A Concept Document
for the
Center for Stormwater Technology Advancement (CSTA)

11 January, 2016

Document Contributors:
R. Dymond[1], A. Godrej[2], T. Grizzard[2],
C. Hodges[1], G. Moglen[2], J. Patteson[3], D. Sample[4], G. Schafran[5]

[1]Virginia Tech CEE Department, Blacksburg, Virginia
[2]Virginia Tech, CEE Department, Occoquan Laboratory, Manassas, Virginia
[3]Fairfax County DPWES, Fairfax, Virginia
[4]Virginia Tech BSE Department, Hampton Roads AREC, Virginia Beach, Virginia
[5]Old Dominion University CEE Department, Norfolk, Virginia

Introduction

Degraded water quality in the Chesapeake Bay and a 30 year history of failed restoration attempts (EPA 2010) have resulted in the promulgation of a Total Maximum Daily Load (TMDL) for bay watershed States and the District of Columbia. The TMDL has set strict load limits for nitrogen, phosphorus, and sediment entering bay tributaries from wastewater discharges, agricultural drainage, undeveloped lands, and urban landscapes. In the last 25 years, dramatic improvements have been made in the nutrient (N and P) removal performance of wastewater treatment facilities throughout the Chesapeake Bay watershed, but commensurate progress has not been made in the improvement of either agricultural or urban stormwater management technologies.

The problems of stormwater pollution are not unique to the Chesapeake Bay watershed. The land use trajectory of the entire Atlantic seaboard of the US is following a pattern of urbanization that has emerged across the world, and may be expected to impact water resources throughout the region. In 2007, for the first time, the urban fraction of the earth's population exceeded 50% (UN 2006, Wimberly et al. 2007). In the US, the transition to more urban landscapes has been particularly evident in the coastal margin, where, in 2011, 20% of the continental land area supported over half the population (CMOP 2011). In the eastern US, nearly 70% of the mid-Atlantic population is served by public water supplies derived from surface water sources (Kenny et al. 2009). In addition, Wickham et al. (2011) reported that 82% of the regional land area lies within a drinking water watershed. In spite of this, in 2012, over 27% of mid-Atlantic lands continued to be classified as agricultural (USEPA 2012). In the first decade of the 21st century, water utilities of the region were producing over 30 million cubic meters of drinking water per day (Kenny et al. 2009). Nationally, rapid urbanization and agricultural intensification have led to widespread nutrient enrichment of surface waters, which recently ranked as the third leading source of water quality impairment in lakes and reservoirs of the US (EPA 2011). The emerging picture seems clear: water quality will continue to be significantly affected by agricultural operations, but will also be *increasingly* affected by the expansion of urban landscapes.

Restoration of the Chesapeake Bay, including meeting the more recent requirements of the TMDL, has resulted in the expenditure of enormous sums for the removal of nutrients from wastewater discharges. In 2003, the Chesapeake Bay Commission projected an ultimate cleanup cost of approximately $19B. Less than two years later, the Chesapeake Executive Council (2004) appointed a Blue Ribbon Finance Panel which identified $28B in required capital costs for the cleanup, along with a need for nearly $3B annually in operation and maintenance expenditures. Of that figure, $6B were seen as the requirement to meet new construction and upgrade needs for wastewater treatment. The total cost for stormwater management, by contrast, was estimated at $15B, of which $9B was estimated to be required for retrofits in areas of existing development. The historical and pending expenditures on wastewater treatment are widely recognized as being a central requirement for the restoration of the Bay. However, the emerging cost dimensions of meeting the stormwater needs have made it increasingly clear that, absent effective programs to deal with nutrient pollution from both agricultural and urban stormwater, much of the current and future investment in point source controls will be at risk.

While the current regulatory focus is largely on the Chesapeake Bay restoration, there is an increased awareness that watershed jurisdictions have other important local needs and objectives related to the hydrologic, physical, chemical, and biological impacts of urban stormwater. Effects on upland watersheds have received increase emphasis as local governments have begun to deal with (1) restoration and maintenance of ecosystem function; (2) reduction of physical impacts from erosion, scour, and deposition; and (3) reduction of short- and long-term water quality impacts from constituents transported into watercourses. Within these categories, there are specific issues with respect to maintenance of particular beneficial uses, including public water supply, recreation, terrestrial and aquatic habitat, and aesthetics, among others. It is sometimes said, “if we take care of our local watersheds, the Bay will take care of itself.” While simplistic, this statement does have the advantage of focusing on the need to manage water quality to the local catchment scale.

In the urban stormwater arena, which is the principal focus of this document, there has been only incremental progress in control technology development in the last 35 years, and it is fair to say that the pace of urban development has dramatically outstripped the development of effective controls. The last nationally significant effort to deal with the understanding and control of urban stormwater pollution was the Nationwide Urban Runoff Program (NURP), which EPA oversaw in the late 1970’s and early 1980’s (EPA 1983). The results from the 30 prototype projects from NURP are still widely seen as the best comprehensive assessment to date devoted to characterization and control of urban stormwater.

At this writing, there remain significant knowledge gaps in the understanding of stormwater management practice performance at all levels. It seems clear that many of these gaps must be addressed in order to insure that funds allocated to urban stormwater management are well spent. In 2009, while the Commonwealth of Virginia stormwater program still resided in the Department of Conservation and Recreation (DCR), there was an effort to establish consistent monitoring protocols so as to provide comparable performance data between BMPs of all types, including manufactured devices, catchment-scale conventional practices, and low impact development (LID) practices. In the original conversations about BMP testing protocols for manufactured treatment devices (MTDs), the idea of an applied research center for urban stormwater management emerged.

Virginia Technology Assessment Protocol (VTAP)

The Virginia Department of Conservation and Recreation (DCR) recognized that the most commonly cited testing protocol for MTDs, the New Jersey Technology Acceptance Reciprocity Protocol (TARP), had been developed to assess only removal of sediment. Given the requirements of the Chesapeake Bay TMDL, it was felt that the best approach in Virginia would be to convene an expert panel charged with the development of an MTD testing protocol for both sediment and nutrients. The expert panel was chaired by Dr. David Sample of the Virginia Tech Department of Biological Systems Engineering (BSE), with the other members as follow:

- Dr. Allen Davis, University of Maryland Department of Civil and Environmental Engineering (CEE)
- Dr. Thomas Grizzard, Virginia Tech Department of Civil and Environmental Engineering (CEE), and the Occoquan Laboratory
- Dr. Rob Roseen, University of New Hampshire Stormwater Center
- Dr. John Sansalone, University of Florida Chemical Engineering Department

The panel was convened in mid-2010, and continued its work through much of 2012, culminating in the proposed Virginia Technology Assessment Protocol (VTAP). After an exhaustive review process, VTAP was initially adopted by the Soil and Water Conservation Board on 07 December, 2012 (DCR 2012). The regulation was subsequently withdrawn and some additional changes made in early 2013. After final adoption, however, responsibility for the stormwater program was moved to the Virginia Department of Environmental Quality (VaDEQ), and shortly thereafter, the VTAP regulation was withdrawn.

The panel report, however, still has significant value. There was careful consideration of the current state of the art in BMP performance assessments, and the final document provided a comprehensive procedural guide to field studies.

Information Needs

Although VTAP was withdrawn as a device testing regulation, most of the key issues it addressed related to the treatment of urban stormwater still remain. While urban stormwater pollution has been recognized as a potentially significant source of water quality degradation for nearly 5 decades, it remains relatively poorly understood, particularly when compared to point source discharges, which are nearly always well-characterized, and for which treatment technology performance is quantitatively assessed on a continuing basis. NURP (EPA 1983), which remains to date the only broad-based, federally funded assessment urban stormwater pollution and treatment in the US, now lies nearly 35 years in the past.

In support of the Chesapeake Bay TMDL, local governments have been tasked with adopting development practices and treatment technologies to accomplish specific reductions in nutrient and sediment loads from developed land. However, these activities must be undertaken in the absence of a well-developed understanding of a wide range of issues related to urban stormwater, including, but not limited to:

- Source characterization and variability (e.g., constituents of interest, Event Mean Concentrations, Loads);
- Integration of observational studies into accurate model representations of urban stormwater sources, including both quality and quantity;
- Performance of development design practice (e.g., LID);
- Performance of non-structural practices (e.g., fertilization protocols and/or ordinances);
- Performance of non-structural practices (e.g., fertilization practice);
- Variability in practice performance as a result of existing seasonal cycles;
- Unacceptable variability in nationally reported BMP performance data
- Effects of event hydrology on practice performance;
- Effects of maintenance condition on practice performance;
- Effects of age on practice performance;
- Feedback of observational studies into development of objective design criteria;
- Development of modeling approaches that account for the uncertainty in performance resulting from seasonality, event type, maintenance, age, etc.
- Feedback of applied experimental and modeling research results into the development of more effective regulatory approaches;
- Lack of scientific rigor and poor quality assurance of studies included in national databases on BMP performance

The notion of feedback of applied experimental results and modeling is critical to improving the development of effective stormwater quality management systems. Due to the relatively low level of fundamental understanding of BMP and LID practice performance, monitoring and cost data are often limited and may be seen to exhibit significant variability. Evaluating performance and cost-effectiveness of a range of installations within a given type of practice would help to address these data gaps, and provide a basis for incorporating the principles of adaptive management into the design process for such systems. Figure 1 illustrates the process with the periodic introduction of monitoring and performance information. The resultant feedback loop is the essence of adaptive management, and enhances system performance, by providing for continuous updates where new developments inform the process.

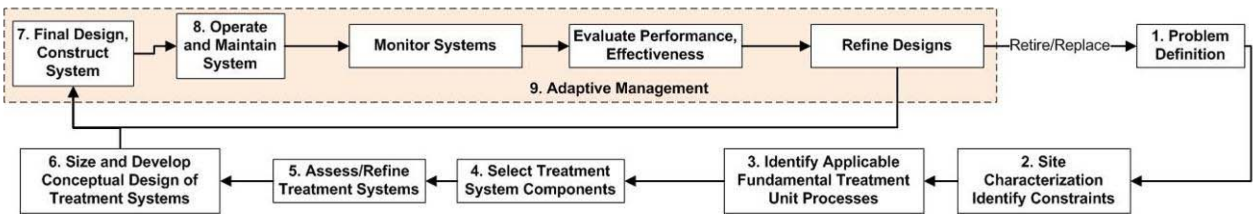

Figure 1. The Design Process and the Impact of Adaptive Management (courtesy D. Sample, as adapted from Quigley et al. 2005).

While not explicitly identified in the list above, there is an overarching link to the potential effects of climate change, which are relevant to each of the identified information need areas. In addition, stakeholder outreach and technology transfer should also be viewed as important components of each of the item in the list.

Discussions to date

During the development of VTAP, faculty from the Virginia Tech BSE and CEE Departments continued discussions about the need for an entity to (1) provide unbiased performance assessments for stormwater treatment technologies, and (2) develop the science and engineering practice of stormwater management through an applied research program.

From 2011 until the present time, the discussions have evolved from the establishment of a testing center to provide VTAP assessments for MTDs to a broader approach that would be capable of addressing the full range of information needs of local governments and regulators seeking to deal with the urban stormwater problem. Presentations have been made at regional and headquarters offices of DCR and DEQ and the Board of the Land Development and Design Initiative (LDDI) at Virginia Tech. More recently discussions were held with the Fairfax County Department of Public Works and Environmental Services (DPWES). A meeting was also held to discuss the concept with a range of stakeholders on 6 October, 2014 at the DEQ Northern Region Office (NRO).

Following the October, 2014 stakeholder meeting, James Patteson, the Fairfax County DPWES Director, distributed a meeting summary and suggested the preparation of a strawman document that would outline objectives, possible funding mechanisms, organizational structure, and governance. Beginning in mid-2015, the authors of this document have met with a number of potential stakeholders to gage interest and to solicit further input on the concept of establishing a Center for Stormwater Technology Advancement (CSTA). Presentations and/or discussions have been held (chronologically) with Virginia Beach, Roanoke, Lynchburg, Arlington County, the City of Alexandria, and Prince William County. In addition, a meeting was held with the Virginia Center for Transportation Innovation and Research (VCTIR) in Charlottesville. While it seems clear that a solid constituency exists for the proposed activities of CSTA, there have been a number of questions raised about the various organizational and funding models that might be adopted. This latest draft of the concept document is intended to address those questions.

CSTA Objectives

The long-term goal of CSTA would be to improve our ability to address urban stormwater problems by advancing the science and engineering to be applied to this growing surface water quality management sector. These improvements will be of direct benefit to the regulatory communities (both federal and state), local governments, and industry by making scientifically rigorous contributions to the understanding of urban stormwater, as well as to the development and improvement of technologies for its management. The research agenda for such an entity would be largely applied, although it is certain that some important basic research components will emerge over time.

With a stronger base of knowledge, improvements in public policy will be possible, wherein Clean Water Act requirements may be addressed with greater confidence in outcomes, and in a more efficient and cost-effective manner. Demonstrations of improved outcomes can only serve to enhance public confidence in state and local programs going forward.

An example of an effective organizational model for an entity such as CSTA could be found in the highly successful Agricultural Research Experiment Centers (ARECs) that exist at most US Land Grant Universities. For decades, such centers have provided basic and applied research outputs that have been a key to the success of agricultural development in the United States. These centers have also played an important role in education and technology transfer to practicing stakeholder communities.

CSTA Organization, Governance, Funding Requirements and Sources

CSTA Organization - Operational

The organizational structure for CSTA is envisioned as a research and evaluation entity that would be staffed by faculty, staff, and students from the Virginia Tech (VT) Departments of Biological Systems Engineering (BSE) and Civil and Environmental Engineering (CEE); and the Old Dominion University (ODU) Department of Civil and

Environmental Engineering (CEE). The two startup university partners provide a geographic distribution that would support projects to be undertaken within all the physiographic provinces of the state (Coastal Plain, Piedmont, Blue Ridge, and Valley and Ridge), and in close proximity to most of the key existing Phase I and Phase II MS4 permittees.

While it may be advantageous to add additional university partners at a future time, proof of concept operations are proposed to be undertaken over an initial period of 5 years within Virginia Tech and Old Dominion University. The two universities already have faculty and appropriate field and laboratory research facilities located in or near the Tidewater, Northern Virginia, and Blacksburg nodes as shown below:

Virginia Tech	
Department of Biological Systems Engineering (BSE)	Hampton Roads Agricultural Research and Extension Center, Virginia Beach, VA
	Main Campus Blacksburg, VA
Department of Civil and Environmental Engineering (CEE)	Occoquan Laboratory Manassas, VA
	Main Campus Blacksburg, VA
Old Dominion University	
Department of Civil and Environmental Engineering (CEE)	Main Campus Norfolk, VA

Both Virginia Tech and ODU have laboratory facilities accredited by the Virginia Environmental Laboratory Accreditation Program (VELAP). The two facilities are located on the ODU main campus, and at the Occoquan Laboratory in Manassas, Virginia. The facilities and operations of both laboratories are regularly reviewed against the National Environmental Laboratory Accreditation Program (NELAP) standard by the Virginia Division of Consolidated Laboratory Services (VaDCLS). In addition, both laboratories participate in a formal quality assurance program (the Data Integrity Workgroup - DIWG) administered by participants in the Chesapeake Bay Program. Having well-equipped laboratory facilities and well-qualified analytical staff are seen as a key competency of the VT-ODU partnership for CSTA.

As will be seen in later sections, it will be advantageous for CSTA to be established under two different funding models. The Industrial Affiliates Program (IAP) at Virginia Tech permits the receipt of funds from members (including MS4 jurisdictions and partners in the private sector) for the purposes of supporting core administrative functions, outreach and training activities. These funds are not subject to the imposition of indirect costs by the University, and may therefore, be directed entirely to program activities. Research funds, on the other hand, are subject to indirect costs, and must be maintained in separate accounts.

Center Governance

The initial governance structure is proposed with an oversight board composed of stakeholder representatives from the partner university departments, Virginia DEQ, VDOT, MS4 communities (perhaps via the Virginia Association of Municipal Stormwater Agencies - VAMSA), facility owners, and the industry sector (e.g., stormwater manufacturers, Virginia Association of Homebuilders, NAIOP-VA). The board will be responsible for approving center operations, including funding, on an annual basis, and will provide guidance on research directions and technology transfer. Annual project reports will be provided to the oversight board as well as to project sponsors. A potential composition of the proposed oversight board is shown in the overall organizational chart in Figure 2.

Core Operations and Funding Requirements

For the initial five year period, core operations will consist of program development, research methods training and development, stakeholder outreach, and research project development.

Initially, CSTA core operations are seen as requiring support for a center director, an operations manager, and some existing field and laboratory staff at the Occoquan Watershed Laboratory. Funding is included for the Center Director and one other faculty member at one month of summer salary for each year. The Operations Manager is funded full time. Occoquan Laboratory staff support is funded at estimated annual requirements ranging from 2.5-5%, and includes participation in research methods training, project site selection, and administration.

While difficult to predict for a 5 year horizon, fringe benefits have been estimated (over all faculty, staff, and student classifications at an overall average of 30.5% of total salaries and wages.

The core operations budget also includes acquisition of a 4 wheel drive vehicle. Vehicle operations for site visits and training, as well as overnight travel costs are also included. Funds are also included to support travel for outreach activities and conferences.

Indirect costs have been estimated at an average of 60% of modified total direct costs for the three year estimate. This value is slightly less than the current Virginia Tech indirect rate, but is expected to be aligned with the site-specific Occoquan Laboratory rate currently under development. Modified total direct costs exclude equipment and tuition. The proposed budget has been prepared with standard Virginia Tech assumptions about increases in salaries and costs of supplies and services.

A five-year budget estimate for core operations is given in Table 1.

Project-Based Funding Requirements

An estimate of project-based funding requirements has been prepared with the assumption of the following three projects:

- Two study sites for an assessment of the infill development-induced stormwater quantity and quality issues experienced in jurisdictions in the northern Virginia and Tidewater areas. The individual studies will require two years each, and will be conducted in years 1 and 2 (northern Virginia), and years 2 and 3 (Tidewater). A further description and rationale for the inaugural project selection may be found in the Appendix.

- An evaluation and refined performance assessment of an innovative BMP retrofit using bioretention in a stable urban catchment. To be conducted in Years 3 and 4 at a location to be determined.

The first year project has been budgeted with a reduced equipment requirement, because some instrumentation is already on hand from a previously funded BMP assessment for Fairfax County. The field study estimate has been prepared based on the following set of assumptions:

- Acquisition of field instrumentation to support acquisition of precipitation, data, as well as flow measurement and automated storm event composite sampling in up to 4 conduits (3 inflow/1 outflow).
- Sampling station housings equipped with solar panels to augment battery power.
- Central data logging and data access through cellular network connections.
- Acquisition of a set of instrumentation spares to insure against significant down time associated with equipment failures.
- Project start-up period of 2 months; a data collection campaign of 18 months; and shut-down, data analysis, and report preparation of 4 months. The schedule would provide overlap periods for two seasons, which would give a more robust dataset.
- Collection and analysis of 35-45 storm events at inflow and outflow points for water quality constituents of interest. Large datasets will provide a rational basis for assessments of uncertainty and performance variability.
- Analyses to include (at a minimum) total suspended solids (TSS), suspended sediment concentration (SSC), particle size distribution (PSD), dissolved and total nutrient species (nitrogen and phosphorus), dissolved and total organic carbon (DOC, TOC), and petroleum hydrocarbons (TPH).
- Where a part of project objectives, other constituents of interest may be included (e.g., trace metals), but have not been included in the example project budgets shown.
- Development of a continuous simulation model for the practice being investigated with a view to providing the ability to estimate performance of similar practices and to provide enhanced understanding of design.

Field studies will be conducted with the goal of establishing reliable mass balances for constituents of interest. Experience has shown that this approach to BMP performance assessments provides the most reliable data, and is consistent with the methods described in some detail in the original Virginia Technology Assessment Protocol - VTAP (DCR 2013).

The inaugural project (years 1-2) will be conducted from the Occoquan Laboratory. A key component of the initial project will be to provide training in methods and quality assurance for faculty, staff, and students at other project nodes. Travel funds budgeted in the core operations budget will be used to provide site visits for up to 4 individuals.

Prototype field study outputs will include performance analysis for the target facility and/or practice. The 24-month project will make it possible to provide estimates of performance variability based on event type and season. Model development will also be included so as to enable the extension of performance findings to other facilities and practices.

Table 2 includes the overall budget for three projects of two year duration each, which have been phased in years 1-2, 2-3, and 3-4. Year 5 activities include final reporting and preparation for follow-on work. The initial project costs are substantially affected by the need to acquire suites of instrumentation for the study, including meteorological and stormwater monitoring equipment, sampling devices, housings, and communications gear. The first three years of the program are burdened with substantial equipment acquisition requirements, although these are defrayed somewhat by some equipment on hand at the Occoquan Laboratory. However, equipment acquisition costs will still exceed $250,000, and will be staged over the first three years of the start-up period. These instruments have a service life that can approach a decade, so it may be assumed that equipment purchases for future studies will benefit substantially from the initial outlay.

Center core staff costs have been estimated with each project director (a faculty member) receiving a month of summer salary for each year of the active work. In addition, the CSTA operations manager will receive 10% CY support in each year. One PhD student GA is allocated to each project with 12-months of support during each two year study period. The remaining staff costs are associated with station construction, measurement validation, quality assurance, and laboratory analytical requirements. Shipping costs are included because most analytical work will be done at either the VT Occoquan Laboratory in Manassas, or the ODU Environmental Laboratory in Norfolk. As noted above, both facilities are certified under the Virginia Environmental Laboratory Accreditation Program (VELAP).

As with the core operations budget, indirect costs for projects at the partner universities have been estimated at an average of 60% of modified total direct costs for the five year period. Fringe benefits have been estimated at a composite rate of slightly over 27%. The indirect cost computation excludes equipment and tuition. The proposed projects budget has also been prepared with standard Virginia Tech assumptions about increases in salaries, as well as the costs of equipment, supplies, and services.

While not explicitly stated in this work plan, it should be noted that each prototype project will represent a baseline dataset that may be used in future studies to assess the impact of age and maintenance practice on performance. Such data are not found in the literature today, but will be essential to insure that stormwater management systems can be designed to provide adequate performance over the life cycle. Of course, revisiting previously monitored sites and practices implies a strong commitment to long-term support of the applied research effort.

CSTA Structure – Identified Funding Entities

It has been assumed that startup operations will be initially funded by subscriber fees from member jurisdictions and/or organizations. If state funding sources can be identified, then membership fees may be decreased proportionally. There are also programs in place at Virginia Tech and at the US National Science Foundation (NSF) that may offer unique opportunities to leverage initial operating funds in a way that will make it possible to achieve a sustainable funding condition for CSTA within five (5) years.

The Virginia Tech Industrial Affiliates Program (IAP)

The Virginia Tech Industrial Affiliates Program (IAP) provides a means *to facilitate the dialogue between academia and industry and the transfer of new knowledge to the general public.* The program provides for the creation and efficient support of centers such as CSTA with membership fees. The mechanism is particularly efficient because core operations, such as administration, outreach, and training may be supported without the imposition of indirect costs (overhead). Programs supported in this way provide an avenue for a particular industry or interest sector to contribute to and sustain needed research activities. Industrial Affiliate Members join the program with annual membership fees, and in return, have access to the products of the Center, including:

- Early access to technical reports and evaluations conducted by the Center;
- Preferential participation in regularly scheduled technical seminars and training provided by Center staff;
- Ready access to Center faculty and staff to address particular local and/or regional stormwater management needs.

The community of MS4 permit holders, equipment manufacturers, and affected state agencies have a unique interest in the proposed activities of CSTA, and would initially derive the most benefit from the evaluation and research outputs of the Center. At this writing, individuals engaged in the planning for CSTA have visited or had dialogues with eight (9) potential partners, including equal numbers of Phase I and Phase II jurisdictions, and one state agency. Within the Commonwealth, the regulated MS4 community currently includes 115 permit holders, including:

Phase I	**No.**
Local Governments	11
State Facilities	0
Federal Facilities	0

Phase II	No.
Local Governments	52
State Facilities	30
Federal Facilities	22

As noted above, the IAP program provides an excellent mechanism to support administration, outreach, and training operations for the Center, but University policy prohibits funds contributed to the IAP from being utilized to support research activities. Organized research operations will require that indirect costs be recovered for all projects, and for that reason, separate funding lines will be required for such activities.

For initial cost estimating purposes, only local jurisdiction partners were considered as founding members in the CSTA IAP. It should be noted, however, that a successful center will ultimately include commercial sector members as well. When estimating required annual membership fees, the Phase I and II MS4 local jurisdiction partners were divided into quartiles based on 2013 population data as follows:

Cumulative MS4 Phase I and II Populations at the Quartiles Indicated	**Quartile**
42,181	0.250
117,582	0.500
333,2278	0.750
1,131,000	1.000

Funding requirements for the IAP were set by an analysis of both programmatic needs and the minimum funding requirements of the NSF Industry/University Cooperative Research Center (I/UCRC) program, which is described below.

National Science Foundation Industry/University Cooperative Research Center (I/UCRC) Program

Since 1973, the NSF I/UCRC program has provided federal funding to foster long-term partnerships between industry, academe and government. Programs are supported that contribute to the enhancement of the research infrastructure base of the United States, and the intellectual capacity of the engineering or science workforce. The stated mechanism is through integration of research and education, and the facilitation of technology transfer.

The initial year of the I/UCRC funding has been assumed to be a planning grant that provides $15,000 of funding to each of the two CSTA sites (VT & ODU). Following the 1-year planning grant (FY17), the funding available to support research activities may continue for up to 15 additional years in Phased increments of 5 years. The funding available from NSF would be based upon the membership revenues generated by the IAP. For example, in order to receive the maximum Phase I funding of $300,000 annually, industrial partner memberships must total $150,000 at both the Virginia Tech and ODU sites.

A prospective analysis of membership fees was done with the MS4 community population quartiles shown in the prior section. A mix of 10 likely MS4 partners was divided equally between the Phase I and II communities, and the maximum population quartile was assigned an annual index fee of $50,000. With those assumptions, the annual IAP fee generation would be estimated to be $350,000. At the end of the first 5 years of Center operations, the membership fees would be revisited by the governing board of the I/UCRC. It is likely that more partners, including a number from the commercial sector, will have joined the program at that point, making it possible to consider reductions in membership fees.

The Virginia Tech Institute for Critical Technology and Applied Science (ICTAS)

The Virginia Tech Institute for Critical Technology and Applied Science (ICTAS) was established by the University to become a *premier institute to advance transformative, interdisciplinary research for a sustainable future*. To that end, ICTAS serves the University, the Commonwealth, the nation, and the world by *supporting high-impact research and scholarship at the intersections of engineering, the sciences -- physical, life, and social -- and the humanities.* Sustainable water is a key thrust area for research activities to be supported by ICTAS. Within the overall category of sustainable water, watershed management, with a focus on management of metropolitan bodies of water, has been identified as a prime area of interest.

It is anticipated that a request for ICTAS support will be viewed in a favorable light by the governing board. Initial feedback has been that funding at a level of $20,000 annually for years 1 and 2 is a reasonable possibility.

Summary

The proposed CSTA budget has been segmented into two lines: core operations and individual project budgets. Core operations will be organized under the Virginia Tech Industrial Affiliates Program, and will be able to take advantage of the efficiencies in program delivery associated with the indirect cost waiver. The core operation will be funded principally by subscriber memberships and will be focused on training, technology transfer and outreach. Some miscellaneous income may be anticipated from non-subscriber enrollments in activities and purchase of materials.

The subscriber fees will be used to provide the cash match basis for funds to be derived from the NSF Industry/University Cooperative Research Program (I/UCRC). In the first four years of five-year Phase I funding, the I/UCRC program may be anticipated to provide the bulk of the funding to support stormwater research projects (~$1.2M).

When coupled with the membership fund balance from the IAP and a requested 2-year startup sum of $40,000 from ICTAS, it is anticipated that the research operation will be self-sustaining by the fourth year, at which time a cumulative funding deficit of slightly over $155,000 will have been retired. From that point, and assuming the renewal of NSF I/UCRC funding into Phases II and III, adequate funding will be available for the governing board to continue a sustained research program. The annual estimated fund deficits and surpluses are shown in Table 2.

An illustration of the potential flow of funding sources is given in Figure 3.

References

Chesapeake Bay Commission, 2003. The Cost of a Clean Bay: Assessing Funding Needs throughout the Watershed. Annapolis, MD. 32p.

Chesapeake Executive Council, 2004. Saving a National Treasure: Financing the Cleanup of the Chesapeake By. Report to the Chesapeake Executive Council from the Chesapeake Bay Watershed Blue Ribbon Finance Panel. Annapolis, MD. 44p.

CMOP, 2011. Center for Coastal Margin Observation and Prediction, http://www.ohsu.edu/ohsuedu/landingpages/coastalmargin/, Oregon Health and Science University, Portland Oregon. Accessed on 11 November, 2011.

Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin, 2009, Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344, 52 p.

United Nations, 2006. *World Urbanization Prospects: The 2005 Revision*. New York: Population Division, Department of Economic and Social Affairs, United Nations. New York, NY.

US Environmental Protection Agency (USEPA), 1983. Results of the Nationwide Urban Runoff Program, Volume I – Final Report. Water Planning Division. Washington, DC.

US Environmental Protection Agency (USEPA), 2010. Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus, and Sediment. Region 3 Water Protection Division, Air Protection Division, Office of Regional Counsel, Philadelphia, PA; Chesapeake Bay Program Office, Annapolis, MD; and Region 2, Division of Environmental Planning and Protection, New York, NY.

US Environmental Protection Agency (USEPA), 2011. National summary of assessed waters of the United States. http://ofmpub.epa.gov/waters10/attains_index.control, U.S. Environmental Protection Agency, Washington, DC. Accessed on 12 November, 2012.

US Environmental Protection Agency (USEPA), 2012. Basic information about agriculture, http://www.epa.gov/reg3wapd/Agriculture/basicinfoaboutag.html, Accessed on 01 December, 2012.

VA Department of Conservation and Recreation (DCR), 2011. Guicance for Evaluating Manufactured Stormwater Treatment Devices: Virginia Technology Assessment Protocol. Soil and Water Conservation Board. Richmond, Virginia.

Virginia State Senate Finance Committee, 2011. Chesapeake Bay TMDL Watershed Implementation Plan: What Will it Cost to Meet Virginia's Goals? 18 November, 2011, Richmond, VA. 21p.

Wickham et al., 2011. Wickham, J.D., T.G. Wade, and K.H. Riitters, An environmental assessment of United States drinking water watersheds. Landscape Ecology, 26:605-616.

Wimberly et al., 2007. Wimberley, R., Morris, L., Fulkerson, G., "World Population Takes a Turn," *The News and Observer,* Raleigh, NC, p. 15A, May 23, 2007.

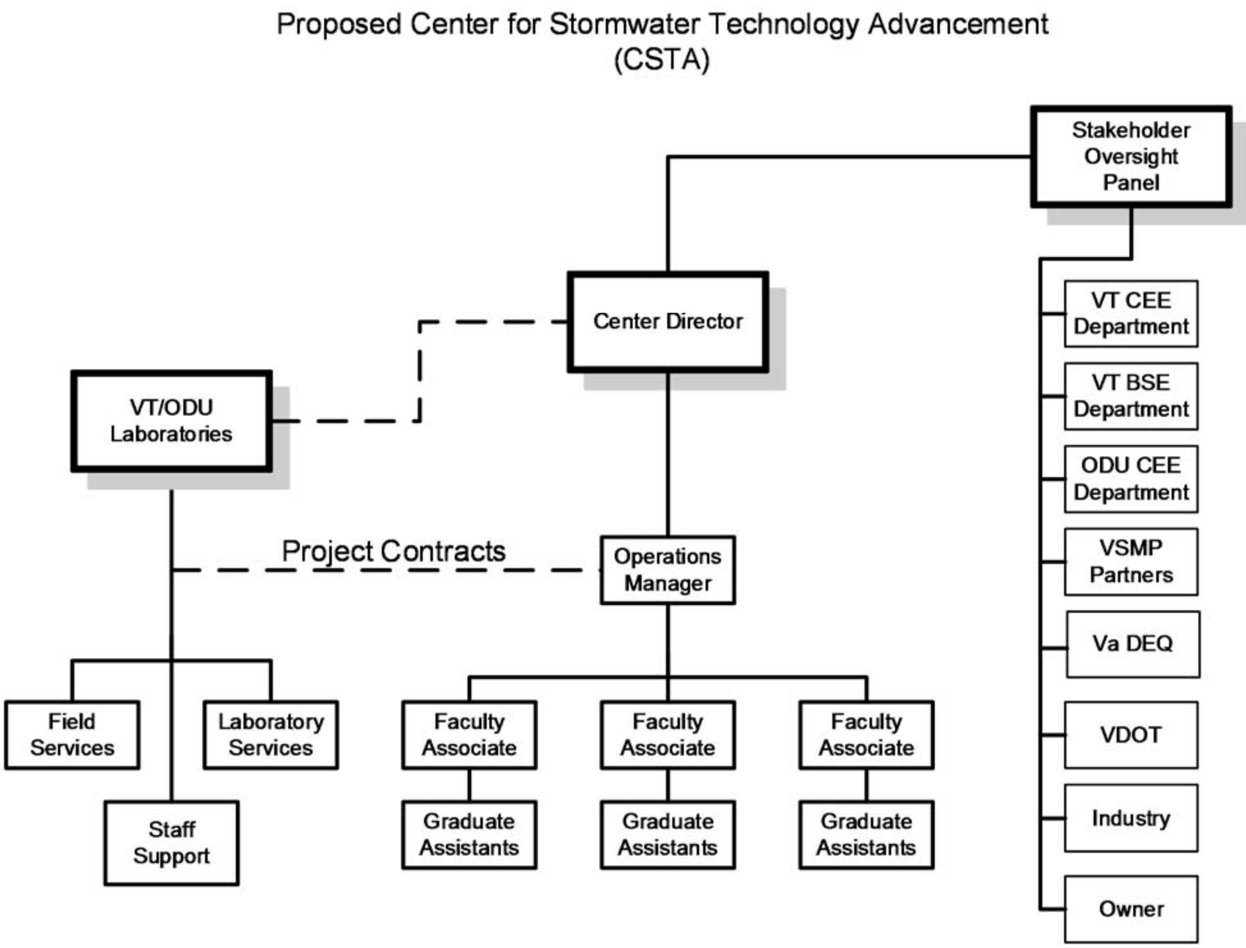

Figure 2. Proposed CSTA Organizational Structure.

Figure 3. Illustration of proposed funding sources for CSTA program activities.

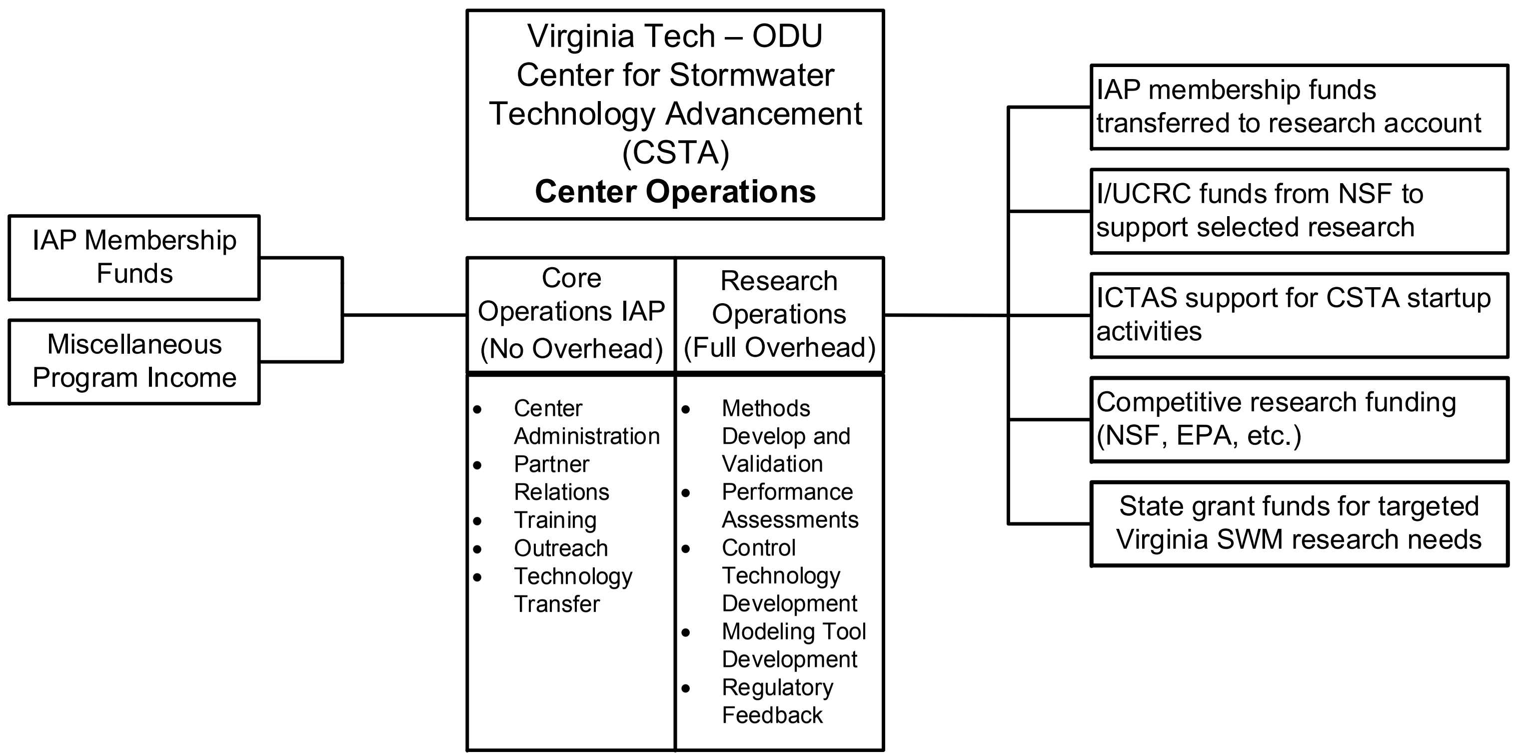

Table 1. Proposed 5-year core operations budget for CSTA with funding sources.

Budget Category	Composite Fringe %	FY17 hrs.	FY18 hrs.	FY19 hrs.	FY20 hrs.	FY21 hrs.	FY17 pct.	FY18 pct.	FY19 pct.	FY20 pct.	FY21 pct.	FY17 Line Item	FY17 FY Total	FY18 Line Item	FY18 FY Total	FY19 Line Item	FY19 FY Total	FY20 Line Item	FY20 FY Total	FY21 Line Item	FY21 FY Total	Total
Salaries																						488,953
Center Director		151	151	151	151	151	7.27	7.27	7.27	7.27	7.27		9,220		9,589		9,972		10,371		10,786	
Center Co-PI		151	151	151	151	151	7.27	7.27	7.27	7.27	7.27		12,233		12,722		13,231		13,760		14,311	
Field Operations Mgr.		1,872	1,872	1,872	1,872	1,872	90.00	90.00	90.00	90.00	90.00		57,893		60,208		62,617		65,121		67,726	
Field Supervisor		104	52	52	52	52	5.00	2.50	2.50	2.50	2.50		4,098		2,131		2,216		2,305		2,397	
Analytical Chemist		52	52	52	52	52	2.50	2.50	2.50	2.50	2.50		1,863		1,937		2,015		2,095		2,179	
Laboratory Specialist Sr.		104	104	52	52	52	5.00	5.00	2.50	2.50	2.50		3,315		3,448		1,793		1,864		1,939	
Pgm. Support Tech Sr.		104	104	104	104	104	5.00	5.00	5.00	5.00	5.00		3,326		3,459		3,597		3,741		3,891	
Office Services Specialist		52	52	52	52	52	2.50	2.50	2.50	2.50	2.50		1,031		1,072		1,115		1,160		1,206	
Students																						149,192
PhD GA (AY Step 17)		780	780	780	780	780	75.00	75.00	75.00	75.00	75.00		20,658		21,486		22,344		23,238		24,168	
PhD GA (Summer Step 17)		260	260	260	260	260	25.00	25.00	25.00	25.00	25.00		6,886		7,162		7,448		7,746		8,056	
MS GA (AY Step 13)		0	0	0	0	0	0.00	0.00	0.00	0.00	0.00		0		0		0		0		0	
MS GA (Summer Step 13)		0	0	0	0	0	0.00	0.00	0.00	0.00	0.00		0		0		0		0		0	
Fringe Benefits																						194,719
Regular Faculty:	34.25%												7,348		7,642		7,947		8,265		8,596	
Research Faculty	37.75%												24,105		24,264		25,235		26,244		27,294	
Classified:	49.25%												3,778		3,930		3,204		3,332		3,465	
Field Operations																						125,371
Equipment													25,000		0		0		0		0	
Truck Replacement												25,000		0		0		0		0		
Vehicle Operation													14,100		14,568		15,055		15,561		16,087	
Expendable supplies (gas)												11,700		12,168		12,655		13,161		13,687		
Maintenance & Repairs												2,400		2,400		2,400		2,400		2,400		
Travel													5,000		5,000		5,000		5,000		5,000	
Office Operations																						117,922
Equipment													6,200		6,248		6,298		6,350		6,404	
Reproduction												1,200		1,248		1,298		1,350		1,404		
Seminar Costs												5,000		5,000		5,000		5,000		5,000		
Tuition/academic fees													15,453		16,316		17,230		18,198		19,225	
Total Direct Costs													223,366		203,116		208,327		216,442		224,905	1,076,157
Indirect Costs:	26.00%												45,945		46,944		48,048		49,892		51,812	242,641
Indirect Cost Waiver for IAP													(45,945)		(46,944)		(48,048)		(49,892)		(51,812)	(242,641)
Total Costs													223,366		203,116		208,327		216,442		224,905	1,076,157
IAP Member Contributions:													350,000		350,000		350,000		350,000		350,000	
IAP Membership Excess Transferred to Research Account													126,634		146,884		141,673		133,558		125,095	

Table 2. Proposed 5-year research operations budget for CSTA with funding sources.

Budget Category	Composite	FY17	FY18	FY19	FY20	FY21	FY17	FY18	FY19	FY20	FY21	FY17		FY18		FY19		FY20		FY21		
	Fringe %	hrs.	hrs.	hrs.	hrs.	hrs.	pct.	pct.	pct.	pct.	pct.	Line Item	FY Total	Line Item	FY Total	Line Item	FY Total	Line Item	FY Total	Line Item	FY Total	Total
Salaries																						259,445
PI 1		0	0	151	151	0	0.00	0.00	7.27	7.27	0.00		0		0		14,334		14,907		0	
PI 2		0	151	151	0	0	0.00	7.27	7.27	0.00	0.00		0		10,703		11,131		0		0	
PI 3		151	151	0	0	0	7.27	7.27	0.00	0.00	0.00		12,233		12,722		0		0		0	
Research Associate - Operations Dir.		208	208	208	208	208	10.00	10.00	10.00	10.00	10.00		6,433		6,690		6,957		7,236		7,525	
Field Supervisor, H. Post		104	208	208	104	52	5.00	10.00	10.00	5.00	2.50		4,098		8,525		8,866		4,610		2,397	
Analytical Chemist, D. Alvi		104	156	156	104	52	5.00	7.50	7.50	5.00	2.50		3,725		5,811		6,044		4,190		2,179	
Laboratory Specialist Sr., G. Underwood		104	104	104	104	52	5.00	5.00	5.00	5.00	2.50		3,315		3,448		3,585		3,729		1,939	
Lab Specialists, Composite Salary, Field		260	447	447	187	83	12.50	21.50	21.50	9.00	4.00		6,276		11,227		11,676		5,083		2,350	
Lab Specialists, Composite Salary, Lab		312	520	520	208	83	15.00	25.00	25.00	10.00	4.00		6,841		11,859		12,333		5,130		2,134	
Pgm. Support Tech Sr., B. Angelotti		42	42	42	42	42	2.00	2.00	2.00	2.00	2.00		1,330		1,383		1,439		1,496		1,556	
Students																						175,406
PhD GA (AY Step 17)		780	1,560	1,560	780	0	75.00	150.00	150.00	75.00	0.00		20,658		42,970		44,688		23,238		0	
PhD GA (Summer Step 17)		260	520	520	260	0	25.00	50.00	50.00	25.00	0.00		6,886		14,324		14,896		7,746		0	
Fringe Benefits																						118,405
Regular Faculty:	34.25%												4,190		8,023		8,722		5,106		0	
Research Faculty	37.75%												5,382		7,937		8,255		6,054		4,568	
Classified:	49.25%												8,748		13,749		14,299		7,603		3,930	
Wage:	0.00%												0		0		0		0		0	
Research Assistants:	6.75%												1,859		3,867		4,022		2,091		0	
Field Operations																						379,940
Equipment													32,300		97,194		100,110		0		0	
Monitoring/Sampling Instrumentation												25,000		77,250		79,568		0		0		
Flumes and Weirs												4,800		4,944		5,092		0		0		
Fiberglass Housings												0		10,000		10,300		0		0		
Gaging Equipment												2,500		5,000		5,150		0		0		
Field Station Utilities (including phones)													800		1,600		1,600		800		0	
Rain Gage Communications												800		1,600		1,600		800		0		
Station and Staff Telecommunications												0		0		0		0		0		
Vehicle Operation													10,590		22,027		22,908		23,825		9,900	
Expendable supplies (gas)												8,190		17,035		17,717		18,425		7,500		
Maintenance & Repairs												2,400		4,992		5,192		5,399		2,400		
Expendable Supplies and Materials													2,500		3,325		3,425		2,732		1,350	
Equipment Maintenance															5,000		5,150		5,305		2,500	
Travel													5,000		5,000		5,000		5,000		5,000	
Laboratory Operations																						53,147
Expendable Supplies and Materials													2,200		4,532		4,668		2,404		1,200	
Contract Services (Analytical work in B'burg)													1,200		4,532		4,668		1,311		1,000	
Contract Services (Instrument Maintenance)													1,500		3,183		3,278		1,639		850	
Contract Services (DCLS VELAP Fees)													400		800		800		400		200	
Contract Services (UPS Sample Shipping)													2,625		2,704		2,785		2,868		1,400	
Office Operations																						130,742
Reproduction													1,200		1,248		1,298		1,350		1,404	
Tuition and academic fees for GA's													15,453		32,631		34,459		18,198		0	
Conference Travel and Training													3,500		7,000		7,000		3,500		2,500	
Total Direct Costs													171,242		354,014		368,396		167,551		55,882	1,117,085
Indirect Costs:	60.00%												73,373		133,764		139,517		88,802		32,687	468,143
Total Costs													244,615		487,778		507,913		256,353		88,569	1,585,228
Membership Excess Transferred from IAP Account													126,634		146,884		141,673		133,558		125,095	
IUPRC Funds													30,000		300,000		300,000		300,000		300,000	
ICTAS Startup Funding													20,000		20,000		0		0		0	
Surplus/Deficit													(67,982)		(20,894)		(66,240)		177,205		336,526	
Cumlative Surplus/Deficit													(67,982)		(88,875)		(155,116)		22,089		358,615	

Appendix

Proposed Inaugural Project for CSTA

Proposed Inaugural Project for CSTA

Problem Statement:
Fairfax County, similar to most other mature, urbanizing communities, face a great challenge with infill developments. Infill, in this instance, is defined as single family detached home construction fitting one of the three scenarios below:

- construction of a home on an existing lot in an existing subdivision not previously built upon
- the tear down of an older, smaller home to build a larger home (McMansionization); or
- the substantial renovation of an existing home to enlarge and create additional impervious area.

In each of these situations, the projects are not subject to the subdivision ordinance which requires much more rigorous public improvements to address stormwater management as well as other public needs. These projects strain existing subdivision infrastructure which is often inadequate or non-existent in older communities.

The desired regulatory outcomes for these developments from a stormwater perspective are to -

- address stormwater quality requirements spelled out in the ordinance and any local TMDLs
- address adequate outfall requirement – improve upon and not exacerbate localized drainage
- improve local streams
- provide consistency, predictability, repeatability in our regulations so they can be practically designed, reviewed, implemented, inspected, and enforced.

The current regulations create challenges to achieving these outcomes.

- Nutrient credits - nutrient credits must be allowed for certain cases – these are the quick “get off the hook” solution for most developers. While this approach may help the Chesapeake Bay, it does nothing to address local streams or localized drainage problems.
- Volume and drainage – most of the local problems are driven by increased volume from greater impervious areas. Our belief is if there were a suite of solutions to address volume (ideally the first inch – which would account for 90% of the rain events) this would go a long way in addressing quality (sediment from in stream erosion)
- Only onsite solutions – lead to multiple small LIDs on private lots – many homeowners do not have the sophistication to adequately maintain these systems.
- Accounting requirements in MS4s – current requirement mandate the onsite LIDs be perpetually tracked, inspected, and maintained. Combined with the bullet above, this is going to create great challenges for communities in the future as they will either become the stormwater police or have to take on public maintenance of these practices on private lots.

- Analysis for adequate outfall and the design of certain LIDs has become complex that in many situations a lot of design dollars are spent for requirements that may ultimately be waived. We'd rather see the dollars go into practical solutions that can go into the ground versus fees to generate more paper.
- One solution (that we have not figured out how to accomplish) is to not take MS4 credit (or only take partial credit) for onsite LIDs or work an agreement with the state that releases the county from future inspection and monitoring of onsite (private) LIDs. Localities will carry a larger burden for meeting nutrient credit requirements. Our focus would instead turn to requiring certain practices that can help address volume and in turn help address quality. Practices such as amended soils, cisterns/rain barrels, disconnected downspouts, bio-swales and rain gardens.

<u>Research Statement</u>
R. Dymond 11/10 Draft

<u>Goal:</u> Develop a potential solution to infill-induced stormwater quantity and quality issues as currently perceived in Fairfax County, VA.

<u>Objectives:</u>

1. Research the prevailing County and State regulations/ordinances
2. Research any pertinent academic literature, conference proceedings, and local government reports
3. Estimate the scope of the infill issue in the County
4. Determine a pilot subdivision that has seen infill growth for study
5. Assess the infill-induced stormwater volume and nutrient load differences over a time period.
6. Estimate designs of onsite, neighborhood, and regional LID strategies to mitigate the differences. Also evaluate designs that will only remove the stormwater volume difference.
7. Estimate life cycle costs for these LID strategies
8. Use the scope of the infill issue in #3 with designs and costs in #6 & #7 to estimate infill-induced LID strategies and costs in the County
9. Draw conclusions from analyses, regulations, and literature