MKA update

SEATTLE GREEN ROOF EVALUATION PROJECT
FINAL REPORT-MARCH 2007

Final Report from the Roof

By Drew A. Gangnes, P.E.

It's hard to believe that it's been 2 years since we erected five green roof test plots around downtown Seattle and started collecting rainfall and runoff data. Come to think of it, MKA has been in the green roof evaluation business for over 4 years now, beginning with our green roof storm water modeling. During that time, we've learned a great deal, but we also have a clearer idea of where we—and the industry—need to go.

This is our final report of findings on the Seattle Green Roof Evaluation Project (GREP). In the last 18 months, we've gathered the most comprehensive set of green roof data in Seattle. With over 1.5 million data measurements collected, it's impossible to report on all the stories, subtleties, and statistical conclusions. Instead, we are providing answers to the questions most-often asked and to those that we asked of ourselves at the beginning of this journey.

Q How much does a green roof reduce the volume of runoff leaving a site?

A The amazing volume-reduction trends reported in our last two newsletters continued for the entire monitoring period, despite record-breaking rainfall events. Cumulative measurable runoff mitigation ranged from 65% to 94%! The graph at right illustrates volume reduction findings for all five test plots.

Q Who should care about runoff volume reduction?

A Every inch of rain (or gallon of runoff) eliminated by a green roof is runoff that does not enter the municipal storm drainage collection system. In Seattle (as in many U.S. cities), much of this system is a "combined sewer," which sends rainfall combined with sewage to wastewater treatment plants. Therefore, every gallon of rainfall eliminated at the building site by a green roof is a gallon that does not require treatment with chemicals, processing, etc. Research also suggests that this local repairing of the hydrologic cycle can reduce urban temperatures, which saves energy as building cooling demands are reduced.

Q Did the project capture average and/or extraordinary rainfall conditions?

A Our official data collection period ran from July 2005 to January 2007, with the first few months after the February 2005 installation devoted to equipment testing, refinement, etc. The data collection period recorded 55.4 inches of cumulative rainfall (versus 56.4 average for that time frame), so total rainfall was indeed quite average. In addition, the period included several extreme dry and wet periods, so we really couldn't have captured a more perfect 18-month data set.

Q Isn't a green roof always wet and ineffective in soggy Seattle?

A No; the data prove that green roofs are amazingly capable of rebounding between events, even in Seattle's wet climate. The article "Record-Wetting Fall" found inside reports on test plot performance during the unprecedented rains of November 2006 and the super-intense storm of December 14, 2006.

Q Can green roofs help fight global warming?

A Yes, but perhaps not in the way most folks think. The biomass associated with green roof plants is so small that CO_2 sequestering and O_2 production are surprisingly negligible compared to, say, planting a tree. However, green roofs help significantly in dealing with a known side-effect of global warming: the increasingly frequent occurrence of extraordinarily intense rain storms.

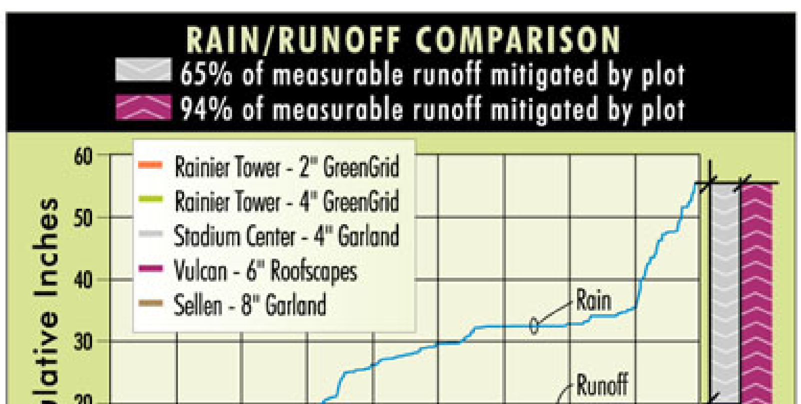
Q Does a building with a green roof also need a conventional storm water detention tank?

A This is certainly THE most frequently asked question, and the answer is, "It depends." The "Green Roof Guide" insert inside discusses this specific issue in detail.

Q What is the optimal green roof thickness?

A For storm water management in Seattle: 4 to 6 inches. Any thinner, and runoff percolates through too quickly; any thicker, and the medium does not dry out between storms. The article "Soil Moisture Rebound = Green Roof Success" provides deeper insight into the moisture-shedding phenomena behind the rebound.

*(see **Q & A**, continued inside back cover)*



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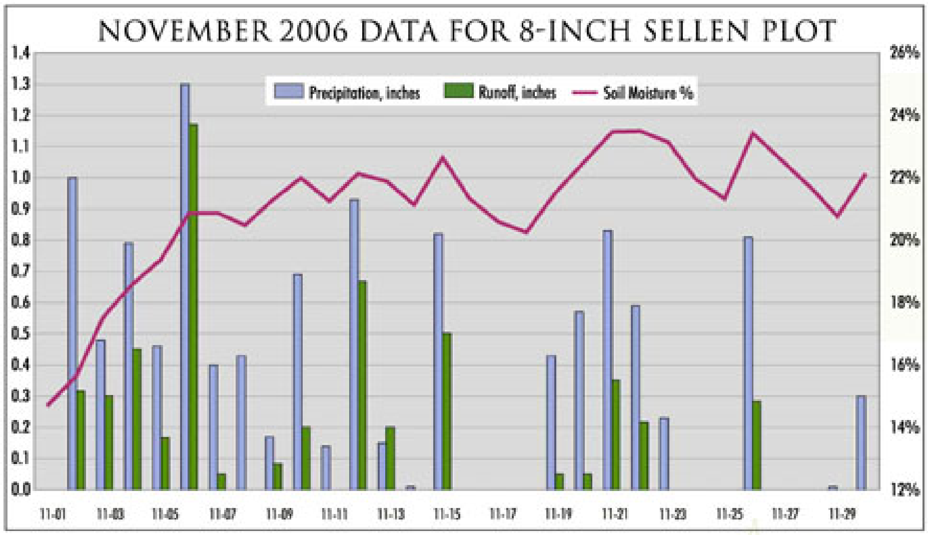
Record-Wetting Fall

November 2006 brought 15.63 inches of rain to the Seattle area, the wettest month on record for 115 years since data collection started in 1891 (5.9 inches is average for November). Despite the historical amount of rain, the test plots persevered, substantially mitigating runoff even during back-to-back storms. The graph illustrates the performance of the Sellen 8" test plot. Note how quickly soil moisture declines after a storm, freeing up capacity for the next storm. A summary of November performance for all five test plots is shown in the table below.



RUNOFF MITIGATION SUMMARY
NOVEMBER 2006

Plot	Volume Reduction (total for month)	Peak Flow Reduction (for worst storm)
Rainier Tower 2"	81%	27%
Rainier Tower 4"	47%	21%
Stadium Center 4"	52%	6%
Vulcan 6"	99%	79%
Sellen 8"	56%	52%

If November wasn't enough, December 14 brought a storm that was more intense than the standard Seattle design storms used to size detention tanks. Once again, the field data show that green roofs can mitigate peak flow rates: the best-performing plot reduced runoff rate by 76% and significantly delayed the runoff from entering the City's already overflowing sewer.

"…[the Seattle GREP] has provided us with a better understanding of how these systems function, as well as quantitative data about their benefits. This knowledge will prove particularly helpful as we prepare to install one of the largest green roofs in the city on the Seattle Center 5th Avenue Garage…"

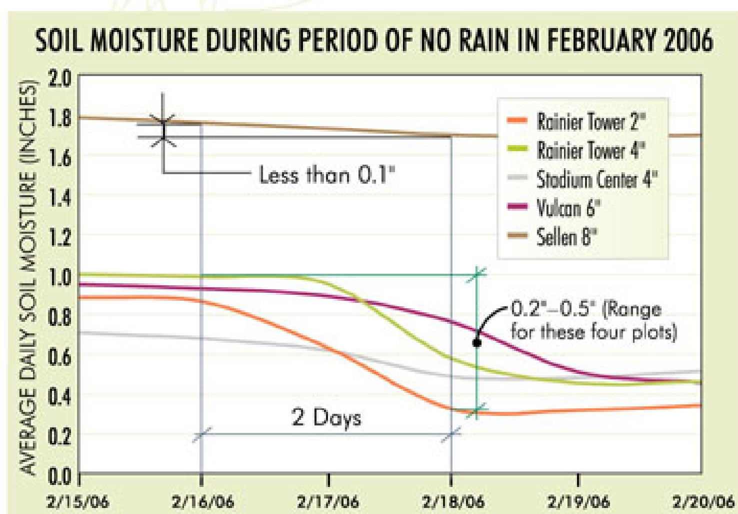
– Jack Avery, Sellen Construction

Soil Moisture Rebound = Green Roof Success

The most important data collected by this project may not be runoff, but *soil moisture*. The soil moisture data provide tremendous insight into how quickly green roofs evaporate runoff in Seattle's climate. This data set is key to calibrating predictive runoff models, as the models can then accurately portray the rate at which a given type/thickness of green roof recharges its sponge-like behavior.

The graph at right shows how the majority of the Seattle GREP plots disposed of 1/2 inch of rainfall in just 2 days. The thickest (8") plot remained relatively constant (moist) over the same period. It is assumed that the 8" plot is actually *too thick* to allow evaporation to occur as readily as the thinner plots.

The Seattle GREP provides the first-ever soil moisture data set for a variety of commercially available soil mixes and thicknesses. These data will allow computer models to predict runoff performance of green roofs in Seattle's climate to a level not yet achieved elsewhere in the country.



*(**Q & A** continued)*

Q Which of the tested planting media do you recommend?

A That depends. If one is interested in the highest level of storm water attenuation, none of those tested meet that criterion. Instead, we would strongly suggest a planting media modeled after those used in Germany (see 2 in the Green Roof Guide insert). However, those soils will likely have fewer planting options, as they are less organic and more mineral. Therefore, if plant choice is the primary goal, any of the tested media would be fine.

Q How important is the drainage layer?

A For storm water attenuation, very! This layer can provide a second level of flow retardation (after the rain makes it through the planting media) if it is the right material. Cellular drainage mats seem to be the default in the United States (presumably due to their ease of installation). However, aggregate drainage layers can perform ten times better and may be cheaper. The drainage zone inherent in many tray systems performs in between these two.


Mulching with pumice can retard weed growth.

Q What about plant recommendations and watering?

A Our field observations have shown that of the approximately 15 species used in the test plots, only a few are best suited for Seattle's climate when planted in conjunction with the given test plot media: sedums and sempervivums. One should plan to irrigate a green roof at least through the establishment period of 2 years. Otherwise, the first dry season may create significant plant die-off that can only be remedied by replanting. Mulching with a thin layer of lightweight pumice will help retain moisture and suppress weedy plant intrusion.

Q You've collected the data—what's the next step?

A Seattle's drainage code allows green roofs as a storm water management technique, but it stipulates that, "Applicant must model the storage capacity and discharge rate of the green roof." The new data collected can be used to specifically address this code caveat. The storm water modeling tool developed by MKA (see 4 in the Green Roof Guide) can be fed actual field-gathered data – or parameters estimated from the data for media that weren't tested – so the runoff mitigation value of virtually any type of green roof can be proven. (See 3 in the Green Roof Guide.)

Q Did the monitoring results meet your expectations?

A Yes and no. While the volume reductions achieved by the test plots were, in some cases, almost double what we expected, the detention benefits were lower than we had hoped for. However, we are thrilled to have the data prove that with the right planting media and drainage layer, a green roof can be self-mitigating in Seattle. We are most excited about the contribution green roofs can make in self-mitigating buildings (see article "Nirvana: Self-Mitigating Buildings").

Q Are green roofs on an upswing in Seattle?

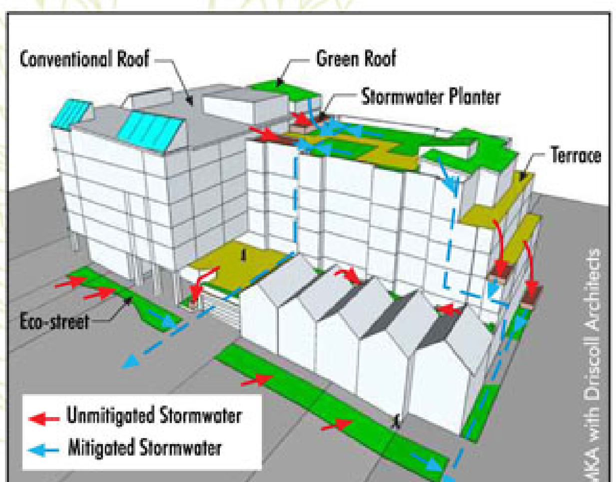
A Yes and no. The public sector continues to ramp up their involvement with green roofs: the biggest green roof in the city is coming to the new Seattle Center Parking Garage, and Seattle Public Utilities has launched its own green roof monitoring effort to build on the information gathered by the Seattle GREP. However, green roofs have not taken off in the Seattle private sector as they have in other U.S. cities, where requirement or incentives have made them the norm (such as Chicago or Portland).

*(see **Q & A**, continued on back)*

Nirvana: Self-Mitigating Buildings

Even though green roofs can be shown to mitigate design storms in Seattle, it can be difficult to render projects "detention-tank free." This is because even with large amounts of green roof, a project's non-green-roof areas (such as conventional roofs, plazas, sidewalks, etc.) often end up controlling detention design. In other words, the green roof may not require detention, but the other areas still do. This should not be perceived as a reason to give up. Rather, it is an underscoring of the fact that green roofs are most effective when used as part of a suite of urban low-impact design or natural-systems-based detention elements in a project.

A good example is the Sedona project planned for Seattle's Wedgwood neighborhood. The Sedona employs a "daisy-chain" of green roofs and storm water planters to treat runoff from conventional roof and terrace areas, rendering the entire building self-mitigating, while eco-streets within the project's frontages mitigate the detention requirement for the disturbed right-of-way areas. This approach successfully eliminates the need for a conventional detention tank and, just as importantly, yields the additional benefits of reduced runoff volume, lower runoff temperatures, and enhanced tenant amenities.



The Sedona project's storm water design is self-mitigating, with no need for a detention tank.

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(Q & A continued)

Q What movement have you seen on a national basis?

A Green roofs are going up in numerous U.S. cities, and they are being talked about more and more. Leading A/E/C publications are writing feature-length articles about the national green roof industry trend (Architectural Record 8/06, CE News 11/05, ENR coming in spring 2007). The American Council of Engineering Companies bestowed MKA's Seattle GREP work with a best-in-state research award; the project is now competing against top national projects from all 50 states. We continue to believe that many major U.S. cities will go the way of downtown Berlin, where green roofs outnumber non-green roofs.

Q What's needed to motivate the green roof industry back here at home?

A Real incentives for the private sector. The City sees its recent efforts in ramping up technical support for green roofs and other green interventions as "incentives" of sorts. However, it is hoped that the City will eventually adopt a program along the lines of Portland, Oregon, where a green roof's first cost is offset by providing developers with something of equivalent value (in Portland's case, it's a building square footage bonus, which has zero cost to city coffers!). We believe the Seattle GREP provides indisputable proof that green roofs ease the burden on City infrastructure and heal the urban ecosystem. Offering an incentive to developers would provide an appropriate reward for their role as pioneers and new urban ecologists.

In closing, thank you for your interest in this green roof journey of ours. We've enjoyed the ride and are thrilled with the support and encouragement we've received along the way. There are so many more questions and answers than we've had space to report on. Please email us at greenroof@mka.com if we've missed one that's important to you.

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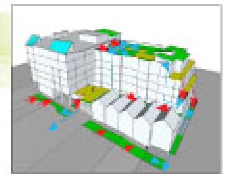
The Seattle GREP received top honors in the Studies and Research category at the ACEC Washington awards competition. It is now competing at the national level.

Thanks again to our Seattle GREP Project Partners:

Urban Visions
Unico Properties
Vulcan, Inc.
Sellen Construction

Additional Contributors: Cedar Grove, Gustafson Guthrie Nichol, McKinstry, Ness Cranes, Sunbelt, Teufel Landscaping, and Weston Solutions



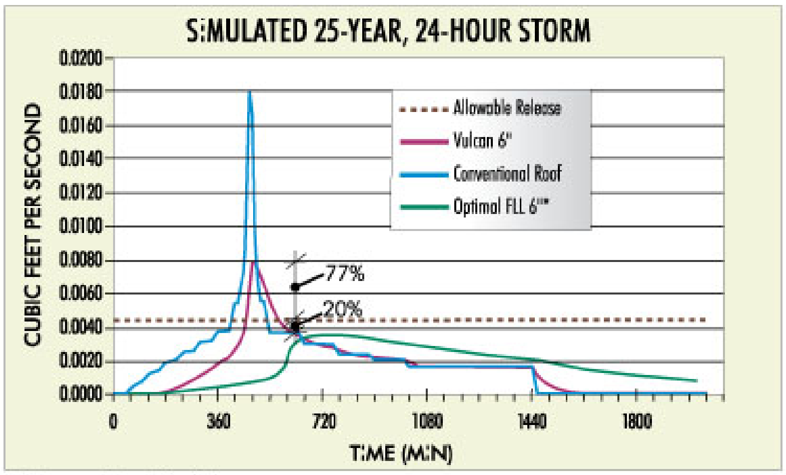
1 Can a Green Roof Replace a Detention Tank?

The answer to this key question begins with an assessment of how a green roof would fare relative to the "design storm" mandated in a city's drainage code. The design storm is a fictitious rainfall event based upon statistical rainfall intensity and frequency information for a region. The design storm carries with it a code-specified maximum allowable release rate. Runoff is typically "managed" to this level via detention tanks that hold runoff and slowly release it after a storm's peak passes. This is standard approach across the United States and the world.

MKA simulated green roof performance in Seattle's "design storm" by using test plot data from the study's 25 largest storms to calibrate modeling parameters. The field data enabled MKA to represent rain absorption and was validated by simulating the super-intense December 14 storm (see article "Record-Wetting Fall") and comparing the modeling results to field measurements.

The graph below illustrates how runoff from the best-performing Seattle GREP test plot would fare relative to the Seattle design storm and its allowable release rate. It shows that even though the test plot significantly reduces the peak runoff rate, it falls short of drainage-code compliance. The table summarizes the level of compliance shortfall for all the test plots.

This information illustrates that none of the tested green roofs are "self-mitigating"; even the best-performing would still require some amount of detention. It's interesting to note that our analysis found that there was no statistical difference in performance for the three least-mitigating plots. The good news is that the data collected can be extrapolated to predict the mitigation benefit of virtually any type of soil media/drainage layer (even types not monitored). Just such analysis has proven that it *is* possible to design a media to be self-mitigating (see 2 below).



* Discussed in article below.

CODE COMPLIANCE COMPARISON	
Roof Type	**Compliance**
Conventional Roof	306% Under
Rainier Tower 4" Sellen 8" Stadium Center 4"	247% Under
Rainier Tower 2"	213% Under
Vulcan 6"	77% Under
Optimal FLL 6"*	20% Over

FLL GUIDELINES: WWW.F-L-L.DE/ENGLISH.HTML

2 What's the Best Planting System for a Green Roof?

The results of the Seattle GREP monitoring underscore that different planting media/drainage layer systems provide different levels of storm water performance. This leads to the questions, "What would be the perfect system for maximum storm water performance?" and "Where can I get that recipe?" The U.S. green roof market is young and still working on guidelines for this and other green roof specification issues. However, we can look to Europe for answers, as they are 30 years ahead of us.

Berlin is a mecca for green roofs (photo, right). For over 20 years, green roofs have been standard operating procedure for new buildings. The German national standard on green roofs, published by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL, translates to: Research Society for Landscape Development and Landscape Design) has been evolving since the late 1980s to reflect state-of-the-art green roof implementation. The FLL standard provides guidance on design parameter ranges and configurations for green roof systems, i.e., a sort of "ASTM standard" for green roofs.

By refining MKA's LIDSWM tool 4 using the findings of the Seattle GREP research, then applying that tool to European systems that are similar but not yet monitored, we are able to predict the performance of virtually any green roof system. One of the configurations we modeled was a 6-inch, single-layer green roof system conforming to FLL standards with properties selected by MKA to maximize storm water attenuation (shown for comparison purposes on the graph above as *Optimal FLL 6"*). Our modeled assessment shows that it is possible for a green roof to reduce peak flow rates enough to comply with City of Seattle allowable release rates with *no additional detention required for the green roof!* This self-mitigating system can be procured in the United States if specifically requested; the green roof designer must take care to specify media and drainage layer property requirements. U.S. green roof suppliers using FLL guidelines can then provide a system equivalent to Optimal FLL 6", or its constituent ingredients could be provided by local nurseries or soil suppliers.

View of Berlin rooftops

THE ADDED PROJECT COST OF PUTTING A UTILITARIAN GREEN ROOF ON A BUILDING CAN BE AS LITTLE AS $7.00/SF OF GREEN ROOF.

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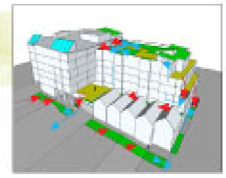
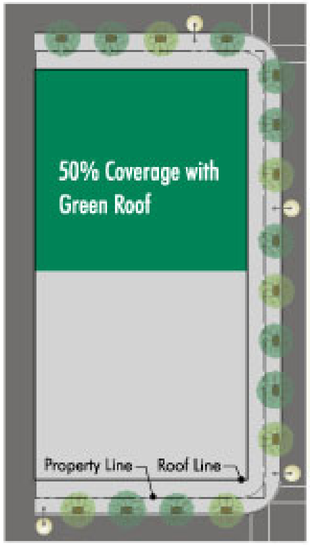


3 How Do You Prove to the City How a Green Roof Will Perform?

The monitoring data collected from the Seattle GREP provide undeniable proof of the runoff retardation aspect of green roofs. Since most projects are not 100% roof, nor are their roofs 100% green roof, a project's drainage design must consider the combined response to rainfall of all the project surfaces. This requires a complicated modeling technique that accounts for the fact that a hard surface's peak runoff intensity occurs at a different time than a green roof's.



MKA's LIDSWM tool (see 4 below) allows green roofs to be "daisy-chained" together with non-green-roof surfaces, so that the overall project detention requirement can be calculated.

For example, consider a hypothetical half-city block project in downtown Seattle (left). Using the modeling tool, it is possible to readily determine the comparative impact on a project's overall detention requirement when the project's roof is 50% covered with Roofscapes 6" or Optimal FLL 6". We have verified with the City of Seattle that this type of analysis is what they expect from permit applicants seeking to use green roofs for detention. We are now "permitting-ready" in Seattle.

	Detention Reduction	
Green Roof Type	Green Roof Only	Total Project
Roofscapes 6"	53%	20%
Optimal FLL 6"	100%	45%

A DETENTION TANK IN AN URBAN BUILDING CAN COST AS MUCH AS $150,000.

4 MKA LIDSWM

Since today's accepted storm water modeling methods do not account for all of the complicated environmental processes at play in low-impact design projects, MKA developed the Low-Impact Design Storm Water Modeling tool (LIDSWM) to fill this technical gap. Eighteen months of Seattle GREP monitoring data have been used to calibrate LIDSWM's green roof runoff simulation routine.

MOST NEW COMMERCIAL BUILDINGS CAN ACCOMMODATE A 4- TO 6-INCH GREEN ROOF WITH NEGLIGIBLE IMPACT TO THEIR STRUCTURAL FRAMING COST.

CITY OF SEATTLE GREEN ROOF RESOURCES: WWW.SEATTLE.GOV/DPD/GREENBUILDING

5 How Do Green Roofs Contribute to LEED and SGF?

An added benefit of green roofs and other natural drainage systems is that projects employing them generally score well with green metrics. Under USGBC's LEED rating system, for instance, the site credit associated with runoff quantity (SS6.1) is typically not attainable with simple drainage code compliance. This is because almost every drainage code in the country only regulates the *rate* of runoff, while LEED requires both *rate* and *volume* reductions (volume is typically only regulated when a drainage basin's receiving body is volume challenged, such as a small lake that would flood homes). Most projects reduce *rate* only, with 100% of the rain landing on the site still eventually leaving (albeit in a slower manner than if no detention tank were present). Natural-systems-based detention actually reduces *volume*, and typically to a level that complies with LEED.

A newer metric on the Seattle scene is the "Seattle Green Factor" (SGF). This project greening requirement is patterned after green zoning requirements that have been in use in some European cities for years. The SGF requires developers to achieve a certain minimum greening ratio (of greenery to site area) of 0.30 by summing the greening contribution of things like conventional landscaping, green walls, and green roofs. A comparison of how an actual project would fare under LEED and the SGF criteria is presented below.

GREEN METRIC COMPARISON FOR "SEDONA"*

Drainage Design Permutation	Detention Tank Required?	LEED Rate Reduced?	LEED Volume Reduced?	SGF
Conventional	Y	Y	N	0.22
Green roof only	Y	Y	Y	0.39
Full LID	N	Y	Y	0.49

* Project discussed in article "Nirvana: Self-Mitigating Buildings"

MANY EXISTING COMMERCIAL BUILDINGS CAN ACCOMMODATE A 2-INCH GREEN ROOF WITHOUT ANY MODIFICATION.

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