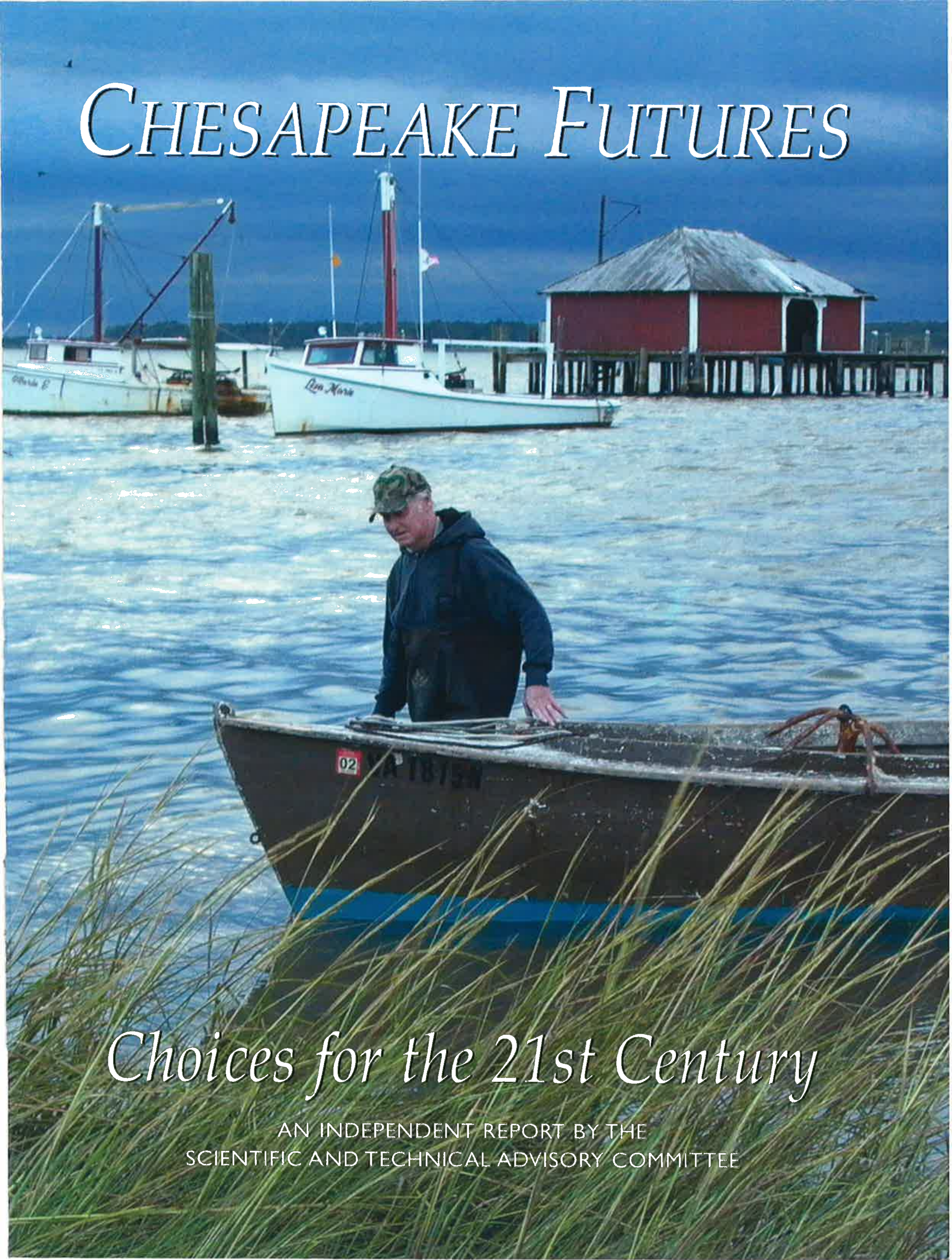

# Chesapeake Futures

## Choices for the 21st Century

An Independent Report by the
Scientific and Technical Advisory Committee

# *CHESAPEAKE FUTURES*
## *Choices for the 21st Century*

*edited by*
*Donald F. Boesch*
*and*
*Jack Greer*

*An Independent Report by the*
*Scientific and Technical Advisory Committee*

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The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program on measures to restore and protect the Chesapeake Bay. As an advisory committee, STAC reports quarterly to the Implementation Committee and annually to the Executive Council.

STAC members come primarily from universities, research institutions, and federal agencies. Members are selected on the basis of their disciplines, perspectives, and information resources needed by the Chesapeake Bay Program.

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# Contents

# Authors and Acknowledgements

The production of Chesapeake Futures was very much a team effort. Donald Boesch and Jack Greer were the principal writer/editors for the report as a whole, but several workgroups, listed here, drafted and contributed the report's many sections. Time given by the workgroup members and other participants was entirely voluntary. STAC offers its appreciation to all who donated their time and effort to produce this ambitious report.

Key to the production of Chesapeake Futures was the extensive help of several assistants and contractors: Caryn Boscoe helped serve as coordinator of the Futures project; Catherine Schmitt filled many information gaps in the report; and Nina Fisher has been central in bringing the project to completion and preparing it for publication. Listed here are the individuals who made up the core group for the Chesapeake Futures project, including the Steering Committee and each Task Force group.

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### Special Thanks

Many contributed to the completion of this report. Although Don Boesch and Jack Greer wrote much of the report and wove the many contributions of technical experts into whole cloth, Joe Tassone, Steve Seagle, and Caren Glotfelty were the primary authors of Development and Sprawl, Forests in Transition, and Adapting Agriculture, respectively. Deborah Weller and fellow staff of the Maryland Department of Planning performed key development analyses. Scientists from the Pennsylvania State University associated with the Mid-Atlantic Regional Assessment of Climate Change made important contributions to Adapting Agriculture and the discussions of the impact of climate change on the Bay. Russ Brinsfield and Dick Weismiller contributed perceptive comments on the future of agriculture in the region. Gary Shenk of the Chesapeake Bay Program Office provided invaluable insight and information concerning the Chesapeake Bay Watershed Model. Jeff Halka offered his understanding of the Bay's sediment budget. The Natural Resource Conservation Service, and especially Jen Pakula from the Annapolis office, helped to provide photographs and maps. The valuable research of Jim Hagy, now of the Environmental Protection Agency, provided revealing insights on what a "saved" Bay might look like. Finally, members of the Scientific and Technical Advisory Committee and representatives of the federal and state agencies that help inform and shape the Chesapeake Bay Program contributed insightful review and helpful comments on drafts.

# Foreword

The Chesapeake Bay—heart of the Mid-Atlantic seaboard—faces enormous challenges in the coming decades. While the Bay has faced the onslaughts of waste dumping and heavy sediment loads in the past, a rapidly increasing population and an even more rapid rate of development have raised the stakes and presented us with many curcial choices. *Chesapeake Futures* outlines the likely consequences of some of the choices we are now making, and their implications for the future of the nation's largest and historically most productive estuary.

This report represents the work of many scientists and technical experts gathered under the auspices of the Chesapeake Bay Program's Scientific and Technical Advisory Committee. The projections and estimates emanate from several data and information sources and do not rely on any one methodological tool or approach. For example, although the Chesapeake Bay Program's Watershed Model was used to estimate past and current nutrient loadings, different assumptions and methods were applied for the projections in this study. Researchers drew upon their own knowledge and examined several models and assessments, including Mid-Atlantic climate models and other regional projections for agriculture, forestry, and land development.

The assumptions and conclusions in *Chesapeake Futures* capture the state of knowledge as viewed by the authors of the report, and do not represent the official position of the Chesapeake Bay Program, the U.S. Environmental Protection Agency, or any other private, state, or federal agency.

While *Chesapeake Futures* presents a series of likely outcomes, or "scenarios," based on current knowledge and projected trends, it does not propose direct policy recommendations. The authors offer this report as constructive advice from a wide-ranging team of technical experts in the hope that the information will assist policymakers, resource managers, and citizens alike as they weigh the choices confronting them in the coming decades. Clearly, every participant in *Chesapeake Futures* has an interest in the restoration and productivity of the Chesapeake Bay, as well as deep concern for the landscape that forms the Chesapeake's drainage basin. Many have spent much or even all of their careers studying issues central to the estuary and its watershed.

In the spirit of open discussion and debate, all of the participants in *Chesapeake Futures* welcome further questioning and analysis as we make our way through the 21st century. We also urge the continued use of environmental science and technology—combined with a strong sense of personal environmental stewardship—to guide our choices as we shape the future of the Chesapeake Bay in the face of constant and inevitable change.

*Tim McCabe, USDA NRCS*

# Highlights

*Chesapeake Futures*, an effort undertaken by scientists and technical experts under the auspices of the Chesapeake Bay Program's Scientific and Technical Advisory Committee, developed three scenarios for the Bay and its watershed, timed to the year 2030. This exercise focuses on long-term possibilities and long-term choices. The three scenarios are for Recent Trends (essentially the status quo), Current Objectives (accounting for current baywide agreements and commitments),[1] and Feasible Alternatives (innovative technologies and aggressive approaches). While all projections and future outcomes presented in this report should be read in context, with an understanding of specific background and assumptions, the following highlights outline some of the key findings of this effort.

The Chesapeake Bay faces an uncertain future. If sediment and nutrient loads continue at levels witnessed at the end of the 20th century, multiplied by a growing population and new development, water quality will worsen. Water clarity and oxygen levels will slide back toward conditions not seen since the 1980s. Specifically, total loadings of nitrogen to the Bay would grow by about 30 million pounds—about 10 percent over current levels—by 2030 representing the loss of more than half of the load reductions achieved between 1985 and 2000. Total phosphorus loadings would grow by about 3 million pounds, nearly 15 percent, losing one-third of the load reductions achieved within this same time period.

Escalating nutrient and sediment loads would result not only from a population expected to reach about 19 million by the year 2030, but also from poor land use planning, with continued rapid loss of farm and forest lands, and only modest improvements in agricultural methods and wastewater treatment.

These additional loads would largely defeat current efforts to restore underwater grasses, cause further loss of oxygen in the Bay's bottom waters, and undermine efforts to restore oysters due to worsening water quality. Such would be the future, if the trends of the latter decades of the 20th century hold to the year 2030.

## The Purpose of Futures

*While resource managers, decision makers, and the rest of us would, of course, love to have clear predictions of the future, the world has rarely proceeded quite as planned. Given the difficulty of prediction, especially with a system as variable as the Chesapeake Bay, what can we expect from Chesapeake Futures?*

*Chesapeake Futures is not meant to be predictive; rather it sets out a series of three possible scenarios based on choices we make now. To create these scenarios, the experts used Bay computer models, past and current, but they also brought personal experiences, observations, and opinions into play. Consequently, some of the reasoning in the report will track well with the computer models, but some will diverge. The purpose of Chesapeake Futures, then, is not to refine the current attempts to model the Bay, but instead to use what we know—in the broadest sense—to guide both our thinking and our management efforts as we journey forward through the first three decades of the 21st century.*

## Current Efforts

The Bay will fare better if we can fulfill several current commitments, as expressed in ambitious Bay agreements, including *Chesapeake 2000*. Total nitrogen loadings from all sources would decline by 45 million pounds, or about 15 percent of recent levels, by the year 2030. With these achievements, nitrogen loadings would remain slightly lower than the 1987 40-percent goal for reducing "controllable" sources. By meeting current objectives, total loadings of phosphorus would decline by some 4 million pounds or 21 percent of 2000 levels. Reductions in nutrient loadings under this scenario would be even greater, if not for a growing population and predicted land use trends.

Given the success of several current Bay programs, underwater grass beds should roughly double in area with consequent improvements in bottom habitats. On the other hand, shoreline erosion would increase and significant areas of tidal wetlands would be lost; with this erosion comes associated increases in light-blocking sediments.

The Bay's primary productivity would decline somewhat, but higher production by bottom-dwelling algae would cause some alteration of food chains, resulting in modest improvements in habitats and production of important Bay fisheries.

## A Brighter Future

With the implementation of numerous alternative strategies and emerging technologies, the future of the Bay looks considerably different. Under a feasible alternatives strategy, the total loadings of nitrogen from all sources would drop by some 143 million pounds, or 47 percent of recent loadings, by 2030. Total phosphorus loadings would drop by 10 million pounds, or 53 percent. Reductions in nutrient and sediment loads, due to highly progressive land development practices, and cutting-edge agricultural and waste treatment methods, would lead to improved water quality in the Bay. The air, too, would be cleaner, with the potential to reduce both mobile and stationary sources of nitrogen oxides by some 70 percent—leading to less atmospheric deposition of nitrogen in the Bay and its watershed.

These changes would ultimately lead to improvements in Bay water quality, with resulting improvements in its food web. Fisheries habitat would recover, especially in the Bay's bottom waters, with positive impacts on bottom-dwelling organisms. These improvements, along with progressive fisheries management, would help sustain fish and shellfish stocks, and bolster the Bay's economic productivity, as well as its ecological health.

## Land Use and Development

*If recent trends continue. . .*

- 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.
- Impervious surface 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.
- Nitrogen loads to the Bay due to land development and population growth will increase by about 35 million pounds per year—only slightly offset by a loss of inputs from agricultural lands, estimated at some 5 million pounds of nitrogen per year. Phosphorus loads coming specifically from developed lands would increase by about 1.8 million pounds per year.
- Air quality will deteriorate as vehicle miles driven grow faster than the population, outstripping improvements in auto emissions technology.

*If current objectives are met. . .*

- Despite policies to preserve open space, new development will cause the loss of about 800,000 acres of forests and agricultural land by 2030.
- The amount of impervious surface will increase significantly, only slightly less than under Recent Trends.
- Though nitrogen loads to the Bay will decrease overall, contributions due to land development and population growth will increase by over 18 million pounds per year (slightly more than half the increase under the Recent Trends scenario).

- Annual phosphorus loads from developed lands will increase by less than 0.7 million pounds.
- 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; vehicle miles driven will continue to grow, but at a reduced pace.

*If feasible alternatives are put in place . . .*

- Creative growth management and strategic land preservation efforts will reduce the development of resource lands in the watershed to about 350,000 acres—about 17 percent of Recent Trends.
- The amount of impervious surface will increase only slightly—a reduction from Recent Trends.
- While overall nitrogen loads to the Bay will decrease, inputs from new development and population growth will increase by about 8 million pounds per year, roughly one-quarter of those projected under the Recent Trends scenario.
- Strategically preserved and restored riparian buffers will further ameliorate nonpoint-source inputs of nutrients resulting from 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 will result in significantly improved air quality.
- The use of feasible programs and technologies could reduce nitrogen loading rates from urban areas—both impervious and pervious surfaces—from an estimated 22 pounds per acre given recent trends to an estimated 19 pounds per acre.

## Forests

*If recent trends continue . . .*

- Despite several decades of increasing forest cover driven by reforestation, the amount of forest cover will level off quickly and then decline.
- Further wide-scale loss of forests will continue in or near metropolitan areas.
- The fragmenting of forests will continue throughout the basin, with fragmentation most acute near metropolitan areas and the Coastal Plain and Piedmont provinces.
- A drop-off in agriculture-to-forest conversion is possible, especially in the Ridge and Valley and Appalachian Plateau provinces, with fewer farms to go out of production.
- Riparian forest buffer restoration will produce positive effects locally, but regional gains will remain small as limited progress towards restoration goals is largely offset by losses elsewhere.

*If current objectives are met . . .*

- A decline in total forest cover within the Coastal Plain and Piedmont will continue, particularly in metropolitan suburbs, with increasing forest cover in other parts of the basin. A net gain in total forest of the Chesapeake Bay basin should result.
- Modest and localized decreases in forest fragmentation will occur, due to better planning of development.
- Gains in riparian buffer mileage will lead to significantly improved local water quality, but only modest decreases in nutrient and sediment inputs to the Bay.
- Despite the positive effects of efforts to preserve resource lands, the links among patches of forest will remain spotty and forest function will improve only slightly beyond the Recent Trends scenario.

*If feasible alternatives are put in place . . .*

- Forest cover will increase much more significantly as forest cover in the Coastal Plain and Piedmont is stabilized.
- Riparian buffers will increase somewhat, and there will be a decrease in forest fragmentation.
- Highly active management of private forestland and non-consumptive management of public forests lead to increased quality and quantity of forests throughout the watershed.

- Better product development and marketing lead to strengthened economic infrastructure for forest products.
- More sophisticated social attitudes and technical knowledge will aid in the development of a rich forestland base, with local and regional nutrient management planning, and potential long-term management of environmental impacts in the watershed.

## Agriculture

*If recent trends continue . . .*

- Sprawling residential and commercial development will result in the loss of almost 700,000 acres of agricultural land.
- With less farmland available to go out of production, agriculture-to-forest conversion could decline, particularly in the Ridge and Valley and Appalachian Plateau provinces.
- Demand for undeveloped land will raise prices, fragment existing farmland, and alter the character of rural areas.
- Small farmers will find it difficult to make a living from traditional farming as global market trends and other economic forces erode their profits.
- Existing farms will experience a greater dependence on intensive agriculture.
- Technology and globalization will have some positive effects on agriculture.

*If current objectives are met . . .*

- Land preservation efforts of the *Chesapeake 2000* agreement will preserve open space and guide development patterns; however, 400,000 acres of agricultural land will still be converted to urban and suburban uses.
- Even if farmlands are preserved, agricultural industries will face economic difficulties and a dwindling number of people may be willing to farm for a living.
- The implementation of soil and water conservation plans on croplands and hay fields will reduce nitrogen loadings by 9 percent and phosphorus loadings by 21 percent.
- Nutrient management plans will be successfully applied to half of the tilled cropland and hay fields in the watershed.

*If feasible alternatives are put in place . . .*

- Land preservation efforts, in combination with programs that target the economic sustainability of farming, will preserve open space and viable rural communities. Fewer than 300,000 acres of agricultural land will be lost to new development.
- Technological advances and policies will resolve animal waste problems, improve efficiency, and provide financial planning and business management aid to farmers.
- Various economic and environmental policies along with behavioral changes could further ensure the existence and success of agriculture in the watershed.

## Chesapeake Bay and its Fisheries

*If recent trends continue...*

- In addition to continued contributions from agricultural and legacy sediment, additional sediment will enter the Bay from rapid land development, bypassing of the Susquehanna dams, and erosion of the shoreline due to accelerated sea level rise. Coupled with the stimulation of plankton growth from increased nutrient loading, water clarity in much of the Bay will decrease.
- Significant areas of tidal wetlands—their landward migration restricted—will be lost to sea level rise.
- As average nitrogen loadings creep back toward 1985 levels due to population growth and development, excessive phytoplankton production will continue. Anoxia and severe hypoxia will be an annual occurrence, worse in high-discharge years.
- Loadings of toxic contaminants will decline slowly, but seafood consumption advisories will continue due to a legacy of contaminants.
- Submerged aquatic vegetation will contract, except in those tributaries remote from increased sources of sediment and nutrients.

*If current objectives are met . . .*

- More limited land development, improved stormwater management and riparian buffer restoration will hold the line for sediment inputs from the watershed, but sediments mobilized from shoreline erosion will increase.
- Water clarity in some regions of the Bay and its tidal tributaries will increase due to decreased nutrient loadings, but not in areas near rapidly eroding shorelines.
- Significant areas of tidal wetlands will ultimately succumb to sea level rise and restrictions to their landward migration.
- Average nitrogen loadings will decline, eventually resulting in demonstrable reductions of excessive phytoplankton growth and severe hypoxia, equivalent to levels of the mid-1970s. Except in the driest years, some anoxia will still occur.
- Loadings of contaminants will decline a bit more rapidly than under Recent Trends, but impairments due to legacy contamination will continue.
- Submerged aquatic vegetation will expand in selected tributaries, approximately doubling in extent through the Bay.
- Benthic microalgae will play a greater role in the Bay's biological productivity, while bacteria and small phytoplankton will contribute less. Production of fish relying on these bottom resources will increase as food chain efficiency increases and preferred habitats expand.
- The biological diversity and resiliency of the Bay ecosystem will increase, buffering the Bay from extreme events and reducing the frequency and severity of algal blooms.
- The socioeconomic value of the Bay's fisheries will increase modestly as the productive capacity of the Bay ecosystem increases and harvests are managed more sustainably.

*If feasible alternatives are put in place...*

Well-managed growth and development, substantial retrofitting of stormwater infrastructure, and removal of sediment behind Susquehanna dams will result in real reductions in sediment loads from rivers. Adaptive shoreline management strategies will help sustain tidal wetlands.

- Water clarity in most regions of the Bay will increase substantially due to decreased nutrient loadings.
- The total acreage of tidal wetlands will be maintained close to present levels by preventing barriers to their landward migration and through active management to enhance soil accretion in deteriorating marshes.
- Average nitrogen loadings will decline to nearly one-half of those experienced toward the end of the 20th century, approaching levels not seen since the 1950s. This decline will result in approximately proportional reductions in plankton productivity and substantial reductions in the extent of hypoxia, again back to levels typical of the 1950s. Significant anoxia will occur only during flood years.
- Practical applications of a zero-discharge ethic in industry, government, and society in general will lead to dramatically reduced loadings of many contaminants. Nevertheless, localized toxic effects will occur despite our best efforts to manage inputs of legacy contaminants and contaminated sediments, as well as our continuing reliance on herbicides in agriculture.
- Submerged aquatic vegetation beds will expand in extent some four- or five-fold.
- Primary production will decrease by one-third, but production of many fish and crabs will actually increase due to greater food efficiency.
- The Bay's useful production, diversity, and resilience will improve even more, approximating conditions characteristic of the 1950s.
- The living resources of the Chesapeake will provide more sustained and profitable benefits to society from the improved health of the Bay.

Endnotes

[1]Current Objectives include many of the concrete objectives in a series of Bay agreements, including *Chesapeake 2000*. This scenario is not, however, identical to those agreements, since much of their language is essentially goal oriented (such as "a toxics-free Bay") and not easily quantifiable for use in this exercise.

# Imagining the Chesapeake

The kind of Bay our children inherit will depend on the choices we make at the dawn of this new century. Already, the projections are sobering. Over 300 people move into the Chesapeake watershed every day, with a projected population of some 19 million by the year 2030. More people will spread out from Norfolk, from Richmond, from Baltimore, from Harrisburg and Philadelphia.

The choices of the 20th century have proven complicated. Many citizens of the Bay region enjoy a standard of living unimagined by their forebears—a life filled with automobiles, refrigerators, CD players, and arguably, the best health care in the world. And yet progress has been uneven and has come at a price. Maryland, for example, has one of the highest cancer rates in the country. The Washington Metropolitan region consistently exceeds ozone standards many times each summer. Watermen throughout the region often seek alternative work, unable to make ends meet by working the Bay. Restaurants and picking houses that once relied on the Bay's blue crab now look elsewhere to meet the demands of a growing population.

*The kind of Bay our children inherit will depend on the choices we make at the dawn of this new century. Already the projections are sobering.*

Although, in the words of the ancient Greek historian Heraclitus, "nothing endures but change," changes now persist at an unsustainable pace—and many of the significant changes in the Chesapeake have resulted from human behaviors and human choices. As we ponder the Bay's future, we must necessarily examine the courses we might follow in the approaching years. What choices do we face for the coming decades? What implications do these choices have for the future Bay?

This report lays out three scenarios for possible Chesapeake futures. The first scenario assumes that we maintain, more-or-less, the status quo, and that current trends prevail. The second scenario assumes that we work hard to meet the objectives already set for ourselves, such as the cap of nutrient inputs to the Bay and the restoration of abundant underwater grasses and oyster bars. The third scenario explores the potential of feasible technologies and management strategies—and considerable political will—to envision what sorts of positive changes are within our reach.

Each scenario carries a promise and a price. In some cases, the cost hits our collective pocketbook. In

*Tim McCabe, USDA NRCS*

other cases, the cost diminishes the Bay's ecosystem—its spawning grounds, oyster rocks, or underwater grass beds. On land, the choices that underlie each scenario affect not only the amounts of runoff that reach the Bay's rivers and streams, but also the kinds of communities we will live in, the connections we will maintain—or lose—with the natural world around us, the quality of life we will enjoy, and perhaps even the attitudes and the values to which we will hold.

Courtesy of VDOT

***Upon completion, this interchange, where routes 95, I-395, and I-495 join in Springfield, Virginia, will look like this enhanced photograph.***

## The State of the Bay

Our sense of the present shapes our perceptions of the future. While *Chesapeake Futures* focuses on the first three decades of the 21st century, a brief summary of our starting point, roughly timed to the year 2000,[1] provides a foundation on which to base likely scenarios. More explicit discussions for each topic area—development, agriculture, forest management, technological change, and the Bay itself—appear in chapters 5 to 9.

Since the Bay is admittedly in constant flux, any snapshot has its limitations. In the broadest terms, however, we can make the following observations about the Bay and its watershed as a whole at the time of this writing, our "present":

- Population continues to grow in the region, with an average of 334 new people moving into the Chesapeake watershed each day.[2]
- Between 1990 and 2000, the rate of land conversion in the watershed more than doubled over the previous decade. Development in many areas of the watershed, especially within commuting distance of large urban centers, is converting large tracts of farm and forest to residential subdivisions and shopping centers, with adverse effects on water quality.
- The Bay continues to receive large amounts of nutrients, especially nitrogen and phosphorus. These nutrient loads come from many sources, including agricultural lands, point sources (such as waste treatment plants), urban areas, and the atmosphere.
- The Bay also receives large quantities of sediment from agricultural lands, eroding shorelines, and urban/suburban areas.
- Hypoxic waters continue to plague portions of the Bay despite efforts to control the overabundance of nutrients that fuels oxygen consumption. In fact, these low-oxygen areas have apparently continued to expand over the past several decades.[3]
- Forests across the watershed as a whole have rebounded from their historical low in about 1900, but forests in key areas close to the Bay and its rivers have become increasingly fragmented.
- Only about 35 percent of the Bay's agricultural lands are currently under nutrient management for water quality protection.[4]
- Riparian buffer restoration efforts continue on a local level, but have encountered some resistance on agricultural property and other privately owned lands.
- Many waste treatment plants still do not use advanced nutrient removal technologies. The Chesapeake Bay Program predicts, however, that by 2005 almost 131 major municipal wastewater

treatment facilities will have biological nutrient removal treating about 63 percent of the wastewater flow in the region.[5]

- Crab stocks continue below the long-term average, according to independent surveys, including the baywide winter dredge survey.
- Oyster harvests continue at historically low levels and oyster populations cover only a fraction of their original range, despite the launching of new oyster reef restoration efforts.
- Striped bass numbers have rebounded since the five-year fishing moratorium ended in the late 1980s, although concerns have emerged about mycobacteriosis and other diseases along with the adequacy of forage species to support the larger population.
- Scientists and managers are analyzing and outlining new multi-species approaches to fisheries management, though current management techniques are primarily species-specific and often reactive rather than proactive, with little power-sharing among stakeholders.
- Recent fish consumption advisories have pointed to the continued presence of toxic contaminants in the Bay, although the advisories themselves have evolved based on changes in federally mandated thresholds for contaminants in food.

## Can We Imagine?

Can we fast forward our minds to imagine the Chesapeake Bay and the vast area that surrounds it in the year 2030?

Do we envision a Bay with dwindling underwater grasses, a Bay with few crabs and fewer oysters?

Do we picture bayside restaurants on the shores of the Patuxent, the Potomac, the Choptank, or the James, where the menu offers seafood mostly from North Carolina, or Louisiana, or Asia?

Can we imagine what changes—both large and small—will come to pass in the Chesapeake watershed?

Will we see a landscape devoid of family farms—a landscape that in some areas stretches toward the horizon in an unbroken maze of subdivisions and shopping centers?

Can we imagine that by the year 2030, highways in the Baltimore-Washington corridor will likely carry an unprecedented number of cars and trucks?

When we peer into the future, do we picture a watershed where runoff from highways, homes, storm drains, and parking lots continues to flush toxic sediments into the waters of the Chesapeake Bay?

Or will our commitment to restore the Chesapeake, combined with ongoing technological advancements, allow us to imagine a different landscape, a different Bay?

Can we envision a landscape in which small towns dot the countryside, separated by forests and fields—a landscape where sustainable farming practices still make sense, ecologically, and economically?

Can we picture streams and rivers lined with native trees and plants carrying waters that run clean from upland woods and hamlets to the Bay?

Can we imagine a Bay where underwater grasses sway in filtered sunlight ten feet beneath the surface and host an a healthy diversity of Bay life?

And, can we imagine large but sustainable harvests of crabs, and fish, and oysters pulled from those clear waters?

Given the enormous demands on our energies and our financial resources, along with conflicting political agendas and differing visions for the future, can we imagine in the end a Chesapeake Bay that will sustain a variety and an abundance of life as we move into and through the 21st century? Can the Bay be returned, at least in part, to what it once was not so very long ago?

## A Vision for the Bay

What Bay country will look like in the future depends on more than mathematical calculations. We must think about what wise stewardship will mean for the future. What do we want Bay country to be?

***Stewardship:*** not taking more than our share. Clearly the Chesapeake of the future will be an impoverished place if we take from it more than nature can replace. This means that fisheries—both commercial and recreational—will need to be mindful of limits, of taking care. It means that boaters and others who use the Bay must be more aware of the impacts caused by their use of the estuary, more careful of their wakes, their exhaust, their noise, their speed, and their discharge of waste or chemical contaminants.

***Sense of scale:*** the right things in the right place. When a giant discount store moves into a small community, it brings cheaper prices. But it can also drive out local businesses and change the community's character. We will need to be sensitive to an appropriate sense of scale. Wide roads, wide sidewalks, towering streetlights, huge stores—while these have become the hallmarks of many beltway communities, they are not necessarily appropriate for the small towns and villages that dot the Chesapeake watershed.

***Sense of place:*** buildings and communities that belong. As Bay Country grows and changes, will we be able to preserve the features that define this region as a very special place? Will we remember enough of our heritage to protect the styles of architecture, the boat designs, the rural character of our Bayside towns? Will we be able to avoid the homogenization of the American landscape and maintain a real sense of place without succumbing to a superficial gentrification?

***Matching form and function:*** making the useful beautiful. As we build retention ponds and plant riparian buffers, can we make them pleasing to the eye and inviting as habitat for birds and other species? Must retention ponds be ringed by chainlink fence? Must urban watercourses all be concrete? Can bridges, overpasses, retention walls, culverts, and streetlights be more attractive and integrated into the landscape? Must the future be one of billboards, utility poles, glaring streetlights, hard curbs, and gutters? As we slow the flow of polluted runoff, can we encourage grass swales and rain gardens that will add to our sense of nature and place?

***Cultivating a new ethic:*** the enlightened citizen. Key laws, such as the Critical Area Act or the Chesapeake Bay Preservation Act, have helped control destructive development practices at the water's edge. But legislation cannot and should not guide all our behaviors and decisions. How can we instill a new ethic, so that the future Chesapeake retains the beauty and productivity that have made it famous? How can we teach our children to treasure the landscape, that their behavior ultimately determines the health of the Bay?

The "Recent Trends" scenario detailed throughout the report is based on these and other current conditions. Projections for this scenario are tied to the assumption that these recent trends will continue into the future, without additional progress in restoring the Bay ecosystem.

The "Current Objectives" scenario, on the other hand, is based on commitments by Bay-area jurisdictions in a series of Bay agreements, beginning with the first and very general agreement of 1983, to the more specific benchmarks set in 1987, to the ambitious *Chesapeake 2000* agreement. Virginia, Maryland and Pennsylvania, the District of Columbia, the Chesapeake Bay Commission and the U.S. Environmental Protection Agency, representing the federal government, are the signatories of these agreements. This report is not intended to critique these commitments; rather, it presents likely outcomes based on the best extrapolations at hand if the quantifiable objectives embedded in the commitments are met largely as stated.

Naturally, the Chesapeake Bay Program, which carries primary responsibility for fulfilling these commitments, has its own measures and metrics for success. Most notable among these are an extensive monitoring effort and intensive use of computer models. While cognizant of the watershed model, *Chesapeake Futures* incorporated a range of data and experience and did not rely solely on any one metric or model.[6]

Current objectives, as stated in the *Chesapeake 2000* agreement, are commendable, but with continued population growth and a range of problems confronting the Bay, the question arises of what the estuary and its watershed will look like in the future. What kind of water quality can we expect if we meet current commitments? Or if we do not? What if we adapt, during the next several decades, new technologies and approaches for the restoration of the Bay leading to a series of "Feasible Alternatives"? These fundamental questions have led to an effort which details three "what if" scenarios—aimed at the year 2030.

## The Chesapeake Futures Project: What We Did and Why We Did It

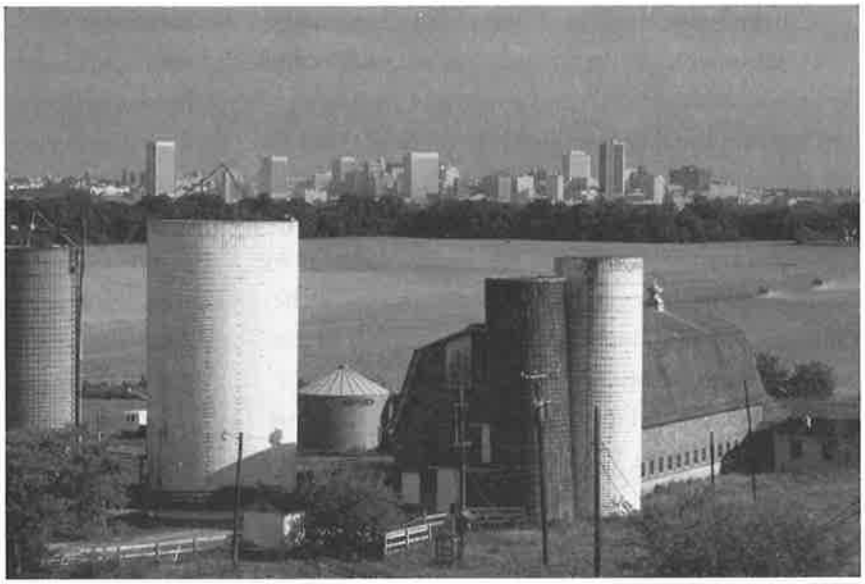
Faced with questions about destructive land use patterns and the decline of water quality in the Chesapeake Bay, the Chesapeake Bay Program and its Scientific and Technical Advisory Committee (STAC) began to ask hard questions about the future. What information did we have that would guide better decision-making? What consequences could we expect if we did not act? The effort to answer these questions, dubbed *Chesapeake Futures*, provides a factual overview, from our turn-of-the-century vantage point, for those with an interest in the future and well-being of the Bay and its watershed. This multi-year effort has incorporated much work and research that have also found outlets in other reports and information documents, including the *Chesapeake 2000* agreement.

*Chesapeake Futures* is not intended as an advocacy document, nor is it meant to bolster a particular program or political position. Rather, it sets out three possible scenarios, based on the observations, analyses, experiences, and reasoned extrapolations of a wide-ranging team of experts from throughout the Bay region and beyond. These experts come primarily from the academic laboratories and departments of research universities in the Mid-Atlantic, but also from state agencies, privately funded research labs, and other experienced consultants and technical experts.

Sandy Rodgers, MD Sea Grant

Many of these experts have brought experience and knowledge from other regions of the country. Many share years of experience living and working on the shores of the Chesapeake Bay. All of them generously volunteered their time to help assemble this report.

This report focuses on three major areas: changes in the land, technologies, and the Chesapeake estuary itself. We have arranged the report as a progression, starting with the caveats and pitfalls plaguing predictions of the future, moving on to the Bay's history, continuing with its current condition given the framework of worldwide climatic change and sea level rise, and then taking steps into its possible futures. Naturally, even armed with a good understanding of the Chesapeake's past, the most current knowledge of its dynamics and present condition, and high-quality data on which to extrapolate, the Chesapeake's future still hinges on some unknowable factors. Given these limitations, we cover an array of possibilities ranging from projections based on recent trends to optimal yet feasible management options.



Tim McCabe. USDA NRCS

***Operational farm on the outskirts of Richmond, Virginia. Cities and suburbs are encroaching on such farms throughout the Chesapeake Bay watershed, and many have succumbed to development pressure.***

With the pace of technological and social change appearing to quicken with each passing year, predicting the region's character in 30 years seems a daunting exercise. We can, however, make reasonable trend projections in areas such as population growth, development methods, and agricultural practices to get a sense of the future's possibilities. Chapter 2, Risky Business, discusses the practices and pitfalls of predicting the future while suggesting the ways in which current information and data are useful for outlining three Chesapeake futures based on the choices we, as a society, ultimately make.

Applying the premise that the past holds the key to the future, Chesapeake Pasts takes a brief look back at the natural dynamics and cultural history that shaped the region. Understanding where we have come from should help us appreciate where we are going. The natural fluctuations that once dictated the structure of the Bay have given way, to a large degree, to the numerous and increasingly widespread anthropogenic factors that now play such a major role in every aspect of Bay dynamics. The chapter concludes with a comparison of the Chesapeakes of the past with the one of the present.

Changing Times paints a broad-brush picture of the ever-shifting Bay, its watershed, and its growing population. The backdrop upon which we paint the Bay and its three possible futures is, itself, ever-changing. Climate varies on many temporal and spatial scales—some of which affect the Bay directly while others have minor or indirect consequences. Sea level is rising in many places around the globe, including the Chesapeake. The effect of consistently rising sea levels is manifested through the erosion of shoreline, the disappearance of islands, greater landward incursion of stormwaters, and the influx of higher sediment loads. Other, less obvious effects, are also taking place. Finally, the chapter introduces the concept of population and its ultimate impact on the state of the Bay.

Development and Sprawl delves into the consequences of centuries of development along the Bay and within its watershed. Clearly, the way we continue to develop the land will have enormous consequences for both the health of the Bay watershed and the quality of life that Bay-area residents will enjoy, or alternatively, suffer through. In addition to development patterns that influence how we assemble our homes, businesses, and industries, large-scale uses of the land—such as forests and agriculture—determine exactly what the watershed looks like on a vast scale. After all, agriculture alone accounted for close to a third of land use in the watershed in 1990 in terms of actual area, and forestry accounted for 59 percent—a total of 92 percent of the watershed's 41 million acres of land. This pattern has, of course, been shifting with burgeoning development and the breakup of large parcels of farm and forest.

Chapter 6, Forests in Transition, deals with why forests make a difference, their environmental impact, and their economic benefits. Forests are the dominant land use in the Bay watershed, followed by agriculture and other open land. Yet, in many areas forests are disappearing at an alarming rate. In a watershed where more forest cover means better water quality, changes in forest cover are crucial.

Adapting Agriculture examines the current status of Chesapeake agriculture. As markets for both forest products and agricultural products become increasingly global, forces far beyond the boundaries of the Bay watershed are often setting cost and price structures. Without sound economics and financial incentives, forests and agriculture as we know them cannot continue to exist. Changes in these sectors will have significant consequences for land use in the Bay region.

New technologies carry not only the promise of solving specific problems but also of reshaping how we approach the future. Technological Solutions details some of the possibilities and feasible alternatives to current tools and methods. Clearly, it would have been difficult to predict in 1970 just how important computers would become in our daily lives only 30 years later. What new technical tools will we rely upon in the year 2030 and how might they influence the environmental character of the Bay?

The streams and rivers that feed the Chesapeake Bay—and the Bay itself—will reflect the way we use these new technological tools and the way we choose to live on and use the land. To picture the physical Chesapeake of the future, we must first understand its shifting hydrodynamics from both natural and anthropogenic changes. Likewise, researchers and others pondered potential changes in the Bay's chemical characteristics driven by physical and climatic factors but also by human behaviors in the watershed. On the receiving end of all of the changes in the land and shifts in development, agriculture, and forestry, lies the Bay itself and its remarkable food web. Integrating all this information, Chapter 9, Once and Future Bay, deals with future estuarine conditions by examining the array of components that make the Bay what it is: its physical characteristics, toxic contamination, trophic status, and finally the life in the Bay itself.


Skip Brown

In each of chapters 6, 7, 8, and 9, we lay out the scenarios for each of the major topical areas for the three Chesapeake futures: Recent Trends; Current Objectives; and Feasible Alternatives. Necessarily, discussions in each of these chapters overlap or closely relate to those in the other chapters as all the individual fibers that make up the Chesapeake closely intertwine.

Chapter 10 closes the report with the choices that face us—choices that are far more than rhetorical. By summarizing the choices that the scenarios offer, readers can assess where and how financial resources and social programs should be focused—and the likely success of our efforts. Limited achievements to date underscore the possibilities of and the need for using a range of innovative and creative techniques to reach the fundamental goal of restoring the Bay's clarity and productivity.

As one researcher said, "The estuary bats last." Whatever impacts we have on the landscape and the many streams and rivers draining it will likely show up in the organisms that live in the Chesapeake Bay. The oysters, crabs, finfish, and other denizens of the Bay will send us signals about how the ecosystem itself is faring—the ecosystem on which all life, including *Homo sapiens*, depends. The haunting question is whether or not we are able to read the signs, and if we can, whether or not we have the wisdom and the will to act.

## Endnotes

[1] For a summary of what is perceived to be the current condition of the Chesapeake Bay, see the Chesapeake Bay Program's State of the Bay report for any given year, available on the web at *www.chesapeakebay.net*. The Chesapeake Bay Foundation also offers an annual report card on the Bay at *www.savethebay.org*. Of course the Bay is a very complex system, and any simple characterization cannot capture either all available data or all the subtle nuances of an estuary in constant flux.

[2] Chesapeake Bay Program. 1997. *Beyond Sprawl: Land Management Techniques to Protect the Chesapeake Bay: A Handbook for Local Governments*. Annapolis, MD.

[3] Cf. Hagy, J.D. 2002. *Eutrophication, Hypoxia, and Trophic Transfer Efficiency in Chesapeake Bay*. Ph.D. Thesis, University of Maryland, College Park, MD. 446 pp. See also D.E. Smith, M. Leffler, and G. Mackiernan, (eds.). 1992. *Oxygen Dynamics in the Chesapeake Bay*. College Park, MD: Maryland Sea Grant, 234 pp.

[4] Chesapeake Bay Commission. 2001. *Annual Report 2001*. Annapolis, MD: Chesapeake Bay Commission, 31 pp.

[5] Delaware, New York, and West Virginia have signed memoranda of understandings and the Chesapeake Bay Program now includes these states (in addition to data from facilities in Maryland, Pennsylvania, Virginia, and Washington, D.C.) in its calculations.

[6] Chapter 9 contains comparisons of *Chesapeake Futures* scenarios with projections from the Phase 4.3 Chesapeake Bay Program model for tiers 1, 2, and 3.

# Risky Business

Looking three decades down the road is indeed a risky business. Not only are our technical capabilities changing rapidly, but so are our policies, our plans, and our political and personal choices. The degree to which protecting the Chesapeake Bay will figure as a central issue in the year 2030 remains unknown, as do so many other factors.

Clearly, as the 20th century closed and the 21st century began, the Chesapeake Bay had become the focus of a rallying call for concern about a range of environmental issues and the impetus for many new and innovative programs to protect and restore the watershed. While initial efforts generally focused on direct inputs to the Bay and its rivers, including more rigorous enforcement of effluent controls under the federal Clean Water Act,[1] the emphasis has shifted over time to include general sources of nutrients and contaminants. Lying behind these inputs remains the difficult-to-address fact of ever-increasing population in the region.

Population numbers in the Bay watershed climbed from about 5 million in 1900 to approximately 8 million in 1950 and over 15 million in 2000. Based on projections, planners expect this number to rise to nearly 19 million by 2030 (Figure 2-1). The greatest concern, as will become clear in this report, is the manner in which the growing population will use the region's resources and impact its ecological systems—especially the Chesapeake Bay. Unquestionably, the issue of just how many people can live in the watershed without straining its carrying capacity will continue to challenge the best thinking of demographers, ecologists, and policymakers. In this report, the focus falls on likely scenarios of environmental impact based on current population projections. Some would suggest that we will actually have to limit the size of the population, but we leave that for another analysis—we merely address the implications of its growth.

If there is any ecosystem for which researchers and managers do have the opportunity to determine the balance between human impacts and ecological function, it may well be the Chesapeake Bay. Thanks to considerable support and effort, especially since the 1976 study of the Chesapeake launched by the EPA and the resultant multi-state and federal partnership known as the Chesapeake Bay Program (CBP) in 1983, scientists have accumulated large amounts of hard data. These data—physical, chemical, biological, and sociological—have driven models designed and constructed by both state planners and the Chesapeake Bay Program. The scientific and technical experts involved in the *Chesapeake Futures* project have taken advantage of these models in writing this report, although they have also drawn

*Mary Hollinger, NOAA*

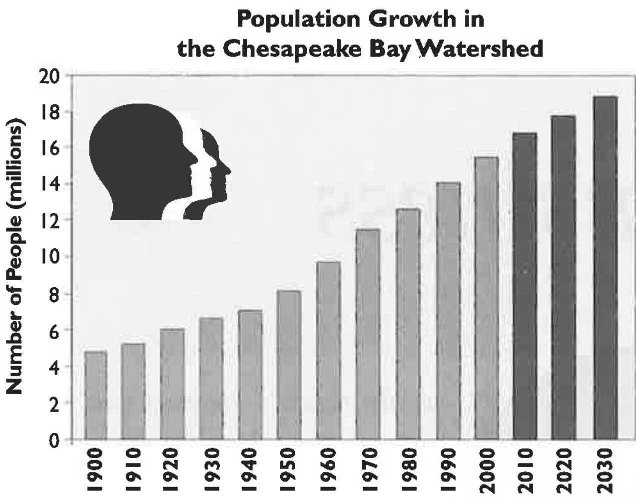



***Figure 2-1. Since the beginning of the last century, population levels have shown a steady increase in the Bay watershed. Experts predict that numbers will continue to rise through the next three decades.***

on other information, including the results of their own data gathering and research. Of particular use were the Bay Program models and data generated by the 2000 census. The population projections used in the U.S. National Assessment of the Consequences of Climate Variability and Change and its Mid-Atlantic Regional Assessment also proved quite useful.

Lying behind the *Chesapeake Futures* effort are other future-oriented reports, such as the study of growth and development known as the 2020 report.[2] That report, written in 1988 and also looking ahead approximately 30 years, depicts a series of visions prescribing an outline for how the Bay watershed *should* look by the time we reach the second decade of the 21st century. *Chesapeake Futures*, while mindful of such observations, is less prescriptive. Rather than a prediction of—or template for—a desirable future, *Chesapeake Futures* examines the evidence at hand and, using all the information and data now available, extrapolates to three different scenarios that describe three possible futures.

The *Futures* approach resembles very closely that of Allen Hammond in his study, *Which World?*, in which he offers three possible futures: Market World, Fortress World, and Transformed World.[3] In Hammond's first scenario, market forces largely run unchecked, creating considerable wealth for some, but abject poverty for others. This scenario presents not the worst of worlds, but far from the best. Of considerable concern is that widening divisions between the very wealthy and the very poor, the haves and have-nots, could well lead to the second scenario, he argues, in which wealthy nations and enclaves become like fortresses, walling out those less fortunate. This second scenario results in several frightening images of a world wracked by the worst kind of social tension, inequities, and violence. Hammond's third scenario, a transformed world, pictures a future in which progressive and intelligent policies have taken advantage of the positive aspects of market-driven economies but avoided the pitfalls of increasing concentrations of wealth. Clearly, this last scenario appears most desirable in Hammond's view, but by laying out all three scenarios he gives the reader an opportunity to consider alternatives all along the way. As Hammond points out, "Scenarios are not predictions or forecasts. Rather they suggest how the world might turn out."[4]

## The Purview of Chesapeake Futures

Drawing on the data at hand, *Chesapeake Futures* presents three possible alternatives for the future. Unlike Hammond's *Which World?*, which focuses largely on economic and social issues, *Chesapeake Futures* has ecological concerns as its main focus—specifically the ecological functioning of the Chesapeake Bay and its watershed. Of course, economic, demographic, and other forces can and will impact environmental outcomes; therefore, such factors surface in several sections, including those dealing with development patterns, agriculture, and forestry. After four context-setting introductory chapters, including this one, each of chapters 5 through 9 provides a descriptive background of conditions and trends and offers three likely scenarios:

- ***Recent Trends*** - based on an extrapolation of the status quo.
- ***Current Objectives*** - based on fulfillment of current quantitative objectives.
- ***Feasible Alternatives*** - based on implementing programs to the reasonable limits of technology and political will.

Each chapter defines likely outcomes for each possible future in that particular area, such as growth and development, agriculture, forestry, and new technologies. Because each area impacts the others, the report has built-in redundancies. For example, a discussion of development patterns will include mention of the impact on forested lands; likewise, a discussion of forestry practices will include mention of changing land use patterns, including development. In some sense, all of these areas merge in the important penultimate chapter on future estuarine conditions (Once and Future Bay). Here a combination of driving forces—land use, agricultural patterns and practices, forest fragmentation, and the use of emerging technologies, as well as climatic and geological factors—all blend to shape the future of the Chesapeake Bay itself.

In composing the scenarios that describe the possible Chesapeakes of the future, we worked within the current guiding principles that shape our thinking about how the Bay works and responds to change. In all science, but particularly in speculative science, theoretical constructs are founded within what T.S. Kuhn coined "a paradigm," which is, in essence, a model of reality. More precisely, a paradigm is "a system of facts, theories, and philosophies that is widely accepted and becomes the framework for thinking about a scientific problem."[5] Paradigms shape the way we perceive reality and approach scientific challenges. In the Chesapeake and elsewhere, we make assumptions—both stated and unstated—based on the paradigms that ultimately mold our approach to environmental management.

Assumptions set boundaries on the problem at hand by circumscribing an area of consideration, so that a problem can be dealt with in a

**Recent Trends**

- Agricultural and Rural Zoning: *Generally permissive*
- Growth Centers: *Generally poorly supported*
- Transferable Development Rights (TDRs): *Negligible*
- Environmental & Resource Conservation Requirements: *Variable*
- Permitting Conventional Septic Systems: *Generally permissive*
- Easement Acquisition Programs (EAPs): *Generally ineffective*
- Infill/Redevelopment: *Negligible*
- Point- and Nonpoint-Source Controls: *As in 2000 progress run, Chesapeake Bay Watershed Model*
- Transportation: *Reactive, primarily to existing or anticipated traffic congestion*

**Current Objectives**

- Agricultural and Rural Zoning: *Moderately restrictive*
- Growth Centers: *Moderately supported*
- Transferable Development Rights (TDRs): *Marginal*
- Environmental & Resource Conservation Requirements: *Moderately progressive*
- Permitting Conventional Septic Systems: *Generally permissive*
- Easement Acquisition Programs (EAPs): *Moderately effective*
- Infill/Redevelopment: *Significant*
- Point- and Nonpoint-Source Controls: *As in continuing existing policies (Tier 1) run, Chesapeake Bay Watershed Model*
- Transportation: *Reactive, to both congestion and demand for mass transit*

**Feasible Alternatives**

- Agricultural and Rural Zoning: *Restrictive*
- Growth Centers: *Well-supported*
- Transferable Development Rights (TDRs): *Effective*
- Environmental & Resource Conservation Requirements: *Progressive*
- Permitting Conventional Septic Systems: *Restrictive*
- Easement Acquisition Programs (EAPs): *Significant*
- Infill/Redevelopment: *Significant*
- Point- and Nonpoint-Source Controls: *As in full implemenation of nutrient control efforts (Tier 3) run, Chesapeake Bay Watershed Model*
- Transportation: *Proactive, focused on enhancing communities and cities*

***Table 2-1. General assumptions for land use scenarios. Explanations of tools and approaches listed here appear in Chapter 5.***

scientifically rigorous manner given expected constraints. Such assumptions are necessary and even inevitable, but problems may arise when they are either unacknowledged or not recognized. Key in this process is being aware of, and then stating, the assumptions up front. In most sections, assumptions are discussed as part of each scenario. For example, Table 2-1 summarizes key assumptions used to develop scenarios for land use trends in the watershed.

The assumptions represent the spectrum of development patterns in the Bay basin, accomplished by measuring development in sample jurisdictions throughout the watershed during the last decade, and compiling descriptions of the land use, zoning, subdivision, and development plans and procedures under which they occurred. The assumptions for Recent Trends reflect the practices and associated patterns currently prevailing through most of the watershed. This scenario projects what would happen if these same techniques and practices were occurring everywhere. More progressive practices and development patterns currently employed by some jursidictions are reflected in the Current Objectives and Feasible Alternatives scenarios. The Current Objectives scenario projects the results if moderately progressive techniques used in some jurisdictions were used throughout the watershed. Similarly, Feasible Alternatives extrapolates the results of the most progressive techniques.

Assumptions about nutrient pollution control in the *Chesapeake Futures* scenarios are based on those used in the Chesapeake Bay Program's Watershed Model (Phase 4.3), specifically the 2000 Progress, continuing existing policies, and full implementation runs, respectively, for each of the three scenarios. *Chesapeake Futures*' development loading rates were derived directly from the Watershed Model (Phase 4) by model segment, with the exception of rates for nitrogen loads from septic systems; these assume that about 42 percent of the per capita nitrogen load entering septic drainfields reaches surface waters. Estimation of the changes in loadings from other sources was more generally made, however, by assuming percentage changes in the delivered loadings to the Bay as estimated by Watershed Model loadings for 2000. This approach allows the opportunity to compare potential future conditions using the same baseline (2000,) but with different analytical methods and assumptions concerning source changes—with *Chesapeake Futures* based on generalized scientific understanding and the Chesapeake Bay Program approaches founded on detailed engineering modeling.

Throughout the report, the scenarios appear at the conclusion of each section; any reader eager to "cut to the chase" can find the scenarios listed in the table of contents. Readers will glean a more complete understanding of the issues from reading entire chapters, however, which provide context, background, and explanation. For those interested in pursuing any particular subject further, references and endnotes point the way toward primary sources, synthesis documents, and other valuable resources.

## Other Glimpses at the Future

*Chesapeake Futures* joins a wide-ranging collection of literature that considers the path of the future. Looking ahead can be simultaneously thrilling and disturbing—encompassing a range of possibilities from the great to the tragic. In fact, the whole notion of peering into the future poses an uncomfortable challenge for humankind, especially given the uncertainty of change. According to Eric Hoffer, "no one really likes the new. We are afraid of it."[6] In Hoffer's view, change—especially rapid, radical change—can sow seeds of discontent. "The revolutionary mood and temper," he says, "are generated by the irritations, difficulties, hungers and frustrations inherent in the realization of drastic change."[7]

Many analyses of the future have been frightening. Aldous Huxley's *Brave New World* (1932) and George Orwell's *1984* (1949) painted pictures of a human society shaped by dark, controlling forces with human choice and individual will crushed by rigid hierarchy. As Huxley said of Orwell's work, "In the context of 1948, *1984* seemed dreadfully convincing."[8] Of course, as with most visions, Orwell's imaginings were more instructive than predictive.

Alvin Toffler's *Future Shock* (1970) warned that the rapid pace of change upon us at the end of the 20$^{th}$ century would literally threaten our physical and psychological health. From his vantage point in 1970, he wrote, "In the three short decades between now and the twenty-first century, millions of ordinary, psychologically normal people will face an abrupt collision with the future."[9] According to Toffler, "the roaring current of change…[is] a current so powerful today that it overturns institutions, shifts our values and shrivels our roots."[10]

For Toffler, "The acceleration of time is, itself, an elemental force. This accelerative thrust has personal and psychological, as well as sociological, consequences."[11] His term, "future shock" denotes "the disease of change." It is "a real sickness from which increasingly large numbers already suffer."[12] And, as others have noted as well, Toffler sees that "the *rate* of change has implications quite apart from, and sometimes more important than, the *directions* of change."[13]

Some might argue that Toffler's book, written toward the end of the especially turbulent 1960s, may have overstated the case, or at least missed some of the more positive dimensions of what he called the post-industrial age. On the other hand, others might argue that recent violent clashes of culture may be symptomatic of frictions caused by differing rates of change and reflecting differing beliefs and philosophies. These violent clashes echo the scenarios depicted in *Which World?* in which differing rates of development lead to ever-expanding difficulties.

Interestingly, Toffler's *Future Shock* was written 30 years before the new millennium, while *Chesapeake Futures* looks another 30 years ahead, to 2030. Just how perceptive such future gazing will prove only history can judge, but clearly Toffler understood the perplexity of the challenge, quoting a Chinese proverb that advises: "To prophesy is extremely difficult—especially with respect to the future."[14] Toffler, in fact, warns against actual "prediction," while lamenting "the perishability of fact" in which facts change before one can even publish a study.[15]

There is agreement though that change is occurring at an increasingly rapid pace. Toffler and others could perceive this trend quite clearly as the new millennium approached. In Toffler's words, as the 20$^{th}$ century moves into the 21$^{st}$ century, "all history is catching up with us."[16] He points out, for example, that if there have been some 800 lifetimes (of about 62 years each) in the last 50,000 years, then while a full 650 of those lifetimes were spent in caves, most of the technological breakthroughs that now shape our daily lives were discovered within the last—the 800$^{th}$—lifetime.[17]

Along with technological change has come population growth. In 1850, Toffler notes, "only four cities on the face of the earth had a population of 1,000,000 or more. By 1900 the number had increased to nineteen, but by 1960, there were 141…"[18] In 1970, when Tofflor was writing his book, the annual rate of worldwide population increase hovered just under 2.1 percent. As of 2000, that rate had declined to just over 1.2 percent per year; however, the worldwide population on which the percentage is based was much larger than in the 1970s, having reached 6 billion people by the end of the century.[19]

As population forecaster Paul Ehrlich has noted, birth rates have slowed somewhat since he and Toffler made their original predictions, but Ehrlich maintains that most demographers "think that growth will not end before the population has reached 10 billion or more."[20] Ten billion, he argues, is too many.

According to Ehrlich, "Global warming, acid rain, depletion of the ozone layer, vulnerability to epidemics, and exhaustion of soils and groundwater are all…related to population size."[21] Yet the topic of overpopulation remains a difficult one to discuss, and most groups, including the media, are reticent to address it head on. "One of the toughest things for a population biologist to reconcile," says Ehrlich, "is the contrast between his or her recognition that civilization is in imminent serious jeopardy and the modest level of concern that population issues generate among the public and even among elected officials."[22]

Ehrlich is well aware of the sensitivity of the subject. "To a degree, this failure to put the pieces together is due to a taboo against frank discussion of the population crisis in many quarters, a taboo generated partly by...groups who are afraid that dealing with population issues will produce socially damaging results."[23]

In *The Greening of America*, another book that appeared three decades before the new millennium, Charles Reich gave voice to rising concerns, especially among the young, over public policies that appeared to ignore the looming social and environmental costs of business as usual. "We think of ourselves as an incredibly rich country," Reich wrote, "but we are beginning to realize that we are also a desperately poor country—poor in most of the things that throughout the history of mankind have been cherished as riches."[24]

When Reich looked toward the future, he saw a "green revolution" coming. This change, he said, would depend on a new way of thinking. "It promises a higher reason, a more human community, and a new and liberated individual. Its ultimate creation will be a new and enduring wholeness and beauty—a renewed relationship of man to himself, to other men, to society, to nature, and to the land."[25]

From the perspective of three decades before the new millennium, Toffler and Reich represent somewhat different approaches to the future. For Toffler, rapid change, though bringing great promise, threatens to harm our health and our adaptive capacities if we remain unthinking and unprepared. For Reich, change is not only good, it is imperative. Proceeding down the familiar paths will not take us where we need to go. For Reich, the new generation (the generation now in power) needs to direct the country in innovative decision-making and new approaches. "At the heart of everything" he claims, "is what we shall call a change of consciousness."[26]

*Chesapeake Futures* must finally leave such larger questions about the character and impact of change to the sociologists and other students of the future. At the same time, however, there is no question that changes in an ecosystem—in this case, the Chesapeake Bay—will remain closely linked to cultural changes and choices made by citizens throughout the region about how they live and how they use the watershed's natural resources.

While gazing some 30 years into the future may be a risky business, past problems have made clear that not looking ahead can prove riskier still. One recalls, for example, the warnings of W.K. Brooks at the turn of the last century, when he foresaw the likely destruction of the Bay's oyster reefs and a squandering of our "birthright."[27] At times, looking ahead can help us avoid falling into the environmental traps we unfortunately have set for ourselves. For a common property resource, such as the irreplaceable Chesapeake Bay, we would do well to avoid as many of these traps as possible.

## Endnotes

[1] A famous example is the lawsuit filed by the "downriver" counties along the Patuxent River against the State of Maryland and the U.S. Environmental Protection Agency. They demanded water quality controls on the "upriver" counties, which had been adding large amounts of sewage effluent to the river.

[2] For a brief summary of the 2020 Report, see the Chesapeake Bay Program. 1993. Cost of Providing Government Services to Alternative Residential Patterns. *www.smartgrowth.org/library/CoPGStARP.html*


[3] Hammond, A. 2000. *Which World? Scenarios for the 21st Century: Global Destinies, Regional Choices.* Washington, D.C.: Island Press, 306 pp.

[4] Ibid., p. 13.

[5] Brennan, R.P. 1992. *Dictionary of Scientific Literacy*, New York, NY: John Wiley & Sons, pp. 233–34.

[6] Hoffer, E. *1952. The Ordeal of Change.* New York, NY: Harper & Row, p. 3.

[7] Ibid., p. 5.

[8] Huxley, A. 1958. *Brave New World Revisited.* New York, NY: Harper & Row, p. 3.

[9] Toffler, A. 1970. *Future Shock.* New York, NY: Random House, p. 9.

[10] Ibid., p. 1.

[11] Ibid., pp. 1–2.

[12] Ibid., p. 2.

[13] Ibid., p. 3.

[14] Ibid., p. 4.

[15] Ibid., p. 4.

[16] Ibid., p. 16.

[17] Ibid., p. 13.

[18] Ibid., p. 21.

[19] 2000 U.S. Census. *www.census.gov*

[20] Ehrlich, P. and A. Ehrlich. 1990. *The Population Explosion.* New York, NY: Simon and Schuster, p. 16.

[21] Ibid., p. 17.

[22] Ibid., p. 13.

[23] Ibid., p. 21.

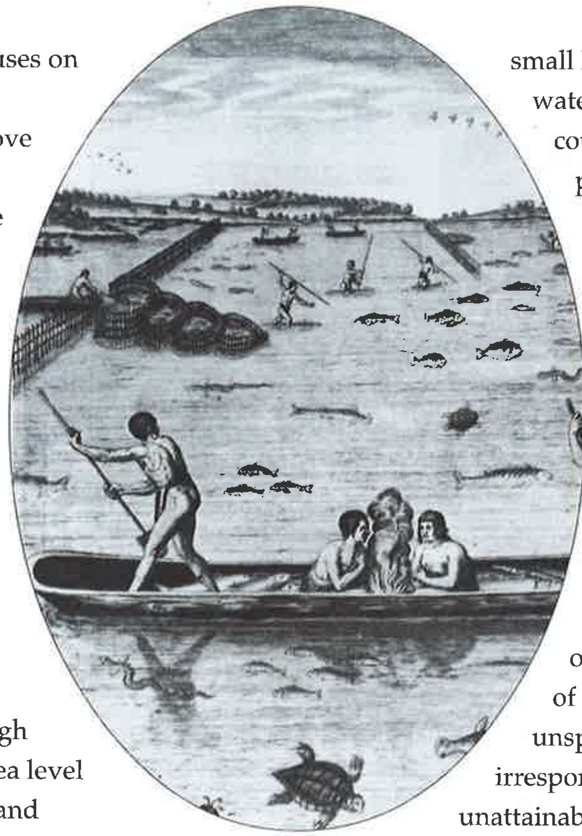
[24] Reich, C.A. 1970. *The Greening of America.* New York, NY: Random House, p. 1.

[25] Ibid., p. 2.

[26] Ibid., p. 3.

[27] Brooks, W.K. 1996. *The Oyster.* Baltimore, Maryland: The Johns Hopkins University Press. Original work published in 1891.

# Chesapeake Pasts



*Chesapeake Futures* focuses on the hard choices that confront us as we move into the 21st century. Before peering three decades into the future and beyond, however, we would do well to cast a brief glance backward to the Chesapeake of the past. We do this for several reasons. First, as the saying goes, those who do not know history are doomed to repeat it. This warning carries special significance due to the way that science has been used—or not used—in past policymaking. Second, although natural forces such as rising sea level and climate change (regional and planetary) constantly shape the Chesapeake, humans have also affected the Bay biologically, chemically, and physically over many centuries.[1] We cannot easily envision the potential scope of such anthropogenic changes without some sense of what they have meant for the Bay over time. And third, by tracking the progress in Bay management—which is considerable—we can better position ourselves for making the best-informed management decisions for the future.

## The Ideal and the Real

How the Chesapeake of the past appears to us will depend on when and where we look. One popular vision pictures a pre-Colonial shoreline swathed in dense forests, occasionally dotted with small Indian settlements, and its waters so thick with life that one could scoop fish with a frying pan.[2] Recent scholars have helped dispel the notion of an entirely untouched landscape. Well before Europeans arrived, native inhabitants used fire to clear underbrush for hunting, and worked the land for living space and agriculture—especially corn.[3]

As Mary K. Blair has observed, clinging to a vision of the early Chesapeake as an unspoiled Garden of Eden is irresponsible; it perpetuates an unattainable fantasy and creates an unrealistic baseline in both our perceptions and our restoration goals.[4] With this admonition against an Utopian ideal, we can generally characterize the estuary prior to European settlement.

Despite changes in long-term climate and other environmental variables (see Changing Times chapter), the Chesapeake had evolved into a remarkable ecosystem when John Smith encountered the height of the Algonquin culture in the early 1600s. What Smith didn't realize is that the Bay he found so hospitable had been created by the melting of huge glaciers. After reaching its maximum around 18,000 years ago, the Pleistocene ice sheet that covered the northern United States and Canada began to melt and retreat, raising worldwide ocean levels and steadily flooding the continental shelf. During the

*Engraving by DeBray from John White*

## Down the Rolling Road: King Tobacco

Sandy Rodgers, MD Sea Grant

Smoked by indigenous peoples, the leafy plant we call tobacco quickly became integral to the economies of the southern English colonies and to the development of Chesapeake Bay country. Early settlers built plantations along the Bay's protected and easily navigated rivers, with the sea serving as the major highway to the rest of the world. Here colonists raised crops either brought from England or adapted from Native Americans. For cash, however, they needed a major export product. That product was tobacco.

Introduced to Sir Walter Raleigh by the Spanish in the late 1500s and promoted by colonist John Rolfe beginning in 1611, tobacco swiftly took root in the leafy soils surrounding the Bay. It also took hold in the markets of the Old World, hailed by many doctors as a cure-all, a *herba panacea*, or even a *herba santa*, something close to divine. Colonists flocked to the New World to grow "sot weed," the new cash crop, and bought up land along the major rivers.[8]

The farming system that resulted had a clear effect on the development of land surrounding the Bay. Historians have noted that more than 90 percent of known 17th-century Maryland sites are located on or near soils conducive to tobacco farming. Getting the tobacco to market usually meant rolling large barrels or hogsheads down a "rolling road" to a pier. It's not surprising, therefore, that 17th-century home sites in Virginia and Maryland were located at a median distance of about 600 feet from the modern shoreline.[9]

Although English authorities encouraged the development of towns, the colonists largely disseminated onto land-hungry farms—especially tobacco farms. "Tobacco culture . . . dictated dispersed settlement."[10] That far-flung settlement pattern, which required the clearing of huge amounts of land, not only to grow tobacco and corn, but to allow exhausted fields to lie fallow for as long as 20 years, set the tone for early land use in the region.

Tobacco brought wealth to the new colony and shaped a way of life in Bay country. It also left an environmental legacy of depleted soils and sediment flushed into Chesapeake waterways. Perhaps the ultimate irony is that tobacco, once hailed as a cure-all, has turned out to cause serious disease. Despite its dark legacy, tobacco will forever be entwined in the history of Chesapeake pasts.

last 10,000 years or so, the Susquehanna River valley flooded in earnest. The drowned valley developed into the estuary we recognize today, providing rich habitat for many marine and estuarine species.

We have known for some time that long-lived, slow-growing species such as sturgeon once flourished in the Bay. Recent estimates suggest that the early Bay, like other coastal waters, not only supported a wide range of species, but that these fish, oysters, and other sea life reached sizes much larger than the same species in modern times.[5] Also well documented are the massive oyster reefs that fringed the pre-Colonial Bay—tall enough to break the water's surface and create navigational hazards.[6] In these ways, the water body we see today is a diminished Bay, with the size and plentitude of many species significantly reduced. As one Bay expert has commented, "Never again would the modern Chesapeake Bay be as grand as that moment. It must have been a magnificent sight."[7]

### Changes in the Land and Water

Although the Bay's pre-Colonial landscape was certainly not Eden, it was largely forested. Changes wrought by native inhabitants paled in comparison to the tree-clearing techniques of European settlers who not only grew food crops but also the major cash crop of the day—tobacco. Researchers who have studied the sediment record, most notably Grace Brush of Johns Hopkins University, have clearly documented changes in pollen types and sedimentation rates that signal the early clearing of the land near the Chesapeake Bay (Figure 3-1).

One obvious dividing line between the Chesapeake of the distant (pre-Colonial) past and the Chesapeake of the American historical past is this layer of sediment that marks the first major clearing of old-growth forests in the watershed. Increased sedimentation had specific and profound effects on the estuary, smothering oyster bars, silting in harbors, and changing the ecology of the benthos (bottom organisms) of the Bay. Chapter 9 discusses these changes along with prospects for the future, including shoreline erosion, the filling and dredging of channels, and the physical dynamics of the Bay.

In addition to sediment problems, growing settlement in the watershed led to another more pressing problem: the disposal of human wastes. The Chesapeake and its tributaries became receptacles for this waste, perhaps inadvertently at first, but also quite intentionally later. Court rulings made it clear that, despite damage to fisheries and oyster beds, receiving raw sewage was a legitimate function of the Bay. According to the Supreme Court of Appeals of Virginia in 1916, "The sea is the natural outlet for all the impurities flowing from the land . . ."[11] Two years later, it reaffirmed this view by citing the "ancient right of the riparian owners to drain the harmful refuse of the land into the sea, which is the sewer provided therefore by nature. . ."[12] Justice Oliver Wendell Holmes, in a 1919 opinion, demonstrated that the U.S. Supreme Court also agreed with the notion of the sea as natural sewer: "The ocean hitherto has been treated as open to the discharge of sewage from the cities upon its shores." [13]

The raw sewage that drained into the Bay caused serious health problems. During the late 19th century, several outbreaks of typhoid linked to tainted oysters caused great concern for human health and the seafood industry. Then, toward the end of 1924, a major typhoid outbreak in Chicago, New York, and Washington, D.C. resulted in 1,500 cases of the disease and 150 deaths. Most cases were traced to contaminated oysters.[14]

## The Core of Time

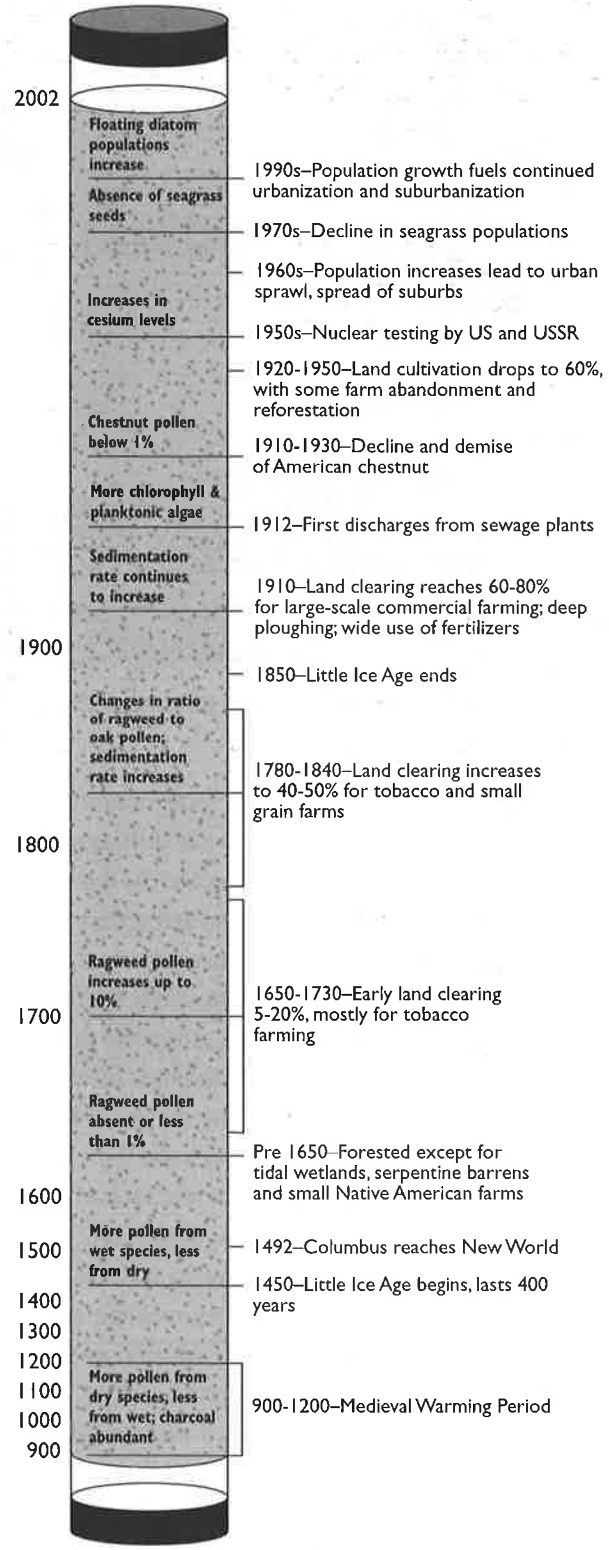



***Figure 3-1. Grace Brush has mastered the art of reading the Bay's history through the pollen record. Shifts in pollen abundance indicate changes in the land around the Bay (courtesy of Maryland Sea Grant).***

***Detail of City Hall ruins after the Baltimore fire of 1904 (reprinted with permission from the Maryland Historical Society).***

In many ways, modern waste treatment in the Chesapeake region owes much to the influence of the watermen and packers who depended on the seafood industry. While Virginia oystermen struggled with contrary court decisions, the political clout of Maryland's bayside districts, particularly on the Eastern Shore, made itself known when the time came for Baltimore to rethink its disposal of waste.

A prime opportunity came after the great Baltimore fire of 1904, which literally cleared the way for the sewer system that Baltimore sorely lacked. The obvious outfall for the new system was direct discharge into the Chesapeake Bay; in fact, the members of a Baltimore sewage commission made such a recommendation.[15] The city needed authorization to float bonds to raise the needed capital, however, and for this they required the approval of the Maryland General Assembly. The legislature gave its blessing, but under the guidance of shoreside delegates sensitive to the oyster industry, it stipulated no direct discharge into the Chesapeake Bay. This caveat led to Baltimore's pledge to carefully process the waste and to the building of the Back River sewage treatment plant from 1911 to 1912, regarded by many at the time as the most sophisticated such system in the world.

The early Chesapeake moved from a largely forested watershed, to an agrarian landscape cleared for farming tobacco and other crops, to a region dotted with growing urban centers. Most of these centers remained quite small—Colonial capitals such as 18th-century Williamsburg and Annapolis housed fewer than 2000 residents each.[16] Even Richmond, unincorporated until 1805, was only 8,000 strong by 1820. Unlike the others, Baltimore surged ahead, reaching a population of 62,000 within the first two decades of the nineteenth century.[17] In the southern Bay, Norfolk emerged as the most prominent port and became a principal destination for timber, particularly from the James River region.[18] Norfolk, Portsmouth, Hampton, and Newport News together soon formed a major population center, with rapid population growth following World War II.

## The Rediscovery of the Chesapeake

Despite the growth of the urban centers, many stretches of Chesapeake country remained sparsely populated and, in a sense, "forgotten" by mainstream America as the country moved into the 20th century. Like today in some remote areas of the Eastern Shore or at the ends of long, low peninsulas in the southern Bay, the landscape remained dotted with small farms. In some instances, these lands became increasingly forested when farm fields turned fallow. The pace of life was slow. In these outlying areas, impacts on Bay water quality, except from sedimentation due to broken-soil plowing, were generally light.

During the early part of the 20th century, the remote peacefulness of long stretches of Bay countryside moved Swepson Earle to call for a rediscovery of the Chesapeake. In a preface to the 1923 edition of his classic tour of the Bay region entitled *The Chesapeake Bay Country*, he wrote, "I think it very desirable that the attention of present and future generations be called to the thousands of acres of fertile lands with picturesque building sites awaiting the coming of those who wish to find homes in this delightful part of our country."[19]

Summoning large numbers of people to build in Bay country these days has become the purview of real estate brokers, but if author Swepson Earle was calling in earnest for people to build by the Bay, his call was clearly heard. In the York River basin in Virginia, annual residential building permits issued jumped from 4,184 in 1990 to 4,981 in 2000—a rise of almost 20 percent within the decade.[20] Similarly, in a recent year in Maryland, developers and others submitted some 700 shoreline projects with nearly half of these in Anne Arundel County, the site of Annapolis as well as many navigable rivers and creeks.[21]

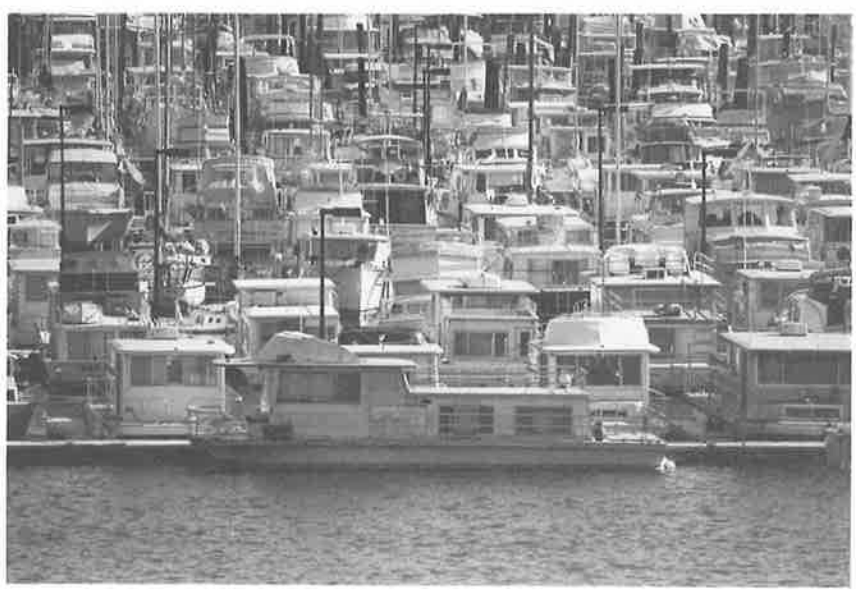
## Differences In Chesapeakes Past and Present

With this brief description as background, we consider several specific factors that have changed significantly since the early days of the Chesapeake. Many of these will be taken up in considerable detail later in the report.

**Demographics**

Without question, a fundamental and considerable difference between the Chesapeake of the past and the Chesapeake of today is the change in population—not only the large increase in the number of people living in the watershed but also where and how they live. By tracking population growth in Maryland, beginning with the late 18th century, the magnitude of this change becomes apparent. In 1800, approximately half a million people lived in the Free State. By 1900, that number had reached about 1.5 million. By 1950, the population had climbed closer to 2.5 million, reaching over 5 million by the year 2000. The vast majority of this growth occurred during the 20th century—largely due to immigration from other parts of the country and the world.

Changing demographics have had distinct impacts on the Chesapeake Bay, but they have also affected political and cultural changes as well. The case of the 1904 Back River sewage treatment plant, for example, reminds us that the influence of the seafood industry—especially the oyster industry—in local politics was considerable in Bay country at that time. Even accounting for the plummeting value of oysters, it is unlikely that such an influence would be played out in quite the same way now, given the huge population shift (and therefore shift in representation) to the suburban counties of the western shore. With the population in the Chesapeake watershed expected to approach 19 million by the



Skip Brown

year 2030, demographics will clearly play a major role in distinguishing the Chesapeakes of the future from the Chesapeakes of the past.

**Lifestyle**

Although commenting on lifestyles in the region is beyond the scope of this report, the advent of countless new inventions and devices, as well as changes in tastes and opinions, have drastically altered the daily lives of those who live in Chesapeake country. These changes have not only meant great advances in convenience, health, safety, and transportation; they have also shifted the distribution of wealth and modified the way many experience life. People now crave bigger houses, new and larger cars, more convenience, "time-saving" gadgets, and greater amounts of leisure time. Bayside houses sell for a premium, more and more people buy boats to spend their free time cruising the Bay, seafood restaurants pack people in with all-you-can-eat blue crab specials. These demands are taking their toll on the Chesapeake. At the same time, citizens are more aware of the consequences of past unchecked exploitations.

**Biological Changes**

The Bay has seen considerable biological change over the last four centuries. Remnant oyster shells, early illustrations of fishing, and historical accounts all point to much greater numbers and much larger

***This early 20th-century photograph gives a sense of the immense quantities of oysters once harvested from the Chesapeake Bay. Note the people standing on the mounds (courtesy of Hampton History Museum, James S. Darling Oyster Packers, Hampton, circa 1910).***

individuals inhabiting the pre-Colonial Bay—large sturgeon, huge oyster reefs, and massive schools of fish (including shad, harvested by George Washington at Mount Vernon). In addition, the European colonization of the Bay brought several invasive species (not counting the colonists themselves). Purple loosestrife (*Lythrum salicaria*), native to Eurasia and apparently planted by early settlers, proliferated and now dominates many marshlands of the Bay.[22] Other species, such as the common reed *Phragmites* and the aquatic plants Eurasian watermilfoil and *Hydrilla* have at times grown aggressively in some rivers and tidal flats.[23] Other noxious animals, absent from the Chesapeake landscape prior to the 20th century, include nutria and mute swan. The former wreak havoc on tidal wetlands (on the Eastern Shore, for example); the latter consume large quantities of submerged aquatic plants, important food and habitat for native species.

Perhaps the most damaging invasive organism to hit the Bay, invisible to the unaided eye, is the Haplosporidian parasite popularly known as MSX. Accidentally introduced into the Delaware and Chesapeake bays during the 1950s, probably during failed attempts to culture the Japanese oyster, *Crassostrea gigas*,[24] MSX rapidly spread through the higher-salinity waters of Virginia and then up toward Maryland. A resurgence of MSX, triggered by drought and higher salinity levels during the mid-1980s, allowed further entrenchment of the disease well up the Chesapeake Bay. The combined attack of MSX and a second parasite, Dermo (*Perkinsus marinus*), has proven devastating to the oyster population both in terms of the Chesapeake oyster fishery and the keystone ecological role played by this reef-building mollusk.

Concerns have grown about the introduction of other exotic organisms, including microorganisms inadvertently carried by large ships in their massive ballast water tanks and dumped as ships clear the tanks to take on freight. The pumping of dirty water into the Bay by ships is not a new concern, however, and some of the earliest complaints about "pollution" centered on oily water flushed from ships' bilges. This particular complaint largely disappeared during the 1950s, after educational efforts by Bay pilots and time-consuming inspections in port—actual or threatened—moved the shipping industry to stop pumping out the oily waste once the ships entered the Bay.[25]

**Municipal Wastes**

Prior to the 20th century, the Bay region often saw little or no treatment of wastes, including human wastes, which often resulted in serious consequences, especially for public health. Even as late as 1955, Edgar L. Jones noted in a landmark article for the *Baltimore Sun* that many of Maryland's cities and towns failed to treat their wastes:

> Twenty-five Maryland cities and towns have public sewers but no treatment plants... Another thirty-two Maryland towns, of sufficient size to have significance from a public health standpoint, have no sewers at all... Still another sixteen Maryland cities and towns have sewers and treatment plants, but they are inadequate to meet the demands made upon them, so that some raw sewage either gets only partial treatment or bypasses the treatment plants altogether and flows directly into streams.[26]

Advances in waste treatment have greatly improved water quality by removing pathogens responsible for typhoid and other life-threatening diseases. Despite these advancements, Washington, D.C., with its aging sewers, still empties untreated waste into the Potomac River with every significant rainfall.[27]

**Nutrients**

Although waste treatment signified an important step in the improvement of water quality, the shear increase in population growth during the 20th century continued to tax many systems. Moreover, in addition to pathogens, municipal and other wastes added considerable quantities of nutrients—particularly nitrogen and phosphorus—to the Bay. During the 1970s, debates raged over whether nutrients posed a significant problem for the Chesapeake. Some resource managers argued that the Bay's flushing rates would prove adequate to handle the problem and doubted whether nutrients presented a real threat to the estuary.[28] Scientific evidence—much of it provided by a baywide study funded by the federal government in 1975 and overseen by the U.S. Environmental Protection Agency from 1976 to 1982—began to hold sway. Ultimately, the Chesapeake Bay agreements of 1983 and, more specifically, 1987 called for significant reductions in the flood of nutrients pouring into the Bay (by 40 percent, according to the 1987 Agreement).

In addition to municipal wastes, diffuse sources of nitrogen and phosphorus also began to contribute to the over-enrichment of the estuary. These harder-to-pinpoint sources included stormwater runoff from urban and suburban areas and seepage of septic tanks into groundwater feeding the Bay and tributaries. While farming had become an integral part of the Chesapeake landscape from the time of European colonization—and even prior, with Indian agriculture—the advent of affordable synthetic fertilizers after World War II meant a rapid increase in nitrogen and phosphorus applied to agricultural land in forms that washed more easily from the soil during rainstorms. The practice of importing animal feed to the watershed also created additional nutrient wastes.

The Chesapeake's past clearly includes increasing quantities of nutrients over time through the expanding use of fertilizers, not only on farm fields but also on lawns and gardens throughout the watershed. In addition to these nitrogen sources came ever-greater numbers of automobiles and trucks, each a mobile source of nitrogen oxides. Now, deposition from the atmosphere is thought to be responsible for 25 percent or more of the nitrogen entering the Bay.

**Contaminants**

Pollution is not new to the Bay; we have just become increasingly aware of its potential for wide-

***An undated photo of women preparing tomatoes in a Maryland cannery. Such cannery operations resulted in early pollution to the Chesapeake Bay and its tributaries (Maryland State Archives - MSA SC 1477-6186).***

spread harm to the estuary and its organisms. The types of pollutants have also changed over time. In addition to municipal waste problems, early Bay pollution also resulted from canning and packing plants. In the words of reporter Edgar Jones:

> Raw sewerage is not the whole problem, either. Into Maryland streams and Chesapeake Bay go the waste materials of big city and small-town production: acid mine waters, toxic chemicals, offal from meat and poultry packing houses, pulp and seed from canning companies, the washings from dairies, oil, grease, coal dust, pulp fibers, clay particles, and other foreign matter, to say nothing of the trash and garbage that householders toss into rivers and brooks.[29]

Much of the pollution described in Jones's 1955 diatribe had been around for decades—some even longer. A report from the Maryland Commissioners of Fisheries at the turn of the 20th century complained about the dumping of refuse, particularly singling out tomato canning establishments.[30] It was not until after World War II, however, that "toxic chemicals" from large industry became increasingly recognized as a major culprit threatening both the Bay and human health. Modern chemistry had created new products, including powerful organics such as DDT and PCBs, which proved extremely persistent and accumulated in tissue over time.

Studies by the U.S. Environmental Protection Agency identified the presence of heavy metals and other contaminants during the 1970s and 80s. The behavior of these contaminants remained uncertain, however, especially given the variation in water chemistry characteristics throughout the Bay. Differing salinities, sediment size, and sediment composition all affect the movement and chemical form of contaminants, making analyses more difficult. Additionally, the interaction among the contaminants and various organisms in the Bay remained difficult to track and characterize.[31]

Recent fish advisories have raised new concerns over the presence of chemical contaminants in seafood. In the Chesapeake's past, worries over shellfish contamination caused by human waste (now carefully controlled and monitored) posed the most pressing seafood concern. With the bacterial contamination problem largely cared for, apprehensions about chemicals in both fish and shellfish have taken center stage.

**Changes in the Land**

Colonial settlement initially followed the rivers. With the creation of roads and railroads, the settlements moved inland following these newly created conduits. Along with this development came the clearing of forests for agriculture. Later, particularly after World War II, individuals began converting farmland into housing developments and shopping centers.

A theoretical satellite image taken periodically over four centuries would show tree cover disappearing at a remarkable rate right up through the beginning of the 20th century, then gradually rebounding as some agricultural lands returned to forests and tree harvesting decreased. Towns and cities spread until they resembled large nerve cells, lit by countless streetlamps: Baltimore[32], Richmond, Norfolk, Washington, D.C. With time, these concentrations of people extended farther in less distinct patterns, as large segments of the population moved from the urban areas into the outlying regions. In some ways, this movement is a return to an earlier distribution pattern, when colonial farmers shunned towns to live on their own private estates—except now there are so many more of us.

Chapters 5 through 7 detail how development patterns, changes in forest cover, and shifts in farming practices are currently affecting the Chesapeake watershed and how they are likely to determine the ecological character of the future Chesapeake. Before moving to an analysis of these important trends, we take one last detour to examine how the Chesapeake Bay ecosystem itself may be transformed in the future. As we shall see, that ecological stage is a shifting one.

## Endnotes

[1] Chapter 4 will detail large forces that continue to shape the Bay. Among these forces was a giant asteroid strike that may have helped direct the flow of rivers to the Bay mouth. Cf. C. Wylie Poag. 2000. *Chesapeake Invader*. Princeton, NJ: Princeton University Press.

[2] Many of our perceptions of an undeveloped Bay come from Captain John Smith and his *True Relation of Occurrences and Accidents in Virginia*, published in 1608.

[3] Cronin, W. 1983. *Changes in the Land: Indians, Colonists and the Ecology of New England*. New York, NY: Hill and Wang. Some scholars argue that it was corn (maize) agriculture that created a distinctive Indian culture in the Chesapeake region. See H. Rountree and T.E. Davidson. 1997. *Eastern Shore Indians of Virginia and Maryland*. Charlottesville: University Press of Virginia. See also J.R. Wennersten, 2001. *The Chesapeake: An Environmental Biography*. Baltimore: Maryland Historical Society, p. 8ff.

[4] Blair, M.K. 1981. Nature as Symbol. *Ethical Aspects of Chesapeake Bay Use*. Baltimore, MD: Citizens Program for the Chesapeake Bay. Blair writes that it is "unethical" to promote the notion of an Edenic Bay, and refers to James A. Mitchner's novel, *Chesapeake*, in this regard.

[5] Cf. Jackson, J.B.C. et al. 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. *Science* 293 (5530): 629.

[6] Captain John Smith, op. cit.

[7] Schubel, J.R. 1986. *The Life and Death of the Chesapeake Bay*. College Park, MD: Maryland Sea Grant College, p. 4.

[8] Smolek, M.A. 1984. "Soyle Light, Well-Watered and on the River": Settlement Patterning of Maryland's Frontier Plantations. Paper presented at the Third Hall of Records Conference on Maryland History, St. Mary's City, Maryland.

[9] Curtin, P.D., G.S. Brush, and G.W. Fisher, (eds.). 2001. *Discovering the Chesapeake: The History of an Ecosystem*. Baltimore, MD and London: The Johns Hopkins University Press.

[10] Walsh, L.S. 2001. Land Use, Settlement Patterns, and the Impact of European Agriculture, 1620–1820. In P.D. Curtin et al., (eds.). op. cit., p. 222.

[11] City of Hampton v. Watson. 1916. *Southeastern Reporter* 89: 81–2. See S.G. Davidson, J.G. Merwin, Jr., J. Capper, G. Power, F.R. Shivers, Jr. 1983, 1997. *Chesapeake Waters: Four Centuries of Controversy, Concern, and Legislation*. Second Edition. Centreville, MD: Tidewater Publishers, pp. 92–3.

[12] Darling v. City of Newport News, 249 U.S. Reports, 540–4 (1918). See Davidson, S.G., et al., op. cit., pp. 93–4.

[13] Holmes cited in S.G. Davidson et al., op. cit., p. 94.

[14] Davidson, S.G. et al., op. cit., p. 98.

[15] Davidson, S.G. et al., op. cit., p. 85. The 1897 Baltimore sewage commission held that there was "but little reason" not to take advantage of the Bay's "diluting effect" and to keep dumping sewage there.

[16] Davidson, S.G. et al., op. cit., p. 26.

[17] Davidson, S.G. et al., op. cit., p. 26.

[18] Curtin, P.D. et al. (eds.). op. cit., p. 157.

[19] Earle, S. 1923. *The Chesapeake Bay Country*. New York, NY: Weathervane Books, p. xiv.

[20] Mills, S. and B. Mills. 2001. *State of the York 2000*, The York Watershed Council, Walkerton, Virginia.

[21] Huslin, A. 2002. Looking Toward Washington Now: Census Confirms Arundel's Shift. *Washington Post*, May 30, page T3.

[22] The Kenilworth Aquatic Gardens in Prince Georges County, Maryland, for example, has mounted a program to eradicate purple loosestrife.

[23] *Exotics in the Chesapeake, Understanding Species Invasions*. Fact Sheet No. 3. 1999. College Park, MD: Maryland Sea Grant. The spread of Eurasian watermilfoil on the Susquehanna Flats was spectacular during the 1950s, growing from no plants in 1957 to 47 percent coverage by 1959. By 1960, coverage of this invasive species had reached 94 percent.

[24] Burreson, E.M., N.A. Stokes, and C.S. Friedman. 2000. Increased Virulence in an Introduced Pathogen: *Haplosporidium nelsoni* (MSX) in the Eastern Oyster *Crassostrea virginica*. *Journal of Aquatic Animal Health* 12: 1-8. Research by Eugene Burreson and colleagues at the Virginia Institute of Marine Science suggests a strong genetic link between MSX as it appears in the native Eastern oyster (*Crassostrea virginica*) and the Japanese oyster (*Crassostrea gigas*), which appears resistant and may serve as a carrier of the parasite.

[25] Cf. Curtin, P.D., op. cit., p. 124. This tactic appeared to work, and "oil disappeared from the list of primary pollution concerns."

[26] Jones, E.L. March 6, 1955. Maryland Pollution: Raw Sewerage, Industrial Waste, Acid Mine Water Poured into the Chesapeake Bay and Streams. *The Baltimore Sun*, p. A3.

[27] Cf. Leffler, M. 1999. Bringing the Anacostia Back. *Maryland Marine Notes* 17: 1–2.

[28] Greer, J. Spring 2002. Our Changing Vision of the Chesapeake. *Chesapeake Quarterly* 1 (1): 4.

[29] Jones, op. cit.

[30] Maryland Commissioners of Fisheries, quoted in Davidson, S.G. et al., op. cit., p. 105.

[31] Cf. Maryland Sea Grant and Virginia Sea Grant. 1997. Chemical Contamination in the Chesapeake Bay. College Park, MD and Charlottesville, VA. Also see Chesapeake Bay Program. 1999. Targeting Toxics: A Characterization Report. Annapolis, MD.

[32] To view an aerial reconstruction of Baltimore's growth over the past 200 years, go the the Science @ NASA website at *http://science.nasa.gov/headlines/y2002/11oct_sprawl.htm*

# Changing Times

The Chesapeake Bay is a work in progress. As researcher and writer Jerry Schubel has pointed out, there have been many Chesapeake Bays—what we witness today is merely one of them. In the midst of this constant change, we depend on what we know not only of the present but of the past. We watch a few lone canvasbacks bobbing on the swells and imagine a flock of thousands. We find oyster shells scattered near the shore and picture huge reefs running along the Bay's shallow fringe mile after mile. When we try to imagine the Chesapeake Bay of the future we inevitably picture the past—and we long for it.

Perhaps the best-known manifestation of this longing for the past is the annual wade-in off Broomes Island in the lower Patuxent River undertaken by former Maryland state senator Bernie Fowler. Fowler remembers vividly how as a young man catching crabs he was able to wade in the water up to his chest and still look down and see his toes. Every June, accompanied by friends and politicians, he attempts to recreate this experience but comes up short. This event not only highlights the changes that have occurred but also tracks our efforts to reverse declines in water clarity.

The notion that the Bay can be returned to a previous, healthier state is clearly implicit both in the public mind and in the minds of the policymakers and environmental managers responsible for carrying out the public will. While even the most optimistic recognize the impossibility of recreating a Bay similar to the one that Captain Smith chronicled in the 17th century—a Bay then surrounded by some 100,000 people as opposed to more than 15 million today—many still believe that returning the Chesapeake to a condition similar to the one of the 1950s might just be achievable. Indeed, this belief was an inherent goal in the original multi-state Bay agreements of 1983 and 1987. Yet, this somewhat idyllic notion ignores countless changes in the world around us, changes that will continue to unfold far into the future.

Simply put, none of the Chesapeake Futures can be precisely like the Chesapeake Pasts. After all, the Bay is an estuary, a naturally dynamic environment that geologically speaking is young and ephemeral. Only a few thousand years old, the Bay is evolving and aging morphologically and ecologically, like all the world's estuaries. Beyond this, the world surrounding the Bay is shifting in ways that the regional community cannot fully control. Our climate, always variable and changing, may experience more rapid change as we move into the future. The human population residing near the Bay's margins and within its watershed will undoubtedly continue to grow and demographics will change. The regional

*Bob Nichols, USDA NRCS*

economy will transform itself in ways that are difficult to predict as new technologies emerge and new adaptations take shape. All of these changes will influence the Chesapeake Bay and its watershed. These unforeseen changes will pose new challenges and new opportunities for those who live in Chesapeake Bay country, as they make choices about their own behaviors and commitments and as they seek ways to achieve Bay restoration goals set for the future. This chapter describes the changes that are likely to be seen in the new century and particularly during the next 30 years. It attempts to characterize the shifting playing field on which we have to weigh our options for choosing among achievable Chesapeake futures.

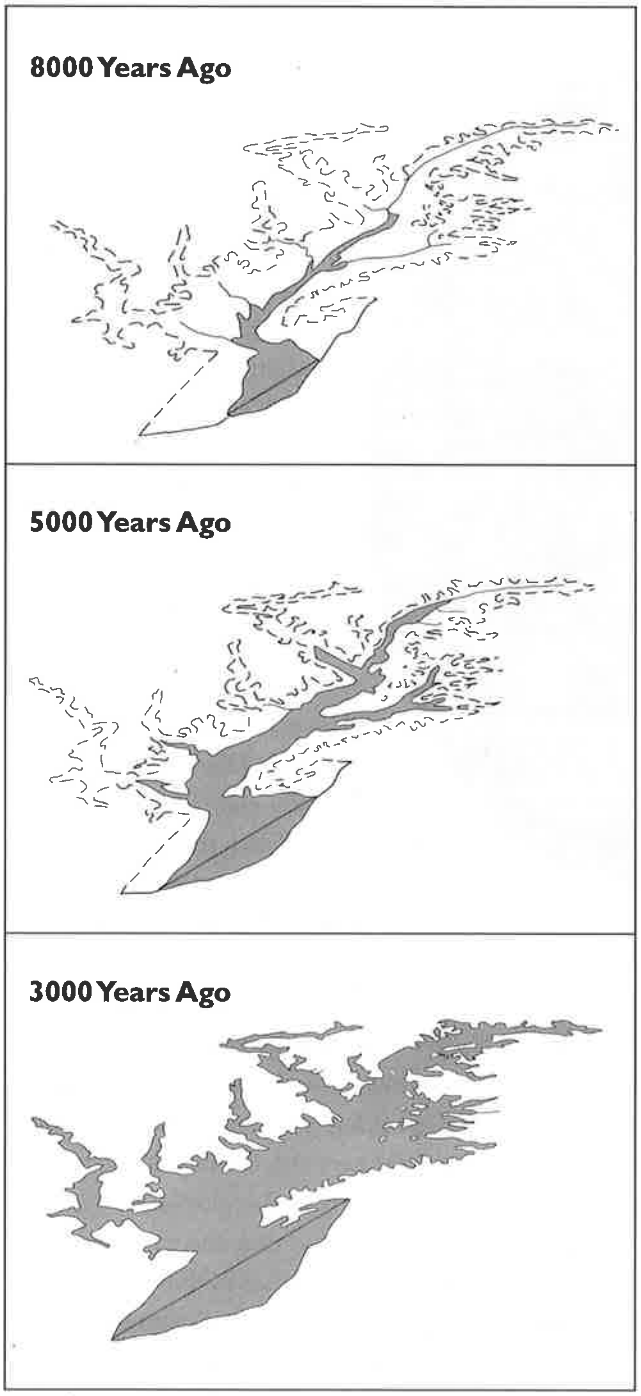



***Figure 4-1. Post-Pleistocene map series of the rising Bay shoreline at 8,000, 5,000, and 3,000 years ago (adapted from S.P. Leatherman, 1995. Vanishing Lands: Sea Level, Society and the Chesapeake Bay).***

## The Aging Bay

Few fully appreciate that the Chesapeake Bay has not been around forever, or even as long as the human occupants of North America. The Bay is, in fact, a young feature, formed only after the last glacial period. When the glaciers reached their maximum some 18,000 years ago, they extended as far south as central Pennsylvania. At that time, the Atlantic coast was approximately 180 miles east of its current position near the edge of the present continental shelf. Sea level was more than 300 feet lower than today. Along the Atlantic coast, tributaries emptied directly into the sea and the small estuaries were essentially little more than river mouths. As the glaciers began to melt and retreat, the volume of the oceans increased. Sea level rose dramatically and the coast retreated westward, intercepting and flooding coastal river valleys. About 6,000 years ago, the rate of sea level rise slowed, leaving some semblance of the present Chesapeake Bay, which achieved its current shape only about 2,000 to 4,000 years ago[1] (Figure 4-1 and Figure 4-2).

Though coastal plain estuaries such as the Chesapeake are relatively young, they tend to age rapidly. This aging occurs principally as soil, formed from eroding rock in the watershed, begins to wash off the land into the estuary. Large estuaries are very effective sediment traps, capturing and sequestering—in bottom deposits and wetlands—much of the sediment moving down the rivers, sweeping in from the ocean with tides or storms, and eroding from the shorelines. Because estuaries exist at the interface between land and sea and because they are such effective sediment traps, their character and shape change rapidly. Their geomorphology evolves over mere hundreds of years even when sea level remains relatively stable.

In the case of the Chesapeake, aging has come even more quickly. Human activities have accelerated the rate of natural aging of the Bay by causing more sediment to wash off the land and into the estuary. Using carbon-14 dating of cores from bottom sediments, scientists have documented that the rate of filling of the deep channel of the upper Bay—after remaining relatively constant for more than 1,000 years—increased more than six-fold during the 18th and 19th centuries as forests were cleared for agriculture and fuel.[2] Even during the 20th century, sedimentation (infilling) rates were about three times greater than in pre-colonial times. Increased soil erosion caused the silting in of many of the Bay's tidal tributaries, including rivers such as the Anacostia and the Gunpowder, that once boasted colonial-era ports. The lower Bay has gradually experienced filling as well, but with mostly sandy sediment coming in from the Atlantic Ocean rather than from sediment eroded from the watershed. Approximately 3 billion metric tons of sediments from all sources were captured by the Bay over a 100-year period ending in the mid-1950s.[3] These sediments are eroded and redistributed by waves and currents, resulting in an ever-evolving Bay that is becoming shallower and has less-pronounced relief in its bottom topography.

Counteracting this shoaling of the Bay to some degree is the slow rise in sea level, not only from the increasing volume of the ocean but because much of the land surrounding the Bay is slowly sinking. This regional subsidence results largely from long-term rebounding of the Earth's crust north of the Bay region following the glacial retreat. While the glaciers did not extend as far south as the Chesapeake, they did cause a peripheral bulge, lifting the crust where the Bay is today. With the weight of the glaciers gone, the crust surrounding the Chesapeake began to subside (and is still dropping) similar to the other end of a seesaw. As a result, relative sea level around most of the Bay (measured relative to coastal lands) has risen at the rate of approximately 1.4 mm per year over the past few thousand years, but at a faster rate of about 3–4 mm per year during the 20th century.[4] A little more than 1 mm per year is due to this regional subsidence effect; the rest results from the rise of the ocean (about 2 mm per year) observed worldwide during the 20th century. Locally, relative sea level rise may be even greater as a consequence of groundwater withdrawals. For example, relative sea level rise at Cambridge, Maryland averaged nearly 9 mm per year between 1930 and 1993.

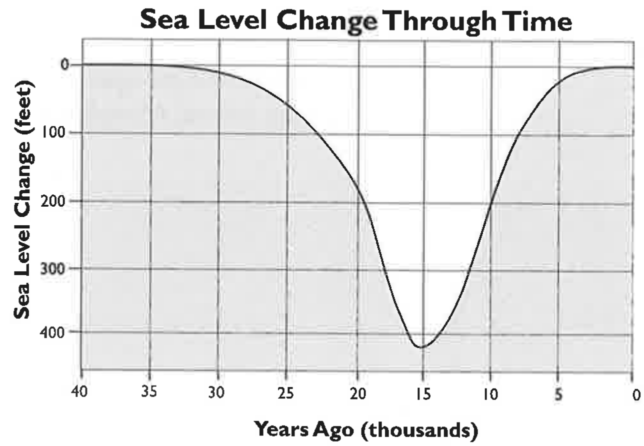



***Figure 4-2. Sea level variations over the past 40,000 years with the advance and retreat of the continental glaciers. The lowest point on the graph represents the maximum of the last glacial period (adapted from Leatherman et al., 1995. Vanishing Lands: Sea Level, Society and the Chesapeake Bay).***

While relative sea level rise makes the Bay slightly deeper, this effect is counteracted by the addition of sediments to the estuary through increased shoreline erosion—an inexorable result of sea level rise acting in consort with wind-driven waves. Even without an increase in the rate of sea level rise due to global warming (as discussed in the next section), rising Bay levels will cause further reductions in size and perhaps outright loss of remaining islands in the Bay over the next 30 years through inundation or increased wave erosion. Many islands in the Bay that were once inhabited, such as Sharps, Poplar, and James (Figure 4-3), have already been submerged or nearly so. Furthermore, other inhabited islands, necks, and low-lying lands around the Bay, particularly on the Eastern Shore and Tidewater Virginia, face increased inundation with retreating tidal wetlands and threatened waterfront communities.

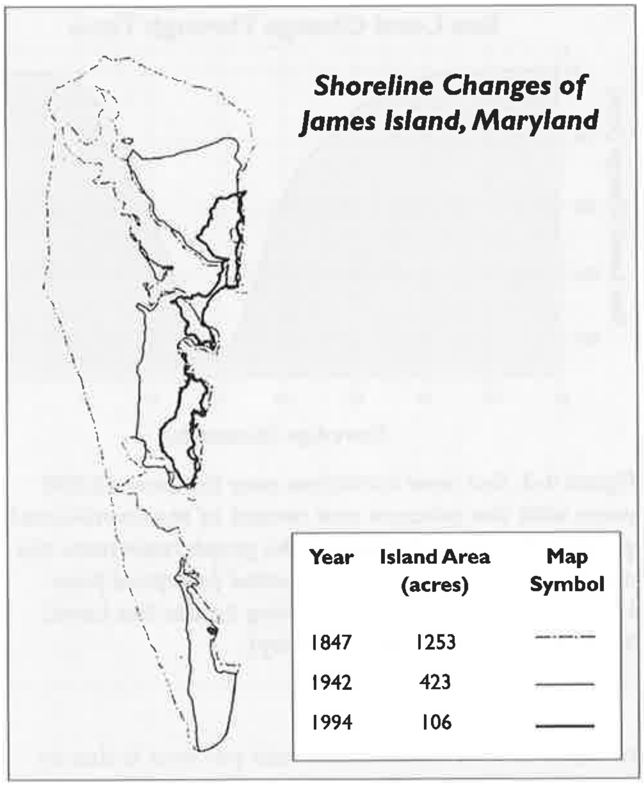



***Figure 4-3. In the mid-1800s, James Island covered 976 acres. By 1994, rising sea level had claimed 884 acres, leaving a mere 92. The island once supported homes, schools, and a store. Now, none of these remain.***

## Climate Variability

There is a growing appreciation, not only in the scientific community but also within the public at large, of the importance of weather events and climate change in coastal ecosystems such as the Chesapeake Bay. Extreme events, such as the floods caused by Tropical Storm Agnes in 1972 and the more recent 1996 floods, have sharpened this awareness (Figure 4-4). The importance of climatic cycles, such those related to the El Niño Southern Oscillation (ENSO), and the specter of long-term global climate change have also gained more broad-based recognition. While climatic variability and extreme events have always been important to the ecology of the Chesapeake Bay, ongoing studies of the chemical and microfossil record in Bay sediments suggest that recent degradation of this ecosystem from human activities has left it more susceptible to the impacts of extreme effects.[5] In other words, the Bay ecosystem has lost some of its resilience in the face of natural stresses. Floods now carry more nutrient and sediment than during pre-Colonial times, and periods of high river flow more easily cause widespread oxygen

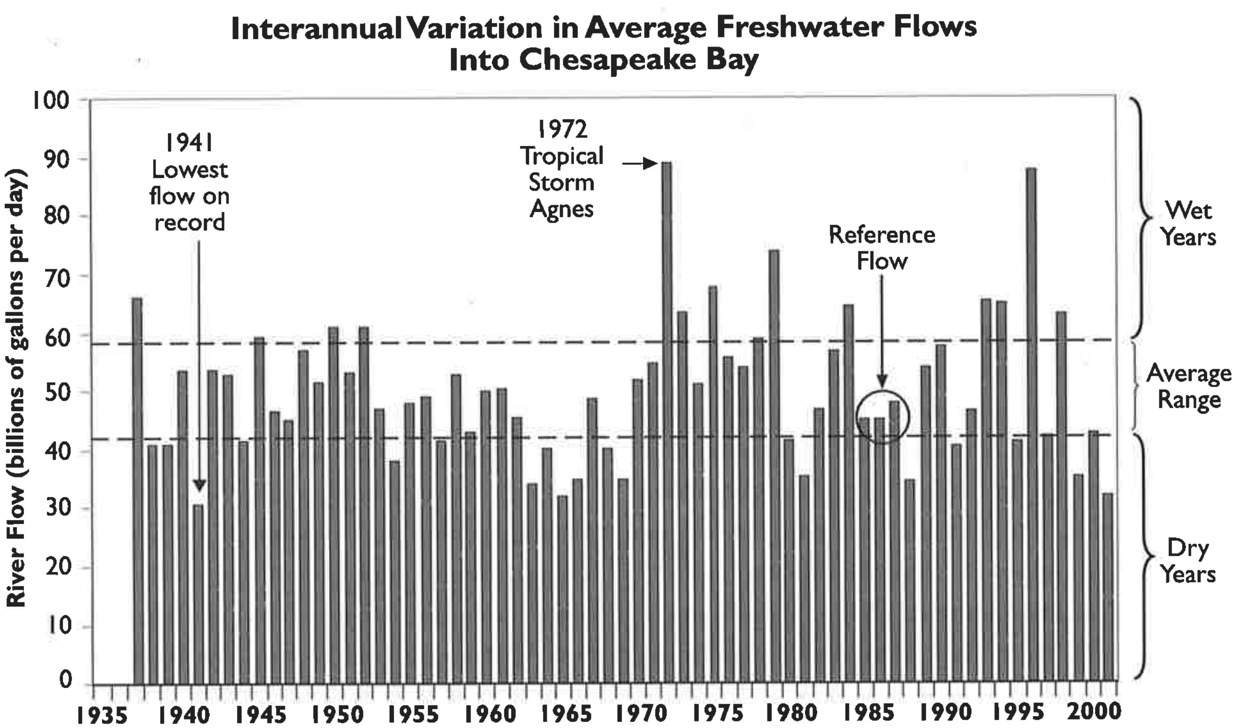



***Figure 4-4. Plot of the average annual freshwater flows into the Bay from 1937 to 2001. Tropical Storm Agnes in 1972 caused the highest freshwater flow to the Bay; however, 1996 was also a particularly high-flow year.***

# Climate Cycles

Kent Mountford

Scientists have demonstrated that climate cycles, with frequencies ranging from a few years to a few decades, can affect many parts of the world. For example, research has shown that El Niño (the ENSO), a phenomenon of the tropical Pacific Ocean, affects temperature, rainfall, and storms not only along the Pacific coast but also over much of the United States. El Niño years tend to produce greater precipitation at least in the southern part of the Chesapeake Bay watershed, while La Niña years are drier.[6]

A more poorly understood climatic cycle in the Atlantic Ocean—the North Atlantic Oscillation (NAO)—might augur even greater consequences for the Chesapeake Bay. During the NAO, which has a cycle of a decade or more, the atmospheric pressure over the Atlantic Ocean shifts. This shift affects the pressure differential between the northern (boreal) and southern (subtropical) regions of the North Atlantic. When the pressure over Iceland is low and the pressure over the Azores is high, as has been the case for most of the 1980s and 1990s, strong westerly flows bring warmer conditions to northern Europe and wetter conditions along the U.S. East Coast.[7] When the reverse occurs, drier conditions are likely along the U.S. East Coast, as during most of the 1950s and 1960s, which were years of below-normal stream flow into the Chesapeake.

Growing evidence suggests that long-term climate cycles, such as the NAO and even planetary cycles, can affect water levels in the Atlantic Ocean and, consequently, the Chesapeake Bay. These cycles may result in varying rates of sea level rise over a decade or even over a few years—changes otherwise not predicted over the long term. For example, relative sea level appears to have been increasing at a faster rate than expected based on tide gauge records from the upper Bay, as much as 10 mm per year during the 1990s.[8] While such periods of more rapid sea level rise may be followed by a few years of little or no sea level rise, the damage in terms of eroded shorelines and submerged wetlands may have already been done. This variation also makes it difficult to distinguish any acceleration of sea level rise due to global warming, which is widely expected by the scientific community during the 21st century.

Since the atmosphere is a continuous medium, changes that take place in one region can affect "downstream" areas; these "teleconnections" can link the climates of different places. For example, climatologists are beginning to document an important teleconnection pattern between oceanographic conditions in the North Pacific Ocean and climatic patterns in the eastern United States. Recent satellite observations suggest that we may be seeing the beginning of a reversal in the Pacific Decadal Oscillation (PDO) that takes place every 20 to 40 years. Under a PDO warm phase, as witnessed during the 1980s and 1990s, the North Pacific is warmer off North America and cooler off Asia. If a PDO cool phase is actually beginning, this shift could portend two or more decades of colder, wetter winters along with a weakening of El Niño effects and a strengthening of La Niña effects, including more hurricanes.

## *IPCC Global Climate Change Predictions*

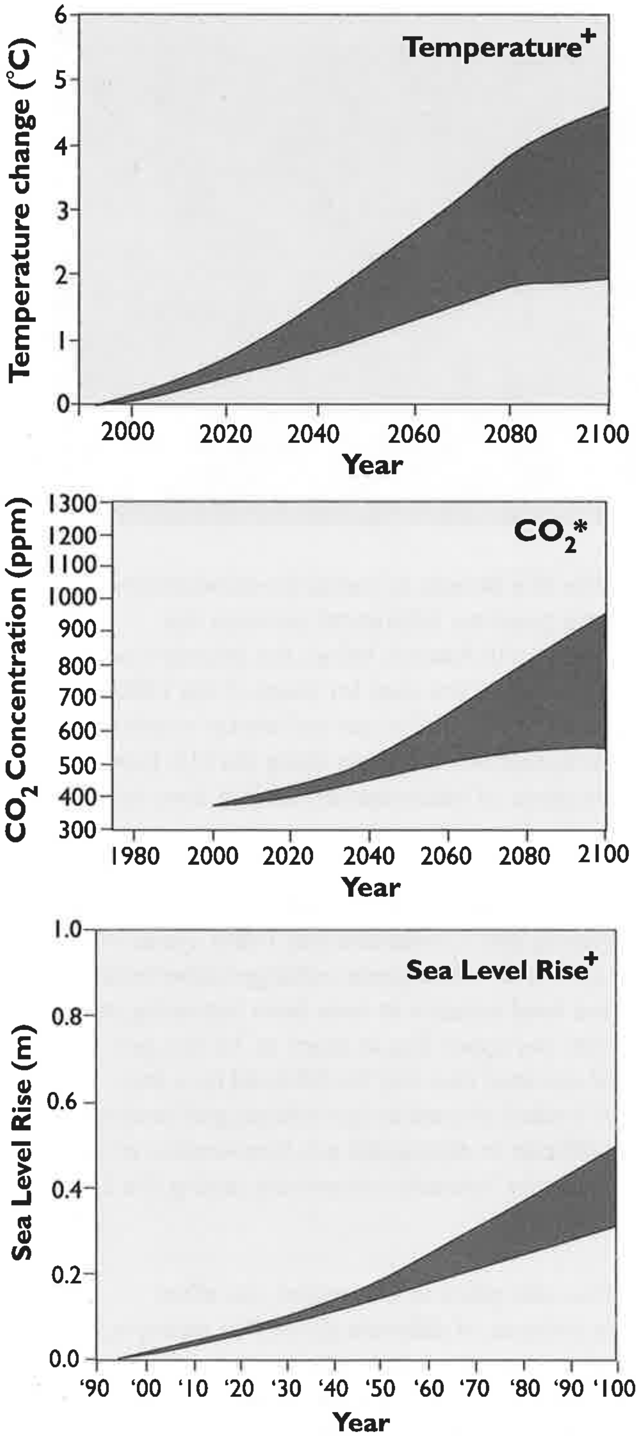



***Figure 4-5. Predictions of global temperature, $CO_2$, and sea level rise to year 2100.***
***+The region in dark shading shows the range of the average of model predictions for all 35 emission scenarios.***
****The region in dark shading shows the entire range of the six emission scenario groups.***

depletion, especially in the Bay's deeper waters. These larger-scale physical and chemical perturbations mean that organisms recover more slowly from otherwise natural flood events.

In addition to extreme storms such as Agnes and the 1996 blizzard—apparently the result of meteorological happenstance—we know that longer-term climate patterns or cycles also have a major influence on the Bay. For example, the 1960s were mostly dry, with much less runoff from the watershed. As a result of low river flow, salinity rose throughout much of the Bay and its tributaries, allowing more marine organisms, from sport fish to oyster parasites, to move farther up the estuary. At the same time, with the reduction of nutrients and sediment carried by runoff, Bay waters became relatively clear and oxygen concentrations rose. During this period, however, other changes continued to take place on the landscape. Their full importance did not become apparent until the drought years ended and precipitation and river flow returned to more normal levels. Of particular significance were both the rising use of chemical fertilizers and purchased feed along with the rapid increase of sprawling development in many parts of the watershed. When the drought ended in the early 1970s, the Bay got the shock of its life. After Agnes, hypoxia (severe depletion of bottom-water oxygen) spread through the Bay and water clarity declined. By 1978, when the first Baywide survey of underwater grasses took place, the area of vegetated Bay bottom had dropped precipitously.[9]

One certainty is that climate variability, as influenced by interactions of cycles such as those described previously (see Climate Cycles box), will continue to bring forth floods, droughts, warm periods, cool periods, and variations in sea level and storms—complicating and constraining the degree to which our society is able to shape our *Chesapeake Futures*. These large climatic shifts, often occurring on a global scale, will continue to surprise us and will no doubt occasionally set back our best efforts to restore the Bay ecosystem. If we are to have any chance at shaping the Chesapeake of the future, or even determining whether our actions are having an effect, we must understand the influences of dynamic shifts in climate on the Bay. We must learn to filter out the background noise in order to detect the signal—the response of the Bay to our best attempts at managing it.

### Climate Change

In addition to changes in the Bay due to geological aging and varying climatic factors such as El Niño, there is the very real prospect that the Chesapeake region will witness a shift in climate during the 21st century due to an increase in greenhouse gases in the Earth's atmosphere. Concentrations of carbon dioxide in the atmosphere have increased by 35 percent since pre-industrial times. Given current trends in fossil fuel combustion, it will increase by approximately 30 percent more by the year 2030.[10] The degree to which we are able to reduce the combustion of fossil fuels in the Chesapeake Bay region alone will have no significant effect on this outcome. Furthermore, global efforts to limit emissions of $CO_2$ and other greenhouse gases, such as those called for by the Kyoto agreement, will make little difference in projected increases in $CO_2$ over the next 30 years. Climatic changes on a global scale are massive with a slow response time; for the next three decades, climatic and atmospheric shifts are already on a given trajectory. The following discussion, therefore, is not offered as an argument for or against controlling greenhouse gases, but rather as an explanation to help us understand and deal with changes that are likely to occur during the early part of the 21st century.

Many uncertainties remain regarding climatic change due to increasing greenhouse gases, particularly within a region such as the Chesapeake Bay watershed. Based on principles of physics, as well as our understanding of the history of the Earth, the most certain change is that the Earth's atmosphere will warm. Disagreements among scientists are not about whether this will be so, but concern how much, how fast, and where. As a result of overall warming, the volume of the ocean will almost certainly expand and sea level will rise faster than it has been rising, with or without the melting of glaciers and polar ice. Again, the scientific debates center on how much and how fast. A warmer atmosphere will also result in more evaporation and, necessarily, more precipitation. Location matters a great deal for precipitation, so it remains less certain whether precipitation will increase or decrease in a particular region. It is assumed, however, that warming will influence the weather-making heat engine of the Earth's fluids (the atmosphere and oceans), likely changing the frequency and intensity of storms and possibly even the course of ocean currents. Significant changes in ocean currents, such as the "conveyor-belt" circulation in the North Atlantic, is the least certain, but potentially the most dramatic consequence of climatic changes that could result from an increase in greenhouse gases.

#### Model Predictions of Climate Change

What, then, can science tell us about how the Chesapeake Bay environment may change as a result of climate change? The National Assessment of Climate Variability and Change has recently projected climate changes and their consequences for regions of the United States and for natural resource

| Parameter | 2030 | 2095 | Reliability of prediction |
|---|---|---|---|
| Sea level rise (inches) | +4.3 to +12.2 | +16.1 to +40.5 | High |
| Temperature (°F) | +1.8 to +2.7 | +4.9 to +9.5 | High |
| Precipitation (%) | -1 to +8 | +6 to +24 | Medium |
| Runoff (%) | -2 to +6 | -4 to +27 | Low |
| Storminess (%, based on precipitation variances) | +18 to +36 | +48 to +64 | Low |

***Table 4-1. Pennsylvania State University projections for several indicators of climate change.***

sectors such as agriculture, forests, water resources, and the coastal zone. A group of scientists from the Pennsylvania State University (PSU) conducted an in-depth assessment for the Mid-Atlantic region,[11] centered on the Chesapeake Bay watershed. Their study yielded the projections shown in Table 4-1 along with the reliability of each projection.

The PSU projections of sea level rise are based on high- and low-rate estimates (Figure 4-5) by the Intergovernmental Panel on Climate Change, with a local component of subsidence for the Mid-Atlantic region that is lower than that currently observed around the Chesapeake Bay. New climate models that take into account various population growth and emissions assumptions are being refined and will continue to provide additional information.[12] Practical projections can be based on recent observed trends in relative sea level around the Bay, assuming 1.4 mm/year for regional subsidence (i.e., the long-term rise before industrialization), and using the various model projections.

A conservative assumption is that relative sea level will continue to rise at the rate actually observed over the past 70 years, resulting in an increase of 10.5 cm (about 4 inches) by 2030 (Figure 4-6). Projecting that trend over the century yields an increase of 35 cm (over one foot) by 2100. It is highly likely, however, that the rate of sea level rise will accelerate over the next century as a result of global warming. A reasonable expectation is that relative sea level will rise by 14.5 cm (nearly 6 inches) by 2030; the increase could possibly reach twice that, however, if warming is more rapid or if significant melting of polar and glacial ice takes place. As we plan for a Chesapeake Future in 2030, we should appreciate that sea level rise is quite likely to accelerate even faster later in the century. A reasonable projection is that sea level will rise by 60-70 cm (at least 2 feet) by the year 2100. Based on the various models, this increase could be as little as 1.5 feet or up to 3.5 feet.

Increases in sea level of that magnitude will have several consequences for such a low-relief environment as the Chesapeake Bay and its margins. Quite likely, shoreline erosion will increase with more islands, lowlands, and coastal settlements inundated compared to the past century (Figure 4-7 and Table 4-2). This inundation will not only jeopardize traditional Tidewater fishing communities but will also worsen periodic flooding and drainage problems in shoreline urban areas ranging from Georgetown to Annapolis to Hampton Roads. Furthermore, the deterioration of intertidal marshes in areas of rapid relative sea level rise due to high local subsidence, such as those within the Blackwater National Wildlife Refuge, suggests that many of the Bay's intertidal wetlands will not be able to trap sediments and build soils rapidly enough to keep pace with increased sea level rise.[13] Telltale signs already indicate that tidal wetlands in many parts of the Bay are succumbing to such inundation.[14] Some of these wetlands may be able to migrate onto newly inundated fastlands. The topography of these lowlands and the actions taken by landowners to prevent this retreat, however, will likely mean that without more proactive management and restoration efforts, the area of tidal wetland habitat will shrink significantly.[15]

Additionally, a rise in relative sea level by up to a meter over the century will add considerably to the volume of the Bay, which currently averages only about 7 meters in depth. Counteracting this effect is the infilling of the Bay with sediments, including those dislodged by increased shoreline erosion. The

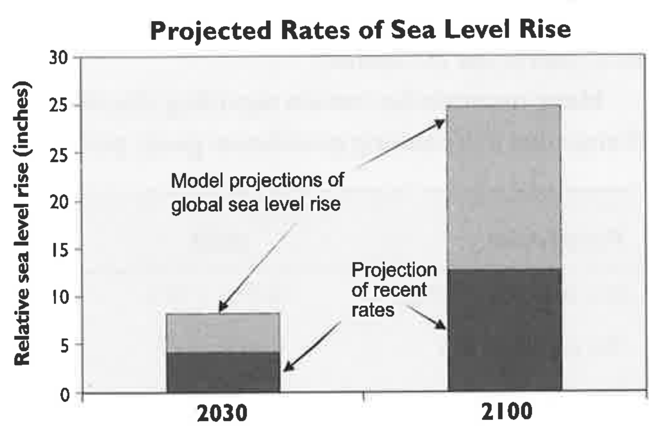



***Figure 4-6. Projected sea level rise, given rates observed in the recent past (dark bars) and expected increases due to global warming (light bars). Together, these stacked bars show the projected mean for future sea level rise in the Chesapeake region.***

## Land Around the Chesapeake Bay Vulnerable to Sea Level Rise

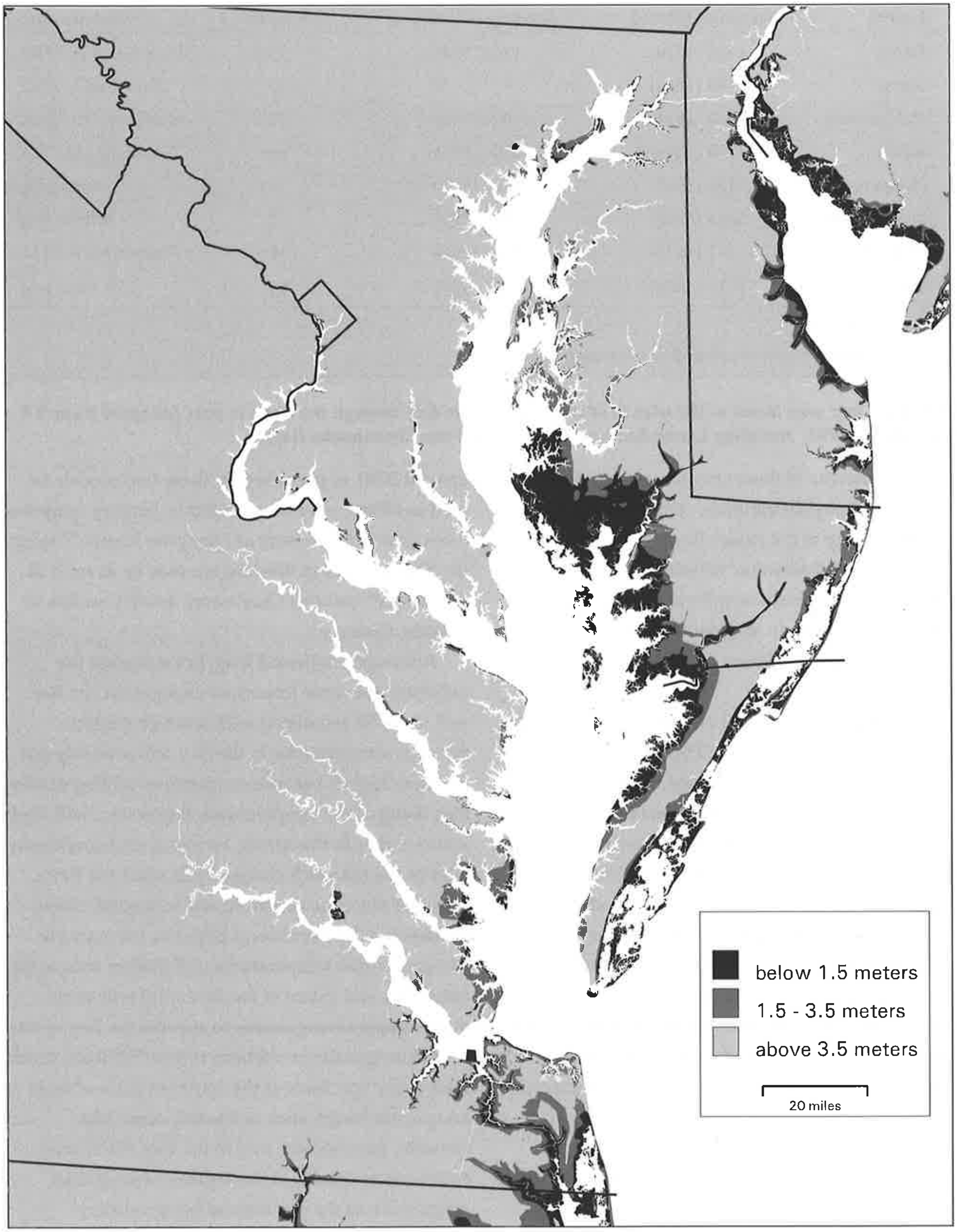



***Figure 4-7. Elevations based on computer models, not actual surveys. Black regions show some areas that might flood at high tide if sea level rises 2 feet in the next century (including tidal variation and subsidence). Although the map illustrates elevations, it does not necessarily show the location of future shorelines.[16]***

| Island | Historic Acreage (Date) | Recent Acreage (Date) | % Lost | Comments |
|---|---|---|---|---|
| Poplar | 1400 (1670) | 125 (1990) | 91 | Abandoned in 1930† |
| Sharps | 890 (1660) | 0 | 100 | Drowned in 1962 |
| St. Clements | 400 (1634) | 40 (1990) | 90 | Abandoned in 1920s |
| Barren | 700 (1664) | 250 (1990) | 64 | Abandoned in 1916 |
| Hoopers | 3928 (1848) | 3085 (1942) | 21 | Submerging |
| Bloodsworth | 5683 (1849) | 4700* (1973) | 17 | Submerging |
| Holland | 217 (1668) | 140* (1990) | 35 | Abandoned in 1922 |
| Smith | 11033 (1849) | 7825 (1987) | 29 | Submerging |

** Mostly marsh land*

*†Poplar Island is now the site of significant reclamation efforts.*

***Table 4-2. Land area losses in the islands of the Chesapeake Bay through the historic past (adapted from S.P. Leatherman, 1995, Vanishing Lands: Sea Level, Society and the Chesapeake Bay).***

ultimate outcome of these countervailing trends will influence salinity distribution, circulation patterns, and the ecology of the future Bay. Rising sea level, combined with freshwater withdrawal, will also exacerbate the problem of saltwater intrusion, especially in relatively shallow wells. Farmers and others on the Eastern Shore are already experiencing this problem.

The range of projections of regional temperature increases (as projected by the PSU group) is based on two state-of-the-art global climate models used in the National Assessment, one developed by the Hadley Centre for Climate Prediction and Research in Great Britain and the other by the Canadian Centre for Climate Modeling and Analysis. Both models replicate the climate of the past century and then simulate future conditions based on similar assumptions for increases in greenhouse gases. These models produced quite dissimilar results beyond 2030, with the Canadian model predicting warmer and drier conditions in the later part of the century. Temperature increases will vary within the Mid-Atlantic region and will also vary seasonally, with greater predicted increases in winter than in summer.[17] While increases of 1.8° to 2.7°F by 2030 may seem small, they are equivalent to a shift southward of 100 miles or more. To put these changes in context, consider that the January temperatures in Washington, D.C. around 2030, as predicted by these two models as well as others, would be similar to January temperatures now characteristic of Hampton Roads, Virginia. By 2090, winters in Washington may be as mild as those of 20th-century Charleston, South Carolina or Atlanta, Georgia.

Although continued long, hot summers are expected, the more important changes for the Bay will likely be associated with warmer winters. Summer temperatures in the Bay will probably not be much higher, because evaporative cooling moderates rising water temperatures. Bay waters will likely warm earlier in the spring, however, and cool down later in the fall. Such changes will affect the Bay's seasonal physical, chemical, and biological cycles, influencing the duration of hypoxia, for example. Warmer winter temperatures will further reduce the frequency and extent of ice cover and will allow more temperate organisms to survive the Bay winter.

While specific predictions remain difficult, some cold-water species near the southern ends of their geographic range, such as the soft clam (*Mya arenaria*), may become rare in the Bay. Alternately, warm-water species at the northern end of their range, such as the commercial brown shrimp (*Farfantepenaeus aztecus*), may establish significant populations in the Bay. Also, warming of winter water temperatures could open the door to other

# The Changing Face of America

PhotoDisc

The region's human population will look different in 2030. Overall, Americans will be older. The Census Bureau predicts that the national median age will increase from 35.7 to 38.5 years. While this increase appears small, the changing age structure means that twice as many people over 65 years of age will live in the country compared to today. In addition to growing demands on Social Security and healthcare services—currently subjects of so much heated debate—this aging of the population has implications for many issues related to the Chesapeake Bay. These effects range from increased demand for recreation to changing dietary preferences to a growing potential cadre of retired volunteers.

As already apparent, the regional community will become increasingly more diverse. In the United States as a whole, the percentage of non-Hispanic white Americans is projected to decline from 72 percent to just over 60 percent between 2000 and 2030. While the percentage of African Americans should change only slightly, the percentage of Hispanic and Asian U.S. residents will grow from 15 to 25 percent. Between 1990 and 2000, according to the 2000 Census, percentages of Hispanics, Asians, and African Americans did increase in Maryland and Virginia. While the shifting appearance of communities in the Chesapeake region may be most apparent in some urban locations, smaller urban and suburban areas and even the agricultural areas of the Eastern Shore will show similar changes. Although social attitudes and behaviors are extremely difficult to predict, racial distinctions may become somewhat less meaningful due to intermarriage, racial mixing, and other factors as we move through the 21st century.[20] In any case, demographic changes may influence development patterns, consumption of goods and services, and policymaking. These changes may also shift the emphasis that the public will place on Chesapeake Bay restoration in light of competing priorities for education, health care, and other social programs.

warm-temperate invaders introduced by the discharge of ballast water by ships, through shellfish transfers, or by other means. In addition to shifts in estuarine species, temperature changes will also likely affect terrestrial species in the watershed. The PSU assessment predicts that the maple-beech-birch forests that characterize the northwestern part of the watershed will retreat, replaced by oak-hickory forests. Oak-pine forests will expand to cover much of the Coastal Plain.

The PSU estimates of changes in precipitation and runoff range widely. Regional variability and the complexity of processes influencing evapotranspiration and precipitation make the predictions of these changes less reliable than those for temperature and sea level rise. These estimates are based on the Hadley and Canadian Climate Centre models, and though the Canadian model predicts less precipitation than most other models, the Hadley model tends to agree with other models in predicting increased precipitation, especially during the winter.[18] Average annual precipitation has, in fact, increased by about 20 percent over the last century.[19] On the other hand, lower precipitation in the summer and increased evapotranspiration may force summer runoff to drop off from 20th-century norms. In addition to obvious effects on salinity distribution in the Bay and its tidal tributaries, such changing hydrography would affect our efforts to control nutrient and sediment runoff into the Bay. In fact, the combination of dry summers and wetter winters would probably result in an increased flux of nutrients into the Bay if all other factors controlling the sources remain constant. Larger winter and spring flows, coupled with warmer spring and summer surface water temperatures, would likely strengthen the density stratification of Bay waters, and thus cause more hypoxia.The PSU assessment also predicts a significant increase in storminess, albeit with low reliability. Such a change would mean more extreme rainfall events that result in stream flooding and the increased flow of sediments and nutrients to the Chesapeake.

We know that the average surface temperature of the earth has warmed by 1.1°F since the late 1800s. This change, when considered with the cooling effects of sulfur dioxide pollution and solar influences, is consistent with model estimates of the greenhouse gas effect. Furthermore, both the scientific community and the public increasingly recognize that the occurrence of some of the warmest years on record during the 1990s probably heralds the human-induced global climate change that will affect our planet and humankind during the 21st century. To be realistic and successful, our efforts to shape the future of the Chesapeake must account for the significant changes likely to occur in the Bay within the next three decades, and beyond.

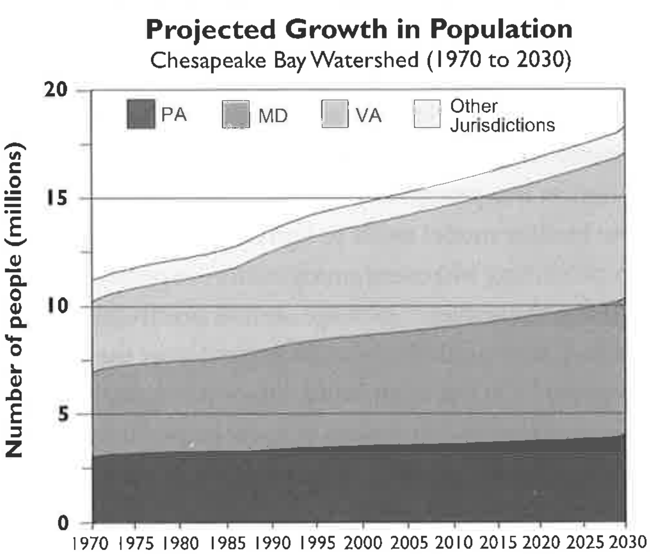



***Figure 4-8. Population projections suggest that Bay-basin residents may approach 19 million by 2030. While the three major Bay states will see increased rates of population growth, Virginia is projected to have the greatest rate in the coming decades.***

## Human Population and the Economy

Unlike some European countries that are experiencing declining populations, the population of the United States is expected to continue growing during the early 21st century, due to its higher ratio of births to deaths and significant net immigration. The mid-range projection of the U.S. Census Bureau is that the U.S. population will reach 347 million by 2030, a 26 percent increase over 2000.[20] While the population of the Chesapeake Bay region is expected to grow at a slightly slower rate than for the nation as a whole, population shifts will vary within the region. For example, by 2030 Virginia's population should increase by a percentage equal to or greater than the national average, while the population of Pennsylvania should increase by less than 6 percent.

The population residing within the Chesapeake Bay watershed is projected to grow about 25 percent from approximately 15 million in 2000 to nearly 19 million in 2030. This jump is due not so much to intrinsically high birth rates or low death rates, but to continued net immigration into the region by foreign immigrants and through domestic relocation in response to economic opportunities and a perceived high quality of life. Chapter 5 considers the distribution of population growth within the watershed and its implications for the future of the Chesapeake Bay in detail. Generally, however, the fastest growing areas are close to the Bay and its tidal tributaries: the Baltimore-Washington metropolitan region, Richmond and Hampton Roads, and the suburbs and exurbs (a prosperous area of residences beyond the suburbs) surrounding these cities. Population growth in the hinterland will remain more modest.

These national, regional, and local population projections still contain obvious uncertainties. The Census Bureau's low-range estimate for the increase in the national population by 2030 is 7 percent; its high-range estimate is 46 percent. Significant population growth within the Chesapeake Bay region is a near certainty, however, barring severe economic problems or epidemics (Figure 4-8). Short of closing the door on the immigration of foreign nationals, no federal or state laws or regulations currently exist that could restrict population growth. Planning and zoning decisions will affect where people live within the region rather than how many people will live here. (Again, Chapter 5 provides additional detail on population and land use projections.)

Economic futures are probably more difficult to predict than environmental ones. Much of the Chesapeake Bay region experienced a booming economy during the 1990s, though a long-term cycle of expansion and recession continues. Discussions move from ways to eliminate the national budget deficit to discussions about a federal surplus and back to deficits again. During the end of the 20th century, the United States experienced what may have been its longest period of robust economic growth and nearly full employment, with inflation remaining at surprisingly low levels. A move toward recession, accompanied by the terrorist attacks of September 11, 2001, raises new concerns and uncertainties about the future. Will we have the economic wherewithal over the next 30 years to continue investing in the restoration of the Chesapeake? Will new economic forces present new risks for the Bay, or will they provide opportunities that allow us to deal with our current vexing problems?

Calvin Edgerton

While it is certainly prudent to consider scenarios under which employment may decline and income may flatten, most assessments suggest that the economic outlook for the Chesapeake region is good and will continue to be propelled by strong positions in technology and government services. Primary industries, including agriculture, mining, and materials manufacturing, have declined in their relative importance; this trend will likely continue due to production cost advantages enjoyed elsewhere in the new global economy. Information technology and biotechnology should become even more important to the evolving, knowledge-based economy.

Globalization of the economy is also increasing international maritime commerce in the United States and this commerce should continue to expand. Trends toward increased volume and larger carriers will present new challenges for maintaining and operating the Bay's channels and ports while improving environmental quality in the Bay. With the new world order, increased concern for national security emphasizes tactical deployment in addition to strategic defense. This focus on national security suggests that military activities in the region will remain an undiminished part of the Bay's future.

For the Bay, the ongoing shift to a service and information economy will continue the transition away from the economic reliance on factories and industrial plants—once the main threats to the Bay. Increasingly, roads and land development pose the biggest risks to the Bay's well-being.

## Technology and Human Development

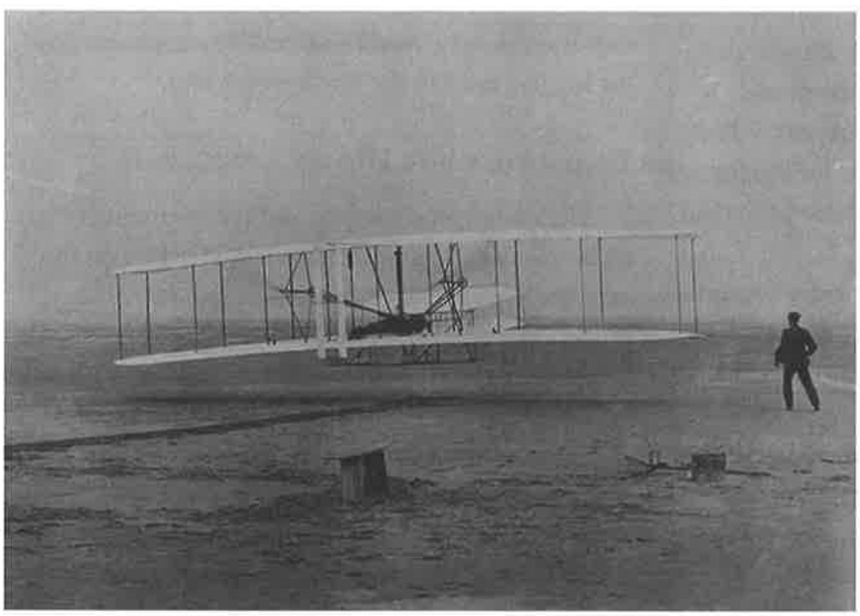
The ending of a century and the beginning of a millennium have produced much reflection on the extraordinary advances in science and technology, especially during the past 100 years. The remarkable technical revolutions of the 20th century have literally reshaped our understanding of the world around us—from subatomic particles to molecules and genes to the biosphere. New technologies have also clearly altered the way we live—from automobiles to pacemakers to the Internet. Although some pessimists may argue that we are at "the end of science,"[21] most futurists would argue that the pace of discovery and application of knowledge is likely to continue accelerating into the 21st century.[22]

As we shape our Chesapeake Future through 2030, we should be mindful that 30 years ago the scientific paradigm of Bay eutrophication that now drives so much of the restoration effort had not yet been clearly formulated. We had developed neither the scientific consensus nor the acceptance of policymakers. We now take for granted that elaborate, science-based models on supercomputers guide our actions in reducing eutrophication. What will the next 30 years hold in terms of practical advances and new explanations of the Bay's mysteries? Surely, we should not take a view of Bay science comparable to that adopted by Charles H. Duell, the director of the U.S. Patent Office, who recommended to President William McKinley in 1899 that the office be abolished because everything useful had already been invented.

What then can we anticipate as science's contribution in guiding us to a better Chesapeake Future? Near the top of the list must be the capability of grappling with the ecosystem's complexities by understanding the interrelationships among environments, actions, and resources in ways that allow more robust predictions of outcomes. Such new insights are becoming more likely thanks to technologies that permit the acquisition and analysis of vast amounts of data and allow development of computer models based on theoretical constructs but informed and corrected by real-world observations. Moreover, the application of existing and emerging technologies in such areas as agricultural production and waste minimization and treatment will shift "the limits of technology" in the forecast models used to assess future Bay conditions.

Chapter 8 covers in detail the opportunities that may be offered by advances of science and technology during the early 21st century. Here we simply point out that in addition to the shifting physical dynamics that will shape the Chesapeake Bay of the future—climate, sea level rise, sedimentation—social and technological changes, many likely unforeseen, will no doubt affect how we study the Bay, how we manage it, and how we use it. Among these changes will be the following:

- Information technologies will change where and how we work, shop, and interact. These changes will clearly have implications for development patterns and transportation systems that will, in turn, affect land use and runoff characteristics.
- Changes in energy technologies loom in the near future, including the potential transformation to a hydrogen technology. Such technologies have obvious implications for atmospheric emissions and, therefore, for deposition characteristics in the Chesapeake watershed.
- Biotechnology will no doubt continue to play an increasing role in agriculture and waste treatment with effects not yet known.
- Advances in environmental monitoring and monitoring technologies will provide better means for tracking the Bay's physical, chemical, and biological dynamics and how they are changing.
- Improvement in management technologies and approaches, such as adaptive management and co-



*Courtesy of Smithsonian Institution*

***Now housed at the Smithsonian Institution's Air and Space Museum, the 1903 Wright Flyer was the first powered machine to achieve flight with a pilot aboard. Its inaugural flight came soon after Charles H. Duell, the director of the U.S. Patent Office, made his remarkable comments.***

management regimes, have the potential to change the way in which we protect and guide the use of our natural resources.

Will those who live and work in the Chesapeake Bay region be able to couple a growing body of knowledge about this complex ecosystem with a mastery of technology and a broad awareness of the requirements for achieving some form of sustainability? The remainder of this report suggests where the challenges may lie as we confront the first three decades of the 21st century and the scenarios that may unfold—depending on what choices we make.

## Endnotes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[8] Kearney, M.S. and J. C. Stevenson. 1991. Island Land Loss and Marsh Vertical Accretion Rate Evidence for Historical Sea-level Changes in Chesapeake Bay. *Journal of Coastal Res.* 7 (2): 403–415.

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[11] Fisher, A., D. Alber, E. Barron, R. Bord, R. Crane, D. DeWalle, C.G. Knight, R. Naijar, E. Nizeyimana, R. O'Conner, A. Rose, J. Shortle, and B. Yarnel. 2000. *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change: Mid Atlantic.* University Park, PA: Pennsylvania State University.

[12] Wigley, op. cit.

[13] Stevenson, J.C., J. Rooth, M.S. Kearney, and K. Sundberg. 2001. The Health and Long Term Stability of Natural and Restored Marshes in Chesapeake Bay. In M.P. Weinstein and D.A. Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology.* Dordecht, Netherlands: Kluwer Academic Press.

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[15] Titus, J. and V. K. Narayanan. 1995. *The Probability of Sea Level Rise.* EPA 230-R-95-008.

[16] Titus, J.G. and C. Richman. 2001. Maps of Lands Vulnerable to Sea Level Rise: Modeled Elevations Along the U.S. Atlantic and Gulf Coasts. *Climate Research* 18: 205-228. This map is based on modeled elevations, not actual surveys or the precise data necessary to estimate elevations at specific locations. The map is a fair graphical representation of the total amount of land below the 1.5- and 3.5-meter contours, but the elevations indicated at particular locations may be wrong. Those interested in the elevations of specific locations should consult a topographic map. Although the map illustrates elevations, it does not necessarily show the location of future shorelines. Coastal protection efforts may prevent some low-lying areas from being flooded as sea level rises; and shoreline erosion and the accretion of sediment may cause the actual shoreline to differ from what one would expect based solely on the inundation of low land. This map illustrates the land within 1.5 and 3.5 meters of the National Geodetic Vertical Datum of 1929, a benchmark that was roughly mean sea level in the year 1929 but approximately 20 cm below today's sea level.

[17] Wigley, op. cit.

[18] Wigley, op. cit.

[19] Karl, T.R. and R.W. Knight. 1998. Secular Trends of Precipitation Amount, Frequency and Intensity in the United States. *Bulletin of the American Meteorological Society* 79: 231–241. The Mid-Atlantic Regional Assessment (MARA) puts this increase at 10 percent.

[20] U.S. Census Bureau report. 2000. *www.census.gov.* Historically, the blurring of racial distinctions has been more common, for example, in South and Central America, and Mexico.

[21] Horgan, J. 1996. *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age.* Reading, MA: Addison Wesley.

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# 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 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

## Cluster Subdivision

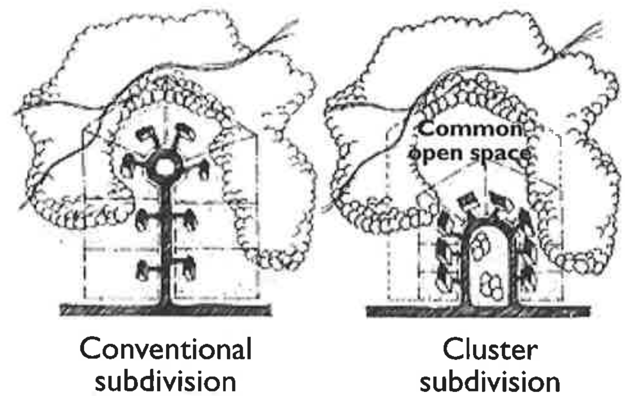



***Figure 5-1. While cluster development reduces a subdivision's footprint, a given parcel of land developed outside planned growth areas and beyond the reach of current infrastructure does not solve many of the problems created by sprawl.***

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)

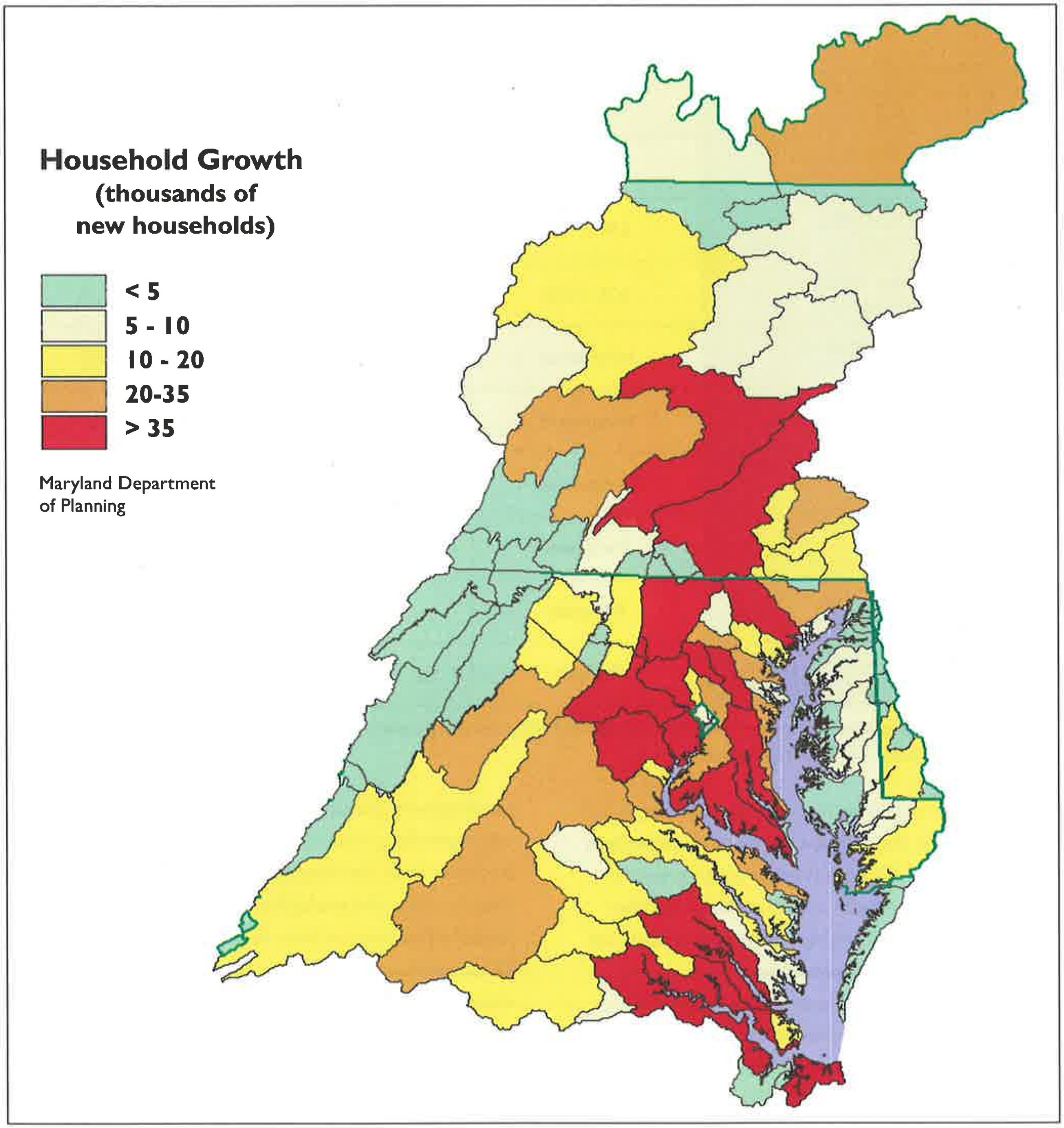



***Figure 5-2. Recalling land use patterns of the Colonial period, new development will likely follow some of the Bay's larger tributaries—the James, the York, the Potomac, the Patapsco. But new development will also spread into the commuter-sheds of large cities, for example west of Richmond, Washington, 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.

## Relationship Between Impervious Cover and Stream Quality

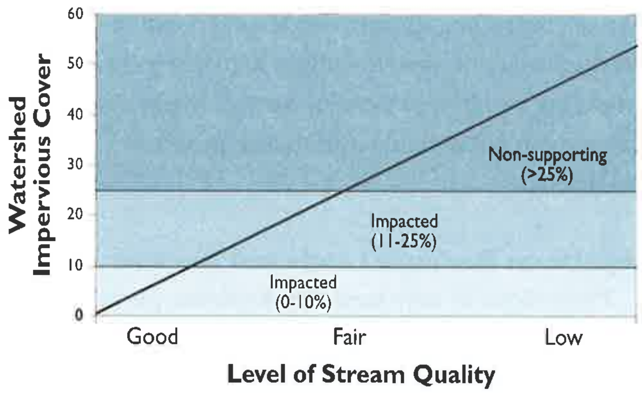



***Figure 5-3. Effect of impervious lands on stream quality. Even small amounts of impervious cover can translate to declines in stream quality.***

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.

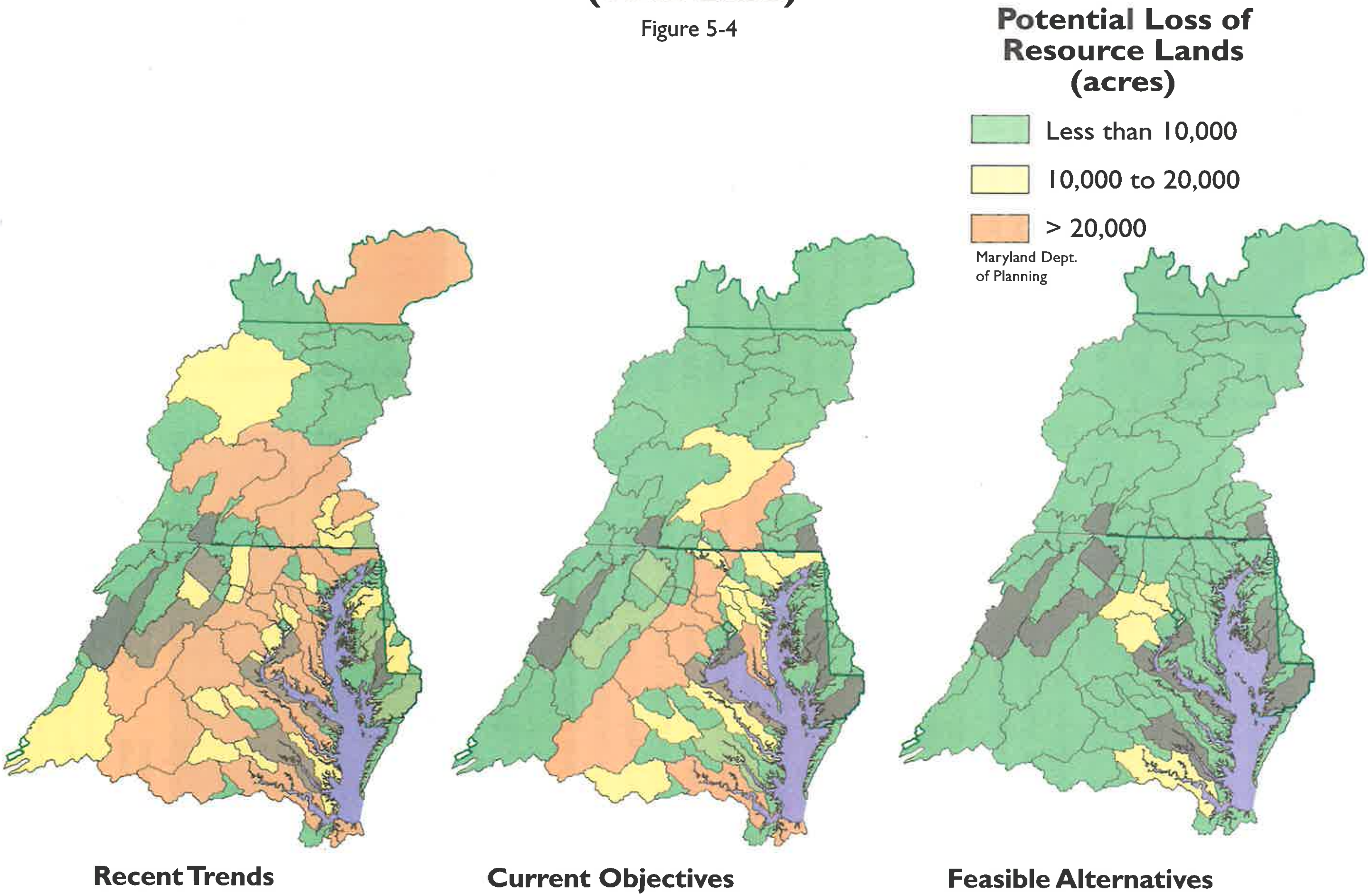
## Scenario 1: Recent Trends

### 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

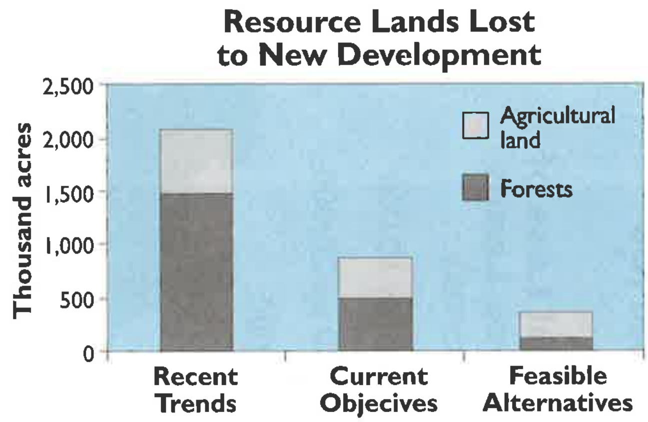
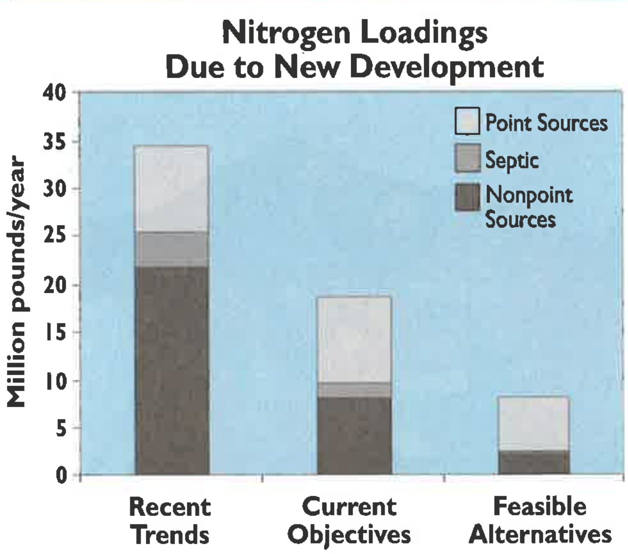



***Figure 5-5 While forests will continue to be lost to new development over time, other factors, such as agricultural conversion, allow generation of new forests and may result in a small net gain in some areas.***




***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.***

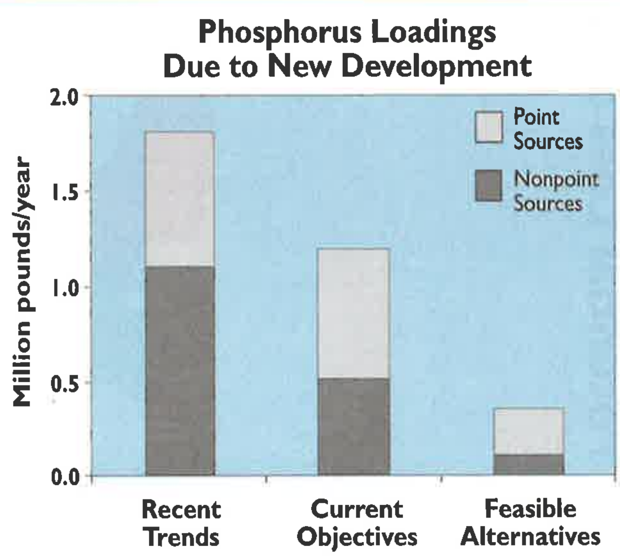



***Figure 5-7. Increases in phosphorus loadings from new development. As with nitrogen, the largest gains in phosphorus control can be made through nonpoint source control.***

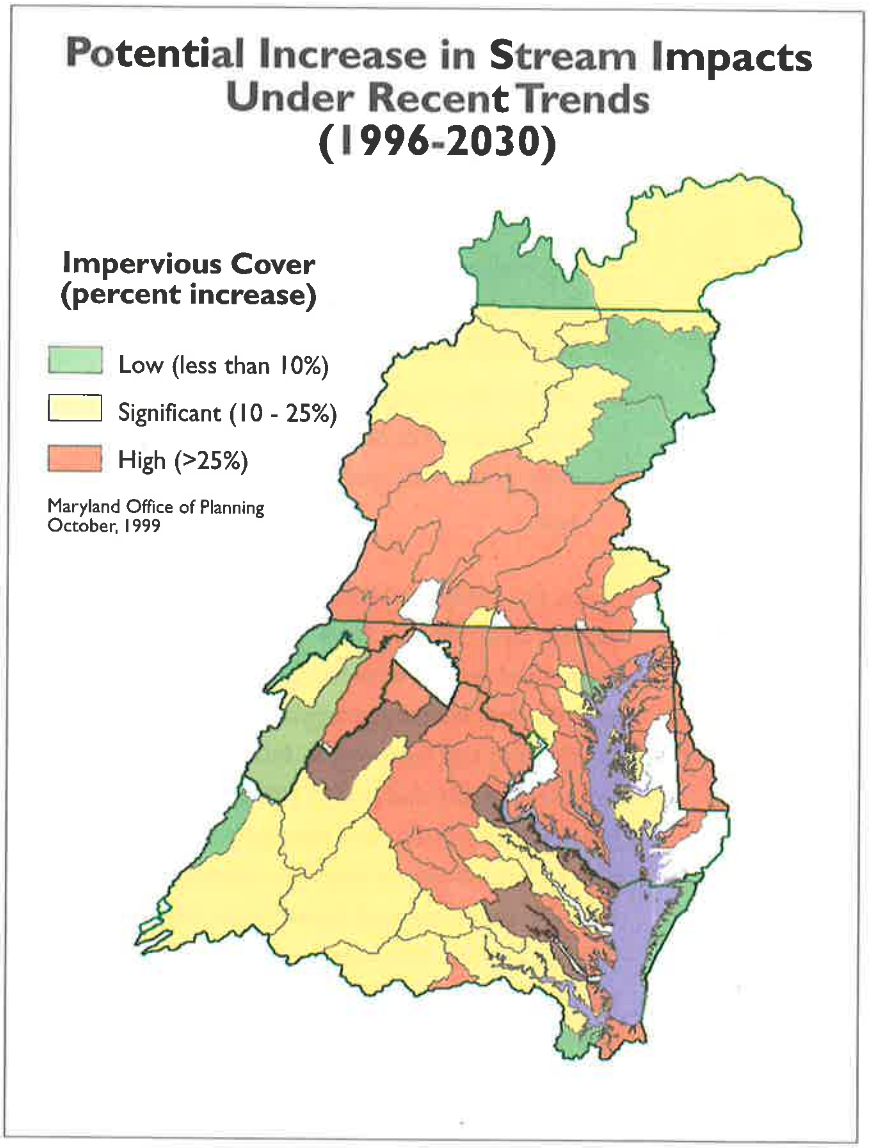



***Figure 5-8. Great stretches of the Cheapeake Bay watershed will likely see more areas covered by impervious surfaces—roads, highways, driveways, rooftops, and parking lots. The areas most acutely affected (see map) will experience increases of 25 percent or more in impervious cover, if recent trends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

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.

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

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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# Forests in Transition

Forests once covered almost the entire vast watershed of the Chesapeake, but land clearing for agriculture, timber, and fuel changed that dramatically, especially in the 19th century. Currently, forests still account for the largest component of the 41-million-acre Chesapeake basin, covering 58 percent of the watershed—an estimated 24 million acres. Agricultural and other open land rank as the second most frequent type of land use, accounting for 33 percent of the land area, followed by urban lands at 9 percent.[1] Although forests remain the dominant land cover, we are currently losing up to 100 acres of forest per day,[2,3] mostly to development. The historical trends and spatial patterns of forests surrounding the Chesapeake clearly coincide with the dynamic interactions among agriculture, forestry, and population growth along with associated urban and suburban development.

While pre-colonial forests were not the pristine environments many assume, approximately 95 percent of the region was forested with only localized impacts arising from Native American agricultural and hunting practices and natural disturbances.[4] By the mid-1700s, however, 20 to 30 percent of the forest had been cleared for agriculture, with this percentage rising to 40 or 50 percent by the mid-1800s[5,6] (Figure 6-1). Forest loss followed settlement patterns as people moved out from the Bay. Less agricultural conversion occurred in the western portions of the watershed due to the generally steep topography of the Blue Ridge and Appalachian Plateau provinces; however, logging could occur throughout the Bay watershed due to the advent of technologies such as cabling systems and the narrow gauge railroad for transporting timber. Historical patterns of agriculture and forestry remain today because broken-soil agriculture is not feasible in most steep topographies and logged areas have been left to regenerate second- and third-growth forests. Following an historic low in 1900, forest cover has since increased to approximately 60 percent of the Bay basin due to less harvesting, old-field regrowth, reclamation efforts, and the establishment of state and national forests or parks.

## Why Forests Matter

Forest cover in a watershed influences the quality of the water reaching an estuary; in general, the more forest cover the better the water quality. Given this presumption, the recent trend toward reforestation of the watershed as a whole can only be viewed as positive. Current forest cover is, however, neither uniformly distributed nor always concentrated in areas deemed most effective for water pollution

Skip Brown

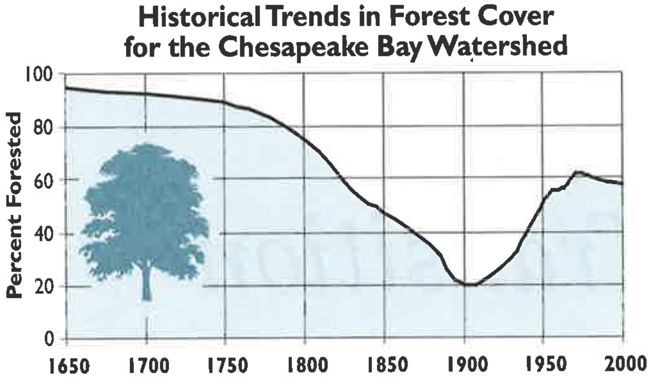



***Figure 6-1. After bottoming out in the early 1900s, forest cover regained acreage throughout much of the last century. Recent decades show a slight decline.***

control. Although the loss of forests in regions with fast-growing populations may be offset by gains in other parts of the watershed, this trade-off in acreage may not translate to equivalent ecological function or environmental service.[7]

The role of forests in the Chesapeake Bay watershed, as in any ecosystem, is multifaceted. Forests function as significant nutrient sinks, storing nutrients from soil, groundwater, and atmosphere,[8,9] thus reducing the quantity of nutrients that enters the Bay and its tributaries. Forests also trap sediment and reduce erosion rates along shorelines,[10,11] lessening sediment input to the water. Large stands of forest take up considerable amounts of atmospheric carbon which helps to mitigate climatic extremes regionally and slow global warming.[12,13] Forests form critical habitat for many types of terrestrial and avian wildlife. Humans rely directly on forests, harvesting them for wood products and using them for recreation and tourism, all of which provide economic viability.

### Nutrient and Sediment Retention

Decades of study by the forest research and management communities have established two indisputable facts. First, forests retain nutrients and sediment much more effectively than virtually all other land uses in the watershed.[14] Although forest harvesting increases nutrient and sediment export, a regenerating forest quickly regains its retentive characteristics and can return to pre-disturbance levels within 3 to 5 years.[15] Forests function as critical filters for the streams and tributaries of the Chesapeake. This same filtering capacity also makes them invaluable in the production of potable water, especially for private wells and communities that rely on small to moderate-sized reservoirs with minimal treatment facilities.[16] Second, the distribution of forests within the watershed relative to the surrounding land type, water flow, proximity to tributaries, and other factors determines the utility of the forests in keeping nutrients and sediments from reaching rivers, streams, and ultimately the Chesapeake Bay. The integrity of riparian forests and the degree of forest fragmentation both influence the effectiveness of forests as sediment and nutrient filters.

### Riparian Forests

Riparian forests provide critical water quality and habitat functions in stream and river corridors (Figure 6-2). Situated along the banks of rivers and streams feeding into the Chesapeake Bay, riparian forests reduce erosion from stream banks and trap sediment washing down from adjacent land. These forests also remove nutrients from groundwater before it enters the surface waters. Although research has shown that riparian buffers effectively filter nutrients and sediment, the buffer structure may need to be tailored to local land types.[17,18,19,20] Jurisdictions should focus on which species of plants are best suited to particular soil types and stream configurations in their efforts to protect and restore riparian buffers, ensuring that the vegetation will thrive.

| State | Total Miles | Percent Buffered |
|---|---|---|
| Pennsylvania | 80,967 | 64% |
| Virginia | 61,147 | 58% |
| Maryland | 31,046 | 53% |
| New York | 14,612 | 53% |
| West Virginia | 9,122 | 58% |
| Delaware | 2,082 | 55% |
| Washington, D.C. | 83 | 29% |
| TOTAL | 199,057 | 59% |

***Table 6-1. Total shoreline and stream (both sides) miles by state in the Chesapeake Bay basin.***

## Minimum Buffer Widths

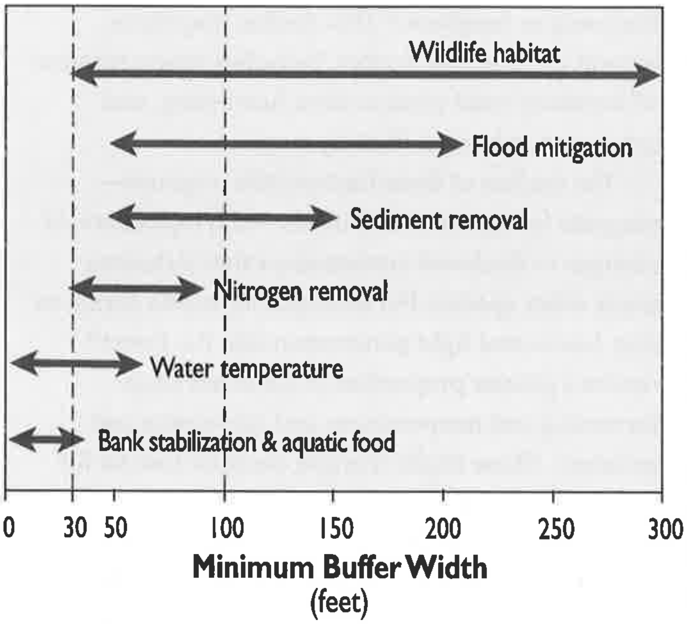



***Figure 6-2. A riparian buffer's effectiveness depends on several factors, including types of vegetation, root depth, and soil composition. It also depends greatly on size—a 30-foot buffer helps shade a stream, but needs to be much larger to function as a significant wildlife habitat (from www.riparianbuffers.umd.edu).***

The *Chesapeake 2000* agreement reaffirmed the earlier commitment to restore 2,010 miles of riparian buffers by 2010. By August, 2002, 2,283 miles of these buffers had been restored, eight years prior to the deadline. Despite this remarkable achievement, however, reforesting significant amounts of remaining stream banks and shorelines within the watershed (Table 6-1) remains a major challenge. A 1997 inventory of the watershed found only 59 percent of the Bay's stream and shoreline is forested within 100 feet on at least one side of the watercourse; over 45,000 miles (40 percent) of the Bay's riparian forest has been removed or severely degraded.[21]

### Forest Fragments

Increasing rates of land clearing for urban and suburban development and the cutting of timber in the watershed have resulted in fragmentation of large contiguous areas of forest into smaller and smaller segments. An analysis of the southern portion of the Chesapeake watershed by American Forests revealed that dramatic changes in tree cover have occurred since 1970. Areas with high tree canopy cover declined from 55 to 38 percent between 1973 and 1997, with particularly severe losses in the Baltimore-Washington corridor.[22] Currently, areas closest to the Bay are losing forests the fastest; they also have the highest degree of fragmentation.[23]

This situation raises the important ecological question of whether scattered small fragments of forest (equal in total area to one larger forest region) are comparable in their ability to preserve watershed functions and good water quality. Researchers have learned that, in many ways, they are not. Consequently, this forest fragmentation is causing widespread concern that continued destruction and division of the forest land base may lead to further impairment of the forest ecosystem's ability to protect water flow and quality, provide healthy and diverse forest habitat, and remain a viable economic resource for recreation, timber, and other wood products and forest services.

Simply given the role of forests in nutrient and sediment transfer across multiple land use types, land use planning that considers forests is critical at larger spatial scales with a focus on the ecological aspect of each land use and its location relative to water flow. For example, could critical portions of the watershed, such as steep, crumbly slopes or highly erodible cliffs, be equally important to riparian zones for maintaining water quality? Can optimal arrangement of forest fragments within the watershed maximize benefits for both water quality and other

*Courtesy of MD Cooperative Extension/ Wye Research and Education Center*

***Aerial photograph showing well-developed riparian buffers bordering a stream. Such vegetation helps to protect the waterway by minimizing the flow of nutrients and sediment into the water.***

key natural resources? These essential questions remain unanswered. Addressing them is of utmost importance since: 1) restoration efforts must be efficient in their allocation of limited capital resources; 2) land use management in developing areas should reconcile concerns for both environmental quality and economics; and 3) conservation of many natural resources must be considered simultaneously to promote overall environmental integrity.

### Forest Wildlife

Birds dwelling in the forest interior epitomize the dilemma for wildlife residing within multiple-use landscapes. Many of these avian species migrate annually between the tropics and North America and are highly dependent on forest interior habitat for nesting sites that provide protection from predators and nest parasites common along forest edges.[24,25,26,27] In the forests of the Chesapeake Bay region, these birds depend on the spring flush of forest insect larvae for food as they breed and raise young.

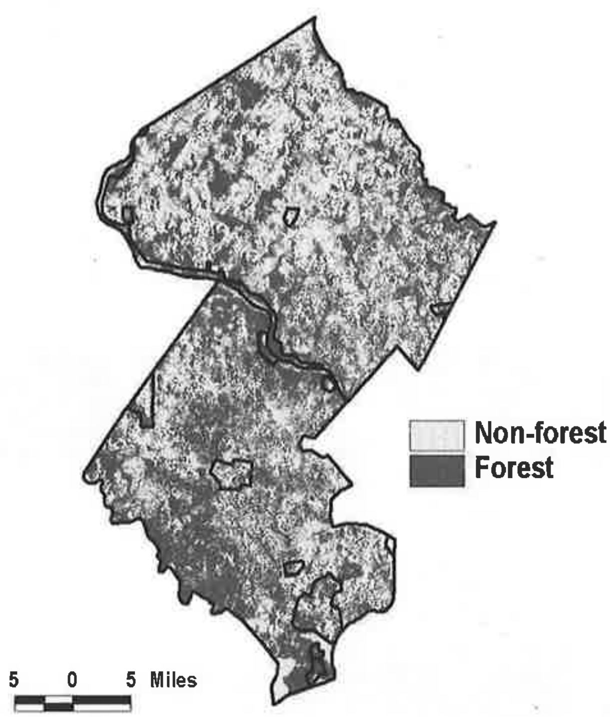



***Figure 6-3. This aerial photo illustrates how fragmentation breaks an area into non-contiguous parcels of forest (courtesy of Mid-Atlantic Regional Earth Science Applications Center).***

Several species of these forest-interior birds are declining in numbers.[28] This decline may have several contributing factors, including fragmentation of forests by road construction, harvesting, and urban and suburban development.

The decline of these high-profile migrants—magnets for recreational birders—is symptomatic of changes in the forest environment that influence many other species. For example, as forests shrink in size, horizontal light penetration into the forest[29] covers a greater proportion of the forest floor, increasing soil temperatures and decreasing soil moisture. These slight changes decrease habitat for native, forest-floor, herbaceous plants and amphibians that require moist conditions. Such changes also decrease the invertebrate populations that aid forest litter decomposition and provide a food source for forest interior birds;[30] spread the growth of weedy edge species throughout the forest; and alter ground cover for forest-floor-dwelling mammals and birds.

As forests become fragmented, forest patches support smaller populations of most non-mobile plant and animal species, resulting in greater likelihood of the elimination of species in each patch. Populations that survive in such a fragmented habitat will be forced to travel between forest patches, across other environments that are often inhospitable. Forest fragment distribution can cause serious disruptions within the ecosystem and is, therefore, a significant feature of multiple-use landscapes (Figure 6-3).

## Forest Economics

Assessing the economic value of forests holistically is difficult. While timber sales and other statistics partially illustrate the worth of forests, estimating a value for aesthetic and mental health benefits remains more complex. But certainly, the economic benefits of the Chesapeake's forests are considerable.

### Forests in the Chesapeake Bay Region Economy

The global market has a significant impact on forest products from the Chesapeake basin, providing opportunities for expanded markets, higher overall demand, increased use of less-used tree species, and lower price volatility. Nationwide, combined timber harvests for domestic use and export are expected to increase by more than 35 percent by 2040. Despite this demand, harvesting from national forests has declined to approximately one-third of its production volume in 1987. Private forests are expected to compensate with a 47 percent increase over 1991 levels, with the majority of the increase in non-industrial private forests. The south, including portions of the Chesapeake basin, is expected to produce more than one-half of the future forest harvest.[31] The economic outlook for national and global marketing of wood products from the Bay region, therefore, is quite good. One challenge, however, will be increasing the amount of value-added product to generate additional income from harvested trees.

Because of the robust demand for products, forests provide a significant source of employment and income for the region. The mid-Atlantic forest industry produces 244,100 jobs and $4.5 billion in real wages per year, accounting for 2 percent of the employment in the region.[32] In addition, non-wood and specialty forest products provide extensive cottage industries and contribute to local economies.

While placing dollar values on the environmental and social benefits of forests is difficult, such values are at least as important as, and likely surpass, wood

## Social Trends Affecting Forests and Their Ownership

With a population of 15 million people and counting and over 64,000 square miles of land area, the average population density in 1995 for the Chesapeake basin was 234 people per square mile. By 2030, the region's population should reach almost 19 million people. As previous sections pointed out, the demographics of this population are changing. Like the United States as a whole, people in the Bay region are moving to the suburbs and, to a lesser extent, into the central cities. The population is also aging. The percentage of people 65 or older will double by 2030 and people are living longer. Retirement age is declining and people are healthier and more active. Jointly, these trends suggest a growing demand for the recreational assets of natural lands[33] with implications for demands on public and private forests as well as for forest ownership and management.

The number of private forest landowners has increased over the last twenty years; individuals now hold about 94 percent of the privately owned forest acres in the watershed.[34] More than 90 percent of the private landowners, however, individually control fewer than 100 acres of forestland. This shift from a few landowners with large holdings to many landowners with smaller holdings is known as parcelization. Parcelization differs from fragmentation, although the two are related. As the number of landowners increases, attitudes and objectives become increasingly diverse. Some landowners may convert their forests to other uses which, in turn, leads to forest fragmentation.[35]

Landowner death, property and inheritance taxes, second homes, and uncertainty about regulation all contribute to parcelization. Such changing ownership demographics and patterns will prove significant, since the behavior of landowners largely affects what happens to private forestlands. In addition, the transition from one to many new landowners makes imparting information about management or good stewardship more difficult.[36] Public programs dealing with such issues will need to shift their focus to become more available and more relevant to a busier, wealthier population with differing values and opinions about what they want from forests. Securing working forests requires practical and sustainable strategies for small parcels. Ultimately, only careful planning at the local level may slow the parcelization process.[37,38]

products. As noted previously, forests prevent pollution and protect against flooding. They increase property values and provide places for learning, restoration, and tranquility. Forests remind us of the eternal processes of regeneration.[39] None of these forest roles are readily quantifiable, yet each is clearly valued by forest owners and much of the general public. These values are reflected in increasing recreational demand, which shapes forest management on both public and private land. In fact, nonconsumptive use of forests and wildlife is expected to grow faster than the nation's population, as the interests and demographics of Americans change.[40] Consequently, many citizens aspire to preserve forests so that future generations have the opportunity to make choices about the use, management, and protection of these forests.

## Forests in a Changing Environment

The environmental benefits of forests must be viewed in the context of environmental change. Interestingly, forests lie at the heart of the three greatest environmental change debates of the latter 20th and early 21st centuries: acid deposition, atmospheric carbon concentration, and land use. Each of these issues has received extensive attention with scientists viewing forest cover as either a primary impacted resource or an integral part of the solution, or both. Despite this attention, specific impacts and concrete solutions remain elusive.

Kent Mountford

The amount of forest cover varies across the Chesapeake watershed based on ownership, transportation networks, urban and suburban development, topography, and the economic value of forest products. This combination of factors has resulted in some general patterns: more forest cover farther from the Bay; clusters of forest on state and federal forest or park lands; and unmanaged forest fragmentation at all spatial scales.

Clearly, not all forest environmental benefits have been lost due to fragmentation—even small, well-placed stands of trees in urban areas can reduce stormwater runoff, lower street temperatures, provide shade that lowers energy use, and filter particulate material from the air. Across the Chesapeake Bay region as a whole, however, the extent of environmental services has become disjointed, locally extirpated, or reduced in magnitude. Examples include decreased forest acreage for carbon and nutrient sequestration, reduced riparian buffers for maintaining high water quality, lost wildlife habitat, increased dominance of non-native and invasive species, and perhaps reduced opportunities for native vegetation to respond to other environmental changes such as climate shifts. In addition, acidic deposition, atmospheric carbon, and land use patterns have interrelated effects that require long-term planning to prepare for changing environmental variables. In general, rethinking the redistribution of forests and the general reduction in forest services demands a tradeoff with the non-environmental services provided by urban and suburban environments and food products from agricultural lands.

### Forests as Nutrient Sinks

Will the forests of the Chesapeake Bay watershed continue to absorb nitrogen deposited from the atmosphere? Atmospheric deposition of nitrogen and sulfur—from coal-fired power plants and other sources of burned fossil fuel—increases the input of these compounds to forest ecosystems, which can influence and interact with the normal forest nitrogen cycle. Conventional theories of terrestrial ecosystems as nitrogen-limited systems suggest that actively growing vegetation, soil biota, or decaying litter serve as sinks for anthropogenic atmospheric nitrogen. Under this reasoning, forests take up whatever additional nitrogen anthropogenic activities introduce to the atmosphere. .

In much of the Chesapeake Bay watershed, however, forests are subjected to such high levels of atmospheric nitrogen deposition[41] that nitrogen saturation may be occurring.[42,43] If this influx of nitrogen is not ameliorated by emission controls and other technologies, scientists and managers must question the continued ability of forests to serve as nitrogen sinks and reevaluate the influence of forest management on forest nitrogen storage and export. For example, how do projected emissions and resultant deposition rates compare with forest retention capacities? How do forest disturbances and fragmentation affect the ability of forests to retain nitrogen? Does disturbance of a nitrogen-saturated forest result in greater pulses of nitrogen release? What is the cumulative impact of forest management activities and other disturbances on the Chesapeake Bay basin? These questions need answers.

**Forests and Global Warming**

Because of their standing biomass and spatial extent, forests constitute a large carbon sink; conversely, deforestation contributes significantly to atmospheric carbon and global warming. While in any final analysis, deforestation constitutes only one factor in global warming, managing forests to sequester carbon plays a major role in solving global warming problems. For long-term planning, the concept of regional carbon balance should be maintained as a backdrop within which local forest management decisions are ultimately made. Regional impacts of climate change on forests should be considered now, because the lengthy life cycles of trees dictates long-term planning to accommodate change and ameliorate potential threats.

The potential for climate change creates additional uncertainty. The Chesapeake Bay region will likely experience higher average annual temperatures and increased winter precipitation.[44] The timing and extent of potential impacts remain very difficult to predict, especially at regional and smaller scales, but over the next 30 years impacts may include:[45,46,47]

- slower forest growth due to water stress during the growing season (higher evapotranspiration);
- increased forest productivity due to the fertilization effect of atmospheric carbon dioxide;
- changes in the severity, frequency, and extent of natural disturbances such as fire;
- lower nitrogen uptake due to decreased forest growth rates;
- altered carbon/nutrient ratios;
- altered decomposition rates of forest litter;
- altered nutritional value of tree tissues for herbivores; and
- gradual changes in forest species composition from shifting climate regimes and competition among tree species (northward expansion of oak-hickory communities, for example).

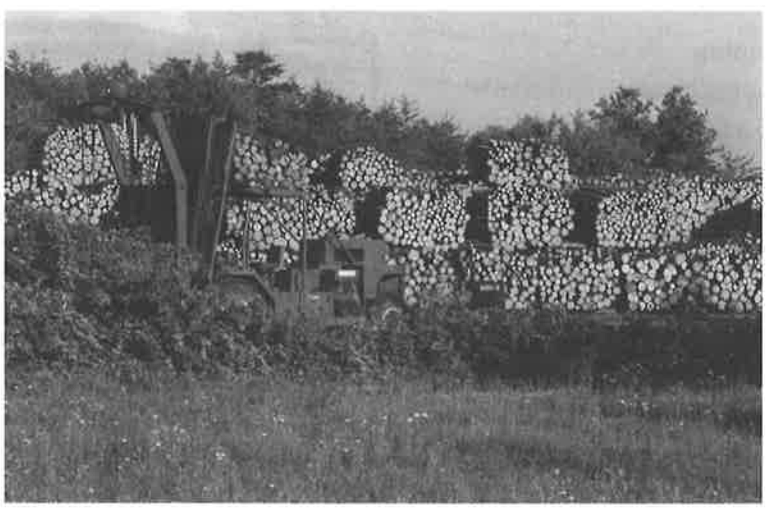
Despite our inability to make specific predictions, climate changes will clearly alter forest conditions and could well decrease the environmental benefits we now enjoy from forests.

## Scenario 1: Recent Trends

**Primary Expectations:**

- *Despite several decades of increasing forest cover driven by reforestation, the amount of forest cover will level off quickly and then decline.*
- *Further wide-scale loss of forests will take place in or near metropolitan areas.*
- *Continued forest fragmentation will occcur throughout the basin, most acutely near metropolitan areas and the Coastal Plain and Piedmont provinces.*
- *Possible drop-off in agriculture-to-forest conversion, especially in the Ridge and Valley and Appalachian Plateau provinces, as fewer farms will exist to go out of production/business.*
- *Riparian forest buffer restoration will produce positive effects on a local level, but regional gains will remain small as limited progress towards restoration goals are largely offset by losses elsewhere.*

Assuming that recent trends are the best predictor under prevailing conditions, timberland ownership and use, as they influence forest cover, were reconstructed from 1955 to the present using U.S. Forest Service data.[48,49,50,51,52] Projections from the present through 2030 were then based on this trend, along with personal communication and professional judgment from forestry professionals.[53] "Timberland" carries a specific definition for the Forest Service: forestland that is producing or is capable of producing crops of industrial wood and that is not withdrawn from timber utilization by statute or administrative regulation. Acres qualifying as timberland are capable of producing more than 20 cubic feet per acre per year of industrial wood in natural stands. Given this definition, results show increasing forest cover in the Chesapeake Bay states over recent decades, with the increase apparently driven largely by greater acreage of private timberland. Clearly agricultural economics since 1950 have led to a large decline (>50 percent to date) in farmer-owned timberland. This decline was offset by a large increase in forest owned by other private citizens along with a relatively modest increase in public timberland. Although forest industry timberland also increased over much of the time period, this ownership category entered a phase of decline in the late 1980s that offset the gains of previous decades. Much of this industry timberland is not being lost, but is shifting to owners who do not engage in direct use of wood products.



*Kent Mountford*

This shift in private ownership primarily reflects two mechanisms: transfer of forest ownership as farmers retired or otherwise discontinued operation; and reversion of cropland to forest with retired or former farmers retaining ownership. Although the data do not separate these mechanisms, the latter category may well have a greater likelihood of further "parcelization" and fragmentation when the owner dies. Given the aging population and declining number of farmers, this decrease in forestland parcel size will likely continue through the next decade. In addition, the likelihood of cropland or grassland reversion to forest will depend on geography and the attractiveness of alternative uses, with rural upland areas showing greater gains in forests and farmland near metropolitan areas (especially on the Coastal Plain and Piedmont) having a greater chance of suburban development.

What are the characteristics of these new, private landowners? In general, the "new" forest landowner is younger, better educated, and earns more than the average owner of a decade ago. The percentage of retired owners increased significantly between 1978 and 1994 (rising from 22 to 31 percent) whereas blue-collar (26 to 16 percent) and white-collar (43 to 32 percent) owners declined. These "baby-boomer" owners are retiring sooner and living longer; many have a strong environmental ethic. Such demographics suggest two possibilities: new owners may not be inclined to harvest because they don't need the income and value forests as part of their residences or as personal green space; or these new owners may be inclined to harvest liberally for additional immediate income and because they lack detailed understanding of forest growth and health. In either case, this profile of the new forestland owner suggests individuals that should be readily approachable concerning professional advice on forest management and economics.

Current trends in forest ownership are likely to continue through 2030. Total timberland in the