of this project.

Transit oriented development (TOD) can be described many ways, though it generally consist of high density, mixed-use development, with a high quality pedestrian environment, all surrounding a transit station and within a transit network. Properly designed and implemented transit oriented developments can help reduce our dependence on the automobile by providing compact, mixed use development within a transit corridor. The mixed use aspect of TOD helps to provide all the resources and amenities that citizens need; such as, housing, employment, dining, leisure activities, and recreation.

Similarly to TOD, green infrastructure can be defined in many ways depending on the context. Generally green infrastructure is defined in terms of stormwater management. However, the essence of green infrastructure is much broader. Mark Benedict and Edward McMahon, holistically describe green infrastructure as “an interconnected network of natural areas and other open space that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife” and “is the ecological framework for environmental, social, and economic health – in short our natural life-support system” (Benedict and McMahon, 2006). Essentially, it is natural framework intended to provide many benefits to people, wildlife, and natural systems.

Both green infrastructure and transit oriented developments can be considered very complicated and complex, with many moving parts; yet, they both share similar characteristics. TOD and green infrastructure both have a variety of applicable scales in which they can be implemented. Initially, they both need to be thought out and developed from the largest scale, in a holistic approach.

Most importantly, they both aim to reduce our environmental footprint, while creating many environmental, social, economic, and health benefits. Coupling TOD design with green infrastructure should further reduce our energy and resource consumption and reduce our dependence on the automobile.

Methodology

In an attempt to review the most authoritative literature on TOD and green infrastructure, Google Scholar and The University of Idaho's online data-base were used to search for the leading authors and researchers on the topic. This method revealed the number of articles published by each author, to determine who has been studying TOD and green infrastructure extensively. Key words for the data-base search included: Transit-Oriented Development, TOD, Transit Communities, Transit-Oriented Development Case Studies, TOD History, Green Infrastructure, Green Planning, Green Roofs, Green Parking Lots, Going Green, etc.

Because green infrastructure and TOD can both be implemented at various scales, and due to the time constraints of this project, the main focus will be on a site specific scale – rather than regional or a community scale. In doing so, through an intensive selection process, one site in the Spokane Region will be select for further evaluation of a fully designed sustainable community, using the best industry practices for TOD and green infrastructure.

The final results for this project will be produced in two methods. The first will be in written format, with the development of a research paper. The second will be in graphic and written format, with the development of a master planned TOD community with incorporated green infrastructure techniques. This second method will include multiple graphic communication

methods (plan views, perspectives, pictures, charts, etc.) which will demonstrate the possible link between green infrastructure and TOD in an actual development manner.

As was mentioned previously, there has been no really push from the planning and design industry to link transit oriented development and green infrastructure. Resulting in little research on the two together. Because of this, both TOD and Green Infrastructure will be evaluated separately in the literature review section of the paper. Ultimately in the results section a link between the two will attempt to be proven.

Literature Review

Transit Oriented Development

Public transit is not a new concept, it has been around for hundreds of years. Transportation has always been, to some extent, responsible for the shaping of cities infrastructure for walking, railroads, streetcars, or automobiles. To the same extent transit oriented development is not a new concept, although it may not have been labeled this in the past. Streetcar suburbs that were developed prior to 1900s, were essentially designed to add value to a residential development, and provide a connection from where people reside to where they work. Often, these communities were developed by one company; to entice residents, the developer would provide streetcar stops with light retail and commercial uses, to serve the local transit users. While these stops were not labeled transit oriented development, they are, in essence, a pioneer of the modern day transit oriented development.

Following WWII and the great depression there was a major shift from public transit to personal automobile transit. Automobiles became more affordable and suburban housing became the

dream of many Americans. The link between transit and development was finally broken with the launch of the Federal Highway Act in 1956, which funded nearly 41,000 miles of highways – developments was no longer dependent on public transit.

The term transit oriented development was first coined by Peter Calthorpe – a well honored urban designer, planner, and architect – in the early 1990s. Calthorpe described TOD as adhering to the following principles:

- Organize growth on a regional level to be compact and transit supportive
- Place commercial, housing, jobs, parks, and civic uses within walking distance of transit stops
- Create pedestrian friendly street networks that directly connect local destinations
- Provide a mix of housing types, densities, and costs
- Preserve sensitive habitat, riparian zones, and high-quality open space
- Make public spaces the focus of building orientation and neighborhood activity
- Encourage infill and redevelopment along transit corridors within existing neighborhoods (Calthorpe, 1993).

Center for Transit Oriented Development (CTOD) defines TOD as “more compact development within easy walking distance of transit stations (typically a half mile) that contains a mix of uses such as housing, jobs, shops, restaurants and entertainment” (CTOD, n.d.). While there has been no specific definition for TOD and many transit agencies and city planning departments, define TOD in their own way; almost all definitions involve some form of the following principles: 1) *Mixed-use development with a variety of housing opportunities.* 2) *Moderate to high density, with*

the greatest densities near the transit station. 3) Pedestrian and transit orientation as the focus, rather than the automobile. 4) Increase transit ridership numbers to lessen the dependence on personal automobile usage. 5) Promote sustainable economic development.

The American demographic is changing, and so too is the housing market. A study performed by the CTOD concluded that 41% of households are occupied by single adults, and the demographic groups growing the quickest – older, non-family, non-white households – show a preference for multi-use housing areas. Professional Builder states that 37% of households want small lots and clustered development, and AARP states that 71% of older households want to be within walking distance of transit (Oberlink, 2008). Coupling these demographic changes with the increasing traffic congestion problems has led to city living becoming more and more enticing. TOD planning also has a focus on smart growth – urban planning and transportation theory that concentrates growth in compact walkable urban centers to avoid sprawl – which in return will save valuable land and wildlife, reduce infrastructure cost, and reduce transportation related costs.

When discussing transit oriented development, it is nearly impossible to forego a discussion of Peter Calthorpe's, *The Next American Metropolis: Ecology, Community, and the American Dream* (Calthorpe, 1993), where he coined the term "transit-oriented development." Calthorpe's book was entirely devoted to defining TOD, outlining guidelines for successful TOD, and providing example projects at various geographic scales. Although Calthorpe's book was published in 1993, and as a society we are largely more auto dependent now than we were then, many of his points are just as valid today as they were 20 years ago.

Calthorpe began by pleading for a change in the characteristics of the "American Dream". A dream that created suburb after suburb throughout the United States, where people chose to

live in attempt to gain “privacy, mobility, security, and ownership;” which in fact led to “isolation, congestion, rising crime, and overwhelming [automotive related] costs” (Calthorpe, 1993, p. 18). Fortunately, it does not have to be this way. With the proper placement of housings, schools, and parks with close proximity to shops, services, jobs, and transit, we can create a healthier, happier, and a less auto dependent environment that is lively and full of human interaction. However, it all must start with the pedestrian. The pedestrian provides meaning and value to the qualities of our communities. Calthorpe states, in large part, “without the pedestrian, a community’s common ground – its parks, sidewalks, squares, and plazas – become useless obstructions to the car” (1993, p. 17). Although the car is not going to be displaced anytime soon, the lack of focus on the pedestrian, in many communities, has been a major failure in many new developments. In order to turn suburbs in to towns, projects into neighborhoods, and networks into communities, it simply takes a greater focus on, and appreciation of, the pedestrian. This principle of a pedestrian focus is also represented by authors Hank Dittmar and Shelley Poticha, writing in *The New Transit Town: Best Practices in Transit – Oriented Development*¹, where they stated, “at the heart of transit-oriented development is the pedestrian, and the purpose of mixed uses is to encourage the pedestrian environment” (2004, p. 37).

A focus on public transit is also pedestrian oriented, since the most important element of a successful transit system is riders (or pedestrians). Calthorpe understood that the most efficient way to provide riders is to develop high-density land uses, dedicated pedestrian rights-of-way,

¹ *The New Transit Town: Best Practices in Transit – Oriented Development*, was written with the help of 15 authors and edited by Hank Dittmar, the president and CEO of Reconnecting America, and Gloria Ohland, a professional journalist and senior editor with Reconnecting America. Reconnecting America is a national, nonprofit organization formed to link transportation networks and the communities they serve.

infrequent stations stops, frequent headways², and mixed-use job destinations. In contrast, our current preferred form of transportation – the automobile – is not focused on the pedestrian. Transit via the private car is ineffective in high-density, mixed-use districts. Instead, this model depends on going fast, with few intersections and many travel lanes; lanes that are wide, with gradual curves; and large freeways systems and even larger parking lots. While these two systems have opposite context requirements to function efficiently, with the proper design, they can coexist.

Calthorpe describes the concept of TOD, simply as development where, “moderate and high-density housing, along with complementary public uses, jobs, retail and services, are concentrated in mixed-use developments at strategic points along the regional transit system” (1993, p. 41). With the TOD principles, outlined in the introduction, along with this concept, Calthorpe expanded his theory by articulating nine components, to provide direction for planning successful transit oriented developments. These TOD elements organized from the general to the most specific, they are as follows: *ecology and habitat; core commercial areas; residential areas; secondary areas; parks, plazas, and civic buildings; the street circulation system; pedestrian and bicycle systems; transit system; and parking requirements and configuration*. Guidelines for the planning of these components differ according to three TOD contexts: Urban TOD, Neighborhood TOD, and Secondary Areas. Finally, Calthorpe describes three settings where TOD can occur: Redevelopment, Infill, and New Growth Sites.

² Headways refer to the time interval between vehicles at a transit stop.

TOD TYPOLOGY.

While Calthorpe recognized the deference in TOD scale, by defining urban TODs and neighborhood TODs, Dittmar and Poticha, argued for a more diverse typology. They did so because Calthorpe was primarily focused on a TOD with a fixed transit system. In reality, many cities use many transit system forms which can benefit TOD. Cities are very complex with differing configurations, although they might have similar densities. Dittmar and Poticha stated that their new typology is “an attempt to recognize the important differences between places and destinations within regions and then to identify appropriate performance and descriptive benchmarks for these places” (2004, p. 33). Their typology of TOD places expanded Calthorpe’s urban TOD and neighborhood TOD (see Table 1.), to include:

Urban Downtown: The downtown district of many cities has seen a loss of jobs to the suburbs, resulting in an increase in residential uses downtown. The urban downtown features, civic and cultural centers. The transit systems in these areas are quite diverse, with many modes and transfer stations. These areas also support the greatest residential densities of all the TOD types.

Urban Neighborhood: These neighborhoods are often composed of historic residences surrounding the downtown districts, and provide shopping and services for the residents. Urban neighborhoods today provide moderate to high density housing, surrounding central shopping streets, schools, and parks.

Suburban Town Center: Because of the rapid growth of many suburbs throughout the country, many new job centers have been created. Many of these feature concentrations

of retail, commercial, and entertainment uses. An example of a suburban town center TOD (the Rosslyn – Ballston Corridor) will be examined later in this report.

Suburban Neighborhood: A community that is located on a transit system that has direct access to the regional center or urban downtown is a suburban neighborhood. TOD planning goals for the suburban neighborhood consists of greater residential density, close proximity to the transit stop, with single-family dwellings further away. Neighborhood and commuter retail is often supported here.

Neighborhood Transit Zone: The neighborhood transit zone is composed of primarily residential area, with very little retail or office space. This can include a park-and-ride type stop.



Figure 1. Neighborhood Transit Zone: Park and Ride Facility in Seattle, WA

Commuter Town:

Communities outside the urban area, but connect to the urban area through transit, are defined as commuter towns. The TOD transit stop in this context can function as a “main street” with retail, professional offices, and limited multifamily dwellings within the core TOD.

TABLE 1. DITTMAR AND POTICHA TOD TYPOLOGY

TOD Type	Land-Use Mix	Minimum Housing Density	Housing Types	Scale	Regional Connectivity	Transit Modes	Frequencies
Urban Downtown	Primary office center, Urban Entertainment Multifamily housing, Retail	60 units/acre	Multifamily Loft	High	High Hub of radial system	All Modes	<10 minutes
Urban Neighborhood	Residential Retail Class B Commercial	20 units/acre	Multifamily Loft Townhome Single Family	Medium	Medium access to downtown sub-regional circulation	Light-rail Streetcar Rapid Bus Local Bus	10 Minutes Peak 20 Minutes Offpeak
Suburban Center	Primary office center, Urban Entertainment Multifamily housing, Retail	50 units/acre	Multifamily Loft Townhome	High	High access to downtown sub-regional hub	Rail Streetcar Rapid Bus Local Buss	10 Minutes Peak 10-15 Minutes Offpeak
Suburban Neighborhood	Residential Neighborhood retail Local Office	12 units/acre	Multifamily Townhome Single Family	Moderate	Medium access to Suburban center Access to downtown	Light-rail Rapid Bus Local Bus Paratransit	20 Minutes Peak 30 Minutes Offpeak
Neighborhood Transit Zone	Residential Neighborhood retail	7 units/acre	Townhome Single Family	Low Access to a Center	Low	Local Bus Paratransit	25 - 30 Minutes Demand Responsive
Commuter Town Center	Retail Center Residential	12 units/acre	Multifamily Townhome Single Family	Low	Low access to downtown	Commuter Rail Rapid Bus	Peak Service Demand Responsive

Table 1. TOD typology. Dittmar and Poticha mention that these numbers and requirements were based on the previous literature and on the five case studies conducted in The New Transit Town. They caution that many of these subjects require additional research, but offer a starting point for each of the typologies. They also note that the densities are expressed as dwelling units per residential acre and does not represent the gross density for the entire TOD acreage, and that the greatest density should be placed closest to the transit stop and gradually decrease with distance.

The Center for Transit-Oriented Development³ along with Reconnecting America have developed a series of reports regarding many important aspects of TOD. One of which, published in 2008 (see Table 2.), presented an expanded typology of TODs that was also divided into six main types, with the focus on centers and districts:

Regional Centers: Regional centers area areas of high economic and cultural activity within any region. Composed of a dense mix of housing and employment, with retail and

³ The Center for Transit-Oriented Development (CTOD) is a collaboration among three organizations: Center for Neighborhood Technology, Reconnecting America and Strategic Economics. According to their mission statement, they are “dedicated to uncovering and deploying the best solutions for integrating community development with transit investments, resulting in an improved quality of life for all who live and work in the U.S.”

entertainment to suit the regional market. Because these centers tend to be very large, many, if not all, forms of transit serve these areas. Examples include San Francisco, Boston, and Denver.



Figure 2. Regional Center: Boston
socialventurepartners.org/boston/

Urban Centers: These centers are very similar to the regional centers, but with slightly lower densities and smaller scale. They tend to have more residential neighborhoods on the outer boundaries, which help retain historic character and preserve many buildings. Examples include the Rosslyn – Ballston Corridor, downtown Baltimore, and Pasadena.

Suburban Center: Suburban centers include a mix of housing and employment, with retail and entertainment at densities similar to urban centers. But unlike the urban centers, they tend to be largely new development with single use zoning of employment and residential areas, but with mixed-use when the entire TOD is considered.

Transit Town Center: These “function more as local-serving centers of economic and community activity than either urban or suburban centers, and they attract fewer residents from the rest of the region” (Reconnecting America’s Center for Transit-Oriented Development, 2008, p. 5). The transit system primarily serves commuters and jobs centers within the region. There is still a mix of housing, retail, and smaller-scale employment.

Urban Neighborhood: Composed of primarily residential areas, which are highly connected to the regional and urban centers. Housing density is considered moderate to high, with retail consisting of local, small businesses.



Figure 3. Urban Neighborhood: Portland's Pearl District

Transit Neighborhood: These neighborhoods consist of primarily residential housing, at moderate to low densities. Because of the lower densities, retail is usually limited to small nodes.

TABLE 2. THE CENTER FOR TRANSIT-ORIENTED DEVELOPMENT TOD TYPOLOGY

TOD Type	Land-Use Mix	Housing Density	Minimum FAR	Housing Types	Scale	Transit Modes	Frequencies
Regional Center	High-density mix of residential, commercial, employment, and civic/ cultural uses	75 - 300 units/acre	5.0 FAR	High-rise and mid-rise apartments and condos	High	All modes	< 5 minutes
Urban Center	Moderate to high density mix of residential, commercial, employment, and civic/cultural uses	50 - 150 units/acre	2.5 FAR	Mid-rise, low-rise, some high-rise and townhomes	High	All modes	5 - 15 minutes
Suburban Center	Moderate to high density mix of residential, commercial, employment, and civic/cultural uses	35 - 100 units/acre	4.0 FAR	Mid-rise, low-rise, some high-rise and townhomes	High	All modes	5 - 15 minutes
Transit Town Center	Moderate-density mix of residential, commercial, employment and civic/cultural uses	20 - 75 units/acre	2.0 FAR	Mid-rise, low-rise, townhomes, small-lot single family	Medium	Commuter rail Local/regional bus hub Light rail	15 - 30 minutes
Urban Neighborhood	Moderate to high density residential uses with supporting commercial and employment uses	40 - 100 units/acre	1.0 FAR	Mid-rise, low-rise townhomes	Medium	Heavy rail Light rail Commuter rail Local bus	5 - 15 minutes
Transit Neighborhood	Predominantly residential district organized around transit station	20 - 50 units/acre	1.0 FAR	Low-rise townhomes, small-lot single family, and some mid-rise	Medium	Light rail Commuter rail Local bus Bus Rapid Transit	15 - 30 minutes

Table 2. The Center for Transit-Oriented Developments TOD typology. The Center states that “every station area whether existing or proposed, faces unique challenges and will require specially tailored strategies to

create high-performing transit-oriented development (TOD) projects. However, many different types of station areas share similar characteristics. These similarities can help planners, citizens, and elected officials quickly and easily understand key planning considerations and what to expect in terms of the character, role and function of the places that will be created” (2008, p. 3). These typologies serve as starting points in understanding how each station plays a role in the greater region. Many of the housing density ranges are very broad because TOD is extremely site specific and varies from case to case, but they do offer a starting point for minimum density.

One category in this table, not included the Dittmar and Poticha typology, is FAR. FAR or floor area ratio, represents the total square feet of a building divided by the total square feet of the lot on which the building is located. For example, a 50,000 square foot building on a 10,000 square foot lot has a FAR of 5. This represents a five story, assuming that the building covers the entire lot. However, FAR codes are often coupled with maximum lot coverage. Therefore, if the building may cover only 50% of the 10,000 square foot lot, the building would be 10 stories (retaining its 50,000 square foot allowance). Nevertheless, a larger FAR number translates into a greater number of stories. The FAR can aid in understanding the character of the density and height of buildings in each TOD type.

MIXED-USE DEVELOPMENT.

The American Planning Association defines mixed-use development as the blending of residential, commercial, cultural, institutional, and where appropriate, industrial uses. Generally creating an increase in density, providing compact and sustainable communities. Greater densities improve location efficiency while reducing resource consumption and automobile dependence, with and overall strengthening of community health and character. Mixed-use development is an essential component of TOD because it provides housing, employment, shopping, and entertainment, all within a transit network. This allows residents to live and work in a region without the burdens of automobile related expenses. Without these expenses, residents are more willing and able to afford better housing and enjoy all the entertainment, shopping, and eating opportunities within the TOD – resulting in a more lively and active community. A mix of employment opportunities within a TOD can improve the energy of the district throughout the day and night, while also helping to balance transit ridership by reducing peak demand. This is because a variety of job opportunities often creates variable working shifts

which means that not everyone is “arriving and leaving from the same place at the same time by the same mode” (Leach, 2004, pg. 150).

Dittmar and Poticha identified five main goals that TOD projects should achieve: location efficiency, rich mix of choices, value capture, place making, and resolution of the tension between node and place. Location efficiency and rich mix of choices, both relate to mixed-use development. Location efficiency, as they put it, “relates to the conscious placement of homes in proximity to transit systems,” to build a region which is equitable and efficient (2004, p. 23). This placement of homes near transit helps to reduce the dependence on the automobile, which has become the second largest cost to Americans, after housing. With this expense reduced, or even eliminated, people can begin to be more active in the economy. Dittmar and Poticha point out that location efficiency is only achieved when: the density is high enough to provide enough people within walking distance to transit; when transit stations are conveniently located within the TOD and are easily reached; and the development is highly pedestrian friendly with properly connected streets and an appropriate pedestrian scale. The last of which can become increasingly difficult when high-rise building are used to increase density. When discussing the next goal, rich mix of uses, Dittmar and Poticha argue that TOD does not force people to live a certain way, rather it “offers a wider range of housing, mobility, and shopping choices than conventional suburban development” (2004, p. 26). This is especially true when it comes to housing; for example, apartments, condos, single family homes, town homes, accessory units (granny flats), can all be found in a TOD. This not only provides many housing options for nearly every economic class, it also allows residents to progress through life, and change residences, without having to leave the TOD.

Three out of Calthorpe's seven principles relate to mixed-use development: place commercial, housing, jobs, parks, and civic uses within walking distance of transit stops; create pedestrian friendly street networks that directly connect local destinations; and provide a mix of housing types, densities, and costs.

While determining the size and quantities of each land use can be difficult, and is unique to each case, Calthorpe has developed a few guidelines to aid in this process. He began by dividing the development into three main areas: *Core Commercial Areas*, *Residential Areas*, and *Secondary Areas* – all of which should involve *Parks, Plazas, and Civic Buildings*.

Core Commercial Areas. 10% of the total land in a TOD should be occupied by commercial space and a minimum of 10,000 ft² of retail space should be adjacent to the transit stop. If shopping opportunities are not conveniently located near the transit stop, pedestrians will lose the incentive to ride transit. A few types



Figure 5. Public Plaza in a mixed use development:
Downtown Burbank, CA
a-listinternational.com

of commercial centers were described as: “convenience shopping and services (10,000 to 25,000 ft²); neighborhood centers with a supermarket, drugstore, and supporting uses (80,000 to 140,000 ft²); specialty retail centers (60,000 to 120,000 ft²); and community centers with convenience shopping and department stores (120,000 ft² or greater)” (Calthorpe, 1993, p. 77). All commercial buildings should be designed to meet the needs of

the pedestrian; meaning, the main entrance locations should face the streets to create a “main street environment,” the parking lot should be placed behind the buildings with secondary entrances permitted, and building setbacks should be no more than 20 feet for proper pedestrian scale to be achieved. Building facades should be varied to a certain degree, as to not create a homogeneous line of buildings, yet they should be able to provide a recognizable design pallet to create some conformity. Mixed-use buildings are encouraged in the commercial zones, to include ground floor retail, and upper floor residential. For safety and security, these mixed-use buildings should include separate entrances and parking for each use.

Residential Areas. The densities of residential areas will vary depending on the current area densities (in attempt to blend the new with the old), but the minimum density for Neighborhood TODs should have 7 units per net acre, with a minimum average of 10 units per acre. While Urban TODs should have a minimum of 12 units per net acre, with a minimum average of 15 units per acre. One way to increase residential density, suggested by Calthorpe, was with the use of “ancillary units.” These units should be placed within the single family housing portion of the residential areas. Often these units will be studio apartments located above the garages, which helps provide a diverse range of affordable housing. As with commercial areas, residential areas should have minimal set back distances between 10 and 15 feet. This creates a great pedestrian friendly environment, while providing larger back yards and safer, more active streets.

Secondary Areas. Secondary areas can be described as: “1) those separated by an arterial but close to the transit stop; 2) those separated by the arterial but further from the transit

stop; and 3) those of greater distance but without arterial separation” (Calthorpe, 1993, p. 87). Generally these areas are best suited for low-density residential housing (6 units per acre), large scale employment, public schools, and large community parks. These secondary areas should still provide strong connections with street layout and bikeway, to the core commercial area and transit.

Parks, Plazas, and Civic Buildings. In many residential suburbs today, parks are often created based on the shapes of the residential lots; meaning, if there is an undesirable lot shape for a home, it will be turned into a park. Likewise, they are also used to create buffers surrounding developments, or to separate buildings from streets. On the other hand, for a successful TOD, parks and plazas should be a focus for every neighborhood. The size and frequency of the parks will vary depending on the amount of residential units, but generally they should account for 10% of the site area, with a minimum of 3.5 acres per one thousand people. Calthorpe stated that “one to four-acre parks should be placed within two blocks of any residence. Five- to ten-acre neighborhood parks with large playing fields should be located at the edge of the TOD or adjacent to schools. Ten- to thirty-acre community parks should be placed along regional open space or bicycle networks” (1993, p. 91). All of which should be designed for both active and passive recreational usage and should reflect the character of the surrounding area.

Although every case is unique and will require specific proportions of commercial, residential, secondary areas, and public space, there is no question that each of these elements is required for successful TOD. Successful in attraction residence to live and work at or near the station, and successful in attracting visitors to use the stations amenities.

Although the notion of mixed-use development has become a key trait in TOD, according to Robert Cervero, a professor and chair of city & regional planning at the University of Cal Berkeley, mixed-uses are difficult to produce. Largely because in typical development, which is single-use, there are separate “lenders, investors, contactors, and financing parameters” involved (Cervero, 2004, p. 107). But in a mixed-use development all these parameters have to work together, which can become difficult and confusing. Cervero quoted TOD designer John Gosling as stating “mixed-use development has many moving parts, making it geometrically more difficult to finance, which translates directly into higher costs,” these higher costs, along with a lack of comparables, leaves many investors leery of involvement in TOD (Cervero, 2004, p. 107). Many developers interviewed in Cerveros reports also stated that vertical mixed-use (mixed-uses in the same building) is much more difficult to develop because of increased insurance cost, multiple owners, and the general complexity in the buildings. As opposed to horizontal mixed-use (mix of uses in close proximity to each other, but on separate lots), with which developers tend to be more comfortable. The developers also note that sometimes mixed-use buildings will only dilute the commercial market in an area that is already sufficiently served; when instead, single-use residential buildings can bring new patrons and increase the existing market (Cervero, 2204).

Cervero states that retail often struggles the most in the case of vertical mixed-use development because retail is not necessarily linked to transit, it is more related to the nearby market, i.e. local residents and workers. Fortunately Gosling offers advice for the retail component: the retail mix, critical mass, and merchandizing strategies should be developed early in the planning process to aid in the design of the development. The retail space should involve a simple layout that maximizes visual impact and foot traffic. One of the most critical elements is to allow the space

to open to the street and the pedestrians, maximizing the potential for “drive-by shopping and impulse buying” (Cervero, 2004, p. 108). Lastly, the building façade can easily detract from the retail “feel” of a building by being engulfed by the upper stories. A separation can be created simply with the addition of awnings, balconies, or eaves on the upper levels.

TOD PARKING.

Throughout the country, single use parking standards are fairly consistent. For example, a retail development in one part of the country will require similar parking needs as another retail development, in a different part of the country – likewise for office and residential developments. These similarities generally occur because the developments are single use, and are planned for one mode of transportation – the automobile (Daisa, 2004). Therefore, decades of research have developed parking standards. Unfortunately TOD parking requirements are not as clearly defined. One reason for this is the complexity of mixed-uses, which increase the difficulty in calculating the proper amount of necessary parking. Another reason is because the goal of TOD is to improve transit ridership; if this is done, then the residential, office, and commercial development would undoubtedly require less parking because people would be using transit and not automobiles. Therefore, it is necessary to know how much the transit use will reduce the parking demand. TOD is a relatively new practice in the U.S. and the number of studies provided on parking has not yet led to definitive guidelines or requirements. Nevertheless, a few different perspectives on TOD parking have emerged.

James Daisa, a transportation planner and engineer, with 25 years of experience in urban infill, states that the two primary components which define parking demand characteristics in TOD are: (1) the demand generated by the transit facility independent of the adjacent land uses, and (2)

the demand generated by the land uses themselves (Daisa, 2004). These two components can contradict each other at times, because the impact of the mixed-use development may reduce travel and parking demands, and “the transit facilities themselves generate demand independent of the land uses” (Daisa, 2004, p. 118). These facility demands will vary depending on the scale of TOD. For example a suburban TOD will typically have a large amount of surface parking, where as an urban TOD will have limited parking specifically associated with transit. Daisa recommended the following strategies to reduce traffic and parking:

- Parking should be designed so that it does not dominate the landscape and impede pedestrian activity. Too much surface parking creates the sense that the automobile is the preferred method of transportation. This can be achieved by placing parking behind the buildings or implementing a parking structure or underground parking
- Charge for parking can reduce the parking demand by up to 30% and increase the user’s willingness to ride transit. This can be done by charging an hourly fee for short-term parking such as retail, or a daily fee for long-term parking such as office.
- Reduce off-street parking facilities. This can be done for a number of appropriate reasons, including “shared parking between complementary uses, internal trips, use of on street parking, TDM⁴ programs, and the trip reduction benefits of transit-orientation,” resulting in a 30% reduction (2004, p. 122).
- Nearby neighborhoods should be protected from spillover parking, or from people not wanting to pay for parking. This can be done by enforcing time restrictions and

⁴ TDM or transportation demand management, refers to strategies that are focused on reducing travel demand, specifically during peak commute hours, rather than increasing the supply of roads.

providing residents with parking permits.

- On-street parking should be utilized to the fullest. This will decrease the need for off-street parking, while improving the pedestrian environment. On street parking should be metered to discourage long term parking and employee parking.
- Remote parking facilities can be utilized for commuter parking. These facilities should provide a shuttle service to and from the major TOD and intermodal transit stations.
- Parking should not be bundled with residential or commercial units. Many development currently bundle the parking and unit space at one fixed price. By getting rid of this notion, tenants would only have to pay for the parking they need, leaving any excess parking to be sold or leased to others, reducing the overall requirements for parking (Daisa, 2004).

Overall, Daisa argues that the implementation of these parking strategies, will help decrease traffic and parking, but he does state that more traffic and parking studies must be conducted to gain greater insight on industry-wide guidelines. And lastly, city agency departments need to be more open minded towards reduced parking standards in order to make the best use of valuable land within TODs. Peter Calthorpe also stated that parking standards should be reduced for TOD. As a general guide, he specified that parking for office space should be 2-4 spaces / 1,000 ft², retail should be 3-5 spaces / 1,000 ft², and light industrial should be 1-3 spaces / 1,000 ft². Of course these number can be difficult to calculate when considering a mixed-use environment (1993). Thus a location specific analysis is often necessary to determine joint parking requirements. Calthorpe noted that joint use parking should consider peak demand of each land

use by the time of day, day of the week, and time of the year (Figure 7). This would ultimately reduce the amount of needed parking when one space can provide for the needs of different uses at different times. The City of Seattle has also implemented shared parking by allowing



Figure 6. Parking Garage Designed to Blend with its Surroundings: Clarendon Station

greatergreaterwashington.org

“typical” daytime uses (commercial, storage, or manufacturing) and “typical” night times uses (entertainment, restaurants, religious facilities, or auditoriums), to share parking spaces (City of Seattle). Calthorpe also mentions that surrounding neighborhoods should be protected from spillover by implementing permit parking (Calthorpe, 1993).

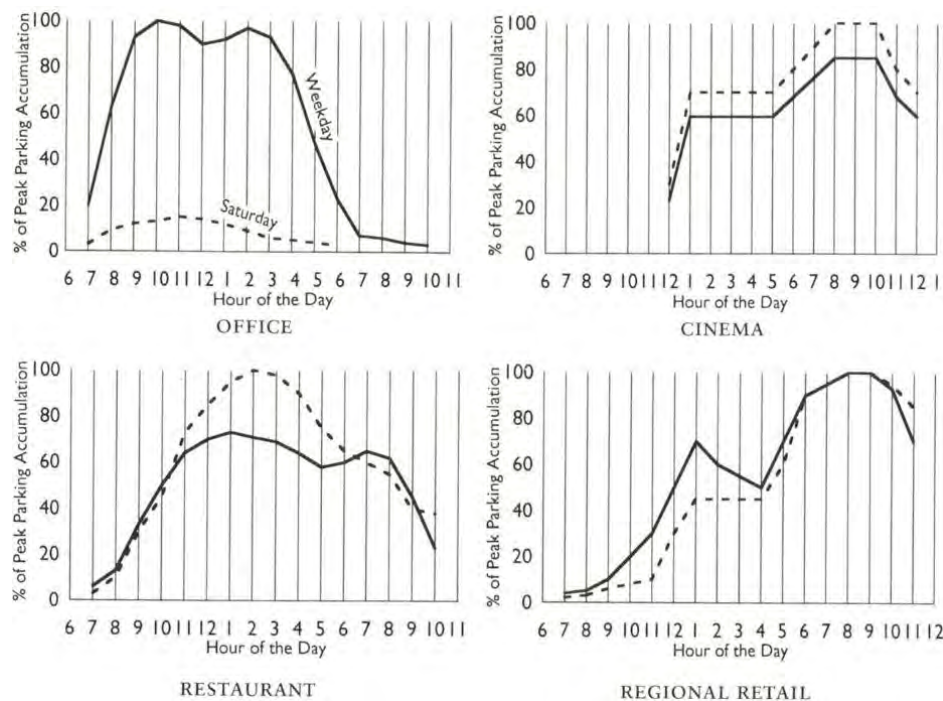


Figure 7. Peak Parking Demand (Calthorpe 109)

In an attempt to improve the pedestrian atmosphere, the parking configuration and developments should also be modified from typical practices. Whenever possible, parking lots should be located at the rear of buildings and they should not occupy more than “1/3 of the frontage, or no more than 75 feet, of any pedestrian-oriented street” (Calthorpe, 1993, p. 110). Parking lot landscaping is also necessary to create a comfortable pedestrian environment, while also creating shade and visually reducing the impact of a large asphalt area. This should be done to provide shade for the pedestrian, yet still allow ample visibility of the building faces. Parking structure can also be implemented where land values reach a certain point, typically \$2.5 million per acre (Martin and Hurrell, 2012, p. 113). These structures then allow for greater development opportunity by utilizing existing surface parking (Figure 8).

Conversely, Peter Martin and William Hurrell, argue that, because one of TODs goals is to increase ridership, then providing station parking is actually the best way to do so. They state that “parking tends to be the primary mode of access at many suburban stations,” meaning the majority of people arrive at a station by car, and use the stations parking (Martin and Hurrell, 2012, p. 110).

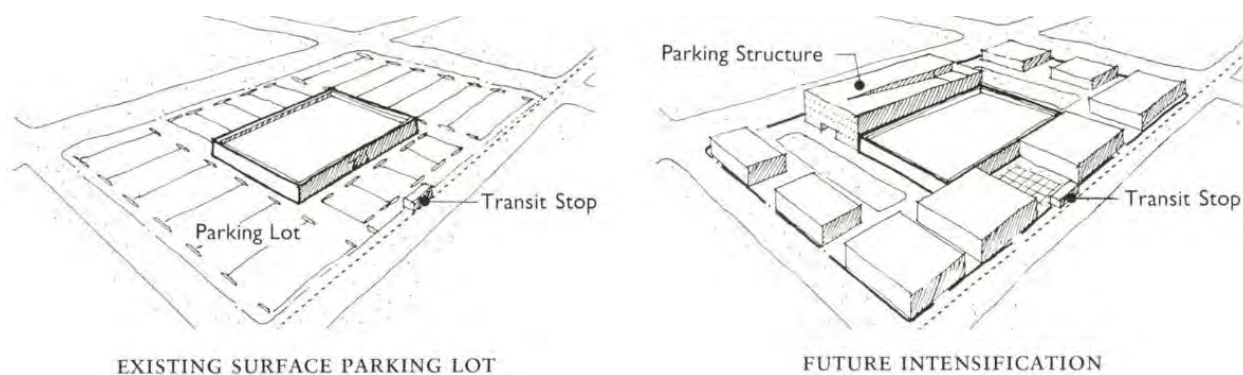


Figure 8. Structured Parking (Calthorpe 111)

Then, using an average of 300 sq-ft for a parking stall, and multiple other averages and efficient rates (provided by the Institute of Transportation Engineers) Martin and Hurrell, concluded that for a 10,000 sq-ft lot:

- 72.6 transit trips would be provided from a park and ride facility,
- 6.0 to 12.1 transit trips would be provided from residential TOD,
- 3.5 to 6.9 transit trips would be provided from office TOD, and
- 5.1 to 25.5 transit trips would be provided from retail TOD (2012).

These final transit trip numbers are outlined in Table 3.

TABLE 3. Martin and Hurrell, Transit Ridership for 10,000 sq-ft Station Parcel

Patronage Determinant	Parking	Residential	Office	Retail
Site Area (ft ²)	10,000	10,000	10,000	10,000
Unit Area (ft ²)	300	1,500	n/a	n/a
Adjustment for Parking (ft ²)	0	300	600	1,050
Site Use Adjustment (ft ²)	0	0	0	0
Number of Units	33	5.6	6,300	4,900
Person Trips Per Unit	2.2	7.2	11	52
Daily Number of Person Trips	72.6	40.3	69.3	254.8
Transit Capture (%)				
Low	100	15	5	2
High	100	30	10	10
Daily Number of Transit Patrons				
Low	72.6	6	3.5	5.1
High	72.6	12.1	6.9	25.5

Given these conclusions that station parking provides the greatest supply of transit riders, Martin and Hurrell suggest that: (1) TOD parking should be restricted to prevent users from abusing it and taking valuable spots from transit users; (2) station parking, such as park and ride facilities, would be best served a short distance away from the TOD (such as the secondary areas described by Calthorpe); (3) once surface parking reaches capacity, users should have to start paying for

the amenity (ultimately equates to about \$2 a day); (4) if TOD is going to replace existing parking, then it must be done by dense, high-rise development (Martin and Hurrell, 2012).

With the previous TOD parking strategies in mind, a few general guidelines emerge:

- The pedestrian should always come first. This relates to the physical layout and design of parking. Where parking should be placed behind buildings and not along roads, on-street parking should be utilized to the maximum, and parking lots should be landscaped to create a comfortable atmosphere.
- Parking should not be provided for free. Free parking only provides an incentive for automobile usage. Charging for parking will promote short-term parking, as well as incentive for transit usage.
- Parking cost should not be bundled into leasing for residential housing or commercial buildings. This will encourage the market to determine how much parking is necessary and allow for unused parking to be utilized by others.
- Shared parking practice should be implemented with land uses that have different peak parking requirements. This will reduce the overall parking need for the TOD.
- Measures should be taken to protect the surrounding neighborhoods from spillover or from people not wanting to pay for parking.
- If parking demands are high, remote parking facilities, or park and ride lots can be implemented, but they should only be provided at, or near, transit stops with little mixed use development potential.

TRANSIT STATIONS.

Calthorpe placed special interest on the location and layout of the transit station itself. He stated, “transit lines must help define the density, location, and quality of growth in a region, [and] they should be located to allow maximum area for new TODs, to access prime redevelopable or infill sites, and serve existing dense residential and employment centers” (Calthorpe, 1993, p. 104). Then going on to mention that transit lines are often located in areas that have very low densities, poor pedestrian quality, and little opportunity for redevelopment. Which is the case with many lines that are built through suburbs, and as a result, park-and-ride facilities begin to dominate the station network, rather than dense mixed-use development (Calthorpe, 1993).

Station location is also very critical for successful TOD. The station should, whenever possible, be centrally located within the core commercial area, while also providing easy access to residential areas. Placing the station in the middle of a TOD with provide the shortest walking distance for all users. Calthorpe also mentions that the station should be located away from arterials, for a safe and quality pedestrian environment. If this is unavoidable, and the station is placed along an arterial, then the commercial zone should also be placed along the arterial to the side of the stop, preventing users from having to cross the arterial (Calthorpe, 1993).

Unlike many commuter train systems, which are often elevated above grade or placed underground, light rail can operate at street level with all other form of transportation, due to its smaller size. This also means that light rail can easily be integrated into existing infrastructure,

with minimal adaptations. Additionally, stations do not require extensive infrastructure, as they can be as simple as a sidewalk station or a raised platform (Figures 9 and 10). Yet, they primary waiting area for a TOD stop should provide a few more amenities.



Figure 9. Sidewalk Station: Houston, TX

At the very least, all transit stops should ttmg.org/pages/siemens/houston-siemens.html

meet a few basic requirement, according to Calthorpe. They should provide year-round shelter from the weather. They should provide comfortable waiting areas, with adequate seating. Stops should allow for convenient drop-off locations, yet not interfere with pedestrian flow. Lastly, they should be safe environment with adequate lighting and security (Calthorpe, 1993). To increase pedestrian use and activity, small vendors or cafes could be incorporated around the stations to fill time between transit stops (Calthorpe, 1993). Another way in increase transit use and

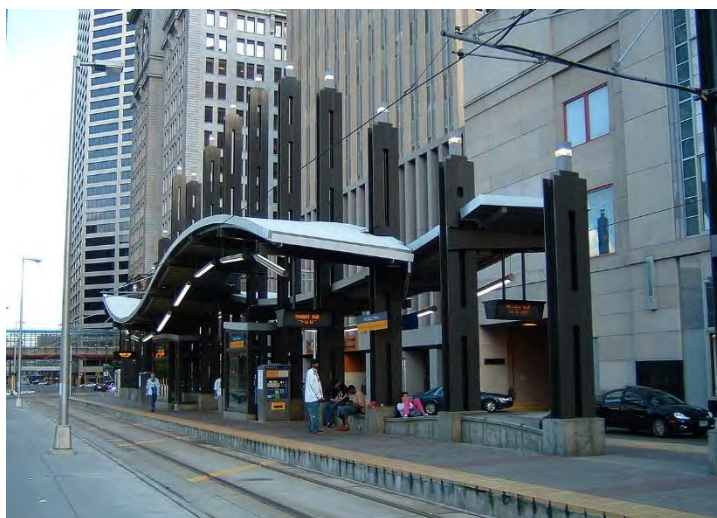


Figure 10. Platform Station: Minneapolis MN

oldtrails.com/LightRail/Minneapolis/railmin11.htm

decrease personal automobile dependence, is to provide bike parking at all stations. This can be as simple as bike racks, or as elaborate as providing a bike check station for more secure bike protection.

Green Infrastructure

Green infrastructure is similar to TOD in the aspect that they both pertain to various scales of application. Transit oriented developments come in many sizes and scales, as well as, connect to different transportation systems, that also come in many sizes and scales. Similarly, green infrastructure can be referred to by various scales. At the regional level, green infrastructure may refer to “interconnected networks of park systems and wildlife corridors, preserve ecological function, manage water, provide wildlife habitat, and create a balance between built and natural environments” (ASLA). At a site scale, green infrastructure may refer to specific techniques which aim to reduce energy consumption and manage stormwater runoff. For the purpose of this study/project, green infrastructure will be focused on a site specific scale, with a wide range of stormwater management techniques, including: 1) Rainwater Harvesting, 2) Green Roofs and Walls, 3) Planter Boxes, 4) Green Parking Lots, 5) Green Streets and Alleys, and 6) Bioswales and Rain Gardens. Next, each of these techniques will briefly be explained, along with a possible application for a TOD site.

Rainwater Harvesting: Rainwater harvesting systems collect and store rainfall for future use. These systems should help reduce the overall peak run off from the site, as well as provide a storage area for the water. Rainwater harvesting can be very useful in arid climates by reducing the demand of city water.

Application: Rainwater harvesting will be implemented for the commercial and business areas throughout the TOD, where it will be recycled for toilet water and/or supplemental irrigation. This will be done with either an above or below ground cistern, which would be connected to the roof gutters, allowing water to be filtered and then flow directly towards and into the cistern.

Additional filtration would be required for recycled grey water uses within the commercial buildings.

Green Roofs and Walls: Green roofs and walls are features of buildings which happen to be covered with vegetation. This in turn helps contain and filter stormwater runoff, creates habitat for wildlife, increase agricultural space, and provide living spaces for people to interact with. It is likely that the rainwater for most storms will never reach the ground because of the absorption capabilities of green roofs and walls.

Application: Green roofs will be implemented throughout the multi-family housing and mixed-used buildings. This will provide stormwater management, as well as increase the private living spaces for the residence.

Planter Boxes: Planter boxes can be used to collect stormwater runoff from sidewalks, parking lots, and streets. They are highly effective in urban areas where space can be limited. In addition to providing stormwater management, they are also used for streetscaping to add visual interest and increase the pedestrian quality of the site.

Application: Planter boxes will be implemented along the streets and plazas within the commercial core, providing stormwater management and visual interest.

Green Parking Lots: Green parking lots can be developed, with permeable pavement or pavers to provide direct infiltration. They can also be developed with traditional pavement, which is then graded towards rain gardens and bioswales in the medians and along the perimeter of the parking lot. It is important to use the proper plants and soil mixes that have the ability to filter car specific contaminants.

Application: Green parking design principles will be implemented throughout all parking areas within the TOD, including the parking lots for the commercial and business areas and all multi-family housing parking lots.

Green Streets and Alleys: Green streets and alleys consist of design techniques such as, permeable pavements, vegetated bioswales, and bioretention devices, to store, filter, and infiltrate stormwater that falls into, and runs into, the streets. Green streets can also help increase the pedestrian quality of the site by providing natural traffic calming due to a greater amount of plants used, compared to traditional grey infrastructure.

Application: Green streets and alleys will be implemented throughout the entire site, except where other green infrastructure techniques will be used (such as planter boxes).

Bioswales and Rain Gardens: Bioswales and rain gardens are similar in that they are both vegetated and are used to collect stormwater, allowing it to slowly infiltrate. The difference is that bioswales will generally act as a transporter (channel) for water, while rain gardens will typically be the final destination for the water.

Application: Bioswales and rain gardens will be implemented within the single family residential areas and all of the parks and trails throughout the development. This will provide stormwater management for the homes, driveways, and sidewalks for the single family homes, and all of the hardscape elements throughout the parks and trails.

Each stormwater management technique is used for a specific purpose, and to manage a specific area from which stormwater will be accumulated. Overall, combining a variety of green

infrastructure techniques will attempt to manage 100% of the stormwater runoff, on site, and without any typical grey infrastructure involved.

Given certain constraints with this report, only a few of these green infrastructure techniques will be examined further. These selected techniques will be green roofs, green parking lots, and bioswales and raingardens.

GREEN ROOFS

Green roofs are exactly what they sound like, they are roofs covered in vegetation. Green roofs can be an integral part of reducing stormwater runoff and minimizing the heat island effect moving forward. Before examining the benefits of green roofs, it is important to understand the different types of green roofs.

Green roofs are generally described as either extensive or intensive. Extensive roofs involve 6 inches or less of planting medium and are designed to meet prescribed stormwater performance goals. While intensive roofs involve deeper planting medium depths and can include more traditional landscaping such as patios, lawns, trees, planting beds, furniture, etc. (Miller, 2016). Because extensive green roofs are primarily concerned with performance, the main challenge is how to “replicate many of the benefits of vegetative open space, while keeping them light and affordable... [resulting in a] new generation of vegetative roofs [that rely] on a marriage of sciences of horticulture, waterproofing, and engineering” (Miller, 2016). For a successful extensive green roof, it is important that the subsystem (elements below the vegetation) is responsible for: *drainage* – roof drainage must both, maximize growing conditions in the planting medium as well as manage heavy rain events to avoid ponding and erosion; *plant support* – planting medium must be specifically engineered for proper water holding capacity, wind

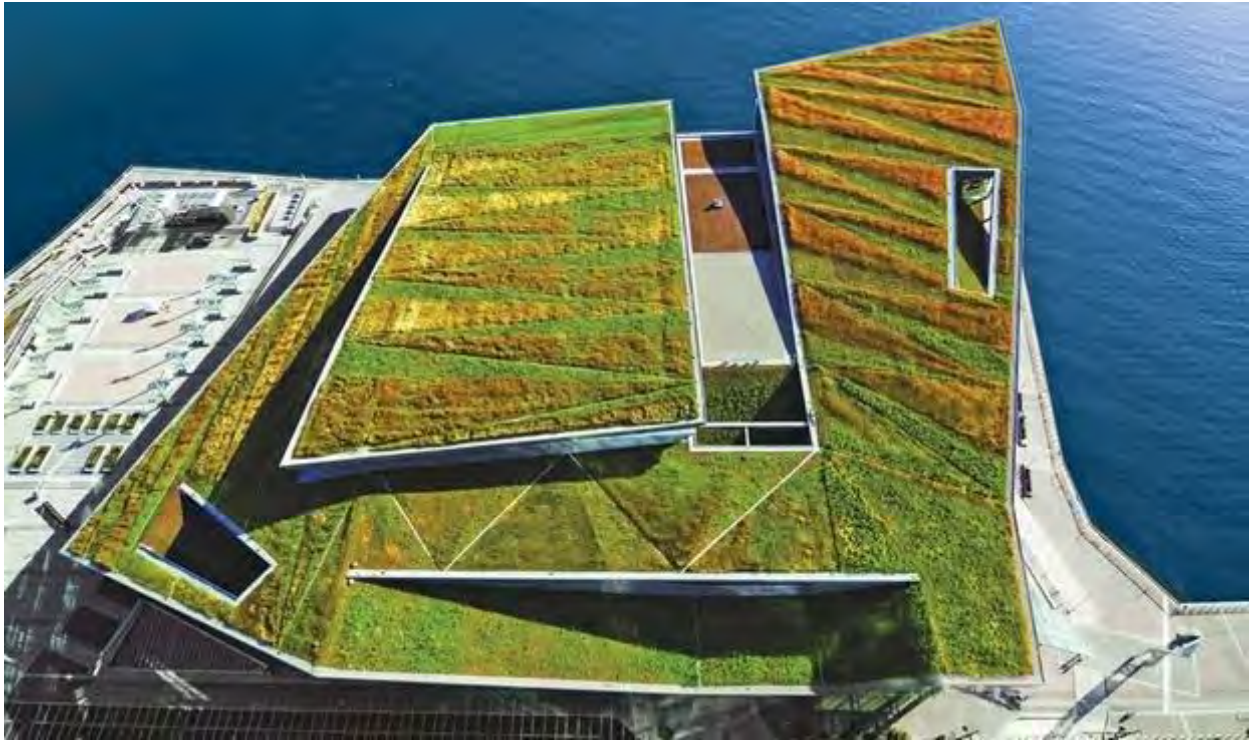


Figure 11. Vancouver Convention Center, Canada. Extensive Green Roof
<http://www.goodnet.org/articles/5-impressive-green-roofs-from-across-globe>

resistance, and to provide proficient growing conditions for the plant material; *waterproofing* – subsystems must contain excellent waterproofing capabilities, to protect the integrity of the building; *waterproofing protection* – along with excellent waterproofing capabilities, the subsystem must also provide protection for the actual waterproofing membrane, often times this is done with a capillary break or a root barrier, to protect the membrane from root intrusion (Miller, 2016); *insulation* – although this is not necessarily required, it is one of the most important aspects of the subsystem for energy conservation purposes (Wark, 2010). In general, the planting medium for extensive green roofs is conserved to be around 4 to 6 inches in depths. As a result of the shallow planting depth, smaller plants with less intrusive roots must be used. These generally include succulents such as sedums, and in some cases they can include herbs, much of the plant selection is dependent upon the local climate.

Intensive green roofs on the other hand, are often concerned with much more than stormwater management performance. Intensive green roofs are commonly used on high profile commercial and residential buildings, largely because of their higher cost. They can be used as an extension of the building because they offer additional living space for residence and guests. Intensive roofs can include paths and walkway, patios and plaza, and any range of planting material including large trees. They can include “benches, tables, planter boxes, greenhouses, ponds, and fountains offer[ing] people places to relax, dine or work in park-like setting” (Hilary, 2010). Intensive roofs require the same elements in their subsystem as the extensive roofs, but they require more “intensive” versions of each. The two main differences between intensive and extensive is how the structure of the building is engineered and the depth of planting medium. Extensive roofs can weigh anywhere from 10 to 35 pounds per square foot, while intensive roofs can weigh more than 150 pounds per square foot, requiring a stronger building structure (Hilary, 2010). Also planting medium for extensive roofs is generally under 6 inches, while on an intensive roof, it can be well over 24 inches, again adding the weight of the roof. While intensive roofs offer more human interaction and benefits, they are require more maintenance and support. They are essentially just like any other traditional landscape, which requires irrigation, fertilizing, mowing, pruning, etc.

There are many benefits of both intensive and extensive green roofs. According to Charlie Miller, a pioneer of green roofs, these benefits include:

Controlling stormwater runoff. Runoff from storm events leads to destructive flooding, erosion, pollution, and habitat destruction. A traditional roof is essentially 100% impervious, because people would obviously prefer all forms of precipitation

to remain outside of their building – but these impervious surface begin to add up when one considers the amount of building and homes throughout the world. It is estimated that roofs make up 40-50% of the impervious surfaces within urban areas (Dunnett and Kingsbury, 2004). Fortunately, green roofs offer a simple solution for this problem. Green roofs can dramatically reduce the peak stormwater runoff by: delaying the start time of the runoff because of the absorption capabilities of the growing medium (soil), reducing the total runoff quantity by retaining some of the water in the growing medium, and by distributing the runoff over a longer period of time (Mentens, Raes, and Hermy, 2006). The more vegetation, the greater the stormwater management benefits, which means, extensive green roofs often perform much better in the category.

Improving water quality. With the benefit of reducing the volume and rate of runoff, green roofs greatly benefit cities with combined sewer and stormwater systems. During large storm events, in many older cities, storm water is collected and drained in the same pipes as the sewage system. This means if the storm event is great enough, then the system can become backup up, cause raw sewage to pour into our streets, streams, and lakes. Green roofs can help prevent this by reduce the volume of water to combined systems.

Mitigating urban heat-island effect. In larger urban areas, many of the roofs are covered in a dark waterproofing membrane. The dark material increases the ambient air temperature around the buildings, which in turn increase the air temperature of the city as a whole. While some roofs have begun to use a white color to reduce these

effects, a vegetative roof has been shown to be much more effective in mitigating the heat-island effect and provide a much greater life span.

Prolonging the service life of roofing materials. Although modern green roofs have not been around for longer than 40 years, researchers expect these roofs to last more than 50 years before significant repair is required. This in turn protects the roof structure which would otherwise be exposed to elements; including, human and animal destruction, dust and debris, all forms of weather, and UV damage from the sun.

Conserve energy. Vegetative roofs conserve energy by providing extra insulation which reduces the amount of heating and cooling required for the building. In the summer months transpiration from the plant leaves helps to cool the surrounding air, lowering the temperatures of the soil and decreasing cool air loss through the roof. In the winter months the insulation layer in the subsystem helps prevent heat loss through the roof, resulting in less energy use for heating. It is widely known that these benefits occur, but there has not been significant studies to show the exact energy savings from green roofs.

Reducing sound reflection and transmission. Although a minor benefit, the vegetation from green roof can play a role in sound dampening. In larger cities with greater noise, green roofs can help absorb sound waves which would otherwise bounce off roofs and back into the city.

Improving the aesthetic environment. Green roofs can help the aesthetic environment and throughout the city by providing color and textures to traditional plane roofs. Intensive roofs often favor the local residents and workers (people actually in the building), because they are able to actually utilize and interact with the roof. While extensive roofs tend to benefit both members of the building, as well as members of surrounding buildings. Because they are all able to look upon and enjoy the aesthetics of the vegetation. The vegetation is also known to can help increase productivity of workers or increase the happiness of residence. In either case, extensive or intensive, the property values of the building with the green roof and the surrounding buildings, will rise.

Mitigation of wildlife. In a largely wildlife free zone, urban areas, can benefit greatly from the increase in biodiversity caused by the vegetated roofs. Green roofs can help improve wildlife corridors for many birds and insects. Of course many of these benefits do not appear unless there are multiple green roofs near each other to create the corridor.

Although green roofs can cost anywhere from 8\$ to more than \$25 a square foot, they have been proven to provide many benefits to the buildings residence, surroundings buildings, cities, water systems, and wildlife.

GREEN PARKING LOTS

In general, green parking lots can be described as, “several techniques applied together to reduce the contribution of parking lots to the total impervious cover in a lot” (Better Site Design Fact Sheet: Green Parking). These techniques can include minimizing the sizes of parking lots,

implemented alternate paving materials, and utilizing bioretention areas to treat onsite stormwater. In 2008, the EPA developed an extensive guide for green parking lots, titled “Green Parking Lot Resource Guide.” The goal of this guide was to present the planning and design concepts of green parking lots and to present the environmental benefits as well as cost savings of green parking lots (EPA, 2008).

The beginning of this guide laid out the main impacts of the traditional American parking lots. One of the most damaging impacts of traditional parking lot design is the effects on water quality. Due to the impervious nature of traditional asphalt or concrete parking lots, during every storm event, the water runs across the parking lot surface, collecting pollutants from the parking lot construction, sealers, and byproducts from automobiles (antifreeze, oil, gas, hydrocarbons, metals from breaks, rubber from tires, etc.). The water then carries these contaminants in to local catch basins, streams, or lakes – polluting the water and wildlife. Additionally to our water quality being affected, our quantity of stored water is also affected. In traditional systems, much of the stormwater does not infiltrate because of the impervious asphalt, and it is then directed into a stormwater treatment facility. Whereas in a natural setting, the water would fall and then be allowed to slowly percolate through the soils and replenish the water table. The guide also mentions the construction and processing of the asphalt leads to health concerns; stating, “asphalt cement plants emit particulate matter, nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon monoxide (CO), volatile organic compound (VOCs), polycyclic aromatic hydrocarbons (PAHs), and carbon dioxide (CO₂) during the manufacturing process. The activities associated with the construction and maintenance of parking lots also generate emissions, typically in the form of dust, fumes, and equipment and vehicle exhaust. For example, the use of hot mix asphalt, a

common process where the asphalt is heated to extremely high temperatures prior to application, can cause health problems for workers including headache, skin rash, fatigue, throat and eye irritation, breathing problems, and coughing” (EPA, 2008). Not only can they affect human health, they also affect plant and animal health. Runoff velocity can erode and alter natural waterways, and eroded sediments can “smother and stress” aquatic habitat (EPA, 2008). Not only does the habitat suffer from physical destruction, it can also suffer from toxic substrates, as mentioned previously, from the byproducts of automobiles.

Similarly to the green roofs, green parking lots can also help reduce the heat island effect. The natural darkness of the asphalt absorbs heat from the sun, and at night, when the sun is falls, the heat is then released from the asphalt, dramatically slowing nighttime cooling affects. Construction of parking lots also tends to clear any surrounding vegetation – reducing the shade cover from trees, leading to greater heat island effect (EPA, 2008). While most areas require developments to plant new trees for a certain shade cover percentage, this can take more than 20 years before the trees are mature enough to provide the required shade.

In addition to environmental impacts, traditional parking lot construction also impacts economic and social aspects of the community. On-site costs for parking lots include; construction, maintenance, operation, and the cost to obtain dispose of materials needed to develop a parking lot such as paving materials, concrete materials for curbs and gutters, and paint material for striping. Other cost come from landscaping, including all the materials and installation, as well as maintenance for mowing, pruning, and irrigation over the years. Other non-direct costs for the parking lot include cost associated with the heat island effect. Causing shorter lifespans for the paving material as well as creating problems for automobiles, including deterioration of paint,

plastics, and tires while the cars are on the parking lot (EPA, 2008). While many of these initial costs are paid for by contractors, developers, and stakeholders, the local governments often pay a price for in for structural damages due to the effects of parking lots. Including damages to local waterways, increasing infrastructure for stormwater management, and damages to roads and bridges from erosion. In addition, large parking lots can cause a lower economic value for nearby businesses, by creating an unpleasant, and sometimes unsafe pedestrian environment.

Although there has been many downsides to traditional parking lot design and implementation, the EPA has laid out multiple techniques to help lessen these effects. They divided these techniques into four categories; planning aspects, on-site stormwater management, parking lot surface material selection, and landscaping and irrigation.

Planning aspects. Planning guidelines can play a pivotal role in reducing many of the negative effects of traditional parking lot designs. For instance, city planners can implement site specific parking requirements, rather than the traditional one size fits all approaches that are currently used for setting parking requirements. Traditionally, parking requirements are based on ratios, for a certain amount of building square footage, there are a certain amount of parking stalls required. Unfortunately this often leads to over development of parking, because the ratios are based on peak times; meaning the parking lots might only be fully utilized for a few hours per day. A few ways these over parking practices can be minimized, are by implementing marking maximums, by providing incentives for reduced parking near public transportation to encourage transit use and lessen the parking demand, and by

combining parking for developments with variable peak parking times, as mentioned previously in the TOD section.

In some cases, developers will opt out of reducing the parking requirements, because they feel this will reduce the marketability of the site. The EPA suggests that in these cases, the municipality can implement area wide parking maximums that essentially level the playing field by reducing parking for other developments nearby. Other planning aspects include the actual design and layout of the parking lot. A key design principal for green parking lots is aesthetics and a high pedestrian quality. A few ways that they EPA suggests developers can reach these principals is by moving the parking lots behind the buildings, creating a much friendlier pedestrian environment at the store front street level. Breaking parking lots up in to various section can also help provide a pleasing appearance, rather than creating one continuous asphalt lot.

On-site stormwater management. One of the most important elements to green parking lots is the stormwater management performance. The key difference from a traditional parking lot and a green parking lot, is how the stormwater management is designed to mimic natural process rather than use man made infrastructure to manage the stormwater. There are several ways in which they can be designed to mimic natural processes – swales, vegetated filter strips/riparian buffers, bioretention areas (rain gardens), dry and wet basins, infiltration systems, and constructed wetlands (EPA 2008). Of these natural techniques, the most useful and most relevant for a transit oriented development of moderate size, would be the swales, vegetated filter strips/riparian buffers, and bioretention areas. Swales are

generally uses along the perimeter of a parking lot, and are designed to be a channel which directs water to a bioretention area. Similarly, vegetated filter strips/riparian buffers, are also generally placed along the perimeter of the parking lot and used to filter stormwater from nearby bodies of water, such as rivers and streams. Bioretention areas are designed to be one of the final destinations for water – where the swales have directed the water towards. They can either consist of all lawn, or can be heavily planted.

Of course, stormwater management not only refers to managing a volume of water, it also refers to managing the quality of water. Table 4. demonstrates the general effectiveness of each type of green parking lot stormwater management technique. All of which are effective in their own right, the use is just dependent on the type of pollutant needing to be reduces, and the amount of available land to implement the technique.

TABLE 4. STORMWATER BEST MANAGEMENT PRACTICES (BMP) FOR POLLUTANT REMOVAL (EPA, 2008).

BMP Type	Typical Pollutant Removal Efficiency (percentage)				
	Suspended Solids	Nitrogen	Phosphorus	Pathogens	Metals
Dry Detention Basins	30-65	13-45	15-45	<30	15-45
Retention Basins	50-80	30-65	30-65	<30	50-80
Constructed Wetlands	50-80	<30	15-45	<30	50-80
Infiltration Basins	50-80	50-80	50-80	65-100	50-80
Infiltration Trenches/ Dry Wells	50-80	50-80	15-45	65-100	50-80
Grassed Swales	30-65	15-45	15-45	<30	15-45
Vegetated Filter Strips	50-80	50-80	50-80	<30	30-65

Parking lot surface material selection. The majority of parking lot surface material used today is asphalt concrete. Asphalt consists of sand, sand dust, gravel, and liquid asphalt cement – a byproduct of crude oil. The final result is an impervious, heat absorbent surface that collects water and directs it off site – leading to many of the negative effect mentioned earlier. Although some developers have chosen to alternatives such as concrete, to reduce the heat island effect, or opt to include recycled asphalt materials to reduce waste. The essential problem of impermeability remains. Fortunately, various solution exist. Porous asphalt and pervious concrete are two alternatives to traditional asphalt and traditional concrete. They are both made and processed in their traditional fashion, with the exception of lager gravel sizes, and a reduction in sands. This creates larger voids in the paving material, allowing water to penetrate and pass through to the subsurface, where it can then be filtered and enter the water table. Another alternative to traditional paving, as well as the porous paving, is permeable pavers. Permeable pavers are modular concrete block that interlock with each other and create about a ¼” gap. This gap is then filled with sand or a very fine gravel, which allows water to penetrate similarly to the porous paving options (see Figure 12.). The main benefit of these types of paving options is the reduced demands for infrastructural techniques for stormwater management, the protection of nearby ecosystems (by reduction pollutants, and damages due to the large volume of water entering the systems), and a reduced cost for repairs. Studies have shown that the porous asphalt holds up better to cracking a potholes than traditional asphalts, because water is allowed to pass through instead



Figure 12. Permeable Paver Parking Lot in Virginia
<http://www.bractwalls.com/permeable-paver-pictures.htm>

of filling in smaller cracks and the freezing to create pot holes (EPA, 2008). Unfortunately there are also negatives to these options as well. The cost for porous asphalt and concrete can be anywhere from 50% to 100% more than traditional asphalt, and permeable pavers can be anywhere from 5 to 10 times more expensive (EPA, 2008). The pores in these systems can also become clogged with debris, rendering them impermeable once again. To solve this problem, the surface may need to be vacuumed or pressure wash a couple times a year. In most cases, it is up to the developer or owner to determine how important the environment and natural systems are, to implement these techniques, due to the added costs.

Landscaping and irrigation. Effective green parking lots often include native plantings and a reduction in irrigation. Parking lots throughout the country often vary

little, in terms of their appearance. This is primarily because they utilize the same designs and similar plants. They typically consist of variety of Kentucky blue grass turf and some popular ornamental plantings. Whereas in a green parking lot, native plants are a key design element. Native plants are more tolerant to local conditions, they require less maintenance, and they reduce damage from large storm events, and help increase biodiversity. Native plants are more tolerant to local conditions because that is where they are used to growing in, which means they will require less water and maintenance to establish and maintain over the years. Once they have become established, they may require maintenance a few times a year, rather than a weekly mowing, which Kentucky blue grass requires. Being they are adapted to local growing condition, native plants also require less fertilizers and chemical to help grow and maintain health. Less chemicals means there will be less pollution to nearby ecosystems, when run-off occurs during storm events.

Although turf grass and non-native plantings are not always avoidable, in which case a high efficiency irrigation system should be implanted. High efficiency irrigation systems include up to date irrigation practices; such as, low flow drip irrigation to plants, low volume rotator spray heads for turf areas, rain sensors, which will turn they system off when rainfall is detected, and in some cases soil moisture detectors, which relay soil moisture information to the irrigation controller to help it determine the correct amount of water to release. It is also important to irrigate during early morning, or late at night, when evaporation is less of a concern.

Rainwater harvesting and utilizing reclaimed water is also a great way to reduce potable water usage and help the retain ground water. Rain water harvesting allows owners and developer the opportunity to collect rainwater, store it, and then use it for irrigation. This reduces the strain that irrigation systems place on potable water usage and helps reduce monthly water costs. Water costs aren't the only financial savings that native planting provide, as mentioned previously, they also reduce maintenance cost. Table 5. Demonstrates the overall financial savings from native plantings compared to traditional turf planting.

TABLE 5. COST COMPARISON FROMM NATIVE PLANTS TO TURF GRASS. 8,000 sq. ft. AREA (EPA, 2008).

	Site Design and Implementation	Installation	Total Maintenance (\$/year)
Native Planting	\$3,673	\$184	\$272
Traditional Turf	\$1,224	\$61	\$3,318
Cost Difference (Native minus Traditional)	\$2,449	\$123	-\$3,046

Overall, with the help of planning aspects, on-site stormwater management, parking lot surface material selection, and landscaping and irrigation, green parking lots can begin to impact our environment in a positive way. By reducing wasted land on oversized parking lots, by managing stormwater on-site before it has the opportunity to contaminate and erode large bodies of water, by reducing the volume of storm runoff with the implementation or permeable parking lot surfaces, and by implementing native planting designs with high efficiency irrigation systems to help reduce our potable water usage and maintenance cost.

RAIN GARDENS

The third and final green infrastructure technique being examined in this report is rain gardens or bioretention areas. I have briefly touched on rain gardens, as they can be implemented in the previous green infrastructure technique, green parking lots. Rain gardens are depressed areas in a landscape that are planted with native perennials, shrubs, and smaller trees. Generally many raingardens have been implemented in residential applications, close to downspouts. Allowing the rain garden to collect, store and filter storm water run-off form the roofs of homes. This has been proven to be a very effective way to manage stormwater on a small, site specific application. With that said, there should be no reason, if planned well, rain gardens could not be implanted on larger commercial sized projects.

Rain gardens provide many environmental benefits due to their innate similarities to natural processes. Ahiablame et al. stated, “they can be efficiently used to capture runoff, promote infiltration, promote evapotranspiration, recharge groundwater, protect stream channels, reduce peak flow, and reduce pollutant loads owing to native and perennial vegetation such as grasses, shrubs, sedges, rushes, and perennial stands, planted on a variety of medium configurations” (Ahiablame et al., 2012). Although they are most known for their beneficial reduction in run-off volume and peak flow. In many smaller storm events, rain gardens often have the capacity to collect and retain 100% of the run-off volume. Not only does the rain garden itself play a role in stormwater management, processes such as infiltration and evapotranspiration can play an important part in reduction the run-off. Chapman and Horner, noted that 48% to 74% of run-off that flows through bioretention systems escaped in the form

of infiltration and evaporation, and Lie et al stated that 20% to 50% of run-off escaped through exfiltration and evapotranspiration (Li et al., 2009 and Chapman and Horner, 2012).

Along with stormwater management, rain gardens have also been known to reduce or remove pollutants from stormwater run-off. Ahiablame et al. developed Table 6. Which represents a summary of pollutant removal from 17 separate bioretention projects throughout the country, between 2001 and 2011. The results suggest that there is a significant reduction in almost every type of pollutant, with the greatest reduction occurring with total suspended solids (TSS), phosphorus (P), copper (Cu), and zinc (Zn).

TABLE 6. SUMMARY OF PERCENT RUN-OFF REDUCTION AND POLLUTANT REMOVAL (AHIABLAME ET AL., 2012)

Study	Location	Runoff	TSS	P/TP	NO ₃ -N	NH ₄ -N	TKN	TN	Cu	Pb	Zn	FC ^a	O/G ^b
Davis et al. (2001)	Lab experiment, USA	–	–	60–80	24	60–80	60–80	–	>90	>90	>90	–	–
Davis et al. (2003)	Lab experiment, USA	–	–	>65	>15	–	>52	>49	>43	>70	>64	–	–
Hsieh and Davis (2005)	Lab experiment, USA	–	–	4–99	1–43	2–49	–	–	–	66–98	–	–	>96
Glass and Bissouma (2005)	Washington, DC, USA	–	98	–3	–	–65	–	–	75	71	80	–	–
Sun and Davis (2007)	Lab experiment, USA	–	–	–	–	–	–	–	88–97	88–97	88–97	–	–
Davis et al. (2006)	Maryland, USA	–	–	70–85	<20	–	55–65	–	–	–	–	–	–
Dietz and Clausen (2006)	Connecticut, USA	–	–	–	67	82	26	51	–	–	–	–	–
Hong et al. (2006)	Lab experiment, USA	–	–	–	–	–	–	–	–	–	–	–	83–97
Hunt et al. (2006)	North Carolina, USA	–	–	–	13–75	–	–	–	99	81	98	–	–
Roscoe et al. (2006)	New Hampshire, USA	–	96	–	27	–	–	–	–	–	99	–	–
Davis (2007)	Maryland, USA	–	47	76	83	–	–	–	57	83	62	–	–
Rusciano and Obropta (2007)	Lab experiment, USA	–	92	–	–	–	–	–	–	–	–	92	–
Hunt et al. (2008)	North Carolina, USA	–	60	31	–	73	44	32	54	31	77	71	–
Zhang et al. (2010)	Lab experiment, USA	–	–	–	–	–	–	–	–	–	–	>82	–
Chapman and Horner (2010)	Washington, USA	48–74	87–93	67–83	63–82	–	–	–	80–90	86–93	80–90	–	92–96
DeBusk and Wynn (2011)	Virginia, USA	97	99	99	–	–	–	99	–	–	–	–	–
Zhang et al. (2011)	Lab experiment, USA	–	–	–	–	–	–	–	–	–	–	72–97	–

^a FC fecal coliform including *E. coli*

^b O/G oil/grease

There are three main aspects for rain gardens to take into consideration before beginning design or construction should begin; size and location, soils, and plant selection. The first aspect to consider, is size and location. The size and location of the rain garden will vary tremendously

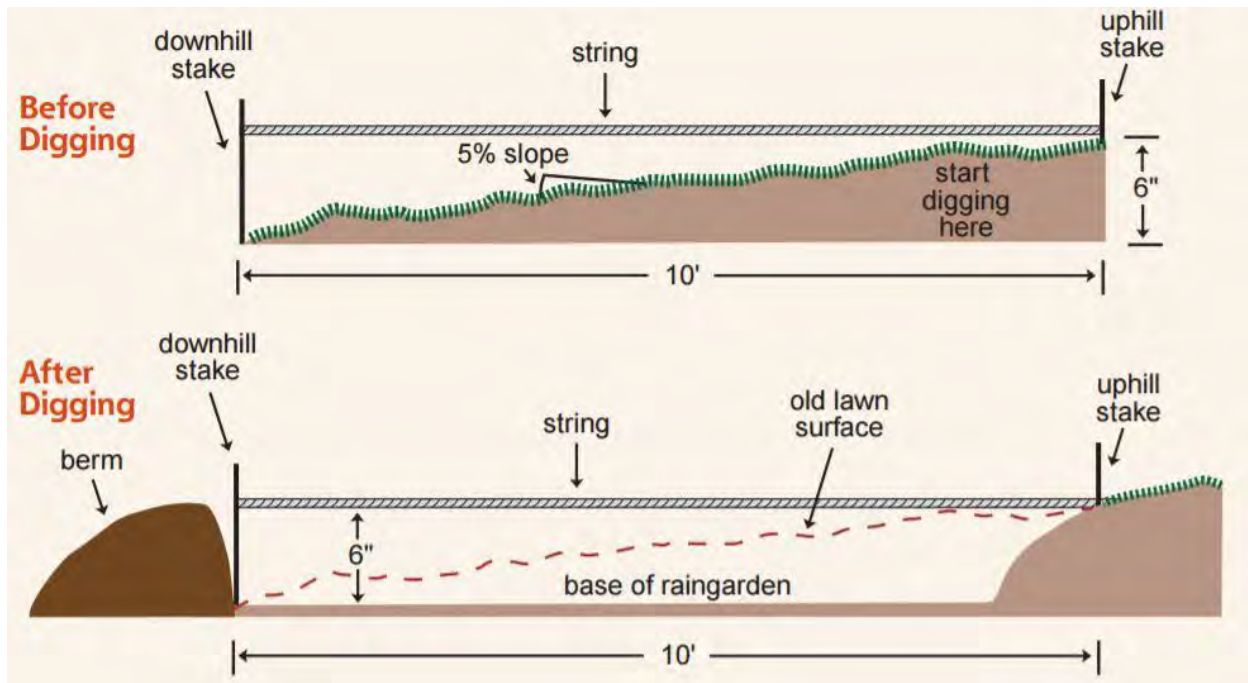


Figure 13. Cut and Fill for Rain Gardens. (Bannerman, 2003).

depending on the project. On smaller applications, it is best to design the rain garden, where the water naturally flow. In the case of commercial rain gardens, this is often a controlled variable because the grading and drainage will be designed and altered. Meaning, where the water naturally flows, may change depending on the civil engineering for the project. In any case, the rain gardens still must be placed *in* the path of water flow to capture and slow the flow, or at the *end* of the water flow path, to collect all of the run-off (NRCS, 2005). A few other notes to consider are microclimates and slopes. Rain gardens, should when all possible, be placed in areas with the greatest sun exposure. The sun will help facilitate evaporation, which as was previously mention can account for up to 48% to 74% of the escaped run-off (Chapman and Horner, 2012). Conversely, if designed in areas with high shade, or under large trees, the run-off will take much longer to evaporate – creating many other problems, such as moss or ponding. In smaller residential applications, rain gardens can be designed on slopes up to 12%, because the amount

of cut and fill for a berm will be minimal (see Figure 13.). Unfortunately on larger commercial applications, rain gardens should be designed on slopes less than 5%. Because there will need to be much more cut if the slope is greater than 5%. This is due to the fact that the rain garden surface area needs to be as flat as possible, to allow for the greatest surface area for water penetration. The depth of the garden will vary depending on the amount of run-off to be collected, the surface area size of the garden, and the rate of water penetration through the soil (Emanuel and Godwin, 2009). For example, Table 7. demonstrates recommended depths based on soil drainage rates.

TABLE 7. RAIN GARDEN PONDING DEPTH BASED ON DRAINAGE RATE (EMANUEL AND GODWIN, 2009)

Drainage Rate	Suggested Rain Garden Ponding Depth
Between 1/2 and 1 inch per hour	12 - 24 inches
Between 1 and 2 inches per hour	6 - 8 inches
Faster than 2 inches per hour	6 inches

Soil is the next aspect to take into consideration for a rain garden. The best suited soils for rain gardens, are those which have excellent drainage properties. Some would assume that a good place for a rain garden would be in an area on the site that is naturally wet. But, this is not the case, because if one area is usually more wet than other areas, this means that that one particular area has poor drainage, and would not be suitable for a rain garden. A soil analysis should always be performed on the site, so the designer knows exactly what soil properties are located on-site. There are generally three types of soils – sand, silt, and clay. The best type of soil for a rain garden would be sand. Sandy soils allow water to penetrate and drain freely, while clay soils tend to hold too much water for a rain garden. Fortunately, whatever soil type that is existing, it can always

be amended for proper drainage. Soil amendment, will again, depend on the existing soil type, but they should generally be placed at least 12" deep and be tilled into the existing soil, up to 24".

Lastly, plant selection should be chosen. In most cases, native plants are best suited for use in rain gardens (NRCS, 2005). Native plants will have the least difficulty adapting to site conditions, and provide the greatest benefit for attracting wildlife. There are many consideration to take into account when choosing the plant material. First, whether the raingarden will be in the sun or the shade. For larger commercial rain gardens this will likely be both. Second, plants should be designed based on their water preferences (Bannerman, 2003). For instances, plants that will survive in wet areas, be can tolerate dry conditions, should be planted at the bottom of the garden because for the majority of the year, there will not be any water in the rain garden. Plants that like dryer conditions, but can tolerate short periods of water, can be planted in the middle tier of the garden. Lastly, plants the primarily survive in dryer conditions, but can tolerate very short periods of water, can be planted on the top tier of the garden. Once planting has been done, it is recommended that mulch be placed above the soil and between the plants (NRCS, 2005). Bark mulch has great water holder capacity, and can help inhibit weed growth in the rain garden, not to mention it adds great esthetic appeal and a finished quality to the garden.

Table 8. represents an accumulation of recommended rain garden plants for the northwest. This has been developed based on plant lists from the Washington State University, the NRCS and The Oregon Rain Garden Guide. The list has been divided into trees and shrubs, perennials, and rushes, sedges, and grasses. In each of these categories, the plants have their botanical and common name listed, their appropriate or most suited moisture zone, and their mature size.

TABLE 8. NORTHWEST RIAN GARDEN PLANTS

Trees and Shrubs

Botanical Name	Common Name	Moisture Zone	Height	Width
<i>Acer circinatum</i>	Vine Maple	Moderate, Dry	15-20'	15-20'
<i>Alnus viridis</i> ssp. <i>Sinuata</i>	Sitka Alder	Wet, Moderate	3-15'	10-15'
<i>Amelanchier x grandiflora</i>	Serviceberry	Moderate, Dry	15-25'	15-25'
<i>Cornus sericea</i>	Red Osier Dogwood	Wet, Moderate, Dry	4-8'	4-8'
<i>Cornus sericea</i> Kelseyi	Dwarf Redtwig Dogwood	Wet, Moderate, Dry	2'	2'
<i>Gaylussacia baccata</i>	Black Huckleberry	Wet, Moderate, Dry	1-3'	3'
<i>Holodiscus discolor</i>	Acean Spray	Moderate, Dry	4-8'	3-6'
<i>Lonicera involucrata</i>	Black Twinberry	Wet, Moderate	7'	10'
<i>Mahonia aquifolium</i>	Oregon Grape	Moderate, Dry	4'	4'
<i>Parrotia perisica</i> Vanessa	Vanessa Persian Parrotia	Wet, Moderate, Dry	10-20'	15-40'
<i>Philadelphus lewisii</i>	Mock Orange	Moderate, Dry	5'	3'
<i>Physocarpus capitatus</i>	Pacific Ninebark	Wet, Moderate	6-13'	6-13'
<i>Rhus aromatica</i> Gro Low	Grow Low Sumac	Moderate, Dry	2'	6-8'
<i>Rhus glabra</i>	Smooth Sumac	Dry	6-12'	10'
<i>Ribes aureum</i>	Golden Currant	Wet, Moderate	6-8'	6-8'
<i>Ribes sanguineum</i>	Flowering Currant	Wet, Moderate, Dry	10'	7'
<i>Rosa gymnocarpa</i>	Baldhip Rose	Wet, Moderate, Dry	2-3'	3'
<i>Rosa nutkana</i>	Nootka Rose	Wet, Moderate, Dry	5'	5'
<i>Salix lucida</i> ssp. <i>Lasiandra</i>	Pacific Willow	Wet, Moderate	13'	10'
<i>Spirea douglasii</i>	Douglas Spirea	Wet, Moderate, Dry	5'	5'
<i>Symphoricarpus alba</i>	Common Snowberry	Moderate, Dry	6'	4'
<i>Syringa vulgaris</i>	Common Lilac	Moderate, Dry	15'	6-12'

Perennials

Botanical Name	Common Name	Moisture Zone	Height	Width
<i>Achillea millefolium</i>	Yarrow	Moderate, Dry	2'	2'
<i>Asarum caudatum</i>	Wild Ginger	Moderate	10"	Spreading
<i>Dicentra formosa</i>	Pacific Bleeding Heart	Moderate, Dry	2'	2'
<i>Echinacea purpurea</i>	Purple Cone Flower	Moderate, Dry	3'	2'
<i>Helianthemum nummularium</i>	Sun Rose	Moderate, Dry	6-12"	2-3'

Perennials

Botanical Name	Common Name	Moisture Zone	Height	Width
<i>Iris tenax</i>	Oregon Iris	Wet, Moderate, Dry	1'	Spreading
<i>Lupinus polyphyllus</i>	Large-Leaved Lupine	Moderate, Dry	3'	2'
<i>Polystichum munitum</i>	Sword Fern	Moderate	3'	3'
<i>Dsolidago canadensis</i>	Canada Goldenrod	Moderate, Dry	3'	2'

Rushes, Sedges, and Grasses

Botanical Name	Common Name	Moisture Zone	Height	Width
<i>Carex densa</i>	Dense Sedge	Wet, Moderate	2'	Spreading
<i>Carex dolichostachya</i> Kaga-Nishiki	Kaga-nishiki Sedge	Wet, Moderate	6-12"	Spreading
<i>Carex obnupta</i>	Slough Sedge	Wet	2-5'	Spreading
<i>Deschampsia caespitosa</i>	Tufted Hair Grass	Wet, Moderate	2'	3'
<i>Festuca occidentalis</i>	Western Fescue	Moderate, Dry	1-3'	1-3'
<i>Juncus acuminatus</i>	Taper-tipped Rush	Wet	3'	Spreading
<i>Juncus effusus</i> var Occidental Blue	Occidental Blue Rush	Wet, Moderate	2-4'	Spreading
<i>Juncus effusus</i> var pacificus	Common Rush	Wet, Moderate	3-5'	Spreading
<i>Juncus ensifolius</i>	Dagger-leaf Rush	Wet	2'	Spreading
<i>Juncus patens</i>	Spreading Rish	Wet	2'	Spreading
<i>Scirpus microcarpus</i>	Smalle-fruited Bulrush	Wet	4'	Spreading

Now that transit oriented development and green infrastructure techniques have be evaluated, multiple case sites will be provided next, to offer insight to real world projects. These projects will be utilizes to understand problems facing transit oriented developments, and how these problems can be avoided with future projects.

Case Studies

Full Case Study: Rosslyn- Ballston Corridor

PROJECT NAME	Rosslyn – Ballston Corridor
LOCATION	Corridor between Rosslyn Metro Station and Ballston Metro Station Arlington County, Virginia
DATE DESIGNED/PLANNED	Regional rail system planning began in 1960. Rail line (Orange line) from Rosslyn to Ballston opened in 1979. Sector plans completed in 1984.
CONSTRUCTION COMPLETED	Majority completed around 2002, but still ongoing.
SIZE	2.0 sq. mi.
CLIENT/DEVELOPER	Arlington County Board, County Departments (Community Planning, Housing and Development, Economic Development, Public Works), Citizen Commissions, Ballston Partnership, Inc.
MANAGED BY	Arlington County and Washington Metropolitan Area Transit Authority (WMATA)

Context. Rosslyn – Ballston Corridor (RBC) has been described as one of the best TOD success stories in the United States, over the past 40 years. The RBC is located in central Arlington County, Virginia; just west of the Potomac River and Washington D.C. (38°53'13.5"N 77°05'42.9"W). This nearly 2.4 mile corridor consists of 5 Metrorail stations (Rosslyn, Courthouse, Clarendon, Virginia Square, and Ballston station), spaced from two-thirds of a mile to seven-eighths of a mile apart. Thus, providing a station that is within a ten to fifteen minute walk from any point in the corridor.

These stations are located on the Orange line of the Washington Metropolitan Area Transit Authority (WMATA) Metrorail; which currently runs from Vienna in Fairfax County, all the way across the Potomac, through Washington D.C. and onto New Carrollton, Maryland. The Rosslyn station acts as a transfer point for the Blue line as well; heading south to the Pentagon, Ronald Reagan Airport, and ultimately to Springfield and heading east to Largo Town Center Station. Both Metrorails had been specifically planned along two arterials – Wilson Boulevard and Fairfax Drive – to promote public and

private development. Opposed to the alternative of placing the rail in the median of Interstate 66 to the north, which would limit development possibilities.

Overall the RBC serves as a well-developed, mixed-use community with each station taking on a distinct function. The Rosslyn and Ballston stations primarily serve as business centers, while the Clarendon station provides many shops and restaurants. The Virginia Square station has become focused on culture and education, and the Court House station acts as a governmental center. Yet, they all manage a delicate balance of residential housing opportunities.

Project Background and History. The RBC can better be described as a transit oriented *redevelopment*, rather than transit oriented development. This is because the Arlington County government understood early on that the Metrorail needed to be specifically designed with the goal of “shaping regional growth in addition to fighting congestion and improving transit” (Cervero, 2004, 229). They were going to use the rail as a tool to redevelop and reshape their existing communities. In the 1960s, the corridor consisted of street front retail stores, shopping centers, apartment complexes, and single family housing – all of which were primarily one and two-story buildings.

Rapid suburbanization in the 1960s and 70s led to a dramatic decline in retail sales as well as population. Many of the exiting retailers and grocery stores were leaving the area for these new suburbs. Between 1972 and 1980 the RBC lost nearly 37% of its population, or eleven thousand residence (Leach 2004). Because of this rapid suburbanization, and the foresight of the county, they began discussion in the 1960s, on how TOD could be used to renew the corridor. These discussions eventually led to the general plan to develop around the stations with a “bull’s-eye” strategy (Leach, 2004, p. 133). Meaning, the greatest intensity in building height and density will be closest to the stations and the further away from the station, the height and density gradually decreases.

With all these plans being developed, the WMATA was created in 1966 to build and operate the metro rail system. The rail opened in the RBC in the late 1970s and has since helped the corridor increase development and increase population to the area. The WMATA is an independent transportation authority with no dedicated funding source, resulting in the reliance on fares and local and state governmental funding (WMATA). Today the agency has become the “second largest transit operator in the United States, carrying over 1 million customers a day on bus and rail.” (Cervero, 2004, 229).

Genesis of Project. The emergence of suburbanization in the 1960s, led to the rapid decline in production of the RBC. Knowing something had to be done, local officials understood the benefit in developing a transit system. Not only did they see the potential as a people mover; but, because of some of their “travel and work experience abroad,” they knew it could be used as a tool to shape regional growth (Cervero, 2004, 230). All three local jurisdictions: Arlington County, Virginia; Montgomery County, Maryland; and the District of Columbia, as well as the Metrorail staff and board, saw this potential and became supporters from the beginning. This collaborative effort eventually led to the framework of joint development for TOD projects (Cervero 2004).

Planning Principals. Once a general plan was created for the direction of the RBC and all stakeholders were in agreement, many planning principles were developed to produce the framework for the corridor to be developed. The majority of these principles have remained consistent over the last 40 years which has benefited developers by creating stability and predictability in the design, process, and outcome. Some of the main guiding principles include:

- The TOD in the RBC would be developed with a “Bulls Eye” approach and the corridor would have definitive boundaries.
- The majority of redevelopment would be focused in a ¼ mile radius around each metro station and include mixed-use development with a heavy emphasis on residential.

- Each station would be clearly distinguishable from the rest, and serve a specific and unique function. As mentioned previously, this ultimately resulted in The Rosslyn and Ballston stations primarily serving as business centers. Clarendon station providing shopping and dining. Virginia Square station having a focus on culture and education, and the Court House station acting as a governmental center.
- The Metrorail was to be used as the primary mode of transportation, thus promoting walkability and reducing the dependence on the automobile.
- A diversity of housing opportunity would be implemented to provide housing for citizens of every income level, creating a diverse community and environment.
- Existing residential neighborhood would be preserved and rejuvenated.
- Joint collaboration between the government, citizens, and developers would be used in the decision making process.

Design, Development and Decision-Making Process. The design and development process, has proven to be a major contributing factor to the success of the RBC. The development process started with five main players, or interest groups: “the Arlington County Board, the staff of several county departments, citizen commissions, other community representatives, and developers and business and property owners” (Leach, 2004, 134). The county board is a group of five elected officials, who set policy on redevelopment and established the redevelopment framework. The county staff includes members from the county’s Community Planning, Public Works, Economic Development, and Housing and Development departments. These staff members aid in much of the research done on TODs. The citizen commissions provide feedback on new policy initiatives and help provide community consensus on difficult issues. They also review all the development projects (Leach 2004). The last group, developers and business and property owners, is fairly self-explanatory.

One initial step in RBC was the preparation of a general land use plan (GLUP). This was used by guiding development decisions in terms of allocating land uses and densities. The next step was to develop sector plans. Sector plans were essentially much more specific land use plans. Each metro station had its own sector plan, which specified land use, zoning, urban design, streetscape design, open space, public facilities, etc. for the area surrounding the stations.

Once the GLUP and sector plans were created and implemented, development could occur. There are two main options a developer has in proposing a project. If the proposal meets the existing density requirements in the intended zone, then the project can be reviewed and approved through an administrative process. But, if the developer wants higher density than the area is zoned for, they can file for a “site plan review,” where they enter into a set of negotiations with the county board, staff, citizen commissions, and the community (Leach, 2004, p. 134). Often times these negotiations lead to the developers agreeing to make significant infrastructural improvements to the surrounding area.

Role of Landscape Architect(s). There has been no specific mention of landscape architects in this TOD, largely because the RBC is a very large example of TOD and development has been ongoing for nearly 40 years – resulting in many different projects, presumably with many different landscape architects. Thus resulting in a broad overview for this case study.

Although, there are many aspects of the RBC that undoubtedly would include the participation of a landscape architect. For example, in 1992 Arlington County adopted an Open Space Policy, which placed and emphasis on the importance of “greenery, parks, and other open spaces to that quality of life” (Cervero, 2004, 239). Ultimately the Open Space Policy has helped the RBC reach the density that TOD requires because the general public are more likely to accept a high rise building if there is a tradeoff, allowing the preservation of some parcels for public lands. As of 2004 there were nearly 122

acres (12% of the total land) of parks or public space in the RBC (Fairfax County Department of Planning and Zoning, 2005).

Another trend that has emerged has been the increasing focus on pedestrian and bicycle access and movement. The county had developed streetscape guidelines to improve sidewalks, landscaping, and underground utilities. Because the WMATA has no tax-raising authority, these improvement cost have be pushed onto the developers and negotiated in the site plan review process (Leach 2004). This has resulted in “more than half of the sidewalk network [having] been improved with wider sidewalks, curb ramps, pedestrian lighting, street trees, and other amenities, and by 2002 there were sidewalks on more than 90 percent of all streets” (Leach, 2004, p. 139). Unfortunately, because these improvements are negotiated on a site by site basis, there has been a noticeable lack of uniformity throughout the corridor. Thus providing the opportunity to include a landscape architect in all site plan review processes to ensure that consistent design criteria is being implemented on each project.

Photographs.



Figure 1. *Rosslyn Station – 1970s*



Figure 2. *Rosslyn Station – 2005*



Figure 3. *Courthouse Station – 2005*



Figure 4. *Courthouse Station – 2005*



Figure 5. *Clarendon – 2005*



Figure 6. *Clarendon – 2005*



Figure 7. *Virginia Square Station – 2005*



Figure 8. *Virginia Square Station – 2005*

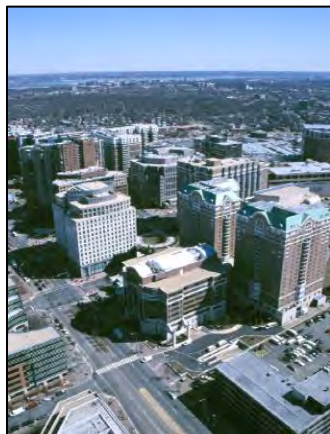
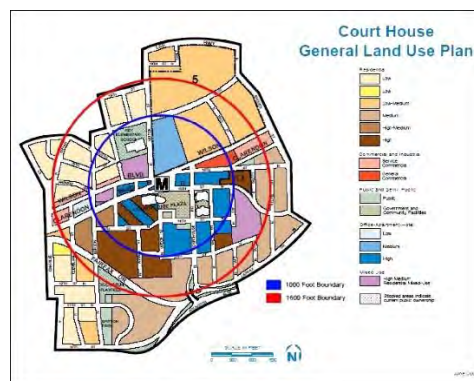
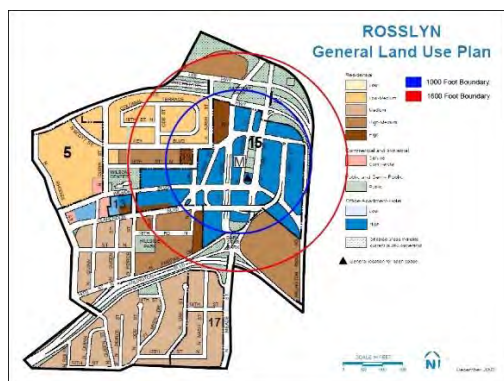
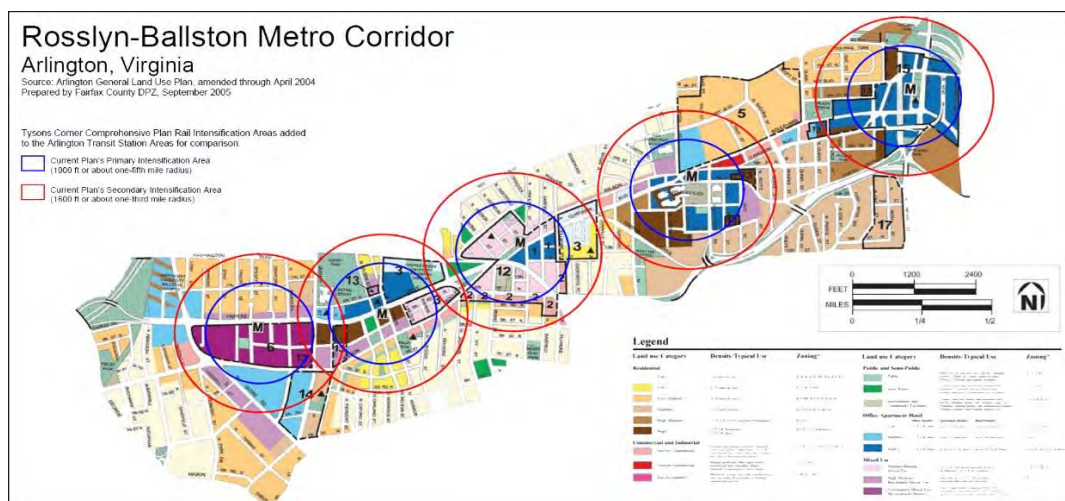
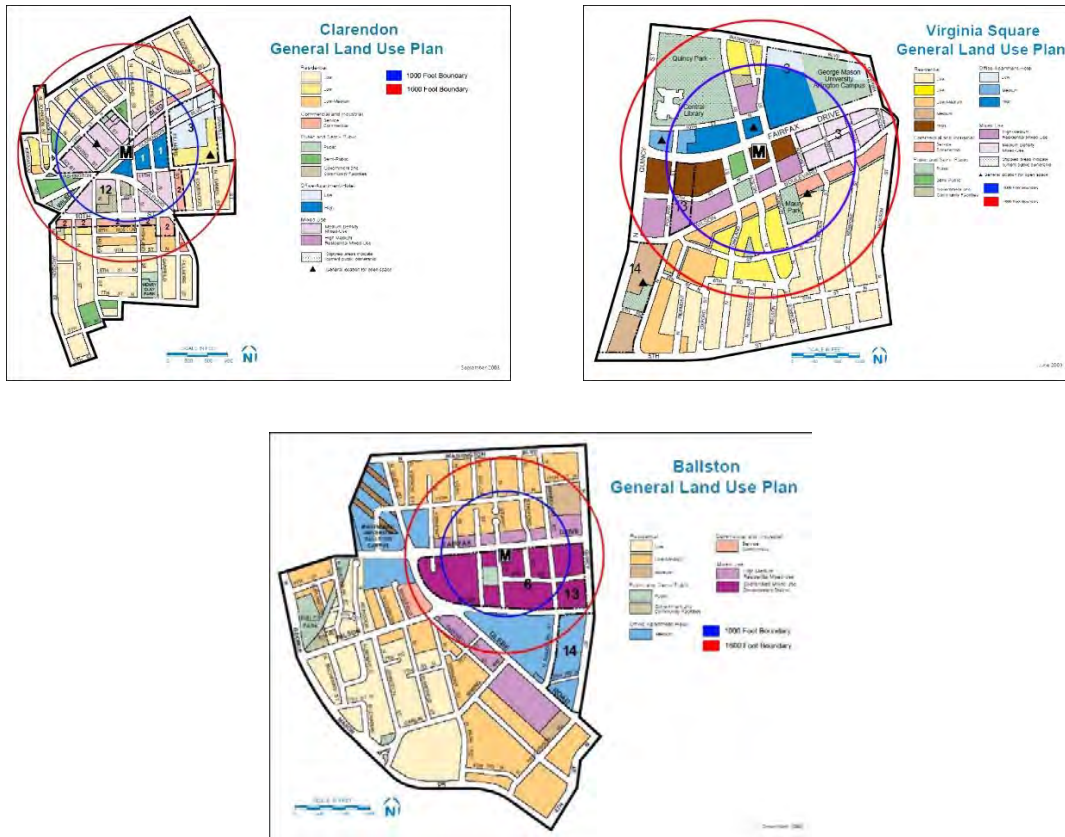


Figure 9. *Ballston Station – 1980*

Figure 10 and 11. *Ballston Station – 2005*

Site Plans. (Fairfax County Department of Planning and Zoning, 2005)





Development Results. There are many attributes to measure the success of TOD; including, transit ridership increases, economic growth, population growth, increasing development, etc. The RBC has demonstrated success in all of these categories. In 1970 the corridor supplied 22,000 jobs with 5.5 million sq.ft. of office space, and 7,000 housing units (Arlington County Department of Community Planning 2008). In 2008 there were more than 90,000 jobs, with 20.8 million sq.ft. of office space and more than 26,500 housing units (Arlington County Department of Community Planning 2008). 26% of people living in Arlington County reside in a Metrorail corridor, even though they only account for 8% of the total land (Cervero 2004). Because the TOD has increase population densities near the stations, from 1980 to 2002, the average daily boarding on the five RBC metro stations has increased from 28,556 to 38,283 (Cervero 2004). Thus resulting in a dramatic decrease in automatable dependence; in 2000, 49.8% of residents living in the Metro corridor commuted to work either by walking, biking, or transit, while only 21.3% of residence outside the Metro corridor did the same (Cervero 2004).

Significant financial returns have emerged with the success of the RBC. As of 2002, the assessed values for the corridor was \$8.88 billion – \$6.7 billion of that for infrastructure and development (Leach 2004). Over a ten year period, since 1992, this has been an 81% increase in values, more than double the rate of inflation over the same period (US Inflation Calculator 2015).

Awards.

- In 2002 the Arlington County Government received a National Award for Smart Growth Achievement, for effective planning, policies and overall excellence in Smart Growth in the Rosslyn – Ballston Metro Corridor. This award was given by the U.S. Environmental Protection Agency (EPA 2002)
- In 2005 Arlington, Virginia was the Best Walking City in America by the American Podiatric Association (Bethesda 2005).
- In 2003 the Arlington Transit received the Outstanding Public Transportation System Award by the American Public Transportation Association (APTA 2003).
- In 2011 The League of American Bicyclists awarded Arlington with a Bicycle Friendly Community designation (League of American Bicyclists 2011).

Criticism. While the RBC has largely been successful on almost any account, criticisms still remain. For starters, residential neighborhoods were to be preserved since the beginning, but that same focus was not on the commercial centers. Because of this, many historic buildings were lost from the existing commercial core. It wasn't until 1976 that the county board took action to preserve the historic landmarks – this was largely because of the controversy over the Interstate 66 proposal, threatening historic neighborhoods. Some of their actions included modifying the zoning ordinance to address historic preservation and creating a Historic Landmark Review Board (Leach 200).

Another shortcoming of the RBC, which it has been increasingly criticized for, is the lack of cohesion of the built environment. As previously mentioned, this is mainly due to the fact that each new development is reviewed on a project-by-project basis and required to make certain infrastructural improvements to the area surrounding their development. Because this review process involves negotiations, there has been some wiggle room, “leading to inconsistencies in the streetscape” (Leach, 2004, 137).

Lastly, the great success of the RBC has resulted in affordability issues for residential housing and developable land prices. Thus, proving difficult for start-ups and less affluent families to move to the corridor. As a result, the county has encourage the development of CBU’s, or community benefit units. These CBU’s can be residential houses or apartments, which have a thirty year agreement with the county, guaranteeing their affordability compared to market rate housing. The county has also allowed developers to build with greater density, if they agree to designate a certain percent of the apartments to be affordable housing. These “density bonuses” can be up to 25% of the development, resulting in a considerable gain for the developer (Leach, 2004, 136).

Significance & Uniqueness of Project. The Rosslyn – Ballston Corridor has been described as being one of the most successful transit oriented development project in the United States, in almost every article written about it. The RBC has become a model for how proper joint development, should be conducted with TOD, along Metrorail stations. Proving to aid in dense economic, population, and development growth, while reducing the dependence on automobiles.

Lessons.

Metrorail can be used as a tool for redevelopment. Since the beginning of the project, local officials were focused on using the rail, not only as a people mover, but as a way to shape the regional

growth. This has led to one of the densest commercial centers in all of the United States. As a result there has been reduction in suburbanization and less of a dependence on personal automobile transportation.

Mixed-use development is essential. The mixed-use aspect allows for a large percentage of the population to live closely to their place of employment. Arlington County has been able to provide close to a one-to-one ratio of commercial development to residential (Leach, 2004, 150). This is because they have placed an emphasis on residential development in the corridor to maintain the benefits of a mixed-use community. Providing a variety of mixed-use development can also benefit the transportation system by balancing out the ridership numbers – less people leaving and arriving at the same time of day.

Developing a planning framework early on is important for predictability and stability. The County developed a GLUP and sector plans before development took place. Thus providing developers with clear boundaries and a specific process on how development needs to occur. This has led to consistent development in the corridor, promoted much less controversy, helped develop a level of trust with the community and the developers, and led to an impelling community for future development.

Involvement from all interest groups is necessary. Involving all interest groups in the planning process has helped the RBC gain community consensus and provided a level of consistency. All in all, over 60 public meetings and workshops were held in the process of creating the GLUP and developing transportation policies (Leach 2004). These meetings were used to help educate the public citizens, who have in turn provided feedback and led to easier consensus building.

Cohesive design is important. Providing a cohesive design palette for the buildings, streetscape, and open space is important in creating community character. This has proven to be a difficult task for

the RBC, mainly because development is evaluated on a project-by-project basis, involving different interest groups and negotiations.

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Brief Case Study: Orenco Station

PROJECT NAME	Orenco Station
LOCATION	Orenco/ 231st stop of the Westside light rail line in Hillsboro, Oregon
DATE DESIGNED/PLANNED	Initially designed in the mid 1900's. Ground broke on Orenco Station in 1996. Westside Max light rail line began operation in 1998.
CONSTRUCTION COMPLETED	Majority completed around 2003, but still ongoing.
SIZE	190 acres
CLIENT/DEVELOPER	PacTrust
CONSULTANTS/ARCHITECTS	Costa Pacific Homes, Iverson Associates, Inc. Fletcher Farr Ayotte, Walker & Macy
MANAGED BY	Arlington County and Washington Metropolitan Area Transit Authority (WMATA)

Context. Orenco station is a 190-acre transit oriented development located in Hillsboro, Oregon, roughly 14 miles west of downtown Portland (45°31'49.0"N 122°54'56.8"W). The station is located along the Blue line of the Portland's light rail, MAX (Metropolitan Area Express). The blue line travels the furthest of the max lines, totaling 33 miles. It runs from the Hillsboro city center, to Beaverton, downtown Portland, across the Willamette River, and eventually to Gresham to the east, with a total of 47 stops. The actual Orenco light rail station is located on the southernmost area of the TOD, with an axial pedestrian corridor and transit buses servicing the stop. Cornell Road, the largest arterial onsite, cuts through the center of the development, just south of the downtown center.

Orenco station, while representing the actual name of the light rail stop, is also the name of, one of the four developments in the transit oriented development site. The other three being, Club 1201, Arbor Gardens, and Sunset Downs. Orenco station development is the largest of the four, containing 60,000 sq.ft. of retail and commercial space; which includes, "a grocery store, a large home and kitchen store, a national coffee chain, and several restaurants and small shops" (Dill 2008). There are also variety of housing options; including, live-work town homes, apartments, cottage style homes, etc. Club 1201, is a condominium development to the south of Cornell Road, with adjacent apartment builds, which include

light first floor commercial and retail. Arbor Gardens, is a development entirely composed of housing, with no commercial or retail. Similarly, Sunset Downs, is also only composed of residential housing and it was the only development in place before the MAX line was implemented.

For the purpose of this brief case study, Orenco Station and Club 1201, will be examined due to the fact that they encompassed the original Orenco station masterplan.

Project Background and History. In 1973, the state of Oregon created the “nation’s first statewide land use planning laws,” requiring all cities and counties in Oregon to create long-range plans, addressing future growth (Fabozzi, 2006, 16). The state’s primary goals were to protect natural resources and promote a wise use of the land. The most important factor of the laws were the creation of the urban growth boundaries. These boundaries are used to designate the separation between rural and urban land, and are set in place to accommodate enough land for the predicted population growth for the next 20 years (Fabozzi 2006).

In 1978, the Portland metropolitan area approved the establishment of Metro. Metro was the first publicly elected regional government in the nation. Their task was to coordinate the land-use plans of the 27 jurisdictions in the region and ultimately established a regional growth boundary. In 1992, Metro implemented a Regional Framework Plan, “which is a comprehensive set of regional policies on land use, water quality, natural areas,” and other regional issues (Fabozzi, 2006, 16). Finally in 1996, Metro adopted the 2040 Growth Concept.

The 2040 Growth Concept, “states the preferred form of regional growth and development and includes the Growth Concept map” and “is adopted for the long-term growth management of the [Metro] region” (Metro, 2011, 1). There are many important components in the 2040 Growth Concept, but one of the most important is the implementation of “centers.” The centers are intended to create “higher density centers of employment and housing and transit service with compact development, retail, cultural and recreational activities in a walkable environment is intended to provide efficient access to goods and

services, enhance multi-modal transportation and create vital, attractive neighborhoods and communities” (Metro, 2011, 2). With the ultimate goal of providing the greatest amount of goods and services in the least amount of land area.

The “centers” are then divided into four sub groups: the central city, regional centers, town centers, and main streets and neighborhood centers. Downtown Portland is the central city, and each other center progressively reduces in population and services. Orenco Station was designated in the 2040 Growth Concept Plan as a “town center.” The backbone to of these “centers” is the MAX line, which supports and connects the centers to each other. MAX is owned and operated By TriMet, the Transit agency, and was first opened in the mid 1980’s and then expanded with the Westside line (connecting downtown Portland to Hillsboro) in 1998.

The visions was finally developed in the mid 1900’s then for Orenco Station. The developer, PacTrust, worked in partnership with Costa Pacific Homes to form a team of development experts, who worked with the city of Hillsboro and the public citizens to create the vision (Fabozzi 2006). This was done by many city meetings and design charrettes. The focus of the vision was “informed by a desire to create both a strong sense of place and an environment conducive to pedestrian activity and public interaction” (Fabozzi, 2006, 23). Finally in 1996 ground was broken for Orenco Station Development.

Planning Principals. Once a general vision was created and the stakeholders were in agreeance, the developers and designers, worked with the City of Hillsboro to create the guiding planning principals and the new land use regulations, based on transit oriented development and New Urbanism. Some of these included:

- Pedestrian orientation would be the main focus of development, with many wide sidewalks and corridors throughout.

- A main “downtown” center would be created with a high density mix-use atmosphere, with light street parking and parking lots behind the buildings.
- A diversity of housing opportunity would be implemented to provide housing for citizens of every income level, creating a diverse community and environment.

Photographs.



Figure 1. *Downtown Live-Work Town Homes*



Figure 2. *Downtown Live-Work Town Homes*



Figure 3. *Downtown Center*



Figure 4. *Downtown Center*



Figure 5. *Club 1201 Condos*



Figure 6. *Single Family Housing*

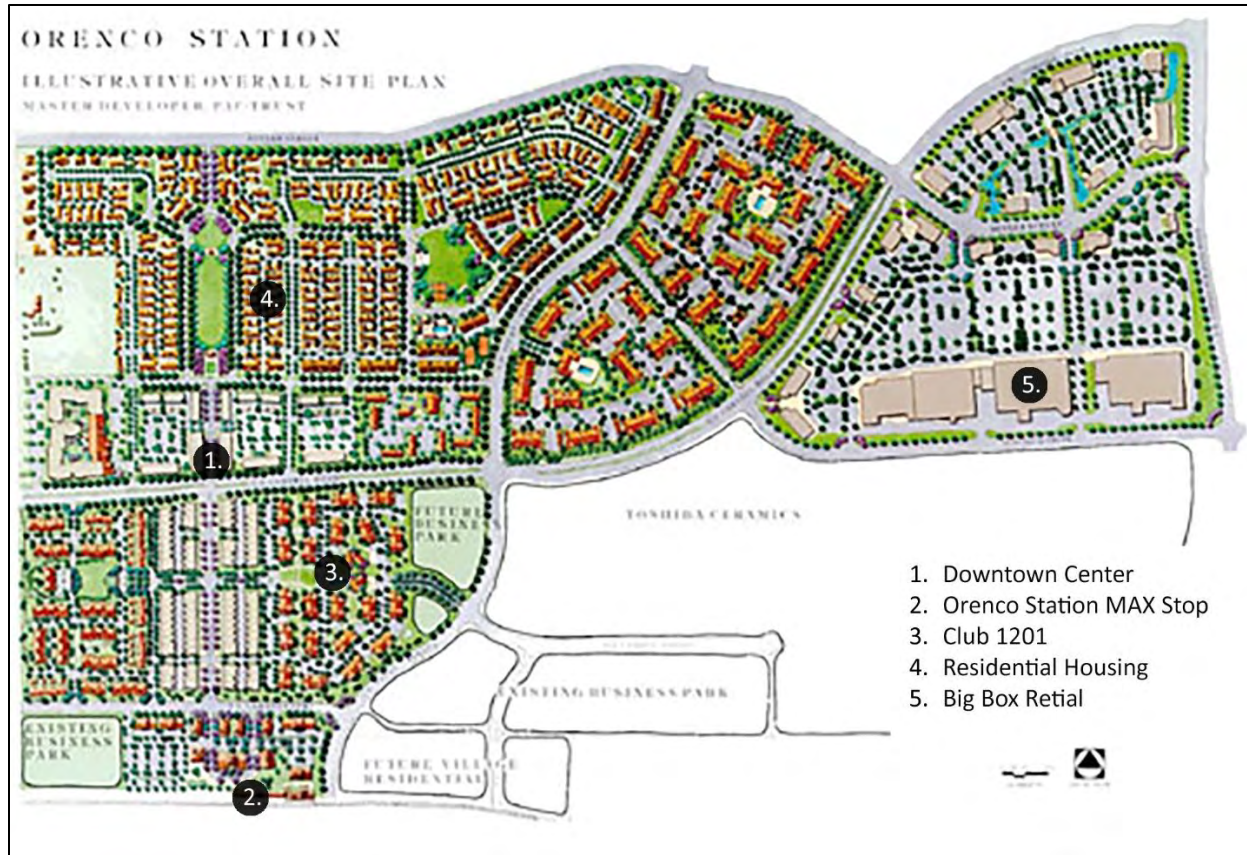


Figure 7. *Orenco Station Central Park*



Figure 8. *Orenco Station Rosebay Park*

Site Plan. (Mehaffy, 2003)



Criticism. The biggest criticism with the Orenco Station was the lack of increased transit ridership; one of the primary goals of transit oriented development. Ongoing studies generated by the Portland Neighborhood Survey group, reported in 2007, that only 15% of households primarily commuted by mass transit or bus; while 64% reported driving alone as their primary form commute (Podobnik 2009). Although 65% of the households reported an increase in mass transit used, since moving to the area. These results indicate a disconnect in the location of the station, and the residential housing in the development. Ultimately the Orenco Station was more focused on the goals and visions of New Urbanism and less on the goals of TOD.

Lessons.

Development should be designed and built around the rail station first. The failure of the team to place the downtown center around the rail station has been shown to drastically reduce the effectivity of

the TOD to increase transit ridership. Although the studies have shown that the community has become increasingly willing to avoid the automobile usage while in the development itself, it has failed to encourage transit ridership to other stops and “centers.” Until recently, the majority of residential housing was outside the ¼ mi radius of the station, which has been use in most TODs, as the maximum distance people are willing to walk to the station.

Transit Oriented Development should be just that, oriented to the transit. Unfortunately Orenco station failed in this aspect. Orenco station is more representative of a transit adjacent development than oriented development. The transit station is not the main focus of the development, the pedestrian and community environment hold that role. Which ultimately has proven to be very successful. Many wide sidewalks and pedestrian corridors have been created, along with narrow road to decrease traffic speeds. This has led to nearly 93% of survey residence stating that they walk to the store at least once a week, and 50% walking five or more times a week (Podobnik 2009). With a large percentage to community members engaging in the development, this has led to a strong sense of community and place.

Involvement from all interest groups is necessary. The partnership of PacTrust and the city of Hillsboro allowed the developer to be incorporated in the rezoning policies and developing the vision for the community. The many meetings and workshops fostered a level of trust between the developer, the local jurisdiction, and community members, which became essential as the project progressed and problems arose.

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Methods

Light rail application in the Spokane region has been examined from as early as the 1970s, when much of today's growth was forecasted (SLR, 2008). In the 1990s, even greater growth increases were being forecasted, which would eventually exceed the current transportation systems capacity. Finally in 1998, the Spokane Regional Transportation Council (SRTC), conducted a study to examine multiple options for future transportation modes to run parallel to Interstate 90. Some of which included "busways, light rail, carpool lanes and traffic flow and bus improvements" (SLR, 2008). After many public meetings, and a year of study, the SRTC Board of Directors recommended light rail as the most viable transportation mode to accommodate future growth. A year later, the SRTC and the Spokane Transit Authority united to conduct further analysis. They began to develop conceptual designs for "light rail alignment, vehicles, station locations, and system operations," as well as conducting financial analysis (SLR, 2008).

As of 2006 (before the recession) the final plan included:

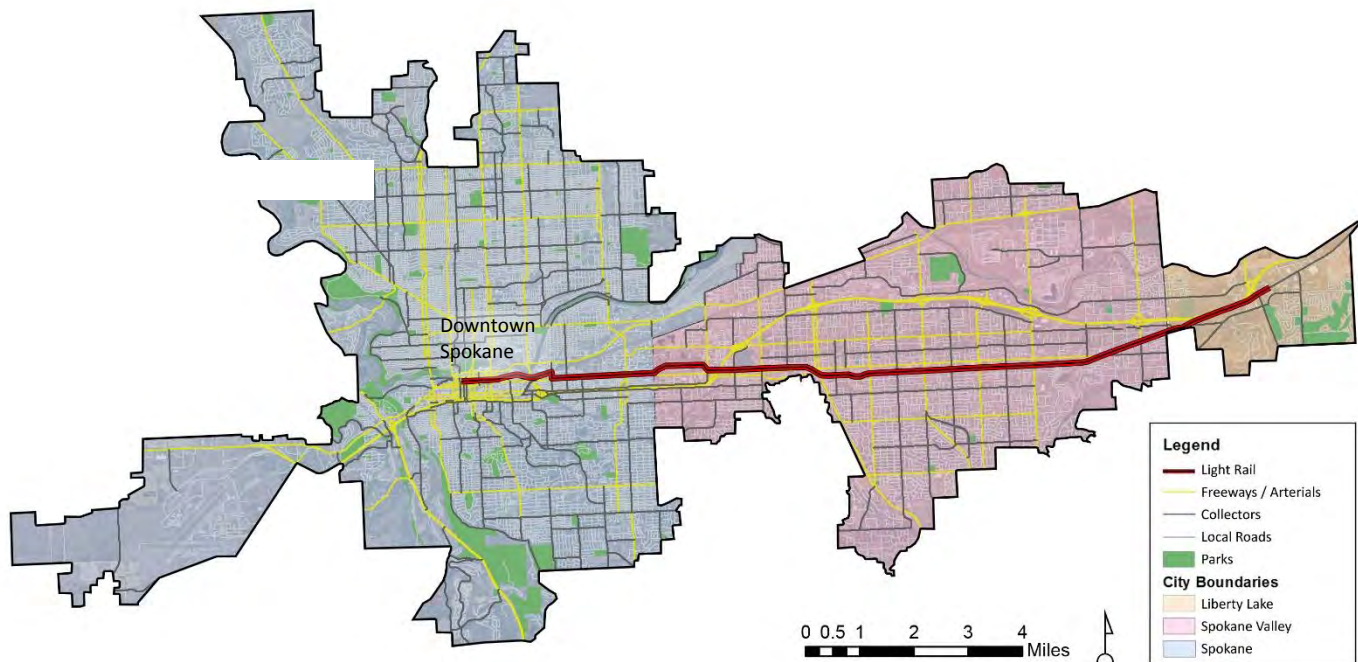
- 15.5 miles
- 14 stations
- 6 light rail vehicles plus 2 spares
- 7 Park & Ride lots
- Small O&M facility at Bowdich
- Single-car trains spaced 15 minutes apart during rush hour, 30 minutes during nights, early AM and Sundays
- Transporting approximately 135-150 passengers per train comfortably; 190 passengers at maximum capacity

- Train speeds up to 55 m.p.h. outside the downtown area, and total travel time is estimated at about 34 minutes between Liberty Lake and downtown Spokane
- 2-way options on Single track with short passing tracks
- Modestly constructed station platforms
- Bus routes reconfigured to facilitate transfers (SLR, 2008)

The study also estimated the cost to be \$263 million (in 2006). Based on historical inflation rates of construction costs, this would equal about \$335 million today (Historical Cost Indexes, 2015).

The overall plan for the light rail was to be developed in two phases. The first phase was intended to connect central Liberty Lake with Downtown Spokane, represented by Figure 14. The rail line would primary be using existing and abandoned railroad right-of-way. After phase one was complete, phase two would then connect downtown Spokane with the Spokane International

FIGURE 14. LIGHT RAIL ROUTE, CONNECTING DOWNTOWN SPOKANE TO LIBERTY LAKE



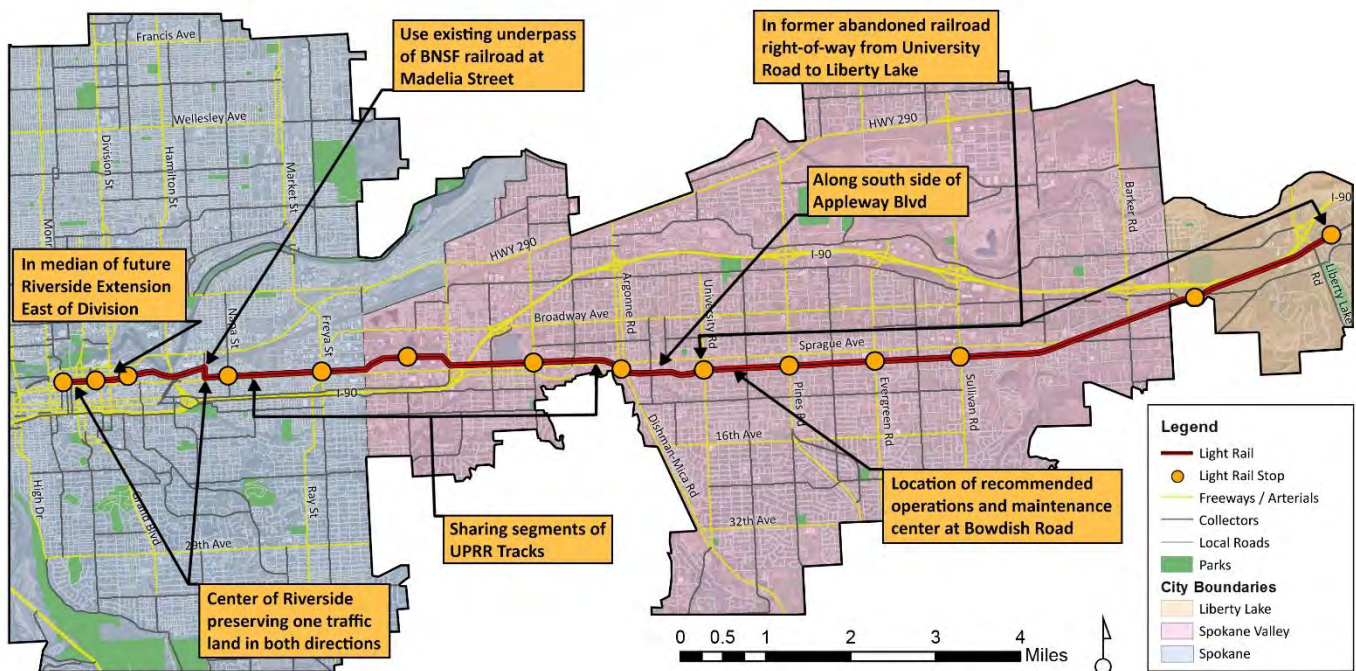
Airport; and Liberty Lake to Coeur d' Alene, ID. Although the Spokane International Airport was highly interested in light rail connection for phase one, it was excluded due to the Latah Creek. Bringing light rail across the creek posed a “daunting and potentially enormous financial hurdle;” thus, many felt it would be best to postpone this connection till phase one was complete (Inland Rail, 2013).

Figure 15. represent the light rail route, with the 14 proposed rail stops, for phase one. The following descriptions of each stop was provided by The Inland Empire Rail Transit Association (Inland Rail, 2006):

- Plaza – On Riverside Avenue, between Post Street and Wall Street, adjacent to the STA Plaza transit center.
- Convention Center – On Riverside Avenue, between Bernard Street and Browne Street.
- Riverpoint (Trent) – North of the BNSF Railway tracks at the WSU Riverpoint Campus.
- Napa – On Riverside Avenue east of its intersection with Napa Street.
- East Central – In the UPRR right of way east of Freya Street.
- Fairgrounds – East of Havana, south of the Spokane County Fair and Expo Center complex. This station will include construction of a new park and ride facility.
- Park – In the UPRR right of way west of Park Road. Consideration of it being an optional station location in the initial phase.
- Argonne – In the northwest quadrant of the intersection of Argonne Road and Appleway Boulevard. This station will include construction of a new park and ride facility.
- University City – Adjacent to the STA Valley Transit Center, in the southwest quadrant of the intersection of University Road and Appleway Boulevard. This station will capitalize on the existing park and ride facility at this location.
- Pines – In the currently vacant, former railroad right of way, east of Pines Road. This station will include construction of a new park and ride facility.

- Evergreen – In the currently vacant, former railroad right of way, east of Evergreen Road.
- Sullivan – In the currently vacant, former railroad right of way on either side of the intersection with Sullivan Road. This station is intended to include development of a park and ride facility at a site to be determined during preliminary engineering.
- Appleway – Located in right of way to be purchased, in the southwest quadrant of the I-90 interchange with Appleway Avenue / Country Vista Road. This station will include construction of a new park and ride facility.
- Liberty Lake – In the currently vacant, former railroad right of way, in the southwest quadrant of the intersection of Appleway Avenue and Signal Road. This station will include interface with or be expanded to replace the existing functions provided by the STA park and ride facility located to the south of the station site

FIGURE 15. LIGHT RAIL ROUTE WITH PROPOSED STATIONS



With the light rail route and station locations set, the next step is to evaluate each stop to determine the greatest suitability for transit oriented development. In 2001 ZHA, Inc. and Zimmerman / Volk Associates, Inc. conducted an extensive suitability study that evaluated each stop based on seven conditions. Each condition was then given a value from 1 to 3, with 1 being the lowest and 3 being the greatest suitability. The following represent the seven evaluated conditions (ZHA, Inc. et al., 2001).

1. *Regional and Local Access:* TOD relies on ample regional and local access due to its mixed use nature. For this category, stations were evaluated based on: 1) traffic volume, 2) accessibility to other modes of transit, 3) direct I-90 access and, 4) two-way streets/ease of access within the quarter-mile radius.
2. *Mix of Surrounding Land Uses:* ZHA, Inc. et al states that the potential for mixed-use developments is much greater in areas that currently have many existing land uses. For this reason, each station was examined for residential, office, retail, industrial, and institutional uses within a quart mile radius.
3. *Anchors within a Quarter-Mile Radius:* Anchors were considered to be “activity generating land uses” (ZHA, Inc. et al, 2001, p. 35). Anchors tend to draw people to an area, thus increasing the opportunity for TOD. Stations with no anchor within a quarter mile receive a “1”, local market anchors such as grocery stores or department stores scored a “2”, and regional market anchor s such as convention centers or business districts scored a “3”.
4. *Adjacency to Planned/Recent Investment:* Recent or planned investments can increase a stations economic values, while also generating market momentum moving forward.

Examples include, road alignment changes, new commercial or office building, or residential developments.

5. *Residential and Employment Density*: The Spokane Regional Transportation Council produced estimates of residential units and employees by transportation analysis zone (TAZ). Based on these estimates, 4,000 or more total residential units and employees score a “3”; 2,000 to 4,000 score a “2”; and less than 2,000 score a “1”.
6. *Vacant Buildings and Land Availability*: Land availability is one of the most important factors when determining feasibility for TOD, as a result, this condition was graded on a scale from 1 to 4. Less than 30% of underutilized land scored a “1”; 31-50% scored a “2”; greater than 50% underutilized land scored a “3”; and large undeveloped parcels exceeding 20 acres scored a “4”.
7. *Land Ownership*: Multiple land owners in close proximity to each other drastically increase the complexity of TOD, which can result in extended timelines and increase budgets.

Table 9. represents the summarized findings from this report. Each station was assigned a rating for each category, and then all the ratings were added to produce the overall suitability for each station. The four highest scoring stations were the Convention Center, Riverpoint (Trent), the Fairgrounds, and Liberty Lake. Although the Fairgrounds station has scored the highest value, based on the research of this report, it would not be the best suited area for TOD. The primary reasons the fairgrounds scored as high as it did, was because of its available land, its anchors, and its land ownership. Unfortunately, these anchors are big box stores and a baseball field, both of which require large amounts of surface parking. Which as discussed previously in this report,

does not condone a quality pedestrian environment. Along with the fact that the surrounding areas of the fairgrounds are primarily zoned as light industrial, heavy industrial, and general commercial. Which again, does not promote a quality pedestrian environment. For these reasons, the fairground would not be the best suited for TOD, though a transit stop should still be provided nearby, because of the demand that the big box stores and the baseball field would supply.

TABLE 9. ZHA, INC. et al. STATION SUITABILITY EVALUATION FOR TOD

Station	Plaza	Convention Center	Riverpoint (Trent)	Napa	East Central	Fairgrounds	Park	Argonne	University City	Pines	Evergreen	Sullivan	Appleway	Liberty Lake
Condition														
Regional and Local Access	1	2	3	2	3	3	1	3	2	3	3	3	2	3
Mix of Surrounding Land Uses	3	3	2	2	1	2	1	2	1	1	1	1	1	1
Anchors Within a Quarter-Mile Radius	3	3	3	1	1	3	1	2	2	1	2	1	2	3
Adjacency to Planned/Recent Investment	3	3	3	1	1	3	1	1	2	1	2	3	1	3
Residential and Employment Density	3	3	1	1	3	2	2	2	2	3	3	1	1	1
Vacant Buildings and Land Availability	2	3	4	4	2	4	3	2	4	1	2	4	2	4
Land Ownership	1	1	3	3	2	3	2	2	3	1	1	3	2	3
Total	16	18	19	14	13	20	11	14	16	11	14	16	11	18

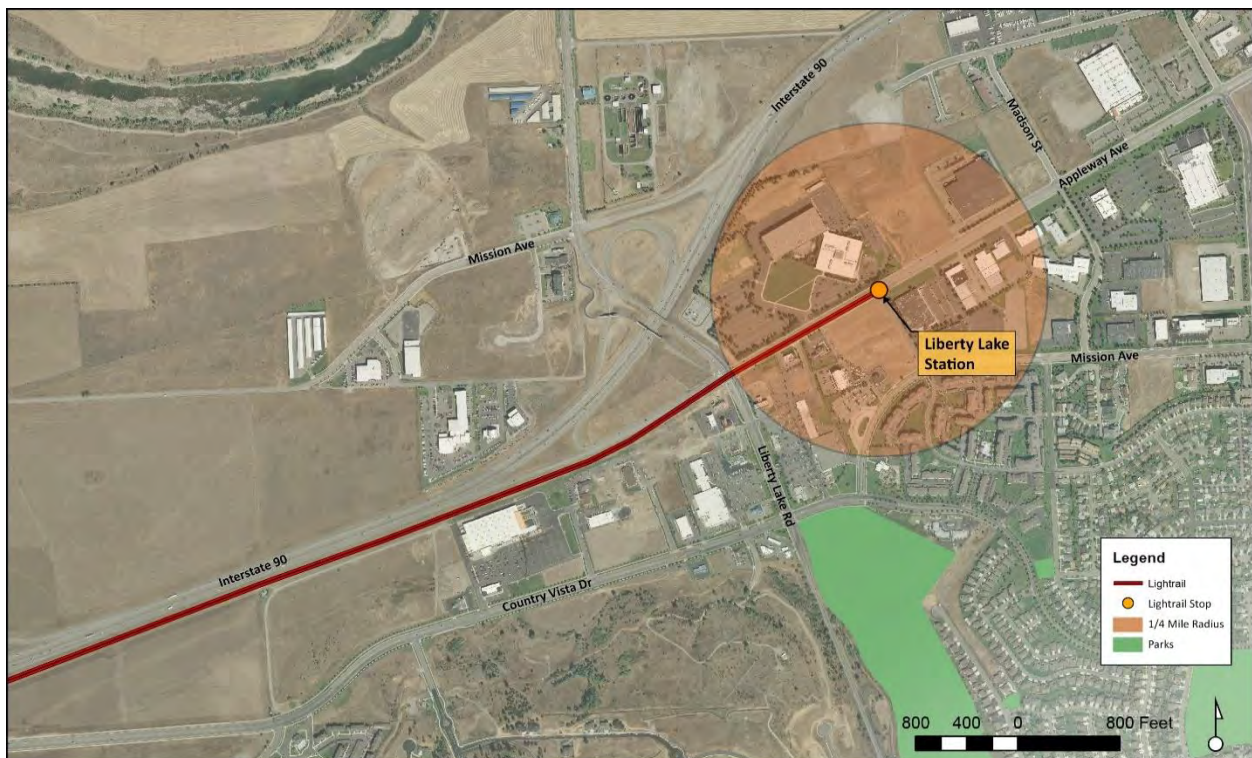
At the time of this study by, ZHA, Inc. et al., there were multiple open parcels of land surrounding the Convention Center. Unfortunately since that time, these parcels have been develop, which would like likely reduce the overall score for “vacant buildings and land availability” at the Convention Center Station.

One reason the Riverpoint and Liberty Lake stations have a high suitability for TOD, is because they both scored the highest in “vacant buildings and land availability,” which demonstrates the availability of large parcels of 20 acres or more that can be developed. Combine that will their score in “residential and employment density,” which was the lowest, and there becomes a great

opportunity to increase the density of residents, as well as employment, with little demolition and infrastructural changes to the current environment. They also both scored the highest in land ownership, resulting in less conflict and a smoother decision making process.

Additionally, Liberty Lake is a prime choice for TOD because of the potential to connect the light rail to Coeur d'Alene, ID. This connection will increase the market for Liberty Lake dramatically by allowing easy access for residences and employees living in Coeur d'Alene. The growth rate of Liberty Lake from 2000 to 2014 was 85.27% or 6.09% annually, if this dramatic increase continues, TOD will be an extremely viable option given its dense nature of development (U.S. Census Bureau, 2014). Whereas Spokane's growth rate has been .59% annually and Spokane Valley's growth rate has been .95% annually, over the same time period (U.S. Census Bureau, 2014). Because of all the previous reasons mentioned, Liberty Lake has been chosen for the study

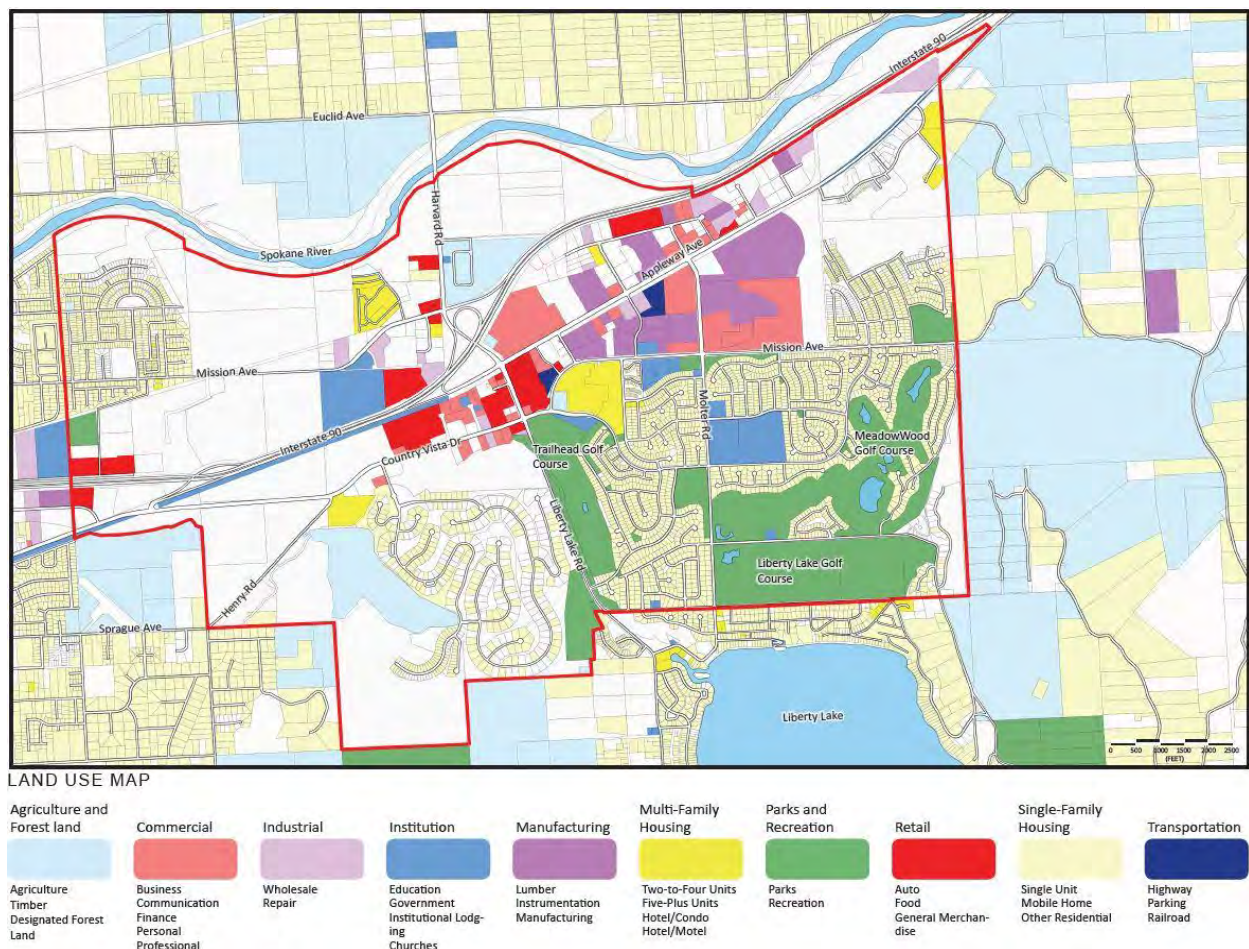
FIGURE 16. LIBERTY LAKE STATION



site. Figure 16. demonstrates the location of a possible Liberty Lake station, in relation to its surroundings. The ¼ mile radius clearly shows various plot of land that would be available for development. This station location was suggested by The Inland Empire Rail Transit Association in 2006. Since 2006 many aspects for Liberty Lake have changed, therefore a new analysis must be completed to determine the area with the greatest suitability for TOD.

The process of determining a site began with examining the existing land use and zoning maps, along with a map of the vacant land thought the city. As we have learned through the literature review section of this report, transit oriented development thrives in or near commercial / business centers. Therefore the existing land use and zoning maps are required. Figure 17

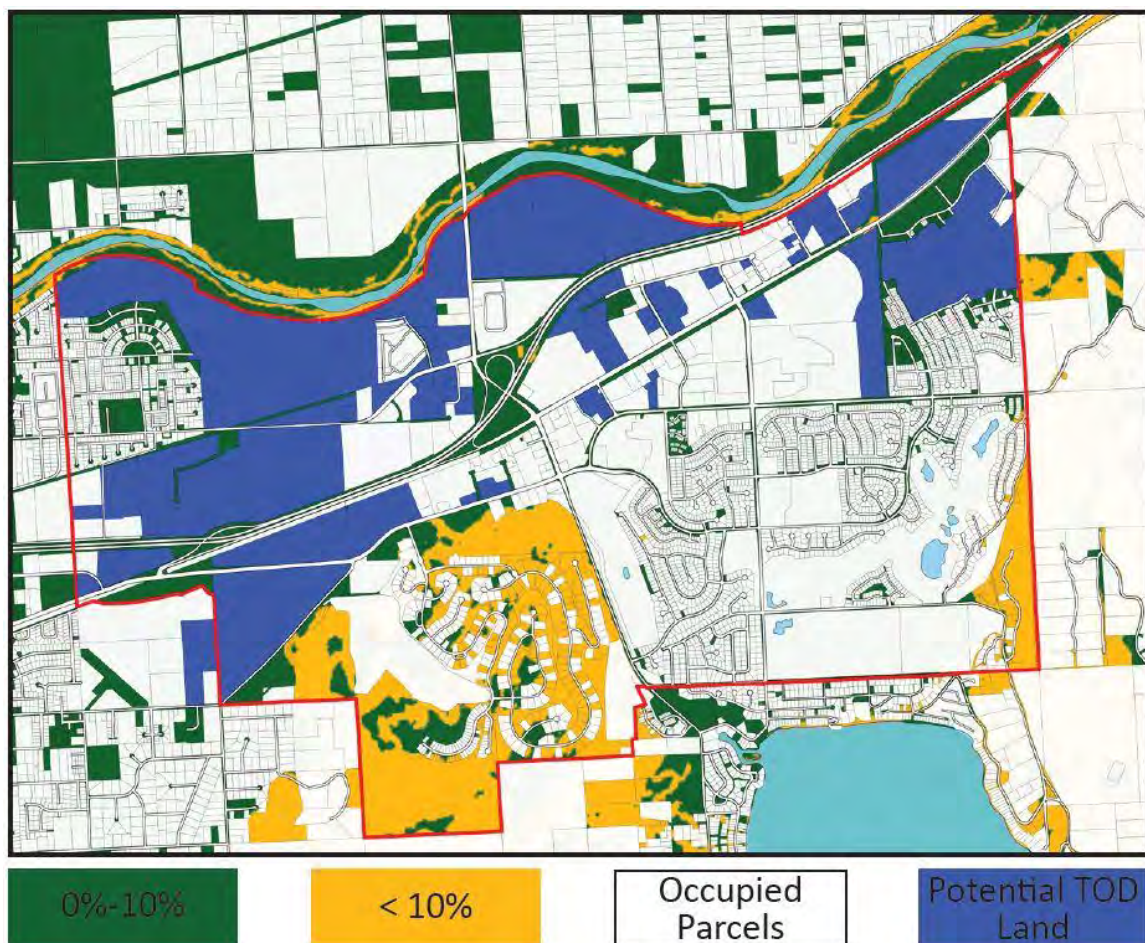
FIGURE 17. LIBERTY LAKE LAND USE MAP



represents the Liberty Lake land use map. Areas to pay attention to are the retail, commercial and vacant area (represented by white). Because they signify the highest suitable areas for development.

The next step is to analyze the city for slopes. It is not recommended for commercial development to take place in areas greater than 10%. Largely due to the increase cost of construction. Therefore, a slope analysis map was developed to determine which areas in the city are under 10% slope. Figure 18 represents the analysis of slope under 10%, overlaid with areas that are vacant. Ultimately leading to the areas of land that have the greatest potential for future development. These final, potential areas are represented by the blue, in figure 18.

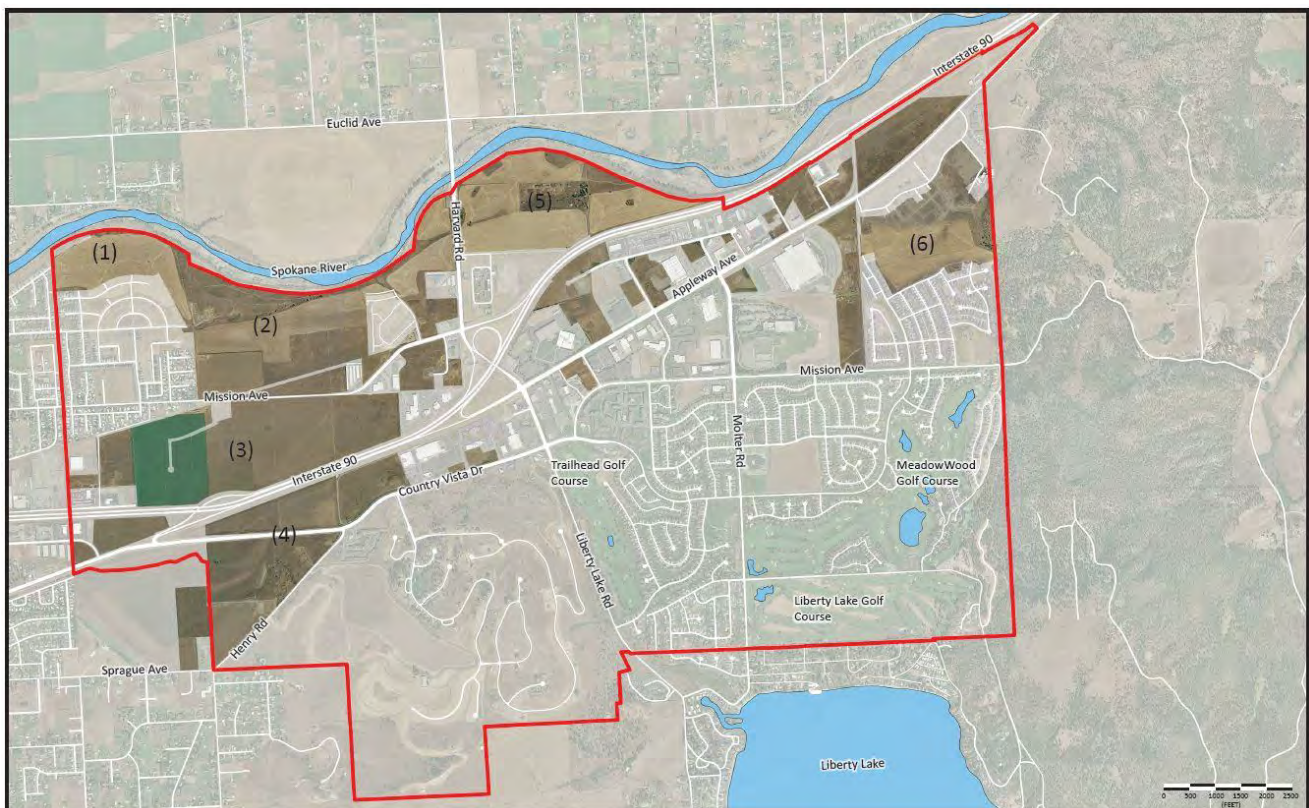
FIGURE 18. LIBERTY LAKE SLOPE AND AVAILABLE LAND OVERLAY



Many of the sites to the north of Interstate 90, presented themselves well for TOD; unfortunately, because of the fact that the light rail route would be implemented on the south side of I 90, this limits the feasibility to develop a TOD to the south side as well. The only route to Coeur d'Alene, would be from the south side of I-90. Therefore, it would not be realistically feasible to route the light rail across I 90, through a development, and then bring it back across the freeway again, in order to reach Coeur d'Alene. As a result, there are only two areas of land that would have the potential to be developed on the south side of Interstate 90 (represented by 4 and 6 Figure 19.).

The surrounding areas of lot 6, have been quickly developing over the past years, there has also be plans to expand development onto lot 6, with a mixed use development. Therefore, the parcels (lot 4) north of Henry Rd and south of Interstate 90, totaling 165 acres, were ultimately chosen to be the *most suitable* area within the City of Liberty Lake, for the potential of transit

FIGURE 19. POTENTIAL TOD LAND



oriented development. Lot 4 provides adequate land for a proper TOD with multiple housing and employment opportunities. There is also easy access provided by Interstate 90 and Country Vista Dr, as well as the future light rail.

The next and final step, was to develop a conceptual master plan designed with the principles of a successful transit oriented development, all the while thinking about many of the green infrastructure elements that would perform the best with TODs. The first concept (Figure 20.) was developed with the original plan to have the light rail placed and run within the Interstate right of way. Keeping within the design principals of TOD, the commercial core was then located around the transit stop, providing the greatest foot traffic to the commercial core. Residential and secondary areas where then implemented around the commercial core, decreasing in density the further away from the transit station. Over all this plan could suffer because the station location is not central, meaning some residents would have to travel further than other. It is also located close to the freeway, resulting in a poor pedestrian environment.

Concept two was then developed with an alternative light rail route which would provide a more central transit stop location, also increasing the centrality of the commercial core (Figure 21.). Similarly to concept one, the residential and secondary areas are implemented around the commercial core, decreasing in density the further away from the transit station. This plan also includes a vegetation buffer from the freeway, to help dampen the traffic noise, and visually block the traffic. Ultimately this plan is much more successful at creating a quality pedestrian environment, as well as, providing a central core for the residence. Once these two concepts were developed, it was then time to produce a final master plan and begin to link transit oriented development with green infrastructure.

FIGURE 20. CONCEPT ONE

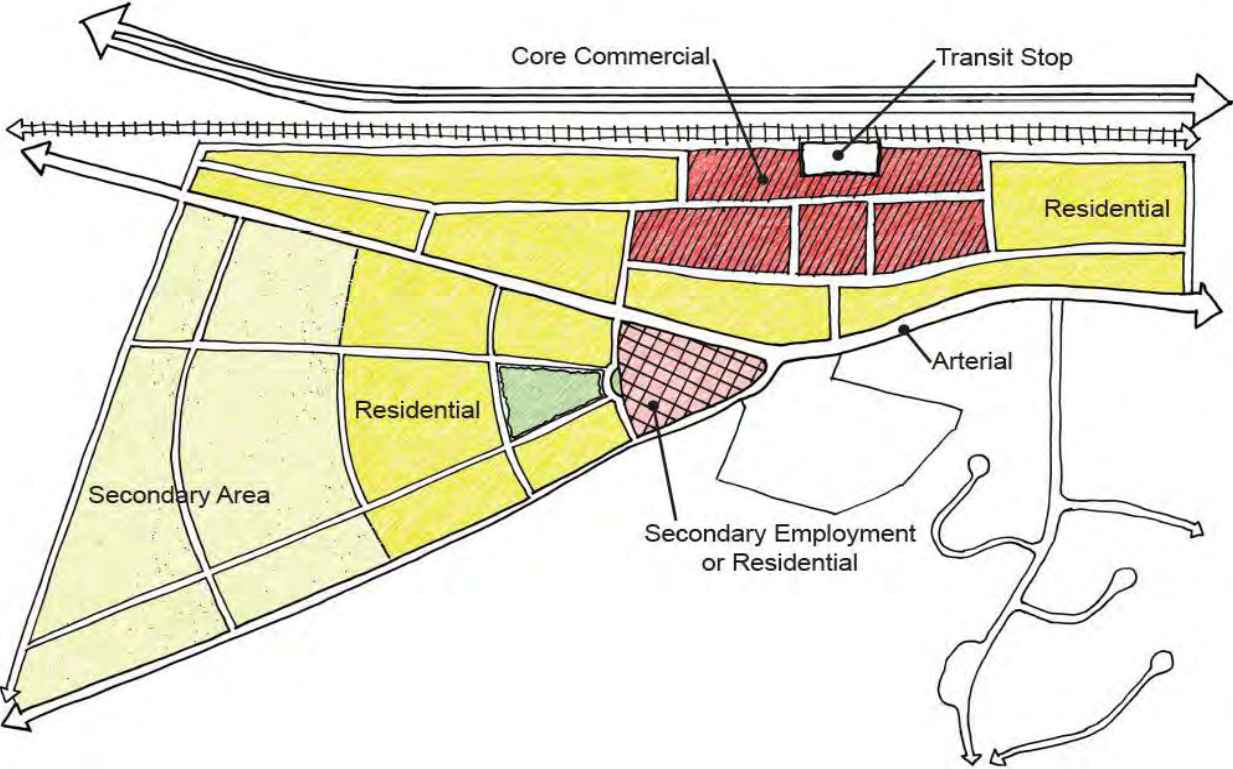
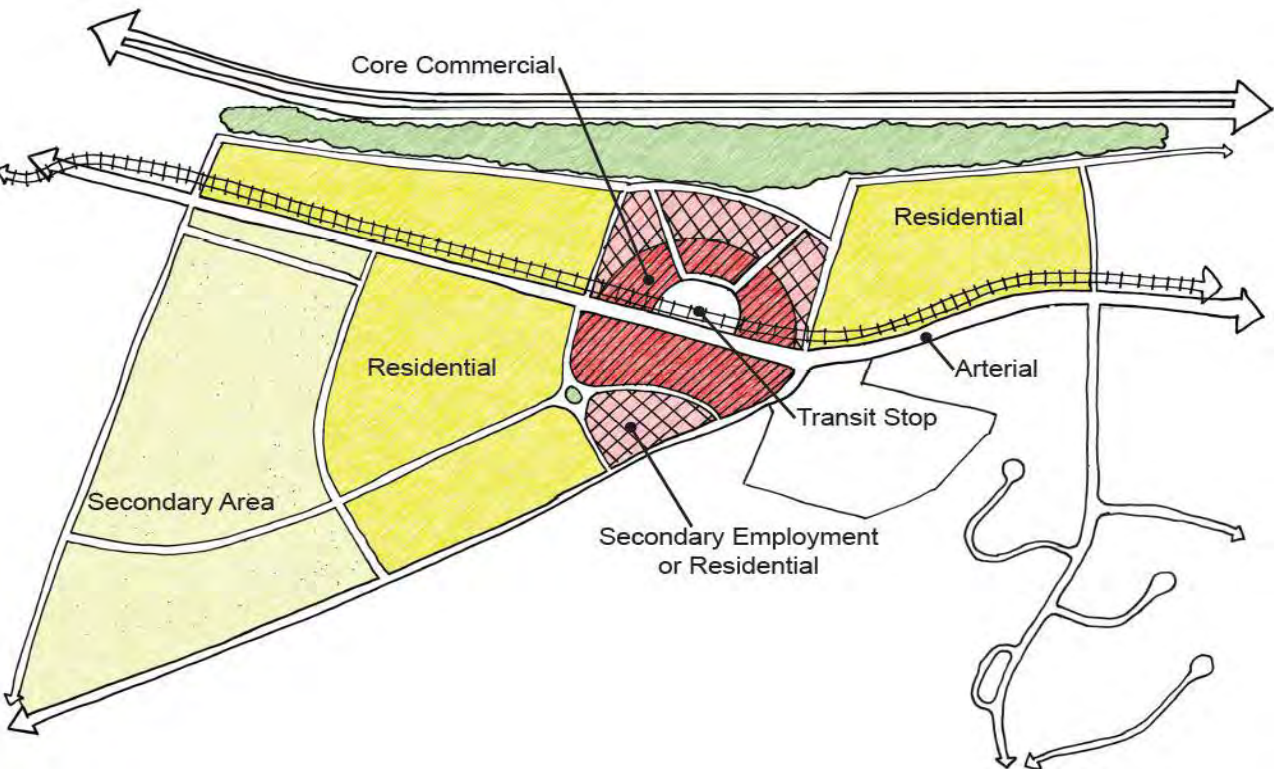


FIGURE 21. CONCEPT TWO

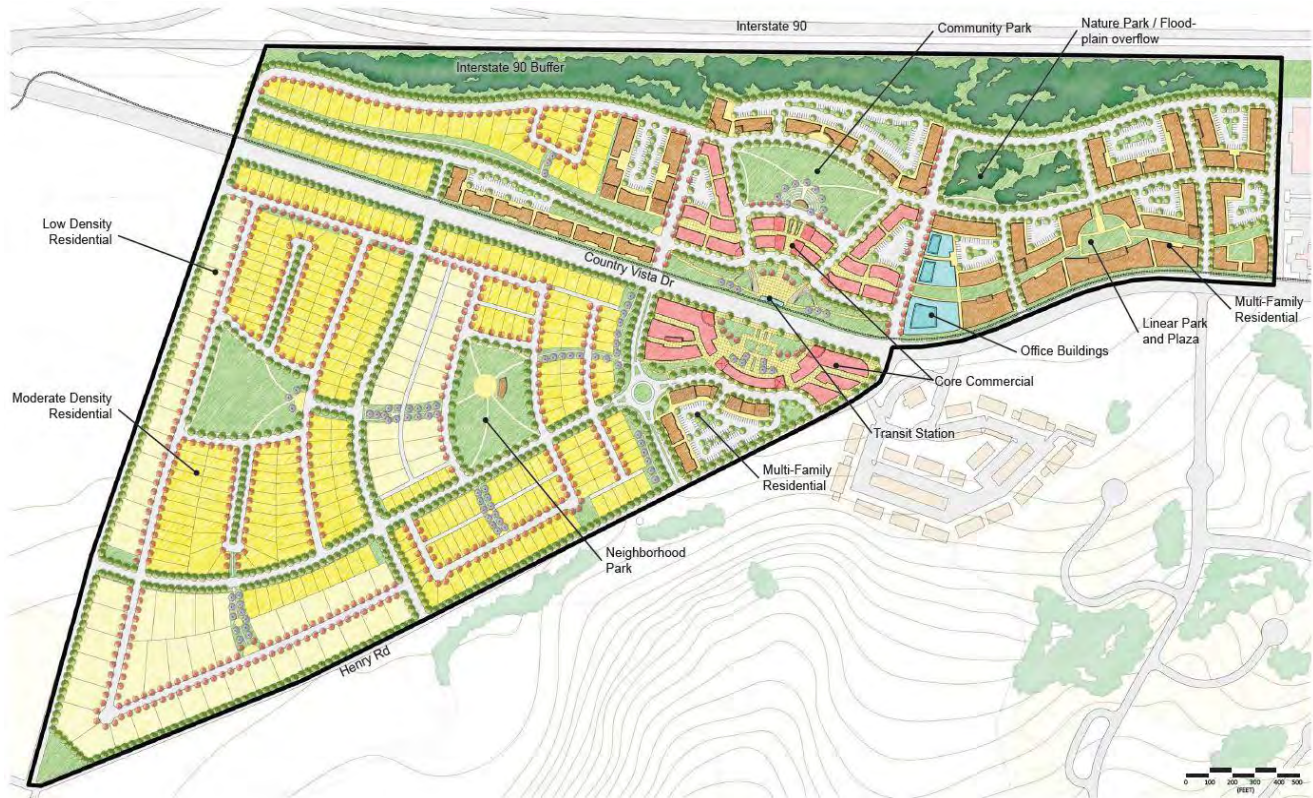


Results

The final Liberty Lake TOD master plan (Figure 22.) was developed based on a combination of the two concepts, with an alternative light rail route and a more central transit stop location. This allows for the greatest foot traffic and visibility towards the commercial areas, which is essential for successful business. This layout provides multiple access routes to the transit station, for pedestrians, via sidewalks along the streets, or through the many path connections through the parks and open spaces.

A variety of housing options have also been implemented to appeal to wide range of the public. There are 75 low density, large lots available; 350 moderate density lots; and 44 multi-family housing buildings, consisting of apartments, condos, and senior living facilities. All of the housing

FIGURE 22. MASTER PLAN



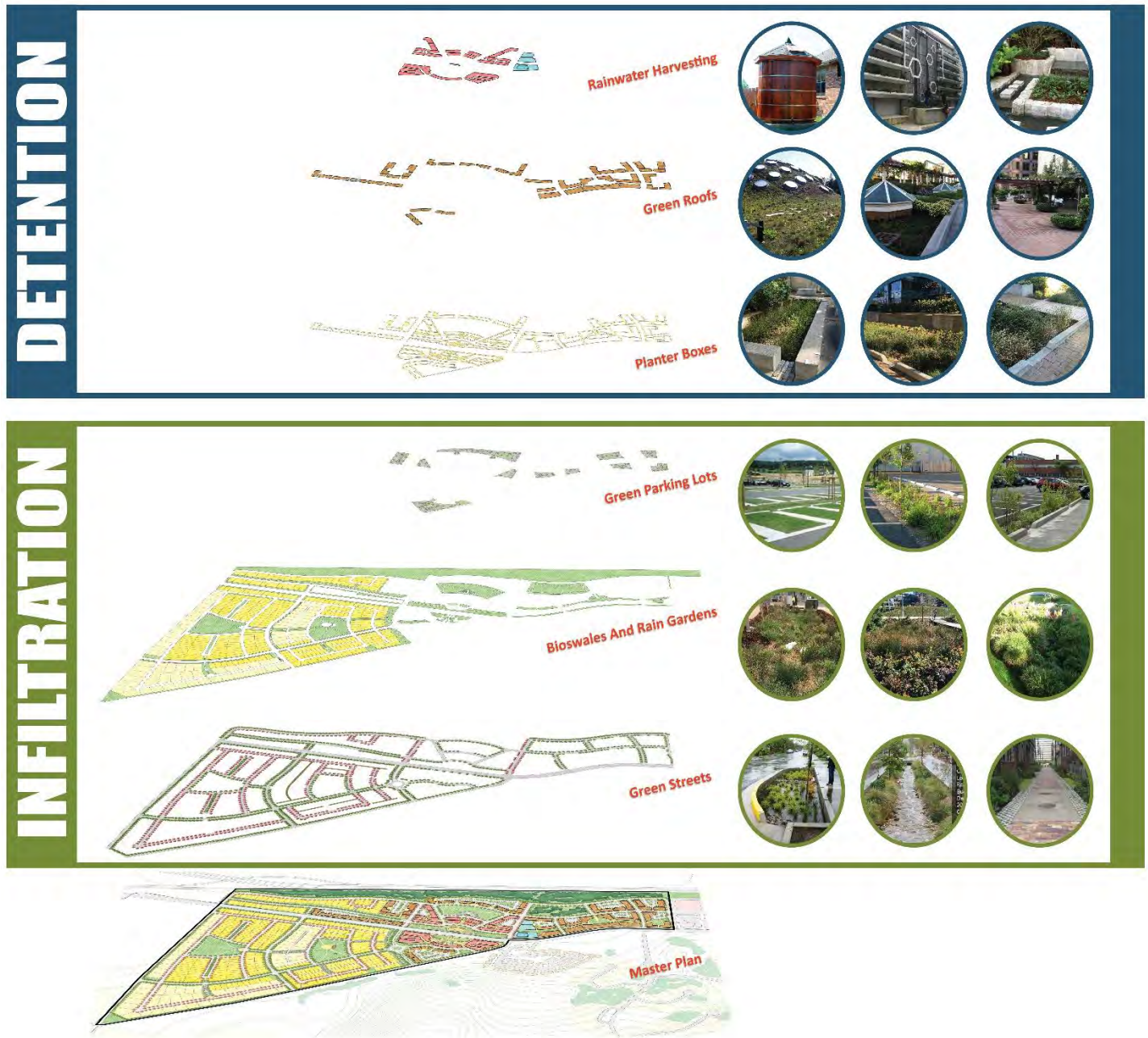
options are within short walking distance to the nearly 20 acres of parks, trails, or public open space, providing great opportunity for active or passive recreation. The parks would also provide ample space for community gatherings and events.

One of the most important aspects of the design is the large vegetative buffer strip placed along the freeway. This will provide a physical barrier from unsightly traffic, as well as help dampen the traffic noise.

Now that the final master plan layout had been developed based upon proper TOD principals, it was time to focus on how green infrastructure should be incorporated into the plan. Given the possible green infrastructure techniques, listed previously in the literature review section – 1) Rainwater Harvesting, 2) Green Roofs and Walls, 3) Planter Boxes, 4) Green Parking Lots, 5) Green Streets and Alleys, and 6) Bioswales and Rain Gardens, a matrix was developed to help demonstrate possible applications with this actual site (Figure 23.). This matrix divided the green infrastructure techniques into two categories, detention and infiltration. Rainwater harvesting, green roofs, and planter boxes were described as detention, because they are primarily water capturing systems. Whereas green parking lots, rain gardens and bioswales, and green streets, were described as infiltration, because they primarily collect, filter, and allow water to infiltrate into the water table.

The next step was then to take a few of these techniques and evaluate them further by going through design development to project more refined plans. The strategy for this was to look at an area on the master plan that could benefit the most from further design, and that could maximize the green infrastructure efforts. The area on the site chosen for this was the transit station and half of the commercial core (Figure 24.). These area would undoubtedly see the

FIGURE 23. GREEN INFRASTRUCTURE IMPLEMENTATION MATRIX



highest pedestrian foot traffic, meaning there is great opportunity to provide a high quality pedestrian environment (essential for a successful TOD). This area would also be able to generate the most revenue from potential developers, which we know is needed most of the time to pay for the more expensive green infrastructure, rather than traditional grey infrastructure. Again because of time constraints with this project, this area chosen to be further examined, would

FIGURE 24. GREEN INFRASTRUCTURE AREA FOR FURTHER DESIGN DEVELOPMENT

only be able to do so with a few green infrastructure techniques. Figure 25. Represents the three techniques which are to be further examine; green parking lots (represented by the blue areas), green roofs (represented by the green areas), and rain gardens and bioswales (represented by the yellow areas). These three techniques were chosen because they have the most viability to be implemented in an actual project in the Spokane region⁵.

Now that the areas and specific techniques were chosen, it was time to begin the design development phases. The first technique developed were the green roof. These roofs were designed on the four central building, between the central park and the transit station. As was mentioned in the literature review, green roofs come in two forms – intensive or extensive. Extensive green roofs generally require very low maintenance and primarily consist of sedum

⁵ Green roofs might not be as viable in this region do to the changing climate and high construction cost, but they will still be examined because of their many social and environmental benefits.

FIGURE 25. GREEN INFRASTRUCTURE COLOR CODED AREAS

plantings. They are generally only used for green infrastructural benefits and not used for additional living space. On the other hand, intensive green roofs offer additional living space by offering patios, and spaces for people to enjoy. They consist of more traditional plantings and have higher maintenance requirements. The green roofs throughout this development will consist of both intensive and extensive green roofs – providing the best of both worlds. These roofs will help contain and filter stormwater runoff, create habitat for wildlife, increase agricultural space, and provide living spaces for people to interact with. In most storm events, rainwater will likely never reach the ground because of the absorption capabilities of the green roofs. Because these roofs help increase the pedestrian living environment, along with enhancing the pedestrian environment, they benefit the both stormwater management, as well as the principals of green infrastructure. Figures 26 – 28 represent the green roof plan, along with supporting perspective images.

FIGURE 26. GREEN ROOF PLAN



Figure 27. View of the intensive portion of the green roof. This roof offers many seating areas, a fire and water feature, and raised cortin planters.

Figure 28. View of the intensive portion of the green roof looking back towards the roof entrance and the extensive green roof.



The next techniques that was further developed was the green parking lots. These two lots were each located behind four of the commercial core buildings⁶. Green parking lots are designed to collect and manage stormwater more efficiently and efficiently than traditional parking lots. In this case, as Figure 29. shows, pavers will be utilized in the parking stalls to reduce peak runoff by allowing water to infiltrate directly into the water table. The parking lot will also contain many vegetative swales along the sidewalks, which will be connected with channel drains. Allowing runoff from the hardscape areas to collect and eventually drain to the two large rain garden swales. These two large swales will manage the majority of on-site stormwater runoff. In order to properly design the swale / rain gardens, the rational method for calculated stormwater runoff was used⁷. The City of Liberty Lake requires stormwater retention swales to be designed to

FIGURE 29. GREEN PARKING LOT PLAN



manage run-off from 25 year, 2 hour storm event. In this case that intensity number happens to be .46. Table 10. Represents the calculations for total stormwater run-off, using the rational method, for a 25 year, 2 hour storm event. This total comes to 3,336 cubic feet of water. To completely manage this about of water, the two rain garden swales have the capacity to hold a combined 4,402 cubic feet of water.

⁶ Locating the parking lots behind the buildings is a key design principal for both green infrastructure and TOD.

⁷ The rational method of stormwater calculations is: $Q=ciA$. Where Q = the peak water discharge, c = runoff coefficient, i = rainfall intensity, and A = drainage area in acres.

TABLE 10. STORMWATER RUN-OFF CALCULATIONS

Parking Lot		
	Building = 21,950 sq/ft (.504 ac) Hardscape = 21,200 sq/ft (.487 ac) Pavers = 4,740 sq/ft (.109 ac) Softscape = 5,775 sq/ft (.133 ac)	
	$q = C i A$ Building: $q = (.95) (.46) (.504)$ $q = .0527 \text{ ft}^3/\text{sec}$ Hardscape: $q = (.90) (.46) (.487)$ $q = .0482 \text{ ft}^3/\text{sec}$ Pavers: $q = (.4) (.46) (.109)$ $q = .0048 \text{ ft}^3/\text{sec}$ Softscape: $q = (.35) (.46) (.133)$ $q = .0051 \text{ ft}^3/\text{sec}$	Building 0.2202 ft^3/sec Hardscape 0.2016 ft^3/sec Pavers 0.0201 ft^3/sec Softscape 0.0214 ft^3/sec 0.463 ft^3/sec
	3,336 ft^3 for 2 hours	
Swale One	2,432 ft^3 Water Holding Capacity	
Swale Two	1,970 ft^3 Water Holding Capacity	

The stormwater calculations from Table 10. color coordinates with Figure 30. Where each of the buildings have been assigned a run-off coefficient of .95 because they are impervious. The hardscape areas were assigned a run-off coefficient of .90 because

they are nearly impervious. The pavers were assigned a run-off coefficient of .4 because they are permeable and allow water to move through them. Lastly, the softscape areas were assigned a run-off coefficient of .35 because they also allow for water movement and transfer.

Figures 31. and 32. Represent perspective images of this green parking lot.

FIGURE 30. COLOR CODED GREEN PARKING LOT PLAN



Figure 31. View looking south towards swale one.

Figure 32. View of the rain garden in swale one, with the boardwalk path.



Lastly, rain gardens and bioswales were examined further. These rain gardens were to be located on both the east and west sides of the transit station. They were designed to capture, filter, and infiltrate water from four of the commercial core buildings around the station, the roads surrounding the station, and all the hardscape areas within the transit station itself. The same steps and calculations were used here, as with the green parking lot. In the end, the two rain gardens will have the capacity to hold over 16,800 cubic feet of water and the 25 year, 2 hour storm event will generate just below 13,200 cubic feet of water. Leaving plenty of capacity for

over flow during larger storm events. Figure 33. represents the final plan view of the large rain garden. At its deepest point, the swale is three feet. To gain greater visitor interaction, a boardwalk has be place throughout the rain garden. Thus allowing guests to become closer to the plants and the process of stormwater infiltration.

Figure 34. demonstrates a typical section cut through the rain garden. The boardwalk is three feet above the ground, at the maximum. This view also shows the 12" of constructed bioswale soil at the base of the swale, along with 6" of topsoil in the remaining planting areas.

FIGURE 33. RAIN GARDEN PLAN

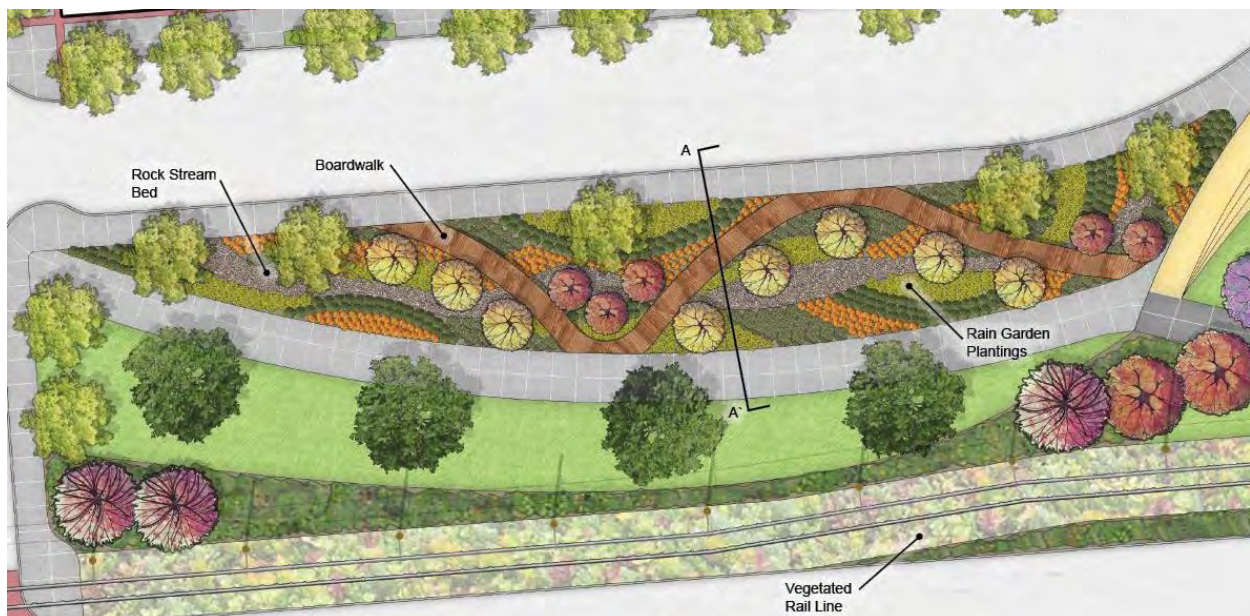


FIGURE 33. RAIN GARDEN PLAN



Discussion

With the previous transit oriented development master plan layout, along with all the green infrastructure techniques and the further examination of three of those techniques, it is clear to see that there is a great opportunity to link TOD with green infrastructure. Because TOD is high focused on the pedestrian environment, it becomes obvious that whichever green infrastructure techniques are to be considered for future developments, that they too place a high focus on the pedestrian. This has clearly been demonstrated to be an effective approach with the design development phase in this project. By providing green roofs that both collect and filter stormwater run-off, along with providing great entertainment spaces for the TOD residence and visitors. Also by creating safe and enjoyable streetscape, that place parking lots behind the buildings. Parking lots that become aesthetically pleasing with concrete pavers, planter boxes, and native rain gardens – all serving double duty by providing great environmental and ecological benefits. Lastly, by turning a rain garden into a public “park like” amenity. By implementing a boardwalk, thus allowing visitors to interact with the rain gardens, as well as creating multiple avenues of transportation through the site.

Green infrastructure and transit oriented development will be important alternatives to traditional design and development in the coming generations. Because of this, coupling the two, intends to produce greater sustainability practices for future development. This can be accomplished by reducing the impacts of sprawl and automobile usage, in addition to, the negative impacts of traditional grey infrastructure; such as, high construction and maintenance costs, river and lake contamination, the loss of native drainage patterns, etc. (Odefey et al. 2012 and “Grey Infrastructure” 2016).

The results from this project have the potential to impact many aspects of community development and the built environment, in an attempt to nudge the current practices towards a more sustainable and “green” approach to development. It has been demonstrated, that various green infrastructure techniques, not only can be implemented with transit oriented development; they can be implemented in a thoughtful manor, resulting in many environmental benefits and greater pedestrian quality.

This project and report has been produced based on literature review, case studies, and site visits, there has been no experiments or first hand observations done on TOD and green infrastructure. In addition to that, there are a lack of available projects that incorporate TOD and green infrastructure; as a result, future research will be required to gain a greater understanding of the possible link between the two, and how the sustainability is improved. This project and report intends to act as a starting point for the link between green infrastructure and transit oriented development in creating sustainable communities.

Conclusion

With current demographic changes, along with increasing traffic congestion, city living has become an enticing alternative to the suburbs. Because of this, dense housings and public transit services have also become more valuable. Both of which transit oriented development takes advantage of. By directing growth with high density, mixed-use development, that provides affordability for all income levels, and placing the focus on the pedestrian rather than the automobile to create a quality pedestrian environment, that is all linked to a transit station. Given the inherent complexity of TOD, four main elements were reviewed for their importance in transit oriented developments:

- 1) *TOD TYPOLOGY* helped to describe various scales for TOD. This then begins to create a network of different types of TODs within a regional transit system, and begins to “identify appropriate performance and descriptive benchmarks” for each type of TOD (Dittmar and Poticha, 2004, p. 33).
- 2) *MIXED-USE DEVELOPMENT* described the importance of having many land uses within a TOD, and began to implement guidelines for proper ratios of each land use.
- 3) *TOD PARKING* is one of the most important elements of a TOD in terms of the pedestrian environment because surface parking lot do not create a comfortable and safe environment for pedestrian. Instead they place the focus and importance on the automobile, which subtracts from the transit usage. As a results, several alternate parking strategies were discussed to avoid large surface parking in TODs.
- 4) *TRANSIT STATION* location is critical to the overall success of the development and the ridership numbers. Stations should be centrally located within the TOD to increase the

incentive for transit usage, and to evenly space land uses for all residence. The importance of this element was highlighted in the Orenco Station case study. Where the station was located on the outer edge of the TOD, and as a result, Orenco station provided minimal transit use along the Westside light rail line in Oregon.

Unfortunately, implementing the principles into TODs is not enough; there must also be plenty of attention paid to the implementation of green infrastructure. Which again can be described at a site scale, as referring to specific techniques which aim to reduce energy consumption and manage stormwater runoff. Six main green infrastructure techniques were then briefly reviewed: 1) Rainwater Harvesting, 2) Green Roofs and Walls, 3) Planter Boxes, 4) Green Parking Lots, 5) Green Streets and Alleys, and 6) Bioswales and Rain Gardens. Finally, three of these techniques – green roofs, green parking lots, and rain gardens were further evaluated based on the high viability to transit oriented development.

All of this information was then used to produce a transit oriented development, with incorporated green infrastructure techniques, in Liberty Lake, WA. The final product clearly showed a high correlation between green infrastructure and transit oriented development, but it all must begin with a focus on the pedestrian. In all aspects of the design process, a high quality pedestrian environment must be the priority.

If many of these principals and goals are used in future development and infill projects throughout our country, we will have a greater opportunity to lead happier and healthier lives, and leave this planet in better state of wellbeing.

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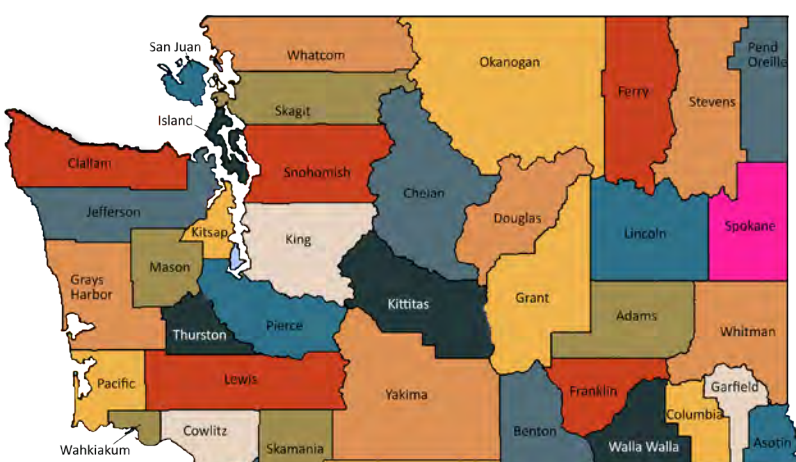
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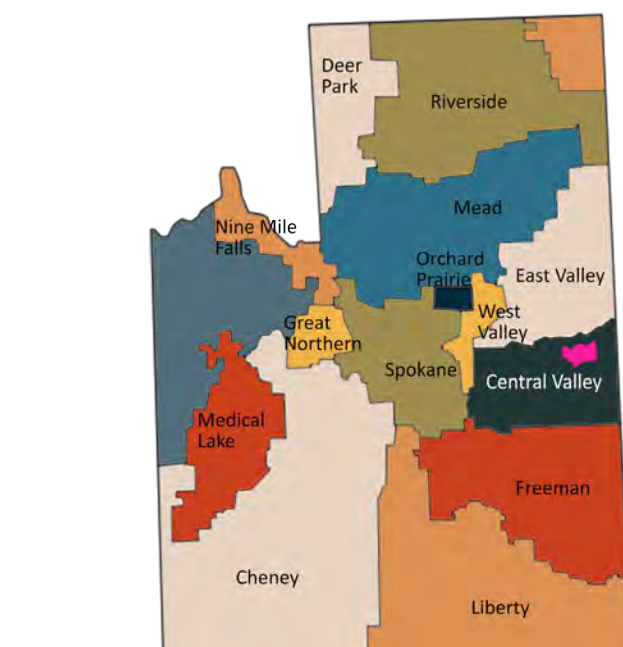
Liberty Lake Transit Oriented Development

Designed with GREEN Infrastructure

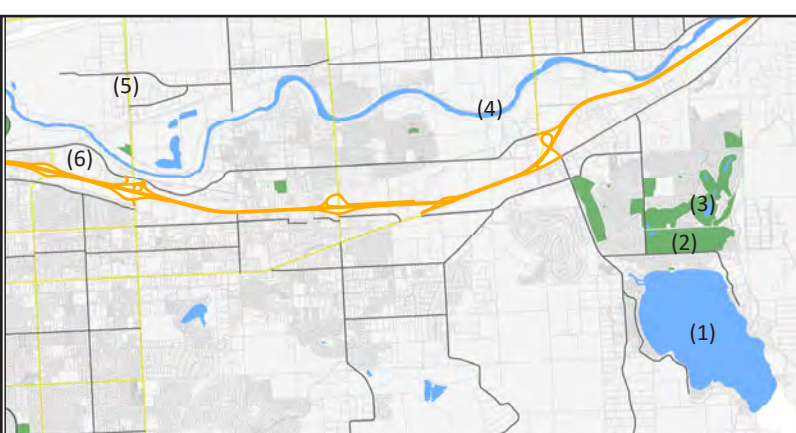
Liberty Lake Site Plan and Context



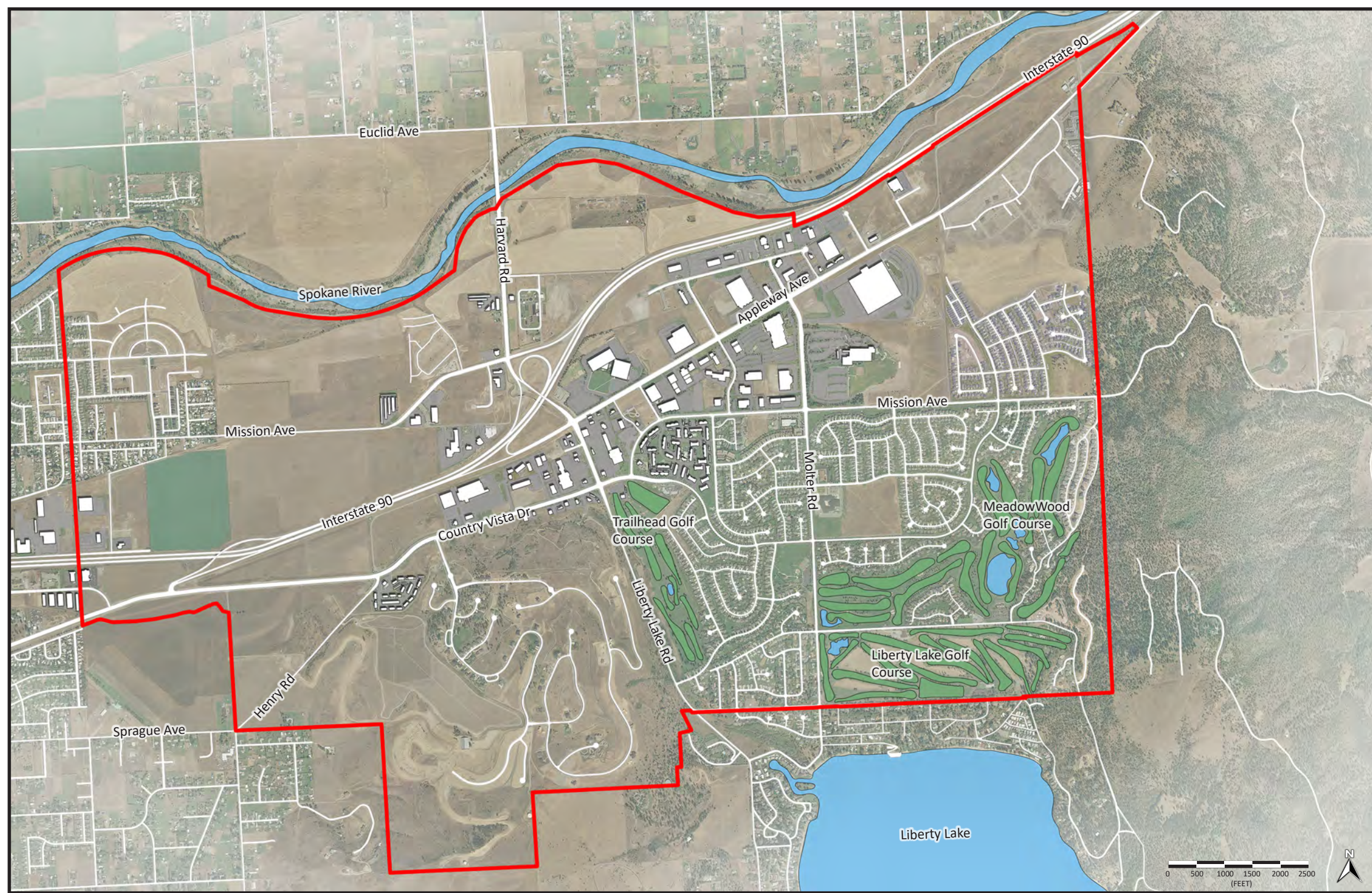
WASHINGTON STATE COUNTIES



SPOKANE COUNTY DISTRICTS



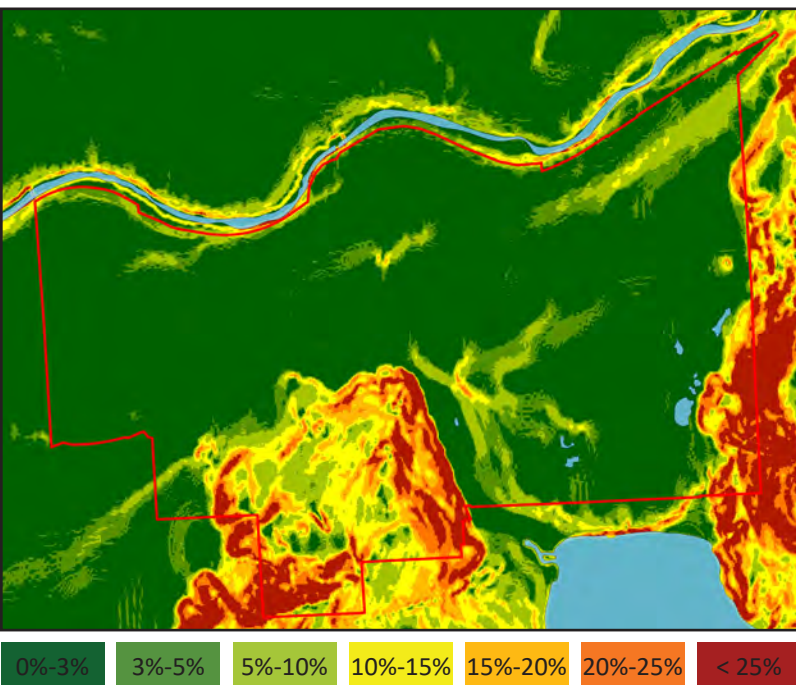
AREAS OF INTEREST



LIBERTY LAKE

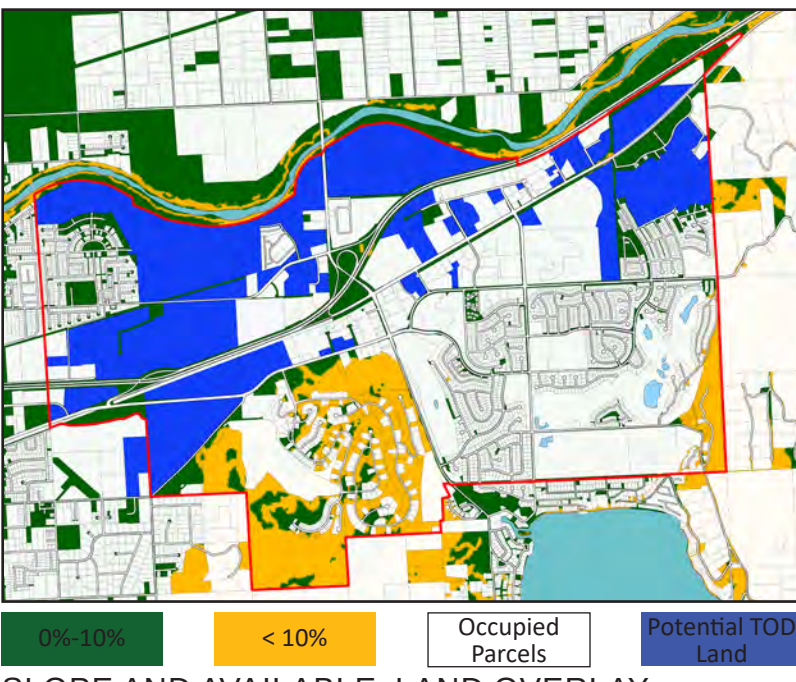


Slope Analysis and Potential TOD Land



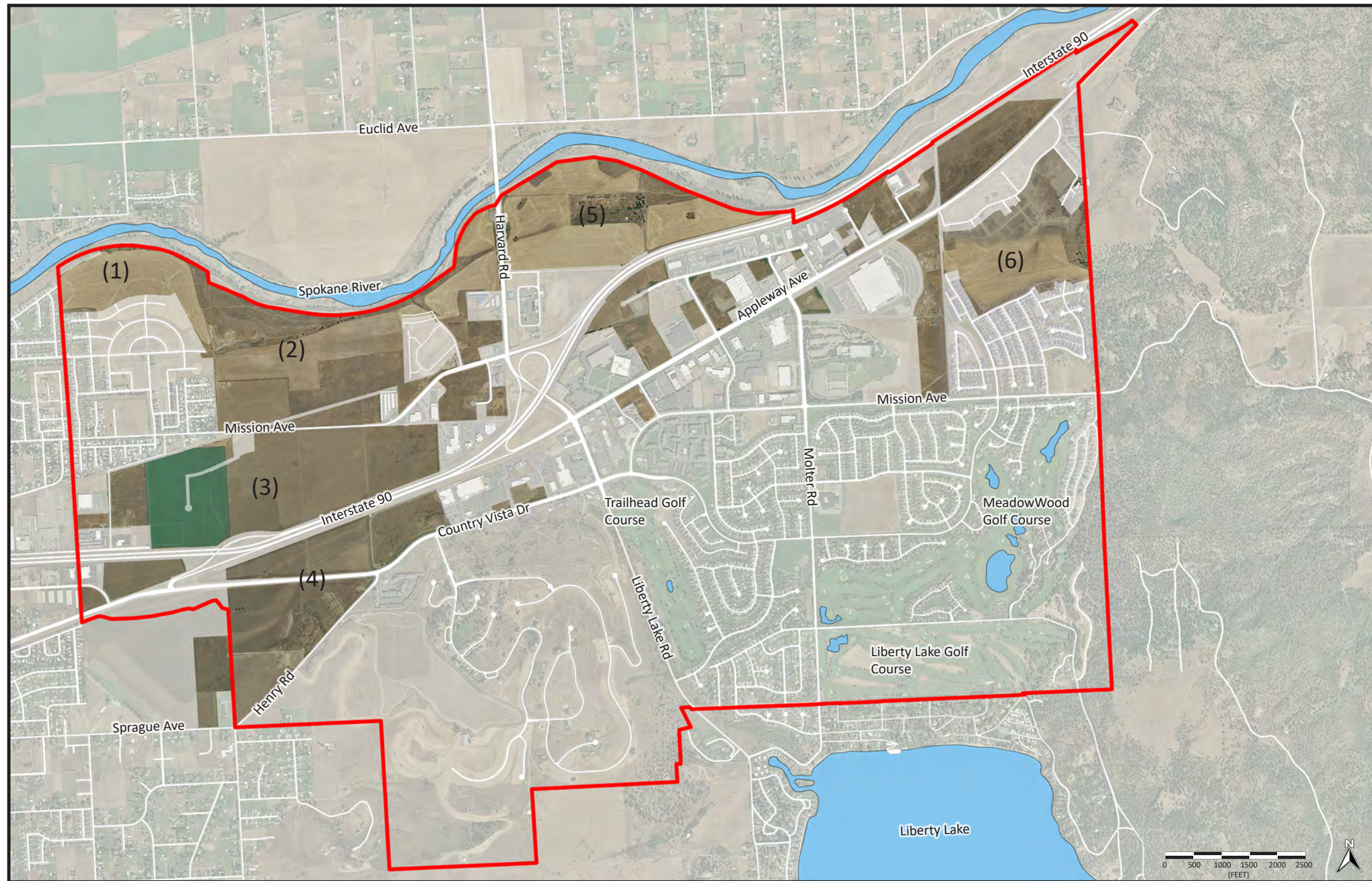
SLOPE ANALYSIS

Slope analysis is vital in understanding the topography of the site. The topography can determine potentially developable and undevelopable areas. Liberty Lake building codes describe slopes over 10% to be excessive; therefore, only slopes under 10% are to be considered for TOD development.



SLOPE AND AVAILABLE LAND OVERLAY

Given that only slopes under 10% are to be considered for TOD, the next step was to reclassify the previous slope map into two categories: slopes greater than 10% and slopes less than 10%. This clearly demonstrates the areas that are to be considered for development (represented by green). Finally, the vacant land map, on the previous page, is overlaid to produce a final map which displayed the potential sites for TOD.



POTENTIAL TOD LAND



Proposed 2006 Liberty Lake Light Rail Route and Stops



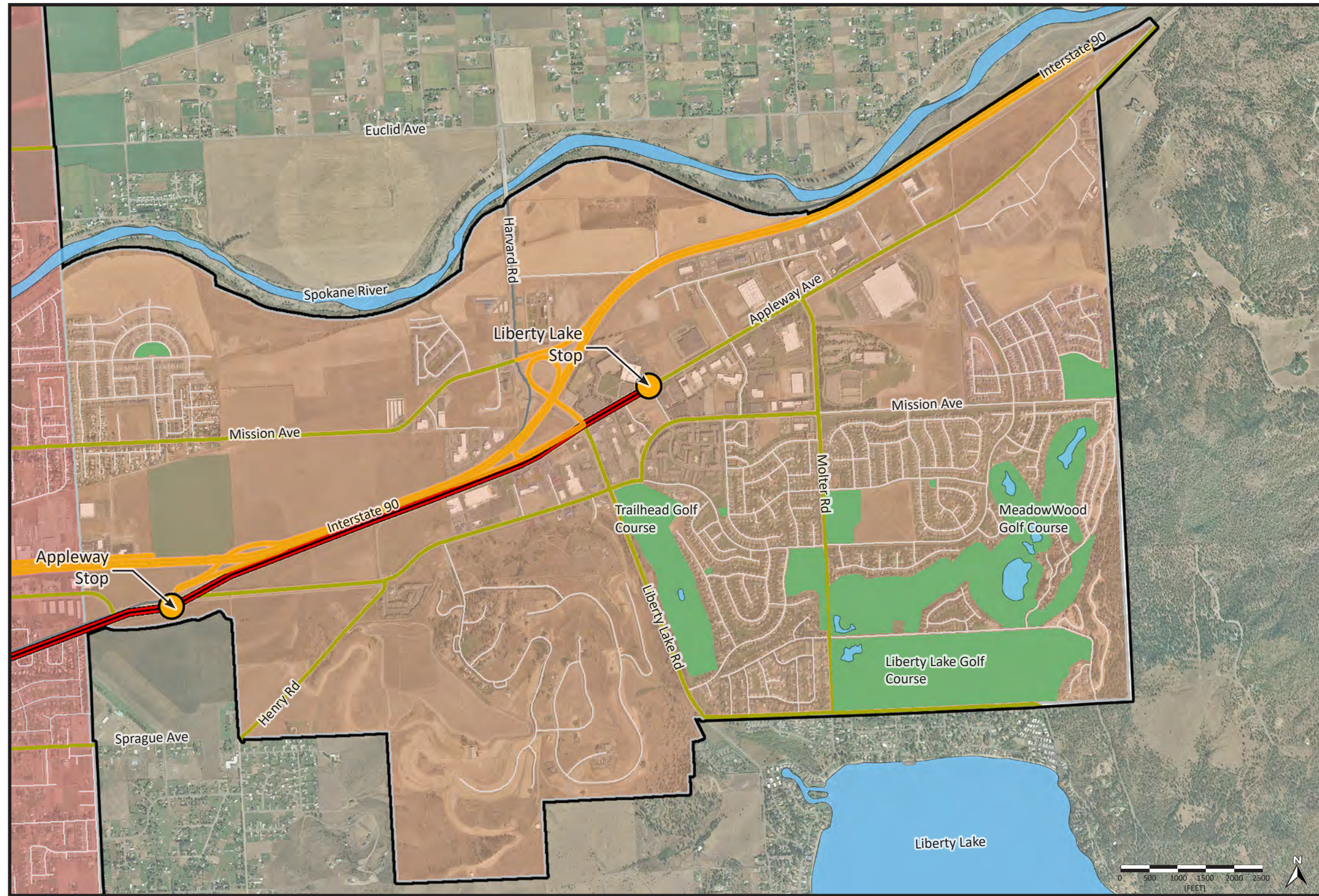
APPLEWAY STOP

Land located in the right-of-way of the southwest quadrant of the I-90 interchange with Appleyway Avenue / Country Vista Road was to be purchased by the transit agency. This station was planned on including construction of a new park and ride facility.

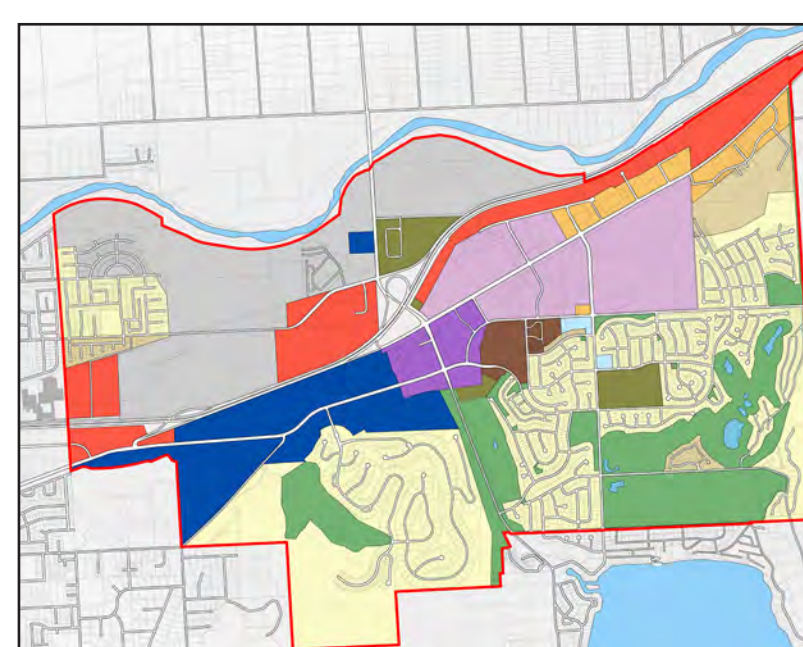


LIBERTY LAKE STOP

The second Liberty Lake stations was to be located in the currently vacant, former railroad right of way, in the southwest quadrant of the intersection of Appleyway Avenue and Signal Road. Because of the existing STA park and ride facility (located to the south of the station site) this station could have potentially been expanded to include the existing functions provided by the STA facility, or replace the existing facility all together.

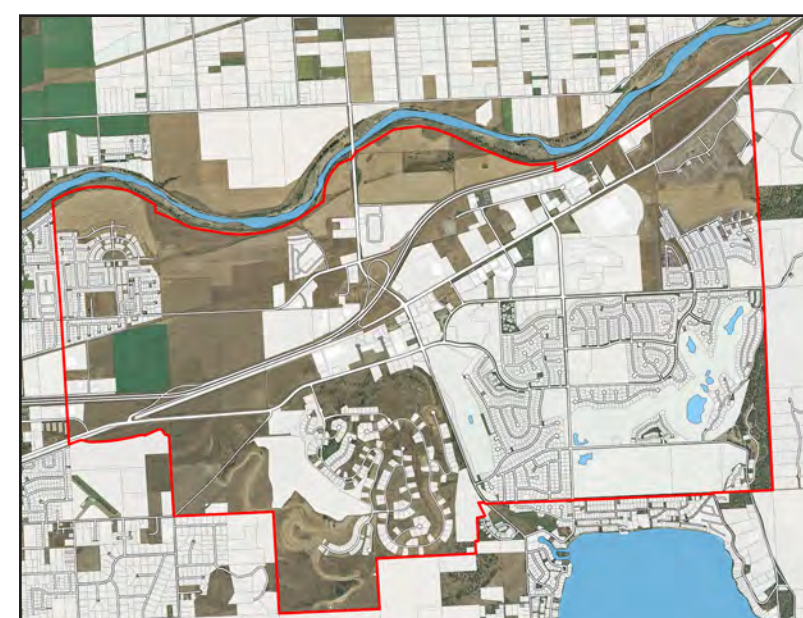


POTENTIAL TOD LAND



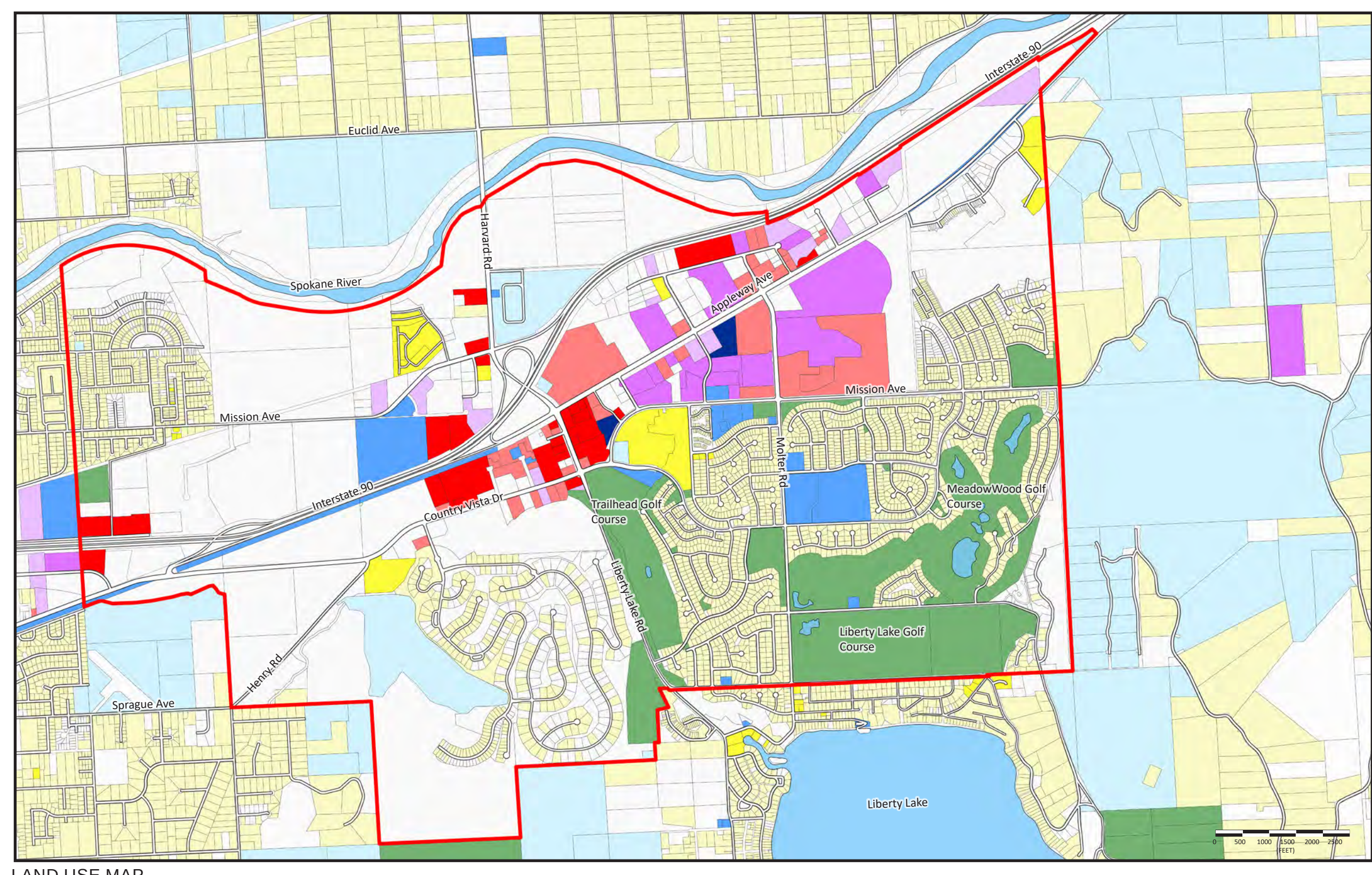
ZONING MAP

Zoning is a form of land use planning, which designates and restricts certain land uses on all areas within a city. Zoning can place requirements on buildings sizes, set backs, facade styles, etc. It can also provide requirements on open space and vegetative plantings. In Liberty Lake, a majority of the city consists of either residential or mixed-use zoning; thus, indicating a level of foresight by the city to provide a livable community.



VACANT LAND

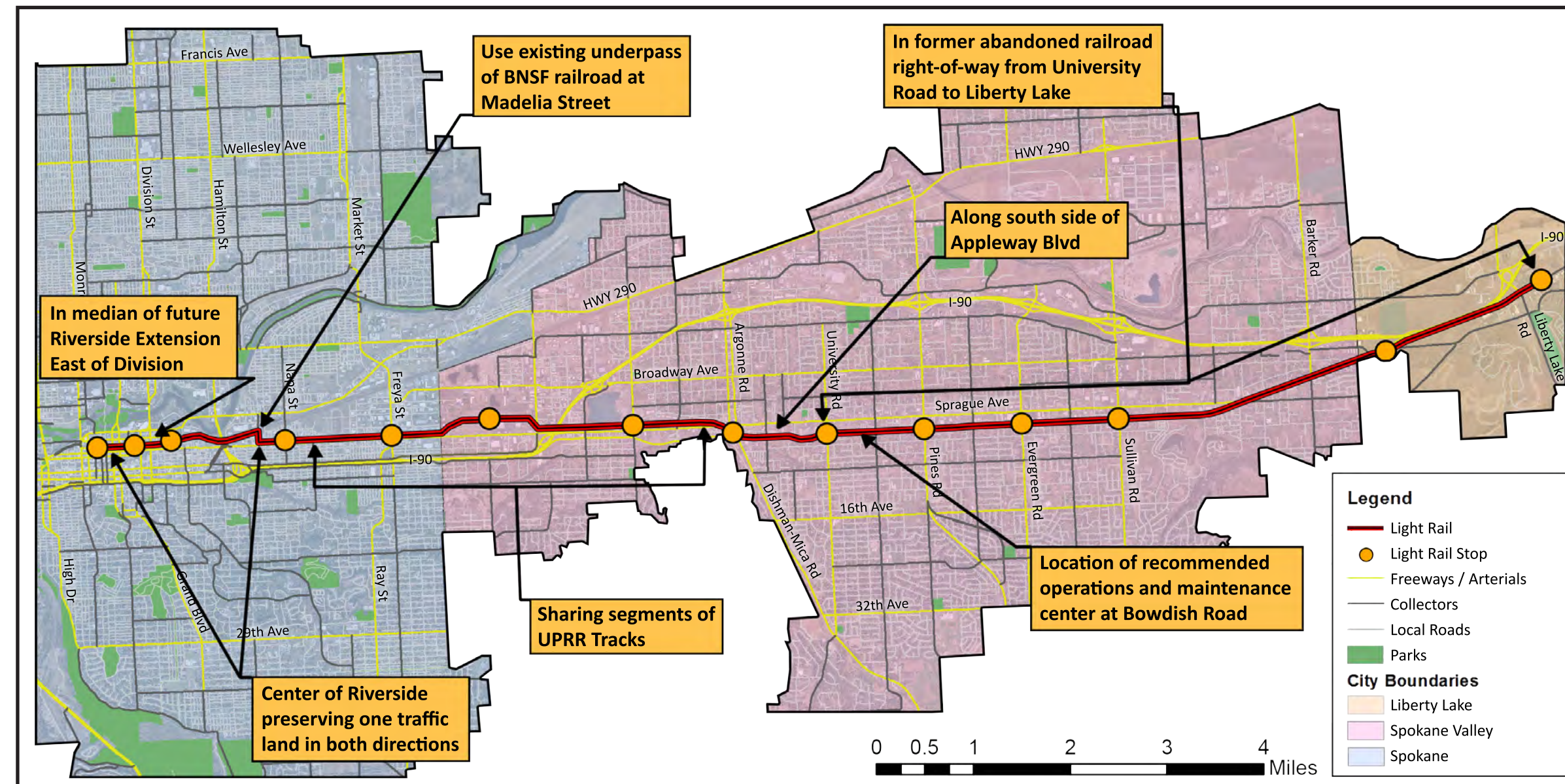
The vacant land map demonstrates all the land which has not been assigned a land use within the city's GIS data. Thus providing a sense of possible TOD development sites.



LAND USE MAP

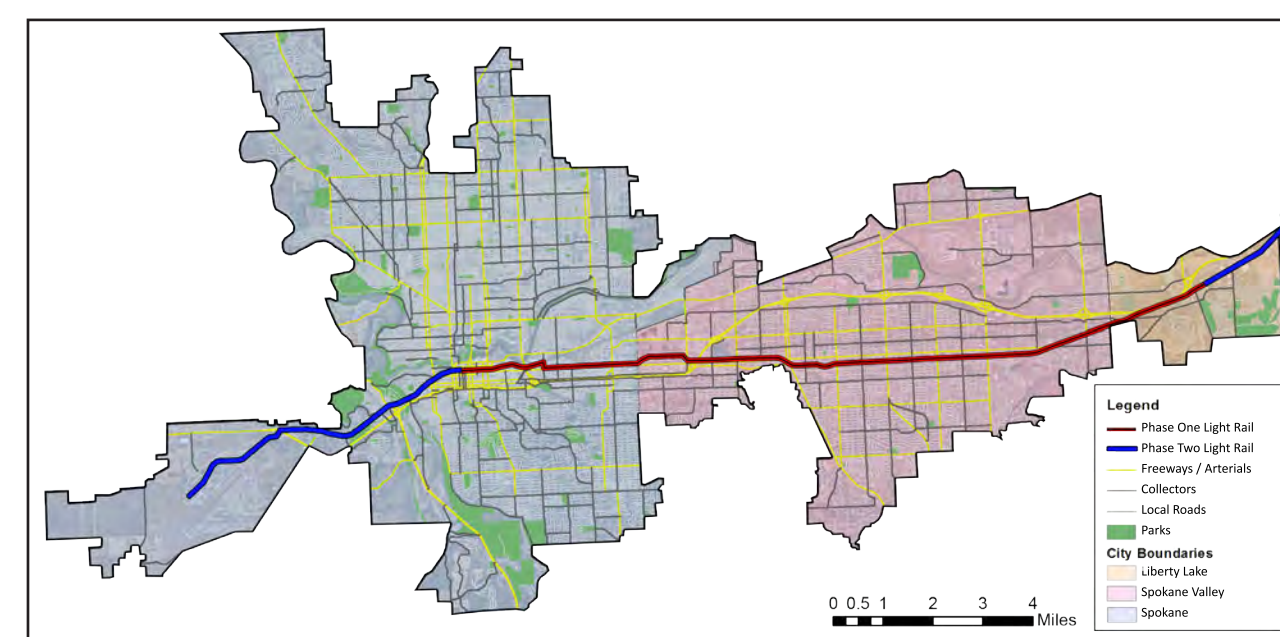
Agriculture and Forest Land, Commercial, Industrial, Institution, Manufacturing, Multi-Family Housing, Parks and Recreation, Retail, Single-Family Housing, Transportation.

Proposed 2006 Spokane Light Rail Route and Stops



LIGHT RAIL PHASES

The overall plan for the light rail was to be developed in two phases. The first phase was intended to connect central Liberty Lake with Downtown Spokane. The rail line would primarily be utilizing existing and abandoned railroad right-of-way, from University Rd to Liberty Lake (shown in the above image). The use of abandoned railroad right-of-way is key to minimizing infrastructural and construction costs. After phase one was complete, phase two would then connect downtown Spokane with the Spokane International Airport; and Liberty Lake to Coeur d'Alene, ID. Although the Spokane International Airport was highly interested in light rail connection for phase one, it was excluded due to the Latah Creek. Bringing light rail across the creek posed a "daunting and potentially enormous financial hurdle"; thus, many felt it would be best to postpone this connection till phase one was complete (Inland Rail, 2013).



LIGHT RAIL MAP

Light rail application in the Spokane region has been examined from as early as the 1970s, when much of today's growth was forecasted (SLR, 2008). In the 1990s, even greater growth increases were being forecasted, which would eventually exceed the current transportation systems capacity. Finally in 1998, the Spokane Regional Transportation Council (SRTC), conducted a study to examine multiple options for future transportation modes to run parallel to Interstate 90. Some of which included "busways, light rail, carpool lanes and traffic flow and bus improvements" (SLR, 2008). After many public meetings, and a year of study, the SRTC Board of Directors recommended light rail as the most viable transportation mode to accommodate future growth. A year later, the SRTC and the Spokane Transit Authority united to conduct further analysis. They began to develop conceptual designs for "light rail alignment, vehicles, station locations, and system operations," as well as conducting financial analysis (SLR, 2008).

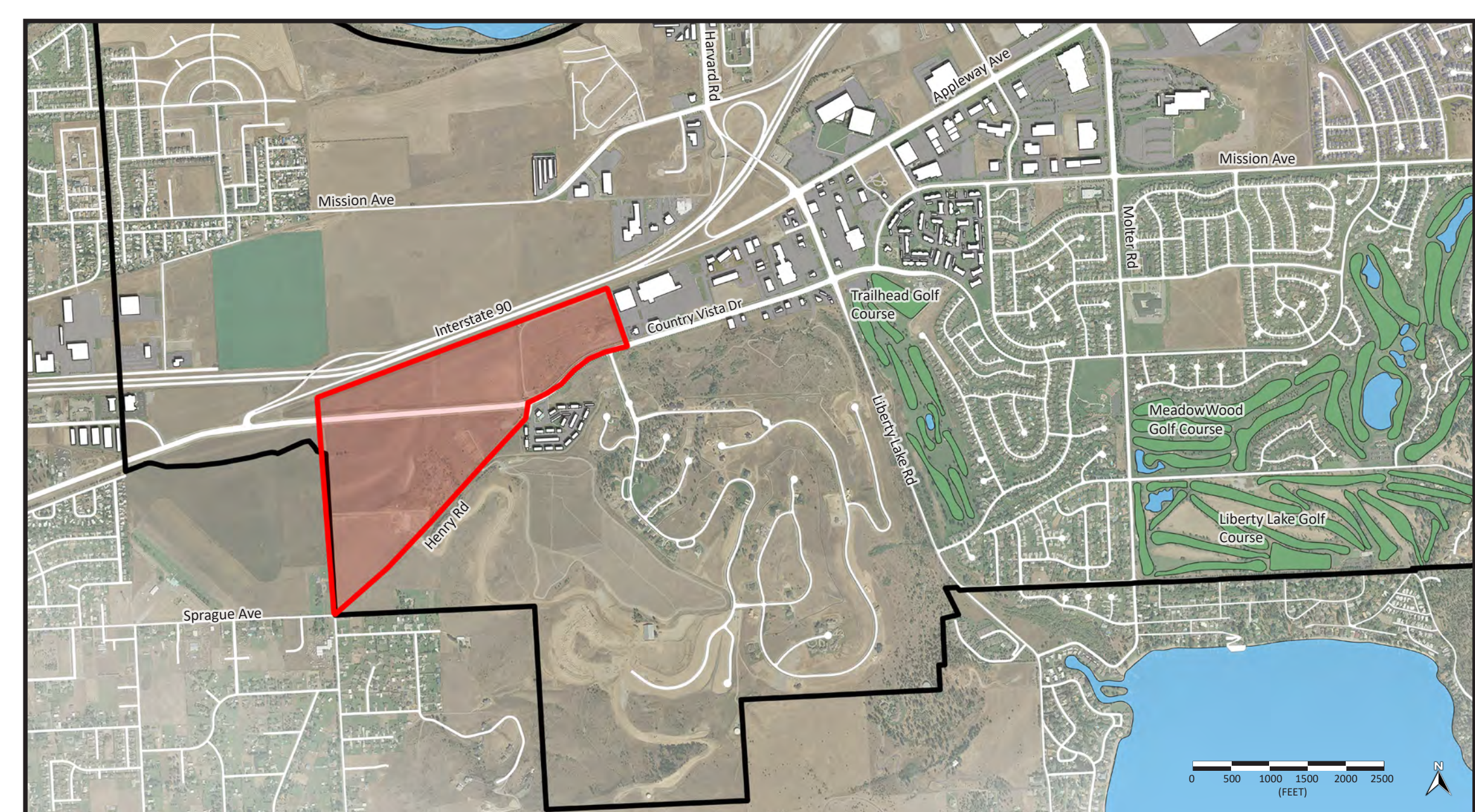
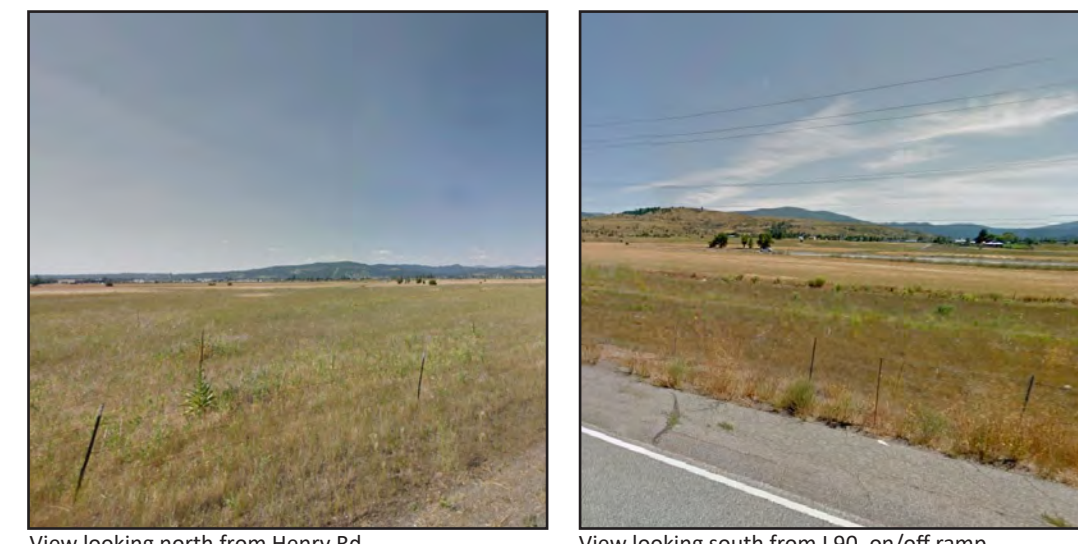
As of 2006 (before the recession) the final plan included:
15.5 miles
14 stations
6 light rail vehicles plus 2 spares
7 Park & Ride lots
Small O&M facility at Bowditch
Single-car trains spaced 15 minutes apart during rush hour, 30 minutes during nights, early AM and Sundays
Transporting approximately 135-150 passengers per train comfortably, 190 passengers at maximum capacity
Train speeds up to 55 m.p.h. outside the downtown area, and total travel time is estimated at about 34 minutes between Liberty Lake and downtown Spokane
2-way options on Single track with short passing tracks
Modestly constructed station platforms
Bus routes reconfigured to facilitate transfers (SLR, 2008)

LIGHT RAIL STOPS

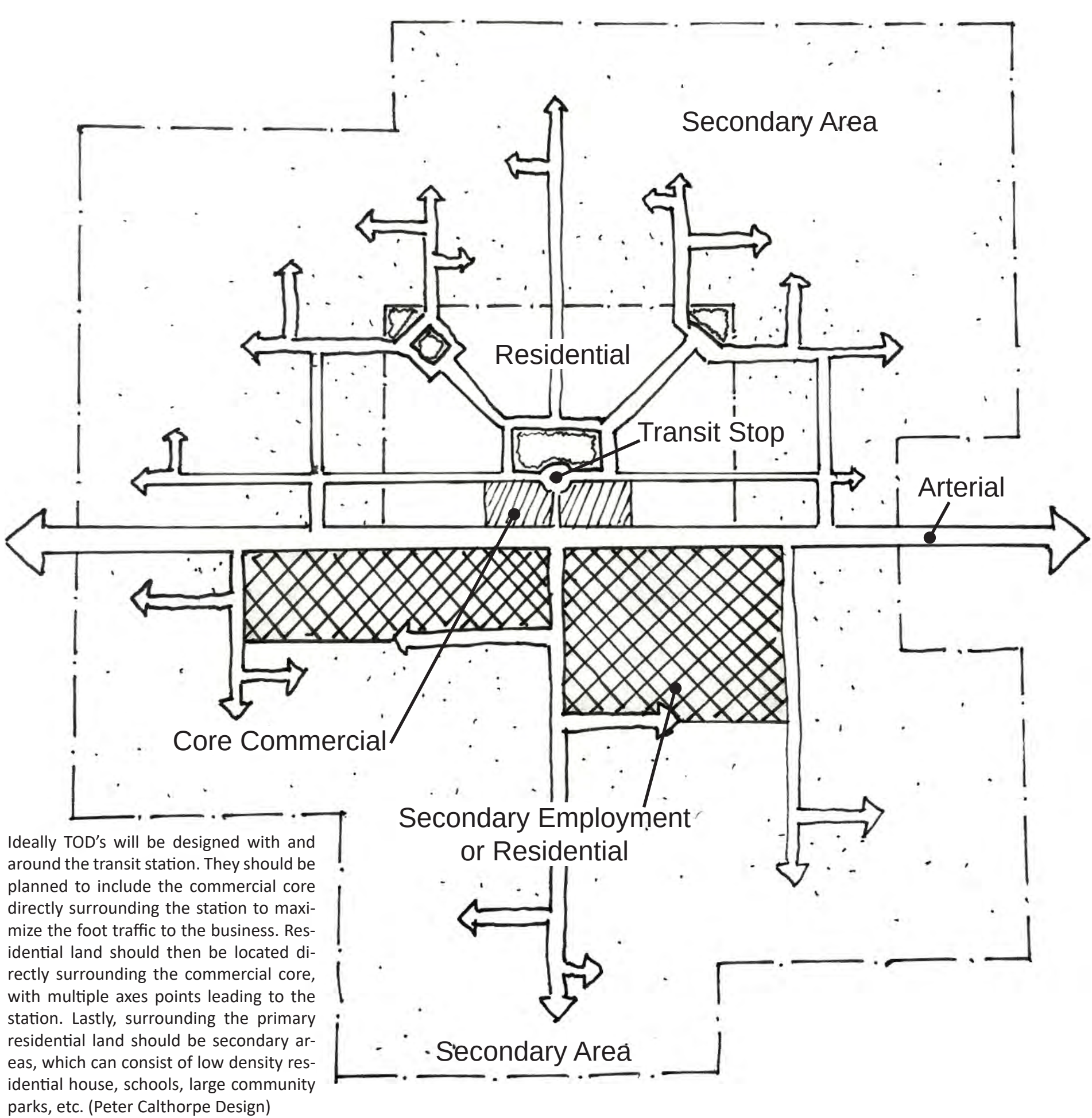
Phase one of the light rail included 14 stops at the following locations (shown on the Light Rail Map):
• Plaza
• Convention Center
• Riverpoint (Trent)
• Napa
• East Central
• Fairgrounds
• Park
• Argonne
• University City
• Pines
• Evergreen
• Sullivan
• Appleyway
• Liberty Lake

SITE SELECTION

Many of the sites to the north of Interstate 90, presented themselves well for TOD; unfortunately, because of the fact that the light rail route would be implemented on the south side of I-90, this limits the feasibility to develop a TOD to the south side as well. The only route to Coeur d'Alene, would be from the south side of I-90. Therefore, it would not be realistically feasible to route the light rail across I-90, through a development, and then bring it back across the freeway, in order to reach Coeur d'Alene. As a result, two areas of land would have the potential to be developed on the south side of Interstate 90 (represented by 4 and 6 on the Potential TOD Land map). The surrounding areas of lot 6, have been quickly developing over the past years, there has also been plans to expand development onto lot 6, with a mixed use development. Therefore, the parcels (lot 4) north of Henry Rd and south of Interstate 90, totaling 165 acres, were ultimately chosen to be the most suitable area within the City of Liberty Lake, for the potential of transit oriented development. Lot 4 provides adequate land for a proper TOD with multiple housing and employment opportunities. There is also easy access provided by Interstate 90 and Country Vista Dr, as well as the future light rail.



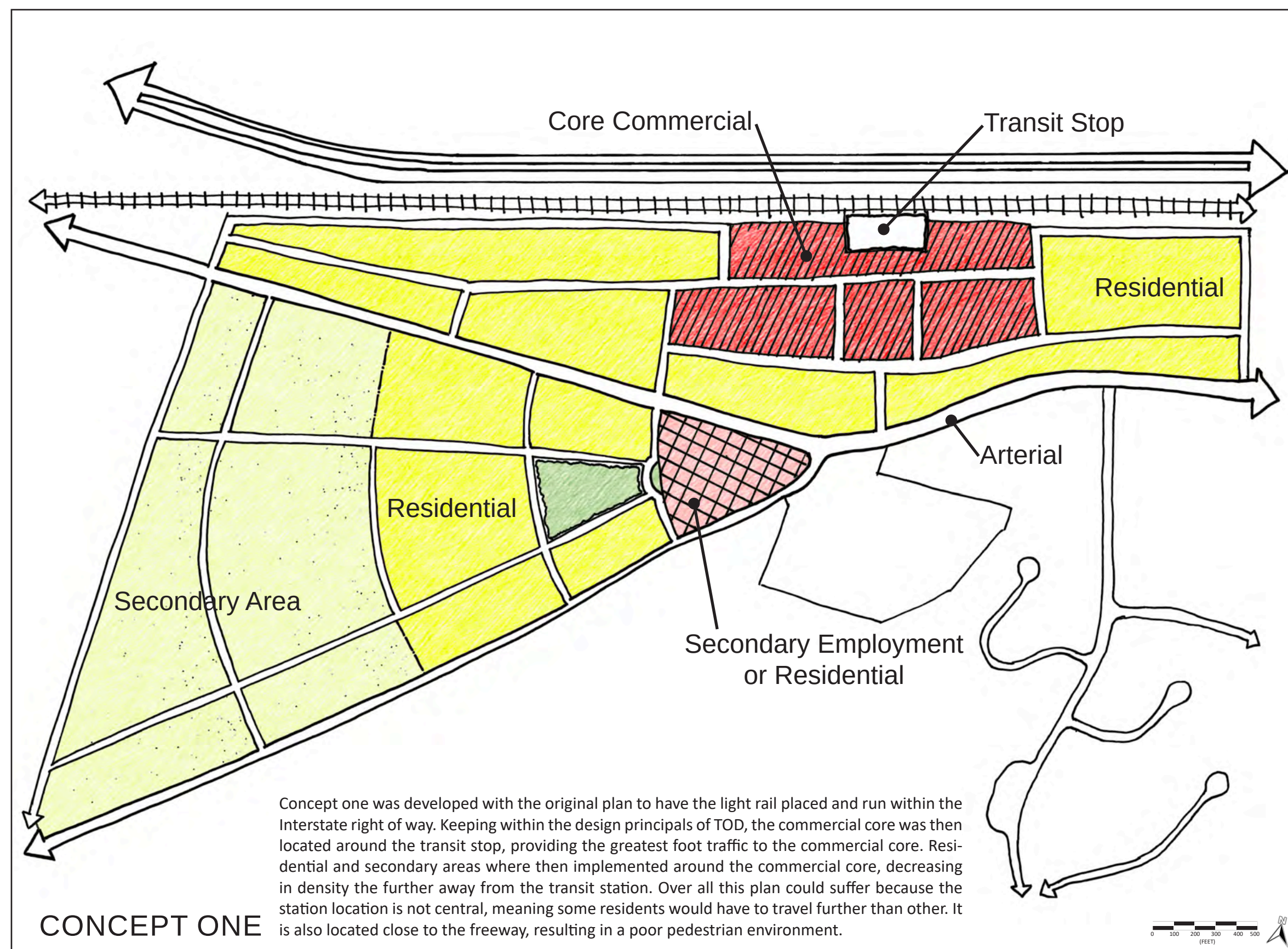
TOD Ideal Schematic



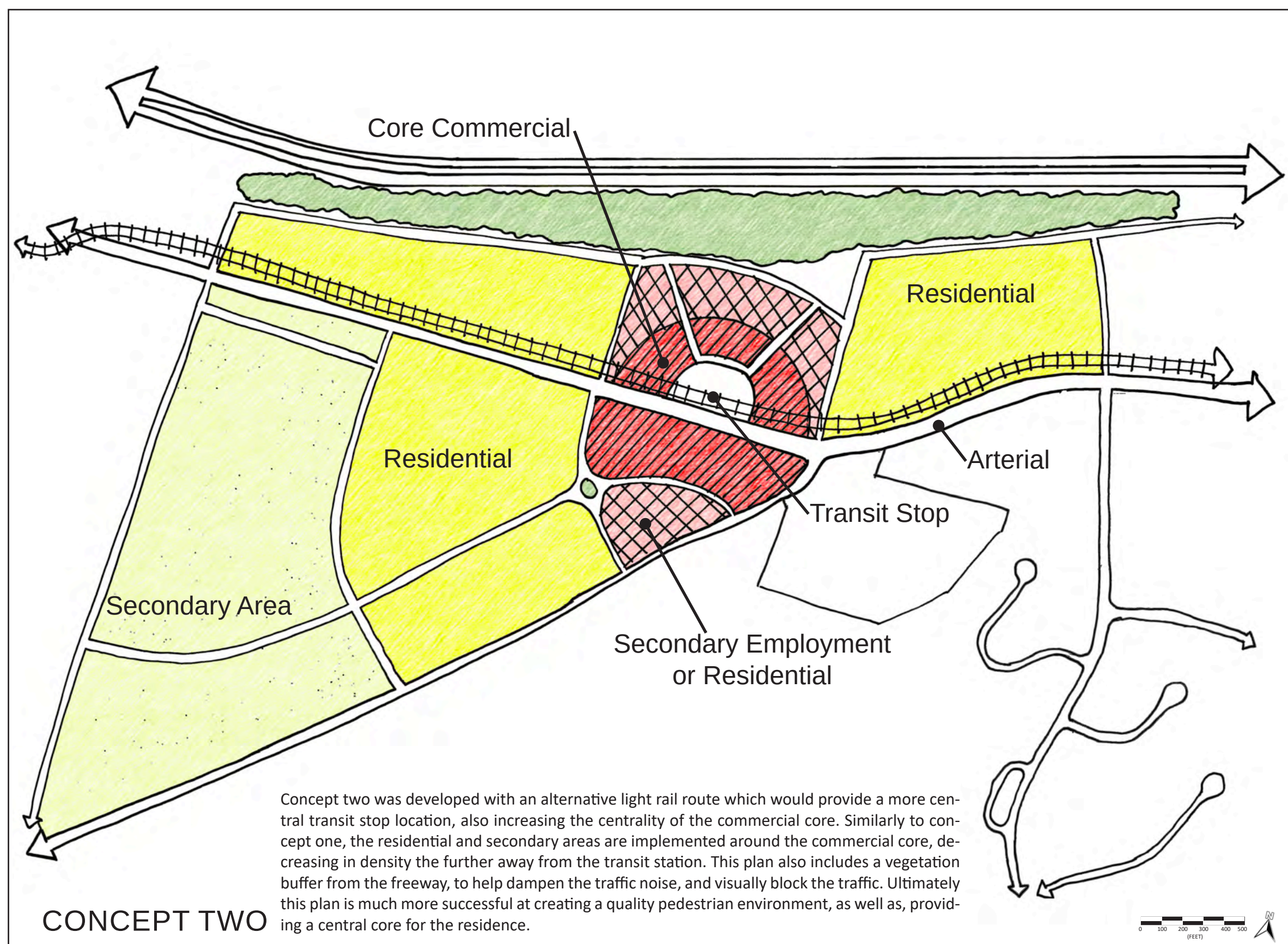
Ideally TOD's will be designed with and around the transit station. They should be planned to include the commercial core directly surrounding the station to maximize the foot traffic to the business. Residential land should then be located directly surrounding the commercial core, with multiple axes points leading to the station. Lastly, surrounding the primary residential land should be secondary areas, which can consist of low density residential house, schools, large community parks, etc. (Peter Cathorpe Design)

TRANSIT Oriented Development

Liberty Lake TOD Concepts



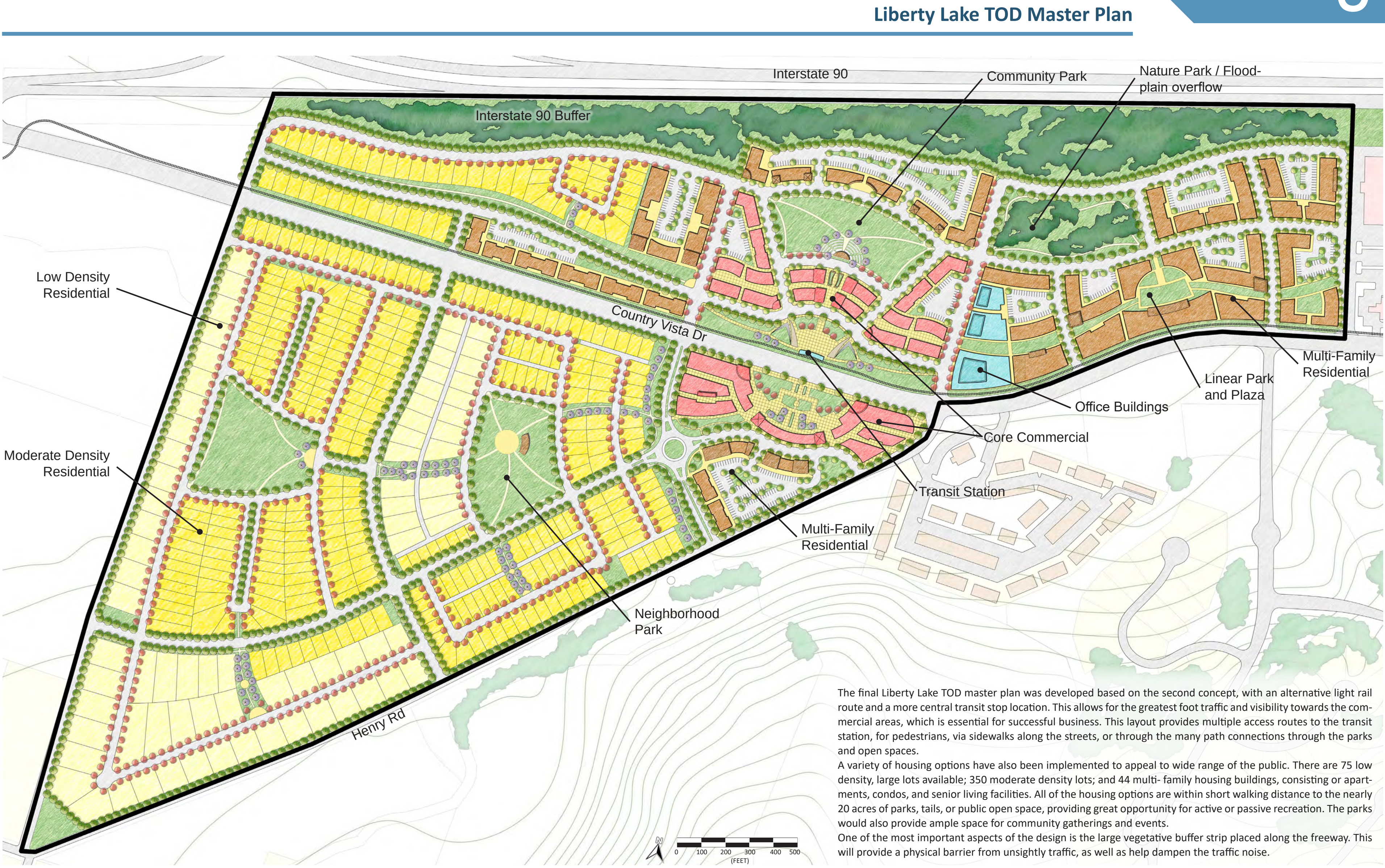
Concept one was developed with the original plan to have the light rail placed and run within the Interstate right of way. Keeping within the design principals of TOD, the commercial core was then located around the transit stop, providing the greatest foot traffic to the commercial core. Residential and secondary areas were then implemented around the commercial core, decreasing in density the further away from the transit station. Over all this plan could suffer because the station location is not central, meaning some residents would have to travel further than other. It is also located close to the freeway, resulting in a poor pedestrian environment.



Concept two was developed with an alternative light rail route which would provide a more central transit stop location, also increasing the centrality of the commercial core. Similarly to concept one, the residential and secondary areas are implemented around the commercial core, decreasing in density the further away from the transit station. This plan also includes a vegetation buffer from the freeway, to help dampen the traffic noise, and visually block the traffic. Ultimately this plan is much more successful at creating a quality pedestrian environment, as well as, providing a central core for the residence.

Liberty Lake Transit Oriented Development

Designed with GREEN Infrastructure



GREEN Infrastructure

DETENTION

Rainwater Harvesting

Green Roofs

Planter Boxes

Rainwater Harvesting - Rainwater harvesting systems collect and store rainfall for future use. These systems should help reduce the overall peak run off from the site, as well as provide a storage area for the water. Rainwater harvesting can be very useful in arid climates by reducing the demand of city water.
Application: Rainwater harvesting will be implemented for the commercial and business areas throughout the TOD, where it will be recycled for toilet water and/or supplemental irrigation.

Green Roofs - Green roofs are covered with vegetation that helps contain and filter stormwater runoff, creates habitat for wildlife, increase agricultural space, and provide living spaces for people to interact with enable rainfall infiltration and evapotranspiration of stored water.
Application: Green roofs will be implemented throughout the multi-family housing buildings. This will provide stormwater management, as well as increase the private living spaces for the residence.

Planter Boxes - Planter boxes can be used to collect stormwater runoff from sidewalks, parking lots, and streets and work well in urban areas when space can be limited. As well as providing stormwater management, they are also used for streetscaping to add visual interest and increase the pedestrian quality of the site.
Application: Planter boxes will be implemented along the streets and plazas within the commercial core, providing stormwater management and visual interest.

INFILTRATION

Green Parking Lots

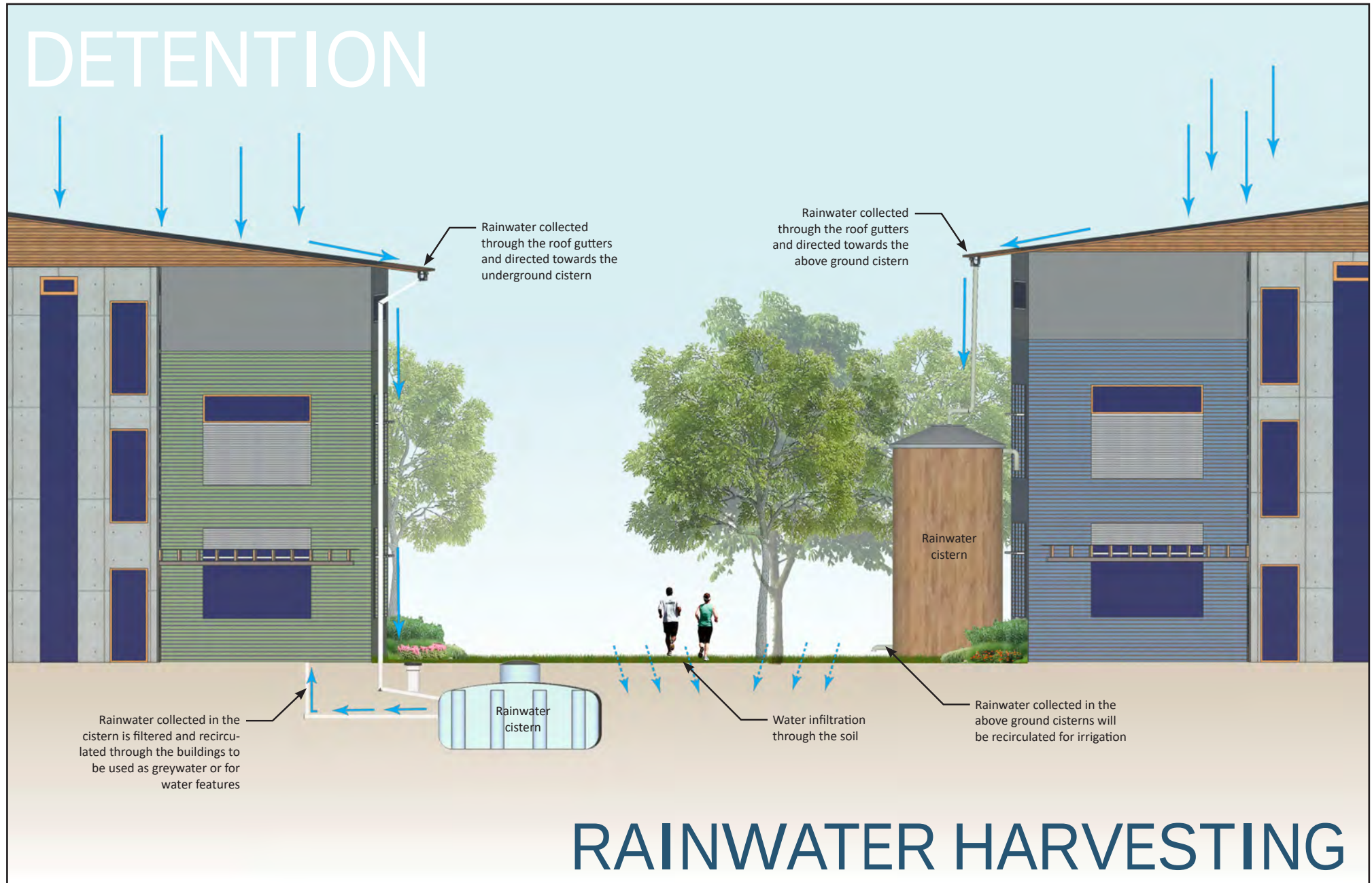
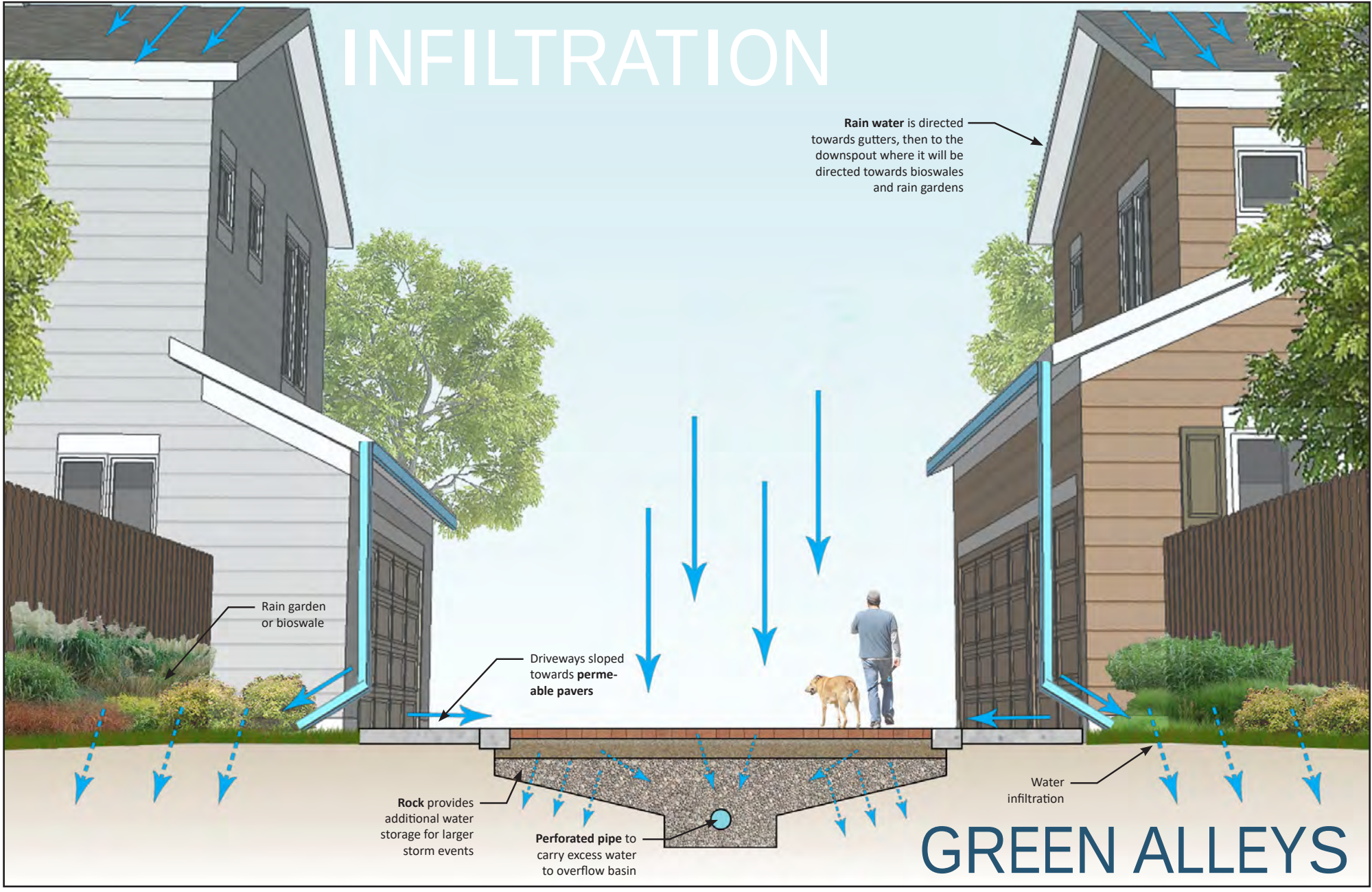
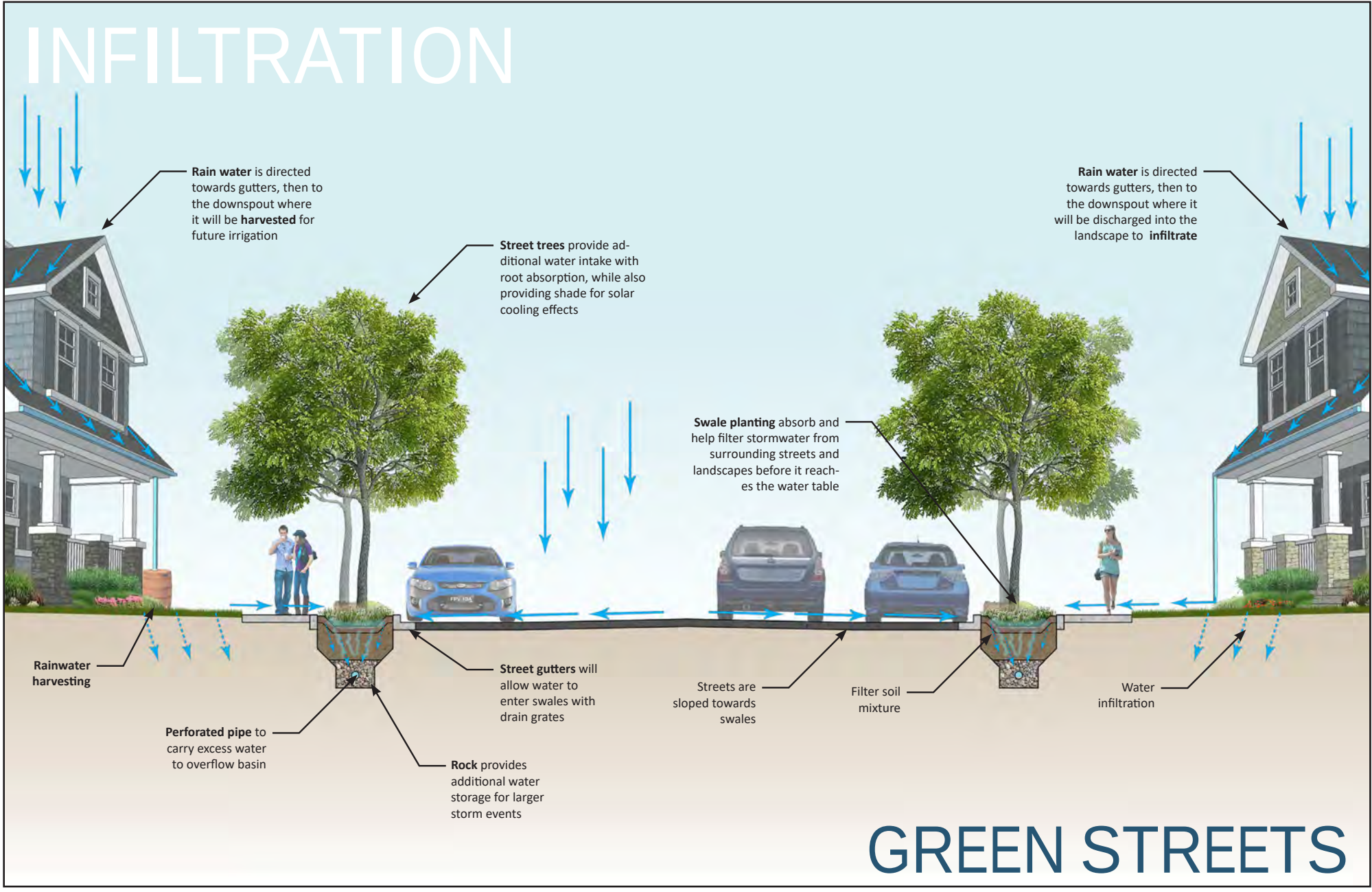
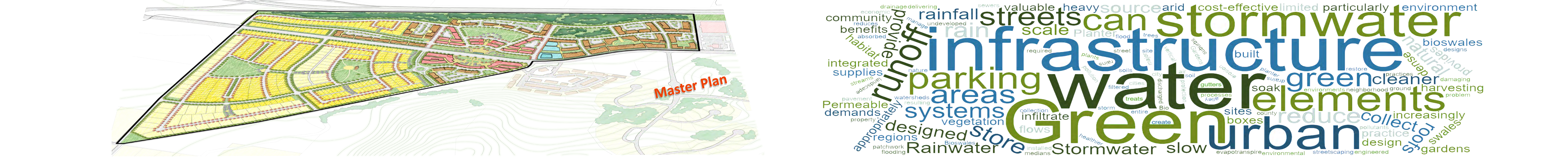
Bioswales And Rain Gardens

Green Streets

Green Parking Lots - Green parking lots can be developed, with permeable pavement or pavers to provide direct infiltration, or they can be developed with traditional pavement which is sloped towards rain gardens and bioswales in the medians and along the parking lot perimeter. It is important to use the proper plants and soil mixes that have the ability to filter car specific contaminants.
Application: Green parking design principles will be implemented throughout all parking areas within the TOD.

Bioswales and Rain Gardens - Bioswales and rain gardens are similar in that they are both vegetated and are used to collect stormwater, allowing it to slowly infiltrate. The difference is that bioswales will generally act as a transport for water, while rain gardens will be the final destination for the water.
Application: Bioswales and rain gardens will be implemented within the single family residential areas and provide stormwater management for the homes, driveways, and sidewalks.

Green Streets - Green streets and alleys consist of design techniques such as, permeable pavements, vegetated bioswales, and bioretention devices, to store, filter, and infiltrate stormwater. Green streets can also help increase the pedestrian quality of the site by providing natural traffic calming.
Application: Green streets and alleys will be implemented throughout the entire site, expect where other green infrastructure techniques will be uses (such as planter boxes).



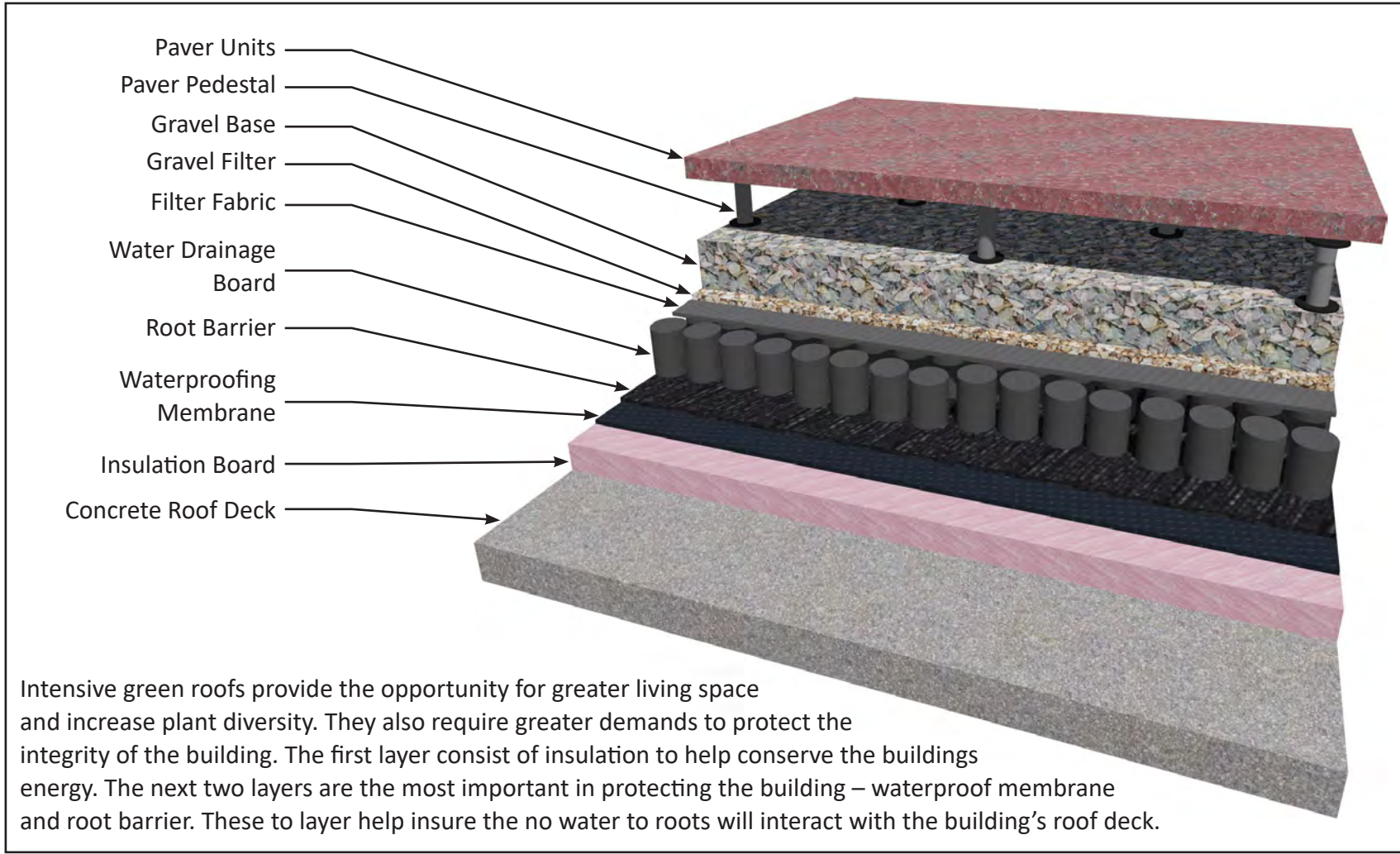
Liberty Lake Transit Oriented Development

Designed with GREEN Infrastructure

GREEN Roof



Green roofs come in two forms – intensive or extensive. Extensive green roofs generally require very low maintenance and primarily consist of sedum plantings. They are generally only used for green infrastructural benefits and not used for additional living space. On the other hand, intensive green roofs offer additional living space by offering patios, and spaces for people to enjoy. They consist of more traditional plantings and have higher maintenance requirements. The green roofs throughout this development will consist of both intensive and extensive green roofs. These roofs will help contain and filter stormwater runoff, create habitat for wildlife, increase agricultural space, and provide living spaces for people to interact with. In most storm events, rainwater will likely never reach the ground because of the absorption capabilities of green roofs.



Intensive green roofs provide the opportunity for greater living space and increase plant diversity. They also require greater demands to protect the integrity of the building. The first layer consist of insulation to help conserve the buildings energy. The next two layers are the most important in protecting the building – waterproof membrane and root barrier. These two layer help insure the no water to roots will interact with the building's roof deck.



View of the extensive portion of the green roof. This green roof will be planted with four varieties of sedums.



View of the intensive portion of the green roof looking back towards the roof entrance and the extensive green roof.



View of the intensive portion of the green roof. This roof offers many seating areas, a fire and water feature, and raised cortin planters.

Green parking lots are designed to collect and manage stormwater more efficiently and efficiently than traditional parking lots. In this case, pavers will be utilized in the parking stalls to reduce peak runoff by allowing water to infiltrate directly into the water table. The parking lot will also contain many vegetative swales along the sidewalks, which will be connected with channel drains. Allowing runoff from the hardscape areas to collect and eventually drain to the two large rain garden swales. These two large swales will manage the majority of on-site stormwater runoff.



Water Calculations

Parking Lot	
Building = 21,950 sq/ft (504 ac)	
Hardscape = 21,900 sq/ft (487 ac)	
Pavers = 4,740 sq/ft (109 ac)	
Softscape = 5,775 sq/ft (133 ac)	
q = C/A	
Building:	
q = (95) (.46) (504)	
q = .0027 ft ³ /sec	
Hardscape:	
q = (90) (.46) (487)	
q = .0082 ft ³ /sec	
Pavers:	
q = (.40) (.46) (109)	
q = .0048 ft ³ /sec	
Softscape:	
q = (.35) (.46) (133)	
q = .0051 ft ³ /sec	
Swale One	2,432 ft ³ Water Holding Capacity
Swale Two	1,970 ft ³ Water Holding Capacity



This green parking lot is designed to capture and infiltrate stormwater runoff from nearby buildings (blue), all sidewalks and hardscape areas (black), landscape areas (green), and the parking lot pavers (red). Using the rational method of storm water calculation, for a 2 hour, 25 year storm event, these areas will produce 3,336 ft³ of water. This water will be held and allowed to infiltrate in two designed rain gardens, with the capacity to hold 4,402 ft³ of water.

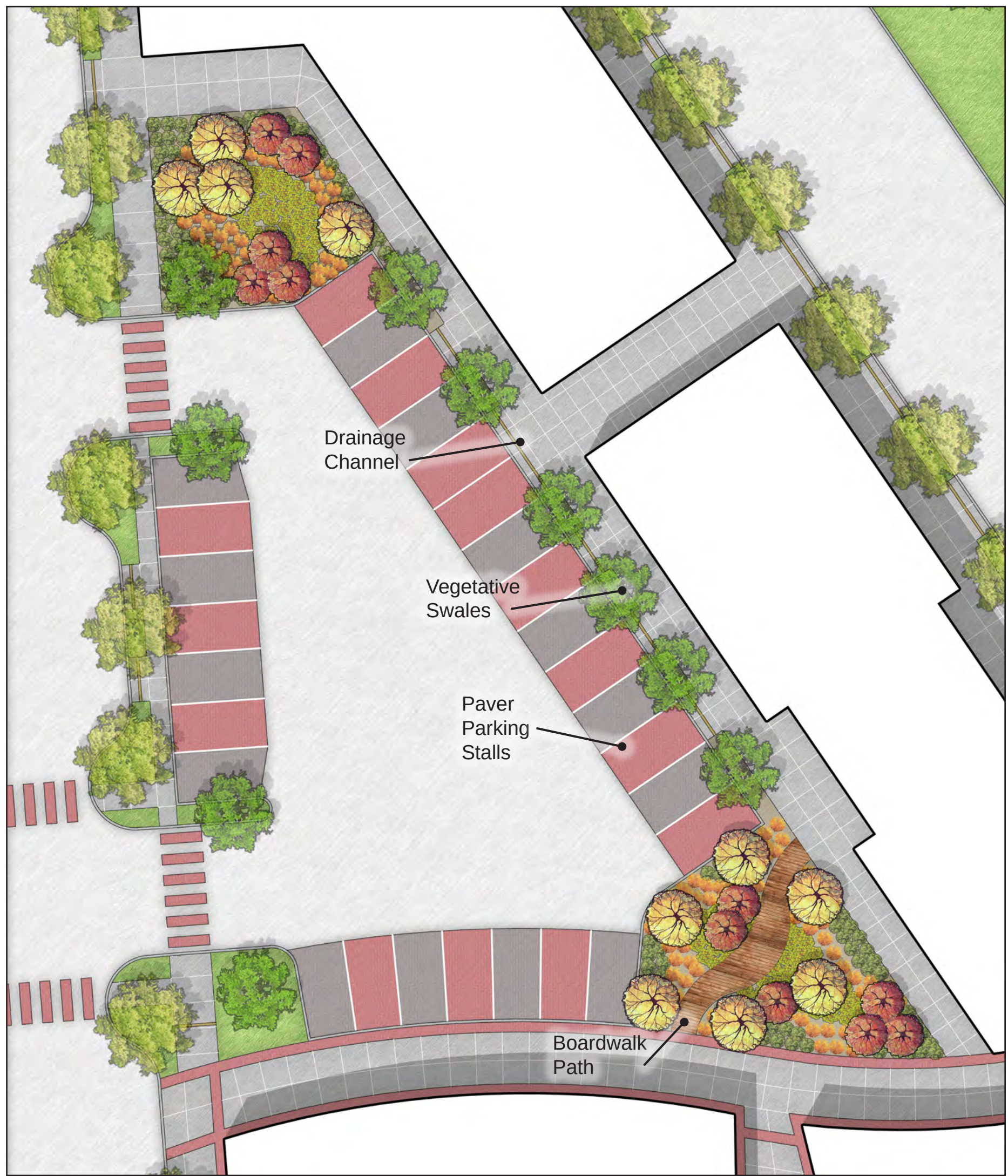


View looking south towards swale one.



View of the rain garden in swale one, with the boardwalk path.

GREEN Parking Lot



RAIN Garden



View of the rain garden at the west entrance to the park.



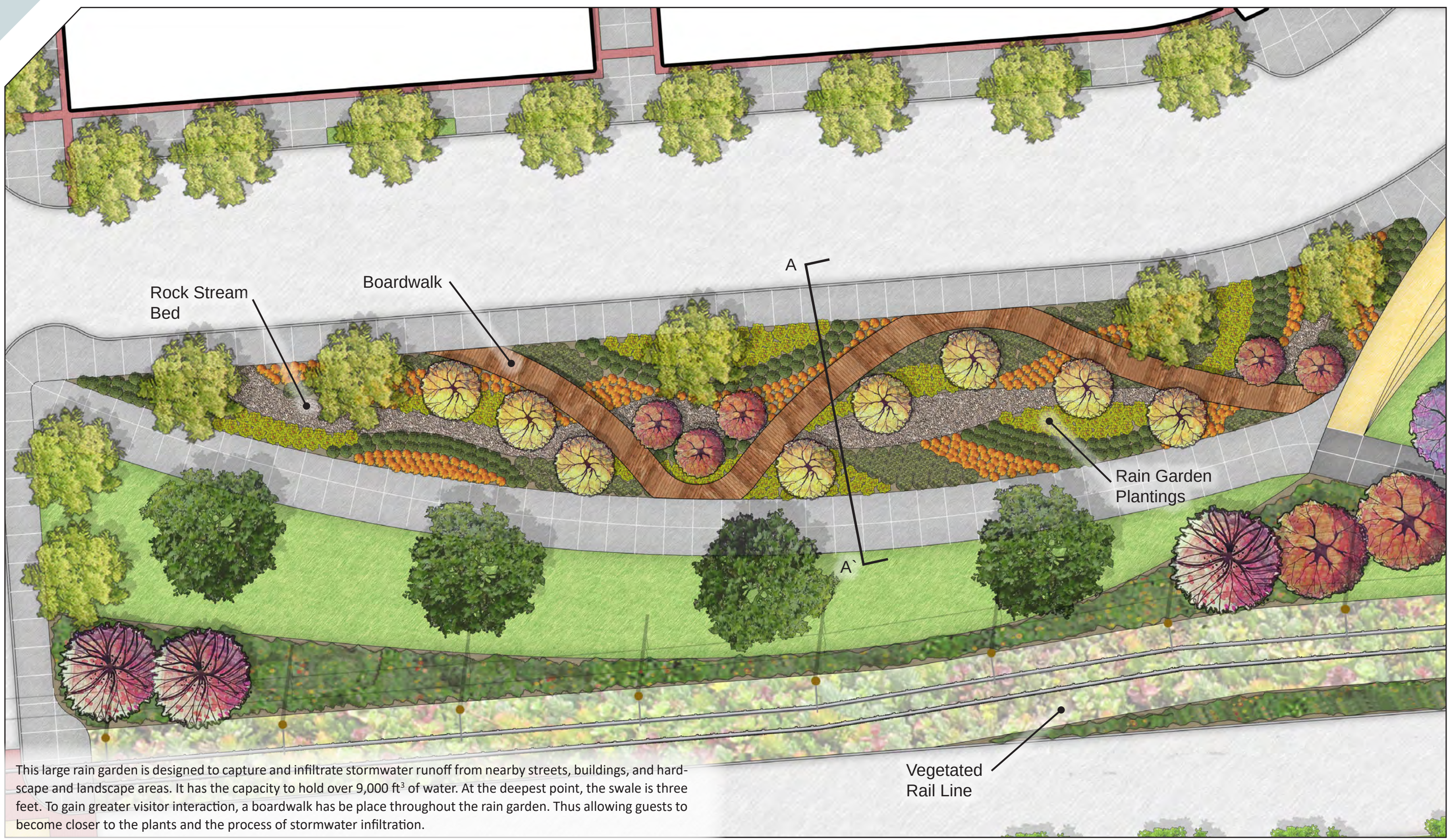
View of the rain garden boardwalk from the west entrance along the street.



View of the rain garden boardwalk at the park side entrance.

Rain Garden Plants

Parrotia persica 'Vanessa'	H: 10' - 20' W: 15' - 40'		
Vanessa Persian Parrotia			
Amelanchier x grandiflora 'Autumn Brilliance'	H: 15' - 25' W: 15' - 25'		
Autumn Brilliance Serviceberry			
Physocarpus capitatus	H: 8' - 10' W: 5'		
Pacific Ninebark			
Cornus sericea	H: 6' - 8' W: 8' - 12'		
Redosier Dogwood			
Mahonia aquifolium	H: 3' - 6' W: 2' - 5'		
Oregon Grape			
Helianthemum nummularium	H: 6" - 12" W: 2" - 3'		
Sun Rose			
Juncus effusus 'Occidental Blue'	H: 2' - 4' W: 18"		
Occidental Blue Rush			
Carex dolichostachya 'Kaga-Nishiki'	H: 6" - 12" W: 12" - 18"		
Kaga-Nishiki Sedge			



This large rain garden is designed to capture and infiltrate stormwater runoff from nearby streets, buildings, and hardscape and landscape areas. It has the capacity to hold over 5,000 ft³ of water. At the deepest point, the swale is three feet. To gain greater visitor interaction, a boardwalk has been placed throughout the rain garden. Thus allowing guests to become closer to the plants and the process of stormwater infiltration.



Section A-A represents a typical section throughout the rain garden. The boardwalk is three feet above the ground, at the maximum. This view also shows the 12" of constructed bioswale soil at the base of the swale, along with 6" of topsoil in the remaining planting areas.