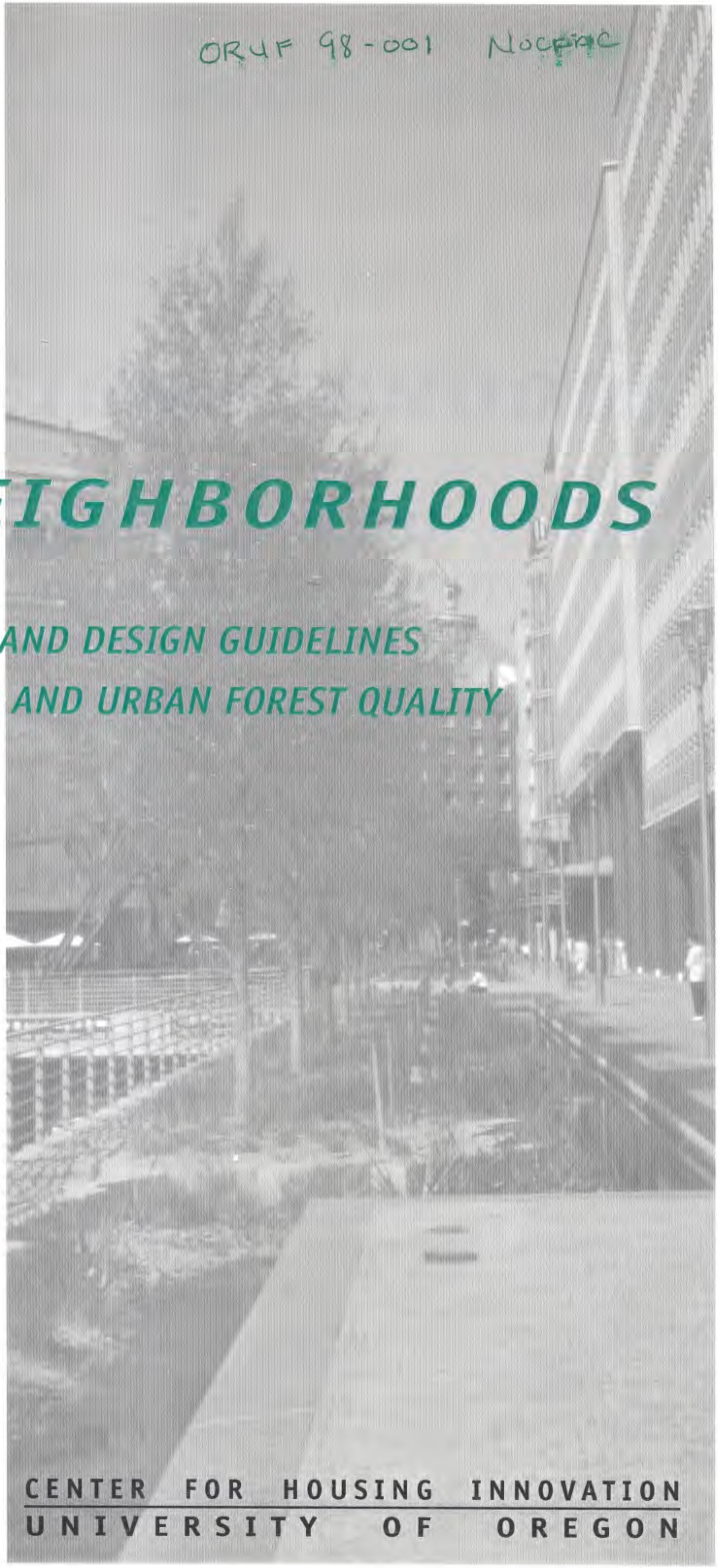
ENVIRONMENTAL ASSETS

AIR QUALITY

GREEN NEIGHBORHOODS

PLANNING AND DESIGN GUIDELINES FOR AIR, WATER AND URBAN FOREST QUALITY



URBAN FOREST

NATURAL DRAINAGE

IMPERVIOUS SURFACES

VEGETATION

CENTER FOR HOUSING INNOVATION
UNIVERSITY OF OREGON

GREEN NEIGHBORHOODS

PLANNING AND DESIGN GUIDELINES FOR AIR, WATER AND URBAN FOREST QUALITY

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ACKNOWLEDGEMENTS

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Many have made substantial contributions to this work. Most directly involved with this publication were our colleagues and students. Jackie Rochefort researched and compiled many of the guidelines on environmental assets, water quality, urban forestry, and surface drainage; Christine Roe researched and compiled much of the guideline on impervious surfaces. Dior Popko shaped and produced this publication. Leah MacDonald, Ted Gresh, and Britten Clark created many of the mapped illustrations. In addition, Sarah Burrows, Prashant Gaba, Nicholas Kohler, Stephen Lamb, and Kristen Lohse all made substantial contributions to the research, methods, and computer-based tools upon which this work depends.

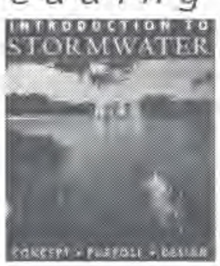
Many others have influenced ideas and issues underlying this work. Chief among them is the work of the Center for Watershed Protection and their 1998 publication *Better Site Design: A Handbook for Changing Development Rules in Your Community,* and the work of Bruce Ferguson and his 1998 book *Introduction to Stormwater: Concept, Purpose, Design.*

We also wish to thank our Community Advisory Group who helped us develop and measure alternatives and define guidelines. This group included Gary Feuerstein of Endex Engineering, Roger Irvin of Benton County Public Works, Jerry Davis and Al Kitzman of Benton County Parks, Fred Towne of the City of Corvallis Planning and Community Development, and Robert Frenkel of Oregon State University. We owe a similar debt of appreciation to our publication reviewers who included Mark Francis of the University of California-Davis, Bruce Ferguson of the University of Georgia, Cheryl Kollin and Alice McEwan of American Forests, Krista Reininga of URS Corporation, Alan Lowe of the City of Eugene Planning and Development Department, Amanda Punton of the Oregon Department of Land Conservation and Development, Ken Snyder of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, and Don Yon of the Oregon Department of Environmental Quality.

And finally, we extend our appreciation to Denny Egner and Lee Leighton of SRI/Shapiro Associates and Bill Lennertz and Lawrence Qamar of Lennertz Coyle, Architects and Town Planners for their work developing the Neighborhood Village Alternative and the opportunity to observe and document much of the planning and design process that created it.

Further Reading

Center for Watershed Protection, 'Better Site Design: A Handbook for Changing Development Rules in Your Community," 1998.



Bruce K. Ferguson, "Introduction to Stormwater: Concept, Purpose, Design," 1998.

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INTRODUCTION

We are teachers and researchers, based in architecture, landscape architecture, and planning at the University of Oregon. Our work is broadly concerned with the growth of communities and its impact on the character and quality of life, place, and environment. We pursue that concern with a bias toward, and emphasis on, the processes and decision-making scales of physical planning and design. Through our work, we hope to influence those decisions that communities make to define, shape, and articulate new and infill development — particularly those larger-scaled, master-planned developments and projects where careful planning and design can accrue significant environmental benefits. Cited elsewhere in this document others pursue similar concerns with an emphasis on smaller scale projects or the processes and decision-making scales of implementation and management.

The models and methods of community planning and design within which our work applies are shifting — from rule-based systems of codes and regulations toward more local, collaborative, and consensus-based systems of negotiated priorities and agreements (Abbott, 1994). There is, as a consequence, an emerging need to cultivate the expectation and the means to consider issues of quality of life, place, and environment alongside the many other factors already a part of public discussion of planning and design in many communities.

Part of that need, and the opportunity, we believe, is an absence of tools and techniques that makes it possible to visualize, measure, and compare environmental impact as early and as readily as a community might measure and compare density or transportation impact or development costs. As a consequence, much of our work is focused on the development of took and techniques that help communities become better informed about the options they consider and trade-offs they make about growth and development. We come to this focus in part out of concern that without appropriate took, consideration of quality of life and environment will be invisible or ambiguous, and therefore, poorly integrated with consideration of other more readily perceived and measured factors, such as density or traffic or economic cost, for example. The need, we believe, is particularly acute early in the planning and design process when the opportunity is greatest to develop strategies that could result in better environmental performance and better overall performance at the same time but the means to make that case are as yet unfamiliar or undeveloped.

Growth manangement design charrette. Eugene, Oregon, 1998.

Our findings suggest that while land use and density does matter in terms of air, water, and urban forest quality, the design resolution of land uses and density may ultimately matter as much or more. Our comparison of three neighborhood plan alternatives, for example, (see Comparing Three Neighborhood Plans and the Appendix of this document) demonstrates that development with goals of higher density and mixed land uses can also achieve goals of air, water, and urban forest quality, if these issues are considered sufficiently early in the planning and design process.

Equal densities, similar land uses, and comparable pedestrian connectivity can either compete with or complement goals of urban forest protection and stormwater runoff reduction. Dense mixed use neighborhoods of finely gridded street networks, for example, may have many positive impacts, such as improving the distribution and proximity of services, con-. nectivity of both vehicular and pedestrian networks, creating cultivated urban forest opportunities, and potentially reducing vehicle use and vehicle miles travelled. Development patterns of this type, however, may also compromise opportunity for urban forest preservation, increase impervious surface area, and increase stormwater runoff. In addition, as much of this runoff is associated with a more extensive network of streets, the opportunity for common street-related pollutants entering watersheds could increase.

A better performing alternative, however, is not inevitably lower density, with less mixed use. With the benefit of planning and design strategies that preserve landscape and open space combined with water quality-oriented surface drainage, some higher density, mixed use development patterns can perform at least as well as lower density patterns against measures of urban forest and water quality — and better in terms of transportation management and infrastructure cost.

The crucial differences — the amount and location of land set aside for open space, the amount and Location of land allocated to streets, and the design of the street and drainage networks — are embedded in the processes and decisions of planning and design. It is only possible to incorporate many key features and systems — notably sufficient open space, surface stormwater networks, and urban forest preservation — if a neighborhood and its network of streets and utilities can be planned and designed with these in mind from the very beginning. Surface stormwater systems, for example, can bring significant opportunity and value to a neighborhood. These systems not only mitigate the runoff and water quality impacts of development, they can also create a largely natural, well connected open space network at the same time. Further, if the street system is reduced and other features designed accordingly, these systems can cost less than conventional piped stormwater alternatives. While it would be possible to incorporate or retrofit some surface drainage features into an existing plan, it would be more difficult and perhaps impossible to incorporate many, once a site and its networks of streets and open spaces have been platted into an incompatible layout. Similar arguments can be made for factors of air and urban forest quality. It is, however, very possible to achieve better integration of development pattern and air, water, and urban forest quality, in tandem with goals for land use, density, and cost, if relevant information and issues are considered and decisions about them made at strategic points of planning and design.

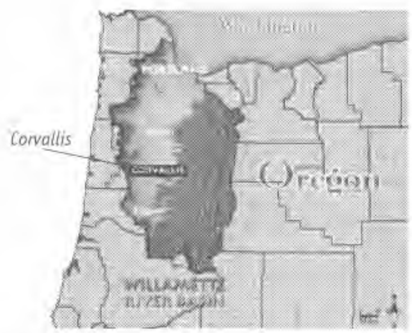
Which brings us to this publication. Informed negotiation and decision-making at the community level depends in significant part on an informed public equipped to discuss their interests and compare alternatives in equitable and substantive ways. And, being better informed is often more about access to the right information, in an accessible form at the right time than it is about more information in and of itself. The content and organization of this publication is intended to speak to the diverse constituency of landowners, neighbors, developers, planners, designers, elected officials, and members of the public who initiate, regulate, or influence neighborhood scale planning and design within their communities. Through it, we hope the diverse group of interests and agendas represented can be sufficiently better informed to ask the questions, seek out the instructive research and examples, and make the frequent, measured comparisons that lead to greener neighborhoods of better air, water, and urban forest quality.

NOTES

REPORT ORGANIZATION

Green Neighborhoods: Planning and Design Guidelines for Air, Water, and Urban Forest Quality was written to inform those in a position to initiate, regulate or influence neighborhood scale planning and design about air and water quality implications and opportunities in decisions they will be called upon to make in those roles. The information and advice within is drawn from many diverse sources, including a rapidly growing body of literature in the area and experience gained from a research-based comparison of neighborhood development patterns.

To simplify presentation of this work, we have organized this publication into three major sections. First, an INTRODUCTION section outlines the research upon which the concepts and content of this document is based. Second, as we are interested in influencing planning and design decisions, a GUIDELINES section outlines the approach to planning and design around which these concepts are organized and presented as advice. In total we present 12 guidelines in 6 chapters that advise processes of design from problem definition to site design. A REFERENCES section cites more fully the research findings, literature, and illustrations upon which the INTRODUCTION and GUIDELINES are based. Also included in this section are additional details on methods and findings presented in summary form throughout.



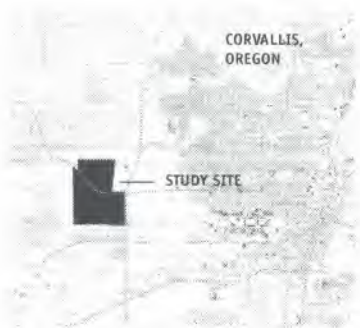
Corvallis is a city of approximately 58,000 in the Willamette River basin of Western Oregon. Source: Institute for a Sustainable Environment, University of Oregon.

Green Neighborhoods: Planning and Design Guidelines for Air, Water, and Urban Forest Quality builds on results and lessons learned from "Comparing the Values of Urban Forests in New Community Development" — a project to compare different neighborhood development patterns against measures of land use, transportation, cost and environmental impact. Three alternative neighborhood plans were created for a demonstration site (about 311 acres of valley floor land in the mid-Willamette River basin near Corvallis, Oregon) then measured and compared.

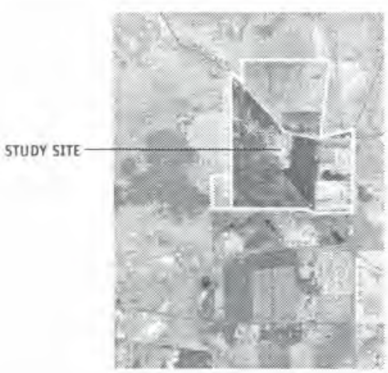
Each of the three alternatives represents a common neighborhood development pattern nation-wide. A conventional low density "Status Quo" (SQ) plan represents many subdivision developments. A denser "Neighborhood Village" (NV) plan represents a more compact and mixed use new urbanist pattern, and finally a lower environmental impact "Open Space" plan (OS) represents similar density and land use mixes to the Neighborhood Village plan with greater open space, urban forest, and stormwater features. Each alternative preserves different amounts of open space and pursues different approaches to infrastructure, urban forests, and stormwater management.

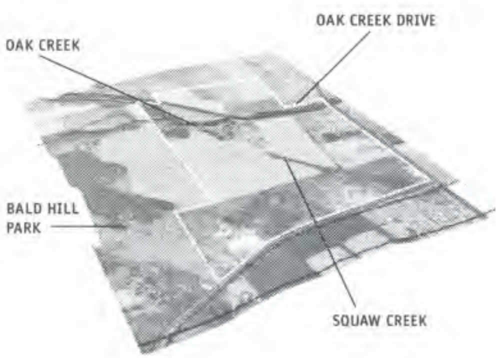
Representative land use cases derived from field-measured examples and data (the Elements of Neighborhood database by CHI) are assigned to appropriate areas of the three alternatives (Kellett, 1997 and 1998, and Girling and Kellett, 1999, describe this process in detail). Based on these case assignments, each plan is inventoried for summary data such as Land use area; dwellings; densities; building coverage; paving coverage; forest, tree; and turf cover; and so on. From these inventories, other measures of land use, environmental impact (such as impervious surfaces, areas of landscape, forest preservation, stormwater runoff, and water quality), and cost are created and compared. CITYgreen (by American Forests) was used to estimate stormwater peak flows for both two-year and ten-year storm events. SUNOM (by the Center for Watershed Protection) was used to estimate annual water pollution loads associated with stormwater runoff. Land, infrastructure, and urban forest costs used to compare alternatives are based on specifications and costs (1999 Dollars) common in the Corvallis area.

COMPARING THREE NEIGHBORHOOD PLANS



The study site is located on the west side of Corvallis near the urban growth boundary.





The results of these measurements demonstrate that development pattern matters. The physical planning and design characteristics of the three alternatives considered reveal significant differences against measures of land use, environmental impact, transportation and infrastructure cost. The following pages summarize the planning and design characteristics of each alternative and report some of the more significant measurement results.

The 311 acre demonstration site, on the western developing edge of Corvallis, Oregon, is one of six proposed 'Neighborhood Villages' in the West Corvallis North Philomath Plan (1996), a regional growth management plan. This site is constrained on four sides by permanent open space including a city park to the west, Oregon State University agricultural research facilities to the north and east, and industrial land to the south. The majority of the site, with the exception of a 30-acre county fairgrounds, is in private ownership. Other existing land uses include a mobile home park, a convenience store, a ranch, pasture, hay fields, and saw mills.

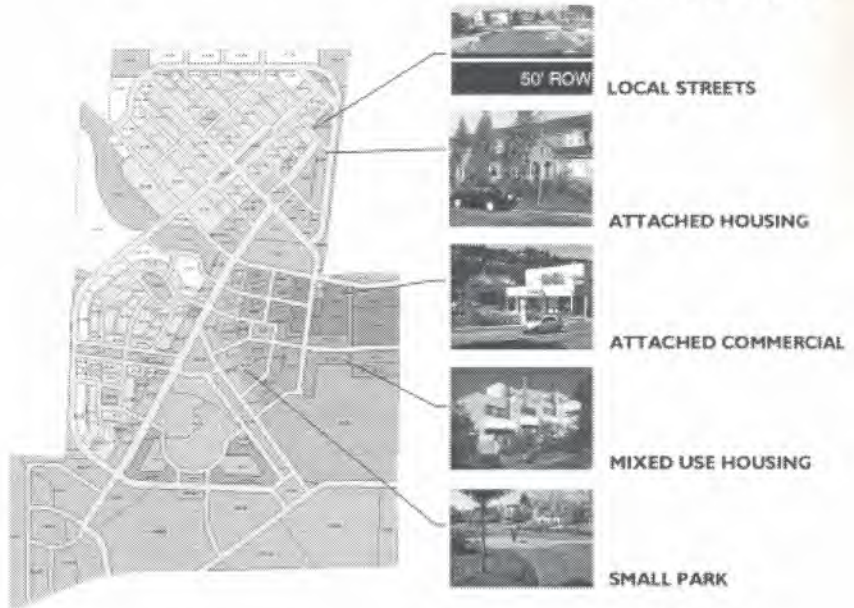
This site also presents a number of environmentally sensitive areas. Three perennial streams and associated tributaries pass through it. A Federal Emergency Management Agency floodway has been mapped along the larger stream, Oak Creek. The two smaller creeks, Mulkey and Squaw, have associated wetlands. The existing forest is approximately 27 acres of Oregon oak stands and partially forested riparian vegetation along all three creeks. Bald Hill Park, a 275-acre natural park immediately to the west, has an increasingly rare Oak-Madrone plant community and wildlife habitat spatially connected to the demonstration site via creek riparian corridors.

The following three fold-out pages present illustrated summaries of each of the three neighborhood plan alternatives developed and compared.

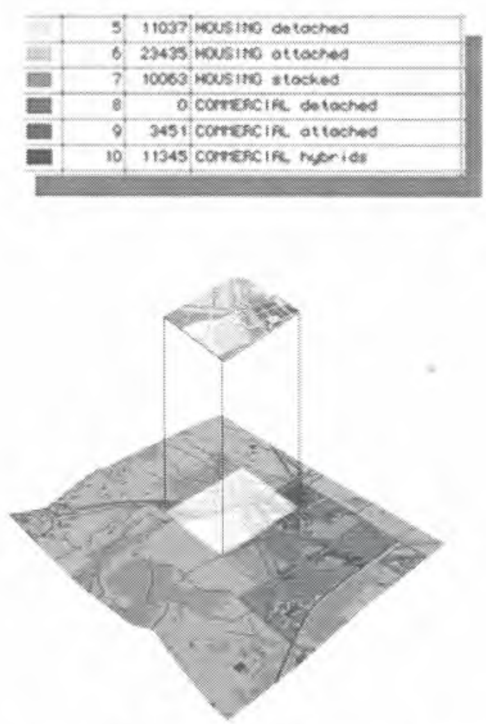
FINDINGS

A complete tabular summary of all measured comparisons is reported in the Appendix of this report. Highlights of comparisons germane to specific air, water and urban forest quality guidelines are reported within the background sections of related chapters.

SAMPLE CASE ASSIGNMENTS



Plan of the Neighborhood Village alternative partially referenced to Elements of Neighborhood cases. Selected case assignments shown for illustration purposes only and represent a fraction of the 63 assigned.



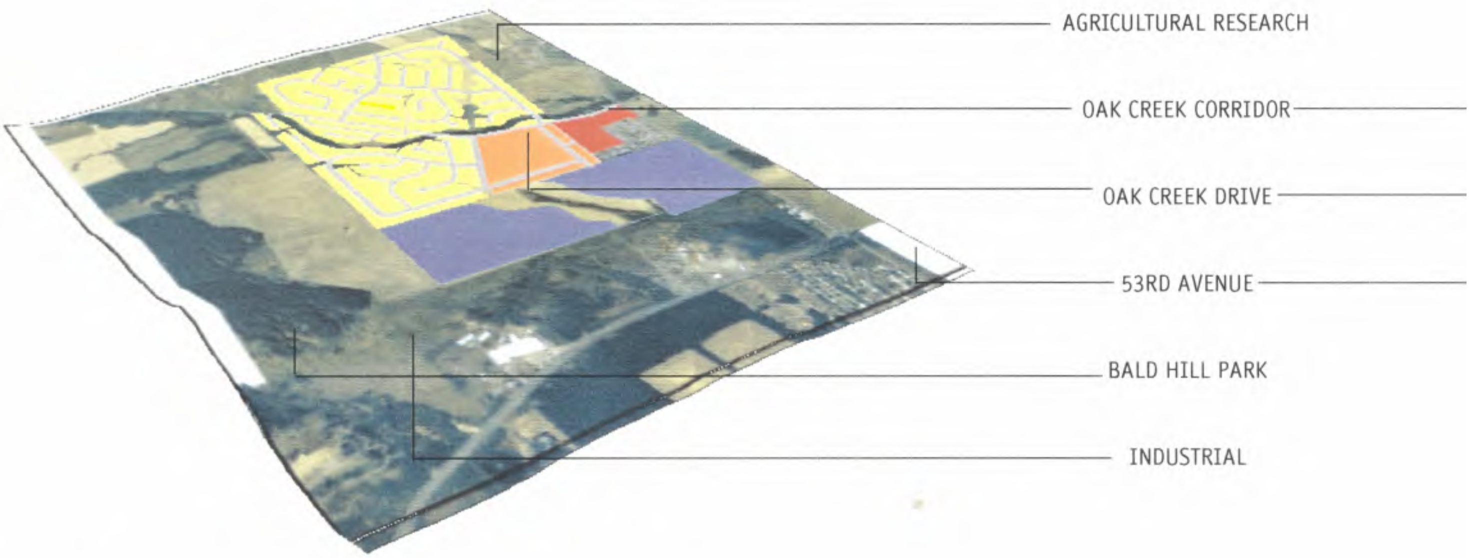
Schematic of land use and infrastructure element inventories.

MEASURED COMPARISONS

For each of the three plan alternatives, land use case studies are assigned to roughly block-sized areas of the plan as illustrated above. Case assignments are selected from a database that, for this project, included a total of 47 examples of land use and infrastructure elements — 7 cases of parks and open space, 19 cases of housing, 7 cases of commercial uses, 6 cases of civic uses, and 8 cases of streets and paths.

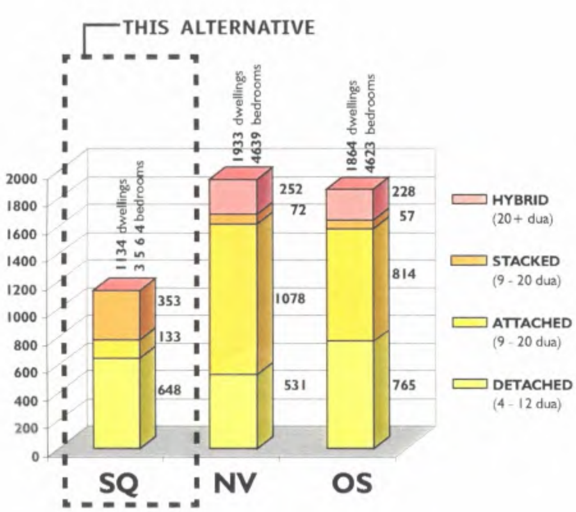
Associated with each case are field-measured data. A housing case, for example, includes data about the area of its site, the number and size of dwelling units, its density, lot coverage, off-street parking spaces, floor area, trees and pervious surfaces, and so on. Based on these case assignments, whole study area quantities can be extrapolated by pro-rating data associated with each case to the full area to which it is assigned. For example, one case of single family housing based on a 5,000 s.f. lot might be assigned to several blocks. If the total area of that assignment was 50,000 s.f., most data about that single family housing case would be multiplied by 10 and reported accordingly. By a similar process, quantities of other attributes can be derived and reported.

Using these quantities, other types of computations can be generated to compare alternatives across a variety of performance indicators. In this particular project, all three alternative plans were compared against 31 measures in categories of land use, environmental quality, transportation, infrastructure, and cost (see Appendix).

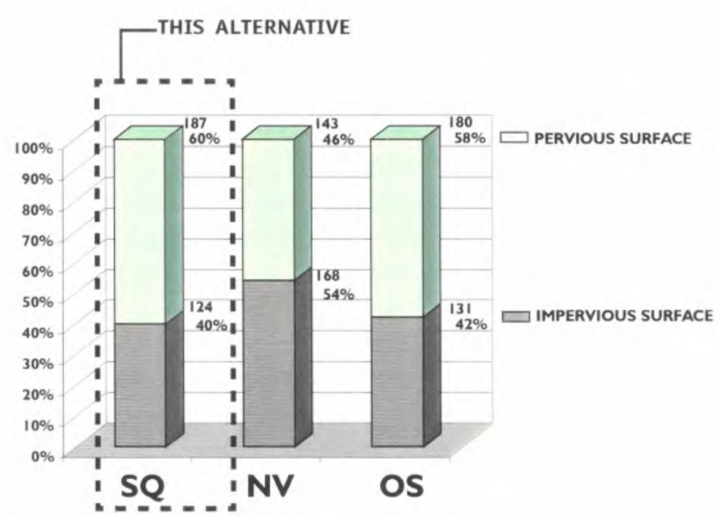


STATUS QUO ALTERNATIVE - *VIEW FROM THE SOUTHWEST*

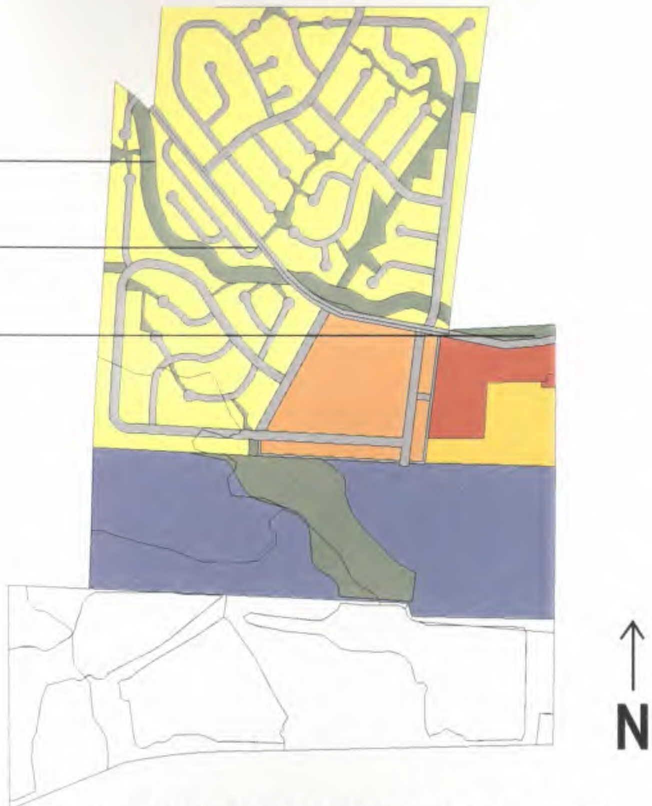
Scheme illustrated was created by the Center for Housing Innovation based on prevailing City of Corvallis Comprehensive Plan (1990) land use designations and comparable development patterns in the Corvallis area.



HOUSING TYPES

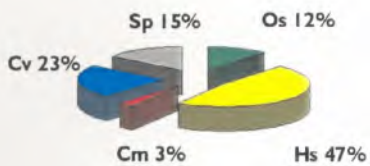


IMPERVIOUS/PERVIOUS SURFACES



STATUS QUO ALTERNATIVE - LAND USE PLAN
STUDY AREA = 311 ACRES

Elkhorn Drive, Eugene and many post-1960 subdivisions like it illustrate the character and scale of the Status Quo alternative.



LAND USE LEGENDS

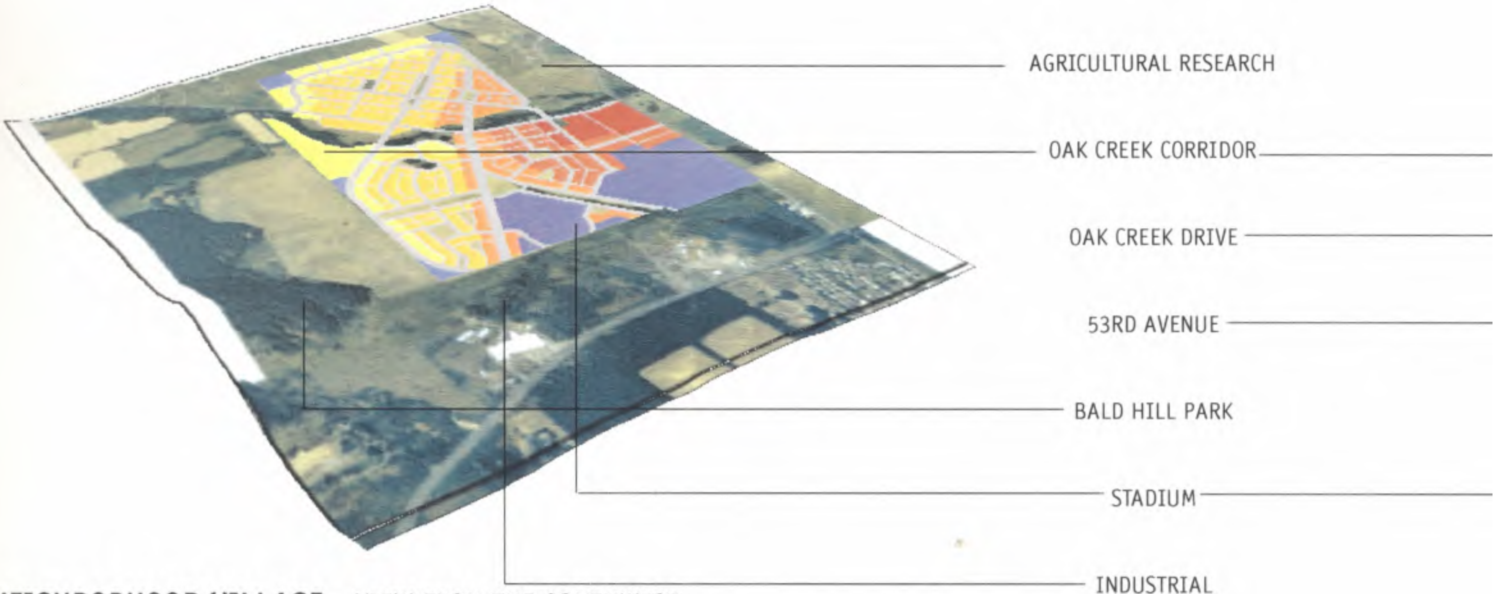
LAND USES BY PERCENTAGES

STATUS QUO ALTERNATIVE

The Status Quo alternative represents the lower density, primarily residential development pattern permitted under 1996 zoning. This plan is characterized by segregated land uses and housing densities, larger blocks and a street hierarchy of looping collectors and local cul-de-sacs. Housing is developed at two densities. Single family uses are typically low density (approximately 4 dwelling units per acre) on ± 8,000 s.f., back to back lots. Multi-family uses are located in the central portion of the site at approximately 20 dwelling units per acre. Streets are typically have sidewalks and planting strips. Parking and garage access is from the street.

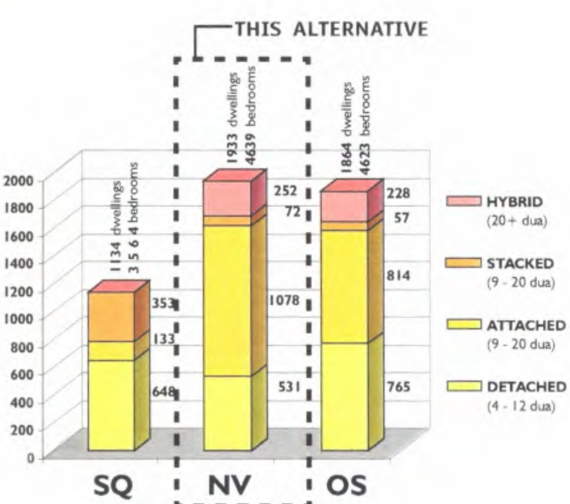
A central intensive development portion accommodates a mix of commercial and residential uses with an overall gross density of 6 units per acre and greater. Along the south edge of the study area is a future expansion of the Benton County Fairgrounds . Common green space follows the Corvallis fault line in the north portion of the site and connects to paths from cul-de-sac ends in other locations.

Street types and network layout conforms to City of Corvallis Transportation Plan (1996). The existing Oak Creek Drive has been expanded to a collector street within a 70' right of way. Loop roads in residential areas are collectors. Cul-de-sacs do not exceed 700' in length and serve no more than 18 households.

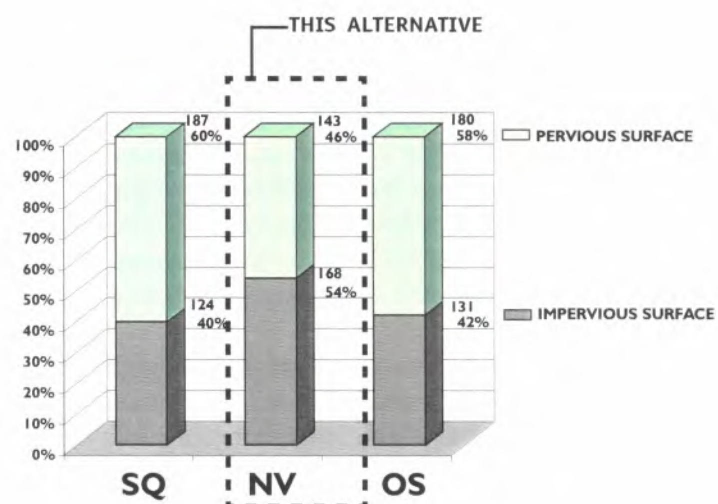


NEIGHBORHOOD VILLAGE - *VIEW FROM THE SOUTHWEST*

Sheme illustrated was created by Lennerts Coyle Associates and SRI Shapiro in collaboration with the City of Corvallis and Benton County.



HOUSING TYPES

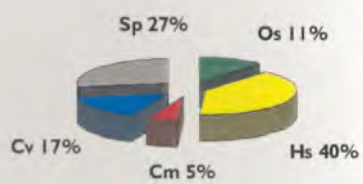


IMPERVIOUS/PERVIOUS SURFACES

NEIGHBORHOOD VILLAGE PLAN VIEW
STUDY AREA = 311 ACRES

- Commercial
- Mixed use
- Med-high density housing
- Medium density housing
- Low density
- Open space
- Civic
- Fairgrounds

LAND USE LEGENDS



LAND USES BY PERCENTAGES

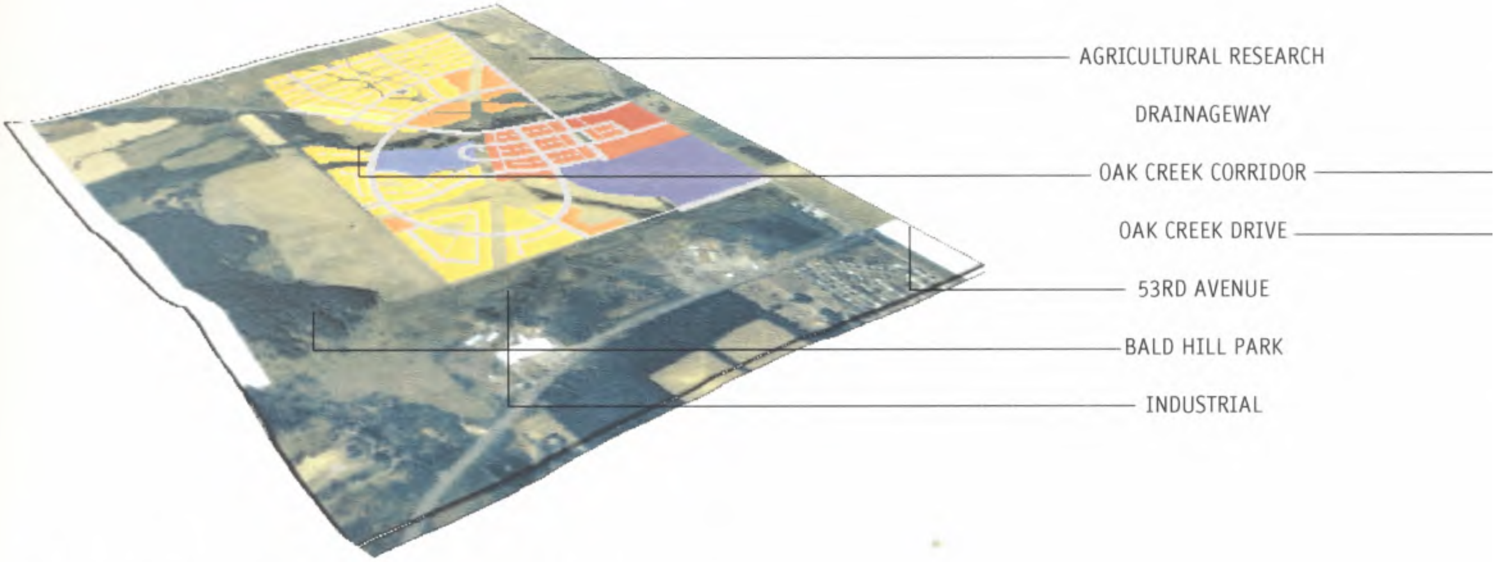
The street system a well connected network of smaller streets and short blocks that accommodate bicycles, pedestrians and cars. Streets are narrow and buildings are sited close to the street. Planting strips, sidewalks, and smaller, distributed open spaces offset the narrower streets and density. Garages are setback or accessed at the rear by way of alleys. Distinct sub-neighborhood areas are defined by principal roadways and open space features. Each has a small associated green space. Some streets align with views of adjacent natural features such as Bald Hill and surrounding hillsides.

Street of zero-lot line houses at Northwest Landing, DuPont, WA, and many recent models of the 'new urbanism' like it illustrate the character and scale of the Neighborhood Village Alternative.

NEIGHBORHOOD VILLAGE ALTERNATIVE

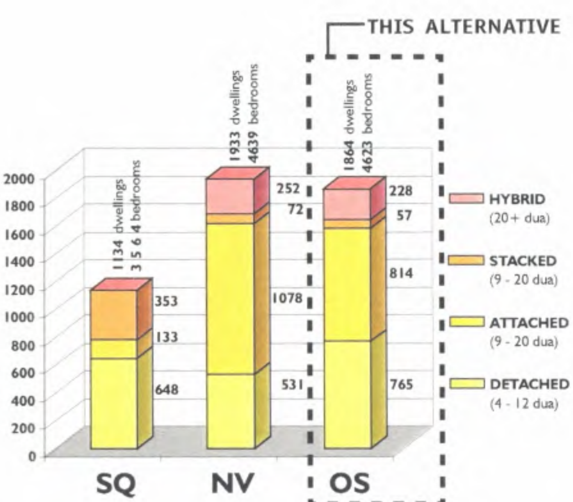
The Neighborhood Village Alternative represents principles of New Urbanism (Katz, 1994). This alternative is organized around a core of mixed land uses surrounded by housing with an overall average gross density of approximately 8 dwelling units per acre and served by a gridded street network. Housing densities vary within the plan. Single family housing variations include some relatively low density (approximately 6 dwelling units per acre) conventional subdivision lots, and higher density small lot and partially attached units (approximately 9 to 12 dwelling units per acre). Multi-family housing variations include rowhouses and apartments (approximately 12 to 20 dwelling units per acre).

At the center of the neighborhood is a commercial area, shopping street and town square off W 53rd and Oak Creek Drive. Pedestrian-oriented commercial buildings front the shopping street. A larger anchor store, such as a grocery, sits between the shopping street and other more automobile-oriented uses on W 53rd. Mixed and higher density residential land uses are closest (within 1/4 mile) to this center. An elementary school is located on the west edge of the site with its play fields located in Bald Hill Park. The southern portion of the site accommodates expansion of the fairgrounds and a sports stadium. A 200 foot wide greenway along Oak Creek is set aside as a buffered riparian corridor. The North Fork of Squaw Creek is protected within a corridor that forms the center median of a divided street and accommodates a sidewalk through the neighborhood to Bald Hill Park.

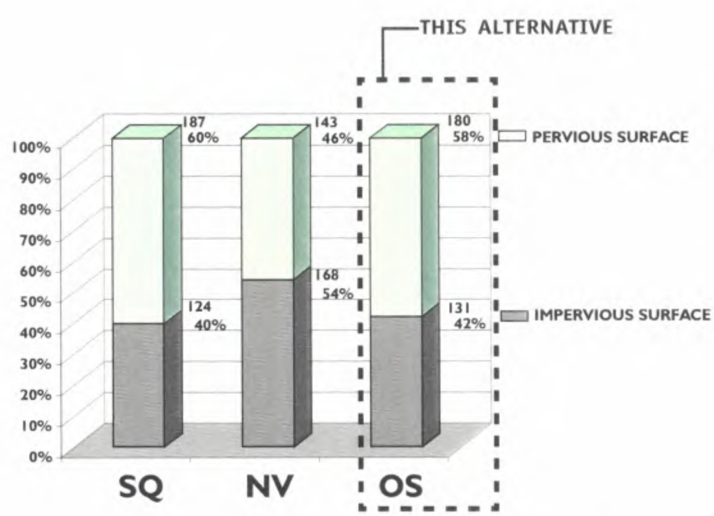


OPEN SPACE ALTERNATIVE - *VIEW FROM THE SOUTHWEST*

Scheme illustrated was created by the Center for Housing Innovation based on better stormwater and management and urban foresty practices.

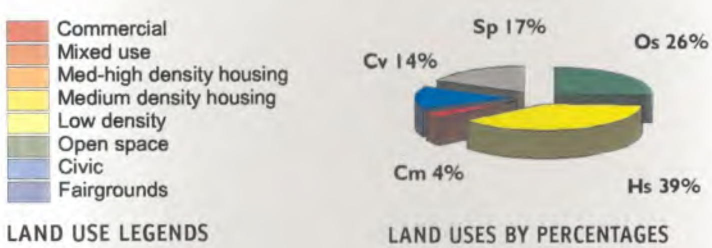


HOUSING TYPES



IMPERVIOUS/PERVIOUS SURFACES

OPEN SPACE PLAN VIEW
STUDY AREA = 311 ACRES



A street in Village Homes, Davis, CA. Planned communities such as Radburn, NJ; and the Woodlands, Houston, TX;and 'eco-burbs': such as Ecolonia, Netherlands illustrate the integration of open space and neighborhood.

Streets are narrow and the network is configured to preserve natural drainage ways. Planting strips, sidewalks and frequent points of access to the open space offset the narrower streets and more dense housing. Over half of the houses have traditional front street access while some front on greenways. All have rear garages accessed by way of alleys.

The entire 100 year floodplain of Oak Creek and the Squaw Creek and Mulkey Creek wetlands are protected with wide greenways. A stormwater and recreation greenway follows the fault line that passes diagonally through the study area. A surface drainage system is built around existing drainage corridors supplemented with a network of drainage easements. Off street trails and pedestrian corridors align with this network. Additional runoff attributable to development is detained and cleansed in wetlands and ponds.

OPEN SPACE ALTERNATIVE

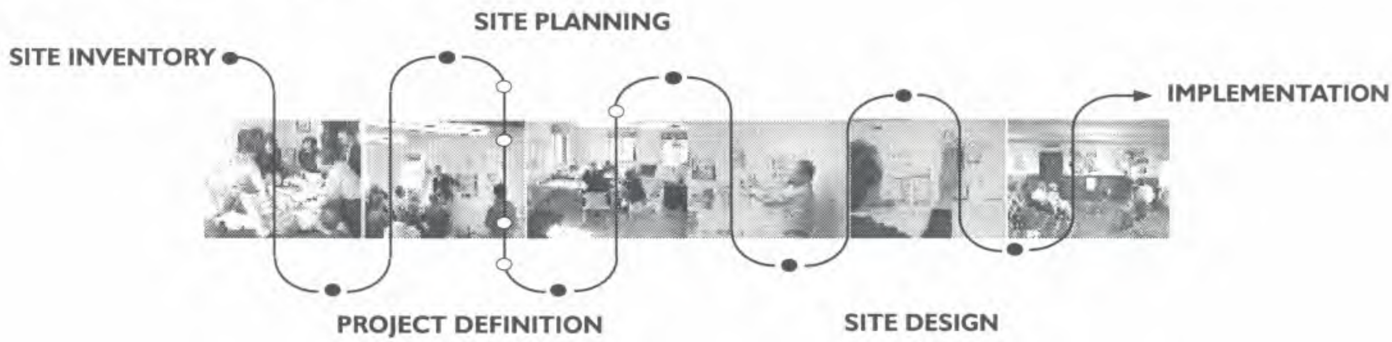
The Open Space Alternative represents a hybrid of the more dense, mixed use development pattern encouraged by the *West Corvallis North Philomath Plan* in combination with greater open space for stormwater management. This plan is organized around a core of mixed land uses and an overall average housing density of approximately 8 dwelling units per acre served with reduced-paving streets and open space networks. Together these support surface stormwater drainage and extensive pedestrian / bicycle paths.

At the center of the neighborhood is a commercial area, shopping street and town square. Pedestrian-oriented commercial buildings front the shopping street. A larger anchor store, such as a grocery, sits between the shopping street and other more automobile-oriented uses on the arterial street to the east. Mixed housing and commercial uses and higher density housing are within 1/4 mile of this center. An elementary school is located along the Oak Creek greenway, 3 blocks from the center. Playfields are located immediately west of the study area in Bald Hill Park. The southern portion of the site accommodates expansion of Benton County Fairgrounds including a new covered arena and additional parking.

Single family housing types include some relatively low density (approximately 6 dwelling units per acre) conventional subdivision lots, and higher density small lot and partially attached units (approximately 9 to 12 dwelling units per acre). Multi-family variations include rowhouses and apartments (approximately 12 to 20 dwelling units per acre).

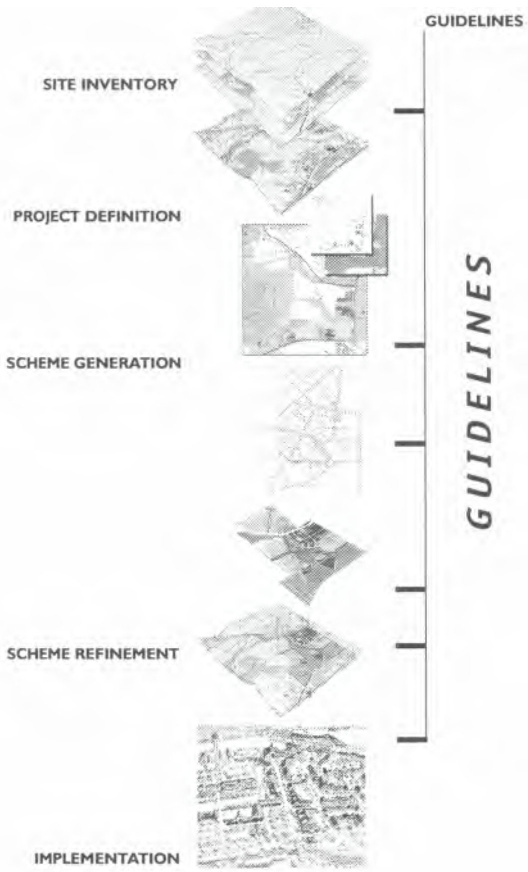
guidelines

A NEIGHBORHOOD PLANNING PROCESS



Once neighborhoods are planned or built, they are very difficult and expensive to change. The best opportunities to influence air, water and urban forest quality, therefore, resides in the beginning stages of decision-making when key principles and strategies that guide development are established. Fundamental questions such as: What land uses does this development include? How many of which kinds of elements and infrastructure (streets, open spaces, utilities, buildings) make up its land uses? How are these elements and networks located and organized on a site?, for example, establish many factors that influence air, water and urban forest quality as well as many other qualities and characteristics.

The guidelines presented in the following section are intended to guide planning and design processes toward 'greener' neighborhoods of better air, water and urban forest quality. In order to influence these decisions, guidelines must present credible information about the implications of poor decisions, convincing examples of better decisions and compelling evidence that backs up the promise. Having information, examples and evidence available, in and of itself, may not be enough — timing and format is also important, perhaps more so. The planning and design of neighborhoods is a very complex process that considers many factors and makes many comparisons and trade-offs. Part of the challenge lies in sorting the useful information, convincing examples and compelling evidence concerning air, water and urban forests in ways that it can be considered in parallel with other factors at appropriate times. To do so demands that guidelines anticipate the nature of the decision-making process they seek to influence.



Much community-based neighborhood planning, for example, follows an iterative decision-making process that:

- begins with decisions about PROJECT DEFINITION — typically goals and principles that define a program of proposed needs and uses (what and how much of which land uses, at what density, with what networks and infrastructure, for example) supported with information and analyses that establish the limits and opportunities of a community or a site to support that program,

- shifts to decisions about SITE PLANNING — typically iterations of generating and testing possible allocations and arrangements of a program on a site within its limits and in response to its opportunities,

- continues to decisions about SITE DESIGN — typically iterations of developing greater specificity and detail about a preferred alternative,

- and concludes in decisions about IMPLEMENTATION — typically regulations and practices intended to realize the construction of the preferred alternative.

Decision-making, and the need for guidance, roughly follows that process in which different kinds and scales of decisions are made at different times but in a generally progressive order. More general attitudes and principles are typically established toward the earlier stages while more specific strategies and details are typically established toward the latter stages.

Take the planning and design of a street system, for example. Alternatives may be considered and decisions made about them at several points in a planning and design process. Earlier decisions may be about the orientation and pattern of the network — how many street rights of way, how far apart, connecting which points, for example. Later decisions may be more about the physical design of the parts that make up the network — how wide is the paving, planting strip, and sidewalk within the right of way, how many trees are planted at what interval, for example.

In support of these decision strategies, our guidelines provide information and examples in a similar, roughly progressive order, illustrated information, and examples appropriate to each decision-making stage. 'Set aside existing forest areas, for example, is a problem definition or early site planning guideline intended to protect the environmental assets of a site before planning alternatives are considered. 'Reduce street widths, on the other hand, is a later site design guideline intended to reduce impervious paved surfaces after, or in parallel with, consideration of street network planning alternatives.

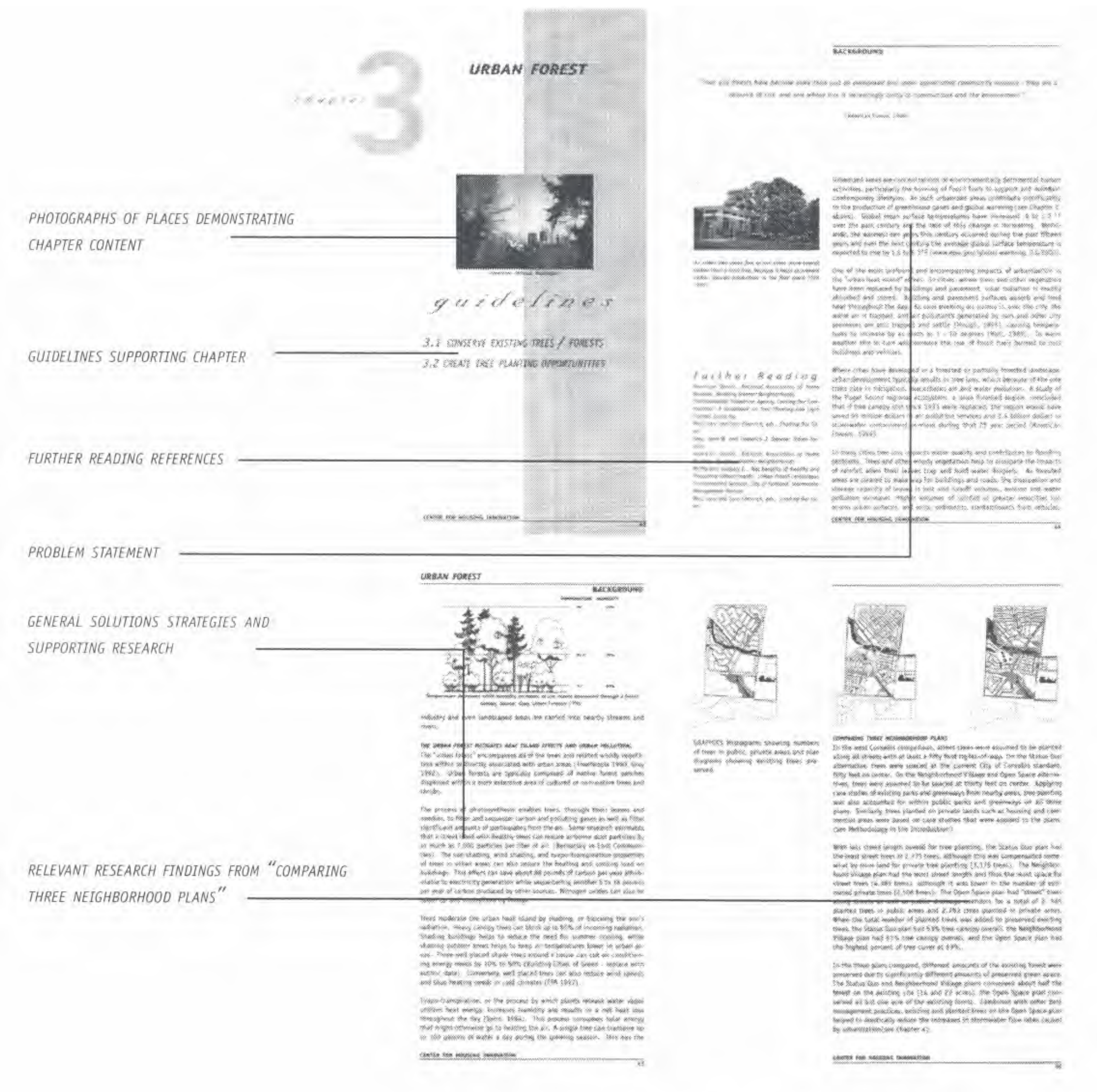
In total, we present 12 guidelines targeted primarily at decisions made in project definition, site planning, and, to a lesser degree, site design stages. Other publications more thoroughly and effectively target decisions made in site design and implementation stages. Several are listed in the "Further Reading" sections in each chapter.

Each guideline principles — ways of thinking about planning and design, and strategies — methods of translating those principles into actions. They are not fundamentally scientific or technical or regulatory in purpose or content. They are, nonetheless, based in sound science and technical concepts that articulate specific actions of planning and design. Their emphasis, however, is not regulation or prescriptive advice but rather arguments for, and illustration of, a variety of approaches that can be more flexibly combined or adapted to the unique and particular needs of specific projects and specific communities.

As illustrated on the following two pages, each guideline is presented in a common format that combines narrative, illustrations, demonstrations, and references to supporting research and literature. Each includes a statement of the problem the guideline is attempting to mitigate or resolve, a summary of the action proposed, illustrations of the planning and design implications of that action, and photographs of examples that demonstrate that action and evidence of the potential effect of that action based on a measured comparison of three neighborhood plan alternatives (see Comparing Three Neighborhood Plans).

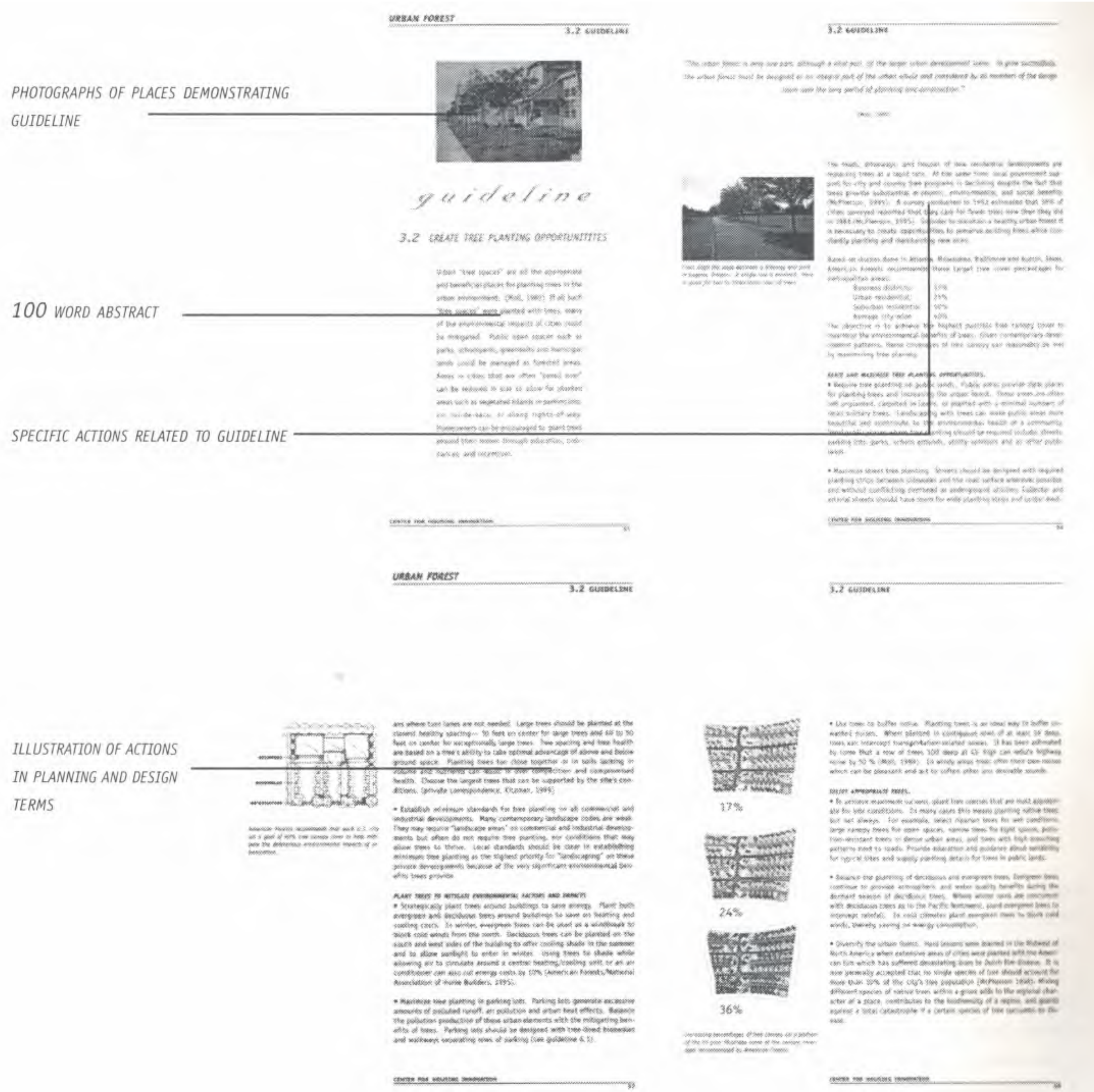
A GUIDELINE CHAPTER

Each guideline's chapter outlines a set of needs or objectives related to a theme - urban forests in this expamle. Each chapter has several parts.



A GUIDELINE

Each guideline within a chapter describes strategies to meet a need or objective within a theme. Create Tree Planting Opportunities is a stratey to improve the quantity and coverage of urban forest in this example. Each guideline also has several parts.



chapter 1

ENVIRONMENTAL ASSETS

Lake Hills Greenbelt Park, Bellevue, Washington

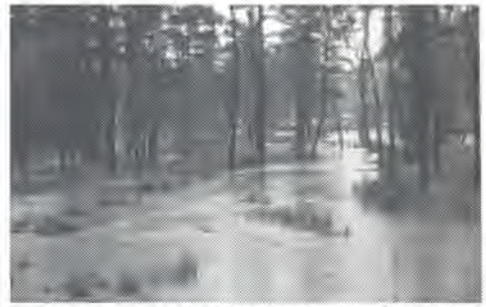
guidelines

1.1 SET ASIDE WETLANDS, STREAMS, FLOODPLAINS, AND NATURAL HAZARD AREAS

1.2 PLAN GREEN INFRASTRUCTURE


Bear Creek at the Woodlands, TX

The entire floodplain of this tributary was protected in a six hundred foot greenway to allow natural flooding and concurrently provide wildlife habitat.


Bear Creek at the Woodlands, TX - flooded

ENVIRONMENTAL ASSETS ARE CRUCIAL TO URBAN ENVIRONMENTAL HEALTH

"Environmental assets" are components of landscape structure and process which together, are vital to the long term health of the urban ecosystem. Examples include riparian corridors, wetlands, meadows, and forests. Natural hazard areas, such as floodplains, landslide areas, or earthquake faults may also be included as places that are particularly prone to environmental processes that produce unexpected and catastrophic events (*naturalhazards.org, 1999).* These natural processes include such events as floods, landslides, and earthquakes. Environmental assets, the key structural components of a landscape, might also be understood as the heart and lungs of ecological processes in an urban environment. They breathe life into an otherwise sterile environment.

URBANIZATION FRAGMENTS AND DAMAGES NATURAL LANDSCAPES

In the 23 year period between 1959 and 1982, the total area of developed lands in the United States increased by 45% (Smith and Helmund, 1993; Heimlich and Anderson, 1987), while during this same period population increased by only 33% (US Census, 1999). Urbanization typically denudes and pollutes lands while concurrently impacting whole watersheds and fragmenting important region-wide wildlife corridors. Remaining natural areas are mere fragments of the former ecosystem. These isolated patches of habitat lead to a decrease in native species diversity, and with decreased area for dispersal, and genetic inbreeding, localized extinction of certain species occurs (Smith and Hellmund, 1993).

Urbanization also causes significant changes to natural hydrology, due to piping and channeling of stormwater runoff, and creates desert-like conditions in cities. Groundwater is depleted, water tables drop, remnant streams dry up and when large rain storms strike, severe flooding is a consequence. Flooding, which occurs more frequently, contributes to streambank erosion and channel downcutting as piped stormwater discharges to natural streams (Ferguson, 1998). This in turn damages habitat, stresses remaining natural landscapes and provides opportunities for invasive species to take over.

Further Reading

American Forests, *www.amfor.org*

The Federal Interagency Floodplain Management Task Force, *"Protecting Floodplain Resources"*

Center for Watershed Protection *(CWP), Site Planning for Urban Stream Protection*

Dwyer, John F., E Gregory McPherson, Herbert W. Schroeder, and Rowan A. Rowntree, *"Assessing the benefits and costs of the* Urban Forest"

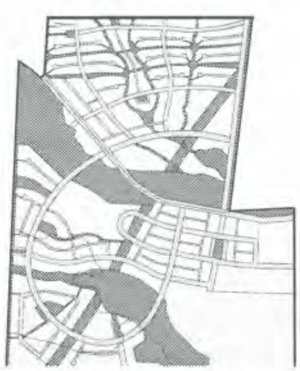
Cook, Edward, A., *Urban Landscape Networks: an ecological planning framework*

Dramstad, Wenche E, James D. Olson, and Richard T.T. Forman, *Landscape Ecology Principles in Landscape Architecture and Land-use Planning*

Smith, Daniel S., and Paul Cawood Hellmund, *The Ecology of Greenways*

Girling, Cynthia L., and Kenneth I. Helphand, *Retrofitting Suburbia. Open Space in Bellevue*

Map of Environmental Assets



Open Space Alternative

A goal to preserve environmental assets heavily influenced the layout of the Open Space alternative in the West Corvallis study.

PROTECTING ENVIRONMENTAL ASSETS IN CITIES HELPS TO PRESERVE ENVIRONMENTAL HEALTH

Protecting or restoring environmental assets such as streams, rivers, wetlands, meadows, and remnant forests can help to mitigate these destructive effects of urbanization and contribute to urban environmental health. When environmental assets are linked to form a network, they are far more effective at protecting water quality, retaining diverse habitat, providing opportunities for recreational corridors, and generally preserving the local ecology (Ndubisi, 1995, and Smith and Hellmund, 1993).

Riparian corridors are among the most diverse and valuable habitat areas. They are home to a rich mix of aquatic, amphibious, and terrestrial species. With adequate width and without significant barriers (such as road crossings) they can also provide movement corridors for both plant and animal species, which help to prevent isolation and increase genetic exchange for healthier populations. (Smith and Hellmund, 1993; Forman and Godron, 1986; Dramstad et al, 1996).

Riparian vegetation along waterways helps to clean both surface water and ground water. Riparian vegetation filters sediments from runoff, utilizes excess nutrients before they reach waterways, and protects stream banks from erosion. In a hypothetical drainage basin of one square mile, an average buffer width of 100 feet along a 1.4 mile stream can reduce watershed imperviousness by about 5% (CWP, 1995). By shading the shallow edges of rivers from the sun, riparian vegetation can help stabilize stream temperatures.

Riparian corridors also provide excellent sites for linear recreation such as walking, jogging, and biking. Immediate contact with nature provides enjoyment, relaxation, and reduced stress levels in most people. Attractive, safe, off-street trails provide incentives for walking and biking (see Guideline 2.2). People with access to nearby natural settings have been found to be healthier than other individuals (Kaplan and Kaplan, 1989).

Wetlands are Nature's sponges. They cleanse and absorb water and are crucial water storage areas in times of flooding. Minnesota Department of Natural Resources reported that increased flood storage capacity due to wetland areas, riparian, and buffers resulted in a cost savings of $300 per acre-foot over "engineered" flood storage strategies (CWP, 1998).

Because plant material and nutriants are abundant, wetlands provide essential habitat (food, migration, and reproduction areas) for a diverse range of plant and animal species. Nearly 1/3 of the country's endangered species are dependant on wetlands for their survival.

Forests provide upland habitat and support different populations of plants and animals than do riparian and wetland areas, particularly if naturally connected to other habitat areas (American Forests, and Smith and Hellmund, 1993). Forests help to cleanse the air and conserve water resources. They convert carbon dioxide to oxygen, absorb other air pollutants, and help cool the urban atmosphere. They conserve water by slowing runoff and improving storage and water infiltration up to 10 times over turf (CWP, 1995) (see Guideline 3.1). Natural forests that are located on steep slopes, landslide-prone areas, or culturally valuable sites are good candidates for protection.

Natural hazard areas, particularly floodplains, are often controlled through state and federal regulations, and while these sensitive lands may be limited in their development potential they can provide valuable contributions to local ecology. Protecting floodplains is flood insurance. Keeping development out of floodplains helps to prevent flooding disasters and provides areas for storage of floodwaters. These are also important areas for recharging ground water and are valuable areas for habitat or public uses such as parks (FEMA, 1996). Floodplains are a danger for human occupation, yet when protected, add to the size and habitat value of riparian corridors. The six hundred foot wide greenway corridor across the floodplain of the Bear Branch of Panther Creek at the Woodlands, Texas, (pictured above) is a major contributor of flood protection to this community. At the same time, this greenway provides valuable wildlife habitat (Spirn, 1984; Smith and Hellmund, 1993).

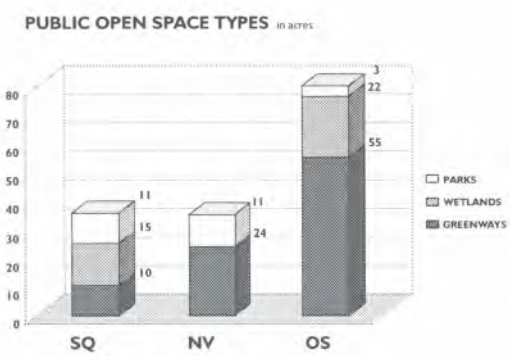
A survey of Realtors conducted by the Bank America Mortgage Company suggested that homes near to parks and natural areas had a 20% higher value (American Forests/National Association of Homebuilders, 1995). Likewise, lots with trees sold for 20 - 30°/a more than similar lots without trees. Mature trees saved during development added more to home value than post construction landscaping (McMahan, 1996).

STATUS QUO

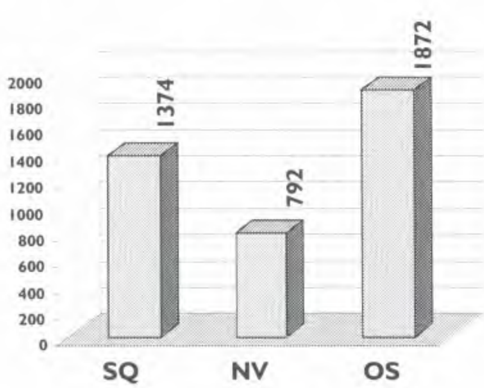
NEIGHBORHOOD VILLAGE

OPEN SPACE

PARKS AND OPEN SPACE



Public Open Space in Public Ownership



Area of open space per dwelling in square feet

COMPARING THREE NEIGHBORHOOD PLANS

On all three West Corvallis plans, all parks, wetlands and greenways that were protected from development were assumed to be in public ownership. The Status Quo and Neighborhood Village alternative were about equal with a total of 36 acres and 35 acres respectively in these land uses. The Open Space alternative had more than double this amount with 80 acres in parks, wetlands and greenways. The Neighborhood Village plan had no protected wetlands in the study area.

On the Status Quo alternative, along Oak Creek, the only perennial stream on the site, a 65 foot per side buffer was protected in accordance with 1996 city codes. On the Neighborhood Village alternative a wider green way was protected, ranging from 50 to 300 feet per side. On the Open Space alternative, the entire floodplain and all adjacent wetland and riparian vegetation was added to the buffer. It ranged from 200 to 350 feet wide per side.

NOTES

The Woodlands, Texas

guideline

1.1 SET ASIDE WETLANDS, STREAMS, FLOODPLAINS, AND NATURAL HAZARD AREAS

Environmental assets, including streams and associated riparian zones, wetlands, forests, and other unique habitat areas, which are crucial to the ecological health of an area, should be preserved and protected. Natural hazard areas, such as floodplains , earthquake fault lines, and landslide-prone areas are a hazard if developed. These also should be protected from development. "Buffering" such resources involves extending zones of protection beyond the resource itself and limiting the allowable human uses. Buffering is an efficient and effective means of preservation and protection.

Bridging a wetland adjacent to a commercial district in Bellevue, Washington

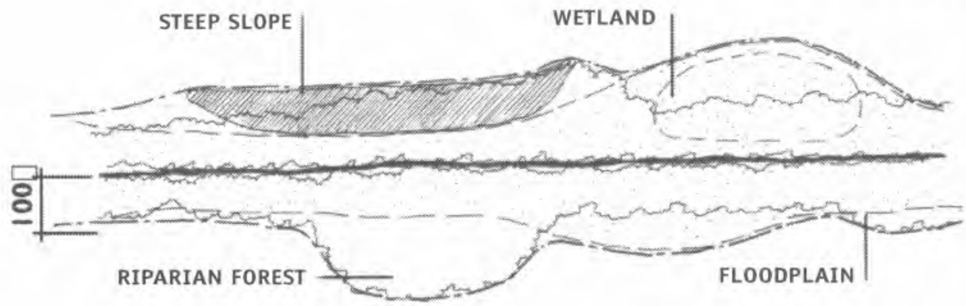
Unless protected, natural resource areas such as riparian corridors, forested areas, and wetlands are consumed or fragmented by new roads, houses, and commercial uses, leaving them unable to perform many of the ecological processes vital to the health and functioning of urban ecosystems. Natural hazard areas should not be developed to protect life and property. Local governments must take the lead in locating and mapping these sites and in developing laws and incentives that enforce or encourage protection of environmental assets and natural hazards.

IDENTIFY AND PROTECT NATURAL RESOURCES AND NATURAL HAZARDS

• Governments should inventory and map natural resources and hazard areas. Continuous stream corridors, undisturbed floodplains, wetlands, and forested areas are among the most important natural resources of a city. Knowledge is essential to protection. While the private sector may be expected to conduct site specific surveys, larger scale indicator information should be available through government. Throughout the planning and development process, local jurisdictions, developers, designers, planners, and contractors should clearly map all natural resources, delineated. wetlands, and their associated buffered areas and set aside these resources.

• Prohibit development on natural hazard areas such as flash flood zones, landslide areas, known earthquake zones, and high fire hazard areas. Governments must also map such sites, then protect public and private safety and property by prohibiting development of these hazard areas. Such sites provide natural resource and open space values, and may be appropriate for uses such as parklands, forest preserves, or conservation zones on private lands.

• Allow conservation incentives such as "Transfer of Development Rights" so that developers can increase density on one part of their land in exchange for increased open space on another (Arendt, 1994; CWP, 1998). This allows developers to leave natural resource and hazard areas in open space so the community won't have to incur the possible associated risks of development.



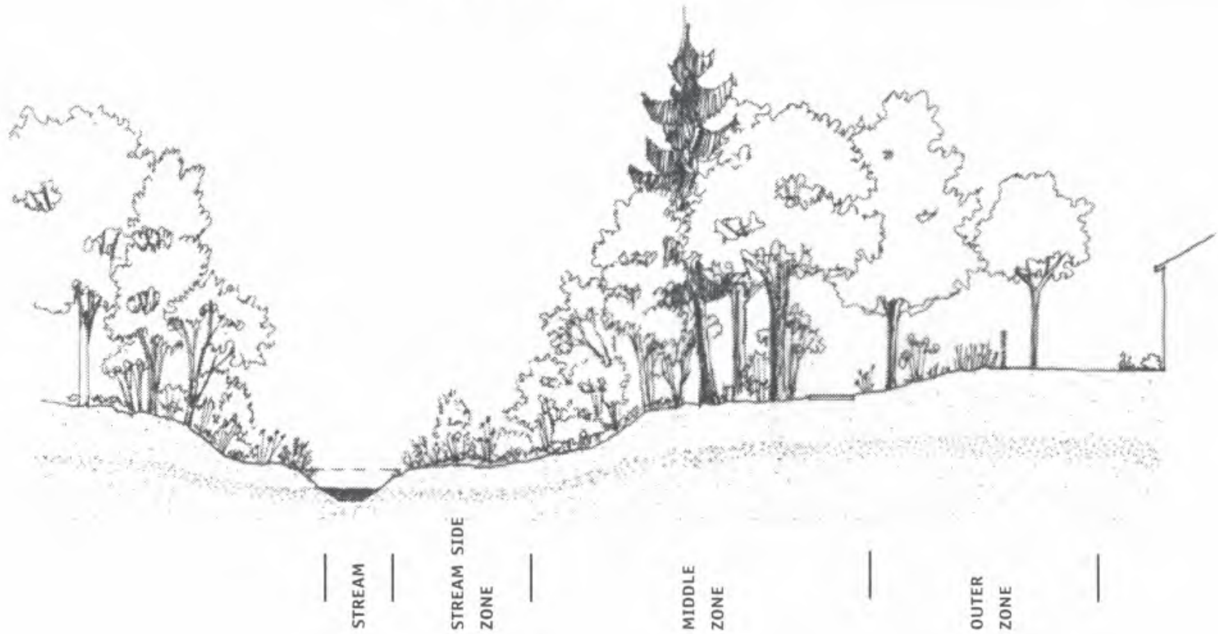
• Assure that somebody will responsibly manage protected lands for their intended purposes. Communities and landowners can employ a range of legal strategies for ownership and management of protected resources. Examples include local jurisdiction ownership and management, ownership and management by homeowners or business associations, and ownership by one entity and management by another such as a conservation non-profit.

ADOPT BUFFER PROTECTION STRATEGIES

• Require stream and wetland buffering. Streams, wetlands, and river corridors are especially valuable because they support a diversity of habitats including aquatic, riparian, and upland communities in a relatively small area (Smith and Hellmund, 1993). These linear corridors can connect dispersed natural areas. Many "conservation" incentives exist to encourage increases in open space and conservation of natural resources (CWP, 1998). Examples of such programs include: buffer averaging (illustraited above), reductions in stormwater fees in exchange for protection, property tax credits for conservation, and density transfers to more developable lands.

• Initiate education and incentive programs geared to landowners to best preserve, restore, and manage these resources. Buffer agreements between property owners and city government should be established to ensure that the property owner fully understands how to provide long-term maintenance of the buffer. In developed and developing areas, natural open spaces require ongoing management and maintenance. A uniform set of policies and management strategies governed by the city, a non-profit group, or a similar supervising body with an understanding of natural resource management should guide and enforce the care and planning of natural areas.

• Provide public education. One of the best ways to prevent damage to natural areas is through public education. Signage and brochures should be provided along buffered areas to allow the public to understand and value the benefits of natural resource protection.



ALLOWABLE USES IN PROTECTION ZONES

Streamside zone: extends from top of bank, at least 25 feet back. This area should be dense native riparian vegetation. Allowable uses would be a bark footpath located near the outer extremity. It may occasionally dip closer to the stream on rock outcroppings or clearings. Above-grade outlook decks may be allowed.

Middle zone: Extends from the edge of the streamside zone to the outer extremity of the floodplain. It should be 50 to 100 feet wide and should include adjacent areas of steep slopes, riparian vegetation, floodplains, and wetlands. Vegetation should be primarily native forest plants. Allowable uses include multi-use trails or bicycle paths and stormwater BMPs.

Outer zone: is the buffer's buffer. This area provides a transition from the native landscape of the buffer to the cultural landscape of the city. It should be approximately 25 feet wide. This area should be primarily undeveloped and it may include turf or trees, shrubs and flowers. Private yards, parks and school grounds are ideal uses.
Source: CWP 1995.

PLAN TRAILS TO PROTECT BUFFER ZONES

- Trails should be installed at the outer edge of the middle zone of a stream buffer (see above), or at the outer edge of a wetland buffer. Particularly when buffers abut development, carefully located trails help to direct human activity to an appropriate location. This helps to prevent negative human impacts on the buffer ecosystem. These trails can also serve as an indicator of the edge between the natural and more cultivated landscapes.

ESTABLISH MINIMUM STANDARDS FOR BUFFERING

- Riparian buffers are typically measured from the centerline of small streams or from the top of bank on higher order streams and on rivers. Buffer dimensions refer to one side only. Buffer averaging (see illustration above) refers to a technique for delineating buffers such that the buffer may be narrow at some points, such as adjacent to existing structures, as long as the average buffer width meets minimum criteria (CWP, 1995). To be effective wildlife corridors, riparian buffers must be 150 to 300 feet wide per side. Delineation should be a site-specific activity. To target specific species for protection, in-depth analyses should be conducted by qualified specialists. Wetland buffers should be at least 100 feet from the edge of the delineated wetland (CWP, 1995).

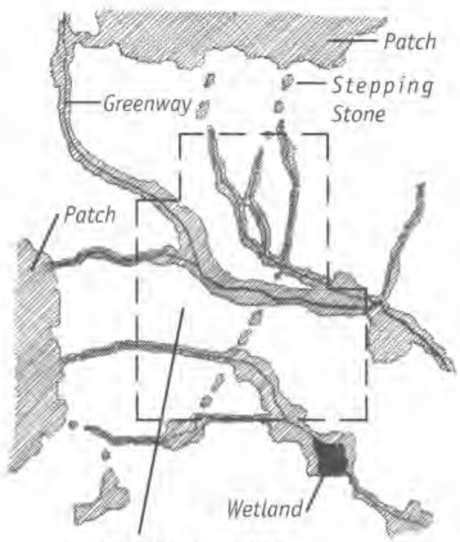
- Local governments should establish minimum standards for buffer delineation and protection. A minimum base riparian buffer should include streamside, middle, and outer zone setbacks within which permitted uses might vary. Current research recommends that riparian buffers should vary in width to include important related resources such as all 100 year floodplains, the riparian forest, any adjacent or upland wetlands, and adjacent steep slopes (CWP, 1995; and Smith and Hellmund, 1993).

Lake Hills Greebelt Park, Bellevue, Washington

guideline

1.2 PLAN GREEN INFRASTRUCTURE

Green urban infrastructure is the preserved ecological structure within an urban area. It is an interconnected system of parks, greenways, trails, surface stormwater conveyances, and natural areas that, together, can provide the fundamental ecological structure within which urbanization may occur. With long-range vision, communities can establish a green urban infrastructure that serves multiple purposes and allows critical natural process and disturbance to continue without damage to life and property. Additionally, such networks serve human purposes such as stormwater cleansing, recreation, and bicycle and pedestrian circulation.



Greenway corridors and "stepping stones" of natural vegetation connect large habitat "patches" to downstream habitat areas in the West Corvallis study area. Source: diagram derived from Dramstad, Olson, Forman, 1996.

Urbanization largely replaces the natural environment, leaving mere remnants of protected or otherwise undeveloped land. These remnants, if conceived as a whole skeletal structure, provide opportunities to restore a level of ecosystem connectivity and health. Ecologically healthy landscapes are typically an interconnected series of "patches" and "corridors" that together form a "landscape matrix" (Cook, 1991). A landscape matrix is defined as a uniform area in which small differential elements appear. In cities, the matrix is urban development. Within this matrix, patches of natural areas occur (Smith and Hellmund, 1993). If the patches are linked by corridors or greenways, this green infrastructure can function at some level ecologically despite the larger urban matrix.

Concurrently, such a green infrastructure can provide a network of natural areas for urban residents. Understood at the system level, these networks of rivers, streams, wetlands, ridgelines, forests, and parks can together form an interconnected system with frequent easy access and diverse opportunities for recreation, education, and transportation as well as visual amenity.

PLAN A GREEN INFRASTRUCTURE

• Plan for a green space network that protects and connects environmental assets and natural hazards. The springboard for creating an integrated network of greenways should begin with the preservation of natural resource areas. (see Guideline 1.1). Long range visioning is then needed to identify opportunities for making connections.

A complex interconnected network of natural and domesticated green spaces and corridors throughout a city can provide a diversity of habitat, and multiple connections between patches of habitat. Concurrently, such a green infrastructure will provide many people with access to natural areas and potentially a network of trails for recreation and transportation. Connecting large "patch" areas such as wetlands and natural parks should be ridgelines, stream corridors and cross-elevational links (such as utility corridors or parkways) (Thorne in Smith and Hellmund, 1993).

Diagram of the surface stormwater system for the Open Space alternative. The surface drainage system utilized existing streams, swales, road verges, and wetlands to create an interconnected system.

• Schematically plan a surface stormwater system and a parks and open space network that incorporates and connects natural resources. Defining corridors to connect these resource areas completes the green infrastructure system. Certain linear urban elements offer ideal opportunities to establish these connections (Cook, 1991):

- transport and utility corridors
- streams
- linear parks
- stormwater conveyances and storage or filtration facilities

• Lay out new development or redevelopment on lands within this green infrastructure. Connect the cultural landscape of the city with streets and other urban infrastructure that bridge the green infrastructure. A finer scaled network of drainage ways, parks and natural resources within neighborhoods can then connect the home to the regional network.

• Take advantage of conservation easements, overlay zones, and environmentally sensitive land ordinances to protect greenway lands (Cook, 1991). Additionally, look for opportunities for landscape reclamation. Abandoned and derelict lands, utility corridors, abandoned railroads and ditches can be revitalized to provide vital greenbelt corridors that will provide open space while connecting natural resources (Girling, Helphand, 1994).

• Promote both the ecological and the economic benefits of the green infrastructure vision. Once set aside as protected areas (Guideline 1.1) and then connected by a series of multi-purpose greenways or corridors, natural resource areas can eventually lead to a linked system that will favor both ecological and economic values. Studies have demonstrated that property values are higher in close proximity to parks and natural areas (McMahan, 1996). For example, homes situated near greenways in Philadelphia demanded a 33% increase in property values (CWP, 1998).

NOTES

chapter 2

AIR QUALITY

Town Center, Reston, Virginia

guidelines

2.1 PLAN COMPACT, MIXED USE, WELL CONNECTED NEIGHBORHOODS

2.2 PROVIDE AN EFFECTIVE PEDESTRIAN AND BICYCLE NETWORK

BACKGROUND

"Every gallon of gasoline burned sends about 20 pounds carbon dioxide, containing 5 pounds of carbon, into the atmosphere. . . . "It's like tossing a five-pound bag of charcoal briquettes out the window every 20 miles or so."

James Ryan, research director of Northwest Environmental Watch, Seattle, quoted in the Oregonian, Friday, November 28, 1997, p. C4

"Every day, motorists drive more than 2.5 million miles on the streets of Eugene-Springfield [ed. note — population approximately 200,000 in 50 square miles] metropolitan area, sending about 1.8 million pounds of carbon dioxide and 19,000 pounds of other pollutants into the air every day. Expect it to get worse . . ." Register Guard, Wednesday, June 30, 1999, p. 1A"

AIR POLLUTION

Air pollution includes a diverse array of particulates and gases suspended or mixed in the air that we breathe. It comes from many different sources, some natural (pollen, dust, forest fires and volcanic eruptions, for example), some stationary and human-made (factories, power plants, and industrial processes, for example) and some mobile and human-made (cars, trucks, and buses, for example). The U.S. Environmental Protection Agency (EPA) evalutes the quality of our air by monitoring levels of six principal pollutants. These are carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (0_3), particulate matter (PM), and sulfur dioxide (SO_2).

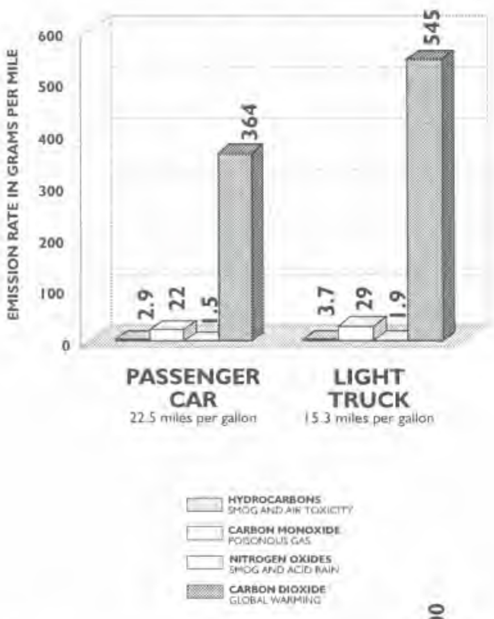
TRAVEL PATTERNS WITHIN AND BETWEEN URBAN AREAS CONTRIBUTE SIGNIFICANTLY TO AIR POLLUTION

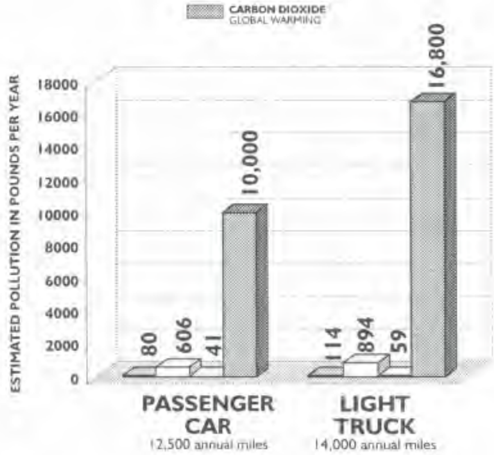
Despite significant and extensive improvements in vehicle technology, automobiles remain a major source of air pollutants and, to a lesser extent, greenhouse gases in metropolitan areas. The rate at which we acquire and use automobiles is growing faster than population. Between 1969 and 1995, while the U.S. population increased 23%, the number of cars and amount we use them increased significantly faster as we went from a society of roughly one car per household to one of roughly two per household. During that same period, the number of cars on the road and the number of vehicle miles traveled a year more than doubled — 143°/0 and 147°/0 respectively (U.S. Department of Transportation, 1995).

In addition to the principal pollutants, automobiles also contribute greenhouse gases — those gases that, when added to the atmosphere, increase its "greenhouse effect" and elevate the temperature of the Earth. Carbon dioxide which accounts for about 85% of the greenhouse gases released in the U.S. is a product of fossil fuel combustion. Automobile exhaust is also a source of nitrogen oxides and volatile organic compounds which contribute to the formation of ground-level ozone or smog, also a greenhouse gas. Transportation contributes just over 30% of U.S. total carbon dioxide emissions and two-thirds of those emissions are produced by automobiles (U.S. Environmental Protection Agency, 1995).

Further Reading

1000 Friends of Oregon, *Making the Connections.*
1000 Friends of Oregon, *The Pedestrian Environment.*
Ewing, Reid, *Transportation and Land Use Innovations.*
JHK & Associates, *Accessiblity Measures and Transportation Impact Factor Study.*
U.S. Department of Transportation, *Nationwide Personal Transportation Survey.*





Annual Emissions and Fuel Consumption for an "Average" Passenger Car and Light Truck

"Average" refers to standard EPA emission models which assume a properly maintained car or light truck (pickup, van, minivan or sport utility vehicle) on the road in 1997 operating on typical gasoline on a summer day (72 to 96 degrees F). Fuel consumption is based on average fuel economy of 22.5 miles per gallon for passenger cars and 15.3 miles per gallon for light trucks. Individual vehicles may travel more or less miles and emit more or less pollution. (U.S. Environmental Protection Agency, National Vehicle and Fuel Emissions Laboratory, EPA420-F-97-037, 1997)

WHERE AND HOW WE USE VEHICLES INFLUENCES THE TYPE AND AMOUNT OF EMISSIONS

The number of miles we travel, the number of trips we make, the speeds at which we travel, and the patterns by which we drive impacts air quality. Carbon monoxide emissions, for example, are a product of incomplete combustion typically generated by any of a number of fuel rich, congested urban driving situations such as cold starts, travel at low speeds, rapid acceleration, and steep grades and decline as speeds approach 55 mph. Nitrogen oxide emissions, on the other hand, increase with speed (1000 Friends of Oregon, 1997). It may be the number of trips, rather than vehicle miles traveled that will become more important in controlling emissions. EPA researchers, for example, estimate that by 2010 more than half of emissions will be attributable to stops and starts rather than to miles traveled (Kessler and Schroeer, 1993).

WHERE AND HOW WE USE VEHICLES IS INFLUENCED BY HOW WE DESIGN COMMUNITIES AND FIT THEM TO THEIR REGIONAL TRANSPORTATION SYSTEMS

The mix and distribution of land uses, the density of housing, the extent and connectivity of the street network, the accessibility of uses, and the attractiveness of routes to pedestrian, bicycle, and transit modes of travel (and many other planning and design factors) all influence the number and length and types of trips we choose to take by automobile or some other public or non-motorized alternative.

While there has not yet emerged a consensus on specific correlations, numerous studies generally agree that higher densities, appropriate mixes of land uses, well designed circulation networks, and attractive pedestrian and bicycle routes can be associated with less automobile travel and therefore, emissions. Factors of household size, age, employment, income and vehicle ownership rates, and regional transportation context, beyond the reach of planners and designers, are also significant and on these points there is greater ambiguity and less consensus (Crane, 1999; 1000 Friends of Oregon, 1997; and Jack Faucett Associates and Sierra Research, 1998).

Of the studies that argue correlation between urban form or development pattern and travel behavior, however, most suggest that lower density

A new bicycle underpass at a freeway on-ramp in Eugene, Oregon. Attractive, safe bicycle routes play a part in encouraging greater bicycle ridership.

community development patterns that segregate residential, shopping and employment centers, or do not provide pleasant pedestrian and bicycle routes, tend to encourage longer and more frequent automobile trips. Some argue that land use mix and density are the most significant factors. Communities that are more dense, tend to produce fewer VMT per capita. Holtzclaw, in particular, provides an example that one mile of transit travel in a dense urban area replaces four to eight miles of automobile travel in lower density suburbs for a similar set of activities (Harvey, 1990, and Holtzclaw, 1990). Others have argued that in addition to density, land use patterns that integrate commercial, employment, and housing, develop transportation networks with direct and accessible transit, sidewalks, and -bicycle routes, and cultivate urban design features such as shade trees and a quality pedestrian environment can influence mode choice for work and shopping trips (1000 Friends of Oregon, 1993, and 1997).

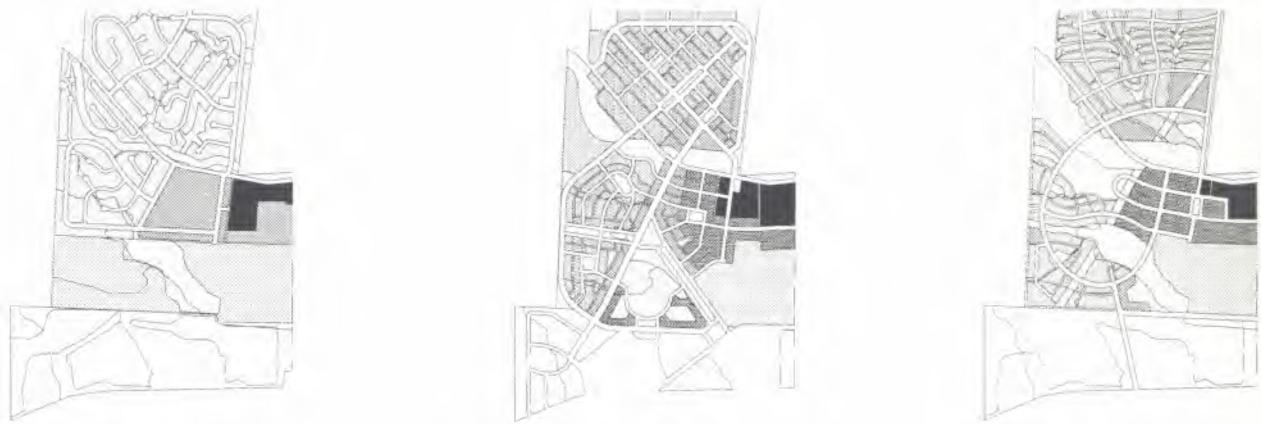
HOW WE PLAN AND DESIGN NEIGHBORHOODS CAN BE A PART OF THE SOLUTION

Development patterns that reduce vehicle use also reduce vehicle miles traveled, vehicle starts, and congestion and may encourage alternative modes of travel. All of these factors reduce the sources of pollution. "[I]ncreased usage of bicycle and walking modes ... replace[s] a motorized person trip with a non-motorized person trip. From the standpoint of traffic congestion and highway capacity, higher rates of bicycle and pedestrian usage should reduce vehicle trip demand and traffic congestion ... From the standpoint of air quality_ because the trips are relatively short, the primary benefit is in the elimination of vehicle trips ("cold start" emissions) over VMT" (U.S. Department of Transportation, 1993, p. 4-2).

This suggests that we should plan communities to meet the demand for daily shopping, recreation, and school trips within the community, preferably in close proximity and with easy access to sufficient numbers of households to support commerce. More compact, more finely grained mixed uses, and more finely meshed street networks that keep trips reasonably direct reduce VMT, travel times, and intersection delay (see list in Ewing, 1997, p. 90). The research establishing how far one is willing to walk or cycle does not make a precise recommendation. One study by Goldsmith of Ontario commuters found an average of 20 minutes or 1.25 miles. Another study by Robinson found that 80% of walking trips were less than 1 mile and 94% were less than 2 miles. The 1990 Nationwide Personal Transportation Survey calculated an average walk for all purposes at 0.7 miles and 0.9 miles for commuting purposes.

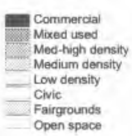
Goldsmith also found that the average bicycle trip is about 2 miles long but that bicycle commute trips may be longer, in the 5 to 6 mile range. The 1990 Nationwide Personal Transportation Survey calculated an average bicycle trip for all purposes at 1.8 miles and 2.1 miles for commuting purposes. Ultimately, tolerable distance is a fundamentally individual variable that depends on physical condition, individual commitment, and site conditions. Some may suggest a willingness to walk further in a survey than they will in practice. Transit studies, for example, routinely find that their customers are generally willing to walk about 1/4 mile to reach a transit stop (U.S. Department of Transportation, 1993).

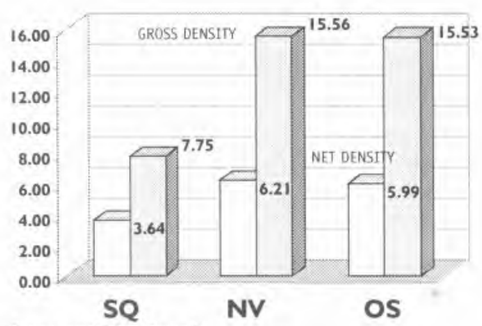
Frank and Pivo found that the relationship of density to non-motorized travel choices was non-linear, with higher densities resulting in relatively higher rates of pedestrians and bicycles (in JHK & Associates, 1996). Planning and design standards are beginning to reflect this linkage. The Institute of Transportation Engineers (ITE, Trip Generation Handbook, 1998), suggests vehicle trip rate reduction factors of 2% to 7% in sufficiently dense, mixed use areas with good pedestrian and bicycle networks, and up to 20% when those areas are also served by transit and light rail.



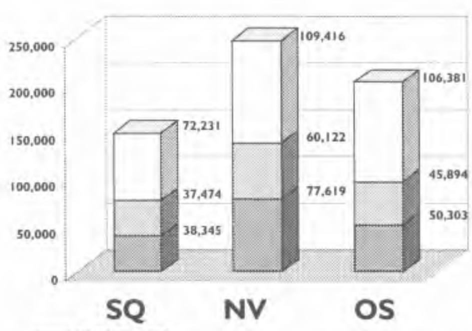
STATUS QUO NEIGHBORHOOD VILLAGE OPEN SPACE

LAND USE





Gross and Net Density



Dedicated pedestrian, bicycle and automobile networks in SQ, NV, and OS

COMPARING THREE NEIGHBORHOOD PLANS

Land Use:

In the West Corvallis comparison, against measures of land use and density, the Status Quo alternative provided about 1100 dwellings at a net density of 7.75 dwellings per acre of housing land and a gross density of about 3.5 dwellings per acre (dua) of site. The Neighborhood Village alternative provided about 1900 dwellings at a net density of 15 dwellings per acre of housing land and a gross density of about 6 dwellings per acre of site. The Open Space alternative also provides about 1900 dwellings at a net density of about 15 dwellings per acre of housing land and the same gross density of about 6 dwellings per acre of site.

All three alternatives accommodated a primary commercial area of about the same size, approximately 10 acres, in about the same location. The Status Quo alternative, however, segregated auto-oriented commercial from residential land uses. Within this pattern, mostly higher density, multi-family (20 net dua) dwellings were located within a 1/4 mile walking distance of the commercial center.

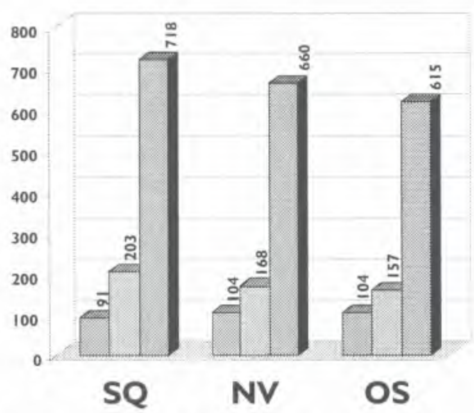
The Neighborhood Village and Open Space alternatives surrounded the commercial center with a more diverse range of higher density housing in a 25 acre (approx.) mixed use area. Within this pattern a range of mid- to higher density dwellings (12 to 20 net dua) and some lower to medium density dwellings (6 to 12 net dua) were located within 1/4 mile walking distance of the mixed use area.

Vehicular Connectivity:

The Status Quo alternative provided the more hierarchical street network that limited opportunities for pass-through traffic on any street below collector designation. It had 38,345 lineal feet of street with 44 intersections and 27 dead ends.

STATUS QUO NEIGHBORHOOD VILLAGE OPEN SPACE

STREET NETWORKS



Average travel time to shopping area (inseconds) by foot, bicycle and automobile.

BY FOOT
BY BICYCLE
BY AUTOMOBILE

At the other extreme, the Neighborhood Village alternative established a more extensive network of fully interconnected streets with at least one full-stop intersection per 350 feet of residential streets. It had 77,619 lineal feet of street with 194 intersections and 3 dead ends.

The Open Space alternative provided a more extensive and interconnected network than Status Quo but Less than Neighborhood Village. It had 50,503 lineal feet of street with 84 intersections and 20 dead ends. All dead ends on the Open Space alternative had pedestrian through-connections so that there were no pedestrian dead-ends.

Pedestrian, Bicycle Connectivity:
In the West Corvallis plan comparisons, the Status Quo alternative provided 5 foot sidewalks along all local, collector and arterial streets. The Neighborhood Village alternative provided 5 foot sidewalks on both sides of all streets and wider sidewalks (10 to 14 feet) on shopping streets. The Open Space alternative provide 5 foot sidewalks on both sides of streets above 50 foot right of way and wider sidewalks (10 to 14 feet) on shopping streets. In all alternatives, dedicated bicycle lanes were provided on collector and arterial streets. The Open Space alternative provided additional pedestrian and bicycle routes along open space corridors.

Based on these network designs, the Status Quo alternative generated the most favorable automobile travel time to the shopping area. However, the Neighborhood Village and Open Space alternatives generated lower average walking and bicycling times for trips to the shopping area — about 16% faster for pedestrians and 29% faster for bicyclists.

NOTES

Lake Oswego, Oregon

guideline

2.1 PLAN COMPACT, MIXED USE, WELL CONNECTED NEIGHBORHOODS

Mixing places of work, shopping, education, and recreation within a compact neighborhood potentially reduces demand for vehicle trips that might otherwise leave the neighborhood or travel farther within it. Bringing those activities that are interdependent closer together, finely mixing those that are mutually supportive where appropriate, and connecting all such activities in ways that attract pedestrian and bicycle travel and reduce the number and length of automobile trips can reduce vehicle-related emissions and improve air quality.

2.1 GUIDELINE

"Every day, motorists drive more than 2.5 million miles on the streets of Eugene-Springfield [ed. note — population approximately 200,000 in 50 square miles] metropolitan area, sending about 1.8 million points of carbon dioxide and 19,000 pounds of other pollutants into the air every day. Expect it to get worse . . ."

Register Guard, Wednesday, June 30, 1999 p. 1A"

Large trees can help to mitigate the air pollution impacts of major thoroughfares. Coburg Road, Eugene, Oregon.

The typical household living in a single family detached house generates about 10 vehicle trips on an average day (ITE handbook) and about 10,000 vehicle miles traveled per capita (U.S. average in 1990) per year (8,175 per capita in Oregon in 1997). Both factors — number of trips and the length of those trips once taken — have economic and environmental impact and, in turn, can be positively or negatively affected by the planning and design choices we make for our communities.

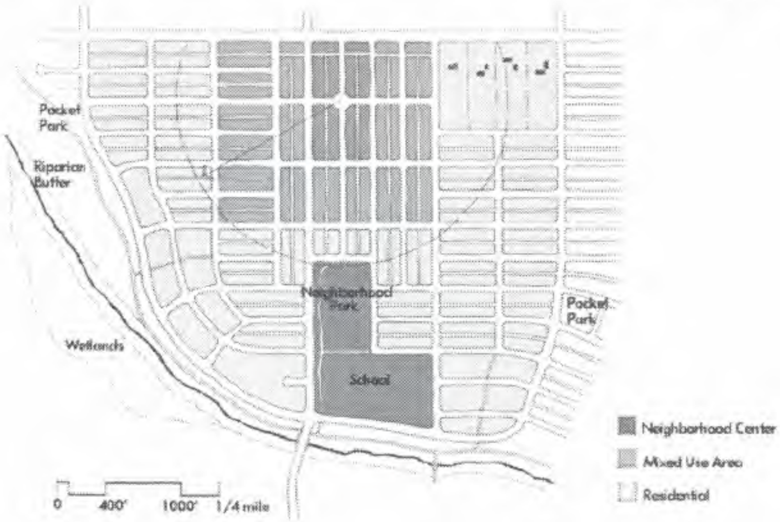
In Rockridge, a community well served by mass transit and featuring walkable neighborhoods with a density of eight units per acre, average vehicle miles traveled annually per household totaled 15,000. By comparison, annual VMT in Danville/San Ramon, a community with more typical sprawl-type development, totaled 30,000 ... At an average cost of 30 cents per mile, the average Rockridge resident spent $4,500 less on transportation than his or her Danville counterpart. This amount translates roughly into $51,500 of mortgage capacity (Calthorpe Associates, TOD Impacts on Travel Behavior, August, 1992).

PLAN COMPACT NEIGHBORHOODS WITH PEDESTRIAN-ORIENTED SERVICE CENTERS

• Establish an appropriately sized commercial and service center in the heart of every neighborhood at or near the intersection of a collector and arterial streets. Gather compatible civic (schools and churches) and recreational uses (parks and squares) nearby. In order for local stores or services to be nearby, however, there must be sufficient potential customers to sustain them economically.

DeChiara and Kopelman (1969) suggest 20 sf/household of retail space for neighborhoods of around 800 families and 18 sf/household for neighborhoods around 1600 families. Lynch (1984) suggests one-half to two-thirds acre (about 20,000 to 30,000 sf) of local neighborhood commercial per 1000 inhabitants.

• Surround the commercial and service center with a flexibly zoned area able to accommodate a fine-grained mix of residential and smaller scale commercial uses (specialty retail, personal services, professional offices,



A neighborhood concept from the West Corvallis North Philomath Plan (City of Corvallis, 1996). This prototype neighborhood plan, the concept behind the Neighborhood Village alternative in this study, proposed an average net density of 9 dwellings per acre with a neighborhood commercial center of 5 to 8 acres. This was surrounded by another 20 to 30 acres of mixed residential/office and higher density residential uses within 1/4 mile of the center. All areas were to be served by a fine-grained street network and connected to natural areas via public open space.

for example). Assure there are frequent and safe pedestrian connections to the commercial area.

Many planning and design professionals, supported by national research, argue that people are more likely to leave their car at home and walk or bicycle to jobs, stores, or services when there is adequate density and mix of services available nearby (JHK & Associates, 1996) and when the routes to them are short, direct, safe, and interesting.

• Allocate a mix of housing types and densities within 1/4 to 1/2 mile of the commercial and service center. To achieve an average net density of about 9 dwellings per acre, mix detached and attached single family and multifamily building types, ranging from about 6 to 20 dwellings per acre of land. Time Saver Housing and Residential Development Standards (1995) propose a minimum of 800 — 1000 households to support neighborhood commercial.

PROVIDE AN ACCESSIBLE AND WELL CONNECTED NETWORK

• Make the street and path networks linking housing to commercial and service centers fine-grained and highly connective. Accessibility refers to the potential to enter and move unimpeded through a network to a destination. Connectivity refers to the potential for choice and flexibility of movement within a network. Greater accessibility can increase the likelihood that potential travelers will have opportunity to use the network. Greater connectivity can reduce traffic volume and congestion and increase choice and variety as travelers choose alternate paths to a common destination. Generally, the greater the number of access points and intersections, the higher the accessibility and connectivity of a network. Lesser accessibility and connectivity directs more vehicles onto fewer streets, increasing traffic volume and congestion which in turn can create a hostile environment (of speed, noise, poor air quality, and few crossing opportunities) for pedestrians and bicyclists.

NOTES

Cal Young Road, Eugene, Oregon

guideline

2.2 PROVIDE AN EFFECTIVE PEDESTRIAN AND BICYCLE NETWORK

- Compact, mixed use neighborhoods can only be effective at encouraging pedestrian and bicycle transportation if they are partnered with fine-grained networks of pleasant pedestrian and bicycle routes — as good or better than those available to automobiles. Frequent, attractive pedestrian and bicycle routes increase the likelihood that one might elect walking or bicycling over driving.

*Factors that **ENCOURAGE** walking*
- *Mixed land uses*
- *Dense land uses*
- *Direct routes*
- *Adequate sidewalks*
- *Adequate crossing points and crosswalks*
- *Slower traffic speeds*
- *Lower traffic volumes*

*Factors that **DISCOURAGE** walking*
- *Complex environments*
- *Fewer streets – larger blocks*
- *Small and fragmented sidewalk systems*
- *Indirect routes*
- *Abundant area devoted to surface parking lots*
- *Poor connectivity*

After Hess, Paul M., Evaluating Pedestrian Environments: Proposals for Urban Form Measures of Network Connectivity with Case Studies of Wallingford in Seattle and Crossroads in Bellevue, Washington, Masters Project, University of Washington, Department of Urban Planning, 1994

Cultivating potential for bicycle and pedestrian travel starts with recognizing the travel situations for which they are most popular. Generally speaking, the most frequent choice of walking or cycling is for social or recreational purposes, and fewer people will choose bicycling over walking. Second most frequent is shopping and personal business purposes. Commuting to and from work is a distant third. In Europe, however, and some older American cities where development patterns are more concentrated and facilities for walking and bicycling are well-integrated, these non-motorized modes are dominant for all trip purposes (U.S. Department of Transportation, 1993).

DECREASE WALKING AND BICYCLING DISTANCES

• Locate the most frequent neighborhood destinations within 1/4 mile of each other and most dwellings. Simple logic suggests that, because of the limitations in the speed at which one can walk (2 to 3 mph for walking and 10 to 12 mph for bicycling) distance establishes an envelope within which trips are likely to be made on foot or by bicycle. Research confirms that distance is the foremost physical variable affecting pedestrian behavior (Handy, 1996 and U.S. Department of Transportation, 1993).

Assuming that 5 to 10 minutes represents a conservative assumption of acceptable travel time for most, pedestrians would be able to travel approximately 1/4 to 1/2 mile and cyclists approximately 1 to 2 miles.

PEDESTRIAN AND BICYCLE NETWORKS SHOULD BE FREQUENT, CONVENIENT, AND SAFE

• Create routes to frequent neighborhood destinations so that travel by bicycle or foot is at least as direct, safe and flexible as the routes available to automobiles. Provide sidewalks on both sides of primary, and at least one side of secondary access routes.

After distance, the next indicator of pedestrian and bicycle infrastructure is the presence (or absence) of a continuous, well-connected, safe, and physically accessible (in terms of topography and surface, for example) network of sidewalks and bicycle paths (1000 Friends, Pedestrian Environment, p. 12). "Places where bicycles tend to be a serious mode of travel

A separated bike path through a residential area, Diemen, The Netherlands

"Skilled bicyclists prefer to travel on the street system along with automobiles. To accommodate them, striped bike lanes or extra wide curb lines are warranted on arterials and collectors. There is some debate about which of the two . . . is safer for bicyclists. In terms of user acceptance (as opposed to safety), the bike lane seems to have an edge." (Reid Ewing, Best Development Practices)

tend to have miles of bike lanes and bike paths, and/or low-volume side streets paralleling arterials. Nearly all examples of mass bicycle commuting to school occur where access is possible by separate bike lanes or bike paths or by low volume residental streets." (Reid Ewing in Best Development Practices, Planners Press, APA Chicago, 1996, p. 78).

- Design street networks with shorter blocks (less than 6 potential crossing points per mile) or provide supplementary pedestrian and bicycle routes where the blocks are longer.

- Keep traffic speeds low — under 25 mph — on streets with shared pedestrian and bicycle routes. Keep traffic volumes low — less than 10,000 ADT — on streets with shared pedestrian and bicycle routes.

For streets and paths, attractiveness may be the perceived safety and interest of the experience. When pedestrians and motorists share the right-of-way, for example, pedestrians benefit from narrow streets and physical buffers between the street and the sidewalk. Streets that are narrow with traffic speeds under 25 mph can create a sense of "friction" that slows motorists and potentially increases their attention to, and anticipation of, activities (a pedestrian attempting to cross or a child chasing a ball) that might impinge on the travel lane at short notice.

PEDESTRIAN ROUTES SHOULD BE COMFORTABLE AND ATTRACTIVE

After proximity and accessibility, design of the environment for pedestrians and for bicyclists matters as well. Perceived character and quality of the environment, for example, also affects decisions to walk or cycle. In general, if proximity and accessibility factors are deemed equal, an active mix of pedestrian-scaled, complementary uses, and activities encourages more pedestrians and bicyclists than less active, less diverse, automobile-scaled uses and activities.

- Create lot sizes and exposures (to traffic and customers) that will attract a complementary mix of store types and sizes to generate activities throughout the day and evening. Locate parking in structures or off-street pocket-sized lots.

"Children and casual adult cyclists outnumber skilled adult cyclists by more than 20 to 1. The less skilled majority must be separated from high-speed, high-volume traffic or they will not ride" (Reid Ewing, Best Development Practices).

• Create opportunities for interest points — uses likely to orient courtyards, sitting or dining areas, attractive storefronts, for example — immediately adjacent to primary pedestrian and bicycle routes.

• Plant trees between the sidewalk and the street. Street trees provide a sense of separation between traffic and the pedestrian area. Trees also help to create a separate, human-scaled space along the sidewalk. Sidewalks that are set back from streets and separated from traffic by a treed planting strip and/or parking lane also contribute to a pedestrian's sense of safety and "insulation" from vehicle traffic.

Attractiveness variables shift with different uses and activities. For commercial areas, attractiveness may be a measure of building or parking lot scale and orientation and the desirability, number, and mix of stores. For schools and community centers, attractiveness may be more a function of the desirability of the services and amenities available (JHK & Associates, 1996).

• Layout pedestrian networks to keep most grades below two percent and few greater than 5%. 2% to 5% gradients are comfortable for walking, bicycling, and wheelchair-bound people. Gradients in excess of 5% become very difficult or impossible to navigate for people in wheelchairs and for less able-bodied people.

chapter 3

URBAN FOREST


View to downtown Bellevue, Washington

guidelines

3.1 CONSERVE EXISTING TREES AND FORESTS

3.2 CREATE TREE PLANTING OPPORTUNITIES

"Trees and forests have become more than just an overlooked and under appreciated community resource - they are a resource at risk, and one whose loss is increasingly costly to communities and the environment."

(American Forests, 1999)

A mature Big Leaf maple was preserved during the construction of this new Nike store in Eugene, Oregon.

Urbanized areas represent environmentally detrimental human activities, particularly the burning of fossil fuels to support and maintain contemporary lifestyles. As such, urbanized areas contribute significantly to the production of greenhouse gases and global warming (see Chapter 2). Global mean surface temperatures have increased .6 to 1.2°F over the past century and the rate of this change is increasing. Worldwide, the warmest ten years this century occurred during the past fifteen years and over the next century the average global surface temperature is expected to rise by 1.6 to 6.3°F (www.epa.gov/global warming, 03/2000).

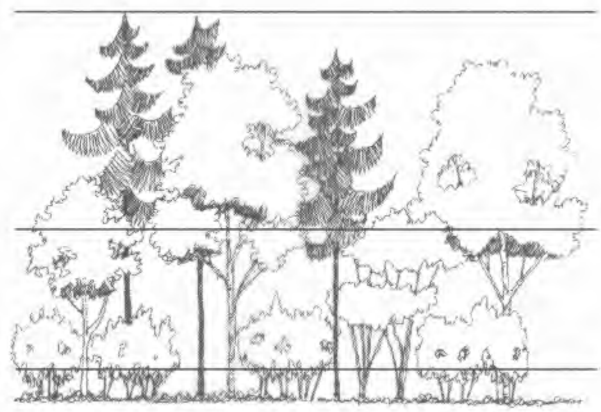
One of the most profound and encompassing impacts of urbanization is the "urban heat island" effect. In cities, where trees and other vegetation have been replaced by buildings and pavement, solar radiation is readily absorbed and stored. Building and pavement surfaces absorb and hold heat throughout the day. As cool evening air comes in over the city, the warm air is trapped, and air pollutants generated by cars and other city processes are also trapped and settle, causing temperatures to increase by as much as 3 - 10 degrees (Hough; 1995, Moll, 1989). In warm weather this in turn will increase the use of fossil fuels burned to cool buildings and vehicles.

Where cities have developed in a forested or partially forested landscape, urban development typically results in tree loss. Because of the role trees play in mitigation, this exacerbates air and water pollution. A study of the Puget Sound regional ecosystem, a once forested region, concluded that if tree canopy lost since 1973 were replaced, the region would have saved $95 million in air pollution services and $2.4 billion in stormwater containment services during that 25 year period (American Forests, 1999).

In many cities tree loss impacts water quality and contributes to flooding problems. Trees and other woody vegetation help to dissipate the impacts of rainfall when their leaves trap and hold water droplets. As forested areas are cleared to make way for buildings and roads, the dissipation and storage capacity of leaves is lost and runoff volumes, erosion, and water pollution increases. Higher volumes of rainfall at greater velocities run across urban surfaces, and soils, sediments, and contaminants from ve-

Further Reading

American Forests, National Association of Home Builders, *Building Greener Neighborhoods*
Environmental Protection Agency, *Cooling Our Communities: A Guidebook on Tree Planting and Light Colored Surfacing*
Moll, Gary and Sara Ebenrick, eds., *Shading Our Cities*
Grey, Gene W. and Frederick J. Deneke, *Urban Forestry*
McPherson, Gregory E., *Net Benefits of Healthy and Productive Urban Forests* Environmental Services,
City of Portland, Stormwater Management Manual



Temperature decreases while humidity increases as one moves downward through a forest canopy. Source: Grey, Urban Forestry, 1996.

hides, industry and even landscaped areas are carried into nearby streams and rivers.

THE URBAN FOREST MITIGATES HEAT ISLAND EFFECTS AND URBAN POLLUTION

The "urban forest" encompasses all of the trees and related woody vegetation within or directly associated with urban areas (TreePeople, 1990; Grey, 1992). Urban forests are typically composed of native forest patches dispersed within a more extensive area of cultured or non-native trees and shrubs.

The process of photosynthesis enables trees, through their leaves and needles, to filter and sequester carbon and polluting gases as well as filter significant amounts of particulates from the air. Some research estimates that a street lined with healthy trees can reduce airborne dust particles by as much as 7,000 particles per liter of air (Bernatsky in EPA Cooling Our Communities). The sun shading, wind shading, and evapo-transpiration properties of trees in urban areas can also reduce the heating and cooling load on buildings. This effect can save about 88 pounds of carbon per year attributable to electricity generation while sequestering another 9 to 18 pounds per year of carbon produced by other sources. Nitrogen oxides can also be taken up and neutralized by foliage.

Trees retain carbon dioxide and control ozone. Trees and other vegetation absorb carbon dioxide in photosynthesis and release oxygen. As a part of this process, trees store or "sequester" carbon, effectively taking it out of circulation, during their life-span. The larger the tree, the more carbon it can store. An average acre of fully stocked forest will remove about 3.6 tons of CO_2 per year (American Forests). The large, mature tree canopy in older areas of Sacramento store 2,343 kilograms of carbon per tree (approximately 1 ton per acre) whereas smaller trees in the suburban areas store only 27°/s of that per tree (McPherson, 1998).

Heavy planting around the perimeter of this parking lot helps to mitigate the impacts of the large paved surface. Eugene, Oregon.

Trees moderate the urban heat island by shading, or blocking, the sun's radiation. Heavy canopy trees can block up to 95% of incoming radiation. Shading buildings helps to reduce the need for summer cooling, while shading outdoor areas helps to keep air temperatures lower in urban areas. Three well-placed shade trees around a house can cut air conditioning energy needs by 10 °/0 to 50% (Environmental Protection Agency, 1992). Conversely, well-placed trees can also reduce wind speeds and thus heating needs in cold climates (EPA 1992).

Evapotranspiration, or the process by which plants release water vapor, utilizes heat energy, increases humidity, and results in a net heat loss throughout the day (Spirn, 1984). This process consumes solar energy that might otherwise go to heating the air. A single tree can transpire up to 100 gallons of water a day during the growing season. This has the same effect as running five average air conditioners for 20 hours (EPA, 1992).

THE URBAN FOREST MITIGATES STORMWATER RUNOFF AND WATER POLLUTION

Trees detain stormwater runoff, encourage infiltration, and filter and dissipate rainfall. Tree canopies intercept rainfall, allowing some to re-evaporate while drip is absorbed into the root system. The higher the percentage of forest, trees and other permeable surfaces, the less runoff reaches piped drainage systems or streams, mitigating the high peaks, erosion, and flooding associated with urban areas. Thus treed areas act like detention facilities, slowing the rate at which urban runoff enters streams. In Sacramento, California, a mature, mixed forest canopy intercepted 36°/0 of summer rainfall at the canopy level. (Drip releases some of that rainfall, thus the net interception is less at the ground level.) Winter interception was far lower in Sacramento due to the Large percentage of deciduous trees in the urban forest (Xiao et al, 1998).

Tree root systems act as sediment filters to trap pollutants from stormwater. Their deep root systems also uptake tremendous amounts of water, and their leaves filter out air particulates. They stabilize slopes and soils and aid in the prevention of construction- and storm-related erosion. In the Gunpowder Falls Basin in the Chesapeake Bay area, forested areas released

Trees are very valuable in the urban environment for mitigating air pollution, and reducing and slowing urban stormwater runoff. American Forests recommends that each U.S. city set a goal of 40% tree canopy cover to help mitigate the deleterious environmental impacts of urbanization.

50 tons of sediment per square mile per year to the local waters, whereas (sub)urban areas contributed 50 - 100 tons, and land stripped for construction released 25,000 - 50,000 tons of sediment, 500 to 1000 times as much as the forest (Moll, 1989).

THE URBAN FOREST IS A COST EFFECTIVE MEANS OF MITIGATING URBAN POLLUTION

Larger, long-lived trees minimize maintenance costs while maximizing environmental mitigation benefits. The "work" trees do to mitigate air and water pollution and runoff volumes is directly related to total leaf surface area, thus larger, denser trees provide more of these benefits.

Recent studies show that when costs of planting, watering, and maintaining trees are considered, tree planting is a more cost-effective energy and carbon dioxide conservation strategy than many other fuel-saving measures (Dwyer et al, 1992). American Forests' recent analyses of the Puget Sound area around Seattle, Washington, and Metropolitan Atlanta, Georgia, have predicted significant potential savings to these cities through re-forestation (American Forests, 1999). While it is generally understood that urban forests are integral to the environmental health of the city, many cities are not making it a priority to maintain this valuable resource. A 1992 survey of urban forestry in California revealed that the average percentage of city operating budgets for tree programs has dropped to less than 1%, an 18% decline over a four year period from 1988 - 1992 (McPherson, 1995).

THE URBAN FOREST PROVIDES WILDLIFE HABITAT

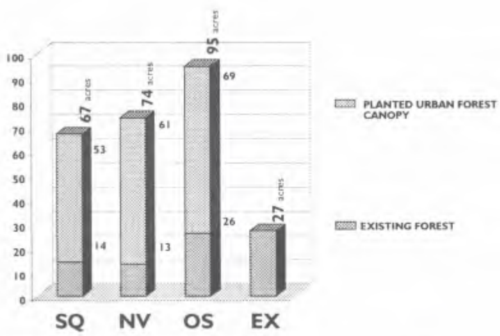
The urban forest is in many cities the last refuge for urban wildlife. Trees provide habitat for urban wildlife, including insects, birds, and small mammals. They supply food and safe havens for these creatures, and are critical nesting sites. Additionally, a continuous canopy of trees can provide air-borne travel corridors for some creatures, keeping them out of harm's way.

BACKGROUND

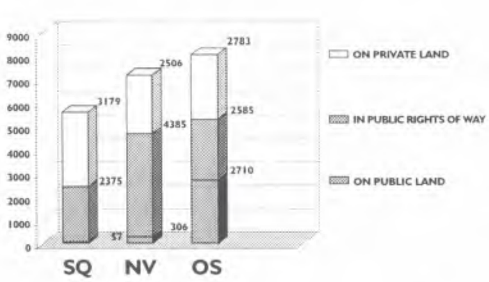
STATUS QUO NEIGHBORHOOD VILLAGE OPEN SPACE

Trees Existing Forest Parks and Open Space

URBAN FOREST



Urban forest canopy in acres

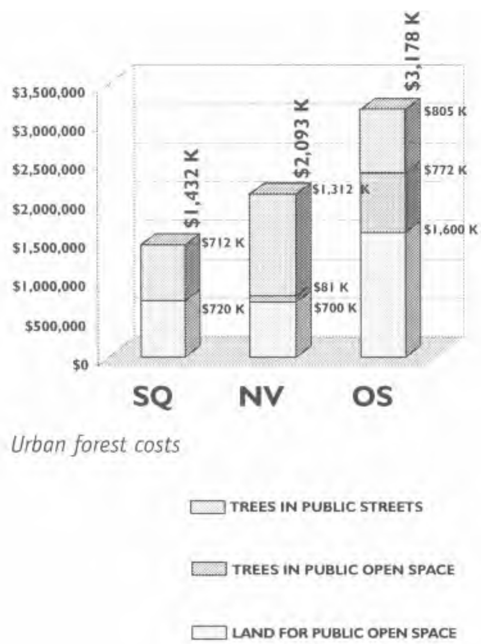


Trees planted on private land, public rights of way, and public land

COMPARING THREE NEIGHBORHOOD PLANS

In the west Corvallis comparison, street trees were assumed to be planted along all streets with at least a fifty foot right-of-way. On the Status Quo alternative, trees were spaced at the 1999 City of Corvallis standard, fifty feet on center. On the Neighborhood Village and Open Space alternatives, trees were assumed to be spaced at thirty feet on center. Applying case studies of existing parks and greenways from nearby areas, tree planting was also accounted for within public parks and greenways on all three plans. Similarly, trees planted on private lands, such as housing and commercial areas, were based on case studies that were applied to the plans (see Methodology in the Introduction).

With less street length overall for tree planting, the Status Quo plan had the least street trees at 2,432 trees, although this was compensated somewhat by more land for private tree planting (3,179 trees). The Neighborhood Village plan had the most street length and thus the most space for street trees (4,691 trees), although it was lower in the number of estimated private trees (2,506 trees). The Open Space plan had "street" trees along streets as well as public drainage corridors for a total of 5,295 planted trees in public areas and 2,783 trees planted in private areas. When the total number of planted trees was added to preserved existing trees, the Status Quo plan had 53% tree canopy overall, the Neighborhood Village plan had 61% tree canopy overall, and the Open Space plan had the highest percent of tree cover at 69°/0.



Urban forest costs

In the three plans compared, different amounts of the existing forest were preserved due to significantly different amounts of preserved green space. The Status Quo and Neighborhood Village plans conserved about half the forest on the existing site (14 and 27 acres), the Open Space plan conserved all but one acre of the existing forest. Combined with other best management practices, existing and planted trees on the Open Space plan helped to drastically reduce the increases in stormwater flow rates caused by urbanization (see Chapter 4).

	Existing site	Status Quo	Neighborhood Village	Open Space
PERCENT CHANGE IN EXISTING FOREST COVER				
Area (acres)	26.87	13.94	12.97	25.75
% change		-48%	-52%	-4%
ESTIMATED NEW TREE CANOPY PLANTED ON PUBLIC LAND				
Canopy area (acres)		22.92	39.46	68.96
Number of trees		2432	4691	5295
ESTIMATED NEW TREE CANOPY PLANTED ON PRIVATE LAND				
Canopy area (acres)		29.96	21.08	23.76
Number of trees		3179	2506	2783
ESTIMATED TOTAL NEW TREE CANOPY PLANTED				
Canopy area (acres)		52.88	60.54	68.96
Number of trees		5611	7197	8078
TOTAL URBAN FOREST				
Canopy area (acres)	26.87	66.82	73.51	94.71
% of site area	8.60%	21%	24%	30%
% change		149%	174%	252%

NOTES

The Woodlands, Texas

guideline

3.1 CONSERVE EXISTING TREES AND FORESTS

One of the best ways to increase and enhance the urban forest is to conserve existing forests. Existing mature trees provides an array of benefits that take decades to replace once they are lost. Natural resources such as forested areas or even small groves of trees should be viewed as an asset for developed and developing areas. The integration of trees and buildings creates a setting that is beautiful, livable, and offers water and air quality benefits.

A forested ridgeline preserved as parkland in Bellevue, Washington

As urbanization sprawls across America, forests are receding. In the Baltimore-Washington area natural and heavy urban forest cover has declined by 32% since 1973. In the urban growth area around Seattle the decline was over 37%, a loss of 600,000 forested acres (American Forests, 1999). This heavy tree loss has resulted in problems with flooding, erosion, and pollution and loss of native forests spells habitat destruction as well. It takes decades to replace these lost trees, if they can be replaced at all. A thirty year old tree lost to urbanization will likely be replaced by a three year old tree that does not have the capacity to intercept air pollutants and stormwater, and due to harsh conditions, may live only ten years (Spirn, 1984).

The construction process itself often results in extensive tree loss. Some contemporary development practices treat forest resources as an inconvenience to be removed rather than a long-term benefit. Without incentives to protect trees and forest, developers often clear soils of most existing vegetation before starting construction. Even when efforts are made to save some vegetation from the site clearing process, specimen trees and forest clumps are often lost. Earthmoving often causes the destruction of tree roots and ultimately the loss of trees. Eighty-five percent of tree roots are concentrated in the top 18" of soil therefore even minimal soil compaction can have a significant effect on trees (American Forests, 1999).

PROTECT REMNANT FOREST PATCHES AND FOREST CANOPY

• For all urban development and redevelopment, employ a natural resource expert to create a landscape preservation plan. In previously forested areas, place limits on the percentage of canopy cover that may be removed for development. Where only small patches of forest remain, lay out new development or redevelopment to protect entire forest patches. Protecting contiguous areas of forest is far better than protecting individual trees because trees that grew up in forest conditions are likely to have interlocking root systems, and they may blow down if left standing alone. Protecting forest patches also maintains associated plants, soil, fauna, and invertebrates and thereby contributes to ecosystem health.

Rather than facing the street, these homes in Northwest Landing, Dupont, Washington, face onto a public green graced with clusters of preserved trees.

• Connect forest patches to each other via greenway corridors. This strategy effectively increases habitat area for many wildlife species by allowing them to safely travel and colonize.

• Restore the natural forest that has been protected. Remove invasive species and restore tree, shrub, and herb layer planting wherever possible. Mimic the patterns and locations of native plants in healthy plant communities and use only native plants in such areas.

PROTECT EXISTING URBAN TREES

• Implement city codes and ordinances to preserve trees. Tree ordinances provide communities with legislation for planting and/or preserving trees. Such regulations can help to ensure that trees will be protected during construction, and typically when the ordinance specifies tree *conservation,* then groves of trees will be emphasized rather than disjointed individuals. The tree ordinance for Atlanta, Georgia, for example, specifies that no more than 50% of existing trees be removed, damaged, or destroyed, that all trees within 30 feet of a construction zone be protected, that no excavation occur within 10 feet of a tree, and that no materials be placed in such a way as to block water and/or air circulation around a tree (Grey, Deneke, 1992).

• Cluster homes to preserve trees. In residential development, limiting construction impacts by clustering houses to a particular portion of a site can help preserve natural forested areas. Although some leniency is required in establishing lot sizes, setbacks, and frontages, these types of changes in planning development can result in the same number of dwellings occupying a smaller amount of land, thus preserving existing trees and forests.

• Minimize the impacts of construction by keeping disturbance and compaction away from trees. Fence off treed areas to the drip-line (outer edge of the canopy) as an absolute minimum. The largest single killer of urban trees is soil compaction (American Forests/National association of Homebuilders, 1995). Trees need pore spaces equaling about 50% of the soil volume. Standard construction practices can be very harmful and even deadly to trees. Soil compaction, heavy equipment, and undue erosion is detrimental to tree roots, often causing irreparable damage.

In the West Corvallis study, by preserving buffers along stream corridors and around wetlands, much of the existing forest was also saved.

• Design sites to not only protect but to feature healthy heritage trees. Extremely large, old, rare, or handsome trees may be solitary but are generally considered specimen trees and deserve special consideration. They can be the central feature of a new development and can add an air of distinction and serve as a landmark, giving unique character to a place.

PROMOTE THE ECONOMIC BENEFITS OF TREE PRESERVATION

• Encourage the development community to preserve the existing forest. Communities and advocacy groups should promote the economic benefits of tree preservation. Preserving native and mature trees on site may increase construction and development costs, but new developments with mature trees demand higher selling prices. The Buckingham Company in Maryland conserved as much vegetation as possible when building an apartment complex. This added $2.50 per square foot to their construction costs but they were able to make up the difference with increased revenues due to the popularity of the complex (CWP, 1998).

New developments with mature trees add value to neighborhoods. People will pay as much as 20% more for a home landscaped with mature trees (American Forests, 1995). Trees are a visual resource and break up the monotony of building walls and roof lines. The US Forest Service estimates that trees can increase property values by 7% to 20%. (Ebenrick in Moll, 1989)

• Save landscape installation and maintenance costs through tree preservation. Less money is needed to landscape new developments if trees are already there. Groves of native trees require little or no maintenance. These groves are usually solid and healthy and well-adapted to the environment. Removal of these trees would most certainly result in the need to plant new trees and/or turf which would require incurring additional costs. Mature and native trees usually do not need any additional water thereby saving irrigation costs. It has been estimated that corporate land owners can save $270 - $640 per acre in annual maintenance costs when open areas are managed as natural areas rather than landscaped with exotic plants (CWP, 1998).

Laguna West, California

guideline

3.2 CREATE TREE PLANTING OPPORTUNITITES

Urban "tree spaces" are *all* the appropriate and beneficial places for planting trees in the urban environment (Moll, 1989). If all such "tree spaces" were planted with trees, many of the environmental impacts of cities could be mitigated. Public open spaces such as parks, schoolyards, greenbelts, and municipal lands could be managed as forested areas. Areas in cities that are often "paved over" can be reduced in size to allow for planted areas such as vegetated islands in parking lots, on cul-de-sacs, or along rights-of-way. Homeowners can be encouraged to plant trees around their homes through education, ordinances, and incentives.

3.2 GUIDELINE

"The urban forest is only one part, although a vital part, of the larger urban development scene. To grow successfully, the urban forest must be designed as an integral part of the urban whole and considered by all members of the design team over the long period of planning and construction."

(Moll, 1989)

Trees align the edge between a bikeway and park in Eugene, Oregon. A single row is minimal. Here is space for two to three more rows of trees.

The roads, driveways, and houses of new residential developments are replacing trees at a rapid rate. At the same time, local government support for city and county tree programs is declining despite the fact that trees provide substantial economic, environmental, and social benefits (McPherson, 1995). A survey conducted in 1992 estimated that 38% of cities surveyed reported that they care for fewer trees now than they did in 1988 (McPherson, 1995). In order to maintain a healthy urban forest it is necessary to create opportunities to preserve existing trees while constantly planting and maintaining new ones.

Based on studies done in Atlanta, Milwaukee, Baltimore and Austin, Texas, American Forests recommends these target tree cover percentages for metropolitan areas:

Business districts 15%
Urban residential 25%
Suburban residential 50%
Average city-wide 40%

The objective is to achieve the highest possible tree canopy cover to maximize the environmental benefits of trees. Given contemporary development patterns, these coverages of tree canopy can reasonably be met by maximizing tree planting.

CREATE AND MAXIMIZE TREE PLANTING OPPORTUNITIES

• Require tree planting on public lands. Public areas provide ideal places for planting trees and increasing the urban forest. These areas are often left unplanted, carpeted in lawns, or planted with a minimal number of small solitary trees. Landscaping with trees can make public areas more beautiful and contribute to the environmental health of a community. Ideal public places where tree planting should be required include: streets, parking lots, parks, school grounds, utility corridors, and all other public Lands.

• Maximize street tree planting. Streets should be designed with required planting strips between sidewalks and the road surface wherever possible, and without conflicting overhead or underground utilities. Collector and arterial streets should have room for wide planting strips and center medi-

The canopies of these thirty year old trees nearly cover the paved surfaces of the parking lot. Eugene, Oregon.

ans where turn lanes are not needed. Large trees should be planted at the closest healthy spacing — 30 feet on center for large trees and 40 to 50 feet on center for exceptionally large trees. Tree spacing and tree health are based on a tree's ability to take optimal advantage of above and below ground space. Planting trees too close together or in soils lacking in volume and nutrients can result in over competition and compromised health. Choose the largest trees that can be supported by the site's conditions (private correspondence, Kitzman, 1999).

• Establish minimum standards for tree planting on all commercial and industrial developments. Many contemporary landscape codes are weak. They may require "landscape areas" on commercial and industrial developments but often do not require tree planting, nor conditions that may allow trees to thrive. Local standards should be clear in establishing minimum tree planting as the highest priority for "landscaping" on these private developments because of the very significant environmental benefits trees provide.

PLANT TREES TO MITIGATE ENVIRONMENTAL FACTORS AND IMPACTS

• Strategically plant trees around buildings to save energy. Plant both evergreen and deciduous trees around buildings to save on heating and cooling costs. In winter, evergreen trees can be used as a windbreak to block cold winds from the north. Deciduous trees can be planted on the south and west sides of the building to offer cooling shade in the summer and to allow sunlight to enter in winter. Using trees to shade while allowing air to circulate around a central heating/cooling unit or an air conditioner can also cut energy costs by 10% (American Forests/National Association of Home Builders, 1995).

• Maximize tree planting in parking lots. Parking lots generate excessive amounts of polluted runoff, air pollution, and urban heat effects. Balance the pollution production of these urban elements with the mitigating benefits of trees. Parking lots should be designed with tree-lined bioswales and walkways separating rows of parking (see guideline 4.1).

A portion of the Open Space alternative illustrates 36% tree canopy cover.

• Use trees to buffer noise. Planting trees is an ideal way to buffer unwanted noises. When planted in contiguous rows of at least 16' deep, trees can intercept transportation-related noises. It has been estimated by some that a row of trees 100' deep at 45' high can reduce highway noise by 50% (Moll, 1989). In windy areas trees offer their own noises which can be pleasant and act to soften other less desirable sounds.

SELECT APPROPRIATE TREES

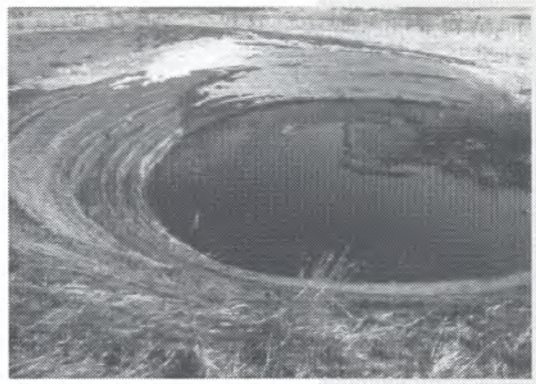
• To achieve maximum success, plant tree species that are most appropriate for site conditions. In many cases this means planting native trees, but not always. For example, select riparian trees for wet conditions, large canopy trees for open spaces, narrow trees for tight spaces, pollution-resistant trees in dense urban areas, and trees with high branching patterns next to roads. Provide education and guidance about suitability for typical sites and supply planting details for trees in public lands.

• Balance the planting of deciduous and evergreen trees. Evergreen trees continue to provide atmospheric and water quality benefits during the dormant season of deciduous trees. Where winter rains are concurrent with deciduous trees as in the Pacific Northwest, plant evergreen trees to intercept rainfall. In cold climates plant evergreen trees to block cold winds, thereby saving on energy consumption.

• Diversify the urban forest. Hard lessons were learned in the Midwest of North America when extensive areas of cities were planted with the American Elm which has suffered devastating loses to Dutch Elm disease. It is now generally accepted that no single species of tree should account for more than 10◦/0 of the city's tree population (McPherson, 1998). Mixing different species of native trees within a grove adds to the regional character of a place, contributes to the biodiversity of a region, and guards against a total catastrophe if a certain species of tree succumbs to disease.

chapter 4

NATURAL DRAINAGE



Shop Creek restoration, designed by Wenk Associates, Aurora, Colorado

guidelines

4.1 PROTECT AND AUGMENT NATURAL DRAINAGE

4.2 TREAT STORMWATER AT THE SOURCE

"Hydrologic restoration is not an economic or technological imposition upon nature. It is just nature. Nature wants to work. It evolves to work... Stormwater management must re-initiate the kinds of long term environmental processes that occurred before impervious surfaces were installed."

(Ferguson, 1998, pg. 11)

The sidewalk at The Woodlands Inn bridges over this intentional infiltration area. The Woodlands, Texas.

URBANIZATION DISRUPTS THE NATURAL HYDROLOGIC SYSTEM

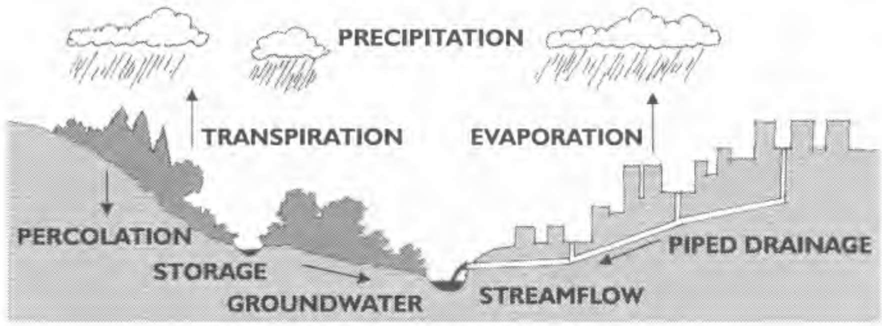
Natural drainage systems are impacted by development. Under natural conditions, rain falls upon vegetation, drips and filters into the ground, and slowly flows into creeks and rivers. The majority of this rainfall is absorbed into the sponge-like ground and slowly moves underground toward surface water systems. Urbanization typically involves building and paving vast areas, then directing runoff into pipes that quickly carry all of the collected rainfall to streams and rivers. The resulting increases in volume and velocity of water entering natural water systems coupled with up to 70% increases in diffuse pollution has a number of negative impacts on water quality. These include eroded stream banks, increased eutrophication, increased stream temperatures, decreases in available oxygen for fish and other aquatic life, and increased sedimentation among other things (EPA, 1999).

As stormwater runoff travels across impervious cover it accumulates and conveys a significant amount of urban related pollutants. Diffuse sources of pollution, known as non-point source pollution, result from the accumulation of many small amounts of pollutants that enter watersheds. In the United States, it has been estimated that stormwater pollution (siltation, salinisation, eutrophication, and water and sediment contamination) and temperature increases are accountable for 70%-80% of all water impairment (Loizeaux-Bennett, 1999). These non-point source pollutants are derived from automobile-related oil and sediment, lawn care related pesticides and herbicides, erosion from construction sites, yard and pet waste, deposition of atmospheric pollutants, and other pollutants resulting from daily urban activities.

The 1972 Clean Water Act specifies that all pollutant discharges to open water should be eliminated. The Clean Water Act requires cities to apply for permits that in turn mandate a stormwater plan to reduce non-point source pollutant discharges in their stormwater system. As the final rules of the Clean Water Act are enforced, urbanized areas will have to find innovative ways to reduce or clean polluted runoff, a primary source of non-point source pollution, before it enters our nation's waters.

Further Reading

Richman, Tom, and Associates, *Start at the Source*
City of Portland, *Stormwater Quality Facilities, A Design Guidance Manual*
DEQ, www.deq.state.or.us/wq/wqfact/wqfact.htm
Bureau of Environmental Services, City of Portland, *Stormwater Management Manual*
EPA, search.epa.gov/s97is.vts
Ferguson, Bruce, *Introduction to Stormwater Watershed Protection Techniques,* Volume 1 Numbers 1,3.
Oregon Climate Service, www.ocs.orst.edu



NATURAL VS. URBAN HYDROLOGY

A NATURAL STORM DRAINAGE SYSTEM PROTECTS THE NATURAL HYDROLOGY

In a forested natural environment, rainfall is intercepted by vegetation, reducing its impact by slowly allowing it to infiltrate and saturate the soil. That which runs off then meanders over rough terrain as sheet flow until it finds a low area where it gathers to become a tiny first order stream. These tiny streams flow together to become higher order streams until the water eventually reaches a river, lake, wetland, or estuary. The time it takes a drop to travel from the canopy of a tree to the second or third order stream is considerable and significant amounts of the rainfall are taken up by plants and soil before reaching the first stream (Ferguson, 1998).

Restorative infiltration starts at the potential sources of runoff, with porous pavements. It continues wherever possible with vegetated swales and basins that bring runoff continuously and repeatedly in contact with vegetation and soil" (Ferguson 1998, pg. 219).

Whereas conventional urban drainage systems gather runoff and move it and its associated pollutants in pipes and channels quickly to nearby streams, "natural" or open storm drainage systems more closely mimic natural hydrology. Protecting and augmenting a natural surface drainage system involves first and foremost protecting riparian corridors, wetlands, floodplains, and the forest canopy and forest floor to the extent possible. It further involves replacing lost storage and infiltration capacity of a developed site through practices such as small scale biofiltration and water harvesting, porous pavements, reducing impervious surfaces, maximizing tree cover, and reducing the use of managed landscapes.

Open storm drainage systems have been successfully implemented in North American cities, among them The Woodlands, Texas, (pop. 150,000) and Bellevue, Washington, (pop. 100,000). Both systems cost a fraction of conventional piped and channeled systems, perform exceptionally well under potential flooding conditions, and concurrently provide multiple other benefits listed below. Both The Woodlands (1979 and 1994) and Bellevue (1984 and 1990) have survived storms in excess of 100 year levels with very Little damage to private or public property. "The final test of the natural drainage system at the Woodlands occurred when a record storm hit the area in April, 1979. Nine inches of rain fell within five hours and no house in The Woodlands flooded although adjacent subdivisions were awash" (Spirn, 1984, pg. 166) In spite of increasing its population

Portions of several golf courses at The Woodlands are located in flood prone areas. When flooding occurs, alternate playing routes are used.

by almost one third between 1980 and 1990, Bellevue experienced less damage from flooding in the more recent storm.

Open drainage systems reduce runoff volumes relative to conventional storm drainage systems, and concurrently recharge groundwater by capturing rain in vegetation, duff, depressions, ponds, and wetlands which allow water to infiltrate rather than to run off.

They maintain water quality by filtering or absorbing sediments and other pollutants. In urbanized areas the natural drainage system may need to be augmented by pre-treatment of polluted runoff with filtering systems such as stormwater ponds or wetlands. Because protection of existing riparian corridors is an important component of open drainage, these systems help with protection of natural vegetation and habitat. Kelsey and Coal Creeks in Bellevue continue to support "salmonid" fish populations, whereas many fish populations in rivers and streams in Pacific Northwest cities are listed as threatened or endangered (National Oceanic and Atmospheric Administration web site, March, 1999).

Open drainage systems minimize capital costs of stormwater drainage systems and spread maintenance costs over several jurisdictions (parks, natural resources, transportation). The cost of implementing an open drainage system at The Woodlands resulted in a savings of nearly $14.5 million from an estimated cost of $18.6 million for a conventional drainage system (WMRT, 1994). More recently, developers of "Somerset," in Prince George's County, Maryland, spent 75% less (1999) on stormwater detention and filtration by replacing the conventional stormwater management practices required by the county, such as stormwater ponds, with "rain gardens" (on-site infiltration areas) and extensive surface drainage throughout the development. In addition, residents are expected to save $100 to $200 each year in runoff-related fees (US EPA "News Notes," 1999). Similarly, in the comparison of three plans for West Corvallis, stormwater system emplacement costs were $300 to $500 less per dwelling unit on the Open Space alternative, which used a partial open drainage system. Annual maintenance costs were $12 to $15 more per dwelling for Open Space.

Meadowbrook Pond in Seattle, Washington, is a flood diversion pond and public park constructed to save a salmon run.

Open drainage systems also provide multiple social goals such as scenic values of natural areas, passive recreation, environmental education, and alternate transportation. By concurrently having more public open space along creeks and around wetlands, Bellevue had ten times more miles of off-road trails than Redmond or Renton, its two neighbors (Girling, 1996).

BEST MANAGEMENT PRACTICES MITIGATE STORMWATER POLLUTION

Best management practices (BMP's, a term created by the EPA) are a whole range of facilities and management practices aimed at reducing the impacts of non-point source pollution. BMP facilities include "structural," such as oil-separating catchbasins and manufactured filtering devices, and "non-structural," such as swales, ponds, and wetlands. Non-structural BMP's can be designed to augment natural or surface drainage systems while greatly reducing pollution impacts of urban stormwater. Such systems are typically inexpensive, natural in appearance, and serve multiple other purposes such as passive recreation and habitat enhancement.

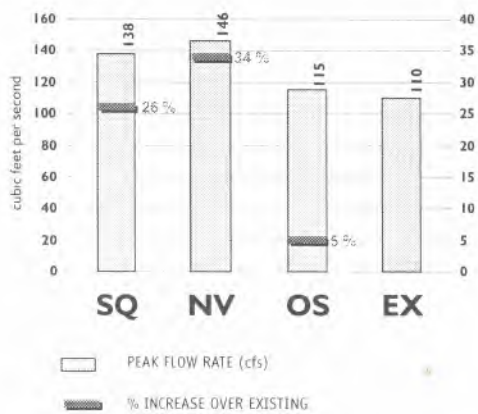
STATUS QUO

NEIGHBORHOOD VILLAGE

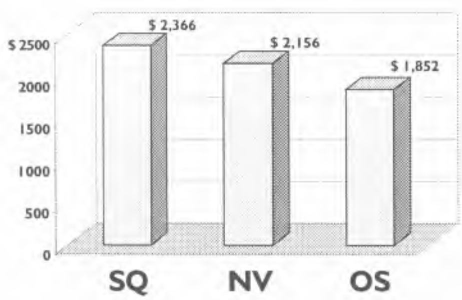
OPEN SPACE

STORMWATER SYSTEM

Stormwater pipes
Existing drainage swale
Grass swale
Stormwater ponds



Estimated stormwater peak flow and increase over existing



Stormwater network costs per dwelling

COMPARING THREE NEIGHBORHOOD PLANS

Both Status Quo and Neighborhood Village used piped stormwater systems, with no constructed detention or filtration facilities. Stormwater was piped to the nearest existing creek. Open Space used a partial piped, partial open drainage system, with extensive surface runoff in vegetated swales, and small stormwater ponds and wetlands for temporary storage and filtration.

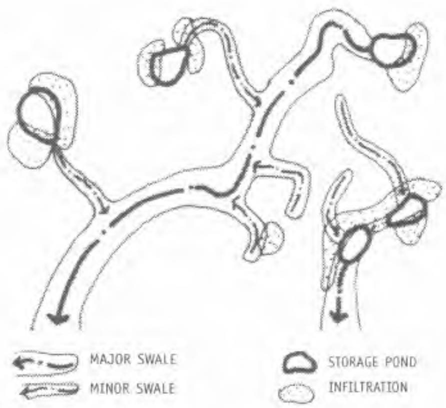
The conventional piped stormwater system of the Neighborhood Village Plan created considerably higher peak flow and more pollutants in comparison to the combined surface and piped stormwater system of the Open Space Plan. Peak flow rates were measured on a 10-year storm of 4" of rainfall in a 24-hour period (the "design storm" for flood control purposes in the Corvallis area). Status Quo increased peak flow rate 26% over that of the existing site. Neighborhood Village increased peak flow by 34°/0, and Open Space increased peak flow by 5%. Thus, the Neighborhood Village plan generated a 27°/0 higher peak flow than the Open Space Plan. To accommodate the open drainage system and goals of maximizing landscape preservation, Open Space allocated more land to open space uses, about 26% of the site. What might be seen as higher open space land costs are offset in part by a lower cost surface stormwater system. Open Space stormwater infrastructure costs were about 17 °/0 less than Neighborhood Village.

Portland, Oregon

guideline

4.1 PROTECT AND AUGMENT NATURAL DRAINAGE

A natural storm drainage system protects and utilizes the natural hydrology to temporarily store and then drain surface runoff. By starting at the watershed scale and planning a nature-based stormwater system, storm drainage can be managed concurrent with protecting natural hydrology and riparian habitat.



This 1974 concept diagram for surface drainage at The Woodlands, Texas, shows infiltration areas adjacent to ponds and a heirachy of drainage swales.

Natural drainage networks utilize and augment the landscape's natural hydrology by protecting perennial streams and mimicking other hydrological patterns such as ponding, infiltration, and groundwater recharge. If a surface drainage network is planned at the earliest stages of development, landscaped areas can be designed to serve these hydrological purposes. The Woodlands in Houston, Texas, incorporated a natural drainage system into their site plan. They began the planning phase by identifying the land characteristics and processes critical to a functioning natural drainage system such as permeable soils for infiltration and "Wailer" ponds for temporary water storage. This information allowed planners to determine best development sites in partnership with natural drainage (WMRT, 1974).

START AT THE WATERSHED SCALE

A naturally based drainage network is most effective when it is comprehensive. A drainage plan that incorporates the watershed, the basin, and the individual lot allows areas with important hydrologic function to be protected and encourages coordinated planning between stormwater, transportation and other infrastructure and development. Neighborhood scale developments can be laid out to allow an open drainage in areas of appropriate slope, soils, and vegetation. Individual lots can contribute to the larger drainage system by conserving established and native vegetation, reducing impervious surfaces, and reducing runoff (Burke, 1997).

• Provide accurate and instructional information. Regional and metropolitan governments should study watershed and basin-scale hydrology. These agencies should conduct stormwater planning at these scales and provide instructive information, guidance, and regulation where necessary to the planners and designers of smaller sites.

"The prevention of floods and the conservation and restoration of water will only be accomplished by the cumulative effect of many individual actions throughout the city" (Spirn, 1984, pg. 154).

PRACTICE INTEGRATIVE STORMWATER MANAGEMENT

Integrative stormwater management is a wholistic approach in which every aspect of land planning and site design considers maintaining site, basin, and watershed hydrology as an important part of the planning or design process. Planning a drainage network early and at multiple scales can generate innovative and integrative possibilities for managing

A stormwater filtration pond designed by Murase Associates intercepts and filters stormwater from a 50 acre residential area before it discharges to the Willamette River in Portland, Oregon.

stormwater runoff while concurrently serving multiple purposes.

• Inventory the site's natural features to take advantage of natural drainage opportunities. An evaluation of topography, slope, natural vegetation, soils, and groundwater will help determine natural drainage opportunities. Preserving or creating areas where water flows naturally, linked with areas for ponding, will enhance natural drainage opportunities. An understanding of a site's hydrology will enable developers to preserve certain places for ponding and infiltration while using other areas for development.

• Lay out a schematic surface storm drainage system early and coordinate this system with streets, infrastructure, development, and parks and open spaces. Opportunities afforded by such an approach include linkages of parks via riparian and other drainage corridors, public access to stormwater wetlands and ponds for passive recreation, multi-use public utility corridors, or details such as bioswales in roadway medians.

• Create integrative stormwater system that includes biofilter strips, swales, ponds, and streams located on every urban site to supplement the natural drainage. Designing sites to retain and infiltrate stormwater keeps it out of the urban system. Minimizing disturbances to the site's soils and vegetation reduces problems associated with erosion such as increased sedimentation and reduced soil permeability. Establishing "sensitive" areas that are to be undisturbed also reduces erosion while simultaneously creating areas where water can pool, be cleansed by vegetation, and infiltrate the ground.

• Locate stormwater filtration sites at all points where urban stormwater may enter the natural system. These filtration facilities must occur above the point of entry of stormwater to natural waters. The outer edges of wide riparian or wetland buffers, parks, edges of school grounds and other public sites, and parcels of leftover land are all ideal sites for stormwater filtration facilities.

NOTES

Village Homes, Davis, California

guideline

4.2 KEEP RAINFALL AT ITS SOURCE

Infiltrating and treating stormwater runoff on site can reduce runoff and pollutant loads by 20◦/0 - 60% (CWP, 1998). Careful site design to maximize water storage, infiltration, and filtration on site helps to reduce the cumulative effects of urban runoff. While there is not one ideal solution, an integrated approach to site design and stormwater management options can produce beautiful and beneficial results.

This large stormwater treatment pond at Ecolonia, The Netherlands is the central landscape feature of the community.

Stormwater runoff has in the past been considered an "end-of-pipe" problem, to be dealt with after stormwater emerges from the piped system. Typical solutions to water quality and flooding problems endemic with "end of pipe" approaches are regional-scaled detention and filtration facilities. These strategies, however, tend to be large, costly, more complex, and less efficient at managing stormwater runoff and they do not mitigate upstream hydrologic changes (Richman and Associates, 1997). When stormwater travels away from its point of origin through a series of pipes, some of the most effective opportunities to reduce quantity and improve water quality are lost.

Conventional stormwater regulations are designed to consider ten year, twenty-five year, and other larger storm events, however, on average across the United States, the majority of rainfall events; generate less than 1" of rain in 24 hours. Rainfall measured in Atlanta, Georgia, demonstrated that 90% of the storms measured during a one year period, generated less than 1.2" of rain (Ferguson, 1998). Similarly, 91% of the rain measured in Eugene, Oregon, generated less than 1" of rain in a 24 hour period (Oregon Climate Service, 1999). These rain storms have been overlooked in stormwater management. The small amounts of runoff generated in these frequent small rainstorms carry the greatest amount of concentrated pollutants. At the same time, these are the very rainstorms that are most treatable on site.

START AT THE SOURCE

• Maximize on-site stormwater management. Keeping stormwater close to home helps to mimic and maintain the natural hydrology. "By starting at the source -- reducing impervious cover and utilizing green space for stormwater treatment -- communities can sharply reduce the volume of stormwater runoff that must be treated" (CWP, 1998, pg. 168).

• Study the unique hydrology of every site. Understanding a given site informs designers of the most effective types of stormwater management practices to employ. For example, although a particular soil may not be very permeable, if the slope is gentle and rainfall comes in small amounts over long periods of time, that soil will infiltrate adequately. Highly per-

This desert garden located in a park in Davis, California provides flood storage and infiltration for the nearby subdivision.

vious soils are ideal for rapid infiltration of clean runoff. Less pervious soils retain water longer, and are suitable for longer treatment times.

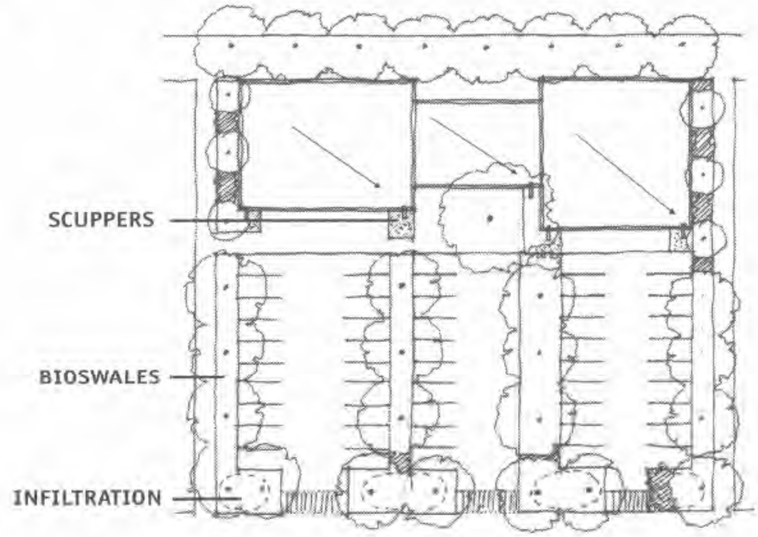
• Understand local rainfall patterns. The nature of rainfall dramatically effects stormwater management strategies. The intensity, frequency, and quantity of rainfall in the majority of rainfall events should be the basis for designing on-site practices. At the same time, flood management must be in place for the less frequent, larger volume events as well.

• Use multiple stormwater management strategies on each site. Vegetated swales, ponds, cisterns, "rain gardens," dry wells, and infiltration basins are all examples. Each of these strategies is suited to certain site conditions and is best at achieving only some aspects of stormwater management.

• Replace pipes with vegetated swales. These are shallow, concave basins that act as alternatives to typical gutter and pipe systems. These channels are characterized by wide bottoms, gently sloping sides and dense vegetation. They slow and detain water for at least twenty to thirty minutes so that it can be cleaned before it reaches natural water systems (CWP, 1998). Grassy swales also slow water flow enough to allow significant amounts of stormwater to be absorbed on site.

Length of swale and time of residence of water in the swale are important. In a 1991 test of a grass biofiltration swale in Washington state, researchers concluded that with a 5 to 10 minute residence time in a minimum 100 foot long biofilter, reliable pollutant removals were achieved. Results ranged from a low of 15% of lead to a high of 72% of phosphorous removed. Doubling the length of the swale significantly improved some pollutant removals *(Center for Watershed Protection Techniques,* Fall, 1994).

To be most effective, open channels are best suited to particular slopes, lengths, and soils. Gentle slopes of less than 5 °/0 allow water to travel slowly enough to be treated. Where slopes are greater than 5%, check dams can be integrated into the swale to allow water to pond, thus delaying its entry into the system. Soils should be permeable so that infiltra-



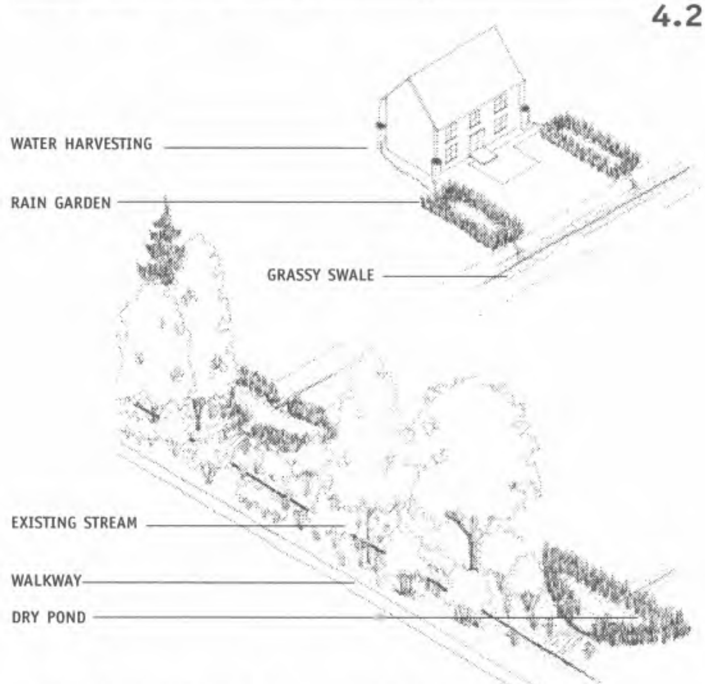
Parking lots can be drained to vegetated bioswales or infiltration areas. These allow filtering and some infiltration of runoff before it enters an underground system.

tion can occur, but not sandy or water will absorb before it can be treated and will make the channel too vulnerable to erosion. Occasional mowing of the grass and routine removal of excess leaves and debris that may block the system improves performance.

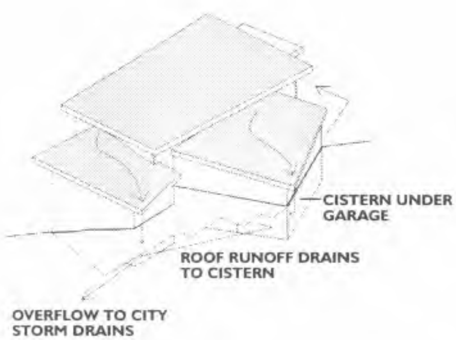
• Use natural processes to filter stormwater. Bio-retention is an alternative management strategy that uses native ecosystems and landscape processes to enhance stormwater quality. Either naturally preserved areas or created basins capture sheet flow and treat the stormwater using microbial soil processes, infiltration, transpiration, and plant uptake. This shallow planted area can be fairly wide and can include trees, shrubs, perennials and groundcovers. Soils are a critical component of bioretention facilities. They must be permeable enough to allow water to infiltrate and they must be vital enough to allow micro-organisms to break down pollutants as they pass through the soil. "Rain Gardens" are small bio-retention areas planted to mimic the physical structure of a local forest. As implemented by a Maryland developer, rain gardens are shallow basins 6" deep and 300 to 400 square feet, located in the low area of each lot. Runoff from typical rainfalls gathers in the basin and infiltrates over a 48 hour period.

• Substitute decorative planters with stormwater planters. Stormwater planters are generally located next to rain gutter downspouts to filter runoff through planter soils. As runoff passes through the planter, ^ pollutants are captured before they infiltrate the native soils. Stormwater planters are designed to drain within 3-4 hours after a storm (Bureau of Environmental Services, 1999). Stormwater planters are an attractive amenity and should be planted with plants that tolerant both periods of drought and inundation.

• Replace decorative ponds with stormwater marshes and ponds. Wetlands, marshes, and ponds detain water so that pollutants can be trapped



A "TREATMENT TRAIN" IN A RESIDENTIAL AREA



An 8,700 gallon cistern under this garage collects roof and driveway runoff from winter rains and stores it for irrigation purposes in the summer. Van Asperdt - Boesjes residence in Eugene, Oregon.

and absorbed by plants as well as slowly absorbed into the ground. Like natural wetlands, stormwater wetlands are shallow depressions that are inundated with stormwater during the rainy season and dry during droughty times. Stormwater ponds work well in small scale residential settings whereas wetlands generally require more land and may be more suited to neighborhood or regional open space areas. An added benefit of wetlands and marshes is that they are beautiful and provide habitat for a variety of wildlife from aquatic to avian species.

• BMP's may be used in isolation or in series as "treatment trains," that working together can often mitigate a broader spectrum of pollutants. Combination systems allow pre-treatment of severe pollutants, such as those generated from automobiles, so that the main treatment facility can function at an optimal level. This type of system also allows stormwater BMP's to better target specific pollutants. For example, sedimentation facilities work best at treating course particulate, while marshes are better at treating fine particulate. Multi-purpose treatment facilities optimize what each intervention does best while compensating for their weaknesses (City of Portland, 1995).

• Harvest rainwater for irrigation. Water harvesting is the direct capture and use of runoff on-site. In some applications water harvesting maintains the water levels in permanent ponds and wetlands. In other cases, water is stored in tanks or cisterns for irrigation or other uses. One family in Eugene, Oregon, constructed an 8,700 gallon tank under their garage. This tank collects all of the runoff from their roof and driveway during the rainy winter months and supplies all of their irrigation needs during Eugene's exceptionally dry summer (Interview with Anita Van Asperdt, November, 1999).

NOTES

chapter 5

IMPERVIOUS SURFACES

Radburn, New Jersey

guidelines

5.1 REDUCE EXTENT OF STREET NETWORK

5.2 REDUCE IMPACT OF PAVED AREAS

BACKGROUND

"More than thirty different scientific studies have documented that stream, lake, and wetland quality declines sharply when impervious cover in upstream watersheds exceeds 10 percent. The strong influence of impervious cover on aquatic systems presents a major challenge to communities in sustainable development."

Center for Watershed Protection, Better Site Design, p. 1

A typical "strip" commercial area is 92% to 95% impervious surfaces.

URBANIZATION INCREASES IMPERVIOUS COVER AND STORM WATER RUNOFF

Urbanization alters natural hydrologic patterns as impervious surfaces replace natural land surfaces. Impervious surface is land covered by roads, rooftops, parking lots, driveways, sidewalks, patios, and any other surface that prevents water penetration into the soil. As land is covered with impervious surfaces, rainwater cannot follow its natural drainage cycle of filtering into the soil, and replenishing groundwater. Instead, precipitation runs off rooftops, over paved surfaces, along street gutters, and into the stormwater system. Water traverses over these relatively smooth surfaces much faster than it would grass or any other vegetated area. Thus, impervious surfaces generate far more runoff than natural areas, which in most cities is piped or channeled to the nearest lake, river, or stream. Runoff generated from an undeveloped watershed can increase by approximately 500% once developed (EPA, 1996).

Conventional North American streets have been designed as wide, paved surfaces edged by curbs and gutters. In fact, most jurisdictions require residential streets to have curb and gutter systems as the primary mode of stormwater transport. In this system, runoff from streets and adjacent sites runs along the street edge to catchbasins where it enters the piped underground system. While curbs and gutters are very efficient at quickly moving water to a piped system, they exacerbate flooding and pollution problems downstream. Stormwater transported through these systems accumulates and concentrates pollutants (Richman and Associates, 1997). When the water reaches its discharge point, pollutants washed from streets and lawns drop directly into natural waters.

EXCESSIVE IMPERVIOUS SURFACE DIRECTLY IMPACTS STREAM QUALITY

As noted above, as the area of impervious surface in a watershed exceeds 10%, sharp declines in water and habitat quality have been observed. Increased volumes of runoff passing through piped and channeled stormwater systems at accelerated rates create high peak flows in downstream waters. Peak flows are said to occur when the greatest volume of runoff passes through a stormwater system and reaches the outlet point. The increased frequency and magnitude of peak flows erodes stream banks, creates potential flooding, increases siltation, increases water tempera-

Further Reading

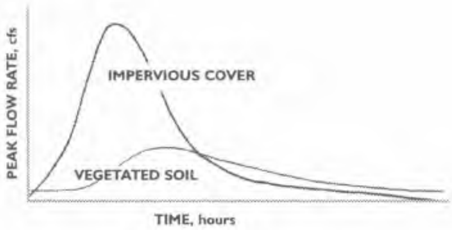
Center for Watershed Protection. "The Importance of Imperviousness."

Center for Watershed Protection, *Better Site Design: A Handbook for Changing Development Rules in Your Community*.

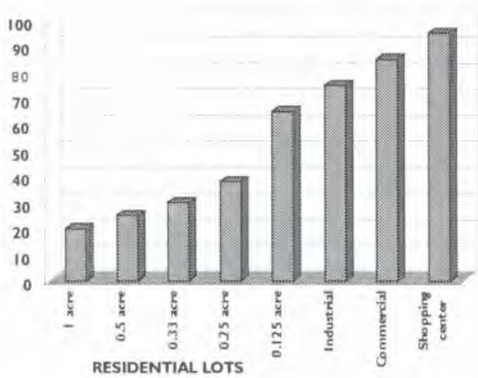
Southworth, Michael, and Eran Ben-Joseph, *Streets and the Shaping of Towns and Cities.*

Richman & Associates, Dress & McKee, and Ferguson, *Start at the Source: Residential Site Planning & Design Guidance Manual for Stormwater Quality Protection*.

University of Georgia School of Design. *Land Development Provisions to Protect Georgia Water Quality.*



Stormwater flows from impervious surfaces peak faster and with higher volumes than flows from vegetated areas.



With conventional development, imperviousness increases with density. Very high percentages of impervious surfaces are common in commercial developments. Integrated design of BMPs such as infiltration basins can mitigate these impacts. Source: Arnold and Gibbons, 1996.

tures, and disrupts habitat (Sediment and Stormwater Program, Delaware Dept. of Natural Resources, 1997). Fish species diversity declines as impervious cover increases. For example, the Maryland Department of Natural Resources studied four similar subwatersheds in the Maryland Peidmont. The watersheds with 10 ◦/0 or less impervious cover, had a total of twelve species, including seven sensitive species, while the watersheds with 55% i mpervious surface, had a total of two fish species and zero sensitive species (CWP,1995).

There is a direct correlation between urban runoff volumes and amounts of stormwater pollution. Pollutants, such as oil, grease, and metals from automobiles, and phosphorus and nitrogen from fertilizer and natural decomposition, accumulate on impervious surfaces between rain storms. Rainfall then washes these pollutants through the stormwater system into natural waterways. Because most urban stormwater is untreated, high percentages of impervious surfaces yield high rates of runoff and equally high rates of stormwater-related pollution (CWP, 1995).

In most North American cities, natural streams, rivers, lakes, or the ocean receive this urban water pollution, and many of these rivers are exhibiting the effects. In Oregon, a state with relatively low levels of urabanization, 26.6°/0 of all streams and rivers were classified by the Department of Environmental Quality as "non supportive" of beneficial uses, such as fisheries, aquatic life, recreation, drinking water supplies, and aesthetics (Community Planning Workshop, 1994).

REDUCING IMPERVIOUSNESS

Development inevitably creates impervious surfaces. The extent to which a watershed is impervious, however, depends on planning and design choices. Reducing the extent of street networks, decreasing street widths, using pervious pavements, reducing the amount of paved parking coverage, and disconnecting some roofs and paved areas from piped drainage will decrease impervious surfaces. Conversely, increasing areas where water can infiltrate, not only decreases impervious area but also helps to recharge groundwater (See Chapter 6).

Potsdammer Platz: 100% of the stormwater runoff from this urban redevelopment project in Berlin is harvested and reused on-site. Photo by Dior Popko

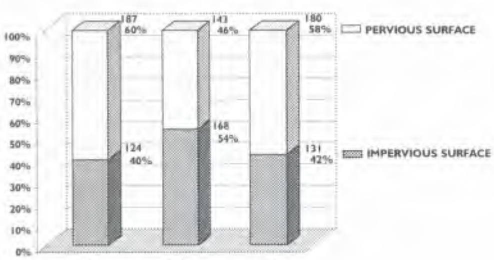
Effective impervious areas are defined as impervious surfaces that generate runoff which must be directed to the stormwater conveyance system. Reducing the effective impervious area is accomplished by draining paved surfaces and roofs into pervious areas such as lawns, gardens and designed infiltration areas. A 1999 study of the effects of disconnecting rooftops in a 2,300 acre watershed found significant results. Annual runoff from this low density residential area with 30% open space could be reduced by 20% and peak flows by 15% if rooftops of all new development in the watershed were disconnected (URS Greiner Woodward Clyde, 1999).

STATUS QUO

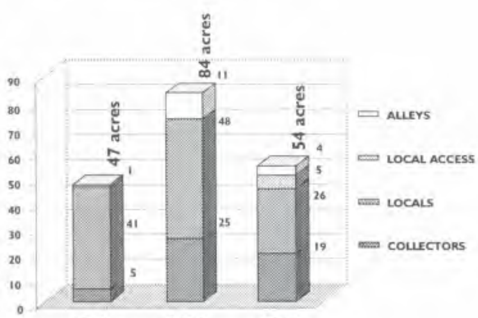
NEIGHBORHOOD VILLAGE

OPEN SPACE

STREET NETWORK



Pervious/Impervious Surface



Land Allocated to Streets

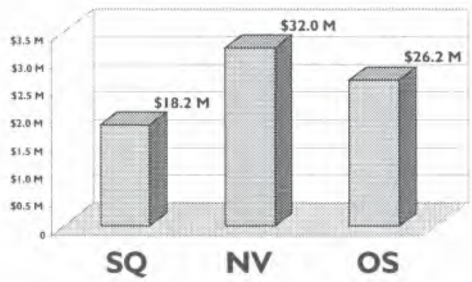
COMPARING THREE NEIGHBORHOOD PLANS

Impervious surfaces have the most direct negative impact on the volume and quality of water running off development into streams. In the CHI comparison of three plans, Neighborhood Village was 54% — over half the land area — in impervious cover. Status Quo and Open Space were roughly equal in areas of impervious cover (40% and 42% of site respectively). For the purposes of this study all impervious surfaces on all plans were assumed to be connected to the stormwater system.

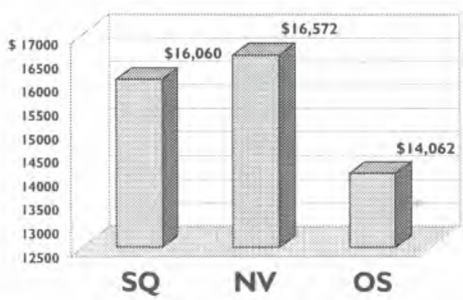
Pervious surfaces, on the other hand, can have beneficial impacts on stormwater by mitigating volumes and potentially improving water quality. Status Quo had the most pervious surface at 60%, while Open Space was a close second having 58% in pervious surface.

Streets are one of the significant components of impervious surface area. Neighborhood Village allocated the most Land, about 27% of the site, to streets and paths and provided the most extensive and diverse street network. Status Quo allocated the least Land, about 15% to streets and paths, and provided the least extensive and diverse street network. Open Space allocated slightly more land than Status Quo — about 17% but provided a more diverse network. Open Space allocated the least amount of street paving per dwelling, while the lower density Status Quo and the higher density Neighborhood Village were about equal.

BACKGROUND



Estimated capital costs of infrastructure (Land for open space and streets, street and utility networks)



Infrastructure costs per dwelling (Land for open space and streets, street and utility networks)

The reduction of impervious surface while maintaining density in the Open Space plan was accomplished by using longer streets with mid blocks and pedestrian paths, skinny streets, T-shaped cul-de-sacs, deep narrow lots with more houses per street block, and pervious alleys. Against measures of infrastructure cost, Status Quo incurs the least total capital cost in infrastructure and associated land — about $18 million or 43% less than Neighborhood Village which is about $32 million and 25°/0 less than Open Space which is about $26 million. Neighborhood Village allocates significantly greater land, and greater cost, to its street system — roughly double that of Status Quo. Open Space allocates significantly greater land, and with it greater land cost, to public open space — more than twice as much as the other two alternatives. However, on a per dwelling basis, Open Space incurs the least capital cost in infrastructure and associated land, approximately $14,000 or about 12% less than Status Quo and Neighborhood Village which are approximately equal at about $16,000.

Champignon Homes, Eugene, Oregon

guideline

5.1 REDUCE EXTENT OF STREET NETWORKS

Streets are significant sources of urban pollutants in residential, commercial, and industrial areas. Vehicular networks, including roads, alleys and parking lots, typically consume about one-half of urban lands. Reducing the extent of the street network through decreased street lengths, skinnier streets, and Less parking area can mitigate negative stormwater-related impacts of vehicular networks.

"Excessive street standards that require wide streets and large setbacks have major social and economic impacts. They waste land, drive up home costs, and negate the essence of residential livability."

Southworth, 1997, p. 6

A convential suburban street in Eugene, Oregon

The two common types of street networks found in the United States are the grid (traditional street networks), and "loops and lollipops," the curvilinear patterns of contemporary subdivision networks (Moudon, 1991). Of these two network types, the grid patterns typically generate 20 to 25% more total street length than the curvilinear patterns (CWP, 1998). Traditional grid networks are designed to have short block lengths, straight streets, and back alleys in every block, hence increasing the network's overall impervious surface. The "loops and lollipops" networks incorporate longer block lengths, branching networks, and cul-de-sacs into the overall design (CWP, 1998).

Although the grid system generates more street length than the curvilinear system, it does have other advantages. Whereas curvilinear street systems tend to be circuitous and can discourage walking, grid street systems provide more direct connections for pedestrians and automobiles, more "livable" streets (with car storage located on the alley side), and the ability to site more homes per unit length of street.

REDUCE STREET LENGTHS

Since street paving represents a significant portion of urbanized areas, planning and design strategies that reduce the total amount of impervious surface attributable to street systems can be important to environmental protection.

- Use longer blocks with pedestrian or mid-block paths. Vehicles move about eight times faster than pedestrians through residential areas . Thus, if time to destination is an important consideration, a well connected street system for vehicles can include longer distances than for pedestrians. Larger vehicular blocks with more finely scaled pedestrian connections will immediately reduce impervious surfaces because of fewer cross streets. Pedestrian or mid-block paths enhance a neighborhood's pedestrian and cycling network by providing off-street choices for pedestrians. These paths are not only narrower, they can also be paved with pervious surfaces.

In 1999, it cost approximately $144.50 per linear foot to pave a twenty foot wide road, with less than a ten percent grade (Center for Housing Innovation, 1999). These costs include pavement (streets and sidewalks), curbs and gutters, and storm sewer construction. Many other infrastructure costs are also related to road length, such as stormwater collector and trunk pipes, and other utility infrastructure costs: gas, water, and electricity, which tend to be distributed to households along road right-of-way.

Modified Grid Street Systems

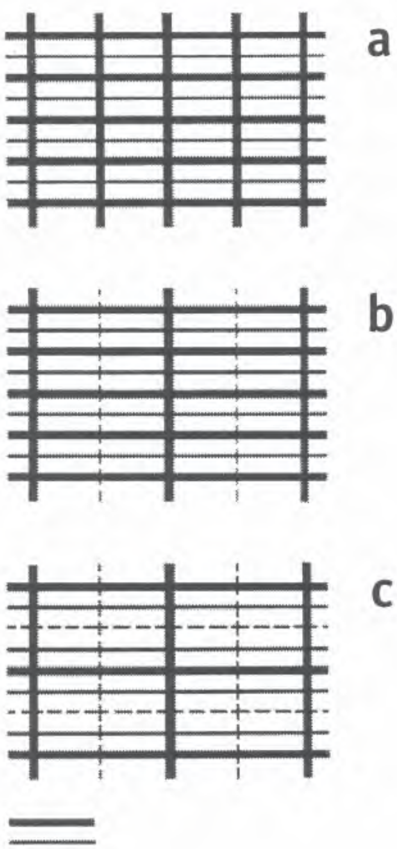


Diagram "a," a common street-and-alley grid system results in 27% of the site in street and sidewalk related pavement. "b," replaces every second cross street with a path and results in 25% of the site in street and side walk pavement, "c," replaces every second street both ways with paths and results in 21% of the site in street and side walk pavement.

• Consider hybrid street systems. For example, traditional grid systems may be combined with pavement reducing streets such as cul-de-sacs. Creating pedestrian connections between cul-de-sacs restores lost pedestrian connectivity without increasing imperviousness. Or, in select cases, alleys may suffice for vehicular connections to homes and front streets may be replaced by greenways.

• Use narrow deep lots in residential areas to create a compact street network. Narrow deep lots increase the total dwellings per unit of street length and conversely result in less overall street network.

• Minimize the pavements in cul-de-sacs or dead-end streets. The radius of a cul-de-sac should be just large enough for emergency vehicles to turn around, and should have vegetation in the center, to reduce overall paving. After on-the-ground testing with fire crews, Portland, Oregon, has reduced the minimum turning radius for cul-de-sacs to 35 feet, whereas the national standard is closer to 45 feet.

• Use pervious paving materials for alleys, cul-de-sacs, and all low volume vehicular areas. Pervious paving should only be used in areas of low vehicle traffic and on appropriate soils (See Guideline 5.2).

INCORPORATE SKINNY STREET DESIGN

In many communities residential street standards call for a 50-60 foot right of way with 36 feet of pavement. However, "several national engineering organizations have recommended that residential streets be as narrow as 22 feet in width (AASHTO, 1994; ASCE, 1990), if they serve neighborhoods that produce low traffic volumes (less that 500 daily trips, or 50 homes)" (CWP, 1999, p. 29). In Portland, Oregon, the city created a Skinny Street program that has reduced many residential streets by as much as 12 feet to 20-26 feet wide depending on parking needs (Southworth, 1997). Simple reductions in the dimension of streets, sidewalks, and rights of way may appear insignificant in streetscape designs from block to block. However, when these changes are compounded at a

Heavy planting along the edges of narrow streets help to reduce impervious surface impacts at Village Homes, Davis, California.

Recent studies indicate that reducing the width of residential streets may increase safety. The Federal Highway Administration (1997), ITE (1997), and ULI (1992) all noted that narrow street widths tend to reduce automobile speeds (CWP, 1998).

larger scale, they can have a tremendous effect on the reductions of impervious surface, stormwater runoff, stormwater pollution, and the overall character of a neighborhood.

- Design streets to have the narrowest paved width appropriate to the street's traffic volume. Use skinny streets, with paved widths 20 to 26 feet wide, for residential streets under 500 average daily trips (ADT). Narrower streets not only decrease the amount of impervious paving but increase safety. They also add opportunity for additional street trees and/or swales for treating stormwater runoff.

- Use queuing streets. The queuing street, allows for parking on one or both sides of the street with the center lane shared by traffic going both ways. Vehicles are required to wait or queue up until there is an opportunity for safe passage. This street type can be appropriate when ADT is under 500 trips per day.

Ecolonia, The Netherlands

guideline

5.2 REDUCE IMPACT OF PAVED AREAS

The impact of the automobile is evident not only through extensive street networks, but also through the amount of land dedicated to vehicle storage. Standard street design follows a formula of a curb and gutter system that quickly funnels stormwater runoff into pipes. Street design can be reconceived to incorporate stormwater treatment. Most parking lots and residential driveways are impervious and directly connected to the stormwater system. By reducing the overall size of paved parking, using pervious pavements, and disconnecting paved surfaces from the piped drainage systems, significant improvements can be made.

5.2 GUIDELINE

"Traditional solutions for stormwater management have not been widely successful; in contrast, permeable pavements can be one element of a more promising alternate approach to reduce the downstream consequences of urban development."

(Booth & Leavitt, 1999, p. 314)

A new residential development near Copenhagen, Denmark, utilized crushed limestone for driveways and parking.

TREAT POLLUTED RUNOFF AT ITS SOURCE

• Treat road-related runoff at the source to reduce cumulative effects. The principle of treating runoff at the source is even more important along roadways, because they are such a significant source of non-point source pollution. This principle should become a priority for highway and street design so that pollutants being conveyed off these surfaces are intercepted before stormwater is collected and discharged into receiving waters (Richman and Associates, 1997).

INCORPORATE WATER FILTRATION IN STREETSCAPE DESIGN

• Incorporate surface drainage as part of the street network by inverting planting strips. Standard "maintained" planting strips along roadways are convex in shape, thus allowing stormwater runoff and plant maintenance-related pollutants to wash off onto streets and into piped drainage systems. This system adds to stormwater runoff and associated pollution. Inverting planting strips so that they are concave allows some runoff from roads to infiltrate the soils of the planting areas while that run off is filtered. Concave planting strips are especially valuable for treating "first flush" runoff which typically carries the highest concentrations of pollutants (Richman and Associates, 1997).

• Design concave road medians as landscaped biofilters in the center of roads. Concave road medians provide an excellent opportunity to catch and clean oils and other pollutants coming directly off of roads. Stormwater runoff from roads would be directed to these median strips where pollutants can be filtered by plants and soils. Because these medians are in direct contact with roads, they provide an optimum condition to manage "first flush" runoff which generally carries the highest concentration of pollutants from automobiles (Richman and Associates, 1997).

• Plant an island in cul-de-sacs. Cul-de-sacs or "lollipops" are a popular suburban road design that is characterized by a single entry road with a round bulb at the end. A planted center island could be a planted basin used as a bioretention area, while concurrently reducing impervious surfaces.

Biofiltration swales replace conventional traffic islands in a Portland, Oregon parking lot. These swales are found to be 90% effective at removing pollutants associated with vehicular areas (Bureau of Environmental Services, 1999)

USE EFFICIENT PARKING LOT DESIGN

Although it is necessary to have adequate parking, a study done by Wilson in 1995, showed that much suburban commercial and office parking has been over-supplied nationwide (rerguson, 1997). Parking standards often require a minimum number of parking spots per land use rather than maximum number. Cities typically require 4 parking spaces per 1,000 square feet of office floor. However, a study by Wilson found that only 2.8 spaces were actually used during peak parking hours (Ferguson, 1997). Developers also tend to size parking lots for the holiday rush instead of everyday use, creating paved areas that are under utilized throughout most of the year. Efficient parking lot design can help to reduce total paved surfaces associated with parking and can decrease imperviousness per stall through smaller stall sizes, using one way aisles, and incorporating pervious areas for overflow parking.

- Evaluate local parking standards. Local governments should require both maximum and minimum parking standards for each land use.

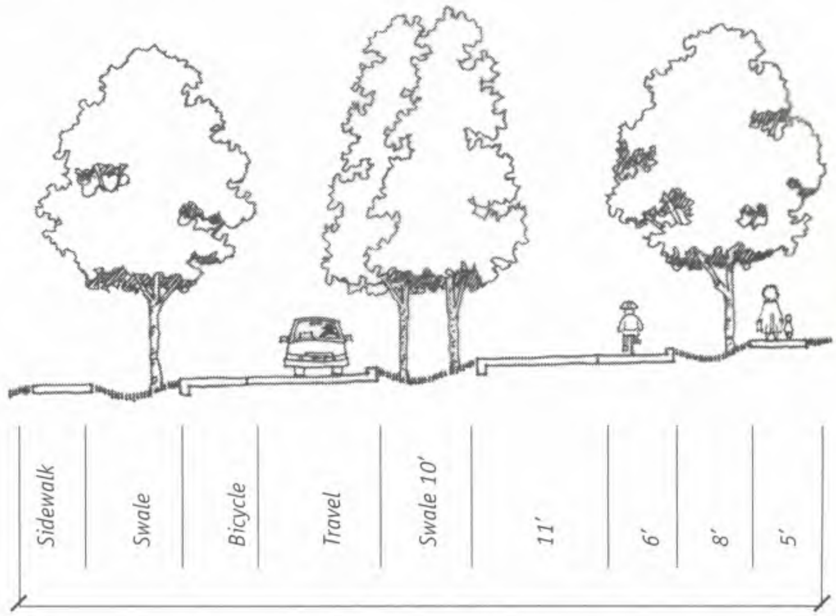
- Define primary parking and overflow parking. Whereas heavily used parking areas may need conventional pavements for durability, low use parking areas are ideal for pervious pavements (See below).

ENCOURAGE PARKING STRUCTURES

- Although parking structures are expensive, incorporating them into building design means far less impervious cover is dedicated exclusively to parking.

- Reduce the amount of impervious cover dedicated to each parking stall. "The standard parking stall occupies only 160 square feet, but when combined with aisles, driveways, curbs, overhanging space, and median islands, a parking lot can require up to 400 square feet per vehicle, or nearly one acre per 100 cars" (Richman, 1997, p. 46). Parking codes often require standard parking stalls geared to larger vehicles, despite the fact that smaller cars comprise 40 to 50% of all cars on the road (ITE, 1994a). Create some parking spaces for compacts and some for larger vehicles and use one-way aisles in conjunction with angled parking when possible.

"Driveways can comprise up to 40% of the total transportation network in a conventional residential development, with streets, turnarounds, and sidewalks comprising the remaining 60%" (Richman, 1998, p. 49).



70' Stormwater collector street

Certain components, such as overhanging spaces and median islands could be a pervious surface.

DISCONNECT IMPERVIOUS SURFACES FROM THE STORMWATER SYSTEM

Conventional parking lots and driveways drain directly into the piped stormwater system. A study in Wisconsin conducted by Bannerman in 1992, found that within commercial and industrial areas, parking lot run-off accounted for one-fourth to two-thirds of the total suspended solids, total phosphorus, total copper, and total zinc loads in the areas studied (CWP, 1998). Redirecting runoff into biofiltration areas within the parking lot detains and cleanses water on site.

• Disconnect impervious parking areas from the stormwater system. Require swales, vegetated areas, and trees to be incorporated in parking lot design, and direct the runoff into these areas. Residential driveways can also be sloped to drain into adjacent vegetated areas. This allows runoff to be treated on site, and reduces total runoff and the amount of pollution entering the stormwater system.

USE PERVIOUS PAVEMENTS

The use of pervious pavements is a practical solution towards reducing impervious surfaces while accommodating urban lifestyles. Pervious pavements such as porous concrete, asphalt and unit pavers, structural or reinforced turf, and grid pavements allow water to infiltrate through the pavement and can be used for most of the same purposes as impervious covers. A recent study found that "the differences in runoff responses from permeable and impermeable surfaces are quite dramatic. If soil conditions are suitable, permeable pavements are quite successful at managing run-

A very narrow access road in Houten, The Netherlands, provides a safe, attractive street environment, while drastically reducing paved area.

off from small and moderate storms" (Booth & Leavitt, 1999, p 323). Several recent studies cited in *Site Planning for Urban Stream Protection* (CWP, 1995) have found that pervious pavements have high pollutant removal performance and do not contribute high pollutant loads to groundwater if properly designed.

• Use pervious pavements in parking lots when proper conditions exist such as appropriate soils and low volume parking. Pervious pavement materials can be used with well draining soils for overflow and other low-traffic parking areas. In high use areas and accessible parking spaces, durable, smooth, even surfaces are necessary, although both porous concrete and asphalt can serve this purpose.

• Use permeable paving for driveways. Residential driveways provide an obvious opportunity to decrease impervious surfaces. Many of these permeable pavements are far more attractive than asphalt and concrete, thus contributing to the value of the home.

NOTES

chapter 6

VEGETATION


REI store in Seattle, Washington

guidelines

6.1 REDUCE TURF AREAS

6.2 USE PLANTS TO ABSORB AND FILTER URBAN RUNOFF

A landscape of shrubs and perennial flowers requires little chemical or mechanical maintenance. Houten, The Netherlands.

LANDSCAPING CAN CONTRIBUTE TO STORM WATER POLLUTION

Conventional landscaping and maintenance practices contribute to the degradation of streams and rivers as fertilizers, herbicides, and pesticides enter natural water systems. While all types of vegetation contribute to the slowing and infiltration of stormwater, some to a greater degree than others, not all types of vegetation contribute to the reduction of water pollution. Those that do not require fertilizers and irrigation, such as native plants, are typically not contributors. Turf lawns and other highly maintained landscapes require a considerable chemical intervention to remain green, lush, and tidy. Large amounts of chemical treatments combined with intense watering regimens encourage pollutants to accumulate and travel. These highly maintained landscapes are net pollution contributors as excess chemicals are washed into nearby rivers and streams. Additionally, the thatch root system of a single species lawn leads to soil compaction, which severely reduces infiltration. Some estimates indicate that 60% of nitrogen applied to lawns leaches into groundwater or is washed off into local rivers and streams (Bormann et al., 1993). Residential lawns contributed 20 ◦/0 of the phosphate load of an urban stream in Wisconsin (Scheuler, 1995).

Increased levels of phosphorous and nitrogen cause rapid growth of aquatic plants and subsequent decomposition using excessive available oxygen, depriving fish and other aquatic life of oxygen, thus causing an eventual failure of a natural ecosystem. Studies have indicated that 44°/0 of nitrogen and 28% of phosphorous fertilizers concentrate in the Mississippi River where nitrate concentrations have doubled in the last century. The Mississippi River has continuously shown increased levels of eutrophication. Although it is difficult to distinguish the source of excess nutrients, urban lawns or agriculture, there is a clear link between the introduction of fertilizers and their impacts on watershed health (Bormann et al., 1993).

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Jenkins, Virginia Scott, *The Lawn A History of an American Obsession*
Kirsch, Kathleen M. Christensen, *Phytoremediation and Wastewater Effluent Disposal: Guidelines for Landscape Planners and Designers*
Malin, Nadav, *Restoring the Tall-Grass Prairie*
Mitchell, Martha S., *Choosing What to Plant*
Natural Resource Conservation Service, *Backyard Wetland*
Thompson, William T., "Let That Soak In," *Landscape Architecture*
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South Amazon Path, Eugene, Oregon, has been allowed to revert to a wildflower and grass meadow. It is mowed twice yearly.

THE AMERICAN LAWN REQUIRES A GREAT DEAL OF MAINTENANCE AND INCURS AN ENVIRONMENTAL COST

"In order to create and maintain the ideal lawn at its desired color, texture, and height we have brought the full weight of modern science to the task. Chemicals encourage or inhibit growth, water is redistributed and polluted, terrain is denuded, and machines mow incessantly" (Girling, Helphand, 1994 pg. 217).

Facts (Bormann et al., 1993)

- Lawnmowers pollute as much in one hour as driving 350 miles
- 30% - 60% of urban fresh water is used to water lawns
- $5,250,000,000 is spent annually on lawn fertilizers derived from fossil fuels
- 67,000,000 pounds of synthetic pesticides are used on US lawns each year
- 580,000,000 gallons of gas are used for lawnmowers each year
- $700,000,000 is spent on lawn pesticides
- Lawn pesticides are carried by stormwater runoff into nearby rivers
- 20,000,000 acres of the United States are planted in residential lawns
- Lawnmowers contribute to noise pollution

LOW MAINTENANCE AND NATIVE LANDSCAPES CAN MITIGATE STORMWATER POLLUTION

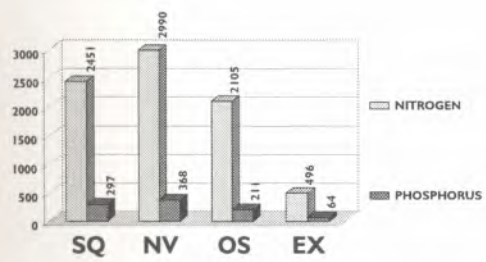
Vegetation in the landscape can contribute to stormwater management in a number of ways. Deep rooted vegetation such as trees, shrubs, and perennial bunchgrasses intercept rainfall by absorbing moisture through their roots and leaves. They also have the unique ability to capture stormwater-related pollutants and either store or degrade them before they reach natural water systems (Ferguson, 1998) (see Guideline 6.2).

Reductions in areas of high maintenance landscapes in favor of native low-maintenance landscapes can help reduce the amount of landscape-related pollutants entering natural systems. The default green land cover in urban areas tends to be the lawn. However, much of this lawn area lies unused, indicating that is unnecessary and could be replaced with water quality enhancing native landscapes. Native landscapes such as forests and meadows are consistently rated highly for attractiveness. People find

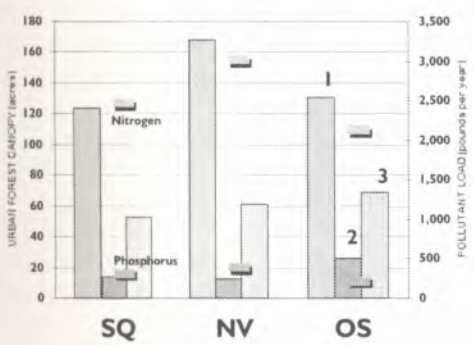
"The democratic symbolism of the lawn may be appealing, but it carries an absurd and, today, insupportable environmental pricetag. In our quest for the perfect lawn, we waste vast quantities of water and energy. Acre for acre, the American lawn receives four times as much chemical pesticide as any US farmland" (Michael Pollen, New York Times, 1991 as quoted in Cities and Natural Processes, Michael Hough, 1995).

natural areas to be both beautiful and restful (Kaplan and Kaplan, 1989). Appropriate native landscaping can enhance the visual appearance of urban landscapes while simultaneously mitigating the effects of pollutants being washed into local watersheds.

Public landscapes such as parks, roadways, public buildings, and storm water management facilities are ideal locations for native landscapes. Those that incorporate native planting such as forests, meadows, wetlands, vegetated swales, and ponds provide public amenities, habitat, and stormwater benefits while providing public demonstration and education opportunities. Such facilities contribute to the cleansing and slowing of stormwater runoff by allowing water to percolate in the ground and by incorporating plants that absorb fertilizer-based pollutants before they enter nearby streams and rivers (The University of Georgia, The School of Environmental Design, 1997). In essence, an integration of landscape design, stormwater management, and development opportunities can best serve people and the environment.



Annual water pollution load in pounds per year



1 IMPERVIOUS SURFACES

2 EXISTING FOREST CANOPY

3 NEW TREE CANOPY

COMPARING THREE NEIGHBORHOOD PLANS

In comparing the three West Corvallis plans, many factors influenced differences in stormwater-related performance. Most importantly, the contrast in total impervious surfaces and the dissimilarities between a piped drainage system with no water filtration on Status Quo and Neighborhood Village and a surface drainage system with extensive water filtration on Open Space. The greater urban forest cover and stormwater management practices of Open Space along with its lower volume of runoff overall yield significantly lower runoff-borne pollution.

There were significant differences between the total amounts of nitrogen and phosphorous estimated to be added after development. Status Quo and Neighborhood Village showed increases of 360 ◦/0 and 425% (respectively) of nitrogen and 400`)/0 and 500% of phosphorous over the existing site. Open Space showed less impact with increases in nitrogen of about 230% and phosphorous of 320 ◦/0. Vegetation played a significant role. Vegetated swales, stormwater ponds, and wetlands filtered 99 ◦/0 of the urban runoff on Open Space. At the same time, the more extensive natural areas had Little stormwater impact.

NOTES

Eugene, Oregon

guideline

6.1 REDUCE TURF AREAS

A reduction in turf area and its associated maintenance regimens could help improve water quality by eliminating chemical runoff from lawns and incorporating plants that slow and filter run-off before it enters natural water systems. Designers and landscape managers should consider alternatives such as groundcovers, meadows, perennials, shrubs, and trees. Landscapes that combine small amounts of lawn with other diverse plantings are beautiful and contribute to the overall health and character of a neighborhood.

6.1 GUIDELINE

"The lawn is the American garden, and grass is the nation's largest crop"

(Helphand, 1993)

Conventional

Meadow

Woodland

In a survey of 200 residents of Corvallis, Oregon, 85% preferred the appearance of the "woodland" front yard, whereas 30% liked the meadow and only 10% liked the conventional yard. (Rochefort, 1999).

As it is conventionally maintained in North America, turf grass or lawn adds excess nitrogen, phosphorous, herbicides, and pesticides to local waterways. Reducing the total acreage of lawn in favor of alternatives will help to mitigate this source of pollution. Lawn alternatives such as groundcovers, meadows, perennials, shrubs, and trees require little or no maintenance in the form of chemical treatments, have root systems that loosen soil so that water can infiltrate rather than run off, and add biodiversity to the ecosystem.

MAXIMIZE BENEFITS OF SHARED LANDSCAPE RESOURCES

• Use neighborhood common areas or parks as shared Lawns and concurrently encourage reductions in private residential lawns. As urban densities increase and lots grow smaller, shared play lawns can become both a necessity and an environmental advantage. Smaller yards with little or no lawn may be supplemented by common lawn areas in nearby play lots or parks. These "common areas" could serve as places for community play and social activities while providing a shared place for lawn-intensive activities. These resources could be managed by members of the community, homeowners associations, or by a maintenance service.

• Restore native landscapes in parks and public lands. Parks and public lands are ideal places for native landscape restoration projects. Underutilized areas of parks such as lawns not specified for sports or difficult to maintain areas, and other undeveloped public lands such as utility rights of way and roadway medians or verges, are examples of sites suited for native landscape restoration. A restoration project is intended to recreate the natural landscape by removing exotics and restoring native plant communities (Smith and Helmund, 1993). Studying other native vegetation in the area can serve as a guide for these types of projects. Native plant restoration reduces areas of maintained landscapes while providing valuable wildlife habitat.

REDUCE TURF AREA

• Evaluate how much lawn is really needed in the landscape. Lawns can provide a level surface for playing games, reading a book, or picnicking. An evaluation of how much lawn is needed for these types of activities

Using shrubs and ground covers, a green pathway is created alongside a parking lot in Eugene, Oregon.

may reveal that residential lawns can be reduced and still meet homeowner needs (Boorman et al., 1993). Other types of land covers such as fine gravel, moss, or groundcover can be alternative surfaces suited to residential yards.

• Utilize lawn alternatives. Meadow mixes that combine short bunchgrasses and wildflowers are available for all regions and for many different growing conditions. Bunchgrasses can take foot traffic, require only small amounts of water, require no fertilizer, and have deep roots that loosen soil and allow for greater infiltration of water. Wildflowers are beautiful, attract butterflies, require only annual mowing, give regional character, and add to local biodiversity. Groundcovers can be used as lawn alternatives and can often serve many of the same functions as traditional turf lawns. They offer the same uniformity and tidiness as turf lawn, but require far less maintenance. When locally appropriate species are selected, groundcovers thrive without the use of fertilizers, pesticides, and routine watering.

• Use trees, shrubs, and perennials to reduce lawn area. Small amounts of turf, meadow or groundcover bordered with perennials and shrubs adds year-round interest to the garden, promotes wildlife and species diversity, and absorbs excess water and pollutants from storm-related runoff. Although shrubs and trees require regular maintenance in the form of watering and pruning they generally don't require chemical intervention and provide a multitude of flowers, foliage, and scent to the landscape.

CHANGE LAWN MANAGEMENT PRACTICES

• Use non-chemical approaches to lawn maintenance. Careful selection of grass species along with selective management practices can greatly reduce the environmental detriments of traditionally managed lawns. When mowing the lawn set the blade for the greatest height possible. Longer blades of grass require less water. Use a mulching mower to chop and leave grass clippings on the ground to substitute for fertilizers. Hand-pull or allow some acceptable amounts of weeds, and water only in the early morning or late evening to avoid evaporation. Allowing lawns to sustain a natural cycle of dormancy —letting it go brown in dry-summer areas — will also reduce watering needs during dry times of the year (Bormann et al., 1993).

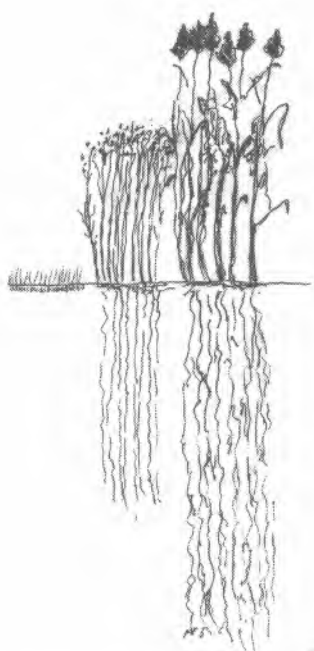
NOTES

Water Pollution Control Lab, Portland, Oregon.

guideline

6.2 USE PLANTS TO ABSORB AND FILTER URBAN RUNOFF

Landscaped areas provide opportunities for the cleansing and infiltration of stormwater. Deep-rooted plants help improve a soil's porosity so that runoff can more easily infiltrate the ground, while the leaves of plants collect, intercept, and absorb rain water before it reaches the ground. Whereas curb-and-gutter systems transport all urban stormwater with virtually no treatment, open vegetated swales, wetlands, and ponds filter pollutants, encourage groundwater recharge, and can reduce the volume of stormwater runoff generated from a site.



Turfgrass, shown on the far left, forms a dense, shallow-rooted mass that encourages runoff. In contrast, native bunch grasses have very deep roots that break up soils and absorb runoff.

USE PLANTS TO ABSORB AND FILTER URBAN RUNOFF

• Use plants to filter urban runoff and absorb and degrade pollutants. Plants are the most natural way to filter runoff. Whether they are lining an open channel, buffering a roadway, or growing in ponds, plants have an excellent capacity to absorb pollutants. Many plants have the ability to absorb excess nutrients, filter out sediments, and break down certain pollutants such as some petroleum products. Organic substances and excess nutrients such as those that wash off of lawns are readily absorbed by plants through water and nutrient uptake. As plants metabolize substances they are incorporated into the leaf or woody structure of the plant or degraded into water and gas.

Through the process of phytoremediation, plants are able to amend soil and water pollution (Kirsch, 1996). Following a toxic spill in southern Oregon, scientists from the University of Washington used hybrid poplars to absorb the toxins that would otherwise pollute groundwater and nearby wells. While it will take some time to collect data from this experiment, they created similar conditions in the laboratory using potted Poplar trees. Results demonstrated that the trees were able to remove 97% of the introduced toxins (www.sciam.com/1297issue/1297techbus4.html).

DESIGN STORMWATER GARDENS NOT LANDSCAPE MOUNDS

• Incorporate stormwater gardens or "bioretention facilities" into the landscape. Bioretention facilities are concave planting areas that clean stormwater and allow infiltration. Bioretention planting areas can be a collection of any plants that are hardy enough to treat pollutants and grow well without chemical interventions. They must be well-adapted to periodic inundation. These shallow planted areas can include trees, shrubs, perennials, and groundcovers. They may be a planted border around a lawn, the boundary between two properties, or a parking lot or road median. Since healthy, permeable soils are a critical component of these facilities, deep-rooted plants that break up soils are important.

• Allow concave landscaped areas. Municipalities may have to revise their landscape codes to allow landscaped areas that are curb-less and concave rather than convex in shape. Convex or mounded landscape areas contrib-

At Ecolonia, The Netherlands, street runoff passes through a mouse hole to dense wetland plants on its way to a stormwater pond that is the central feature of the community.

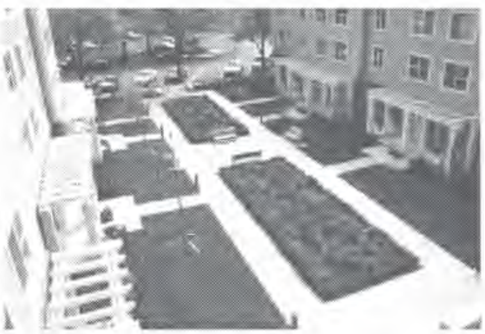
ute to stormwater runoff and pollution whereas concave landscaped areas planted with appropriate plants will help to reduce stormwater related impacts.

• Popularize stormwater gardens for residential uses. Just as lined decorative ponds have become popular recently, so could stormwater gardens become a positive garden feature. Governments should educate the landscape industry and the public about the benefits of disconnecting roof drains and directing them into stormwater gardens. In a residential setting much of the stormwater comes from rooftops. Directing rooftop runoff through a vegetated area before it reaches roads, pipes, and eventually drains into rivers can help reduce runoff volume by as much as 50°/0 (Scheuler, 1998). Careful design consideration must be given to ensure that runoff is directed away from the foundation of a house, and temporarily held so it can be cleaned and absorbed.

• Use other landscape elements such as stormwater ponds and wetlands to temporarily store, filter, and clean runoff from nearby lawns, rooftops, and pavement. Stormwater ponds are designed specifically to temporarily store and filter runoff. These features could easily replace plastic-lined ponds so popular today. Stormwater ponds and wetlands can be beautifully landscaped with grasses, shrubs, trees, and herbs that withstand both wet and dry periods. They attract wildlife, add regional and biodiversity to a site, and are generally considered to be valued amenities.

USE STORMWATER-ADAPTED PLANTS

• Select plants that are hardy to the site's unique growing conditions to ensure success. Plants that are well-adapted to periodic inundation as well as long dry spells are logical choices for stormwater facilities. Good root structure breaks up soils increasing permeability and allowing water to infiltrate. For example, riparian plants such as Redosier dogwood and many willows are ideal shrub species. Native bunchgrasses tend to have very large root systems with as much as 90 °/0 of the plant's biomass occurring below the ground (Environmental Building News, 1995). These massive root systems stabilize soils to prevent erosion, help plants survive dry periods, and contribute to stormwater infiltration.



Stormwater planters at Buckman Heights Apartments in Portland, Oregon collect runoff from roofs and the plaza for up to five year storm events. Over flow is directed to drywalls.

For stormwater management facilities there are common groups of plants that are uniquely appropriate to inundations and drought conditions. The following is a list of common trees, shrubs, herbs, and grasses. These plants will be listed by genus only as species vary from region to region.

Trees:

- *Acer* (Maple)
- *Fraxinus* (Ash)
- *Betula* (Birch)
- *Salix* (Willow)

Shrubs:

- *Corpus stolonifera* (Red Osier Dogwood, occurs throughout U.S.)
- *Amelanchier* (Serviceberry)
- *Salix* (Shrub willows)
- *Rosa* (Wild Rose)
- *Spirea* (Hardhack)

Herbaceous and Flowering Plants:

- *Iris* (could be considered a grass)
- *Mimulus* (Monkeyflower)
- *Ranunculus* (Buttercup)
- *Saggitaris* (Arrowhead)

Grasses:

- *Deschampsia* (Tufted Hairgrass)
- *Juncus* (Rushes)
- *Carex* (Sedges)
- *Festuca* (Fescues)

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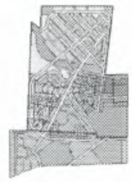
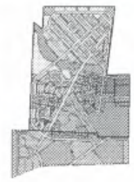
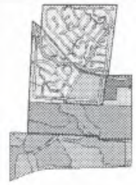
TABULAR RESULTS OF COMPARING THREE NEIGHBORHOOD PLANS

			
LAND USE MEASURES	**Status Quo SQ**	**Neighborhood Village NV**	**Open Space OS**
1 SCENARIO SUMMARY			
.1 LAND ALLOCATION	**311**	**311**	**311**
Public Open Space	36	35	80
Housing	146	124	120
Commercial	10	17	13
Civic	72	52	44
Public Streets and Paths	47	83	54
.2 DWELLING UNITS PROVIDED	**1134**	**1933**	**1864**
Total bedrooms	3564	4639	4623
.3 GROSS DENSITY	**3.64**	**6.21**	**5.99**
2 OPEN SPACE ALLOCATION			
.1 LAND ALLOCATED TO PUBLIC OPEN SPACE	**36**	**35**	**80**
Greenways	10	24	55
Wetlands	15	0	22
Parks	11	11	3
.2 PUBLIC OPEN SPACE PER DWELLING (in square feet)	**1,383**	**789**	**1,870**
3 HOUSING ALLOCATION			
.1 LAND ALLOCATED TO HOUSING (in acres)	**146**	**124**	**120**
.2 HOUSING TYPES (in dwelling units)	**1134**	**1933**	**1864**
Detached (<6 dua)	544	164	14
Detached (>6 <9 dua)	0	143	269
Detached (>9 dua)	104	224	482
Attached (>9 <20 dua)	0	401	337
Attached (>20 dua)	133	677	477
Stacked (>9 <20 dua)	0	72	57
Stacked (>20 dua)	353	0	0
Hybrid (>20 dua)	0	252	228
.3 HOUSING FLOOR AREA (in square feet)	**2,368,231**	**3,035,938**	**2,962,616**
.4 HOUSING NET DENSITY (dwellings per acre of housing land)	**8**	**16**	**16**
.5 HOUSING SITE AND FLOOR AREA PER DWELLING (in square feet)	**7,696**	**4,365**	**4,393**
Average housing floor area per dwelling	2,088	1,571	1,589

			
Average housing site area per dwelling	5,608	2,794	2,804
4 COMMERCIAL ALLOCATION			
.1 LAND ALLOCATED TO COMMERCIAL (in acres)	**9.9**	**17.0**	**13.0**
Land allocated to commercial only areas	9.9	14.0	7.0
Land allocated to commercial in mixed use areas	0.0	3.0	6.0
.2 LAND ALLOCATED TO COMMERCIAL BY TYPE			
Detached	0.2	2.5	2.0
Attached	9.7	14.1	10.6
Hybrid *	0.0	7.8	7.1
* includes land also assigned to housing			
.3 COMMERCIAL FLOOR AREA (in square feet)	163,208	286,775	220,877
.4 COMMERCIAL NET FLOOR AREA RATIO	0.38	0.40	0.40
.5 COMMERCIAL LAND AND FLOOR AREA PER DWELLING (in square feet)	**528**	**531**	**423**
Commercial floor area per dwelling	144	148	119
Commercial land area per dwelling	384	383	304
5 CIVIC ALLOCATION			
.1 LAND ALLOCATED TO CIVIC (in acres)	**72**	**52**	**44**
Fairgrounds / stadium	72	45	34
Schools	0	1	10
Churches	0	3	0
Daycares	0	3	0
.2 CIVIC FLOOR AREA (in square feet)	**258,286**	**205,852**	**169,157**
.3 CIVIC NET FLOOR AREA RATIO	**0.08**	**0.09**	**0.09**
.4 CIVIC LAND AND FLOOR AREA PER DWELLING (in square feet)	**2,994**	**1,278**	**1,119**
Civic floor area per dwelling	228	106	91
Civic land area per dwelling	2,766	1,172	1,028
6 STREETS AND PATHS ALLOCATION			
.1 LAND ALLOCATED TO PUBLIC STREET AND PATH R.O.W. (in acres)	**47**	**83**	**54**
Collectors	5	25	19
Locals	41	48	26
Local access lanes	0	0	5

				
5 URBAN FOREST				
.1 EXISTING FOREST CANOPY PRESERVED IN PUBLIC LAND (in acres)	14	13	26	2 7
% of existing	52%	48%	95%	100%
.2 FREESTANDING TREES PLANTED (in trees)	5,611	7,197	8,078	
In public open space and civic land	57	306	2,710	
In public street rights of way	2,375	4,385	2,585	
In private land	3,179	2,506	2,783	
Total freestanding tree canopy (in acres)	53	61	69	
TRANSPORTATION MEASURES	**SQ**	**NV**	**OS**	
1 TRANSPORTATION NETWORK HIERARCHY				
.1 NETWORK ELEMENT LENGTHS (in feet)	38,345	77,619	50,303	
Collectors	3,203	15,839	11,707	
Locals	32,911	38,867	20,944	
Local access lanes	0	0	9,970	
Alleys	2,231	22,913	7,682	
.2 DEDICATED NETWORKS (in feet)	148,050	247,157	202,578	
Dedicated automobile network	38,345	77,619	50,303	
Dedicated bicycle network	37,474	60,122	45,894	
Dedicated pedestrian network	72,231	109,416	106,381	
2 TRANSPORTATION NETWORK DESIGN				
.1 NETWORK CONNECTIVITY (intersections)	71	198	109	
3-way intersections	40	158	57	
4-way intersections	4	38	27	
Dead-ends	27	2	25	
.2 TRIP GENERATION	15,351	26,854	20,073	
.3 TRAFFIC VOLUMES (ADT)	15,351	26,854	20,073	
North bound trips	0	0	0	
South bound trips	3,088	5,406	4,119	
East bound trips	10,737	18,752	14,428	
West bound trips	1,526	2,696	1,526	
.4 COMPARATIVE TRAVEL COST (in seconds)				
Maximum time on automobile network to shopping	170	196	192	
Maximum time on bicycle network to shopping	382	316	369	
Maximum time on pedestrian network to shopping	1226	1162	1188	

Average time on automobile network to shopping	91	104	104
Average time on bicycle network to shopping	203	168	157
Average time on pedestrian network to shopping	718	660	615
UTILITY INFRASTRUCTURE MEASURES	**SQ**	**NV**	**OS**
1 STORMWATER NETWORK			
.1 STORMWATER NETWORK ELEMENTS	**33,018**	**50,082**	**52,735**
Major trunk	394	1,386	0
Minor trunk	1,113	832	0
Major collector	10,311	14,639	2,659
Minor collector	21,200	33,225	39,135
Grass swales	0	0	10,941
2 SANITARY SEWER NETWORK			
.1 SANITARY SEWER NETWORK ELEMENTS	**34,700**	**47,725**	**43,131**
Trunk (in feet)	4,017	6,193	4,728
Collector (in feet)	29,977	40,140	37,239
Laterals (connections)	706	1,392	1,164
3 WATER SUPPLY NETWORK			
.1 WATER SUPPLY NETWORK ELEMENTS	**34,603**	**52,706**	**45,757**
Major distribution pipe (in feet)	3,981	6,738	3,836
Minor distribution pipe (in feet)	29,916	44,576	40,757
Building service (connections)	706	1,392	1,164
INFRASTRUCTURE COST MEASURES	**SQ**	**NV**	**OS**
1 TOTAL INFRASTRUCTURE COST	**$18,212,610**	**$32,033,902**	**$26,211,993**
TOTAL INFRASTRUCTURE COST PER DWELLING	**$16,061**	**$16,572**	**$14,062**
1.0 COST OF LAND ALLOCATED TO INFRASTRUCTURE	**$1,660,000**	**$2,360,000**	**$2,688,000**
2.0 INFRASTRUCTURE EMPLACEMENT COSTS	**$0**	**$0**	**$0**
3.0 INFRASTRUCTURE ANNUAL MAINTENANCE COSTS	**$425,025**	**$739,081**	**$646,074**
4.0 INFRASTRUCTURE EMPLACEMENT COSTS / DWELLING	**$14,597**	**$15,351**	**$12,624**
5.0 INFRASTRUCTURE ANNUAL MAINTENANCE COSTS / DWELLING	**$375**	**$382**	**$345**
2 PUBLIC OPEN SPACE AND URBAN FOREST COST	**$1,496,860**	**$2,191,706**	**$3,240,988**
Cost of land allocated to public open space	$720,000	$700,000	$1,600,000

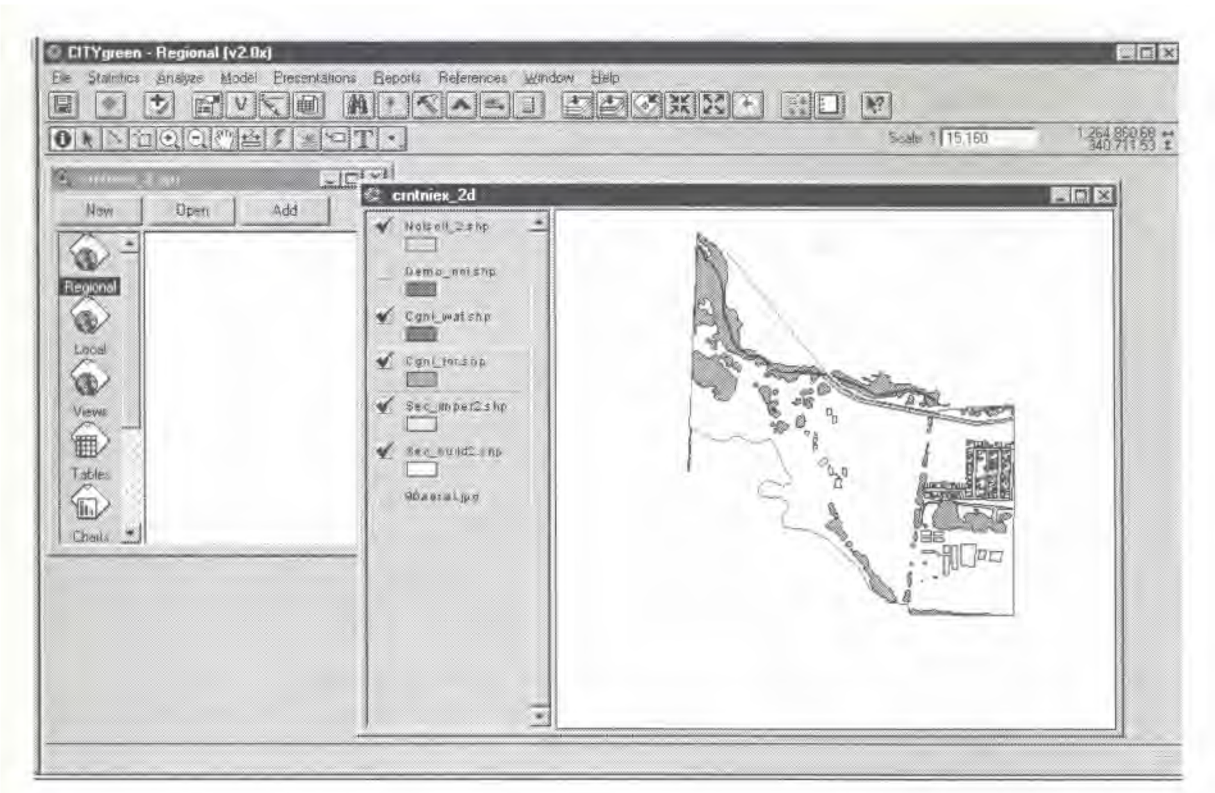
			
Cost of turf emplacement in public streets	$64,360	$98,206	$62,988
Cost of tree emplacement in public open space	$0	$81,000	$772,500
Cost of tree emplacement in public streets	$712,500	$1,312,500	$805,500
1.0 COST OF ANNUAL TREE MAINTENANCE IN PUBLIC SPACE	**$3,973**	**$7,709**	**$8,192**
Cost of freestanding trees in public open space annual maintenance	$0	$1,600	$3,916
Cost of freestanding trees in public streets annual maintenance	$3,716	$5,716	$4,026
Cost of turf in public streets annual maintenance	$257	$393	$250
2.0 COST OF OPEN SPACE LAND AND TREE EMPLACEMENT / DWELLING	**$635**	**$404**	**$1,272**
Cost of public open space land per dwelling	$635	$362	$858
Cost of freestanding tree emplacement in public open space per dwelling	$0	$42	$414
3.0 COST OF PUBLIC OPEN SPACE TURF AND TREE ANNUAL MAINTENANCE PER DWELLING	**$4**	**$3**	**$2**
Cost of tree emplacement in public streets per dwelling	$3	$3	$2
Cost of turf emplacement in public streets per dwelling	$1	$0	$0
3 TRANSPORTATION NETWORK COST			
1.0 COST OF LAND ALLOCATED TO PUBLIC STREETS AND PATHS	**$940,000**	**$1,660,000**	**$1,080,000**
2.0 COST OF PUBLIC STREETS AND PATHS EMPLACEMENT	**$6,637,680**	**$13,384,556**	**$9,094,430**
Collector/Arterial	$762,314	$4,283,118	$3,435,754
Local on Grade	$3,927,300	$4,587,804	$2,545,920
Alleys (paved)	$178,480	$1,833,040	$1,511,860
PCC sidewalk (5')	$1,263,990	$1,914,710	$1,142,785
Curb and gutter	$505,596	$765,884	$458,111
3.0 COST OF PUBLIC STREETS AND PATHS ANNUAL MAINTENANCE	**$79,915**	**$174,311**	**$121,751**
Collector/Arterial	$10,890	$61,187	$49,082
Local on Grade	$65,455	$76,463	$42,432
Alleys (paved)	$3,570	$36,661	$30,237
4.0 COST OF PUBLIC STREETS AND PATHS EMPLACEMENT PER DWELLING	**$6,682**	**$7,783**	**$5,458**
Cost of land for streets and paths	$829	$859	$579
Cost of streets and paths emplacement	$5,853	$6,924	$4,879
5.0 COST OF PUBLIC STREETS AND PATHS ANNUAL MAINTENANCE PER DWELLING	$70	$90	$65
4 STORMWATER NETWORK COST			
1.0 COST OF STORMWATER NETWORK EMPLACEMENT	**$2,683,600**	**$4,169,175**	**$3,452,760**
Major collector pipe	$866,124	$1,229,676	$223,356

			
Minor collector pipe	$1,505,200	$2,358,975	$2,778,585
Major trunk pipe	$125,292	$440,748	$0
Minor trunk pipe	$186,984	$139,776	$0
Grass swale	$0	$0	$311,819
Major pond	$0	$0	$54,000
Minor pond	$0	$0	$85,000
2.0 COST OF STORMWATER NETWORK ANNUAL MAINTENANCE	**$37,971**	**$57,595**	**$83,645**
Major collector pipe	$11,858	$16,835	$3,058
Minor collector pipe	$24,380	$38,209	$45,005
Major trunk pipe	$453	$1,594	$0
Minor trunk pipe	$1,280	$957	$0
Grass swale	$0	$0	$12,582
Major pond	$0	$0	$6,000
Minor pond	$0	$0	$17,000
3.0 COST OF STORMWATER NETWORK EMPLACEMENT PER DWELLING	**$2,366**	**$2,157**	**$1,852**
4.0 COST OF STORMWATER NETWORK ANNUAL MAINTENANCE PER DWELLING	**$33**	**$30**	**$45**
5 SANITARY SEWER NETWORK COST			
1.0 COST OF SANITARY SEWER NETWORK EMPLACEMENT	**$3,321,840**	**$5,394,245**	**$4,683,465**
Trunk pipe	$261,105	$402,545	$307,320
Collector pipe	$1,648,735	$2,207,700	$2,048,145
Laterals	$1,412,000	$2,784,000	$2,328,000
2.0 COST OF SANITARY SEWER NETWORK ANNUAL MAINTENANCE	**$137,936**	**$220,233**	**$192,218**
Trunk pipe	$10,043	$15,483	$11,820
Collector pipe	$74,943	$100,350	$93,098
Laterals	$52,950	$104,400	$87,300
3.0 COST OF SANITARY SEWER NETWORK EMPLACEMENT PER DWELLING	**$2,929**	**$2,791**	**$2,513**
4.0 COST OF SANITARY SEWER NETWORK ANNUAL MAINTENANCE PER DWELLING	**$122**	**$114**	**$103**
6 WATER SUPPLY NETWORK COST			
1.0 COST OF WATER SUPPLY NETWORK EMPLACEMENT	**$3,132,630**	**$5,234,220**	**$4,459,940**
Major distribution pipe	$278,670	$471,660	$268,520
Minor distribution pipe	$1,794,960	$2,674,560	$2,445,420
Building service	$1,059,000	$2,088,000	$1,746,000

			
2.0 COST OF WATER SUPPLY NETWORK ANNUAL MAINTENANCE	$165,231	$279,222	$238,539
Major distribution pipe	$11,943	$20,214	$11,508
Minor distribution pipe	$89,748	$133,728	$122,271
Building service	$63,540	$125,280	$104,760
3.0 COST OF WATER SUPPLY NETWORK EMPLACEMENT PER DWELLING	$2,762	$2,708	$2,393
4.0 COST OF WATER SUPPLY NETWORK ANNUAL MAINTENANCE PER DWELLING	$146	$144	$128

CITYGREEN 2.0 METHODOLOGY

CITYgreen developed by American Forests is an extension of the GIS application ArcView The application maps and analyzes urban ecosystems for the beneficial impacts of urban forests on air and water quality. Using a series of datalayers, CITYgreen combines urban ecological information to measure the impacts of growth and development. An analysis of a site begins with using an aerial photo underlay to map existing land use features. Using that as a baseline for measurement another map is created to show proposed features including buildings, pavement, roads, trees, and groundcover. This information is compiled in a database to be used for analysis and interpretation.



An example of mapped features of the existing site

CITYgreen specifically measures urban run-off using the National Resource Conservation Service's (NRCS) TR55 as a calculation method. The procedures and formulas for this calculation were then adopted by CITYgreen and the Natural Resource Conservation Service to account for the impacts of urban forests. After the mapping and statistics are done CITYgreen combines "land cover percentages with average precipitation data, rainfall distribution information, percent slope, hydrologic soil group, and swamp factor to estimate how trees affect runoff volume, time of concentration, and peak flow. In addition, the program estimates the volume of water, in cubic feet, that would have to be detained if trees were removed" (CITYgreen User's Manual). CITYgreen also measures water quality, air quality, and energy savings as a result of increased tree canopy on a site.

Curve Numbers: CN (weighted) = Total Product of (CN x Percent land cover area) / Total Percent Area or 100

Potential Maximum Retention after Runoff begins: $S = ((1000 / CN) - 10)$

Runoff Equation: $Q = [P - 0.2((1000 / CN) - 10)]^2 / P + 0.8((1000 / CN) - 10)$

Flow Length: $F = (\text{total study area acres}^{0.6}) * 209.0$

Lag Time: $L = ((F^{0.8}) * ((S + 1.0)^{0.7}) / (1900 * ((\text{slope})^{0.5})))$

Time of Concentration: $Tc = 1.67 * L$

Unit Peak Discharge: $\log(qu) = C_0 + C_1 \log(Tc) + C_2[\log(Tc)]^2$

Peak Flow: $\text{Peak} = (qu * Am * Q * Fp)$

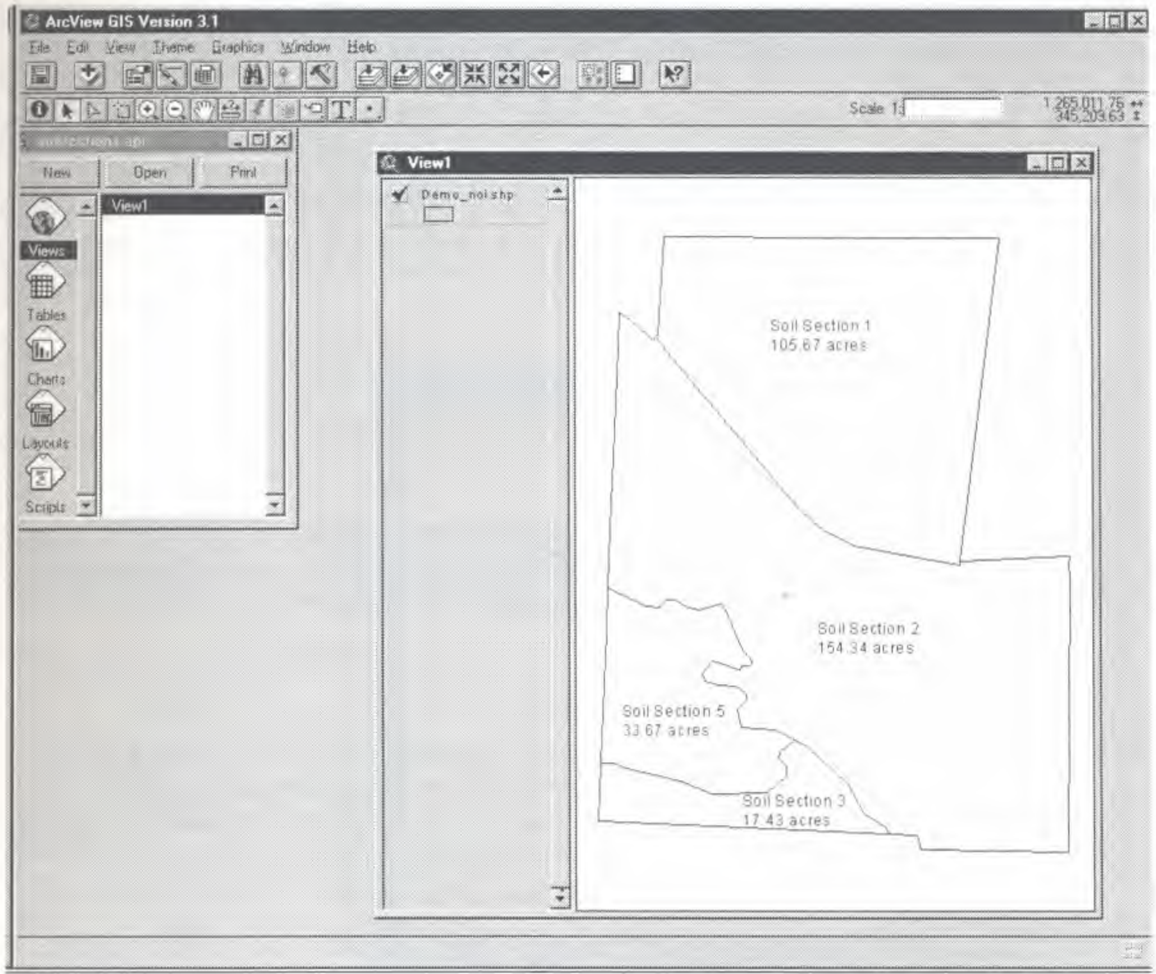
Storage Volume: $Vs = Vr * (C_0 + (C_1(qo/qi)) + (C_2((qo/qi)(qo/qi))) + (C_3(qo/qi) * (qo/qi) * (qo/qi))) * \text{study area acres} * 43560.17 / 12$

Q = Runoff (inches)
P = Average Rainfall for a 24 hour period (inches)
CN = Runoff Curve Number (weighted)
F = Flow length (feet)
S = Potential Maximum Retention after Runoff begins (in)
L = Lag Time (hours)
Tc = Time of Concentration (hours)
qu = Unit Peak Discharge (csm / in)
Peak = Peak Flow (cfs)
Am = study area acres / 640 to determine square miles
Fp = Swamp pond percentage adjustment factor
Vs = Storage volume (cubic feet)
Vr = Runoff Volume (in)
qo =Existing peak flow condition with trees
qi = Peak flow without trees
$C_0 \ldots$ = TR 55 Coefficents in accordance with raintype

Taken from The CITYgreen Manual these numbers describe the TR55 formula

The Center for Housing Innovation uses the stormwater run-off calculations as our primary method of measuring the way development affects run-off quantities. We also use CITYgreen to get a preliminary idea of how tree planting affects pollutants in the air and water. For the purposes of this study we will not use the energy savings feature of the CITYgreen analysis.

The CITYgreen software is capable of analysis at two general scales; regional and local. The regional analysis is designed to analyze large areas using satellite imagery. The Local analysis is designed to measure small areas including neighborhoods, blocks, or even individual lots. The scale of our study area falls between the regional and local categories. To make the analysis more accurate and more in keeping with a smaller (local) scale, we have divided our site into four discreet study areas that are defined by their soil hydrology class and slope.

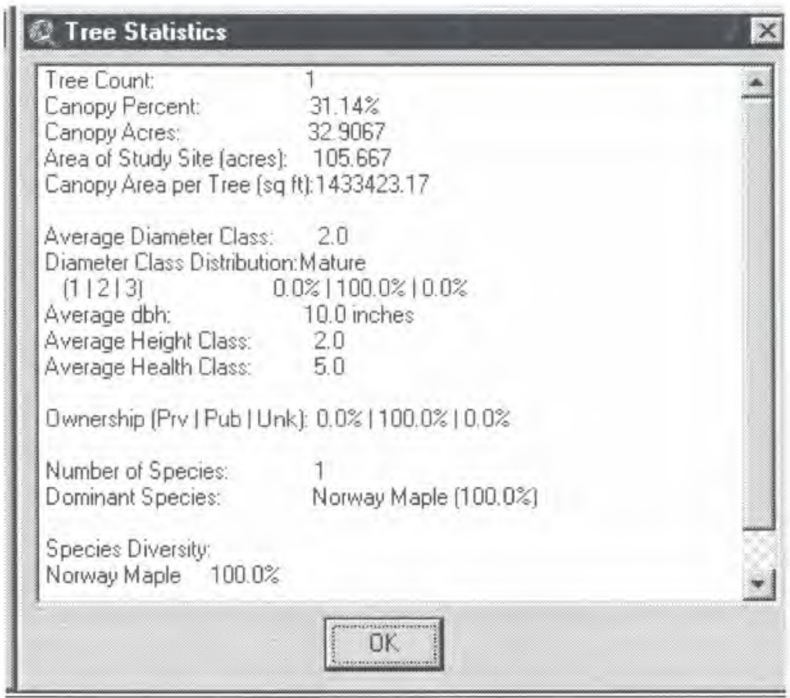


The entire site divided into four soil section

The Center for Housing Innovation use CITYgreen to measure the impacts of three different development scenarios for a 311 acre site in Corvallis, Oregon. Estimates of roof cover, pavement, and street trees was extrapolated from the NEC database and applied to the site to simulate different neighborhood types. We make certain assumptions about tree size based on projected sizes at full growth, and how these trees behave in urban conditions. Given that certain trees don't reach full maturity in urban conditions, we use a 2/3rds growth projection to determine tree size. Tree types are grouped into small (less than 30'), medium (30 - 60') and large(over 60'). In situations where we don't what type of street tree is used in a case study, we determine which size category it best fits and use an average size.

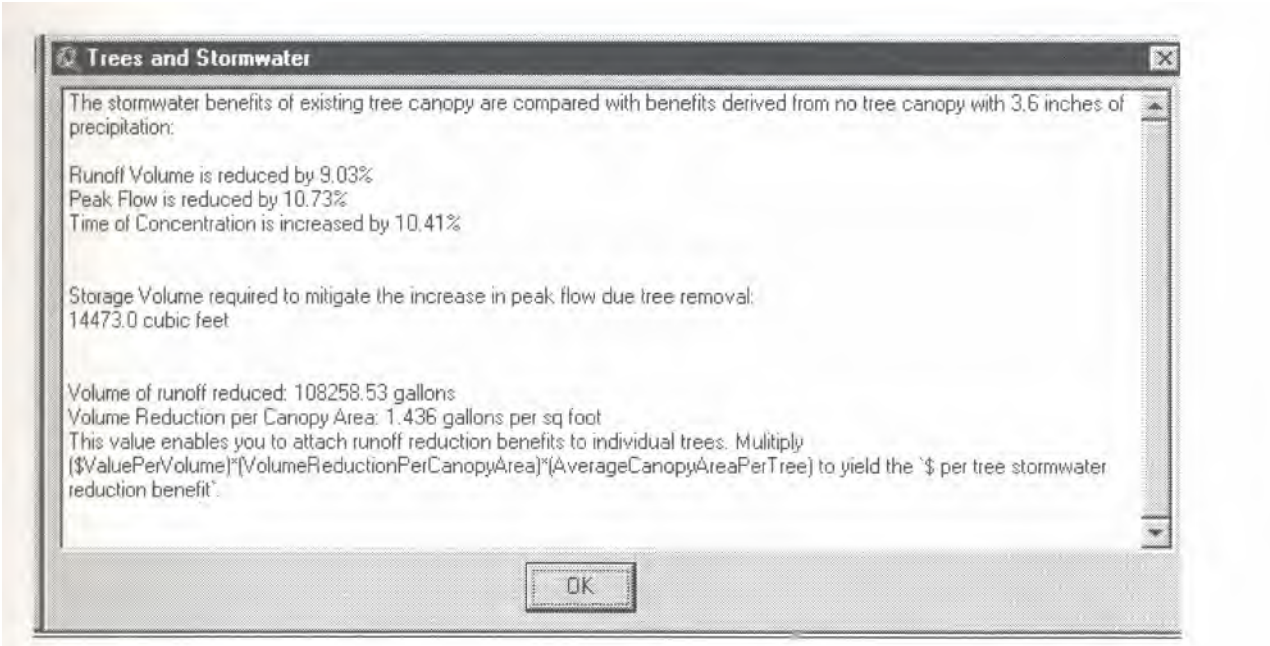
Forest cover is measured in overall canopy size rather than by the numbers of individual trees. After much consideration, we have determined that since forested areas are often very dense it is unrealistic to identify each tree from an air photo and beyond the scope of this project to do field work. All land features, forest cover, street tree cover, ponds, buildings and pavement areas are mapped and drawn using AutoCad. These AutoCad drawings were then converted to ArcView layers. ArcView in this application is primarily used to estimate areas of land cover and tree canopy in square feet and acres. From there the CITYgreen analysis begins.

Once the data layers are made CITYgreen calculates the percent cover of tree canopy, water, and pervious and impervious cover. We like to differentiate between forest canopy and street tree cover, so we gather those statistics separately and then combine them later in the analysis process. Once the land cover statistics are gathered we begin a stormwater runoff analysis based on a ten year storm event and assuming 4.0 inches of rain for a 24 hour period in Corvallis, Oregon.



Statistics on amount of canopy coverage

CITYgreen has been particularly useful in estimating stormwater run-off (calculating peak flows and time of concentration) for the three alternative plans. The results of the CITYgreen analysis has enabled us to compare the three plans and determine how each of the different development scenarios affect stormwater quantities relative to the existing undeveloped site. The statistics table allows us to compare each different type of land cover so that we can make some inferences about how different combinations of trees, or pavement, or rooftop affects run off. These results can be transferred to a spread sheet program and be created and compared to give a clear understanding of overall trends in peak flow based on the three different development scenarios.



Information about stormwater discharge

CITYgreen presents a number of limitations for our project. Since the scale of our project does not fall into the category of regional or local scale we have had to adapt the site specific methodology to suit our larger sites. This has involved representation of pavement, building, tree and forest, and water cover as summary polygons laid over the neighborhood plans. This detailed information does not yet exist, but has been estimated.

It has been difficult to accurately create and map a plant palette that is appropriate for our site in the Pacific Northwest. CITYgreen currently requires that you select plants from a plant list that is built into the program. The plant palette that CITYgreen offers reflects a bias towards plants found predominately in the hardwood forests of the east coast of the United States. Many of the trees that define the Pacific Northwest are not included. The trees have a size code that has a maximum number that is not big enough to accurately describe the trees found in Pacific Northwest forests.

Vegetation cover in CITYgreen accounts for trees and turf. A rich shrub layer can have a significant impact on stormwater management, yet CITYgreen does not calculate shrubs as a specific vegetation type. Additionally, groundcovers can not be distinguished from turf.

CITYgreen does not differentiate between evergreen and deciduous trees. Evergreen trees are a significant tree type in the Pacific Northwest. Since most of the rainfall in Corvallis is in winter this can have a consequential effect on stormwater runoff and peak flow. Evergreen trees, therefore, can have a significant effect on the amount of canopy cover a site has during the winter months and thus stormwater runoff. CITYgreen is biased to east coast conditions where they receive most of their rainfall in summer when the trees are leafed out, again our rainfall occurs in winter when many trees have lost their leaves.

In conclusion CITYgreen has proven to be a useful tool for certain aspects of this project. It has enabled us to measure and compare stormwater quantity of our three different development scenarios. We must, however, warn that the stormwater runoff numbers, while clearly informative as comparisons, cannot be seen as accurate estimates of the increases in runoff that this site will incur after development.

WATER QUALITY: SIMPLIFIED URBAN NUTRIENT OUTPUT MODEL (SUNOM)

Assessing the water quality of stormwater runoff is an important measurement in determining ecological impacts of urban growth. Currently, there are many stormwater models on the market for determining stormwater quality. Stormwater models vary greatly in sophistication, cost, the amount of information needed for input, and the type of material and time available for running the model. After reviewing a host of stormwater models, such as the TR-55 method, City Green, and other GIS models, we have chosen a spreadsheet based loading model called the Simplified Urban Nutrient Output Model (SUNOM) for our water quality measurements.

The Center for Watershed Protection (CWP) developed SUNOM in 1998, to compute pollution export loads in stormwater runoff. The CWP specifically developed this model to compare water quality among alternative development scenarios, exactly what our project intended to evaluate.

The Simplified Urban Nutrient Output Model (SUNOM) computes annual nutrient loads for a site in pounds/year. It is based on the Simple Method, another model developed by the Center for Watershed Protection. The Simple Method is designed to get a quick and easy estimation of pollutant exports from urban development sites, smaller than a square mile. The Simple Method is based on the simple empirical relationship between annual rainfall, impervious cover, and estimated pollutant loads per impervious cover type.

SUNOM uses the same empirical relationship as the Simple Method for calculating nutrient export from sites. However, SUNOM then adjusts this number to reflect the mean removal capacity of best management practices (BMPs) incorporated into designs. BMPs can both reduce nutrient loads and increase infiltration.

"The subsurface component of the model utilizes annual subsurface recharge rates (based on the site's prevailing hydrologic soil group) and monitored baseflow nutrient concentrations in the receiving waters to estimate the annual subsurface nutrient export from urban areas. This figure is then adjusted to reflect conditions of a site that cannot recharge (such as impervious cover) and areas that are hindered from inf—ltrating by other conditions (such as compacted gravel)" (CWP, pS).

SUNOM measures phosphorus and nitrogen output levels (lbs./yr.) of a site, land use coverage (°/0 of different land covers), runoff and infiltration (in./yr.), and infrastructure, BMP, and landscaping costs. For our project we are primarily using SUNOM to determine nitrogen and phosphorus output levels for the Corvallis site. This model not only measures nutrient loads for a site, it also breaks down the amount of nutrients exported without BMPs and with BMPs of a plan, making the benefits of BMPs interpretable. We ran the model on the existing site, the Status Quo plan, the Neighborhood Village plan, and the Open Space plan, then compared the amount of nitrogen and phosphorus loads exported from each of these plans.

DATA needed for the model:
SUNOM is a spreadsheet based loading model that requires three types of data; general site data, land cover data, and stormwater BMP data from each plan.

1. This first data type, general site data, was the site's total site area (sq. ft.) and annual rainfall (in./yr.). This information was entered on the Site Data sheet.

2. Land cover data (sq. ft.) was the second type of data. Land cover data includes the following categories: forest/wetland, meadow, lawn, pervious surfaces, rooftops, parking lot, other impervious area, road, and sidewalk. When entering the forest/wetland, meadow, lawn, and pervious surfaces' data, the soil type needs to be included. The total surface area of ponds/wetlands and other BMPs (swales, channels, and infiltration data) are also included in the land cover data. This information was entered on the Site Data sheet.

3. Stormwater BMP data was the final type of data needed. The type of BMP used, the fraction runoff from natural areas captured by this BMP, the fraction of runoff from urban areas captured by this BMP, and the fraction of all total rainfall that is captured by this BMP was calculated and entered into the model. This information was entered on the BMP sheet.

Data used for the Corvallis project: CHI generated all the general and land cover data, except the annual rainfall measurements, from the CHI lab's Elements of Neighborhood's database. For each plan, a variety of case studies (from the NEC data base) were assigned to each plan. We extrapolated information, such as building, paving, turf, road, other impervious, forest, wetland, and water coverage, from each case study (NEC database) based on soil type. This information was summarized in excel spreadsheet format. These numbers were then entered into the Site Data sheet on SUNOM. We broke the information into soil type for each plan, because it makes it easier for the next step, determining BMPs, however, it is not necessary for this step to separate case studies by soil type.

Rainfall data came form the Oregon Climate Service's webpage. We used 42.71 in/year for Corvallis' average precipitation. This average is based upon data recorded from 19611990.

Stormwater BMP data came from analyzing the site's stormwater system. We determining the size of BMPs used for the plans, what type of land use drained into them, and what size storm they are designed for. All BMPs on the Open Space plan are assumed to hold a two year storm. BMPs used for this plan were; dry ponds, wetlands, swales, and forest lands. No BMPs are included in the Status Quo and Neighborhood plan. However, forest/wetland areas exist on these sites, allowing for information to be entered in these categories for the BMP data.

Reference for SUNOM:

Center for Watershed Protection. 1998. *Nutrient Loading from Conventional and Innovative Site Development.* Silver Spring, MD: Chesapeake Research Consortium.