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"Green Roofs: Feasibility and Practicality for Stormwater Management in Cold Climates"

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Title for Proceeding Submission: "Green Roofs: Feasibility and Practicality for Stormwater Management in Cold Climates"

(Abstract: 95 words)
Green Roof technology is only slowly emerging in the United States. Historically, traditional sod roofs were effectively used to protect building inhabitants from extreme climate fluctuations mostly in northern regions, such as Scandinavia, Greenland, and Alaska. This paper will address and compare the contemporary use of green roofs in Europe and the US. It will point out, by providing some detail about design and construction, how green roofs can be used to maximize stormwater benefits. The paper will also discuss how varying design parameter influence the practicality of green roof technology particularly in Cold Climates.

(Article: 2578 words – including endnotes)

Green Roof technology describes the contemporary use of a rather old building practice. Traditionally, sod roofs have long served as protection against extreme climates, especially in cold climates like Iceland, Scandinavia, Alaska. Using natural building materials were merely a principle of resourcefulness and availability as well as economical. Tree bark was used as waterproofing and ballasted with sod bricks and kept in place with old fisher nets on steeply sloped roofs. The effect of the sod on the roof was a cooler building inside in the summer. During cold and enduring winters, the cozy warmth stayed inside.

Presently, green roofs are used for different reasons. There are two distinct types of green roofs intensive and extensive. This paper exclusively discusses extensive green roofs, shallow soil layer with horizontally spreading vegetation, as an effective means for onsite stormwater management in cold climates.

Extensive green roofs become accepted primarily for their ecological value. The potential to society can be enormous, if the wide array of benefits are fully understood and realized. Green roofs provide the following benefits:

- Innovative Solution to Urban Runoff

- Increase Energy Performance of Buildings
- Mitigate Urban Heat Islands
- Contribute to Urban Green Space and Filter the Air

Planning Green Roofs

When we think about infrastructure design and stormwater management we think about pipes, culverts and drains. We look for ways to "efficiently" collect and conveying rainwater from impervious surfaces immediately after it falls and turns into runoff. In short, we are caught in a tradition of considering rain a great nuisance rather then a resource.
But expanding or building new stormwater infrastructure, including storage and treatment systems, is merely a passive response to minimize the consequences of imperviousness. This approach is a passive response to deal with the impacts of impervious surface cover and fails to address the source of the problem.

Looking for alternatives is challenging and it takes time. But nature is and remains a great resource for looking for unconventional alternatives. Forests fulfill complex functions and play an important role in the natural hydrological cycle. As water slowly percolates through the soil and infiltrates into shallow and deep aquifers, trees take up water and transpire it back into the air. Raindrops from leave surfaces evaporate which also helps balance fresh and clean air. Forests protect watersheds by filtering rain and buffering streams from pollution and thus help maintain the health of aquifers and open streams. Nature provides these complex functions as services for free – free of charge. Historically, these free ecological services had been recognized and utilized as part of resource efficiency but have been forgotten as our western developed society started to rely more on mechanical systems.

Natural vegetation cover does not only play an important role in the natural hydrological cycle, it is essential for habitat, and it also provides recreational value. New sustainable design principles put more emphasis on natural systems again and aim at incorporating them into our contemporary uses.

Growth and urban development with new buildings, roads, parking and other impervious surfaces have grossly altered the natural hydrological cycle. As forests and green spaces disappear, rainwater can no longer infiltrate and no water is being used by vegetation. The result is a staggering increase in runoff, which has to go somewhere. Rain is instantly repelled from sealed surfaces and shed off as runoff and also referred to as the peak flow runoff. The first half-inch of rain causes the peak flow runoff and is considered the culprit of major environmental problems for watersheds and ecosystems especially in urban areas because it flushes sediments and pollution, collectively known as non-point source pollution, into urban streams.

Nobody disputes the direct link between impervious surface cover and degradation of streams anymore. Studies have shown and confirmed that greater impervious surface cover in a watershed leads to more adverse changes in shapes of streams, water quality, water temperature, and the health of insects, amphibians, and fish.

The result of runoff can be clearly traced. Discoloring of rivers usually indicates sedimentation deposits and algae bloom indicates nutrient over enrichment (eutrophication).

Germany requires mitigation for open space and pervious surfaces that are lost to construction. Mitigation requirements vary from jurisdiction to jurisdiction, but are intended to reduce runoff and avoid overloading of storm sewers. Almost everywhere, new commercial developments are obligated to green their roof surfaces. Newly constructed residential developments require extensive green roofs on garages, carports and porches. Additionally, many incentive programs encourage homeowners to consider improving to a green roof and pervious pavements. The incentive programs include the added benefit of exemption from rain tax - tax imposed for the amount of impervious surface cover on properties that generate runoff which overloads local storm sewers.

In the U.S., these types of regulations and incentive programs do not yet exist. This paper highlights three important functions that urban forest and vegetation perform in nature. It extrapolates these functions onto the roofs, where, though not in the same capacity, green roofs could potentially become building-integrated air conditioner, and filtering devises for rain and air. Making better use of roofs offers in part solutions to combat urban environmental problems and accommodates nature even in densely populated areas where restoration of urban forests is physically.

Green roof technology is only one methods of sustainable design within emerging low impact development practices. This paper discusses how green roofs can serve to control stormwater in cold climates, improve air quality, and contribute in mitigating urban heat islands. These three functions must be part of greening cities, whether in warm or cold climates, to create healthy urban conditions. Effectively including nature back into people's life ought not be considered a fashionable gesture but rather a highly rational, complex, and vital undertaking.

What are the local issues?

Aside from increased runoff and non-point source pollution that result from unprecedented second home developments along the coast and on the islands, Maine is facing a much starker problem. Fishery and tourism are the economic basis of this small North-Easter state.

But shell disease has basically wiped out the lobster industry for most of New England south of Maine, and it is moving up north. Ground fishery for cod, halibut, and other inshore ground fishing has been devastated. The working waterfront is dwindling and imminent regulations and restrictions will like have further impacts on Maine's economy.

Could stormwater runoff and non-point source pollution be a contributing factor to these pressing local issues? Nobody knows for sure, but the impacts of stormwater runoff and combined sewer overflow on the Chesapeake Bay are well documented. Most environmental problems in watersheds, estuaries, and coastal marine ecosystems are caused by the accumulation of nitrogen and phosphorus in fresh water on its way to the sea. The three most common sources of nutrient over-enrichment in watersheds are urban stormwater runoff, discharge from septic systems, and atmospheric deposits, collectively called non-point source pollution. Nitrogen and phosphorus are the two most-tracked, non-point source nutrients that threaten the health of aquifer and surface water resources, as well as people and wildlife. As of 1996, nearly 14 percent of all nitrogen and 13 percent of all phosphorus non-point source pollution stemmed from developed lands.

The interrelated local issues in Maine point to the need for new solutions to manage stormwater and present opportunities to engage in unconventional and innovative approaches. The challenge is to identify feasible and practical ways to reduce impervious surface areas, mostly vehicle-oriented pavements, or vegetating unused roof surfaces to utilize water onsite.

Stormwater Quantity Control

Designing an extensive green roof for effective stormwater retention, one can divert from the conventional 100-year storm approach that assumes the retention capacity has to meet a 100-year storm. The most frequently recurring storms are those of less then half-inch intensity. Over 90 percent of all rain events occur as low intensity rain events.

This means that the low intensity rain events should be the focus of alternative stormwater control measures from a cost-benefit perspective; cost-benefit in two ways – first on the project level where green roofs serve primary stormwater quality and quantity control and second on a regional level where green roofs reduce non-point source pollution intake into receiving bodies of water. To put things into perspective, a major two-inch rainstorm generates 1.25 gallons per square foot. The water retention and storage capacity of a 2-inch-deep extensive green roof is approximately 0.7 inches or 0.44 gallons of water per square foot green roof surface. This means an only 2-inch-deep extensive green roof is able to trap and filter up to 40 percent of rainwater.

The water retention capacity of an extensive green roof is approximately 75 percent of all water that falls onto it on annual average. Only about 25 percent of water becomes runoff and this usually occurs several hours after the rain. This means that peak flow rates are greatly reduced. Additionally, because the green roof shades the roof and prevents the roof surface from gaining solar heat the excess storm runoff does not pick up heat from the roof surface and thus eliminates the adverse impact of thermal shock on aquatic life.

Stormwater Quality Control

Physical, chemical and biological processes occur based on the symbiosis of fungi and bacteria associate with root systems within the soil. These processes are imperative for hydrology, (storage, evaporation, recharge, and detention of water) but also for water quality (filtration and detoxifying of organic and inorganic materials). Plant roots provide vertical pathways for water to slowly percolate through the soil. Microorganisms in the soil treat the water and break down pathogens, heavy metals and other pollutants. Vegetation takes up nutrients such as phosphorous, nitrogen, and carbon as food.

With the many plants, green roofs treat stormwater runoff biologically, through contact between water and the roots. The bacteria and fungi attached to the dense root system break down nitrogen and phosphorus to make it available for the roots to take up as nutrients. This process—photosynthesis—occurs naturally, powered by the sun, and its intensity depends on the season, slowing during the dormant season. The treatment efficiency increases over the lifetime of the green roof because plants mature and grow denser. A *New York Times* article pointed out that "harnessing the absorptive power of a plant's roots appears poised for a much-expanded role. Hundreds of species of plants, together with the fungi and bacteria that infuse the rhizosphere (the ecosystem around roots) represent the botanical equivalent of a detox center."

John Cox, the City engineer with the Department of Public Works–Stormwater Services in Durham North Carolina, believes that the greatest benefits of green roofs lays in the potential for controlling nutrients. Cleanup efforts in North Carolina require local governments to reduce the amount of nitrogen in stormwater runoff and to limit nitrogen in any new development. Studies by the Department of Public Works in Durham, North Carolina, found that impervious surface cover produce 21 pounds of nitrogen per acre per year. Under state regulations, any new development in Durham will be limited to 3.6 pounds of nitrogen per acre per year, which represents a stiff 83 percent reduction in nutrients from runoff. Developers in this area will have to be creative to meet this reduction level because conventional treatment practices for treating stormwater runoff - wet detention ponds and sand filters - remove only 25 to 35 percent of the nitrogen. The city of Durham does not prescribe a specific technology or approach by which to achieve the new reduction level, but it recognizes the benefits of green roofs and welcomes green roofs for new development as a low-impact alternative. "There are only a few gems for every hundred of new technologies, and green roofs seem to be the most promising method for stormwater control," says John Cox, an engineer with the Department of Public Works–Stormwater Services.

Designing Green Roofs

Designing with vegetation and natural ecological services in mind requires a fundamental rethinking of master planning by engineers, planner, architects and landscape architects alike. It requires an extension of the sustainable design principles – primarily building oriented at present – to beyond the building envelope and property lines.

Extensive green roofs or shallow soil applications are very effective in absorbing and recycling rainwater through soil and plants and primarily valued for their environmental benefits. The technology incorporates natural functions into building design and presents a radical new approach to stormwater management.

Green roofs can be applied on new buildings or existing buildings can be retrofitted. Residential, commercial or office buildings can be considered for green roof applications as long as the structural load baring capacity is being verified prior to installation.

Using green roofs for storm water management requires careful planning and design and selection of materials. Especially the growing media, type and depth, will define the characteristics of the water retention capacity and the lasting performance of the green roof. Considering that metropolitan areas, from a birds eye view, consists of acres and acres of rooftop available to be greened, the use of green roofs for storm water management can potentially become exceptionally beneficial for the urban ecology and environment.

Implementation barrier for the use of green roofs in cold climates are primarily based on the concern of performance during freezing. While the concern is well taken, precipitation during cold seasons falls as snow. Snow builds up on a green roof and protects the vegetation layer. As it thaws, the same principles apply as rain falling on it – it percolates through the soil layer and either absorbed or drained away if the retention capacity of the soil layer is exceeded. In the event of an ice rain over a frozen green roof layer or ground surface, runoff is shed off comparable to impervious surfaces.

The green roof also functions as a barrier for airflow, preventing temperature exchange through the roof. This in turn eliminates ice damming, which is often experienced on roofs in cold climates during thaw and freeze cycles.

Conclusion

Contrary to what is widely believed green roofs are practical and feasible in cold climates. Originating in the cold climates of Scandinavia, Iceland and Alaska the use of green roofs has been proven and tested. In North America, the use of contemporary green roofs is expanding into areas of cold climates like Minnesota and Illinois. In these cold regions green roofs proof to be as effective in absorbing rain and recycling it through plants. Thereby stormwater runoff is greatly reduced, filtered and treated, which in turn prevents air born pollution to be washed into waterways. The vegetation cover of green roof protects the roofing membrane and prevents rooftops from absorbing solar heat gain. Through plant transpiration a green roof actually cools the air and provides a healthy microclimate.

Green Roofs present a cost-effective alternative to conventional stormwater management. To maximize the urban buffer functions and help cities reduce their liabilities in combating pollution, green roofs must be combined with other proven conservation efforts and integrated into a comprehensive urban best management practices plan.

More information about Green Roofs can be found at:

- Urban Land Magazine June issue 2001: Green on Top – by Katrin Scholz-Barth article focuses on tangible green roof benefits for developers and how to use green roofs to meet local stormwater requirements.
- Environmental Design and Construction Magazine Jan./Feb. Issue 2001: Green Roofs: Stormwater Management from the Top Down – by Katrin Scholz-Barth http://www.edcmag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,4120,18769,00.html
- School Construction News July/August 2001 Issue: Applying Green Roofs to Schools – by Katrin Scholz-Barth http://www.schoolconstructionnews.com/archives/ja2001/feature1ja01.html
- Katrin Scholz-Barth, phone: 202-544-8453 or email: katrin@scholz-barth.com