Making the Connection: Smart Growth and Water Resource Protection

Changes in land use are linked to impacts on water resources (Figure 1). This module illustrates how historical trends in growth patterns and activities on land have become the most significant challenge for preserving water quality and meeting future water resource goals.

Factors such as traffic congestion, air quality, and public health figure prominently in discussions on urban growth and development today. This module focuses on the connections between smart growth approaches and Clean Water Act programs. It also includes tools, resources and case studies illustrating how land use decisions made at the local and state levels can help protect and restore water resources by using innovative approaches that meet economic, environmental and social goals.

Figure 1

Meeting the Nation’s Water Quality Goals

Since 1972 the Clean Water Act (CWA) has had considerable success in controlling water pollution from point sources such as municipal wastewater treatment plants and industrial discharges. Today pollutants generated by nonpoint sources are the largest cause of impairments to State Water Quality Standards (http://www.epa.gov/watertrain/cwa/cwa2.htm) and the “fishable/ swimmable” goals (http://www.epa.gov/watertrain/cwa/cwa8.htm).

Figure 2 shows watersheds at the 8-digit Hydrologic Unit Code (HUC) and the percentage of waterbodies that do not meet water quality standards. Only around 10 percent of these impairments can be resolved by addressing point sources alone.

Activities such as excavating and clearing associated with urban development and new construction are major sources of siltation and sediment. Once urban settlements are established, additional problems for nearby waterbodies are caused by increased runoff that transports pollutants such as automobile fluids, lawn care products, pet waste and trash. The process of urban development also affects wetlands, drinking water and ground water, and habitat for fish and wildlife, which are covered later in Chapter 1.

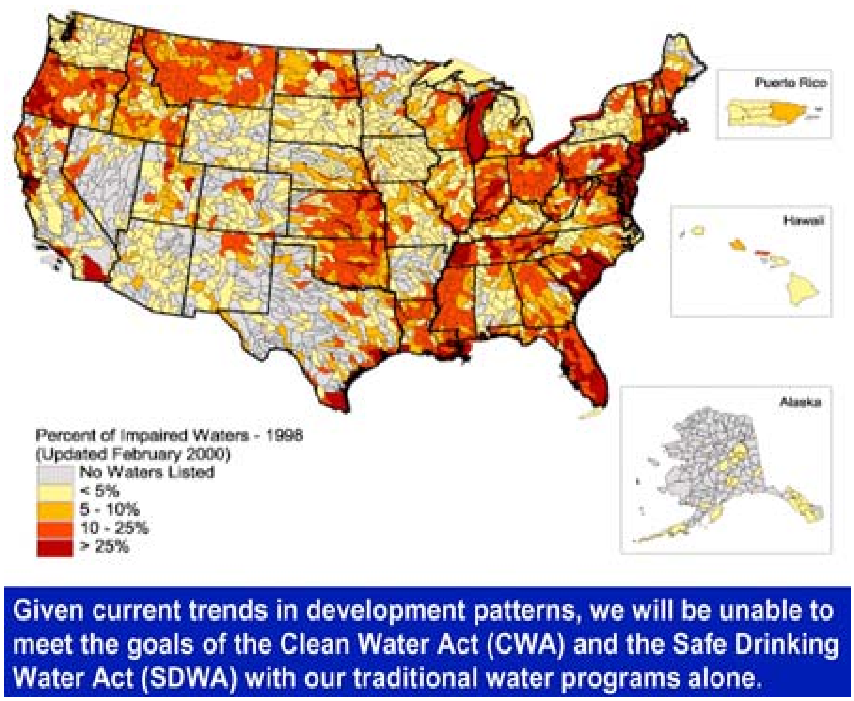


Figure 2

In the *2000 National Water Quality Inventory, Chapter 1* (http://www.epa.gov/305b/2000report/) EPA reported that the leading sources of impairments across all waterbody types (including streams and rivers, lakes, ponds, and estuaries) are nonpoint sources such as agriculture and land-based activities in urban areas (USEPA 2000).

Smart growth offers an alternative approach to the patterns and legacy of growth that we have inherited over the past century, which are illustrated in the following sections.

Rate of Land Development vs. Rate of Population Growth

The rate of land conversion to urban uses is due more to modern settlement patterns than to population growth. According to the U.S. Department of Agriculture's National Resources Inventory, developed land in the contiguous United States increased 34 percent between 1982 and 1997. During the same 15-year period, population grew by about 15 percent; thus land consumption occurred at more than twice the rate of population growth (USDA NRCS 2001; U.S. Census Bureau 2000).

More than a quarter of all the land conversion from rural to urban and suburban uses since European settlement occurred between 1982 and 1997 — a period of only 15 years. Figure 3 demonstrates the potential for more than 68 million additional acres of land to be developed by 2025 if current trends continue.

Figures 4-8 show the growth trend of urban land expansion outpacing population growth in select cities across the United States.

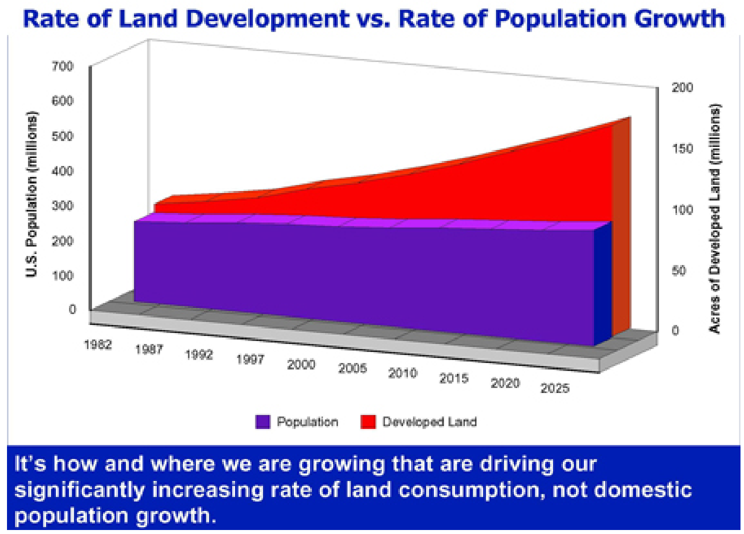
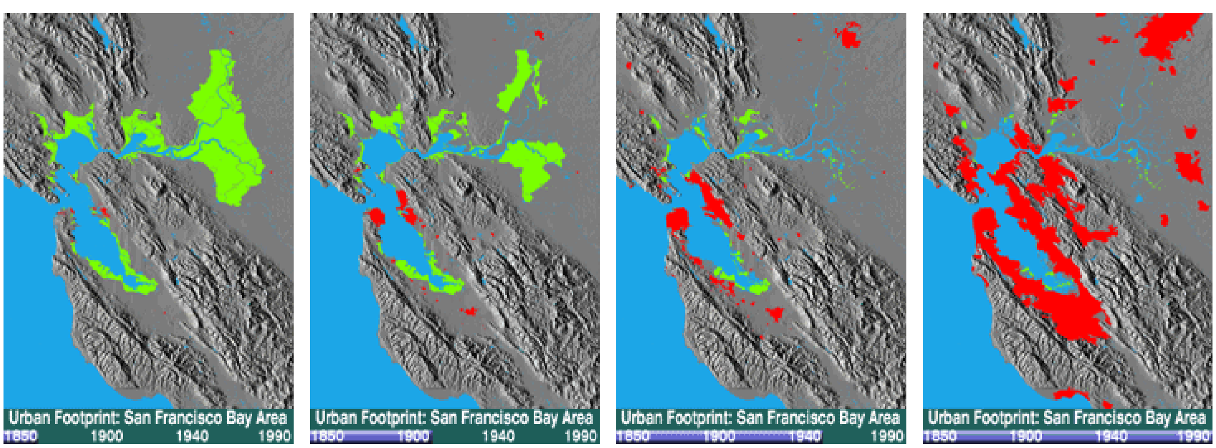


Figure 3

San Francisco Bay Area
Urban Expansion, 1850 – 1990

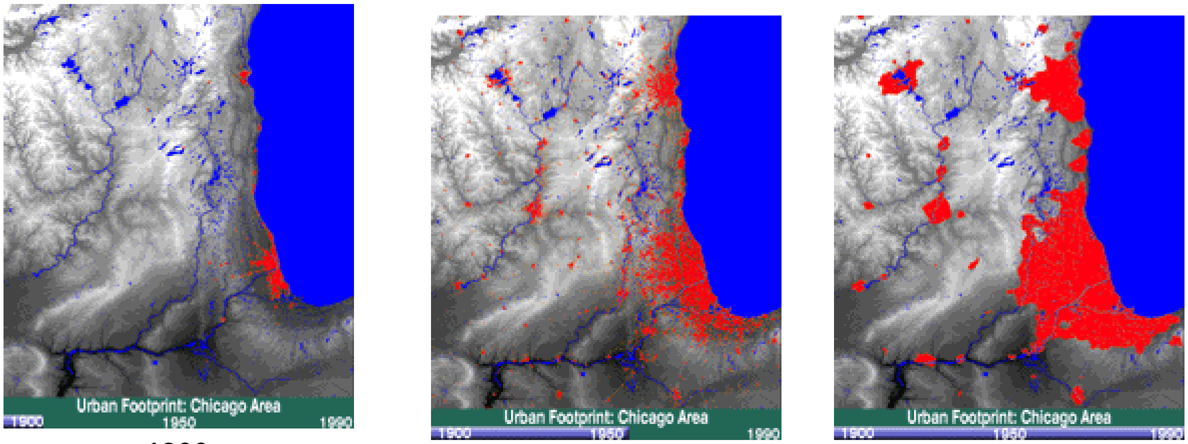


1850 **1900** **1940** **1990**

Key: Green = wetlands, Red = urban footprint

Figure 4

Chicago Area
Urban Expansion, 1900 - 1990

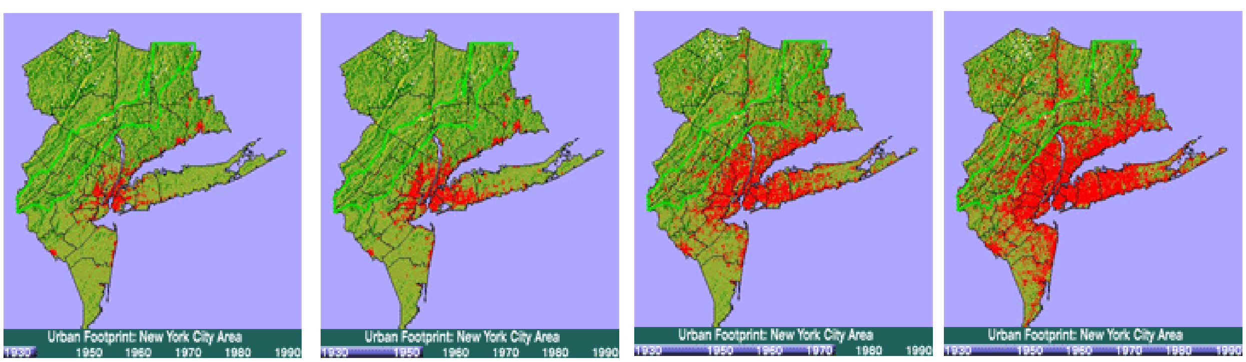


1900 **1950** **1990**

Key: Red = urban footprint

Figure 5

New York City Area
Urban Expansion, 1930 – 1990

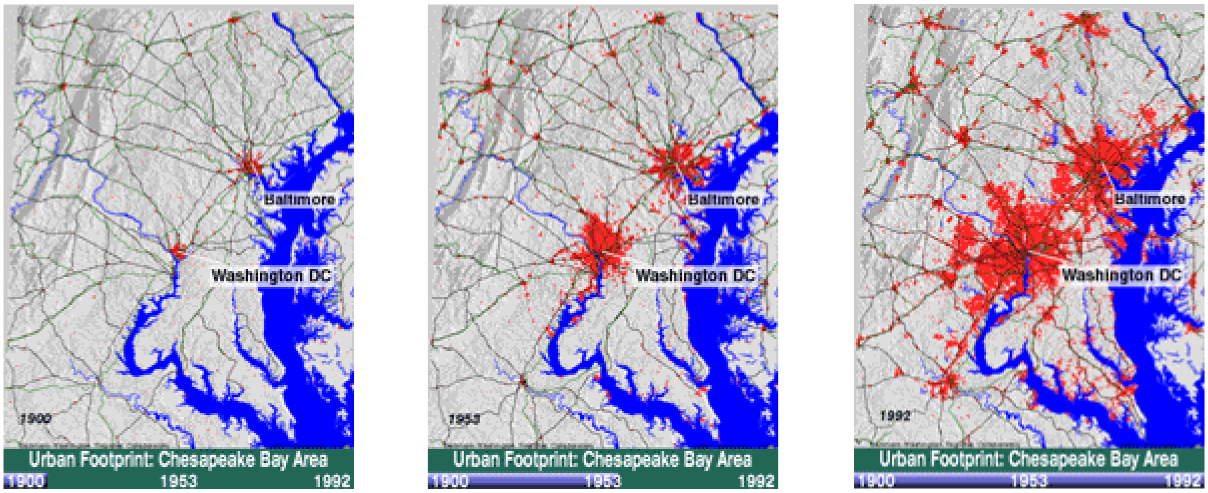


1930 **1950** **1970** **1990**

Key: Red = urban footprint

Figure 6

Chesapeake Bay Area
(Baltimore/Washington, DC, Area)
Urban Expansion, 1900 – 1992

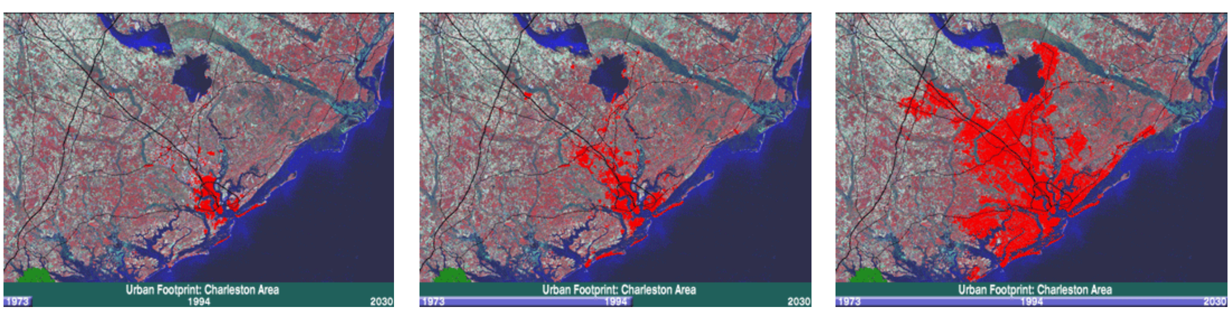


1900 **1953** **1992**

Key: Red = urban footprint

Figure 7

Charleston Area
Urban Expansion, 1973 – 2030



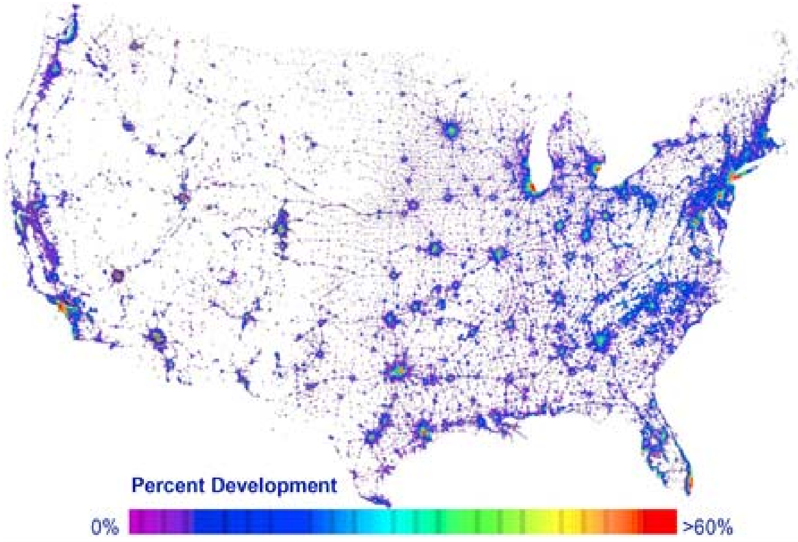
1973 **1994** **2030**

Key: Red = urban footprint

Figure 8

Low-Density Development

This composite satellite image (Figure 9) from space shows that low-density urban development is the predominant pattern of urban land cover in the nation today. The blue areas indicate that low-density urban land cover is much more widespread than the highly urban centers and is closely associated with the national highway network. This diffuse urban expansion is popularly termed sprawl.



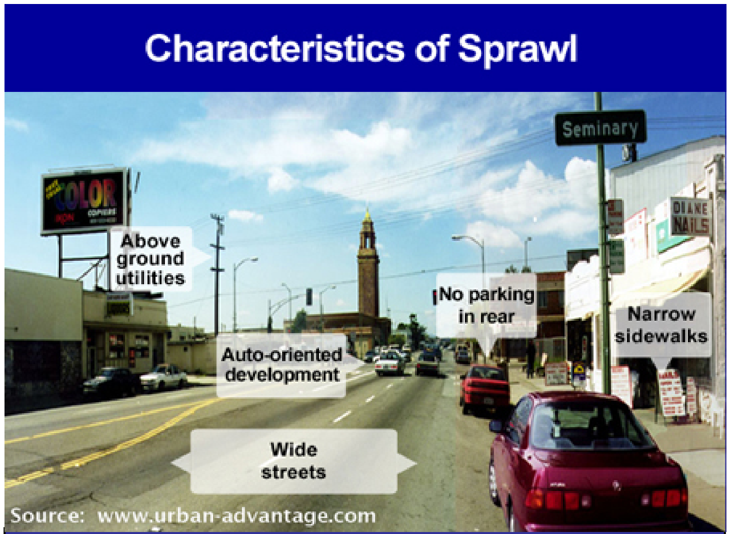
Low-density urban development is the predominant pattern of urban land cover in the United States.

Figure 9

Prevailing patterns of development in these areas include separate zoning for residential and commercial uses. Because there are not always other transportation options for everyday activities such as shopping, going to work, entertaining and running errands, this dispersed development pattern results in greater automobile dependency and more vehicle miles traveled.

Characteristics of Sprawl

Sprawl is described as low-density, automobile-dependent development outside compact urban and village centers, along highways and in rural countryside (Planners Web , 2001, http://www.plannersweb.com/articles/sprawl-articles.html). However, sprawl is also described within a spatio-temporal context, in which the rate of increase of urban land in comparison to non-agricultural or non-natural uses exceeds the rate of population growth. Characteristics of sprawl (Figure 10) include the following:



Low-density Commercial Development—Single-use zoning.

Figure 10

- Excessive land consumption and fragmented open space
- Low population densities
- Lack of travel choices
- Higher service and infrastructure costs
- Lack of choice in housing types and prices
- Geographical separation of everyday functions
- Loss of rural character and agricultural land
- Visual clutter and scattered appearance
- Commercial buildings surrounded by large parking lots

Sprawl contributes greatly to changes in the hydrologic balance of watersheds because sprawling development paves over natural land with impervious pavement and concrete. Water behaves differently over paved surfaces, changing the nature of the watershed in terms of both water quality and water quantity.

Trends in Vehicle Miles Traveled

The number of vehicle miles traveled increased after World War II, but over the past 20 years, the number of miles Americans drive every year has increased at four times the rate of population growth (Figure 11). Pollutants associated with atmospheric deposition from automobile emissions and runoff from roads are recognized as an increasingly significant source of water pollution. As this pattern of development has eliminated transportation options for many Americans, related impacts on quality of life such as time lost in traffic congestion, longer commuting times, more aggressive driving and more accidents have worsened.

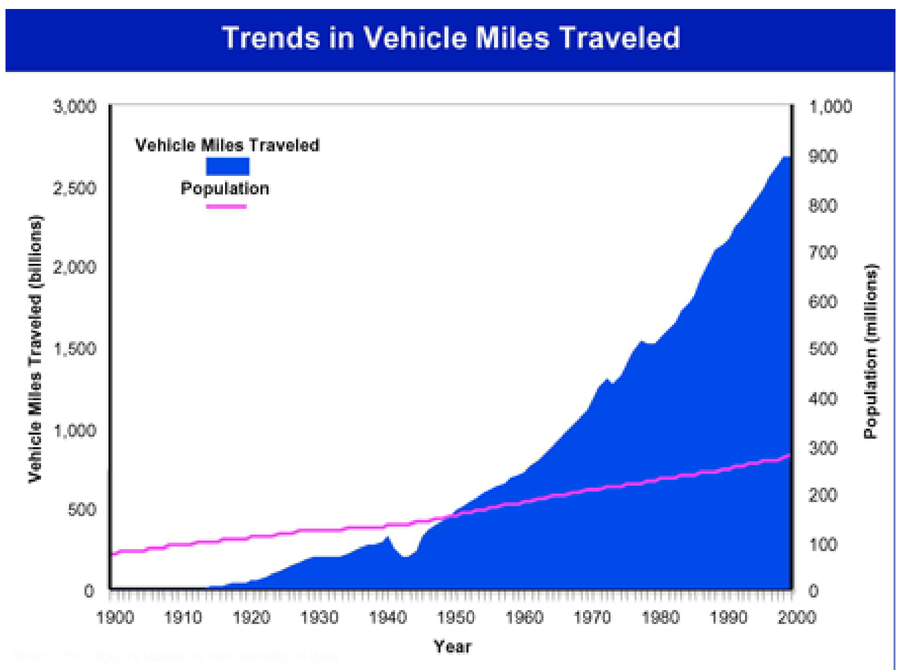


Figure 11

One study concludes that the number of miles traveled per household falls by 35 percent when residential densities move from 2 units per acre to 10 units per acre (Holtzclaw 1994). Studies of transit usage establish seven to eight residential units per acre as the minimum housing density necessary to support regular transit service (Pushkarev and Zupan 1977).

Watersheds Under Development

The hydrologic change in watersheds at the national scale is illustrated in terms of percentage of watersheds in developed (or urbanized) land cover across the nation. In 1982 (Figure 12), 5.4 percent of watersheds (at the 8-digit HUC) had 15 percent or more of their area developed to urban land cover. By 1997 (Figure 13) that percentage had nearly doubled: 9.5 percent of the watersheds in the United States had 15 percent or more of their area developed to urban land cover.

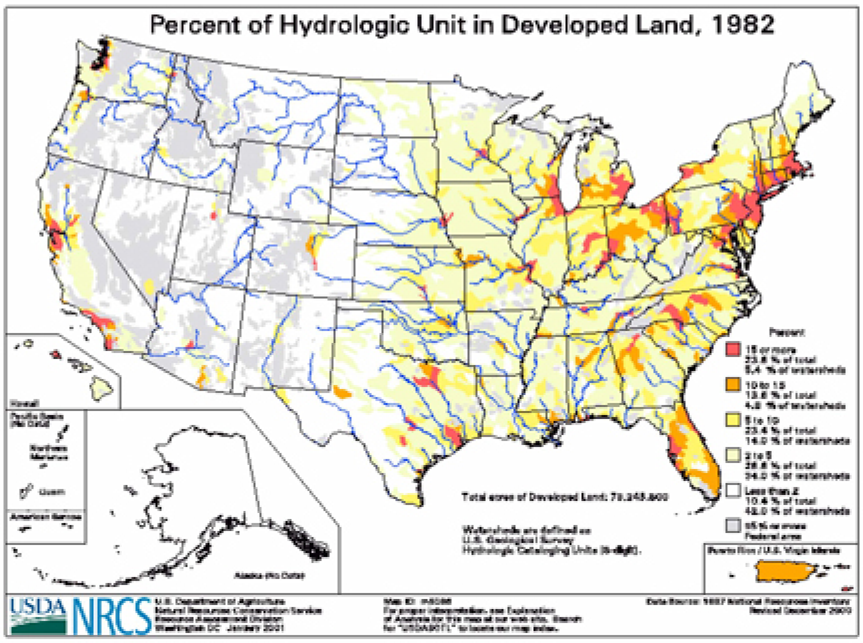


Figure 12

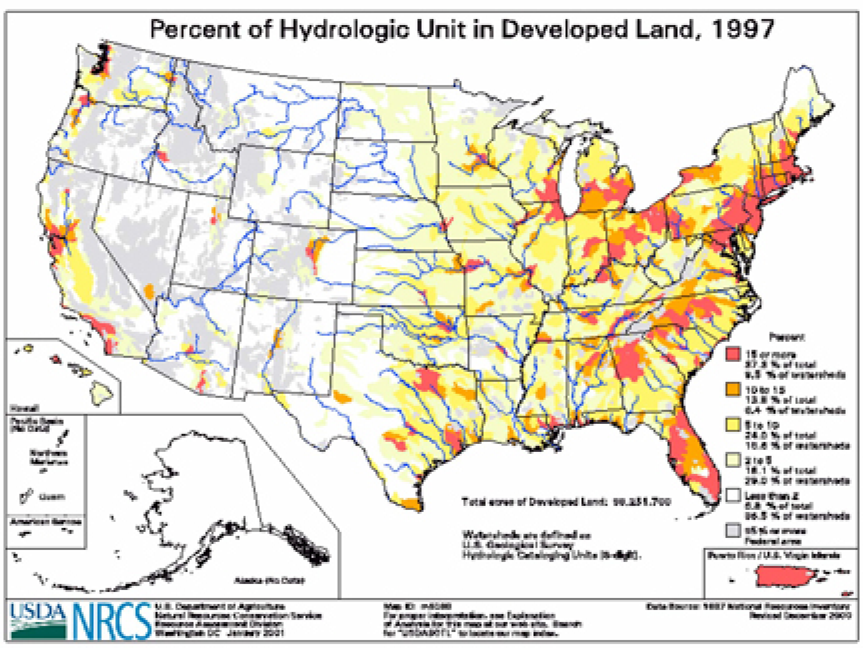


Figure 13

Impervious Surfaces and the Hydrologic Balance of Watersheds

Low-density residential suburbs and office parks might not seem to create much impervious surface, but they are served by roads, services such as shopping centers, recreational centers, schools, utilities and their associated parking lots, which together add up to increased impervious surfaces. Furthermore, soils that have been compacted by heavy machinery during construction, landscaping, or farming often function somewhat like paved surfaces. For example, a parking lot might be 95 percent impervious, a residential lawn might be 40 percent impervious and natural land covers are nearly 0 percent impervious (Anacostia Restoration Team 1991). Imperviousness results in fundamental changes in the characteristics of land cover. Ground water recharge, soil-based capture and retention of rainfall, vegetative growth, and the overall water balance and maintenance of the hydrologic cycle essential to environmental health can be negatively affected by increases in impervious surfaces (Figure 14).

In terms of the hydrologic cycle, less water is infiltrated and more runs off at the surface. This is an important point because the effective impervious surface in a watershed affects the physical structure of streams and waterbodies, as well as the diversity and abundance of aquatic life. It is also related to the amount of pollution caused by human activities that is transported directly to waterbodies in storm events, rather than being filtered through soil.

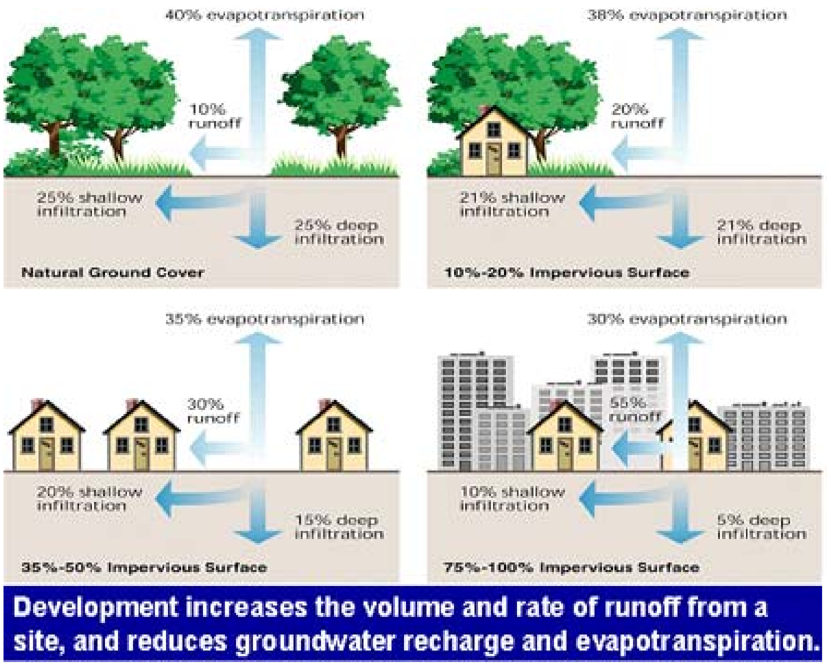


Figure 14

Factors Influencing Patterns of Growth Following WWII

Land use, regional growth and development (Figure 15) are affected by a number of factors, such as

- Markets
- Federal policies
- Regional and state policies
- Local laws and practices
- Actions of developers, real estate investors
- Lending practices

We will examine several key historical federal influences because they reveal the potential for changes in federal policy to allow or encourage state and local alternatives. Federal initiatives in transportation, environmental stewardship, housing policy and education policy all have the potential to encourage smart growth where decisions are made on the ground by municipalities, regions, towns, tribes and states.

Figure 15

Transportation Funding

Under the provisions of the 1956 Highway Act, the federal government subsidized new highways by paying 90 percent of their cost supported by revenue from the federal gasoline taxes. In contrast, localities paid a much higher percentage for investment in mass transit. These financial structures set up powerful incentives to neglect mass transit and focus regional transportation investments solely on roads. More than any other measure, urban studies scholars cite the influence of the 1956 Highway Act as creating the decentralized, automobile-dependent metropolis we know today (Figure 16).

Figure 16

Transportation Affects Location Decisions

With the growth of federal investment in highways, roads displaced railways as the primary mode of transport to move raw materials to manufacturing and on to the market. They provided greater flexibility of service, greater responsiveness to new product and traffic demands, and changing origin and destination points. Old rail networks that reached efficiently into cities no longer conferred location advantages and thus became obsolete. As trucking gained prominence, it played into location decisions. Manufacturing industries moved out to areas where they could benefit from cheaper land, taxes, labor and other subsidies. The evidence of this pattern is visible today in industrial parks and office parks located in outlying suburbs of towns or encroaching into farm fields and green space at the edge of urban areas, in contrast to abandoned railroad and industrial yards known as greyfields and brownfields near old downtown areas.

Federal Financing Programs

Post-1945 suburbia was supported by the financial foundation of the Federal Housing Administration's low-down-payment, long-term, fixed-rate mortgage, which made homeownership more accessible to the middle class. Moreover, FHA mortgage insurance was channeled in ways that physically shaped the postwar metropolis. For example, the FHA refused to insure mortgages on older houses in inner city urban neighborhoods. Private enterprise capitalized on these federal initiatives. Mass-produced housing that could be cheaply and speedily erected in suburban tracts (Figure 17) was pioneered by Levitt & Sons in Long Island and, through financing mechanisms, became the standard "consumer good" in the 1950s.

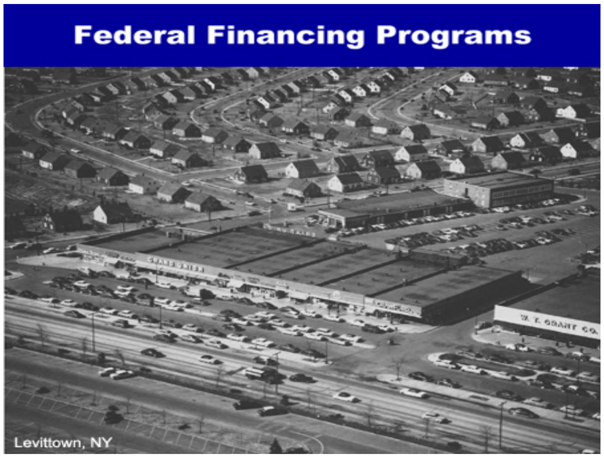


Figure 17

Housing Initiatives

As new roads and highways were built, they became part of an urban renewal strategy that, along with the loss of manufacturing firms, destabilized older urban neighborhoods with their old street grids and established communities and character. Highways were superimposed on older city neighborhoods, leaving many downtowns a pedestrian-unfriendly patchwork of highway ramps, empty lots, parking structures and isolated buildings (Figure 18).

The 1949 Housing Act aimed to redevelop downtowns and create public housing projects to relocate existing residents. Using modernist architecture to create high-rise apartment buildings that replaced older neighborhoods did not have the intended effect of creating a new downtown. Suburbs had caught on as the model of affluence, and they were the new trend in housing development.

Figure 18

Land-Use Planning and Zoning

EPA recognizes that local-level decisions make all the difference in strategizing and implementing a coherent vision of growth. The key elements of such strategies are master plans and zoning ordinances. Master plans form the basis for making public and private decisions on land use regulation and development, future investment and the allocation of critical resources.

Master plans also deal with growth boundaries and define where future developments are planned.

Zoning ordinances define the permitted uses of land and buildings, the size of lots and yards around homes and buildings, the size of parking lots, the width of roads and other characteristics of development (Figure 19). Existing zoning determines the form of our communities: most of what we see is simply built to conform with existing local laws. These highly proscriptive guidelines define for developers a path of least resistance for conventional, low-density, automobile-dependent development. Towns like many of the historic cities and towns that people cherish and love to visit can no longer be replicated under current zoning requirements. Multiple variances would be required, costing developers time and money. As long as innovative practices require exceptional treatment from local governments, they will not become mainstream.

Planning and zoning dictate the pattern shown above as the path of least resistance for developers. Ordinances must be changed in order to facilitate mainstreaming of innovative alternatives.

Figure 19

Community growth and management strategies should allow for the following:

- Periodic revision of master plans to reflect evolving community visions and goals
- Mainstreaming of innovative landscape design modifications, such as low-impact development techniques, and traditional patterns of development (i.e., New Urbanism) that help to achieve watershed protection goals.
- Updating of zoning ordinances that use outdated justifications or rely on historical conventions, such as parking lot requirements that have excess capacity in areas that offer transit alternatives.

Consequences of Current Growth Patterns

A wide range of adverse impacts on the environment, economy and quality of life are linked to the current growth patterns that have resulted in part from federal, state, local policies on housing, transportation and funding (Figure 20).

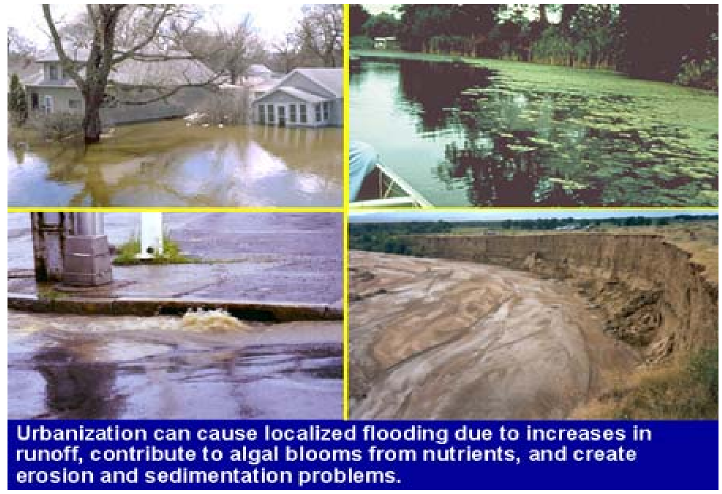


Figure 20

Environmental

Water Quantity and Hydrology

The effects of urban and suburban runoff are most dramatic when natural land is first developed. Land that was once able to soak up a half-inch of rain or more without a rise in stream levels behaves quite differently after roofs, roads and other impervious surfaces are constructed or created. Examining the hydrograph of a watershed (Figure 21) before and after the watershed has been developed reveals the challenges that planners face: greater volumes (Q) of precipitation run off the land more quickly, resulting in a sharp spike in stream levels, which can cause or worsen flooding. High stormwater flows that cause flooding and increased frequency of flooding are associated with urbanization.

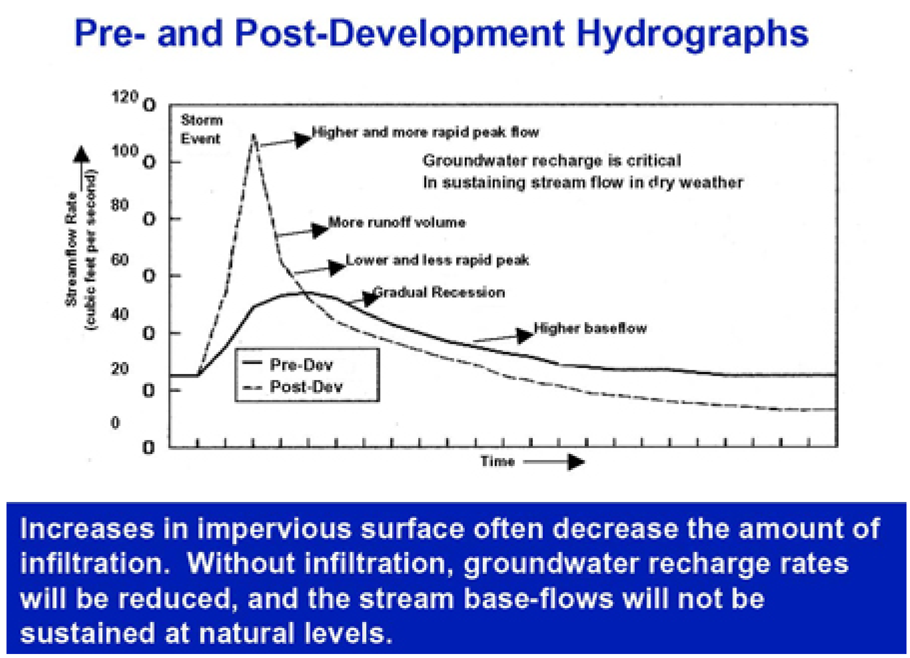


Figure 21

Changes to watershed hydrology are also apparent in aquifers and stream networks. The number of stream channels is reduced because stormwater conveyances are used to channel water away from developments. Stream "baseflow," or normal dry-weather flow, is lower because rainfall and snowmelt are not infiltrated and are not available to recharge streams or aquifers. In areas where residents depend on wells for their drinking water supply, underground aquifers can be depleted due to increasing demand from new development and an associated decrease in infiltration as impervious surfaces replace natural land cover. Fewer streams result in sudden large flows from storm events that cause channel erosion and widening. Widely accepted research indicates that stream channels begin to erode when effective impervious cover approaches 10 percent of a watershed. When effective imperviousness exceeds 25 percent, channel erosion and habitat degradation become significant, as well as the potential for contamination of drinking water sources. A large volume of scientific and technical research literature has established the association between impervious surfaces and negative impacts on waterways. In fact, effective impervious surface can be used as an indicator of aquatic health and biodiversity.

Water Quality and Habitat Impacts

Increased vehicle use, roads, construction site sediment runoff and residential trash and waste are all potential sources of concern for waterbodies during urbanization and post-urbanization. Greater paved surface area per capita results in increases of nonpoint source pollution from vehicles, pets and lawn care activities (Figure 22). Discontinuous, low-density, auto-dependent growth patterns that result in increased impervious surface can lead to the following:

- Disturbance of forests, soils, and wetlands that once served as buffers and filters
- Destruction of habitat for fish and wildlife and impaired aquatic health
- Increased nutrient pollution in waterways, causing algal blooms and eutrophication
- Thermal flashes and damaging temperature ranges in streams and creeks
- Contamination of drinking water sources
- Increases in polluted runoff from human and household sources
- Decreased ground water recharge

Figure 22

Economic Costs

The economic costs of unplanned or poorly planned growth might not be recouped by the resulting tax base. Communities nationwide have found that low-density, disconnected layouts in residential subdivisions are inefficient and that many costs associated with the long-term operation and maintenance of service infrastructure that is extended out to these subdivisions might not be fully accounted for up front. The city of Fresno, California, has doubled in size since 1980, producing $56 million in yearly revenues, according to the Sierra Club. Yet the costs of services has risen to $123 million, not including costs for roads and sewers.

New residential development demands more in services than it contributes in taxes, and existing residents typically foot the bill. A comparative study of two townships in central Michigan shows that for every $1 in revenue, residential development costs were $1.20 or $1.47 while farmland and open forest land required only $0.24 or $0.27. Farmland and open space conservation also have indirect positive tax benefits, such as reducing costs for flood control and water supply, and add to the aesthetic value and character of a community, often capitalized in land value.

Typical service and utility infrastructure for new developments includes: roads, wastewater pipelines, street storm sewer drainage systems, drinking water pipelines, street lighting (Figure 23), trash collection, street sweeping, landscaping and mowing, snow plowing, fire services, and other civic amenities such as public transportation, schools and utilities. Many of these costs are borne by local governments and are exaggerated by distance, total number and spatial layout.

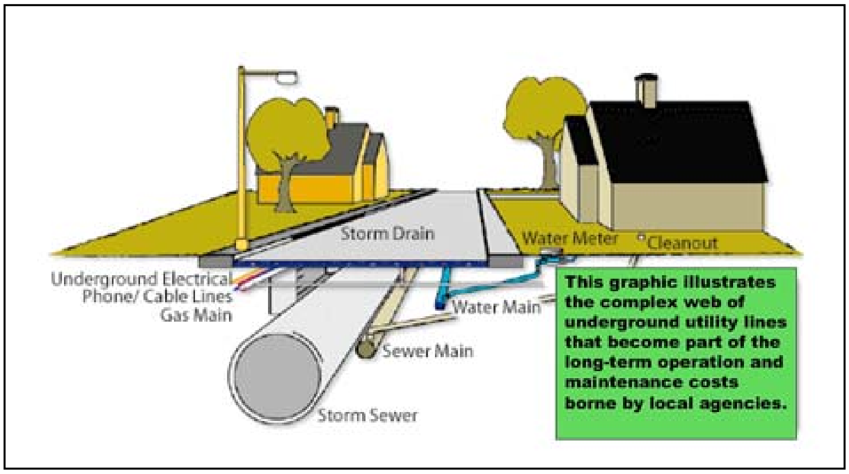


Figure 23

Examples include the following:

- In the traditional low-density residential layout, multiple individual narrow-diameter pipelines must be laid to service single homes that connect to a central collector line. This is more expensive than laying one large-diameter pipe that collects directly from houses laid out in clusters.
- If new development is focused around areas with existing service and utility infrastructure, the marginal costs to local governments are expected to be lower than the costs of new suburban development located beyond existing grids.
- The cost to run road maintenance programs and trash vehicles over greater distances is higher in low-density suburbs than in compact layouts and close-in locations.
- Energy costs for the individual consumer and for highway-related maintenance are higher in far-lying locations.

According to Eben Fodor (author of *Better not Bigger*), "Compact, well-planned growth consumes about 45 percent less land and costs 25 percent less for roads, 20 percent less for utilities, and 5 percent less for schools."

Economic costs are also associated with lost agricultural lands and agricultural products because of encroachment on high-quality agricultural lands that border existing urban centers. (See *Development at the Urban Fringe and Beyond: Impacts on Agriculture and Rural Land*, http://www.ers.usda.gov/publications/aer803/)

Quality of Life, Public Health, and Cultural Costs

The current prevalent pattern of growth has affected the cultural fabric of our communities as well as environmental health (Figure 24). People in spread-out locations drive much more, resulting in environmentally linked social costs, including

- Poor air quality (smog and ozone problems) and increases in atmospheric deposition
- Health problems from air pollution and ozone days due to traffic
- Reduced worker productivity
- Less leisure time
- Increased stress due to traffic congestion
- Longer commuting times and more aggressive driving patterns
- Reinforced spatial disparity between income groups
- Increasing obesity due to sedentary automobile-dependent lifestyles
- Greater traffic-related morbidity and more accidents
- Increased nonpoint source pollution from deposition of airborne pollutants generated by automobiles
- Impacts on drinking water quality

Figure 24

Solutions – It Is Possible To Do Better

Communities across the country are seeking new ways to grow as their quality of life is challenged by decreasing open space, fewer transportation options, and higher taxes to cover the costs of new growth. Smart growth has emerged as a way to approach community, economic and environmental goals in a more integrated fashion. It is a sound alternative to continuing the traditional approach of piecemeal, discrete development across the landscape, where the change of an individual site seen alone might not seem to exact an environment cost but actually leads cumulatively, over the long term, to the issues and problems associated with sprawl. In the image at right (Figure 25), the smart growth development pattern on the right can accommodate more people in less space while preserving agricultural and natural areas through effective urban design elements at the street scale (Figure 26).

Smart growth efforts have taken different forms around the country, but the 10 guiding principles (Figure 27) address a variety of goals. In the context of a watershed approach, smart growth offers great potential for achieving water resource management and water quality goals.

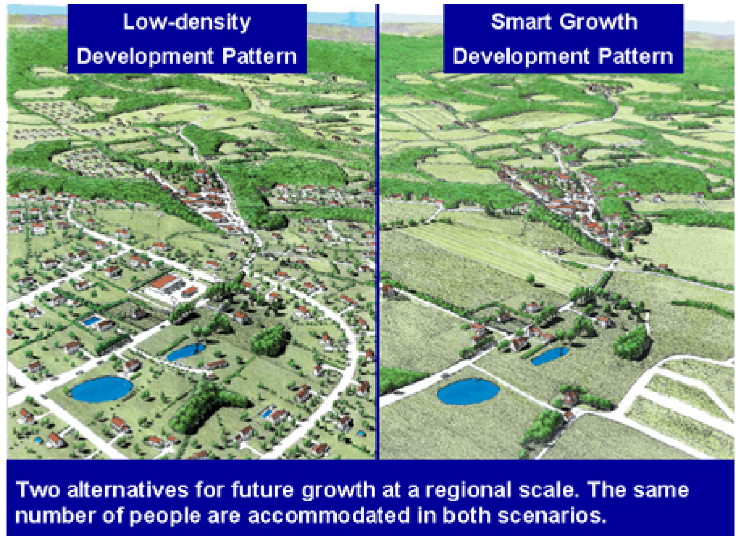


Figure 25

- Water quality standards are better met using smart growth methods.
- Conservation of open space and clustered development patterns protect water quality.
- Taking a long-term approach to zoning helps to avoid sprawl through better planning.


Figure 26

Figure 27

Factoring Location Decisions into Watershed Health

An important element of smart growth is the redevelopment and infill of existing urban areas. Many cities have reinvested in older sites that offer connections with existing infrastructure such as road systems and riverfronts. Cleaning up and using these areas often helps to preserve green space and other environmental infrastructure such as wetlands, which might otherwise be developed to accommodate growth. Using brownfields can help save natural lands from sprawl by redeveloping existing urban infrastructure into new urban uses such as shops, commercial buildings and entertainment complexes. For every acre of brownfields redeveloped, it is estimated that an average of 4.5 acres of greenfields are saved (Deason et al. 2001).

Figure 28

As we redevelop most urban parcels every 50 years, we have an opportunity to add best management practices such as raingardens, green roofs, and rainwater storage cisterns.

This photo (Figure 28) of Providence, Rhode Island, was taken near the confluence of the Woonasquatucket, Moshassuck and Providence Rivers.

Until the early 19th century, the area was a large salt marsh known locally as "the cove."

By 1860 development in Providence had surrounded the tidal marsh, and the cove had become known as the "cove basin," featuring a promenade adjacent to the city's railroad station. Until the 1870s Providence did not treat its wastewater, and sewage was discharged directly into the three rivers. After cholera and typhoid epidemics in the late 1800s, the cove basin was filled in (Figure 29).

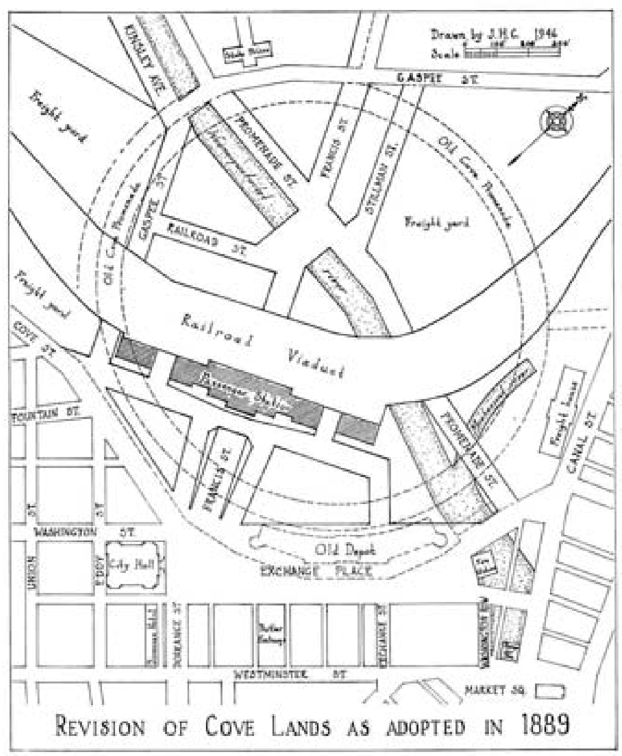


Figure 29. Revision of Cove Lands

Before the cove area was redeveloped in the early 1990s, the three rivers had disappeared into box culverts that were mostly underground and covered by roads. Today the confluence of the rivers is open, and the cove basin has been replicated on a smaller scale.

Figure 30. Air view of civic center from the southeast, c. 1925

Like many cities, Providence developed along waterways when its economy relied on them for power and transportation. The city also used the rivers for waste disposal, transforming them into sewers that the city then ignored. Now the rivers are a central feature of the city's renaissance (Figure 30), a testimony to both the success of wastewater treatment and good urban design improving the quality of life and the local economy.

Promoting Environmentally Friendly Building Practices

An important component of smart growth is design at the site level. In terms of street design, there are opportunities to create choices for transportation other than automobiles. Adding trees can help regulate the urban heat island effect, improve urban air quality and retain stormwater.
In the example (Figure 31), this redesigned street reflects a traditional neighborhood development design.

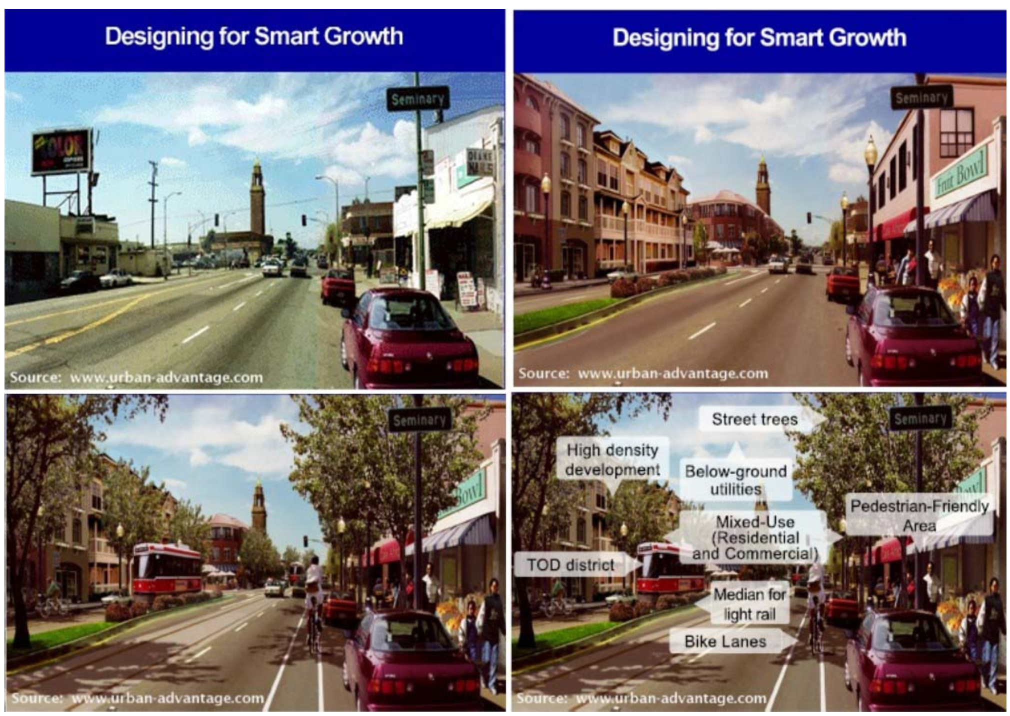


Figure 31

This neighborhood has mixed land uses, making it more visually and commercially appealing by co-locating shops, restaurants, and offices and transportation.

Another smart growth technique for street design involves the incorporation of natural drainage systems. These systems replicate pre-development hydrology (Figure 32) in contrast to the increased peak flows and reduced ground water recharge caused by traditional storm sewer systems. In Seattle (Figure 33), such systems have been highly successful in reducing urban street runoff and promoting infiltration, which reduces both downstream peak flows and runoff pollutants. A characteristic of natural drainage systems is that they also have associated vegetation and wildlife, thereby improving the aesthetic value of the streets on which they are installed. They help to meet multiple planning goals—community amenities, wildlife habitat, water resource management and aesthetic value.

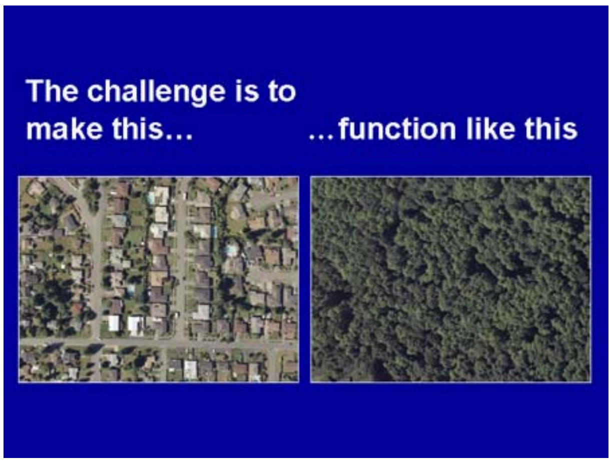


Figure 32

Figure 33

Low-impact development (LID) (Figure 34) is another aspect of smart growth that ties in well with water resource management. Natural approaches to stormwater management, soil amendments, vegetated swales, green roofs, bioretention areas, and raingardens are just some of the techniques that fall under the umbrella of this innovative approach. As the Puget Sound Action Team in Washington indicates in its March 2003 publication "Natural Approaches to Stormwater Management," LID is best distinguished by its central focus on stormwater management. LID can support smart growth development and retrofitting of existing urban areas to improve watershed management. However,

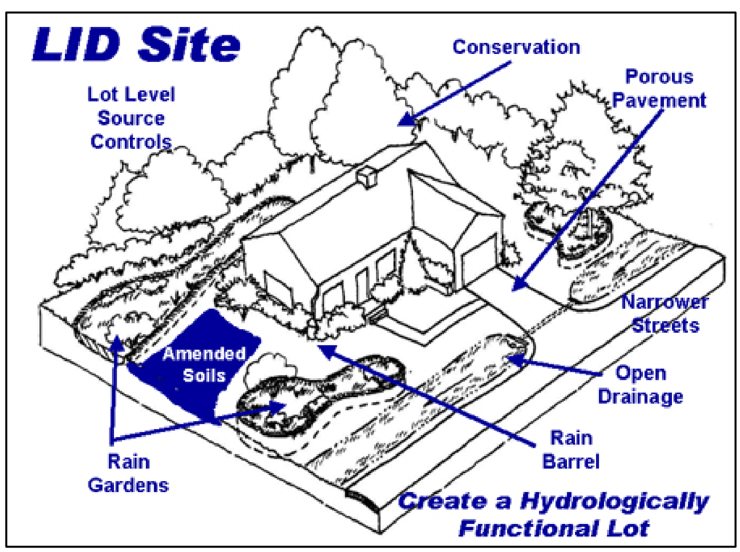


Figure 34

LID should be only part of the smart growth solution to a community's growth management issues. LID does not replace local land use planning; rather, it is a set of tools to better manage stormwater from areas appropriately designated for growth.

In summary, the smart growth principles of building, street and site-design promote

- Innovative development decisions (i.e., green roofs and narrow roads) through predictable, fair and cost-effective paths to plan approval
- Mixed-use development
- The use of LID techniques.

In addition, such techniques are acceptable compliance measures for regulatory programs such as the National Pollutant Discharge Elimination System (NPDES) Stormwater Phase II program.

Self Test

Click on the appropriate response to each question below. After you've completed the quiz, you can calculate your score and compare your answers to the correct answers by clicking on the calculate score button that follows the quiz.

1. By 2000, the leading sources of impairments to water quality standards across all waterbodies in the United States were from

☐ **A.** Point sources such as municipal wastewater treatment plants and industrial discharges

☐ **B.** Nonpoint sources such as runoff from agriculture and land-based activities in urbanized areas

☐ **C.** Atmoshperic deposition from mobile sources

☐ **D.** All of the above.

2. The leading pollutant of concern for most waterbodies in the United States is

☐ **A.** Sediment

☐ **B.** Nutrients like nitrogen and phosphorus

☐ **C.** Heavy metals such as lead and mercury

☐ **D.** All of the above.

3. **Up until 1982, 80 million acres in the United States had been converted from undeveloped land to urban and suburban land uses. In the following fifteen year period from 1982 to 1997, U.S. population increased by 15%. During that same period, the total percentage of developed land increased by**

☐ **A.** approximately 5% (significantly less than the rate of population growth)

☐ **B.** 15% (the same as the rate of population growth)

☐ **C.** More than 30% (over twice the rate of population growth)

☐ **D.** None of the above.
☐

4. **The prevailing pattern of development in the last twenty years**

☐ **A.** is closely associated with the highway network

☐ **B.** has a dispersed, low density development pattern that increasingly relies upon automobiles for transportation.

☐ **C.** increasingly relies upon automobiles for transportation

☐ **D.** all of the above.

5. **From 1980 – 2000, the number of miles driven by Americans every year increased**

☐ **A.** at the same rate as population growth

☐ **B.** at twice the rate of population growth

☐ **C.** at four times the rate of population growth

☐ **D.** none of the above.

6. From 1982 – 1997, the number of watersheds in which at least 15% of the land cover was developed

- ☐ **A.** doubled
- ☐ **B.** tripled
- ☐ **C.** quadrupled
- ☐ **D.** none of the above.

7. Increased imperviousness resulting from new roads, driveways and rooftops

- ☐ **A.** increases peak flows, the total volume of runoff, and the frequency of flooding
- ☐ **B.** decreases infiltration and the rat of groundwater recharge
- ☐ **C.** is correlated with decreasing abundance and diversity of aquatic life
- ☐ **D.** all of the above.

8. Among the factors influencing growth patterns in the United States since World War II are

- ☐ **A.** federal transportation funding
- ☐ **B.** local land use planning and zoning
- ☐ **C.** historic federal financing programs and housing initiatives
- ☐ **D.** all of the above.

9. Many studies have found a strong correlation between imperviousness and the health of streams. Most of this research shows that the biodiversity and physical structure of streams begin to show measurable adverse impacts when the impervious surface of their watershed

☐ **A.** exceeds 5%

☐ **B.** approaches 10%

☐ **C.** crosses a threshold of 30%

☐ **D.** exceeds 50%

10. True or False: Low-density development results in fewer vehicle miles traveled each year

☐ **A**. True

☐ **B.** False

11. The economic and environmental benefits of encouraging development where we have existing communities include

☐ **A.** Cost savings due to the ability to use existing infrastructure and services

☐ **B.** An expedited and predictable permitting process under most current land use zoning ordinances

☐ **C.** Preserving nearby natural areas that might otherwise be developed to accommodate growth

☐ **D.** A and B

☐ **E.** B and C

☐ **F.** A and C

12. **Which of the following statements is false? The prevailing pattern of low density development has been shown to contribute to**

☐ **A.** increased obesity levels linked with more time spent in cars and less physical activity

☐ **B.** loss of leisure time due to increased commute times and more time spent in traffic

☐ **C.** increased socio-economic integration of residential neighborhoods

☐ **D.** none of the above.

13. **For every acre of brownfields that are redeveloped, how many acres of greenfields (or undeveloped landscapes) are extimated to be preserved?**

☐ **A.** 2 acres

☐ **B.** 4.5 acres

☐ **C.** 25 acres

☐ **D.** None of the above.

14. **"Green Infrastructure" such as trees in a street in a developed area can**

☐ **A.** regulate heat, improve air quality, retain storm water and mitigate flooding

☐ **B.** prevent droughts

☐ **C.** none of the above

☐ **D.** all of the above

15. LID is an acronym that stands for

☐ **A.** Lower Infiltration Devices, a class of impermeable membranes that can prevent basement flooding

☐ **B.** "Living In Dallas", a book about the future of water resources in Texas

☐ **C.** Low Impact Development, an approach to site design that preserves its pre-development hydrology

☐ **D.** None of the above.

Correct Answers to Self Test

Q-1: **B**	Q-6: **A**	Q-11: **F**
Q-2: **A**	Q-7: **D**	Q-12: **C**
Q-3: **C**	Q-8: **D**	Q-13: **B**
Q-4: **D**	Q-9: **B**	Q-14: **A**
Q-5: **C**	Q-10: **B**	Q-15: **C**

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Figure 5: "Urban Land Cover in the United States." NOAA National Geophysical Data Center. Greenwire Web site. Contact: Christopher Elvidge at chris. elvidge@noaa .gov.

Figure 7: "Trends in Vehicle Miles Traveled." Urban Advantage. 2004.

Figure 8: U.S. Department of Agriculture, Natural Resources Conservation Service. 1982. "Percent of Hydrologic Unit in Developed Land, 1982." U.S. Department of Agriculture.

Figure 9: U.S. Department of Agriculture, Natural Resources Conservation Service. 1997. "Percent of Hydrologic Unit in Developed Land, 1997." U.S. Department of Agriculture.

Figure 10: FISRWG (10/1998). Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US gov't). GPO Item No. 0120-A; SuDocs No. A 57.6/ 2:EN 3/ PT.653. ISBN -0 -934213 -59 -3.

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Figure 18: Maine Nonpoint Source Training and Resource Center. 2004. Photo of parking lot runoff. Maine NPS Photo Gallery.

Figure 19: Graphic of San Antonio's water and wastewater infrastructure.

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