2. Land Use: Recent Trends and Environmental Impacts

2.1 Trends in Land Use

Urban form has changed dramatically over the past century. In the early 1900s, most urban areas were compact and monocentric—that is, most had a strong central business district—and industrial facilities such as ports served as major employment centers. Small neighborhood shops were frequently fixtures in residential areas. Suburbs grew in tandem with extensions of streetcar and railroad lines, and residential developments were clustered along grid street networks. Residential development typically extended only as far from streetcar lines as a person might comfortably walk.

The geographic size and the nature of urban development have undergone tremendous change. Metropolitan areas are polycentric, with multiple clusters of development dispersed over a large area. Increasing numbers of Americans live in suburban communities quite far from the old urban centers.[2] The automobile has become central to mobility, as new subdivisions are constructed in locations separated from commercial services and business parks are built in areas that require vehicle travel not only for access but also for internal circulation. Interstate highways connect geographically dispersed locations, and shopping malls and business parks have become important places for commerce.

One of the most noticeable trends in urban form is the dramatic expansion in the geographic size of metropolitan areas. Virtually every urban area in the United States has expanded substantially in land area in recent decades. Between 1954 and 1997 (the most recent year analyzed in the U.S. Department of Agriculture inventory), urban land area has almost quadrupled, from 18.6 million acres to about 74.0 million acres in the contiguous 48 states.[3] In 1997, developed land totaled about 7 percent of the nation's nonfederal land area—a seemingly small amount. However, from 1992–1997, the national rate of development more than doubled. During this five-year period, more land was developed (nearly 16 million acres) than during 1982–1992 (about 13 million acres). The newly developed land has come mostly from forestland, pasture and range, and cropland.[4] A 1994 study by the American Farmland Trust showed that urban development already has consumed nearly a third of the country's most highly productive farming regions.[5] Developed land

[2] From 1950 to 1990, the percentage of the U.S. urban population in the central counties of today's 50 largest metropolitan areas fell from 46.5% to 37.6%. (U.S. Census Bureau).

[3] U.S. Department of Agriculture, Economic Research Service, Natural Resources and Environment Division. *1997 National Resources Inventory.* 1997.

[4] U.S. Department of Agriculture, Economic Research Service, Natural Resources and Environment Division. *Agricultural Resources and Environmental Indicators (AREI) Updates, No. 3.* "Major Land Use Changes in the Contiguous 48 States." June 1997.

[5] American Farmland Trust. *Farming on the Edge: A New Look at the Importance and Vulnerability of Agriculture Near American Cities.* 1994.

area has increased rapidly in many states, particularly in the South and Southwest, as shown in Table 2-1.[6]

Table 2-1: Increase in Developed Land Area for Selected States, 1982-1992

State	Percent increase in developed land, 1982-1992
Arizona	35.1%
California	19.1%
Colorado	22.4%
Florida	34.6%
Georgia	32.8%
Illinois	8.4%
Massachusetts	21.7%
Michigan	14.3%
Nevada	26.3%
New Jersey	23.1%
New York	8.0%
North Carolina	36.2%
Ohio	15.3%
Pennsylvania	14.6%
Texas	20.5%
Tennessee	25.2%
Virginia	25.7%

Source: Noss, R. and R. Peters. *Endangered Ecosystems: A Status Report on America's Vanishing Habitat and Wildlife.* Washington, DC: Defenders of Wildlife, December 1995. Derived from data from the U.S. Bureau of the Census. *Statistical Abstract of the United States, 1994.*

Many urban areas have increased in size by 50% during the past 30 years, with the increase in land development far outstripping population increases. U.S. Census data for the 34 metropolitan areas with populations of more than one million show that urbanized land area has grown on average 2.65 times as fast as population has.[7] In urban areas with relatively slow population growth, the contrast between population growth and urbanized land area growth is especially dramatic. For example, the Census reports that from 1950 to 1990, the Pittsburgh urbanized area grew more than 21 times as fast as its population (from 1.533 million people and 254 square miles

[6] Developed areas include urban and built-up areas in units of 10 acres or greater, and rural transportation. Most recent data available are for 1992. An inventory of U.S. land resources by type of use/cover was conducted by the Soil Conservation Service in 1982, 1987, and 1992, and were most recently published in the *1992 National Inventory of Land Resources* (See Statistical Abstract of the United States: 1998. September 1998.)

[7] The Census Bureau delineates urbanized areas to provide a better separation of urban and rural territory in the vicinity of large places. Urbanized area is defined as one or more places ("central place") and the adjacent densely settled surrounding territory ("urban fringe") that together have a minimum of 50,000 persons and a density of least 1,000 persons per square mile. The urban fringe also includes outlying territory of such density if it was connected to the core of the contiguous area by road and is within 1 1/2 road miles of that core, or within 5 road miles of the core but separated by water or other undevelopable territory. Other territory with a population density of fewer than 1,000 people per square mile is included in the urban fringe if it eliminates an enclave or closes an indentation in the boundary of the urbanized area. Metropolitan areas with population over 1 million in any decennial census from 1950 to 1990 were analyzed.

in 1950 to 1.678 million people and 778 square miles in 1990).[8] As Table 2-2 shows, the trend is widespread.

Table 2-2: Growth in Land Consumption Exceeds Population Growth in Metro Areas, 1950-1990

Urbanized Area	Population Growth, 1950-90	Urbanized Area Growth, 1950-90	Ratio of Area Growth to Pop. Growth
Pittsburgh	9.50%	206.30%	21.72
Buffalo	6.60%	132.50%	20.08
Milwaukee	47.90%	402.00%	8.39
Boston	24.30%	158.30%	6.51
Philadelphia	44.50%	273.10%	6.14
St. Louis	39.00%	219.30%	5.62
Cleveland	21.20%	112.00%	5.28
Cincinnati	49.10%	250.70%	5.11
Kansas City	82.70%	411.40%	4.97
Detroit	34.30%	164.50%	4.80
Baltimore	62.70%	290.10%	4.63
New York	30.50%	136.80%	4.49
Norfolk	243.60%	971.00%	3.99
Chicago	38.00%	123.90%	3.26
Minneapolis-St. Paul	110.70%	360.20%	3.25
Atlanta	325.40%	972.60%	2.99
Washington	161.30%	430.90%	2.67
34 Metro Areas with Pop. > 1 million	**92.40%**	**245.20%**	**2.65**

Source: The Public Purpose. "Demographic Briefs and Urban Policy." Calculated based on data from the U.S. Census Bureau.

A 1996 study of traffic congestion trends by the Texas Transportation Institute provides further evidence of the dramatic growth in urbanized area compared to population. Based on data collected from metropolitan planning organizations, the study shows urbanized area continuing to increase faster than population growth in most metropolitan areas, as shown in Table 2-3. Among the areas studied, urbanized area increased on average 43 percent faster than population growth between 1982 and 1996.

Not only have people moved farther from the old city centers, but the nature of development has changed dramatically. Commercial and office developments are surrounded by large parking lots, with few sidewalks or connections to other developments. Hierarchical street patterns channel traffic to a number of large arterials, and wide streets and driveways are common in residential areas. As a result, people are using more land per capita than in the past. According to a report on development in the Chesapeake Bay Watershed,[9] residential and commercial development used 0.65 acre of land per person in 1988 compared with about 0.18 acre in the 1950s. According to the

[8] U.S. Census Bureau.

[9] 2020 Panel. "Population Growth and Development in the Chesapeake Bay Watershed to the Year 2020." Annapolis, MD: 1988.

report, Dorchester County, on Maryland's rural Eastern Shore, actually lost population between 1980 and 1990, yet gained hundreds of new homes. During that time period, less than one-tenth of new population consumed half the newly developed land—due to development on large suburban and rural lots.

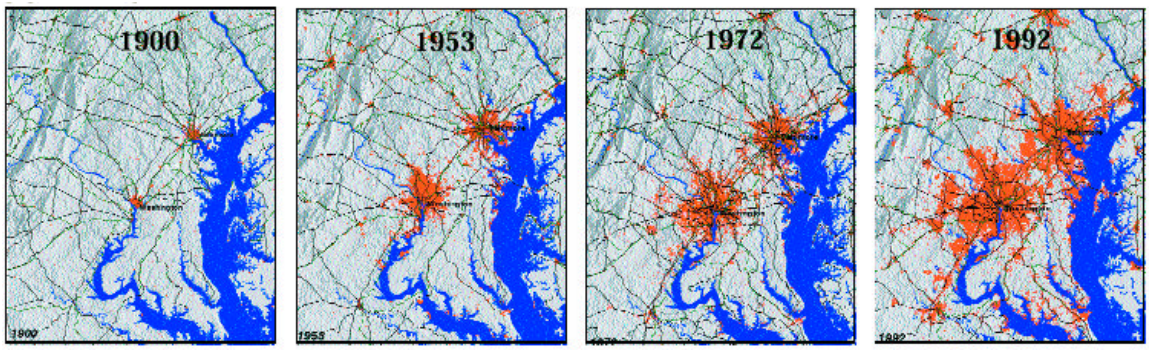
Table 2-3: Growth in Land Consumption Exceeds Population Growth, 1982-1996

Urbanized Area	Population Growth, 1982-96	Urbanized Area Growth, 1982-96	Ratio of Area Growth to Pop. Growth
Detroit, MI	-1.1%	19.6%	–
Rochester, NY	-3.1%	15.5%	–
Buffalo-Niagara Falls, NY	0.0%	52.0%	–
Pittsburgh, PA	6.6%	39.0%	5.9
Harrisburg, PA	14.5%	72.0%	5.0
Boston, MA	5.6%	26.9%	4.8
Chicago-Northwestern IN	10.9%	44.2%	4.1
Cleveland, OH	6.3%	23.8%	3.8
New York-Northeastern NJ	2.9%	10.1%	3.4
St. Louis, MO-IL	9.2%	30.8%	3.3
Baltimore, MD	26.2%	64.4%	2.5
Nashville, TN	25.0%	53.9%	2.2
Tucson, AZ	42.2%	86.7%	2.1
Las Vegas, NV	138.9%	243.8%	1.8
Los Angeles, CA	23.4%	22.7%	1.0
Houston, TX	27.5%	9.8%	0.4
Avg. Of 70 U.S. Metropolitan Regions	**20.2%**	**28.8%**	**1.43**

Source: Calculated based on data from Texas Transportation Institute. Mobility Study (*Urban Roadway Congestion: Annual Report 1998*).

Urban decentralization and growth in transportation infrastructure, mostly in the form of highway construction, have dramatically increased total developed land (and impervious) surface area. Figure 2-1 provides a visual image of growth in urban development for the Baltimore-Washington region, based on a study sponsored by the U.S. Geological Survey.

Figure 2-1: Baltimore-Washington Growth



Temporal databases and mapping document the dramatic increase in urban development following World War II and continuing to the present day in a number of metropolitan areas. Each urban database focuses attention on the forces influencing current spatial patterns and corridors. As seen in the Baltimore-Washington maps, the amount of land area developed has expanded tremendously in the 20th century. In 1900, urban development was located almost exclusively in the cities of Baltimore and Washington, with a vast amount of undeveloped and agricultural land between the two. By 1992, development was so widespread that the two formerly distinct areas shared common suburbs. The U.S. Census Bureau now recognizes the region as one large consolidated metropolitan area.

An analysis of development and transportation clearly demonstrates the influence that transportation infrastructure (roads, railroads, and seaports) exerted on development patterns. Roads alone take up considerable space. Nationwide, roads take up approximately 11.1 million acres of land, or 17,375 square miles, not including road shoulders and medians.[10] This area equals the geographic size of the states of Maryland and Delaware combined. Buildings and parking lots also take up considerable area. According to one estimate, land devoted to parking ranges from 1,910 to 3,035 square miles (or approximately 1.2 to 1.9 million square acres) in the United States.[11]

The exact percentage of land area in U.S. urban areas consumed by streets and parking is unknown.[12] Nonetheless, road and parking areas are known to be increasing. Although the rate of new highway construction has slowed from the growth rates characteristic of the 1950s and 1960s, transportation infrastructure continues to claim new land. A net increase of 91,357 road miles occurred between 1990 and 1997.[13] Each year from 1993 to 1997, an average of 16,389 miles of roadway projects financed with federal aid were underway.

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[10] Figure is for 1997. U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, *Indicators of the Environmental Impacts of Transportation: Highway, Rail, Aviation, and Maritime Transport.* October 1999, EPA 230-R-99-001.

[11] Delucchi, M.A. "Bundled Private Sector Costs of Motor Vehicle Use." Report No. 6 in Series: *The Annualized Social Costs of Motor-Vehicle Use in the U.S., Based on 1990-91 Data.* Davis, CA: University of California, Davis, Institute of Transportation Studies. 1995.

[12] There are many problems inherent in calculating this sort of statistic. In particular, some road or parking areas are rarely used by vehicles and may actually function as open space, such as a driveway alongside a house. Many pre-auto cities contained wide streets and boulevards, suggesting that it is inappropriate to consider all roads and parking as associated with automobiles. Still, it is certain that impervious surface area has increased with the development of new roads and parking. There is no data on the share of urban land devoted to parking, and some estimates of land area consumed by roads have been found to be of questionable basis. See Shoup, Donald. "The Pedigree of a Statistic." *Access.* University of California Transportation Center. Berkeley, CA: Fall 1997, 11: 41.

[13] U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics (1990* and *1997)*. Table HM-12.

2.2 Causes of Land Use Change

Observed increases in rates of urbanization and population dispersion are enabled and influenced by a variety of factors. New communications and transportation technologies, along with changes in public policy have facilitated increases in the size of metropolitan areas. Reductions in the monetary and time costs of travel play a particularly important role in these trends. The widespread adoption of the automobile as the predominant travel mode and major investments in transportation infrastructure have been important factors in encouraging the dispersal of residential and commercial development within metropolitan areas. However, social and economic dynamics have also played a large role in this shift.

Highway Development and Reduction in Travel Costs

New highways open up land for development by increasing the accessibility of locations that once were remote or difficult to reach.[14] Just as the opening of streetcar lines allowed the development of streetcar suburbs in the early 1900s, the development of interstate highways and other freeways allowed the expansion of residential development into formerly rural areas.

According to economic theory, accessibility is one factor that affects the desirability and therefore the price of land. All else being equal, reduced travel costs increase the relative value of land at the periphery of a metropolitan area to urban residents and workers. The increased price leads potential residents to outbid farmers for land near the urban region's edge. At the same time, transportation infrastructure enables more land to be available for development. The availability of more land allows people to use more transportation and land resources without an increase in transport cost. However, as a World Bank report emphasizes, "where transport prices do not reflect full social and environmental costs, the land market can generate inefficient land-use patterns."[15]

One of the basic tenets of modern location theory, well articulated since the 1920s, is the influence of transport costs on a company's choice of location. As the relative importance of transportation costs decreased (both due to lower transportation costs and economic shifts from manufacturing to services), transportation's role diminished in location choices, and more locations become viable site alternatives. Reduced transportation costs thus greatly facilitated the dispersal of employment.

For manufacturers, improvements in highway connections simplified the use of trucks for intercity traffic. As manufacturers switched from trains and ships to trucks, they were freed from dependence on railheads and ports, generally located near the city centers, and were able to move manufacturing facilities to sites accessible to interstate highways. The shift from rail and ship to trucks also facilitated the evolution from concentric development around major transport facilities (the port and railyard), to axial and polycentric development patterns.[16]

Finally, changes in commodity flows and the development of modern logistics concepts such as

[14] World Bank. *Sustainable Transport: Priorities for Policy Reform.* Washington, D.C.: 1996, p. 59.

[15] *Ibid.* p. 61, citing Egal, Y. 1994. "Des effets positifs de la densité urbaine." *Transports Urbains.* 83 (avril-juin) 27-31.

[16] Button, K.J. *Transport Economics.* Hampshire, England: Gower Publishing Co. Ltd., 1982, p. 261-263.

just-in-time delivery reduced dependence on central locations. The *freight*-generating characteristics of land uses were surpassed in importance by the truck *trip*-generating characteristics, reducing the influence of manufacturing and industrial facilities on land use and development patterns of cities.[17]

Firms with highly skilled work forces have also changed their locational patterns in recent years. Because these firms draw employees from the entire metropolitan area, they need to locate at a point accessible from all points in the area. In the streetcar city, the city center (hub) was the most accessible location. In the modern automobile city, firms may choose to locate in the urban core, but often they are drawn to locations along an urban highway or suburban beltway, since such sites are accessible to a large population via automobile.[18] This change is further reinforced by the tendency for the peripheral suburbs to contain a relatively high proportion of wealthy, well-educated, well-trained workers.[19] In sum, increased highway development loosens ties to the central business district (CBD), allowing the suburbanization of firms. Highway development facilitated similar suburbanization of retailers. If shoppers have access to private vehicles, suburban stores may be more accessible than center city locations. In fact, as residential suburbanization occurred, many retailers followed consumers out to the suburbs to be closer to their markets.

Public Policy

Public policy plays an important role in shaping the built environment. After World War II, federal funding for highway construction opened vast areas of land for development. A survey of experts by the Federal National Mortgage Association ("Fannie Mae") declared "More than any other single measure, the 1956 act created the decentralized, automobile-dependent metropolis we know today."[20]

Efforts to promote homeownership—through the G.I. Bill of Rights and mortgage subsidies, for example—encouraged movement to new subdivisions. In addition, the federal tax deduction of interest paid on home loans provides a subsidy for homeownership. Federal mortgage programs promote housing consumption and increase the relative attractiveness of the suburbs.

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[17] Ogden, K.W. *Urban Goods Movement: A Guide to Policy and Planning.* Hampshire, England: Gower House, 1992.

[18] This has been associated with both the growth of new outer rings of land-use development, and subsequently of edge cities. Burchell, R. "Understanding Sprawl." *On the Ground.* Vol. 2, No. 2, 1996.

[19] Largely in consequence to standard rent-bid curves that have been influenced by auto ownership patterns, mortgage subsidies, and rent control and public housing policies, among other factors such as school quality, perceptions of crime, and racial bias.

[20] Robert Fishman, "The American Metropolis at Century's End: Past and Future Influences." Washington, DC: Fannie Mae Foundation, Winter, 1999. Dr. Fishman's survey included a list of 25 possible influences on the American city over the past century and a list of 19 potential future influences. Fishman surveyed 149 urban and regional historians, planners, and practitioners and asked them to rank the 10 most powerful influences--looking at the past 50 years and into the next century.

Government also subsidized suburban development by funding the construction of new water and sewer infrastructure. The effect of subsidizing any kind of infrastructure is to subsidize the type of growth that depends on the infrastructure, which in this case was growth on the urban edge.

Inequitable support for suburban development comes not only from public policies, but sometimes also from private companies. For example, anecdotal and statistical evidence indicates that many insurance companies either resist writing insurance in minority and low-income communities, or only provide over-priced, inferior insurance policies in such areas—a practice commonly referred to as "insurance redlining." Although states are working to eliminate this practice through testing and litigation, redlining still remains a serious deterrent to investment in many areas.

Zoning also has played a large part in the nature of land development. Minimum parking standards, put in place to reduce parking problems, encourage vehicle travel.[21] Similarly, zoning that separates residences from commercial and office development often makes mixed-use communities impossible—the walkable neighborhoods with neighborhood stores that were once common would be illegal to build in most places today. In addition, competition among localities for economic development has led to intra-regional competition for jobs, which has hurt older city centers.

Growing Affluence and Social Change

Changes in the national economy and social attitudes contribute to the dispersal of urban development. Because land is a "normal good" in the parlance of economists, increases in income lead to increases in the demand for land. Historical increases in income led to greater demand for large homes and lot sizes.[22] In turn, single family detached homes on large lots became increasingly associated with monetary success and social prestige. This combination of rising incomes and changing values has encouraged land use patterns marked by low density development, declining urban cores, and a strong reliance on the automobile.

Central city problems, real and perceived, also contribute to movement from city centers. Empirical studies of the suburbanization process provide support for the theory that central city attributes have had some effect on the pace of suburbanization.[23] The appeal of newer and larger

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[21] Donald Shoup, "An Opportunity to Reduce Minimum Parking Requirements," *Journal of the American Planning Association*, Winter 1995, pp. 14-28; Willson, Richard W. "Sububan Parking Requirements: A Tacit Policy for Automobile Use and Sprawl." *Journal of the American Planning Association.* Vol. 61, No. 1 Winter 1995. pp. 29-42.

[22] On the other hand, as real income increases, so should the opportunity cost of commuting. As a result, an increase in income should also lead to greater demand for dwellings close to work, all else equal. However, increases in income occurred concurrently with reductions in travel costs associated with highway development. As a result, increased opportunity costs of commuting have been minimized.

[23] See the following: Wasylenko, Michael. "Disamenities, Local Taxation, and the Intrametropolitan Location of Households and Firms." *Research in Urban Economics.* Vol. 4. Ed. Robert Ebel. Greenwich, CN: JAI Press, 1984; Bradbury, Kathernine, Anthony Downs, and Kenneth Small. *Urban Decline and the Future of American Cities.* Washington, DC: Brookings Institution, 1982; Frey, W.H. "Central City White Flight: Racial and Non-Racial Causes." *American Sociological Review.* 44, 1979, pp. 425-88; Grubb, W.N. 1982. "The Flight to the Suburbs of Population and Employment, 1960-1970." *Journal of Urban Economics.* 11: 348-67.

homes and lots in suburban areas, coupled with issues of race, ethnicity, education, and safety, have contributed to considerable out-migration from the urban core. Fiscal problems in the central city, including high taxes and in some cases lower-quality schools and services, also have led many people to leave for the suburbs.[24] A study based on 121 metropolitan areas for the period 1970-75 found that cities experienced relatively rapid suburbanization if their central area had (1) a relatively old housing stock, (2) relatively high taxes, and (3) a relatively large African-American population. In addition, the larger the number of suburban governments to choose from, the more rapid the suburbanization.[25] Another study found that metropolitan areas with high taxes, high crime rates, and low educational expenditures experienced the most rapid suburbanization.[26]

2.3 Environmental Consequences of Land Use Trends

Although changing development patterns provide many social benefits, they also come at a cost to the natural environment and our communities. This section addresses the two major direct environmental impacts of development: (1) habitat loss and fragmentation and (2) the degradation of water resources and water quality.

The effects of land development on the environment are particularly important because development patterns have long-term effects that are not easily reversible. Degradation of water resources can have adverse effects over many generations of wildlife, and habitat and species loss may forever alter ecosystems. As a result, the cumulative effects of development decisions are important when considering the long-term health of the environment and communities.

Habitat Loss and Fragmentation

Habitat loss and fragmentation are two of the most direct impacts of development on previously undeveloped land.[27] According to recent studies, habitat destruction is the main factor threatening

[24] The causality goes both ways: fiscal problems can lead to suburbanization, and suburbanization can contribute to central-city fiscal problems.

[25] Bradbury, Kathernine, Anthony Downs, and Kenneth Small. *Urban Decline and the Future of American Cities.* Washington, DC: Brookings Institution, 1982.

[26] Frey, W.H. "Central City White Flight: Racial and Non-Racial Causes." *American Sociological Review*. 44: 1979. pp. 425-88.

[27] Habitat impacts from human development have been documented extensively. See: Dobson, A. P., J. P. Rodriguez, W. M. Roberts, D. S. Wilcove. "Geographic Distribution of Endangered Species in the United States," *Science*, Volume 275, Number 5299. January 24, 1997. pp. 550-553; LaRoe, Edward T., Gaye S. Farris, Catherine E. Puckett. *Our Living Resources - A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems*. U.S. Department of the Interior, National Biological Service, Washington, 1995; Noss, Reed F. and Robert L. Peters. *Endangered Ecosystems: A Status Report on America's Vanishing Habitat and Wildlife*. Washington, DC: Defenders of Wildlife, December 1995; Peters, Robert L., Evan Frost, and Felice Pace. *Managing for Forest Ecosystem Health: A Reassessment of the 'Forest Health Crisis*. Washington, DC: Defenders of Wildlife, April 1996; Boucher, Norman, "Species of the Sprawl," *Wilderness*. Defenders of Wildlife, Washington, DC, Summer 1995. pp. 10-24; Soule, Michael E. "Land Use Planning and Wildlife Maintenance - Guidelines for Conserving Wildlife in an Urban Landscape." *Journal of the American Planning Association*. Volume 57, Number 3, Summer 1991. pp. 313-323.

80 percent or more of the species listed under the federal Endangered Species Act; more than 95 percent of listed species are endangered to some extent by habitat loss or alteration.[28]

In many metropolitan areas, development has consumed thousands of acres of woodlands, wetlands, and other natural habitats. The Washington, DC, region, for example, lost 211,062 acres of farmland, forest, wetlands, and other open space in the 1980s, according to a study by the National Center for Resource Innovations.[29] The Occoquan Reservoir, which supplies water to much of northern Virginia, is being developed so rapidly that if current trends continue, a full 40 percent of the watershed's open space will be lost by 2020.[30]

Impact of Low Density Development on Wildlife: A Case Study

From 1958 to 1990, low-density development in the Tuckahoe Creek, Virginia watershed dramatically increased, resulting in severe impacts on local warm water fish species. The acreage of low-density development increased from 7% to 8% (seemingly small, but an increase of 300%); the number of houses in the watershed increased from 7,800 to 28,000 (an increase of 250%); road-stream crossings increased from 43 to 85; and road miles increased by 137%, with the area of road pavement increasing by 155%.

Effects on local fish species were startling. Six indigenous fish species became locally extinct, while the population of the remaining fish species declined 80%. Fish species diversity (a measure of resilience or a species' ability to rebound from adverse conditions) declined significantly.

Source: Weaver, L. Alan, and Greg C. Garman. "Urbanization of a Watershed and Historical Changes in a Stream Fish Assemblage." *Transactions of the American Fisheries Society*, Vol. 123, 1994, pp. 162-172.

And though habitat destruction may be most obvious in cities experiencing explosive growth, such as Phoenix, Las Vegas and Atlanta, it is certainly not limited to these areas. For example, in the lower 10 kilometers of Cape May, New Jersey, 40 percent of the habitat critical to migratory and residential wildlife has been lost to development over the last 20 years[31]. Habitat in even our most protected open spaces is endangered by development. A recent study by the Missouri State Department of Natural Resources indicated that the biological integrity of 27 state parks is currently threatened by increasingly dispersed patterns of development.[32]

Another impact—one that frequently follows the destruction and/or degradation of habitat—is the invasion of non-native species. Disturbed habitat is readily invaded by exotic plants. For example, in the Florida Everglades, the Australian melaleuca tree invades after water diversions. In Florida, the non-native melaleuca, Brazilian pepper, and Australian pine now dominate many land areas. In addition, the exotic hydrilla and water hycinth have adversely affected many aquatic communities by outcompeting native species and altering water chemistry. In California, introduced European grasses have altered the structure of fragile coastal dune communities and invaded almost all

[28] Flather, C.H., L.A. Joyce, and C.A. Bloomgarden. 1994. (as cited in: Noss, Reed and Fobert Peters. Endangered Ecosystems: A Status Report on America's Vanishing Habitat and Wildlife. Washington, DC: Defenders of Wildlife, December 1995. p. 46)

[29] *Washington Post.* "As the Economy Grows, the Trees Fall." March 23, 1997. p. A1.

[30] Baley, Janet and Glenn Besa. *Sprawl Costs us All.* Sierra Club, 1997.

[31] Department of Environmental Protection, State of New Jersey. *New Jersey's Environment 1988.*

[32] Etling, Kathy. "Of Owls and Interstates." *Missouri Conservationist.* Volume 54, Number 11, Nov. 1993. pp. 6-9.

remaining valley grasslands. Cases like these are common; more than 50 percent of federally listed species are affected by interactions with non-native species.[33]

Housing developments, roads, and associated infrastructure have the potential to destroy existing forests and vegetation and also cause fragmentation of natural habitats. Road infrastructure in the United States is extensive and growing. In 1997, public roads occupied an estimated 17,345 square miles of land, a 2 percent increase over the road area in 1990.[34] Fragmentation negatively affects wildlife in a number of ways. It interferes with wildlife travel, decreases habitat size, and reduces interaction with other wildlife communities. Fragmentation produces declines in both the number of species (diversity) and populations (abundance).[35] For example, a study of the influence of narrow forest-dividing corridors (small roads and power lines) on forest-nesting birds in southern New Jersey revealed that, although not generally viewed as sources of forest fragmentation, such corridors measurably affect the diversity and abundance of birds in ways that are associated typically with the effects of forest fragmentation.[36]

HABITAT FOCUS: WETLANDS

In recent decades, it has become increasingly clear that wetlands, once viewed as unproductive, perform important ecological functions. Wetlands mitigate flooding and damage from erosion, wind, and waves; they facilitate sediment replenishment; provide habitat for water life, waterfowl, mammals, and reptiles, many of which are economically important; and improve water quality by removing excess nutrients and some chemical contaminants. For this reason, the United States has given particular priority to saving wetlands.[37]

More than half (53 percent) of the wetlands in the lower 48 states were lost between the late 1700s and the mid-1980s.[38] In recent years, urban development and road construction has been a

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[33] Flather, C.H., L.A. Joyce and C.A. Bloomgarden; Scemske, D.W., B.C. Husband, M.H. Ruckelshaus, et al. 1994. (As cited in: Noss, Reed and Fobert Peters. *Endangered Ecosystems: A Status Report on America's Vanishing Habitat and Wildlife.* Defenders of Wildlife, December 1995. p. 47.) Also see Bright, C. "Understanding the Threat of Bioinvasions." *State of the World.* Ed., Starke. New York: W.W. Norton & Co., 1996. pp. 95-113; Groves, R.H. and J.J. Burdon, eds. *Ecology of Biological Invasions.* Cambridge, UK: Cambridge University Press, 1986.

[34] Estimate based on data from U.S. Department of Transportation, Federal Highway Administration. "Highway Statistics:" 1990, 1995, 1996, and 1997. Table HM-60.

[35] Tolley, R.S. and B.J. Turton. "Transport Systems, Policy, and Planning: A Geographic Approach." *Longman Scientific and Technical*. 1995. There is a large literature on urban wildlife, critical habitat, and wildlife corridors. See: Beatley, Timothy. *Habitat Conservation Planning and Urban Growth*. Austin, Texas: University of Texas Press, 1994; and Leedy, Daniel and Lowell Adams. "Wildlife in Urban and Developing Areas: An Overview and Historical Perspective." in *Integrating Man and Nature in the Metropolitan Environment: Proceedings of a National Symposium on Urban Wildlife*, 4-7 ed. Adams and Leedy. Columbia, MD: National Institute for Urban Wildlife, November 1986.

[36] Rich *et al*., 1994.

[37] The U.S. Environmental Protection Agency adopted a No Net Loss of Wetlands goal (U.S. Environmental Protection Agency. *EPA Strategic Plan.* Washington, DC: 1997.), and the Federal Highway Administration has adopted a strategic goal of a 50 percent *increase* in net wetland acreage resulting from Federal-aid highway projects in 10 years (U.S. Department of Transportation, Federal Highway Administration. *FHWA National Strategic Plan.* 1997.)

[38] Dahl, T.E. and C.E. Johnson. *Status and Trends of Wetlands in the Conterminous United States*. Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, 1991.

major source of wetland loss. Of the 12 states that listed wetland losses, six reported that they suffered significant losses due to highway construction, and 10 reported that they had significant wetland losses due to residential growth and development.[39]

Wetland loss has been significant in many states. Ninety-one percent of California's original 5 million acres of wetlands have been drained or filled, and it is estimated that wetlands in California continue to be lost at a rate of almost 5,000 acres per year.[40]

In a report on the status and trends of wetlands in the United States between 1970 and 1980, the U.S. Department of the Interior concluded: "Road construction in and across wetlands has led to direct and indirect wetland loss through the effects of filling, fragmentation, and alteration of hydrology." Constructed highways also have indirectly led to wetland loss by enabling or inducing secondary development.[41] Another report concludes that "between approximately 310,000 and 570,000 acres of wetlands could potentially have been lost due to the construction of Federal Aid Highway Program roads between 1955 and 1980, at a cost to replace of between $153 million and $6 billion."[42]

Compensatory mitigation efforts attempt to address wetland loss due to highway projects. However, a 1992 Federal Highway Administration study evaluated 23 highway wetland mitigation projects and found that true one-for-one replacements were executed for only a few sites.[43]

Degradation of Water Resources and Water Quality

Many watersheds are rapidly becoming developed. For example, urban land use in the Occoquan watershed in northern Virginia is projected to increase from 7.3 percent in 1977 to 55.7 percent in 2020. Impervious cover—the imprint of land development on the landscape, composed of the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces—in the watershed is expected to grow from 11 percent of the basin in 1995 to 20 percent in 2020.[44] This development has serious environmental consequences. Stormwater runoff has been identified as one of the major contributors to ongoing water quality problems in this country. According to EPA's *National*

[39] U.S. Environmental Protection Agency. *National Water Quality Inventory: 1996 Report to Congress*. 1998.

[40] Noss, Reed and Robert Peters. *Endangered Ecosystems: A Status Report on America's Vanishing Habitat and Wildlife.* Washington, DC: Defenders of Wildlife, 1995. p. 28.

[41] LaRoe, Edward T., Gaye S. Farris, Catherine E. Puckett. *Our Living Resources - A Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems*. Washington, DC: U.S. Department of the Interior, National Biological Service. 1995.

[42] Apogee Research, Inc. "Quantifying the Impacts of Road Construction on Wetlands Loss - Final Report." Bethesda, MD: September 1997.

[43] U.S. Department of Transportation, Federal Highway Administration. *Evaluation of Wetland Mitigation Measures, Volume I: Final Report.* 1992.

[44] Baley, Janet and Glenn Besa, *Sprawl Costs us All,* Sierra Club, 1997.

Water Quality Inventory: 1996 Report to Congress, impacts of increased imperviousness due to development on rivers include the following:[45]

- 38 percent of assessed estuary miles are impaired, with approximately 46 percent of impairment attributable to urban runoff.
- 36 percent of the total river miles recently assessed by states are still impaired, with urban runoff causing about 12 percent of the problem.
- 39 percent of assessed lake acres are impaired, with urban runoff causing 21 percent of the impairment.
- 13 percent of assessed ocean shorelines are impaired, with approximately 55 percent of impairment due to urban runoff through storm sewers.

Development significantly alters water balance and water quality in a number of ways, including impacts stemming from the following:

- Changes in hydrology (and reduced groundwater recharge)[46]
- Increased water pollution and nutrients
- Increased acidity
- Higher water temperature

These effects are discussed below.

CHANGES IN HYDROLOGY

Development in a watershed changes natural drainage patterns. Increases in impervious areas associated with development increase the volume and the rate of surface water runoff. In a study of 40 runoff monitoring sites across the nation, a 1-acre parking lot was found to produce a runoff volume almost 16 times as large as the runoff volume produced by an undeveloped meadow. Peak discharge, velocity, and time of concentration of storm water runoff were also found to be much greater. Furthermore, transportation-related impervious surfaces seem more often to exhibit a greater runoff volume than disconnected rooftop-related imperviousness of the same surface area.

[45] Note that the percentage of assessed water resources is quite low and differences in the resources being surveyed preclude making historical comparisons based on prior inventory reports. Source: U.S. Environmental Protection Agency, Office of Water. *National Water Quality Inventory: 1996 Report to Congress*. Washington, DC: 1998.

[46] U.S. Environmental Protection Agency. *Environmental Impacts of Storm Water Discharges - A National Profile*. (EPA 841-R-92-001) Washington, DC: June 1992.

Channelization projects, such as concrete retention walls or lining along stream beds, channel realignment, and diversion of streams through culverts, also increase flow velocities. [47]

Increased peak discharges and shorter lag times between storms and the resultant runoff lead to larger and more frequent incidents of local flooding.[48] Because the faster runoff prevents percolation of water that would normally feed regular stream flow, floods are followed by longer periods of below-normal stream levels. Lower flows during periods between storms may affect the aquatic habitat and the ability of a stream to dilute toxic spills.[49] Higher flows often result in stream bank erosion, increased sedimentation in the channel, and decreased stability. Streams may widen to two to four times their predevelopment width if stormwater from developed areas is uncontrolled. Research models suggest that a threshold for urban stream stability exists at about 10 percent site imperviousness.[50]

Sediment pollutant loads created by increased erosion can cause a broad range of impacts in receiving waters, including reduced water storage capacity, impaired dissolved oxygen for aquatic organisms, decreased light penetration, increased need for dredging, increased costs for water treatment, accumulation of pollutants, and adverse effects on fish and shellfish.

When runoff increases in volume and velocity, soils have less opportunity to absorb stormwater. This loss of groundwater recharge can reduce residential and municipal water supplies, decrease base flow into stream channels during dry weather, and threaten the health of local wetlands that rely on groundwater to maintain wet conditions during dry periods of the year.[51]

INCREASED WATER POLLUTION AND NUTRIENTS

Stormwater is often polluted by pesticides and fertilizers from homes, farms, heavy metals, antifreeze, lead and partially oxidized hydrocarbons from gasoline- and diesel-fueled vehicles, oil, urban debris, and spillage from accidents. Pollutants accumulate on impervious surfaces. These pollutants are quickly washed off during storms and delivered through pipes and ditches to

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[47] Schueler, Tom. *Environmental Land Planning Series: Site Planning for Urban Stream Protection.* Center for Watershed Protection. Publication No. 95708. Washington, DC: Metropolitan Washington Council of Governments, December 1995. pp. 21-23.

[48] Field, Richard, Hugh Masters, and Melvin Singer. "Porous Pavement: Research, Development, and Demonstration." *Transportation Engineering Journal of the American Society of Civil Engineers*. Vol. 108, No. TE3, May 1982. pp. 244-258.

[49] *Bellevue NURP Report.* In 1978, the EPA began The National Urban Runoff Program (NURP) to comprehensively study 28 project locations across the county, acquiring data on the receiving water impacts of urban runoff and evaluating management practices. The NURP studies provided the first national assessment of the increased levels of contaminants such as sediment, heavy metals, oil and grease, phosphorus, nitrogen, chemical oxygen demand, bacteria, viruses, and solid wastes in storm water.

[50] Schueler, Tom. *Environmental Land Planning Series: Site Planning for Urban Stream Protection.* Center for Watershed Protection. Publication No. 95708. Washington, DC: Metropolitan Washington Council of Governments, December 1995. pp. 23-24.

[51] Harbor, Jonathon M. "A Practical Method for Estimating the Impact of Land–Use Change on Surface Runoff, Groundwater Recharge, and Wetland Hydrology." *Journal of the American Planning Association*. Volume 60, Number 1, Winter 1994.

streams, lakes, and estuaries.[52] Monitoring and modeling studies have shown consistently that urban pollutant loads increase with watershed imperviousness.[53]

Natural nutrient cycles may be altered by land use activities within a watershed. Excessive nutrients overstimulate the growth of aquatic plants, which may result in low oxygen levels in water, accelerate eutrophication, cause unsightly conditions, interfere with navigation and treatment processes, and cause unpleasant tastes and odors. Eutrophic conditions are evidenced by surface algal scums, reduced water clarity, odors, and dense algal growth on shallow water substrates.[54] Algal blooms block the light needed by submerged aquatic vegetation, removing habitat for juvenile fish and shellfish. After blooms or at the end of a growing season, the decomposition of dead vegetation may cause reduced oxygen levels. Lower oxygen levels may, in turn, cause the death of fish and mass mortality of benthic organisms.

INCREASED ACIDITY

Nitrogen oxides (NO_x) and sulfur dioxide (SO_2) are the primary air pollutants that result in acid rain and highly acidic stormwater. Acid rain occurs when SO_2, emitted primarily by electric utilities fired by coal, and nitrogen oxides (NO_x), emitted primarily by transportation sources and utilities, are deposited in the form of wet or dry deposition.

Several aspects of urbanization tend to create local conditions that may make receiving waters susceptible to impacts from acidity. High levels of airborne SO_2 and NO_x in large urbanized areas increase the acidity of the rainfall to levels above those typically found in the region. Runoff from paved surfaces and other impervious surfaces may have little or no opportunity to contact soils that could buffer the acidity of the rainfall. In urbanized areas with acidic rain, higher runoff volumes and rates associated with urban development can increase the acidity of receiving streams rapidly and lead to high peak acidity levels.

HIGHER WATER TEMPERATURE

High volumes of runoff from hot paved surfaces and rooftops may cause a rapid increase in surface water temperatures. Discharges from stormwater management devices, which retain collected runoff in unshaded ponds, also may increase stream temperatures.

Increased temperature can harm fish and other aquatic life. Water holds less oxygen as it becomes warmer, which may affect habitat and make the water more susceptible to oxygen-demanding pollutants. Sustained water temperatures in excess of 70°F are considered stressful or lethal to many cold water fish species and stream insects. The availability of food, attendant life cycle chemistry, and water quality changes are all affected by water temperature.

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[52] Center for Watershed Protection. *Blueprint to Protect Coastal Water Quality.* Land Ethics, Inc. p.3.

[53] Schueler, Tom. *Environmental Land Planning Series: Site Planning for Urban Stream Protection.* Center for Watershed Protection. Publication No. 95708. Washington, DC: Metropolitan Washington Council of Governments, December 1995. p.24.

[54] Schueler, Tom. *A Framework for Evaluating Compliance with the 10% rule in the Chesapeake Bay Critical Area.* Annapolis, MD: Maryland Critical Area Commission, 1987.

2.4 SUMMARY

The size of virtually every metropolitan area in the United States has expanded dramatically in recent decades. As automobile ownership became increasingly common, residential development spread farther from urban centers. Although the sources of development dispersal are numerous and include demographic and socio-economic factors, public policies on highway construction, taxes, and land use also play an important role in shaping urban form.

The direct environmental consequences of dispersed development patterns can be divided into two broad categories: habitat loss and fragmentation, and adverse effects on water resources. Housing developments, roads, and associated infrastructure have destroyed existing forests and vegetation, and displaced or eliminated wildlife populations. Road construction has fragmented natural habitats, causing a decline in the diversity and abundance of populations. In the span of only about three human generations, we have witnessed the extinction of nearly 1 percent of the nation's flowering plants, more than 3 percent of our birds, and about 12 percent of the U.S.'s freshwater mussels.[55] Wetlands, in particular, have been affected substantially. Wetlands trends on nonfederal lands indicate a loss rate of between 70,000 and 90,000 acres annually, most of which is due to increases in development.[56]

Water resources and water quality are also threatened. Increasing acres of impervious surfaces lead to higher runoff volumes, larger and more frequent incidents of local flooding, and longer periods of below-normal stream levels. Development patterns also lead to reduced groundwater recharge and various negative effects like increased sedimentation, increased water acidity, and higher water temperatures. Water quality in many of our nation's rivers, lakes, and estuaries is degraded to a point where those water bodies can no longer support basic uses such as fishing and swimming, and cannot be relied on as sources of clean drinking water. According to EPA's most recent National Water Quality Inventory, approximately 40 percent of surveyed bodies of water in 1996 were too polluted for basic uses.[57]

Clean water and healthy habitat are national priorities, so it is important to understand the impacts that development patterns can have on our natural resources.

[55] Sierra Club. "The State of Disappearing Species and Habitat." (http://www.sierraclub.org/habitat/speciesloss.asp)

[56] U.S. Environmental Protection Agency. Office of Water wetlands webpage: http://www.epa.gov/OWOW/wetlands/vital/status.html.

[57] U.S. Environmental Protection Agency. "National Water Quality Inventory: 1996 Report to Congress." 1996. This report summarizes information submitted by 58 states, American Indian tribes, territories, Interstate Water Commissions, and the District of Columbia in their 1996 Section 305(b) reports.

3. Vehicle Travel: Recent Trends and Environmental Impacts

Vehicle travel has increased substantially in recent decades. Factors contributing to this trend are numerous. Although some new travel can be attributed to shifting demographics and market characteristics, substantial evidence suggests that much of the increase is a direct result of changing development patterns.

As development becomes more dispersed, with increasing numbers of families living on large lots at the urban fringes, and as jobs and housing become increasingly segregated from one another, distances between destinations have increased. Further, people are forced to make more trips by car, since the distances between destinations are often too great to walk or bike.

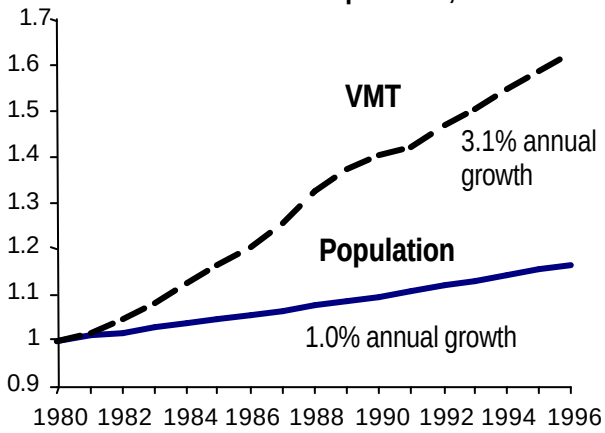
Rapid increases in vehicle travel have negatively affected the environment in numerous ways. The growth in travel degrades air quality, impairs water quality, and increases traffic noise.

3.1 Trends in Vehicle Travel

Vehicle travel increased substantially in recent decades. Total vehicle miles of travel (VMT) in the United States increased 63 percent between 1980 and 1997. VMT has more than doubled since 1970.[57] As shown in Figure 3-1, the rate of growth in VMT has exceeded the rate of population growth significantly over the last decade. VMT growth also outpaced employment growth and economic growth.

VMT is projected to grow considerably into the future. FHWA projects that light-duty VMT will grow at an annual rate of approximately 2.16 percent over the next 20 years, resulting in a 53 percent increase in VMT.[58] (See Figure 3-2.) As a result, FHWA has projected significant increases in annual travel delay times through 2005.

Figure 3-1: Growth in Vehicle Miles of Travel and Population, 1980-1997



Scale: 1980 value = 1.0

Sources: U.S. Department of Transportation, Federal Highway Administration. *Highway Statistics (Summary to 1995*, and annual editions, *1996* and *1997)*, Washington, DC.

[57] U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics (Summary to 1995*, and annual editions, *1996* and *1997.)* Washington, DC.

[58] U.S. Department of Transportation, *1997 Status of the Nation's Surface Transportation System: Condition & Performance Report to Congress*, 1998. p. 60.