Section 2
Stormwater Quality Planning For New Development and Redevelopment

2.1 Introduction

State and Federal programs require BMPs to be implemented by developers, property owners, and public agencies engaged in new development or redevelopment activities. Understanding new development and redevelopment in the context of the project life cycle is important for proper selection and implementation of BMPs as shown in Figure 2-1. The concept, planning, and design phases of a project may be spread over a period of months to many years. BMPs incorporated into the concept, planning, and design phase are much more cost-effective than the retrofit of BMPs.

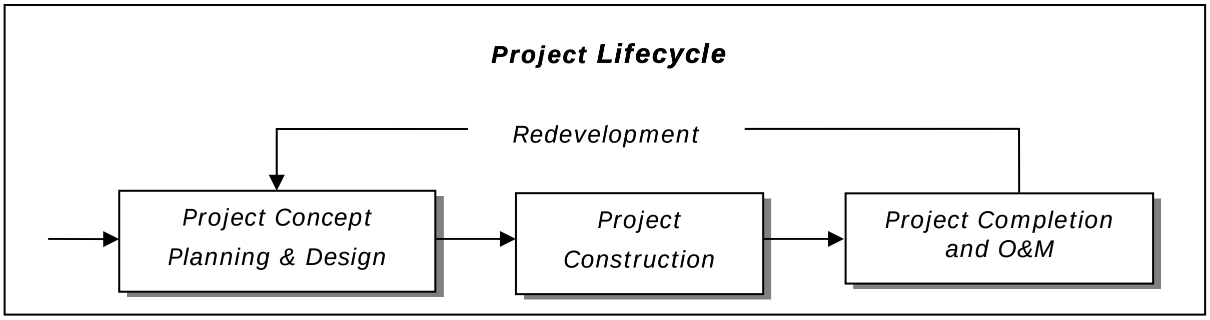

Figure 2-1
Project Lifecycle

2.2 Permit Requirements

New development BMPs are required under NPDES permits shown in Figure 2-2. The intent of incorporating BMPs in new private development and public capital projects is to prevent any net detrimental change in runoff quantity or quality resulting from new development and redevelopment.

Typical permit requirements that are now being included in all Phase I MS4 permits and are incorporated in the Phase II General Permit include:

- Specific thresholds for "Priority Projects" that must include both source and treatment control BMPs in the completed projects (typical project thresholds are shown in Figure 2-3).

NPDES Stormwater Permit Requirements

Phase I areas (large urban areas and major industries)

- Under permits since early 1990s
- Individual municipal permits all include a program element for new development or "post construction" BMPs

Phase II areas (small urban areas and additional industries)

- Under General Permit since early 2003
- Permit includes new development requirements similar to Phase II.

Figure 2-2
NPDES Stormwater Permit Requirements

- A list of source control (both non-structural and structural) BMPs and treatment control BMPs to be included or considered
- Specific water quality design volume and/or water quality design flow rate for treatment control BMPs
- A requirement for flow control BMPs when there is potential for downstream erosion
- Adopt a standard model or template for identifying and documenting selected BMPs including a plan for long-term operations and maintenance of BMPs

Typical California Municipal Permit Thresholds for Treatment BMPs

- Residential ≥ 10 units
- Commercial ≥ 1 acre
- Parking lots, road project ≥ 5,000 square feet
- Redevelopment ≥ 5,000 square feet impervious
- Retail Gasoline Outlets
- New and Redevelopment projects above 1 acre or 10,000 square feet of impervious area.

Figure 2-3
Typical Treatment BMP Thresholds

This standard model or template originated with the Los Angeles Municipal Stormwater permit and is called a Standard Urban Stormwater Mitigation Plan (SUSMP) under that and several other permits, although other terms such as Water Quality Management Plan (WQMP), Stormwater Quality Urban Impact Mitigation Plan, (SQUIMP), and C.3 Provisions have been used in other permits for equivalent programs. The SUSMPs list BMPs that are required for designated projects. Additional BMPs may be required by ordinance or code adopted by the Permittee and applied generally, or on a case-by-case basis. Private developers and public agencies must then include these SUSMP requirements in their project plans as applicable. Permittees then review and approve project plans as part of the development approved process for projects covered under SUSMP requirements.

Many of the permits also allow permittees to include the use of regional or watershed-based programs as alternatives to incorporating all of the BMPs to be on-site or project-based. Under this approach, programs would be developed and adopted that address specific water quality and pollutant concerns, achieve at least equivalent pollutant reduction that would have been required for all new development and redevelopment projects in the watershed through project-based BMPs, and can provide additional benefits by reducing impacts from existing developed areas. Where regional or watershed programs are developed, there will typically need to be a partnership between the planning agencies or permittees and the development community to clearly define the approach for satisfying the Permit requirements and evaluating choices between project-based and regional BMPs.

An effective mechanism for documenting the incorporation of stormwater quality controls into new development and redevelopment projects on a site, regional, or watershed basis is to develop a written plan known as a Stormwater Management Plan or SMP. An effective SMP clearly sets forth the means and methods for long-term stormwater quality protection. The SMP is a valuable document and can be used as part of the construction Stormwater Pollution Prevention Plan to describe post-construction stormwater management, and will also prove to be useful during ownership transitions to convey critical stormwater quality control information to subsequent owners. Section 2.3 of this handbook describes the development of a stormwater management plan. Section 2.4 of this handbook describes planning principles appropriate for consideration during new development and redevelopment stormwater quality planning.

2.3 Developing a Stormwater Management Plan

Developing an effective stormwater management plan depends on making effective BMP choices. This section describes the basic steps and process one would go through to develop a plan with appropriate BMPs. Such a plan would include reviewing the full suite of BMPs that are available and identifying the dominant site factors that should go into the decision making process. Assessment of the regional area, specific site conditions, site constraints, site hydrology, and project type, are central to successful planning to minimize pollutants during development as well as during the life of the project. The basic steps in the stormwater management plan process are to:

- Assess site and watershed conditions
- Understand hydrologic conditions of concern
- Evaluate pollutants of concern
- Identify candidate BMPs
- Develop plan for BMP Maintenance

The specific requirements of a Stormwater Management Plan are usually specified by the local planning agency based on requirements in their MS4 permit. Typically, the following information is required:

2.3.1 Assess Site Conditions

Site and watershed assessment includes assessing and describing the pre and post-development site conditions and how the site fits into the overall watershed or drainage area. The assessment should include sufficient detail to allow for assessment of the need for and application of stormwater BMPs. Information typically required is listed below.

- Site information
    - Historic features
    - Existing features
    - Planned features
    - Drainage Patterns
    - Discharge Locations

- Vicinity information
  - Major roadways
  - Geographic features or landmarks
  - Area surrounding the site
  - General topography
  - Area drainage
- Watershed or drainage area information
  - Received waters
  - Watershed drainage

2.3.2 Understand Hydrologic Conditions of Concern

Development of impervious areas changes the landform and therefore the runoff hydrograph. Modifications to the runoff hydrograph change downstream hydrology. New development typically results in more runoff volume and higher rates of runoff. Many BMPs, such as detention basins, which detain volume, effectively remove the top part of the hydrograph, but extend the duration of flow. See Figure 2-4.

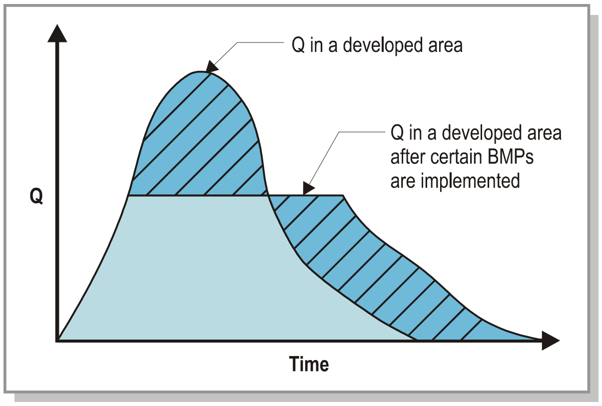

Figure 2-4
Hydraulic Alteration
After Certain BMPs are Implemented

Recent findings indicate that while such actions mitigate peak flows, the increased duration associated with these actions has impacts as well. Problems include washing out habitat, eroding streambed and banks, and changing downstream ecosystems. In addition to volume, rate, and duration, other factors such as the amount of energy in the water and peak flow impact downstream conditions.

A comprehensive understanding of these factors is necessary to develop meaningful stormwater management plans. To be effective, these solutions must be done on an individual watershed basis.

Ideally, the runoff hydrograph that exists after construction would parallel the pre-construction hydrograph. It is difficult to ask upstream developers to be concerned about what is happening several miles below them in a watershed. On the other hand, stormwater planners and policy makers must ask what can be done to make the watershed more stable, and what enhancements are needed to balance impacts to the watershed from development. A stream balance equation can be used to make qualitative predictions concerning channel impacts due to changes in runoff or sediment loads from the watershed. This concept and the equation are described more fully in Appendix A.

The best way to resolve the watershed stability and balance issues is through a comprehensive drainage water master plan. A formal drainage study considers the project area's location in the larger watershed, topography, soil and vegetation conditions, percent impervious area, natural and infrastructure drainage features, and any other relevant hydrologic and environmental factors. A drainage study is typically prepared by a registered civil engineer. As part of the study, the drainage report includes:

- Field reconnaissance to observe downstream conditions
- Computed rainfall and runoff characteristics including a minimum of peak flow rate, flow velocity, runoff volume, time of concentration and retention volume
- Establishment of site design, source control and treatment control measures to be incorporated and maintained to address downstream conditions of concern

2.3.3 Evaluate Pollutants of Concern

The stormwater management plan should identify anticipated pollutants of concern. Pollutants frequently identified in the 303d list for specific water bodies in California include metals, nitrogen, nutrients (but often nutrients without specifying nitrogen or phosphorus), indicator bacteria (i.e., fecal coliform), pesticides, and trash. Less commonly cited pollutants include sediment, PAHs, PCBs, and dioxin. With respect to metals, typically, only the general term is used. In some cases, a specific metal is identified. The most commonly listed metals are mercury, copper, lead, selenium, zinc, and nickel. Less frequently listed metals are cadmium, arsenic, silver, chromium, molybdenum, and thallium.

As discussed in Section 2.2, some Phase I communities have developed very prescriptive urban stormwater requirements. For example, the Los Angeles SUSMP requires permittees to develop a procedure for pollutants of concern to be identified for each new development or significant redevelopment project. The procedures should include, at a minimum, consideration of:

- receiving water quality (including pollutants for which receiving waters are listed as impaired under Clean Water Act section 303(d)
- land use type of the development project and pollutants associated with that land use type
- pollutants expected to be present on site;
- changes in stormwater discharge flow rates, velocities, durations, and volumes resulting from the development project
- sensitivity of receiving waters to changes in stormwater discharge flow rates, velocities, durations, and volumes.

A general list of anticipated and potential pollutants generated by land use type is shown in Table 2-1

It is important to realize that pollutants of concern for a water body can extend beyond those pollutants listed in 303d list as causing impairment. For example, trash is a pollutant of concern in most communities, yet only a few water bodies are presently listed as impaired by trash. The key to remember is that a pollutant need not be causing an immediate impairment to be considered when developing a stormwater management plan.

2.3.4 Identify Candidate BMPs

Selecting BMPs based on pollutants of concern is a function of site constraints, constituents of concern, BMP performance, stringency of permit requirements, and watershed specific requirements such as TMDLs. Pollutants of concern are especially important in water limited stream segments and must be carefully reviewed in relationship to BMP performance. BMP performance is discussed further in Section 5.

When no specific pollutant has been targeted for removal, regulators may address pollutant removal through flow and /or volume-based requirements. Under these circumstances, cost can become an important differentiator in BMP selection. BMP specific cost information is included in Section 5.

Large reductions in treatment BMP size and investment can be made by:

- Reducing runoff that needs to be captured, infiltrated, or treated
- Controlling sources of pollutants

These two strategies are the most effective in managing stormwater. A third strategy includes implementation of treatment BMPs. The principles and methodologies for incorporating these strategies into site facility planning and design are discussed in Section 2.4 and Section 3, respectively. Fact Sheets for source control BMPs and treatment control BMPs are included in Section 4 and Section 5, respectively.

2.3.5 Determine BMP Size/Capacity

Based on the selected BMPs, the capacity and primary design sizing criteria must be established using a combination of local hydrology, project drainage characteristics (e.g., percent imperviousness or runoff coefficient), and the local permit or New Development Program numerical sizing requirements. BMPs will be either volume-based or flow-based, as discussed in more detail later in this Handbook and must be able to effectively treat the design quantity. Peak storm event flows must also be taken into account if the BMP is a flow-based BMP, or a volume-based BMP that must also safely pass the design storm (e.g., an in-line detention basin). The volume-based BMP can safely pass the design peak event while maintaining its water quality functions up to the water quality design volume.

Table 2-1 Anticipated and Potential Pollutants Generated by Land Use Type

Priority Project Categories	**General Pollutant Categories**								
	Pathogens	**Heavy Metals**	**Nutrients**	**Pesticides**	**Organic Compounds**	**Sediments**	**Trash & Debris**	**Oxygen Demanding Substances**	**Oil & Grease**
Detached Residential Development	X		X	X		X	X	X	X
Attached Residential Development	P		X	X		X	X	P(1)	P(2)
Commercial/ Industrial Development >100,000 ft2	P(3)		P(1)	P(5)	P(2)	P(1)	X	P(5)	X
Automotive Repair Shops		X			X(4)(5)		X		X
Restaurants	X						X	X	X
Hillside Development >5,000 ft2 In SDRWQCB			X	X		X	X	X	X
Hillside Development >100,000 ft2 In SARWQCB			X	X		X	X	X	X
Parking Lots		X	P(1)	P(2)		P(1)	X	Ps	X
Streets, Highways & Freeways		X	P(1)		X(4)	X	X	P(5)	X

X = anticipated
P = potential
(1) A potential pollutant if landscaping exists on-site
(2) A potential pollutant if the project includes uncovered parking areas
(3) A potential pollutant if land use involves food or animal waste products.
(4) Including petroleum hydrocarbons.
(5) Including solvents.

2.3.6 Develop Plan for BMP Maintenance

BMP maintenance arrangements take place during the planning phase of development and redevelopment projects. A permittee is committed to providing for water quality protection by requiring that a mechanism for ongoing, long-term maintenance of BMPs is in place. To ensure that BMP maintenance will take place, permittees require evidence that project proponents have executed an approved method of BMP maintenance, repair, and replacement before construction approvals are issued. Mechanisms used by permittees to assign responsibility for maintenance to public and private sector project proponents include:

- Covenants
- Maintenance Agreements
- Conditional use permits
- Deed restrictions
- Other legal agreements

The permittee requires that an Operation and Maintenance (O&M plan) be prepared by the project proponents. These plans are normally attached to approved maintenance agreements and describe a designated party to manage:

- BMPs
- Employee training program and duties
- Operating schedule
- Maintenance frequency
- Routine service schedule
- Specific maintenance activities
- Copies of resource agency permits
- Funding
- Other necessary activities

Permittees often require annual inspection and servicing of all BMPs within maintenance agreements, and O&M forms documenting all required maintenance activities. The party responsible for the O&M plan is required to retain O&M forms for at least five years.

A BMP maintenance plan is particularly valuable during ownership transitions. For example, when a developer transitions maintenance to a homeowners association, or when a developer turns over maintenance to a new owner, the BMP maintenance plan is also important when valuating properties for acquisition, allowing long-term costs associated with BMPs to be factored into the property purchase agreement.

A more extensive discussion of long-term BMP maintenance is included in Section 6.

2.4 Planning Principles

Planning and design for water quality protection employs three basic strategies in the following order of relative effectiveness: 1) reduce or eliminate post-project runoff; 2) control sources of pollutants, and 3) treat contaminated stormwater runoff before discharging it to natural water bodies. See Figure 2-5. These principles are consistent with the typical permit and local program requirements for Priority Projects that require a consideration of a combination of source control BMPs (that reduce or eliminate runoff and control pollutant sources) and treatment control BMPs with specific quantitative standards. The extent to which projects can incorporate strategies that reduce or eliminate post project runoff will depend upon the land use and local site characteristics of each project. Reduction in post project runoff offers a direct benefit by reducing the required size of treatment controls to meet the numeric standard included in the local permit. Therefore, project developers can evaluate tradeoffs between the incorporation of alternative site design and source control techniques that reduce runoff and pollutants, and the size of required treatment controls either included as part of the project or as a commitment to an offsite watershed-based program.

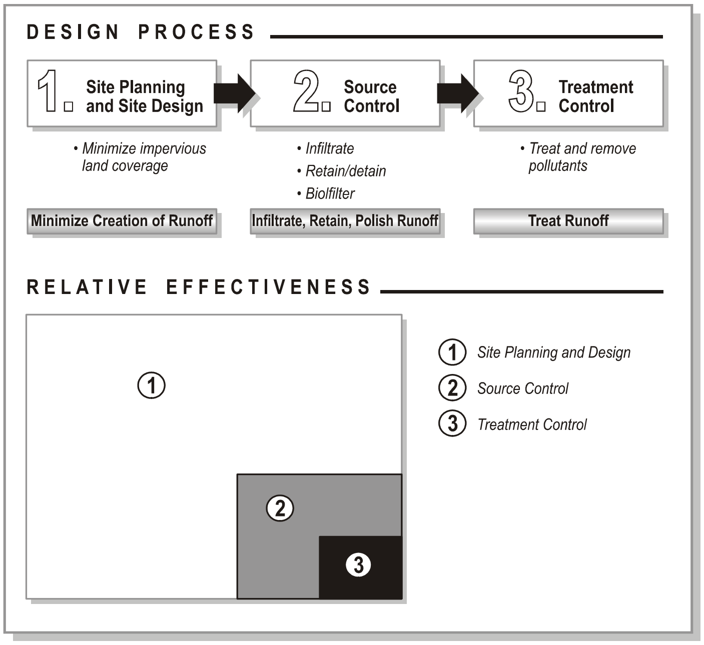

Figure 2-5
Planning Principles

2.4.1 Reduce Runoff

The principle of runoff reduction starts by recognizing that developing or redeveloping land within a watershed inherently increases the imperviousness of the areas and therefore the volume and rate of runoff and the associated pollutant load; and outlines various approaches to reduce or minimize this impact through planning and design techniques.

The extent of impervious land covering the landscape is an important indicator of stormwater quantity and quality and the health of urban watersheds. Impervious land coverage is a fundamental characteristic of the urban and suburban environment -- rooftops, roadways, parking areas and other impenetrable surfaces cover soils that, before development, allowed rainwater to infiltrate.

Without these impervious coverings, inherent watershed functions would naturally filter rainwater and prevent receiving water degradation. Impervious surfaces associated with urbanization can cause adverse receiving water impacts in four ways:

- Rainwater is prevented from filtering into the soil, adversely affecting groundwater recharge and reducing base stream flows.
- Because it cannot filter into the soil, more rainwater runs off, and runs off more quickly, causing increased flow volumes, accelerating erosion in natural channels, and reducing habitat and other stream values. Flooding and channel destabilization often require further intervention. As a result, riparian corridors are lost to channelization, further reducing habitat values.
- Pollutants that settle on the impervious pavements and rooftops are washed untreated into storm sewers and nearby stream channels, increasing pollution in receiving water bodies.
- Impervious surfaces retain and reflect heat, increasing ambient air and water temperatures. Increased water temperature negatively impacts aquatic life and reduces the oxygen content of nearby water bodies.

Techniques for reducing runoff range from land use planning on a regional scale by permittees or other local planning agencies, to methods that can be incorporated into specific projects. These techniques include actions to:

- Manage watershed impervious area
- Minimize directly connected impervious areas
- Incorporate zero discharge areas
- Include self-treatment areas
- Consider runoff reduction areas.

Brief summaries of the following techniques are presented:

Manage Watershed Impervious Area

Land use planning on the watershed scale is a powerful tool to manage the extent of impervious land coverage. This planning has two elements. First, identify open space and sensitive resource areas at the regional scale and target growth to areas that are best suited to development, and second, plan development that is compact to reduce overall land conversion to impervious surfaces and reliance on land-intensive streets and parking systems.

Impervious land coverage is a practical measure of environmental quality because:

- It is quantifiable, meaning that it can be easily recognized and calculated.

- It is integrative, meaning that it can estimate or predict cumulative water resource impacts independent of specific factors, helping to simplify the intimidating complexity surrounding non-point source pollution.

- It is conceptual, meaning that water resource scientists, municipal planners, landscape architects, developers, policy makers and citizens can easily understand it.

Water resource protection at the local and regional level is becoming more complex. A wide variety of regulatory agencies, diverse sources of non-point source pollution, and a multitude of stakeholders make it difficult to achieve a consistent, easily understandable strategy for watershed protection. Impervious land coverage is a scientifically sound, easily communicated, and practical way to measure the impacts of new development on water quality.

Impervious area reductions also provide additional benefits such as reduced urban heat island effect, resulting in less energy use to cool structures and more efficient irrigation use by plants. Reductions have also been attributed to more human-scale landscaper and higher property values.

Minimize Directly Connected Impervious Areas (DCIA)

Impervious areas directly connected to the storm drain system are the greatest contributor to non-point source pollution. The first effort in site planning and design for stormwater quality protection is to minimize the "directly connected impervious area (DCIA)" as shown in Figure 2-6.

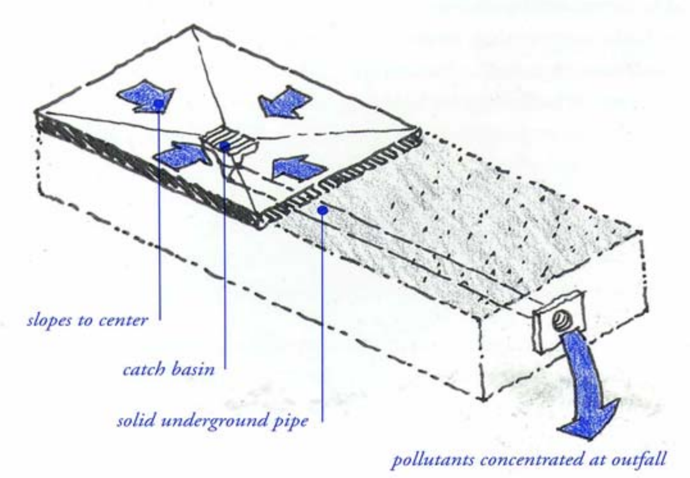

Figure 2-6
Directly Connected Impervious Area

Any impervious surface that drains into a catch basin, area drain, or other conveyance structure is a "directly connected impervious area." As stormwater runoff flows across parking lots, roadways, and paved areas, the oils, sediments, metals and other pollutants are collected and concentrated. If this runoff is collected by a drainage system and carried directly along impervious gutters or in closed underground pipes, it has no opportunity for filtering by plant material or infiltration into the soil. It also increases in speed and volume, which may cause higher peak flows downstream, and may require larger capacity storm drain systems, increasing flood and erosion potential.

Minimizing directly connected impervious areas can be achieved in two ways:

- Limiting overall impervious land coverage

- Directing runoff from impervious areas to pervious areas for infiltration, retention/detention, or filtration

Strategies for reducing impervious land coverage include:

- Cluster rather than sprawl development
- Taller narrower buildings rather than lower spreading ones
- Sod or vegetative "green roofs" rather than conventional roofing materials
- Narrower streets rather than wider ones
- Pervious pavement for light duty roads, parking lots and pathways

Example strategies for infiltration, retention/detention, and bio-filtration include:

- Vegetated swales
- Vegetated basins (ephemeral- seasonally wet)
- Constructed ponds and lakes (permanent- always wet)
- Crushed stone reservoir base rock under pavements or in sumps
- Cisterns and tanks
- Infiltration basins
- Drainage trenches
- Dry wells
- Others

Unlike conveyance storm drain systems that convey water beneath the surface and work independently of surface topography, a drainage system for stormwater infiltration can work with natural landforms and land uses to become a major design element of a site plan. Solutions that reduce DCIA prevent runoff, detain or retain surface water, attenuate peak runoff rates, benefit water quality and convey stormwater. Site plans that apply stormwater management techniques use the natural topography to suggest the drainage system, pathway alignments, optimum locations for parks and play areas, and the most advantageous locations for building sites. In this way, the natural landforms help to generate an aesthetically pleasing urban form integrated with the natural features of the site.

Incorporate Zero Discharge Areas

An area within a development project can be designed to infiltrate, retain, or detain the volume of runoff requiring treatment from that area.

The term "zero discharge" in this philosophy applies at stormwater treatment design storm volumes. For example, consider an area that functionally captures and then infiltrates the 80th percentile storm volume. If permits require treatment of the 80th percentile storm volume, the area generates no treatment-required runoff.

Site design techniques available for designing areas that produce no treatment-required runoff include:

- Retention/Detention Ponds
- Wet Ponds
- Infiltration Areas
- Large Fountains
- Retention Rooftops
- Green roofs (roofs that incorporate vegetation) and blue roofs (roofs that incorporate detention or retention of rain).

Infiltration areas, ponds, fountains, and green/blue roofs can provide “dual use” functionality as stormwater retention measures and development amenities. Detention ponds and infiltration areas can double as playing fields or parks. Wet ponds and infiltration areas can serve dual roles when meeting landscaping requirements.

When several “zero discharge” areas are incorporated into a development design, significant reductions in volumes requiring treatment may be realized.

“Zero discharge” areas such as wet ponds, detention ponds, and infiltration areas can be designed to provide treatment over and above the storm volume captured and infiltrated. For example, after a wet pond area has captured its required storm volume, additional storm volume may be treated via settling prior to discharge from the pond. In this case, the “zero discharge” area converts automatically into a treatment device for runoff from other areas, providing settling for storm volumes beyond treatment requirements. Another example is a grassy infiltration area that converts into a treatment swale after infiltrating its area-required treatment volume. The grassy infiltration area in this example becomes a treatment swale for another area within the development.

Figure 2-7 illustrates a residential tract, and a tract incorporating Zero Discharge Area techniques (infiltration areas). The Zero Discharge Area designed tract represents a design to infiltrate (i.e., achieve zero discharge from) a portion of the tract’s runoff, reducing total runoff from the tract.

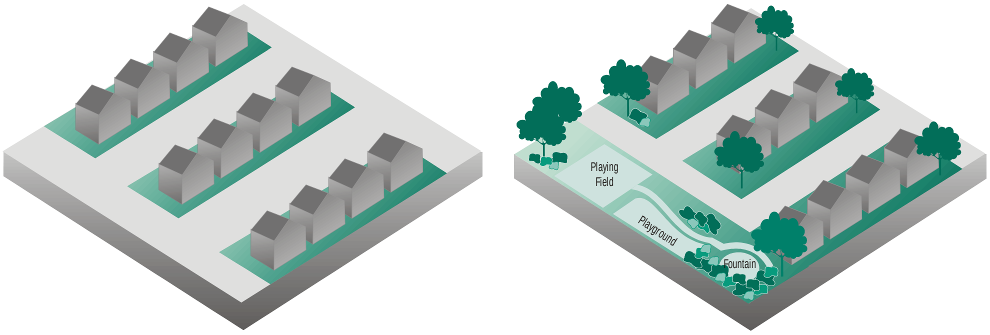

Figure 2-7
Zero Discharge Area Usage

Include Self-Treatment Areas

Developed areas may provide “self-treatment” of runoff if properly designed and drained.

Self-treating site design techniques include:

- Conserved Natural Spaces
- Large Landscaped Areas (including parks and lawns)
- Grass/Vegetated Swales
- Turf Block Paving Areas

The infiltration and bio-treatment inherent to such areas provides the treatment control necessary. These areas therefore act as their own BMP, and no additional BMPs to treat runoff should be required.

As illustrated in Figure 2-8, site drainage designs must direct runoff from self-treating areas away from other areas of the site that require treatment of runoff. Otherwise, the volume from the self-treating area will only add to the volume requiring treatment from the impervious area.

Likewise, under this philosophy, self-treating areas receiving runoff from treatment-required areas would no longer be considered self-treating, but rather would be considered as the BMP in place to treat that runoff. These areas could remain as self-treating, or partially self-treating areas, if adequately sized to handle the excess runoff addition.

Consider Runoff Reduction Areas

Using alternative surfaces with a lower coefficient of runoff or “C-Factor” may reduce runoff from developed areas. The C-Factor is a representation of the surface’s ability to produce runoff. Surfaces that produce higher volumes of runoff are represented by higher C-Factors, such as impervious surfaces. Surfaces that produce smaller volumes of runoff are represented by lower C-Factors, such as more pervious surfaces. See Table 2-2 for typical C-Factor values for various surfaces during small storms.

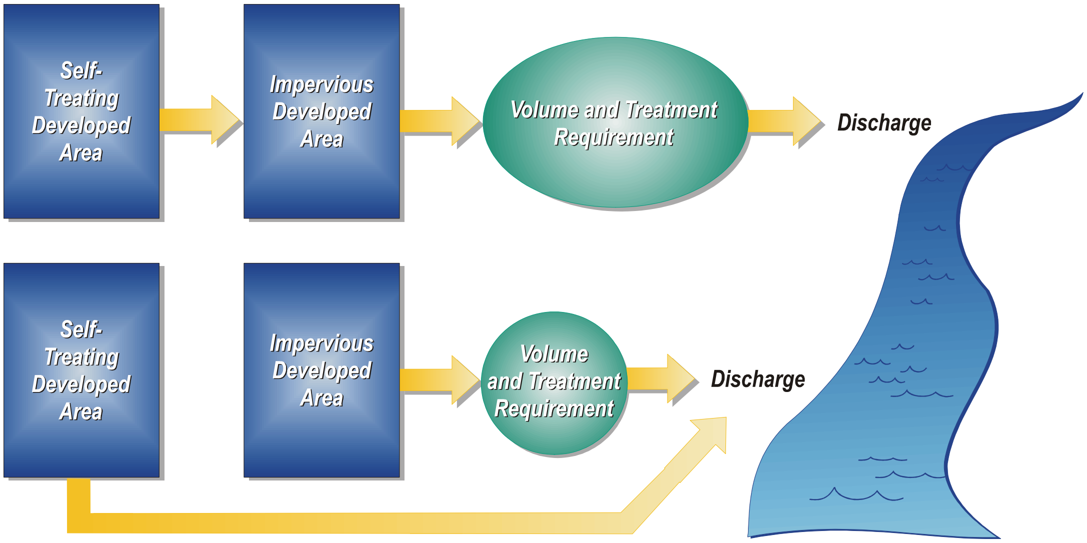

Figure 2-8
Self-Treating Area Usage

Table 2-3 compares the C-Factors of conventional paving surfaces to alternative, lower C-Factor paving surfaces. By incorporating more pervious, lower C-Factor surfaces into a development (see Figure 2-9), lower volumes of runoff may be produced. Lower volumes and rates of runoff translate directly to lower treatment requirements.

Table 2-2 Estimated C-Factors for Various Surfaces During Small Storms

Paving Surface	C-Factor
Concrete	0.80
Asphalt	0.70
Pervious Concrete	0.60
Cobbles	0.60
Pervious Asphalt	0.55
Natural Stone without Grout	0.25
Turf Block	0.15
Brick without Grout	0.13
Unit Pavers on Sand	0.10
Crushed Aggregate	0.10
Grass	0.10
Grass Over Porous Plastic	0.05
Gravel Over Porous Plastic	0.05

Note: C-Factors for small storms are likely to differ (be lower) than C-Factors developed for large, flood control volume size storms. The above C-Factors were produced by selecting the lower end of the best available C-Factor range for each paving surface. These C-Factors are only appropriate for small storm treatment design, and should not be used for flood control sizing. Where available, locally developed small storm C-Factors for various surfaces should be utilized.

Table 2-3 Conventional Paving Surface Small Storm C-Factors vs. Alternative Paving C-Factors

Conventional Paving Surface C-Factors	Reduced C-Factor Paving Alternatives
Concrete Patio/Plaza (0.80)	Decorative Unit Pavers on Sand (0.10)
Asphalt Parking Area (0.70)	Turf Block Overflow Parking Area (0.15)
	Pervious Concrete (0.60)
	Pervious Asphalt (0.55)
	Crushed Aggregate (0.10)

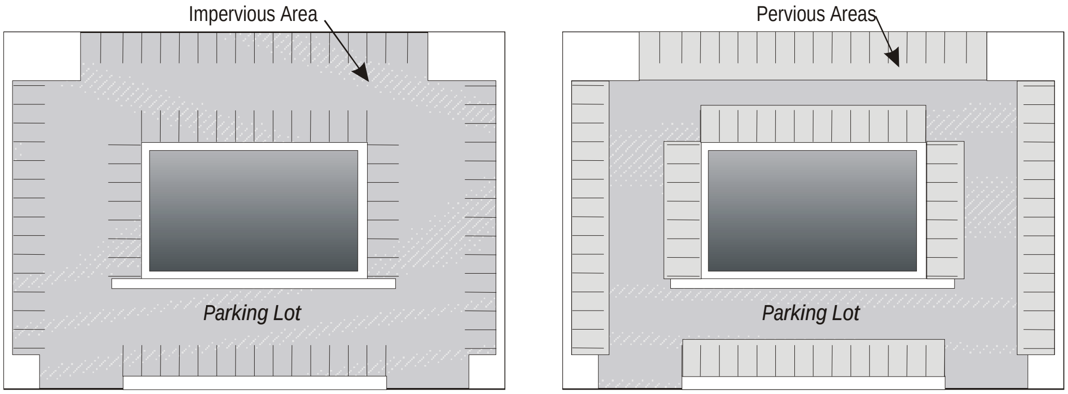

Figure 2-9
Impervious Parking Lot vs. Parking Lot with Some Pervious Surfaces

Site design techniques that incorporate pervious materials may be used to reduce the C-Factor of a developed area, reducing the amount of runoff requiring treatment. These materials include:

- Pervious Concrete
- Pervious Asphalt
- Turf Block
- Brick (un-grouted)
- Natural Stone
- Concrete Unit Pavers
- Crushed Aggregate
- Cobbles
- Wood Mulch

Other site design techniques such as disconnecting impervious areas, preservation of natural areas, and designing concave medians may be used to reduce the overall C-Factor of development areas.

Table 2-4 presents a list of site design and landscaping techniques and indicates whether they are applicable for use in Zero Discharge Areas, Self-Treating Areas, and Runoff Reduction Areas. Several different techniques may be implemented within the same design philosophy. Some techniques may be used to implement more than one design philosophy. Where feasible, combinations of multiple techniques may be incorporated into new development and redevelopment projects to minimize the amount of treatment required.

Table 2-4 Site Design and Landscaping Techniques

Site Design and Landscape Techniques	Design Criteria		Design Philosophy		
	Volume-Based Design	Flow-Based Design	Zero Discharge	Self – Treating	Runoff Reduction
Permeable Pavements					
Pervious concrete	X				X
Pervious asphalt	X				X
Turf block	X			X	X
Un-grouted brick	X				X
Un-grouted natural stone	X				X
Un-grouted concrete unit pavers	X				X
Unit pavers on sand	X				X
Crushed aggregate	X				X
Cobbles	X				X
Wood mulch	X				X
Streets					
Urban curb/swale system	X	X			X
Rural swale system	X	X			X
Dual drainage systems	X	X			X
Concave median	X	X	X		X
Pervious island	X	X			X
Parking Lots					
Hybrid surface parking lot	X				X
Pervious parking grove	X				X
Pervious overflow parking	X			X	X
Driveways					
Not directly connected impervious driveway		X			X
Paving only under wheels	X			X	X
Flared driveways	X				X
Buildings					
Dry-well	X		X		X
Cistern	X	X	X		X
Foundation planting	X	X			X
Pop-up drainage emitters		X			
Landscape					
Grass/vegetated swales	X	X		X	X
Extended detention (dry) ponds	X		X	X	X
Wet ponds	X		X	X	X
Bio-retention areas	X		X	X	X

2.4.2 Control Sources of Pollutants

There are a number of items that can be routinely designed into a project that function as source controls once a project is completed. They include such items as marking new drain inlets and posting informational signs; improving landscape planning and efficient irrigation methods; using water quality friendly building materials; implementing roof runoff controls; properly designing outdoor material and trash storage areas; and permanently protecting slopes and channels from erosion. They also include design features for specific workplace or other activity areas such as vehicle washing areas, outdoor processing areas, maintenance bays and docks, and fueling areas.

Design of BMPs to control workplace exposure to pollutants is guided by three general principles:

- Prevent water from contacting work areas. Work and storage areas should be designed to prevent stormwater runoff from passing through shipping areas, vehicle maintenance yards, and other work places before it reaches storm drains. The objective is to prevent the discharge of water laden with grease, oil, heavy metals and process fluids to surface waters or sensitive resource areas.

- Prevent pollutants from contacting surfaces that come into contact with stormwater runoff. Precautionary measures should be employed to keep pollutants from contacting surfaces that come into contact with runoff. This means controlling spills and reviewing operational practices and equipment to prevent pollutants from coming into contact with storm or wash water runoff.

- Treating water before discharging it to the storm drain. Treatment of polluted runoff should be employed as a last resort. If source control options are not possible, treatment measures that comply with NPDES permit requirements must be adopted.

Once BMPs are designed into a project, they must be appropriately operated and maintained throughout the life cycle of the project in order to accomplish the BMPs pollution control objectives. For information on post construction operation and maintenance of BMPs built into the project, the reader is referred to the Stormwater Best Management Practice Handbook – Industrial and Commercial, companions to this handbook.

2.4.3 Treat Runoff

Until recently, stormwater and street design systems were designed to achieve a single objective – to convey water off-site as quickly as possible. The primary concern of conveyance systems was to protect property from flooding during large, infrequent storms. Drainage systems designed to meet this single volume control objective fail to address the environmental effects of non-point source pollution and increases in runoff volume and velocity caused by development.

Today's drainage systems must meet multiple purposes: protect property from flooding, control stream bank erosion, and protect water quality. To achieve this, designers must integrate conventional flood control strategies for large, infrequent storms with stormwater quality control strategies.

There are several basic water quality strategies for treating runoff:

- Infiltrate runoff into the soil
- Retain/detain runoff for later release with the detention providing treatment
- Convey runoff slowly through vegetation
- Treat runoff on a flow-through basis using various treatment technologies

Solutions should be based on an understanding of the water quality and economic benefits inherent in construction of systems that utilize or mimic natural drainage patterns. Site designs should be based on site conditions and use these as the basis for selecting appropriate stormwater quality controls. The drainage system design process considers variables such as local climate, the infiltration rate and erosivity of the soils, and slope. Many of the negative impacts associated with urban development can be alleviated if policy alternatives encourage developers to protect and restore habitat quality and quantity, include measures to improve water quality, and provide buffers between development and stream corridors.

Unlike conveyance models, which are assessed by simple quantitative measures (flood control volumes and economics), water quality designs must optimize for a complex array of both quantitative and qualitative standards, including engineering worthiness, environmental benefit, horticultural sustainability, aesthetics, functionality, maintainability, economics and safety.

2.4.4 Planning Development Strategies in Practice

The importance of site planning in stormwater quality protection is illustrated in the following examples of development strategies: conventional residential subdivision (Figure 2-10, Alternative 1), conventional subdivision employing BMPs (Figure 2-11, Alternative 2), and a mixed-use transit-oriented development (Figure 2-12, Alternative 3). All three examples are intended to accommodate approximately 660 housing units on a 220-acre site adjacent to a creek.

The conventional residential subdivision (Alternative 1) accommodates 660 single-family homes on individual lots. One-sixth acre lots are accessed by a network of 40 ft wide cul-de-sac streets, with 5 ft sidewalks adjacent to the curb on each side of the street. The street and sidewalks are located within a 60 ft right-of-way, which is covered with a 40 ft wide street and two 5 ft sidewalks, or 50 ft of pavement, 100% impervious land coverage (streets only), and no room for street trees. No variation exists in housing types (all single-family).

Figure 2-10
Alternative 1: Conventional

Both the streets and the open space features lack structure or hierarchy. The few direct connections through the neighborhood result in long stretches of overly wide streets that discourage walking.

Conventional development design does not use the recreational or stormwater benefits of the available open space and does not respond to natural and topographic features. Preservation of open space is a low priority, and the setback between the development and the creek is minimal. The remaining open space character is remnant space offering residents no creek access or parks. Stormwater travels through a 15,000 ft network of drainpipes and in the absence of current permit requirements would discharge untreated runoff directly into the creek. However, applying typical permit requirements, the development would still be required to incorporate runoff treatment for the water quality design volume defined in the local permit or MS4 new development program. For example, if the permit required treatment of the runoff from 0.75 inches of rainfall, the development as planned had an overall percent impervious value of 45%, and the designer was considering the use of an extended detention basin for treatment, this would require a treatment volume of approximately 6.2 ac-ft. Based on typical detention basin design practices, this could result in the need to dedicate approximately 2-3 acres of land, or the equivalent of approximately 12-18 lots to incorporate the basin into the development near the point where drainage enters the creek. Alternatively, if a watershed or regional master plan for water quality had been adopted in which the development could participate financially, the project would contribute financially based on its required treatment volume and the cost allocation plan for the watershed program.

The hybrid/best practices subdivision (Alternative 2) illustrates a conventional neighborhood that applies some stormwater management practices. This attempt accommodates 660 single-family homes on individual lots. Streets are narrower, with the interior access streets at 28 ft wide, while internal neighborhood collectors are 32 ft wide. All streets have detached sidewalks that accommodate street trees planted between the sidewalk and the curb. This development sets the houses 100 ft back from the creek and offers residents 12 acres of access to open space and parks. The overall imperviousness has been reduced to about 41%, thereby reducing the volume to be treated to approximately 5.6 ac-ft. A detention basin has been created in open space within the development. Nearly one fourth of the 13,000 ft network of piped stormwater drains to a detention pond.

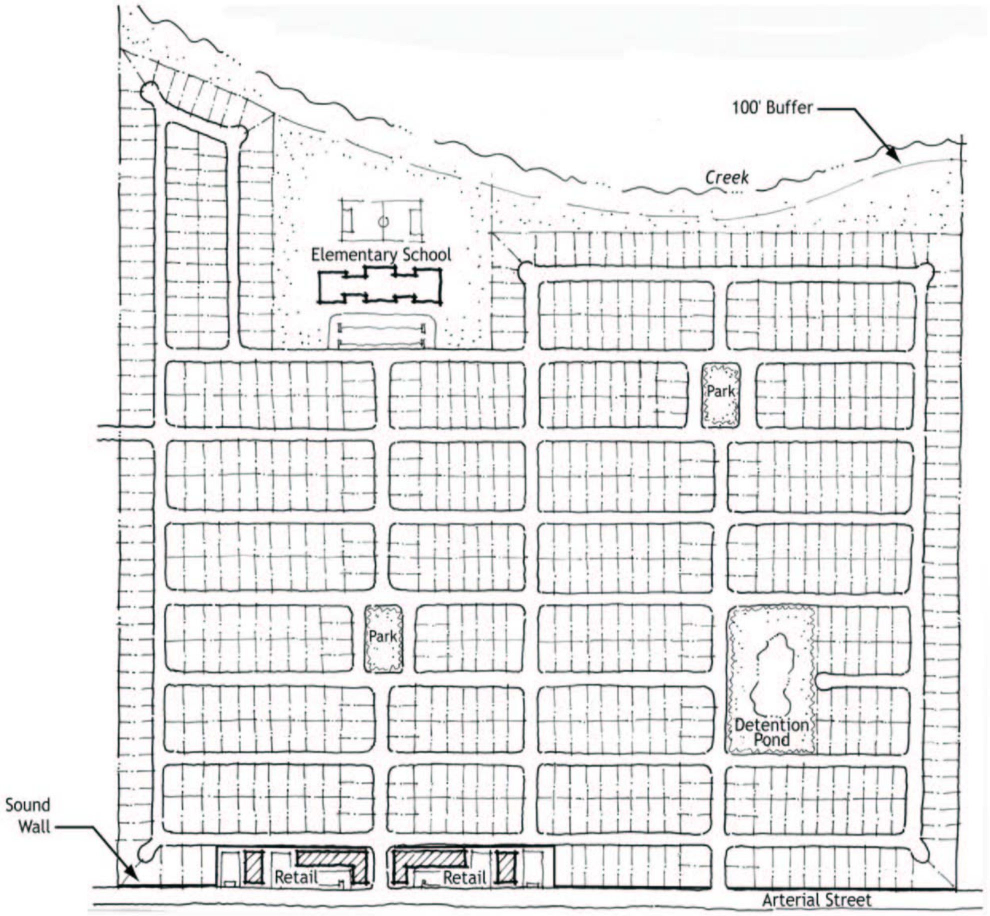

Figure 2-11
Alternative 2: Hybrid/Best Practices

By employing a hierarchy of narrower streets this neighborhood requires 1475 ft^2 of street per housing unit, a reduction of 19% relative to the conventional sub-division.

The neo-traditional mixed-use neighborhood is illustrated as Alternative 3. This neighborhood includes 660 housing units, but also introduces other uses: retail, office, and live-work, within a network of tree-lined streets and open space. The neighborhood drains to an open space park adjacent to the creek, naturally and efficiently filtering stormwater before it enters the creek. Bioswales along key streets capture and treat stormwater en-route to the creek, providing aesthetic appeal and recreational opportunities. Alternative 3 requires 965 ft^2 of street per housing unit, a reduction of 47% relative to the conventional sub-division. A strategically located transit system stops near shops and higher density housing makes transit feasible. Every dwelling unit in the neighborhood is within a 5-minute walk from shops or transit. The overall imperviousness of this site has been reduced to approximately 36%, further reducing the treatment volume. In addition, there are a variety of opportunities to incorporate treatment for all of the remaining runoff within the open space park without the need to dedicate any additional developable land.

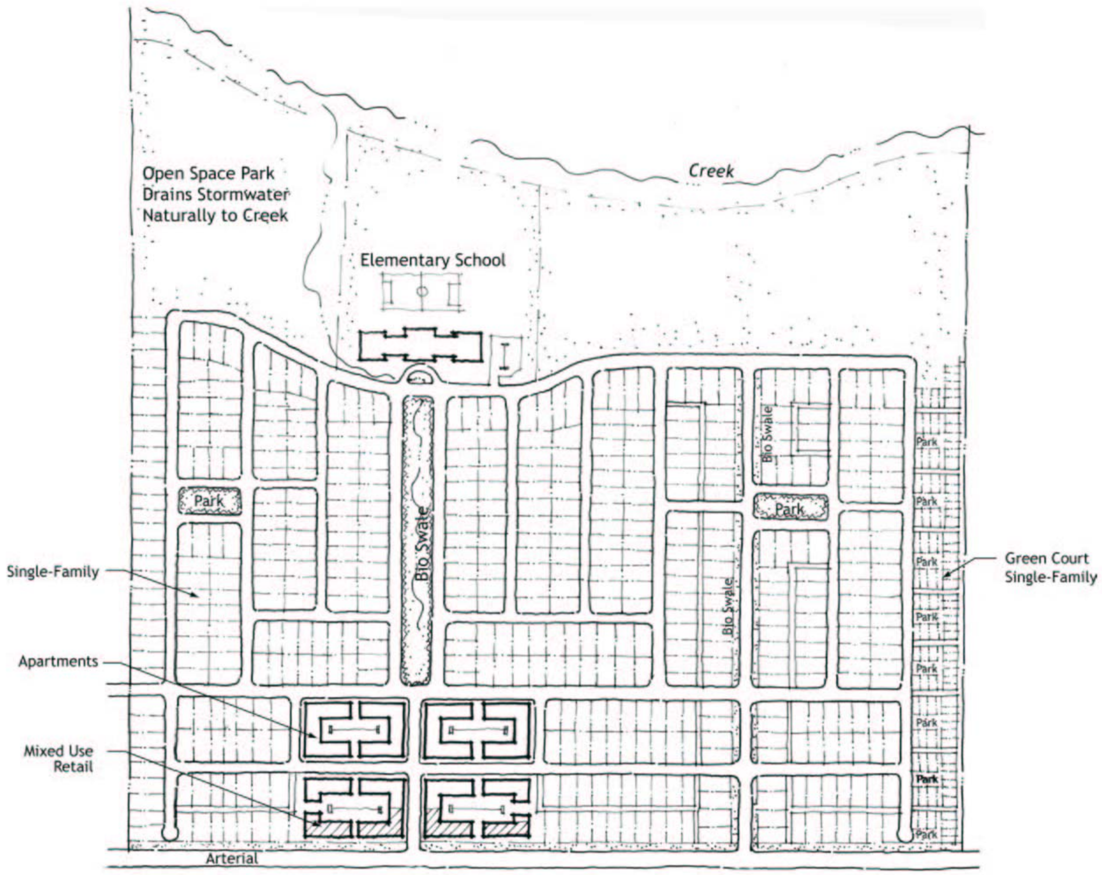

Figure 2-12
Alternative 3: Neo-Traditional

A comparison of the three alternatives is shown in Table 2-5.

Table 2-5 Comparison of Three Alternatives

	Alternative 1	Alternative 2	Alternative 3
Total Site (Ac)	220	220	220
# Of Housing Units	660	660	660
Parks & Open Space (Ac)	0	12	52
Creek Setback (Ft)	0	100	500
Impervious Land Coverage - Streets (Ac)	28	22	15
% Of Site that is Impervious - Streets Only	13%	10%	7%
% Of Site that is Impervious - Streets Only (Relative to Conventional)	100%	81%	53%
Linear Feet of Pipe	15,000	13,000	10,000
Linear Feet of Swale	0	0	4,700
Width of Major Streets (Ft)	40	32	32
Width of Minor Streets (Ft)	None	28	28

Typical lots in Alternatives 2 and 3 are illustrated in three forms: street loaded, alley fed and rural. In the street-loaded form, lot size is still approximately 1/6 acre, but the lot is narrower and deeper, thus reducing the amount of street frontage per household. The two-car garage is accessed from a front driveway. This front-loaded street accounts for 63% impervious land coverage in the 60 ft right-of-way.

Looking at a typical street, the traditional residential neighborhood reduces the number of feet of street and sidewalk per housing unit by nearly 40% compared to the conventional subdivision. This is accomplished by two means: a narrower street width (28 ft versus 40 ft), and narrower, deeper lots (60 ft versus 65 ft wide). Narrower lots mean less street frontage per lot.

In the alley-loaded form, the street right-of-way is narrowed to 50 ft, leaving 4 ft for trees between the sidewalk and curb. This form also employs the narrower street, achieving a 40% reduction in pavement dedicated to street and sidewalk. A 16 ft wide alley is provided in the back to access a garage at the rear of each lot. Additional pavement for the alley is balanced by elimination of pavement for the front driveway. This model assumes an impervious asphalt or concrete alley. Gravel alleys are feasible, and improve permeability. In this form, narrower, deeper lots are employed to accommodate the depth required for the alley.

The rural street form dramatically reduces impervious land coverage. The street is 19 ft wide with gravel shoulders for trees and parking. Pedestrians walk on the gravel shoulder or share the street with slow-moving cars.

Looking at a typical street, the rural form provides the greatest reduction in impervious land coverage. Only 570 ft^2 of pavement of street is required per housing unit, a reduction of 62% compared to the conventional sub-division.