Multnomah County Building Ecoroof Performance Supplemental Report

Introduction

Ecoroofs, also known as green roofs, are basically low maintenance gardens growing on the flat roofs of commercial and institutional buildings. An ecoroof was installed on the Multnomah County Building (MCB), located at the corner of SE Hawthorne and SE Grand in Portland, OR. Multnomah County and City of Portland personnel are interested in how the MCB ecoroof can affect both storm water runoff and building energy consumption. Given the importance of knowing ecoroof performance for the MCB and mixed signals from previous studies, a performance monitoring plan was developed for the MCB. This report gives the results of monitoring the rainwater discharge of the MCB ecoroof for one full year, specifically the annual water year from October 1, 2004, to September 30, 2005.

Methods

<u>Water Discharge Monitoring</u>

The MCB ecoroof was installed on a flat roof above fourth floor offices. The general concept for monitoring the rainwater discharge was to measure the amount of rain falling on the ecoroof using a electronic rain gauge. The amount of that rain discharged was measured with an electromagnetic flowmeter mounted on the roof drain. Details of the measurement system have been described previously (1).

During the monitoring year, minor changes and corrections were enacted to the system:

- Rain gauge – A dedicated rain gauge was installed on the MCB in October. Installed and maintained by the City of Portland Bureau of Environmental Services, this rain gauge provides on-line rain data through the City of Portland HYDRA Rainfall Network; station #181. Prior to this installation, the rainfall on the MCB was estimated as the average of two neighboring sites, station #1 in downtown Portland and station #171 in Southeast Portland. Comparison of that average to the actual MCB rainfall for the first two months of operation showed very close agreement.

- Low flow Indication – After six months of continuous operation, a systematic difference was detected in the measured discharge between the two separate portions of the ecoroof. Each system had a stand-alone flowmeter and signal conditioner, with separate data generated. Cumulative monthly discharge for the North meter was consistently higher than that for the South meter, averaging about 40% greater. Examination of the data revealed low flow values were not being recorded for the South meter when compared to the North meter. Investigation into the set-up configuration for each flowmeter signal conditioner identified a "low flow cutoff" function that had been inadvertently activated during installation. This setting was deactivated on May 15, 2005. Subsequent readings produced low flow data and comparison between the North and South meters, for the same input, produced almost identical discharge readings. Based on these comparisons, the measured discharge for the South meter prior to the reset of the low flow cutoff was corrected based on the measured values for the North meter. A correction factor of 1.4 was applied to data collected between October, 2004, and April, 2005. For May, 2005, the correction factor of 1.2 was applied, based on the fact that the data for second half of May were accurate. No correction was applied for the months June, 2005, through September, 2005.

- Missing Data – Intermittently, data were lost. Typical occurrences lasted from a few hours to two days. Whenever these events occurred, all rainfall and discharge accounting were simply deleted from the accumulation.

Rooftop Energy Monitoring

Roof surface temperatures were measured using thermocouples mounted on the top of the roof, either beneath the ecoroof or beneath a protective rock bed or protective concrete pavers. Heat flux was calculated from the measured temperature difference. This calculation indicated that the heat flux through the MCB ecoroof was substantially lower than that through the roof sections with conventional (rock ballast) construction. However, as reported earlier (1), most of that difference was attributed to the roof construction rather than the ecoroof itself.

As an indication of the likely effect of the MCB ecoroof, preliminary results from another ecoroof of very similar construction are offered. The Broadway Building on the Portland State University campus, located about one mile from the MCB, has an ecoroof that is being monitored for rooftop heat flux. As with the MCB, temperature differences are measured across the structural roof, both beneath the ecoroof and beneath a conventional ballast roof. The main difference arises from the test arrangement: For the Broadway Building, both heat flux measurements are conducted in a location where the roof structure is known to have the same thickness. A portion of roof was isolated from the ecoroof by a retaining wall, with a conventional roof installed within. This is shown in Figure 1. Surface-mount RTD sensors measure the roof temperature beneath the ecoroof and beneath the rock ballast; a similar set of RTD's measure the indoor surface temperature directly beneath the rooftop sensors. These measured temperatures drive a finite difference model of the roof structure to account for thermal inertia of the transient temperature signals and to calculate the instantaneous heat flux into or out of the building. These heat flux values are then integrated over time and the total monthly heat flux is calculated and compared for the ecoroof and conventional roof. Results have been compiled for the Broadway Building for the months of January, 2005, through September, 2005, but results are missing for June and July, 2005, due to a malfunctioning temperature sensor.

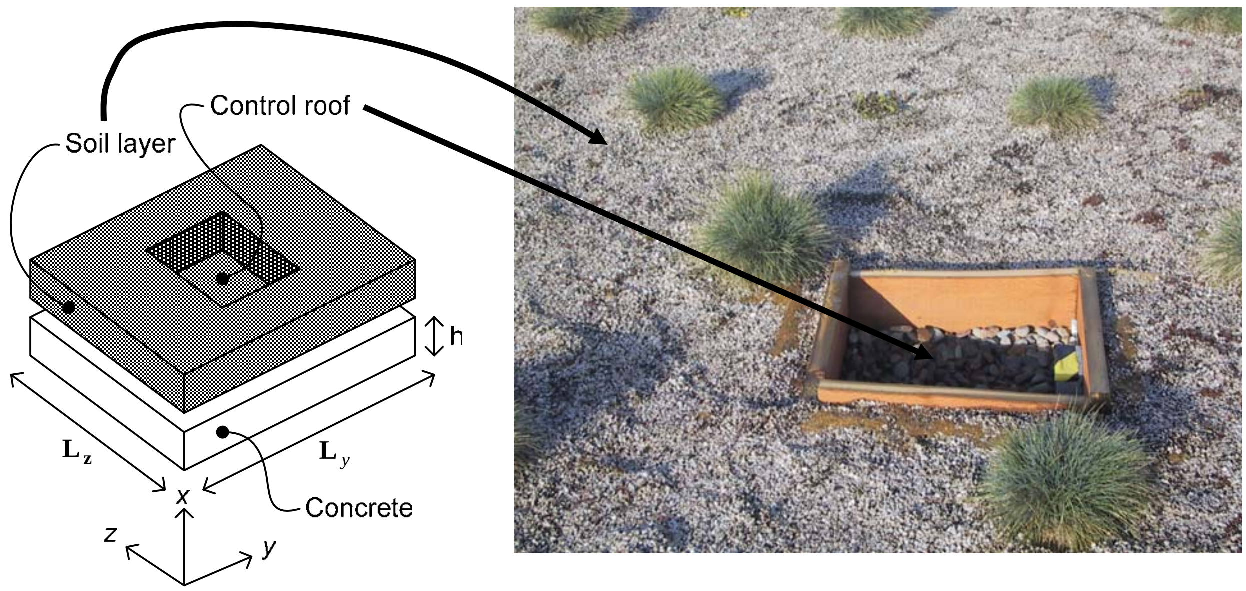

Figure 1. Rooftop temperature measurement on the Broadway Building.

Results and Discussion

<u>Rainwater discharge</u>

For the time period October 2004 – September, 2005, the rainfall for Portland was somewhat less than the normal rainfall for a typical year. This rainfall was recorded, along with the discharge from the two flow meters, North and South. Each month's time history of rainfall and discharge, for each ecoroof section, are appended. Two obvious but important observations appeared:

1. Rainwater discharge events corresponded directly with rain events. Simply put, the monitoring equipment was functioning properly. Given that electromagnetic flow meters are hardly, if ever, used for such intermittent flows, this direct correlation between input and output lent credibility to the instrumentation.

2. The peak discharge rates were always less than the rain rates. Again, this is what would be expected by conservation of mass, but lent credibility to the method for measuring rainwater discharge.

The cumulative rainfall and discharge for the entire year for the north ecoroof and south ecoroof are given in Table 1. The north ecoroof received about 54,000 gallons of rainfall for the water year period October, 2004, through September, 2005. Because of slightly less area, the south ecoroof received slightly less rainfall. Based on measurement, 71% of the rainfall on the north ecoroof was subsequently discharged into the storm drain while 69% was discharged on the south ecoroof. Overall, the ecoroof discharge was 70% of the total rainfall.

Table 1. Cumulative rainfall and discharge for the ecoroof.

MONTH	Rainfall		Discharge				Combined
	North	South	North	South	North	South	Total
October	6814	6662	3684	3934	54%	59%	57%
November	4395	4297	2463	2461	56%	57%	57%
December	6958	6803	5440	5598	78%	82%	80%
January	3855	3769	2197	1947	57%	52%	54%
February	1908	1866	248	309	13%	17%	15%
March	6245	6106	6302	6125	101%	100%	101%
April	5243	5126	3478	2288	66%	45%	56%
May	9319	9111	4434	4265	48%	47%	47%
June	4530	4428	631	799	14%	18%	16%
July	636	622	431	402	68%	65%	66%
August	675	660	2977	2807	441%	425%	433%
September	3701	3618	6010	5658	162%	156%	159%
TOTAL	54278	53067	38295	36592	71%	69%	70%

General observations:

1. For both north and south ecoroof sections, relatively less discharge occurred when less rain fell. For example, the ecoroof discharged 80% when about 14,000 gallons of rain fell in December but only discharged 54% of the 7,600 gallons in January. For less rainfall, the percentage of rain lost by evaporation was greater, as would be expected.

2. As reported previously (1), rainfall "events" where very heavy rain fell over a short period of time, the ecoroof appeared to saturate and retain very little of the rain. When this happened, the discharge was essentially 100% of the rainfall. March, 2005, was characterized by a few of these heavy rainfall events, so the discharge was very high.

The time lag between the pear rainfall and the peak discharge for an event was typically about 2 hours. This is illustrated in Figure 2 for a sustained rain event on September 30, 2005. For this event, the total discharge was about 100% of the rainfall.

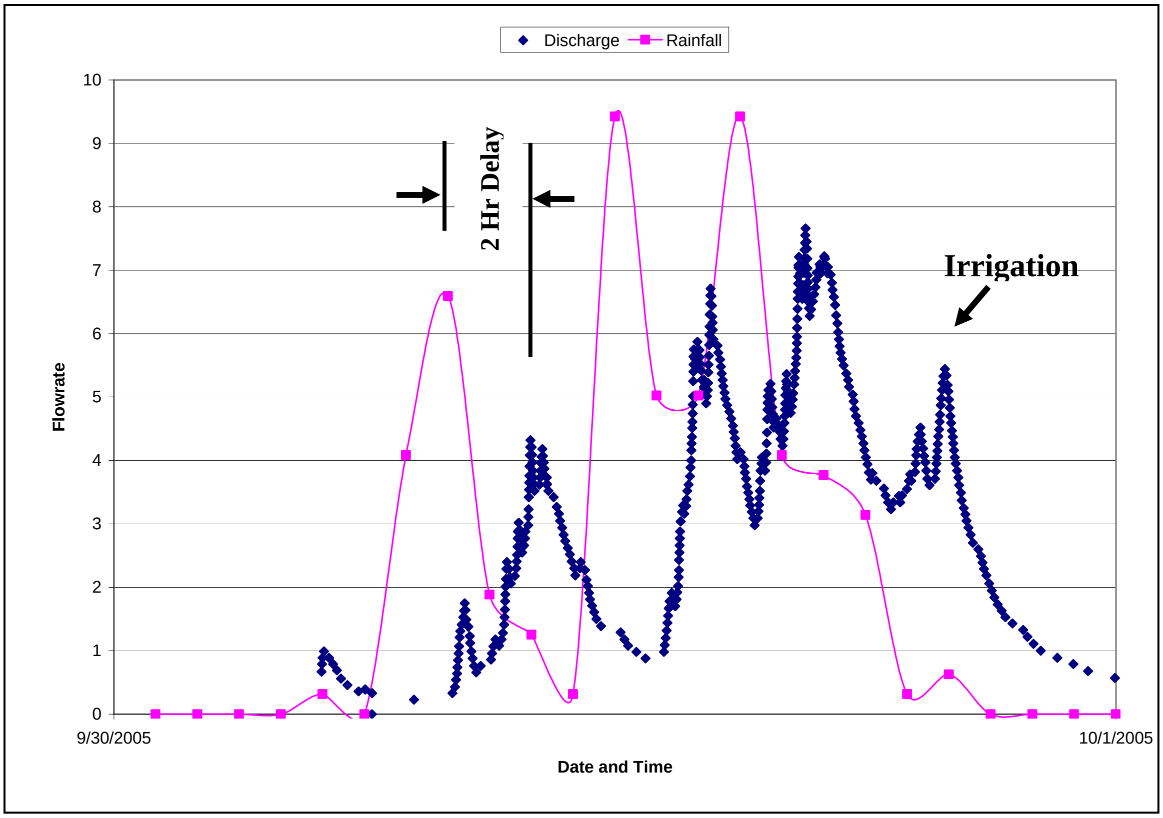

Figure 2. September 30, 2005, rain event and discharge for South ecoroof.

Irrigation – The ecoroof was irrigated during the summer. Irrigation was started on July 23, 2005, and stopped on October 3, 2005. Irrigation timing and duration was varied, based on a variety of factors. Discharge from irrigation is clearly observable from the flowmeters, as illustrated in Figure 2 and Figure 3. In Figure 2, the irrigation adds to the input of a rainfall event and appears as a peak in the discharge without a corresponding peak in the rainfall. In Figure 3, the irrigation appears in a series of peaks during a time with no rainfall. It can be seen in Figure 3 that the irrigation was applied daily for the first two days and then increased to a twice per day schedule for the remainder of the week. Discharge is higher for the more frequent watering schedule.

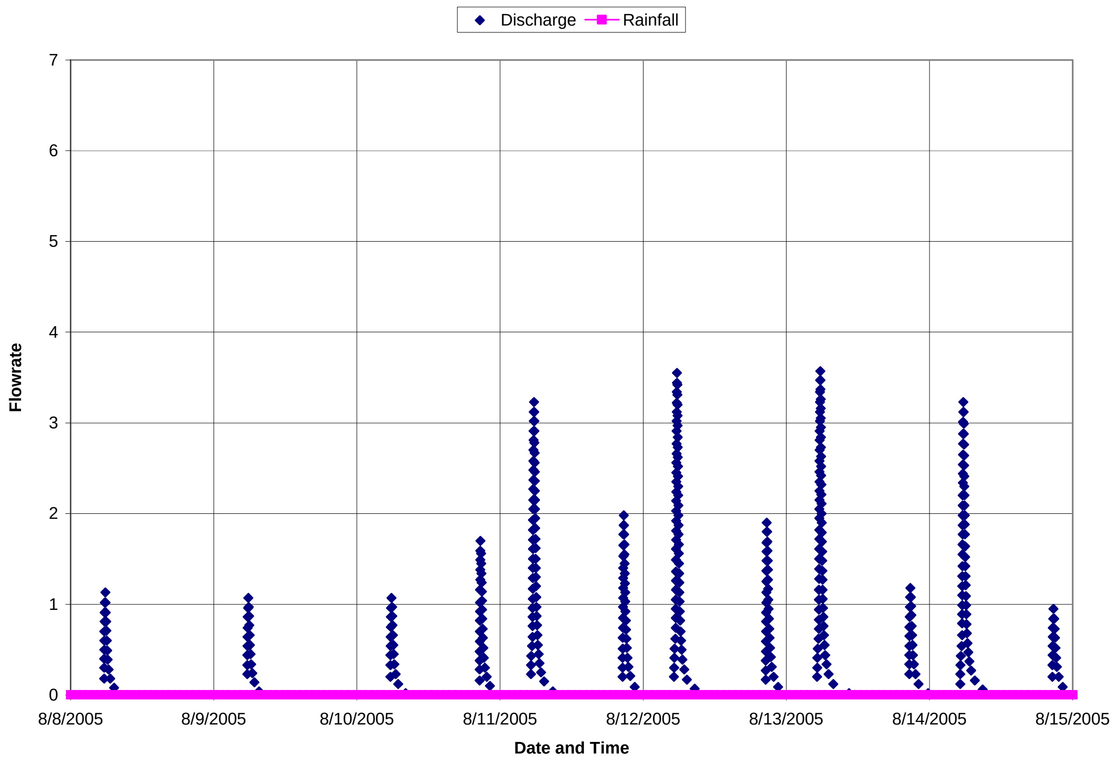

Figure 3. Discharge for North ecoroof for one week in August showing irrigation discharge.

Irrigation runoff accounts for a significant portion of the summer discharge, leading to discharge rates higher than rainfall rates, as seen in Table 1. For the irrigation season, started on July 23, 2005, and stopped on October 3, 2005, the total rainfall on the monitored ecoroof was about 10,000 gallons but the discharge was almost 20,000 gallons. It would appear that the irrigation schedule may need adjustment to reduce the amount of irrigation water being wasted.

Table 2. Ecoroof rainfall and discharge during the irrigation season.

MONTH	Rainfall		Discharge		Combined
	North	South	North	South	Total
July	0	0	317	328	Undefined
August	675	660	2977	2807	433%
September	3701	3618	6010	5658	159%
October	598	584	663	772	121%
TOTAL	4974	4862	9967	9565	199%

Roof heat loss

The Broadway Building on the Portland State University campus is offered as a surrogate for the MCB roof, with very similar ecoroofs. The rooftop heat flux for the Broadway ecoroof, when compared to a conventional roof construction, is shown in Figure 4.

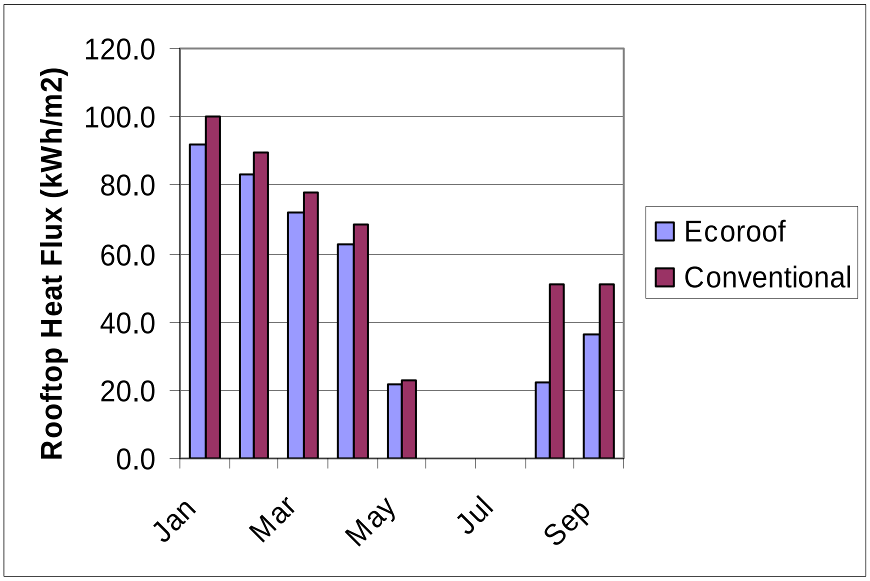

Figure 4. Rooftop heat flux for Broadway ecoroof and conventional roof

As can be seen, the heat flux is higher in January than in May, as would be expected. The ecoroof offers a slight reduction in the heat lost from the building during the winter and spring, probably due to the thermal resistance of the soil layer on the roof. Interestingly, though, during the summer (August and September) the ecoroof appears to offer a significant reduction of heat gain through the roof. This effect may be attributed to evaporative cooling occurring from the ecoroof, either plant evapotranspiration or evaporation of surface water from the soil layer, due to irrigation water. More testing is necessary to confirm the consistency of this trend. But, if validated, the MCB should be receiving a comparable benefit from its ecoroof relative to summer cooling demand.

Conclusions

A retrofit ecoroof was installed on the Multnomah County Building in Downtown Portland, Oregon. This project monitored the physical performance of that ecoroof with respect to discharge of rainwater into the storm sewer and roof energy loss.

A full year of monitoring has yielded the following findings:

- Discharge of rainwater into the storm sewer appears to be reduced by about 30% due to the ecoroof. Events of heavy rain, however, are not significantly attenuated. The time delay between peak rain and peak discharge appears to be about two hours.

- Irrigation of the MCB ecoroof contributes to the stormwater discharge. Over the summer irrigation season, about 2 ½ months, the stormwater discharge from the ecoroof was twice the rainfall. This discrepancy can be directly attributed to irrigation runoff.

- Winter heat loss and summer heat gain through the ecoroof should be reduced, based on results measured for a similar ecoroof. Winter savings should be about 6-8%, but summer savings could be closer to 25-50%. Summer savings would be greater because of evaporation of rooftop water.

References

1. Spolek, G., “Multnomah County Building Ecorrof Performance,” Technical Report (2005).