Pembroke Woods: Lessons Learned in the Design and Construction of an LID Subdivision

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Introduction

The Pembroke Woods Subdivision (Figure 1) is a ½ acre residential development located in northern Frederick County, Maryland, near the state line with Adams County, PA, and is not only the first Low Impact Development (LID) subdivision permitted in Frederick County, but also the first subdivision designed and under construction using the LID Design Manual developed by Prince George's County, Maryland (P.G. 1997, EPA, 2000a,b, Clar, 2001, 2002a,b). LID is an innovative approach to stormwater management (SWM) that attempts to mimic the pre development hydrology of a development site thus maintaining the hydrologic functions of the site and precluding the environmental impacts especially the water quality degradation of receiving streams, lakes and estuaries that are normally associated with land development activities.

Because LID is a relatively new technology that substantially changes a number of the design paradigms used for stormwater management, one can anticipate a substantial learning curve for stormwater practitioners to understand and apply the technology. The Pembroke project site, being one of the first subdivisions designed and built with this technology, provides a valuable case study related to the issues that will be encountered in the application of this technology.

Background

Low Impact Development (LID) is an innovative technology to control stormwater quantity/quality impacts at the source using micro-scale management practices distributed and integrated throughout the landscape. This technology, developed by Prince George's County, Maryland, to address perceived problems in conventional approaches to stormwater management within the County and the State, makes multifunctional use of the urban landscape allowing one to design a hydrologically functional site (P.G. 1997). This approach results in an ecologically based approach to stormwater management that is usually more aesthetically pleasing, precludes impacts to receiving waters, and is generally less costly to construct and maintain than conventional end of pipe systems.

The LID design process integrates SWM controls into a site's landscape by using a series of innovative micro-scale practices such as; rain-gardens, bio-swales and rain barrels in conjunction with better site planning techniques such as; reduction and disconnection of impervious areas and fingerprinting techniques for site grading. This approach to stormwater is being adopted as the standard for green building site design on a nationwide basis, and is also perceived as part of the smart growth toolbox by a number

of local, state, and federal agencies.

Figure 1. Pembroke Woods Subdivision

Design Objectives

The design objectives of the Pembroke site were to demonstrate the win/win potential of LID technology which includes the following elements:

- Maintain pre-development hydrology
- Minimize and reduce development impacts
- Mitigation for runoff impacts
- Reduce land development costs

The primary goal of LID technology is to mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff. Use of these techniques helps to reduce off-site runoff and ensure adequate groundwater recharge. Since very aspect of site development affects the hydrologic response of the site, LID control techniques focus mainly on site hydrology.

A few additional goals typically associated with the use of Lid technology include:

- Provide an improved technology for environmental protection of receiving waters

- Provide economic incentives that encourage environmentally sensitive development
- Develop the full potential of environmentally sensitive site planning and design
- Encourage public education and participation in environmental protection
- Helps build communities based on environmental stewardship
- Reduce construction and maintenance costs of the stormwater infrastructure
- Encourage flexibility in regulations that allow innovative engineering and site planning to promote "smart growth" practices
- Encourage debate on the economic, environmental, and technical viability and applicability of current stormwater practices and alternative approaches.

Design techniques

A number of LID design techniques were used in the site design. These design techniques include:

- Minimization / reduction of impacts (Site fingerprinting).
- Reduction of impervious areas (rural/narrow streets, eliminate curb & gutter, eliminate sidewalks)
- Disconnection of impervious areas (streets, driveways, roofs)
- Mitigation for runoff impacts (LID IMPs)

Minimization / reduction of impacts (Site fingerprinting). One of the major design objectives of LID design is to minimize or reduce the impacts of land development as close to the source as possible. At the Pembroke site fingerprinting techniques (Figure 2) were used to achieve this goal. Site fingerprinting (minimal disturbance techniques) can be used to reduce the limits of clearing and grading, thereby minimizing the hydrologic impacts. Site fingerprinting includes restricting ground disturbance by identifying the smallest possible area and clearly delineating it on the site. Site fingerprinting provides the following benefits:

- Reduces the need and cost for mass clearing and grubbing of construction sites
- Preserves the important soils functions of undisturbed areas
- Helps to maintain the predevelopment curve number (CN) and time of concentration (Tc). Extensive use of site fingerprinting technique, an elemental LID design feature, and a green building design feature, allowed the site design to preserve approximately 50% of the site in undisturbed wooded condition. This design feature was essential for maintaining the pre- development curve number (CN), which is very difficult on a wooded site.
- Reduces the amount of soil erosion and sediment delivered to receiving streams

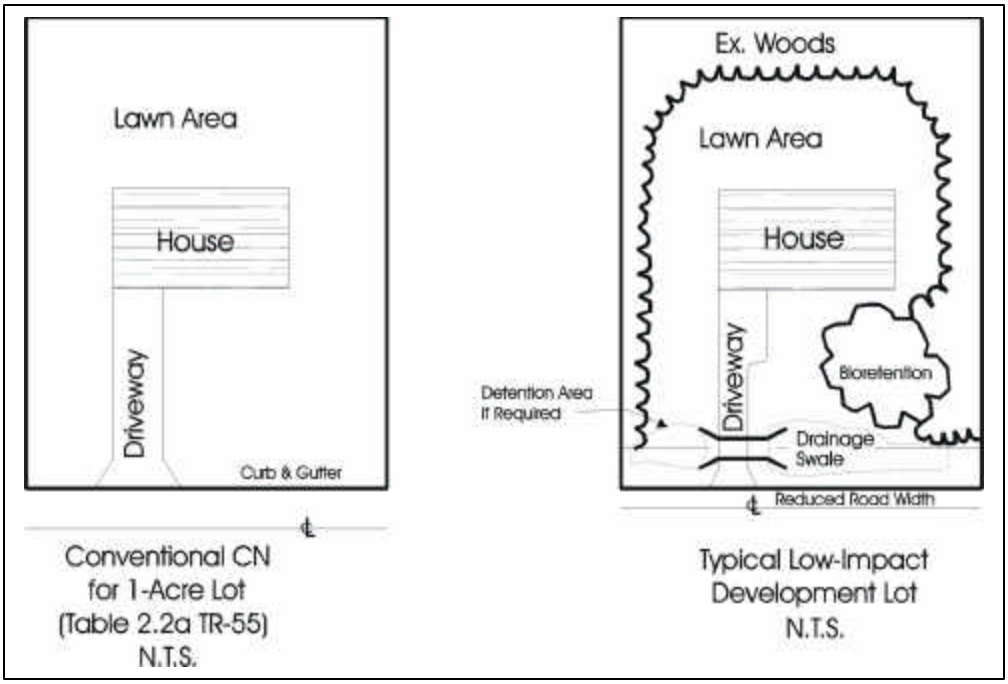

Figure 2. Site Fingerprinting

Reduction of impervious areas (rural/narrow streets, eliminate curb & gutter, eliminate sidewalks). The creation of impervious areas is one of the major impact areas of land development activity. Thus one of the LID design objectives is to reduce the total amount of impervious area that is created by development. At the Pembroke site this reduction in impervious areas was achieved with the following techniques:

- Use of rural/narrow road sections
- Elimination of curb and gutter and use of grass swales
- Reduction of the use of sidewalks
- Use of shared driveways

Reduced road width section are an alternative that can be sued to reduce total site imperviousness as well as clearing and grading impacts. By using a rural residential road section in place of a primary residential section, the width of paving can be reduced, and the use of concrete curb and gutter can be eliminated and replace with roadside swales. This techniques provides several benefits that include:

- Reduced impervious cover and runoff volume
- Increase time of concentration and decrease peak discharge
- Reduces use of construction materials and infrastructure costs
- Impervious areas are disconnected by grass swales

Disconnect impervious areas (roofs, driveways, streets. After the impervious areas have been reduced, the impacts of these impervious areas can be further reduced by disconnection. At the Pembroke site we achieved close to 100 percent disconnection of impervious areas. All the roof areas were discharged to pervious surfaces. All driveways were also directed to pervious areas or to the road surfaces which are discharged to the bio-swales.

Mitigation for runoff impacts (LID IMPs). LID technology employs micro-scale and distributed management techniques, called integrated management practices (IMPs), to achieve the desired post development hydrologic condition. Some of these IMPs include: bioretention, grass swales, dry wells, filter/buffer strips, rain barrels, cisterns, and infiltration trenches. The Pembroke site used the Maryland dry swale (bio-swale) practice as the primary BMP (Figures 3 and 4). In addition filter/buffer strips was also used extensively throughout the site.

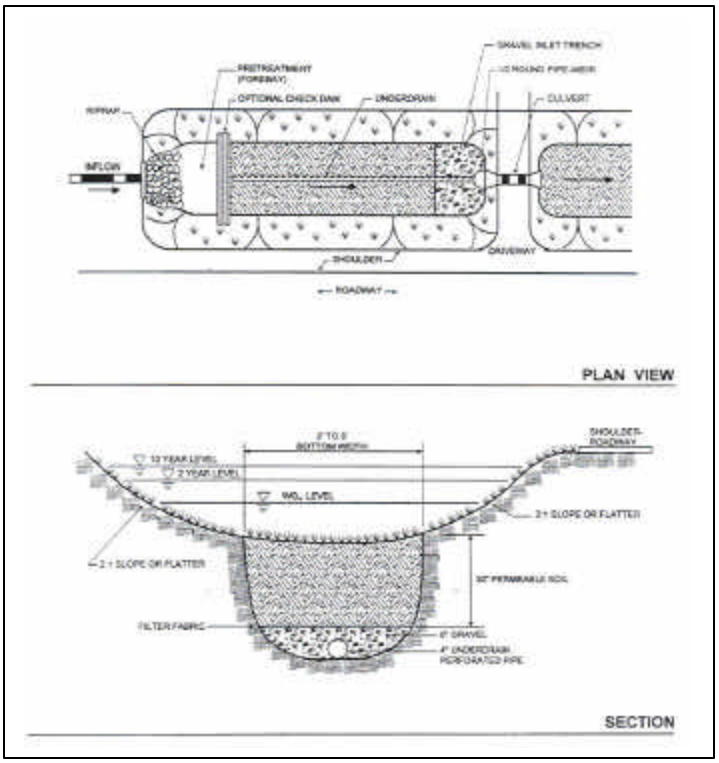

Figure 3. Maryland Dry Swale Detail (MDE, 2000)

Hydrologic Analysis

In order to satisfy County criteria for adequate downstream conveyance a downstream hydrologic impact analysis was conducted. The analysis examined the ability of an LID site design to maintain predevelopment peak discharge conditions for a range of storms including the 1, 2, 10, 50 and 100 year storms. Many public works personnel perceive innovative SWM techniques such as LID capable of addressing water quality issues, but

insufficient to provide downstream peak discharge control for the larger flood flows associated with the 10, 50 or 100-year storms.

Figure 4. Rural Road Section with Dry Swale and Check Dams

Initially the site LID hydrologic analysis was based on the 1-year storm (2.5 inch rainfall) which was Frederick County's criteria for water quality control. The downstream analysis revealed that the 1- year storm design was not sufficient to maintain predevelopment peak discharges for the 10-year and larger storms. An incremental iterative procedure was then used to determine the additional control requirements that would be required to provide the required downstream control. The analysis showed that by increasing the design storm to the 2-year storm (3.0 inches of rainfall), the required downstream protection for the complete range of flood events (10, 25, 50 and 100-year storms) was achieved. Table 1 provides a summary of the hydrologic analysis.

Table 1. Summary of Hydrologic Analysis

DA	Acres	CN2/10	Tc	Q1	Q10	Q25
#1 – Existing	11.4	58	0.45	1	10	13
Proposed	10.6	58/63	0.45	1	11	14
#2 – Existing	15.4	58	0.41	1	15	19
Proposed	15.7	58/61	0.41	1	16	19
#3 – Existing	12.6	69	0.44	3	21	25
Proposed	13.0	69/71	0.31	3	21	25
#4 – Existing	7.79	70	0.27	3	21	24
Proposed	7.88	70/71	0.25	3	20	24

Cost Savings

Pembroke Woods was originally designed in the early 1990's as a ¼-acre lot conventional subdivision with 97 lots, 2 SWM ponds and closed section streets. The original design also required a sewage pump station and most of the wooded site would have been required to be cleared. When redesigned as an LID subdivision, it exhibits and benefits from the win/win attributes of the LID process which include:

1. The use of LID allowed the site design to eliminate the use of two SWM ponds which had been envisioned in an earlier concept plan for the site. This represents a reduction in infrastructure costs of roughly $200,000.
2. In place of the SWM ponds 2.5 acres of undisturbed open space and wetlands were preserved. Again a considerable savings in wetlands mitigation impacts were realized.
3. Also the site plan gained two additional lots increasing the 43 acre site yield from 68 to 70 lots. This added roughly $90,000 in additional value to the project.
4. Extensive use of site fingerprinting technique, an elemental LID design feature, and a green building design feature, allowed the site design to preserve approximately 50% of the site in undisturbed wooded condition. This reduced the clearing and grubbing costs by $160,000.
5. The site fingerprinting process also substantially reduced the overall site grading costs, but this savings was not calculated.
6. Approximately 3000 linear feet of roads were converted from an urban road section to a rural road. This design feature replaced curb & gutter with grass bio-swales (Figure 3), a savings in construction costs of $60,000. Also the rural road section is a green building design feature that reduces the paving width from 36 to 30 foot width, a 17% reduction in paving costs.

Conclusions / Lessons Learned

The design and construction of the Pembroke Woods LID subdivision identified a number of issues related to the permitting, design and general acceptance of this technology. Some of theses issues are summarized below.

Permitting. The permitting process can represent a considerable challenge for LID technology. Currently, with the exception of Prince George's County, MD, very few local governments have a permitting process that enables the use of LID technology. Thus LID projects require permitting as demonstration projects, which was the case at Pembroke Woods, and this will typically increase the permitting process by six to twelve months.

Design. Many of the LID design techniques and IMPs are contrary to established subdivision and drainage practices. The following practices are typically opposed by public works and transportation agencies:

- Use of rural road sections and narrow streets
- Elimination of curb & gutter

- Elimination of sidewalks
- Use of IMPs on individual lots and private property

Other issues related to design include the need for design methods and computational procedures that are compatible with currently used technology. Prince George's County developed a design method that is based on the sue of the NRCS TR-55 model and can be easily used in other subdivisions. Delaware ahs recently developed the Delaware Urban Runoff Model that allows designers in Delaware to model the use of LID practices referred to as "Green Infrastructure". The State of New jersey is in the process of developing a new stormwater management design manual that will also enable the sue of LID technology. Pennsylvania has also recently begun the process of developing design methods that will accomplish this purpose. All of these new efforts will require considerable training of both design and review personnel to bring them up to speed on this new technology.

The hydrologic analysis of Pembroke Woods revealed that volume control of the 2-year storm can provide peak discharge control of the entire range of design storms including the 10, 25, 50 and 100-year storms. This is an important conclusion that has significant implication for stormwater management technology.

Public Outreach. The developers of the Pembroke woods subdivision were not sure of the appeal of this LID subdivision to the general public. There existed a general concern related to how the public would accept a new concept subdivision that placed a number of restrictions on the sue of the property, particularly the ability to clear the protected woodlands. The demand for the subdivision has exceeded all estimates and removed all concerns related to the viability of this type of development, and the developers are having a difficult time keeping up with demand. Pembroke woods has demonstrated that LID produces a superior product.

The property owners do require some education and outreach effort. A critical component of the success of the LID approaches is the proper maintenance of installed IMPs by the property owner, or other responsible entity. Local agencies wishing to adopt Lid technology must be prepared to develop and provide basic information to property owners on their responsibilities as well as available agency resources for the management and maintenance of these practices.

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