# *Development and Sprawl*

Just as the history of land use in the watershed has had major effects on the Bay ecosystem, so too will changes in the landscape of the Chesapeake over the next 30 years determine the Bay's future. There are four key driving forces that will paint the landscape portraits of the 21st century: climate, urban and suburban development, agriculture and forestry, and land conservation. Before addressing changes in agriculture and forestry, we first examine the patterns and effects of development throughout the watershed. The spread of suburban development, in particular, has reshaped the landscape during the last half-century, increasing sediment loads to the Bay and its tributaries and flushing nutrients into the estuary.

## Patterns of Growth

The coastal regions of the United States, including portions of the Chesapeake region, are experiencing some of the fastest population growth rates in the country.[1] An average of 334 new people move into the watershed each day.[2] According to the 1997 Natural Resources Inventory, 128,000 acres of "natural" land are converted to urban and suburban uses every year in the watershed.[3] Between 1990 and 2000, the rate of land conversion in the watershed more than doubled over the previous decade.

Of greater concern, however, is change in the *ways* people live. Many metropolitan areas throughout the United States have witnessed an exodus of tax-paying residents as people move out of the cities and into the suburbs. Baltimore, Washington, and Richmond have experienced population losses for decades as their surrounding, traditionally rural counties swell with new residents.[4] Out-migration from the urban core to the suburban fringe, conversion of natural lands into low-density, haphazard development, and burgeoning road and other transportation systems have led, in part, to the phenomenon known as sprawl.

The Sierra Club rated Washington, D.C. the third most sprawl-threatened large city in the U.S.[5] Over the past 16 years, the number of houses in this part of the country has increased more than *twice* the rate of population growth;[6] one-third of all development in the watershed has taken place since 1982.[7] Furthermore, the average size of new single-family houses grew from 1,500 square feet in 1970 to 2,265 square feet in 2000,[8] and the amount of land that each individual home consumes has increased by almost 60 percent. At the same time, the number of people per household has decreased.[9] Collectively, these facts signify that each person is occupying more space and consuming more resources.

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# Sprawl Begets Sprawl

In recent decades, the modern version of the "American Dream" has caused some of the greatest impact on the Bay and its watershed. Acquiring an individual detached home on a private lot, away from the urban life, has become that dream. In the fifties and sixties, the pursuit of this goal resulted in suburban development on small to moderate lots, often in sewered areas expanding from metro cores. Now, the dream is increasingly fulfilled on agricultural and rural land subdivided into large lots on septic systems.

A prerequisite for the extensive sprawl in the Bay watershed is a large market of homebuyers who can afford residences in these areas. These homebuyers are generally employed in metropolitan areas, commuting to these jobs on a daily basis. As highways expand and design speeds rise to accommodate the resulting traffic, the "commuter-shed" (the areas from which people are commuting to metro employment centers) also enlarges and leads to a damaging cycle of self-perpetuating residential, commercial, and highway development.

The following factors lead to sprawl and its consequent problems:

- The desire to live near open space leads to conversion of rural lands and subsequent loss and degradation of existing open space. New development must then locate even farther away, or leapfrog, so that it can also be near receding open spaces.
- For different reasons, people are leaving many of America's cities. Often the poor are left behind—as has happened in Baltimore—which steadily lost population for five decades. Baltimore possesses 63 percent of Maryland's welfare caseload despite having only about 12 percent of its population.[10] As schools, infrastructure, and employment worsen, more people leave.[11]
- Older suburbs can experience deterioration similar to that of the urban core. These suburbs are often overlooked for newer suburbs closer to open space.[12]
- The search for better schools often leads to a population influx in districts with a reputation for quality education. Ironically, the increased number of students strains classroom space and resources, threatening the quality of that education.[13,14]
- Jobs are also moving out of cities. Communication technology enables some people to live farther away from work, bringing both positive and negative effects. Residential development can follow employment growth to the suburbs.[15] A study of the Washington, D.C. metropolitan area, for example, found that despite its infrastructure, the city itself has only one-quarter of the jobs in the region.[16] As jobs move to the suburbs, unemployment in urban areas increases for those who cannot afford the automobiles and other costs associated with commuting.[17]

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Several factors contribute to this type of development, with sprawl itself often exacerbating the undesirable trends and creating a vicious cycle (see "Sprawl Begets Sprawl" box). Factors often cited at the root of sprawl include: zoning policies; a lack of effective regional planning; government subsidy of roads, highways, and housing; competition among local governments for tax revenues; and residents' desire for a higher quality of life, including good schools and proximity to open space. Though towns promote growth for many reasons, they don't always specify what kind of growth is desirable and often fail to articulate a vision for their future.[18]

## Consequences of Sprawling Development

New residential development around the Chesapeake Bay generally exhibits the familiar "checkerboard" pattern that has typified suburban development throughout the United States over the past forty years. Subdivisions look the way they do in part because they are governed by engineering and zoning restrictions for minimum road frontage, setbacks, and lot size. Importantly, typical suburban designs incorporate the "basic ingredients of many popular, stable neighborhoods with high property values."[19]

Developed land actually occupies a smaller percentage of watershed acreage than forests and agriculture. When development converts open natural land into impervious surfaces, however, it can create or worsen water quality problems. Urban and suburban lands contribute greater amounts of nutrient pollution on a pound-per-acre basis than any other land use other than broken soil agriculture.[20]

The uniform placement of houses in subdivisions frequently does not account for each parcel's ecological and physical characteristics. In fact, large land tracts are often stripped of all vegetation and regraded prior to construction. This practice changes a region's hydrology, disrupting natural waterflow patterns, greatly increasing sediment and nutrient loads into nearby streams, and eliminating any on-site benefits due to the original vegetation (e.g., shading, animal habitat, sediment retention).[21] Subsequently planted vegetation, such as young trees and lawns, may require years to provide equivalent ecological benefits. Often they never reach their former levels of benefit.

Where development impacts riparian forests, it often reduces the important ecological values and functions of these forests. Riparian forests—wooded areas along a river or stream bank—connect natural communities and foster the movement and exchange of plants, animals, nutrients, and energy.[22] Riparian forest vegetation moderates the light and temperature of streams and their associated corridors. Its complex of tree roots, woody debris, and other organic matter filters runoff and sequesters nutrients.[23,24,25] Streamside vegetation also stabilizes the channels, moderates water temperatures in the bordering streams, prevents erosion, and attenuates flooding. Widespread upland disturbance, which can increase sediment loads and flow rates, impairs the ability of riparian forests to protect water quality.[26] As population numbers swell, the quantity of nutrient-rich wastewater discharged to the watershed also rises. In areas served by municipal sewer facilities, increased population adds to the volume of wastewater requiring treatment.

Since new development increasingly takes place in rural areas, individual septic systems are frequently necessary to treat wastewater. Unfortunately, septic systems often discharge nutrients directly to groundwater, which may feed into surface waters and contribute significant quantities of nitrate to streams, rivers,[27] and groundwater. Failing septic systems can cause shellfish contamination and introduce unsafe levels of human pathogens to surface waters.[28]

Approximately 25 percent of the housing units in the watershed are served by septic systems, which contribute an estimated 33 million pounds of nitrogen per year to the watershed, mostly to groundwater. Almost one million pounds are loaded directly to the coastal zone of the Bay.[43] While advanced nitrogen-removing septic designs exist, they are not required in most cases.

## Paving the Land

The increase in impervious surfaces associated with development—roads, rooftops, driveways, and parking lots—significantly affects the hydrology of the landscape[29] and, consequently, the Bay. Precipitation that formerly penetrated the soil and replenished the groundwater becomes concentrated. This concentration leads to increased volumes of stormwater runoff, higher peak flow rates, and in some areas, prolonged bankfull stream flow. Compared to pre-development conditions, these changes in hydrology result in severe direct and indirect impacts on surface water and groundwater quality:

- Increased and more severe flooding and erosion.
- Streambank erosion, channel instability, and loss of good aquatic and riparian habitat.[30]
- Lower baseflows from reduced rates of groundwater recharge.[31]
- Changes in the hydrologic and biological character of streams with impervious surfaces covering as little as 10 percent of a watershed.[32,33,34,35]
- Declines in macroinvertebrate and fish species diversity in streams experiencing upstream development.[36,37,38,39]
- Increased inflow of pollutants such as pesticides, fertilizers, animal wastes, sediments, nutrients, and heavy metals, as stormwater runoff sweeps contaminants into streams and eventually the Bay. As land conversion increases and activities change and intensify, the concentrations and types of contaminants also increase.[40]

| Land Use | Percent Impervious Cover | Percent Runoff | Stream Habitat |
|---|---|---|---|
| Open Areas | 0 - 10 | 10 | Protected |
| Residential, Low Density | 20 - 40 | 20 - 30 | ↑ |
| Residential, Medium Density | 35 - 45 | 30 | ↕ |
| Residential, High Density | 45 - 60 | 30 - 50 | ↓ |
| Business District or Shopping Center | 95 -100 | 55 | Degraded |

***Table 5-1. Percentage impervious cover associated with various land uses.***[41,42]

Typically, septic systems require that individual lots be spread out to provide adequate space for leach fields. Sewer systems, on the other hand, transport wastewater to a central location for treatment before releasing it to the aquatic environment, thus allowing for higher-density development. Most wastewater treatment plants use secondary treatment, which removes little of the nitrogen from the effluent. Since nitrogen has become a significant pollutant in the Chesapeake Bay, however, this region has become a leader in the application of advanced wastewater treatment—such as biological nutrient removal (BNR) and nutrient reduction technology (NRT)—for wastewater treatment. Currently, BNR technology treats about half of the wastewater discharges in the watershed during the warmer months of the year with more complete implementation anticipated (see Technological Solutions chapter).

New development entails more than residential construction. In addition to houses, the driveways, curbs, connecting streets, sidewalks, sewer systems, and septic tanks all become part of the development package. Local governments of sprawling municipalities experience increased costs of services such as water, sewer, roads, and school systems, because revenues from new growth often do not offset costs associated with greater demand for services.[44]

The movement of middle and upper class residents from the urban core to the rural fringe has implications for both the cities left behind and the newly inundated rural communities. Sprawling towns often experience a change in—or even loss of—community identity. On the other hand, towns often shun municipal sewer services and preserve large-lot zoning to maintain their rural character, often resulting in—"land-hungry septic tank sprawl."[45] Sprawl threatens the existence of farmland and creates conflict between newly settled suburbanites and the resident agricultural community. People who move to small towns for their picturesque, rural character suddenly find themselves complaining about the nuisances of the country: noise, odors, stray animals, pesticide spraying, farm vehicle traffic, and dirt roads. Such conflicts can result in new residents rejecting and remaking the very character that attracted them to a place.

## Fighting Sprawl

Across the country, communities increasingly frustrated with sprawl are turning to new kinds of land use policies that allow towns to grow with less impact on the surrounding environment. The Chesapeake Bay region is considered, in many ways, a leader in this effort. With the *Chesapeake 2000* agreement, for example, the Bay states have committed to permanently preserve 20 percent of the watershed from development, reduce the rate of "harmful" sprawl by 30 percent, and restore 2010 miles of riparian buffer by the year 2010.

Virginia, Maryland, Pennsylvania, and Washington, D.C. have made considerable progress in achieving the *Chesapeake 2000* goal to "permanently preserve from development 20 percent of the land in the watershed by 2010." As of the turn of the millennium, almost 7 million acres in the watershed were preserved, with just over one million acres still in need of protection. Reaching this goal, however, will likely require new programs and innovative sources of funding.[46]

In 1999, Pennsylvania dedicated $65 million for establishment of its Growing Greener Program. This program focuses on preserving farmland and open space, restoring watersheds and abandoned mines, supplying new and upgraded water and sewer systems, and eliminating the maintenance backlog in state parks. At the same time, the state's nationally recognized Land Recycling Program develops vacant brownfields (abandoned industrial sites) into productive and safe job-producing sites. The program offers various incentives—from a streamlined review process to improved funding to liability protection—to encourage renewal of these sites.

In Maryland, the state's Smart Growth initiatives promote alternatives to sprawl, focusing on the location and design of new development. Underlying the Smart Growth concept is the notion that infill development, or redevelopment, on previously unused or underused land in existing centers can revitalize these communities and preserve surrounding natural land. "Filling-in" existing communities reduces the number of vehicle miles traveled, uses existing infrastructure, reduces the use of septic systems, and encourages remediation of contaminated "brownfields" sites.[47] Smart Growth programs direct state resources to support new construction in areas where infrastructure is planned or already in place. Local governments designate areas for growth as "Priority Funding Areas" which are eligible to receive state infrastructure funding, as well as economic development, housing, and other program monies. Master plans and land conservation programs can then target natural resource areas and historical landmarks for preservation.

"Harmful sprawl" is poorly planned expansion that destroys green space, exacerbates traffic, and inflicts costs on those in the community.[56] The key to reducing sprawl is more concentrated development, with much of the growth in designated growth areas. Such a strategy steers new housing toward centralized sewer systems, which effectively treat wastes and reduce nutrient loads to the watershed.

Importantly, this concentrated development requires far less land conversion per household than do various forms of sprawl, including traditional suburban and large-lot residential subdivisions in areas lacking infrastructure and services, such as sewer. The latter type typically results in residential lots ranging from about a quarter of an acre up to five or more acres. Well-designed, concentrated, desirable mixed-used neighborhoods can average ten or more dwellings per acre. Thus, concentrated development can accommodate a given population on much smaller amounts of land.

Concentrated development also centralizes the population along with the resources and services that help boost the quality of life. People travel short distances to jobs, school, shopping, and entertainment, resulting in fewer roads, less traffic, reduced auto emissions, and, if advanced waste water treatment is used, minimal pollution from human sewage.

In contrast, sprawling suburban and rural development separates people and their everyday destinations, requiring extensive roads, generating additional traffic, and resulting in more air pollution. The total amount of impervious cover grows to accommodate the roads and services demanded by a rising population. The impacts on

## On the Road Again

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The migration of residents from urban areas means that people often live farther from where they work, shop, or go to school; suburbanites generally drive farther and spend a greater amount of time in their cars. While the nation's population increased by 35 percent between 1970 and 2000, the increase in the area of developed land was more than twice that. Meanwhile, the increase in the number of licensed drivers rose nearly twice as fast as the population, the number of vehicles almost three times, and the number of miles driven grew more than four times faster than the U.S. population. In the Chesapeake watershed, the population grew by 27 percent between 1970 and 1995, while the number of vehicle miles rose by 106 percent.[48] One study estimated that commuters in Washington D.C. spend the equivalent of 76 hours per year stuck in traffic jams.[49] This tremendous increase in the reliance on vehicles results in greater air pollution and contaminated runoff and requires new roads, more road repair, and additional money spent on car repair and gasoline. Increased traffic and narrow roads are oft-cited reasons for building new and bigger roads, but some studies have found that building these roads has little long-term impact on road congestion and can actually generate additional traffic.[50]

Automobile-related sources of pollution include motor oil, by-products from tire and road wear, soot, and exhaust. Studies of lake and reservoir sediments have revealed that increased concentrations of polycyclic aromatic hydrocarbons (PAHs) associated with combusted fossil fuels coincided with increased automobile use in the watersheds. Increased vehicle traffic in the watershed can adversely affect water quality, even if the actual growth occurs outside of the watershed.[51]

Vehicle emissions are responsible for 49 percent of the nitrogen oxides and 37 percent of volatile organic compounds released to the atmosphere.[52] There, they combine to form low-level ozone, a chemical that causes acute respiratory problems, aggravates asthma, and reduces lung function.[53,54] In 2002, from May 1 to September 11, Washington D.C. had 15 Ozone Action Day Forecasts (12 Code Red and 3 Code Orange), in which air quality reached unhealthy levels, especially for children and the elderly.[55] With issuance of a Code Red standard, people are advised to avoid strenuous activities outdoors.

land resources and watersheds—including habitat destruction, pollution, and stream impacts—are widely distributed. Areas of agriculture and rural natural resource populations that require large contiguous tracts of undisturbed land become rare or nonexistent. Streams become degraded by altered hydrology, prolonged bankfull flow, erosion, and pollution from runoff and septic systems.

Successful concentrated growth areas require a necessary counterpart: restrictions on the amount of development outside of growth areas. One objection to this practice is that it reduces land values: "If I can't develop as many houses on my property, it's not worth as much." Where significant development pressure for rural land exists, however, restrictive zoning is very effective when used in combination with programs to transfer or purchase development rights from the owners of the restricted land, and does not reduce land values.[57] Where little or no development pressure exists, such restrictions become irrelevant to land value; in these cases the value rests on the usefulness of the land for rural resource-based usages, such as farming.

One alternative form of residential subdivision—cluster or open-space zoning—has received considerable attention across the country, especially in rural areas (Figure 5-1). The intent of cluster zoning is to provide housing for the same number of people on the same total amount of land as does traditional suburban subdivision, but with less severe impacts on the rural land and associated resources. In this way, it can avoid landowner objections about the impacts of restrictive zoning on land values. The objectives of clustering are accomplished by concentrating houses on closely spaced, small lots, leaving key ecological, physical, and historical characteristics on each parcel undisturbed.[58] This undisturbed land in the resulting community is then preserved as natural area or open space, for use by all of the residents.

Despite the attention received by the concept, cluster zoning in its popular forms causes essentially all of the same impacts as suburban and rural sprawl when compared to concentrated development, although the impacts may be slightly

## Cluster Subdivision

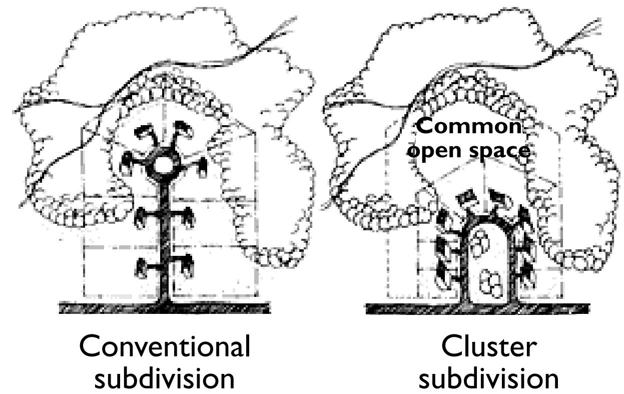



***Figure 5-1. While cluster development reduces a subdivision's footprint, a given parcel of land developed outside planned growth areas and beyond the reach of current infrastructure does not solve many of the problems created by sprawl.***

less. Cluster subdivisions are most common in outlying or rural areas, separating people from their everyday destinations and resulting in many of the same demands and impacts as sprawl.

More importantly, clustering often doesn't succeed in providing a significant measure of protection to rural land and associated resources. To do so, the areas to be protected and preserved, as well as the appropriate extent of those areas, must be given first priority in the cluster development process. The appropriate number and location of clustered houses can then be determined on the remaining land.

Unfortunately, few cluster ordinances operate in this way. Rather, developers first locate the same number of houses and septic systems that would be possible without clustering, focusing on preservation objectives secondarily. This process results in the use of prime agricultural soils and proximity to desirable landscape features for houses, lawns, and septic drainfields—often compromising the use of the remaining land for agriculture. This situation is particularly true if the houses make up a residential neighborhood; residents don't like the nearby spread of manure, crop dusting or farm machinery noise. It also compromises the ability of the remaining land to support wildlife that requires continuity of habitat. Thus, one of the principal selling points of clustering—high lot yields—compromises its ability to deliver on environmental protection in a manner comparable to restrictive zoning, including ultimate impacts on the Bay. And, while cluster development may represent an improvement over more common suburban and rural residential subdivisions, in most cases its benefits for rural terrestrial resources, as well as the Bay, are likely marginal.

In some communities, custom "packet" systems hold promise as a means to process household wastes. At present, however, such alternative applications are rare. Progressive and innovative nonpoint source pollution control practices, such as low-impact development (LID) and alternative stormwater management techniques, can also lessen the impacts of development on water resources and the environment. For example, narrower streets, sidewalks on only one side of the road, and the use of pervious materials (e.g., gravel) for driveways limit the amount of impervious surface. The use of rain barrels, rain gardens, sunken medians, roof drain infiltrators, and other tools to catch or stall rainwater instead of funneling it into culverts can moderate the amount of water and sediment entering nearby streams. These approaches depend on participation from individual homeowners, as well as developers and planners. The strength of LID strategies is that they do not require huge government investment, but rather commonsense conservation measures by those living in the watershed. Just as farmers employ best management practices (BMPs), homeowners could also use appropriate BMPs that result in more native plants, less runoff of rainwater, and less area dedicated to lawns that require fertilizer, herbicides, pesticides, and mowing with gasoline-powered lawnmowers.[59]

Thus, while it may seem counterintuitive to advocate higher density development to protect land and water resources, it is, in fact, fundamental to successfully limit the impacts of continued growth and development on the Bay and its watershed. This situation would not exist if the overall population in the watershed was small, where most could live in houses scattered sparsely over extensive tracts of preserved forest and farm fields and travel only short distances to everyday destinations. Given the current population and its continuing rise, however, such a situation is simply not possible.

High-intensity developments, even when well planned, still cause environmental impacts to the Bay. Current and future population numbers, however, dictate that the alternative is some form of sprawling residential and commercial growth. The impacts of such an alternative on land and water resources, whatever the details, will be worse, for the reasons discussed previously. With an expected population increase of nearly 4 million residents by 2030, concentrated growth in areas served by well-planned infrastructure, and corresponding protection of large, extensive tracts


Tim McCabe, USDA NRCS

***If sprawl continues unabated, expansive rural landscapes such as this one will become increasingly rare.***

of rural resource lands, appears to be the only hope if we are to minimize the impacts of an increased population on the Bay and its watershed resources.

Accomplising such planned development would mean overcoming many obstacles in order to change the social behaviors that determine land use patterns. Since these behaviors are well-established, all parties involved—state and local governments, lending institutions, developers, and citizens—raise considerable resistance to the change. Cookie-cutter subdivisions are arguably easier and faster to build, finance, and manage than carefully designed infill development or redevelopment of existing communities.

These obstacles notwithstanding, positive change will require a shift in economic and social behavior toward development of these types. In addition to the environmental imperative, careful community designs that place residents close to the daily necessities and amenities that are part of a healthy lifestyle—jobs, shops, groceries, entertainment, open space, and recreation—also contribute to fiscal stability for businesses, government, and individuals, enhancing the region's quality of life.

Approaching issues in a coordinated fashion—whether on town, county, or regional scales—can achieve impacts with greater efficiency. Such coordinated strategies can include developing public transportation networks, restoring stream habitats that pass through multiple jurisdictions, designating urban growth boundaries, and purchasing land for conservation.[60] Effective growth management will require comprehensive regional approaches because techniques that only limit growth within a particular locale can drive development to other areas with no restrictions.[61]

Furthermore, focusing solely on growth management and land preservation does not address the social and economic problems of urban areas exacerbated by sprawl, such as the depopulation of urban centers and the exit of capital and community services.[62] Such problems demand different solutions, such as regional tax-base sharing and development of quality low-income housing.[63]

Finally, actions to slow and prevent sprawl will require not only modifications in policies and regulations, but also changes in what people view as desirable in where and how they live. These transformations can only occur through efforts of state and local governments and the development community, coupled with increasingly widespread public understanding of the issues and values at stake.

Unless developers are guided by motives other than amount and ease of profit, the incentives to invest in concentrated development must outweigh those in favor of more sprawl. In turn, the market for development products—potential businesses and residents—must insist on quality from the development community and from local government overseeing land use and development. The result will be successful, concentrated developments, such as mixed-use communities in and around existing neighborhoods, which gradually become an increasing force in the market. The main question is can such developments become the norm, and how soon? The answer will determine which Chesapeake future becomes reality.

In a survey by the Chesapeake Bay Program, those living in rapidly developing areas cited population growth as the leading cause of pollution.[64] Though the general public has expressed growing concern about this issue, the way in which citizens vote with their dollars will largely mold how development unfolds in the future. No matter how land use patterns take shape, balancing growth demands with concerns for environmental quality will prove crucial for the future health of the Chesapeake.

## Scenario Assumptions

Projections for different land use patterns over this large watershed during the next thirty years could cover an entire spectrum of possibilities. In this exercise, consistent with the entire *Futures* project, we focus on three specific scenarios that present plausible alternatives for different levels of growth management throughout the watershed. They represent a quantitative analysis of the outcome of diverse management practices for one of the definitive changes in the watershed over the next century—the increase in the sheer number of people living on the land surrounding the Chesapeake.

Naturally, in a predictive exercise such as this one, we necessarily make many assumptions. Assumptions are inherent in the scientific process, but recognizing the import and limitations of the assumptions is critical. Chapter 2 contains a more complete discussion of the assumptions used and their role in the process.

### Population Projections

Analyses by NPA Data Services, Inc.[65] for the National Assessment of the Potential Consequences of Climate Variability and Change[66] provided the population projections for all of the counties falling—either entirely or in part—within the Chesapeake Bay watershed. These are the same projections used in the Mid-Atlantic Regional Assessment,[67] which included the Chesapeake watershed.

The NPA projections include population by age class, households, employment by sector, and income by source for three growth scenarios. Only estimates of the total population by county under the middle growth (baseline) projection were used here. The NPA projections cover the entire region, use consistent methodology and assumptions, and extend to the year 2050. The projections for a specific county may vary from those developed by the states or local jurisdictions, but the NPA projection provides a reasonably sound basis for this generalized analysis, especially considering the highly speculative nature of 50-year projections.

### Development Projections

How projected population growth (Figure 5-2) will translate land resources into residential, commercial, public facility, transportation and other forms of development is, of course, the key issue. The way in which local governments manage land use and growth will determine, in large part, the result. Predicting each local government's performance in this regard is beyond the scope of this general, basinwide analysis. Rather, current growth patterns and associated land use management practices were sampled in numerous jurisdictions throughout the watershed. We recognize that this synoptic approach may not be directly applicable for any given locale within the basin, but believe that it does provide a reasonable basis for comparing the consequences of the three *Futures* development scenarios for the watershed as a whole.

In a nutshell, the Recent Trends scenario projects recent land development patterns into the future as a function of population growth; the assumptions under the Current Objectives scenario reflect measured results of more progressive land use management approaches being implemented in some regions of the watershed; and the Feasible Alternatives scenario simulates even more advanced development management techniques, currently practiced by relatively few jurisdictions in the watershed.

These projections were accomplished by measuring growth patterns and rates of land use change associated with those land use practices prevailing in most jurisdictions and quantifying the rates of land use change on a per-new-household basis (Recent Trends). The same exercise was carried out for practices and patterns that represent typical Current Objectives for land use and growth management among the Bay states as well as for those practices and patterns representing the very best growth management techniques currently in use within the Chesapeake watershed (Feasible Alternatives).

The set of "multipliers and associated management practices" listed in Table 5-2 represents the results of these exercises. The multipliers quantify the rate at which each land use change occurred in the "average" rural or metropolitan locality (corresponding to the low- and high-rates for each parameter in Table 5-2) practicing land management approaches that correspond to the scenario definitions. These numbers were derived from studies by the Maryland Department of Planning in over 300 small watersheds, in

# Projected New Households in the Chesapeake Bay Watershed (1996 to 2030)

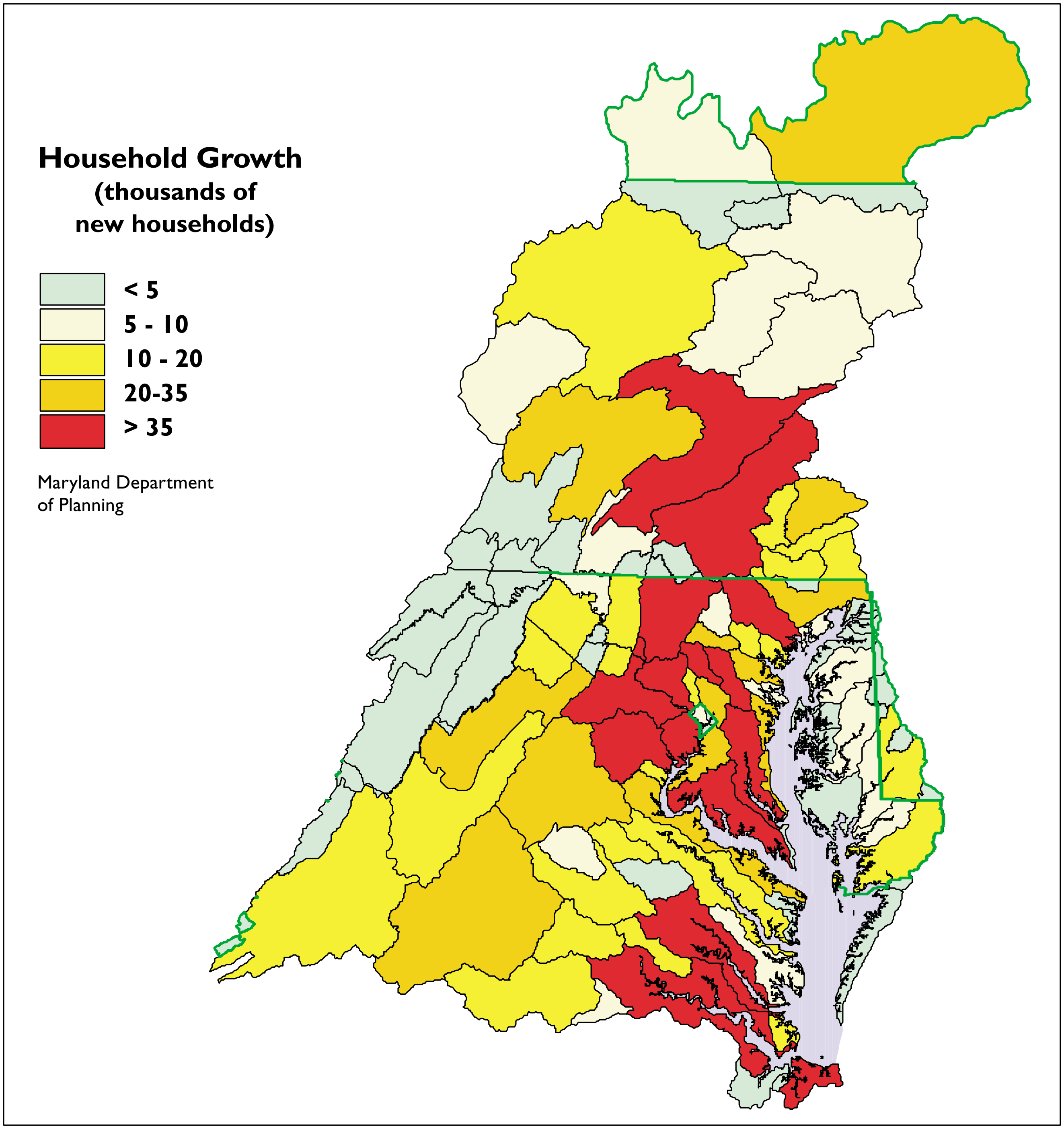



***Figure 5-2.** Recalling land use patterns of the Colonial period, new development will likely follow some of the Bay's larger tributaries—the James, the York, the Potomac, the Patapsco. But new development will also spread into the commuter-sheds of large cities, for example west of Richmond, Washington, Baltimore, and Philadelphia. How much land these homes consume will depend on land use planning, connections to current infrastructure, and the evolving demands and behaviors of new homebuyers.*

| | Recent Trends Scenario | Current Objectives Scenario | Feasible Alternatives Scenario |
|---|---|---|---|
| **Percent new households on sewer** | 56 – 74% | 74 - 82% | 90 - 98% |
| **Acres commercial/industrial land per new household** | 0.10 | 0.06 - 0.09 | 0.03 - 0.04 |
| **Acres infill/redevelopment per new household** | 0 | 0.06 - 0.12 | 0.07 - 0.15 |
| **Acres resource land lost per new household** | 1.03 – 1.55 | 0.42 - 0.91 | 0.14 - 0.24 |
| **Density of new residential development (units/acre)** | 0.6 – 1.1 | 1.1 - 2.4 | 2.9 - 5.9 |
| **Average lot size (acres) per new household** | 0.91 – 1.45 | 0.41 - 0.93 | 0.17 - 0.34 |
| **Acres impervious cover per new household** | 0.21 – 0.31 | 0.13 - 0.21 | 0.08 - 0.11 |
| **Forest conservation on development sites** | Inconsistent | 5% - 25% | 10% - 50% |
| **Riparian buffer conservation on development sites** | Inconsistent | 50 feet | 100 feet |
| **Open space conservation on development sites** | Inconsistent | 10% - 75% | 10% - 75% |
| **Conventional septic system permitting** | Permissive | Permissive | Restrictive |
| **Transferable Development Rights zones: acres preserved/acres lost** | Negligible | 1/20 | 4/1 |
| **Rural land acres preserved/acres lost** | Negligible | 1/3 | 1/2 |

***Table 5-2. Multipliers and associated management practices for projected development patterns under the three Chesapeake Futures scenarios.***

jurisdictions experiencing different development pressures and practicing a range of management approaches.[68] Although these multipliers vary among the watersheds and may differ in other jurisdictions, they provide an empirical basis for determining future projections.

Information about land use management practices and limited data on rates of land use change from jurisdictions in Pennsylvania and Virginia indicate that rates in these states are generally equal to or greater than the Recent Trends multipliers. Thus, the multipliers for Recent Trends probably result in conservative estimates of land use impacts on a watershed-wide scale. Table 2-1 enumerates the typical zoning, subdivision, and development plans, regulations, and procedures corresponding to each scenario. Under each scenario, land use changes were estimated by county, using the multipliers in Table 5-2 and the projected number of new households in the county. These estimates of change due to new households were then added to (or subtracted from) the corresponding statistic for each county for the year 1996. The results for each county are estimated total numbers for 2030 of new households on sewer and septic; acres of commercial/industrial land; acres of new development of various types; acres of impervious cover; and acres of resource land (both forest and agriculture) converted to new development.

## Effects on Nutrient Loadings

The county population land development projections were allocated to the geographic segments of the Chesapeake Bay Watershed Model (which represent smaller watersheds, or segments thereof, within the Chesapeake watershed) proportionally. That is, if a county lies across three model segments, it was assumed for simplicity that the new land developed within the county would be distributed among the watershed segments in proportion to the relative amount of the county's land area that falls within that segment.

The effect of this land development on nutrient loadings to the tidal waters of the Chesapeake Bay was then estimated using in-stream loading rates of nitrogen and phosphorus that are functions of the amount of land developed.[69] Table 5-3 shows the median loading rates for nonpoint runoff, point sources, and septic system inputs for the three scenarios. In actuality, the rates applied ranged around these means depending on the location of the model segment within the watershed. The loading rates do not change considerably among scenarios, with the exception of point source nitrogen rates, which assume progressively more advanced waste treatment in each scenario (see Technological Solutions chapter).

For septic systems, this analysis assumed that 50 percent of the new septic systems under the Feasible Alternatives scenario would be of an advanced design that would allow greater nitrogen source control. On the other hand, in areas where the limited availability of public sewer is used as a way of controlling growth, widespread use of alternative septic systems might actually increase sprawling residential development if conventional systems are not a viable option due to soil conditions.

| | Loading Rate (lbs/acre/yr) | | |
|---|---|---|---|
| **Scenario** | **Recent Trend** | **Current Objectives** | **Feasible Alternatives** |
| **Pervious Urban, N** | 9.6 | 9.5 | 8.7 |
| **Pervious Urban, P** | 0.40 | 0.37 | 0.34 |
| **Impervious Urban, N** | 11.0 | 11.0 | 9.1 |
| **Impervious Urban, P** | 0.94 | 0.92 | 0.88 |
| **Point Sources, N** | 5.1 | 4.0 | 2.1 |
| **Point Sources, P** | 0.35 | 0.33 | 0.12 |
| **Septic Systems, N** | 4.2 | 4.2 | 2.1 - 4.2 |

***Table 5-3. Median in-stream loading rates used in the development scenarios.***

## Impacts on Resource Lands and Streams

Projections of new land development permit general estimates of the impacts on resource areas—forests and agricultural land. We estimated losses of agricultural versus forested land by allocating the total estimated resource land lost in a Watershed Model segment to these two categories in proportion to their relative size (aerial extent) in the base year. In this analysis, larger losses of resource lands also represent bigger losses of forest corridors, wetlands, riparian vegetation, and associated habitats.

Development projections include estimates of the increase in the amount of impervious cover (roads, sidewalks, driveways, building footprints, etc.) based on the multipliers in Table 5-3. Studies have shown that degradation of small streams (assessed by its ability to provide excellent habitat and maintain good water quality) can begin when more than 5 percent of the stream's watershed area becomes impervious (Figure 5-3). Low stream impacts occur when impervious cover reaches from 5 to 10 percent of a small watershed unit; significant impacts typically occur between 10 and 25 percent; and highly unstable conditions and severe impacts occur with over 25 percent of the watershed area impervious.[70] Hydrologically degraded streams are less effective at removing in-stream nutrients. Therefore, in addition to the estimated nutrient loading increases that result directly from land conversion under the three scenarios, greater stream degradation (as exemplified in Recent Trends) will result in additional nutrients reaching the Bay's tidal waters.

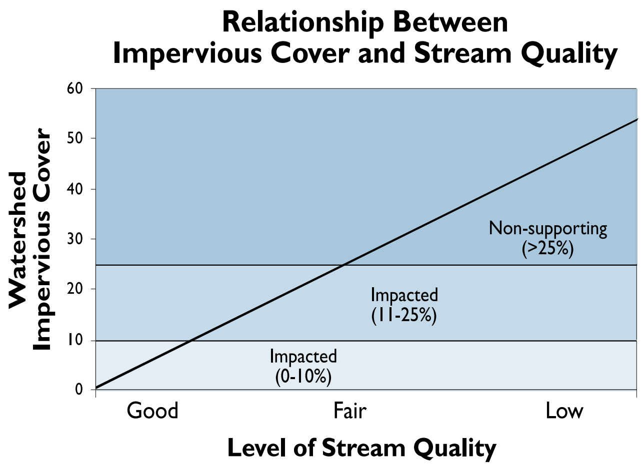



***Figure 5-3. Effect of impervious lands on stream quality. Even small amounts of impervious cover can translate to declines in stream quality.***

Percent impervious cover is a good indicator of stream quality and integrity in relatively small first- and second-order streams. Watershed Model segments are much larger; thus different streams within a segment (with, for example, 8 percent impervious cover overall) may be subject to vastly different impacts. For instance, the watershed of one small stream in the larger watershed may be 30 percent impervious while another may be 1 percent. Because interpretation of percent impervious cover is relatively meaningless at the scale of model segments, the change in impervious cover (absolute or percent increase) is primarily employed as an indicator of potential impacts to streams in each segement that would result from the new development estimated in each scenario.

### Caveats

*Chesapeake Futures* growth and development scenarios do not presume to predict the future. Such predictions would require measurement of recent development trends and management practices for each jurisdiction in the watershed as well as modeling the effects of individually tailored management alternatives. This is well beyond the scope of *Chesapeake Futures*. Instead, the scenarios aspire to provide the best estimate of what is likely to happen if general recent trends in growth and development continue, and to characterize the potential benefits to the watershed if selected alternatives, with demonstrated ability to influence outcomes, are widely implemented.

The scenario projections in this chapter are based on an early version of Phase 4 of the Chesapeake Bay Watershed Model.[71] While the current version of the model (Phase 4.3) incorporates several improvements, the primary objective here is to compare the three scenarios in a relative way and, therefore, the results are little affected by these model improvements. The exercise examines whether the choices made to manage future population growth and development within the region, using a reasonable range of assumptions, will be consequential or trivial to the health of the Bay. It will also help determine the degree to which moving beyond current management objectives would lessen the impact of development on the Bay.

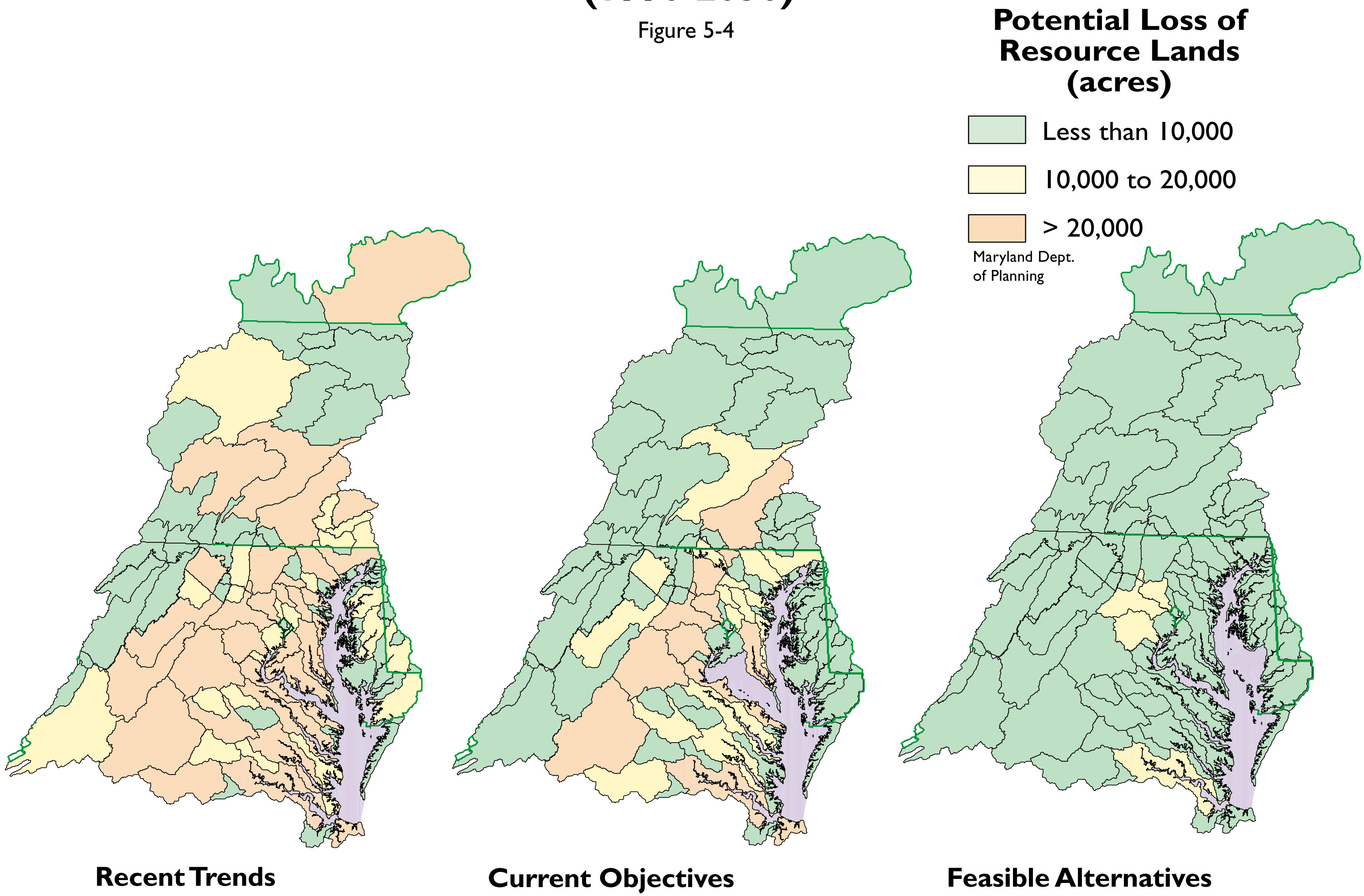
## Scenario 1: Recent Trends

### Primary Expectations:

- *The area of developed land in the watershed will increase by more than 60 percent by 2030, resulting in the loss of more than two million acres of forests and agricultural land (Figure 5-4 and Figure 5-5).*
- *Impervious land area will increase by more than 25 percent in many sub-watersheds, further degrading the quality of streams throughout the central part of the Chesapeake watershed.*
- *Recent progress in reducing sediment loads to the Bay is expected to reverse as soil disturbances from the high rate of land development (along with water-based factors) contribute new sources of sediment.*
- *Nitrogen loads to the Bay due specifically to land development and population growth will increase by about 35 million pounds per year (approximately 10 percent of current total nitrogen loadings from all sources) from increased nonpoint runoff, sewage discharges, and septic systems. Phosphorus loads will grow by about 1.8 million pounds per year (about 8 percent of current totals).*
- *Local positive impacts from riparian buffer and stream restoration efforts may occur; however, large-scale improvements will remain unrealized.*

# Potential Loss of Resource Lands Under Three Scenarios (1996-2030)

Figure 5-4



◆ *Air quality will deteriorate as the vehicle miles driven continue to grow faster than the population, ultimately outstripping improvements in auto emission technology.*

◆ *Billions of dollars of transportation funds will be used to expand highways connecting sprawling residential communities with metropolitan job destinations, perpetuating the sprawl cycle.*

◆ *Local governments continue to realize very limited success in efforts to fulfill conflicting ambitions: encouraging growth versus preserving landscape, water, and environmental quality.*

If the trends of recent decades continue over the next three decades, the landscape of the Chesapeake Bay watershed will become increasingly dominated by various forms of sprawl: expanding rings of suburbs and low-density development in rural areas and ubiquitous strip commercial development along highways—first outside of and then between older communities. The rate of land development will greatly outpace the rate of population growth. Each new household will consume more than an acre of land based both on the housing construction and the development of support services (highways, schools, parking lots, and related services). Relatively little of the population growth will be accommodated by reconstruction or revitalization of existing developed areas in the cities and older suburbs. The majority of the new construction, therefore, will convert agricultural lands and forests to new development. This conversion will result in the loss of about 2 million acres of resource lands by 2030, about two-thirds of which are forests (Figure 5-5).

Much of this loss will occur in the regions experiencing the largest growth around the existing

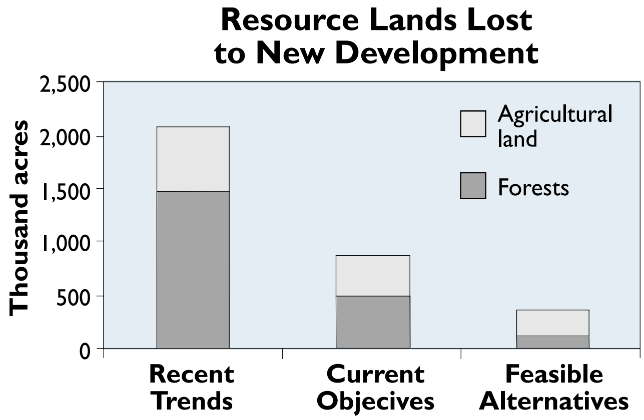
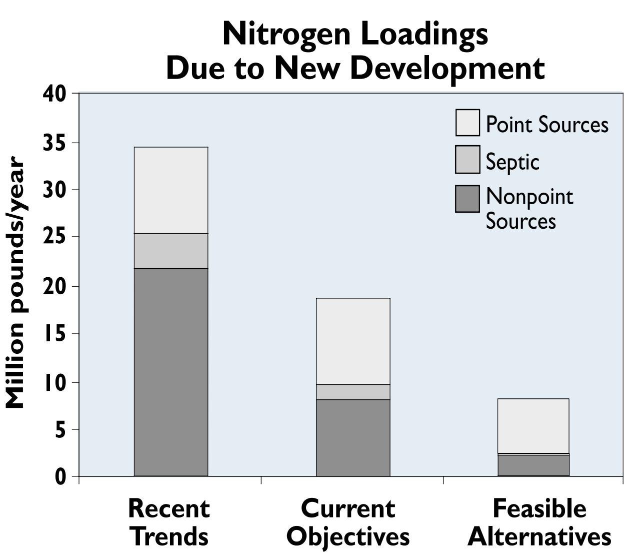



***Figure 5-5 While forests will continue to be lost to new development over time, other factors, such as agricultural conversion, allow generation of new forests and may result in a small net gain in some areas.***




***Figures 5-6. Increases in nitrogen loadings from new development. The largest gains can be made by controlling nonpoint sources of nitrogen, such as stormwater runoff.***

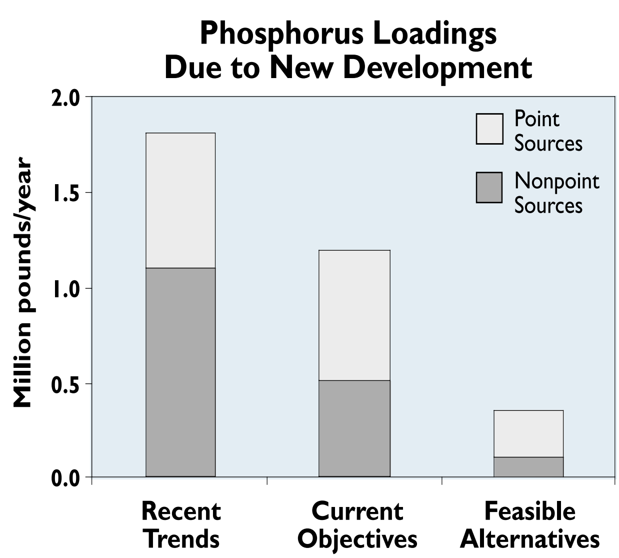



***Figure 5-7. Increases in phosphorus loadings from new development. As with nitrogen, the largest gains in phosphorus control can be made through nonpoint source control.***

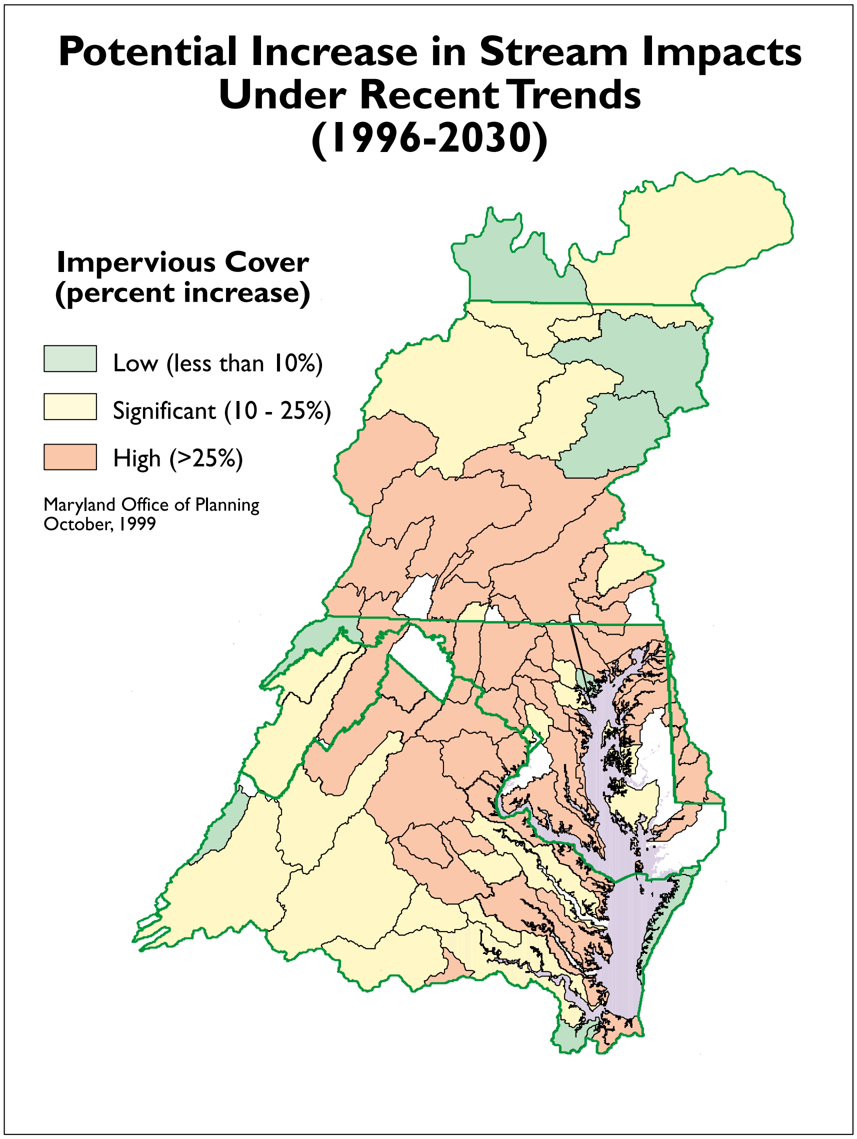



***Figure 5-8. Great stretches of the Cheapeake Bay watershed will likely see more areas covered by impervious surfaces—roads, highways, driveways, rooftops, and parking lots. The areas most acutely affected (see map) will experience increases of 25 percent or more in impervious cover, if recent trends persist.***

metropolitan areas of Washington, D.C., Baltimore, Hampton Roads, and Richmond (Figure 5-2). These cities are close to the Bay and its tidal tributaries, but large resource land losses will also extend into western and southern Virginia and south-central Pennsylvania.

The combination of nonpoint runoff from developed land, ground- and surface-water pollution from septic systems, and discharges of treated sewage from wastewater treatment plants will result in widespread increases in loadings of nitrogen (Figure 5-6) and phosphorus (Figure 5-7) to the tidal estuary due to new development. Under the Recent Trends scenario, 29 percent of the new housing units will be served by septic systems, which have less efficient nutrient removal capabilities than publicly owned treatment works. Throughout the watershed, new development will cause an increase of nearly 35 million pounds of nitrogen and 1.8 million pounds of phosphorus.

Both forests and riparian areas effectively filter nutrients, sediment, and contaminants. Despite localized achievements in preserving these important lands, however, net losses will continue, particularly in regions undergoing high development rates. Growth patterns predicted under this scenario will result in an increase in impervious cover over a large portion of the watershed (Figure 5-8). Impervious cover within the watershed will significantly change local streams, causing extremely high water flows during storms, followed by extremely low flows during dry periods due to diminished groundwater supplies. Such extremes result in eroded stream banks, loss of habitat, and degraded water quality.

Additional dispersed development will force more vehicles on the road, bringing additional hours of driving time, more traffic congestion, and increased air pollution.[72] Projection of recent trends would result in a two- to three-fold increase in vehicle miles driven in the Washington, D.C. metropolitan area, creating enormous pressures for new road construction. Emissions of nitrogen oxides—precursors of ground-level ozone formation and significant sources of atmospheric deposition of nitrogen—will increase as the number of vehicle miles driven grows faster than the efficiency of emission controls currently in place. Between 20 and 35 percent of the total controllable nitrogen load coming in to the Chesapeake Bay is from atmospheric deposition.[73] Regionally, vehicles contribute approximately 35 percent of the sources of NOx.[74]

Similarly, new energy demands from population growth and development will outstrip the slow improvements in energy efficiency of recent decades, necessitating additional electricity generation. Existing regulations will, at most, stabilize nitrogen oxide emissions from stationary sources. Ozone levels will worsen in present non-attainment areas and air quality threats will spread with development.

In sum, if recent trends continue, localized improvements to air and water quality due to source controls will likely be reversed. New inputs of nitrogen and phosphorus to the estuary from development will offset much of the recent reduction in point-source inputs. Large amounts of resource land will be converted to urban and suburban uses, with consequent impacts on rural areas, agriculture, forests, and ecologically valuable lands, especially local streams and watersheds throughout many portions of the Chesapeake Bay basin.

## Scenario 2: Current Objectives

### Primary Expectations

- *Despite policies to preserve open space, new development will cause the loss of nearly 900,000 acres of forests and agricultural lands by 2030.*
- *Impervious surface will increase by 24 percent, only slightly less than that expected under Recent Trends.*
- *Efforts to restore 2,010 miles of riparian forest buffers and to significantly constrain development will produce substantially lower sediment loadings than under Recent Trends, but only modest reductions from present levels.*
- *Nitrogen loads to the Bay will grow by about 18 million pounds per year due to land development and population growth (slightly more than half the growth under the Recent Trends scenario). Phosphorus from developed lands will increase by less than 0.7 million pounds per year.*
- *Riparian buffer restoration goals will be met or exceeded, resulting in significant improvements in local water quality.*
- *Modest improvements in air quality will be achieved with tightened auto emissions standards; vehicles miles driven will continue to grow, but at a reduced pace.*

In this imagined future of the Chesapeake region, land use practices throughout the watershed would effectively incorporate current policies that lessen the impact of development. As a result, land use conversion falls by over 50 percent from that estimated under Recent Trends. New households would each consume between 0.5 and 1 acre of land, built on smaller, clustered lots near existing shopping and services. In addition, 13 percent of new development would occur on previously developed lands. Centralized wastewater treatment facilities would serve about 80 percent of the new housing units, allowing more effective removal of nutrient wastes.

Despite implementation of policies and practices to slow sprawl and preserve undeveloped land, commercial and residential development throughout the watershed will still consume over 800,000 acres of resource land (Figure 5-5). Many of the outlying regions will show significant reductions in land use conversion, although the urban areas and a north-south band through the center of the watershed will still exhibit considerable effect from development (Figure 5-4).

Increases in nitrogen loading due to new population growth and development will be almost one-half of that under the Recent Trends scenario (Figure 5-6), due to less nonpoint runoff from the smaller footprint of development and less reliance on septic systems. Nitrogen loadings from point sources will remain about the same as that under

Recent Trends, despite improvements in waste treatment efficiency, since treated waste volumes will rise as more households link into sewerage. Phosphorus loadings will show significant reductions due to reduced nonpoint source runoff compared to the Recent Trends scenario (Figures 5-7). Newly developed landscapes generally result in large phosphorus loadings associated with soil erosion.

Achieving the riparian forest restoration goals under Current Objectives will further ameliorate increased loadings associated with new development. Localized preservation of these forests, along with improvement of water quality, will result. The effectiveness of riparian buffer restoration in stemming nutrient pollution on the watershed scale, however, depends greatly on the geographic targeting of these efforts. The degree of preservation, restoration, and maintenance of riparian forest lands in areas of development is critical.

Although vehicle miles driven will continue to grow under the Current Objectives scenario, the rate of growth will decline considerably due to constrained sprawl and increased use of improved transit systems that reduce reliance on automobiles.[74] Public transportation will provide options for those who choose to moderate their automobile use. At the same time, worsening traffic congestion will make public transportation more attractive and vehicle miles traveled will begin to level off within 10 to 15 years.

In sum, new development—even within the constraints of current policy objectives—will result in a substantial loss of resource lands and significant additional nutrient loadings to the Chesapeake. It will place a significant burden on waste treatment technologies and controls of other nutrient sources, particularly those from agriculture and atmospheric deposition, to meet and sustain the nutrient reduction goals set forth in the 1987 Bay Agreement. Achieving the more ambitious goals for nutrient reduction under the *Chesapeake 2000* Agreement will remain a challenge under this restrained sprawl scenario.

## Scenario 3: Feasible Alternatives

**Primary Expectations:**

- *Creative growth management and strategic land preservation efforts will reduce the development of resource lands to about 350,000 acres—less than 17 percent of Recent Trends.*
- *Impervious surface will increase by 15 percent, a smaller percentage than either of the other scenarios.*
- *Significant reductions in sediment loading from the watershed would result due to reforestation of large areas of the watershed, tightly constrained development of new lands, more effective control of sediment loss from construction sites, aggressive retrofitting and maintenance of stormwater management infrastructure in developed areas, and riparian zone restoration.*
- *Nitrogen loads to the Bay specifically from new development and population growth (about 8 million pounds/year) will be about one-quarter of those projected under the Recent Trends scenario. The net increase in phosphorus loads due to growth and new development will be about 1 percent of current total loadings.*
- *Strategically preserved and restored riparian buffers will further ameliorate nonpoint source inputs of nutrients due to development.*
- *New and expanded public transportation networks will stabilize or reduce the use of automobiles. Improved emission control technologies, increased fuel efficiency and alternative technologies (e.g., fuel cells) adopted to reduce greenhouse gas emissions all result in significantly improved air quality.*
- *Billions of dollars of transportation funds will be used to make it easy, pleasant, and efficient to move within and between communities, cities, and newer mixed-use developments, using public transportation and the pedestrian- and bicycle-friendly environments.*

The vision developed under the Feasible Alternatives scenario demonstrates that creative land management strategies can considerably decrease the propagation of developed lands, loss of forests and farms, and nutrient pollution throughout the Chesapeake Bay watershed. Houses clustered in small communities with significant tracts of land set aside as natural areas and open space result in each new household consuming less than one-quarter acre of forest or agricultural land.

In this scenario, sprawl will be contained with some 40 percent of all new development occurring on previously developed land, tapping into existing roadways, schools, shopping, and other services. Fewer than 400,000 acres of resource lands will be converted to development by 2030 (Figure 5-5). This loss is still considerable, but far less than the amounts predicted under the Recent Trends and Current Objectives scenarios. Some areas, such as the regions west of Washington, D.C. and surrounding the James River, will experience significant changes in land use due to development permitted under this scenario (Figure 5-4).

Sprawl will be constrained, reliance on automobiles reduced, and investment in public transportation expanded. Energy efficiency will also improve, eventually offsetting the growth in demand for power from the growing population. This development will allow the NOx emission controls established to achieve the goals of the Clean Air Act to overtake demand growth, resulting in air quality improvement and a reduction in the atmospheric deposition of nitrogen (see Technological Solutions).

Up to 98 percent of new development would be connected to centralized wastewater treatment facilities, dramatically reducing the quantity of nutrients from private septic systems. Advanced waste treatment technologies (see Technological Solutions chapter) will further reduce loadings of nitrogen and phosphorus to less than half those under the Current Objectives scenario. Zoning regulations will also preserve significant amounts of natural resource land, including 100-foot riparian buffers along stream banks throughout the basin.

Other point and nonpoint pollution control efforts will lower nutrient loading rates. Key among these will be "low-impact development" strategies (LIDs), including the use of rain barrels, rain gardens, sunken medians, roof drain infiltrators, green roofs, and other tools to catch, slow, or stall rainwater rather than funneling it into local culverts and streams. In this scenario, homeowners can choose to have more native plants, minimal rainwater runoff, and less lawn area requiring fertilizer, herbicides, pesticides, and mowing with gasoline-powered mowers.

In a future that takes advantage of feasible alternatives for wise land use, the increase in nutrient loads due to new development between today and 2030 will be relatively small. In conjunction with the effects of advanced technologies on load reductions, total loads from all development sources will be less in 2030 than they are today, despite the presence of an additional 3.8 million people in the watershed. Perhaps even more surprising, local watersheds and land resources throughout the basin would generally be in as good as, or in some cases, better condition than they were at the dawn of the 21st century.

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[63] Downs, A., op. cit.

[64] Chesapeake Bay Program. 2002. A Survey of Chesapeake Bay Watershed Residents: Knowledge, Attitudes and Behaviors Towards Chesapeake Bay Water Quality Issues. Prepared by J. McClafferty. Virginia Tech. Annapolis. MD: Chesapeake Bay Program. The survey notes that "the Baltimore/Washington Metro and North-central Virginia regions (both rapidly growing areas) indicated that population growth is the greatest source of pollution..." p. iv.

[65] NPA Data Services. 1999. *Development of Three Alternative National Projections Scenarios, 1997–2050*. Arlington, VA: NPA Data Services, Inc.

[66] National Assessment Synthesis Team. 2000. *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change.* Cambridge, U.K.: Cambridge University Press.

[67] Mid-Atlantic Regional Assessment (MARA). See *www.essc.psu.edu.mara/*

[68] Maryland Office of Planning. 1998. *Smart Growth Options for Maryland's Tributary Strategies*. Publication #99-03, Appendix.

[69] The effects of land use and nutrient pollution control measures on nutrient loadings to the Bay's tidal waters were estimated using in-stream loading rates and delivery rates for nitrogen and phosphorus, derived by model segment and source type from Phase 4 of the Bay Watershed Model. Rates for *Futures* scenarios in this chapter were derived from three model runs corresponding to the desired assumptions of the three scenarios, specifically the 1996 Progress Run (Recent Trends), 2000 Tributary Strategies (Current Objectives), and 2000 Full Voluntary Implementation (Feasible Alternatives). In the land use analyses in this chapter, assumptions about pollution control management practices are essentially identical to the watershed model run from which loading rates were derived: the practices and associated rates of implementation are the same as those achieved (for the 1996 Progress Run) or assumed (for the Tributary Strategies and Full Voluntary Implementation runs) in each jurisdiction/watershed model segment.

[70] Schueler, T. 1994. Site Planning for Stream Protection. In *Watershed Based Zoning*. Ellicott City, MD: Center for Watershed Protection.

[71] While an early version of Phase 4 of the Chesapeake Watershed Model was used for these development scenarios, Phase 4.3 was used for the summary assessments in Chapter 9.

[72] Burchell, R.W. and D. Listokin. 1991. *Technical Studies for the Governor's Commission on Growth in the Chesapeake Bay Region*. Baltimore, MD: Maryland Office of Planning.

[73] The Chesapeake Bay and the Control of NOx Emissions: A Policy Analysis. Resources for the Future. *http://ww.rff.org/CFDOCS/disc_papers/summaries/9846.htm#nox.*

[74] Sources of Atmospheric Deposition. Maryland Department of the Environment. *http://www/dnr.state.md.us/streams/atmosphere/sources.* (Originally from the Environmental Protection Agency, 1997.) See also Chesapeake Bay Program. *Beyond Sprawl: Land Management Techniques to Protect the Chesapeake Bay, A Handbook for Local Governments*, op. cit.