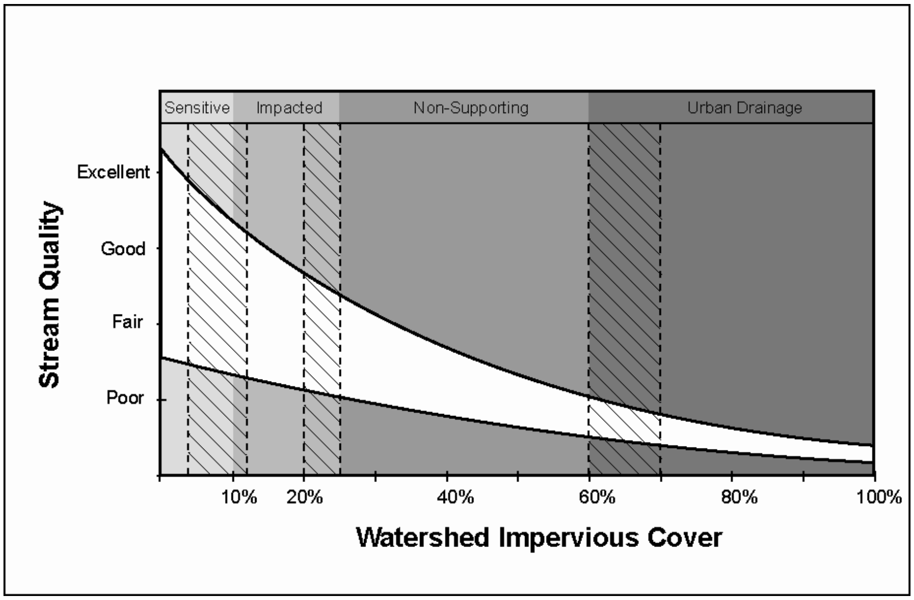
CSN TECHNICAL BULLETIN No. 3

IMPLICATIONS OF THE IMPERVIOUS COVER MODEL: STREAM CLASSIFICATION, URBAN SUBWATERSHED MANAGEMENT AND PERMITTING

VERSION 1.0



Providing Input on this Technical Bulletin

Recent research has largely confirmed or reinforced the Strong relationship between watershed impervious cover and the decline of a suite of stream indicators. The key challenge for local watershed managers is how to handle the numerous planning implications of these relationships. This bulletin presents some initial ideas on how to address these topics, and is open for comment until November 1, 2008 for comment. So please give this a careful review, and e-mail your comments to Tom Schueler at watershedguy@hotmail.com, or post comments or upload information at chesapeakestormwater.net. A final version of this bulletin will be produced based on your comments. Thanks in advance for your participation in this important project.

The Impervious Cover Model (ICM) was first proposed in 1994 as a management tool to diagnose the severity of future stream problems in urban subwatersheds. The basic model has been recently modified to reflect more recent research on the relationship between subwatershed impervious cover (IC) and various indicators of stream quality. As might be expected, the ICM has engendered much debate and confusion among planners, engineers and regulators. Most communities continue to struggle with how to influence the location and intensity of subwatershed IC and/or apply techniques to mitigate its impact.

This working paper begins by reviewing the strengths and weaknesses of the broad range of watershed management tools that communities have used to respond to the ICM. The next section outlines new ideas for using the ICM as an urban stream classification system to set realistic and achievable objectives for stream protection or restoration. The third section applies the proposed urban stream classification system to develop integrated subwatershed management strategies for four classes of urban streams -- high quality streams, impacted streams, non-supporting streams and urban drainage. These strategies are customized to promote the most effective combination of planning, engineering, economic and regulatory tools within each subwatershed class.The paper concludes with a proposed sub-watershed based permitting approach to provide accountability that a community is providing the maximum degree of stream protection or restoration, given its current inventory of streams.

IS IMPERVIOUSNESS IS STILL IMPORTANT

Impervious cover (IC) has unique properties as a watershed metric in that it can be measured, tracked, forecasted, managed, priced, regulated, mitigated and, in some cases, even traded. In addition, IC is a common currency that is understood and applied by watershed planners, stormwater engineers, water quality regulators, economists and stream ecologists alike. IC can be accurately measured using either remote sensing or aerial photography (Goetz et al. 2003 and Jantz et al. 2005). IC is also strongly correlated with individual land use and zoning categories (Cappiella and Brown 2001; Slonecker and Tilley 2004) which allows planners to reliably forecast how it changes over time in response to future development.

Schueler (1994) and Arnold and Gibbons (1996) first proposed impervious cover (IC) was an important metric for projecting expected stream quality in urban subwatersheds. Since then, the ICM has been refined (CWP, 2003), and slightly reformulated (Schueler et al, 2008). While the ICM has generated considerable debate and controversy in planning, smart growth and stream ecology circles, it has proven to be a fairly resilient model. For example, a recent national review of peer reviewed papers that tested the relationship between subwatershed impervious cover and stream quality found that nearly 70% of the 35 studies confirmed or reinforced the basic tenets of the ICM (See Schueler et al, 2008).

Watershed planners now routinely apply the ICM (and other watershed metrics) to predict changes in stream health as a consequence of future development (CWP 1998b).

As might be expected, the application of the ICM to local planning and regulations has engendered much confusion among planners, engineers and regulators and scientists. In addition, recent advances in GIS technology have shown that the amount of new IC created is growing rapidly at the local, regional and national scales. For example, Jantz et al. (2005) found that IC increased at a rate five times faster than population growth between 1990 and 2000 in the Chesapeake Bay watershed. At a national level, several recent estimates of IC creation underscore the dramatic changes in many of our nation's watersheds as a result of recent or future growth (Elvidge et al. 2004, Beach 2002, Nelson 2004, Exum et al, 2006). Given such rapid growth in IC, watershed managers are keenly interested in management tools to mitigate its possible impacts, and have responded in many different ways to protect stream quality, as is described in the next section.

PART 1
REVIEW OF MANAGEMENT RESPONSES TO THE ICM

The diversity in management responses to the ICM is fairly impressive. Table 1 classifies the nearly 20 different planning, engineering, regulatory and economic tools that have been used (or proposed) to respond to the ICM. In general, each of these individual professional disciplines has adopted their own tools and methods to mitigate the effect of land development on water quality, and have rarely coordinated with other disciplines. This section reviews the strengths and weaknesses of the many different approached to managing IC at the watershed and community scale.

Table 1. Range of Responses to Mitigate the ICM

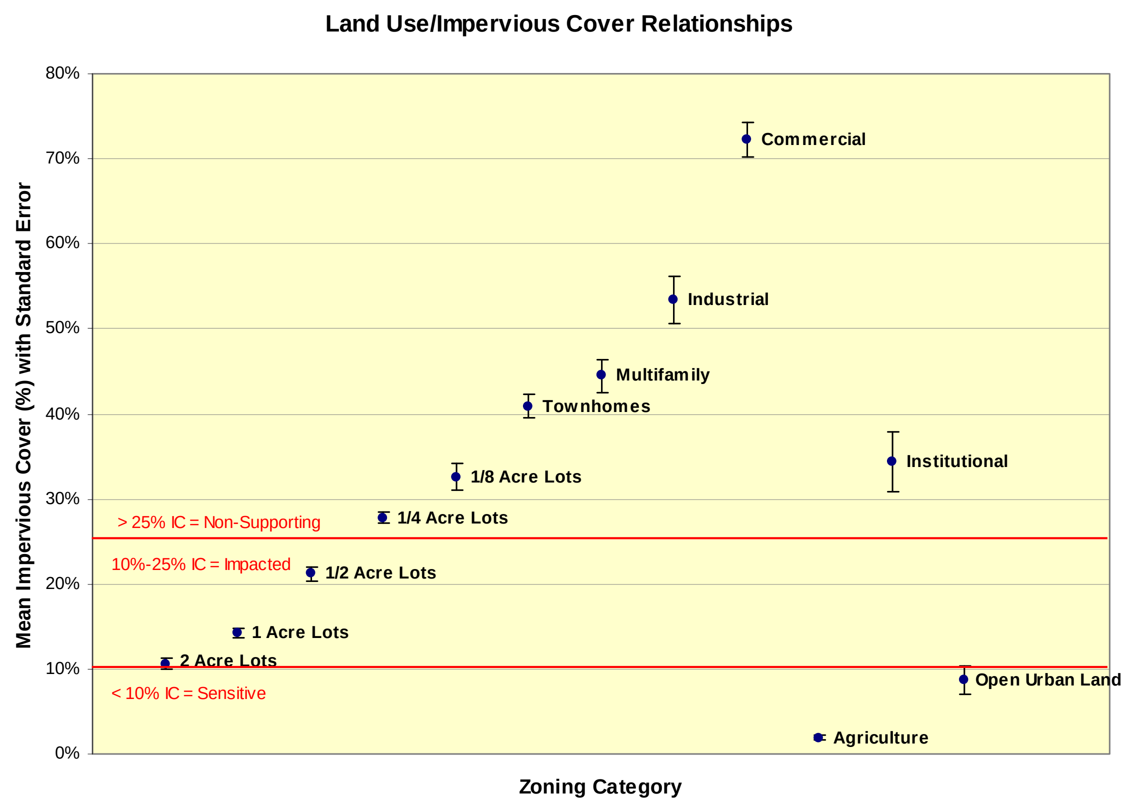
Planning and Zoning Tools	*Engineering Tools*
• Better Site Design • Large-lot Zoning • Site-based IC Caps • Watershed-based IC Caps • Development Intensification • Watershed-based Zoning • Watershed Planning	• Traditional Stormwater Treatment Requirements • Runoff Reducation Practices • Special Subwatershed Stormwater Criteria • Watershed Restoration Plans
Regulatory Tools	*Economic Tools*
• Anti-Degradation Provisions • IC-Based TMDLs • Watershed-Based Permitting	• IC Based Utilities • Excess IC Fees • IC Mitigation Fees • Subwatershed IC Trading

Planning and Zoning Responses to the ICM

Planning responses are handicapped by the fact that that nearly all rural and suburban zoning categories produce more than 10% IC. This can be seen in Figure 1 which portrays data from Cappiella and Brown (2001) on the IC produced by different rural and suburban zones in four Chesapeake Bay communities. Only agricultural preservation zones and open urban land (e.g., parks, cemeteries and golf courses) produced less than

10% IC. This suggests that even low levels of new land development in a subwatershed will degrade streams and receiving waters to some degree.

Figure 1. Relationship between impervious cover and zoning category (adapted from Cappiella and Brown, 2001)



This creates a difficult choice for land planners. On one hand, low density development reduces the extent of stream damage but spreads it out over a wider geographic area and thereby accentuates sprawl. More intense development, on the other hand, greatly increases local stream degradation to the point that many urban communities cannot meet water quality standards and may be subject to an uncertain future restoration liability. Communities have responded to this dilemma by pursuing several planning and zoning responses, as described below.

Better Site Design: This strategy relies on the fact that nearly 65% of new impervious cover can be classified as car habitat (Cappiella and Brown 2001) and focuses on changing local development codes to minimize the geometry of roads, parking lots, sidewalks, cul-de-sacs and other new development infrastructure. These techniques, collectively referred to as Better Site Design (BSD), can also include greater use of swales, relaxed lot geometry, natural area conservation, open-space subdivisions, pervious paving and other site design techniques (CWP 1998a). Several dozen communities across the country have changed their local codes and ordinances to promote BSD through a roundtable process to gain consensus among development stakeholders. The strength of the BSD approach is that numerous modeling studies have demonstrated it can reduce IC, pollutants and development costs by as much as 10 to 40% at individual development sites (Kloss and Calarusse 2006; CWP 1998b). The weakness of BSD is that it lacks a watershed context and therefore reductions in site IC may be not be enough to meet subwatershed objectives.

Extremely Large Lot Zoning. Several communities have adopted extremely large lot zoning to protect sensitive streams in designated planning areas. Often, these zones are accompanied by decisions to restrict or exclude public water and sewer service. This form of very low-density residential development often involves densities ranging from 0.5 to 0.05 dwelling units per acre, and may also involve conservation easements to protect existing forests, buffers and other natural areas. Large lot zoning has been most frequently applied to protect drinking water reservoirs and trout streams, or generally maintain rural character.

The strength of large lot zoning is that it is relatively easy to implement in the context of existing zoning, and provides some measure of permanent protection for sensitive watersheds. The weakness is that the extensive road networks used to connect individual lots produce more IC area per dwelling unit than any other zoning category. When growth pressures are high, large lots tend to spread development over a wide geographic area and contribute to regional sprawl (U.S. EPA 2006). In addition, large lot zoning does not regulate how future property owners will manage their land, which can result in tree clearing, extensive turf or high density hobby farms. Lastly, large lot zoning obviously has no application in the more urban subwatersheds where the impacts of IC are the greatest.

Site-based IC Caps. Several communities have established IC caps within the context of a comprehensive land use plan or functional master plan for the express purpose of protecting drinking water or sensitive streams. Numerical IC caps are imposed on individual residential lots in order to stay below a designated IC threshold for the watershed as a whole. Individual development proposals are closely scrutinized to ensure the development footprint is below the IC cap, or is otherwise mitigated, disconnected or treated. For example, Montgomery County, MD has designated four sensitive watersheds as special protection areas that have an 8 to 10% IC cap for all new development (MCDEP, 2003). The strengths and weaknesses of IC caps are generally similar to those for large lot zoning. IC caps also have the added weakness that they require frequent monitoring to ensure that individual owners do not add more IC in the post-construction phase.

Watershed IC Caps. Direct watershed IC caps have been considered in a number of communities but seldom have been implemented. The caps can be used to protect both sensitive and impacted watersheds. The main drawback is the difficulty in measuring the aggregate change in a subwatershed IC cap over time as a result of many individual zoning and development decisions. A more indirect way to implement a watershed IC cap is through the watershed-based zoning approach.

Development Intensification. Higher density development generates less runoff and pollution per capita, per household or per increment of job growth (U.S. EPA 2006). Therefore, many urban planners and smart growth advocates have suggested that density be intensified within certain subwatersheds or designated planning areas in order to reduce development pressure in sensitive subwatersheds elsewhere. Intensification often involves high rise development, parking garages, mass transit, mixed uses and other features to decrease per-capita IC creation. Intensification is often created by drawing urban growth boundaries and then using incentives and public infrastructure investments to attract redevelopment. Portland (OR) and Toronto (ONT) are two well-known examples where urban growth boundaries were used to promote intensification.

The strength of intensification is that it confers numerous social, community and economic benefits and should result in less dramatic change to stream quality if the area is already developed (e.g., shifting from non-supporting to urban drainage). The weakness of intensification is that it cannot directly protect sensitive or impacted watersheds when multiple communities are involved. At the regional scale, it is often possible for both intensification and low density sprawl to occur at the same time, in response to different market forces and consumer preferences (e.g. land prices, affordable housing, commuting distances, employment centers and the like).

Watershed-based Zoning. Watershed-based zoning is a planning technique that directly ties comprehensive planning or zoning to the ICM. Local planners evaluate current zoning within individual subwatersheds present in their community (Schueler 1994). Current and future IC are forecasted for each subwatershed as a result of buildout of existing zoning. Land is then rezoned within each subwatershed to either increase or decrease IC to achieve the desired ICM classification, which is then incorporated into the local land use master plan or comprehensive plan. The process may also involve special overlay zones that set forth more specific buffer, stormwater and land conservation requirements within each subwatershed management category. To date, several communities have directly or indirectly utilized elements of watershed-based zoning, but none have fully implemented the entire process. The primary reason has been the inherent disconnect between local watershed planning and comprehensive land use planning in most communities.

Watershed Planning Watershed plans can be guide land use decisions to change the location or quantity of IC created by new development. Numerous techniques exist to forecast future watershed impervious cover and its probable impact on the quality of aquatic resources (CWP, 1998 and MD DNR 2005). The level of control that can be achieved by watershed planning is theoretically high, but relatively few communities have aggressively exercised it. In particular, few communities have fully integrated their watershed planning efforts into their comprehensive planning and zoning process. Consequently, many watershed plans contain recommendations for implementation of watershed practices, but few substantative changes in zoning or land use decisions. Powerful consumer and market forces often drive low-density sprawl development, regardless of the recommendations of the watershed plan.

Even when land use is an explicit component of local watershed plans, these local decisions are reversible and often driven by other community concerns such as economic development, adequate infrastructure, and transportation. Many of primary reasons identified as to why local watershed plans are not fully implemented detailed in Schueler (1996) still exist today. Consequently, many communities continue to struggle with how to influence the location and intensity of subwatershed IC in their watershed plans and lack an accountability mechanism to fully implement them (such as a watershed-based permit).

Engineering Responses to the ICM

Traditional Stormwater Treatment Requirements: Many communities have relied on engineering rather than planning solutions to address ICM impacts. The major trend has been to adopt stormwater management requirements to treat both the quality and quantity of runoff from individual development sites. The most common practice has been to pipe runoff into a stormwater detention or retention pond. Performance research studies indicate that ponds do have modest flood control and pollutant removal capability (ASCE, 2007 and CWP 2007). Traditional stormwater ponds, however, have not been shown to improve stream quality indicator scores. For example, seven research studies have concluded that stormwater ponds are incapable of preventing the degradation of aquatic life in downstream channels (MNCPPC 2000; Maxted 1999; Stribling et al. 2001; Galli 1990; Horner and May 1999; Horner et al. 2001; Jones et al. 1996). Given that current stormwater technology cannot fully mitigate land development impacts, the engineering community has explored new sizing criteria and stormwater technology to improve their performance.

Runoff Reduction Approach: The prevailing stormwater paradigm has recently shifted to what is known as the Runoff Reduction Approach (Schueler 2008). The goal is to mimic natural systems as rain travels from the roof to the stream through combined application of a series of small practices distributed throughout the entire development site. Runoff reduction is operationally defined as the total runoff volume reduced through canopy interception, soil infiltration, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapotranspiration. The overall site design objective is to replicate the runoff coefficient for all storms up to a certain design storm event for the native predevelopment land cover.

Runoff reduction practices include rain tanks, rain gardens, infiltration, bioretention, dry swales and linear wetlands, among others. The comparative runoff reduction rate achieved by various stormwater practices varies greatly, as shown in Table 2. Several traditional stormwater practices, such as ponds and sand filters have little or no capability to reduce incoming stormwater runoff volume (Strecker et al. 2004), whereas other practices can achieve annual runoff reduction rates ranging from 40 to 90%, depending on their design. Typically, multiple practices are needed at each site to incrementally reduce the total stormwater runoff volume delivered to the stream. The major challenge with runoff reduction is how to size and arrange the individual practices to meet the appropriate stream protection objective with a subwatershed. The most recent approach is to define a variable runoff reduction volume based on the subwatershed management designation. The shift to runoff reduction is quite recent, so monitoring efforts to demonstrate its effect on improving stream quality indicator scores at the subwatershed scale have yet to be completed. Several recent studies have shown that LID or runoff reduction approaches can be effective at the scale of the individual site (Phillips et al, 2003, Selbig and Bannerman, 2008).

Table 2: Comparative Runoff Reduction Rates of Selected Stormwater Practices in the Chesapeake Bay

Practice	Level 1 RR (%)	Level 2 RR (%)
Infiltration	50	90
Bioretention	40	80
Pervious Paver	45	75
Green Roof	45	60
Dry Swale	40	60
Rain Tanks/Cisterns	10	40
Rooftop Disconnection	25	50
Grass Channel	15	30
Dry ED Pond	0	15
Wet Pond	0	0
Constructed Wetland	0	0
Sand Filter	0	0

Source: CSN(2008) and CWP (2008)

Special Subwatershed Stormwater Criteria: Another approach has been to define special subwatershed design criteria that govern the size, selection and location of the structural and non-structural practices needed to protect aquatic resources in sensitive subwatersheds. Several recent state stormwater manuals have established more prescriptive criteria to protect sensitive waters, such as wetlands, lakes, and trout streams (see Wenger at al 2008 and MSSC 2005) or to focus on increasing the removal of a specific pollutant of concern in a more developed situation (see Schueler 2008).

Watershed Restoration Practices: Stormwater retrofits, stream repair, riparian and upland reforestation, discharge prevention and pollution source controls have all been applied to restore stream quality in urban subwatersheds. A full description of their strengths and weaknesses can be found in the Small Watershed Restoration Manual Series produced by the Center for Watershed Protection. The individual and aggregate effectiveness of restoration techniques appears to be inversely related to the amount of IC present in a subwatershed (Schueler 2004). The best prospects for improving stream quality indicator scores occurs in sensitive and impacted watersheds, whereas the cost and feasibility of restoration climbs rapidly in non-supporting and urban drainage subwatersheds (Schueler et al. 2007).

Most communities assemble individual restoration practices within the context of a larger watershed restoration plan to achieve defined stream quality objectives. The key problem of watershed planning tends to be one of implementation. Many communities have fine plans, but have only implemented a handful of actual restoration projects. The poor track record in implementation is created by the inherent difficulty of delivering dozens or hundreds of restoration projects over time, their high cost, and the lack of dedicated financing to build them. In addition, most local watershed restoration plans lack accountability mechanisms to ensure progress is maintained over the 10 to 15 years required for full implementation.

Regulatory Responses to the ICM

Beneficial uses and related water quality standards are frequently exceeded in most urban subwatersheds, so regulatory agencies continue to grapple with the ICM as it relates to the many complex provisions of the Clean Water Act. Some recent trends include:

Anti-Degradation, Tiered Uses and Wet Weather Standards. Several sections of the Clean Water Act could potentially protect sensitive and impacted streams, or allow greater flexibility in meeting standards in non-supporting streams. For example, anti-degradation provisions can protect waters that currently achieve or exceed water quality standards or their designated use, but are threatened by future watershed development. States such as Ohio and Maine have crafted anti-degradation rules to regulate discharges or activities by NPDES permitees in the watershed to protect healthy waters. States also have the capability to designate tiered uses and wet weather standards to set more realistic water quality goals for non-supporting and urban drainage subwatersheds, although, to date, few have exercised this option.

Impervious cover based TMDLs. Total Maximum Daily Loads or TMDLs are the primary tool to document how pollutant loads will be reduced to meet water quality standards. Maine, Vermont and Connecticut have recently issued TMDLs that are based on IC rather than individual pollutants of concern (Bellucci 2007). In an IC- based TMDL, IC is used as a surrogate for increased runoff and pollutant loads as a way to simplify the urban TMDL implementation process. IC-based TMDLs have been issued for small subwatersheds that have biological stream impairments associated with stormwater runoff but no specific pollutant listed as causing the impairment (in most cases, these subwatershed are classified as impacted according to the ICM).

A specific subwatershed threshold is set for effective IC, which means IC reductions are required through removal of IC, greater stormwater treatment for new development, offsets through stormwater retrofits or other means. Since IC-based TMDLs have only appeared in the last year, communities have little or no experience in actually implementing them. Traditional pollutant-based TMDLs continue to be appropriate for non-supporting and urban drainage subwatersheds, although they could be modified to focus compliance monitoring on priority urban source areas or subwatersheds that produce the greatest pollutant loads.

Watershed-Based Permitting. U.S. EPA (2007) has issued technical guidance to promote watershed-based permitting, which has the potential to integrate the many permits to improve water quality conditions in urban watersheds. States and localities, however, have yet to implement watershed-based permitting at the sub-watershed scale in the context of the ICM. This regulatory tool does show promise and several recommendations for applying to urban watersheds as part of the NPDES Ms4 stormwater permit program are presented in Part 4 of this paper.

Economic Responses to the ICM

Economists have been attracted to IC because it is easy to measure and can act as a common currency that spans and transcends the site and watershed scale. In recent years, economists have tried to value or price IC so as to better use market forces to improve urban watershed management. These efforts are mostly in their infancy and face the twin problems of defining the unit price of IC and how it varies among subwatersheds with different IC. Several economic approaches that utilize IC are described below:

IC Based Utilities: Several hundred communities have adopted stormwater utilities that charge residents and businesses a monthly or quarterly charge based on their IC. Funds are used to operate stormwater programs, maintain stormwater infrastructure and comply with their stormwater permits. Utility charges typically range from $30 to $120/year/ residential unit and apply only to existing development. In most cases, an average unit IC charge is applied to all homes and businesses, since most communities lack enough GIS or political resolution to estimate IC and charge for individual parcels. The utility fee can be an incentive to reduce site IC by reducing charges for homeowners that install retrofits such as rain gardens.

IC Mitigation Fees: IC mitigation fees can be applied to new development to discourage the creation of excess IC or to pay for off-site restoration when on-site stormwater compliance is not possible. In the first case, communities establish a maximum IC cap within an individual zoning category or for the subwatershed as a whole. New development projects that exceed the cap are charged a unit fee used to finance restoration practices elsewhere in the subwatershed. In the second case, an IC-based fee-in-lieu is charged when an individual site cannot meet stormwater runoff reduction requirements in full or in part. The basic IC pricing mechanism is the same in both cases: the average per IC acre cost to provide an equivalent amount of restoration or stormwater treatment elsewhere in the watershed. The weakness of mitigation fees involves difficulty in accurately matching the fees collected to actual construction of cost-effective restoration projects in the desired subwatershed that needs restoration.

Subwatershed IC Trading. Trading of IC among subwatersheds is still a novel concept although its theoretical elements have been outlined by Parikh et al. (2005). Like other water quality trading programs, development sites that face higher pollution control costs can meet their regulatory obligations by purchasing environmentally equivalent (or superior) pollution reductions or “credits” from another subwatershed at lower cost, thus achieving the same water quality improvement at lower marginal cost. IC is a logical currency for stormwater trading, and may be most efficient in shifting costs among different subwatersheds to produce the greatest water quality improvement. For example, the higher compliance cost in an urban drainage subwatershed might be traded to a sensitive subwatershed to provide greater protection by purchasing lower cost conservation easements.

Summary

The preceding review suggests that no single planning, engineering, economic or regulatory tool appears capable of effectively protecting or restoring stream quality over the full range of subwatershed IC. Some individual tools work reasonably effectively across a narrow range of impervious cover, but most have significant weaknesses, particularly when it comes to implementation. In addition, most communities tend to use only one kind of tool to mitigate the impact of IC (i.e. planning approaches versus engineering solutions). As a result, most communities are unsatisfied with the outcomes of their urban watershed protection or restoration efforts to date.

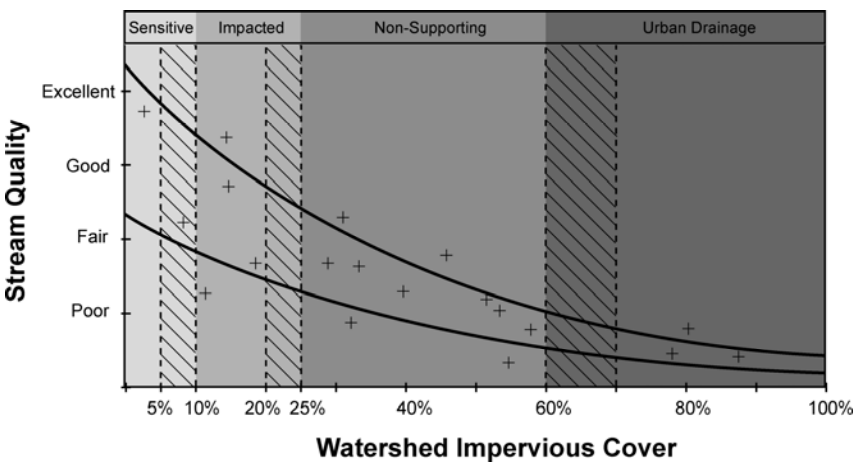
The review also suggests some possible management remedies. The first is that many communities set unrealistically high expectations for stream quality given their development intensity. In this instance, it may be wise to set more realistic and achievable stream quality objectives (several recommendations are made in the ensuing section. Second, communities may wish to apply a combination of planning, engineering, economic or regulatory tools at the same time. Third, communities should classify their subwatersheds to make sure they are applying the most effective and appropriate tools within the prescribed range of subwatershed IC. Lastly, communities may need to develop more stringent accountability mechanisms to ensure that the tools they use are fully implemented. The remainder of this white paper expands on these possible management remedies.

PART 2
SUBWATERSHED CLASSIFICATION AND MANAGEMENT OBJECTIVES

The reformulated ICM is best used an urban stream classification tool to set reasonable expectations for stream quality indicators over broad ranges of subwatershed IC (Figure 2) In general, the predictions of the ICM are as follows: Stream segments with less than 10% IC in their contributing drainage area continue to function as **high quality streams**, and are generally able to retain their hydrologic function and support good to excellent aquatic diversity. Stream segments that have 10 to 25% IC in their contributing drainage area behave as **Impacted Streams** and show clear signs of declining stream health. Most indicators of stream health will fall in the fair range, although some segments may range from fair to good as riparian cover improves.

The decline in stream quality is greatest towards the higher end of the IC range. Stream segments that range between 25 and 60% subwatershed impervious cover are classified as **non-supporting streams** (i.e., no longer supporting their designated uses in terms of hydrology, channel stability habitat, water quality or biological diversity). These stream segments become so degraded that any future stream restoration or riparian cover improvements are insufficient to fully recover stream function and diversity (i.e., the streams are so dominated by subwatershed IC that they cannot attain pre-development conditions). Stream segments whose subwatersheds that exceed 60% impervious cover are eliminated or physically altered so that they merely function as a conduit for flood waters. These streams are classified as **urban drainage** and consistently have poor water quality, highly unstable channels and very poor habitat and biodiversity scores. In many cases, these urban stream segments are eliminated altogether by earthworks and/or storm drain enclosure.

Figure 2 The Reformulated Impervious Cover Model (Schueler et al, in press)



As such, the ICM helps define general thresholds where current water quality standards or biological conditions cannot be consistently met during wet weather conditions. These predictions help watershed managers set realistic objectives to protect stream quality based on both current and future conditions. A provisional set of stream objectives for the four subwatershed categories are outlined in Table 3. They were initially derived by examining the upper limit of maximum stream quality from existing data (i.e., the top curve in Figure 2 and increasing it upward to reflect reasonable expectations for future performance improvements for stormwater treatment and restoration practices. These rather stringent objectives should be achievable, but may be modified by future monitoring activity. It should also be noted that the stream quality expectations outlined in Table 3 presume some portion of the subwatershed has already been developed, thereby limiting attainment of objectives. If a subwatershed is not yet developed, managers should shift expectations up one category (e.g., urban drainage should behave like it is non-supporting).

Table 3: Expectations for Different Urban Subwatershed Classes

Sensitive Streams (2 to 10% IC) [1]
• Maintain or restore ecological structure, function and diversity so streams provide a "rural" benchmark to compare other stream categories against • Specific stream quality indicators for sensitive streams should be compared to streams whose entire subwatersheds are fully protected (e.g. national parks).
Impacted Subwatersheds (11 to 25% IC)
• Consistently attain good stream quality indicator scores to ensure enough stream function to adequately protect downstream receiving waters from degradation. • Function is defined in terms of flood storage, instream nutrient processing, biological corridors, stable stream channels and other factors.
Non-Supporting Subwatersheds (26 to 59% IC)
• Consistently attain fair to good stream quality indicator scores. • Meet bacteria standards during dry weather and trash limits during wet weather • Maintain existing stream corridor to allow for safe passage of fish and floodwaters
Urban Drainage Subwatersheds (60 to 100% IC)
• Maintain good water quality conditions in downstream receiving waters • Consistently attain fair water quality scores during wet weather and good water scores during dry weather • Provide clean "plumbing" in upland land uses such that discharges of sewage and toxics do not occur
[1] the specific ranges of IC that define each management category should always be derived from local or regional monitoring data

PART 3: A PROPOSED URBAN STREAM MANAGEMENT SYSTEM

Once realistic expectations have been set for a subwatershed, the specific combination of planning, engineering, economic and regulatory tools that are needed becomes more obvious. Some potential combinations for each subwatershed management category are detailed in Tables 4 through 6. It should be strongly emphasized that these are a starting point for developing a local watershed management strategy, and that they will always need to be modified for local conditions.

Management Strategies to Protect High Quality Streams

One of the more troubling findings of the ICM, and much of the recent urban stream research, is that it does not take very much subwatershed development to degrade high quality streams – depending on the ecoregion, as little as 3 to 7% IC. Many high quality streams have evolved in response to the forest (or native cover) of their subwatersheds, and have unique habitat conditions that support trout, salmon or spawning of anadromous fish.

Table 4. Management strategies to protect high quality streams

Subwatershed Outcomes Need to Protect High Quality Streams
• Restrict subwatershed IC to less than 10% (or regional IC threshold)* • Retain more than 65% forest or native vegetative cover in subwatershed • Ensure forest or native cover on at least 75% of stream network • Do not allow more than one crossing per stream mile, and none that create a barrier to migration
Recommended Watershed Planning and Engineering Practices
• Require full runoff reduction up to the two year storm for all new IC by maximizing the use of runoff reduction practices and discouraging conventional detention ponds and large diameter storm drain pipes • Establish wide stream buffers for the entire drainage network, including zero-order streams (100 to 200 feet) • Apply conservation practices to all croplands and keep livestock out of streams • Use site or subwatershed IC caps, extremely large lot zoning, watershed based zoning, farm preservation or conservation easements to limit subwatershed IC • Limited stream restoration to restore habitat, remove fish barriers and correct past mistakes
Recommended Regulatory and Economic Measures
• Protect healthy streams using anti-degradation provisions of the Clean Water Act • Monitor the geomorphic stability and biological diversity of the streams to verify compliance • Reduce public infrastructure investments in subwatershed to discourage growth • Increase technology and permit requirements for private water and sewer infrastructure • Designate these subwatersheds as receiving areas for IC mitigation fees to finance restoration and secure conservation easements

Given the vulnerability of these streams, watershed managers must commit to an aggressive protection strategy to mitigate the impacts of land development (Table 4). The comprehensive strategy involves watershed zoning, land conservation, preservation of the riparian network and stormwater practices that create no net increase of runoff volume or velocity up to the two year design storm event.

Additional regulatory and economic tools are also needed to protect and maintain the quality of exceptional streams, as shown in Table 4. While the proposed strategy is much more stringent than what most communities currently allow, it is technically achievable, and provides greater reliability in meeting the objectives of maintaining exceptional stream biodiversity and function. From the standpoint of implementation, it is important to formally designate these subwatersheds as being exceptional, and then using the anti-degradation provisions of the Clean Water Act to provide regulatory support for the development restrictions.

Management Strategies for Suburban Streams

Stream quality in suburban subwatersheds (10 to 25% IC) exhibits a great deal of variability or scatter. Indicator scores can range from poor to fair to good (but not excellent). A reasonable management objective is to achieve both good indicator scores and maximize stream function to adequately protect downstream receiving waters from degradation (e.g., flood storage, instream nutrient processing, biological corridors, stable stream channels, etc.). Given the relatively light development intensity of suburban watersheds, there is room to apply a broad range of management practices in the uplands and the stream corridor (Table 5).

The basic upland management prescription for suburban streams is to maximize tree canopy and minimize both turf and impervious cover across the subwatershed. Stormwater practices that achieve full runoff reduction up to the two year storm event are applied in a roof to stream sequence to reduce channel erosion and maintain recharge. The prescription for the stream corridor is to protect and enhance buffers around streams, wetlands and floodplains, with special emphasis on minimizing the enclosure of zero order streams (i.e., maintaining them as a open stormwater treatment system). Some elements of the stream corridors may require stream repairs, reforestation or wetland creation.

Table 5. Management strategies to protect impacted subwatersheds (suburban)
Recommended Watershed Planning and Engineering Practices
• Require full runoff reduction up to the one year storm for all new IC created in the subwatershed • Minimize subwatershed IC, maximize forest cover and conserve soil quality using runoff reduction practices from roof to stream • Conserve and protect stream buffers, floodplains, wetlands and river corridor in a natural state and in public ownership • Adjust zoning to limit IC to meet 20 to 25% subwatershed IC caps • Use Better Site Design roundtable process (CWP, 1998a) to seek 25% reduction in average IC and turf cover produced by each zoning category • Implement selected stream restoration and storage retrofits to mitigate effect of existing development in the watershed • Establish an ultimate subwatershed tree canopy goal of 40 to 45%
Recommended Regulatory and Economic Measures
• Utilize IC-based TMDLs to set specific targets for runoff reduction and removal of pollutants of concern • Invest in public infrastructure to enhance the quality of drinking water, wastewater and stormwater • Designate these subwatersheds as receiving areas for IC mitigation fees to finance retrofits and other restoration practices • Impose IC mitigation fees for both new and existing development to discourage creation of needless impervious cover, finance restoration and maintain stream protection and stormwater infrastructure

Table 5 also outlines the regulatory and economic tools needed to implement and maintain watershed practices for suburban streams. The key management challenge is to prevent a gradual "creep" in IC over time through rezoning, redevelopment and homeowner expansions. Consequently, watershed managers should set clear goals for maximum future IC, and track it over time to ensure it remains within prescribed limits.

Strategies to Manage Highly Urban Streams

The quality of highly urban subwatersheds will be inevitably degraded by the combination of IC creation, soil compaction and stream alteration. Highly urban streams can have one of two management designations -- non-supporting (25 to 60% IC) and urban drainage (60 to 100% IC). Urban drainage subwatersheds generally have little or no remaining surface stream network, whereas non-supporting streams still have some surface streams, although they are often highly degraded and fragmented. The management goal for both stream classes is to limit the extent of degradation, while at the same recognizing these subwatersheds are an intense human habitat, both in the uplands and the remaining stream corridor. The proposed management strategies for non-supporting and urban drainage subwatersheds are presented in Table 6.

Table 6. Strategies for Non-Supporting and Urban Drainage Subwatersheds [1]
Recommended Watershed Planning and Engineering Practices
• Encourage intensification and redevelopment • Require runoff reduction for the 90th percentile storm as part of the redevelopment process (NS subwatersheds) or a fraction thereof (UD subwatersheds) • Provide sufficient upland retrofit, discharge prevention, and pollution prevention practices to treat stormwater hotspots • Utilize street cleaning and storm drain inlet cleanouts to remove gross pollutants from the dirtiest source areas. • Maintain a forest canopy goal of at least 25% and 15% for NS and UD subwatersheds, respectively • Manage the remaining stream corridor as a greenway and protect/restore large natural area remnants
Recommended Regulatory and Economic Measures
• Utilize conventional TMDLs to reduce pollutants of concern at the most polluted subwatersheds and urban source areas. • Conduct dry weather water quality monitoring in streams (NS) or receiving waters (UD) to assure progress towards goals • Designate these subwatersheds as sending areas for IC mitigation fees to finance retrofits and other restoration practices in less dense subwatersheds • Impose IC mitigation fees for redevelopment when full site compliance with runoff reduction targets cannot be attained.
1 for space purposes, the strategies for non-supporting (NS) and urban drainage (UD) have been combined together since they differ primarily in the scope or extent

of treatment, except where noted

The basic approach is to protect public health and safety through stormwater management, pollution prevention and discharge prevention practices in the uplands, and to use the stream corridor as a greenway and a conduit for floodwaters. While it is not possible to achieve high levels of aquatic diversity, the watershed practices can reduce pollutant export to downstream receiving waters, and ensure safe water contact during dry weather periods. The land use planning strategy for these subwatersheds encourages both intensification and redevelopment. The impacts from increased IC can be ameliorated by green buildings, expanded urban tree canopy, and selected stormwater retrofits and watershed restoration projects.

For some, this strategy sacrifices urban streams, and enables municipalities to violate existing water quality standards. The key point, however, is that IC and associated infrastructure has such a dominant influence on these streams that aquatic diversity and water quality standards could never be met, regardless of the investment. Implementation of the stringent measures outlined in Table 6 can result in incremental improvements in local waters and substantial pollutant reduction to downstream waters.

PART 4
INTEGRATING WATERSHED PLANS INTO ENFORCEABLE PERMITS

As noted earlier, most of the planning, engineering, and regulatory responses to the ICM are not effective unless they are applied together in the context of a local watershed plan. The mere existence of a plan is also not effective unless it is fully implemented. Relatively few watershed protection or restoration plans have progressed into actual implementation, primarily because there is no mechanism for accountability and enforcement. The clear implication is that local subwatershed plans must be translated into a long term watershed-based permit to ensure implementation. The best permitting vehicle appears to be the municipal NPDES stormwater permit system. With some adaptation, these permits can be implemented on a subwatershed basis, using the process outlined below:

Step 1. Define interim water quality and stormwater goals (i.e., pollutants of concern, biodiversity targets) and the primary pollutant source areas and hotspots that cause them

Step 2. Delineate subwatersheds within community boundaries

Step 3. Measure current and future impervious cover within individual subwatersheds

Step 4. Establish the initial subwatershed management classification using ICM

Step 5. Undertake field monitoring to confirm or modify individual subwatershed classifications)

Step 6. Develop customized management strategies within each subwatershed classification, that will guide or shape how land use decisions are made at the subwatershed level, and how watershed practices will generally be assembled at individual sites

Step 7. Undertake restoration investigations to verify restoration potential in priority subwatersheds

Step 8. Agree on the specific implementation measures that will be completed within the permit cycle. Evaluate the extent to which each of the six minimum management practices can be applied in each subwatershed to meet municipal objectives

Step 9. Agree on the maintenance model that will be used to operate or maintain the stormwater infrastructure, assign legal and financial responsibilities to the owners of each element of the system, and develop a tracking and enforcement system to ensure compliance.

Step 10. Define the trading or offset system that will be used to achieve objectives elsewhere in the local watershed objectives in the event that full compliance cannot be achieved due to physical constraints.

Step 11. Establish sentinel monitoring stations in select subwatersheds to measure progress towards goals.

Step 12. Revise subwatershed management plans in the subsequent NPDES permitting cycle, based on monitoring data

The core of the approach is to customize management strategies for each class of subwatershed so as to apply the most appropriate planning, engineering and regulatory tool (see Table 7). The benefit of subwatershed-based permits is that it also provides accountability mechanism in the form of compliance monitoring on a subwatershed basis. In all subwatersheds, it makes sense to measure and track changes in both IC created and IC treated. Within individual subwatersheds, however, the focus of monitoring efforts may differ. For example, monitoring of biological metrics is recommended in sensitive and impacted streams to ensure they are meeting their objectives. Outfall monitoring continues to be important for non-supporting streams, particularly if stormwater quality data are compared to action levels to identify the most polluted subwatersheds for greater treatment.

Table 7: Examples of Customized Subwatershed Management Strategies

Subwatershed Management Issue	Sensitive Streams (2 to 10% IC	Impacted (IC 10 to 24%)	Non-Supporting (IC 25 to 59%)	Urban Drainage (60% + IC)
Land Use Planning and Zoning	Extensive land conservation and acquisition to preserve natural land cover. Site-based or watershed IC caps	Reduce IC created for each zoning category by changing local codes and ordinances	Encourage redevelopment, and intensification of development to decrease per-capita IC utilization in the landscape. Develop watershed restoration plans to maintain or enhance aquatic resources	
Site-Based Stormwater Reduction and Treatment Objectives	Treat runoff from two year design storm using practices to achieve 100% runoff reduction volume	Treat runoff from one year design storm using practices to achieve 75% runoff reduction volume	Treat runoff from the 90% annual storm and achieve at least 50% runoff reduction volume	Treat runoff from the first flush storm and achieve at least 25% runoff reduction volume
Site-Based IC Fees	Establish Excess IC Fee for projects that exceed IC zoning category		Allow IC Mitigation Fee	Allow IC Mitigation Fee
Subwatershed Trading	Receiving Area for Conservation Easements, Restoration Projects and Retrofit		Receiving or Sending Area for Retrofit	Sending Area, for Restoration Projects
Stormwater Monitoring Approach	Measure instream metrics of biotic integrity	Track subshed IC and measure practice performance	Check outfalls and measure practice performance	Check municipal actions levels at outfalls
TMDL Approach	Protect using anti-degradation provisions	IC-based TMDLs that use flow or IC as a surrogate for traditional pollutants	Pollutant TMDLs to identify problem subwatersheds	Pollutant TMDLs to identify priority source areas
Dry Weather Water Quality	Check for failing septic system	Outfall and channel screening for illicit discharges	Dry weather sampling in streams and outfall screening	Dry weather sampling in receiving waters
Addressing Existing Development	Ensure farm, pasture and forest best practices are used	Stream repairs, riparian reforestation & residential stewardship	Storage retrofits and stream repairs	Pollution source controls and municipal housekeeping

SUMMARY

Managing urban watersheds can be challenging. The best chance of achieving stream quality objectives arises when the many tools of watershed protection and restoration are organized and aligned in the context of an ICM-based stream classification system and an enforceable watershed-based permit system is established to implement them. The proposed approaches outlined in this working paper are intended to be an initial guide to help local managers to shift to a new subwatershed approach.

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