

Land Development Provisions To Protect Georgia Water Quality

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Executive Summary

As the Twentieth Century nears its conclusion, Georgia finds itself undergoing a period of unprecedented growth. The population in the state has soared in the past ten years, and this trend appears to be continuing. School systems are strained to the limits of their capacity as more people move into the State. Cities and counties across Georgia struggle to provide infrastructure such as roads, bridges, and sewer systems to accommodate the growth.

This period of growth is also exhibited by the booming demand for the construction of new subdivisions, schools, office parks, and shopping centers. Every day, hundreds of acres of woodland and farm land are being cleared and leveled for these new developments. Unfortunately, along with the boom of new construction and economic prosperity, come harmful consequences to the environment as well as to the quality of life of Georgia's citizens.

The condition of Georgia's streams and other aquatic systems is being adversely affected by the recent practices in land development. These practices have acted to increase the quantity of impervious surfaces such as roads, driveways, and parking lots. Impervious surfaces prevent stormwater from following its natural route into and through the soil. The quality of the runoff has also declined as more pollutants from the impervious surfaces are carried directly into storm drainage systems and eventually into neighboring streams.

It would be easy to blame the real estate developers for all of these problems. It would also be wrong to do so. In fact, the developers are just following the ordinances developed by local municipal governments. Local land development codes have demanded wider streets, and curbs on every

street in new developments. The result has been to turn what should be quiet neighborhood streets into speedways. Local codes also frequently dictate excessive quantities of parking, resulting in vast expanses of unused impervious surfaces.

Zoning codes have required the separation of virtually all types of land uses. This segregation of land uses has greatly increased citizens' dependence upon the automobile. In most communities today, residents have no alternatives but to use their cars for virtually every trip to school, work, or recreation. There are alternatives to these patterns of development. This document offers some of those alternatives.

The alternatives frequently cost less to implement than the current practices that are being used. Thus neighborhoods and shopping centers can cost less to build. Citizens can have alternatives to using the automobile for every daily destination. And the water quality of Georgia's streams and aquatic systems can be protected or even improved in the process.

Land Development Provisions to Protect Georgia Water Quality describes provisions that could be modified in or added to local development regulations for the purpose of protecting water quality. The provisions outlined here are intended to address new development only. The scope of this project did not allow the opportunity to develop provisions aimed at the retrofit of existing urban and suburban areas.

The provisions outlined in this document were developed from reported experiences and studies around the country. They were refined in a series of dialogues with a task force of Georgia citizens. The task force contained representatives from local

governments, the land development industry, land planners, and environmental interest groups.

Municipal ordinances where these provisions could be used include zoning and subdivision ordinances, erosion and sediment control codes, stormwater management ordinances, and design standards documents. These types of documents control the construction and use of impervious surfaces by defining and segregating land uses. They define options for transportation and specify the dimensions and materials of streets, parking lots, and residential lots.

This document is intended to serve as a partial "menu" from which each municipality can select appropriate provisions and adapt them to the local conditions. The document explains the provisions' role in runoff water quality protection, and their effects of safety and cost. The provisions in this document are grouped into four general categories.

Land Development Provisions To Protect Georgia Water Quality

Overall measures of development

Density zoning is regulation of development intensity by the quantity of development on a site as a whole, not by minimum lot size. It gives flexibility to adapt to site-specific topography and drainage, locating streets, homes and lots in ways that are at once economical, environmentally protective, and appropriate to local markets.

Stream buffers are reservations of undeveloped land adjoining stream channels. Undisturbed buffer vegetation filters inflowing runoff, prevents channel erosion, and creates habitats for functioning ecosystems. Siting construction away from drainage courses avoids the costs associated with flood damage and poor drainage.

Limited impervious cover controls the proportion of a site that can be covered in impervious roofs and pavements without treating the runoff. Limiting unmitigated impervious cover controls the generation of runoff and pollution at the source, while allowing development of any type and intensity.

Land use combination blends different, but mutually supportive, land use types in the same zoning districts. Certain types of commercial and office uses can be combined with residential uses, reducing dependence on automobiles and the pavements they require, and the consequent auto emissions and runoff.

Paths for biking and walking allow individuals the choice of non-automotive transportation. Biking and walking reduce automobile use, the quantity of pavement, and the quantity of pollutants generated from paved surfaces. In most of Georgia, the moderate terrain and mild climate favor biking and walking.

Infill zoning allows relatively high-density, mixed-used development or redevelopment where it would be compatible with an existing neighborhood. The local concentrations of runoff and pollutants are of course high. But infill development limits impervious cover and auto usage in the region as a whole. It accommodates some growth without destroying pristine areas, and without requiring large quantities of pavement to support routine automobile use.

Streets and pavements

Limited street width and curbing limits street development to that needed for each street's specific function. This limits both runoff and construction cost. Narrow pavements encourage cautious driving, and eliminate the "speedway" feel of wide streets. They do not hinder emergency access, where they are correctly applied only to streets with little traffic and little on-street parking.

Limited pavement in turn-arounds eliminates unnecessary pavement areas at the ends of cul-de-sacs. In the centers of turn-arounds, pavement is unusable for vehicles. Replacing it with vegetated soil reduces runoff and provides infiltration and treatment. It reduces construction cost, but requires provision for maintenance.

Limited amount of parking eliminates unused portions of parking areas. In commercial and office areas, parking areas have been oversupplied. Limiting parking limits paved areas and runoff. It reduces construction cost and land consumption.

Porous pavement materials replace impervious pavements so the underlying soil can absorb rainfall and treat pollutants. Porous pavement materials can economically provide safer driving surfaces than the impermeable materials they replace. However they should be avoided on steep slopes.

Drainage

Drainage in vegetated swales carries, stores, treats and infiltrates runoff in contact with permeable soil. Where vegetated swales replace curbs or drainage pipes, they reduce construction cost.

Swale "biofiltration" velocity control assures effective runoff treatment and infiltration by prolonging contact with soil and vegetation. Although the quantity of treatment is small in a few large storms, the cumulative long-term effect of many small storms is vital.

Treatment of "hot spots" assures runoff treatment specifically at a few small, highly concentrated runoff and pollutant sources such as dumpster pads and gasoline stations. This secures "point" treatment, even where treatment of runoff from other impervious surfaces cannot receive the same degree of careful attention.

Inlet labeling identifies swales and drainage inlets to the public, and indicates their purpose. This inhibits dumping of pollutants and educates the public about the environmental systems around them.

Construction process

Limited clearing, grading and disturbance confines construction work to those areas that construction actually requires. This preserves existing trees and pervious soils that attenuate, treat and infiltrate rainfall and runoff.

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Introduction



Purpose of This Report

The process of developing land into subdivisions, shopping centers, or office parks typically has a tremendous impact upon the quality of streams in the vicinity of the development. In many cases, the land development regulations under which many of these types of developments are built, both unnecessarily restrict the developer and do little to protect the neighboring streams from longterm impacts.

Land development regulations can hurt Georgia's streams, or help them. By writing informed provisions into development regulations and keeping unconstructive ones out, it is possible to improve water quality, reduce erosion, and maintain water supplies and stream ecosystems while each watershed and each municipality develops functionally and economically.

Stormwater management has in the past been seen as a separate technical component of development. It has been aimed exclusively at drainage and flood control during large storms that occurred only at intervals of years. And it has been implemented exclusively with specialized add-on structures; land uses themselves were unchanged.

Today's concern with runoff quality places new demands on some aspects of urban development — while telling us to reduce the stringency of regulating certain other aspects. The way to develop with more environmental sensitivity is, in many instances, to develop more economically.

Every time rain falls on an urban development, it washes off oils, bacteria, litter, sediment, fertilizers, and foreign chemicals from streets, parking lots, lawns, dumpster pads, and metal roofs. The streams erode with great volumes and rates of runoff. Stream habitats, wetlands, and water supplies are lost to flooding, pollution, erosion, and summer drought. Knowledgeable design of urban development can solve the problem of runoff quality at the source — in the land uses where pollutants are first generated and rain water first touches the ground. The solution is embedded in transportation, land use, soil and vegetation, and only secondarily requires separate engineering structures. Georgia's municipalities can guide their new development to meet these concerns.

This report outlines the types of provisions that could be modified in or added to local development regulations that could improve runoff quality. "Runoff quality" as used in this report includes the quantity of runoff during storms, its constituents, and all of its direct and indirect effects on ground water, water supplies, streams and wetlands. The report explains the potential provisions' roles in runoff quality protection, and comments on their effects on cost, safety, and other issues. More is known, scientifically, than is being put into practice today in Georgia's development patterns. Dissemination and implementation of new practices has been below the state of the science and below the needs of Georgia's watersheds.

The provisions in this report were developed from reported experiences and studies around the country, and refined in dialogs with a task force of Georgia citizens and government and business representatives. Further comments and experiences are welcome: send them to Georgia Environmental Protection Division, NonPoint Source Management Program, at the address listed at the end of this report.

The provisions can be used in the existing ordinances through which municipalities are already regulating new development and its runoff: zoning and subdivision ordinances, erosion and sediment control laws, tree protection ordinances, stormwater management ordinances, and design standards documents.

The existing ordinances in Georgia's municipalities do not have enough detailed provisions in common to justify characterizing a "typical" existing ordinance (six of them were reviewed as part of the background study for this report), even though the general practices that are being used in streets,

pavements, residential development and stormwater management are more or less conventionalized state-wide. At issue are not “typical” existing provisions, but the extremes, wherever regulations rigidly require homogeneous and over-engineered land use to the detriment of the environment and the economy alike.

This report begins with two sections introducing the problem of runoff quality and its relationship to urban development, before outlining the potential provisions. People who are already familiar with how urban runoff is generated can go directly to the provisions in Section 3. Others, who need to be introduced to the issues that provide reasons for controlling development this way, can invest time reading Sections 1 and 2.

The provisions in Section 3 comprise at least a partial “menu” that can act as a base for selection and refinement. Section 3 is not a technical manual for “best management practices”: This section addresses the form and pattern of new development, not the BMPs that are attached to it.

Neither is Section 3 intended to be a “model ordinance” to be adopted as a whole. Individual municipalities must make choices based on their own experiences. A municipality may choose to adopt some provisions and not others, or to modify details of a provision before adopting it. But all the listed provisions can work together toward the same end of improved runoff quality.

Most of these provisions contain their own “incentives”. To municipalities, they help meet legal requirements to control non-point source pollution. To developers, they can reduce construction cost, allow greater flexibility in design, or prevent later maintenance problems. These advantages can, by

themselves, be economically persuasive. However, some municipalities might choose to add incentives for developers to use some of these provisions fully. For example, developers who preserve fully effective stream buffers could be given density bonuses, in which they are allowed to develop more intensely on the land remaining outside the buffer.

At stake are the aquatic and riparian habitats of Georgia’s urban watersheds, and the water supplies, streamside properties, and human health that depend on them. The issue of runoff quality is driving exploration and adoption of new development approaches. It is working in parallel with simultaneous concerns about energy conservation, open space preservation, cost of living, traffic congestion, air quality, and quality of life. This report is intended to contribute to the knowledge and use of what is possible.



Section One: The Rise and Fall of Runoff Quality



Georgia's urban development has always been "managing" runoff quality — inadvertently. The following reviews the effects that past and present land use have had, to establish a base for where we are now, how we got that way, and the kinds of changes that may now be necessary.

A natural system that works

In undisturbed Georgia forests, soils evolve, out of physical necessity, to absorb the state's rain and make it part of the ecosystem. Roots of grasses and trees reach into the soil; root hairs separate mineral particles; ants and beetles excavate voids in the soil; roots decompose, leaving networks of macropores; leaves fall from the trees each autumn to form a mulch over the soil; earthworms pull the leaves into their burrows, where they ingest them and add their organic matter to the soil structure; the boles fall to the earth and feed mosses as they decompose. Mineral soil is made

open and porous. Clay takes on the permeability of gravel. William Bartram saw this kind of soil when he walked through Georgia two centuries ago, and nature is working to maintain and restore it whenever natural processes are given a complete chance to work freely.

By accepting and absorbing rainfall, Georgia's native environment maintains its equilibrium and its health. Organic matter and soil pores suspend the water in the soil, making it available to the roots of native plants. They filter out passing solid particles and build them into the soil matrix. Storage in the soil turns intermittent pulses of rainfall into a perennial moisture supply. Microorganisms decompose pollutants and turn them into nutrients for the living system. Deeper below, sheets and pools of ground water discharge to streams slowly, and almost steadily, months after the rain falls, to the streams and wetlands where aquatic organisms survive over dry summers.

To Georgia's people, it is of great benefit — or at least potential benefit — that nature evolves to work that way. Where we allow the system to work, water that infiltrates the soil replenishes the aquifers where we take our well water. Its gradual discharge from the earth makes floods moderate. The streams and reservoirs are full of water and fish, the wetlands are sustained, and erosion is unknown. These naturally sustained qualities decrease care, work, and worry; where they are allowed to persist, they make controls and replacement systems exceptional rather than routine.

Early urban development

Urban development has been changing all that. Impervious pavements are collection pans that concentrate runoff and all the pollutants that accumulate on them, and propel everything immediately into streams without treatment.

A hundred years ago, of course, there were fewer people in Georgia. But the forms we gave our cities and the ways we lived in them helped keep us relatively out of nature's self-regulating way.

At that time, pedestrians shared the rights-of-way with streetcars and horse-drawn vehicles. Railroads were the best way to travel from one town to the next. Traffic control was almost unnecessary because of the low number and low speed of vehicles. Publicly accessible streetcars and trains moved large numbers of people cheaply. They supported downtown business districts by bringing shoppers and workers from all over the urban regions. Development in the suburbs was kept within walking distance of streetcar lines. Land use combinations evolved within the constraints of daily walking distances.

City streets were paved with cobblestones, permeable to small amounts of rainfall and runoff. Minor residential streets had no curbs; instead they were usually flanked by swales or ditches that kept streets passable during moderate rainfalls. Undersized and often partially blocked culverts at driveways and intersections typically caused the swales to store the watershed equivalent of half an inch of runoff (Jones, 1989).

Auto-oriented development

Since the automobile was developed in the early years of this century, its use has been subsidized with public investment and land use regulation. Local governments spent million of dollars to widen the cobbled streets and repave them with asphalt. Traffic signs and signals were installed by the thousands. Police forces were enlarged and motorized to control traffic. A commission under President Hoover concluded that the automobile was the "most potent influence" on the rise of local taxes between 1913 and 1930 (Kunstler, 1993, p. 90).

The federal government began subsidizing auto use in 1916 and 1921 with Federal Road Acts to construct and improve auto roads, support the formation and operation of state highway departments, and link state highways into national networks. To enable Georgia to participate in the new program, the General Assembly created a State Highway Board in August 1916. The law provided that when the Board disagreed with local authorities, "the judgment of the State Highway Board shall prevail" (Kundell et al., 1989, p. 66). In 1925, federal highway spending topped \$1 billion per year. In 1956, the federal government began the Interstate system, which added 41,000 miles of connecting and beltway expressways and subsidized the widening of local roads to collect auto traffic onto them. By the early 1970s paving was referred to as "the nation's biggest endowed business" (Sorvig, 1993). In the United States each year we are paving or repaving half a million acres (Ferguson, 1996).

The new highways opened up remote hinterlands to suburban development. Georgia's citizens moved from farms to urban areas, and from the central sections of cities to the fringes. Sewer and water lines were extended into low-density suburbs.

City development was refitted to accommodate the car. Zoning codes, originally devised to protect residential neighborhoods from incompatible industries, grew to segregate every detailed category of land use from every other. They imposed exclusive reliance on cars for daily transportation by requiring homogeneous, low-density residential development across large areas. Street pavement widths increased by more than 50 percent to favor rapid, unobstructed automobile traffic. Parking lots became essential adjuncts to suburban stores and offices that had once fronted on city sidewalks. In

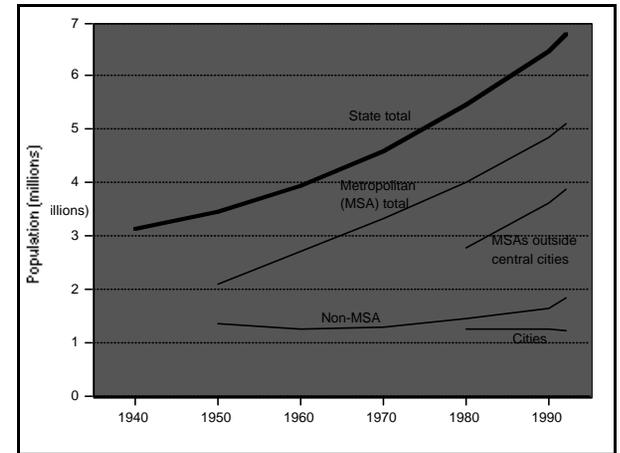
most suburbs, it is physically dangerous to attempt to travel even short distances on routine business by any means other than a car. The amount of driving costs American people time in cars equivalent to weeks per year.

As land uses spread farther apart with only auto roads as connectors, more cars were needed to link them back together, and more asphalt and concrete were needed to maintain the connectors. Following the principal of traffic generation, each highway built to alleviate congestion on an earlier existing road generated a larger aggregate amount of traffic for all roads.

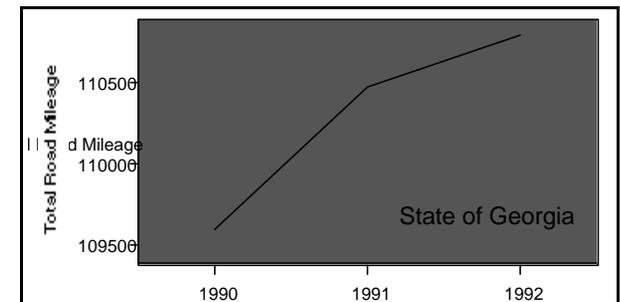
Effects of impervious surfaces

All development requirements that increased the dimensions of streets, driveways and parking lots while multiplying demand for auto transportation, caused increased impervious pavement. The new impervious pavements generated runoff. The new curbs made structural channels that accelerated it.

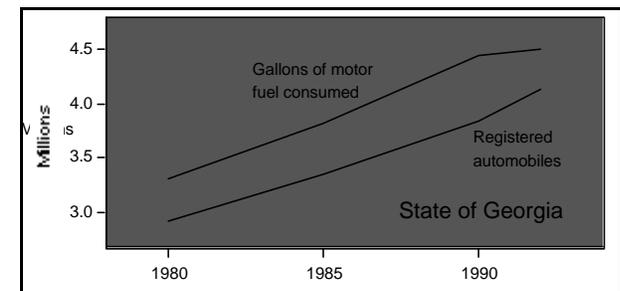
Impervious surfaces include typical roads, rooftops, parking lots, driveways, sidewalks and patios. Almost any contemporary land use produces impervious coverage over 10 percent. Even residences dispersed on 2 acre lots produce impervious cover of 12 percent. Denser residential densities produce greater concentrations of impervious cover; the percent coverage ascends through industrial and office uses to shopping centers, at nearly 100 percent coverage. Of the impervious areas, the pavements of the roads and parking lots, where cars are, make up the major portion.



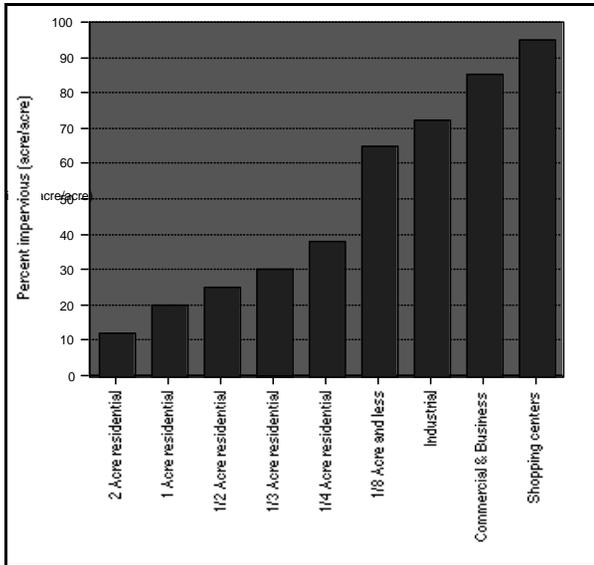
Georgia's growth (Akioka, 1994).



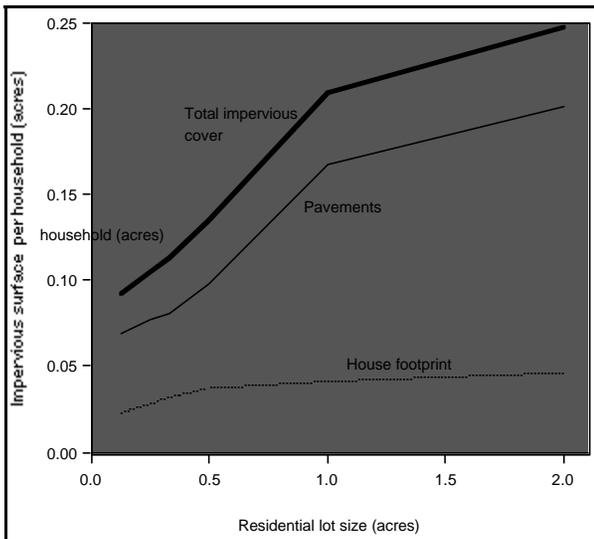
Georgia's investment in roads (Akioka, 1994).



Georgia's growth in cars and their use (Akioka, 1994).



Most impervious surfaces are pavements



Residential effects on impervious surfaces

Impervious roofs and pavements are collection pans and discharge chutes for rainwater and pollutants. They seal over the soil pores, depriving the root zone of water and air. They deflect rain water into surface channels, where it concentrates into downstream floods. Runoff carries with it oils from cars, parking lots, maintenance yards and storage areas; metals from construction materials; and herbicides, pesticides and nutrients from over-maintained landscapes.

Streets and parking lots, with the automobiles that use them, are the impervious surfaces having the greatest area and highest pollutant loads in most land use categories. Automobiles drop hydrocarbons from oil, and metals from the wearing of brake pads and tires; all are washed off pavements and into streams by runoff. Autos are the biggest source of pollutants in urban areas, after soil and streambank erosion. Auto exhaust emissions pollute the air, and end up back in the runoff with precipitation.

In the days or weeks between rain storms, oils and sediments accumulate on pavements. When the first rain falls on pavements, essentially all of it turns to runoff. It flushes the accumulated pollutants into streams, concentrating them in the “first flush” of every storm. As the rain continues, growing volumes of runoff erode stream banks, destroying habitats and producing further sediment pollution. Stream bed materials shift; banks slough in; biota of all types are flushed out of shifting chute-like channels. After the storm flow passes, base flow declines (Ferguson and Suckling, 1990). Fish gasp for oxygen in the shallow, warm, sluggish water.

Roofs are among the smaller impervious surfaces, seldom exceeding half of all urban impervious cover (Arnold and Gibbons, 1996). Their contribu-

tion to runoff is proportional to their area. Many residential roofs drain to lawns or foundation plantings without direct connection to drainage systems, further reducing their runoff contribution. In terms of water quality, the runoff from roofs is usually relatively benign.

Stream and wetland health, as measured by criteria such as pollutant loads, habitat quality, and aquatic species abundance and diversity, decline with overall impervious coverage. Significant impacts begin at 10 percent coverage. At impervious coverage over 30 percent, impacts on streams and wetlands become severe and degradation is almost unavoidable (Arnold and Gibbons, 1996). Three broad categories have been established using simple numeric thresholds illustrating the general relationship between impervious coverage and stream health:

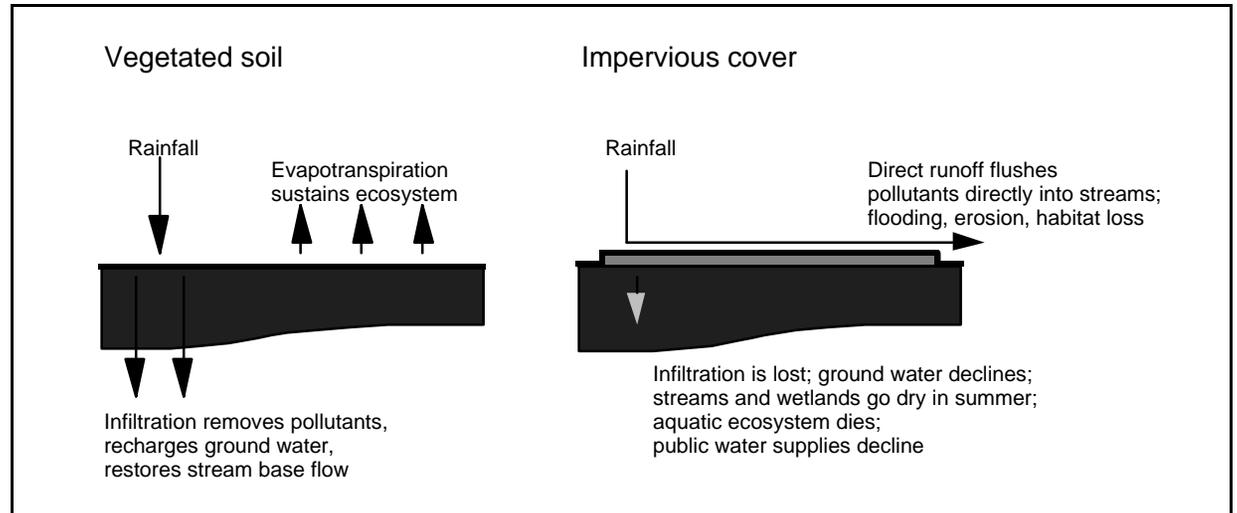
Impervious coverage	Stream health
<10%	“Protected”
10 to <30%	“Impacted” if not mitigated
≥30%	“Degraded” if not mitigated

In addition to the impervious surfaces, urban lawns can produce surprising quantities of nitrates, phosphates and organic chemicals. In the U.S., lawns cover a greater land area than any one agricultural crop, and many are maintained so intensely that excess herbicides, pesticides and fertilizers leach out and overbalance stream ecosystems (Bormann, Balmori and Geballe, 1993).

Many Georgia communities have required stormwater detention in new developments, to reduce the peak rate of flow leaving each development site. But detention has failed to fundamentally solve drainage problems downstream, because it does not reduce flow volume, and the timing of tributary flows bring them together in unforeseen



Residential effects on water quality



peaks (Hess and Inman, 1994). Even where detention successfully reduces the peak rate of flow, it does not remove pollutants, prevent stream erosion or restore base flow. The quality of land uses remains the source of the problem.

Today's urban watersheds

Today, urban streams are the most disturbed and degraded in Georgia (Mikalsen, 1993). The beneficial uses of the state's urban streams not influenced by wastewater discharges have been severely impaired in four of five cases and the impacts are much greater than in streams influenced by agriculture and silviculture (Mikalsen, 1989). Downhill portions of communities today are suffering frequent flooding where they rarely

occurred in the past (Jones, 1989). In watersheds with significant impervious cover, stream bank erosion is commonplace, and chemical, biological, physical and thermal water quality is poor. Georgia's urban streams have been characterized by high bacterial density, high oxygen demand, high concentration of solids and nutrients, high turbidity, and high concentrations of metals and organic compounds. The numbers and diversity of fish are low, and they decline as the density of land use in the drainage area increases.

Hardly 7 percent of Georgia's land is classified as urban (Akioka, 1994), but this is where 74 percent of the people live. They live among the most degraded streams in the state — and runoff

problems are only one kind of symptom of the problem of urban sprawl. Today's cities and suburbs suffer from traffic congestion, energy consumption, air pollution, and daily dependence on automobile transportation. Each year residents pay millions of dollars in excess taxes to support the sprawling roads and utilities, and each family pays thousands of dollars for the cars that require it (Keys, 1997). The pattern of development is the source of the problem, and the biggest part of any real solution.

Section Two: Patterns of Development That Affect Water Quality

Georgia can accommodate all of its anticipated population growth without causing further harm to its streams, as long as the pattern of development is different from that of the last half-century.

The appropriateness, cost and effectiveness of specific land use patterns and drainage practices depend on conditions where they are applied, and their integration with each other and with the surrounding community. Porous soil, native vegetation, streams and riparian corridors are present in all regions of Georgia. However, each economic and natural region presents a distinctive combination of relative constraints and opportunities. In the Ridge and Valley region of the northwest, different soil types, like the highways, follow the linear hills and valleys; valuable ground water is present in valleys that are underlain by limestone. In the mountains of the Northeast, soils are shallow, and slopes are steep and sometimes potentially unstable; development often creeps up from the valleys onto the slopes. In the large Coastal Plain of the south, widely varying sands, clays and loams follow the underlying sedimentary layers; in low-lying places ground water mounds up to the surface. In the Piedmont, where the most rapid and extensive urbanization is, fine-textured soil mantles low hills where old roads and towns are located; the only systematically occurring masses of ground water

are in low areas along streams and rivers.

Transportation

In Georgia today, the demand for pavements and the generation of pollutants upon them is a function largely of the amount and kind of transportation. A given population can reduce its need for pavements by reducing the dependence on the automobile.

As alternative means of transportation, walking and biking save energy, reduce traffic congestion, improve air and water quality, and reduce street noise. They maintain individual health by combining exercise with commuting. Because of their low cost, they meet the transportation needs of all classes of people. Walking and bicycle traffic are compatible with residential streets in a way that automobile traffic is not. The traveling lanes for bikes are only half as wide as those for cars. More than 15 bikes can be parked in the space required for one car. Allowing people to walk among nearby related land uses prevents pollution in the most effective way: by never generating it in the first place. Where people are not using their cars, there are no emissions.

Development that allows non-automotive transportation provides compact mixes of land use

where most of people's everyday needs can be met within small distances. It provides safe and convenient paths for local walking and biking. This kind of development produces little total runoff, and little pollution in the runoff.

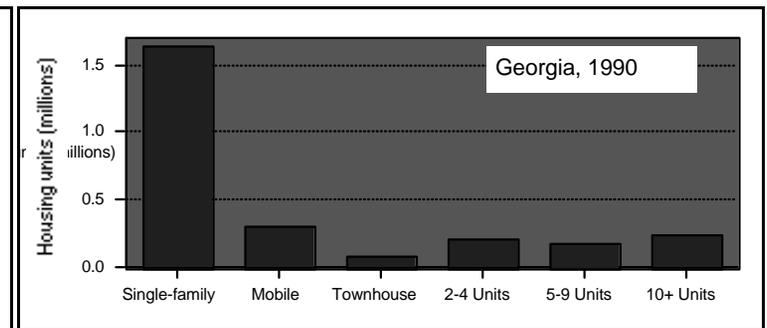
Land use intensity and diversity

Many municipalities have the opportunity to distinguish between sprawling outlying areas where dispersed, low-density land use would depend on the automobile, and the vicinities of old towns where infill developments would complement old land use and transportation patterns. As a municipality develops, both patterns of land use increase impervious cover, but they do so to different degrees and in different ways.

Very large, homogeneous residential lots are a way to protect runoff quality, in the locale where they are used. For example, in the sensitive drainage areas of water-supply reservoirs, communities in Georgia and North Carolina have adopted minimum lot sizes of three to five acres (Cowie and Cooley, 1988, p. 11-12). This effectively limits population and impact in those local watersheds. The runoff from such dispersed residences is relatively easily absorbed by the large amount of vegetated soil.

	High density, diverse (infill) land use	Low density homogeneous (dispersed) land use
Land consumption for a given population	Low	High
Total quantity of runoff and pollution for a given population	Low	High
Local concentration of runoff and pollution	High	Low
On-site absorption of runoff and pollution	Low	High

The distinction between two types of land use patterns.



Most of Georgia's housing is in dispersed single-family residences.

However, on a regional scale, dispersed land use creates large total and per capita quantities of runoff and pollutants. Because the amount of area cleared, graded, and paved to connect a given number of dispersed buildings is large, autos are necessary for transportation. The sprawling fabric disperses a given amount of development over a large area, leaving few remaining areas pristine. Within the overall sprawling pattern, low-density residences are inevitably supported by intensely paved shopping centers, commercial strips and connecting highways, as big and intensely paved as any old town center.

Infill development includes building in vacant parcels near town centers, and redevelopment of parcels with deteriorating or underused structures. Infilling at high densities works together with mixing of land use types to make nonautomotive transportation a viable alternative.

Infill development in and near older developed environments results in high imperviousness in those town centers. The local concentrations of runoff and pollutants are high because pavements, autos and people are concentrated in small areas. But accommodating a given amount of development in a few dense locales leaves other large areas pristine (Real Estate Research Corporation, 1974, p. 50). It limits impervious cover and auto usage in the region as a whole. It uses schools, transportation services, roads and sewers efficiently. Annual road maintenance costs are sometimes only one quarter of those for dispersed land use (City of Olympia, 1955, p. 68).

As an overall model of development, the “traditional town” pattern can produce layouts that are mixed-use, compactly adapted to specific sites, and pedestrian-accessible. Computer modeling of a traditional town design in South Carolina found that the traditional town would perform better than nearby suburbs in all aspects of runoff quality (*Nonpoint Source News-Notes #44*, 1996, p. 11-

13). On a 583-acre site, the traditional town plan provided relatively high residential densities, mixed residential and commercial land uses, and street and parking configurations following those in nearby older towns, while preserving open spaces along stream corridors. A contrasting layout for the same amount of residential, commercial, office and industrial uses on the same site developed all available land, segregated large areas of single-family houses from commercial areas, and used lot sizes, street widths and parking configurations specified in existing local ordinances. The traditional town used less impervious surface to serve the given land uses. It also reduced automobile use (because contiguous land uses allowed some walking and biking) and lawn fertilization (because lawns were smaller). Consequently, it generated 43 percent less runoff during storms, and 67 percent less sediment.

Adaptation to site

The cluster concept has been advocated as an alternative to homogeneous sprawl since the 1920s. On a given development site, cluster development concentrates a given quantity of land use on the most suitable portion of the available land, leaving the remainder in vegetated, permeable soil. Cluster development utilizes a site’s full development potential while preserving open space such as stream corridors and steep bluffs. It minimizes the construction costs of buildings, streets and utilities.

Cluster’s advantages specifically for runoff quality have been seen for decades. Where cluster development is competently implemented, it concentrates construction where drainage can be most efficiently handled, and leaves the bulk of the natural drainage system alone to carry and treat the runoff through vegetated open space. In contrast, homogeneous, sprawling development generates large quantities of impervious surfaces and runoff, requiring long, large and expensive drainage systems, at the same time, paradoxically, that it cuts

down the capacity of natural drainage systems to convey and treat the runoff by blocking them, filling them, and paving them over (Whyte, 1964, p. 19-20).

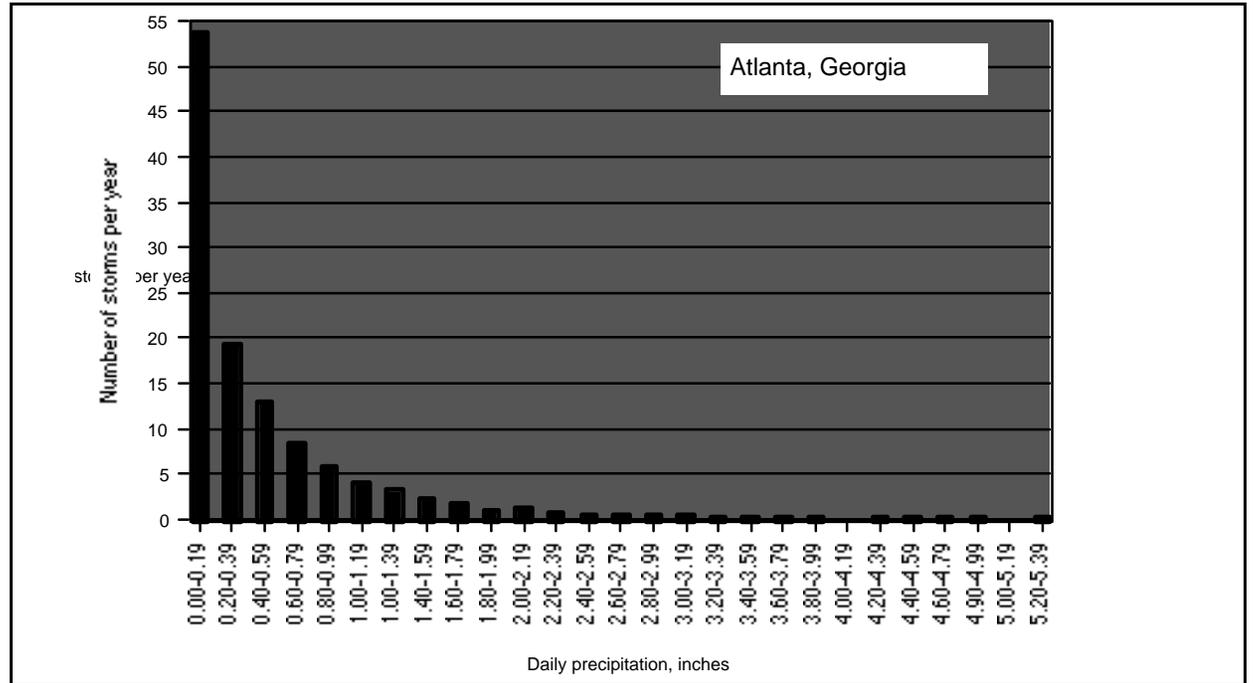
Construction dimensions and materials

Given a type and quantity of land use to be developed, the dimensions of pavements can be limited to efficiently fit the specific functions they serve. Studies have found that suburban office parking, for example, has been oversupplied nationwide by about one third (Wilson, 1995). For local residential streets, some municipalities require uniformly wide pavements when pavements one third smaller would do. Excess pavements that are unused by people are “used” by rainfall during every storm to generate runoff and flush pollutants. Limiting the dimensions of pavements that serve a given land use can reduce runoff and pollution. It limits the “heat island” effect that raises temperatures and requires more energy for air conditioning. It reduces construction and maintenance cost.

Given a required area of pavement, many large pavement areas can be made permeable. Permeable pavement brings rain water into contact with the underlying soil, giving it the chance to infiltrate and improve quality before draining into ground water or streams. Two old, reliable and low-cost permeable “pavement” materials are grass and crushed stone (“gravel”), which have been used everywhere for overflow parking, parking stalls, residential drives and pedestrian areas. Since about 1970, porous asphalt, porous concrete, and open-celled pavers have opened permeable pavements to streets, golf cart paths, bike-ways, sidewalks, emergency access lanes, and highways. Today’s availability of a variety of alternative paving materials admits a wide range of applications, amid varying cost, aesthetic, and traffic constraints. Ideally, impervious pavements need be built only as special cases, in response to specific local on-site hazards such as unstable soil.



Vegetated swales



Most rainfall comes in small storms.

Drainage Restoration

Drainage restoration needs to start at the sources of runoff, with small, numerous swales near the downspouts of buildings and the edges of pavements all over each development area. As the remaining excess runoff continues downstream, it should continue to be treated by getting it repeatedly into contact with vegetation and soil in a series of swales and basins.

There will always be some runoff left, from roofs and unavoidable impervious pavements. The remaining runoff must, to the highest degree possible, be moderated, treated, and returned to its restorative path in the soil. Drainage systems that do so compensate to a degree for the impervious cover that is built.

Runoff should, to the extent possible, be conveyed in vegetated swales, not paved gutters or structural pipes. Vegetated soil infiltrates, treats and stores rainfall and runoff, and discharges it gradually to streams weeks after storms are past. It is a substrate for microorganisms that biochemically transform and destroy pollutants. Gentle swale gradients and, where necessary, check dams, produce low velocities that prolong contact with soil and vegetation, assuring effective treatment.

Shopping centers are such intense developments that there is almost no room left over for vegetated swales and ponds. In this kind of development, drainage can still be restored with infiltration basins constructed of open-graded aggregate under the land surface, leaving the surface to be reclaimed for parking or other functional uses.

Slowly permeable soils such as those in the Piedmont improve water quality substantially during small storms and the beginning of large storms, and restore a substantial portion of annual rainfall to the soil. In these soils infiltration cannot reduce peak rate of discharge during the big storms for which flooding and drainage overflows are issues. Nevertheless, treating only a small volume of water for each runoff event is sufficient to restore most of a watershed's function. Water quality is a concern in every small storm. For ground water replenishment, most of the water that is available over a year is in small, frequent storms.

Section Three: Specific Potential Provisions

The following are specific provisions that can be adapted and incorporated into local development regulations. In putting each of them to use in local ordinances, jurisdictions may adapt the specific wording to fit local needs. Each one can help runoff quality when used alone. They can all also work together as a system; every one reinforces the effect of every other. They begin with overall measures of development, then focus on specific components of streets, pavements, drainage, and construction process.

OVERALL MEASURES OF DEVELOPMENT

Density zoning

Provision: *This provision is intended to regulate development density by specifying an allowable amount of development per acre, not by specifying a minimum lot size.*

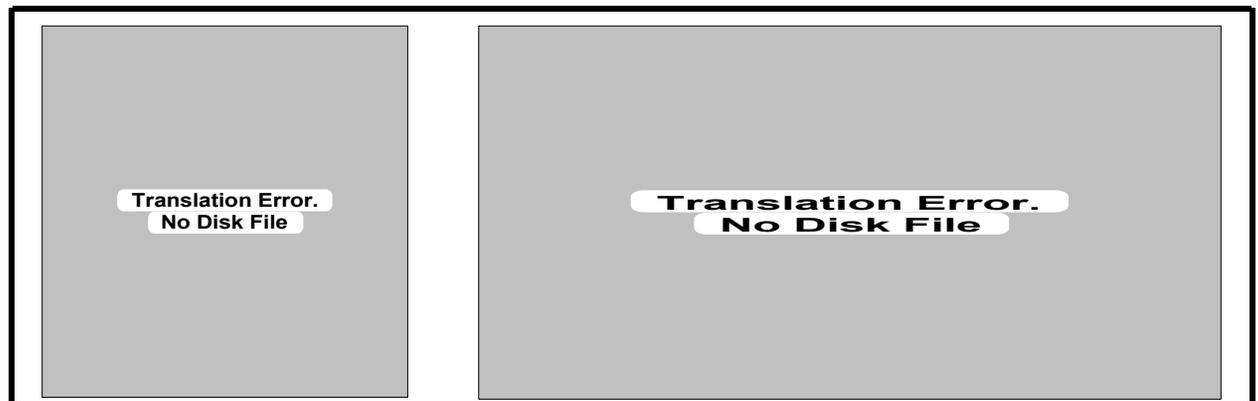
Example of typical existing provision:	Example of potential provision:
In residential zones, minimum lot size such as 0.5 acre applies to every lot.	In residential zones, maximum density such as 2 homes per acre governs allowed quantity of development.

Purpose:

- Density zoning gives freedom to the ingenuity of designers and developers to adapt to site-specific topography, drainage and technical constraints. The developer can locate streets, homes and lots in ways that are at once economical, environmentally nondestructive, and appropriate to local markets, on a site-by-site basis. This freedom is almost essential for complying with a stream buffer requirement.
- identify floodplains, stream buffers, steep slopes, valuable trees, and other features to which the layout should be adapted.
- If a municipality chooses to require the dedication of open space in density-zoned districts, then the type of zoning could be called “cluster zoning” or “open space zoning”.
- When density zoning is used to its full advantage, it can result in economies in streets, utilities, and drainage structures.
- Density zoning’s flexibility allows preservation of sensitive areas of a site, whether or not those areas are protected by ordinances.
- When used together with a stream buffer requirement, density zoning assures that stream channels and riparian corridors can be preserved within the constraints of costs, markets, and specific sites.

Issues:

- In the zoning districts where density zoning applies, it replaces zoning by minimum lot size.
- Density zoning by itself does not require clustering of houses or dedication of open space. It leaves the flexibility to adapt to specific sites and development conditions by using different lot sizes, whether larger or smaller than the average. It may be used to produce clustering and dedicated open space in some developments, and not in others.
- Taking full economic and protective advantage of density zoning’s layout flexibility requires site analysis, before layout decisions are made, to



Density zoning gives the flexibility to protect stream buffers.

Stream buffers

Provision: *This provision recommends the preservation and maintenance of undeveloped areas around streams that protect stream quality.*

Example of typical existing provision:	Example of potential provision:
Site layout should assure that roadways, buildings, and other features of development conform to the site's particular topography, soils, drainage patterns and natural vegetation.	All clearing, earth moving, construction, and ground disturbance must remain at least 75 feet from channels of perennial streams and outside the designated 100 year flood plain. Exceptions include bike and foot path of permeable material, utility crossings, road crossings perpendicular to the stream, and wetlands for stormwater treatment.



Residential stream buffers

Issues:

- Separating clearing, earthwork, and construction from streams with vegetated riparian areas prevents direct discharge of sediment, excess runoff, and urban pollutants. Water flowing from the developed uplands is given time and room for attenuation and treatment in riparian soil and vegetation (Welsch, 1991).
- Stream buffers filled with native vegetation raise residential property values (EPA, 1995).
- Setting aside stream buffers without financial sacrifice requires density zoning, so that a given quantity of development on a site can be flexibly arranged without encroaching on streams.
- Keeping buildings, streets, parking lots, and other construction out of flood plains prevents the cost of damage to homes, roads, and people. It reduces construction and post-construction drainage problems resulting from flooding and poorly drained soil.
- Unobstructed flood plains allow flood waters to disperse and attenuate, reducing flood peaks.
- Vegetated buffers provide "right of way" for a channel's natural lateral movement, while self-regenerating vegetation slows stream bank erosion.
- Stable vegetation around streams creates habitats for functions aquatic and riparian ecosystems. It regulates shade, temperature, and nutrient balance, and produces woody debris that structures aquatic habitats (Welsch, 1991).
- A careful combination of distance and flood plain restrictions encompasses, without exceeding, the corridor where essentially all vital riparian hydrologic and ecological functions take place, including wetlands, alluvial soils, and riparian vegetation.
- The specific limit of 75 feet is based on ecological research which has derived the following functional zones around streams in the eastern United States (Welsch, 1991, p.11):

Purpose:

- For protecting runoff quality, stream corridors are the specific features of sites to which development must conform. Stable vegetation in stream buffers filters inflowing runoff, prevents channel erosion, and creates habitats for functioning ecosystems. Siting construction and earthwork away from drainage courses preserves vegetated buffers and protects stream quality.

Distance from stream bank	Zone	Function and required management
0 to < 15 feet	Undisturbed forest	Maintenance of stream habitat with shading and production of organic matter and woody debris. No disturbance permitted.
15 to <75 feet	Managed forest	Sediment and nutrient uptake and transformation. This zone must be wide enough to filter sediment from surface runoff: effective removal depends on uniform, shallow flow. Compatible management need not reduce the effectiveness of this zone.
< or equal to 75 feet	Runoff control	Runoff entering the stream corridor from outside must be converted to slow, nonerosive flow with vegetated swales, infiltration basins, or additional buffer width.

- A 75 feet wide buffer based on runoff quality function is within the range established by previous initiatives in Georgia. The 1989 amendment to the *Georgia Erosion and Control Act* requires a 25 feet wide undisturbed vegetated buffer between flowing streams and land disturbing activities. The state's 1991 *Mountain and River Corridor Protection Act* specifies a 100 feet wide natural buffer on either side of a river with a mean annual flow of 400 cfs or more (Mikalsen, 1993).
- The "managed forest" zone of streamside buffers is an appropriate place for greenway trails for recreation and nonautomotive transportation, certain utility line crossings, and stormwater wetlands.
- In order to assure compliance during construction, buffers need to be clearly marked on the site with stakes, ribbons or silt fences.
- Stream buffers in either public or private ownership meet at least some of the hydrologic and ecological objectives of buffers. Simply leaving stream corridors uncleared in the backs of private lots is a practical means of compliance for some developers on some sites. That kind of development can be controlled by simply regulating initial clearing during development. Stream buffers that are legally set aside in public or semipublic easements or open spaces can be developed for access to the water and as greenway links among neighborhoods.
- Buffers in private ownership should be recorded on deeds as utility and drainage easements.
- The remaining provisions in this report are aimed at the outermost zone in the aforementioned table. In the "runoff control" zone, runoff is delivered from the urban construction area to the riparian corridor. Runoff must be delivered with rate and volume quality such that the regenerative processes of the riparian corridor can absorb them and build them into the riparian ecosystem.



Streamside buffers are excellent places for greenway trails



Streamside buffers can be linked to form neighborhood parks

Impervious cover

Provision: *Limitation of the total amount of impervious cover that can be installed in a development.*

Example of typical existing provision:	Example of potential provision:
[No provision in typical ordinance]	Total impervious cover not mitigated by vegetated swales or infiltration basins shall not exceed 10 percent of the total site area draining to each drainage discharge point.



This provision would prohibit the use of excessive impervious cover as seen in this photo.

Purpose:

- This provision limits total runoff and the pollution it carries by controlling the unmitigated impervious surface coverage in new development.

Issues:

- Limiting impervious cover reduces the generation of excess runoff and nonpoint pollution at the source. Runoff that is generated on the remaining impervious surfaces can be effectively treated by contact with the adjacent vegetated soil.
- The specific limit of 10 percent unmitigated impervious area allows the construction of unmitigated impervious roofs and pavements up to the amount that causes watershed impact (Arnold and Gibbons, 1996).
- This kind of provision allows each developer to trade an amount of mitigation for an amount of impervious cover. If a development provides no mitigation with vegetated swales or infiltration basins, then total impervious cover is limited to 10 percent. If a development contains mitigative protection, then the intensity of coverage can be increased. Impervious covers that are mitigated by vegetated swales or infiltration basins are disconnected from the direct drainage system that takes runoff to streams. Their runoff has the opportunity to attenuate, infiltrate, and be treated before joining the drainage system downstream.
- This kind of provision also allows each developer to trade an amount of porous pavement material for an amount of paved surface cover. Only strictly impervious surfaces need to be limited in order to protect stream health; these include the roofs of buildings, specifically impervious asphalt and concrete pavements, and other specifically impervious pavement materials such as mortared masonry. Unlimited porous surfaces can be built; they are not counted in impervious cover. Pervious surfaces include porous asphalt and concrete pavements, crushed stone and gravel pavements, grassed parking areas, wooden decks, open-celled pavers, pavements of spaced unmortared masonry, and turf lawns and sports fields.
- Qualifying the limit on cover by both strictly limiting only impervious cover and allowing any excess impervious cover to be mitigated allows land use of unlimited intensity. These “safety valves” allow land use of any desired intensity, without exceeding a threshold that would impact stream health. Without them, a limitation of impervious cover would encourage sprawl by requiring all developments to be of low intensity.
- Under a limitation of this type, intense land uses such as offices, shopping centers, and multi-family residences must be allowed to use flexible layouts and permeable pavements. Clustering of site layouts, reduction of street lengths, sharing of driveways, permeable pavement materials, and drainage swales in the remaining vegetated area are all necessary to allow intense land uses to meet a rigorous limitation on impervious cover. Other provisions listed in this report supply ways for developments to meet such a limit.
- Impervious cover is measurable in proposed site plans using ordinary scaling techniques.

Land use combination

Provision: This provision is intended to mix different types of land use to reduce the need for transportation between them.

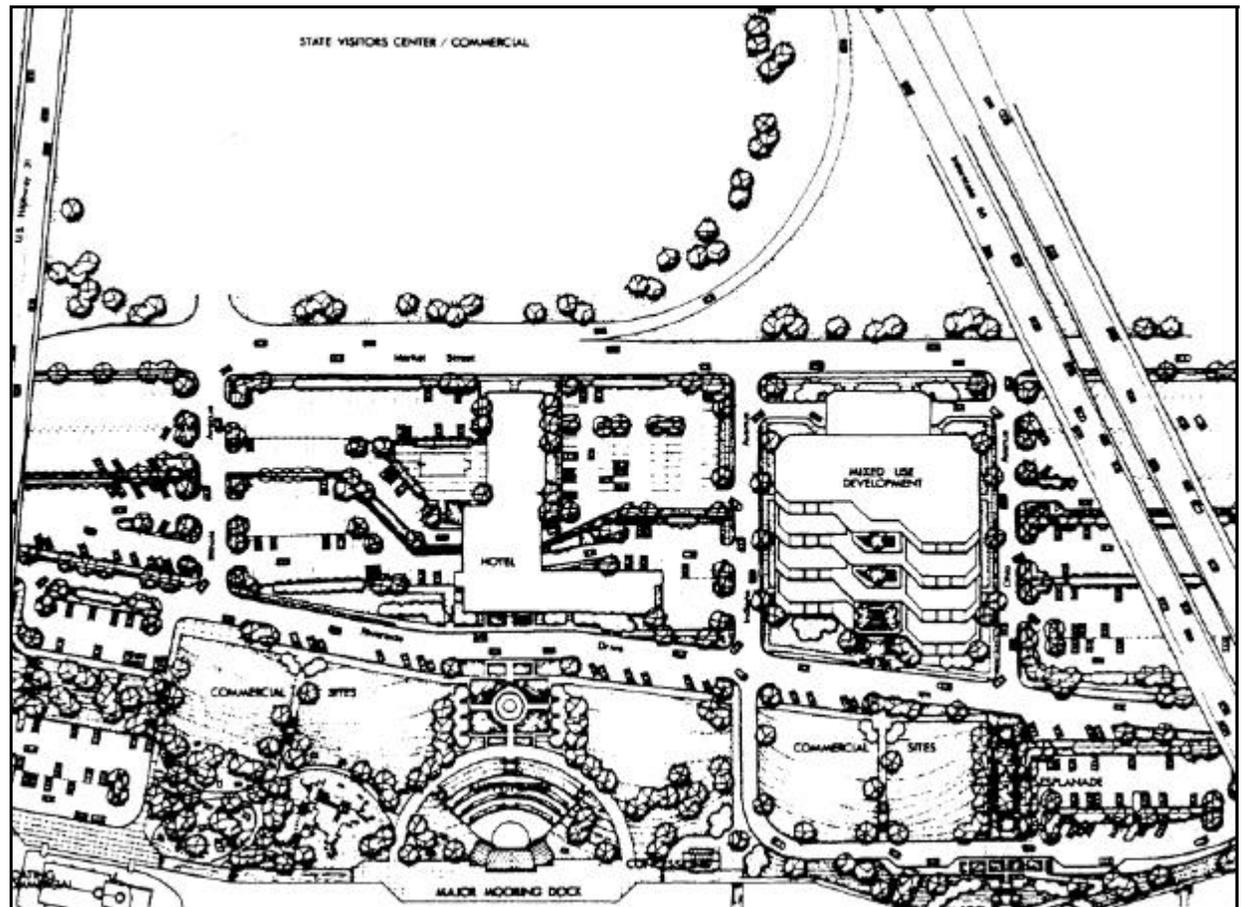
<p>Example of typical existing provision: In residential zones, commercial, office and school uses are excluded.</p>	<p>Example of potential provision: In certain specified residential zones, specific types of commercial and office uses are permitted. In certain commercial and office zones, specific types of residential uses are permitted. A new zone, the multi-use neighborhood zone, freely combines a variety of residential, commercial and office uses.</p>
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Purpose:

- This provision blends compatible and functionally related land uses into single zones, to reduce dependence on automobiles and the pavements they require, and the consequent auto emissions and runoff.

Issues:

- Multiple-use zoning connects peoples' residences with the places they need to go. Functionally related land uses support each other economically. Compactness multiplies their interaction.
- Compact land use, combining work and shopping close to homes, produces significant preference shifts from autos to bicycles and walking (Evans, 1992, p. 11). Short trips for work, shopping and personal business make biking and walking transportation feasible.
- Where automobiles are used less in daily life, the amount of pavement needed to store and move automobiles is reduced; water and air pollution from automobile use declines.
- Parking pavements can be reduced where certain different types of land uses are mixed. For example, a church can use the parking space of nearby offices when the office is unoccupied for the weekend.
- It is still appropriate to segregate truly incompatible land uses, such as residences and certain industries.



Proposed Riverside master plan. Jefferson, Indiana by Blalock, Barbour, Cooper, and Associates, Inc.

Paths for biking and walking

Provision: *This provision is intended to provide facilities to allow non-automotive transportation.*

Example of typical existing provision:	Example of potential provision:
[No provision in typical existing ordinance. Most municipalities today provide for no transportation routes or facilities other than automobile pavements.]	Direct and convenient nonvehicular transportation within each development and connecting to adjacent neighborhoods and commercial and employment centers shall be accommodated, by continuous connection of public streets under “urban” and “rural” standards, or by dedicated marked, paved paths in permanently dedicated open spaces.



A greenway bike trail system.

- A good transportation system offers choices of speed and mode to fit a variety of human purposes (Mumford, 1963, p. 236).
- Walking and biking are real transportation — where they are safe and convenient. In the relatively pedestrian-accessible city of Portland, Oregon, walking accounts for 13 percent of all trips made in the city (Leccese, 1996).
- In most of Georgia, the moderate terrain and mild climate are favorable for biking and walking.
- An example of a thorough path program is that of Peachtree City, Georgia. In this city, every new residential and commercial development must include paths that facilitate pedestrian and golf cart access to schools, parks and other city amenities by connecting to the city’s path system. If at the time of development there are no completed adjacent city paths to which the development’s paths can be linked, the developer must dedicate the necessary easements and deposit a cash payment into a city path construction fund. The city council is obligated to use the deposit to construct the paths in the development, when the path system is extended to the development’s boundary.
- Although current levels of biking and walking in the U.S. displace only 1 percent of automobile travel miles, they prevent consumption of 1 billion gallons of motor fuel, and prevent automotive emissions of 10 million tons of carbon dioxide, 1 million tons of carbon monoxide, and 20,000 tons of the nitrous oxides that cause acid rain (Komanoff and Roelofs, 1993, p. 4-5).
- Alternative transportation supports the purpose of land use combination. Land use combination creates feasible distances among related land uses for walking or biking; alternative transportation supplies the facilities for people to do so.
- Today 63 percent of the auto trips in the U.S. are less than 2 miles long, prime biking and walking distances. Lack of paths safe from auto traffic is the most common deterrent to biking and walking (Evans, 1992, p. 10-11).
- “Urban” and “rural” street standards are outlined later in this report. In “rural” (low-density) neighborhoods, careful layout of an interconnecting pattern of local streets is all that is required to allow alternative transportation; no additional construction expense is required. In “urban” (high-density) neighborhoods, the construction of sidewalks on both sides of streets adds \$10 per lineal foot to the cost of streets. But this cost is shared by the densely fronting houses; walks may add \$350 to the cost of each home.
- Off-street foot and bike paths are compatible with stream buffers. They can be fit to rugged topography and winding stream corridors more easily than streets.
- All bike and foot paths should be made of permeable material.

Purpose:

- This provision creates public facilities that allow individuals the choice of non-automotive transportation, reducing automobile use and the pavements autos require, and the consequent auto emissions and runoff.

Issues:

- Allowing people to walk and bike among nearby related land uses prevents pollution in the most effective way: by never generating it in the first place. When people are not using their cars, there are no emissions, and there is no demand for large parking spaces or wide streets.
- The cost to individuals of non-automotive transportation is low. This benefits low-income neighborhoods in ways that automobile subsidies never can.

Infill zoning

Provision: *This provision is intended to promote dense development of mixed land uses in and adjacent to pre-existing neighborhoods of the same type, to reduce the need for automotive transportation.*

Example of typical existing provision:	Example of potential provision:
Minimum lot sizes and exclusive land use types apply in all zoning districts.	In areas previously developed as villages and towns with mixed land uses, developments and redevelopments may equal and, in certain places, exceed the density and diversity of the neighborhoods where they are located.



Purpose:

- This provision allows relatively dense development where it would be compatible with and complement a preexisting neighborhood. This accommodates some of a municipality's growth without destroying pristine areas, and without requiring this part of the population to demand large quantities of pavement to support routine automobile use.

Issues:

- High-density mixed use on some sites makes nonautomotive transportation feasible, because of the short distances among related land uses. This reduces auto emissions and the demand for large streets and parking areas. The most suitable place to do this is in the midst of old neighborhoods where this pattern is already established.
- Meeting a rigorous limit on impervious coverage, such as 10 percent, is impossible in many

infill developments. The purpose of infill development is complete utilization of the land, not conservation of the site's preexisting soil. The local concentrations of runoff and pollutants should be expected to be high because autos and people are concentrated in a small area.

- Nevertheless infill development has conservation value as clustering on a municipal scale. It concentrates some of a municipality's growth and impervious surfaces in the most suitable portions of the municipality, without spreading development out into pristine watersheds. It limits impervious cover and auto usage in the region as a whole by absorbing some population growth in intense, mixed-use centers.
- Redeveloping a site that was previously poorly developed by today's standards can improve runoff quality by bringing new types of materials, layouts and drainage approaches to the site.

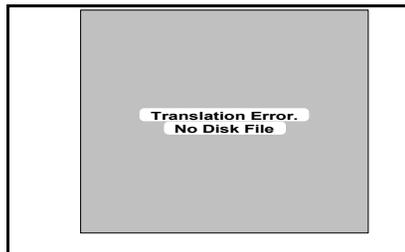
STREETS AND PAVEMENTS

Limited street width and curbing

Provision: *This provision is intended to limit street construction to what is needed only for the function of each specific street. Street function is defined in urban and rural street categories, which refer to fronting land uses greater or less than 3 residences per acre.*

Example of typical existing provision: Minimum paved width of all local streets is 24 feet.	Example of potential provision: The paved width of each street shall be determined by street category and traffic volume according to the table below.
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	Rural		Urban		
	Access	Local	Access	Local	Collector
Fronting land use	< 3/acre	< 3/acre	≥ 3/acre	≥ 3/acre	None
Daily traffic (ADT)	0 to 100	101 to 500	0 to 100	101 to 500	≥ 500
Pavement width	16 ft	20 ft	18 ft	26 ft	Based on traffic volume
Off-street parking	Driveways	Driveways	Driveways & parking lots	Driveways & parking lots	None (no fronting lots)
On-street parking	None	None	One parking lane	Two parking lanes	Emergency shoulder
Edge control	Shoulder	Shoulder	Curb with drainage notches	Curb with drainage notches	Shoulder
Design speed	15 mph	20 mph	15 mph	20 mph	Varies
Sidewalks	None	None	One side	Two sides	Two sides



Street layout influences the amount of street traffic .

Purpose:

- Limiting pavement width to no more than that needed for the function of each specific street limits runoff. Space remaining in the street right of way is available for nonautomotive transportation and for runoff drainage and treatment in vegetated swales. Limiting curbing allows street runoff to be treated immediately.

Issues:

- Streets constitute a major part of the impervious coverage in a community, and tend to produce pollutant-laden runoff (Arnold and Gibbons, 1996).
- Streets can be designed to minimize their impact on runoff quality while accommodating the functions they are to serve. A joint report of the Urban Land Institute and others (1990) stated that communities nationwide have adopted

street standards without desirable prior research, and that many have adopted unnecessarily rigorous standards without adding to street utility, safety, convenience or value. In contrast, Boulder, Colorado; Portland, Oregon; Davis, California; and San Jose, California have adopted street standards that balance environmental, access, service, and quality of life functions (Schueler, 1995).

- The quantity of traffic in a proposed development can be predicted from the proposed layout of streets and land uses. A typical single-family home generates 10 trips each day (Average Daily Traffic, ADT). The direction of those trips in the street network can be logically predicted from the street layout. The expected local traffic volume at a given point on a street is the

product of the number of trips per residence and the number of residential units generating traffic toward that point.

- The table specifies the narrowest width and least amount of curbing capable of fully meeting the traffic and parking demands that actually occur on specific types of streets. They were first developed by the ULI and others (1990). They were confirmed by Schueler's (1995) compilation of experiences around the country, and further articulated by Richman (1997).
- Limiting pavement width saves money. If street construction costs \$10 per square foot of pavement, then an "access" street that is 6 to 8 feet narrower than a uniform 24 feet wide street saves \$60 to \$80 per lineal foot of street. This amounts to \$2,700 to \$3,600 per lot where 90 feet wide lots occur on both sides of the street. Narrower pavements also mean less cleaning and repaving for municipalities. In a residential community in Wichita, Kansas, reducing street widths below excessive local standards reduced street construction costs by 28 percent and street maintenance costs by 20 percent (Cahn, 1976).
- Narrow pavements encourage cautious driving, and lower traffic speeds. They are consistent with efforts to emulate the compact, tree-lined, quiet, safe streets found in pre-war residential neighborhoods. They need not hinder

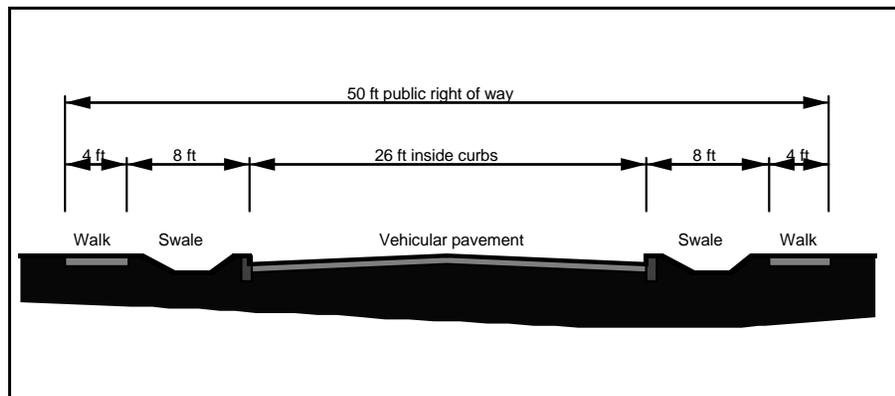
emergency access, where they are correctly applied only to streets with little traffic and little on-street parking.

- Curbs have important functions, where they are appropriately applied: they collect runoff for discharge, they protect the pavement edge from overrunning cars, they prevent vehicle trespass into pedestrian space, and they organize street cleaning and on-street parking. However, curbs collect and concentrate pollutants while preventing runoff from being treated in contact with soil and vegetation. Therefore they should be installed only where they are actually needed for the specific functions of a particular street. Omitting curbs from both sides of a street saves construction cost of \$15 per foot of street.
- "Rural" streets are those with residential land uses with density of less than 3 homes per acre. The lots are large enough that their driveways can accommodate daily on-street parking. Curbs are not needed for safety or structural integrity in rural streets (Arnold and Gibbons, 1996). On streets with low traffic volume, sidewalks are not needed; pedestrians walk on the vehicular pavement or on the shoulder.
- "Urban" streets are those with nonresidential land uses, or residential density of 3 units per acre or more. This is dense enough to generate on-street parking (Schueler, 1995). Curbs

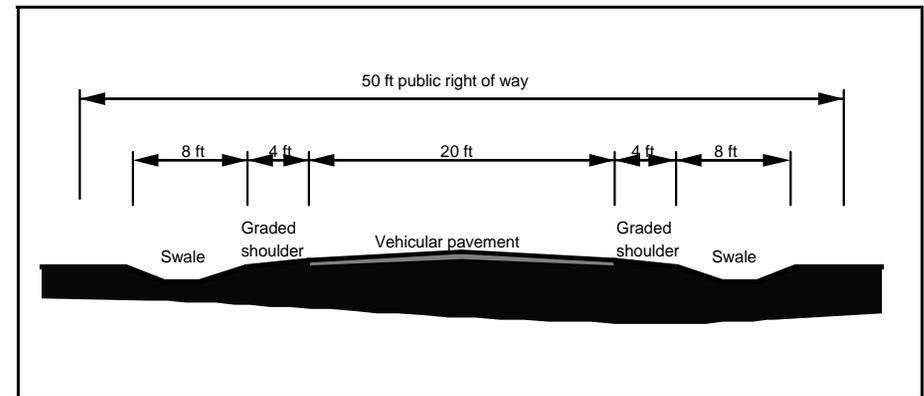
organize the parking, and appropriate additional width is allocated to make room for it.

Sidewalks carry pedestrians past the parked cars. Curbs should be frequently notched to drain into vegetated swales, such as at every driveway or at the corner of every fronting lot. The swales treat and abate runoff, and make "parkway" spaces for street tree planting and separation of pedestrians from cars.

- At very low traffic volumes, occasional two-way traffic can "share" a lane with on-street parking, turning aside for opposing cars at driveways and other places where cars are not parked.
- Small parking bays can displace some continuous parking lanes. Bays can be located at intervals alongside streets or in the centers of cul-de-sac turnarounds. They can be built of aggregate or other permeable materials, even where the main traveling pavement is of impermeable material.
- Through traffic, and thus part of the need for wide pavement, can be eliminated by the arrangement of streets in a development layout.



An example of an "urban" street in a 50 ft right of way.



An example of a "rural" street in a 50 ft right of way.

Limited pavement in turn-arounds

Provision: This provision is intended to reduce the amount of unnecessary paving in cul-de-sacs.

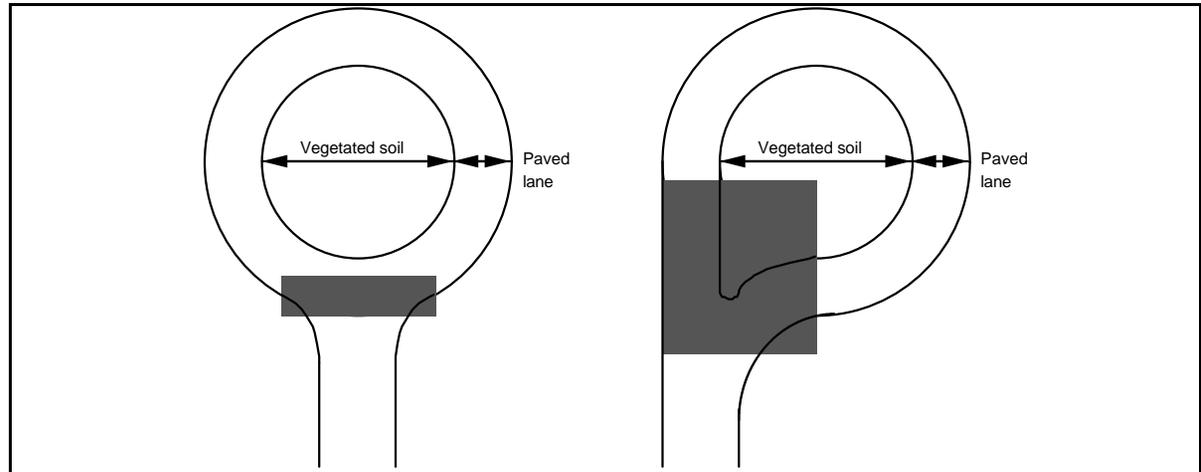
Example of typical existing provision:	Example of potential provision:
Cul-de-sac streets shall be terminated by circular turnarounds of 90 feet paved diameter	Cul-de-sac streets shall be terminated by turn-arounds with an internal turning radius of at least 20 feet, and a paved lane 16 feet wide on "rural" streets and 18 feet wide on "urban" streets.

Purpose:

- Replacing unused pavement in the centers of turn-arounds with vegetated soil reduces runoff and provides infiltration and treatment.

Issues:

- In the centers of turn-arounds, pavement is unusable for vehicle movement and has no purpose. This area should be unpaved, vegetated, and permeable. Reducing the quantity of pavement reduces runoff and construction cost.
- The vehicular lane remaining around the outside need not be wider than 16 or 18 feet, according to the table of pavement widths in the previous section.
- The vegetated central space can be part of the swale system to treat, attenuate, and infiltrate runoff, where it is depressed to make a concave form lower than the adjacent pavement.
- If the outside of the street pavement requires curbing to organize parking due to the density of the fronting land use, then the center of the turn-around also requires curbing for the same reason. Curb notches can maintain drainage through the vegetated space.
- Provision for maintenance of the central space must be made, such as through a street tree commission or a local homeowners' association.



This provision would reduce the amount of pavement in typical cul-de-sacs like the one shown here.

Limited amount of parking

Provision: *This provision is intended to require no more parking to be installed than the amount actually needed for specific land uses.*

Type of existing provision:	Aspect for potential review:
Quantity of parking in office, commercial, multifamily, and other land uses.	Required quantity of parking should be reviewed for potential reduction.



An example of excessive parking this provision would prohibit



Excessive parking inhibits water infiltration into the soil.

Purpose:

- In commercial and industrial zones and other zones with public use, parking areas are important candidates for reduction in impervious cover. They are the largest component of impervious cover in these land uses, and they have frequently been oversupplied. Each municipality can gauge the potential for reduction in specific land use categories based on its own experiences.

Issues:

- Adequate parking space is necessary to accommodate all vehicles in an organized, safe and convenient way.
- But suburban commercial and office parking has been over-supplied nationwide. Average utilization is barely half the amount that has been supplied. Although a ratio of about 4 parking spaces per 1,000 square feet of office floor space is commonly required in ordinances, a ratio of 2.8 is the need found by observing actual peak parking utilization (Wilson, 1995).
- Parking of 4 spaces per 1,000 square feet occupies from 30 percent to 70 percent of office sites. Excess unutilized parking adds no value to a commercial development; it reduces development intensity below a site's potential. Parking that is unused by commuters is "used" by rainfall every time it rains.
- The generous provision of free parking subsidizes and encourages the use of automobiles for transportation, and specifically increases the

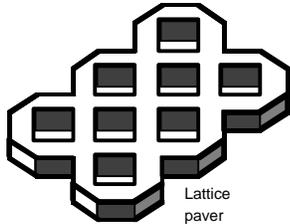
level of solo driving. It increases traffic congestion and the need for more street and parking pavements elsewhere in the community.

- Limiting parking limits the amount of paved surface and runoff. It prevents unnecessary land consumption and reduces construction cost. It raises a municipality's potential tax revenues from development of available land (Wilson, 1995). It increases feasibility of alternative transportation.
- Federal air quality regulations require many jurisdictions to consider transportation control measures such as managing the parking supply.
- The required amount of parking varies among types of land use and with distances from town centers and public transportation.
- The effects of limited parking are reinforced by infill zoning, land use combination, and alternative transportation.
- Where parking is in fact under-supplied, alternatives to larger on-site parking include controlled on-street parking, co-operative arrangements with neighboring underutilized developments, ride sharing programs, cash commute allowances, and leasing of available parking spaces to reduce demand.
- Seldom-used portions of a parking area can be used for stormwater detention. Detention here can help water quality if the pavement in this area is porous.

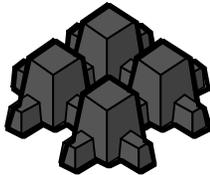
Porous pavement materials

Provision: *This provision is intended to require the use of well-known permeable materials to replace impermeable pavements so runoff can be treated and infiltrated in the underlying soil.*

Example of typical existing provision:	Example of potential provision:
Pavement composition shall be 2" Type E or F wearing course and 6" Graded Aggregate Base, with subgrade compacted to 95% dry density. [This specification produces an impervious surface.]	Porous pavement may be used for street pavements, and shall be used on all public and private driveways, parking lots, sidewalks, bike and footpaths walkways, and pedestrian plazas and courts, except where it is infeasible due to site-specific constraints such as steep unstable slopes, swelling soils, proximity of structural foundations, or steep slope of pavement subgrade. In new developments and in additions to developments where similar porous pavements have not previously been used, representative portions of porous pavements shall be marked by permanent stencil or sign identifying the porous pavements, their purposes, and special



Lattice paver



Castellated paver



Purpose:

- For areas that must unavoidably be paved, porous pavement materials limit runoff at the paved source. They eliminate auto oil and other street pollutants by treating them in contact with the soil wherever they are generated.
- However, permeable pavement should not be used in specific site conditions where additional soil moisture might endanger the pavement or adjacent slopes or structures. Conditions such as swelling soils, highly plastic soils, proximity to foundations of structures, and steep slopes where moving water in the base course could erode the subgrade must be identified on each specific site prior to design.

Issues:

- Streets and the automobiles that use them are concentrated sources of runoff and pollution in all land use types. For the heavy traffic loads of public streets and the traveling lanes of parking lots, the available porous pavement materials are porous asphalt (Thelen and Howe, 1978) and porous concrete (Florida Concrete and Products Association, no date).
- The first installation of porous asphalt in Georgia was a residential driveway in Macon, constructed on "Helena" clay soil in 1990 to protect the root zones of nearby trees. The figure

shows the pavement materials. The pavement is still in excellent condition, and the trees area still thriving. More recently, the state DOT has been using a porous asphalt surface as an overlay on impervious concrete highways to improve traction and visibility. It can be seen, for example, in the HOV (high-occupancy vehicle) lanes on Interstate highways around Atlanta. DOT specifies this material as pavement type D (Georgia DOT Standard Specifications section 828.02, "Open Graded Surface Mixture"). This mix differs from other surfacing materials in that it uses a uniformly sized, open-graded aggregate (#7), rather than a graded mixture of sizes.

- The first installation of porous concrete in Georgia was a driveway at the Southface Energy and Environmental Resource Center in Atlanta, constructed in 1996. The principle features of porous concrete are analogous to those of porous asphalt: open-graded aggregate bound by portland cement.
- In many technical respects porous asphalt and concrete pavements are superior to their impermeable cousins. They are better drained, because water falls through the voids in the pavement surface. In wet weather they produce

Materials recommended in this provision can easily be incorporated into the landscape.

better traction and better visibility, because they are not covered with a sheet of surface water and vehicles don't kick up mist from their wheels. They produce less noise and glare. Their structural performance is in most respects equal or superior, because saturation of the subgrade during storms is already within the design guidelines for all pavements (Forsyth, 1991, p. 4; National Stone Association, 1987, p. 7; Sorvig, 1993; Thelen and Howe, 1978).

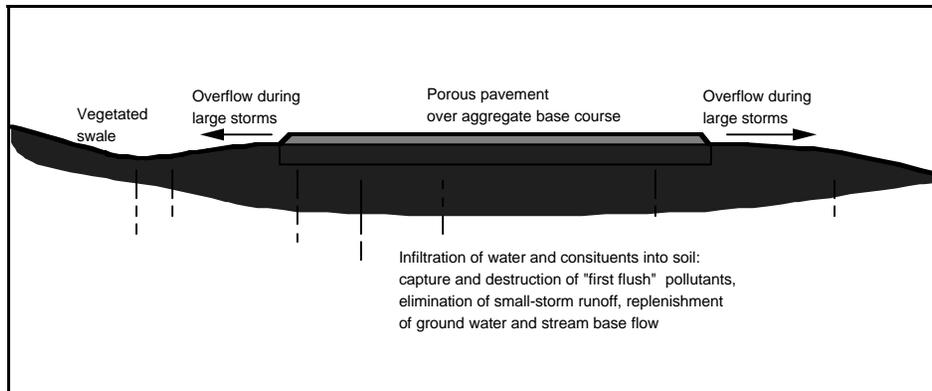
- Porous asphalt and porous concrete add about 10 percent to the cost of a pavement, because they are little used and constitute specialty items. This markup could disappear with increased use. In addition, porous pavement is not just a pavement structure; it is also part of the runoff treatment and drainage system. On sites where something must be done to treat runoff, the use of porous pavement eliminates the necessity for specialized treatment structures downstream. On favorable sites with sandy, highly permeable Coastal Plain soils, porous pavement can save more than 30 percent of the combined cost of pavements and

drainage (Sorvig, 1993).

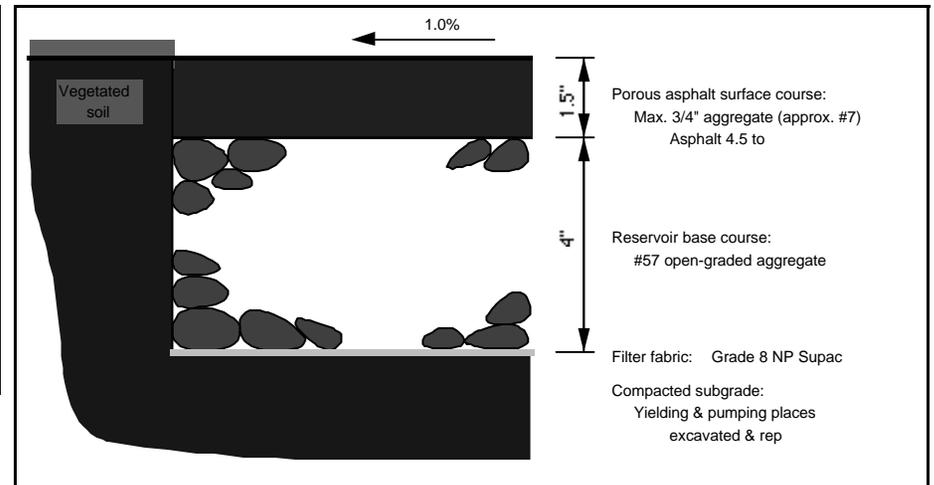
- For the light traffic loads of pedestrian, parking and driveway pavements, porous asphalt and concrete are joined by a wide variety of simple, familiar, inexpensive materials such as aggregate and turf. To make parking pavements permeable is to eliminate one of the least necessary sources of urban runoff. Parking lots occupy more than half the area of commercial sites, but parking spaces distant from building entrances are hardly ever used. Although parking pavements produce only moderate concentrations of pollutants, their size and consequent volume of runoff are enormous (Arnold and Gibbons, 1996).
- Permeable crushed stone ("gravel") aggregate is cost-competitive with almost any other pavement material. The aggregate must be open-graded in order to be permeable and to avoid yielding fine particles that wash into streams. Parking must be clearly organized in order for the area not to appear abandoned or neglected. On aggregate where painted lines are not possible, parking can be organized by bollards,

wheel stops of concrete or wood, arrangements of planted trees, or paved traveling lanes adjacent to the stalls. Incidental or long-term parking such as that of RVs and boats is very appropriate for crushed stone surfaces, because of the small amount of moving traffic.

- Open-celled pavers are concrete or plastic grids with voids that are filled with porous topsoil and seeded, or filled with porous aggregate (Southerland, 1984). An example is a grass-covered access lane at the Southface Energy and Environmental Resource Center in Atlanta. Commercially available pavers differ in their construction cost and difficulty for some persons to walk on (Nichols, 1995; Sipes and Roberts, 1994).
- Grass has been used everywhere for overflow parking, where it maintains its health, appearance and permeability at parking frequencies up to once per week. Reinforced turf is economical for occasionally used parking surfaces and emergency access lanes.
- For pedestrian areas other materials are wooden decks, well spaced paving stones, and wood



Top: Porous materials limit runoff at the paved source.
Right: Porous pavement installed in a Macon Driveway in 1990.



DRAINAGE

Drainage in vegetated swales

Provision: *This provision is intended to encourage the use of vegetated swales for drainage, replacing pipes and paved channels, wherever feasible.*

Example of typical existing provision:	Example of potential provision:
All streets shall be provided with curb and gutter on both sides.	Runoff from all roofs and pavements, including overflow from permeable pavements, shall be passed immediately and continuously through vegetated swales or infiltration basins, to the edge of the construction area, except where shown to be infeasible due to site-specific conditions such as proximity of structural foundations. In new subdivisions and in additions to development where similar practices have not previously been applied, representative swales or basins shall be marked by permanent stencil or sign identifying them, their purposes, and special restraint applied to their use and maintenance.

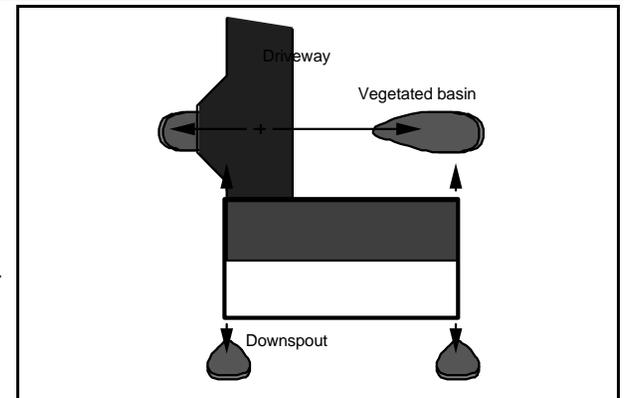


Illustration of a residential vegetated swale mulch (Ferguson, 1994, p. 52-55).

chance to be treated.

Issues:

- In street drainage, swales supplement or replace curbs and gutters while adding the functions of runoff attenuation, infiltration and treatment.
- Where swales replace storm sewer pipes they reduce construction cost. A vegetated swale 4 feet wide and 1 foot deep costs less than \$1 per foot for excavation, seeding and erosion control, but it may have the capacity of a concrete pipe costing \$40 per foot. Each inlet into a pipe costs from \$500 to \$1,500. The savings in pipes and inlets can add up to \$1,400 to \$2,000 per home on “urban” streets.
- Vegetated swales can reduce maintenance cost. Unlike curbed streets, which must be cleaned with sweepers or blowers, swales allow organic debris to decompose in place and to become part of the underlying soil.
- Providing treatment and infiltration at every source of runoff uses the full capacity of a site’s vegetation and soil for rehabilitation, and prevents runoff from becoming a larger, more concentrated problem downstream. Mitigating the runoff from impervious surfaces helps a development meet a provision limiting unmitigated

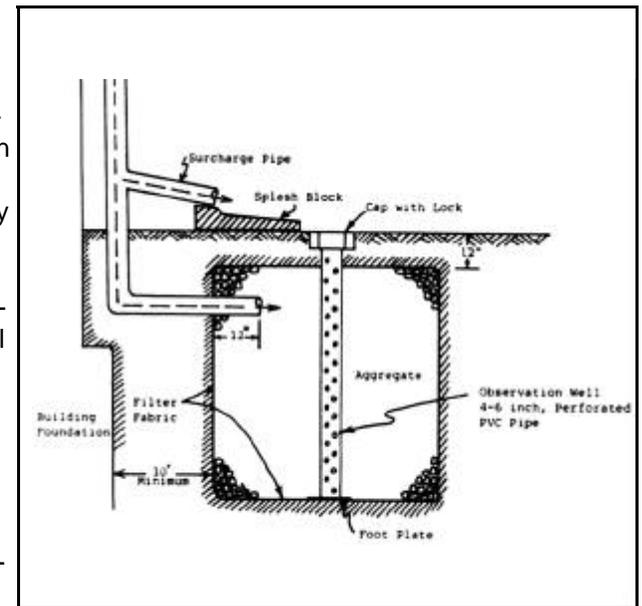


Swales and ponding in a residential lot.

Purpose:

- Vegetated swales store, treat, and infiltrate runoff. In contrast with gutters, pipes, and paved channels, they mitigate the effects of impervious cover by eliminating at least some runoff and most of its pollutants. Swales also give the overflow from permeable pavements another

- impervious cover.
- An example of swale drainage is the Southface Energy and Environmental Resource Center in Atlanta, where roof and driveway runoff are routed through planted swales with intermittent shallow ponding. Well documented examples of this approach outside Georgia are The Woodlands, Texas (McHarg and Sutton, 1975), and Village Homes, Davis, California (Thayer and Westbrook, 1989).
- Swales must be properly designed and constructed to prevent erosion that would generate sediment pollution. They must be wide and gently sloping to hold down erosive velocity. Where steep slopes are unavoidable, small check dams confine velocity as described in the next section. Sodding, rather than seeding, is advisable for immediate protection against erosion. Gravel or rock is available for protecting against erosion, although it reduces the treatment advantage of living vegetation.
- Because of the need to protect against erosion, swales tend to be most feasible along streets and drainage ways with slopes less than about 8 percent slope.
- Where carrying and ponding runoff in open swales and basins is not desired, infiltration may be in “dry wells” constructed of open-graded aggregate. Many dry wells may be located in the stone base course of pavements.
- Fulfilling this provision completely and efficiently requires that designers pay attention to on-site details. Swales and basins should be small, numerous, and located at runoff sources including every individual downspout, every individual curb cut, and every small area of pavement. Creating vegetated areas to receive runoff is simple — it requires only giving concave forms to areas adjacent to pavements and roofs — but it must be applied consistently.
- Stormwater infiltration basins shall not be constructed in areas having high pollution susceptibility as defined by “Groundwater Pollution Susceptibility Map of Georgia” by Victoria P. Trent, 1992. Dry wells are defined as a Class V well and as such require a permit to be obtained according to the “Rules and Regulations for Water Quality Control, Chapter



An illustration of “dry wells”

Swale “biofiltration” velocity control

Provision: *This provision is intended to recommend specific technical design standards for vegetated swales to assure effective runoff treatment and infiltration.*

Example of typical existing provision:	Example of potential provision:
<p>[No written provision in typical ordinances. Swales and other conveyances are conventionally of continuous gradients, carrying water at moderate velocities without ponding.]</p>	<p>All drainage swales shall be in continuous vegetative cover such as grass. Elevations and gradients of swales and connected drainage structures shall be set to produce either flow velocities of no more than 0.5 fps, or continuous ponding along the length of the swales when runoff occurs. Ponding depths shall be limited to produce ponding durations of no more than 24 hours. In new subdivisions and in additions to development where similar swales have not previously been applied, representative portions of swales or ponding areas shall be accompanied by signs identifying them, their purposes, and restraint applied in their use and maintenance.</p>

391-3-6.

Purpose:

- This provision sets the technical standards for swales and basins that make them effective at protecting runoff quality.

Issues:

- Vegetated swales that are specifically designed for runoff treatment have been called “biofilters”. The specific velocity limit of 0.5 feet per second gives runoff sufficient time in contact with the environment to be treated to significant levels (Municipality of Metropolitan Seattle, 1992, p. 1-3). Swales with this velocity capture 63 to 83 percent of pollutants that are particulate in character and that adhere to vegetation, including sediment, metals adsorbed on sediment, and oils. Swales are less effective for dissolved metals and nutrients (29 to 46 percent removal);

effectiveness for bacteria is variable.

- Limited velocity assures that swales will not erode and become sediment sources. In well vegetated swales, erosion is not expected below velocities of 3 or 4 fps (feet per second). Swales with low velocity tend to be densely vegetated, broad, and gently sloping.
- A provision limiting flow velocity requires a technical, but relatively routine, evaluation of velocity during project design.
- The very low velocity limit of 0.5 fps usually cannot be met in moderate topography such as that of the Piedmont. Treatment performance can be restored by ponding (Municipality of Metropolitan Seattle, 1992) with numerous small check dams of earth, stone or wood. Stone check dams are familiar in Georgia’s land

development: they are practice “Cd” in the

state’s erosion control manual (Georgia Soil and Water Conservation Commission 1992); each one costs about \$50. Earthen check dams cost nothing except care during construction that the correct dimensions and elevations have been graded into place.

- An example of ponded drainage is at the Ecology Building on the University of Georgia campus in Athens, where a basin formed by an earthen check dam is planted with a variety of native wetland plants. Since it was installed in 1985, it has infiltrated all runoff from lawns, sidewalks and roofs in its small watershed, without overflowing or prolonged ponding.
- Street swales can be ponded at driveway crossings by elevating culverts above the swale bottom. Some culverts can be omitted entirely, making each crossing into a check dam, where occasional shallow flow across driveways is tolerable. The levels of the driveways must be carefully set to control frequency and depth of overflow. Omitting culverts under driveways saves about \$300 per home.



- Limiting ponding time to 24 hours maintains healthy, deeply rooted vegetation and complete decomposition of organic matter into humus. (Ferguson, 1994). Ponding time is controlled by the depth of ponding and the soil infiltration rate. Infiltration rate is indicated by soil “texture”, which is mapped in county surveys and can be confirmed by simple on-site

Texture	Infiltration rate (in/hr) (Rawls et al., 1982)	Maximum pond depth (inches) for a 24 hour ponding time
Loamy sand	2.41	57.8
Sandy loam	1.02	24.5
Loam	0.52	12.5
Silt loam	0.27	6.5
Sandy clay loam	0.17	4.1
Clay loam	0.09	2.2
Silty clay loam	0.06	1.4
Sandy clay	0.05	1.2
Silty clay	0.04	1.0
Clay	0.02	

- investigation.
- In the slowly permeable soils of the Piedmont, only small storms and the first flush of large storms can be infiltrated within the one-day ponding limit. Nevertheless this small daily amount is vital to water quality and ground water replenishment, because of the cumulative effect of small, frequent storms.
 - Building treatment and attenuation into every inch of the drainage ways in a construction area reduces need for downstream reservoirs, which would disturb preexisting stream buffers and cost tens of thousands of dollars.
 - Individual municipalities may impose additional requirements for control of peak rate of flow



Swale treatment of runoff



Ponding in vegetated swale



Ponded swales in a street right-of-way.

Treatment of “hot spots”

Provision: *This provision is intended to recommend specific treatment of runoff from small concentrated pollutant sources, even where treatment in other parts of a development is not feasible.*

Example of typical existing provision:	Example of potential provision:
[No provision in existing ordinances]	Specific facilities that may produce locally high concentrations of runoff pollutants, such as dumpster pads, recycling areas, automotive maintenance and cleaning areas, and gasoline stations, shall be drained immediately into and continuously through permeable pavements, vegetated swales or infiltration basins.

during large, rare storms.

Purpose:

- This provision assures “point” treatment of a few small areas vital to runoff quality, even on sites where treatment of runoff from large areas of everyday impervious surfaces cannot receive the same degree of careful attention.

Issues:

- “Hot spots” can be identified in development plans. Gas stations and auto cleaning areas produce very high levels of hydrocarbons and heavy metals (Schueler, 1994). Areas where trash is stored or handled produce litter, bacteria, dissolved metals, and nutrients.
- Treatment of hot spots is highly feasible, because it is focused in area. “Hot spots” produce concentrated pollutants from areas of very limited size. Infiltrating or ponding only the “first flush” from these areas is sufficient to improve runoff quality during most storms.
- Where pertinent, stormwater infiltration basins shall not be constructed in areas having high pollution susceptibility as defined by, “Groundwater Pollution Susceptibility Map of Georgia” by Victoria P. Trent, 1992. Runoff could drain rapidly through the soil and potentially pollute the groundwater. All required permits must be obtained before constructing



Dumpsters are easily identified “hot spots”.

Inlet labeling

Provision: *This provision is intended to identify drainage inlets to inhibit dumping and educate the public.*

Example of typical existing provision:	Example of potential provision:
[No provision in typical existing ordinances]	Representative inlets to storm sewers, mouths of culverts drainage curb cuts, heads of swales, and other entries to the storm drainage system shall be marked by permanent stencil or sign identifying the inlets, their purposes, and special restraint that needs to be taken in using and maintaining them.

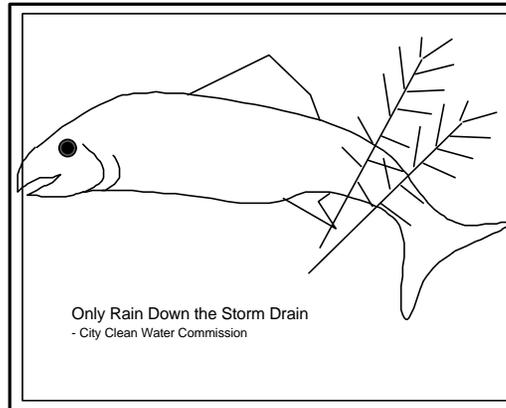
infiltration basins.

Purpose:

- This provision inhibits dumping of concentrated pollutants such as automotive oils and detergents directly into the drainage system, and educates the public about the vital systems around them and their relationships with them.

Issues:

- Municipalities can install educational signs and stencils in older, established urban areas where dumping may have occurred in the past, in addition to requiring them in new develop-



CONSTRUCTION PROCESS

Limited clearing, grading and disturbance

Provision: *This provision is intended to prevent unnecessary disturbance of vegetated soil outside the area actually needed for construction.*

Example of typical existing provision:	Example of potential provision:
[No provision in typical existing ordinance.]	Clearing, grading and soil disturbance shall be confined to those areas of the site actually required for construction. The edge of the construction area, beyond which construction traffic may not pass, must be fenced or ribboned in the field prior to construction and maintained and respected for the duration of construction. Outside the marked construction boundary, vegetation shall be left intact and earth shall be undisturbed.

ments.

narrow parking pavements.

provision.

Purpose:

- Preserving preexisting vegetated, pervious, uncompacted soil areas uses these areas as resources to attenuate, treat and infiltrate all rainfall and runoff.

- Conventional silt fences are effective markers of the construction area boundary. If silt fences are conscientiously installed and maintained as they are supposed to be for erosion control, then no additional step is necessary to meet this

- However, it is very difficult to control additional clearing by individual homeowners after a community has been occupied.

Issues:

- Limiting of clearing preserves trees and pervious soils. It tends to limit areas of maintained turf, which can generate chemicals that run into streams. This kind of provision is consistent with established erosion and sediment control guidelines (Georgia Soil and Water Conservation Commission, 1992).
- An example of aggressive preservation of native forest soil was the Jones Bridge headquarters of the Simmons Company, built near Atlanta in the 1970s (Marvin, 1978). Two hundred parking spaces were dispersed in groups of two and three among preexisting forest trees. The landscape architect ribboned the outline of every parking space and lane, and adjusted it on the site to preserve topography, drainage and vegetation. Construction vehicles were prohibited from crossing the ribbon and damaging protected vegetation. The native forest soil and vegetation, preserved between parking bays, infiltrates, attenuates and treats the runoff from the



Silt fences would effectively control erosion problems like these.

Section Four: Provisions Conditioned by Local Circumstances

The following aspects of development affect impervious surface coverage and runoff quality, as do the potential ordinance provisions listed in the previous section. However they can have conflicting effects on runoff and on quality of life, depending on their relationships to specific site conditions and local community character. Therefore, for these aspects of development, this report offers no specific provisions for potential adoption. Instead, municipalities can review the corresponding provisions in their ordinances from the viewpoint of runoff quality, in addition to the other concerns they may have. Modifying such provisions in a relative way may, in some instances, help municipalities achieve runoff quality in their specific circumstances.

Limited residential lot size

Type of provision:

- Minimum residential lot sizes. These vary among municipalities, and among zoning districts within municipalities.

Issues:

- All minimum lot sizes inhibit, to some degree, the ability of a development to adapt to the site suitabilities, marketing approach, and technical constraints of its specific site. They require spreading out of each layout, eliminating stream buffers.
- Minimum lot sizes effectively regulate population density and dispersal. Small minimum dimensions of residential lots could allow compact land use, which reduces amount of connecting pavements, preserves open space, and makes alternative transportation feasible. Maximum lot sizes have been proposed for districts where compact land use is vital to transportation or open space preservation.
- However, within a municipality, it is appropriate that different specific lot sizes adapt to local conditions such as location, slope, soil, transportation access, and utility access. Appropriate lot sizes vary among different municipalities and among different topographic positions and technical constraints. We have no scientific basis for establishing a specific, uniform lot size for any category of residential lot.
- Density zoning replaces the entire concept of minimum lot size with a flexible standard that allows development to adapt to every site-specific constraint.

Setback from right of way

Type of provision:

- Minimum setback of buildings from public right of way.

Issues:

- Setbacks reinforce minimum lot sizes to regulate the construction area where pervious vegetated soil must be cleared and paved over.
- Small setbacks compress the overall development, making possible preservation of open spaces such as stream corridors, and reducing lengths of paved driveways.
- However limited setbacks concentrate impervious surfaces near the street, which may make it harder to treat runoff in contact with the remaining vegetated soil. Like clustering, limited setbacks trade locally concentrated impervious surfaces for low total quantities of impervious surfaces and the potential for open space.
- Specific appropriate setbacks vary among different municipalities, and among zoning districts within a municipality.

Street length

Type of provision:

- Combination of provisions that produce long streets for a given amount of development, such as large lots and wide street frontage.

Issues:

- Long streets serving a given quantity of development are one of the generators of excess pavements and runoff. Long travel distances inhibit nonautomotive transportation.
- However street length cannot be regulated directly. All lot size, setback and frontage standards work together on specific sites to produce street length.
- The appropriate street length for a given development must be consistent with site-specific constraints such as the type and quantity of land use to be supported, topography, site shape, and neighborhood context.

Street right of way width

Type of provision:

- Right of way width for local and access streets.

Issues:

- Right of way width regulates, with building setbacks, the spacing between street and building, and thus the amount of space cleared and the quantity of driveway pavement installed to serve a given quantity of development.
- Narrow rights of way allow short driveways, limiting total paved surface for a given land use, and allow the layout to compress into a given small land area, potentially preserving stream buffers and pervious soil areas.
- However space in the right of way is required for utilities, signage, street trees, nonautomotive transportation, and treatment and drainage of street runoff in vegetated swales.
- Where a wide right of way is appropriately laid out, furnished, planted and maintained, it is a positive element of the community. Some great examples of community design, such as Riverside, Illinois, have been based on oversized rights of way that were utilized for pedestrian transportation and linear open space.

Erosion and sediment control

Type of provision:

- Erosion and sediment control during construction.

Issues:

- Construction sites are major sources of sediment pollution.
- Nevertheless erosion and sediment control measures are familiar in Georgia land development. They are defined in the *Manual for Erosion and Sediment Control in Georgia* (Georgia Soil and Water Conservation Commission, 1997). Their provision and enforcement are already mandatory under Georgia state law. Outlining specific provisions here would be largely redundant to the system already established by the state.

Tree protection

Type of provision:

- Prohibition against cutting certain types or sizes of trees without commensurate replanting.

Issues:

- Tree harvesting may be considered an agricultural activity not subject to ordinary zoning.
- Protecting trees during the development stage does not necessarily prevent later cutting by occupants.
- Runoff quality is determined more by the soil cover at the ground surface than by individual trees. Provisions for limited clearing, grading and disturbance protect the soil surface more directly than does protection of isolated trees.
- Examples of strong tree protection ordinances are in the cities of Alpharetta and Savannah.

Resources

Contacts

- Georgia Environmental Protection Division, NonPoint Source Management Program, Floyd Towers East, Suite 1070, 205 Butler Street, S.E. Atlanta GA 30334 (404)656-4887
- Georgia Soil and Water Conservation Commission P.O. Box 8024, Athens GA 30603 (706)542-3065
- Southface Energy and Environmental Resource Center P.O. Box 5506, 241 Pine St. at Piedmont Avenue, Atlanta GA 30307 (404)525-7657
- Terrene Institute (For U.S. Environmental Protection Agency) 4-B Herbert Street, Alexandria VA 22305 (202)833-8317
- Center For Watershed Protection 8630 Fenton St., Suite 910, Silver Spring, MD 20910 (301)589-1890

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U.S. Environmental Protection Agency, c/o Terrene Institute
4 Herbert St., Alexandria, VA 22305, fax (202)260-1517 or fax (202)296-4071

Watershed Protection Techniques

Center For Watershed Protection
8630 Fenton St., Suite 910, Silver Spring, MD 20910, phone (301)589-1890

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DeKalb County Zoning Ordinance, 1990
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Gwinnett County Zoning Resolution, 1991
Hall County Official Code, Title 17 Zoning
Hall County Subdivision Regulations, 1991

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Task force members

Paige Bronk, Chatham County - Savannah Metropolitan Planning Commission
Robert Drewry, Chatham County Department of Engineering
Bryan Hager, Sierra Club - Georgia Chapter
Steven Haubner, Atlanta Regional Commission
Sandra Johnson, Alpharetta City Council
Ellen Keys, The Georgia Conservancy
Clair Muller, Atlanta City Council
Rick Porter, Richport Properties
Joe Robinson, Peachtree City Development Corporation
Don Rutzen, Post Properties
Jim Santo, Atlanta Regional Commission
Tom Stanko, Atlanta Regional Commission

Project staff

From University of Georgia School of Environmental Design

David Nichols, Associate Professor, principal investigator
Mary Anne Akers, Assistant Professor
Bruce K. Ferguson, Professor
Scott Weinberg, Professor
Shannon Cathey, Graduate Assistant
David Spooner, Graduate Assistant

From Georgia Department of Natural Resources

Ted Mikalsen