INTRODUCTION
Feasibility of numerous innovative technologies and alternative material applications were reviewed for possible implementation in Roadway Infrastructure Projects. Specifically, sustainable (“green”) infrastructure construction materials and water resource management practices were reviewed based on performance criteria and feasibility. Two major categories were considered:

1. **Recycled (Reused) Construction Materials** – This category generally consists of using recycled materials otherwise considered waste products as alternative construction materials. Reuse of existing materials after processing or reconditioning is also included.

2. **Low Impact Development (LID)** – This major change in design standards for stormwater systems marks a shift toward mitigating impacts to natural resources (i.e. waterways, aquifers, etc.) posed by the traditional stormwater management approach (i.e. collect, pipe and discharge). The basis of Low Impact Development (LID) practices is to mimic natural stormwater hydrology by separating impervious surfaces, diversifying vegetation (i.e. tiered canopy), treating runoff “in situ” (before contaminate concentration in a pipe network) and encouraging groundwater recharge.

Feasible recycled construction materials and LID design elements for typical roadway projects in urban and rural environments are summarized in the following pages.
**Recycled and Reused Construction Materials:**
Sustainable infrastructure construction materials consisting of recycled aggregates and alternative pavements for roadway and sidewalk construction were evaluated. Environmental benefits are based on optimizing use of recycled materials or re-use of waste products to reduce disposal to landfills or other facilities. The following alternative materials were considered (see Attachments A – D):

1. Crushed Glass (“Cullet”)
2. Recycled Concrete (as aggregate)
3. Asphalt Rubber Pavement
4. Rubber Sidewalks

**Low Impact Development (LID):**
Numerous innovative stormwater and water resource management practices have recently emerged with increased land development impacts and population density. As a result, LID practices have surfaced throughout the development industry as a sustainable means to control and improve the quality of stormwater runoff. The essence of LID is to mimic natural stormwater hydrology by treating runoff “in situ” and encouraging groundwater recharge. In practice, LID elements are typically designed using a treatment train approach combining several treatment elements in series. The stages of treatment in a typical treatment train are summarized in the line diagram below:

Note that LID design elements such as Gravel Wetlands, Wet Ponds, Biofilters, Sand Filters and Infiltration Units are most appropriate for end of pipe treatment in a treatment train used with stormwater management system retrofits, roadway corridors with available open space (e.g. vacant parcels) or for site development. LID design elements such as Hydrodynamic Separators, Water Quality Units and Modified Catch Basins are intended for pre-treatment only and are appropriate for any site or roadway corridor drainage system.

Contact Underwood Engineers for more details and fact sheets on established LID design elements. See Attachment E for a matrix summary of LID elements for urban design applications.

**Urban Roadway Corridors**
Based on the selection of innovative technologies evaluated, conceptual work plans (Attachment F) were developed to illustrate possible “green” construction materials and LID design applications for urban roadway corridors. A total of four recycled material alternatives were evaluated and determined to be feasible for urban roadway corridors. Of the thirteen LID applications evaluated the Rain Garden, Tree Filter, Porous Pavement and Porous Concrete are considered most feasible for urban roadway corridors.
The stormwater (LID) features selected for use in urban roadway corridors were evaluated based on site controls using the LID Matrix (Attachment E). Ideal locations to implement LID features are roadways with expansive green space (e.g. grass strip separating curb line and sidewalk areas), existing landscape features and streetscapes. A hybrid design application can be implemented by connecting the underdrain system for LID elements to the existing storm sewer system. This may be desirable depending on site soil conditions and existing infrastructure adjacent to the proposed LID design elements.

**Urban Infrastructure Project – Keene, New Hampshire**

Eight design alternatives are summarized in the Urban Roadway Corridor Application Summary Table on Page 5, presented graphically in the attached conceptual schematics and cross sections (Attachment F) and presented conceptually in UE Fact Sheets (available upon request).
Rural Roadway Corridors
Given the nature of rural roadway corridors and the tendency to use open drainage systems for stormwater conveyance due to available open space, typical swales have been modified to incorporate LID design principles. For this approach, the roadway cross section includes a modified swale with a drainage reservoir course to promote infiltration and treatment of stormwater contaminates from impervious surfaces directly at the source. If treatment by infiltration is not feasible due to soil or groundwater conditions, treatment by filtration can be achieved by adding a filter course consisting of an engineered soil medium. Infiltrating drainage structures may be implemented in areas where swales are not feasible due to land or other constraints in coordination with or as an alternative to the water quality swales.
## Urban Roadway Corridor Application Summary Table

<table>
<thead>
<tr>
<th>Design Element</th>
<th>Description</th>
<th>Purpose</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recycled Materials</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass Cullet</td>
<td>Crushed glass</td>
<td>Alternative unbound aggregate (i.e. structural base, drainage layer etc.)</td>
<td>• Blend with conventional construction aggregates (i.e. gravel)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Use as drainage layer for stormwater cells (e.g. rain garden)</td>
</tr>
<tr>
<td>Recycled Concrete</td>
<td>Crushed (monolithic) concrete</td>
<td>Alternative unbound aggregate (i.e. structural base)</td>
<td>• Use in roadway subbase (in place of bank run gravel)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Substitute as drainage layer for stormwater cells (e.g. rain garden)</td>
</tr>
<tr>
<td>Asphalt Rubber</td>
<td>Crumb rubber emulsified with asphalt pavement</td>
<td>Enhanced asphalt performance to lengthen pavement life (i.e. less cracking, oxidation, maintenance requirements)</td>
<td>• Apply as wearing course pavement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Treatment for worn or failed pavements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Owner maintenance application</td>
</tr>
<tr>
<td>Rubber Sidewalks</td>
<td>Modular rubber panels</td>
<td>Alternative material for sidewalk construction</td>
<td>• Sidewalk construction</td>
</tr>
<tr>
<td><strong>Low Impact Development</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rain Garden</td>
<td>Landscaped stormwater treatment cell</td>
<td>Stormwater treatment by mimicking natural plant (disbursement) and soil conditions (infiltration) with aesthetic enhancements</td>
<td>• Convert grass median (between curb and sidewalk) to rain gardens for stormwater treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Coordinate with streetscape</td>
</tr>
<tr>
<td>Tree Filter</td>
<td>Tree planter modified for stormwater treatment</td>
<td>Stormwater treatment by mimicking natural plant (disbursement) and soil conditions (infiltration) with aesthetic enhancements</td>
<td>• Combine tree installation for streetscape improvements with filter cells for stormwater treatment</td>
</tr>
<tr>
<td>Porous Concrete</td>
<td>Concrete with pervious surface and subsurface detention</td>
<td>Stormwater attenuation, filtration/infiltration, mitigation of pervious surfaces (i.e. runoff, puddling etc.)</td>
<td>• Sidewalk construction</td>
</tr>
<tr>
<td>Porous Pavement</td>
<td>Concrete with pervious surface and subsurface detention</td>
<td>Stormwater attenuation, filtration/infiltration, mitigation of pervious surfaces (i.e. runoff, puddling etc.)</td>
<td>• Roadway shoulder/parking construction</td>
</tr>
</tbody>
</table>
COST CONSIDERATIONS

**Crushed Glass Cullet:**
Typical costs for crushed glass cullet (i.e. order of magnitude) range from $50/Ton to $70/Ton not including freight charges (if hauled over long distances). Alternatively, some communities may have cullet available at the waste transfer station or landfill at no cost.

**Recycled Concrete:**
Cost information for recycled concrete is limited. Based on experience, using recycled concrete as aggregate from materials existing on the project site is cost effective for use as construction materials.

**Asphalt Rubber Pavement:**
Asphalt Rubber pavement ($120/Ton) typically costs approximately 40% more than standard asphalt pavement ($85/Ton – Summer 2011). However, increased material unit costs may be offset by reduced installation thickness to achieve the equivalent strength of traditional pavement.

**Rubber Sidewalks:**
Typical costs for material including subbase and installation are approximately $20/SF (compared to concrete sidewalks at $5/SF).

**LID – Stormwater Management:**
Costs based on treatment areas (and some square foot costs) are identified in the LID Matrix (Attachment E). Conceptual examples of cost comparisons and unit costs for feasible LID alternatives are provided in Attachment E.

FUNDING OPPORTUNITIES
Stormwater utilities are becoming a common means of generating revenue for implementation of ongoing green infrastructure improvements. Fees typically consist of a rate charge based on impervious area coverage with discounts offered for implementing green design practices (i.e. LID features) onsite. In some cases the fee structure is coordinated with zoning regulations to support community efforts for sustainable development and/or redevelopment. For example, an overlay district could be established within existing business, commercial and urban zones which would offer incentives to developers that implement sustainable, LID and/or energy efficient site and building designs. Incentives may include stormwater fee reduction and relaxed building restrictions (e.g. setback, area of coverage, height, etc.)

The Clean Water State Revolving Fund (CWSRF) administered by NHDES under Section 309 of the Clean Water Act offers low interest loans (avg. 2.1%) up to 100% of the project cost
without matching funds from the borrower. Funds for repayment of the loan can be generated from unrelated funding sources (e.g. municipal fees, licensing fees, special taxes, business revenues etc.).

Similarly, the NHDES Watershed Assistance Grant program administered by NHDES under Section 319 of the Clean Water Act offers grant funding to qualified candidates. The program supports local projects which target nonpoint source pollution that result in water quality enhancements benefitting an entire watershed area.

**CONCLUSIONS**

*Recycled Construction Materials:*
- Recycled construction materials and reuse of waste products as construction material offer benefits to the environment by reducing waste directed to landfills.
- Although technically feasible, glass cullet may be cost prohibitive depending on availability of cullet. However, access to cullet from the waste transfer station or landfill may be available in some communities.
- Recycled construction materials may offer cost savings.
- Asphalt rubber pavement offers long term cost benefits in addition to numerous performance benefits (e.g. low maintenance, extended service life, reduced material quantities).
- All four recycled construction materials (cullet, recycled concrete, asphalt rubber and rubber sidewalks) are feasible for typical roadway projects.

*Stormwater and Resource Management (LID):*
- LID practices are often comparable or less in cost than traditional stormwater treatment applications.
- LID practices offer effective treatment of stormwater pollutants and control stormwater volume (i.e. runoff).
- LID practices incorporate natural vegetation which enhance aesthetics
- LID practices are becoming standardized (e.g. revised NHDES regulations released January ‘09 include LID for stormwater treatment requirements)
- Four of the thirteen LID applications (rain garden, tree filter, porous pavement and porous concrete) evaluated are feasible for urban roadway corridor applications.

Contact Underwood Engineers to obtain additional information on available technologies including fact sheets, sample illustrations and conceptual figures.
SUMMARY OF ATTACHMENTS
A. Crushed Glass Cullet
B. Recycled Concrete
C. Asphalt Rubber
D. Rubber Sidewalks
E. LID Design Elements
F. Conceptual LID Work Plans

REFERENCES
5. UNH Stormwater Center: The University of New Hampshire, Durham, NH 03824
**Crushed Glass Cullet**
Crushed glass for use as unbound aggregate is referred to as cullet. When used as a granular backfill or pipe bedding material cullet is highly stable in wet environments and resists settling with proper compaction. Cullet typically fails to meet standardized material based specifications because the material properties (e.g. maximum dry density) differ from natural aggregate.

On behalf of the NHDOT, the US Army Corps of Engineers Cold Regions Research and Engineering Laboratory completed research and testing for frost susceptibility of glass cullet. Tests completed based on ASTM testing procedures suggest that glass aggregates have a low or negligible susceptibility to frost heave. Some traditional gravel aggregates (Perry Stream Gravel – Pittsburgh NH) were less susceptible to frost heaving when mixed with 30% glass cullet by weight.

Typical costs for crushed glass cullet (i.e. order of magnitude) range from $50/Ton to $70/Ton not including freight charges (if hauled over long distances). Price variations are largely due to the proximity of glass processing plants to established markets. A concentration of glass processing plants (and therefore established markets) exists toward the midwest (IL, MI, OH, western NY and PA). New England states (e.g. ME and CT) appear to ship their recycled glass materials out of the region. Use of glass cullet may be cost prohibitive until a local market and processing facilities are established.

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**ACTION POINT:**
The City of Keene used crushed glass cullet as a subbase for sidewalks constructed adjacent to the roundabout at the intersection of Main and Marlborough Streets in conjunction with the 2006/2007 Infrastructure Project. The cullet used in the 2006/2007 Infrastructure Project was taken from the City’s waste transfer station.
Recycled Concrete
Recycled concrete material for use as a subbase (bank run gravel equivalent) can be specified as a requirement or at the Contractor’s option. The existing concrete roadway material can be processed and use as bank run gravel in the roadway subbase. Although the material will meet the gradation requirement, meeting the 95% modified proctor density compaction requirement may be difficult if not installed properly. Compaction efforts may be improved by limiting lift thickness.

Cost information for recycled concrete is limited. Processing recycled materials existing on the project site may be cost effective for use as construction materials. Based on experience with using recycled concrete as aggregate, no direct cost benefit was observed. However, providing the option to use recycled materials may have contributed to more competitive bid pricing for unit items (i.e. bank run gravel). In the future, the bid could be structured with the recycled material identified as a bid alternative which would give a better indication of any direct cost benefits.

**ACTION POINT:**
The City of Keene’s 2009 and 2010 Infrastructure Projects incorporated recycled concrete material into the roadway subbase. The concrete material was taken from an existing concrete roadway slab within the project area.
**Asphalt Rubber**

Asphalt Rubber (AR) typically consists of a blend of liquid asphalt, approximately 20% crumb rubber (ground tires) and extender oil (optional). This mixture is typically used for road rehabilitation and maintenance practices for crack/joint sealing (i.e. chip or fog seal). When mixed with aggregate, the AR can be applied as an overlay to extend the life of existing roadways. Because of the binding capability of the AR, less material is required for an overlay (i.e. thinner lifts). AR applications provide longer service life (up to 20 years), lower maintenance requirements and increased skid resistance.

Many attempts to produce a rubber asphalt product were pursued over the last 70 years. Research and experience have proved that producing AR by the “wet process” is critical to successful projects. The fundamental element of the “wet process” is the 45 minute (minimum) contact time between the liquid asphalt and crumb rubber which allows the rubber to fully react and bond with the liquid asphalt. Because the rubber component of the AR pavement binder adds strength to the pavement mix, the fines content is often reduced and the pavement is designed and applied as an open graded friction course (or gap graded pavement). This is the same mix design used for porous pavement applications. Therefore, AR pavement offers reduced road spray and ponding during wet weather.

AR applications are currently used extensively in Arizona, California and Texas. Installations in Arizona and California offer a basis for evaluation in cold weather regions with successful AR road rehabilitation projects completed in mountain areas (7,000 foot elevations with temperatures reaching -20° F).

Installation requirements are generally similar to industry standards for pavement installation. The only proprietary equipment necessary is a “rubber plant” used to blend the crumb rubber with the asphalt at the asphalt plant. Alternatively the AR can be premixed elsewhere and delivered to the asphalt plant by tanker truck.

A comparison of capital costs (i.e. installation) suggests AR may be more expensive (between 30% and 50%) than traditional pavement applications. However, significant cost savings are realized over the long term life cycle cost, minimum maintenance requirements (i.e. less overlays and chip seals), and reduced material requirements (i.e. thinner applications of ~1/2” compared to 1” or 2” using standard pavement).

The initial unit cost for AR pavement may be higher than standard pavement. AR pavement ($115/Ton) typically costs approximately 40% more than standard asphalt pavement ($80/Ton – January ’08). However this is offset by reduced material requirements (thinner lifts/total depth) and long term maintenance free installations, which exceed standard pavement performance.
**Advantages:**
- Improved resistance to surface cracking due to high (rubberized) binder content
- Improved resistance to aging and oxidation due to high binder content
- Improved visibility due to contrast in pavement striping because oxidation is limited (i.e. pavement stays black)
- Improved resistance to pavement fatigue (failure) due to the elastic nature of rubber binder content
- Reduces thickness of pavement course ~ 50%
- Reduced road noise due to increased binder film and texture of open graded mix design
- Reduced splash and spray during wet weather
- Reduced maintenance requirements
- Reduced life cycle costs due to extended pavement life
- Provides beneficial application for waste products (i.e. tires)

**Disadvantages:**
- Higher initial cost (therefore, surface course application most common)
- Detailed specifications required to ensure correct construction practices and installation procedures
- Difficult to install by hand (i.e. hand paving at driveways or utility structures)
- Mix temperature range is limited (i.e. can’t cool off before installation)
- Limited public knowledge/awareness may present initial resistance
Rubber Sidewalks

Rubber sidewalks constructed of modular paving tiles can be configured for widths of 4, 5 and 6 feet and are offered in colors such as gray, green, blue, black etc. The paver units are rated for loadings up to 3,000 psi, are suitable for wheeled traffic and resist impact at cold temperatures. The seams between units are permeable (2 in/hr) and may provide opportunity for infiltration depending on soil type and subbase materials. The modular units (54 lbs ea.) can be removed for maintenance requirements (e.g. tree root trimming or underground utility access).

The initial installation and material costs for Rubber Sidewalks are greater than standard concrete sidewalks. Typical costs for material (including subbase) and installation are approximately $20/SF (compared to concrete sidewalks at $5/SF).
**LID Design Application Summary**

Numerous innovative stormwater and resource management practices have recently emerged with increased land development and impacts from increased population density. The major change in design standards for stormwater systems is a shift toward Low Impact Development (LID) to mitigate impacts to natural resources (i.e. waterways, aquifers, etc.) posed by the traditional approach to stormwater management (i.e. collect, pipe, (treat) and discharge). The basis of LID practices is to mimic natural stormwater hydrology by separating impervious surfaces, diversifying vegetation (i.e. tiered canopy), treating runoff “in situ” (before contaminate concentration in a pipe network) and encouraging groundwater recharge.

LID retrofits (i.e. implementing LID within existing infrastructure) often employ a hybrid design of LID treatment elements adjacent to existing drainage structures. This approach allows stormwater treatment for small or initial runoff volumes by LID features and control of excess flows by existing structures (i.e. catch basins, ponds etc.). A summary of established LID design elements and appropriate applications are identified in the attached LID Matrix.

Current research supports optimum LID performance in cold weather climates. When properly designed, LID elements function well in cold weather because the porous pavements drain any surface water before there is an opportunity to freeze on the surface. Additionally, because the drainage course (typically 3-4’ deep) often extends to the frost line, the interface with the warmer soil at the frost line keeps the void spaces from freezing. Porous pavements (asphalt/concrete) require less winter maintenance (i.e. plowing and/or salting) because any snow/ice is melted and ultimately drains into the void spaces.

A summary of established LID design elements (such as rain gardens, tree filters, porous pavement etc.) and appropriate applications are identified in the attached LID Matrix. In addition to the LID Matrix, Summary Fact Sheets for some additional LID elements identified are provided to offer a more detailed explanation of the function and performance of each application.
In general, comparison of LID features and traditional stormwater conveyance systems (i.e. storm sewers) indicate a savings in favor of the LID features. The cost savings offered by LID features is due to the limited piping costs associated with the construction of such units. Costs based on treatment areas (and some square foot costs) are identified in the LID Matrix. Some conceptual examples of cost comparisons are provided below:

Cost of Rain Garden = Cost of Landscaped Island (shrubs and bark mulch)
Porous Pavement Section = Standard Pavement Section w/ Closed Drainage
Tree Filter = $2,500 each
Porous Concrete = $7.00 per square foot
<table>
<thead>
<tr>
<th>ID</th>
<th>Component and Description</th>
<th>Typical Location</th>
<th>Space Requirement</th>
<th>Capital Cost</th>
<th>Maintenance</th>
<th>Treatment Efficiency</th>
<th>Filtration</th>
<th>Infiltration²</th>
<th>Hybrid Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Gravel Wetland - densely vegetated detention area with subsurface gravel cells connected to outfall by under drain network. Basis of treatment is filtration and anaerobic microbe activity.</td>
<td>Collection system outfall</td>
<td>High</td>
<td>$22,500/Ac treated</td>
<td>Low to none</td>
<td>High</td>
<td>TSS: 100% N: 100% P: 50%</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>B2</td>
<td>Wet Pond - vegetated detention area which maintains a standing pool of water with outlet controlled by perforated stand pipe. Basis of treatment is primarily through sedimentation with additional treatment by vegetation and microbical activity.</td>
<td>Collection system outfall</td>
<td>High</td>
<td>$13,500/Ac treated</td>
<td>Low</td>
<td>Medium High</td>
<td>TSS: 75% N: 40% P: 20%</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>B3</td>
<td>Wet Swale - vegetated conveyance swale constructed within the water table to maintain permanent saturation. Basis of treatment similar to gravel wetland (above). Treatment in warm weather only.</td>
<td>Pretreatment before outfall, detention pond retrafo</td>
<td>Medium</td>
<td>$12,000/Ac treated</td>
<td>Medium (bi-annual)</td>
<td>Medium High</td>
<td>TSS: 70% N: 40% P: 45%</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>B4</td>
<td>Dry Swale - vegetated conveyance channel with subsurface filter media (stone or permeable fill) and optional under drain. Basis of treatment is filtration.</td>
<td>Anywhere; curb cuts, parking islands, street scapes, residential areas, street islands,遍布等</td>
<td>Low - High</td>
<td>$15,500/Ac treated (or $10/5F)</td>
<td>Medium (bi-annual)</td>
<td>Medium High</td>
<td>TSS: 70% N: 40% P: 10%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>B5</td>
<td>Biofilter - densely vegetated detention area underlain by bio engineered soil and filter media with under drain network connected to standpipe outlet. Basis of treatment is biological (vegetation) and filtration.</td>
<td>Collection system outfall</td>
<td>Medium</td>
<td>$18,000/Ac treated</td>
<td>High (initial) Low (long term)</td>
<td>High</td>
<td>TSS: 100% N: 30% P: 10%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>B6</td>
<td>Sand Filter - detention area with sand filter bed (floor), under drain system and outlet structure (riser pipe). Basis of treatment is filtration.</td>
<td>Street scapes, parking islands, curb ed areas, adjacent to catch basins, sidewalks</td>
<td>Low</td>
<td>$22,000/Ac treated (52,500 ea.)</td>
<td>Low</td>
<td>High</td>
<td>TSS: 100% N: 40% P: 0%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>B7</td>
<td>Tree Filter - retrofit street tree planter consisting of concrete vault filled with bio engineered soil, under drain and overflow pipe. Basis of treatment is filtration and through tree root system.</td>
<td>Parking areas, sidewalks</td>
<td>Low</td>
<td>$4/5F</td>
<td>Low</td>
<td>High (with sand course)</td>
<td>TSS: 100% N: 100% P: 40%</td>
<td>Optional</td>
<td>Yes</td>
</tr>
<tr>
<td>B8</td>
<td>Porous Pavement - open graded friction course (i.e. asphalt pavement without fines content) underlain by stone reservoir (sand filter course optional). Basis of treatment is filtration if sand course is installed. Primary function is stormwater detention.</td>
<td>Parking areas, sidewalks</td>
<td>Low</td>
<td>$7/5F</td>
<td>Low</td>
<td>High (with sand course)</td>
<td>TSS: 100% N: 100% P: 40%</td>
<td>Optional</td>
<td>Yes</td>
</tr>
<tr>
<td>B9</td>
<td>Porous Concrete - underlain by stone reservoir (sand filter course optional). Basis of treatment is filtration if sand course is installed. Primary function is stormwater detention.</td>
<td>Street scapes, parking islands, curb ed areas, adjacent to catch basins, sidewalks</td>
<td>Low</td>
<td>$22,000/Ac treated (52,500 ea.)</td>
<td>Low</td>
<td>High</td>
<td>TSS: 100% N: 40% P: 0%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>B10</td>
<td>Hydrodynamic Separator - precast chamber (manhole) with swirl device insert to enhance particle settling to sump. Basis of treatment is sedimentation and flotation of oil/grease.</td>
<td>Pretreatment before outfall, closed drainage systems</td>
<td>Low</td>
<td>$22,000/Ac treated (52,500 ea.)</td>
<td>Low</td>
<td>High</td>
<td>TSS: 100% N: 40% P: 0%</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>B11</td>
<td>Infiltration Unit - network of subsurface plastic (HDPE) chambers filled with sand media. Typically includes pretreatment sediment chamber. Basis of treatment is filtration.</td>
<td>Collection system outfall, below parking areas or other expansive impervious surfaces</td>
<td>Medium - High</td>
<td>$50,000/Ac treated</td>
<td>High</td>
<td>High</td>
<td>TSS: 100% N: 0% P: 80%</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>B12</td>
<td>Filter Unit - subsurface vault with filter cartridges. Typically includes pretreatment swirl device. Basis of treatment is physical settling and chemical reaction (carbon media).</td>
<td>Collection system outfall</td>
<td>Medium - High</td>
<td>$31,500/Ac treated</td>
<td>High</td>
<td>Medium</td>
<td>TSS: 60% N: 0% P: 25%</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Note 1: Bio Engineered Soil consists of organic top soil blended with sand at a ratio which contains enough soil to support vegetation growth while maintaining high permeability.

Note 2: Infiltration capacity is dependant on native soil types.
The attached Conceptual Work Plans represent the evaluation and selection process pursued in order to develop the LID Pilot area for Final Design of the 2010 Infrastructure Project in Keene, New Hampshire. Construction was completed in the 2010 and 2011 construction seasons.
NOTE:
1. WATER DEPTH SHOWN (TYPICALLY 6"-12" MAX) REFLECTS CONDITIONS DURING RAIN EVENT. RAIN GARDEN IS NORMALLY DRY.
SECTION A-A

PAVED WIDTH = 50'

5' POROUS CONCRETE SIDEWALK
8' GRASS STRIP
12' PARALLEL PARKING
5' BIKE PATH
12' TRAVELED WAY
12' TRAVELED WAY
5' BIKE PATH
8' PARALLEL PARKING
7' GRASS STRIP
5' POROUS CONCRETE SIDEWALK

4" POROUS CONCRETE

24" SAND FILTER

24" STONE RESERVOIR

1" ASPHALT RUBBER PAVEMENT

CRUSHED GRAVEL

2" BASE COURSE PAVEMENT

4" CHOKER COURSE

GRAPHIC SCALE

1 INCH = 5 FEET