Recognizing Engineering Excellence

Spreading the word about best practices and projects as widely as possible ensures that these practices and projects will be emulated, and that even the envelope will be pushed.

Compiled by BRIAN BRENNER

The American Council of Engineering Companies of Massachusetts (ACEC/MA) Engineering Excellence Awards (EEA) competition recognizes firms and projects that have made outstanding contributions to the engineering profession and society through technical excellence and innovation. The competition pays tribute, not only to these exemplary projects and firms, but also to the engineering industry at large and its profound contribution to the built environment and society in general.

Process

Each entrant prepares a project notebook, which was reviewed by a panel of judges. For the 2007 awards, eleven projects completed the requirements. The judges narrowed the field to the top five entries, and after listening to oral presentations and interviewing the finalists, selected the winners of Gold Awards, the Platinum Award and the Grand Conceptor Award. These five finalists were eligible to compete in the national ACEC EEA Competition in Washington, D.C. Both written and oral presentations were evaluated based on:

- Original or innovative application of new or existing techniques;
- Future value to the engineering profession and perception by the public;
- Complexity of the project;
- Exceeding the owner's and the client's needs; and,
- Social, economic and sustainable design considerations.

The engine behind the process was the ACEC/MA EEA Committee. In 2007, Committee members included: Steve O'Neill, co-chair, Meridian Associates; Joel Goodmonson, co-chair, Architectural Engineers; Gene Bolinger, Weston & Sampson Engineers; Bruce Conklin, CDM; Peter Piattoni, FST; Tom Spearin, Metcalf & Eddy; Terry Tolosko, SEA Consultants; Colleen Moore, [then] ACEC/MA's Deputy Executive Director; and Jim Pappas of Stantec, the committee's liaison to the ACEC/MA Board.

The panel of judges was comprised of highly respected professionals from the architectural community, the construction industry, the public sector, academia and the field of communications and public relations. The judges took on the daunting task of reviewing and evaluating all of the notebooks submitted in the competition, carefully deliberating the merits of each, selecting the five finalists who made oral presentations and ultimately selecting this years' winners from a very deep and competitive field of entrants. Judges included:

- Brian Brenner, a Professor of Practice at Tufts University Department of Civil and Environmental Engineering and American Society of Civil Engineer's Chair of Committee on the Performance of Structures during Construction.
- John Carroll, the long-standing General Manager for the Town of Norwood, considered by many to be the dean of Massachusetts Town Administrators, and member of the Massachusetts Water Resources Authority Board of Directors.
- Tony Miliote, a Project Executive with Shawmut Design and Construction, a Boston-based general contracting and construction management firm.
- Daniel Perruzzi, a principal at Margulies & Associates, an award-winning architectural and interior design firm serving the corporate, real estate and institutional communities. He is also a member of the Boston Society of Architects Board of Directors.

Finalists

After reviewing all notebooks, engaging in provocative discussion and deliberating thoughtfully, the judges narrowed the field, selecting the Silver Award winners and five finalists for the Gold, Platinum and Grand Conceptor awards. On March 7, 2007, ACEC/MA honored all of the firms that participated in the competition. The Silver Award winners were:

- *Rotch Playground Rehabilitation Project*
  Presented by: CDM
  Client: Emerson College and the Boston Parks and Recreation Department
- *HDD Utility Tunnel to Peddocks Island/Fort Andrews*
  Presented by: Environmental Partners Group
  Client: The Island Alliance
- *Revitalization of the Cape Cod Rail Trail*
  Presented by: Fay Spofford & Thorndike
  Client: Massachusetts Department of Conservation and Recreation
- *Project InfoFiscal Management and Project Tracking Data Management Systems*
  Presented by: Geonetics, Inc.
  Client: Massachusetts Highway Department
- *The Jewett City Water Pollution Control Plant Replacement Project*
  Presented by: Metcalf & Eddy, Inc.
  Client: Jewett City, Connecticut, Department of Public Utilities
- *2006 MassHighway Project Development & Design Guide*
  Presented by: Vanasse Hangen Brustlin, Inc.
  Client: Massachusetts Highway Department

The five top awards were represented by three categories: Gold, Platinum and Grand Conceptor. The Gold Award winners were:

- *Runway 14-32 and Associated Taxiways at Logan International Airport*
  Presented by: HNTB Corporation
  Client: Massport
- *Creation of an Innovative Infrastructure Management System*
  Presented by: SEA Consultants, Inc.
  Client: Town of Framingham, Massachusetts, Department of Public Works
- *Providence College Fitness Center Field & Underground Parking Garage*
  Presented by: Symmes Maini & McKee Associates and JJA Sports
  Client: Providence College

The Platinum Award winner was:

- *Overhead Coverage Systems Program, Iraq*
  Presented by: Tetra Tech
  Client: U.S. Army Corps of Engineers – Transatlantic Programs Center

And the Grand Conceptor Award winner was:

- *Meadow Creek Regional Stormwater Management Plan*
  Presented by: Nitsch Engineering, Inc.
  Client: University of Virginia

These five finalists competed among over 170 projects in the national competition. In a ceremony on May 8, 2007, in Washington, D.C., the ACEC/MA Grand Conceptor Award winner — the Meadow Creek Regional Stormwater Management Plan— won an Honor Award at the national level.

Runway 14-32 & Associated Taxiways

Presented by: HNTB CORPORATION
Client: MASSPORT

For more than 84 years, Logan International Airport has been Boston's premier center for aviation and a gateway to New England. Today, Logan is the largest passenger airport in New England, the nineteenth busiest airport in the country and thirty-seventh busiest in the world. Built in 1923, Logan is New England's largest transportation center, accommodating more than 27 million passengers annually. As an origination and destination (O&D) type facility, Logan experiences significant amounts of passengers (93 percent) that either begin or end their trip there, rather than travelers looking to transfer to another aircraft. As such, to enhance the passenger's experience in Boston, it is imperative that all airport facilities remain congestion-free.

As Logan continues to function as the region's principal long-haul and international gateway hub, passenger volume is expected to significantly increase. In light of this increase and the ever-changing New England weather, improvements were needed to reduce delays by separating smaller aircraft arrival streams from larger jet arrival streams, as well as to improve aircraft taxiing operations.

In 2005, Logan was ranked the fourth highest U.S. airport in terms of aircraft arrival delays. A significant portion of Logan's delays is caused by the reduction in operational capacity during periods of strong northwest winds. In this situation, landing and departing operations are limited to one runway. On a normal day, Logan can accommodate up to 120 aircraft operations (landings and take-offs) per hour on three runways. On days with strong northwest winds, the operational capacity is reduced to 60 operations per hour. With the addition of Runway 14-32 — a 5,000-foot bituminous concrete, uni-directional runway, along with its associated taxiways — delays will be reduced by shifting the arrival of smaller aircraft to the new runway, thus correcting the operational deficiency in the runway system and rectifying inefficiencies and bottlenecks in the airfield's taxiway system.

Complexity

This project involved numerous factors that posed challenges during design and construction. Some of these factors included sophisticated construction phasing, imposed height limitations for construction equipment adjacent to three active runways, potential interference to Federal Aviation Administration (FAA) low-visibility instrument landing systems (ILS) and extensive dynamic airport security requirements.

An analysis of the runway's CFR Part 77 clear 7:1 transitional surface to the 20:1 visual approach surfaces indicated that the "7:1 transitional" surface for Runway 32 landings was penetrated by the FAA's airport surveillance radar (ASR-9) antenna located near Governor's Island.

Additional studies indicated that there was a line-of-site issue between the air traffic control tower's (ATCT) view of the proposed Taxiway J leading onto the Runway 32 end, and cargo buildings located between the ATCT and Runway 14-32. Since site grading was restricted due to existing conditions, a different solution was needed.

The FAA's low-visibility ILS consists of two primary components: a localizer antennae array and a glide slope antenna. A localizer provides aircraft with longitudinal direction (left/right of runway centerline) and a glide slope provides aircraft with vertical direction (vertical approach angle) to the runway. Each of these electronic systems has well defined "protection zones" that must remain clear of materials and equipment in order not to distort their electronic signals to the approaching aircraft.

The airport's Perimeter Road becomes a safety concern whenever the runway is open for use. A significant portion of the road is located within Runway 14-32's safety area; therefore, a warning system needed to be devised to ensure that no vehicles would traverse this portion of the Perimeter Road during those periods when Runway 14-32 is open to aircraft operation. Such an intrusion would be considered a "runway incursion" by the FAA.

During data collection efforts, it became apparent that temporary utilities incorporated into the construction of the portion of the Ted Williams Tunnel (TWT) within the proposed Runway 14-32 limit of work had not been removed after construction of the TWT.

Due to stringent grading requirements required by the FAA's Advisory Circulars (the FAA's design standards) with respect to runway and associated taxiway elevations, as well as vertical intersection requirements and the inherently flat elevations of airports in general, it was a significant challenge to capture stormwater runoff and to facilitate treatment of this runoff prior to discharge into Boston Harbor. Design efforts included consideration to minimize air, noise and light emissions and other impacts to the surrounding community.

Two taxiway routes had to be maintained to and from Runway 9-27 as well as to the low-visibility Category IIIa Runway 4R at all times. The challenge was to maintain access to both of these runways while at the same time demolishing portions of existing adjacent taxiways that served these runways. Another major challenge was the need to provide the contractor with large enough work areas to be productive while maintaining minimal or no impact to airport operations.

Original or Innovative Application of New & Existing Techniques

Runway 14-32 is the first wind-restricted unidirectional runway in the country, making it both original and innovative. In an effort to significantly reduce delays, while addressing community concerns regarding noise, air pollution and quality of life, Massport negotiated an effective solution with the FAA and Community Advisory Council. They agreed that the new runway would be used only when northwest or southeast winds reach 10 knots or greater, and for emergencies. The wind-restricted runway will increase efficiency during adverse weather conditions and help mitigate wind-related delays.

Currently, Runway 14-32 intersects at the approach of two major runways and the end of a third, one being a Category IIa low-visibility runway. By making the runway unidirectional (which is unique to New England), aircraft may only land on Runway 32, arriving over Boston Harbor, or departing on Runway 14 over Boston Harbor.

ASR-9 Obstruction to Approach Surface of Runway 32. A review of the original alignment of the new runway with respect to the imaginary approach surfaces revealed that holding the Runway 14 end in place and rotating the Runway 32 end a matter of 20 feet (±) would eliminate the ASR-9 penetration of the approach surface. This geometric re-alignment was accomplished and approved by the FAA for final design.

Line-of-Sight Conflict. After performing the line-of-sight study, the design team proposed the installation of a closed circuit television (CCTV) camera near the intersection of Taxiway J and the Runway 14 departure end. The design team presented this solution to the Technical Advisory Committee, who recommended the solution for submission to the FAA. After discussions with FAA air traffic controllers and New England Regional staff, this solution was incorporated into the design documents. FAA staff were trained on the use of the pan/tilt/zoom operational parameters of this CCTV camera and agreed to its use.

FAA ILS Equipment Protection. Construction was phased using scheduled runway shutdowns and taking advantage of favorable wind conditions in the field, which enabled the contractor to perform its desired work with no signal degradation to the arriving aircraft. The existing Runway 27 localizer originally in the area of the proposed relocated Taxiway B safety area (TSA) was relocated and upgraded to a MARK 10 14-element antennae array. Additionally, the Runway 22L localizer antennae array equipment was relocated outside of Runway 14-32's 400-foot-wide safety area also in order to meet FAA NAVAID siting requirements.

New Utility Conflicts With Ted Williams Tunnel Temporary Utilities. Although some of the conflicts were discovered during the data collection stage, the majority of these conflicts were not identified until contractor personnel attempted to install new utilities near the underground TWT site area. In order to expedite solutions to this problem, a continuous survey watchdog service was provided that allowed work crews to continue installations in a timely manner. One such conflict was resolved by insulating an existing water supply line that, due to the new grading requirements, would end up above the local frost line. This solution eliminated the need to intercept the water supply to a large portion of Harborside Drive, to lay down a new water line below the frost line and saved construction costs and time.

Perimeter Roads Penetration of the Runway 14-32 Safety Area (RSA) While Runway Active. In order to comply with FAA regulations to remain clear of the RSA whenever the runway is active, a sophisticated system of visual warning signals was developed to warn all vehicles approaching the RSA. Through research and discussions with air traffic controllers, airport operations staff and various equipment suppliers, it was determined that the strategic siting of variable message signs (VMS) would greatly improve the ability of the airport to eliminate the potential for runway incursions. When the runway is active, Massport operations staff will clear the Perimeter Road of all men and equipment and contact their staff in the ATCT Operations Center. Once declared open, the VMS displays a message that Runway 14-32 is open and that no traffic is to pass by the VMS site. Additional safety initiatives were incorporated such as installing runway guard lights (alternately flashing red lights facing oncoming vehicular traffic with adjacent "hard panel" signs with the same pronouncement as the VMS). At strategic points prior to the actual points of potential incursion, additional strobe lights, runway guard lights and signs were installed to prevent traffic from even entering the Vehicle Service Road leading to the Perimeter Road. It is believed that this type of incursion prevention system is the first such system in use in the country.

Stormwater Treatment Solutions. The FAA's grading requirements made it impossible to install standard closed-system collection systems in various locations within the project site, particularly in the vicinity of the Perimeter Road. Sand filter trenches were installed along much of this road in order to intercept runoff prior to overland flow over the paved surfaces into the harbor. This system included a perforated pipe collection system underlying a stone filled intrusion surface. The design also incorporated the use of low-flow water quality devices at strategic locations that increased the amount of airport runoff that receives treatment. These devices provide for a first flush treatment of runoff and achieve a high degree of removal and storage of the first flush of suspended solids and flotables.

Noise Impacts. Noise impacts depend not only on the number of arriving and departing aircraft, but also on the flight paths that aircraft follow. With the addition of Runway 14-32, additional flight paths are created with arrivals to Runway 32 coming from the harbor over water, while departures from Runway 14 turn to climb out over the water. Runway 14-32 will shift approximately 25,000 flights annually from over land to over water, avoiding the use of airspace over the residential area known as Jeffries Point in East Boston. The addition of this unidirectional runway will reduce noise impacts for the most severely affected populations in East Boston, South Boston, Revere and Winthrop. Additionally, noise mitigation measures were incorporated into the contract documents. Items such as restricting the contractor to the use of updated Central

Artery/Tunnel-approved noise mitigated equipment and prohibiting "tail gate slamming" were major requirements in this area.

Air Quality. In past years, runway delays have not only become an inconvenience to the traveling public, but also increased air pollution. Implementation of this runway and associated taxiways will reduce emissions and improve ambient air quality by reducing delays. These benefits reflect improved airfield efficiency and shorter delay periods. By directing flights over Boston Harbor rather than the city, this project also reduces smog by letting planes land immediately rather than circle the airport waiting for a landing slot.

Light Emissions. By restricting the direction of temporary lighting plants used during off-peak hour construction, the work was accomplished without any light emission complaints from the nearby communities or pilots.

Traffic Mitigation. To minimize truck traffic impacts, construction vehicles accessed the airport on designated haul routes via the TWT or Route 1A to avoid impacting local residential streets. No traffic complaints were received in nearly two years of construction.

Safety During Construction. The construction of Runway 14-32 was the first project constructed at Logan using the International Civil Aviation Organization's (ICAO) "Engine Out" Takeoff Surfaces. These height restrictions for objects, including construction equipment, are much more demanding than the FAA's imaginary and approach surfaces. In order to comply with this requirement, ICAO surface diagrams were developed for project-affected runways. In turn, these diagrams were used by the engineering consultant, contractor and Massport's operations staff to determine height limitations based on their location on the work site. The charts were also used by the operations department as a reference to base their decisions on whether the work could proceed in certain areas of the project that day.

Sophisticated Phasing. Due to the critical nature and safety issues involved with airside construction, construction during off-peak hours was incorporated into the design. Work requiring the closure of existing runways required that the contractor work either on a consecutive 24-hour basis until completion or perform work on a nightly basis from 11:00 P.M. to 6:00 A.M. The actual staged construction phasing required multiple phases to be completed in an orderly fashion in order to meet the operational parameters required of the project. In order to maintain taxiing access to Runways 27 and 4R at all times, a portion of the new Runway 14-32 was completed and then temporarily converted into temporary Taxiway B. This move allowed construction of a new relocated Taxiway B, which provided a continuous second access to both Runway 9-27 and Runway 4R-22L. Once the aircraft were using temporary Taxiway B, the contactor had access to demolish and relocate the original Taxiway B. Similar hopscotch-type work area shifts allowed the work to progress with no delays to the airport's operations.

Cost-Saving Measures. To decrease costs, instead of building a full parallel taxiway, a turnaround was designed at the end of Runway 32 allowing aborted departures from Runway 14 to turn around and return to the terminal or hangar facilities. As work progressed, the contractor ran into better than expected sub-grade materials. To take advantage of the unforeseen site conditions, a directive was issued for the contractor to change the excavation and earthwork operations and leave this material in place. The pavement section was revised from a 39-inch pavement box section to a 30-inch box section, thus saving importation of 9 inches of P-154 aggregate sub-base course (gravel) over a large portion of the runway area, resulting in a significant savings to the project

Technical Value to the Engineering Profession

Delays at Logan primarily result from two causes. One of these causes is due to the number and alignment of Logan's runways. The airport has five runways, of which four are capable of handling large aircraft. Of those four, only three may be used concurrently. In good weather, this runway configuration has a capacity of approximately 120 flight operations per hour. However, during times of strong northwest winds, which occur approximately one-third of the time at Logan, the number of operational runways is often reduced to two, and sometimes one, runway, resulting in a dramatic reduction in the airport's operational capacity from 120 to as few as 60 operations per hour. This reduction in capacity is one reason for the increasing number of delays. The addition of Runway 14-32 will help to alleviate the problem and represents an effective solution that may be applied at other airports across the country. The unidirectional Runway 14-32 is 5,000 feet ong by 100 feet wide, with 35-foot paved shoulders and additional paved safety areas at each end. This runway will help alleviate the reduction in operational capacity during adverse weather conditions and help mitigate weather-related delays. The runway will not increase airport capacity as its use is restricted by both runway length and environmental mandate, but its use during periods of strong northwest winds will help reduce delays not only at Logan but also nationwide, since a delayed flight at Logan typically causes chain-reaction delays to all connecting airports.

The second cause of delays at Logan is due to FAA regulations stating that there needs to be a greater distance between large and small aircraft during take-off and landing. With strong northwest winds, however, smaller aircraft are often forced to share the only available runway with larger aircraft, which increases delays. Runway 14-32 will allow air traffic controllers to separate these large and small aircraft from the approach streams to Logan during northwesterly winds. The smaller aircraft will land on Runway 32, while larger aircraft will land on Runway 33L. This configuration will significantly alleviate delays by separating the aircraft streams. Without Runway 14-32, Logan would have relied more heavily on the north-south runways, creating an unfair burden on the communities affected by this runway configuration. By providing an alternative and a solution to Logan, as well as other airports struggling with the same problems (insufficient operational efficiency, airfield safety, delays, growth in aviation activity), this project adds technical value to the engineering profession.

Social & Economic Considerations

Handling more than 27 million passengers annually and supporting more than 100,000 jobs, Logan plays a critical role by contributing more than $7 billion to New England's economy. Yet, to prevent costly flight delays, capacity issues at the airport needed to be addressed. In past years, commercial aviation delays have resulted in more than $9 billion in negative economic effects on the U.S. economy and have cost commercial airlines more than $3 billion. Studies on the impact of civil aviation have also shown that if there were no new investments in airport construction or in the air traffic system, delays could potentially cost the economy $13.5 billion in 2007 and $17.2 billion in 2012. By improving airside operating conditions, the amount of time that aircraft are delayed in the air and on the ground will be reduced. These improvements to Logan will also reduce air emissions from aircraft into the community environment.

Public Opinion

Throughout this process special efforts were also made to include the surrounding community and increase public participation. As part of the public outreach, technical assistance was given to the Community Advisory Council. Numerous community meetings took place to address the concerns of neighboring communities and to achieve consensus as to the restrictions for the new runway. These restrictions include:

- Arrivals to Runway 32 and departures from Runway 14 only;
- Wind restrictions of 10 knots or greater;
- Wind has to be within 275 degrees to 005 degrees for Runway 32 arrivals; and
- Wind has to be within 095 degrees to 185 degrees for Runway 14 departures.

Design of the runway portion of the assignment was completed in September 2004 and bid results ($45M) came in approximately 10 percent under the engineer's estimate. Construction commenced in March 2005 and current cost closeout projections indicate that Runway 14-32 will come in under the authorized budget. Runway 14-32 now has the ability to reduce delays up to 90 percent on northwest wind days, 45 to 55 percent in good weather and 20 to 30 percent annually. It will now also allow 75,000 flights per year (more than double the number today) to take off and land over the water. The benefits to the airport and surrounding community include:

- Reduction of overall delays by up to 30 percent;
- Directing more than 75,000 flights a year over Boston Harbor and away from Boston-area neighborhoods;
- Greater in-air and on-ground flexibility to air traffic controllers;
- Improvement in air quality as aircraft will spend less time idling on taxiways and circling overhead; and,
- Reduction of noise pollution for surrounding communities

Creation of an Innovative Infrastructure Management System for the Town of Framingham

Presented by: SEA CONSULTANTS, INC.
Client: TOWN OF FRAMINGHAM, MASSACHUSETTS, DEPARTMENT OF PUBLIC WORKS

A geographic information system (GIS) and a risk assessment system were developed for the Town of Framingham's Department of Public Works to prepare a town-wide Comprehensive Wastewater Management Plan (CWMP) to evaluate the town's aging sewerage system. Major tasks included GIS mapping and inventory of the entire sewer system; conditional assessment of 230 miles of sewers and fifty pumping stations; hydraulic modeling; preparation of a prioritized capital improvement plan (CIP); and development of a Work Order Management System.

As documented in the *International Infrastructure Management Manual* (published by a consortium of public and private organizations in Australia and New Zealand), risk management is utilized in the field of infrastructure asset management because it provides the context to save money by strategically identifying and prioritizing work activity and capital projects. The challenge of risk management for sanitary sewer systems is that no standardized method exists to assess risk. Therefore, to realize the benefits of risk management, this project required innovation to develop an intuitive, usable and repeatable method to assess risk in a manner consistent with its definition in the emerging field of infrastructure asset management. Since most authoritative publications in the field define risk as the product of the consequence of failure and the probability of failure, the project team based the risk assessment methodology on this principle. Consequences of failure are normally defined in a manner that reflects the values of the community and stakeholders. Examples of consequences include environmental damage, health and safety, and disruption to the community. Probability of failure can be measured for a number of failure modes including condition, age, capacity, efficiency, inflow/infiltration (I/I) and sulfide levels in a sewer system. To thoroughly assess risk with consideration to all these variables, the asset management software was configured to identify the consequences, assign weights and ratings, and establish a matrix of consequences and failure probabilities to produce a utility risk factor (URF) for each pipe, structure and pump station within the town's wastewater system. With these features built in, the software allows the user to analyze the sewer system against any of the variables that contribute to the URF as well as the overall URF score. Results of the analysis can then be viewed on a GIS map, used in reports and/or used in the software's capital planning module to formulate budgets and prioritize when and where investments should take place.

Future Value to the Engineering Profession & Perception by the Public

Over the past century, the United States and other developed countries have made substantial investments in wastewater collection systems that have had fundamental benefits to the health and welfare of modern society. Today, however, the country faces a challenge to sustain its aging infrastructure. According to the American Water Works Association, U.S. water and wastewater systems are entering a replacement era that calls for different management techniques focused on sustaining the level of service these systems provide. The transportation industry has been dealing with similar issues for the past thirty or more years and has formulated universal standards for pavement management and bridge ratings that can be used to quantify and rate the severity of deterioration. Because of these standardized techniques, the transportation industry is able to quantify and compare the needs across the country with a uniformed approach. In comparison, the wastewater industry has only recently started to create similar methods and remains a long way from standardization.

The methodologies developed for this project may be used as a major step toward bringing standardized methods to the industry using a holistic approach that considers multiple failure modes within a framework of accepted practices of asset management. Moving toward standardization is crucial for the engineering profession since it will allow faster determination of needs and will eliminate the time-consuming process of developing new methodologies. The public stands to benefit by knowing how their system compares with others. Standardization will also enable the use of information and fee structures so that the public can better determine how well their system is being managed. Even without standardization, the residents of Framingham will benefit from this program because they now have the tools to benchmark their system over time and to see that their user fees are being put to use strategically in a way that would not have been possible without this program in place.

Complexity of the Project

The goal of this project was to develop a prioritized CIP for the entirety of Framingham's wastewater collection system. The system had received only a few upgrades over the last twenty years, and substantial reinvestment was required to return the system to an acceptable level of service. This reinvestment needed to be focused and prioritized on the most "critical and urgent needs" of the system. The CIP also needed to prioritize improvements based on ways in which the system "fails" and not solely on the age of assets. Among the ways that the wastewater collection system can fail are: excessive infiltration and inflow, high sulfide, inadequate capacity, age and inefficiency. In addition, other factors associated with each asset — such as location, use, safety, cost and regulatory compliance — needed to be factored into the CIP since they affect the consequence of failure. Prioritization would determine, for example, that an old and leaky 8-inch side street lateral sewer is in less need of rehabilitation than a thirty-year-old interceptor passing through a critical intersection with insufficient hydraulic capacity and elevated sulfide.

This project took the probability of failure (capacity, I/I, sulfide, condition, efficiency and age) and factored them against the consequence of failure (environmental impact, health and safety, cost to operate, cost to repair, loss of service, property damage, public relations, regulatory impact and disruption to community). The product of these two factors results in a URF score. This score was used to assist in developing the CIP, which encompassed over 20,000 different assets in the sewer system alone.

This project was complicated by several additional factors. The tools developed to assist in the analysis had to take into account that the various assets provide very different functions in the collection system and are of different life spans and construction/rehabilitation methods. The types of assets analyzed included all types of sewer infrastructure: gravity sewers and manholes as well as force mains, siphons and pumping stations. All of these assets require different types of analyses, but with over 225 miles of sewer pipe and fifty pumping stations, the overall program needed to effectively compare these diverse assets to develop a single prioritized CIP. The project included the flexibility to expand the analysis to other types of assets. The tools created for this project provide the ability to assess other types of infrastructure within the community, including: water distribution systems, storm drain systems and roadway networks in order to develop a comprehensive town-wide CIP.

Lastly, as with most large comprehensive plans, the project needed to satisfy many different stakeholders. The unique difference was that the CIP developed from this tool acknowledges the requirements of the regulatory agencies: the Massachusetts Department of Environmental Protection (MADEP) and its monitoring of sewer system overflows (SSOs); the Massachusetts Water Resource Authority (MWRA) and its focus on sulfide; the planning, development and desire for smart growth and multi-use development; the need to manage the costs of a large-scale CIP; and the desire to protect open space. The formulation of the analyses tools took these factors into consideration in the development of the CIP without giving preferential attention to any single group. The analytical data generated by the asset management system took all of these factors into consideration and provided the fact-based, real-time information on which the strategic and focused CIP was based.

Exceeding Client's/Owner's Needs

The Town of Framingham's vision for this project was to transform its old, out-dated paper plan system to an electronically-based, web-enabled updatable program for its sewerage system. The town's expectations have been far exceeded by the creation of this specific asset management application. With the successful development of this tool for the municipal wastewater collection system, the town decided to expand its use to the water and stormsewer systems. The town has also seen extended use in its Department of Public Works (DPW), where field personnel routinely use the software in their daily operations. Managers, operation personnel, GIS and information technology departments are also now fully dependent on the use of the asset management system. Even the town's Financial Department (where its GASB 34 system is being set up using VUEWorks) depends on it. Now, the town's annual report can be done automatically as opposed to its current more labor-intensive manual method.

This powerful planning and management tool is vital in helping the town's DPW better manage and maintain a very large municipal infrastructure system — one of the leading challenges in many cities and towns throughout the United States. This efficiency and improved effectiveness has translated into tangible savings to the town in terms of time, dollars and labor.

Social, Economic & Sustainable Design Considerations

Wastewater collection systems are fundamental to the social and economic health and welfare of modern society. But, as these systems age and the population grows, this fundamental infrastructure is becoming increasingly vulnerable and, if left alone, could threaten our modern lifestyle. At the same time, the amount of federal money available for maintaining these systems has declined substantially, leaving utilities and local governments with a greater responsibility to sustain these systems through water fees and local taxes. *Sustain* is the key word since it implies that the system must be able to maintain a target "level of service" as determined by a number of factors, including: the number of sewer overflows per year; the number of inspections required; how inspections are performed (video, visual, etc.); length of pipe cleaned; condition ratings or URF score; capacity limits; sulfide limits; I/I limits; pump station costs; the number of unscheduled maintenance calls; regulatory compliance; the number of customer complaints; and more. The asset management program placed in Framingham is designed to track all of these factors so that progress can be measured against targeted levels of service. The risk assessment measures provide the means to weigh social and economic considerations such as health and safety, cost to operate and environmental impact — each of which carries value to modern society. To address sustainability, the software's multi-year budget planning features are used to forecast the amount of capital expenditures required to achieve target goals. The town utilizes this information to forecast revenue needs with enough time to prepare customers for fee adjustments, implement them over time and provide information to explain how the fee structure is required for sustainability (thereby increasing the likelihood of customer understanding and support). The GIS-based VUEWorks application also helps garner public support by illustrating areas of need on a map of the town.

Providence College Fitness Center Field & Underground Parking Garage

Presented by: SYMMES MAINI & MCKEE ASSOCIATES & JJA SPORTS
Client: PROVIDENCE COLLEGE

With a land-locked urban campus and significant site constraints, Providence College urgently needed creative engineering solutions to build new athletic fields to meet demand associated with fast-growing intramural and Title 9 women's athletic programs. One of the only available sites was at a small hillside parking lot site, burdened by sharply sloping terrain, unsuitable soils and layers of underground utilities. The design solution combined half the new field atop the parking structure and half installed at grade. Opened in May 2005, this solution is the first successful project of its kind in the United States.

The design consisted of a multipurpose, synthetic turf sports field constructed partially over an on-grade condition and partially over the structured parking level. This solution required a complex structural system above the parking structure, plus an innovative, subsurface design for the field to ensure a stable, low-maintenance, long-life and cost-efficient combined facility. The key accomplishment was the design: a synthetic playing surface and all-underground support systems to create equal field performance on both the at-grade and above-deck sides. The solution involves a subsurface "transition zone" to overcome drainage, waterproofing and stability problems. Because the existing parking lot had to remain in use until the end of the spring semester, construction had to occur within a short four- to five-month schedule, further challenging the design team. Innovations included the development of structural framing and foundation systems, which responded to both environments, while at the same time preventing minor differential settlement that could potentially bring the field out of compliance with both National Collegiate Athletic Association (NCAA) and International Hockey Federation (FIH) rules.

Future Value to the Engineering Profession & Perception by the Public

The solution of an artificial turf field half on grade and half on structure is the first successful project of its kind in the United States. The details for the field system, including the multiple drainage systems at both the structure over the parking and on grade (as well as within the transition system between the two conditions), will serve as a model for similar projects in the future.

The precast form system, although conventional, provides a recent successful solution for projects in which a custom design to solve durability, erection speed and appearance issues are critical to success.

Complexity of Project

Field hockey synthetic turf fields are regulated by NCAA and FIH standards, which require that competition fields maintain a level of planarity and meet strict requirements for drainage and porosity through the field system. Inconsistent subsurface conditions ranging from well-drained soils, to highly frost-susceptible soils, to the hard concrete slab surface over the parking level, created an immense challenge to develop systems that would provide consistent subsurface moisture conditions.

Field on Grade. In order to create a consistent subsurface condition and avoid zones of frost heave, a membrane liner system was designed with a system of low-profile panel drains installed in a herring-bone pattern across the on grade field. This system was tied into a collector drain system around the perimeter of the field. A layer of specially designed "dynamic stone" (developed for its permeability and ability to be graded to a tolerance of ± 0.125 inches over a 10-foot straight edge), was placed on top of the drainage layer and provided the base for an elastic layer shock pad and the turf surface.

Field on Structure. In order to provide drainage consistent with the on-grade portion of the field, the concrete surface of the structured level was constructed with compound slopes to interior drains. The slopes had to be closely coordinated with the field surface to maintain consistency with the depth of dynamic stone material on top of the slab. In addition, an impermeable liner and a unique system of low-profile panel drains installed in a crisscross pattern ensured consistent drainage.

Transition Zone. The transition between the structured and on-grade portions of the field was critical. A hinged slab, fixed at one end on the edge of the structured slab and floating on grade at the other end, was the key component to the transition. A subsurface drainage system utilizing components from both the structured and on-grade systems was installed on top of the slab, and a zone of well-drained material tied into a collector drain was installed below the slab.

Surface Drainage. In addition to the subsurface drainage system, the top surface of the field was sloped at a rate of 0.0625 inches per foot to a perimeter trench drain system to provide the required surface drainage.

Structural System Over the Parking Structure. In addition to being strong, stiff (to minimize deflections), economical and durable, the framing also had to be able to be constructed quickly to meet the fast-track construction schedule. A framing system was developed that consisted of structural steel beams supporting a concrete slab cast on 2.5-inch-deep precast concrete forms that were incorporated into the slab. This arrangement resulted in a surface at the underside of the slab that was not only extremely durable but also far more attractive than conventional slab-forming systems.

Site Complexity. The project site was severely limited both horizontally and vertically by existing conditions. The field was wedged between two buildings along the long axis of the field and there was the additional challenge to provide spectator seating along one side of the field. In addition, it was critical that the elevation of the playing surface be low enough to be compatible with the adjacent buildings, while at the same time the parking level had to be high enough to clear existing underground utilities that could not be relocated. When all of the minimum required clearances for fire lanes, NCAA and FIH field requirements, and ADA access were considered, there was a tolerance of only 3 inches between the existing buildings and approximately 8 inches vertically in which to construct the field. This tight tolerance resulted in the need to underpin adjacent building foundations and in one location (adjacent to an indoor pool) provide an elaborate earth retention system that consisted of a unique system of soil anchors supporting a reinforced gunite/shotcrete liner installed in increments along the face of a deep sloped (4:1) excavation.

Exceeding Client/Owner Needs

High Field Utilization. Instead of the traditional twenty hours per week of use from a traditional grass field, the synthetic field at Providence can provide sixty hours of field use due to lower maintenance/recovery time and an all-weather playing surface.

Land Utilization. By successfully combining the parking and the athletic field into one site, the program's land footprint was only 2 acres. Separate facilities would have required 5 to 7 acres on this land-starved campus.

Parking Increase & Containment. The engineering solution at Providence College increased parking spaces from 100 to 110. The inclusion of these spaces helped preserve other open space for future buildings or for leisure/green space on the campus.

Social, Economic & Sustainable Design Considerations

Sustainability. The project design made significant use of highly recyclable materials such as concrete, steel and the shock-absorbing layer in the field. The synthetic field reduces water consumption by 800,000 gallons per year through reduced irrigation, while keeping fertilizers and pesticides needed on traditional turf out of the stormwater collection and municipal sewer systems. Rain water passing through the drainage system below the field is captured and reused for lawn irrigation elsewhere on campus.

Reduced Maintenance Costs. The field required only 25 percent of the labor and materials cost of a traditional field, a 75 percent savings in annual maintenance for the college.

New Public Space. The project has created a green space and state-of-the-art facility that can be used by all members of the campus community. The field meets the client's institutional campus image goals, strengthening student recruitment and retention.

Overhead Coverage System Project, Iraq

Presented by: TETRA TECH
Client: U.S. ARMY CORPS OF ENGINEERS – TRANSATLANTIC PROGRAMS CENTER

As a result of random and deadly terrorist attacks on U.S. bases in Iraq, the U.S. military faced the task of how to establish safe facilities for its troops as quickly and efficiently as possible in that war-torn country. As part of improving its protective posture, one of the military's focuses has been the enhancement of high-density locations requiring protection from indirect fire attack in Iraq.

To solve the problem of how best to retrofit existing facilities in Iraq to protect troops against attack, the military engaged subject matter experts from the U.S. Army Corps of Engineers' (USACE) Engineer Research and Development Center (ERDC) and from the USACE Protective Design Center (PDC). A solution was required that would provide cost-effective and expedient protection and that could be implemented with no or minimal impact to the operation of existing facilities.

After much collaboration between the ERDC and the PDC, a solution was developed, tested and validated. On behalf of the Gulf Region Division in Iraq, the USACE Transatlantic Programs Center (TAC) subsequently initiated the construction project. Known as the Overhead Coverage System Project, the project was to include the design and construction of protective structures at multiple facilities in Iraq.

Original or Innovative Application of New or Existing Techniques

In general, the approach developed by the ERDC and the PDC required that a multi-layered protective system be constructed over existing facilities. The system, based on innovative uses of commercially available materials, was developed to intercept and mitigate incoming munitions. No as-built documentation existed for any of the facilities to be protected.

The overall design for the protective cover included a superstructure that generally consisted of a steel frame with the primary members (columns and roof beams) made up of welded tapered plate sections with rigid joint connections. The secondary members supported by the roof beams were cold-formed Z channels. The overall structures were founded on reinforced concrete spread footings or continuous footings depending on the individual structure and site geotechnical conditions. In addition to the blast live load to simulate weapons effects, the design also addressed the issue of how to prevent the progressive collapse of these structures. It was important to ensure that the overhead cover structure itself did not become an even larger threat to the inhabitants of the facility. This design was based on the requirements of the *United Facilities Criteria (UFC) Manual 4-023-03*, which was developed by the PDC. Failure was not an option in this fast-track project.

Future Value to Engineering

Sharing Technology & Know-How. The Iraq Overhead Coverage System Project is unique and could provide a model for retrofitting other existing structures for force protection. A properly designed overhead cover, combined with sidewall protection using simple t-barriers, can allow for enhancing the force protection qualities of a facility in a short period of time and can be applied anywhere in the world.

Demonstrating the Value of Design/Build. This project involved providing overhead protective structures for more than fifty facilities at multiple installations in a very aggressive timeframe. Most of these facilities have been completed and are already in use by the military with the remaining facilities to be completed within a few months. The success of this project demonstrates the value of design/build for this type of time-critical project. For example, the lead design engineer prepared separate design packages for the utilities and equipment relocation that needed to be performed before excavation could begin. This package was followed by a separate foundation package that allowed field work to begin at the earliest possible time. A third package was then provided that included the structure and all associated building components. At the end, an integrated 100 percent design package was provided to pull all of the pieces together, often after the structure was already partially constructed. Without the ability to use a design/build fast-track approach and perform the design and construction concurrently, the aggressive schedules could never have been achieved.

Creating a Model for Future Work in Iraq & Other Parts of the World. By demonstrating the success of a project such as this one, a model was created for retrofitting other existing structures for force protection in Iraq or in other parts of the world. This project has saved the military time and money and, most importantly, has contributed to saving lives.

Complexity of Project

The project was very complex due to the unique challenges it presented. Coordination was required with multiple government agencies. Significant logistical and technical obstacles had to be dealt with. Site survey and geotechnical investigations had to be conducted in remote and hostile environments.

Need for Coordination Among All Parties. The concept for constructing these facilities had never been implemented before. Therefore, it required intense and careful coordination at every step along the way. In addition to demonstrating compliance with the International Building Code (IBC), the documentation had to allow the ERDC and the PDC to confirm that the designs were fully compliant with the force protection criteria and models.

Significant Logistical & Technical Challenges. The initial data-gathering effort required multiple teams, each working 12 hours per day, 7 days per week in extremely hot weather and in remote and hostile areas. In some cases, the team performed field work 24 hours a day. Hot weather concreting measures were often required when daytime temperatures exceeded 110°F. Many of the overhead covers were provided at remote locations where safety was always of utmost concern. Because of the project's location on the other side of the world, team members sometimes found it difficult to exchange information about how the project was proceeding. Safety and security were always issues, often making it difficult to expedite construction. Given the unique nature of the new structures, the applicability of many code and guide document requirements were unclear and, in some cases, not applicable to the design. These issues had to be identified and agreement reached with all parties regarding how these issues were to be addressed. Even though the structures were large enough to be considered substantial in typical applications, they were unoccupied retrofits built to cover existing structures. This condition, and its bearing on the project, had to be addressed and concurrence reached and factored into the design.

In all cases, the protective facilities had to be constructed over and around an existing structure. To minimize cost, the new structure was constructed as close as possible to the existing structure. This construction method resulted in critical interface issues between existing and new structures and footings. Designs, while first-of-a-kind structures, had to utilize simple materials and construction techniques. Due to the long-term hostilities in Iraq, construction materials, skilled labor and special construction equipment were very limited and in many cases nonexistent. The designs had to always be based on using easy-to-obtain materials, semiskilled labor and simple equipment.

Exceeding Client/Owner Needs

Construction of the first overhead cover began in January 2006, less than ninety days after notice to proceed. All facilities remained in operation during the execution of the work. Careful coordination was required at every step. The close relationship between all parties that developed during the duration of the project ensured its success.

The contract schedule required all facilities to be completed by March 1, 2007. Many of the structures were delivered ahead of the original completion schedule. Most of the structures are completed and in use by the U.S. Army, with additional structures being completed weekly.

Social, Economic & Sustainable Considerations

The Overhead Coverage System Project is providing vital protection for U.S. personnel in Iraq. The protective structures are safeguarding the troops every day by assisting to ensure that they remain safe from attacks. The structures enable the troops to go about their mission in Iraq with an additional measure of safety. In this sense, they are an important step toward securing peace and promoting nation-building in Iraq. Also, they provide an important model that can be used for retrofitting more structures for force protection in other dangerous areas. This project demonstrated how the government and the private sector can work together to achieve what initially appeared to be an almost impossible task. The positive collaboration and teamwork achieved by the TAC, ERDC, PDC, contractor and Tetra Tech was a small but important component of support to U.S. forces.

University of Virginia Meadow Creek Regional Stormwater Management Plan

Presented by: NITSCH ENGINEERING, INC.
Client: UNIVERSITY OF VIRGINIA

The University of Virginia (UVA) faced stormwater problems. Rather than managing stormwater at each building, which was inefficient and costly, a first-of-its-kind regional stormwater management plan was developed using natural systems such as created wetlands, daylighted streams and feature ponds. Water quality was improved, stormwater flow from campus has been reduced and beautiful amenities were added.

The Regional Stormwater Management Plan (SWMP) was prepared to develop workable solutions to address hydrologic and water quality issues, and to relieve the stressed stream condition of Meadow Creek, while allowing the capacity for numerous new campus projects in the watershed area. UVA needed effective regional stormwater management combined with easy stormwater management facility maintenance to enable academic and residential development in support of the university's mission. Watershed modeling and analyses of existing and proposed build-out developments were conducted, and based on these models and analyses mitigation solutions were designed for three regional facilities. Successful completion of

The Dell at the University of Virginia. (Courtesy of Nelson Byrd Woltz Landscape Architects.)

these projects prepared the watershed for future development.

Stormwater management issues for UVA's Meadow Creek posed serious problems. During peak storms, the overloaded Meadow Creek would overtop its banks. Stormwater quantity and quality flowing from the 1,350-acre campus via Meadow Creek to the Rivanna River and Chesapeake Bay created serious downstream issues. Addressing stormwater issues on a building-by-building basis was not cost-effective, and required costly and time-consuming ongoing maintenance. All these issues would be compounded by the impacts of planned future development of projects in a $700-million capital program. Finding a campus-wide solution was essential for UVA.

The regional solution avoided reliance on traditional engineering solutions; instead, it took advantage of the retention and treatment capacities of natural systems. The result was a low-impact, natural approach to campus-wide stormwater management. Existing streams that were piped underground in culverts are now daylighted, creating beautiful campus amenities. Biofiltration areas featuring natural plants along the streams were developed for pretreatment of stormwater. The use of biomimicry allows sediments to settle and be dispersed throughout the natural systems. The sediment dispersion facilitates bioaccumulation (the natural process where plants absorb nutrients like phosphorus, the major pollutant in the project watershed). Oil and grease, which had previously flowed downstream via the piped stream, are now emulsified by the plant stems and broken down by sunlight.

The regional stormwater mitigation solutions in separate reaches of the watershed — the Dell, the Athletic Precinct Garage site, and the Arena site — restored vital sections of the Meadow Creek watershed and allowed for future development in the watershed.

Based on hydrology, the Dell area was found to be the most effective site for a regional stormwater management facility. Once an open stream, this section of Meadow Creek in the Dell had been culverted. The new stormwater management system brought the natural stream back to the surface by daylighting 1,100 lineal feet of it, restoring lost flood plain and creating wetlands and a new feature pond.

Located near the campus student center, the attractive new feature pond is now a popular gathering place for students, faculty and visitors. The pond has a sediment forebay designed to be drained and maintained, a biofiltration island and vegetated filters. The dominant pollutant removal mechanism in the natural system is sedimentation. The wet pond landscape feature at the Dell acts as a retention basin, retaining up to 175,500 cubic feet of stormwater. During storm events, large volumes of stormwater passing through the system are retained in the wet pond; pollutants settle out there and then the stormwater is discharged gradually into the stream channel through a controlled overflow. To avoid hydraulic overloading, a diversion around the pond was designed to handle flows in excess of the system's capacity.

At the site of the proposed Athletic Precinct garage, a stream tributary used to flow in a culvert across the site. Rather than designing and constructing a new culvert to divert the existing stormwater flows around the proposed facility, a stream and wetland restoration plan were developed, rerouting the stream tributary and daylighting 700 lineal feet of it. The plan included a culvert under the stream to transport approximately 80 percent of the stormwater. By splitting the runoff between the stream and the culvert, flooding was relieved in the culvert and treatment was provided at the surface. This daylighted stream now flows through stands of trees and a native grass and wildflower meadow. Wetlands created along the stream banks retain and pretreat stormwater, and an in-line detention basin is used as a wetland ponding area. During large storm events, stormwater can flood these two wetland areas, regulating the flow rate in Meadow Creek.

At the John Paul Jones Arena site, culvert modifications were designed to create additional stormwater storage. A 200-foot section of stream was daylighted. Wetlands were enhanced with floodplains, vegetated buffers and aquatic benches. The gently sloping floodplain areas along stream banks now act as a buffer between developed areas and water resources. The aquatic benches allow various depth zones to enable a variety of vegetated plants to emerge and to augment pollutant removal.

For the overall system, the low-impact, economical solutions effectively managed stormwater quantity and quality, provided campus amenities and reduced maintenance. Reestablishing natural ecological processes provided an opportunity for the ecosystem to accommodate and offset the effects of development. As a result of this campus-wide approach, individual site development projects no longer need their own stormwater management systems; instead, they reap the benefits of the three regional facilities installed across the campus.

The restored natural systems are expected to remove greater amounts of pollutants than traditional best management practices (BMPs). Furthermore, while BMPs tend to take up large areas of land within developed sites, a regional approach enabled developed sites to retain large areas of open space that can be preserved to enhance the local environment or can be developed for future uses.

Complexity of Project

The large UVA campus, with the complex and varying hydrology of the Meadow Creek watershed, complicated the development of a regional plan and required thoughtful study. Developing a solution involved reaching beyond the expectation of an engineered solution and necessitated being open-minded in considering different approaches to solve stormwater management issues in a non-traditional way.

Due to prior campus development, large areas of naturally occurring streams had been diverted through subsurface storm sewers and culverts.

The Meadow Creek watershed consists of thirteen sub-basins; over half of this area is UVA property. A hydrologic study evaluated the entire 850-acre watershed, determining the rate of runoff in each sub-basin by the slope and flow lengths, the soil type and the surface cover type. A stormwater hydrology model was developed to assess these existing hydrologic conditions and to analyze the effects of future development conditions presented by the UVA. Several potential alternative stormwater management applications were evaluted to mitigate the impacts while improving water quality and reducing flooding and downstream flow rates.

Consensus building was a complex and critical issue for this project. The highly complex, technical issues needed to be presented to stakeholders in understandable terms and simple solutions so that individuals from UVA's design and facilities management staff and from state agencies could see that their own interests were represented.

Future Value to the Engineering Profession & Perception by the Public

One great benefit of low-impact, non-engineered designs is that they put the solutions in front of people rather than underground. Beautiful, natural areas become living resources for public education about stormwater management and sustainable design. At UVA, public acceptance and enjoyment of new natural areas adjacent to campus facilities are evident in the immediate and sustained use of these amenities.

The UVA SWMP provides lasting value to the engineering profession by demonstrating "regional" solutions that could be adapted for use at similar sites. This approach embraces and epitomizes the overarching goal of creating a more sustainable environment nationally and worldwide.

The project resulted in Virginia's Department of Conservation and Recreation (DCR) redefining the use of regional planning. The stormwater management measures fulfill the obligations of UVA under its regional stormwater management plan to mitigate for future development within the watershed. As UVA's projects approach the design stage, they are checked for compliance by the DCR with the SWMP. Projects consistent with the SWMP are considered permitted in accordance with DCR regulations for regional facilities. For UVA, the regional designation results in reduced administrative processes and expedites development programs. This designation could also benefit other colleges, universities and institutions in Virginia that have large campus areas. Longer term, the success of this project serves as an example of effective regional planning that is applicable to programs and requirements in other states.

Exceeding Client/Owner Needs

UVA needed to find a way to solve the problem of managing stormwater for upcoming development, while still taking into account the very limited campus space available. Earlier attempts to address stormwater management issues at individual facilities at UVA did not meet UVA's needs, and were costly and inefficient. At Scott Stadium, stormwater treatment traps required significant and costly ongoing maintenance. Because these traps collected oily runoff from a parking area, it created an expensive hazardous waste disposal issue. In some cases, addressing the stormwater issues on a project-by-project basis was completely impossible: UVA needed to build a new basketball arena, but the land allocated for the project was not large enough to accommodate the new arena and the huge detention basin that would be required to solve stormwater problems at the site. UVA needed another option.

Facilities maintenance is always an important factor. UVA wanted a simple, easy-to-maintain system that did not create additional problems or strain the operating budget — being realistic about ongoing maintenance was an important consideration in finding a solution. The design's simple solutions to the complex issues exceeded UVA's needs, even introducing the word *pretty* to the facilities' maintenance staff vocabulary.

Social, Economic & Sustainable Design Considerations

The total cost of the Meadow Creek stormwater improvements was estimated to be about 30 percent of the total net cost if stormwater management facilities had been designed and built project-by-project. In addition, significantly less land was used for stormwater management, making that land available for new campus facilities like the arena or for additional open space.

Implementation of the stormwater management plan resulted in an immediate 25 percent decrease in stormwater flow to the Charlottesville's city system. Furthermore, campus areas previously susceptible to flooding have not had these problems since the new facilities were installed. Once all planned facilities are built within the watershed, there will still be an additional 10 percent decrease in stormwater discharged to the city, a benefit welcomed by Charlottesville.

The use of "natural systems" such as streams, wetlands and ponds exemplified sustainability. Natural treatment processes were used to cleanse, retain and infiltrate stormwater by mimicking nature.

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