San Luis Obispo County
San Miguel Alleyway Redesign

California Polytechnic State University,
San Luis Obispo
College of Architecture and Environmental Design
City and Regional Planning
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Project Summary Statement

The purpose of the alleyway redesign plan is to produce drainage and design guidelines that will help guide the retrofitting of the current alleyways. This plan will focus on improving the drainage of the existing alleyways in San Miguel while also maintaining an aesthetic focus which will further enhance the alleyways for the residents. This has been accomplished through the introduction of permeable materials, biofiltration trench, vegetation, and a gutter system. The completed plan can be used by the client as a guide for the improvement of the alleyway system.

Understanding

As the consultants for this plan, we understand the need for a better-suited system of drainage that will result in the conservation and reuse of water. The current drainage system within San Miguel is in rather poor condition, something which we have taken note of in our previous class. There has been research conducted in the Community Services and Circulation Elements of the San Miguel Plan Update that shows issues with flooding and proper drainage.

The retrofitting of the alleyways will have multiple benefits, including a reduction of flooding within neighborhoods, enhancement of water circulation, and the increase the rate of water recharge.

Approach

We have taken all information gathered from our previous works and expanded upon this information. It was important to note any prior constraints, such as feasibility and environmental issues. We then continued onto opportunities and identifying potential drainage solutions based on both constraints and opportunities. The next step was to develop a design with specific measures that would be taken including, what types of materials, vegetations, and connectivity to use.

We used all information previously gathered in San Miguel Design Studios, including the final San Miguel Update Plan and the current General Plan for the County of San Luis Obispo. Design tools that we used include GIS, AutoCAD, In Design, and Excel.
Background Data

Existing Conditions

San Miguel consists of two major alleyways between K Street - L Street and L Street – Mission Street, spanning from San Luis Obispo Road to 16th Street. These two sections of San Miguel are the designated redevelopment areas for the alleyway improvement plan. We are proposing to redesign these alleyways in their entirety by replacing materials and improving circulation, among many other things.

It is important to note that these paths are often used as the primary entrances to homes, due to vehicular parking spots being in the backside of some homes. Meaning, they sometimes receive higher pedestrian and vehicular traffic than the actual street-fronts. These paths are undeniably narrow, but currently they are kept as two-way streets (making it rather difficult to properly circulate traffic). Although most alleyways are constructed with the idea in mind that they will be used for vehicular traffic or a place to hide garbage bins from street-fronts, they are used by San Miguel residents to navigate on foot through the town. In cities across the U.S., they are being turned into a source of utility instead of just an inconvenient space. Our goal is to provide a better sense of connectivity and walkability for surrounding neighborhoods.

Visible as well, is the lack of proper drainage and connectivity to the current drainage system. There are no curbs or gutters that could potentially help with guiding water back into the water table, and regulating the build-up of hazardous material in the streets.

As they currently stand, there is a visible lack of maintenance and upkeep within said alleyways. The town of San Miguel does not currently have any sort of program to help regulate conditions in the alleyways. Included is a lack of lighting and aesthetically pleasing vegetation.

On a more positive note, there is plenty of opportunity for these alleyways. Due to a lack of any real design, we have the opportunity to really be creative and take into consideration what the people of San Miguel have suggested.
Figure 1 - Existing Conditions

Figure 2 - Existing Conditions

Figure 3 - Existing Conditions
Constraints

We are aware that not all of concepts with which we came up with would be feasible either because of financial restraints, topographic issues, etc. Therefore, we have compiled a list of constraints that may play a large role in the design and development of this project. It is incredibly important to know about any restraining factor before commencing any solid plan design.

- Topographic Constraints
- Financial Feasibility
- Difficulty Circulating within Drainage
- Not enough Water being Conserved
- Property Ownership
- Alley Width
- Maintenance

Opportunities

The purpose of this plan is to provide a more balanced streetscape, which will lead to improved safety, livability and sustainability. We wish to integrate a variety of tactics that will turn these streets into something more than just vehicular roadways, something of a common place for residents.

- Ability to create a connection to the current drainage system/ Conserve Water
- Recreational opportunities
- Green design & Sustainability
- Connectivity and Walkability
- Improved Livability
Community Goals

The San Miguel Community Plan identifies numerous goals of the community that closely relate to the need for the alleyway improvement plan. This plan aims to address each of the following goals and policies in its design to ensure that the plan utilizes the guiding Community Plan. The following goals and polices can be found in the Circulation and Noise, Community Services and Facilities, and Natural and Historic Resources Elements. These elements in the Community Plan aim to improve circulation in the community by incorporating a variety of modes of transportation while also enhancing the drainage system in the San Miguel. A focus of the plan will be to enhance the drainage system by incorporating curb and gutter systems along with bioswales to help prevent any flooding issues. The following goals and policies can be found in the San Miguel Community Plan Update:

Circulation and Noise
GOAL C1: DEVELOP A SAFE, MULTI-MODAL AND EFFICIENT CIRCULATION SYSTEM.
• Policy C1.1: Integrate accessibility of multiple modes of circulation into the street network.

Community Services and Facilities
GOAL CS4: PROVIDE INFRASTRUCTURE TO SUPPORT THE NEEDS OF CURRENT AND FUTURE RESIDENTS.
• Policy CS4.3: Existing and future development should utilize sustainable practices with regard to water use.
• Policy CS4.4: Establish effective drainage methods within the community.

Natural and Historic Resources
Goal NHR3: PROMOTE ENERGY EFFICIENCY AND IMPROVED AIR QUALITY IN SAN MIGUEL.
• Policy NHR 3.4: Encourage efficient use of building materials and promotion of recycling.

Goal NHR4: PROTECT THE RESIDENTS AND PROPERTY OF SAN MIGUEL FROM NATURAL HAZARDS.
• Policy NHR 4.2: Improve drainage and reduce storm water runoff where needed in San Miguel.
  o Implementation Strategy NHR 4.2.A – Expand the curb and gutter network and retrofit current street drainage system.
  o Implementation Strategy NHR 4.2.B – Streetscaping will include bioswales and pervious materials in new developments.
San Miguel Alleyway Redesign

Figure 4 - Existing Conditions

Figure 5 - Location Map
Case Studies

The Chicago Green Alley Handbook
Richard M. Daley, Mayor of Chicago
Cheri Heramb, Acting Commissioner Department of Transportation
CDOT

As stated within our project description, our team has taken direction from previously conducted case studies from around the country. We are aware that these could be used to reinforce the ideas that the team may have. The first of these case studies is a Green Alley Program, implemented by the City of Chicago, Illinois. The project is based on the redevelopment of the current alleyway system within the city. “With approximately 1,900 miles of public alleys, Chicago has one of the most extensive and important pieces of infrastructure of any city in the world. That’s approximately 3,500 acres of paved impermeable surface that provides an opportunity to better manage our resources and improve our environment”. Although the City of San Miguel is a lot smaller, we feel that we can integrate the same principals from the Chicago case study to our own San Miguel project.

Storm-water Management
All alleys, whether they are permeable or not, should be properly graded and pitched to allow water to run to run to the center of the alley and then flow to the street. This prevents the need for additional sewer infrastructure and prevents adjacent properties from flooding.

- Proper pitching and grading to direct water down and to the center
- Runoff is collected by existing drainage system
- Prevents flooding

Permeable Pavement
Permeable pavement has pores or openings that allow water to pass through the surface and percolate through the existing subsoil. Permeable pavement comes in the form of permeable asphalt, permeable concrete, and permeable pavers. In areas where soils do not drain freely, permeable pavement can be used in combination with subsurface drainage systems, like pipe under drains or storm-water infiltration trenches to slow runoff and reduce stress on the combined sewer system.

- Reduces the rate and quantity of storm-water runoff
- Reduces the stress on the sewer system
- Recharges the ground water
- Filters silt, pollutants and debris
High Albedo Pavement
High albedo pavement material is light in color and reflects sunlight away from the surface. With less sunlight absorbed by pavement, the pavement radiates less heat. High albedo pavement therefore reduces the urban heat island effect. This reduces cooling costs, helps the survival of urban vegetation, and improves air quality, which can help reduce the symptoms of some respiratory diseases.

- Reduces the urban heat island effect
- Can be used under a wide variety of site conditions
- Conserves energy by reducing cooling costs
- Improves air quality

Recycled Construction Materials
Recycled construction materials can be incorporated in a variety of ways in green alleys. Recycled concrete aggregate can be used in the concrete mix and as a base beneath surface paving. Also, slag, a by-product of steel production, can be used as a component of the concrete mix, reducing industrial waste. Ground tire rubber can be used in porous asphalt and reclaimed asphalt pavement in nonporous asphalt.

- Reduces waste hauled to land
- Reduces the need to extract virgin natural resources
- Develops new technologies and saves money

Dark Sky Compliant Light Fixtures
Energy efficient, dark sky compliant light fixtures are specially designed to direct light downward, focusing light where it’s needed. These fixtures can also incorporate the latest technologies in energy efficiency while maintaining adequate light levels. New alley fixtures will also use metal halide lamps, which produce white light, instead of the yellow light produced by the existing high-pressure sodium fixtures. This will help people to be able to distinguish color at night.

- Reduces light pollution from site
- Reduces glare and provides better light uniformity
- White light produced by metal halide fixtures has a high “color rendition index” and therefore allows people to perceive color more accurately

(Information taken from The Chicago Green Alley Handbook)

Using techniques much like the ones used in our case studies, our team has developed a comprehensive design plan for the San Miguel Alleyway Redesign.
North Common Alleyways Project
Groundwork Lawrence, Inc.
60 Island Street, Lawrence, MA 01840

The North Common Alleyways Project was designed for Groundwork Lawrence of Massachusetts. The project is highlighted by its use of low impact design (LID). They aimed to transform the run down, polluted alleyways of the community and develop them into “safe, healthy and environmentally sound pedestrian, bike and vehicle passageways.” The report was prepared to serve as a guiding document, much like the one being developed for the community of San Miguel.

The North Common Alleyways Project gained support from various groups and residents, making the program possible. Assistance was provided from a variety of sources, including; MET’s “Water’s Role in Ecosystem Health” program, the Horsley Witten Group, the Lawrence Community Works Organizing Department. Each of these groups held specialties in specific aspects of the project, such as design of the alleyways and holding public workshops. Since 2004, two of the fourteen targeted alleyways have been improved, much assisted by voluntary cleanups and grant money.

“The Orchard Street “Green Alleyway” Project – With a $12,000 grant from CZM, we worked to create a passive green habitat and pedestrian conduit. Our Green Alleyway project was the very first iteration of low-impact development techniques applied in the alleyways; in addition to the use of reclaimed cobblestone for planter beds and terracing to slow the flow of storm water, the project featured the use of native drought-tolerant plants that were attractive to birds, butterflies, and bees. Despite some ongoing maintenance challenges this alleyway is currently wholly cared for by nearby residents who helped design and implement the improvements.”

“The Union & Mechanic LID Alleyway Community Garden Project – With $30,000 in funding from CZM, Groundwork Lawrence retained the landscape design services of David Buchanan, principal at Stillman Restoration & Design, to design volunteer-built raised community garden beds, an LID patio, and a series of rain gardens that help manage storm water runoff from an adjacent site that had been creating erosion further downhill. Still high-functioning as an LID Demonstration Site, Groundwork Lawrence owns the alleyway in trust and oversees a network of eight active community gardeners who cultivate food and flowers there.”
Beyond these two completed alleyways, the plan incorporates a series of design proposals for four other alleyways, identified on a location map. These four alleyways have been selected to serve as demonstration of how they can be upgraded, and the other alleyways can utilize similar techniques even though they are not specifically addressed. The demonstrations include before and after images, utilizing Adobe Photoshop to show display what the completed projects would look like. This particular method will be extremely useful for the San Miguel Alleyway improvement project to show the potential improvements that are proposed. In addition to these images, cross sections of the alleyways are provided to demonstrate the construction materials and hydrology improving methods.

Finally, a design palate is provided to serve as a guide to what materials and plants should be used to accomplish the goals of LID. These specific materials include “alleyway surfaces, storm water infiltration, bio-retention plantings, and lighting elements.” The roads in the plan are made of either recycled bricks or a plastic gravel paver grid. These two surfaces are semi-permeable, allowing water to drain through and prevent flooding and allow recharge. The surfaces can also support daily traffic that would be traveling through the alleyway. Bordering the road on either side, the plan provides options for gravel trenches, soil beds from excavation in redevelopment, and various plantings (native species are listed). Lastly, the plan establishes the desire to utilize rain barrels to allow water capture for irrigation of the gardens and solar lighting which will power itself. These final two elements are sustainable practices and should be encouraged in the San Miguel Alleyway Plan.

The costs of the example projects (500’ long alleyways) were between $35,000 and $70,000. This wide range in cost potentials is due to various donations of materials and services throughout the projects. This project has been successful thus far and is an excellent example for how to address the issues of San Miguel’s alleyways.
Project Components

Dark Sky Compliant Light Fixtures

A dark sky compliant light fixture has a variety of uses, all of which we feel are crucial to creating a more welcoming environment within the San Miguel alleyways, while creating an energy and cost saving system of lighting.

Safety

Outdoor lighting should provide security for both residents and passersby. This can be accomplished by the reduction of glare that dark sky light fixtures can provide. Loss of glare enables those walking by to see further away and therefore are more aware of potential oncoming dangers. Shielded fixtures like those compliant with the code, allow for control of light shine in a direction that is most beneficial as well as a reduction of shadows as well. When a light is too bright and too dispersed throughout, it can sometimes prevent proper vision of obstacles in the dark. The proposed light fixtures will be able to prevent this.

Energy and Cost Saving

Dark Sky Compliant light fixtures will also reduce the use of lighting. This will be accomplished because, light will only be used in the space that is allotted by controlling the angle. Typically, lights that use full shield require a lesser wattage than otherwise. This is because the fixture can be pointed in a specific direction and therefore light is not wasted nor does it need to be used as much.

“A lesser wattage lamp can now be used effectively because you aren’t lighting the sky or your porch roof as well as your steps. Cost savings on your utility bill will pay for the fixture within the year. Switching from a 75-watt incandescent bulb (cost: $0.75) to a 20-watt compact fluorescent (CFL) bulb (cost: $4.00) can save money the first year if it is used only two hours every day. Switching to a CFL that is on for up to 12 hours a day can save over $200.00 over five years... Additional energy savers include putting timers, dimmers, and motion sensors on outdoor lighting. These features allow you to use the light when you need it without constant use “just in case” you need it.”

(International Dark Sky Association)
Figure 6 - Dark Sky Compliant Light Fixture

Figure 7 - Solar Light Fixture
Materials

Block Pavers
Block pavers are constructed primarily from concrete. The blocks interlock with one another, but leave open void space between the pavers to permit water to infiltrate into the underlying gravel reservoir. A typical concrete block pavement installation consists of a soil sub-grade, a gravel base, a layer of bedding sand, and the grid pavers. The void space around the pavers can be filled with either gravel or soil and grass.

Uni-Eco Optiloc
Uni-Eco Optiloc is a permeable concrete paver designed for larger scale projects such as streets and parking lots. In pursuit of the major goal of increasing on-site water drainage efficiency, Uni-Eco Optiloc has been shown to reduce flooding potential. The pavers can be either permeable or impervious, and work by interlocking among each other and leaving small gaps filled with gravel. Beneath the surface pavers is a soil sub-grade, a gravel base, and a layer of bedding sand. The water passes through these sub-layers and undergoes a filtration process.

Figure 8 - Uni-Eco Optiloc Paver
Permeable Pavement

Permeable pavement works much like the semi-permeable pavers. The main difference is that the pavement itself is porous and non-interlocking. This pavement is made through a similar process to conventional concrete, but does not include the fine particles in the mixing process. The removal of these fine particles allow for small openings in the pavement which creates a porous surface for the water to pass through. After the water passes through the porous surface, it is temporarily stored in an underlying crushed rock storage reservoir and slowly released into the underlying soils. A geo-textile filter fabric is placed on the floors and sides of the recharge bed to prevent fine soils from migrating into the bed.

Porous concrete and porous asphalt are suitable for residential streets, plazas and sidewalks, as well as light residential traffic and bike paths. Both require annual inspection to clear debris from the void spaces. There is also a chance of deterioration if road has continuous heavy traffic.

Figure 9 - Porous Asphalt
## Cost of Materials

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<th>San Miguel Alley</th>
<th>Road ID</th>
<th>Length</th>
<th>Width (Ft.)</th>
<th>Cost (3.07/Sq. Ft.)</th>
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Table 1

## Cost for Turfstone

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Table 4
Drainage

Biofiltration trench
A biofiltration trench is a common drainage practice used to remove contaminants in urban runoff. Small treatment trenches can be placed throughout the alleyways. These areas should consist of a grass strip, sand bed, ponding area, a mulch layer, and plants. These layers are designed to slow the water runoff and distribute it into the biofiltration pond. Here, the water will either slowly evaporate or infiltrate the ground soil, preventing contaminants from reaching the groundwater basin.

Gravel Trench
Gravel trenches have been recognized as a cheap, efficient method for groundwater management. They typically consist of a three foot wide trench, and range from one to three feet deep. A perforated pipe is placed in the trench and extends throughout the entire length of it. The pipe helps redirect the water away from an area to prevent any immediate flooding. The gravel serves as a filling material that can withstand heavier vehicular and pedestrian traffic on it.

Rain Barrels
Rain Barrels should be located throughout the alleyways in San Miguel to reduce the impact on the water supply. Rain Barrels are simple, effective means of water storage that can later be used for a variety of purposes. Typically, rain barrels are used by connecting to rooftop gutters and direct rainwater capture. This water is then stored in a large tank and can be used during the dryer months for vegetation and other outdoor uses.
Figure 10 - Rain Barrel

Figure 11 - Gravel Trench
Native Plant Species

California Buttercup

The California Buttercup is a flower species native to the state of California. The flower generally grows to a height ranging between two and three feet. The flower blooms from February through May in most climates.

Foothill Penstemon

The Foothill Penstemon is a species commonly found in California. At maturity, the Foothill Penstemon is generally about two feet tall. The Penstemon species are suitable for environments which receive anywhere between 10-40 inches of annual rainfall, and require no additional watering. They are found in dry environment with lots of sun exposure. The Penstemon are also a cold tolerant species, surviving in temperatures as low as -10 Deg. F.

Mock Orange

The Mock Orange is a drought tolerant, shrub type plant. They come in a variety of sizes, ranging anywhere between 3-15 feet tall. They are commonly used as screen type plants which can serve as alternatives to fences for privacy. They are a pest free species that requires very little maintenance.
Brittle Bush

This plant is a leafy bush with small, yellow flower heads. The brittle bush generally grows to about 1-3 feet high. It is a perennial species that blooms between March and May. This species thrives in low rainfall environments with high sun exposure.

Black Sage

The California Black Sage is a species commonly found in dry coastal ranges near the California coast. The black sage is a drought tolerant species, needing only about 12 inches of rain annually. It is found in high sun exposure environments, but can survive in some shade. It is also a common habitat for hummingbirds and butterflies.
Before and After 1

Figure 17
Before and After 2

Figure 18
Cross Sections

Figure 19
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Appendix A
San Luis Obispo County

San Miguel Alleyway Redesign

Spring Quarter 2011
Jon Emlen & Omar Salazar
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Project Summary Statement

The purpose of the alleyway redesign plan is to produce drainage and design guidelines that will help guide the retrofitting of the current alleyways. This plan will focus on improving the drainage of the existing alley in San Miguel while also maintaining an aesthetic focus which will further enhance the alleyway for the residents. This will be accomplished through the introduction of permeable materials, bioswales, vegetation, and a curb/gutter system. The completed plan can be used by the client as a guiding document for the improvement of the alley.

Understanding

As the consultants for this plan, we understand the need for a better-suited system of drainage that will result in the conservation and reuse of water. The current drainage system within San Miguel is in rather poor condition, something which we have taken note of in our previous class. There has been research conducted in the Community Services and Circulation Elements of the San Miguel Plan Update that shows issues with flooding and proper drainage.

The retrofitting of the alleyways will have multiple benefits, including a reduction of flooding within neighborhoods, enhancement of water circulation, and the increase the rate of water recharge.

Approach

We will take any and all information gathered from our previous project and expand upon what we have already learned. It will be important to note any constraints prior, such as feasibility and environmental issues. We will then continue onto opportunities and identifying potential drainage solutions based on both constraints and opportunities. The next step would be to develop a design with specific measures that will be taken including what types of materials, vegetations, and connectivity within the current drainage.

We will use any information previously gathered in 411, including the final San Miguel Update Plan and the current General Plan for the County of San Luis Obispo. Design tools that we will use can include GIS, Sketch Up, In Design, and Excel.

County Planning department could be of assistance in case we come upon information that needs to be clarified, such as issues dealing with property owners.

The final product will be composed of a report that will identify the issues and provides solutions to said issues. It will include images of the design proposal as well as images gathered on existing conditions and other case studies.
Task Description

Task 1 – Meetings & Coordination
The purpose of the meetings and coordination is to ensure that the project is completed in a manner which the client agrees with. This allows for progress to be tracked and will be completed in 30 minute meetings ever Wednesday. During the 7th week, a presentation shall be prepared for the client as a preliminary presentation with the project approximately 75% completed.

- Products for each meeting are described in the following tasks.
- Product for the week 7 presentation will be a powerpoint presentation discussing all the progress and current status of the plan.

Task 2 – Gather previously obtained data
The purpose of gathering data is to ensure that there is a need for our plan and to be assured that all areas of information are covered. We must be sure that our project complies with the current codes and policies regarding drainage.

- Create a 5-6 page background report containing both previously gathered information and any new found data. Report will also contain visuals from past visits to San Miguel.
- Includes list of opportunities and constraints, which may limit our capacity for designing certain solutions. Will allow us to approach our design in a way that will circumvent the limits we may come across. Identifying opportunities allow us to design the most efficient product that we can provide.
  - 2 hard copies to be made – 1 color copy for J. Knight, 1 color copy for County
  - Electric copy will be sent to J. Knight - Color

Task 3 – Review several case studies
The purpose of reviewing case studies is so that we have examples as to how other communities have dealt with similar issues. We will be looking for examples of feasible drainage solutions.

- The team will provide a 2-3 page write up, comparing the similarities and differences between case studies researched and our own plan proposal. This will include information regarding the steps taken within researched case studies.
  - 2 B/W hard copies and 2 electronic color copies produced
  - J. Knight and the County will each receive 1 b/w hard copy and 1 color electric copy

Task 4– Develop Design Plan
In this section, we will apply all the information gathered in the first three steps to develop a specific plan proposal. This step will incorporate a more creative approach, providing solutions to the issues. This is also where we will provide a focus on aesthetic value.

- Gather images from San Miguel’s alleyway system and case studies
- Review different styles of alleyways design from past projects
- Define the landscape within the alleyways
- Incorporate new materials and ways to improve connectivity/sustainability
  - Will provide a 2-4 page write up (images included) – color electronic versions sent to J. Knight and County
  - 11x17 poster delivered electronically to J. Knight and County – will include proposed images and design layouts

Task 5 – Use various tools to present information this task seems like it’s really part of the previous task.

This step will be our visual representation of the information that we have gathered. Including a site plan done in either GIS or Sketch Up, cross-section completed by hand drawing or possibly Sketch Up, and photographs of example alleyways and drainage systems.

- GIS will be used to determine the most beneficial way to connect the proposed alleyways to the current drainage system.
- 1 Color 11x17 poster (1 printed color copy will be provided)
  - Cross sections and other design concepts
  - Sketch-Up model of alleyway with proposed layout + design
  - Brief descriptions of actions taken
  - Cross sections of current alleyways as well as of our proposed design improvements
    - 11x17 poster will be delivered electronically
- PowerPoint Presentation
  - To be presented on final day

Task 6 – Finalize and place into report format

- This will be an organized final report and poster that can be used by the clients.
  - 32x24 Color Poster
  - 2 color copies of 25 page Report in 8.5x11
  - PowerPoint presentation – electronic copy to be sent to County and J. Knight
Schedule:

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<th>Task 1: Meetings and Coordination</th>
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<td>Task 3: Review relevant case studies</td>
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Appendix B
CONSULTANT PROPOSAL AND SCOPE OF SERVICES AGREEMENT
For (San Luis Obispo County – e.g.: City of Santa Maria, County of San Luis Obispo, or Private Developer)

(Jon Emlen & Omar Salazar), hereinafter referred to as CONSULTANT, agrees to provide consultant services to the (San Luis Obispo County), hereinafter referred to as CLIENT, as further described below. This proposal is made as partial fulfillment of the requirements of City and Regional Planning 463 – Senior Project, a course conducted under the auspices of the Department of City and Regional Planning, College of Architecture and Environmental Design, California Polytechnic State University, San Luis Obispo, California.

1. TERM. The term of the proposed SCOPE OF SERVICES AGREEMENT (hereafter referred to as SCOPE) shall be from the date of CLIENT approval of this proposal until acceptance or completion of said services but no later than June 9, 2011. All work products shall be submitted to CLIENT representative no later than 5:00 p.m., Thursday, June 9, 2011. Materials received after that time will not be accepted.

2. CLIENT REQUIREMENTS. This SCOPE is based on and is intended to fulfill the CLIENT requirements, as described in the CRP 463 Course Syllabus, Spring 2011. Said document is hereby incorporated into this proposal by reference.

3. FEE SCHEDULE. As this SCOPE is intended to meet academic requirements, no actual fees will be paid or received. However, a preliminary budget has been prepared which identifies hours by task or work product (based on $65/hour). Reimbursable expenses (i.e., travel costs, copies, phone, etc.) are estimated at 10% of the labor costs. Overall fee to complete the services specified in this agreement is estimated at ($13,390). A more detailed fee estimate will be prepared and submitted at week #2.

4. CLIENT CONSIDERATION. CLIENT representative, Scott Bruce/John Knight, agrees to assist CONSULTANT by providing base information, technical support and guidance during the course of this project; pursuant to his role as instructor for said course, to the extent feasible and reasonable.

5. CONSULTANT'S OBLIGATIONS. For the consideration noted above, and to fulfill the requirements of CRP 463, CONSULTANT proposes and agrees to: A) provide consultant services as described more particularly below, B) to meet University and Department of City and Regional Planning requirements regarding senior project completion, and C) to complete all required work in a timely, thorough and professional manner, to the approval of the CLIENT representative.

6. AMENDMENTS. Amendments to this proposal, once accepted, are strongly discouraged. Any amendment, modification or variation from this proposal shall require prior written approval by the CLIENT representative and where necessary, by the Department of City and Regional Planning, and then only for compelling reasons that are beyond control of CONSULTANT, or as determined necessary by the CLIENT representative.

7. SCOPE OF SERVICES. CONSULTANT hereby proposes and agrees to provide the following services:

   A. Proposed Project
The purpose of the alleyway redesign plan is to produce drainage and design guidelines that will help guide the retrofitting of the current alleyways. This plan will focus on improving the drainage of the existing alley in San Miguel while also maintaining an aesthetic focus, which will further enhance the alleyway for the residents. This will be accomplished through the introduction of permeable materials, bioswales, vegetation, and a curb/gutter system. The completed plan can be used by the client as a guiding document for the improvement of the alley.

B. **Key Tasks & Deliverables:** The following key tasks will be completed:

**Task 1 – Meetings & Coordination**

- Products for each meeting are described in the following tasks.
- Product for the week 7 presentation will be a powerpoint presentation discussing all the progress and current status of the plan.

**Task 2 – Gather previously obtained data**

- Create a 3-4 page background report containing both previously gathered information and any new found data. Report will also contain visuals from past visits to San Miguel.
- Includes list of opportunities and constraints, which may limit our capacity for designing certain solutions. Will allow us to approach our design in a way that will circumvent the limits we may come across. Identifying opportunities allow us to design the most efficient product that we can provide.
  - 2 hard copies to be made – 1 color copy for J. Knight, 1 color copy for County
  - Electric copy will be sent to J. Knight - Color

**Task 3 – Review several case studies**

- The team will provide a 2-3 page write up, comparing the similarities and differences between case studies researched and our own plan proposal. This will include information regarding the steps taken within researched case studies.
  - 2 B/W hard copies and 2 electronic color copies produced
  - J. Knight and the County will each receive 1 b/w hard copy and 1 color electric copy

**Task 4 – Develop Design Plan**

- Gather images from San Miguel’s alleyway system and case studies
- Review different styles of alleyways design from past projects
- Define the landscape within the alleyways
- Incorporate new materials and ways to improve connectivity/sustainability
Will provide a 2-4 page write up (images included) – color electronic versions sent to J. Knight and County
11x17 poster delivered electronically to J. Knight and County – will include proposed images and design layouts

Task 5 – Use various tools to present information this task seems like it’s really part of the previous task.
• GIS will be used to determine the most beneficial way to connect the proposed alleyways to the current drainage system.
• 1 Color 11x17 poster (1 printed color copy will be provided)
  o Cross sections and other design concepts
  o Sketch-Up model of alleyway with proposed layout + design
  o Brief descriptions of actions taken
  o Cross sections of current alleyways as well as of our proposed design improvements
    • 11x17 poster will be delivered electronically
• PowerPoint Presentation
  • To be presented on final day

Task 6 – Finalize and place into report format
• This will be an organized final report and poster that can be used by the clients.
  o 32x24 Color Poster
  o 2 color copies of 25 page Report in 8.5x11
  o PowerPoint presentation – electronic copy to be sent to County and J. Knight

C. Methods and Resources: The primary methods and resources that will be used include:
We will take any and all information gathered from our previous project and expand upon what we have already learned. It will be important to note any constraints prior, such as feasibility and environmental issues. We will then continue onto opportunities and identifying potential drainage solutions based on both constraints and opportunities. The next step would be to develop a design with specific measures that will be taken including what types of materials, vegetation, and connectivity within the current drainage.

We will use any information previously gathered in 411, including the final San Miguel Update Plan and the current General Plan for the County of San Luis Obispo. Design tools that we will use can include GIS, Sketch Up, In Design, and Excel.

County Planning department could be of assistance in case we come upon information that needs to be clarified, such as issues dealing with property owners.
The final product will be composed of a report that will identify the issues and provides solutions to said issues. It will include images of the design proposal as well as images gathered on existing conditions and other case studies.

8. **Budget:** The preliminary budget is estimated at:

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A. **Schedule of Services:** The 10 week schedule is as follows:

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9. **CONSULTANT TEAM.** CONSULTANT’s team shall consist of the following member(s): Jon Emlen & Omar Salazar. CONSULTANT hereby states and agrees that team members will be equally and jointly responsible for completion of all work products, and that final work projects will clearly and accurately identify individual team member’s contribution to the total work product to enable the Instructor to assign final class grades.

10. **COMPLETE AGREEMENT.** This written agreement, including information incorporated specifically by reference, shall constitute the complete agreement between CONSULTANT and CLIENT. CONSULTANT understands that failure to meet the requirements and obligations under this agreement will result in failure 11. to pass CRP 461/462 – Senior Project.
12. AGREEMENT APPROVED:

CONSULTANT:

__________________________________________________________
(signature of team member 1) date

__________________________________________________________
(signature of team member 2, if applies) date

CLIENT REPRESENTATIVE (Instructor):

__________________________________________________________
Scott Bruce/John Knight date

CLIENT REPRESENTATIVE (City of Santa Maria/County of San Luis Obispo if applicable):

__________________________________________________________
(print name) date
Appendix C
Agenda for 4-27-11

- Discuss previous meeting and summarize deliverables to be presented.
- Review progress in relation to schedule
- Talk about tasks that have been completed
- Talk about current works (cross sections, posters, and photoshop images)
- Talk about goals for next week including starting the presentation for week 7 and posters
- Conclude with any other comments and questions
Agenda for 5-25-11

- Review last meetings minutes
- Review progress in relation to schedule
- Discuss works in progress
- Questions about upcoming presentation
- Talk about goals for the upcoming week
- Conclude with questions and show product visuals
Appendix D
Meeting Minutes

Date: April 13\textsuperscript{th} 2011  
Time: 7:40pm – 8:00pm  
Location: Bd. 021 Rm 0120B  
Head of Meeting: John R. Knight

Attendees Present:  
- Omar Salazar  
- Jon Emlen

Summary of Meeting

- Proposal Contract - still needs to be completed with Items inserted  
- Completed portion of Background information with Constraints and Opportunities  
- Find smaller more residential communities that have an alleyway redevelopment  
- Time to develop a table of contents and who will complete what part of report  
- Take case study of Seattle’s underground gravel systems
Meeting Minutes

Date: April 20th 2011
Time: 7:40pm – 8:00pm
Location: Bd. 021 Rm 0120B
Head of Meeting: John R. Knight

Attendees Present:
- Omar Salazar
- Jon Emlen

Summary of Meeting

· Began with discussion of project’s timeline
· Went on to present two case studies.
  o Omar presented a case study from Chicago on
  o Jon presented a case study from Massachusetts
· We handed in our contract agreement
· We then had a brief discussion on what needs to be done by the week 7 presentation
· Concluded the meeting with a brief discussion on organization of final product (the report).
Meeting Minutes

Date: April 27th 2011
Time: 7:40pm – 8:00pm
Location: Bd. 021 Rm 0120B
Head of Meeting: John R. Knight

Attendees Present:
- Omar Salazar
- Jon Emlen

Summary of Meeting

· The meeting began with a discussion about the agenda for the phone conference:
  o Begin meeting with summary of last meeting
  o Followed the summary with discussion of the current works in progress
  o The third topic was about products that shall be brought for next meeting
  o Conclude the meeting with a discussion on week 7 presentation
· Talked about previous meeting and deliverables
  o We have completed our existing conditions chapter, obtained relevant background information, performed a site visit and took pictures, and have began our materials poster.
· Talked about tasks that have been completed
  o This portion was talked about in the previous portion of the agenda.
  o We went on to discuss our goals for next week’s meeting which includes: Materials poster, Photoshop images to display what the completed alleyway could potentially look like, two cross sections of the alleyways, and Sketchup model with images and a flyby for the final presentation.
· Talked about current work
  o We are currently working on each of the products listed above. Thus far, we have completed a materials poster and have begun work on the other products.
· Talked about next week
  o Aim to have a rough Sketchup model with images from it for the week 7 presentation.
  o Photoshop of existing alley with potential design
  o Materials poster
  o Cross sections (rough)
· Concluded with week 7 topic
  o Talked about options for the presentation
  o What we should have done for it
  o Would like to see some deliverable next week
Meeting Minutes

Date: May 18th 2011
Time: 7:40pm – 8:00pm
Location: Bd. 021 Rm 0120B
Head of Meeting: John R. Knight

Attendees Present:
- Omar Salazar
- Jon Emlen

Summary of Meeting

• Review of Week 7 presentation
  o Talk about critique
  o John explained a summary of grade distribution
• Talk about work in progress
  o Other material that should be completed by finals week
  o Preparation for week 10 presentation
• Finalization of San Miguel Alleyway Redesign Report
  o Included information
  o Information still needed
Meeting Minutes

Date: May 25th 2011
Time: 7:40pm – 8:00pm
Location: Bd. 021 Rm 0120B
Head of Meeting: John R. Knight

Attendees Present:
- Omar Salazar
- Jon Emlen

Summary of Meeting

- Talked about last week’s meeting
  - Discussed progress on the cross section images, progress on final report, and other design related issues.
- We then moved on to discuss our work completion to show that we are on schedule with all of our tasks. At this point we are on task 5 (design graphics for proposal) and are compiling our information for the final powerpoint.
- Final report format and requirements were discussed to ensure final product will meet all requirements.
- Questions relating to upcoming presentation
- Attempted to show visuals but computer connection did not work
Appendix
PURPOSE

- Our team’s plan is to redesign and retrofit current alleyway system
- Introduction of new and sustainable materials
- Development of a more efficient drainage system
- Addition of native plant species and permeable pavement surfaces

APPROACH

- Gathered information through previous classes and county documents
- Case studies were used as templates for our plan design and strategy
- Our product will consist of a report, several posters, and other images
EXISTING CONDITIONS

- Two main alleyways (run parallel to each other)
- Western Alley: .7 miles
- Eastern Alley: .64 miles

EXISTING CONDITIONS

- Lack of vegetation and lighting
- No street direction for cars or pedestrians
- Cracked and worn pavement
- Very little shading
- Potential to flood
- Main garbage collection area
- Primary vehicular access to some houses

OPPORTUNITIES

- Connection to current drainage system
- Green Design & Sustainability
- Connectivity & Walkability
- Improved Livability

CONSTRAINTS

- Financial feasibility
- Potential difficulty circulating within drainage
- Not enough water being conserved
- Property ownership
- Alleyway width
### MATERIALS

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**BLOCK PAVER**

- Constructed primarily from concrete
- Blocks interlock with one another but leave open, void space between the pavers to permit water to infiltrate into the underlying gravel reservoir
- A typical concrete block pavement installation consists of a soil subgrade, a gravel base, a layer of bedding sand, and the grid pavers
- The void space around the pavers can be filled with either gravel or soil and grass

**BLOCK PAVER**

- Turfstone
  - Suitable for vehicular access and driveways
  - Replacement gravel may be necessary
  - Paver cost between 2.25/ft² and 2.70/ft²
- UNI Eco-Stone
  - Suitable for residential access roads, driveways and parking lots
  - Periodic maintenance to clean debris from drainage
  - Paver costs begin at 3.07/ft²

**POROUS PAVEMENT**

- Very similar to their conventional counterparts, but they are mixed without the fine particles to allow for the passage of storm-water through the surface
- After the water passes through the porous surface, it is temporarily stored in an underlying crushed rock storage reservoir and slowly released into the underlying soils
- A geotextile filter fabric is placed on the floors and sides of the recharge bed to prevent fine soils from migrating into the bed
POROUS PAVEMENT

• Porous Concrete
  • Suitable for residential streets, plazas and sidewalks
  • Annual inspection for material deterioration needed
  • Materials cost from 2.00/ft^2 to 4.00/ft^2

• Porous Asphalt
  • Suitable for light residential traffic, sidewalks and bike paths
  • Annual inspection for material deterioration needed
  • Material cost from 0.50/ft^2 to 1.00/ft^2

VEGETATION

• Native Species
  • Drought Tolerant
  • Low Maintenance

CASE STUDY – CHICAGO GREEN ALLEY

• Implemented by the City of Chicago, Illinois
• Approximately 3,500 acres of paved impermeable surface
• 1,900 miles of public alleys - Chicago has one of the most extensive and important pieces of infrastructure of any city in the world

ELEMENTS

• Permeable Pavement
  • Reduces the rate and quantity of storm-water runoff
  • Reduces the stress on the sewer system
  • Recharges the ground water
  • Filters silt, pollutants and debris

• Storm-water Management
  • Proper pitching and grading to direct water down and to the center
  • Runoff is collected by existing drainage system
  • Prevents flooding
ELEMENTS

- Recycled Construction Materials
  - Reduces waste hauled to land
  - Reduces the need to extract new natural resources
  - Develops new technologies and saves money

- High Albedo Pavement
  - Reduces the urban heat island effect
  - Can be used under a wide variety of site conditions
  - Conserves energy by reducing cooling costs
  - Improves air quality

ELEMENTS

- Dark Sky Compliant Light Fixtures
  - Reduces light pollution from site
  - Reduces glare and provides better light uniformity
  - White light produced by metal halide fixtures has a high “color rendition index” and therefore allows people to perceive color more accurately

BEFORE AND AFTER

BEFORE AND AFTER
THANK YOU!
Appendix F
The Chicago Green Alley Handbook
An Action Guide to Create a Greener, Environmentally Sustainable Chicago

Printed on recycled paper, 30% post-consumer waste

Richard M. Daley, Mayor
City of Chicago

Cheri Heramb, Acting Commissioner
Department of Transportation
Welcome to the Green Alley Program

OFFICE OF THE MAYOR
CITY OF CHICAGO

RICHARD M. DALEY
MAYOR

GREETINGS

Thank you for your interest in the Green Alley Handbook.

With more miles of alleyways than any other city in the world, Chicago has a unique network of infrastructure integrated into the very fabric of our city. Recognizing this advantage, we have established new alley designs that help conserve our resources and improve our environment.

Green Alley designs showcase innovative, environmental technologies to help manage stormwater, reduce heat in urban areas, promote recycling and conserve energy. The Green Alley Handbook will introduce you to each of these benefits while highlighting ideas that are applicable in varied parts of the city.

The Green Alley program is just one of the ways that the City of Chicago is working to protect the environment and improve the quality of life in our communities. I encourage you to investigate this handbook and take simple steps to benefit the environment on your property. Working together, we can conserve Chicago and build a sustainable city for generations to come.

Sincerely,

Mayor
The Green Alley Program is a new approach to CDOT’s existing alley program. Alleys provide a great benefit for the City, but like all infrastructure, they also require maintenance and periodic reconstruction. Flooding is often an issue in alleys because many alleys in the City were built without a connection to the City’s combined sewer and stormwater system.

While one solution to this problem is to install expensive connections to the City sewer system, the Green Alley Program also looks at other more sustainable solutions. In particular, where soil conditions are appropriate, water is allowed to infiltrate into the soils through permeable pavement or infiltration basins, instead of being directed into the sewer system or onto adjacent property. This not only solves a persistent problem, but it also provides an environmental benefit by cleaning and recharging the ground water. Furthermore, by not sending additional water to the combined sewer system a green alley can help alleviate basement and other flooding issues.

You, the adjacent property owner, can make a difference by instituting other best management practices (BMPs) on your property. These can range from recycling to installing your own rain garden, which can help alleviate flooding even further.

This handbook will explain why the city is interested in sustainable alley design, illustrate the BMP techniques the City will use in green alley design, and provide sample layouts of how these elements have been combined in pilot applications. In addition, information and resources are provided for property owners interested in implementing their own environmental BMPs.
Why is the City Interested in Green Alleys?

With approximately 1,900 miles of public alleys, Chicago has one of the most extensive and important pieces of infrastructure of any city in the world. That’s approximately 3,500 acres of paved impermeable surface that provides an opportunity to better manage our resources and improve our environment.

**Stormwater Management**
Imagine if all of the alleys in Chicago were green alleys. Up to 80% of the rainwater falling on these surfaces throughout the year could pass through permeable paving back into the earth, thereby reducing localized flooding, recharging groundwater and saving taxpayer money that would otherwise be spent treating stormwater.

**Heat Reduction**
Imagine if all the alleys had a light, reflective surface (high albedo) that reflected heat energy, staying cool on hot days and thereby reducing the “urban heat island effect”, a condition where dense urban areas become several degrees warmer due to the density of buildings and amount of heat-absorbing paved areas.

**Material Recycling**
Imagine if all of the alleys were constructed with recycled materials, thereby reducing the amount of construction and industrial waste hauled to landfills and reducing the burden on our natural resources.

**Energy Conservation and Glare Reduction**
Imagine if the thousands of light fixtures that provide a safe environment in the alleys were energy efficient and reduced glare and light pollution to the point where you could see the stars at night.

All of these benefits can be accomplished within the alley’s right of way! In this document you can learn what you can do to increase the benefits of the green alley by implementing your own sustainable practices on your property.
The City is committed to creating a greener, more sustainable environment by using best management practices in alley improvements and construction. Some or all of the following techniques will be used when designing green alleys.
Technique 1:
Alley Drainage Improvement through Proper Alley Pitching and Grading

All alleys, whether they are permeable or not, should be properly graded and pitched to allow water to run to the center of the alley and then flow to the street. This prevents the need for additional sewer infrastructure and prevents adjacent properties from flooding.
Permeable pavement has pores or openings that allow water to pass through the surface and percolate through the existing subsoil. Permeable pavement comes in the form of permeable asphalt, permeable concrete, and permeable pavers. In areas where soils do not drain freely, permeable pavement can be used in combination with subsurface drainage systems, like pipe underdrains or stormwater infiltration trenches to slow runoff and reduce stress on the combined sewer system.

**Potential Benefits**
- Reduces the rate and quantity of stormwater runoff
- Reduces stress on the sewer system
- Recharges ground water
- Filters silt, pollutants and debris

High albedo pavement material is light in color and reflects sunlight away from the surface. With less sunlight absorbed by pavement, less heat is radiated by the pavement. High albedo pavement therefore reduces the urban heat island effect. This reduces cooling costs, helps the survival of urban vegetation, and improves air quality, which can help reduce the symptoms of some respiratory diseases.

**Potential Benefits**
- Reduces the urban heat island effect
- Can be used under a wide variety of site conditions
- Conserves energy by reducing cooling costs
- Improves air quality
Technique 4: Recycled Construction Materials

Pavement produced using slag, recycled concrete and/or ground tire rubber

Subbase containing recycled concrete

Recycled construction materials can be incorporated in a variety of ways in green alleys. Recycled concrete aggregate can be used in the concrete mix and as a base beneath surface paving. Also, slag, a by-product of steel production, can be used as a component of the concrete mix, reducing industrial waste. Ground tire rubber can be used in porous asphalt and reclaimed asphalt pavement in non-porous asphalt.

Potential Benefits
- Reduces waste hauled to landfills
- Reduces the need to extract virgin natural resources
- Develops new technologies and saves money

Technique 5: Dark Sky Compliant Light Fixtures

Conventional alley light fixture

Dark sky compliant alley light fixture

Energy efficient, dark sky compliant light fixtures are specially designed to direct light downward, focusing light where it’s needed. These fixtures can also incorporate the latest technologies in energy efficiency while maintaining adequate light levels. New alley fixtures will also use metal halide lamps, which produce white light, instead of the yellow light produced by the existing high-pressure sodium fixtures. This will help people to be able to distinguish color at night.

Potential Benefits
- Reduces light pollution from site
- Reduces glare and provides better light uniformity
- White light produced by metal halide fixtures has a high “color rendition index” and therefore allows people to perceive color more accurately
The following four pilot approaches illustrate how different combinations of green alley techniques can be used to suit a variety of site conditions.
Green Alley Pilot Approach #1: Green Pavement Materials with Conventional Drainage

1. Properly graded and pitched alley surface directing stormwater towards the center of the alley, into adjacent streets, and finally into the existing sewer system.
2. High albedo concrete paving with recycled aggregate and slag.

Green Alley Pilot Approach #2: Full Alley Infiltration Using Permeable Pavement

1. Permeable pavement material (permeable asphalt, permeable concrete, or permeable pavers).
2. High albedo concrete paving with recycled aggregate and slag.
3. Optional inlet structure with pipe under drain.
4. Energy efficient dark sky compliant light fixture.
Green Alley Pilot Approach #3:
Center Alley Infiltration Using Permeable Pavement

1. Permeable pavement material (permeable asphalt, permeable concrete, or permeable pavers)
2. High albedo concrete paving with recycled aggregate and slag
3. Optional inlet structure with pipe under drain
4. Energy efficient dark sky compliant light fixture

Green Alley Pilot Approach #4:
Green Pavement Materials with Subsoil Filtration System

1. Inlet structure with perforated sides
2. Stormwater infiltration trench below for additional storage capacity
3. Recycled concrete base material
4. Energy efficient dark sky compliant light fixture
Green Alley Construction

What to Expect During Alley Construction

- The Chicago Department of Transportation will notify you in advance of an alley improvement project.
- Access to garages and driveways will be temporarily restricted.
- Garbage pickup will be temporarily relocated.

How Do I Identify a Green Alley?

You will be able to easily identify a green alley because this image will be stamped into the driveway aprons at either end. Furthermore, if a catch basin is open to the subsoils and not connected to the storm sewer system it will be labeled “infiltration: no dumping - only rain down the drain” for easy identification.

Green Alley Dos and Don’ts

Do:
- Keep your green alley clean of dirt and debris
- Install rain gardens and bioswales to absorb and filter water before reaching the alley
- Implement other sustainable BMPs on your own property to increase the performance of the green alley
- Shovel or plow alley as required, salt can be used in moderation

Don’t:
- Dump chemicals or toxic materials on or near the green alley
- Spread sand or dirt on or near permeable paving in the green alley
- Remove stone from between permeable pavers
- Seal permeable asphalt or concrete
Property owners can play a significant role in helping to create a greener, more sustainable Chicago, and further enhance the performance of their green alley, by implementing the variety of best management practices illustrated on the following pages.
Recycling products like glass, plastic, and metal containers through the Chicago Blue Bag Recycling Program or through your local collection center, is a simple and inexpensive way to reduce waste hauled to landfills, while saving energy and natural resources.

**Potential Benefits**
- Reduces waste hauled to landfills
- Reduces the need to extract virgin natural resources
- Requires little cost to the homeowner

Kitchen scraps, yard waste and even some paper products can be placed into an inexpensive composting bin to decompose. With very little maintenance, the waste will soon break down into a rich, organic material that can be mixed directly into garden soil or used as fertilizer for trees and shrubbery. Not only does composting save space in our garbage trucks and landfills, but its product also provides a nutrient boost to poor urban soils.

**Potential Benefits**
- Reduces waste hauled to landfills
- Reduces the need to extract virgin natural resources
- Requires little or no cost to the property owner
- Improves soil structure
- Provides natural fertilizer to plants
Shade trees can play a large part in reducing the urban heat island effect and improving air quality. Planting a tree near the alley shades the alley and thereby reduces the amount of thermal energy emitted by the pavement.

**Potential Benefits**
- Reduces the urban heat island effect
- Provides habitat for birds and wildlife
- Reduces energy costs for heating and cooling if placed appropriately
- Improves air quality

Plants and trees native to northern Illinois are uniquely adapted to the local weather, water and soil conditions. Choosing these species for your landscaping can reduce the amount of watering, fertilizing and maintenance required on your property.

**Potential Benefits**
- Reduces the urban heat island effect
- Reduces energy costs for heating and cooling if placed appropriately
- Provides habitat for birds and wildlife
- Requires little or no irrigation once established
- Requires little or no fertilizer, pesticides or herbicides
- Low maintenance once established
A rain garden is a landscape feature that is planted with native perennial plants used to slow down the stormwater runoff from impervious surfaces (such as roofs, sidewalks and parking lots) and allow it to infiltrate back into the soil.

**Potential Benefits**
- Provides attractive garden area to receive discharge from downspouts
- Filters silt, pollutants and debris
- Reduces rate and quantity of stormwater entering the sewer system
- Recharges ground water
- Provides habitat for birds and wildlife
- Can help reduce localized flooding

<table>
<thead>
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<th>Technique 5</th>
<th>Rain Garden</th>
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<td>$3-$6 per square foot</td>
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<th>Technique 6</th>
<th>Rain Barrel / Cistern</th>
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<td>$10-$5,000</td>
<td>✔️ Residential ✔️ Commercial ✔️ Industrial</td>
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A rain barrel or cistern is a container used to collect and store rainwater from a building roof for various uses including irrigating plants.

**Potential Benefits**
- Recycles rain water
- Conserves water
- Reduces the quantity of stormwater runoff
- Can provide water for plant irrigation
Technique 7
Permeable Pavement

| $3-$15 per square foot | Residential | Commercial | Industrial |

Permeable paving allows rainwater to penetrate through the surface and stone base material and infiltrate into the soil below. It is ideal for small areas of outdoor household paving such as patios, driveways and parking slabs.

Potential Benefits
- Reduces the rate and quantity of stormwater runoff
- Recharges ground water
- Filters silt, pollutants and debris
- Reduces the urban heat island effect
- Provides paving options for site specific applications

Technique 8
Green Roof

| $10-$30 per square foot | Residential | Commercial | Industrial |

A “green roof” is a roof that is partially or completely covered with plants. A green roof system includes waterproofing, a drainage system, soil and plants. Green roofs can be installed on most flat roofs and are well-suited to garages, provided that they are constructed to accommodate the structural load.

Potential Benefits
- Reduces the rate and quantity of stormwater runoff
- Reduces the urban heat island effect
- Reduces energy costs for heating and cooling
- Increases longevity of roofing materials
- Provides habitat for birds and wildlife
- Provides opportunity for accessible garden space
- Increases rent or property value of units with views or access
Energy efficient/dark sky light fixtures are designed to direct lamp light downward and outward where it is useful rather than upward where it wastes energy and contributes to glare and light pollution.

**Potential Benefits**
- Reduces energy costs
- Reduces light pollution from site
- Reduces glare and provides better light uniformity

Naturalized detention is an area used to temporarily store stormwater on site and slowly release it at a controlled rate. These areas are intended to look and function as native wetlands and include native plants growing both above and below the normal water level.

**Potential Benefits**
- Reduces the rate and quantity of stormwater runoff
- Filters silt, pollutants and debris
- Reduces erosion of pond edges
- Provides an attractive amenity
- Provides habitat for birds and wildlife
The Chicago Green Alley Handbook
An Action Guide to Create a Greener, Environmentally Sustainable Chicago

Printed on recycled paper, 30% post-consumer waste

Richard M. Daley, Mayor
City of Chicago

Cheri Heramb, Acting Commissioner
Department of Transportation
Technique 11  |  Bioswales and Vegetated Swales
---|---
$8-$30 per linear foot | Residential ✔️ Commercial ✔️ Industrial ✔️

A bioswale or a vegetated swale is a shallow trench or shoulder landscape with native plants used to slow the speed of surface run-off and allow stormwater to infiltrate back into the ground instead of flowing directly into storm sewers.

**Potential Benefits**
- Filters silt, pollutants and debris
- Reduces rate and quantity of stormwater entering sewer system
- Recharges ground water
- Reduces storm sewer piping and structures
- Can reduce detention requirements
- Provides opportunity for wildlife habitat
Example Residential Applications

- Green roof
- Disconnected downspout with rain barrel
- Compost bin
- Rain garden
- Permeable paving
- Dark sky light
- Shade tree planted near alley
- Native plants
- Patio made with permeable paving
- Green alley with permeable paving
- Disconnected downspout with rain barrel
Example Commercial and Industrial Applications
Frequently Asked Questions

Q: What do I do if my green alley does not appear to be draining?
A: Contact your Alderman’s office or call 3-1-1 to report any problem with your alley.

Q: Will my green alley overflow during large storms?
A: Each green alley is designed to allow almost all rainfall to infiltrate into the subsoil. In the case of an uncommonly large rain event, each alley is designed so that water will run into the adjacent streets and into the storm sewer.

Q: What will happen when it snows?
A: If needed, a green alley can be plowed like any other street. Rock salt can be used in the winter, however, fine particles such as sand, gravel or kitty litter can clog the openings in pervious pavement surfaces and should not be used.

Q: Will ice be a problem in the winter?
A: In most cases, icing will be reduced because melting snow can permeate through the alley pavement.

Q: Will water still infiltrate in freezing temperatures?
A: The voids in the permeable paving and sub-base will allow water to infiltrate even when the ground is frozen. In general, a permeable alley is “warmer” than a traditional alley in winter because it allows air to circulate to the earth below, which is a constant 55 degrees Fahrenheit.

Q: Will access to my alley be restricted during construction?
A: Yes, access will be restricted during construction. CDOT will work with your Alderman’s office to ensure that all residents are notified in advance and parking and garbage needs are coordinated.

Q: Will my alley be darker with dark sky compliant full cutoff light fixtures?
A: No, the same number of alley lights and the same footcandles (brightness) will be provided, but the new fixtures will direct light downward and outward instead of upward. In addition, the light will be white (metal halide) instead of yellow (high pressure sodium). White light has a high “color rendition index,” which means that it allows people to perceive colors more accurately.

Glossary of Terms

Best Management Practices (BMPs)
Design solutions used to reduce adverse effects of development such as pollution, the “urban heat island effect” and stormwater runoff.

Dark Sky Light Fixture
A light fixture designed to allow no light trespass beyond 90 degrees from the center line of the fixture.

Green Alley
An alley designed and constructed incorporating best management practices of environmentally sustainable design.

Green Roof
A planted roof system composed of waterproofing, a drainage system, planting soil and plants.

High Albedo Pavement
Pavement with a high level of light reflectance used to reduce the amount of thermal energy released from pavement materials contributing to the “urban heat island effect”.

Permeable Pavement
Pavement that allows water to infiltrate into the subsoil. Materials can include concrete permeable pavers, concrete and asphalt.

Slag
A by-product of steel production that can be used as a component of concrete mix to reduce the amount of industrial waste that goes to the landfill and lighten the color of concrete.

Sustainability
The concept of meeting today’s needs without compromising resources for future generations.

Urban Heat Island Effect
The phenomenon of higher temperatures in dense urban areas resulting from thermal energy given off by pavement and buildings.
Publications

Permeable Pavers
Paver Search.
www.paversearch.com/permeable-pavers-menu.htm

High Albedo Pavement
Lawrence Berkeley National Laboratory. Cool Pavements Lower Temperatures
http://eetd.lbl.gov/HeatIsland/

Dark Sky Lighting
International Dark Sky Association
www.darksky.org

Green Roofs
www.cityofchicago.org/Environment

City of Chicago Rooftop Garden
www.cityofchicago.org/Environment

Bioswales
United States Environmental Protection Agency. Grassed Swales.
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

Rain Gardens
Raingardens.org
www.raingardens.org

Naturalized Detention
United States Environmental Protection Agency. Post-Construction Storm Water Management in New Development & Redevelopment: Wetponds
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

Native Landscaping
Wild Ones. Native Plants, Natural Landscapes
www.for-wild.org

Rain Barrels
Rain Barrel Guide. Harvesting Rainwater with Rain Barrels, an Old Idea with a New Following
www.rainbarrelguide.com

Composting
Compost Guide. Why Make Compost?
www.compostguide.com

How To Compost
www.howtocompost.org
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Appendix G
North Common Alleyways Project

Using low impact development to improve Lawrence alleyways

June 2008
This project is funded by the Massachusetts Environmental Trust.

This document was produced by the Horsley Witten Group, Inc. for Groundwork Lawrence.

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Groundwork Lawrence is pleased to present the **North Common Alleyways Project: Using Low Impact Development to Improve Lawrence Alleyways.** This project highlights the potential for the reclamation of Lawrence’s alleyways utilizing low impact development (LID) methods to create safe, healthy and environmentally sound pedestrian, bike and vehicle passageways. We would like to thank the Massachusetts Environmental Trust for its financial support and our partners the Horsley Whitten Group and Lawrence CommunityWorks for making this project possible. Most importantly, we would like to thank the residents, business owners, and city employees that provided their input and feedback ensuring the identified solutions meet the neighborhood’s interests and needs. This report represents a culmination of our efforts to understand the conditions of the North Common Alleyways, to reach out to the surrounding community members affected by the alleyways’ current conditions, and to develop a plan to guide future improvements of the alleyways.

**North Common Alleyway Project - an Introduction**

Created in spring of 2008, with funding through MET’s “Water’s Role in Ecosystem Health” program, the North Common Alleyways Project allowed Groundwork Lawrence to explore redevelopment possibilities for the North Common Neighborhood Alleyways through the lens of low-impact development (LID), highlight potential redevelopment scenarios for the alleyways using a variety of LID techniques, and educate the public (residents, business owners, City officials, developers) about these possibilities with the guidance of a qualified LID/engineering firm. By holding a series of focus groups with interested residents living adjacent to the alleyways, Groundwork Lawrence confirmed the host of current alleyway uses, as well as overall concerns about their current condition. Armed with that information, we hired engineers from the Horsley Witten Group (HW) to create a palette of LID design/enhancement scenarios for four of fourteen alleyways. (The four alleyways in question were chosen because together they represent the array of current and desired alleyway uses in the North Common Neighborhood.) Along with each LID scenario, HW presented details about each feature’s stormwater management function, an estimated cost analysis, and a description of maintenance requirements that helped further inform our evolving discussion surrounding reclaiming Lawrence’s alleyways. As an additional component of our Alleyway Project team, Lawrence CommunityWorks’ (LCW) Organizing Department provided community outreach support by publicizing our endeavor, especially the alleyway focus groups, among residents in the neighborhood. LCW helped us gather detailed input—most especially among those residents who were unable to attend our focus group, but whose feedback was extremely valuable.

**History of Groundwork Lawrence’s Alleyway Focus in Lawrence**

Since 2004, under the leadership of Groundwork Lawrence and in addition to broad volunteer-driven cleanups, two alleyway improvement initiatives in the North Common neighborhood have featured the use of LID techniques. Thanks to funding provided by the Massachusetts Office of Coastal Zone Management (CZM), Groundwork Lawrence was able to design and construct the following two alleyway projects:

- **The Orchard Street “Green Alleyway” Project** – With a $12,000 grant from CZM, we worked to create a passive green habitat and pedestrian conduit. Our Green Alleyway project was the very first iteration of low-impact development techniques applied in the alleyways; in addition to the use of reclaimed cobblestone for planter beds and terracing to slow the flow of stormwater, the project featured the use of native drought-tolerant plantings that were attractive to birds, butterflies, and bees. Despite some ongoing maintenance challenges this alleyway is currently wholly cared for by nearby residents who helped design and implement the improvements.
The Union & Mechanic LID Alleyway Community Garden Project – With $30,000 in funding from CZM, Groundwork Lawrence retained the landscape design services of David Buchanan, principal at Stillman Restoration & Design, to design volunteer-built raised community garden beds, an LID patio, and a series of rain gardens that help manage stormwater runoff from an adjacent site that had been creating erosion further downhill. Still high-functioning as an LID Demonstration Site, Groundwork Lawrence owns the alleyway in trust and oversees a network of eight active community gardeners who cultivate food and flowers there.

Additional funds and these improvements have enabled us to leverage funding and ongoing civic engagement in the form of volunteer labor from nearby residents, local youth in our Green Team program, along with The Timberland Company and New Balance Athletic Shoe, who have supplied hundreds of their employees to help complete the build-out and ongoing maintenance of these projects. This funding also leveraged additional momentum necessary to build a campaign to reclaim all the alleyways in the city—an ongoing Groundwork Lawrence initiative. For instance, in 2007 the Merrimack Valley Planning Commission received an EPA Brownfield Assessment Grant, with which they conducted a Phase I Environmental Site Assessment for twelve alleyways in the North Common neighborhood. With this Phase I information, we have been able to continue creating a knowledge base documenting the alleyways’ prior uses, potential contamination concerns, and overall site constraints that could potentially impact future build-out scenarios.

Next Steps for Alleyway Improvements
In regards to the overall solutions proposed in this guide for the alleyways, City officials and citizens at the presentation of these solutions were excited about the redevelopment possibilities presented, but citizens carefully tempered their excitement by explaining that improvements alone cannot remedy dumping and other illegal activity in the alleyways, and reiterating the need for more frequent oversight and accountability from the city, particularly in response to the illegal dumping that occurs in the alleyways. Mostly importantly, attendees felt that the proposed improvement scenarios could alleviate most safety concerns by improving accessibility and installing lights, thereby making law enforcement of all types that much easier. To continue evolving this discussion, and in response to desires expressed for a comprehensive plan going forward that includes not only the residents living adjacent to alleyways but also the City of Lawrence, and owners of the alleyways, Groundwork Lawrence hopes to create an ongoing Sustainability Campaign that could feature (among other strategies) coalition-building via subsequent LID Alleyway presentations to city administrators and commissioners, developers, apparent alleyway owners, residents, and other interested community groups as a means for broadening the support for the use of LID in any redevelopment project. Our next step is to nurture ongoing collaborations with the City of Lawrence and our growing group of interested residents and stakeholders, with whom we hope to define and implement a comprehensive plan for a more sustainable Lawrence with the city itself a major stakeholder.

Our hope is that this report will serve as a guide to further sustainable development in the City of Lawrence as we address similar issues in vacant lots, brownfield properties, residential development and commercial redevelopment.
Purpose of this Booklet

The purpose of this booklet is to provide ideas to improve the conditions of the alleyways of the North Common neighborhood in Lawrence, Massachusetts, through the use of Low Impact Development (LID) techniques and other “green” approaches. These alleyways serve as pedestrian walkways and provide vehicle access to garages for neighboring residences and businesses. Unfortunately, they are also commonly used as dumping grounds for unwanted trash and debris, often have poor drainage resulting in standing water, and are in generally poor condition from a lack of maintenance.

This booklet is designed to demonstrate potential improvements to the function of the alleyways that enhances the aesthetics as well as improves their environmental footprint. This guide also provides ideas that could be imitated, expanded on, and implemented by various developments or projects in the entire city and beyond. As with any improvement project, there are costs associated with materials and labor, but we have tried to select materials that are readily available, relatively inexpensive, easy to install, functional, and durable.

Introduction to Low Impact Development

Low Impact Development (LID) is a site design technique and landscaping that aims to preserve the natural hydrology of a site and manage stormwater in an ecologically sensitive manner. To estimate the natural hydrology of a site, one should picture a site in a natural undeveloped condition, with trees, understory vegetation, leaf litter, organic soils, and a natural ability to capture and retain rainwater from most rainstorms. When the town constructs buildings, driveways, roads, or alleyways, we typically add impervious areas where water can no longer infiltrate into the ground. Instead, it collects and runs off the land surface into low points, sometimes causing erosion and/or flooding and carrying with it pollutants that it collects along the way. The goal of LID is to use elements based on natural features, such as vegetation, soils, and infiltration, to improve the hydrology and aesthetics in these long developed and essentially impervious alleyways.

In This Booklet…..

This booklet contains three proposed alleyway design concepts that incorporate LID techniques. They are based upon observations made during field visits on March 25, 2008. These are contrasted by photographs of the existing conditions in four pilot alleyways in the North Common neighborhood. Each of the elements presented in the alleyways designs is described in more detail to help the reader understand the purpose, installation requirements and benefits of the element. A host of suitable plantings are also identified.
Existing Conditions of North Common Alleyways

This project has focused on four pilot alleyways as inspiration for the conceptual designs. These alleyways were selected based on the variety of uses they represent, including pedestrian traffic, vehicle traffic and gardening. These alleyways are:

#4. From Garden Street to Orchard Streets (between Newbury and Union Streets)

#12. From Haverhill Street to Elm Street (between Newbury and East Haverhill Streets)

#13. North of Elm Street (between Newbury and East Haverhill Streets)

#14. From Jackson Street to Elm Street (east of Jackson Street)

The Alleyway numbers refer to the North Common Alleyway Inventory, which includes 14 alleyways, prepared by Groundwork Lawrence.

Alleyway #4. Garden Street to Orchard Street

This alleyway is closed to vehicular traffic and has been the subject of previous improvements, including granite entry posts, a stone bench and pergola, and flower garden plantings along each side of the alleyway. The alleyway slopes downhill from west to east, and there is a single, heavily clogged catch basin at the base of the alleyway. It is lined with houses on either side. The edge of the alleyway is defined primarily by chain link fence, along with some recently painted bright murals.
Alleyway #12. Haverhill Street to Elm Street

This alleyway is located in a residential neighborhood. It is used for some vehicular traffic as well as access to garages and parking areas in the rear of adjacent residences. The alleyway will serve as access to parking for a housing complex in development at the southern end of the alleyway. Pedestrian use is limited due to trash, debris and safety concerns. The alleyway is lined by a combination of chain link fence, picket fence, garages and murals, as well as several large mature trees. The grade is flat, and the ground surface is a combination of pavement in poor condition and compacted dirt.

Alleyway #13. North of Elm Street

This alleyway is used primarily for vehicular access to residential garages and parking. Pedestrian use is limited due to trash and debris and safety concerns. The alleyway is lined by a combination of chain link fence and garages. The grade is flat, and the ground surface is a combination of pavement in poor condition and compacted dirt. There are several large trees lining the edge of this alleyway, which provide shade and improve the aesthetics of the alleyway.

Alleyway #14. Jackson Street to Elm Street

This L-shaped alleyway is used primarily for pedestrian travel, as granite columns at the Elm Street end prohibit vehicles from entering the alleyway. Recent improvements have been made, including the installation of raised planting boxes used by neighbors for flowers and vegetables. The alleyway is lined by a combination of chain link fences, picket fence, houses and a large brick commercial building. The grade is flat on the eastern end and slopes downhill to the west toward Jackson Street. The ground surface is a combination of pavement in poor condition and compacted dirt. There are several large trees lining the edge of this alleyway.

Alleyway for pedestrian travel only.

Photo enhancement of proposed design.
Recommended Alleyway Design Elements

**Design Approach**
An integrated approach was designed that includes alleyway surfaces, stormwater infiltration, bioretention plantings and lighting elements. The recommended geometry provides for the infiltration and treatment of one-inch of stormwater runoff from the alleyway surface, consistent with the Massachusetts Stormwater Standards.

**Recycled Bricks:** In a traditional mill area such as Lawrence, bricks may be readily available for reuse from the City DPW or building restoration sites. Bricks are highly suited to heavy traffic, and can be used to create a stable surface for a walking path or vehicle driveway. Installation can be somewhat intensive and should be performed or guided by an experienced installer. It generally requires a 4 to 8” dense aggregate subbase and a 1-inch bedding of high strength sand.

**Plastic Gravel Paver Grid:** This plastic grid system provides an alternative road support for heavy load bearing while also allowing rainwater to be stored and infiltrated into the ground. This grid system will reduce runoff during the more common smaller storms, and will slow peak flows during larger events. They also reduce the formation of ice on the road surface. This system can be plowed, though gravel may need to be replaced over time.

**Gravel Trench:** A trench filled with gravel is a simple way to provide storage for runoff during rain events, and can help water to infiltrate into the ground rather than overwhelming downstream catch basins and adjacent streets. It will also provide for the development of a root-zone and its associated microorganisms that provide significant water quality treatment. This trench is approximately 1 to 2’ wide.
Fill from Excavation: Materials excavated out of the trenches along the edges of the alleyways can be used to create the desired elevation and grading along the surface of the alleyway. Given the history of these alleyways, the excavated material will likely include significant fill material, and some materials such as concrete asphalt may need to be removed before reusing the excavated materials.

Planting Soil: Planting soil along the edge of the alleyways can provide an environment for beneficial plants and ivy. It can also absorb water that would otherwise run off the land surface. This planting soil should be a mixture of about 40% sand, 30 - 40% compost and 20 - 30% topsoil.

Plantings (Modified Green Walls): Based upon the unique geometry of the narrow alleyways and the limited available planting areas, a modified green wall concept was developed. Evergreen climbing vines (including Boston Ivy, English Ivy and Virginia Creeper) are recommended as they will adapt well to the limited horizontal spaces and more plentiful vertical planting areas (building walls and chain-link fences).
**Rain Barrels:** Rain barrels can be used to capture rain water from rooftops for irrigation and other non-potable uses. Direct the downspout from the rooftop into the top of the rain barrel, which should be outfitted with a screen to prevent leaf litter from entering the barrel. Attach a faucet and hose to the bottom of the barrel and an overflow hose from a hole near the top of the barrel. Raise the barrel up on some blocks to use gravity to drain the water out. Paint the rain barrels with creative designs to brighten up your backyard area with some “green” artwork.

**Solar Lighting:** These lights contribute to improved safety and ambience in the alleyways, while requiring no electricity from the City or the neighboring residents. There are many styles of solar lighting available for landscape lighting, ranging from tall street lights, to smaller lantern-style lights that can be mounted on posts, to even smaller lights installed along the ground to line a pathway.

**Ground Plantings:** Plantings can help to absorb some of the moisture from rainfall events through their roots as well as through interception. Plants also remove a certain level of pollutants from the runoff since they use nutrients to grow. It is best to use a variety of plants and to select hearty, non-invasive perennials that are suited to the northeast climate, can withstand somewhat harsh conditions and will continue to grow year after year. In some cases, limited low-growing plantings can be added to supplement the climbing vine plantings. Plant examples include Creeping Juniper, Switch Grass, Common Periwinkle and Moonbeam Tickseed.
Estimated Costs

Costs will depend on the specific design of the alleyway improvements, the amount of volunteer versus professional labor available or required, the amount of donated or readily available materials, and the combination of plants selected. Material and greenery selections for these sustainable alleyway enhancements were chosen based on their feasibility and ease of implementation.

Below is a summary of estimated planning level costs to help develop a basic budget. Based on these estimates, the estimated cost of materials outright for a 500’ long alleyway with bricks or gravel pavers may range from $35,000 to $70,000. However, with donated recycled bricks, economic solar lighting, and discounted soils, the cost can be significantly reduced. Additional costs may include permit fees, bonds or insurance for this work. Permitting, engineering, and contingency costs can be estimated as an additional 10-20% of the total cost.

<table>
<thead>
<tr>
<th>Plant*</th>
<th>Spacing</th>
<th>Estimated Wholesale/Retail Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creeping Juniper</td>
<td>5 - 7’ on center</td>
<td>$6.25/$10.15 per 1 gallon pot</td>
</tr>
<tr>
<td>Switch Grass</td>
<td>3- 4’ on center</td>
<td>$6.25/$12.15 per 1 gallon pot</td>
</tr>
<tr>
<td>Common Periwinkle</td>
<td>12 - 18” on center</td>
<td>26.25/$42.55 per flat (24 plants), or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$2.60 per 3” pot</td>
</tr>
<tr>
<td>Moonbeam Tickseed</td>
<td>1’ - 2’ on center</td>
<td>$5.60/$9.50 – 1 gallon pot</td>
</tr>
<tr>
<td>Boston Ivy</td>
<td>6-12” on center</td>
<td>$10.50/17.00 per 1 gallon pot</td>
</tr>
<tr>
<td>English Ivy</td>
<td>12” on center</td>
<td>$25.75/$45.00 per flat (100 plants)</td>
</tr>
<tr>
<td>Virginia Creeper</td>
<td>3 - 4’ on center</td>
<td>$14.50/23.50 per 1 gallon pot</td>
</tr>
</tbody>
</table>

* Labor and other materials (soil amendments, additional compost, mulch) usually cost approximately 2 to 3 times the wholesale cost of the plants.

ESTIMATED MATERIALS COSTS#

<table>
<thead>
<tr>
<th>Description</th>
<th>Material</th>
<th>Professional Labor##</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick walkway with base course</td>
<td>$50/square yard</td>
<td>$100/square yard</td>
</tr>
<tr>
<td>Gravel Paver Plastic Grid</td>
<td>$30/square yard</td>
<td>$50/square yard</td>
</tr>
<tr>
<td>Gravel Backfill for Paver Grid (3/8” stone)</td>
<td>$20/ton</td>
<td>$8/ton</td>
</tr>
<tr>
<td>Washed stone gravel for gravel trench (3/4” stone)</td>
<td>$17/ton</td>
<td>$8/ton</td>
</tr>
<tr>
<td>Gravel/planting soil trench excavation</td>
<td>$0</td>
<td>$6/cubic yard</td>
</tr>
<tr>
<td>Planting Soil</td>
<td>$30/ton</td>
<td>$10/ton</td>
</tr>
<tr>
<td>Solar lighting</td>
<td>$20 - $5,000 each</td>
<td>Up to $500 each</td>
</tr>
<tr>
<td>Rain Barrel</td>
<td>$50-100</td>
<td>$0</td>
</tr>
</tbody>
</table>

# For cost estimating purposes, the average alleyway dimensions are assumed to be 14’ wide by 500’ long. Costs for gravel trenches and planting soil are based on 1’ wide by 2’ deep trenches along each side of the alleyway.

## Labor rates are estimated contractor costs, not prevailing wage rates for city contracting. Professional labor costs have been provided here for reference, but can be significantly offset by volunteer labor.
Groundwork Lawrence, Inc. (GWL) is a locally-based 501(c)3 non-profit organization working to create sustainable environmental change through community-based partnerships. Groundwork is committed to “changing places and changing lives” through on-the-ground projects, education, and volunteer programs that help to transform local communities. To accomplish this, GWL leads and supports a variety of partnership-driven efforts that bring together the public, private, and non-profit sectors to solve complex environmental problems and sustain a long-term vision for neighborhood change and renewal. Groundwork Lawrence is an affiliate of Groundwork USA.

To download a copy of this booklet, please visit www.groundworklawrence.org

Groundwork USA • www.groundworkusa.org

Project Partners

Horsley Witten Group

This project is funded by the Massachusetts Environmental Trust.
Appendix H
Permeable Pavement: What’s It Doing On My Street?

An introduction to permeable pavement alternatives
November 2005
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An Introduction to Permeable Construction Materials

Whether you're a Town board member, a professional contractor, or a homeowner with a driveway, a little information about permeable pavement can explain why you might want to consider this popular alternative construction material.

A wide range of permeable materials have become more readily available and widely used over the last two decades as alternatives to conventional road construction materials. These have proven to be practical, cost-effective, and environmentally sustainable due to their ability to reduce urban stormwater runoff. Because these permeable materials allow water to pass through the surface (in the case of porous asphalt and porous concrete) or through void spaces (in the case of concrete or grid pavers), both runoff volume and water quality impacts are reduced. That keeps nuisance flooding down, recharges groundwater supplies, and helps to keep drinking waters healthy.

These permeable pavements are appropriate for a variety of uses, such as pedestrian walkways, overflow parking areas, parking lots, and residential roads. For best success, a few key factors must be considered when undertaking a project involving permeable alternatives. For example:

1. Choose the correct paver for the task at hand. Permeable pavement options vary based on light, moderate, or heavy use. Therefore, it is imperative to choose the right material for the expected use.
2. Prepare the subbase. Choose the appropriate subbase preparation for the application. The type of subbase used and depth of the subbase materials determines the amount of infiltration provided, as well as durability over time. In locations with numerous freeze-thaw cycles, poor soils or an extremely cold climate, a thicker subbase is usually required. Install properly. In many cases, the manufacturer will install, oversee the installation, or recommend certified contractors.
3. Understand and carry out maintenance requirements; it's critical to the durability of permeable materials.

This technical bulletin describes the range of permeable pavements currently available to help you evaluate alternatives that will best suit your needs. The permeable pavement information presented in this manual is organized according to strength and durability: 1) concrete block pavers have the highest load bearing capacities, followed by 2) porous pavement and then 3) plastic grid pavers. We begin with a one-page overview of these three types, followed by more detailed information on various products available under each group with case studies of constructed projects. For more information, contact local distributors. This bulletin may not include all products available, nor does it constitute an endorsement of any product. Any errors or omissions are the sole responsibility of the authors.
Block Pavers
These pavers are constructed primarily from concrete. They interlock with one another but leave open, void space between the pavers to permit water to infiltrate into the underlying gravel reservoir. The thickness of the gravel subbase, and the type of material used to fill in the void spaces, determines the amount of infiltration permitted. A typical concrete block pavement installation consists of a soil subgrade, a gravel base, a layer of bedding sand, and the grid pavers. The void space around the pavers can be filled with either gravel or soil and grass.

Block pavers are recommended for use in parking lots, overflow lots, residential streets, medians, driveways, sidewalks, fire lanes, pedestrian plazas, and roof ballast. Proper site preparation, installation, and maintenance are key to the block pavers’ long-term success. Examples of some of the concrete block pavers that are described in greater detail on the attached sheets are shown below.
Porous Pavement

Porous asphalt and porous concrete are very similar to their conventional counterparts, but they are mixed without the fine particles (i.e. those less than 600 µ) to allow for the passage of stormwater through the surface. After the water passes through the porous surface, it is temporarily stored in an underlying crushed rock storage reservoir and slowly released into the underlying soils. A geotextile filter fabric is placed on the floors and sides of the recharge bed to prevent fine soils from migrating into the bed.

The load bearing capacity of porous pavement is less than conventional pavements because of the absence of the fine particles. Therefore, large commercial vehicles should not be permitted to park in lots paved with permeable materials. Porous pavement projects require less stormwater pipes and inlets than conventional pavement, and detention basins are not required.

The long-term success of any porous pavement project is dependent upon proper site positioning, design, construction, and maintenance. A failure to properly test for soil drainage capacity and water table height, to leave paved areas unprotected from construction-related sediment losses, or to ignore recommended periodic maintenance can result in their premature clogging and failure. The use of these materials is recommended for passenger vehicle parking lots, overflow or event parking areas, roadways with light traffic (i.e. residential subdivision streets), bike paths, and pedestrian walkways.
Plastic Grid Pavers

These pavers are constructed primarily from recycled plastic materials. They can be filled with either gravel or soil and grass, with the former being a better choice for more frequently used areas.

Due to their flexibility plastic grid pavers can be used on sites with uneven terrain, but they do not have as much intrinsic strength as concrete pavers. The plastic grid pavers' load bearing capacity ranges from 24,000 lbs/ft$^2$ to 823,680 lbs/ft$^2$. They do not require drains, detention or retention ponds, or any other associated drainage facility, but proper site placement, installation, and maintenance are key to their overall success. For example, it is important to avoid directly routing large volumes of runoff from adjacent impervious areas onto the grid pavers, because that could clog them with sediment and deposit salt on the vegetation in the winter. Plastic grid pavers are recommended for use in parking areas, residential driveways, fire lanes, emergency access roads, golf cart paths, sidewalks, and bike paths.
Block Paver
Fact Sheets
Local projects in Rhode Island include Great Island, Harbor Island, and Boston Neck Road in Narragansett, and Carver Lane and Schooner Cove in Pt. Judith. A private subdivision in Connecticut is also planning on installing Aquaterra pavers in the near future.

<table>
<thead>
<tr>
<th>Type of Paver</th>
<th>Applications</th>
<th>Performance</th>
<th>Installation Details</th>
<th>Maintenance</th>
<th>Costs</th>
<th>Local Retailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquaterra™</td>
<td>Suitable for residential and emergency access roads, driveways and parking lots.</td>
<td>Mean compression strength is greater than 1,584,000 lbs/ft² (11,000 psi). In comparison, a concrete slab has a mean compression strength less than 432,000 lbs/ft² (3,000 psi). The pavers have a lifetime guarantee and are easy to repair.</td>
<td>Installation requires a contractor. The thickness of the gravel base depends upon the anticipated loads, necessary stormwater drainage, and subgrade soil conditions. For residential uses on adequately drained soil, the gravel base can be omitted and the block pavers placed directly on the sand bedding layer. For heavier vehicle loads or frequent usage, a minimum of 6” of compacted gravel base is recommended. The sand bedding layer is loosely spread by hand screening or with equipment to a depth of at least 1”. The pavers are placed in the bedding layer by hand or machine and the void spaces surrounding the pavers are filled with gravel.</td>
<td>Periodic maintenance is required to clean silt and debris from the voids/drainage openings with street sweepers and refill the displaced gravel when necessary. Salts and sands should be used sparingly, if at all, for deicing in the winter. A snowplow may be used to clear the surface. The blade does not need to be lifted.</td>
<td>The paver costs ~$2.98 per square foot. A project calculator is available online at <a href="http://www.unilock.com/ProjectCalculator.asp">http://www.unilock.com/ProjectCalculator.asp</a> for estimating project costs.</td>
<td>Unilock New England 35 Commerce Drive Uxbridge, MA 01569 (508) 278-4536 Territory Manager: Matthew Foley Unilock will provide information on at least two authorized contractors that can supply labor and materials to interested parties.</td>
</tr>
<tr>
<td>Type of Paver</td>
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<td>Costs</td>
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<tr>
<td><strong>UNI Eco-Stone®</strong></td>
<td>Suitable for residential and emergency access roads, driveways and parking lots.</td>
<td>The average compression strength is at least 1,152,000 lbs/ft² (8000 psi) with no individual unit less than 1,036,800 lbs/ft² (7200 psi). The pavers have a lifetime guarantee and are easy to repair.</td>
<td>Installation requires a contractor. The thickness of the gravel base depends upon the anticipated loads, necessary stormwater drainage, and subgrade soil conditions. For residential uses on adequately drained soil, the gravel base can be omitted and the block pavers placed directly on the sand bedding layer. For heavier vehicle loads or frequent usage, a minimum of 6” of compacted gravel base is recommended. The sand bedding layer is loosely spread by hand screening or with equipment to a depth of at least 1”. The pavers are placed in the bedding layer by hand or machine and the void spaces surrounding the pavers are filled with gravel.</td>
<td>Periodic maintenance is required to clean silt and debris from the voids/drainage openings with street sweepers and refill the displaced gravel when necessary.</td>
<td>The paver costs begin at $3.07/ft². A project calculator is available online at <a href="http://www.unilock.com/ProjectCalculator.asp">http://www.unilock.com/ProjectCalculator.asp</a> for estimating project costs.</td>
<td>Conklin Limestone 25 Wilbur Road Lincoln, RI 02865 (401) 334-2330 <a href="http://www.conklinlimestone.com">http://www.conklinlimestone.com</a></td>
</tr>
</tbody>
</table>
UNI Eco-Stone® Example Application - Jordan Cove National Project in Waterford, Connecticut

**Site Description:** Some of the cul-de-sacs, streets, and driveways in the best management practice (BMP) section of the Jordan Cove National Project in Waterford, CT are paved with UNI Eco-Stone pavers. The Jordan Cove Urban Watershed Section 319 National Monitoring Program Project is a ten year study designed to ascertain how the quality and quantity of stormwater runoff is affected by pollution prevention BMPs used throughout an urban subdivision.

**Design Details:** Approximately 15,000 ft² of the UNI Eco-Stone pavers were installed in the BMP watershed to construct a 6.1 m-wide road (~20 feet), the cul-de-sacs, and some of the homeowners’ driveways.

**Cost Information:** The cost of constructing the road and curbs with UNI Eco-Stone pavers and conventional asphalt was $102,500 and $18,860, respectively. The cost of the driveways and driveway aprons paved with UNI Eco-Stone pavers was $7,896 and $1,318 per lot, respectively whereas the conventional asphalt driveways and driveway aprons cost $1,318 and $280 per lot, respectively. Additional cost information is available online at http://www.canr.uconn.edu/jordancove/bmp_costs.htm.

**Maintenance:** Periodic maintenance is required to clean silt and debris from the voids/drainage openings with street sweepers and to refill the displaced gravel.

**Contacts:** Bruce Morten, Aqua Solutions (860) 295-1505 or Aquasoln@aol.com

<table>
<thead>
<tr>
<th>Type of Paver</th>
<th>Applications</th>
<th>Performance</th>
<th>Installation Details</th>
<th>Maintenance</th>
<th>Costs</th>
<th>Local Retailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF-RIMA™</td>
<td>Suitable applications for the gravel filled pavers include parking lots, residential roads, driveways, sidewalks and patios. Suitable applications for the grass filled pavers include overflow parking lots, street medians, driveways, patios, and garden paths.</td>
<td>The compression strength is at least 1,152,000 lbs/ft² (8000 psi). The pavers have a water absorption maximum of 5%. The pavers have a lifetime guarantee and are easy to repair. Installation can be done by a contractor or homeowner. The thickness of the gravel base depends upon the anticipated loads, necessary stormwater drainage, and subgrade soil conditions. The overlying bedding layer should not exceed 1” in thickness. The pavers are placed in the bedding layer and the void spaces surrounding the pavers are filled with either gravel or soil and grass, depending on which design (i.e. spacer to side or spacer to spacer) was chosen.</td>
<td>Maintenance includes mowing, irrigation fertilization, and seeding. Intermittent replacement of gravel may be necessary over time. Deicing salts should not be used because it will kill the grass. A snowplow may be used to clear the surface. The blade does not need to be lifted.</td>
<td>The paver costs range between $3.10/ ft² and $3.20/ ft² and are sold in bundles of 67 ft². When the pavers are filled with gravel, 2.7 stones are required per sq. ft. When the pavers are filled with grass, 1.9 stones are required per sq. ft.</td>
<td>The paver costs range between $3.10/ ft² and $3.20/ ft² and are sold in bundles of 67 ft². When the pavers are filled with gravel, 2.7 stones are required per sq. ft. When the pavers are filled with grass, 1.9 stones are required per sq. ft.</td>
<td>Conklin Limestone 25 Wilbur Road Lincoln, RI 02865 (401) 334-2330 <a href="http://www.conklinlimestone.com">http://www.conklinlimestone.com</a> Hartford Materials 112 Old Pocasset Road Johnston, RI 02919 (401) 942-8857 Paver cost is $2.56/ ft² Riverview 147 Kennedy Drive Putnum, CT 06260 (860) 928-4222 Paver cost is $3.20/ft² but can be less depending on the amount purchased.</td>
</tr>
</tbody>
</table>

Local projects in Rhode Island include a 35,000 ft² parking lot at the Misquamicut Beach in Watch Hill.
<table>
<thead>
<tr>
<th>Type of Paver</th>
<th>Applications</th>
<th>Performance</th>
<th>Installation Details</th>
<th>Maintenance</th>
<th>Costs</th>
<th>Local Retailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turfstone</td>
<td>Suitable for overflow parking areas, emergency vehicle access roads, patios, driveways, spillways, and embankments.</td>
<td>The average compression strength of the Turfstone manufactured by Unilock is 720,000 lbs/ft(^2) (5000 psi) with no individual unit less than 648,000 lbs/ft(^2) (4500 psi). The compression strength of the Turfstone manufactured by Cambridge is 1,440,000 lbs/ft(^2) (10,000 psi). The pavers have a lifetime guarantee and are easy to repair.</td>
<td>May be installed by contractor or homeowners. A gravel base may be required to provide additional stability based on soil type and use expectations. The base is usually 6” of compacted gravel, but can vary based on intended use. Geotextile reinforcement is recommended between the subbase and gravel base for vehicular traffic. The pavers are embedded in ~ ¼ to ½ inch of concrete sand and should not be compacted. The final level of topsoil/gravel should be flush with surface.</td>
<td>Maintenance includes mowing, irrigation fertilization, and seeding. Intermittent replacement of gravel may be necessary over time. Deicing salts should not be used because it will kill the grass. A snowplow may be used to clear the surface. The blade does not need to be lifted.</td>
<td>The paver costs between $ 2.25/ft(^2) and $2.70/ft(^2). A project calculator is available online at <a href="http://www.unilock.com/ProjectCalculator.asp">http://www.unilock.com/ProjectCalculator.asp</a> for estimating project costs.</td>
<td>Conklin Limestone 25 Wilbur Road Lincoln, RI 02865 (401) 334-2330 <a href="http://www.conklinlimestone.com">http://www.conklinlimestone.com</a> Paver cost is $2.25/ft(^2)</td>
</tr>
<tr>
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<td></td>
<td>Unilock New England 35 Commerce Drive Uxbridge, MA 01569 (508) 278-4536 Territory Manager: Matthew Foley Paver cost is $2.32/ft(^2)</td>
</tr>
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<td>Hartford Materials 112 Old Pocasset Rd. Johnston, RI 02919 (401) 942-8857 Paver cost is $2.16/ft(^2) but can be less depending on the amount purchased.</td>
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<td></td>
<td>Riverview 147 Kennedy Drive Putnum, CT 06260 (860) 928-4222 Paver cost is $2.70/ft(^2) but can be less depending on the amount purchased.</td>
</tr>
</tbody>
</table>
Turfstone Example Application - Purchasing Building, University of Rhode Island, Kingston, R.I.

**Site Description:** An emergency vehicle access road was constructed with Turfstone outside of the Purchasing Building, which is located at the bottom of Flagg Road on the University of Rhode Island’s Kingston campus.

**Design Details:** The area where this access road was constructed is prone to mud formation when the top layer defrosts on a cyclical basis in the spring. The University wanted to ensure a stable foundation for emergency access vehicles.

**Maintenance:** Regular maintenance includes mowing, irrigation, and fertilization.

**Notes:** According to David Bascom, Assistant Director of the Landscapes and Grounds Department at the University of Rhode Island, the Turfstone emergency access road is easy to maintain and has held up very well.

**Contacts:** David Bascom, Assistant Director of the Landscapes and Grounds Department. (401) 874-5515 or b'snest@uri.edu
### Hastings Checker Block®

**Description:** This product is a light duty, square shaped (2’x2’) lattice concrete paver with small cross-shaped internal openings that can be filled with either soil and grass or gravel. The ratio of grass or gravel to concrete is ~70%.

**Manufacturer:** Hasting Pavement Company  
http://www.hastingspavers.com/chblock.html

![Diagram of Hastings Checker Block Pavers](image)

<table>
<thead>
<tr>
<th>Type of Paver</th>
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<th>Local Retailer</th>
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</thead>
</table>
| Hastings Checker Block® | Suitable for overflow parking, service roads, fire access lanes, and tree pits. Suitable for stabilizing embankments along water bodies. | Achieves a concrete strength of 5,000 psi. | A base can be either undisturbed earth or fill compacted to 95% maximum dry density. Sand is placed in a 2” compacted layer over the base. The void can be filled either with crushed gravel or topsoil. | Grass can be maintained using a conventional lawn mower. | The 2’ x 2’ pavers are sold in bundles of 20, which covers 80 square feet. Price is determined by retailer and size of project. | UBS-United Builders Supply  
30 Oak Street  
Westerly, RI 02891  
(401) 596-2831  
don’t carry; may be able to order  
PO Box 417  
Wyoming, RI 02898  
(401) 539 3033  
don’t carry; may be able to order |
Porous Pavement Fact Sheets
<table>
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<tr>
<th>Type of Paver</th>
<th>Applications</th>
<th>Performance</th>
<th>Installation Details</th>
<th>Maintenance</th>
<th>Costs</th>
<th>Local Retailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porous Concrete</td>
<td>Suitable for parking lots, residential streets, plazas, play courts, bike paths and sidewalks. It is much more difficult to get the porous concrete mix right in comparison to porous asphalt. In addition, it is much coarser looking than conventional concrete. Therefore, concrete asphalt is usually a better option for smaller areas where aesthetics are an important factor.</td>
<td>The load bearing capacity of porous concrete is usually between 259,200 and 345,600 lbs/ft$^2$ (1800-2400 psi). depending on the soils with high permeability, such as sands and sandy loams, have the best ability to carry loads. Porous concrete becomes stronger and more stable when it gets wet. Therefore, it does not deteriorate as fast as other paving materials. Expected lifespan of 15-20 years if properly sited, designed, installed, and maintained. The porous concrete is installed over a 1” layer of chocker course and bed of uniformly graded, clean washed crushed rock that is usually 18-36” deep. A layer of geotextile fabric separates the crushed rock from the underlying soil to prevent any fines from moving up into the storage bed. The bottom of the recharge bed is excavated to a level surface and is not compacted to allow the water to distribute and infiltrate evenly over the entire bottom bed area.</td>
<td>Vacuum sweeping to remove sediment that has accumulated on the surface. Annual inspection of the surface for deterioration. Potholes and cracks can be filled with patching mixes unless more than 10% of the surface needs to be repaired. Spot clogging may be fixed by drilling 0.5” holes through the pavement layer every few feet. Winter abrasives such as sand or cinders should not be applied on the pavement surface. Deicing salts should not be applied in areas near groundwater drinking supplies, but environmentally benign deicers are permissible. Snowplow blades must be raised ~1” to protect the surface.</td>
<td>The cost of porous concrete is about four times greater than the cost of porous asphalt. The cost depends on the amount produced and usually costs somewhere between $2.00-$4.00/ft$^2$. The underlying stone bed is usually more expensive than a conventional compacted subbase, but is offset by the reduction in stormwater pipes, inlets and elimination of detention basins. Generally, porous pavement installation does not require deep excavations and there is less earthwork.</td>
<td>Cahill Associates 104 South High St. Westchester, PA 19382 (610) 696-4150 BETA Group, Inc. 6 Blackstone Valley Place Lincoln, RI 02865 (401) 333-2382 Kevin Read Comprehensive Environmental, Inc. 64 Dilla Street Milford, MA 01757 (800) 725-2550</td>
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<tr>
<td>Type of Porous Pavement</td>
<td>Applications</td>
<td>Performance</td>
<td>Installation Details</td>
<td>Maintenance</td>
<td>Costs</td>
<td>Local Retailer</td>
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<tr>
<td><strong>Porous Asphalt</strong></td>
<td>Suitable for passenger vehicle parking lots (i.e. daily, overflow or event parking), light traffic residential streets, play courts, bike paths and sidewalks. Driveways are usually too small for a contractor to prepare the specialized mix. Homeowners interested in other permeable options are referred to the fact sheets on block pavers and plastic grid pavers.</td>
<td>The load bearing capacity of porous asphalt is less than that of porous concrete. Sufficient asphalt content (5.75% to 6% bituminous asphalt by wt) is essential to pavement durability. Sites that used lower asphalt content show surface scuffing and/or raveling on the surface. Declines in the amount of black ice formation have been reported. The porous asphalt is installed over a 1” layer of chocker course and bed of uniformly graded, clean washed crushed rock that is usually 18-36” deep. A layer of geotextile fabric separates the crushed rock from the underlying soil to prevent any fines from moving up into the storage bed. The bottom of the recharge bed is excavated to a level surface and is not compacted to allow the water to distribute and infiltrate evenly over the entire bottom bed area. Vacuum sweeping to remove sediment that has accumulated on the surface. The materials removed by the vacuum must be disposed of properly.</td>
<td></td>
<td></td>
<td>Cahill Associates 104 South High St. Westchester, PA 19382 (610) 696-4150 BETA Group, Inc. 6 Blackstone Valley Place Lincoln, RI 02865 (401) 333-2382 Kevin Read Comprehensive Environmental, Inc. 64 Dilla Street Milford, MA 01757 (800) 725-2550</td>
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Porous Asphalt Example Application – The University of Rhode Island’s Porous Asphalt Parking Lots

Site Description: Two porous asphalt parking lots were built in 2002 and 2003 at the University of Rhode Island to provide 1,000 additional parking spaces near the newly constructed Ryan Convocation Center, a venue for sporting, community, and family events. The University is located on Route 138 in Kingston, R.I. The 800-vehicle lot is located on the northwest side of the intersection of Plains Road and West Alumni Road, and the 200-vehicle lot is located on the northern side of West Alumni Road.

Design Details: The larger porous asphalt parking lot is 5.5 acres, while the smaller lot, which is a retrofit of a pre-existing lot near the former Dairy Barn, is 1.47 acres. The layer of porous asphalt in the two lots is 2.5 inches thick with a slope of less than 2% to allow for maximum seepage through the pavement. Located below the layer of porous asphalt is a 1 inch thick layer of chocker course and 3 to 3.5 feet of uniformly graded, clean crushed rock. The crushed rock has approximately 40% void space to receive, temporarily store, and infiltrate the incoming rainfall and any sheetflow from the adjacent landscaped areas. The crushed rock storage reservoir is separated from the underlying subsurface materials by a layer of geotextile filter fabric. The purpose of this material is to prevent the movement of fine soil particles into the overlying reservoir, which could impede the infiltration of surface water into the storage bed. The entrance areas of the parking lots are paved with conventional bituminous asphalt because of heavier use and sediment deposition from tires as vehicles enter the lot. Landscaped parking lot islands were designed as bioinfiltration areas throughout the parking lot to provide a secondary route of infiltration during intense rainfall and in case the pavement surface begins to clog. The outer areas of the lot are landscaped with trees and grass is maintained around the parking lots’ boundaries to keep wind blown dust from nearby agricultural activities and eroded soil from accumulating on the porous asphalt.

Soil excavation and placement of crushed rock. Stone reservoir surrounded by geotextile filter fabric. Rainwater infiltrates the porous asphalt yet accumulates on adjacent areas paved with conventional mat.
**Costs:** The construction costs for building the two porous lots totaled $3,033,700. The design fees were approximately 10% of the aforementioned construction costs. Therefore, the cost per parking space was approximately $3,337. It is important to note that this particular project had site specific costs such as the demolition of the Dairy Barn, removal of stone masonry walls, and installation of emergency telephones and security cameras, which would not be encountered in all porous parking lot situations. The construction costs of URI’s two porous parking lots were comparable to equivalent sized conventional parking lots.

**Maintenance:** University personnel are responsible for the maintenance of the porous parking lots. Cahill Associates and Beta Group Inc., the two design firms, recommend vacuuming of the lots at least four times per year with a commercial cleaning unit, maintaining the adjacent vegetation, not applying sand, cinders, or deicing salt to the pavement surface, but using environmentally benign deicers such as Ice Ban instead because of the proximity of the Pawcatuck sole source aquifer, plowing with the blade lifted 1" higher than normal, and inspecting the surface annually for signs of deterioration or spalling.

**Notes:** According to David Bascom, Assistant Director of the Landscapes and Grounds Department at the University of Rhode Island, there have not been any instances of water ponding on these lots after rainfall events, even very intense ones. However, he has observed some ice buildup following freezing rain events because the water freezes on the surface before it has time to infiltrate through the layer of porous asphalt. He also notes that the environmentally benign deicer Ice Ban does not work as well as more conventional chemicals or salts if it is not applied within thirty minutes of a snow event. The University’s maintenance crew has also started to see some surface defects at the northeast corner of the parking lot, which has been attributed to outright abuse from people turning their wheels while their vehicles remain stationary. According to Dan Wible, of Cahill Associates, this type of unraveling is not unique to only porous parking lots, and laboratory research conducted to date has shown that the unraveling does not compromise the drainage capabilities of the porous lots. If one wants to repair the surface for aesthetic purposes, areas less than 50 square feet can be patched with standard asphalt while those greater than 50 square feet should be patched with an approved porous asphalt. Those interested in learning more about the porous asphalt parking lots at URI are referred to *The University of Rhode Island’s Permeable Parking Lots.*
### Contacts:

<table>
<thead>
<tr>
<th>Company</th>
<th>Contact</th>
<th>Phone Number</th>
<th>Email Address</th>
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<tbody>
<tr>
<td>Cahill Associates</td>
<td>Dan Wible</td>
<td>(610) 696-4150</td>
<td><a href="mailto:dwible@thcahill.com">dwible@thcahill.com</a></td>
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<td></td>
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<td>Porous Pavement Email: <a href="mailto:porous@thcahill.com">porous@thcahill.com</a></td>
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<tr>
<td>BETA Group, Inc.</td>
<td>Brian Brosnan</td>
<td>(401) 333-2382</td>
<td><a href="mailto:Bbrosnan@BETA-Inc.com">Bbrosnan@BETA-Inc.com</a></td>
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<tr>
<td>Raymond Wilcox</td>
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<td><a href="mailto:raywilcox@uri.edu">raywilcox@uri.edu</a></td>
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<tr>
<td></td>
<td>Construction Project Manager</td>
<td>(401) 874-5288</td>
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<td>(401) 874-5288</td>
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<td></td>
<td>David Bascom</td>
<td>(401) 874-5515</td>
<td>b'<a href="mailto:snest@uri.edu">snest@uri.edu</a></td>
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<tr>
<td></td>
<td>Assistant Director of the Landscapes and Grounds Department</td>
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<td>University of Rhode Island</td>
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<td>Kingston, R.I. 02881</td>
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David Bascom
Assistant Director of the Landscapes and Grounds Department
Facilities Services – Sherman Building
University of Rhode Island
Kingston, R.I. 02881
(401) 874-5515
b'snest@uri.edu
Plastic Grid Paver
Fact Sheets
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<tr>
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<th>Installation Details</th>
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<th>Local Retailer</th>
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<tr>
<td>Grasspave²</td>
<td>Suitable for various types of parking lots (i.e. overflow, event employee, handicap), on-street parking, driveways, fire lanes, emergency access roads, utility access, pedestrian access, golf cart paths, and infiltration basins.</td>
<td>Load capacity is 823,680 lbs/ft² (5,721 psi, which is nearly two times the strength of 2” of concrete). It has UV inhibitors. In sandy soils, it can absorb up to 6” of rainfall over 24 hours.</td>
<td>Installed on top of a sandy gravel subbase. It is unrolled and pinned into place. The plastic rings and spaces between them are filled with a soil/sand mix and planted with grass. The sand in the mix helps to ensure proper drainage, proper oxygen and carbon dioxide levels, strength and stability.</td>
<td>Maintenance includes mowing, irrigation fertilization, and seeding. Individual grids may need to be replaced overtime. Existing equipment can be used for snow removal as long as skid plates/rollers are adjusted to keep the plow blades 1” above the surface.</td>
<td>The cost is highly variable depending on the size of the project. For a 10,000 ft² project, the cost will be ~$2.50/ft², which includes the gravel subbase layer, seeding etc.</td>
<td>Invisible Structures, Inc. 14704-D East 33rd Place Aurora, CO 80011 1-800-233-1510 <a href="http://www.invisiblestructures.com">www.invisiblestructures.com</a> Distributor in R.I. A.H. Harris &amp; Sons 25 Graystone Street Warwick, RI 02886 (401) 737-5136 <a href="http://www.ahharris.com">www.ahharris.com</a></td>
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**Grasspave² Example Application – West Farms Mall**

Emergency access roads paved with Grasspave² have been installed at St. Andrews school in Barrington, R.I., the Naval War College in Newport, R.I., and AMG Headquarters in Beverly, MA. This product has also been used for overflow parking lots; a case study of one in Connecticut is presented below.

**Site Description:** The West Farms Mall overflow parking lot was built to provide 700 additional parking spaces during the peak seasons, and it was paved with Grasspave². The mall is located off of I-84 at exit 40 on New Britain Avenue (Route 71).

**Design Details:** The overflow parking lot covers approximately 200,000 ft², and athletic paint is applied each November to demarcate the parking spaces. A few drains were installed under the Grasspave² to ensure proper drainage during very heavy storms.

**Cost Information:** The total cost of the paving system (including the base layers) was estimated to be less than half of the projected cost of a detention pond that would have been required if conventional asphalt paving was installed.

**Maintenance:** The overflow lot requires mowing on a regular basis and must be watered and fertilized occasionally. The lot must be plowed in the winter with rollers to ensure that the surface is not damaged. The entrances to the aisles have begun to show some signs of wear and will need to be replaced. The West Farms’ maintenance staff is responsible for the year round care of the lot.

**Notes:** According to the University of Connecticut’s NEMO website, Joe Leiberis, West Farms’ facilities director, stated that after four years of having the Grasspave² overflow parking lot, he no longer worries about it. He is happy with its durability after witnessing how well it can handle the winters, summers, hurricanes, and heavy traffic. Additional information on this particular case study can be found at http://web.uconn.edu/nemo/case_studies/west_farms_cs.htm.

**Contacts:** Richter & Cegan Inc., Landscape Architects and Urban Designers rcinc@richtercegan.com

Photography: UCONN NEMO website (http://web.uconn.edu/nemo/case_studies/west_farms_cs.htm)
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<tr>
<td>Gravelpave²</td>
<td>This product should be used in areas where higher traffic will injure the grass. It is suitable for permanent and overflow parking lots, parking aisles and bays, handicap parking spaces, driveways, service and access roads, parks, trails, boat ramps, golf courses, high-use pedestrian areas and infiltration basins.</td>
<td>Load capacity is 823,680 lbs/ft² (5,721 psi, which is nearly two times the strength of 2” of concrete). The circular rings when filled with 1” of gravel and placed above a 6” thick standard road base of sandy gravel can percolate approximately 35” of rain/hr.</td>
<td>Installed on top of a sandy gravel subbase. The depth of the subbase is dependent upon site conditions and intended use. The Gravelpave² is unrolled and pinned into place. The plastic rings and spaces between them are filled with 1” of gravel.</td>
<td>Replacement of gravel fill over time. Replacement of specific grids over time. Existing equipment can be used for snow removal as long as skid plates/rollers are adjusted to keep the plow blades 1” above the surface.</td>
<td>The price of the pavers are ~$2.25/ft²</td>
<td>Invisible Structures, Inc. 14704-D East 33rd Place Aurora, CO 80011 1-800-233-1510 <a href="http://www.invisiblestructures.com">www.invisiblestructures.com</a></td>
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<td>A.H. Harris &amp; Sons 25 Graystone Street Warwick, RI 02886 (401) 737-5136 <a href="http://www.ahharris.com">www.ahharris.com</a></td>
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The West Farms overflow parking lot, which was presented in the preceding case study, used Gravelpave² for the heavier traveled aisles and is satisfied with the product.
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| **Geoblock Porous Pavement System** | Suitable for access roads (emergency & utility access lanes), auxiliary parking areas, driveways, pedestrian walkways, wheelchair access ways, and golf cart path shoulders and aprons. | Total load bearing capacity is 130,000 lbs/ft²  
The product has chemical resistance  
The 87% top open area per unit and 40% bottom open area per unit allows for high rates of percolation. | To maximize permeability, the pavers should be installed over a rock and sand subbase and filled with sandy loam topsoil. Prior to installation, it is necessary to remove all foreign materials. The recommended subbase ranges between two to six inches depending on the designated loads. Ordinary tools can be used to cut the units and no special fasteners or connection devices are required for installation. | Maintenance includes mowing, irrigation fertilization, and seeding.  
Minor grid replacement after 10 years. | The prices of the pavers, which are ~20” x 40” x 2” are $2.75 per square ft. | Manufacturer Info.  
www.prestogeo.com  
1-800-548-3424 or (920) 738-1118  
Local Distributor Jennian Enterprises  
6 Eastman Place Suite 206  
Melrose, MA 02176 (781) 665-7915 |
Grassroad Pavers® Plus

**Description:** This product is comprised of interlocking plastic grid units (48” x 24”) with a hexagon mat design that can be filled with soil and grass. The honeycomb matrix helps to reinforce the soil and protects the root structure of the vegetation. The paver is constructed with high density plastic and is capable of resisting compression, impact and lateral movement.

**Manufacturer:** NDS Incorporated. Additional information is available online at www.grassroad.com

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<td>Grassroad Pavers® Plus</td>
<td>Suitable applications include access roads, driveways, RV access, boat parking areas, sidewalks, &amp; paths</td>
<td>Load bearing capacity on the hexagonal vertical walls is 120,000 lbs/ft²</td>
<td>Installation does not require a contractor. Homeowners can often do the installation themselves. The pavers are snapped together by the Flex Lock nesting system, and placement times can range as high as 800 sq. ft/hr. After the pavers are placed over a proper subbase, which is site dependent, the pavers are filled with either seed or sod.</td>
<td>Maintenance includes mowing, irrigation fertilization, and seeding. Replacement of sections over time</td>
<td>The pavers are 4’ x 2’ and sold in packages of 16 or 24. The cost is $43/paver.</td>
<td>Manufacturer Info. NDS Incorporated <a href="http://www.grassroad.com">www.grassroad.com</a> 1-800-726-1994 Warwick Win Water 62 Wyoming Ave. Warwick, R.I. 02888 (401) 732-5151 E.J. Prescott 80 Gilbane Street Warwick, R.I. (401) 738-7611</td>
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## Tufftrack Grass Pavers

**Description:** This product is comprised of interlocking plastic grid units (~24” x 24” x 1.5”) with a hexagon mat design that can be filled with soil and grass. The honeycomb matrix helps to reinforce the soil and protects the root structure of the vegetation. The paver is constructed with high density plastic and is capable of withstanding light or heavy vehicular traffic, resisting compression, impact and lateral movement.

**Manufacturer:** NDS Incorporated. Additional information is available online at http://www.sitefabric.com/tufftrack_grass_pavers.htm

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<tr>
<td><strong>Tufftrack Grass Pavers</strong></td>
<td>Suitable applications include parking lots, overflow parking lots, emergency access roads, driveways, RV parking pads and roadways, pedestrian walkways, bike paths, and golf cart paths.</td>
<td>The empty pavers have an ultimate compression load rating of 98,500 lbs/ft². UV inhibitors and chemical resistance.</td>
<td>For heavy load and fire lane access the planting base should be 1” to 1.5” and the sub-base 6” to 8”.</td>
<td>Maintenance includes mowing, irrigation fertilization, and seeding.</td>
<td>The pavers are 2’ x 2’ x 1.5” in height. The cost is $20/paver.</td>
<td>Manufacturer Info. NDS Incorporated 1-800-726-1994 Warwick Win Water 62 Wyoming Ave. Warwick, R.I. 02888 (401) 732-5151 E.J. Prescott 80 Gilbane Street Warwick, R.I. (401) 738-7611</td>
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![Group of Three Nested Cells](https://via.placeholder.com/150)

![1.25" dia. opening](https://via.placeholder.com/150)

![-.13" cell wall thickness](https://via.placeholder.com/150)

![.47" x .20" slot openings common to all cells](https://via.placeholder.com/150)
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<tr>
<td>Netpave 50</td>
<td>Suitable for permanent and overflow parking lots, driveways, fire and emergency access roads &amp; bicycle/walking paths.</td>
<td>Load bearing capacity is ~27,870 lbs/ft²</td>
<td><strong>Gravel Installation</strong>&lt;br&gt;Remove topsoil and add a DoT Type 1 subbase. The depth requirements range between 7.5-28.5” for fire truck emergency access to 6-21” depth for light vehicles and overflow parking lots. A 0.8-1” thick layer of gravel is placed over the subbase. The pavers are placed on top and additional gravel (preferably 2 to 5 mm) is used to fill the paver cells to the top. The pavers can be cut using either a hand or power saw to fit around obstructions and contours. Pieces that are less than half of the original size should not be used.</td>
<td><strong>Gravel pavers</strong>&lt;br&gt;may require intermittent replacement of gravel and minor grid replacement over time.</td>
<td>The prices of the pavers, which are ~20” x 20” x 2” (4 per m²) range between $2-3 per square foot. The exact price is dependent upon quantity, material and logistics.</td>
<td>Grid Technologies Inc.&lt;br&gt;Admiral Gate Tower Suite 507 221 Third Street Newport, R.I. 02840 &lt;br&gt;www.gridtech.com (401) 849-7920</td>
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**Description:** This product is comprised of ~20” x 20” x 2” square, flexible plastic grid units with small openings that can be filled with either stone or soil and grass. The cellular structure helps to retain the stone by preventing displacement while the open base enables unrestricted root growth and high levels of infiltration. The paver is constructed with 100% recycled plastic and the units are connected together with ‘T’ lugs and slots, eliminating the need for pins.

**Manufacturer:** Netlon Turf Systems. Additional information is available online at [http://www.netlon.co.uk/_turfsystems/prod-netpave50.htm](http://www.netlon.co.uk/_turfsystems/prod-netpave50.htm)
Netpave 50 Example Application - Middletown’s Soccer Field

Site Description: The Middletown soccer field parking lot was built in October 1999 and paved with Netpave 50. The soccer field is located at the intersection of Wyatt and Mitchell Lane in Middletown, Rhode Island.

Maintenance: Thomas O’Loughlin, the Public Works Director for the Parks and Recreation Department in Middletown, states that he has to periodically top off the gravel because it tends to wash out overtime. The grid has not deteriorated or failed, and overall he has been very pleased with the results.

Notes: Overall, this has been a successful application, but it does demonstrate the need to ensure that the natural drainage patterns of the site are incorporated into final design plans. According to Arthur Erhardt, the President of Grid Tech, the puddling water and deposition of fine material shown in the center of the parking lot area is due to the fact that the contractors hired to build the lot did not place the storm drain in the correct location or use the soil recommended by Grid Tech. The cars park on both sides of the lot, and as shown in the picture below, the grass continues to grow and in many areas completely covers the pavers.

Contacts:
Thomas O’Loughlin
Public Works Director
Middletown Parks and Recreation Department
(401) 846-2119
publicworks@ci.middletown.ri.us

Arthur Erhardt
President of Grid Tech
(401) 849-7920
info@gridtech.com
Netpave 50 Example Application - Coventry Center Greenway

Site Description: A one hundred foot test section of Netpave 50 was installed by contractors hired by the R.I. Department of Environmental Management (DEM) at the western end of the Coventry Center Greenway bike path in 2003. The bike path is located along the south side of Route 117 in Coventry, and the start of the test section is located just west of the Propane store located on Rte 117.

Costs: The cost of paving this section of the Coventry Center Greenway with Netpave 50 was approximately two times the cost of standard bituminous asphalt.

Notes: An in-house DEM construction crew installed a 50-foot long section of Netpave 50 at the Nicholas Farm Management Area in 2001. Lisa Lawless, an engineer at DEM, stated that the in-house crew did not construct any shoulders and that unraveling began to occur shortly after installation. Therefore, the Coventry Center Greenway test installation was built with a stabilized shoulder and has held up much better. Lisa Lawless stresses the importance of a good stabilized shoulder and adequate gravel cover. The DEM has been very pleased with the test section and is planning on paving the entire western end of the bike path, which is 2.1 miles, with the Netpave 50. The project is scheduled to go out to bid for construction in one to two years.

Contacts: Lisa Lawless, Engineer at the R.I. DEM (401) 222-2776 ext. 4312, lawless@dem.state.ri.us
<table>
<thead>
<tr>
<th>Type of Paver</th>
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<tr>
<td><strong>Netpave 25</strong></td>
<td>Intended for use on existing grass surfaces to provide a level of protection intermediate between the Netpave 50 and Turfguard. Suitable for parking lots, driveways, and paths.</td>
<td>It is able to support light traffic on firm ground, but it is not designed to compensate for weak ground conditions where more structured solutions are necessary. Load bearing is ~27,870 lbs/ft². To determine if Netpave 25 is suitable, Netlon advises people to drive a vehicle onto the area after a heavy rainfall. If it does not rut, than this product is appropriate. Product lifetime: 120 years. It has both chemical and UV resistance and is resistant to deformation and fracture, and able to conform to irregular surfaces and gradients.</td>
<td>Installation does not require substructure or excavation. It is simply laid upon the grass surface. Prior to installation, the existing grass should be cut as short as possible and depressions should be filled with a blend of sharp sand and topsoil to firm the surface. The Netpave 25 should be laid out from one edge to the opposite side with all of the lugs facing in the direction of laying. The area can be used immediately following installation, but it is preferable to let the grass become fully established before use. Maintenance includes mowing, irrigation, fertilization and seeding. Mower blades should be set high for the first 2-3 cuts. The plow blade should be either raised slightly or outfitted with a flexible rubber bottom piece to ensure that the Netpave is not lifted from the surface.</td>
<td>Maintenance includes mowing, irrigation, fertilization and seeding. Mower blades should be set high for the first 2-3 cuts. The plow blade should be either raised slightly or outfitted with a flexible rubber bottom piece to ensure that the Netpave is not lifted from the surface.</td>
<td>Pavers are ~20” x 20” x 1” (4 per m²) The prices of the pavers range between $2-3 per square foot and are dependent upon quantity, material and logistics.</td>
<td>Grid Technologies Inc. Admiral Gate Tower Suite 507 221 Third Street Newport, R.I. 02840 <a href="http://www.gridtech.com">www.gridtech.com</a> (401) 849-7920</td>
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<tr>
<td><strong>Turfguard</strong></td>
<td>Suitable for occasional access routes for light vehicles, overflow parking lots, driveways, taxiways for light aircraft, and pedestrian walkways.</td>
<td>Tensile strength: 5.8kN/m (397 lbs/ft)</td>
<td>Installation does not require a contractor or any groundbreaking. Homeowners can easily install it. To install Turfguard, unroll it and lay it flat on a grass surface that has been leveled out with a 70:30 mixture of sharp sand and topsoil. Anchor in place with Netlon pegs or staples.</td>
<td>Mower blades should be set high for the first 2-3 cuts. Occasional light rolling, irrigation and fertilization are necessary. Plow blade on casters to ensure that the Turfguard is not damaged.</td>
<td>The Turfguard is available in 30m x 2m rolls (~98 ft. x 6.6 ft) and costs about $390 a roll.</td>
<td>Grid Technologies Inc. Admiral Gate Tower Suite 507 221 Third Street Newport, R.I. 02840 <a href="http://www.gridtech.com">www.gridtech.com</a> (401) 849-7920</td>
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**Description:** This product is comprised of plastic mesh that is laid over a pre-existing grass surface. The paver is constructed with polyethylene, which is tough, flexible, long lasting and suitable for occasional access on stable ground.

**Manufacturer:** Netlon Turf Systems. Additional information is available online at [http://www.netlon.com/turfsystems/prod-turfguard.htm](http://www.netlon.com/turfsystems/prod-turfguard.htm)

Examples in the Northeast: A 2-acre overflow parking lot was constructed with Turfguard at Dorris Duke’s farm in New Jersey in the fall of 2003 and spring of 2004. For additional information contact Arthur Erhardt at Grid Tech.
<table>
<thead>
<tr>
<th>Type of Paver</th>
<th>Applications</th>
<th>Performance</th>
<th>Installation Details</th>
<th>Maintenance</th>
<th>Costs</th>
<th>Retailer</th>
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<tr>
<td><strong>Advanced Turf</strong></td>
<td>Suitable for event areas, sport playing fields, occasional use access roads,</td>
<td>This product when installed over a proper base and subbase can withstand axial</td>
<td>Installation requires a contractor. A sand:soil:Netlon mesh blend is placed over an aggregate subbase layer and seeded with grass. The thickness of the subbase is dependent upon vehicle loading and subgrade strength. It usually ranges between 4-20” with greater thickness used in cases of weak subgrade conditions or use by heavy vehicles.</td>
<td>Maintenance includes mowing, irrigation, fertilization and seeding. If the grids migrate to the surface over time, a lawn mower should be able to cut through them. A flame torch can also be used to melt them away, or the area can be top dressed and reseeded.</td>
<td>The advanced turf is $1.00 per square foot (at the surface) with 4” depth. This price does not include blending the materials into the soil or installation. The costs of the base, subbase and installation vary based on site conditions. Grid Tech provides all of the materials and labor as packages and quotes can be given following site visits.</td>
<td>Grid Technologies Inc. Admiral Gate Tower Suite 507 221 Third Street Newport, R.I. 02840 <a href="http://www.gridtech.com">www.gridtech.com</a> (401) 849-7920</td>
</tr>
</tbody>
</table>
Advanced Turf Example Application - Brown University’s Lincoln Field

Site Description: An advanced turf system was installed in Lincoln Field on Brown University’s campus in 1994. Lincoln Field, which is located off of Thayer Street in Providence, R.I., is a low-lying area that was subject to frequent flooding prior to the installation of the ATS.

Design Details: A contractor installed eight inches of the advance turf/ high sand content growing medium above properly prepared base and subbase layers. This composite design (i.e. the layer of ATS/sand mix, the subbase and base) took into account the specific conditions of the site and the anticipated use, specifically occasional vehicular traffic and numerous University events.

Maintenance: According to Patrick Vettere, the Ground Superintendent, this area requires a lot more watering than other grass areas on campus. A few grids were visible on the surface in June 2004, but these can either be cut up by a lawn mower or melted with a flame torch.

Notes: Patrick Vettere also stated that it took a while for the organic material to take hold. In hindsight, he believes that they should have probably used a little more organic material. Overall though he is very happy with how well the ATS system has worked and held up over the past ten years.

Contacts: Patrick Vettere, Brown University Ground Superintendent

Lincoln Field prior to the installation (March 1994)

Lincoln Field ten years after installation (June 2004)

ATS poking through soil
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Contributing authors: Catherine McNally (Coastal Fellows intern), Lisa DeProspo Philo, and Lorraine Joubert.

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Appendix I
**Permeable Pavers**

Permeable Pavers should be used as the primary alleyway surface throughout San Miguel. A wide variety of materials are available and at costs similar to typical asphalt. Permeable pavers work by allowing water to pass through the surface, preventing water buildup and flooding while also allowing water recharge to the groundwater.

**Water Conservation**

Throughout the alleyways in San Miguel, water conservation is encouraged to further reduce water runoff. Methods for conservation include the use of rain barrels, bioretention trenches along the roadsides, and gravel trenches. These three techniques are the primary methods suitable in the context of the alleyway system. The bioretention and gravel trenches work by allowing water to slowly drain through the soils and return to the water basin.

**Lighting**

Street lights in the alleyways should be solar-powered, dark sky lights. These lights, as displayed in the images above, direct light towards the ground, preventing night light pollution for the residences. Further, solar-powered lighting will reduce costs of running the lights but will not decrease the visibility or safety that comes with traditionally powered lights.
Appendix
Project Designs

Before and After

Cross Sections

Before and After