Sustainable Roadside Design and Management for Urban Freeways in Western Washington

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Roadside Maintenance

SUSTAINABLE ROADSIDE DESIGN AND MANAGEMENT FOR URBAN FREEWAYS IN WESTERN WASHINGTON

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16. ABSTRACT:

This report addresses the question: What does it take to achieve and maintain sustainable urban roadside restoration projects in Western Washington that provide for necessary roadside functions at lowest lifecycle costs? It makes recommendations under five categories: general, agency communication and process, design, construction, and maintenance. It identifies two major problems common to urban roadsides: the establishment of transient encampments and intense invasive weed pressures. Urban roadside environments are extremely varied and serve many functions; therefore, the report does not recommend a single type of roadside planting or maintenance suitable for all situations. Integrated Vegetation Management is a key tool for planning and implementing urban roadside maintenance.

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TABLE OF CONTENTS

FIGURES

EXECUTIVE SUMMARY

The Washington State Department of Transportation (WSDOT) is responsible for an extensive highway system and its attendant roadsides and vegetation. As a responsible steward of its resources, WSDOT wishes to develop and maintain functional and aesthetically-pleasing roadsides with the lowest possible lifecycle costs. This study examined urban roadsides in Western Washington, using twelve case study sites and extensive discussions with WSDOT maintenance and design staff, to reach conclusions about how best to achieve low lifecycle cost roadsides.

WSDOT's land holdings are unique among land-owning state agencies. They consist of long narrow strips of land that pass through every type of natural and developed landscape in the state. These contrast with the typically large, contiguous tracts of land owned and managed by other agencies. WSDOT's ribbons of roadside land are thus more prone to ecological and physical/social disturbances throughout their length than other state lands. Furthermore, disturbances are more intense, frequent, varied, ubiquitous, and disruptive than disturbances typically experienced by other state lands. Urban roadsides are particularly susceptible to disturbances, and two types of disturbance, in particular, have major implications for the design and management of these roadsides: invasive weed pressures and transient encampments. As a result, managing urban roadsides is a more complex, demanding, and resource-intense task than managing comparable areas of land in other locations and configurations.

The physical conditions of roadsides vary dramatically, as do the functions that they serve. Urban roadsides typically exhibit greater variety and extremes of physical conditions and serve more diverse and demanding functions. Although it would be satisfying to report that one type of roadside vegetation is the single best plant community to provide lowest lifecycle cost urban roadside landscapes, and that that kind of plant community should be applied throughout urban roadsides, we cannot reach this conclusion. The variety of urban roadside conditions, the disturbances they experience, and the varied functions they serve make it impossible to conclude that one type of roadside vegetation is best for all situations.

Managing urban roadsides and assessing lifecycle costs are complex questions with no easy, right answers. Integrated Vegetation Management (IVM) practices have been developed and applied by WSDOT maintenance personnel and are very effective tools for rationally allocating resources and implementing effective roadside maintenance work. WSDOT should continue to support the use of IVM for managing its roadsides. However WSDOT can effectively implement IVM only if it has dependable, adequate budgets that do not fluctuate with biennial funding cycles and stable, dedicated maintenance staff levels under the control of area managers. These conditions are essential to achieve lowest lifecycle cost roadsides.

The goal of lowest lifecycle cost urban roadside landscapes is a "moving target" or, in ecological terms, a dynamic balance that requires constant adjustment to meet, not a static end state to be reached and maintained. Factors that influence the lifecycle costs of these landscapes include ecological/biological considerations and how to achieve relatively stable, mature plant communities while managing for disturbances from weed invasion; social questions that include discouraging transient encampments and providing desired physical and aesthetic appearance of roadsides, particularly at urban gateways; and a complex array of policy, political, and economic considerations that affect allocation of resources to and within the agency. In addition, we examined the influences of project construction decisions on the physical environments in which plants must subsequently grow, plant establishment requirements to minimize weed invasion, planting design

effects on addressing functional needs, and maintenance considerations of how to rationally and effectively allocate scarce resources to the competing demands of dynamic roadside landscapes.

Experiencing the never-ending effects of dynamic plant growth and, in particular, the perpetual pressure of weed invasion (both resulting from Western Washington's favorable growing climate) continually reemphasized the points that maintenance is a never-ending task and that to achieve lowest lifecycle cost for any roadside plant community requires unceasing maintenance to prevent them from becoming overrun with invasive plants. The most effective way to minimize lifecycle costs of all roadside landscapes is to provide steady, continuous maintenance to prevent weeds from overwhelming them. As plant communities become firmly established and mature, opportunities for weeds to invade and become established diminish, particularly on roadsides with continuous tree cover, and maintenance costs decline. Urban roadsides, however, continue to require relatively intense maintenance, and in these settings IVM practices are particularly important for achieving lowest lifecycle cost roadsides.

On the basis of this research, we conclude that for many reasons, trees are desirable components of urban roadsides and contribute to low lifecycle costs; therefore, they should be considered wherever they satisfy functional needs. However, we also conclude that, for functional reasons and aesthetic and perceptual considerations that contribute positively to a varied and engaging driving experience, as well as for better integration of highways with adjacent properties, the entire extent of urban roadsides should not be covered with trees and that other plant communities are important components of urban roadsides. Therefore, it is more important to maintain each type of roadside in ways that minimize the lifecycle cost of that particular type of plant community than it is to try and provide a single lowest lifecycle cost plant community throughout all urban roadsides.

In answer to the research question—What does it take to achieve and maintain a sustainable urban roadside restoration project that provides for the necessary roadside functions at the lowest life-cycle cost?—we make the following specific recommendations under five broad categories:

GENERAL RECOMMENDATIONS

- Continue to develop and implement IVM with a focus on long-term management strategies.
- Ensure adequate, dedicated, ongoing maintenance funding, as preventive management is the most effective method of controlling invasive weeds.
- Create “demonstration” roadside projects to generate public interest in roadside management possibilities.

AGENCY COMMUNICATION AND PROCESS RECOMMENDATIONS

- Establish and facilitate procedures to improve communication among project development design teams, construction supervisors, and maintenance staff throughout project planning and construction stages to communicate the design intent/ function and goals of roadside restoration vegetation.
- Set baselines for design intent / functions to be met and document these in Area Integrated Roadside Vegetation Management (IRVM) Plans.

- Design teams and maintenance staff should create processes and policies to design, review, and prioritize urban roadsides for different levels of maintenance.
- Require (at least) bi-monthly communication among field inspectors, regional landscape architects, maintenance staff, and/or the construction supervisors throughout the design, construction, and establishment stages of restoration projects.
- Improve the Maintenance Accountability Process (MAP) to more accurately measure and document the level of service provided (such as 3A5/Landscape Maintenance and 3A3/Nuisance Vegetation Management activities).

DESIGN RECOMMENDATIONS

- Consider the impacts of transient encampments on urban roadsides with regard to functional design solutions, visual surveillance, and maintenance regimes.
- Consider the long-term ecological and biological impact of plant species and spacing choices to ensure the functional, operational, environmental, and visual goals---such as quick canopy coverage and rapid cover of the ground.
- When design functions permit, plant trees, as these are the best performing plant material over time. Where functional and aesthetic conditions permit, specify shrub communities under trees.
- Continue to research and specify low- and densely growing ground cover plants that establish quickly, compete with invasive weeds, withstand drought conditions, and tolerate periodic mowing.
- Ensure that construction contractors and maintenance crews understand and strictly abide by plant installation "planting windows" and effective herbicide application times.

CONSTRUCTION RECOMMENDATIONS

- Provide a plant establishment period adequate for plants to completely and densely cover the ground through longer contract establishment periods, contract performance specifications, or additional maintenance resources.
- Require and enforce a high percentage of plant survival in the first and second years of construction contracts. Extend contract establishment periods at no cost to WSDOT when first- and second-year plant survival rates are not met.
- Separate roadside plant installation work from other roadwork in independent construction contracts to allow highway construction contracts to be closed out before the end of plant establishment periods.
- Approve and accept roadside restoration project work by a trained construction inspector with expert knowledge of soil preparation, plant health and vigor, recognition of invasive vegetation, plant specifications, and successful plant establishment.

MAINTENANCE RECOMMENDATIONS

- Expand the successful IVM program to include educating maintenance personnel to understand and accept roadside design function.

- Re-organize regions and areas to have dedicated, skilled, and knowledgeable landscape leads and crews (permanent and seasonal) to exclusively perform roadside restoration work under maintenance managers.
- Create and consistently administer a standard maintenance agreement and contract for all city gateway landscapes on WSDOT roadsides.

INTRODUCTION

The Washington State Department of Transportation (WSDOT) is responsible for the development and the safe and efficient management of the state's extensive highway system. This system includes the lands and vegetation that flank roads throughout the state. This report examines a relatively small portion of these roadsides: urban freeways in western Washington. (More specifically, the report deals with vegetation in Zone 3, the portion of roadside that is beyond the maintained zones immediately adjacent to the edge of pavement. Refer to the roadside cross-section in Figure 1 and report definitions below.) Although a very small percentage of the total system, these roadsides are crucial because they are intensively used and viewed by a large percentage of the state's roadway users and because they present unique and difficult design and maintenance issues.

WSDOT design, construction, and maintenance practices have changed significantly over the past fifty years in response to many factors, including developments in construction technology; growth of urban areas; fluctuating funding levels; numerous new county, state, and federal environmental laws and acts; adoption of Integrated Roadside Vegetation Management practices; and increasing awareness of the varied environmental functions performed by roadside vegetation.

The variety and complexity of contemporary roadside restoration functions that must be considered by WSDOT have increased dramatically, while the available roadside to provide these functions in urban areas has been greatly reduced or limited. Therefore, the goals of contemporary function-based design are more comprehensive and include landform and vegetation restoration for site-specific, context-sensitive functions.

In addition, WSDOT has responded to increased pressure to reduce the use of pesticides for weed suppression and control. These factors have greatly changed the toolbox that WSDOT can

use to create and sustain urban roadsides; however, there has not been a commensurate increase in funding or care to compensate for these factors.

Roadsides, unlike roadways and other non-living facilities developed and managed by WSDOT, are living vegetation communities; that is, they are dynamic, growing systems responsive to environmental and site conditions. To preserve these living systems in a functionally and aesthetically acceptable condition requires continuous design adaptation and ongoing, appropriate maintenance. Crucial to successful roadside plant community maintenance is the development of management approaches based on an appreciation of the dynamics and function of each roadside. This requires understanding and maintaining roadside plant communities in ways that are different from the ways that non-living facilities are considered and maintained. Much of this has been successfully accomplished by WSDOT's Integrated Vegetation Management (IVM) program.

DEFINITIONS OF REPORT TERMS

Some misunderstandings often surround the use of certain words. While the following definitions may have slightly different meanings in different contexts, the definitions below are intended to clarify how the terms are used throughout this report.

Landscape function for roadsides – An informed approach to design that considers multiple and diverse factors simultaneously, with attention to site-specific, context-sensitive issues and conditions (landform, hydrology, plant selection and design) that need to be addressed with the restoration of each roadside. Some examples of these functions include head-light glare reduction; storm water runoff attenuation; water quality maintenance or improvement; CO_2 and/or water absorption and/or sequestration; erosion and sedimentation control; canopy-coverage for invasive species control; protection of animal habitat, particularly in relation to threatened and endangered species; visual buffer or screen, especially for urban freeway roadsides and gateway interchanges

because the visual quality reflects on the surrounding community; and pedestrian safety. The restoration of roadside vegetation is purposely designed to be easily maintained and to address particular contextual issues while performing the desired function.

The WSDOT Roadside Classification Plan (RCP) defines roadside function as: "*Any activity or role for which the roadside is specifically suited and used. The roadside is managed to fulfill operational, environmental, and visual functions. In reality, these functions are interrelated and inseparable.*" (Refer to the RCP for a detailed description of operational, environmental, and visual functions.)

Plant community – A symbiotic grouping of vegetation—often incorporating multiple scales, i.e., groundcover, shrub, and tree—that best provides the desired landscape effect and function, with emphasis on ecological and biological balance.

Self-sustaining landscape – A vegetated landscape (usually a tree and/or shrub and/or groundcover combination) that is designed (or exists) to take advantage of site conditions while providing the appropriate level of roadside function and to thrive with minimal maintenance. The specified plants are intended to (with proper plant establishment and minimal maintenance) provide a canopy and/or surface coverage to hinder invasive vegetation. The establishment period for these high-performance landscapes—if constructed and maintained properly—can be 5 to 10 years. Once established, these landscapes in the long term are most efficient because after the establishment period they require minimal maintenance.

Lifecycle cost – According to the WSDOT Roadside Classification Plan (RCP), lifecycle cost is "*An assessment of all the significant costs (planning, design, construction, and maintenance) of ownership over the anticipated life of an asset.*"

Specifically, in this document, lifecycle cost for functioning roadsides refers to the

following: A long-term approach to planning, design, construction, and maintenance that involves selecting and caring for plant communities that thrive under the given site conditions, provide the necessary level of roadside function, and in time will become as self-sustaining as possible. Lifecycle costs typically use a long time frame to demonstrate quantifying positive effects and include the value and costs of ecological, social, and economic issues.

Low cost maintenance – An approach to caring for landscapes that involves the reality of budgets and past performances. It is often considered short-term planning. One report reviewer commented: "*The maintenance approach is reactive and short term, often to the detriment of establishing long-term goals such as a sustainable plant community. It is not a lack of vision so much as a need to meet immediate perceived needs within budget constraints … Least expensive and most expeditious pretty much describes the maintenance philosophy for the bulk of what we do…*" (This definition is included because often low cost maintenance and low lifecycle costs are either misused or misunderstood.)

Integrated Vegetation Management (IVM) – A coordinated decision-making and action process that uses the most appropriate and effective vegetation management methods and strategies, along with a monitoring and evaluation system, to achieve roadside maintenance program goals and objectives in an environmentally and economically sound manner. WSDOT has developed Area Integrated Roadside Vegetation Management (IRVM) plans for each of the 24 maintenance areas in the state. These plans serve as a guide to set priorities and direct maintenance actions for roadside vegetation management within each area's highway corridors.

Urban roadside – The roadsides along WSDOT highways that surround, connect and divide areas of large populations centers (typically large towns and cities). These are usually limited access roadways. (Limited access roadways are "*Long lengths of highway—multiple miles—*

without an exit or entry ramp, often connecting two urban centers" (from the RCP). Limited access roadways typically have a property line fence and/or noise walls and locked gates, and access to the right of way from adjacent property is restricted.

Specifically, this report deals with vegetation in Zone 3, the portion of these areas beyond the operationally maintained zones immediately adjacent to the edge of pavement. Within the first 20 to 30 feet of the edge of pavement (Zones 1 and 2), roadside vegetation requires some degree of maintenance on an annual basis in order to provide for traffic safety and highway operation. Where there is adequate right of way width beyond these zones (Zone 3), there is opportunity to design, establish, and manage plant communities. For urban roadside settings there is a public expectation of higher visual quality/neatness/more maintenance attention than along rural roadways. (Refer to the Figure 1.)

Urban Gateways – Freeway on and off interchanges in cities or towns are considered "gateways" to the city /town. Planting design and maintenance treatment of gateways reflect on the image of the city and its local economy. Local governments typically desire higher visual quality/neatness of roadsides in these locations.

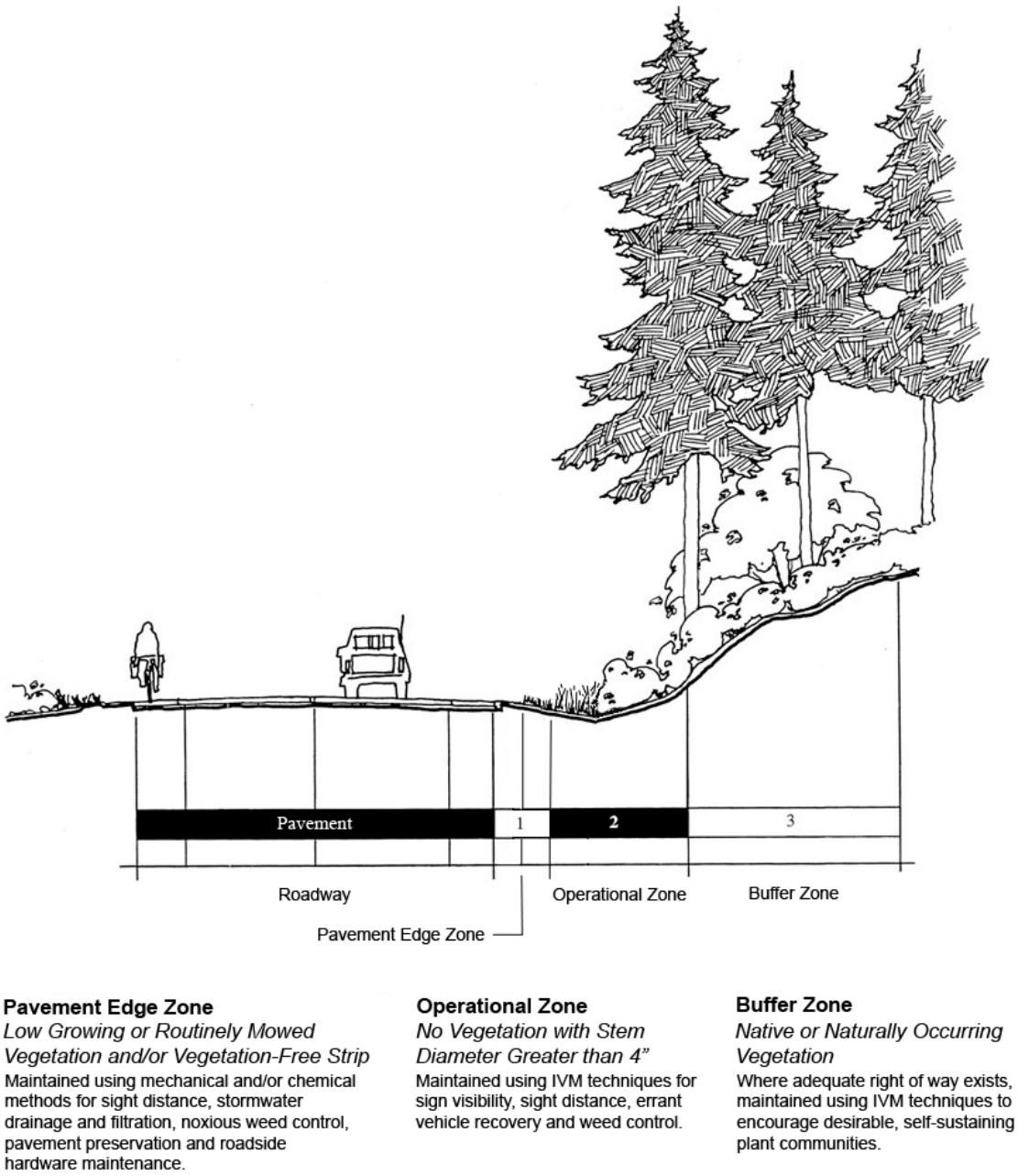


Figure 1. Roadside Cross-Section

Sustainable Roadside – A sustainable roadside is one that is designed, constructed, and maintained with an emphasis on long-term appropriateness and maintaining a low lifecycle cost. "*A roadside that fulfills design intent and roadside functions over the long term, and protects the*

environment wherever possible, within present and future available funding, personnel, equipment, and methodologies" (from the RCP). To achieve sustainable roadsides, roadside partners must strive to utilize, protect, and support the physical and ecological resources necessary for a fully functioning roadside. The primary management considerations for sustainable roadsides are as follows (from the *WSDOT Roadside Manual*):

Design intent: Roadside functions (operational, environmental, visual and auxiliary) and maintenance standards, criteria, and actions are coordinated and balanced to the greatest degree possible to achieve the design intent at all levels. The roadside is designed to achieve the long-term goals of IVM. (Refer to Integrated Vegetation Management for Roadsides.)

20-year planning horizon: All roadside management decisions are weighed in their long-term context, including projected land use and public health, safety, and welfare considerations. Future adjacent land uses and roadside functions are addressed in designing present-day projects.

Projected lifecycle costs: All roadside management decisions are in keeping with present and future available funding, personnel, equipment, and methodologies. What are the costs of the project over its "lifetime"?

Utilize, protect, and support the roadway and roadside infrastructure: All roadside management decisions are balanced with the need to sustain, preserve, restore, and enhance the roadside character and natural environment. The emphasis is on careful management of existing and volunteer native vegetation.

Continued cooperative involvement: Roadside management decisions are based on continued active involvement among all roadside partners within WSDOT. This begins at the earliest planning stages with communication among all affected parties through an open, collaborative

management process and designated lines of communication between roadside partners.

THE DESIGN GOAL: ROADSIDE FUNCTION WITH LOW LIFECYCLE COSTS

Roadside function, as stated in the definitions above, is an informed approach to design that considers multiple and diverse factors simultaneously, with attention to site-specific, context-sensitive issues and conditions (landform, hydrology, plant selection and design intent) that need to be addressed with the restoration of each roadside. The desired function is dependent on the existing site conditions—slope, aspect, width of right-of-way (ROW), and proximity to urban centers. Long-term ecological costs (health / air quality / protection of the environment) and social costs (safety and welfare) are included in the restoration equation used by the design team, as are aesthetic and visual issues because of concern with public perception. These "costs" are difficult to convert to a dollar amount and, therefore, are often viewed as subjective. The WSDOT landscape architects and design teams work diligently to create restoration plans that meet the minimal function at the lowest cost.

The WSDOT Environmental Policy has three major categories: protection of the environment, public safety, and public perception/use of public resources. The design team interprets and applies the policy through the process of establishing the appropriate roadside function.

THE CONSTRUCTION GOAL: CREATING ROADSIDES WITH LOW LIFECYCLE COSTS

The goal of construction activities for roadside restoration is to create the platform for healthy and successful vegetation growth and to produce proper soil conditions. Good soil preparation will encourage full plant establishment with rapid canopy coverage to provide

vegetative cover that excludes invasive weeds. Plant care during the construction contract plant establishment period is crucial to getting roadsides in maintainable conditions, which affects short- and long-term roadside plant health and minimizes project lifecycle costs.

The way in which construction contracts are structured, their contract provisions, and how they are supervised are important considerations in reaching the construction goal. It is desirable to manage the factors that WSDOT can control to minimize lifecycle costs of roadside projects that include managing construction operations and outcomes. The most effective way to accomplish this is by preservation of existing functional roadsides. The creation or preservation of environmental conditions conducive to healthy plant growth is essential to long-term, low lifecycle cost, and is an important goal of construction contracts.

THE MAINTENANCE GOAL: ROADSIDE CARE/IVM AND LOW LIFECYCLE COSTS

Care of WSDOT lands is and must remain a major consideration for the agency. While good management practices, such as IVM practices—may reduce the amount of maintenance required over time, it can never entirely eliminate the need for maintenance.

The goal in an IVM approach is to effectively remove and prevent the growth of undesirable vegetation while at the same time encouraging and enhancing desirable vegetation. The IVM process is an annual cycle of monitoring roadsides based on biological and horticultural science and planning actions that are properly timed and conducted by knowledgeable and competent employees. IVM develops strategies and methods to prevent invasive weeds from overwhelming roadsides and planted roadside vegetation. The adoption of IVM practices has allowed WSDOT to conduct roadside maintenance work in a more rational and planned way and

has also resulted in environmental benefits such as the refinement and reduction of the use of herbicides in the last decade.

Natural plant communities, when undisturbed by external forces, tend toward relatively stable, self-regulating states, and the maintenance goal is to have WSDOT's Zone 3 roadside areas replicate a self-sustaining system as closely as possible. If successful, such systems require the minimum maintenance effort to keep them in an acceptable states; in other words, roadsides incur the lowest lifecycle cost and are thus sustainable. While it is possible to reduce lifecycle costs for roadside vegetation through appropriate design, construction, and maintenance practices, it is not possible to eliminate the need for some level of ongoing vegetation management throughout the life of a roadside.

REVIEW OF PREVIOUS WORK

The WSDOT Environmental Policy Statement, revised in 2009, *"… directs WSDOT employees to follow sound environmental protection practices in the planning, design, construction, operation, and maintenance of WSDOT's transportation systems and facilities …"*.

WSDOT's Maintenance Accountability Program (MAP) contains a *Prioritized Matrix* that determines the priority for all maintenance work, including roadside restoration (Figure 2). Work is listed under 33 activities, with floating bridge operations first and disaster operations second. The priorities of most roadside maintenance activities are relatively low. Control of vegetation obstructions is the highest priority of the five identified roadside maintenance activities at 17th because of its role in improving traffic safety. Noxious weed removal is 26th; nuisance vegetation control is 31st; landscape maintenance is 32nd; and litter removal is last at 33rd. (*Note: Most, if not all, of the maintenance activities discussed in this report are considered either nuisance vegetation control or landscape maintenance and fall under the two second to lowest priority maintenance activities within the entire WSDOT organization.)*

WSDOT's Roadside Classification Plan outlines policies and guidelines for coordinating planning/design and construction. One of the intentions stated in this plan is to *"… minimize roadside project construction costs and long-term demands on maintenance resources."* This goal is consistent with lowest lifecycle costs for functional roadside restoration.

2009-2011 Maintenance Activities
Priority and Level of Service Matrix

					Policy Objectives												
STATEWIDE MAP PRIORITIES		07-09 Actual Dollars (Millions) (through May 2009)	2008 LOS Delivered	09-11 LOS Target	Safety of Travelling Public and Employees		Operate the Highway System and Keep the Road Open		Meet Environmental Responsibilities		Maintaining the Infrastructure		Address Legal Mandates Other than Environmental (Including Torts)		Contribute to Comfort, Aesthetics or Convienience		Total Priority
Num.	MAP Activity				10		9		7		7		7		2		
4B1	Movable & Floating Bridge Operations	$7.0	A+	B+	6	60	9	81	6	42	9	63	9	63	6	12	321
9B2	Disaster Operations	$30.9			9	90	9	81	9	63	9	63	3	21	0	0	318
6B1	Traffic Signal System Operations	$7.6	C-	C+	9	90	9	81	3	21	6	42	9	63	3	6	303
5B1	Snow & Ice Control Operations	$94.3	A	A-	9	90	9	81	6	42	0	0	9	63	9	18	294
4B2	Keller Ferry Operations	$1.4	B	B	3	30	9	81	3	21	9	63	9	63	6	12	270
4B3	Urban Tunnel Systems Operations	$3.3	B	B	3	30	6	54	3	21	9	63	9	63	6	12	243
4A2	Structural Bridge Repair	$8.3	D+	C	6	60	3	27	6	42	9	63	6	42	3	6	240
6A4	Regulatory/Warning Sign Maintenance	$1.9	C	C+	9	90	6	54	0	0	3	21	9	63	6	12	240
2A5	Slope Repairs	$5.3	A	B	6	60	6	54	6	42	6	42	3	21	3	6	225
6B3	Intelligent Transportation Systems(ITS)	$5.1	B	B-	6	60	9	81	3	21	6	42	0	0	9	18	222
2A3	Maintain Catch Basins & Inlets	$3.6	D+	B	6	60	6	54	6	42	6	42	3	21	0	0	219
1A1	Pavement Patching & Repair	$19.0	C+	B	6	60	3	27	3	21	9	63	6	42	3	6	219
4A1	Bridge Deck Repair	$1.8	C	B-	6	60	3	27	3	21	9	63	6	42	3	6	219
6A7	Guardrail Maintenance*	$1.5	B+	A	9	90	3	27	0	0	6	42	6	42	3	6	207
6A1	Pavement Striping Maintenance	$10.7	C	C+	9	90	6	54	0	0	0	0	6	42	9	18	204
6A2	Raised/Recessed Pavement Markers	$1.6	C	B	9	90	6	54	0	0	0	0	6	42	9	18	204
3A4	Control of Vegetation Obstructions	$6.1	D+	B-	9	90	3	27	0	0	3	21	6	42	6	12	192
7B1	Rest Area Operations	$10.7	B	B	3	30	3	27	6	42	6	42	3	21	9	18	180
1A4	Sweeping and Cleaning	$7.0	A	B+	3	30	3	27	9	63	3	21	3	21	9	18	180
2A1	Maintain Ditches	$9.7	B	B	3	30	3	27	6	42	6	42	3	21	3	6	168
6B2	Highway Lighting Systems	$10.9	C+	B+	6	60	3	27	0	0	6	42	3	21	9	18	168
6A6	Guidepost Maintenance	$1.3	D+	C-	6	60	3	27	3	21	3	21	3	21	9	18	168
1B1	Safety Patrol	$5.2	C	C	9	90	3	27	0	0	3	21	3	21	3	6	165
2A2	Maintain Culverts	$4.1	D-	C	3	30	3	27	6	42	6	42	3	21	0	0	162
6A3	Pavement Marking maintenance	$2.1	C	C-	6	60	3	27	0	0	0	0	9	63	6	12	162
3A2	Noxious Weed Control	$4.8	A	B	0	0	0	0	9	63	3	21	9	63	3	6	153
1A3	Shoulder Maintenance	$2.0	B+	B-	3	30	3	27	3	21	6	42	3	21	3	6	147
6A5	Guide Sign Maintenance	$3.5	B	B-	3	30	6	54	0	0	3	21	3	21	9	18	144
2A4	Maintain Detention/Retention Basins	$0.2	C	C	0	0	0	0	9	63	3	21	6	42	0	0	126
4A3	Bridge Cleaning & painting	$2.1	B	C	0	0	0	0	9	63	6	42	0	0	6	12	117
3A3	Nuisance Vegetation Control	$8.7	A	B-	0	0	0	0	6	42	3	21	3	21	9	18	102
3A5	Landscape Maintenance	$3.3	D+	C-	0	0	0	0	3	21	3	21	3	21	9	18	81
3A1	Litter Pickup	$7.1	D	C-	0	0	0	0	3	21	0	0	3	21	9	18	60

Figure 2. MAP Priority Matrix

Appendix A provides other referenced, authoritative WSDOT policies and documents that influence the design, construction, and maintenance of roadsides. Historically, the prime functions of roadsides and roadside vegetation were erosion control, visual buffers, aesthetic appeal, and headlight glare reduction. Refer to Appendix B, WSDOT Timeline, for a detailed account of WSDOT designs, construction, and maintenance activities by decade.

RESEARCH APPROACH

RESEARCH QUESTION

What does it take to achieve and maintain a sustainable urban roadside restoration project that provides the necessary roadside functions at the lowest lifecycle cost?

The objective of this research was to provide WSDOT with recommendations for roadside restoration planning, **design**, **construction,** and **maintenance** that will result in successful, functional, and attractive urban roadsides with the most cost-effective initial construction, the least long-term maintenance, and the lowest lifecycle costs.

RESEARCH METHOD

A combination of research methods was employed for this report: a WSDOT policies review; employee interviews; site map investigations; construction plan, specifications, and cost data sheet review; and site visits /explorations for case study comparisons. The researchers interviewed agency landscape architects and maintenance personnel, and they evaluated current site and vegetation conditions. Construction plans and specifications were referenced, along with the history of maintenance methods and a review of construction and maintenance cost sheets prepared for each case study site by WSDOT maintenance staff. (For purposes of comparison, costs for all activities were estimated in today's dollars.) Refer to Appendix C for Individual Site Costs and for Construction and Maintenance Summary Cost Charts.

In making case study site selections, the Advisory Team considered design, construction, and maintenance and selected sites that represented the range of issues that are common at each of these phases. The selected case study sites were located in urban areas and/or at urban gateway interchanges on limited access freeways in Western Washington. They varied considerably and

illustrated the variety of conditions commonly found in urban roadsides. The selected range of site conditions contained adequate variation to compare and draw conclusions as to best practices in sustainable roadside design and management. (Refer to Appendix D for a list of the Advisory Team members and other WSDOT personnel who contributed to the project.)

The site selection criteria agreed upon by the WSDOT Advisory Team and UW researchers were as follows:

- All three western WSDOT regions (Southwest, Olympic, and Northwest) will be represented.
- The study will focus exclusively on Zone 3 of urban gateway interchanges and limited, linear access roadways / medians.
- Vegetation on case study sites will be deemed currently "successful."
- Plants on case study sites will be considered "established."
- Twelve case study sites will be included in the report.
  (Refer to Appendix E for a complete list of Specific Site Selection Criteria.)

SELECTED CASE STUDY SITES

The twelve sites selected for study were as follows:

Northwest Region

NW-1. **I-5/SR526 Interchange** - Planting islands and edges, balanced with expansive open space/meadow; no irrigation; no transient activity.

NW-2. **I-90/Rainier Ave. Interchange** - Tree mass, limbed up to discourage use by transients; originally planted with evergreen shrubs and English ivy groundcover but converted to rough grass for ease of maintenance; originally established with irrigation; extensive transient activity.

NW-3. **I-5 Noise wall plantings between 175th and SR104** - Mix of large and small trees in narrow edge/strip planting between mature stands of existing trees; scotch broom and nuisance

weeds controlled on the roadway edge for safety and sight distance; only occasional selective control of nuisance weed species in Zone 3; no irrigation, steep slopes in some areas; no transient activity.

NW-4. **SR518/SeaTac Airport Interchange** - Older planting successfully sustained by consistent maintenance over the first 30+ years; balance of expansive rough mowed grass with islands and edges of large shrubs and trees; starting to show signs of aging, originally established with irrigation, some steep slopes; no transient activity.

Olympic Region

O-1. **I-5/Marvin Road Interchange** - Balance of open rough grass with masses of medium height shrubs mixed with trees; planted by volunteers; successfully established without irrigation; history of transient activity (addressed by opening sight lines and working with local law enforcement).

O-2. **I-5/Martin Way Interchange** - Completely established native forest of trees and large shrubs; no grass; irrigation for establishment; transient activity beginning.

O-3. **I-5/Sleater-Kinney Interchange** - Tree mass, ivy bed successfully maintained underneath; irrigated for a number of years beyond plant establishment, but not currently; history of transient activity (trees have been limbed up for visibility).

O-4. **US101/Black Lake Blvd. Interchange** - Low growing mix of shrubs with minimal tree cover; planted by volunteers; no irrigation but Dry-Water on trees; no transient activity (assumed that low growing vegetation and sparse tree planting preclude opportunities).

O-5. **I-5 through Tumwater** - Edge/strip planting with mix of shrubs and small and large trees on back slope, grass on shoulder in slope; established with drip/bubbler irrigation on trees; no transient activity.

Southwest Region

SW-1. **I-205 south of interchange with I-5** - 25-year-old mix of trees and large shrubs balanced with interweaving mowed grass strips; no irrigation; minor transient activity.

SW-2. **I-5/E. Mill Plain Boulevard** - Ornamental mix of trees and medium shrubs; permanently irrigated lawn; extensive transient activity.

SW-3. **SR14/Columbia House Boulevard Interchange** - Solid mass of ornamental trees and large shrubs; established with drip irrigation; no transient activity.

CASE STUDY FACT SHEETS

To begin the study, University of Washington researchers and WSDOT design and maintenance personnel visited candidate and selected case study sites and discussed site histories and current conditions in detail. Planting plans for selected case study sites were provided when available. WSDOT maintenance personnel from three Western Washington regions provided the Case Study site maintenance data.

Case Study: NW-1

Location: **I-5 @ SR 526 Interchange**

Installation Date: Original mid-1970; renovated 2002 (costs from 2002 only)

History: Original design completed during period of Federal Highway Beautification Act; 2002 renovation completed during implementation of IRVM Plan and state and/or county requirements for reduced use of herbicides on highways

Irrigation: Irrigation for 2002 renovation establishment period only

Plant Establishment: Three-year

Soils: Topsoil unknown; soil amendment + mulch used only in shrub areas; compost not used

Existing Conditions: Some older trees from original planting; large shrubs and trees in island masses; some open meadow/grass areas

Slope: Very steep in areas; planted densely with shrubs

Function: Storm water management; reduce headlight glare; native planting

Maintenance: Routine annual mowing; spot application of herbicide to control weeds; one-time use of Spyder (mid '90s) and brushhead

Maintenance Costs:	Construction Costs:
$88 /acre, since 2002	$881,683/acre, since 2002

Site observations: This site offers an unfavorable image due to the amount of invasive vegetation. Without proper, routine maintenance, blackberry plants will take over the site. Weed control and storm water management (clean-out of catch basin) is an ongoing critical issue. Steep slopes create difficult areas to maintain.

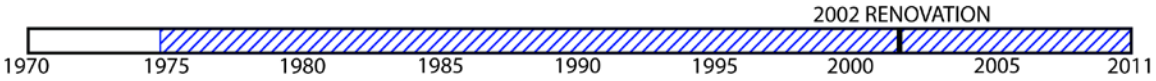


Figure 3. NW1: I-5 @ SR 526 Interchange

Case Study: NW-2

Location: **I-90 @ Rainier Avenue Interchange**

Installation Date: Original 1996; renovated 2002 (by maintenance crew)

History: Original design completed during implementation of the Roadside Classification Plan (RCP), the Roadside Manual, and the Maintenance Accountability Program (MAP); fewer dedicated maintenance roadside crewmembers

Irrigation: Irrigation for plant establishment period and occasional use during drought; abandoned when ivy was removed in 2002

Plant Establishment: Three-year

Soils: Topsoil was deemed "bad dirt" from pre-loading; soil amendment used on entire area; mulch used on non-grass and large grass areas; compost not used

Existing Conditions: Transient encampment area; limbed-up trees with open meadow/grass areas

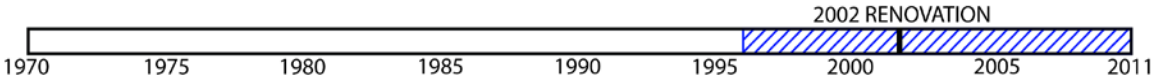
Slope: Gentle slope

Function: Storm water management (water vault on site); transient control (2002)

Maintenance: Annual transient clean-up; routine mowing; annual application of pre-emergent herbicides to control weeds in first years; tree limbing and tree removal as needed.

Maintenance Costs:	Construction Costs:
$1,536 /acre prior to 2002	
$669/acre, since 2002	$199,300/acre, since 2002

Site observations: This site offers an unfavorable image because of public safety/transient issues. Without proper, routine maintenance, transients will take over the site. Limbing trees is an ongoing critical maintenance issue. Gentle slopes provide ease of maintenance.



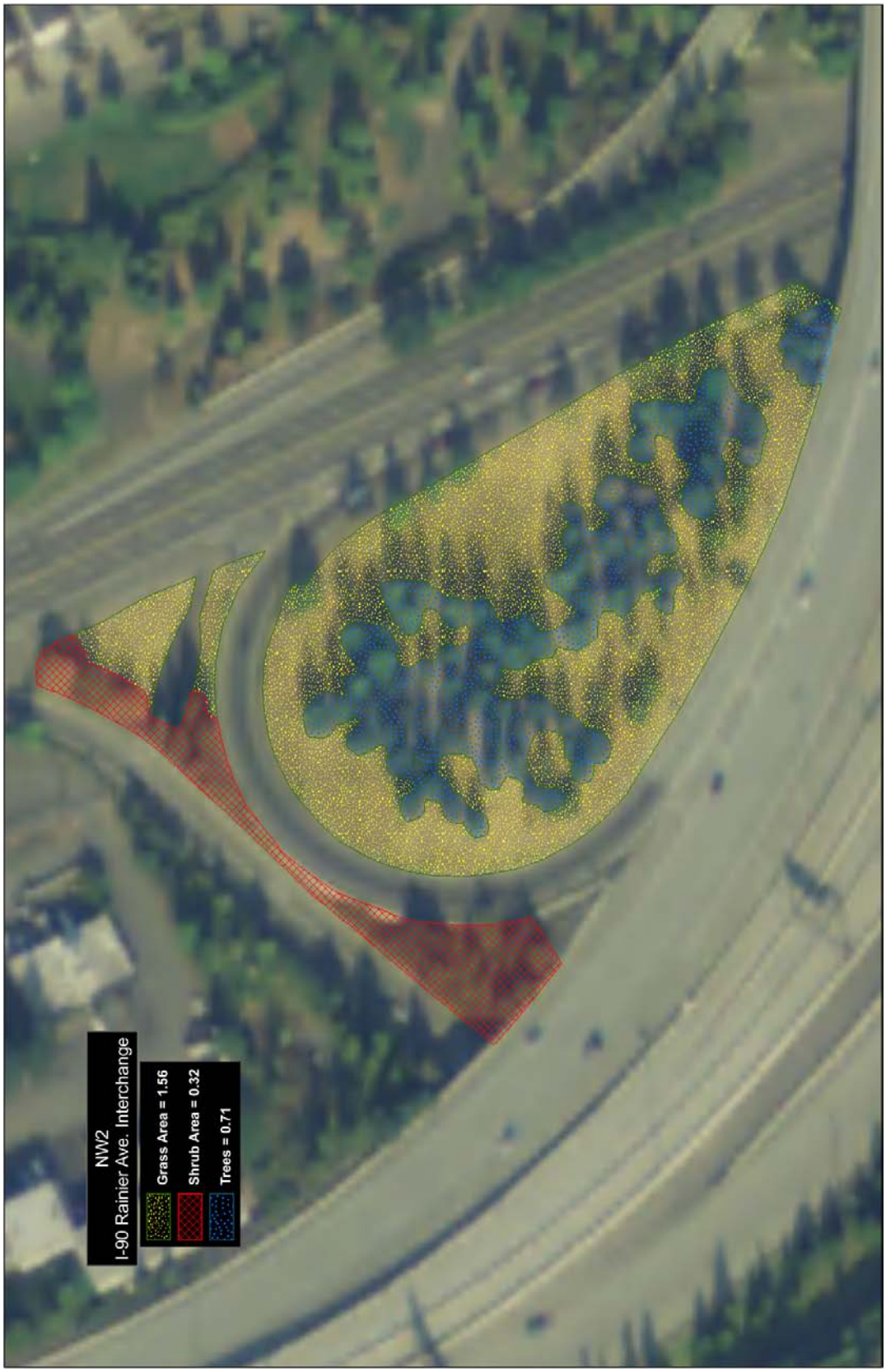


Figure 4. NW 2: I-90 @ Rainier Avenue Interchange

Case Study: NW-3

Location: **Noise Wall: I-5 South between Exit to SR 104 and 185th St. Overcrossing**

Installation Date: Original planting mid-1970s; renovated 1999 (study will use results from 1999 only)

History: Renovation completed during implementation of the Roadside Classification Plan (RCP), the Roadside Manual, and the Maintenance Accountability Program (MAP); fewer dedicated maintenance roadside crewmembers

Irrigation: Water trucks during plant establishment

Plant Establishment: Three-year plant establishment

Soils: Built on compacted gravel; topsoil and soil amendments were added

Existing Conditions: Some older trees from original planting; trees and large shrub masses with grass areas. No access road along top of noise wall. Wall is 15 to 20 ft high.

Slope: Very steep slope

Function: Preserve existing trees; storm water management

Maintenance: Periodic mowing; periodic selective spot application of broadleaf herbicides to control scotch broom and blackberry.

Maintenance Costs:	Construction Costs:
$24/acre, since 1999	$130,350/acre, since 1999

Site observations: This site offers an unfavorable image due to invasive vegetation issues. Without proper, routine maintenance weeds will take over the site. Steep slopes create difficulty for maintenance crews.

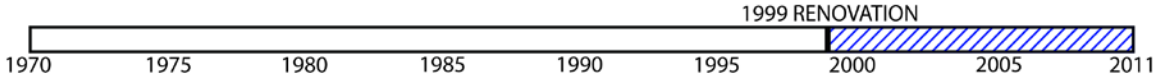


Figure 5. NW 3: Noise Wall I-5 South between Exit to SR 104 and 185th St Overcrossing

Case Study: NW-4

Location: **SR 518 @ SeaTac Airport Interchange**

Installation Date: Original 1972

History: Completed during the era of the Federal Highway Beautification Act, which had an aesthetic focus to planting. The plantings were typically highly ornamental and water-dependent. Maintenance had dedicated roadside crews until 2001.

Irrigation: Temporary system, turned off in 1978, removed in 1981

Plant Establishment: Three-year (In the 1970s FHWA mandated a three-year establishment period for federally funded projects.)

Soils: Compost and mulch used on shrub areas (minus existing vegetation areas)

Existing Conditions: 11.5 planted acres; open grass areas with significant masses of large shrubs and trees

Slope: Gentle slope to areas with steep slope

Function: Gateway Interchange

Maintenance: Application of pre-emergent herbicides in early years, periodic removal of scotch broom and blackberry by hand and spot application. Herbicides not used for past five years because of disbanded dedicated roadside crew; mowing several cycles in growing season; treated site for knotweed.

Maintenance Costs:	Construction Costs:
$271/acre, since 2001	$87,628/acre

Site observations: This site offers a very favorable public image due to a thorough and mature canopy coverage. Certain areas of this site have evidence of blackberry and other weeds on site. There are many acres of grass to mow.

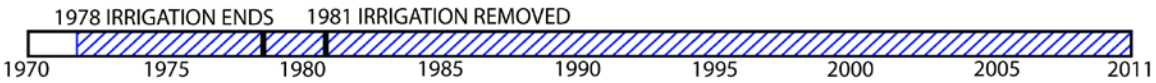


Figure 6. NW 4: SR 518 @ SeaTac Airport Interchange

Case Study: O-1

Location: **I-5 @ Marvin Road (SR 510) Interchange**

Installation Date: Original planting late 1960s; new shrub masses installed 2000-01

History: Revised during the era of reduced herbicide use. IRVM Plans instituted.

Irrigation: No irrigation except for Dri-Water (slow release gel) on street trees during plant establishment

Plant Establishment: Three-year by WSDOT Olympic Region Restoration Crew

Soils: Light, dry, free-draining rocky soil; compost and mulch used on shrub areas (minus existing vegetation areas)

Existing Conditions: Minor transient activity; new shrub masses and some older trees from original construction.

Slope: Gentle slope to areas with steeper slope

Function: Canopy coverage by more native, drought tolerant, and naturalized plants. The planting design specified smaller plants at a higher density (4-ft O.C.), soil amendments, and mulch/chips.

Maintenance: Annual transient clean-up (selective tree limbing); annual mowing; application of herbicides (by hand and spot) for removal of scotch broom, blackberry and other undesirables.

Maintenance Costs:	Construction Costs:
$269/acre, 2001	$50,700/acre

Site observations: This site offers both a very favorable public image (due to a lack of undesirable plants and a thorough canopy coverage) and an unfavorable image (due to public safety /transient issues).

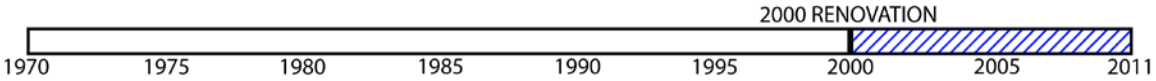


Figure 7. O-1: I-5 @ Marvin Road (SR 510) Interchange

Case Study: O-2

Location: **I-5 @ Martin Way Interchange**

Installation Date: Original planting 1987-88; reworked in 2010

History: In early 1980s, drought conditions encouraged conservation methods. In 2010, CPTED drives design.

Irrigation: Irrigation impact system for three years; phased out in 1992.

Plant Establishment: Three-year

Soils: Soil amendment and mulch used.

Existing Conditions: Solid massing of large trees and shrubs. (Former transient camp with 15 people.)

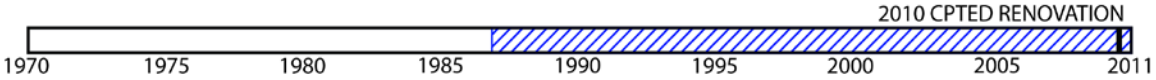
Slope: Gentle slope to areas with steeper slope

Function: Retain sight lines; canopy coverage via more native, drought tolerant, and naturalized plants; vegetation "competition" concept.

Maintenance: Annual transient clean-up and selective tree limbing; removal of scotch broom, and blackberry by hand and spot application.

Maintenance Costs:	Construction Costs:
$210/acre, since 2010	$191,775/acre

Site observations: This site offers both a very favorable public image (due to a lack of undesirable plants and a thorough canopy coverage) and an unfavorable image (due to public safety /transient issues being adjacent to a park & ride and bicycle path). Wet conditions; aspen doing well.



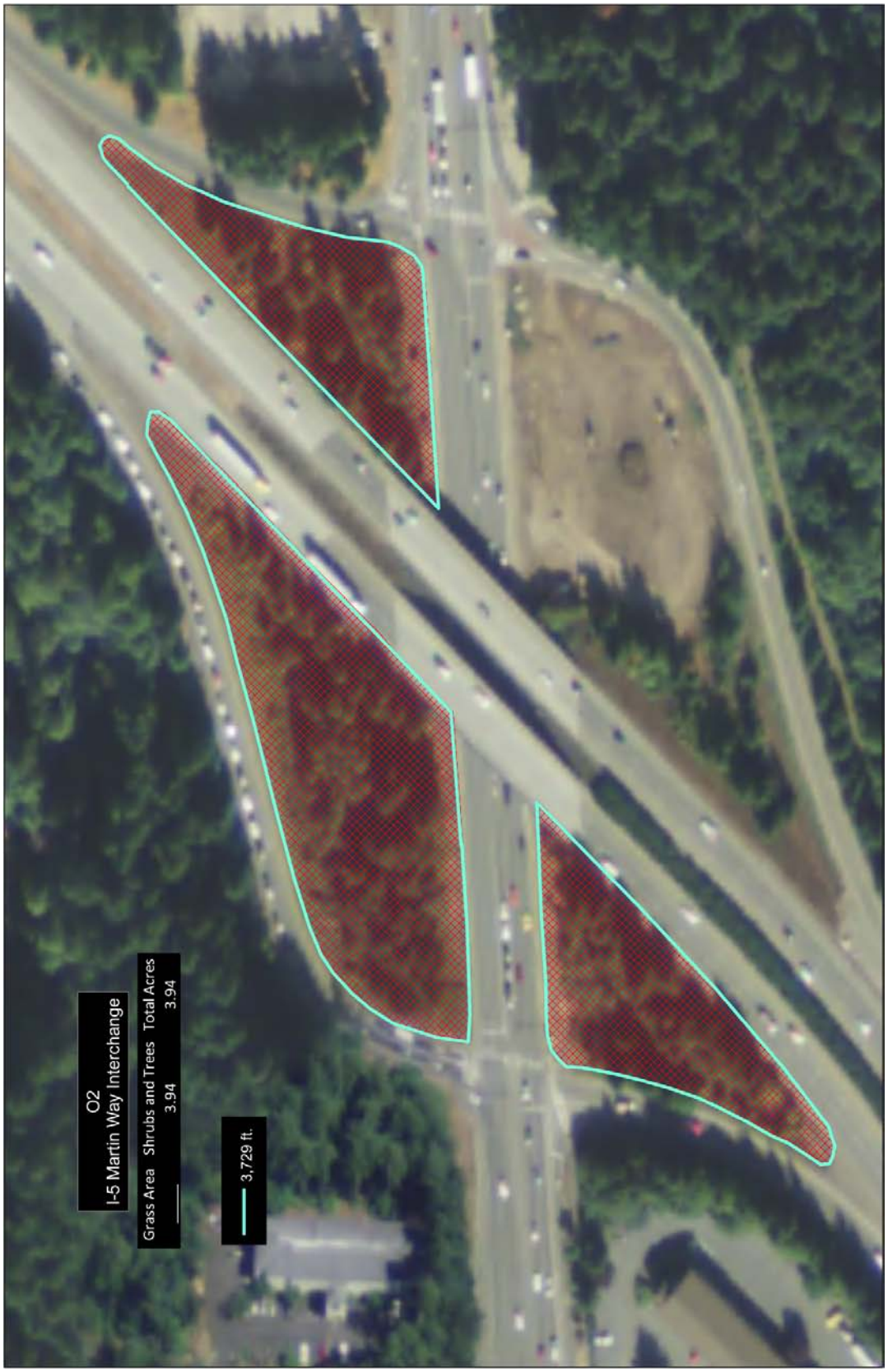


Figure 8. O-2: I-5 @ Martin Way Interchange

Case Study: O-3

Location: **I-5 @ Sleater-Kinney Interchange**

Installation Date: Original planting 1987.

History: In early 1980s, drought conditions encouraged conservation methods.

Irrigation: Irrigation system for three years; phased out in 1995.

Plant Establishment: Three-year, weed control during establishment contract.

Soils: Soil amendment and mulch used. (Pre-compost project)

Existing Conditions: Evidence of transient camp; trees and groundcover (ivy); shrubs girdled by rodents; no evidence of scotch broom or blackberry.

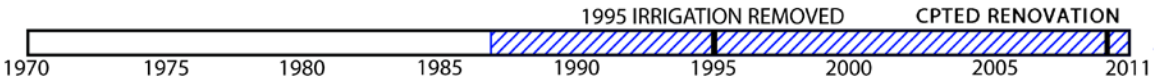
Slope: Gentle slope to areas with steeper slope

Function: Erosion control; retain sight lines for law enforcement; canopy coverage via more native, drought tolerant, and naturalized plants.

Maintenance: Dedicated landscape crew. Annual transient clean-up and selective tree limbing; application of pre-emergent herbicides in early years; removal of scotch broom and blackberry by hand and spot application. CPTED clean-up/tree limbing.

Maintenance Costs:	Construction Costs:
$274/acre	$252,950/acre

Site observations: This site offers both a very favorable public image (due to a lack of undesirable plants and thorough canopy coverage) and an unfavorable image (due to public safety /transient issues). Ivy is no longer used as a groundcover by WSDOT because of the climbing and eventual choking of trees and the invasive nature of the plant. The rodents attack the ornamental shrubs more than the native plants.



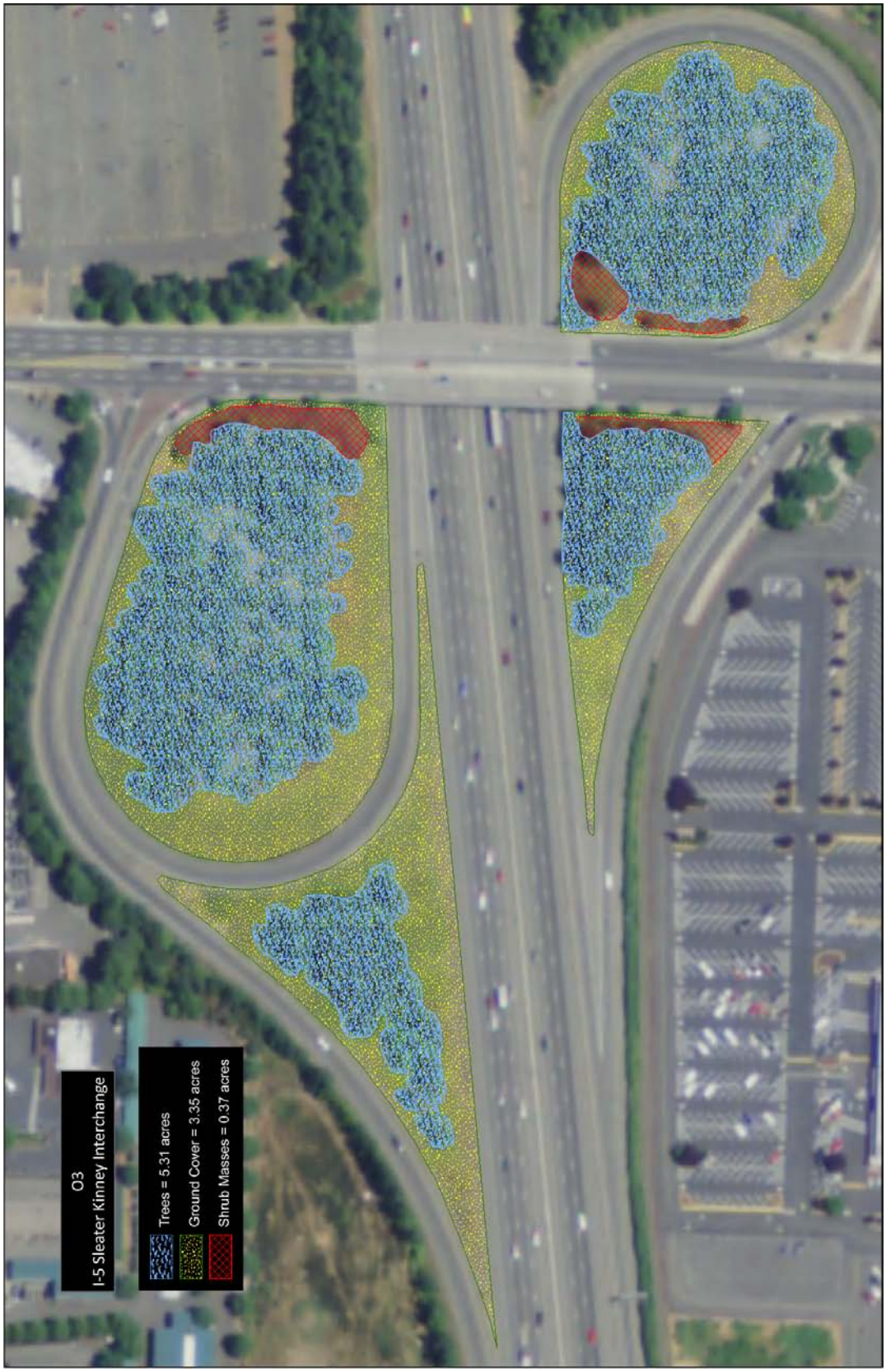


Figure 9. O-3: I-5 @ Sleater-Kinney Interchange

Case Study: O-4

Location: **US 101 @ Black Lake Boulevard Interchange**

Installation Date: Original planting installed 2000-2001.

History: First Urban Interchange in Washington State with a patented design (Grinner Engineers); pre Roadside Classification Plan; volunteer planting project

Irrigation: No irrigation except for Dri-Water on trees during plant establishment

Plant Establishment: Three-year establishment by WSDOT Olympic Region Restoration Crew

Soils: Compost and mulch used - 3 in. each.

Existing Conditions: Very narrow, linear, steep site; solid mass of low growing shrubs/groundcover with a few trees (existing trees are outside of clear zone); naturalized plantings that are drought tolerant. Sound wall.

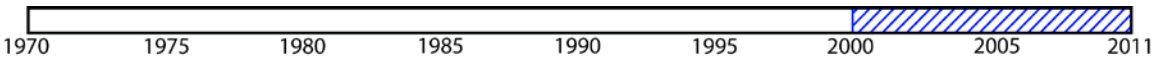
Slope: Steep slopes

Function: Erosion control; retain sight lines for law enforcement; canopy coverage via more native, drought tolerant, and naturalized plants.

Maintenance: Dedicated roadside crew; removal of scotch broom, blackberry and other undesirable vegetation by hand and spot application of selective herbicides; pre-emergent herbicides use is unknown.

Maintenance Costs:	Construction Costs:
$405/acre	$87,606/acre

Site observations: This site offers a very favorable public image due to a lack of undesirable plants and thorough canopy coverage. There is no mowing because of a lack of grass.



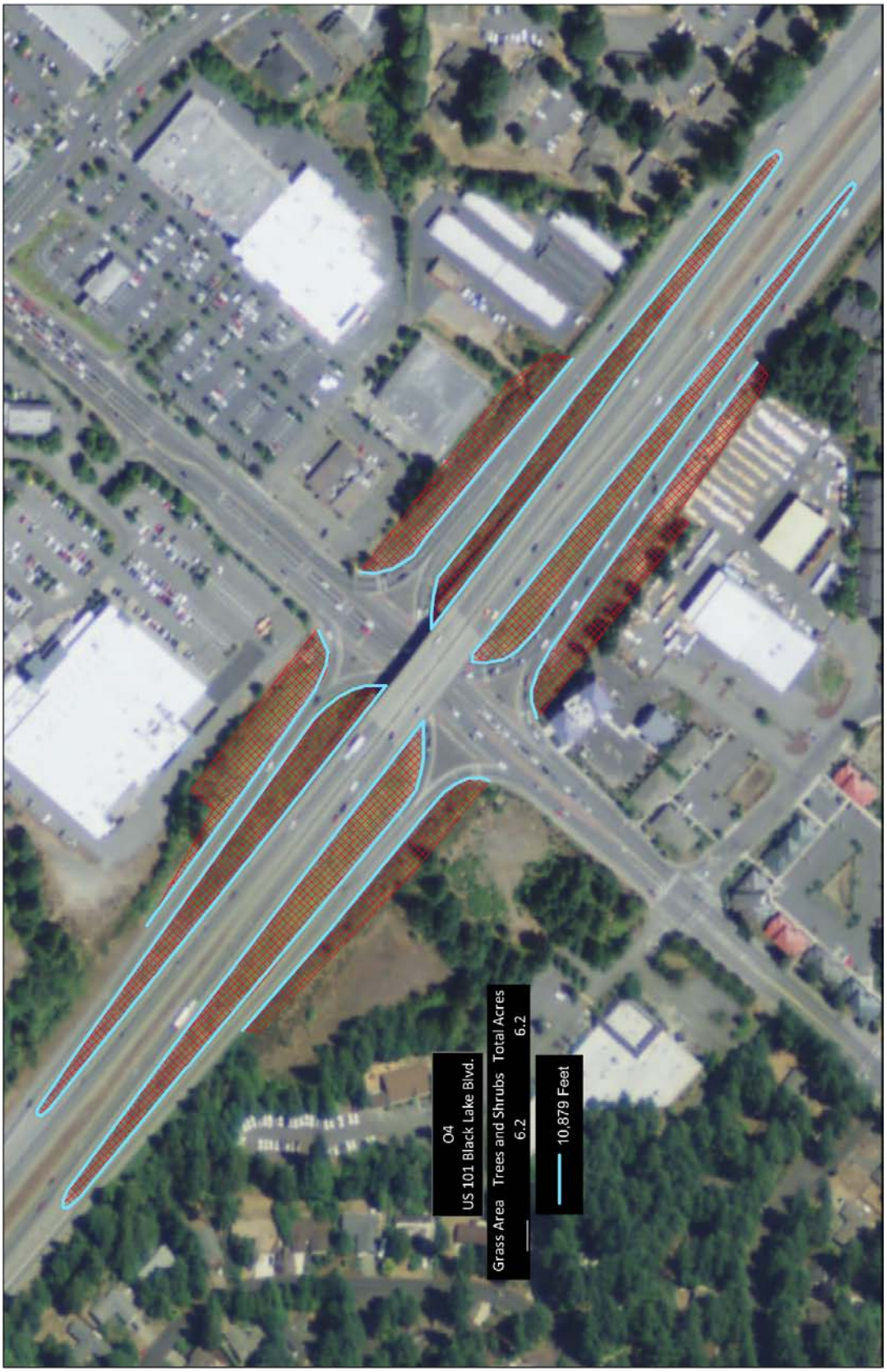


Figure 10. O-4: US 101 @ Black Lake Boulevard Interchange

Case Study: O-5

Location:	**I- 5 @ Trosper Road to Tumwater Boulevard**
Installation Date:	Original planting installed 1992.
History:	No trees larger than 4" diameter, per Federal Highway Protection Act. Roadside Classification Plan and Roadside Manual stressed the importance of low-lifecycle costs and sustainability in roadside restoration work.
Irrigation:	Bubbler irrigation system during three-year plant establishment.
Plant Establishment:	Three-year
Soils:	Compost and mulch used - 3" each.
Existing Conditions:	Very narrow, linear, steep site; solid mass of medium-sized shrubs, small trees and large trees on the fence line; drought tolerant, naturalized (headed toward native) plantings, grass on shoulder; very few weeds; sound wall is part of roadway.
Slope:	Steep 2:1 slopes in many areas
Function:	Erosion control; canopy coverage via more native, drought tolerant, and naturalized plants.
Maintenance:	Dedicated roadside crew; mowing of grass shoulder (one to two times/year); pre-emergent herbicides used in earlier years; replacing rugosa rose with snowberry; removal of undesired vegetation using IVM.

Maintenance Costs:	Construction Costs:
$347/acre	$189,080/acre

Site observations: This site offers a very favorable public image due to a lack of undesirable plants and a thorough canopy coverage. Exhaust from vehicles adheres to the trees and turns leaves black when it rains. Shoulder used to be gravel, now composted and seeded with grass for better storm-water infiltration.

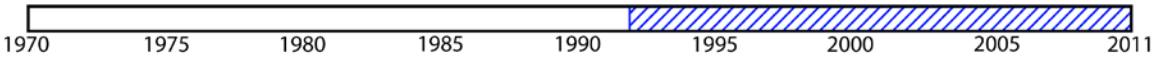


Figure 11. O-5: I-5 @ Trosper Road to Tumwater Boulevard

Case Study: SW-1

Location: **I-5 @ I-205 Interchange**

Installation Date: Original planting installed late 1970s –to 1980.

History: Post Clean Water Act, no mitigation. Although planted during the era of the Federal Highway Beautification Act, this site is considered an older and progressive site because of the use of native and naturalized plants.

Irrigation: No irrigation

Plant Establishment: Three-year

Soils: Planted with topsoil and mulch.

Existing Conditions: Evidence of transient camps; masses of medium to large shrubs and trees interspersed with grass areas; naturalized plantings (native and/or native looking); formerly a rural site with wetland or stream. Site has a wide median and ROW.

Slope: Slope is gentle to flat with some steep and narrow areas

Function: Succession forest concept; erosion control; managed succession with native plants.

Maintenance: Partial dedicated roadside crew; selective long-term maintenance; mowing of grass shoulder (one to two times/year); removal of scotch broom, blackberry and other undesirable vegetation by hand and with spot application of selective herbicides. First selective hazard tree removal since construction is being conducted.

Maintenance Costs:	Construction Costs:
$43/acre	$49,685/acre

Site observations: This site offers both a very favorable public image (due to a lack of undesirable plants and thorough canopy coverage) and an unfavorable image (due to public safety /transient issues). Transient issue requires much time and effort. The IVM manual requires the removal of invasive vegetation, yet there is much evidence of blackberry, clematis, and ivy.

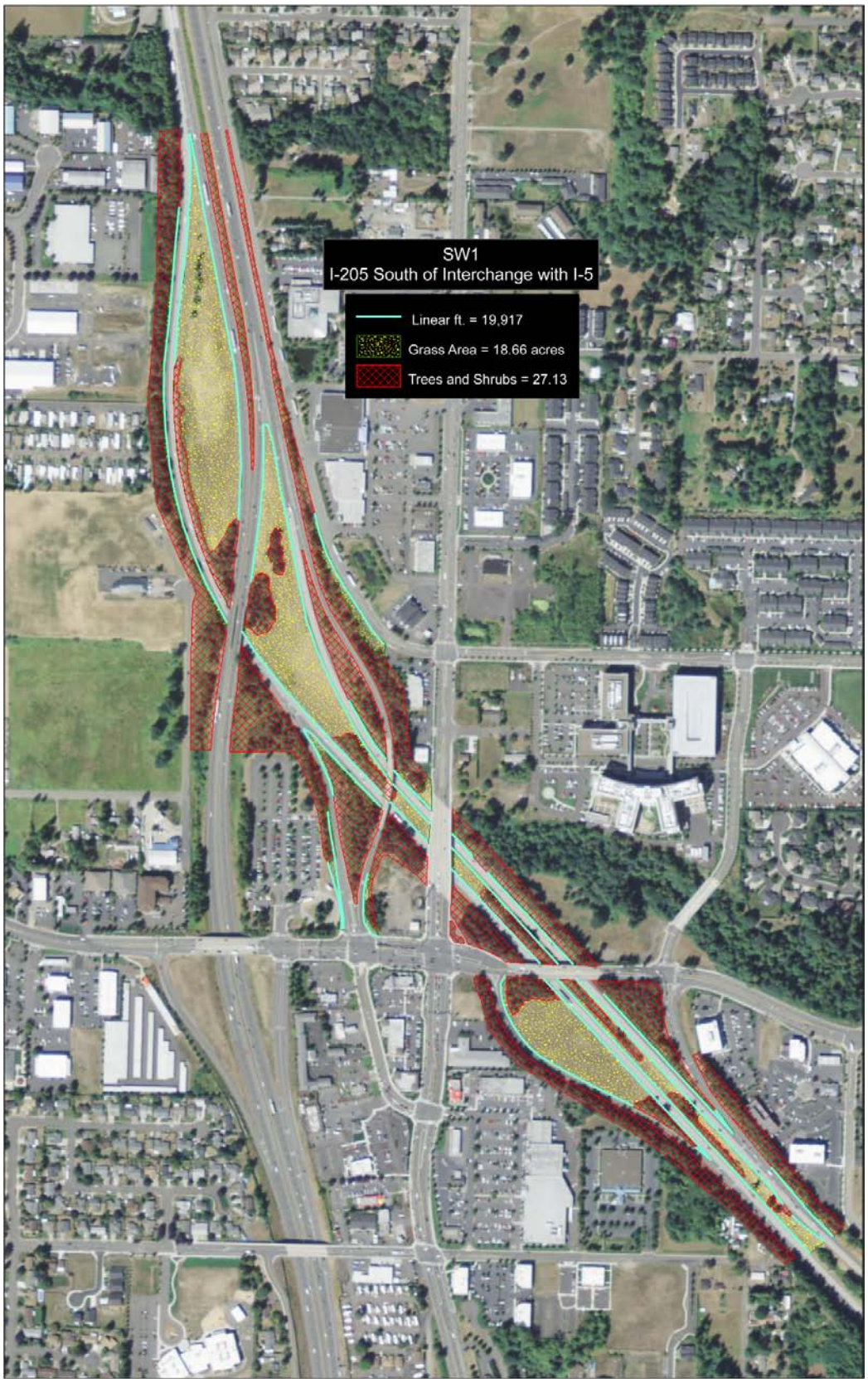


Figure 12. SW-1: I-5 @ I-205 Interchange

Case Study: SW-2

Location: **I-5 @ East Mill Plain Boulevard Interchange**

Installation Date: Original planting installed in 1985.

History: Planted during the era of the Federal Highway Beautification Act, this site is considered an old-style/obsolete planting design today.

Irrigation: Irrigation for grass areas; shrub areas irrigated for establishment and during drought periods through the '90s

Plant Establishment: Three-year

Soils: Planted with topsoil and mulch.

Existing Conditions: Evidence of former and current transient camps; ornamental planting of trees, shrubs, and groundcover (ivy) with irrigated lawn/grass areas

Slope: Gentle slopes with some steep slope areas

Function: Gateway Interchange with ornamental planting design. Currently, undergoing transient-proof retrofit for law enforcement visibility.

Maintenance: Partial dedicated roadside crew; transient clean-up and tree limbing; mowing of lawn areas weekly throughout the growing season; annual spring maintenance and winterization of irrigation system; periodic application of pre-emergent herbicides in early years; removal of scotch broom, blackberry and other undesirable vegetation by hand and with spot application of selective herbicides.

Maintenance Costs:	Construction Costs:
$1,435/acre	$158,628/acre

Site observations: This site offers both a very favorable public image (due to a lack of undesirable plants and a thorough canopy coverage) and an unfavorable image (due to public safety /transient issues). Transient issue requires much time and effort. Evidence of fire near underpass.

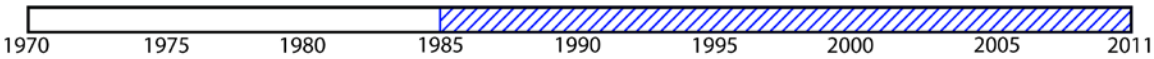


Figure 13. SW-2: I-5 @ East Mill Plain Boulevard Interchange

Case Study: SW-3

Location: **SR 14 @ Columbia House Boulevard Interchange**

Installation Date: Original planting installed in 1995.

History: Roadside Classification Plan was used; plant height restriction was enforced.

Irrigation: Drip irrigation for trees only through plant establishment

Plant Establishment: Three-year

Soils: Sandy soils from dredge spills; planted with 6 to 12 in. of topsoil and mulch.

Existing Conditions: Ornamental planting of trees and large shrubs. Very few blackberry plants.

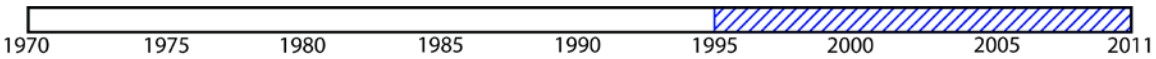
Slope: Very steep slopes

Function: Visually unite with I-5 planting, erosion control

Maintenance: Partially dedicated roadside crew; annual application of pre-emergent herbicides in early years; some periodic manual removal of weeds and undesirable trees; cleaning of catch basin.

Maintenance Costs:	Construction Costs:
$307/acre	$97,838/acre

Site observations: This site offers a favorable public image due to a lack of weeds and canopy coverage. Cottonwood trees across highway are a seed source. CB can become plugged with leaves from deciduous trees.



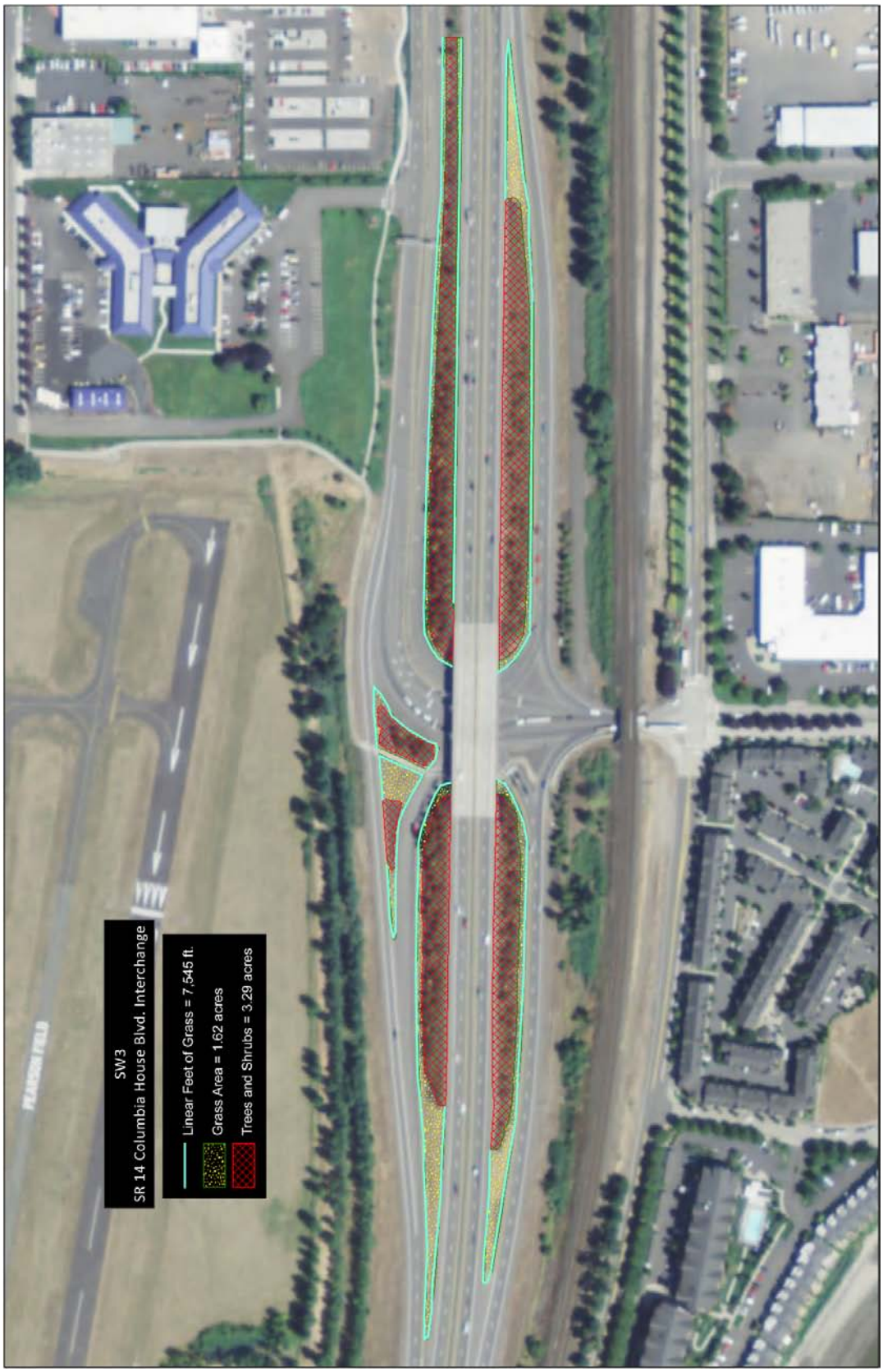


Figure 14. SW-3: SR 14 @ Columbia House Boulevard Interchange

FINDINGS / FACTS / DISCUSSION

The research provided multiple significant and relevant facts regarding issues that affect the function, sustainability, and maintenance of urban roadsides and thus affect the determination and implementation of low lifecycle costs. These issues are categorized as follows:

- biological disturbances of roadsides
- human disturbances of roadsides
- physical and ecological characteristics of roadside environments
- the restoration design process
- construction contracts for site preparation and soils for roadsides
- plant communities and plant establishment for roadsides
- roadside maintenance and Integrated Roadside Vegetation Management (IRVM) Plans
- WSDOT organizational structure / considerations.

BIOLOGICAL DISTURBANCES OF ROADSIDES

Biological disturbances take the form of invasion by large stature invasive plant species. Invasive weed pressure is WSDOT'S single most prevalent and extensive roadside maintenance problem and will remain so in the future. This problem pervades the entire highway system but is often more acute on urban roadsides because they experience more frequent disturbance, withstand more stressful growing conditions, and are surrounded by more weed seed sources. Roadside weeds require ongoing, unrelenting maintenance to keep invasions in check.

Invasive plants are legally classified in different ways, and the dynamics of how they invade varies. WSDOT is legally required to give priority to dealing with plants classified as noxious weeds and designated by the local county for required control. However, some of the most persistent and ubiquitous invasive “nuisance” weeds are not designated for required control and must therefore be dealt with as a lower priority according to MAP. These nuisance weeds grow so vigorously that they can, in relatively short periods of time, overwhelm planted areas unless controlled shortly after they emerge. In Western Washington, examples of invasive, nuisance

vegetation include plants such as Himalayan blackberry, wild clematis, butterfly bush, Clematis vitalba, and English ivy. Himalayan blackberry and Clematis vitalba are two vigorously growing and fast-spreading species that are particularly significant, as they can overwhelm shrub beds and small trees, and Clematis can quickly swamp even mature trees.

English Ivy once functioned as the backbone of groundcovers for urban roadsides and is now considered an invasive plant. It is a particularly persistent plant that covers large sections of the case study sites in Olympia (Site O-3) and Vancouver (Site SW-2) and formerly in Seattle (Site NW-2). Despite all of ivy's advantages as a cheap, quick-growing, evergreen, and versatile plant, it is no longer specified by WSDOT and cannot be used because of its extremely invasive nature (by seed and plant part).

There is no quick or easy fix to the problem of invasive weeds, but the most effective short- and long-term strategy is persistent control to prevent them from overwhelming roadside areas. If not controlled, these types of invasive plants have the potential to completely out-compete planted areas, regardless of the kind, age, or condition of the plantings, and if regular maintenance is not provided they may do so in a relatively short period of time. Once roadside vegetation communities are overrun by invasive weeds, it is extremely difficult and costly to restore them to preexisting conditions. Particularly in urban settings, the need for consistent and persistent control of unwanted invasive plants is essential. When maintenance is stopped or is intermittent, roadside vegetation in urban areas is likely to be overwhelmed with invasive weeds, resulting in a condition that is hard to recover.

HUMAN DISTURBANCES OF ROADSIDES

Human disturbances of roadsides take many forms, from disruptions necessitated by transportation system upgrading to disturbance by users and adjacent property owners (such as by

fires, vehicles running off roads, neighbors cutting vegetation for views etc.). These problems occur throughout the state's road system but are more intense in urban locations.

A far greater problem for managing roadside vegetation, and one exclusive to urban roadsides, is the influx of transient encampments, on the state right of way (ROW). Six of the twelve case study sites have experienced problems with transient encampments demonstrating the severity and extent of this problem on urban roadsides (sites NW-2, O-1, O-2, O-3, SW-1, and SW-2). This problem has important implications for urban roadsides that are likely to increase as the region continues to urbanize. Encampments favor flatter, heavily vegetated roadsides, located at large intersections, and are less common, but not unknown, on steep slopes immediately adjacent to busy freeways. Transients favor conditions where encampments are secluded, i.e.,. not visible from freeways, on- and off-ramps, or adjacent properties, and where there is easy access to food and drink services and opportunities for panhandling.

PHYSICAL AND ECOLOGICAL CHARACTERISTICS OF ROADSIDE ENVIRONMENTS

It is important to typify urban roadsides to understand their characteristic physical and ecological conditions and the forces and processes to which they are subjected. The land in WSDOT's care comprises an enormous area, but its configuration is unlike public lands managed by other state or federal agencies, which typically own large, contiguous blocks. WSDOT's lands consist of relatively small areas stretched out to enormous lengths (with associated property boundaries) of long, narrow, continuous or broken parcels——roadsides—with roads in their center. This may seem so obvious as to not need stating, but it makes clear one of the most important conditions: roadsides are particularly vulnerable to disturbances from the roads themselves—road use activities, and repair and expansion work—and are vulnerable to many

different kinds of disturbance from adjacent land uses, which may damage roadside vegetation, alter hydrologic patterns on roadsides, or introduce a wide variety of weed seeds and plants. Because of their configuration and exposure to adjacent properties, roadside lands require far more extensive and intensive maintenance than do public lands in large contiguous blocks.

Urban roadside conditions range across a wide spectrum of narrow, often steep cut or fill slopes along freeways to expansive flat to sloping areas at freeway intersections. These typically provide different growing conditions and serve different functions. Long, narrow strips of land that closely flank the edges of very busy roads result from expensive right-of-way (ROW) acquisitions in urban areas. For road engineering construction reasons, these roadsides often contain steep cut or fill slopes. Such areas are often difficult to safely and conveniently access and are typically unsuitable for large transient encampments. By contrast, extensive areas typically occur at intersections and frequently contain large amounts of flat or gently sloping land. Parts of these kinds of roadside are distant from busy road edges and are often sheltered by mature vegetation. These areas are often more easily accessed by maintenance personnel and by transients and are thus more likely to be used for encampments than narrow strips of sloping land. When such areas are located close to food sources and/or panhandling opportunities, as is common in urban environments, the desirability for transient encampments increases.

This great variety of roadside site and growing conditions generates planting design responses that are specific to each set of site conditions and their functional needs. Different roadside vegetation and site conditions require different maintenance responses. It is unrealistic, therefore, to expect that design and maintenance should be the same for all roadside conditions in all locations. Appropriate lowest lifecycle cost landscape designs and maintenance methods must be specific to site conditions and functional needs.

Ecologically, roadsides experience a variety of relatively frequent disturbances—including new construction—all of which both adversely affect the growth of planted vegetation into mature stable plant communities and provide greater opportunities for invasive plants to become established. Urban conditions exacerbate all of these problems, as they contain a larger and more diverse weed seed pool in close proximity to the ROW.

RESTORATION DESIGN PROCESS

Successful design outcomes of talented WSDOT design professionals are witnessed daily by thousands of drivers on the I-5 corridor and beyond. Design teams consisting of registered landscape architects and landscape designers work diligently to create roadsides that positively reflect the WSDOT environmental policy and the specific design goals appropriate to each segment of roadway. Design teams transform a general set of ideas and criteria into functional living landscapes, while addressing the immediate and long-term goals of the restoration planting. Along with plant selection, design teams must identify site functions that need to be provided and know how this function will be actualized, based on site-specific conditions.

To attain successfully restored roadsides, design teams emphasize the need for constant and open conversations with the maintenance staff, the professional engineers, the construction contractors, field inspectors, and typically representatives from the county, city, or adjoining neighbors. These dialogues and involvement must happen at all phases of the design process: concept, design development, construction installation, and especially during the three-year plant establishment period.

Key elements for creating and maintaining high performance restoration landscapes, under the direct control of design teams, are educating all parties about the reasons for the restoration project decisions (why and what is happening); attending to and resolving any conflicts as early as

possible; inspecting for proper weed control on project sites; examining the application of soil amendments—especially depths of compost and mulch; reviewing all plant material to ensure best quality; and reviewing the timing of plant installation/irrigation windows.

CONSTRUCTION CONTRACTS FOR SITE PREPARATION AND SOILS FOR ROADSIDES

The condition of roadside soils and how they are treated during construction operations can affect vegetation positively or negatively for decades. Important conditions to specify and to inspect during construction include the condition of existing soils, soil compaction, soil type, and soil preparation / amendments. Therefore, design decisions and supervision and acceptance of construction work have long-term effects on roadside maintenance work and lifecycle costs. Money saved on soil preparation during construction often means added maintenance costs, poor plant performance, and reduced function over the life of a project.

Avoiding disturbance to previously established vegetation and preventing soil compaction are very effective ways to reduce short- and long-term roadside maintenance costs. Roadsides with minimal disturbance, where existing desired vegetation is retained, tend to become self-sustaining more quickly than disturbed sites with replanted communities. For example, healthy native vegetation and soils had been retained undisturbed on the I-5 Marvin Road Interchange (Site O-1), and this site showed less weed invasion than was typical on other case study sites.

Healthy plant growth requires a soil structure with pore space for water and air to penetrate and for roots to grow. Soil compaction (i.e., the reduction or elimination of pore space in soils) is a particularly important consideration on roadsides, as there may be conflicts between the desire to compact solids to meet engineering functions such as slope stabilization and the need for soils to contain voids for roots to penetrate them and for plants to grow vigorously and healthily. Avoiding

soil compaction wherever possible is a crucial consideration for plant survival and the short- and long-term success of roadside planting. Soil compaction can occur when heavy equipment drives across an area, even if only infrequently, and it is especially severe when soils are wet or waterlogged. The soil of an area may also be compacted by storing equipment or materials on them. It is difficult and expensive to restore the open structure of soils after they have been compacted. It is, therefore, desirable to prevent compaction of roadside soils if low lifecycle costs are to be achieved for plant communities.

Structural materials suitable for highway construction are rarely good growing mediums for desirable vegetation and may require extensive amendment in order to establish restoration plantings. Similarly, grading practices (steep slopes, compaction, etc.) that make sense for engineering purposes typically create completely unsuitable soil conditions for plant growth, as they fail to retain moisture or allow air and root penetration. Desired restoration vegetation growing in these conditions may be difficult to maintain; however, invasive weed plants are often well suited to these condition, and they thrive. For example, desired plants growing on river dredge spoils on Site SW- 3 showed signs of severe stress, and the plants on the steep cut bank of Site NW-3 were difficult to access for maintenance. Plants on the fill slopes of the Site O-4 were growing well, as the fill material was more open and conducive to growth than the subsoil exposed on the cut slopes and the dredge spoil material. Adverse soil conditions occur on many roadsides, but these conditions are frequently more extreme in urban locations and add to the other stresses that plants experience in these locations.

Over the years, WSDOT has refined its soil amendment requirements and recognizes the importance of soil structure and fertility for plant health. Roadsides requiring the least maintenance in the case study sites were areas planted with native vegetation and soils that had been adequately

amended with organic matter and nutrients following road construction, such as Site O-2. Soil amendments such as, topsoil, mulch, and/or compost had been added to all case study site soils. Some sites received 3 inches of compost and 3 inches of mulch; some used soil amendments only around planting holes; some used either compost or mulch but not both; and some incorporated compost into soil while others did not. The application of 3 inches of compost and 3 inches of mulch contributed to the most vigorous plant growth and successfully suppressed noxious and nuisance weeds. Mulch is crucial to plant establishment and long-term plant vigor. Mulch holds water, reduces evaporation, and keeps soils moist and cool, thus promoting plant establishment and healthy growth. Proper use of quality-grade mulch (weed seed free) reduces weed seed germination. DOT personnel noted that compost availability has greatly increased over the past 20 years, thus providing adequate supplies for the large-scale highway projects.

RESTORATION PLANT COMMUNITIES AND PLANT ESTABLISHMENT FOR ROADSIDES

Design teams and maintenance crews tend to favor different restoration plant communities. Design teams considering the functional and aesthetic needs of road users and adjacent properties, varying site and environmental conditions, and larger ecological considerations tend to favor plant communities that meet the specific conditions and needs of each restoration roadside location. They tend to favor woody plant communities of trees and shrubs. Maintenance personnel, recognizing severe budgetary and staffing constraints and the variability of budgets from year to year, favor plant communities and conditions that can be managed efficiently using large power equipment, which translates to large areas of grass, with or without trees, except on steep slopes where grass mowing is impracticable.

Restoration Plant Community Types

To provide a sense of the variety of urban roadside conditions examined in this study, urban roadside restoration plant communities—from the case study sites—may be divided, very basically, into the following five categories:

- ***Undisturbed native (or existing) desired plant communities of trees and shrubs***
  The most extensive example of this condition, where existing native vegetation has been retained and continues to thrive, is Site O-1 (I-5 Martin Way Interchange). Typically these communities provide complete screening year-round.
- ***Forest communities (trees as specimens or in continuous stands)***
  The best examples of this condition are long-established roadsides with mature trees, such as occur at Site NW-4 (SR 518/SeaTac Airport Interchange) and Site O-3 (I-5 Sleater-Kinney Interchange). Typically these communities have reached a level of maturity that tends to reduce weed invasion to a relatively low level.
- ***Shrub communities (shrub masses with or without trees)***
  Shrubs come in many sizes and shapes. Examples of this roadside condition occur on Site NW-1 (I-5/SR 526 Interchange) and Site O-5 (I-5 through Tumwater). For this study we considered the mature growth of low shrubs to be a maximum of 4 ft tall; and tall shrubs to be higher than 4 ft. Shrub masses serve varied functional and aesthetic purposes. Depending on their height and density (and the inclusion of trees in the shrub mass) they may screen views or provide views over the top of the shrubs, woody ground cover plants, with and without trees. The best example of this condition occurs at Site O-3 (I-5 Sleater-Kinney Interchange), where scattered trees grow in a large, well-maintained ivy bed.
- ***Grass with or without trees***
  Site NW-2 (I-90/Rainier Ave. Interchange) has extensive grass areas, as does Site NW-1 (I-5/SR526 Interchange).
- ***Woody groundcover communities (with or without trees)***
  For this study we considered the maximum height of woody ground cover to be 2 to 3 ft.

These categories are intended to characterize the variety of roadside planting in the study areas, not to suggest that the categories are uniform throughout or that they are sharply distinct from

each other. The types of roadside planting examined in this study shaded each other and exhibited many variations of species composition, proportions of different kinds of plants, and densities of planting, etc. Plant communities occur on sites with widely varying environmental and social conditions, and growth patterns respond to these and to different maintenance regimes. Each set of environmental and road conditions represents a different set of functional needs. It is important to keep in mind throughout the following discussion that each segment of roadside has been designed to address the specific site conditions and functional and aesthetic needs of the roadway at that location. Therefore, lowest lifecycle costs for roadside landscapes cannot be considered in abstract but must recognize the unique conditions and functions that they are designed to address. It is, therefore, crucial that WSDOT designers and maintenance personnel work together not just during the construction and plant establishment phases of projects but throughout the entire lifespan of roadsides.

Plant Establishment

The rate at which full site coverage by vegetation is achieved, after completion of the roadwork part of a contract, depends on a combination of factors, including site environmental and soil conditions, mulch application, and water treatment. It also depends on design and maintenance decisions. Design issues include plant species selection, types specified (large or small trees, shrubs, ground cover, etc.), size, and spacing. Maintenance issues include herbicide use and plant care during establishment. WSDOT landscape architects and restoration designers have experimented with design approaches and developed successful plant combinations and communities that respond to varied environmental conditions, requirements, and changing aesthetic preferences. Successful plant establishment depends on appropriate maintenance, with IVM being an important management approach and application tool for selecting and using the most appropriate

maintenance methods. The Northwest Region's plant establishment crew is another way in which WSDOT is successfully responding to this critical period in the life cycle of all roadside vegetation.

The plant establishment period for large-scale roadway construction contracts is typically three years. Urban roadsides are more stressful environments than typical planting conditions, and plants may be slower to become established. As a result, it may be desirable to have longer plant establishment periods for urban projects. Plant loss, during the establishment period, is typically due to installation of plants outside of the planting window, lack of watering or other care by the contractor, and/or acceptance of plants that were not hardened off, all of which can be controlled by careful observation and acceptance of installation by WSDOT designers. Plants replaced at the end of the three-year plant establishment period are essentially newly planted, i.e., less than fully established, when the project is handed over to WSDOT for maintenance. Projects in which the percentage of replaced plants is high require considerably more work by WSDOT maintenance personnel than do fully established projects and place an undue burden on maintenance resources and budgets. Indeed, all work that disturbs established roadside vegetation, even small-scale work such as installing light poles, utility infrastructure, etc., results in increased work for maintenance, as it converts areas of existing roadsides from relatively low maintenance levels to conditions with higher maintenance needs for a period of time.

Plant spacing and eventual plant size are interrelated design decisions. Typically, plants are installed closer (4 to 6 ft O.C.) when smaller container sizes (6-in. vs. 2-gal. pots) are used and farther apart for larger sizes. Data from the case study sites were insufficient to determine whether cover occurs faster using more small-container plants at closer spacing than using fewer larger-container plants at wider spacing. It is likely that there is no single “right” answer to this question, as many factors affect how quickly plants become established and cover the ground. Currently,

WSDOT practice is to specify smaller container sizes at a closer spacing, usually 4 feet on center triangular spacing for shrubs, with trees included in the mix every 12 to 16 feet apart. WSDOT reports higher plant survival rates and canopy coverage with this practice than with more widely spaced, larger-container plants. More critical to successful plant establishment than container size and spacing is the level of care that sites receive during establishment periods, such as weed control, watering, and timely plant replacement.

The choice of plant species may influence speed of soil coverage and long-term viability of roadside vegetation. For urban areas, WSDOT policies favor native species but allow use of non-natives when these better serve functional and aesthetic needs or are tougher and more resilient. Most urban roadsides have been highly disturbed and are very different from undisturbed environmental conditions. Therefore, native plants may be no better suited to urban roadside conditions than ornamental plants. There is a preference among WSDOT designers, and the public, for roadside landscapes that "look natural" and perpetuate the natural character of Washington, so the appearance of plants may be a more critical selection criterion than their place of origin. Satisfying this "natural preference" may be easier to accomplish in large interchanges than on narrow, steep urban roadside conditions, but these are design decisions that should be made during the design process on a case-by-case and site-by-site basis. In selecting plants, the following factors are more important than place of origin: well adapted to the stressful conditions typically encountered in urban roadsides; able to achieve functional needs; present no characteristics that may be safety hazards in the future; and possess qualities that do not make maintenance difficult. These considerations significantly limit the choice of suitable plant species.

According to construction data provided by WSDOT, five case study sites had full irrigation system coverage during the establishment period, one had minimal coverage, and five had

no irrigation system (data unavailable for one site). The need for irrigation varies with site conditions and types of plants. WSDOT's approach of providing watering (by truck or temporary irrigation), as needed, during plant establishment makes sense in terms of minimizing the lifecycle costs of roadside projects and ensuring successful coverage.

ROADSIDE MAINTENANCE AND INTEGRATED VEGETATION MANAGEMENT (IVM)

WSDOT has developed and implemented IVM plans for roadsides that have rationalized and standardized management practices across regions and that provide specific best management practices to follow. The goal of IVM is to determine the best mix of maintenance techniques for sustainable roadsides. Roadside maintenance using IVM practices is cost effective and provides environmental benefits such as the reduction of herbicide use in the last decade. Issues that IVM must consider are complex and constantly changing. For example, as understanding of the environmental costs of chemical controls changes, practices that were acceptable in the past are no longer. Furthermore, the relative costs of hand and mechanical control vary relative to each other, and increases in the cost of equipment fuel will continue to change the relative costs of mechanical and hand-maintenance. IVM is an important planning and programming tool for minimizing the cost of roadside vegetation management.

Vegetation management using chemicals includes applying soil active pre-emergent herbicides, selective spraying, and dabbing cut stems. Chemicals vary in their soil mobility, toxicity, and environmental persistence. WSDOT has done extensive analysis and risk assessment of the chemicals it uses for vegetation management. Chemical treatments form an essential part of IVM treatment plans; however, the agency has significantly reduced the amount of herbicides used over the years. Current IVM practice balances the benefits of site specific, selective spot treatments

(cut and dab applications) to control weedy vegetation with the goal of minimizing herbicide use for environmental and safety reasons.

Vegetation on some older case study sites, such as Site NW-4 (SR518/SeaTac Interchange) and Site SW-1 (I-205 and I-5), showed evidence of previous and extensive use of herbicides in the form of distorted plants and suppressed growth. With the adoption of IVM, such practices have been discontinued for many years.

While the use of pre-emergent herbicides remains an important method for reducing weed germination, invasive weeds formerly controlled by spraying must now be controlled by other means. Hand maintenance methods include hand-held equipment and chemical backpack sprays and dabbing equipment. Hand maintenance is expensive, and there is always a desire to minimize it in favor of chemical and mechanical vegetation control methods. In some locations WSDOT has controlled hand-maintenance costs by using Department of Corrections crews to perform roadside maintenance work.

Designing areas that are more easily maintained by large mechanical mowers can reduce the costs of mechanical control. However, replacing other types of plant community with grass or grass and trees is a design decision that may have significant functional implications and should only be implemented after discussions with WSDOT design personnel. The close communication between WSDOT design and maintenance personnel that occurs during construction contracts and plant establishment periods should continue, though on a less frequent basis, throughout the lifespan of each roadside. This will allow design and maintenance personnel to understand the issues and concerns that each group encounters and to reach agreement about how to respond.

Although sometimes labor intensive, IVM is cost effective in the long term if applied persistently, as it can prevent weeds from becoming established and overwhelming desired roadside

vegetation. While small numbers of invasive plants within a restoration planting area can be controlled with relative ease, if they are allowed to remain, grow, and reproduce, they will eventually overwhelm the planting to the point that it is impractical or uneconomical to recover the planting area. It is extremely labor intensive, or completely impractical, to reclaim plant beds by means of handwork if invasive weeds, such as blackberry, overrun them. If roadsides that have become "overwhelmed" or "swamped" are managed by mowing, this will remove desired, installed plants as well as invasive plants, thus preventing the design from performing its intended functions. This occurred on Site NW-2, (I-90 Rainier Ave.) when blackberry began to invade Zabel laurel and ivy beds, and maintenance personnel converted the area to rough grass, modifying the function of the interchange as a gateway to Seattle.

Mowing is another element of the IVM maintenance program. In urban settings and gateway interchanges, frequent mowing is a common practice to keep an area in an aesthetically acceptable condition and to suppress the spread of weed seeds. Mowing frequencies depend on functional and aesthetic issues as well as site conditions, and they may range from several times per year to once every two years. WSDOT maintenance staff favors mowing because it is relatively quick, effective, and requires little handwork.

Before maintenance personnel removes large areas of woody plants in areas heavily invaded with weeds, they should meet with WSDOT designers and discuss the situation, purpose, and intended function of the plantings. If meetings are held on a regular basis, and in the field, then together designers and maintenance personnel may develop approaches that negate the need to remove planted vegetation.

WSDOT ORGANIZATIONAL STRUCTURE / CONSIDERATIONS

WSDOT's approach to roadside maintenance is governed by legislation and the prioritization of activities in the Maintenance Accountability Program (MAP). As stated earlier, in descending order of importance, vegetation maintenance activities include control of obstructing vegetation for safety, noxious weed control, nuisance vegetation management, and landscape maintenance. How maintenance personnel are organized varies within each region (Northwest, Olympic, and Southwest). Within each region are areas, and each area reviewed for this study organizes its maintenance crews differently**.** Whether or not maintenance personnel are involved in the planning and understanding of the reasons behind their work has a significant effect on their dedication to the task of roadside vegetation maintenance. When roadside crews are assigned to tasks other than vegetation management or when roadside vegetation suffers from lack of consistent maintenance, it is hard to retain pride in the condition of roadsides. This is expressed organizationally by the difference between dedicated (i.e., landscape only) crews and crews who have to fit roadside work into many other aspects of highway maintenance. The Northwest Region uses non-dedicated crews for most roadside vegetation management and maintenance; the Olympic Region uses a dedicated landscape crew for urban roadside management in areas around Tacoma and Olympia. The Southwest Region uses a combination of dedicated and non-dedicated crews.

Dedicated landscape crewmembers, because they are engaged with (and trained in) vegetation maintenance year round, are more knowledgeable and tend to take more ownership of the condition of the roadsides. These crews are responsible for specific roadside restoration areas, and the quality of their work is evident in the roadsides for which they are responsible. Non-dedicated landscape crewmembers may participate in routine highway maintenance; thus they may be patching pavement or repairing a bridge or guardrail one week, and mowing roadside grass the next. Because the workforce is in perpetual flux, the region has less ability to plan a consistent

vegetation maintenance program. As a result, non-dedicated crews tend to pay less attention to roadside work, and consistent, appropriate roadside maintenance is harder to plan, implement, and sustain, making it harder to achieve sustainable roadside conditions.

USE OF STATE DEPARTMENT OF CORRECTIONS (DOC) CREWS AND VOLUNTEERS

State and local corrections crews (inmates and work-release programs) are sometimes available to perform weed control and trimming activities. Work performed by Department of Corrections (DOC) crews saves WSDOT money, as the daily expense of a 10-person crew with a supervisor is substantially cheaper than performing the same work with WSDOT personnel.

Local community volunteers have contributed to WSDOT roadside restoration efforts, through tree and shrub planting parties, on several sites in the Olympic Region. As a result of their participation, volunteers take pride in and "ownership" of the landscapes, strengthening WSDOT's positive image in these communities. WSDOT has a successful Adopt a Highway program for litter control, and in some cases vegetation management is also adopted. While volunteers can assist with roadside planting, and to some extent vegetation maintenance, this contribution will only be possible in a very small percentage of construction and maintenance situations.

CITY GATEWAYS

Urban roads accommodate heavier traffic volumes, and therefore a larger percentage of the state's population sees these roadsides, particularly those in the Western Washington cities studied in this report. Many cities desire visually attractive gateways to mark their entrances and welcome travelers, and for diverse reasons, urban businesses and property owners may be more concerned about the appearance of roadsides adjacent to their property. The need for more intensive maintenance is increased by municipalities' expectations for well-maintained and aesthetically

pleasing entrances and the larger number of users seeing these roadsides. These conditions change what had been assumed—at the start of this study—to be an ecological problem of determining low lifecycle restoration techniques into what is in many areas a social or behavioral problem—installing roadsides to meet desired restoration functions while discouraging the establishment of transient encampments. Local jurisdictions or businesses may wish to fund extra maintenance in these gateway areas.

CONCLUSIONS

As a result of this study of how to achieve and maintain urban roadside restoration projects that provides the necessary roadside function at the lowest lifecycle cost, we make the following conclusions.

The design, construction, and maintenance of roadsides at the lowest lifecycle costs are important goals for WSDOT to achieve in order to fulfill its mandate and to manage its resources wisely. Low lifecycle costs are not the same as low cost maintenance because the methodology of lifecycle costs looks at multiple factors, with emphasis on time, energy, economic costs, and long-term ecological and social costs.

Because urban roadsides are more frequently disturbed, stressful for plants, and prone to invasive weeds and transient encampments, they require proportionately more maintenance effort to maintain them in satisfactory condition than comparable areas in other parts of the state road system.

It is desirable to minimize the likelihood of occurrence of factors beyond WSDOT's power to control by limiting the sources of invasive weeds and not creating conditions conducive to transient encampments.

RESPONSE TO BIOLOGICAL DISTURBANCES

One of this study's most important conclusions is that it is essential to control invasive weeds during the plant establishment period. Immediately following construction, all bare or mulched ground, if not properly maintained, will present an easy opportunity for weed invasion and the establishment of a weed seed bank. Quick vegetative cover of disturbed roadsides also reduces the opportunity for invasive weeds to become established. Once established, invasive weeds become extremely difficult to remove without also removing desired planted shrubs and ground

cover, though trees can usually be saved. The control of weeds affects the short- and long-term success of roadside vegetation, and thus reduces ongoing maintenance costs.

In recent years WSDOT has developed an IVM program for roadsides that plans and balances the use of complementary maintenance methods over time. IVM goals are to effectively control invasive weeds as soon as possible after they emerge and to manage desirable vegetation to form a competitive ground cover, thereby keeping roadsides in functionally and aesthetically pleasing states at lowest possible costs. Continuous monitoring of roadside conditions is also key to insure that emerging weeds can be controlled before they have a chance to get a foothold.

Because of this important conclusion, it is imperative that consistent maintenance and adequate budgets are supported to keep invasive weeds from becoming established in woody vegetation communities. Hand cutting and dabbing stumps with herbicides, or backpack and spot application of herbicides, are the preferable methods of control, rather than broadcast spraying which (as was evident on several case study sites) may damage desirable vegetation as much as it kills weeds.

RESPONSE TO HUMAN DISTURBANCES

Reducing opportunities for transient camps to form has become an important design and maintenance consideration for urban roadsides. This is a relatively recent phenomenon and changes the way we consider sustainable urban roadsides. WSDOT thus faces the dilemma that, in some urban areas, the design and maintenance practices and goals that are desirable for ecological and biological reasons may not make sense for social reasons. This dilemma is at the heart of how to design, develop, and apply appropriate low lifecycle maintenance methods on urban roadsides in the long-term.

Transient encampments make it difficult to achieve the goal of maintaining roadside vegetation in a state approaching a self-sustaining system. For transients, trees can provide an overhead canopy (roof), and large shrubs may provide shelter (walls) for encampments Therefore, the presence, or threat, of transient encampments may require a higher level of effort and preclude the establishment of a self-sustaining roadside. .

The potential transient situation becomes part of the design team's equation for function. The threat of transient encampments makes the use of large shrub masses undesirable in locations where homeless have easy access and where food services are conveniently located. Furthermore, roadside vegetation should be designed and managed to maintain clear sight lines into and through vegetation for easy surveillance, i.e., shrub masses should be below the 4-ft level, and trees should have high branching habits or be easily limbed up. The public is at risk in or around transient encampments because of a lack of sanitation, rodent infestation, fire hazards, and the presence of illegal activities. Removing transient encampments presents health and safety hazards for WSDOT personnel, as it includes removal of personal possessions, large amounts of garbage, human waste, and, potentially, drug paraphernalia. The costs of transient camp removal are high—funds come directly from the maintenance budget—and complex, involving the participation of state or local law enforcement. WSDOT has used State Correctional crews to assist with transient camp removal, but this work nevertheless is a drain on already-tight maintenance budgets.

RESPONSE TO PHYSICAL AND ECOLOGICAL CHARACTERISTICS OF ROADSIDES

Urban freeway roadsides have different physical characteristics and unique environmental conditions and thus serve different functions and have different maintenance needs than those typical in suburban and rural roadsides throughout the state. Physically, urban roadsides range

from narrow strips of land along roadways, often with steep slopes, to large areas of relatively flat land at interchanges. The design functions of, and maintenance approaches suitable for, narrow strips may differ from the functions and maintenance methods appropriate for large expanses of land typical of roadside interchanges. For example, traffic adjacent to long, narrow strips of roadside is likely to be moving faster than at interchanges, and thus the vegetation may be less obtrusive in those areas. Large urban interchanges may be entrances to cities, suggesting a need for more intensive maintenance and greater visibility and distinctiveness. The design responses and maintenance regimes required to provide road users with a safe, comfortable, and enjoyable experience will vary from open stretches of freeway to negotiating interchanges.

As a general rule, the more frequent and intense the disturbances experienced by roadside vegetation, the greater the maintenance efforts necessary to restore them. Because urban roadsides are subject to frequent and repeated disturbances, it is unrealistic to expect them to become stable, self-sustaining plant communities without more concerted efforts. The effort, and thus costs, necessary to maintain urban roadsides in acceptable conditions are likely to be higher than those necessary to maintain rural or suburban roadsides.

Lowest lifecycle costs cannot be applied uniformly to all roadsides, as functional and site considerations alter the kinds of plant communities that are appropriate. Similarly, different or higher levels of maintenance may be appropriate for gateway interchanges than on other parts of the highway system. These are policy and design decisions that should be made through discussions among program administrators, design teams, and maintenance personnel. Maintenance is a form of design, an extension of the original design that takes place throughout the life of the roadside. Hence the need for continued communication between WSDOT design and maintenance personnel

is desirable throughout the life of roadsides so that maintenance work responds to the design functions.

RESPONSE TO THE ROADSIDE RESTORATION DESIGN PROCESS

Communication among WSDOT design teams, construction teams, and maintenance personnel is key to achieving low lifecycle cost roadsides. Design teams carefully consider the diverse criteria and needs of specific roadside sites. Teams then develop plans for new vegetation and landforms in response to the multiple conditions of the functional aspects of the design—i.e., the design intent. Generally speaking, the term ”function” equates to multiple meanings within WSDOT. For design teams, ”function” is the outcome—in physical form—of the investigation and analysis of the multiple factors at play on a site and the best practices to address them. The goal of the design team with each restoration site is to provide the best possible function for the least overall long-term cost. Maintenance crews, however, may think of “function” as a subjective and vague term that design teams use to justify their choices of plant species and landform configuration. Divisions between design teams and maintenance personnel that may arise around the topic of ”function” should be resolved by frequent communications. It is imperative that design and maintenance resolve misunderstandings about design function for the long-term success of roadside restoration.

WSDOT design teams must have a platform or process by which to discuss restoration function and design intent with maintenance personnel—before, during, and after construction. Ideally, design teams will meet directly with maintenance staff. If maintenance does not clearly understand the process and reasons behind the design intent, maintenance crews may unintentionally destroy or compromise the restoration function. During the design and construction phases, it would be natural for this effort to be initiated and led by the landscape designer, while

maintenance is the natural lead and should initiate this effort once plantings have been returned to maintenance.

Design never ends. Design teams need to become (more) pro-active in communicating design intent in all phases of development—concept, construction, plant establishment, and beyond. The beyond-phase is important in following up with how well the restoration area is doing three years after the plant establishment period has ended. this provides a clear indication of the success of the plant species and the maintenance regime necessary to sustain the restoration. Annual, dedicated time should be set aside for "visit-the-site" days with relevant members of design and maintenance teams. Procedures should not assume that the oral history of each site will continue, as WSDOT personnel change. The teams need to get into vans and visit sites together on an annual basis. Also important are reviews of specific types of projects, especially after the three-year plant establishment period. Such meetings should include open reviews of what is /is not working and why and discussions of the restoration functions and the maintenances challenges. Team members should keep an open mind to differing perspectives.

RESPONSE TO CONSTRUCTION CONTRACTS FOR SITE PREPARATION AND SOIL FOR ROADSIDES

In general, the more disturbance or disruption to existing conditions during construction, the greater the effort and cost necessary to establish and sustain roadside vegetation. Where soil conditions following construction provide poor growing conditions, subsequent maintenance efforts and costs tend to be higher over the lifespan of the roadside. Regarding construction, two outcomes are crucial: good soil conditions and full plant establishment.

Attention to proper site preparation and soil conditions, especially during the construction phase, is the essential base line for establishing long-term health and vigor of roadside vegetation.

Using materials such as dredge spoils (or construction spoils) as fill on roadsides may reduce capital construction costs, but unless such materials are extensively modified they cannot support healthy vegetation. Poorly selected and prepared soils are likely to incur additional long-term maintenance costs or result in the decline and failure of plants. Such construction savings are illusory, as they may be offset many times over by higher maintenance costs throughout the life of a restoration project. WSDOT soil amendment and mulching specifications are only effective if rigorously enforced during construction.

Of equal importance to appropriate soil preparation is the use of mulch in all planting areas. Mulch helps suppress weeds during plant establishment and aids in soil moisture retention, thus increasing the speed at which the ground surface will be covered in planted vegetation. Small expenditures on mulch will save maintenance funds and reduce roadside lifecycle costs. In many cases, the high value that mulch adds may justify placing a fresh layer of mulch into planting beds just prior to turning plantings over to maintenance. In areas that have not yet developed dense vegetative cover, an application of mulch could improve weed suppression and moisture retention during the critical first years of maintenance.

Personnel installing and approving work on capital projects should keep in mind that some measures taken to cut overall construction costs might result in very significant long-term additional roadside maintenance costs and increased lifecycle costs. Capital savings that result in weed infested, over-grown roadsides risk losing the entire investment in plant installation.

RESPONSE TO RESTORATION PLANT COMMUNITIES AND PLANT ESTABLISHMENT

Although an analysis of construction contracts is beyond the scope of this study, research suggests that when contracts are closed out before plants have been fully established, which may be

desirable for administrative reasons, the projects frequently require more intensive maintenance by WSDOT personnel without provision of additional funds. This is equivalent to requiring WSDOT maintenance personnel to perform work that was part of a construction contract. Changes may be made to contract provisions, acceptance of work, and contract management during plant establishment periods to reduce lifecycle costs and increase the sustainability of roadside systems.

Many roadside projects suffer from the effects of roadsides being turned over to WSDOT following the three-year establishment period because the plants may be established but not yet sufficiently large or the ground may not be sufficiently covered for project plants to compete successfully with invasive weeds. WSDOT may benefit in lower lifecycle roadside project costs by increasing the length of the establishment period from three to five years to ensure better plant establishment. Alternatively, WSDOT could adopt performance specifications for plant establishment in which contractors may be released from roadside contracts only after plants have attained a specified level and density of cover, rather than after a particular length of time. This might be an effective way of encouraging contractors to care for new vegetation more carefully and could result in contractors completing WSDOT roadside vegetation contracts more efficiently and effectively.

Plant community establishment (and maintenance issues) may be exacerbated or mitigated by design and construction on roadsides following construction. Methods for minimizing problems include appropriate restoration design and plant selection for prevailing conditions; appropriate soil preparation (since urban roadsides soils are typically highly disturbed by construction and are rarely well-suited to plant growth); and sound plant establishment to achieve solid cover. Solid vegetative cover is an essential method of desired plant establishment because it provides effective competition and weed suppression. .

The Northwest Region stated that it had had great success by requiring a certain amount of coverage within a ten-year establishment period. By actively managing the plant establishment period through a centralized program, it finds that most sites meet coverage requirements between years seven and ten. This region's centralized plant establishment program/process should be widely shared with other regions, and lessons learned should be applied to the establishment of roadside plantings.

In the Olympic region, having dedicated maintenance crews makes it easier to prioritize maintenance work, resulting in successful landscapes.

Plant Establishment

Strong plant establishment with effective weed control is a necessary first step to ensure low lifecycle costs for projects. The plant establishment period is typically three years following plant installation. This period is intended to quickly, fully, and densely establish desired plants in a weed-free state on roadsides to minimize the potential for subsequent weed invasion, which is more likely to occur on bare or un-vegetated ground. Roadsides with poorly established vegetation at the end of the establishment period fail to meet WSDOT specifications, and if accepted by WSDOT they will result in extra, unbudgeted work for WSDOT maintenance crews. Transferring roadside projects to maintenance crews in poorly established conditions may result in short-term savings but will increase the likelihood of long-term weed infestation problems.

In the case of shrub communities a three-year plant establishment period may not be sufficient to ensure good vegetative cover of soil and associated reduction in weed pressure. Unlike other highway elements such as concrete, plants do not immediately fill the need when installed. Additional or more prescriptive standards may be necessary to ensure that shrub beds provide dense

vegetative cover before being turned over to WSDOT maintenance. These standards could take the following forms:

- standards for plant vigor and plant health
- standards for complete vegetative coverage prior to shifting the area to maintenance
- standards for plant survival (for example, 90 percent of plants have been in the ground and in a healthy, vigorous growing condition for at least two years).
- standards for highway construction contracts that require additional years of plant establishment before responsibility is shifted to the maintenance staff.

Long-term maintenance costs will be reduced by achieving, as quickly as possible, a level of plant establishment that reduces opportunities for invasive vegetation to become established. Some of these methods may entail adopting different design solutions, some may require changes to construction contracts or to installation methods, and some may result from changing maintenance practices during the establishment period. To minimize lifecycle costs of roadside vegetation, WSDOT should explore all realistic methods of ensuring quick and full plant establishment.

We found that case study sites in the region with dedicated maintenance crews were more successful than those in regions without dedicated crews. While additional factors may affect the success of projects in different regions, such as differences in maintenance budgets proportionate to the areas of roadside to be maintained, higher traffic volumes, and more severe growing conditions, the conclusion is clear: dedicated maintenance crews increase individual commitment to the work and satisfaction with a job well-done, and these result in better projects that have lower lifecycle costs. Roadside maintenance benefits and low lifecycle costs are more likely when maintenance crews and personnel have a long-term commitment to the work and a sense of ownership. Contracting out roadside maintenance is unlikely to result in the same level of long-term commitment that can be achieved by dedicated WSDOT maintenance crews.

Restoration Plant Communities

For any given location, the functional design with the lowest lifecycle costs depends on factors that are beyond WSDOT's control and that are, in some cases, unpredictable, such as social changes generating homelessness, fuel costs, climate change, and the predictability and stability of maintenance budgets. This discussion does not take into account functional considerations and how they influence the selection of plant communities in any particular area. For discussion, we divide urban restoration plant communities into the following categories, recognizing that, in reality, these community types merge into each other:

- forest communities (trees as specimens or in continuous stands)
- shrub communities (shrub masses, with and without trees)
- grass with or without trees
- woody ground cover communities, with and without trees.

Forest Communities

In general, trees are the longest-lived plants in roadside communities, and once established, they tend to require low annual maintenance. Therefore, although environmental, social, and economic conditions will change the dynamics of lifecycle costs, the single consideration that can be stated with relative confidence is that trees, when selected and planted to fit site conditions and meet required functional and aesthetic needs, remain a viable roadside vegetation type with low lifecycle costs. Trees provide functional, aesthetic, and larger environmental benefits and are the longest-lived and most stable type of vegetation. Large trees in functionally appropriate locations are likely to be the backbone of roadside vegetation in many roadside locations. Evergreen trees, especially Western Red Cedar, provide good weed competition at ground level but may require limbing up to provide surveillance in areas subject to the pressures of homelessness. Evergreen trees may be more effective at suppressing weeds than deciduous trees, as their shade persists year-round. The needles of evergreens are also less likely to block drains than the larger leaves of deciduous

trees. Tree root systems may be important for stabilizing slopes. At maturity, trees will suppress the growth of all but Clematis vines which can grow into the canopy of trees of any height and eventually smother them.

Because of canopy shade and root competition, establishing trees is an effective way to reduce opportunities for invasive weeds to become established and grow vigorously. Evergreen canopies and continuous canopy cover will be more effective, but there may be functional reasons for using deciduous trees or more widely spaced evergreen or deciduous specimen trees in some locations.

From an ecological perspective, completely self-sustaining roadsides that emulate natural forest systems are unlikely to be achievable in urban lowland Western Washington because of frequent disturbances and environmental conditions that are very different from natural conditions. For many reasons, attempting to create such communities is not a practicable goal on typical urban freeway roadsides. However, a tree canopy cover—if it meets functional needs—remains a viable way of reducing long-term maintenance costs and thus achieving lowest lifecycle cost roadsides.

Shrub Communities

The costs of maintaining tree and shrub communities, as long as they are consistently maintained to prevent weeds (such as Himalayan blackberry and Japanese knotweed) from becoming established, will decrease over time and reach a steady, low-cost state. Therefore, given their long-term 40-year life spans, the high initial establishment costs for shrubs tend to be countered by lower maintenance costs in later years. Thus shrub communities are likely to have lower lifecycle costs than roadsides of grass or trees and grass, as the latter require some level of mowing. Mowing frequency affects this relative cost dynamic, and there may be locations where the costs of maintaining grass communities are competitive with those of shrub communities.

Shrub communities in urban areas are subject to two kinds of disruption that may make them unsustainable: 1) if maintenance budgets are not consistent, shrub communities are likely to be overrun by invasive weeds, which can result in complete removal of the plantings, and 2) shrubs may need to be substantially or completely altered to remove the conditions of visual cover favored by transients. The latter concern suggests that urban roadside shrub communities must be very carefully monitored to prevent the establishment of transient encampments. Because of these concerns, shrub and shrub and tree communities may be more appropriate in areas unlikely to be favored by transients, but they must be monitored closely for transient encampments and controlled to prevent establishment of invasive weeds. Under these conditions, shrub communities with or without trees are desirable community types for low lifecycle cost roadsides.

Preventing the establishment of and removing transient encampments involves complex social, economic, and political issues that require clear policy directives from WSDOT for roadside maintenance and close cooperation with law enforcement agencies. If maintained to prevent weed species from becoming established, shrub communities may be viable for some roadside restoration areas. Shrub community management requires that maintenance personnel be trained to maintain woody vegetation manually, with cut and dab procedures. This reinforces the importance of current efforts to establish IVM practices throughout WSDOT and emphasizes the desirability of dedicated roadside maintenance crews trained to properly manage roadside vegetation.

Grass with or without Trees

The costs of maintaining grass and grass and tree communities vary with site and environmental factors such as steepness of slopes; extent and contiguity of areas for mowing; accessibility for mowing equipment; types of grass/forb; weed pressures; soil growing conditions;

and the desired appearance of grass areas. These factors affect the type and equipment that can be used, the efficiency and frequency of mowing, and thus annual and lifecycle costs.

The need for grass mowing never ends, although it may decline as grass cover becomes denser; therefore, the lifecycle costs of grass may be higher than those of woody vegetation. However, with large equipment, mowing is relatively simple, fast, and easy, and the appearance of newly mowed areas can impart a sense of order and care to roadsides.

The advantage of grass over shrub communities is that if grass is left unmaintained for some time and weeds become established, it can quickly be recovered with a single mowing. For these reasons, maintenance crews tend to prefer grass as a roadside treatment, and in some locations (such as Site NW-2, I-90 Rainier Ave. Interchange) shrub and ground cover communities have been converted into grass and trees to gain an easily recoverable landscape. Ongoing communication between WSDOT designers and maintenance personnel is desirable to ensure that necessary functions and commitments are not compromised by such conversions.

Predicting the future costs of grass mowing in relation to other roadside maintenance costs is complex and beyond the scope of this study. However, changes will affect the costs of maintaining different roadside communities and thus their lifecycle costs relative to each other. Under current fuel relative to labor costs, roadside grass is a viable maintenance cost option and provides for functional needs in many areas. Grass and grass and tree communities are likely to remain appropriate options in some locations, but grass will entail an annual maintenance cost throughout the life of the roadside. Clearly, cost considerations cannot be allowed to compromise functional and safety considerations in deciding how to plant and maintain roadside vegetation.

Woody Groundcover Communities with and without Trees

Woody ground cover communities (with or without trees) provide the benefits of woody vegetation (i.e., infrequent mowing cycles) while preserving the benefits of grass communities. In the past this could be accomplished quickly and easily by planting varieties of English ivy with trees. This is no longer a viable option for roadside vegetation, as English ivy has become perhaps the single worst, and certainly the most pervasive, invasive weed in Western Washington and should never be planted. There are very few alternative low-growing woody plants that can thrive under periodic mowing or trimming, but several plants show promise as roadside treatments with infrequent, carefully timed, and high mowing or trimming. These include sword fern, salal, coralberry, Hypericum calycinum, and cotoneaster dammeri. WSDOT should continue to explore and access low-growing plants that can tolerate relatively infrequent mowing or trimming, will provide a dense, continuous cover that suppresses weeds, and are drought tolerant.

RESPONSE TO ROADSIDE MAINTENANCE AND IVM PRACTICES

The IVM program is based on careful planning of annual and longer-term maintenance operations to address the specific needs and prevailing conditions of each roadside area and its vegetation – especially the WSDOT policy regarding control of noxious and nuisance vegetation. Continuous monitoring of roadside conditions is also critical to insure that emerging weeds can be controlled before they have a chance to get a foothold. In the long-term, a steady, even management program is less expensive than a short-term, reactive approach. However IVM can only be effective if decisions can be made on the basis of predictable, steady budgets and the availability of workforce. Successful implementation of IVM plans requires a minimum level of budget allocation and knowledgeable staff to carry out activities.

Because plants grow continually and because weed invasion pressures are ever-present realities, consistent and continual maintenance is one of the most fundamental prerequisites to achieving low lifecycle costs for roadside. If planned maintenance schedules are not followed, invasive weeds are likely to become established, and at a certain point it becomes difficult, if not impossible, to remove them without also removing much, or all, planted, desired vegetation. Discontinuous roadside vegetation maintenance, for whatever reason, may result in a loss of years of investment in plant maintenance and initial planting costs. In addition, removal of dense vegetation can reduce the ability of the landscape to resist invasive weeds, resulting in an increased weed problem. Prevention of weed invasion through consistent maintenance is cheaper and more effective in the long term than trying to restore areas that have become infested or overgrown with weeds.

Two other important conclusions regarding maintenance practices are as follows:

1. Knowledgeable staff to carry out maintenance activities is critical. If each region (or area) cannot manage to have a dedicated landscape crew, WSDOT could have several dedicated Western Washington landscape crews that move from region to region as needed.
2. The maintenance role is to care for the restored areas. It is not the maintenance role to re-design restoration areas. When maintenance has a need to re-work a landscape restoration area, maintenance should contact and communicate concerns directly with the design team. The design team will then reassess the area for functional needs and revise the restoration plan as necessary.

RESPONSE TO CONSTRUCTION AND MAINTENANCE COST INFORMATION

Aggregated over the long term, maintenance costs are the most significant contribution to roadsides lifecycle costs and they are therefore a crucial consideration in determining lifecycle costs.

Maintenance methods, and thus maintenance costs, vary for each plant community type and site condition---thus design decisions affect lifecycle costs. Roadside vegetation types cannot retroactively be changed to align with these maintenance methods. Maintenance costs are dependent on the costs of fuel and equipment and labor. Changes in the costs of fuel and labor relative to each other may change the kinds of roadside vegetation with the lowest lifecycle cost.

To ensure that urban roadsides are adequately maintained, the allocation of regional maintenance budgets should take into account the fact that urban roadsides are more difficult and costly to maintain than comparable areas of rural roadside.

This report is not a low lifecycle cost analysis. A true lifecycle cost analysis would use costs for fuel, equipment, labor, materials, etc., for all phases of the project ,from planning to completion of life span. For this study, WSDOT personnel generated individual case study cost sheets and summary cost sheets for construction and maintenance. (Refer to Appendix C.) Some costs were difficult to determine because of a lack of accurate historical records regarding plant replacement costs, water (irrigation) amounts and prices, and equipment/fuel / labor costs. The relative costs of fuel and labor cannot be predicted with any accuracy even in the short term, much less in terms of lifecycles of roadsides.

Shrub and tree masses will only have low lifecycle costs if they are cared for in ways that prevent the establishment of invasive weeds. When maintenance budgets vary from biennium to biennium and steady staffing cannot be assured, we cannot assume that sufficient resources and trained crews will be available to manage invasive weeds and prevent shrubs and trees from becoming overgrown. Currently, maintenance budgets and staffing conditions favor easily mown grass roadsides over trees and shrubs.

This dilemma can be handled by creating standards and priorities to establish a baseline of certain functions for high priority roadsides (i.e., gateway interchanges, necessary visual screening /buffers, etc.). These standards and priorities would be documented in the Area IRVM plans to set design goals and maintenance expectations.

However, for functional and aesthetic reasons, a balance of types of landscapes (i.e., open grass landscapes and shrub masses) might be desirable for visual variety and differing design intentions.

Trees have many desirable environmental, aesthetic, and functional characteristics. For example, they sequester carbon, screen undesirable views, and convey a sense of place. Trees also have desirable maintenance characteristics: they are long lived and when used in continuous canopies or masses, they provide shade, making roadsides less susceptible to invasive weeds. Also, because they can be limbed up, they allow surveillance to control transient encampments. Thus, trees are among the most desirable vegetation element in Zone 3 urban roadsides where conditions, design function, and space permit.

RESPONSE TO WSDOT ORGANIZATIONAL STRUCTURE

WSDOT Regional Organizational Efficiencies Are an Issue

Although the WSDOT personnel who participated in this study displayed exceptional dedication to their work and reflect well on WSDOT as a state agency, the conditions of the case study sites made it clear that dedicated crews result in better maintained roadsides, which are more likely to be self-sustaining landscapes and create a positive public image of WSDOT. Dedicated landscape crews not only allow personnel to develop specific knowledge and skills but also result in crews and individuals taking greater ownership of and pride in the quality of their work. Skilled supervisors and crewmembers are critical factors to achieving low lifecycle restoration costs.

The use of volunteers and Department of Corrections (DOC) crews is valuable and cost-effective for some roadside work, but only as a supplement and not a substitute for trained staff in many operations. Becoming reliant on DOC crews to perform routine maintenance work has risks, as WSDOT does not control access to this workforce. DOC crews should not be considered as an essential component of sustainable roadside management. Equally, volunteers are not a viable factor as a contribution to long-term roadside vegetation sustainability.

Stable Annual Maintenance Budgets Are Crucial

Stable budgets are necessary for planning roadside management and implementing the work required to nurture plant communities to the point of reaching mature, relatively stable, weed free conditions that are as self-sustaining as possible.

As noted, urban roadside environments are more stressful for plants, typically adding work to regular roadside maintenance. Also, public expectations for the appearance of urban roadsides are higher. Budgets for maintenance areas with responsibility for urban freeways should reflect this added difficulty of establishing mature, weed free landscapes.

A necessary condition for sustainable roadsides is adequate, consistent, and secure funding from year to year. Minimizing lifecycle costs depends on consistency of maintenance work from year to year and thus on the ability to plan and implement maintenance work (IVM) over the life span of roadsides. Adequate budgets and individual crews' responsibility and control over their work are necessary conditions for establishing and maintaining sustainable roadsides. Budgets that are inadequate or vary from year to year prevent consistent planning and implementation of maintenance work, and as a result, roadside vegetation and maintenance personnel morale suffers. The approaches used to allocate annual maintenance budgets vary from region to region. Some regions are able to plan and more successfully implement their annual maintenance plans, while

others are thwarted by ”exceptions” to their planned work that are so demanding, that their annual budgets need to be constantly re-worked. Roadside maintenance work frequently receives short-shrift because of budget restraints and its low priority in the prioritized matrix (MAP). Unfortunately, roadsides are not as easily recovered as other facilities after a period of reduced funding; therefore, a steady flow of funds and effort is essential to the long-term sustainability of roadsides.

The Maintenance Accountability Process (MAP) Needs Attention

The MAP facilitates measurements that are used to determine state funding. Is it providing the proper information to the legislature? Work may be needed to improve the MAP ”grading” procedures to accurately measure success, which translates into funding, and/or to amend the document to permit greater flexibility to utilize the funding. Funds currently dedicated for landscape and nuisance control could be assigned to regional crews with knowledge and skill in vegetation management for plant establishment.

City Gateways Require Special Maintenance

Many cities desire visually attractive gateways to mark their entrances and welcome travelers and, for diverse reasons, urban businesses and property owners may be more concerned about the appearance of roadsides adjacent to their property. The need for more intensive maintenance is increased by municipalities’ expectations for well-cared for and aesthetically pleasing entrances and the larger number of users seeing these roadsides. These conditions change what had been assumed—at the start of this study—to be an ecological problem of determining low lifecycle restoration techniques to what is in many areas a social or behavioral problem: -installing roadsides to meet desired restoration functions while discouraging the establishment of transient encampments.

CHANGING THE WSDOT MANDATE AND PUBLIC ATTITUDES TOWARD ROADSIDES

The urban freeways are used by thousands of people a year. This situation offers incredible visibility and opportunities for WSDOT to promote innovative work. Similar to installing billboards, WSDOT could use the roadsides to get noticed, too! WSDOT could create "demonstration" roadsides that allow the public to witness the effects and transformation of roadsides sites. Examples include the following:

- demonstrate what a bio-fuel growing area would look like
- exhibit an artistic concept of a roadside … e.g., imagine an interchange full of sunflowers!
- reveal a phyto-remediation site
- make obvious the cleaning of storm water.

The examples are endless; the idea is to make the public aware of roadsides in a new way.

Roadside conditions considered aesthetically, functionally, and environmentally acceptable have changed over time and are likely to continue to change in response to social and environmental factors such as climate change, road use patterns, and economic viability. For example, we may become more or less tolerant of invasive weeds and alter our opinions of some species as our understanding of their long-term effect on roadsides and adjacent areas change. The most likely short- and long-term changes will be in the cost of equipment fuels, but technological developments may create alternative fuel sources, such as bio-fuels grown on WSDOT ROW lands. It seems prudent, however, that in moving to the goal of low lifecycle roadsides, WSDOT should minimize reliance on mechanical control methods that require large quantities of fuel.

RECOMMENDATIONS

RESEARCH QUESTION

What does it take to achieve and maintain a sustainable urban roadside restoration project that provides the necessary roadside functions at the lowest lifecycle cost?

The following recommendations to assist with the goal of achieving low lifecycle cost roadsides in urban areas of Western Washington are intended for implementation consideration by agency staff in the design, construction, and maintenance sections of WSDOT. Recommendations are organized by topic area but are not prioritized.

GENERAL RECOMMENDATIONS

Continuous and adequate funding for skilled and dedicated maintenance is a crucial consideration for developing and maintaining low lifecycle cost roadsides.

1. For true sustainability of roadsides—with the lowest lifecycle costs—focus efforts on the ***continued development and implementation of the IVM*** planning program and focus on long-term management strategies in all regions and areas.
2. WSDOT leaders must ***ensure an adequate level of dedicated, ongoing maintenance funding***, especially for nuisance vegetation management in Zone 3, as preventative management is the most effective method of controlling invasive vegetation.
3. ***Get noticed! Create "demonstration" roadside projects*** to help the public recognize and value the roadside. For example, plant roadsides to showcase bio-fuels, art projects, storm water management, and/or phyto-remendiation projects.

COMMUNICATION/PROCESS RECOMMENDATIONS FOR ALL WSDOT PERSONNEL

Maintenance crews may be unaware of the design intent of roadside vegetation and therefore may not manage the roadside with the design intention in mind. Communication

between the design team and maintenance staff and dedicated time to understand how maintenance activities support the design intent are necessary to ensure low lifecycle costs.

4. ***Improve communication***. WSDOT staff must ***establish and facilitate procedures*** to ensure that design teams, construction supervisors, and maintenance staff work ***to determine low lifecycle costs and to communicate the design intent / function and goals of roadside restoration vegetation***. WSDOT leaders should ***institute methods by which this dialogue/exchange can happen.***
5. Establish design goals and maintenance expectations, create standards and priorities that ***set baselines for design intent/functions to be met***, and ***document these in the Area IRVM plans***.
6. Design team and maintenance staff should create a process and policy ***to design, review and prioritize urban roadsides for different levels of maintenance*** (e.g., high, medium, and low) based on mutually agreed methods of evaluation.
7. For active restoration projects, WSDOT should ***require bi-monthly communication*** (minimum) with the field inspector, regional landscape architect, maintenance staff, and/or the construction supervisor ***during the design, construction, and plant establishment phases***. WSDOT should ***institute a method to document*** this communication.
8. ***Improve the accuracy of the MAP measurements*** as reported to the state.

DESIGN RECOMMENDATIONS

Design decisions affect lifecycle costs. The choice of plant community types plays a significant role in the success of the restoration project and in achieving low lifecycle costs.

9. Continue to seriously ***consider the impact of transient encampments*** on urban roadsides ***in developing functional design solutions*** and subsequent maintenance regimes. Clear visibility is necessary for law enforcement surveillance.
10. Continue to ***consider the long-term ecological and biological impacts of plant species choice*** to ensure the functional, operational, environmental, and visual roles of the

roadside. Specify species that provide quick canopy coverage and rapid cover of the ground.

11. ***When design functions permit, plant trees***. Trees sequester carbon, screen undesirable views, convey a sense of place, are long-lived, and are more easily maintained. Where functional and aesthetic conditions permit, specify shrub communities under trees or shrub communities with trees in them for lowest lifecycle cost roadsides.
12. WSDOT should ***continue to research and specify low-growing ground cover plants*** that can create a very dense evergreen groundcover, compete with invasive vegetation, and withstand drought conditions and occasional infrequent mowing.
13. ***Discuss the timing of plant installation and herbicide applications*** (i.e., winter months for certain residual herbicides to be effective) ***with maintenance crew in detail.*** Strictly abide by "planting windows" for plant installation vegetation and seasonal herbicide application.

CONSTRUCTION RECOMMENDATIONS

Plant establishment and weed suppression are crucial to successful restoration landscapes and for achieving low lifecycle costs.

14. ***Provide for an adequate plant establishment period***. This may be done by increasing the length of contracted establishment periods or by developing performance specifications for completeness and density of ground coverage.
15. In construction contracts, ***require a high percentage of plant survival*** in the first and second years. Extend the contract establishment periods when the first- and second-year plant survival rates are not met.
16. ***Separate roadside plant installation work from other roadwork in independent construction contracts***. Allow road construction contracts to be closed out before the end of plant establishment periods, thus alleviating pressures to approve and accept roadside vegetation before plants are fully established.
17. ***Final approval and acceptance*** of roadside restoration projects should be completed ***by a trained expert*** with knowledge of proper soil preparation, plant health and vigor, invasive vegetation, and plant specifications/establishment issues.

MAINTENANCE RECOMMENDATIONS

Aggregated over the long term, maintenance costs are the most significant contribution to roadsides lifecycle costs and are therefore a crucial consideration in determining low lifecycle costs.

18. ***Adapt the IVM program to include a section on education*** to assist maintenance personnel ***in understanding and accepting roadside design function***.
19. ***Re-organize regions*** (and areas within each region) ***to have dedicated, skilled, and knowledgeable landscape crews*** (or access to dedicated landscape crews) for all roadside restoration work. Maintenance managers should have control over the allocation of permanent and seasonal crews to perform maintenance tasks.
20. Regarding city-requested interchange landmark landscapes, WSDOT should ***create and apply a standard maintenance agreement and contract for all city*** gateway landscapes on WSDOT roadsides.

In conclusion, there is no single best plant community that can achieve low lifecycle costs for all roadside conditions. All plant community types examined in this study have appropriate functions and uses. Design and maintenance personnel should make decisions regarding plant community types—how they should be installed and maintained—collaboratively.

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APPENDIX A

WSDOT Policies, References and Documents That Influence This Project

APPENDIX A
WSDOT POLICIES, REFERENCES AND DOCUMENTS THAT INFLUENCE THIS PROJECT

Other WSDOT policies, references and documents that influence the design, construction, and maintenance of roadsides are below:

- ***WSDOT Environmental Policy Statement***, revised 2009. " The Executive Order directs WSDOT employees to follow sound environmental protection practices in the planning, design, construction, operation, and maintenance of WSDOT's transportation systems and facilities. This includes, but is not limited to, pollution prevention, energy conservation, environmental impact avoidance and mitigation, and compliance with environmental laws." *'Sound environmental protection practices' includes the elimination of noxious weeds and their seed. Adequate maintenance practices can offer compliance with this policy.*

- ***EIS and Permit requirements –*** The Environmental Impact Statement (EIS) is a national requirement for State highway projects. Following the EIS approval, a permit to proceed with work is issued. The actual highway permit determines of the type of roadside vegetation mitigation that will be required for the project. An Environmental Impact Statement (EIS) is required for maintenance practices regarding pesticide use.
  - Programmatic EIS for Roadside Vegetation Management – this process selects preferred alternatives using Integrated Pest Management (IPM) principles and develops roadside management plans.

- ***Federal Highway Administration Policy*** - The Federal Highway Administration (FHWA) administers the federal highway program, including allocation of federal funds and design approval for federally funded portions of the state highway system. Numerous FHWA policies affect the state highway roadsides. Among these policies are the FHWA 1994 Environmental Policy Statement that seeks to strengthen the link between environmental and highway policy. The Federal Highway Administration is also responsible for encouraging state agencies to comply with the April 26, 1994, Presidential Memorandum on Environmentally Beneficial Landscaping, directing the use of more environmentally and economically beneficial landscape practices wherever federal dollars are spent. (See FRL-5275-6, Federal Register, August 10, 1995.) The practices are based on five guiding principles:
  - Use regionally native plants.
  - Design, use, or promote construction practices that minimize adverse effects on the natural habitat.
  - Seek to prevent pollution.
  - Implement water and energy efficient practices.
  - Create outdoor demonstration projects.

- ***Maintenance Accountability Process (MAP) Manual –*** a system to measure landscape performance and landscape outcomes. According to the MAP introduction, "… *MAP is a comprehensive planning, measuring, and managing process that provides a means for*

communicating to key customers the impacts of policy and budget decisions on program service delivery … In the 2006-2007 biennium, maintenance (activities) accounted for 5.8% of the total WSDOT budget … Roadside and Vegetation Management accounted for 10.9% of the maintenance budget." 1996

- ***Roadside Classification Plan (RCP)*** – The RCP states: "…The intent of this Plan is to provide a uniform framework for consistent, pro-active roadside management statewide, and to facilitate cost-effective restoration of state roadsides. (The Plan) sets statewide goals and objectives for roadside management, establishes roadside character classifications, and records roadside character designations in the *Roadside Classification Log*. (The Plan) provides guidelines for roadside restoration and advocates the use of native plants, Integrated Vegetation Management (IVM), and a long-term management approach to achieve sustainable roadsides." The RCP provides roadside policies and guidelines in coordination with the Transportation Policy Plan for Washington State, the Statewide Multimodal Transportation Plan, and the Federal Highway Administration policies. 1990 (begun) -1996 (completed).

- ***Roadside Manual*** – WSDOT developed the Roadside Manual to provide coordination between all WSDOT partners responsible for roadside activities, and to establish a common basis for consistent roadside management decisions statewide. It also establishes a convenient and accessible reference for new and previously unpublished material related to roadside management including planning, design, construction, and maintenance. In addition, the manual supplements statewide roadside guidelines established in the Roadside Classification Plan. Excerpts include:

  Operational Functions - Those functions that provide safe and multiuse roadsides. Operational functions include access control, and providing recovery areas and sight distances with accommodations for signs and utilities, and snow storage. The *Design Manual* remains the primary guidance for operational design guidance.

  Environmental Functions - Those functions that protect and enhance our natural and built surroundings. Environmental functions include water quality preservation, protection and improvement, stormwater detention and retention, wetland and sensitive area protection, noxious weed control, noise control, habitat protection, habitat connectivity, air quality improvement, and erosion control.

  Visual Functions - Those functions that are designed and experienced primarily from a visual perspective. Visual functions promote a positive quality of life and are integral to operational, environmental, and auxiliary functions. They include positive guidance and navigation, distraction screening, corridor continuity, roadway and adjacent property buffering, and scenic view preservation. There are two primary roadside views: those from the roadway, and those toward the roadway. In addition, many environmental functions, such as noxious weed control, wetland and sensitive area preservation, and habitat preservation are readily perceived and evaluated through sight.

  Auxiliary Functions - Those functions that provide additional operational, environmental, and visual functions for a complete transportation system. Examples of auxiliary facilities are community enhancement areas, safety rest areas, roadside parks, viewpoints, agricultural uses, heritage markers, bicycle and pedestrian facilities,

park and ride lots, and quarries and pits.
(from the Roadside Manual Chapter 110 Roadside Development, July 2003, 110-2)

- ***Integrated Vegetation Management (IVM) for Roadsides*** – "… Integrated Vegetation Management (IVM) is the establishment of low-maintenance beneficial vegetation, and the suppression of unwanted vegetation, through integration of biological, cultural, manual, mechanical, and educational tactics. Chemical controls are used only when needed. IVM uses plant growth characteristics, principles of plant succession, and knowledge of natural and human-related factors affecting environmental change to achieve management goals, while minimizing impacts on the environment." (from the RCP)

- ***Integrated Roadside Vegetation Management (IRVM) Plans*** – These Plans are created by each WSDOT region to best outline the maintenance procedures for the roadsides within its region. An example from the Olympic Region's IRVM Plan: "*The primary objectives in maintenance of roadside vegetation within the area are in relation to safety of the highway users, preservation of the highway infrastructure, and control of legally designated noxious weeds where they occur on the right of way. Other considerations include protection and preservation of natural environment, preserving and enhancing the natural scenic quality of the roadside, and being a good neighbor to the many adjoining property owners. In all cases, roadside vegetation maintenance activities are planned and conducted in a way that discourages or eliminates unwanted vegetation and promotes desirable vegetation. This is the basic premise of Integrated Vegetation Management (IVM) and the foundation of the program.*"

- ***Herbicide risk assessment and use guide*** - "Herbicides are efficient and effective tools for vegetation management and weed control. However, WSDOT recognizes there may be potential impacts to health and the environment, and minimizes herbicide use wherever possible. We uses herbicides two ways:
  - to maintain a vegetation-free strip at the edge of the pavement where necessary
  - to selectively control and eliminate undesirable plants

Historically, about 60 percent of the herbicides used by the agency were for annual maintenance of a vegetation-free strip at the edge of pavement. WSDOT is currently studying alternatives to this practice to determine the most appropriate and cost effective methods for varying roadsides around the state". (From the WSDOT website titled 'Herbicide Use".)

- ***Standard specifications*** – specification manual used on WSDOT roadside projects.

- ***Special Provisions for each project*** – *this is a supplemental manual beyond the standard specifications, specific to the project.*

- ***WSDOT Maintenance Manual***: According to this manual "… The primary objectives for maintenance of roadside vegetation are to provide for safe highway operation and to comply with legal regulations for control of noxious weeds and protection of the environment.

- **CPTED – *Crime Prevention Through Environmental Design* –** a national list that provides criteria for design considerations relating to safety and crime prevention.

- ***Olympic Region Maintenance: Considerations for Scoping, Design and Construction***, revised August 2010. " It's made up of successful tips, considerations and lessons learned by various region work-group organizations from past WSDOT construction projects."

Websites:

Overall WSDOT maintenance policy and procedures for roadside vegetation are defined in Chapter 6 of the *WSDOT Maintenance Manual* (M51-01, March 2002)";
http://www.wsdot.wa.gov/Publications/Manuals/M51-01.htm

Herbicide Risk Assessment
http://www.wsdot.wa.gov/Maintenance/Roadside/herbicide_use.htm

Roadside Classification Plan http://www.wsdot.wa.gov/publications/manuals/fulltext/M25-31/RCP.pdf

Maintenance Accountability Process
http://www.wsdot.wa.gov/Maintenance/Accountability/default.htm

Roadside Manual
http://www.wsdot.wa.gov/publications/manuals/fulltext/M25-30/Roadside.pdf

IRVM Plans
http://www.wsdot.wa.gov/Maintenance/Roadside/mgmt_plans.htm

APPENDIX B

WSDOT Timeline – History of Design, Construction and Maintenance Activities by Decade

APPENDIX B
WSDOT TIMLINE – HISTORY OF DESIGN, CONSTRUCTION AND MAINTENANCE ACTIVITIES BY DECADE

1960 - 1980:
Legal Matters*:* The Federal Highway Beautification Act required states to beautify the roadsides. This Act established a surge of independent highway designs throughput the State, without true consideration of long-term maintenance.
Restoration Design and Function: This time period had an aesthetic focus. Urban areas were designed with highly ornamental and non-native plant palettes. Ivy was commonly used as a ground cover during this timeframe. (Today ivy is considered an invasive species.) The planting style – while fitting the concept of beauty, at the time - was water-dependent and maintenance intensive. (The lifecycle costs - of these plantings – are today viewed as extremely high life cycle cost designs. Landscape function-based design was not a priority at this time.)
Construction Practices: In 70's, justified to FHWA a 3-year plant establishment period to be included in the federally funded project costs.
Major Roadside Construction Projects: I-5 through Seattle, Everett and Bellingham; I-90 through Spokane; I-82 through Yakima; SR518 in SeaTac and Burien
Maintenance Practices*:* The State highways had dedicated landscape personnel that worked with the maintenance crews. This time period was notable due to the heavy use of herbicides. All plants needed to be able to survive the use of pre-emergents, many of which were granular; thus the common use of ivy.

1980 – 1990:
Legal Matters*:* The completion of Interstate Highways in the state reduced the WSDOT highways budget. There was concern that the I-90 Interstate Highway project would set a precedent for roadside design and maintenance. The awareness of the benefits of long term (or permanent) erosion control – as a landscape function - resulted in roadside vegetation management plans, mitigation requirements, and monitoring of some critical areas.
Restoration Design and Function: In the early 80's, due to drought conditions (and a slim budget) the use of water conservation methods were encouraged such as mulch, soil amendments, elimination of unnecessary irrigation systems, use of recycled yard-waste, and adjustment of the size of plants installed (the proportion of root to top growth was greater to provide a better adaptation to site conditions).
During this timeframe terminology was changed from 'landscaping' to 're-vegetation', to better convey the purpose of the landscape work.
Construction Practices: Vegetation areas were installed with a specified 3-year plant establishment period.
Major Roadside Construction Projects: I-5 and I-205 in Vancouver; I-5 in Olympia; I-705 in Tacoma
Maintenance Practices: Maintenance personnel are asked to work with the design team. Detailed maintenance plans were developed by designers and were used to justify additional maintenance

funding and personnel. Maintenance crews are still specialized. There are dedicated roadside crews and separate highway repair crews.

For the I-90 project there was a dedicated roadside crew and supervisor. The funding and commitment for this level of maintenance activities was the result of an agreement with Mercer Island and the City of Seattle.

1990 - 2000

***Legal Matters**:* Establishment of the *WSDOT Task Force* (looked at roadside staffing issues); writing of the *Roadside Classification Plan* (defined policy and established a consistent level of management for: planning, design, construction, and maintenance); and development of the *Roadside Manual* (a guide for policy decisions) were all begun with an emphasis on sustainability and low-lifecycle costs.

[The Roadside Classification Plan (RCP) was responsive to funding categories. It established levels of treatment that could be standardized and included in all projects. For example: Treatment Level 1 - Maintenance; Treatment Level 2 - Standard restoration of projects; Treatment Level 3 – If commitments require (public EIS), it has to be approved. The policy defined in the RCP advocates the use of native plants, due to the sustainability of natives over time.]

• Compost Law – WSDOT committed to use yard waste

• Environmental Mitigation Laws – New requirements are instituted at the County, State, and Federal level. Permit conditions require longer-term monitoring.

• Environmental Impact Statement (EIS) was required for maintenance practices regarding pesticide use.

• Programmatic EIS for Roadside Vegetation Management – this selected preferred alternatives using Integrated Pest Management (IPM) principles and developing roadside management plans.

Restoration Design and Function: This era fully established the concept of function-based restoration design, or the design of highway areas to respond more site-specifically to the context. There was an increased use of native plants due to sustainability goals and function-based restoration designs.

During this timeframe terminology was changed from 're-vegetation' to 'roadside restoration' to better convey the function of the landscape work.

***Construction Practices**:* On large contracts, the prime contractor (usually a Professional Engineer or PE) manages the project; on small contracts the regional Landscape Architect may manage the project. This role differs from region-to-region.

• Mitigation contracts may remain open for 10 years, depending on permit conditions. The Washington Conservation Corp from the Department of Ecology (DOE) maintains the mitigation sites through plant establishment.

• Contract requirements and specifications were not fully enforced, especially regarding planting designs.

Major Roadside Construction Projects: I-90 in Seattle, Mercer Island and Bellevue; I-405 in Bellevue, Tukwila and Renton

Maintenance Practices: The process was formally defined for maintenance staff to be present at 30, 60, and 90 percent completion reviews with design team.

• Maintenance budget cut by 30% (1995), maintenance personnel create Maintenance Accountability Program (MAP) for greater accountability and to justify funding.

• Early 1990's the dedicated roadside maintenance crew became part of the overall NW Maintenance staff. Late 1990's the roadside crew was dispersed even more.

2000 – Present:

Legal Matters*:* Herbicide use was reduced by 80% on roadsides. (No legislation was enacted, but there was renewed public interest in WSDOT herbicide use.) Legal challenges and decisions on herbicides were in relation to ESA / salmon.

• Updated Environmental Impact Statement (EIS) - The herbicides risk assessment was updated and it placed self-imposed buffers and restrictions to sites, based on findings.

Restoration Design and Function: The planting design specified smaller plants at a higher density, soil amendments, mulch/chips, and minimal (temporary) irrigation systems for plant establishment.

Construction Practices*:* No specialized vegetation or maintenance personnel required for landscape construction contract administration.

Design/Build project model began.

Major Roadside Construction Projects: SR18 Auburn to Tiger Mt.; SR16 in Tacoma

Maintenance Practices: Increase in maintenance activity, as much time is committed to restoring existing roadside sites that have become overgrown with weeds, due to reduced use of herbicides.

• WSDOT partners with local towns and cities for long-term maintenance at gateway interchanges.

• Integrated Roadside Vegetation Management (IRVM) Plans were developed for all maintenance areas; annual planning / update cycle initiated to document roadside maintenance.

• Maintenance funding continues to fall behind due to lack of additional funding for inflation and additions to the system.

APPENDIX C

Cost Tables

APPENDIX C
COST TABLES

The cost tables in Appendix C were compiled by WSDOT, and not the researchers.

TABLE C-1: CONSTRUCTION COST SUMMARY

Case Study Site	NW1	NW2	NW3	NW4	O1	O2	O3	O4	O5	SW1	SW2	SW3
Seeding, Fertilizing, and Mulching		grass area **$2,496**		grass areas **$24,624**	**$6,160**				grass area along road edges **$7,104**	**$29,856**		one grass area **$192**
Bark or Wood Chip Mulch	shrub areas **$922**	non-grass area and area orig. planted in ivy **$36,260**	planting areas **$33,180**	shrub areas **$198,940**	shrub areas minus ex. veg areas **$106,960**	**$55,160**	**$126,420**	**$86,000**	planting beds **$73,220**	planting beds **$379,820**	planting beds **$81,000**	all except grass **$46,060**
Topsoil				shrub areas **$341,040**						planting beds **$651,120**	all areas **$265,680**	all areas **$117,840**
Soil Amendement (incorporate organic matter)	shrub areas **$10,881**	entire area **$51,000**	planting areas **$47,400**			**$78,800**	**$180,600**	**$124,000**				
Compost (3" layer, brown or bladed)					shrub areas minus ex. veg areas **$106,960**				**$1,353,800**			
Seeded Lawn Installation											grass areas **$75,690**	
Planting at 3' o.c.		original ivy planting **$137,789**					all areas except shrub beds **$525,662**				ground cover beds lowfast cotoneaster **$58,879**	
Planting at 4' o.c.		shrub area **$13,696**		shrub areas **$608,188** includes bare root tree liners	shrub areas minus ex. Veg areas **$326,992**	**$169,632**	shrub beds along Sleater-Kinney **$15,836**	**$265,360**	planting beds **$223,844**		shrub beds **$145,520**	shrub beds **$140,812**
Planting at 5' o.c.	shrub areas (plan sheets) 26.36 acres **$869,880**									planting beds **$895,290**		
Trees - Individual (street trees)		13 trees along Rainier Ave. **$3,250**				28 street trees on Martin Way **$7,000**	25 trees along S-K **$6,250**				counts from plan sheets **$31,250**	counts from plan sheets **$91,000**
Trees - Individual (medium size)		98 trees **$14700**			240 trees **$36,000**	344 trees **$51,000**	752 trees **$112,800**	512 trees **$76,800**	439 trees **$65,850**	2,100 trees **$315,000**		
Trees - Mass planting at 10' o.c.			planting areas **$49,770**									
Irrigation Installation - Full Coverage Overhead		entire area **$259,000**		shrub beds only **$1,421,000**		**$394,000**	**$1,309,000**				all areas **$1,107,000**	
Irrigation Installation - Drip												planting beds **$82,250**
Irrigation Installation - Bubblers on Trees									trees only quantity **$104,600**			
Total Constuction Cost	**$881,683 (Renovation in 2002)**	**$518,190 or $199,300/acre**	**$130,350 (Renovation in 1999)**	**$2,593,790 or $87,628/acre**	**11.5 acres planted - $583,072 or $50,700/acre**	**$755,590 or $191,775/acre**	**$2,276,570 or $252,950/acre**	**$543,160 or $87,606/acre**	**$1,828,420 or $189,080/acre**	**$2,271,086 or $49,685/acre**	**$1,756,020 or $158,628/acre**	**$487,154 or $97,838/acre**

TABLE C-2: MAINTENANCE COST SUMMARY

Case Study Site	NW1	NW2	NW3	NW4	O1	O2	O3	O4	O5	SW1	SW2	SW3
Annual Irrigation Maintenance for Turf											**$633** yearly maintenance cost	
Irrigation Water											5.22 = 94.69 ccf X $5.00 X 12 = **$5,681** yearly water cost	
Clean out Transient Camps		One day per year average $1156 other transient litter control included in mowing cost			Three days per year $3,465 average annual cost	Three days per year $3,465 average annual cost	Three days per year $3,465 average annual cost			Three days per year $3,465 average annual cost	Three days per year $3,465 average annual cost	
Applying Pre-emergent Herbicides in Plantng Beds		Once a year, 2.6 acres $351 = $912 annual cost through 2002		14 acres X $351 once a year = $4,920 through 1985			9 acres X $362 = $3,258 once every 3 years = **$1,086** average annual cost				5.85 acres X $362 = $4,235 once every 3 years = **$706** average annual cost	3.29 acres X $362 once every 3 years = **$396** average annual cost
Weed Control in Turf, Fertilze and Herbicide											5.22 acres X $213.50 once every two years = **$557** average annual cost	
Cont. Undesirable Veg. in Grass using Broadleaf Herbicide	18.16 acres X $35.34 once every 3.5 years - **$214** average annual cost	2.27 acreas X $35.34 once every 2 years - **$40 average** annual cost	15.3 acres X $35.34 once every 3 years = **$180** average annual cost							27.13 acres X $35.34 once every 3.5 years = **$274** average annual cost		
Removing Undesirable Veg with IVM in Planting Beds	7.1 acres X $347 once per year = **$1,075** average annual cost	.32 acres X $347 once per year = **$111** average annual cost		14.2 acres X $347 = $4,856 once every 3.5 years = **$1,387** average annual cost	8.87 acres X $347 once a year = **$3,078** average annual cost	3.94 acres X $347 once every three years = **$455** average annual cost		6.2 acres X $347 once a year = **$2,151** average annual cost	5.23 acres X $347 once a year = **$1,815** average annual cost		5.85 acres X $347 once a year = **$2,030** average annual cost	
Handpulling Undesirable Vegetation							9 acres X $262 + $2,358 once every three years = **$786** average annual cost					3.29 acres X $262 once every 3 years = **$287** average annual cost
Trim Edges along Road						.7 miles X $546 once every three years = **$182** average annual cost	1.1 miles X $546 once every three years = **$200** average annual cost	2 miles X $546 once every three years = **$364** average annual cost				
Limb/Prune/Remove Dead Tress		Once day every 3 years = **$394** average annual cost			One day every 5 years = **$236** average annual cost		One day every 3 years = **$394** average annual cost				One day every 3 years = **$394** average annual cost	
Remove undesirable trees						One day every 10 years = **$189** average annual cost				5 days every 10 years = **$946** average annual cost		
Mowing around Trees with Slope Mower + Litter Control		1.56 acres X $304.24 - 2.5 times per year - **$1,187** average annual										
Mowing Irrigated Turf											5.22 acres X $45.15 25 times per year = **$5,892** average cost per year	
Mowing Rough Grass with Slope Mower	18.16 acres X $179.44 once every 3.5 years - **$931** average annual cost		3.19 acres X $179.44 once evry three years = **$190** average annual cost									1.62 acres X $180 = $292 two times per year = **$584** average annual cost
Mowing Rough Grass with Triple Deck				15.39 acres X $42.09 = $647.76 X 1.5 per year = **$972** average annual cost	3.85 acres X $42.09 1.5 times per year = **$245** average annual cost					18.66 acres X $42.09 once per year = **$785** average annual cost		
Total Average Annual Maintenance Cost	**$2,220**	**$1,732**	**$370**	**$2,360**	**$3,528**	**$826**	**$2,466**	**$2,515**	**$1,815**	**$2,005**	**$15,893**	**$1,510**
Average Annual Cost per Acre	**25.26 acres = $88/acre**	**2.59 acres = $669/acre**	**15.3 acres = $24/acre**	**29.6 acres = $79/acre**	**13.1 acres = $269/acre**	**3.94 acres = $210/acre**	**9 acres = $274/acre**	**6.2 acres = $405/acre**	**5.32 acres = $347/acre**	**45.8 acres = $43/acre**	**11.07 acres = $1,435/acre**	**4.91 acres = $307/acre**

TABLE C-3: CONSTRUCTION COSTS

	Agreed upon average					Assumptions:
1.) Seeding, Fertilizing, and Mulching NW1, NW2(post construction maintenance), NW3, NW4, O1, O5, SW1	Average $/acre	$1,600.00				Apply to all non-irrigated grass areas
2.) Bark or Wood Chip Mulch All sites	Average $/acre	$14,000.00	or	$35.00	per CY	Apply to all planting bed areas, 3" depth
3.) Topsoil NW4, SW1, SW2, SW3	Average $/acre	$24,000.00	or	$30.00	per CY	Typical application 6" depth, average price for most readily available type Apply to planting bed areas in these cases
4.) Soil Amendment (incorporated organic matter) NW1? NW2, NW3(select areas) O2, O3, O5	Average $/acre	$20,000.00				Soil Amendment (compost, ground bark, etc.) 3" layer incorporated to 12"
5.) Compost (3" layer, blown or bladed in place) O1, O4	Average $/acre	$14,000.00	or	$35.00	per CY	Compost placed on surface 3" (not incorporated), graded or blown over
6.) Seeded Lawn Installation SW2	Average $/acre	$14,500.00	or	$3.00	per SY	Includes fine grading and surface prep per specs
7.) Planting at 3' o.c. Check plan sheets	Average $/acre	$60,700.00				Includes PSIPE, plus $8K/acre each for 2nd and 3rd year plant est. $8/plant, #1 cont., 5585 plants/acre triangular sp.
8.) Planting at 4' o.c. Check plan sheets	Average $/acre	$42,800.00				Includes PSIPE, plus $8K/acre each for 2nd and 3rd year plant est. $8.50/plant, 80% #1 cont. and 20% #2 cont., 3150 plants/acre triangular
9.) Planting at 5' o.c. Check plan sheets	Average $/acre	$33,000.00				Includes PSIPE, plus $8K/acre each for 2nd and 3rd year plant est. $8.50/plant, 80% #1 cont. and 20% #2 cont., 2000 plants/acre triangular
10.) Trees – Individual (medium size) NW3, O1, O2, O3, O4, O5, SW1	EACH	$150.00				Includes PSIPE, plus $100 each for 2nd and 3rd year plant est. $150.00/plant, 4-5' conifer and 6-8' deciduous and includes staking/guying
11.) Trees – Individual (street trees) NW2, NW4 (check plan sheets)	EACH	$250.00				Includes PSIPE, plus $100 each for 2nd and 3rd year plant est. $250.00/plant, 2" caliper deciduous and includes staking/guying and bark mulch apron.
12.) Trees – Mass planting at 10' o.c. Check plan sheets	Average $/acre	$21,000.00				Includes PSIPE, plus $8K/acre each for 2nd and 3rd year plant est. $25.00/plant, #2 cont., 10' o.c., 500 trees/acre, triangular sp.
13.) Irrigation Installation – Full Coverage Overhead NW2, NW4 (planting beds only), O2, O3, SW2	Average $/acre	$100,000.00				Applies to entire area
14.) Irrigation Installation – Drip SW3	Average $/acre	$25,000.00				Applies to entire area
15.) Irrigation Installation – Bubblers on Trees O5	Average $/acre	$20,000.00				Applies only to planting beds

APPENDIX D

Contributors

APPENDIX D
CONTRIBUTORS

WSDOT personnel who were part of the Advisory Team:
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APPENDIX E

Specific Site Selection Criteria

APPENDIX E
SPECIFIC SITE SELECTION CRITERIA

Each WSDOT region was asked to propose sites that best represented the general criteria and that have data available for review by the research team. Different regional sites will be selected to best represent the following specific criteria.

Design criteria:

- Represent design function (the intent and goals of the restoration vegetation and landform configuration) - such as, CO-2 absorption, storm water quality, canopy coverage, headlight glare control, noxious weed management, steep slope stabilization, and other permit requirements.
- Embody the three (3) basic vegetation concepts used for urban roadways:
    1. island concept (trees, shrubs and groundcover planted together) surrounded entirely by lawn;
    2. massing concept (tree, shrub and ground cover) plant to cover the entire area;
    3. tree + grass concept (no shrubs, only trees) and lawn areas
- Represent vegetation plans with a variety of plant species – including native plants, ornamental plants, and possibly 'trim-able' plants (plants that can be mowed down and that will revive), such as salal and snowberry.

Construction criteria - different sites will be selected to best represent:

- A range of plant establishment periods, including different watering / irrigation regimes
- Different weed control efforts implemented
- Contractor compliance (or lack of) with the WSDOT contract
- Varying age of sites – a chronicle of the WSDOT roadside process

Maintenance criteria - different sites will be selected to best represent:

- Sites with a dedicated landscape crew and sites without a dedicated crew
- Variable funding for project maintenance