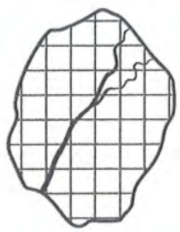
Design Concepts and the Environment. Town Planning Commission Presentation Handouts. September 2009.

Storm-Water Management and Residential Street Design

EXHIBIT 8: Time Series Build-out Analysis: Build-out in 2000

Scenario A	Scenario B	Scenario C
		
10,000 houses on 10,000 acres at a density of *1 house per acre* consume 1 entire watershed.	10,000 houses on 2,500 acres at a density of *4 houses per acre* consume ¼ of 1 watershed.	10,000 houses on 1,250 acres at a density of *8 houses per acre* consume ⅛ of 1 watershed.

As previously demonstrated in Example 3, building at higher densities consumes, or converts, less land within the watershed. Scenario A, developing at one unit per acre, requires the entire 10,000-acre watershed to accommodate 10,000 houses. Scenario C, on the other hand, developing at eight units an acre, requires significantly less land to accommodate the same amount of development.

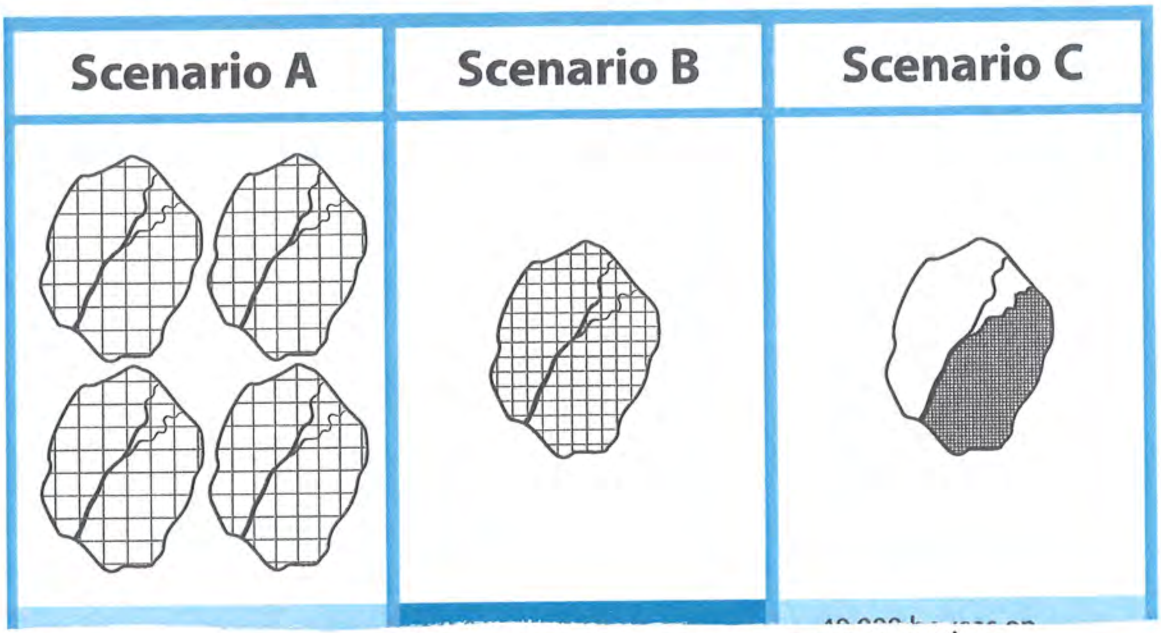
EXAMPLE 7: TIME SERIES BUILD-OUT ANALYSIS: BUILD-OUT IN 2020

Scale of Analysis	Scenario A	Scenario B	Scenario C
Hypothetical build-out in the year 2020	20,000 houses built on 20,000 acres, or 2 watersheds	20,000 houses built on 5,000 acres, or ½ of 1 watershed	20,000 houses built on 2,500 acres, or ¼ of 1 watershed

Fast-forwarding 20 years, the population in the hypothetical community has doubled from 10,000 houses to 20,000 houses. Each scenario must accommodate this additional growth at different development densities. Exhibit 9 demonstrates how this development might look.

The hypothetical community continues to grow and, in another 20 years, population has doubled again, requiring each scenario to accommodate 20,000 more homes at different development densities. Exhibit 10 demonstrates how this development might look.

EXHIBIT 10: Time Series Build-out Analysis: Build-out in 2040



As Exhibit 9 demonstrates, Scenario A, developing at one house per acre, requires another whole watershed to accommodate the additional growth. Scenarios B and C, developing at higher densities, can accommodate the additional growth within the same watershed. Moreover, by developing at higher densities within the watershed, ample open space or otherwise undeveloped land remains to perform critical watershed functions. No such land exists in Scenario A, and, as previously discussed, lawns typically associated with one house per acre are not able to provide the same type of watershed services as forests, meadows, or other types of unconverted land.

EXAMPLE 8: TIME SERIES BUILD-OUT ANALYSIS: BUILD-OUT IN 2040

Scale of Analysis	Scenario A	Scenario B	Scenario C
Hypothetical build-out in the year 2040	40,000 houses built on 40,000 acres, or 4 watersheds	40,000 houses built on 10,000 acres, or 1 watershed	40,000 houses built on 5,000 acres, or ½ of 1 watershed

surfaces at the site level. They believe that limiting densities within particular development sites limits regional imperviousness and thus protects regional water quality. The next section examines this proposition and finds that low-density development can, in fact, harm water quality.

Low-Density Development—Critiquing Conventional Wisdom

As discussed, studies have demonstrated that watersheds can suffer impairment at 10 percent impervious cover and that at 25 percent imperviousness, the watershed is typically considered severely impaired. Communities have often translated these findings into the notion that low-density development at the site level results in better water quality. Such conclusions often come from analysis such as: a one-acre site has one or two homes with a driveway and a road passing by the property. The remainder of the site is lawn. Assuming an average housing footprint of 2,265 square feet[4] (National Association of Home Builders, 2001), the impervious cover for this one-acre site is approximately 35 percent (Soil Conservation Service, 1986). By contrast, a higher-density scenario might have eight to 10 homes per acre and upwards of 85 percent impervious cover (Soil Conservation Service, 1986). The houses' footprints account for most of the impervious cover. Thus, low-density zoning appears to create less impervious cover, which ought to protect water quality at the site and regional levels. However, this logic overlooks several key caveats.

1. *The "pervious" surface left in low-density development often acts like impervious surface.* In general, impervious surfaces, such as a structure's footprint, driveways, and roads, have higher amounts of runoff and associated pollutants than pervious surfaces. However, most lawns, though pervious, still contribute to runoff because they are compacted. Lawns are thought to provide "open space" for infiltration of water. However, because of construction practices, the soil becomes compacted by heavy equipment and filling of depressions (Schueler, 1995, 2000). The effects of this compaction can remain for years and even increase due to mowing and the presence of a dense mat of roots. Therefore, a one- or two-acre lawn does not offer the same infiltration or other water quality functions as a one- or two-acre undisturbed forest. Minimizing impervious surfaces by limiting the number of houses but allowing larger lawns does not compensate for the loss of watershed services that the area provided before development (USDA, 2001).

   Lawns still contribute to runoff because they are compacted and disturbed.

2. *Density and imperviousness are not equivalent.* Depending on the design, two houses may actually create as much imperviousness as four houses. The impervious area per home can vary widely due to road infrastructure, housing design (single story or multistory), or length and width of driveways. To illustrate, a three-story condominium building of 10 units on one acre can have less impervious surface than four single-family homes on the same acre. Furthermore, treatment of the remaining undeveloped land on that acre can

[4] The average house built in 2001 included three or more bedrooms, two and a half baths, and a two-car garage.

vary dramatically between housing types. For example, in some dispersed, low-density communities, such as Fairfax County, Virginia, some homeowners are paving their front lawns to create more parking for their cars (Rein, 2002).

3. *Low-density developments often mean more off-site impervious infrastructure.* Development in the watershed is not simply the sum of the sites within it. Rather, total impervious area in a watershed is the sum of site developments plus the impervious surface associated with infrastructure supporting those sites, such as roads and parking lots. Lower-density development can require substantially higher amounts of this infrastructure per house and per acre than denser developments. Recent research has demonstrated that on sites with two homes per acre, impervious surfaces attributed to streets, driveways, and parking lots can represent upwards of 75 percent of the total site imperviousness (Cappiella, 2001). That number decreases to 56 percent on sites with eight homes per acre. This research indicates that low densities often require more off-site transportation-related impervious infrastructure, which is generally not included when calculating impervious cover.

   Water quality suffers not only from the increase in impervious surface, but also from the associated activities: construction, increased travel to and from the development, and extension of infrastructure.

   Furthermore, water quality suffers not only from the increase in impervious surface, but also from the associated activities: construction, increased travel to and from the development, extension of infrastructure, and chemical maintenance of the areas in and surrounding the development. Oil and other waste products, such as heavy metals, from motor vehicles, lawn fertilizers, and other common solvents, combined with the increased flow of runoff, contribute substantially to water pollution. As imperviousness increases, so do associated activities, thereby increasing the impact on water quality.

4. *If growth is coming to the region, limiting density on a given site does not eliminate that growth.* Density limits constrain the amount of development on a site but have little effect on the region's total growth (Pendall, 1999, 2000). The rest of the growth that was going to come to the region still comes, regardless of density limits in a particular place. Forecasting future population growth is a standard task for metropolitan planning organizations as they plan where and how to accommodate growth in their region. They project future population growth based on standard regional population modeling practices, where wage or amenity differentials, such as climate or culture (Mills, 1994)—and not zoning practices such as density limits—account for most of a metropolitan area's population gain or loss.[5] While estimates of future growth within a particular time frame are rarely precise, a region must use a fixed amount of growth to test the effects of adopting

   Growth is still coming to a region, regardless of density limits in a particular place.

[5] The most widely-used such model—the REMI® Policy Insight™ model—uses an amenity variable. However, even this is implemented as an additional change in the wage rate. See Remi Model Structure. <www.remi.com/Overview/Evaluation/Structure/structure.html>. The in-house model used by the San Diego Association of Governments is an advanced example of the type used by councils of governments around the country.<www.sandag.cog.ca.us/resources/demographics_and_other_data/demographics/forecasts/index.asp>.

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

***Figure 1-8:** Stormwater facilities filter sediments and other pollutants in runoff; which results in improved water quality.*

SOURCE: NEVUE NGAN ASSOCIATES

***Figure 1-9:** Stormwater facilities slow the flow of stormwater runoff through the interaction of the water with plants and soil.*

SOURCE: KEVIN ROBERT PERRY - CITY OF PORTLAND

***Figure 1-10:** Stormwater facilities collect and absorb stormwater to reduce the overall volume of runoff.*

The Three Stormwater Management Goals

Sustainable stormwater design should achieve the following three goals to the greatest extent possible:

Water Quality Goal

Stormwater facilities should filter and **remove** excess sediments and other pollutants from runoff. By allowing water to interact with plants and soil, water quality improvements are achieved through a variety of natural physical and chemical processes. Even if soils are not conducive to infiltration, or if there is a high water table, water quality is still enhanced through pollutant settling, absorption into the soil, and uptake by plants.

Flow Reduction Goal

Stormwater facilities should **slow** the velocity of runoff by detaining stormwater in the landscape. Flow rate reduction can often be achieved by integrating design strategies (such as pervious paving, planter boxes, swales, and rain gardens) that provide stormwater detention. By detaining and delaying runoff, peak flow rates are attenuated and downstream creeks are protected from erosive flows. Conveying runoff through a system of naturalized surface features mimics the natural hydrological cycle and minimizes the need for underground drainage infrastructure.

Volume Reduction Goal

Whenever possible, facilities should collect and **absorb** stormwater to reduce the overall volume of runoff. Retention facilities offer long-term stormwater collection and storage for reuse or groundwater recharge. Plants contribute to retention capacity by intercepting rainfall, taking up water from the soil, and assisting infiltration by maintaining soil porosity. Volume reduction does not require stormwater facilities to be extremely deep. In fact, it is usually best to employ a highly integrated and interconnected system of shallow stormwater facilities.

SITE LAYOUT STRATEGY: Utilize Surface Conveyance of Stormwater

In order to promote and mimic a more natural hydrologic condition, it is important to remember that the natural landscape does not convey stormwater runoff quickly off of a site. Rather, stormwater infiltrates into the ground, or is conveyed slowly on the surface to low spots in the landscape. The latter condition is the kind of design scenario that this guidebook hopes to recreate.

Designing a network of small stormwater surface conveyance features can be done for new development and retrofit projects. Traditional landscape areas can be transformed into naturalized stormwater conveyance systems simply by depressing greenspace into the existing landscape. Larger stormwater facilities can be interconnected with swales, runnels, trench drains, and other surface conveyance systems. Having this conveyance network reduces peak flows and volumes, recharges groundwater aquifers, and provides water quality treatment.

Allowing stormwater to flow on the surface has other benefits besides improving water quality, such as:

• Increasing awareness and connecting people to natural systems. Stormwater is no longer perceived as "out of sight, out of mind."

• Reducing stormwater facility sizes. Stormwater facilities that accept runoff from surface conveyance are generally less deep than stormwater facilities receiving underground piped runoff.

• Simplifying maintenance. It is easier to detect and repair any problems when stormwater conveyance is on the surface.

• Reducing up-front installation costs. Surface conveyance systems can be less expensive to install than underground systems.

***Figure 2-23:** A trench drain connects runoff between two landscape areas.*

***Figure 2-24:** A concrete valley gutter allows water to flow through an intersection on the surface. The landscape system in the background is a good candidate for a vegetated swale retrofit.*

***Figure 2-25:** Vegetated channels like this can be designed even in urban conditions for the purpose of conveying stormwater runoff.*

Street Applications

Figure 2-52: *Residential street with a vegetated swale.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-53: *A vegetated swale alongside a steep residential street.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-54: *An arterial street with a vegetated swale.*

Parking Lot Applications

Figure 2-55: *An elementary school parking lot with a vegetated swale.*

Figure 2-56: *A vegetated swale within a large parking lot.*

SOURCE: NEVUE NGAN ASSOCIATES

Figure 2-57: *A commercial center with a parking lot vegetated swale.*

Figure 72. Residential street in Paynter's Mill.

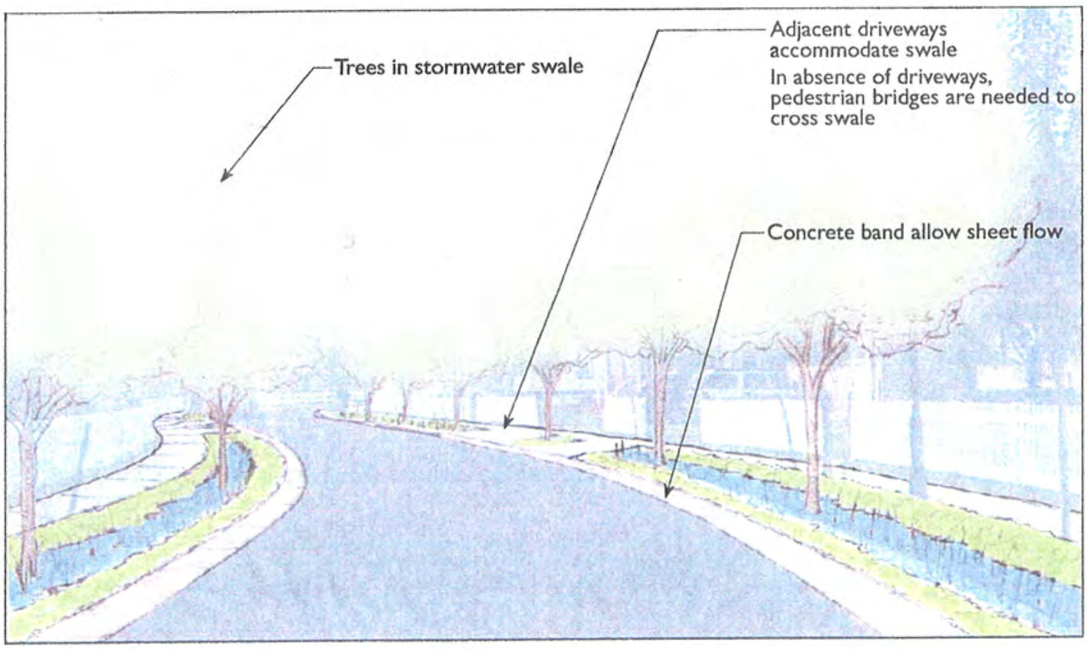


Figure 73. *Retrofit potential:* Swales on both sides of "curbless" street to accept sheet flow of runoff.

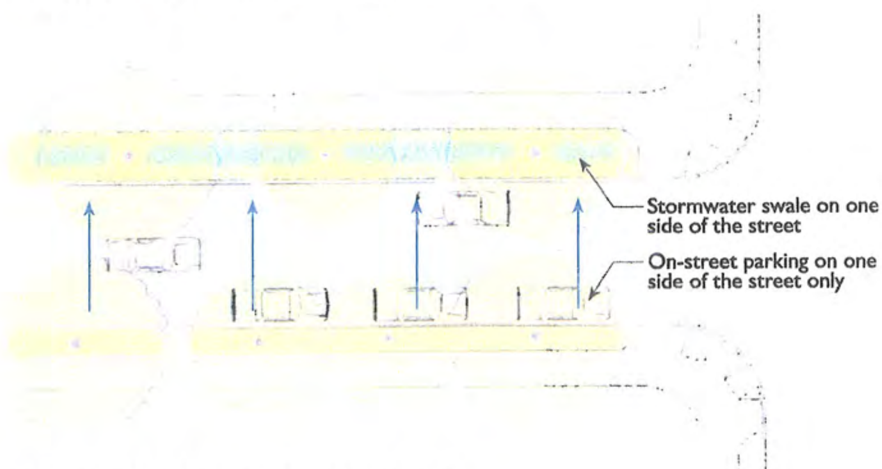


Figure 74. One side swale (parking on one side)—plan view.

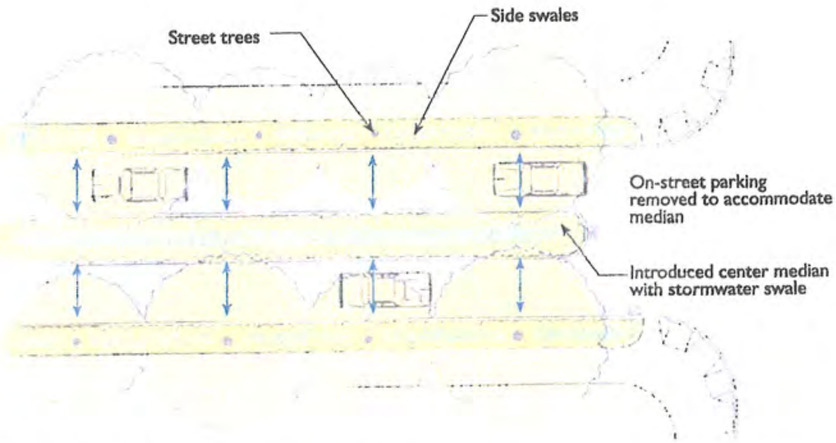


Figure 75. Two side swales and median swale (no parking)—plan view.

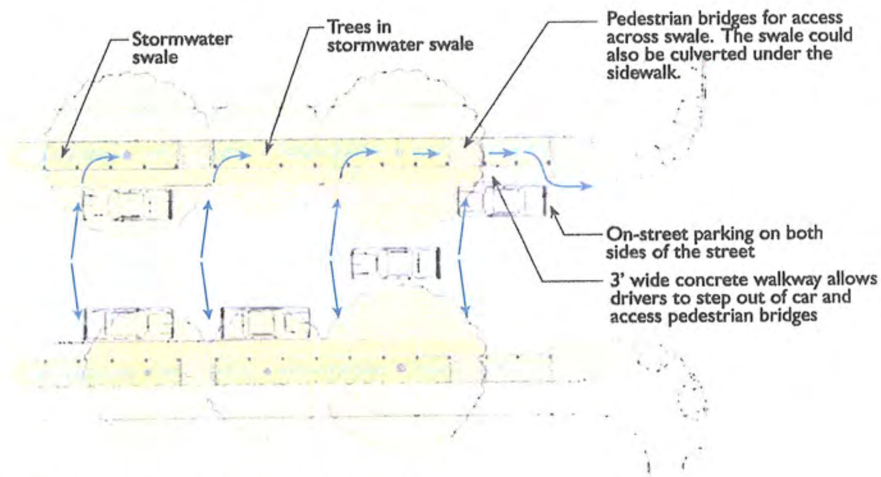


Figure 76. Two side swales (parking on both sides)—plan view.

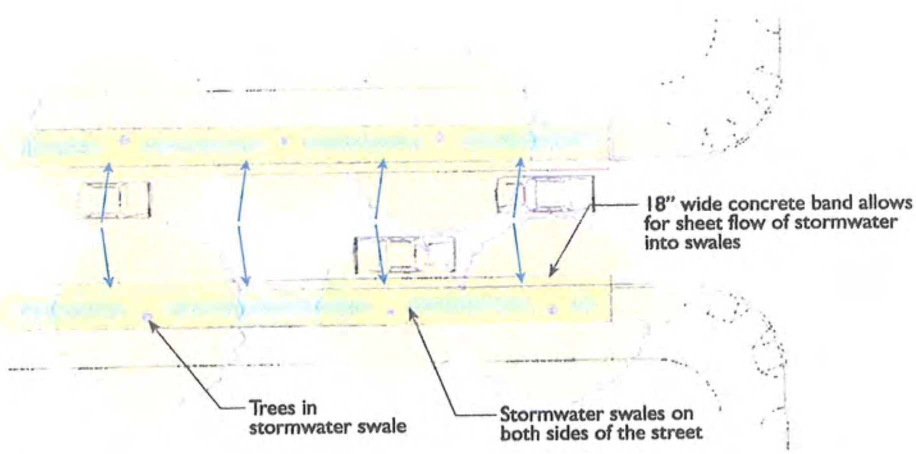


Figure 77. Two side swales (no parking)—plan view.

Street Applications

Figure 2-74: A simple residential street rain garden.

Figure 2-70: A large rain garden retrofitted in a school parking lot.

Good Places for Rain Gardens

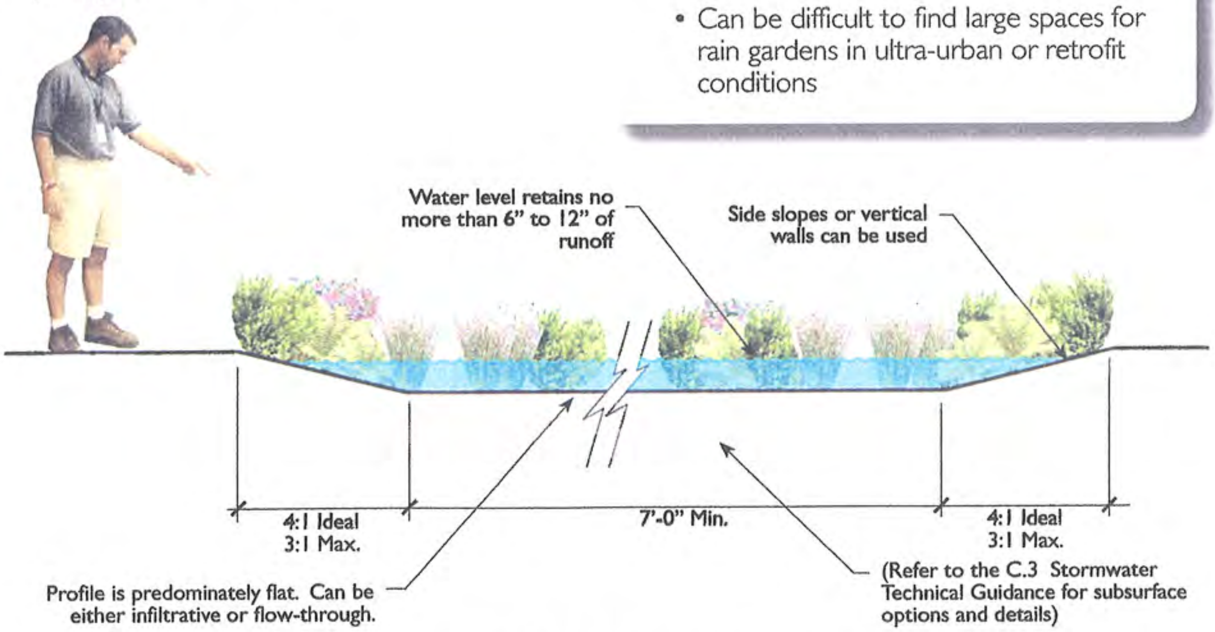
- Underutilized space adjacent to parking lots and streets
- Large parking lot islands
- Residential areas
- Left over spaces created by angled street intersections

Why Choose Rain Gardens:

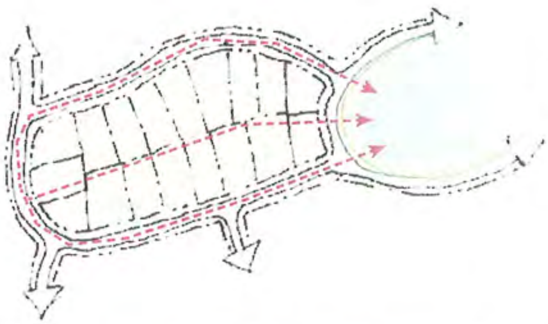
- Can often significantly "green" a space that would otherwise be leftover asphalt area
- Can be inexpensive to build depending on the amount of hardscape and pipe system used
- Can provide the greatest stormwater flow and volume benefit because of their large size
- Offer versatility in shape

Potential Constraints:

- Often more maintenance required because of their large size
- Can be difficult to find large spaces for rain gardens in ultra-urban or retrofit conditions

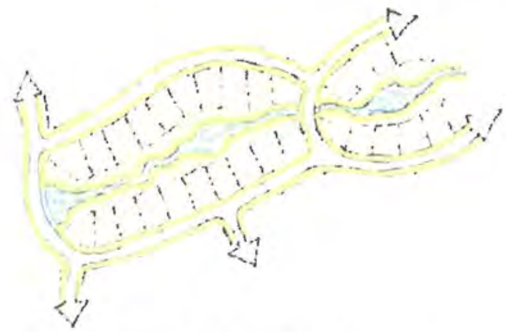


TYPICAL RAIN GARDEN PROFILE



Nevue Ngan Associates

Figure 35. A conventional residential site plan. Stormwater is whisked away quickly via underground pipes into a large storage pond.



Nevue Ngan Associates

Figure 36. A redesigned site plan with a well-connected stormwater system. Rainfall is collected and conveyed through interconnected rain gardens, creating a more natural condition while still allowing development to occur.

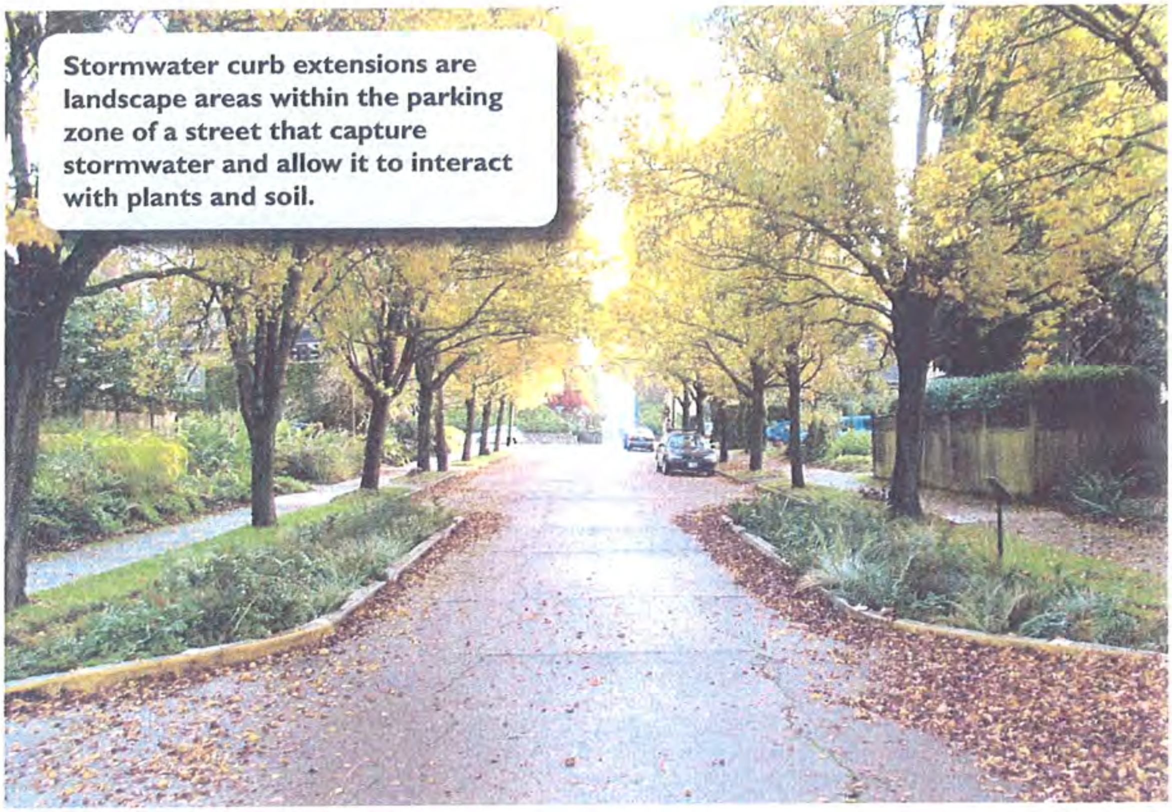
swarthmorepa.org

Figure 37. A well-integrated residential rain garden.

only mimics a more natural drainage condition, it also has the potential to save the project significant infrastructure costs.

Sometimes having an overflow pond system to manage large storm events will be necessary. However, by designing the site to first manage stormwater on the surface and within smaller interconnected rain gardens, the footprint of the overflow pond might be reduced to allow for more developable land and a more aesthetically pleasing project. This was the case in the High Point development in Seattle, Washington. By using an interconnected network of natural infiltration techniques, the development was able to use a one-acre wet pond instead of a five-acre pond. This "saved" four acres that could then be developed. A smaller wet or dry pond allows more flexibility to design the facility so it blends in better and becomes a neighborhood amenity.

STORMWATER FACILITY STRATEGY: Stormwater Curb Extensions

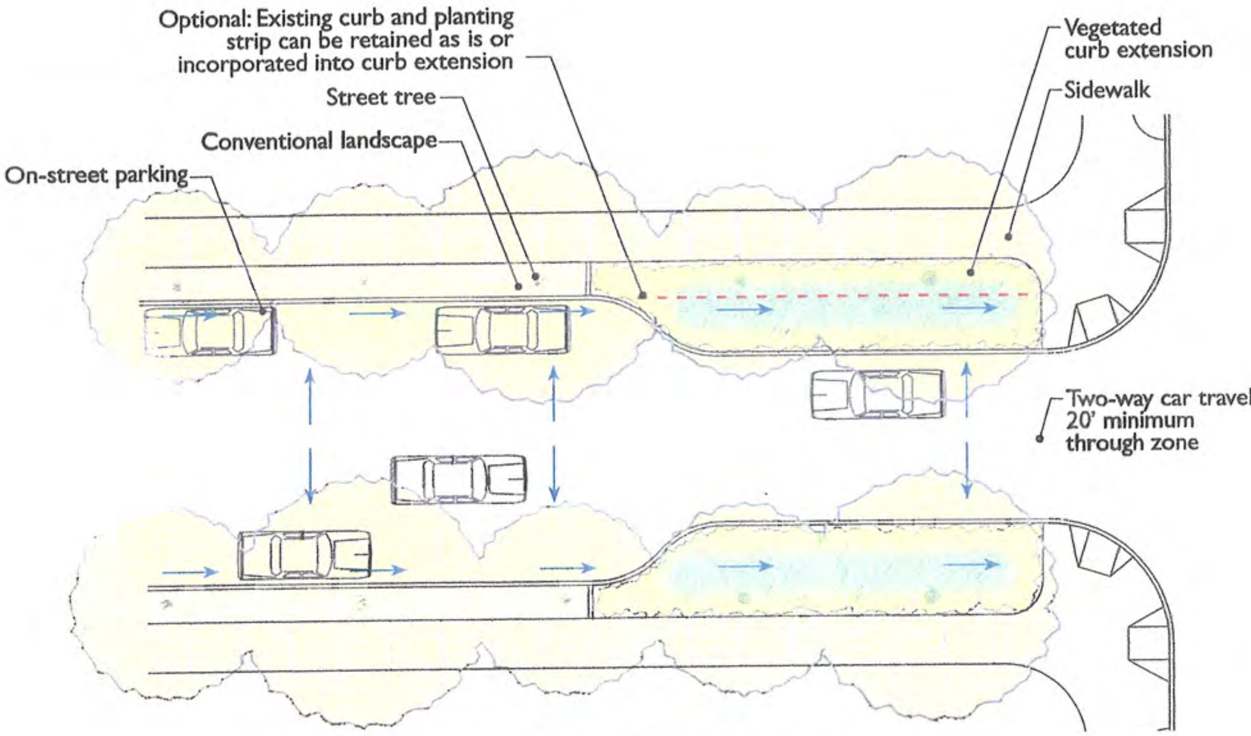


SOURCE: KEVIN ROBERT PERRY, CITY OF PORTLAND

Stormwater curb extensions are landscape areas that extend into the street and capture stormwater runoff. Conventional curb extensions (a.k.a. bulb outs, chokers, chicanes) are commonly used to increase pedestrian safety and help calm traffic. A stormwater curb extension shares these same attributes plus adds a stormwater benefit by allowing water to flow into the landscape space. This landscape space can be designed with the physical characteristics of vegetated swales, planters, or rain gardens depending on the available space and specific site conditions.

Stormwater curb extensions are particularly advantageous in retrofit situations because they can often be added to existing streets with minimal disturbance. The small footprint of stormwater curb extensions allows for an efficient stormwater management system that often performs very well for a relatively low implementation cost.

Stormwater curb extensions can be used in a variety of land uses from low-density residential streets to highly urbanized commercial streetscapes. Curb extensions are excellent to use in steep slope conditions because they can act as a "backstop" for capturing runoff from upstream flow. For use in green street applications, curb extensions should have check dams installed for street slopes over 2%. For streets slopes over 5%, the interior of the curb extensions should be terraced with check dams and act more as a series of planters. Stormwater curb extensions can be planted with a variety of trees, shrubs, grasses and groundcovers, depending on site context and conditions.



Stormwater Curb Extension at Intersection Plan View

SOURCE: NEVUE NGAN ASSOCIATES

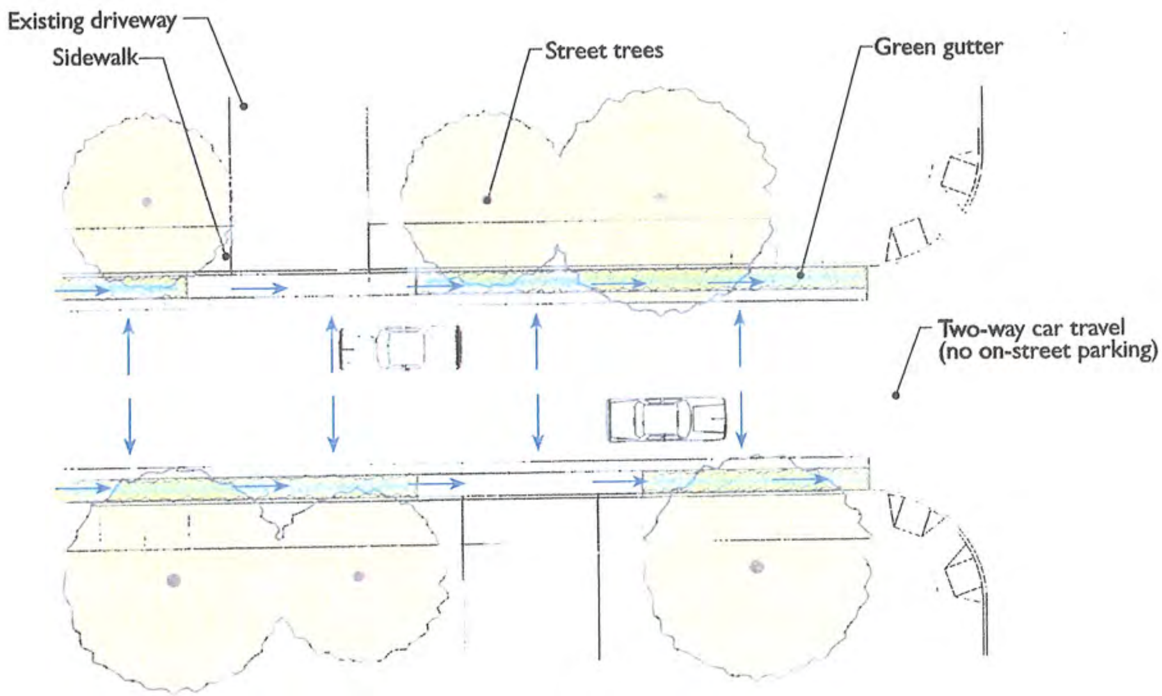
Figure 4-7: EXAMPLE: *A pair of stormwater curb extensions used in a residential street's parking zone. Notice that there is still plenty of on-street parking available.*

Don't need parking? Big opportunity.

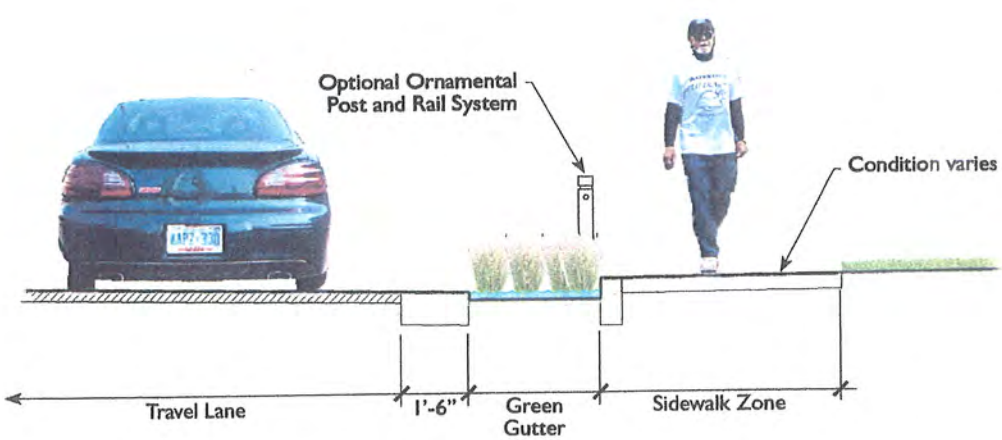
Residential streets that have a wide right-of-way and do not need on-street parking are good candidates for retrofitting with a "green gutter" system. A green gutter is a narrow stormwater planter that can be placed alongside streets that do not need on-street parking. Green gutters are typically shallow and designed to slow and filter stormwater runoff. By removing a couple of feet of asphalt on both sides of this street, a green gutter system is viable without impeding two way travel along the street. The example below illustrates a "curbless" condition where runoff can sheet flow into the green gutters. A standard curb and gutter, however, can also be built with frequent curb cuts if there is a concern about vehicular traffic.

Figure 4-12: EXISTING: *A typical wide residential street in San Mateo County.*

Figure 4-13: RETROFIT OPPORTUNITY: *The same residential street retrofitted with a green gutter system.*



Green Gutter Plan View



Green Gutter Typical Cross Section

Street Applications

Figure 2-63: *Stormwater planters located on a street without on-street parking.*

Figure 2-64: *Stormwater planters located on a street with on-street parking.*

Figure 2-65: *A bold example of an urban residential stormwater planter.*

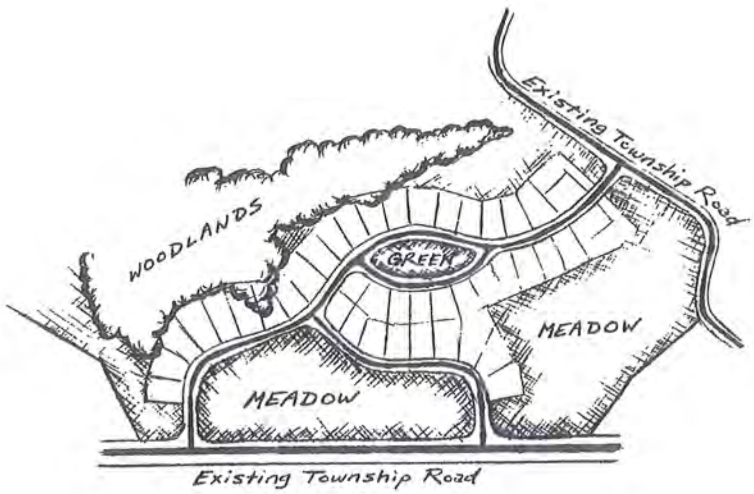
Parking Lot Applications

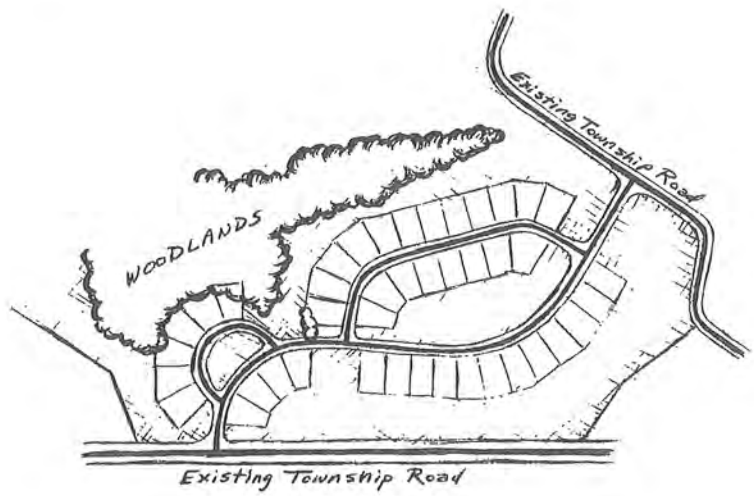
Figure 2-66: *A stormwater planter within a parking lot's landscape island.*

Figure 2-67: *A narrow stormwater planter on the edge of a parking lot.*

Figure 2-68: *A stormwater planter within the interior median of a parking lot.*

Figure 2-15. Site layouts with/ without vegetation retention





Once the predevelopment hydrology objectives have been met, the designer can complete the site plan by incorporating the typical details, plan views, cross sections, profiles, and notes as required.

References

Bay Area Stormwater Management Agencies Association (BASMAA). 1997. *Start at the Source: Residential Site Planning and Design Guidance Manual for Stormwater Quality Protection.* Prepared by Tom Richman and Associates, Palo Alto, California, 94301.

Booth, D.B., and L.E. Reinelt. 1993. Consequences of Urbanization Aquatic Systems-Measured Effects, Degradation Thresholds, and Corrective Strategies. In *Proceeding of Watershed '93.*

Source: Prince George's County Md., Department of Environmental Resource Programs and Planning Division

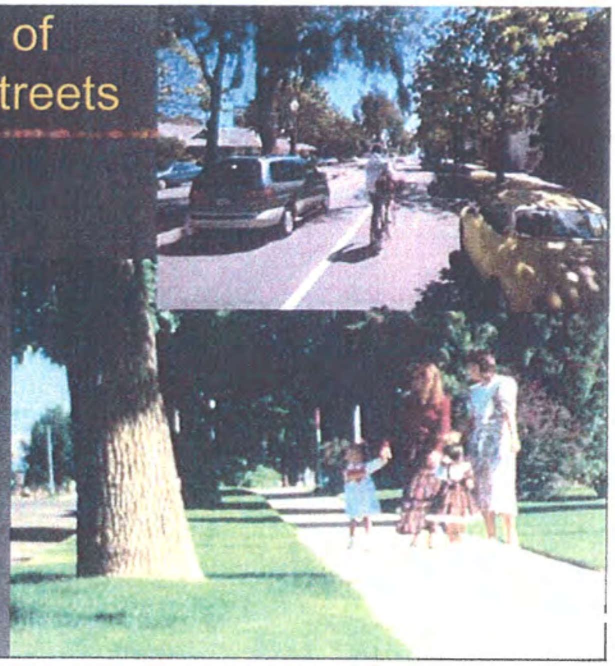
Publications by fringe groups

The End of Civilization: 26 ft parking 2 sides

The street as amenity

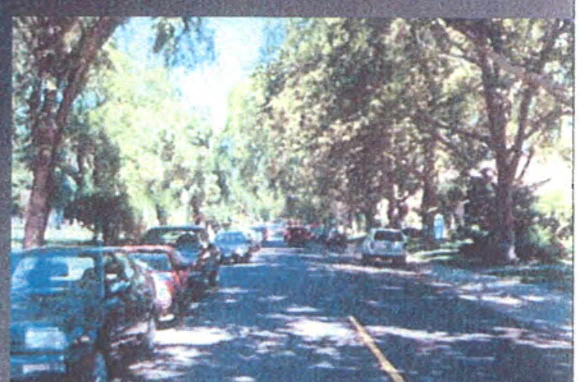
Principles of Healthy Streets

- Streets designed for people, not just cars
- Friendly to cars, pedestrians and cyclists



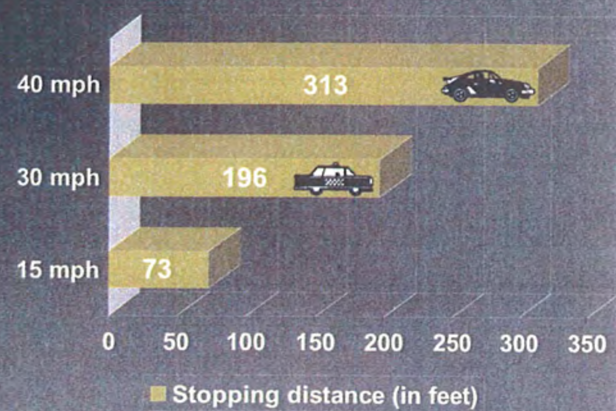
Principles of Healthy Streets

- Streets designed so drivers feel comfortable at slow speeds
  - 15-25 mph on neighborhood streets
  - 25-35 mph on avenues and boulevards



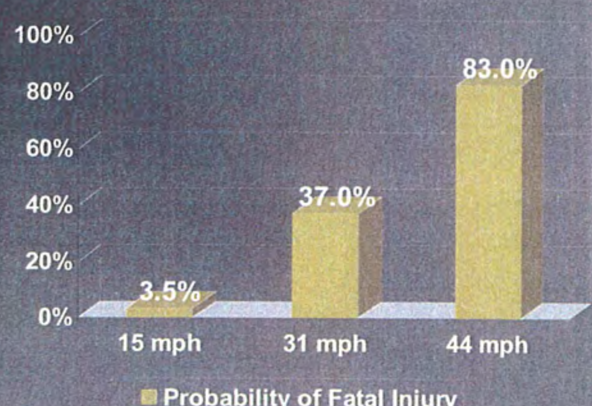
Principles of Healthy Streets

- Slow streets are safer streets
  - What happens when a driver slams on the brakes?



Principles of Healthy Streets

- Slow streets are safer streets
  - What happens when a vehicle hits a pedestrian



Principles of Healthy Streets

- Narrower streets are slower and safer
  - Longmont, CO study of 20,000 accidents
    - Found street width had the greatest relationship to injury accidents
  - Accidents/mile/year were higher on wider streets
    - 40-foot wide street 2.23 a/m/y
    - 36-foot wide street 1.21 a/m/y
    - 24-foot wide street 0.32 a/m/y

Source: "Residential Street Typology and Injury Accident Frequency," Swift and Associates, Longmont, CO, 1997

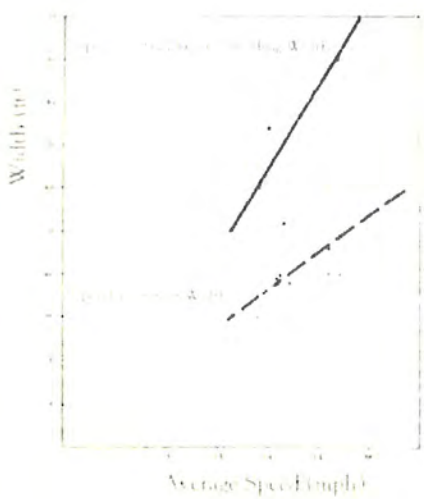


Figure 5.51 Speed versus Pavement Width and Pavement Width Plus Setbacks.

From: *Residential Streets*, Third Edition, ULI, ITE, NAHB, ASCE, 2001

Joint ITE-CNU Project

Developing Guidance For Context Sensitive Design of Major Urban Thoroughfares

- FHWA, states, cities working on context-sensitive design
- AASHTO's Bridging Document
- EPA smart growth program
- ITE smart growth & traditional design work
- CNU design work
- Developed joint project

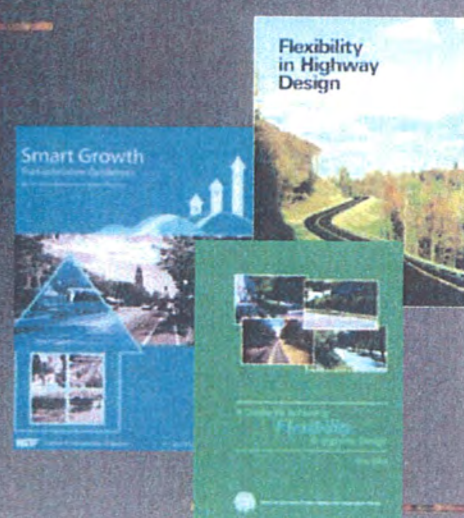


TABLE 3B: Vehicular Lane/Parking Assemblies. The projected design speeds determine the dimensions of the vehicular lanes and Turning Radii assembled for Thoroughfares.

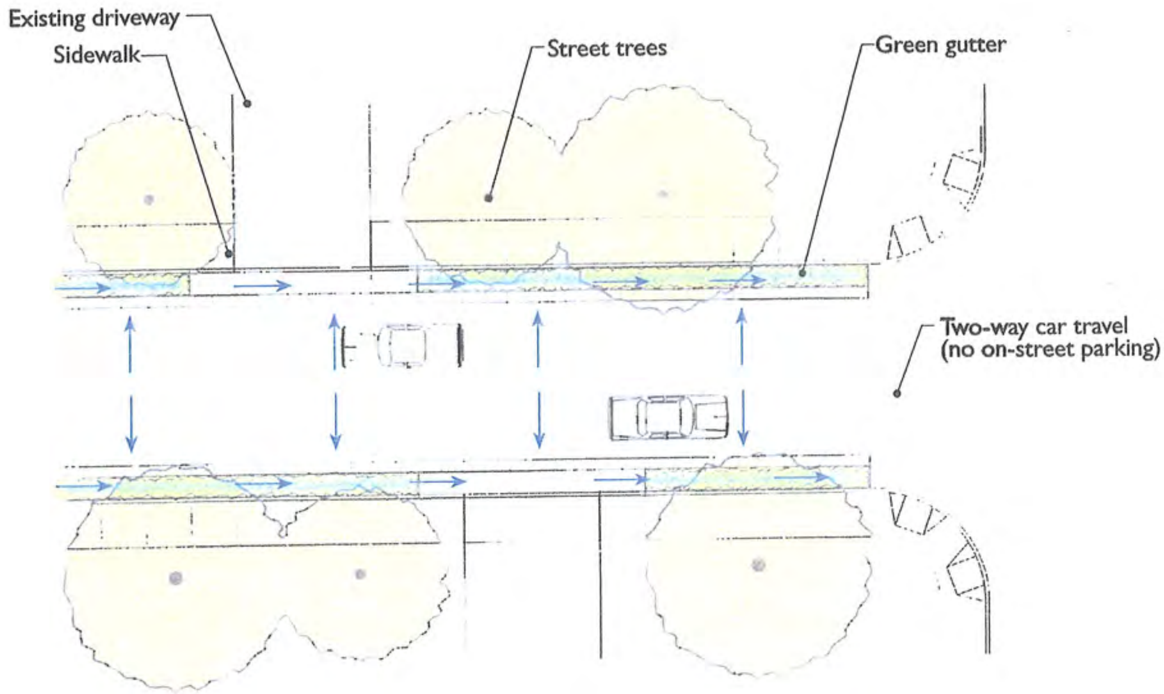
	ONE WAY MOVEMENT		TWO WAY MOVEMENT		
a. NO PARKING	T1 T2 T3	T1 T2 T3	T1 T2 T3	T1 T2	T1 T2
Dimensions	10'	8', 8'	9', 9'	11', 10', 11'	12', 12', 12', 12'
Design ADT	300 VPD	600 VPD	2,500 VPD	22,000 VPD	36,000 VPD
Pedestrian Crossing	3 Seconds	5 Seconds	5 Seconds	9 Seconds	13 Seconds
Design Speed	20 - 30 MPH	Below 20 MPH	20-25 MPH		35 MPH and above
b. YIELD PARKING	T3 T4		T3 T4		
Dimensions	18'		7', 12', 7'		
Design ADT	1,000 VPD		1,000 VPD		
Pedestrian Crossing	5 Seconds		7 Seconds		
Design Speed					
c. PARKING ONE SIDE PARALLEL	T3 T4	T3 T4 T5	T4 T5	T4 T5 T6	T5 T6
Dimensions	7', 8'	8', 10', 10'	8', 10', 10'	7', 11', 11', 7'	9', 12', 12', 12', 12', 9'
Design ADT	5,000 VPD	18,000 VPD	16,000 VPD	15,000 VPD	32,000 VPD
Pedestrian Crossing	5 Seconds	8 Seconds	8 Seconds	11 Seconds	13 Seconds
Design Speed	20-30 MPH		25-30 MPH	25-30 MPH	
d. PARKING BOTH SIDES PARALLEL	T4	T4 T5 T6	T4 T5 T6	T5 T6	T5 T6
Dimensions	7', 9', 7'	8', 10', 10', 8'	8', 10', 10', 8'	8', 10', 11', 10', 8'	9', 12', 12', 12', 12', 9'
Design ADT	8,000 VPD	20,000 VPD	15,000 VPD	22,000 VPD	32,000 VPD
Pedestrian Crossing	7 Seconds	10 Seconds	10 Seconds	13 Seconds	15 Seconds
Design Speed	Below 20 MPH	25-30 MPH	25-30 MPH	25-30 MPH	35 MPH and above
e. PARKING BOTH SIDES DIAGONAL	T5 T6	T5 T6	T5 T6	T5 T6	T5 T6
Dimensions	18', 20', 18'	18', 24', 18'	18', 24', 18'	18', 12', 10', 12', 18'	18', 12', 10', 10', 12', 18'
Design ADT	18,000 VPD	20,000 VPD	15,000 VPD	22,000 VPD	31,000 VPD
Pedestrian Crossing	15 Seconds	17 Seconds	17 Seconds	20 Seconds	23 Seconds
Design Speed	Below 20 MPH	20-25 MPH	20-25 MPH	25-30 MPH	25-30 MPH
f. PARKING ACCESS			T3 T4	T5 T6	
Dimensions			10'	24'	
Design ADT					
Pedestrian Crossing			3 Seconds	6 Seconds	
Design Speed					

TABLE 3A: Vehicular Lane Dimensions. This table assigns lane widths to Transect Zones. The Design ADT (Average Daily Traffic) is the determinant for each of these sections. The most typical assemblies are shown in Table 3B. Specific requirements for truck and transit bus routes and truck loading shall be decided by Warrant.

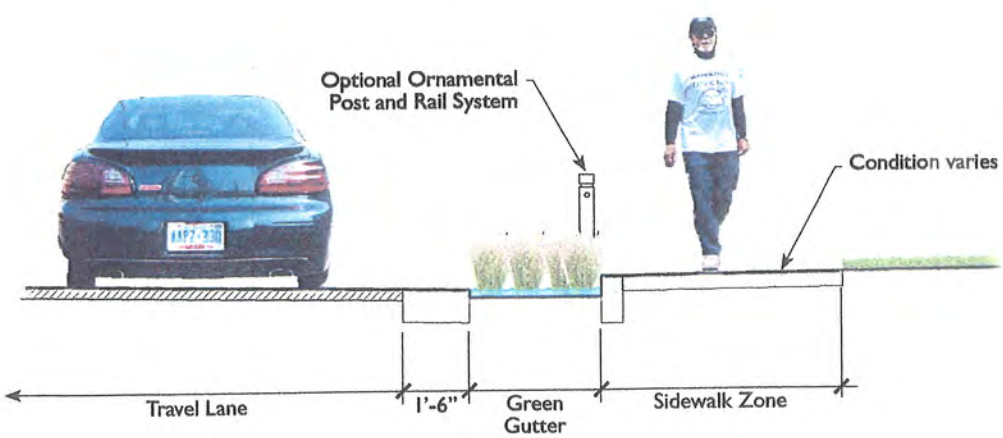
DESIGN SPEED	TRAVEL LANE WIDTH	T1	T2	T3	T4	T5	T6
Below 20 mph	8 feet	■	■	■	□		
20-25 mph	9 feet	■	■	■	■	□	□
25-35 mph	10 feet	■	■	■	■	■	■
25-35 mph	11 feet	■	■			■	■
Above 35 mph	12 feet	■	■			■	■
DESIGN SPEED	**PARKING LANE WIDTH**						
20-25 mph	(Angle) 18 feet					■	■
20-25 mph	(Parallel) 7 feet				■		
25-35 mph	(Parallel) 8 feet			■	■	■	■
Above 35 mph	(Parallel) 9 feet					■	■
DESIGN SPEED	**EFFECTIVE TURNING RADIUS**						(See Table 17b)
Below 20 mph	5-10 feet			■	■	■	■
20-25 mph	10-15 feet	■	■	■	■	■	■
25-35 mph	15-20 feet	■	■	■	■	■	■
Above 35 mph	20-30 feet	■	■			□	□

■ BY RIGHT

□ BY WARRANT



Green Gutter Plan View



Green Gutter Typical Cross Section