Green Space Categorization as a Function of Run off and Infiltration Rates

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Abstract:

The University of Vermont campus is subject to high amounts of foot traffic and maintenance vehicle use. The effects of this use cause a drop in infiltration capacity because of green space being used for roads and paths. We defined four categories of green space condition and mapped an area of the campus. In our research, we found that good green space occupied 44% of the test area. Moderate green space occupied 5% of the test area. Poor green space occupied only 1% of the test area. The remaining 50% consisted of impervious surfaces such as paved areas and buildings. We found that although only 1% of the green space in our test area was degraded enough to lower infiltration rates to less than 0.05 cm/hr, the effects of the lowering of infiltration rates had direct effect on the surrounding areas. Impervious ground surfaces made up 50% of the test area, and many of the degraded green spaces were located adjacent to the impervious areas, providing channels through which runoff could be directed. Non-point source pollution and other problems associated with low infiltration areas could be greatly reduced with improved green space management. We suggest different methods of remediation, through fencing and paving options that could divert the flow of foot traffic and allow degraded areas to be brought back to health.

Introduction:

Green space is an important factor in the transport of water from land's surface to aquifers, lakes, rivers, and streams. For the purpose of this study, we define green space as any vegetated area in an urban setting, with vegetation primarily consisting of grass. The health of a green space is determined by how well it can absorb water, as well as its aesthetic characteristics, i.e. vegetation density. In urban environments, the issue of green space health is becoming increasingly important (U.S. EPA, 1993). At the main University of Vermont campus, located in Burlington, Vermont, it is vital that high-quality green space is maintained for both aesthetic value and for issues involving storm water.

The purpose of this study was to classify campus green space conditions by performing a visual survey of green space within a designated study area, located on UVM's main campus, shown in figures 1-6, pages 10-15, the study area maps. At two of our study areas, we implemented Dunne and Leopold's Coffee-cup Calorimeter infiltration rate test (Dunne and Leopold, 1978). This was done to rank infiltration rates for our types of green space. An infiltration rate is defined as "the maximum rate at which water can penetrate into the soil," (Chorley, 1969). Footpaths formed by individuals finding the shortest distance between two points has caused degradation of green space quality at the University. Healthy green space areas were used as a comparative measure against which the degraded areas of the footpaths could be analyzed. Vegetation in green space areas signified a certain level of health that was used to infer how well soils could absorb water.

Methods:

At each study site, we focused on natural footpaths and degraded green space bordering paved or concrete walkways. Green spaces were broken up into three groups, according to their condition. Green space health was categorized as good, moderate, and poor. Locations specified as good were completely covered by vegetation. Locations specified as moderately degraded had roughly 30 to 70% cover of vegetation. Included in this category were areas of landscaping such as mulch. Locations specified as degraded had less than 30% cover by vegetation, and in most cases there was exposed soil and no vegetation.

Following Dunne and Leopold's (1978) method for conducting infiltration rate experiments; we used a coffee can as our infiltrometer. The experiment was conducted six times on six different test sites. Four tests were performed within the study area, while two were performed on the campus green, where green space is considered ideal. The experiment was done by taking a coffee can with both ends cut out, and driving it into the soil approximately 2cm. Then a line was made on the inside of the can to use as a water level marker. Water was added up to the line, and its level consistently maintained for twenty minutes

Using Vermont orthophotos taken in 1999, and obtained through the UVM library's map room, a visual record was compiled of the four predominant surface features in the study area. Those features being impervious features, and the three designated green space types. These field notes were sketched onto orthophotos using ArcView v3.2 GIS software. The GIS software calculated the area of the polygons representing green space, paths and buildings within the study area (fig. 2, pg.12). Within ArcView, the study area was defined and then broken into four sub-quadrants. Four different levels of infiltration capacity were mapped out on the test area and polygons were drawn in to calculate areas of both sub-quadrants and the entire study area (fig. 3-6, pp.12-15). The features were digitized using the union features overlay process. The four layers defined in the map are good, moderate, poor, and impervious. Impervious areas are buildings and paved areas. Data on areas of differing green space health was exported to Microsoft Excel and analyzed.

<u>Data</u>:

Within our six test sites, we defined three different categories of green space condition. In table 1 (pg. 8), good green space sites located on the campus green and the lawn in front of Cook had infiltration rates of 6.16cm/hr and 4.31cm/hr respectively. Moderate green space sites for example the old Aiken path as well as the tree located on the campus green, had infiltration rates of 0.06cm/hr and 1.2cm/hr. Poor green space sites of the new Aiken path and the Cook path had infiltration rates of 0.04cm/hr and 0.03cm/hr respectively. Table 2 (pg. 8) shows the area, as well as the percentage, of each green space category. Good green space occupies 63640m^2, or 44% of the study area. Moderate green space consists of 7410m^2, or 5% of the study area. Poor green space quantifies 2040m^2, or 1% of the study area. Impervious surfaces covered 69920m^2, or 50% of the study area.

Discussion:

Green spaces with high infiltration rates and full vegetative cover should be maintained on campus, for aesthetic and environmental reasons. The quality of vegetation is a factor in soil porosity which directly limits or promotes water infiltration. The porosity of the soil relates directly to how much water can be stored within the topsoil (King, 1992). Areas that have been compacted by foot traffic and maintenance vehicles, such as the Aiken and Cook paths, thereby reducing the soil porosity and increasing soil density, have significantly lower infiltration rates. Vegetation plays a large role in how well soils can infiltrate water. Vegetation lessens the impact of rainfall on soils and creates soils that have a higher capacity to accept water through providing a thicker, porous layer into which water can easily flow (Chorley, 1969), (Dunne and Leopold, 1978). Areas without vegetation, in the event of rainfall, do not protect the soils from erosion. Fine particles become suspended in the runoff due to rainfall impact and deposited in the open pores in the ground, creating an impervious layer that reduces infiltration capacity (King, 1992), (Nix, 1994). With a reduced infiltration capacity, water flows along the surface, filling in depressions and following the general gradient of the surface. Urban runoff has been noted as a key source of non-point pollution (Nix, 1994). When infiltration rates are lowered through compaction, urbanized impervious areas, and overland flow sediment transport, the higher the opportunity for sources of pollution to be carried along with the runoff (U.S. EPA, 1993).

The average infiltration rates for each green space category were computed in table 3 (pg. 9), and visually quantified in graph 1 (pg. 9), with good green space having an average infiltration rate of 5.24cm/hr. Moderate green space had an average infiltration rate of 0.63cm/hr, and poor green space had an average infiltration rate of 0.035cm/hr. In looking at the distribution of green space qualities, the poor, degraded areas make up only a small percentage (1%) of the overall study area. These spaces are critical however in understanding overland flow. With impervious surface areas accounting for 50% of the study area, the runoff from these areas is channeled into either storm drains, or green spaces. The result is channels that allow high volumes of runoff and suspended sediment to flow and erode the surfaces more due to their low infiltration capacities. The moderately degraded areas exhibit an ability to infiltrate water at a reasonable rate, but are not nearly as effective as areas that have 100% vegetation and low foot traffic. Although the percent of degraded green space is less, the impact of these green spaces on runoff and non-point pollution into streams and lakes, is far greater.

The mapping of different green space categories allows a visual representation of the areas that are similar in their infiltration characteristics. There has been a significant change over time in the amount of impervious surfaces within our study area (fig. 7-11, pp.16-20), and this change directly relates to the need for optimal green space health. One problem with the ortho-photographs was with interpolating known green space boundaries that were obscured from view by roof overhangs and elevation features.

We recommend that areas, such as paths that have no vegetation and highly compacted soils, be blocked off either by fencing or planting shrubs to encourage those who travel the path to follow the paved paths. The areas could then be tilled and reseeded to encourage root development and provide optimal soil conditions for the developing grass. Another management option is to pave the natural paths and fence off the surrounding green space, to accommodate the natural development of these footpaths. Along impervious paths where some of the poor quality green space is located, we suggest fencing to keep traffic from wandering off the path, and to discourage maintenance vehicles that are too wide for the paths, and aid in the compaction of the soil. In moderately degraded areas, we suggest that the ground be aerated and reseeded. These areas should then be fenced off in order to reduce foot traffic and other causes of degradation.

Summary:

We have found the majority of permeable green space within our study area to be in good to moderate condition. Good green space areas like the campus green demonstrate much higher infiltration capacities than moderate or poor areas of degradation. Location and functionality of poor green space presents a management problem to the university because the majority of degraded areas are adjacent to impervious surfaces, magnifying runoff problems. Our recommendations are to accommodate or deter foot traffic in these areas either through engineering or landscaping methods.

References

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King, R.B. Overview and Bibliography of Methods for Evaluating the Surface-Water-Infiltration Component of the Rainfall-Runoff Process. U.S.G.S. Water Resource Investigations, Report 92-4095, Urbana, IL, 1992

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Nix, Stephan J. Urban Stormwater Modeling and Simulation. Boca Raton: CRC Press, Inc. 1994

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Table 1				
Infiltration Rates and Green Space Categorization				
Test Site #	Test Site	Infiltration Rate (cm/hr)	Vegetation Cover (%)	Greenspace Category
1	Aiken path (new)	0.04	0	poor
2	Aiken path (old)	0.06	70	moderate
3	Green (bench)	6.16	100	good
4	Green (tree)	1.2	30	moderate
5	Cook (path)	0.03	0	poor
6	Cook (green)	4.31	100	good

Table 1: Shows the correlation between infiltration rate and vegetation cover, providing a classification scheme for comparative analysis.

Table 2

Area Totals and Percentages of Green Space Categories				
Study Area	Surface Condition	Area (m²)	Area (Acres)	Percent of Total
1	Good	63640	15.7	44
2	Moderate	7410	1.8	5
3	Poor	2040	0.5	1
4	Impervious	69920	17.2	50
	Total	143010	35.2	100

Table 2: Shows the areas and percentages that the green space categories make up within the study area in meters, acres

Table 3

Average Infiltration Rates for Green Space Categories

Green Space Condition	Average Infiltration Rate (cm/hr)
Good	5.24
Moderate	0.63
Poor	0.035
Impervious	0

Table 3: Shows that good green space has a much higher average infiltration rate than moderate or poor green spaces. It is represented graphically below in Graph 1.

Graph 1

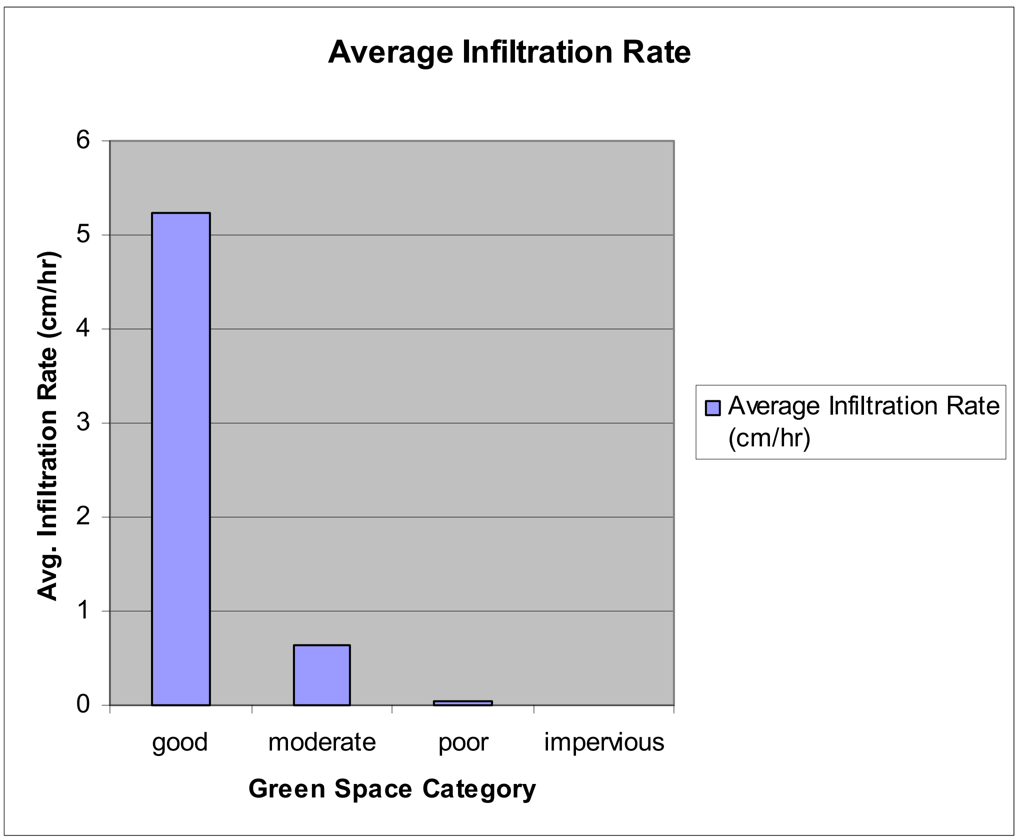


Figure 1

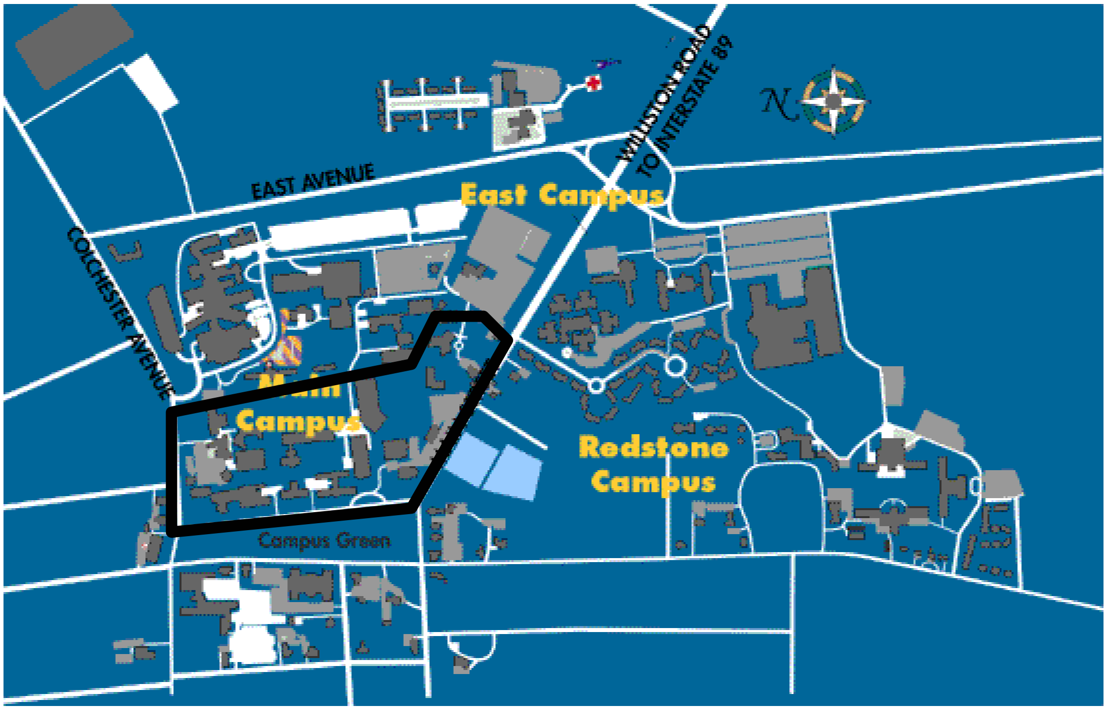
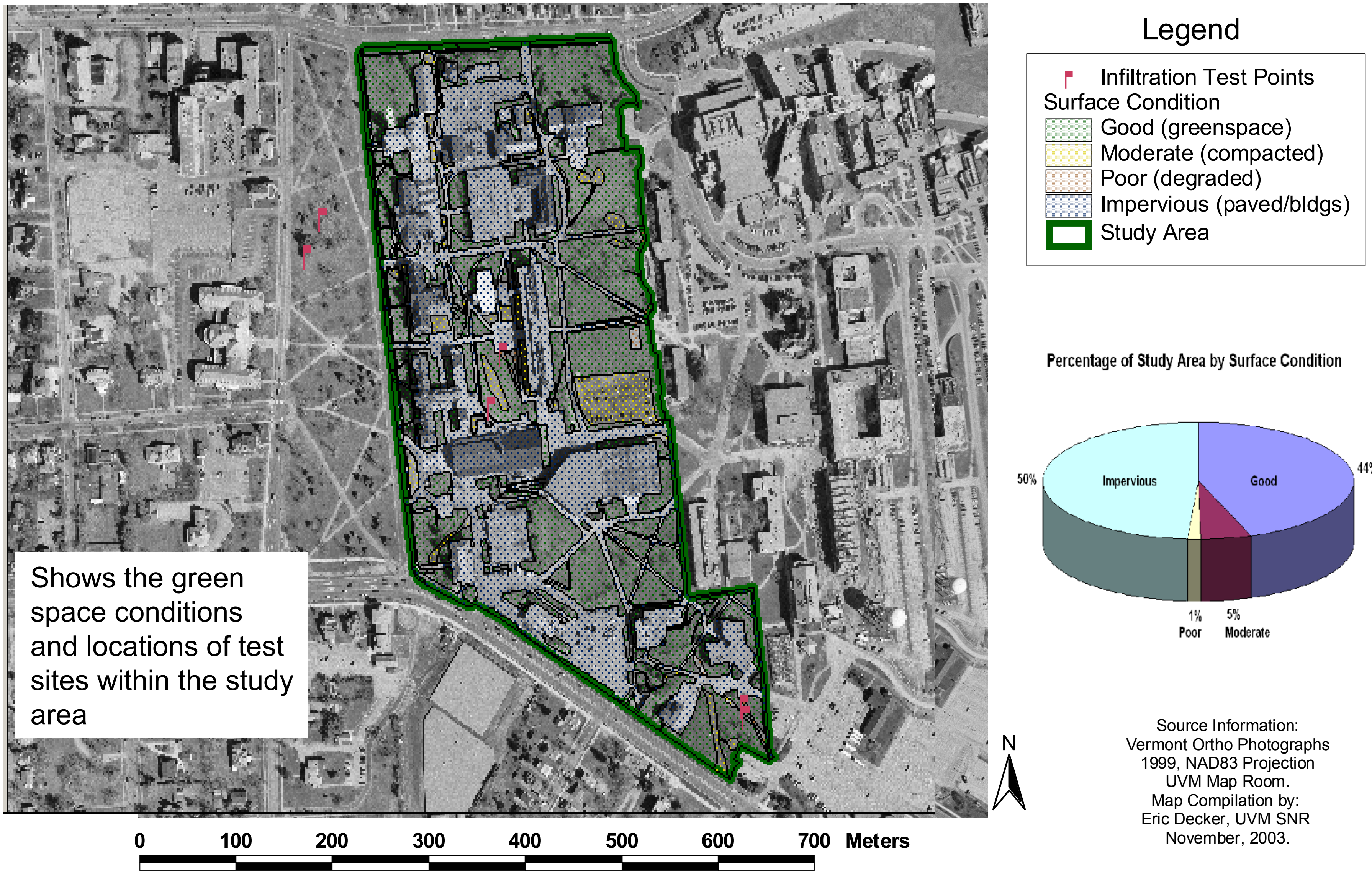


Figure 1: Location of study area within UVM Main Campus.

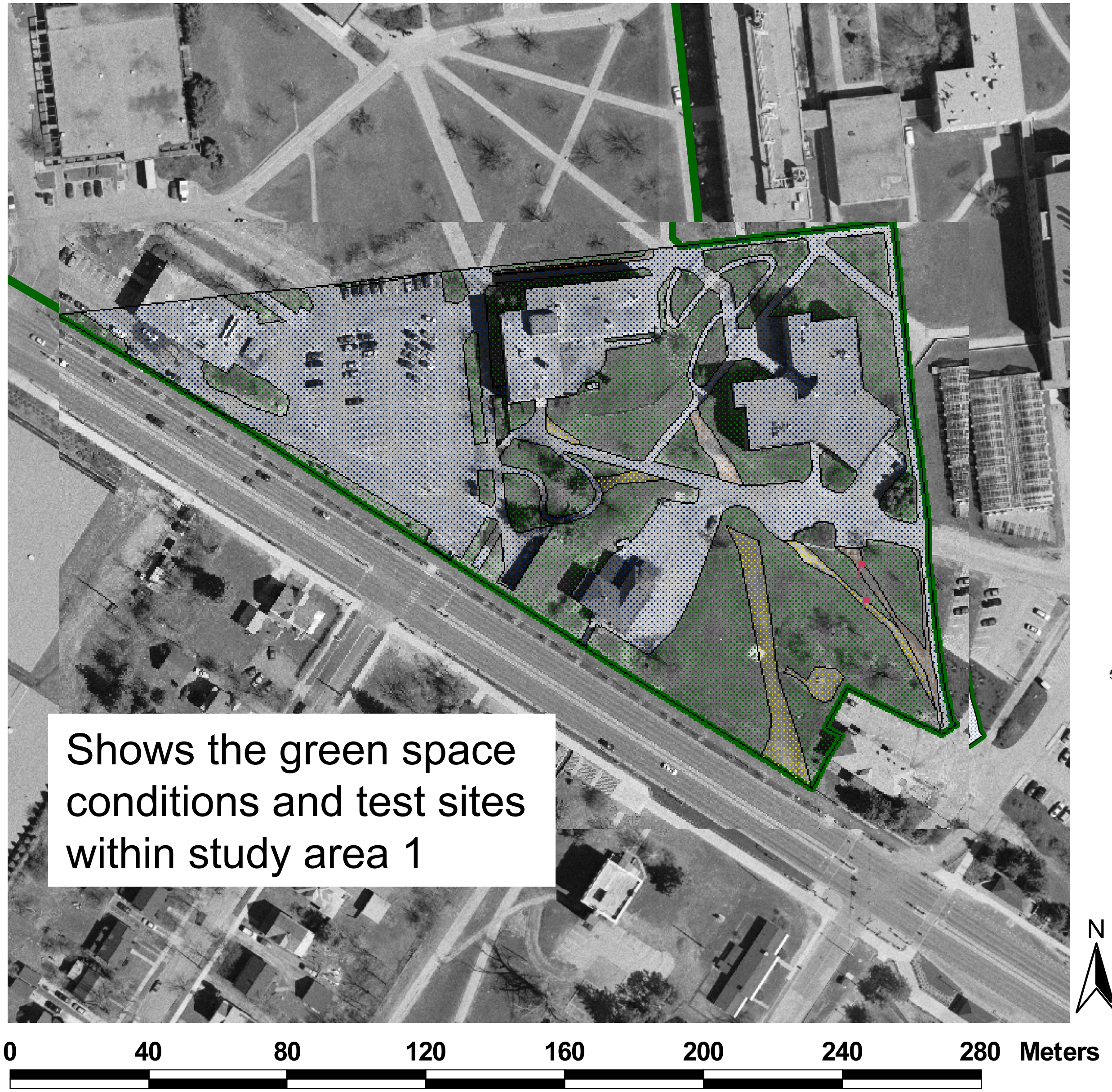
Figure 2

Campus Surface Condition and Infiltration Study Area



Source Information:
Vermont Ortho Photographs
1999, NAD83 Projection
UVM Map Room.
Map Compilation by:
Eric Decker, UVM SNR
November, 2003.

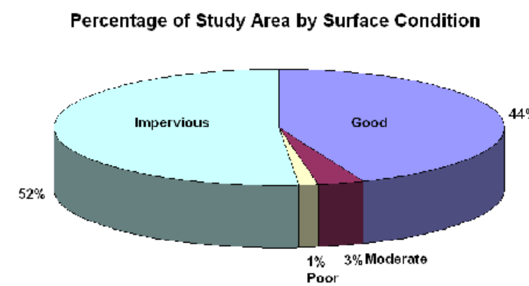
Figure 3
Campus Surface Condition and Infiltration Study Area 1



Shows the green space conditions and test sites within study area 1

Legend

Infiltration Test Points
Surface Condition
Good (greenspace)
Moderate (compacted)
Poor (degraded)
Impervious (paved/bldgs)
Study Area



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UVM Map Room.
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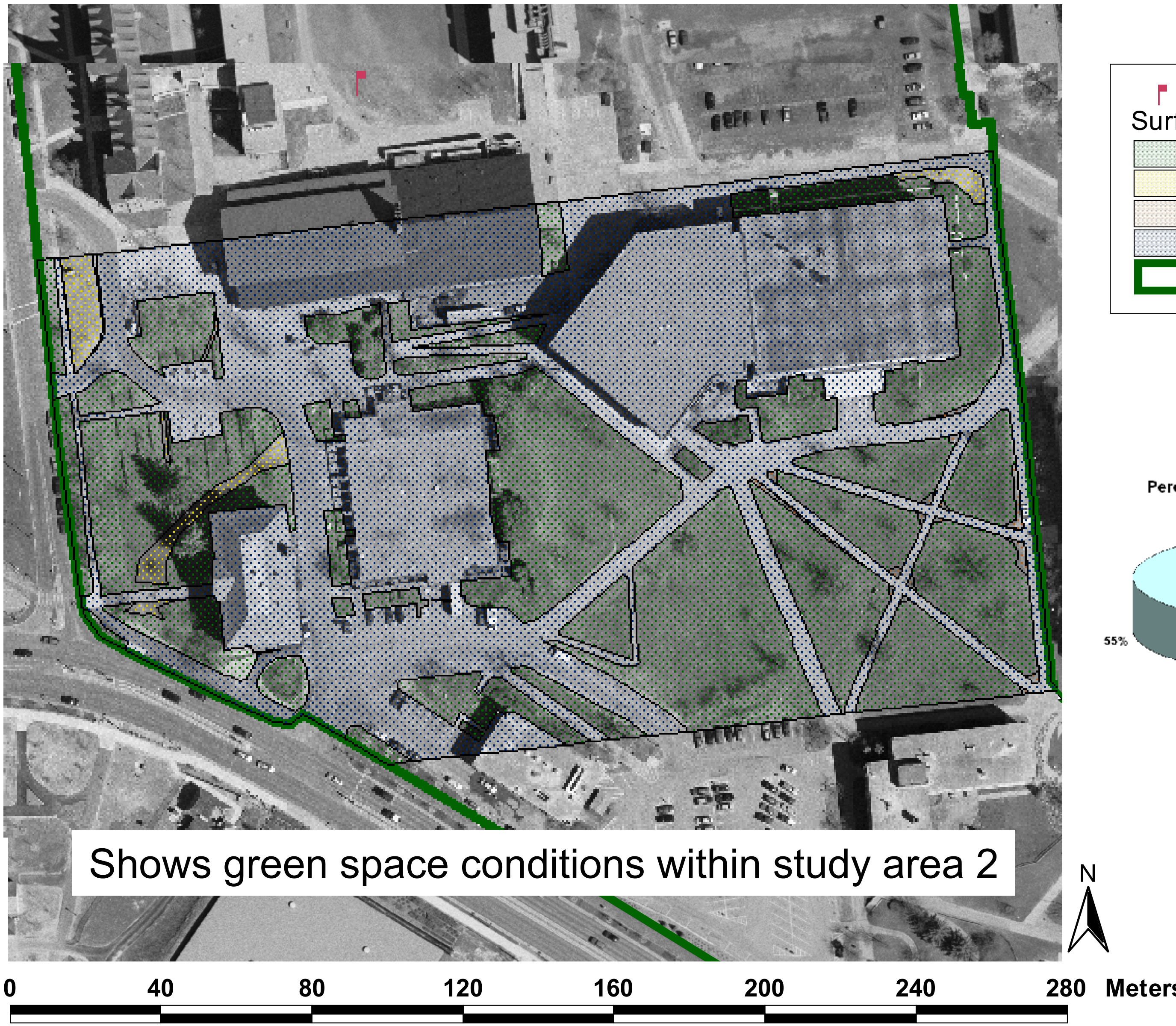
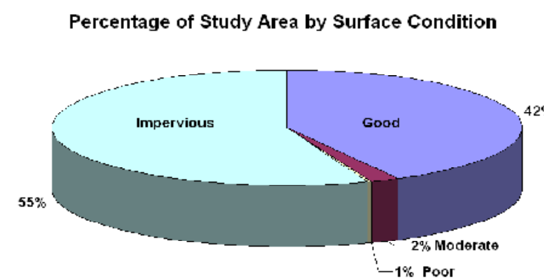
Figure 4

Campus Surface Condition and Infiltration Study Area 2





Source Information:
Vermont Ortho Photographs
1999, NAD83 Projection
UVM Map Room.
Map Compilation by:
Eric Decker, UVM SNR
November, 2003.

Figure 5

Campus Surface Condition and Infiltration Study Area 3

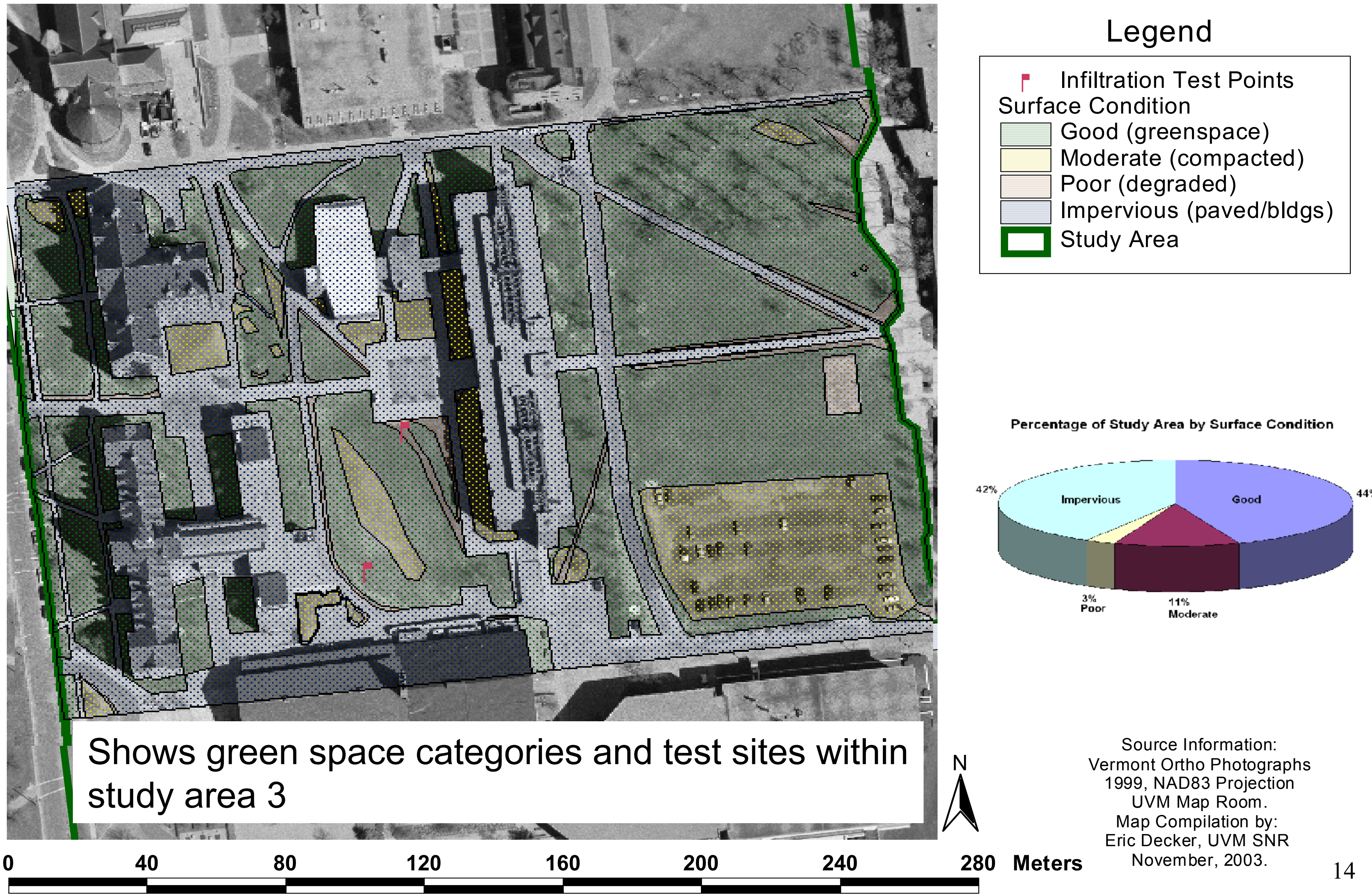
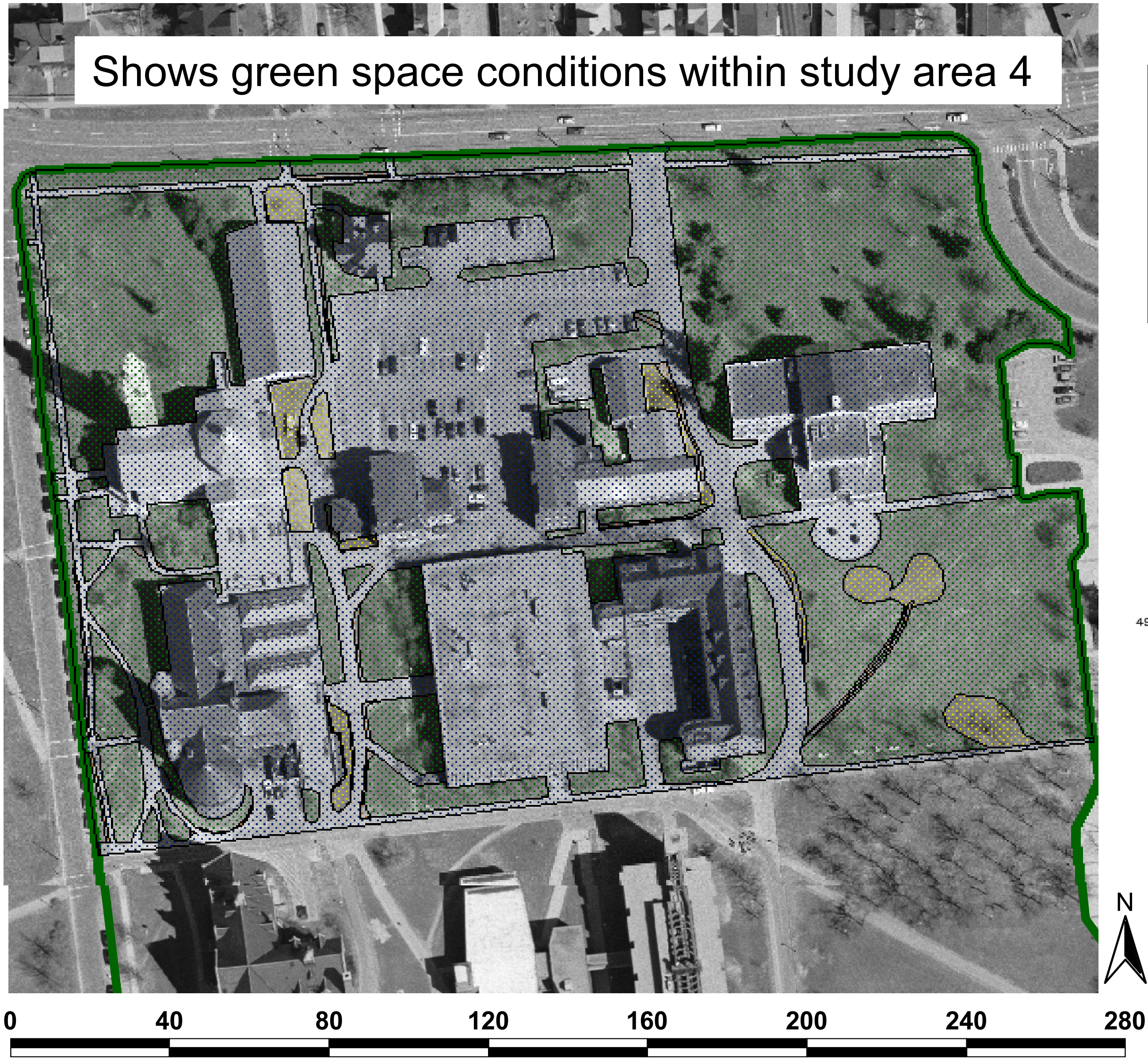


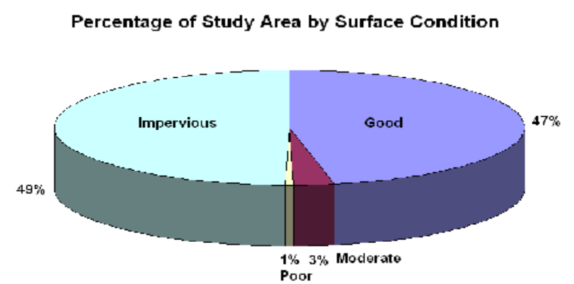
Figure 6

Campus Surface Condition and Infiltration Study Area 4



Legend

Infiltration Test Points
Surface Condition
Good (greenspace)
Moderate (compacted)
Poor (degraded)
Impervious (paved/bldgs)
Study Area



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1999, NAD83 Projection
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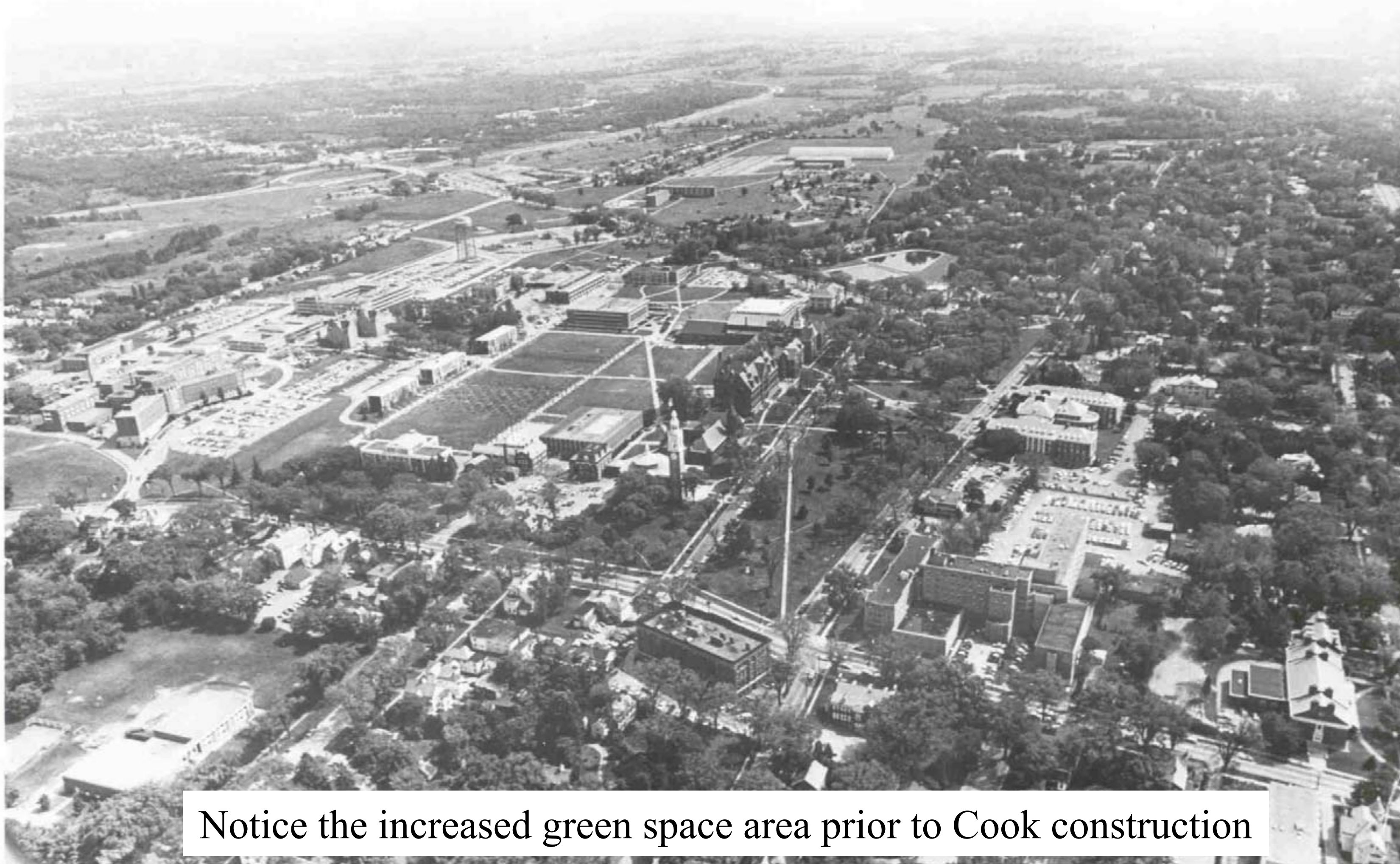
Figure 7

Historical Aerial Photograph of UVM Campus



Notice the increased green space area prior to Cook construction

Figure 8

Old Mill

Old mill historical comparison showing green space areas that have since changed. Notice architecture from before and after fire and subsequent renovation.

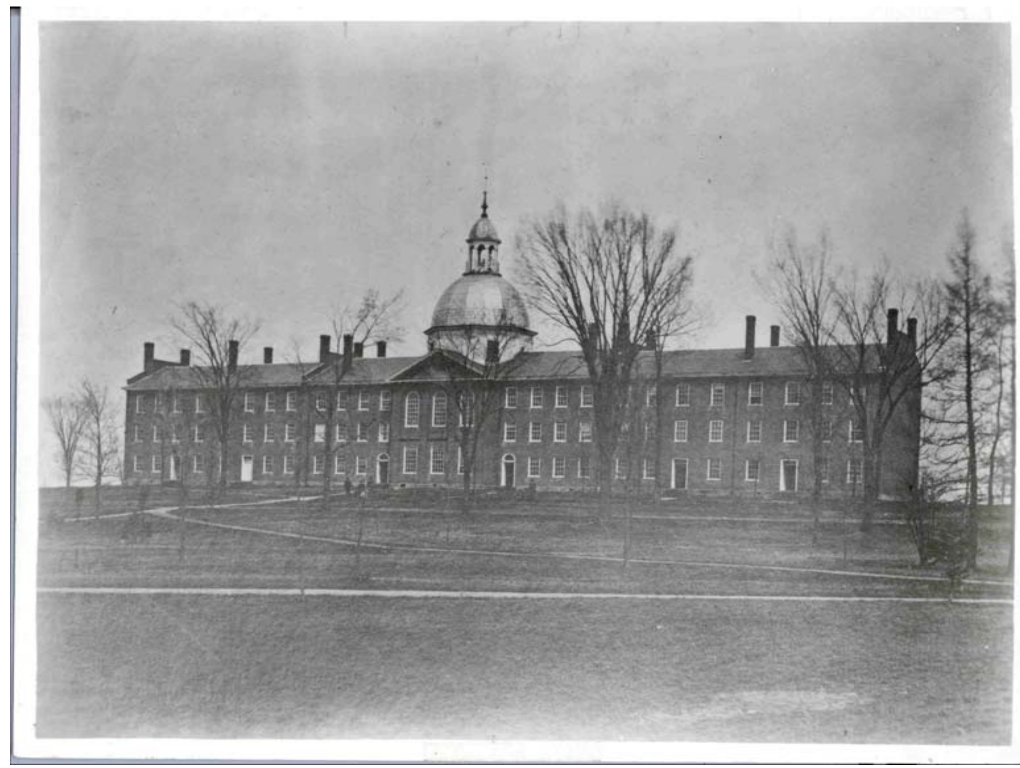
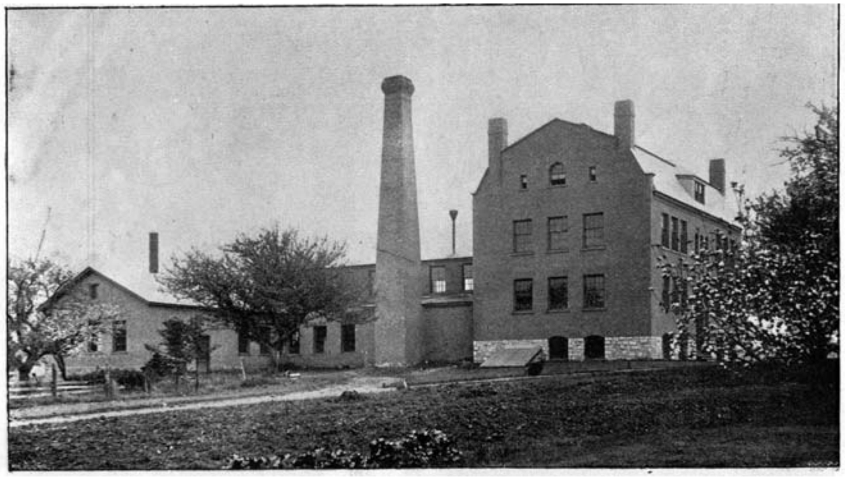


Figure 9

Perkins Geology Museum



Notice building addition and parking lot. Impervious surfaces replace historical green space and dirt road.

Figure 10

Old Mill and Statue

Notice change in landscaping composition and density surrounding statue, as well as change from dirt to paved path.

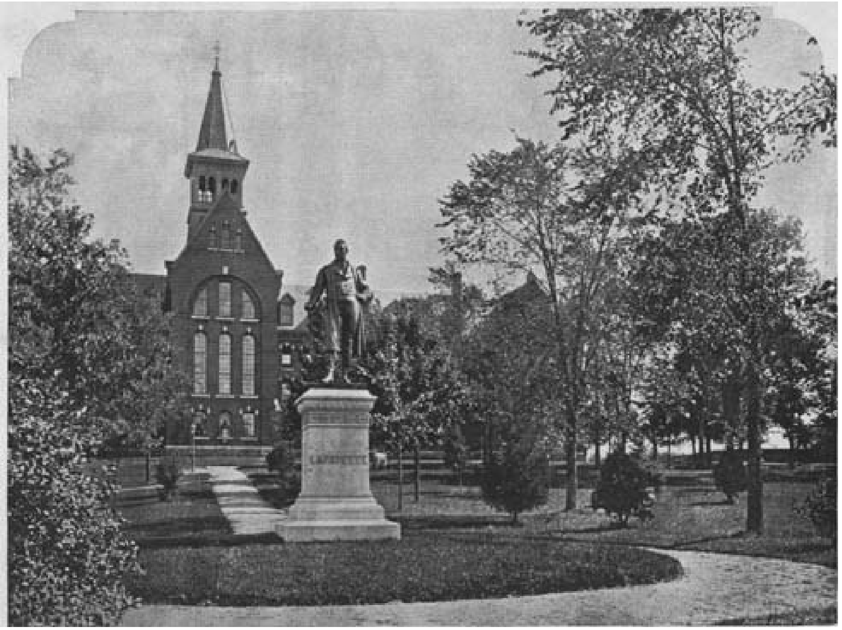


Figure 11

Ira Allen Chapel

Notice little change in the northwest corner of campus, except for widening of road.