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INTEGRATING IMPERVIOUS SURFACE MANAGEMENT AND SMART GROWTH DEVELOPMENT IN NEW JERSEY

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ABSTRACT: *The process of urbanization is a dramatic transformation of land from a natural or rural state into a built environment of human habitat. In a rapidly urbanizing region such as the state of New Jersey, the combined impact of hundreds of independent development projects occurring over the course of a year can have ecosystem-wide implications greater than the site-level impacts that are reasonably managed under current local land use regulation. Characterizing, quantifying and modeling ecosystem-wide impacts of urbanization is quite challenging to incorporate into land management policies. Nonetheless, over the past decade impervious surface has emerged as a single proxy indicator of the multiple environmental impacts associated with urbanization. Impervious surface is relatively easy to measure and is highly correlated with a wide variety of environmental impacts imposed by urbanization. This paper investigates the potential for impervious surface regulation to be utilized more directly in the land management process as a powerful planning tool for achieving ecosystem-wide management goals and objectives. Furthermore, impervious surface-based land management holds potential for being a mechanism for achieving the state's smart growth goals. This study explores the potential for New Jersey to be a test bed for developing a system of land management based on impervious surface cap and trade integrated with smart growth metrics.*

Keywords*: Impervious surface, Land management, Smart growth*

INTRODUCTION

At only five million acres in territory, New Jersey is the fourth smallest state in the nation, yet it is also contains the eleventh highest total population. This equates to a population density of 1,134.5 people per square mile (US Census Bureau, 2009), which not only makes New Jersey the most densely populated state in the nation, but places it at a higher overall population density than Europe, Japan, China or even India (Central Intelligence Agency, 2009). New Jersey's population pressure stems largely from its geographic location, wedged between New York City and Philadelphia, respectively the nation's first and fifth largest metropolitan centers. These factors have resulted in New Jersey maintaining its status as one of the most rapidly urbanizing states in the nation for the last half century (National Resources Conservation Service, 2007). Developing at a rate of over 15,000 acres per year, the Garden State is on track to becoming the concrete state as it is likely to be the first state to reach buildout sometime near the middle of the century (Hasse and Lathrop, 2008).

One of the consequences of urbanization is the creation of impervious surface. Impervious surfaces are any man-made materials or activities that impede or prevent the natural hydrologic process of infiltration (Figure 1). Impervious surfaces can include pavements (roads, parking lots, driveways and sidewalks) that are covered by impenetrable materials such as concrete, asphalt, brick and stone. Impervious surfaces can also include buildings, structures, and even in some cases soils surrounding development that have become compacted by the development process (Zampella et al., 2007).

This paper explores the conditions of impervious surface in New Jersey, looking not only at the problematic effects but also at the opportunities to leverage impervious surface into a tool to better achieve the goals of smart growth and environmental protection. The study utilizes one of the most detailed statewide digital land mapping databases in the nation to map the geographic pattern of New Jersey's impervious surface footprint and its mode of increase in recent decades.

Figure 1. Impervious surface has significant implications for water quality and flooding as runoff and non-point source pollution is channeled rapidly into stream systems.

IMPERVIOUS SURFACE AS A META INDICATOR OF ENVIRONMENTAL IMPACT

Over the past several decades impervious surface has emerged as a robust indicator of the impacts of urban development on water quality degradation (Arnold and Gibbons, 1996; Brabec et al., 2002). Studies have demonstrated that accelerated runoff from impervious surfaces directly channeled into water bodies leads to increased frequency and magnitude of flooding and subsequent, potentially disastrous consequences (Carter, 1961; Wilson, 1967; Seaburn, 1969; Hammer, 1972). Impervious surface also impacts water quality by concentrating non-point source pollutants such as road salts, sediments, hydrocarbons and refuse, channeling them directly into waterways (Klein, 1979; Booth, 1991). Other research has indicated that the overall environmental quality of water within a watershed is directly related to the amount of impervious surface within that basin. For instance, important impacts such as changes in alkalinity, nutrient loading and chemical contamination have been associated with impervious surface coverage (Alley and Veenhuis, 1983; Booth, 1991; Horner, et al., 1996). Impervious surface reduces or eliminates the capacity of the underlying soil to percolate water and thus increases the direct discharge of storm-water into water bodies, effecting water quality and flood vulnerability (Hurd and Civco, 2004; Zampella et al., 2007).

Indicators of stream quality impact are generally broken down into biotic and abiotic factors, with the biotic more conducive for assessing the long-term health of the water body (Karr, 1987). Abiotic factors can include variables such as pH, specific conductance, calcium, magnesium, chloride, sulfate, nitrogen, and phosphorus. Biotic factors of water quality can include stream vegetation and stream-fish, impoundment-fish, anuran assemblages and macro invertebrates. For example, research in the New Jersey Pinelands has suggested that impacts on abiotic and biotic indicators of stream health begin to be measurable at proportions as low as 10% altered land cover (urban and agriculture) within a watershed (Zampella et al., 2007). The amount of impervious surface associated with developed land is directly related to land use category.

As the proportion of impervious surfaces within a watershed increases, the physical changes to the stream change in a corresponding manner, including the magnitude of stream bank erosion and channelization (May et al., 1997). Although the relationship is continuous, there are thresholds that have been identified at which the water quality condition makes a demonstrable transition. Schueler's (1994) review of 11 previous studies documented thresholds of water impact beginning when a watershed became covered with 10-15% impervious surface. Arnold and Gibbon's (1996) seminal paper further refined the threshold discourse by demonstrating a fairly consistent relationship of 10% impervious cover resulting in water quality "impact" and 30 % impervious coverage resulting in water quality "degradation" as stream ecology can no longer adequately function in its original capacity. Furthermore, because expanses of directly connected impervious surfaces may have greater potential to impact runoff quantity and quality, watersheds characterized by greater proportions of directly connected impervious surfaces may have increased water quality issues, as distinguished from those with more scattered patterns of impervious coverage (Allan, 2004).

The vital associations to water quality demonstrated in the literature are leading impervious surface coverage to become increasingly relied upon as a defensible environmental indicator for basing land planning decisions (Arnold and Gibbons, 1996; Brabec et al., 2002). Furthermore, looking beyond water quality, the increase in impervious surface associated with development may also be linked to other environmental impacts including the loss and fragmentation of important land resources such as farmlands, forests, wetlands, and wildlife habitats. For example, many New Jersey municipalities that experienced the greatest increase in impervious surface in recent decades were the same municipalities that lost the greatest amounts of important land resources (Hasse and Lathrop, 2008). These losses occur because the urbanization process entails a transformation of land from a natural or rural state into a built environment. In a rapidly urbanizing region such as the state of New Jersey, the combined impact of hundreds of independent development projects occurring over the course of a year can have ecosystem-wide implications greater than the site-level water quality impacts that are reasonably managed using best management practices (BMPs) under current local land use regulation. Incorporating every ecosystem-wide impact of urbanization into land management policy is impractical. However, more effectively incorporating *impervious surface* into land management policy has the potential to benefit many environmental issues in addition to protecting water quality. For this reason we consider impervious surface a *meta indicator* for environmental land management.

NEW JERSEY'S IMPERVIOUS FOOTPRINT

In order to get a handle on the geographic distribution and temporal change of impervious surface, this study evaluated the New Jersey 2002 digital land use database. This Land Use/Land Cover (LU/LC) digital dataset was released by the New Jersey Department of Environmental Protection (NJDEP) in January of 2007 (New Jersey Department of Environmental Protection, 2007). The dataset was compiled from digital aerial photography and contains a high level of accuracy identifying land features as small as an acre throughout the entire state. Each of the over 800,000 polygons that make up the dataset include an estimated percentage of impervious surface at 5% increments. Statistical analysis of the data reveals the remarkable extent of impervious surface statewide.

The findings indicate that as of 2002, New Jersey's landscape was covered with nearly 490,000 acres of impervious surface or about 10% of the state's total land area (Figure 2). To put this vast amount of impervious surface into perspective, it is the equivalent of a wall to wall slab of concrete the size of the state's Ocean County. During the study period of 1995 to 2002, 35,809 acres of impervious surface were added to New Jersey's landscape, representing an annualized rate of 5,116 acres of impervious surface increase per year. This rate of impervious surface formation is roughly equivalent to paving 1,742 new parking spaces every day. The data revealed that growth trends of the 1980s and 90s added one acre of impervious surface for every 4.2 acres of development. In other words, land developed between 1995 and 2002 is, on average, 23.8% impervious surface.

Figure 3 illustrates the impervious surface conditions for New Jersey's watersheds. Ten watersheds, representing 315,351 acres or 6.4% of watershed lands in New Jersey were 30% or greater impervious surface as of 2002. This indicates that stream water quality in these basins has a high likelihood of being in a *degraded* condition (Arnold and Gibbons, 1996). These watersheds are located in the highly urban areas of the state adjacent to the cities of New York and Philadelphia. Forty watersheds representing 1,372,189 acres of New Jersey's watershed lands are between 10% and 29.9% impervious surface, indicating a high likelihood of *impacted* water quality (Arnold and Gibbons, 1996). Twenty-nine watersheds representing 1,006,060 acres of New Jersey's watershed lands are between 5% and 9.9% impervious surface, suggesting *impending* water quality impacts as any further impervious surface creation will likely affect water quality (Zampella et al., 2007). The remaining seventy-three watersheds representing 3,015,159 acres of New Jersey's watershed lands are less than 5% impervious surface, indicating relatively *non-impacted* water quality (Zampella et al., 2007) (this does not include possible agricultural impacts).

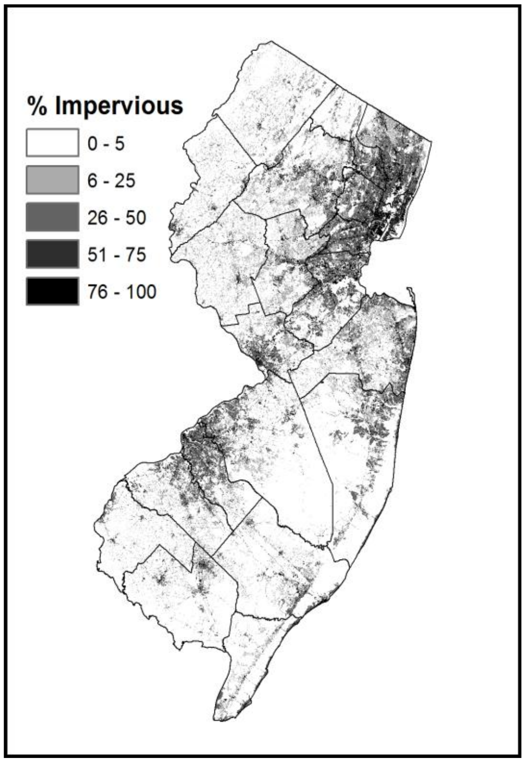

Figure 2. Impervious surface. This map depicts the pattern of impervious surface in NJ. Darker shades of gray represent higher percentage of impervious cover.

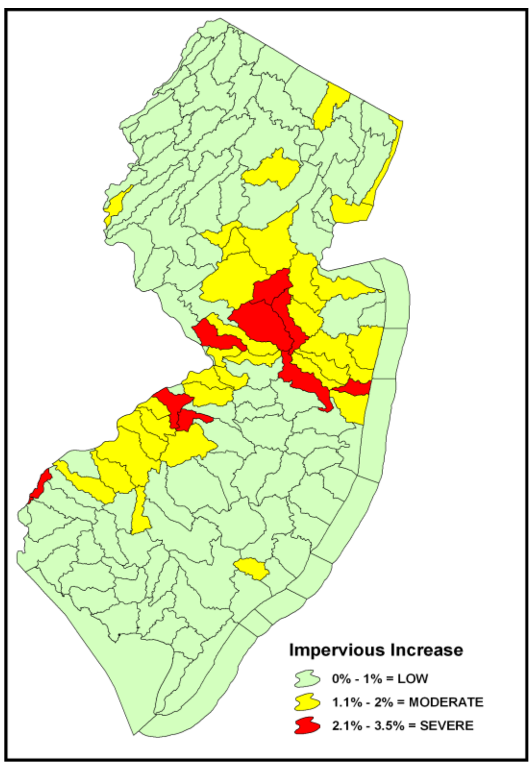

Figure 3. Impacted and degraded watersheds as indicated by percent impervious surface cover.

The amount of impervious surface has been increasing in-step with urban growth. Figure 4 maps the increase in impervious surface by watershed. During the 1995 to 2002 study period, 32 watersheds increased their total impervious surface coverage by 1-2% and nine watersheds increased their total impervious surface coverage by more than 2%. These rapidly growing watersheds are at the greatest risk for experiencing degradation of water quality. Impervious surface management has the potential to play an important role in sound land management practice. While the 10% and 30% thresholds have become generally accepted rules of thumb for correlating water quality with impervious surface (Schueler, 1994; Arnold and Gibbons, 1996; Zampella et al., 2007), further research is needed to clarify the unique relationship of impervious surface to water quality particular to the various physiographic regions of New Jersey. For example, recent research in the New Jersey Pinelands confirms the extreme vulnerability of stream water quality to human altered land use (Zampella et al., 2007). In the Pinelands, even at impervious surface covers of below 5%, significant water quality impacts have been observed (Conway, 2007).

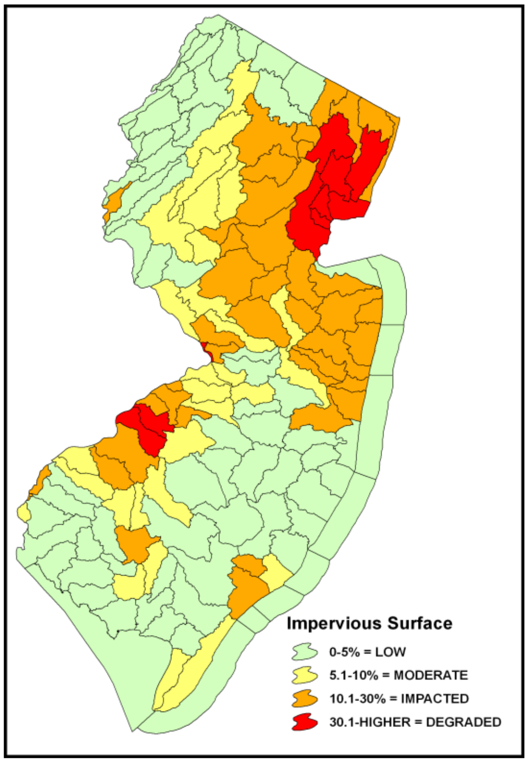

Figure 4. Impervious surface increase from 1995 to 2002.

IMPERVIOUS SURFACE MANAGEMENT AS A COMPREHENSIVE PLANNING TOOL

In a rapidly urbanizing region such as the state of New Jersey, the combined impact of hundreds of independent development projects occurring over the course of a year can have ecosystem-wide implications. We argue that site-specific water quality regulations and best management practices (BMPs) are inadequate for regional level ecosystem protection and demand a new approach. We suggest that intelligent regulation of impervious surface can become the hinge pin uniting environmental protection and management with smart growth development. Impervious surface is relatively easy to measure and is highly correlated with the magnitude of multiple environmental impacts imposed by urbanization.

While other factors such as the amount of forested land and the location of the impervious surface within a watershed can also have an independent relationship to water quality (Brabec et al., 2002), the percentage of total impervious surface within a watershed and the corresponding water quality is remarkably consistent across many studies. Low impact development (LID) practices (Dietz, 2007) and best management practices (BMPs) in storm water management can help to reduce water quality impacts, but do not offer a universal solution and should be considered only one part of a water treatment train (Schuster et al., 2005). BMPs have been shown to be most effective at low percentages of impervious surface, yet limited at levels higher than 20% (Maxted and Shaver, 1999). Ultimately, BMPs in and of themselves are not a comprehensive solution and can carry their own disadvantages such as unsightly retention basins.

We propose that the comprehensive solution lies in expanding impervious surface regulation under New Jersey's land use regulatory system. While Booth et al. (2004) have cautioned about usage of impervious thresholds for specific predictions of stream health or "acceptable" thresholds of development, we don't suggest its use in a manner that will produce a predictable site specific outcome. Rather we suggest impervious surface caps as a comprehensive means for managing the urban footprint of state that will soon be reaching buildout. The rationale is based on multiple planning goals beyond water quality alone. Since ecosystem impacts span municipal boundaries, impervious surface regulation should be handled at the watershed level. The New Jersey DEP has already developed a system for regionally organizing environmental management activities that delineates twenty Watershed Management Areas (WMAs) (Figure 5). The WMAs better match the natural functioning of the ecosystems than the haphazard municipal and county political boundaries. The NJDEP already organizes some water quality and resource protection and restoration efforts on the WMA basis.

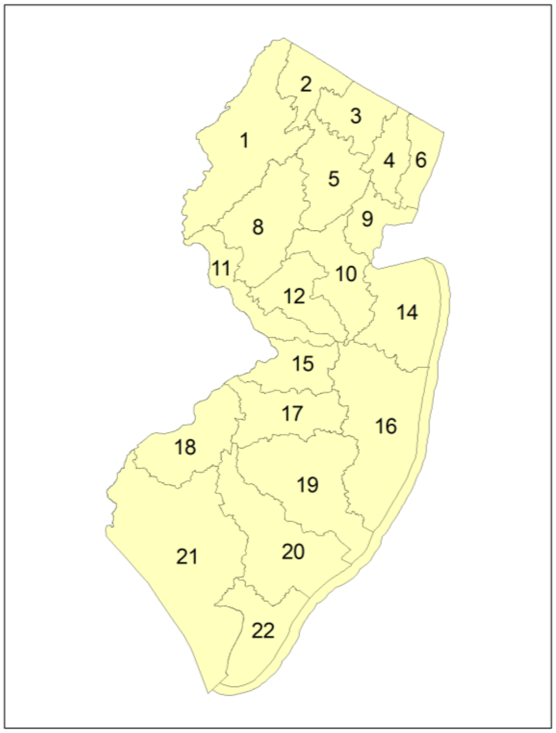

Figure 5. New Jersey Watershed Management Areas.

However, inserting impervious surface regulation into the existing land management system will not be an easy task. New Jersey is a home rule state, meaning that land use decision-making and regulation occurs at the municipal level. Dismantling home rule does not seem politically likely in the foreseeable future. We instead support an overlay approach where local zoning and planning decisions are still handled by the municipality, but regulation of the creation of impervious surface is handled at the Watershed Management Area level. A number of different models could be adopted. For example, the Lake Tahoe Regional Planning Agency (TRPA) in California and Nevada has developed a system of allowing impervious surface credits to be purchased from properties in the most sensitive areas of the basin in order to be sold to properties that want to develop in less sensitive areas (Imperial and Kauneckis, 2003). Although the interstate TRPA is not a model directly applicable to New Jersey, we recommend development of a similar cap and trade system of impervious surface management administered on Watershed Management Area basis. Underlying zoning ordinances could remain in effect, but the impervious surface credits could be bought and sold throughout the WMA to maintain a total impervious cap below the threshold of water quality impact.

The impervious surface cap and trade system that we propose would be a variation of Transfer of Development Rights. Transfer of Development Rights (TDR) is a land use mechanism that aims to cluster development in certain areas at increased density while leaving other areas undeveloped but able to receive an economic share of the compensation for the development. Best management practices and requirements for low-impact development (LID) are maintained in the area of increased density, while the parcel that sells its development rights is deed-restricted from future development. Conceptually TDR sounds ideal, but in actuality it is difficult to successfully implement. Since TDR first came on the scene in the 1970s, the top twenty most successful programs have preserved over 350,000 acres throughout the United States (Pruetz and Standridge, 2009). Unfortunately, while the top twenty have demonstrated that TDR can be quite successful, there are dozens of less successful TDR programs that have preserved little or no open space since their inception due to inherent difficulties with TDR (Levinson, 1997; Danner, 1997; Pruetz and Standridge, 2009).

The state of New Jersey has played an important role in developing TDR. The Pinelands Development Credit program, created in 1981, has preserved 55,905 acres as of 2008, the second most successful program in the country in terms of acres preserved (Pruetz and Standridge, 2009). Burlington County, New Jersey has had a TDR program on the books since the 1989 Burlington County Demonstration Act. In 1998, Chesterfield Township became one of the first municipalities to implement a TDR in that county (Gottsegen and Gallagher, 1992), preserving 2,272 acres within 10 years (Pruetz and Standridge, 2009). The 2004 State Transfer of Development Rights (TDR) Act made New Jersey the first state in the nation to adopt statewide enabling legislation for TDR. Furthermore, the 2004 New Jersey Highlands Water Protection and Planning Act has also developed a TDR system that encompasses 88 municipalities within seven counties (New Jersey Highlands Council, 2007).

We suggest that an impervious surface-based TDR system in New Jersey should be judiciously integrated with the smart growth goals of the New Jersey state plan. For example, New Jersey could provide impervious surface credit bonuses for development that demonstrably accomplishes the smart growth goals of the state plan. A system could be set up in which development approvals were expedited for projects that purchased impervious surface credits from sensitive planning areas to be used for development in the smart growth planning areas. In addition, a regional storm water utility could be an important complement to a system of impervious surface TDR and may be important for ensuring adequate management of the program. This kind of development management coupled with the environmental protection benefits of limiting impervious surface creation could add a much needed empowerment that the New Jersey state plan has long lacked.

CONCLUSION

The literature has clearly documented the correlation of impervious surface to water quality. In this study we have documented the state of impervious surface cover and the trends of increase in New Jersey through 2002. We have also glimpsed the relationship between impervious surface increase and the loss of other important land resources such as prime farmlands and wildlife habitat. Our finding is that not only is impervious surface a robust indicator of environmental impact attributable to urbanization, but that impervious surface management has the potential to become the hinge pin planning tool that can unite environmental protection with the smart growth goals of the NJ state plan.

Land is a limited resource, or in Will Rodgers words “they ain’t making any more.” With each acre of land that becomes covered with impervious surface through urbanization, a corresponding acre of prime farmland, wildlife habitat, forest, ground water recharge area or other important environmental resource is usually lost. For a state such as New Jersey that is perhaps only decades away from build-out (Hasse and Lathrop, 2001), the degree to which farming becomes unviable, habitat becomes overly fragmented, or carbon sequestration becomes more difficult to achieve due to forest loss will also have a relationship to the amount of impervious surface created by urbanization.

We conclude that by shifting toward a model of impervious surface-based land use regulation, New Jersey’s remaining undeveloped lands can be managed in a manner that is scientifically as well as politically justifiable. Utilizing a *cap and trade* approach, we propose that impervious surface management become an umbrella regulation that allows development to occur within the ecosystem limitations of New Jersey’s remaining available lands. By limiting the amount of future impervious surface that can be created, the magnitude of urbanization can be justifiably managed to exemplify sustainability and the principles of smart growth.

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