Yale Swale Assessment Report 2013-2014

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INTRODUCTION

The Yale Experimental Watershed ("Swale") is 5.5-acre wetland in the Science Hill portion of Yale University's campus. It is bordered by Prospect Street on the east, Mansfield Street to the west, Hillside Place to the north, and the Sachem parking garage to the south. Research and fieldwork at the Swale began in 2012 as part of the Hixon Center for Urban Ecology's Urban Resources Initiative (URI) intern program.

Previous research has characterized several aspects of site conditions. This includes tree identification and mapping, coarse woody debris sampling, soil sampling, watershed delineation, land cover mapping, and groundwater level monitoring. Results and summaries can be found in past reports stored on the URI server.

Research conducted in 2013-2014 focuses on site hydrology and instrumentation, soil testing, data management, avian habitat, and public outreach. This report provides both the methodology and results as well as recommendations for future research opportunities.

HYDROLOGY

Methods & Instrumentation

In 2012, high stream flows in the swale contributed to flooding on the southwest corner of the Swale. In order to prevent future damage and improve stormwater management on campus, the Swale was included in the 2013 Yale Office of Facilitiese Stormwater Management Plan. During the 2012-2013 year, URI interns mapped and quantified impervious and pervious surface areas in and surrounding the Swale. In addition, Arc-Hydro and regional climate data was used to determine the volume of stormwater flowing in and out of the Swale on an annual basis. Prior to fall 2013, groundwater wells and two initial v-notch weirs had been installed to monitor discharge and subsurface water levels in the Swale. In order to refine and streamline hydrologic data collection, 2013-2014 interns installed several new pieces of instrumentation under the direction of Dr. Gaboury Benoit.

These new monitoring devices included a Hobo tipping bucket rain gauge and radiometer for measuring precipitation and solar radiance (Fig. 1). In addition, the previous discharge monitoring system was upgraded. The prior system (Fig. 2), which featured a v-notch weir at the inlet and outlet coupled with a pressure transducer, was replaced with an upgraded YSI sonde system. The new system (Fig. 3) monitors both flow and water quality data continuously and, in contrast to the old system, is completely automated, allowing for off site monitoring and removing error associated with monthly collection and calibration.

Figure 1. Hobo rain gauge

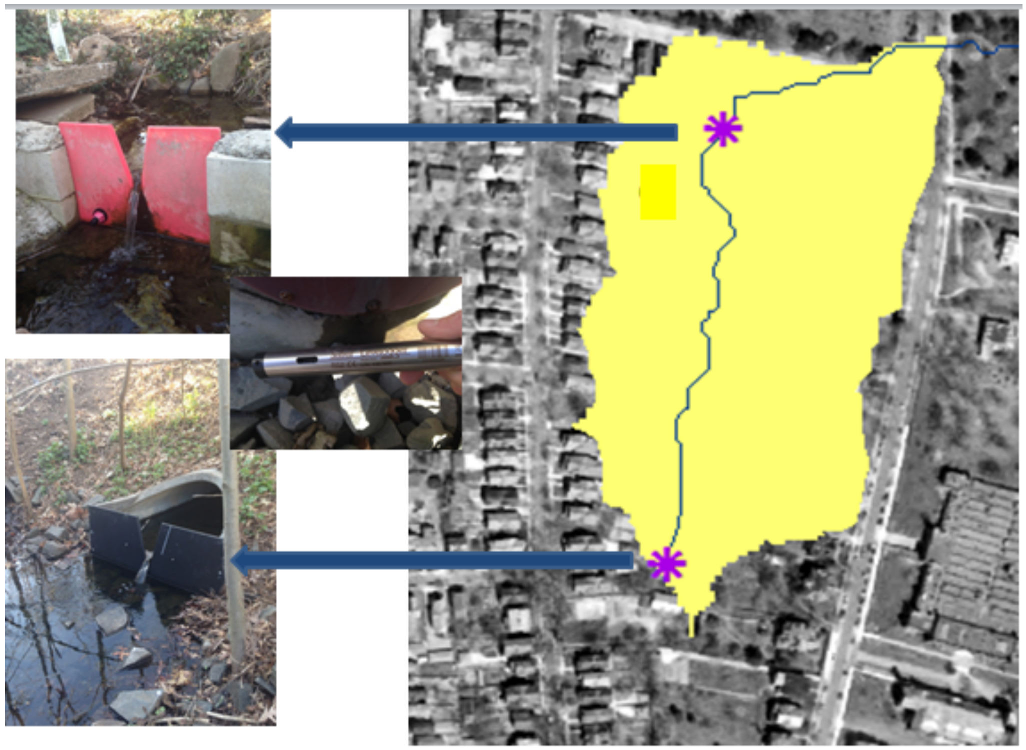

Figure 2. V-notch weir

Figure 3. New system

Data is available online at the following sites:

- http://www.ysieconet.com/public/WebUI/Default.aspx?hidCustomerID=205
- stormcentral.waterlog.com/public/yale

Water Balance

Besides enhancing student understanding, the 12+ months of collected discharge and climate data enable the creation of a basic water budget (Fig. 4). Measured terms in the water budget include precipitation, inlet flow and outlet discharge. In Connecticut, evapotranspiration has a wide seasonal variability, ranging from < 2mm/month to over 80 mm/month during peak growing season (NOAA 2014). For our period of record, evapotranspiration was considered to be negligible in the winter months. The following equations were used to estimate groundwater flow and groundwater storage.

- Groundwater Flow (GWF) = Outlet - Inlet
- Δ Groundwater Storage (ΔGWS) = Precip (P)–Evapotranspiration (ET) +Inlet -Outlet

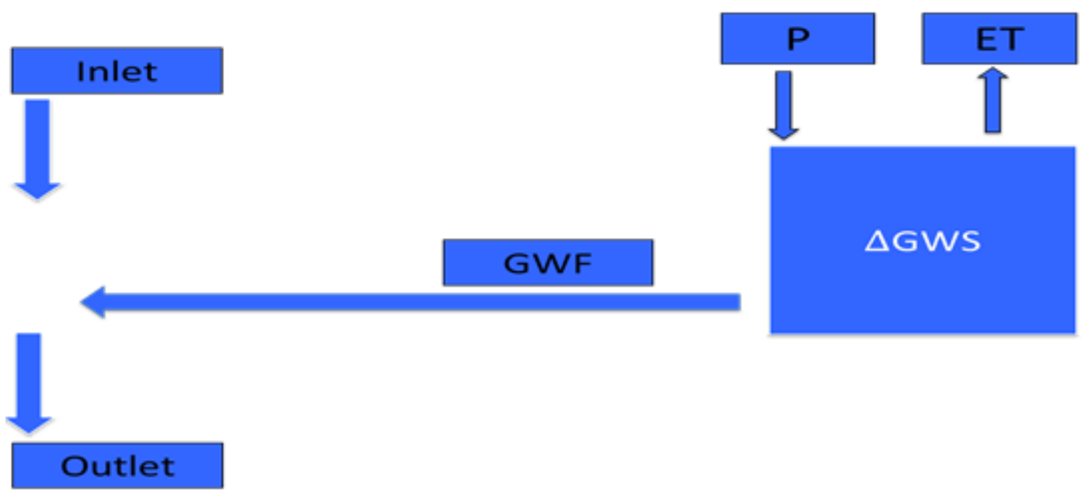

Figure 4. Water budget conceptual model

This budget was used to establish a basic hydrologic relationship between precipitation and outflow, a useful relationship for teasing out watershed response to varied flow levels.
By using this basic budget, we are also able to estimate terms in the water budget unmeasured by our current integrated monitoring system.

Results from the first year of monitoring (Fig. 5) show several trends.

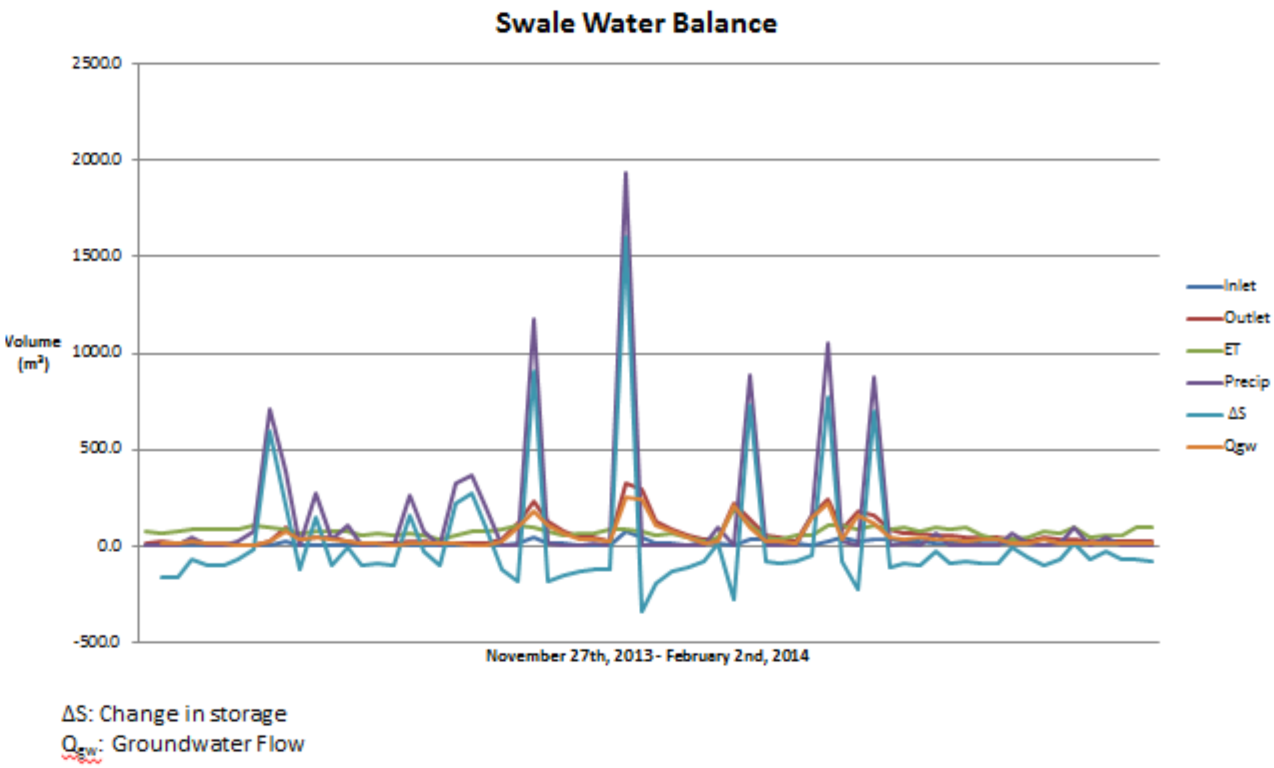

Figure 5. Discharge over time

Major precipitation events begin to appear as signals in the hydrograph in late November. Coming out of the dry summer period of minimum flows, discharge remains fairly low after the first few storms events in the late fall. Continued precipitation causes an increase in soil saturation leading into the wetter winter. During storms, soil saturation eventually increases, forcing increases in lateral flow and groundwater flow which contributes to elevated stream discharge values.

Values for stream discharge (Fig. 6) during this study period range from 0.25-3.77 liters per second for the outlet but only a thousandth of a liter per second to 0.8 liters per second for the inlet. Results how the inlet comprises only 22% of the total discharge leaving the outlet. Therefore, 78% of the discharge in the outlet is entering the swale as the stream travels from the inlet to the outlet. The greater volume of outflow relative to inflow suggests groundwater flows make a significant contribution to the stream over the length of the study reach.

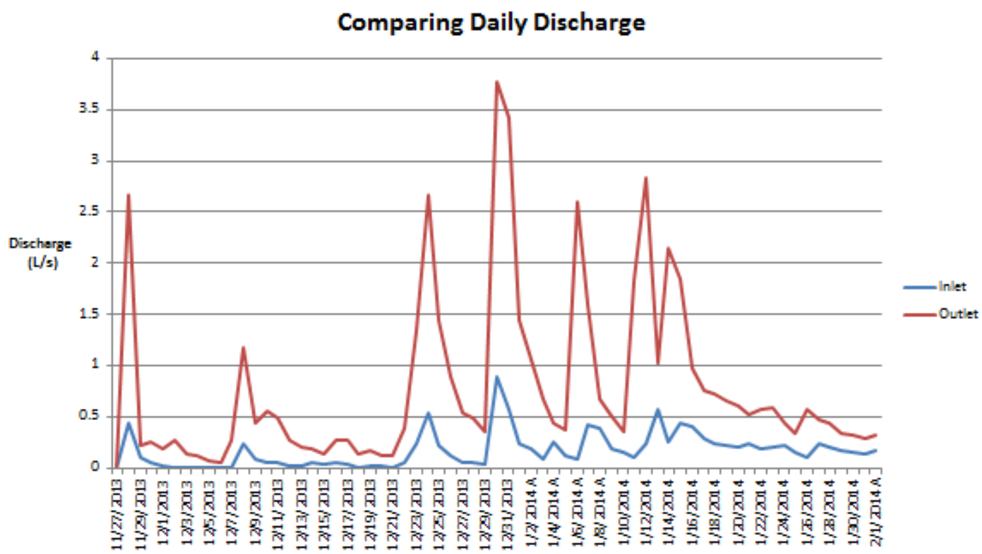

Figure 6. Daily discharge

According to preliminary estimates, groundwater plays a significant role in Swale hydrology. A large amount of the precipitation entering the stream as baseflow while another portion of it is being applied towards groundwater recharge. An estimated at 1,229,000 liters of water fall on the swale without exiting via the outlet and are stored in the swale for this period of record (Fig. 7). Groundwater storage increases in response to precipitation events as rain fills soil pores and spaces. Based on this period of record, the Swale is able to hold a large amount of precipitation, releasing this stored groundwater slowly into the stream throughout the winter. Groundwater storage is an important metric to monitor. Storing storm water instead of releasing it immediately to the stream can help improve flood management.

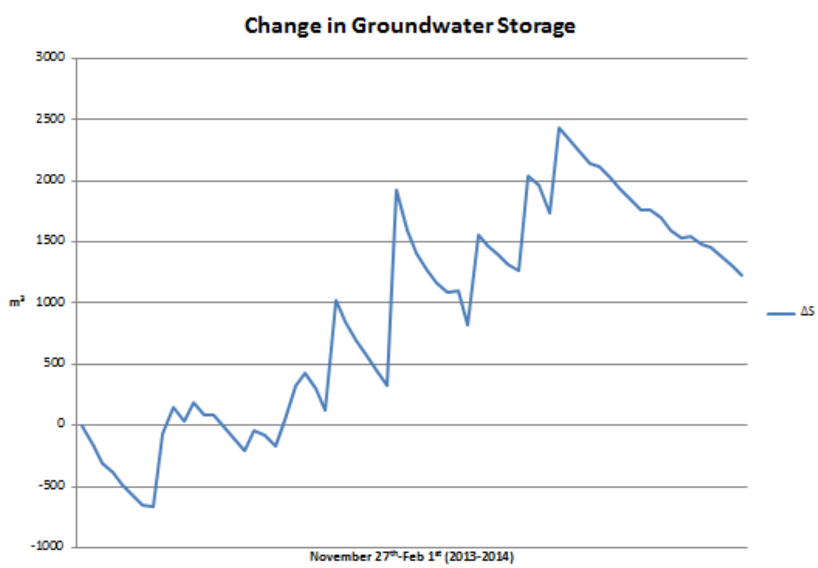

Figure 7. Groundwater storage

Rainfall Verification

In order to determine if the spatial heterogeneity of storms significantly influenced our precipitation readings, we compared our local readings with Tweed airport. While the general rainfall pattern (Fig. 8) from the two gauges was comparable, the Tweed data varied significantly based on the results of a simple regression. Three independent measures from the Swale site were taken in April 2014, confirming the accuracy of the tipping bucket. Given the small scale of the study, using on-site instrumentation instead of regional data clearly provides a higher degree of accuracy.

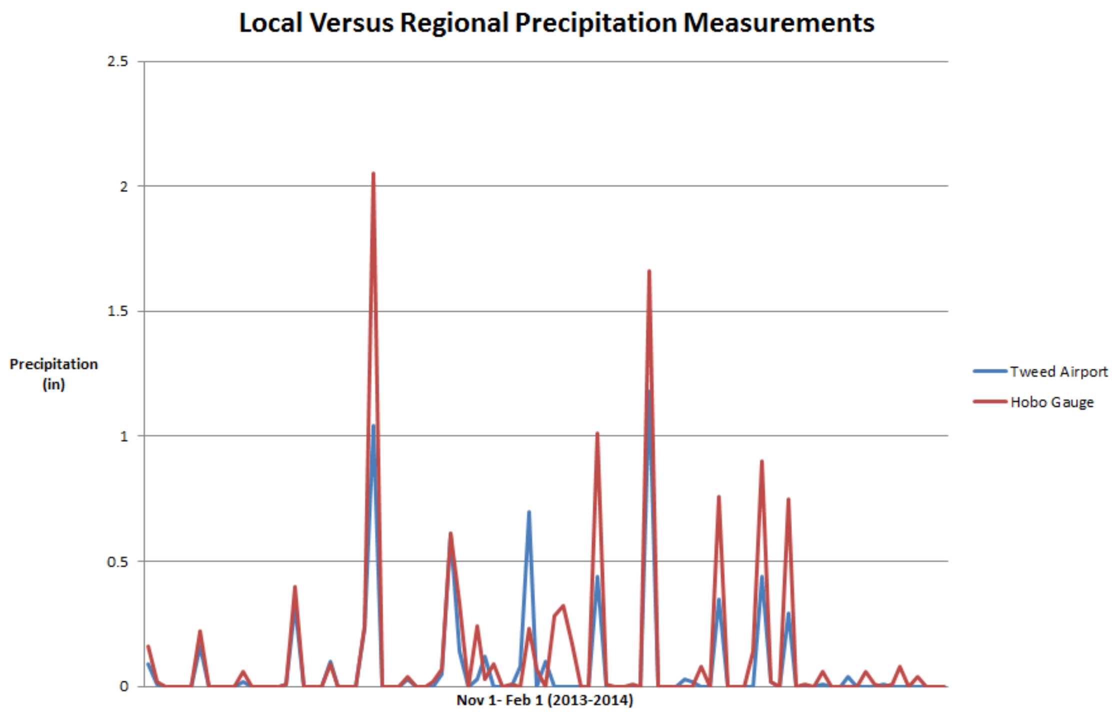

Figure 8. Precipitation graph

Evapotranspiration

Evapotranspiration is often one of the more difficult terms to estimate in balances. While there are simple equations such as the Blaney Criddle, accurate results are difficult to achieve without intensive data collection. As part of a coursework project, student Selena Pang estimated evapotranspiration using a modified Samani Hargreaves equation. Her work is currently the only physically-based estimate of ET for this site and can be found on the URI server under the file name Pang_Swale_ET in the water balance folder.

SOIL TESTING

Methodology

43 sampling points, 80 feet from each other, were laid out on a grid system using ArcGIS in 2012. 3 points were unused. These points were used for vegetation analysis in 2012. In 2013,

soil samples from each point were collected. An 8-cm diameter corer was used to take soil from a depth of 0-10 cm (D1) and 10-30 cm (D2) for a total of 80 soil samples. Soils were analyzed for carbon, nitrogen, water holding capacity, gravimetric moisture content, and macronutrients (Ca, Mg, P, and K).

Soil sample analysis continued into 2013 for lead and mercury. 20 samples, chosen at random, were tested for lead (Table 1). Soil samples were analyzed for lead using a two-step process. First, soil samples were digested according to EPA method 3051A, "Microwave Assisted Acid Digestion of Sediments, Sludges, Soils, and Oils" (See Appendix A for procedure). Second, digested products were analyzed using inductively coupled plasma mass spectrometry (ICP-MS).

Results

Lead levels above 400 parts per million (ppm) in residential soils were designated to be significant, according to the U.S. EPA's standards.[1] The U.S. EPA determined that exposure to lead levels above 400 ppm can be dangerous to human health. 7 samples have significant levels of lead. The high levels of lead may be due to paint runoff from houses nearby or atmospheric deposition. Because there are no activities in the Swale that require major soil disturbance except for research, high levels of lead are not a current health concern.

Sample ID	Pb (ppm)	
	Depth 1	Depth 2
S1	180	177
S9	184	118
S10	301	251
S16	**535**	205
S17	**489**	**411**
S18	268	114
S27	152	73.3
S31	194	71
S38	**893**	**560**
S41	**441**	**483**

Table 1. Lead results (ppm)
Significant results in bold

[1] http://www.epa.gov/superfund/lead/products/oswerdir.pdf

Samples with significant lead levels were further tested for mercury (Table 2). In 2013, Connecticut DEEP set a regulatory threshold of 20 ppm in residential soil for mercury.[2] All 7 samples tested for mercury exceed this threshold and are significant. As stated above, because there is minimal soil disturbance in the Swale, high mercury levels do not pose a significant health concern.

Sample ID	Hg(ppm)	
	Depth 1	Depth 2
S16	591.22	N/A
S17	513.71	455.65
S38	1094.37	930.93
S41	1011.44	2354.2

Table 2. Mercury results (ppm)

Lead and mercury analysis were completed with the help of Dr. Helmut Ernstberger in the Environmental Chemistry Lab run by Dr. Gaboury Benoit.

AVIAN HABITAT

In 2013, biologist Celia Lewis conducted avian breeding area surveys in the Swale to determine which species of birds utilized the swale for reproduction. Her work catalogued the presence of 14 species of birds (Table 3). To support her work, spatial representations of her surveys were created using ArcMap 10.1. Her handdrawn maps were scanned and georeferenced. Polygons for each species were created and appending notes were attached to each feature class. Based on her results, the Swale plays an important role in providing habitat for migratory and resident bird species. More information on avian breeding in the Swale can be read in Lewis's report for URI.

Common Name	**Latin Name**	**Breeding Area (m2)**
Northern Flicker	*Colaptes auratus*	pending server access
Downy Woodpecker*	*Picoides pubescens*	
Northern Cardinal	*Cardinalis cardinalis*	
Song Sparrow	*Melospiza melodia*	
Woodthrush	*Hylocichla mustelina*	

[2] http://www.ct.gov/deep/lib/deep/regulations/22a/22a-133k-1through3.pdf

Black-capped Chickadee	*Poecile atricapillus*	
House Wren	*Troglodytes aedon*	
Northern Baltimore Oriole*	*Icterus galbula*	
Common Yellowthroat	*Hylocichla mustelina*	
Grey Catbirds	*Dumetella carolinensis*	
American Robin	*Turdus migratorius*	
Red-Bellied Woodpecker	*Melanerpes carolinus*	
Cedar Waxwing*	*Bombycilla cedrorum*	

Table 3. Avian species and habitat in the Swale

*Sighted but not breeding

FENCE REMOVAL

12 abandoned internal fences totaling 271 meters are located throughout the Swale (Fig. 9). These fences cause obstruction to easy access to the site and provide space for growth of invasive vines. The 2012-2013 Yale Swale assessment report recommended removing these fences and installing a new one along Hillside Place.

Figure 9. Abandoned fences

The Yale Office of Facilities removed the fences in 2014. Work to install a new fence along Hillside Place has not yet taken place and is expected to occur in the near future.

GROUNDWATER MONITORING WELL INSTALLATION

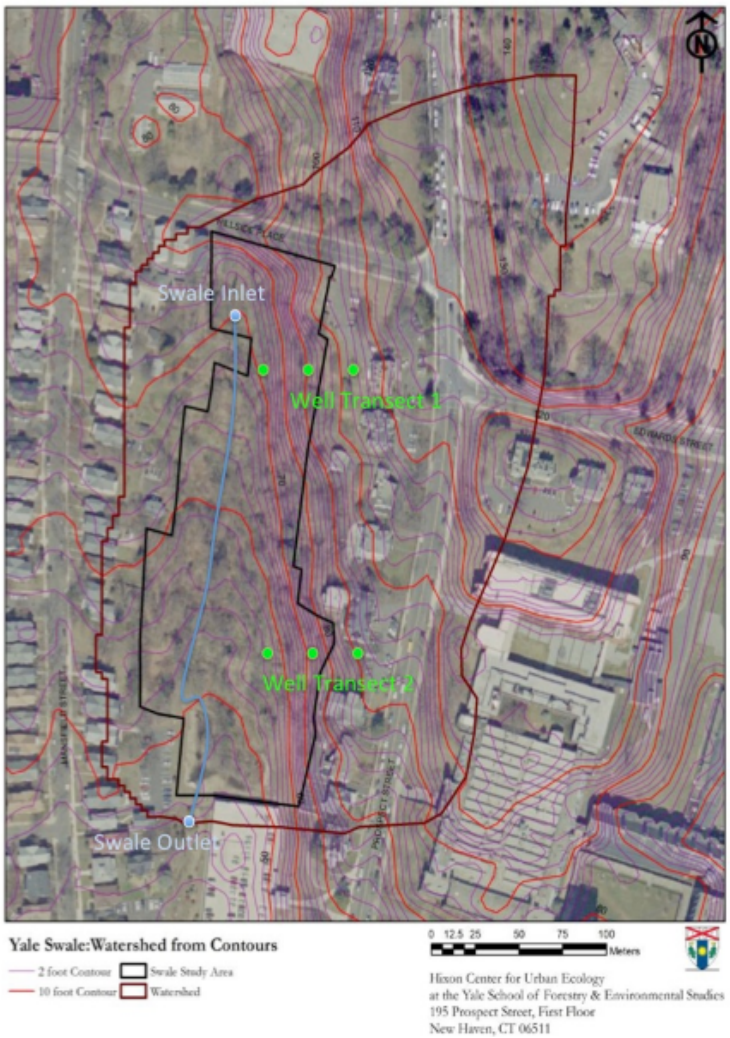

Figure 10. Well clusters

Dr. Gaboury Benoit and Dr. Jim Saiers identified locations for six new groundwater monitoring clusters to be installed along two transects on the eastern, sloped portion of the Swale (Fig. 10). The first transect would consist of three well clusters installed approximately 150 meters north of the Prospect / Sachem Parking Garage, and the second transect would consist of three well clusters installed approximately 100 - 200 meters south of Hillside Place.

Each well cluster would consist of two groundwater wells spaced immediately adjacent to one another that would bottom at two different depths. The wells would be shallow - bottoming below the water table but above bedrock - and are anticipated to be approximately 10 - 15 feet in depth adjacent to the stream and 20 - 40 feet in depth along the hill slope. Further, construction of the wells would entail: a) that 2” PVC with a 3’ screen be used for each well; b) a filter pack of clean sand be emplaced above and around the screened intervals; c) a bentonite or neat cement seal should be installed above the filter pack; and d) a steel protective casing with lockable lid surround each well casing for termination at the top of each well.

The Yale Office of Facilities completed work on installing all proposed groundwater monitoring clusters in 2014.

TRAIL DELINEATION

With the assistance of Dr. Gaboury Benoit, a site walk was conducted to delineate a trail throughout the Swale. The trail would traverse the Swale from south to north, beginning in the southeast and exiting the site in the northeast (Fig. 11).

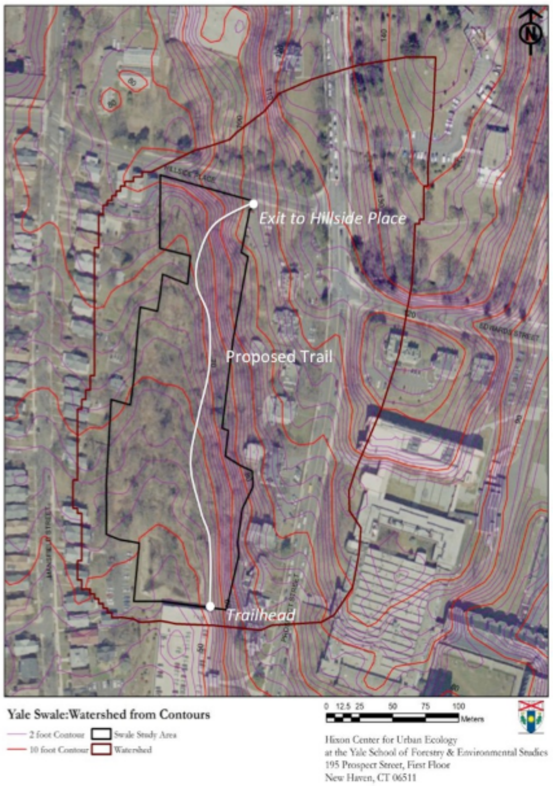

Figure 11. Proposed trail path

The trail would be approximately six feet in width and pink flagging tape was used to mark a path and tag features (i.e. native trees and installed groundwater wells) that should not be removed. The trail path would be constructed with a crushed gravel or sand medium that would be temporary in nature and need to be reevaluated on a yearly basis to determine if improvements would be necessary. In addition, the trail would be marked with interpretive signage which would allow for easier and more direct access to groundwater wells, the Swale inlet, and identified sampling points. This increased access would assist in future Swale research efforts and allow for adjacent communities to understand what research is being done in the Swale.

The Yale Office of Facilities has temporarily delayed the construction of the Swale trail. Work on constructing the trail does not currently have a future start date scheduled; however, trail work may continue at some point in the near future.

BOARDWALK PLANS

Discussion and meetings were held to develop plans to install a boardwalk over the wetland located within the Swale. The Swale wetland is located adjacent to soil sample plot 29 and is surrounded by the invasive *Fallopia japonica*, or Japanese knotweed. More preliminary work needs to be conducted on the boardwalk in order to: a) determine where to install boardwalk supports; b) delineate a path through the Japanese knotweed; and c) connect the boardwalk trail to the proposed Swale trail.

REGIONAL OUTREACH

Conferences

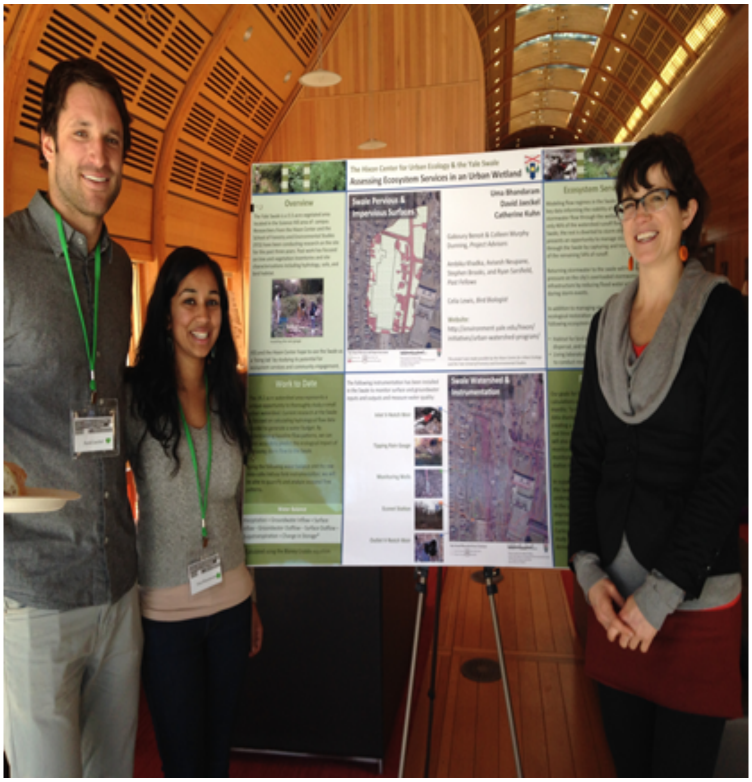

Figure 12. Yale Urban Ecosystems Services Symposium

Two conferences were attended over the course of the 2013 - 2014 academic school year to present research conducted on the Swale: 1) the Yale Urban Ecosystem Services Symposium; and 2) the Society for Ecological Restoration's Designing for Success: Ecological Restoration in Times of Change Conference. A poster presentation entitled: *The Hixon Center for Urban Ecology & the Yale Swale, Assessing Ecosystem Services in an Urban Wetland*, was given at the Yale Urban Ecosystem Services Symposium on January 24, 2014 (Fig. 12). The poster summarized past and current work on the Swale related to research efforts, ecosystem services, and future management plans.

In addition, during the symposium a tour of the Swale was given to Mike Houck, Executive Director of the Urban Greenspaces Institute, to receive feedback on future site management.

Both a poster and oral presentation were given at the Society for Ecological Restoration's Designing for Success: Ecological Restoration in Times of Change Conference on April 25, 2014. Catherine Kuhn gave an oral presentation entitled: *Baselines for Restoration: Calculating a Water Budget for a Small Urban Wetland*, and David Jaeckel presented the Hixon Center for Urban Ecology's poster entitled: *The Hixon Center for Urban Ecology & the Yale Swale, Assessing Ecosystem Services in an Urban Wetland*. Catherine's talk described the methods used to calculate a water balance for the Swale, and David's poster summarized Swale research efforts, potential restoration projects, and future site management. Both Catherine and David received awards for the conference's best student oral presentation and best poster presentation, respectively.

ON-CAMPUS OUTREACH

Faculty Surveys

Surveys were conducted in the fall semester of 2013 in order to identify Yale Faculty that may have interest in the Swale. A list of all potential interested faculty members was created with the assistance of Dr. Gaboury Benoit and Colleen Murphy-Dunning. Interviewed faculty were: Drs. Mark Ashton, Shimon Anisfeld, Graeme Berlyn, Anne Camp, Amity Doolittle, Alex Felson, Bradford Gentry, Xuhui Lee, Timothy Gregoire, Peter Raymond, James Saiers, Karen Seto, Dave Skelly, and Julie Zimmerman.

Faculty members were surveyed through in-person interviews and each interview was transcribed and presented to Gaboury Benoit and Colleen Murphy-Dunning. The interviews conducted led to the establishment of the spring 2014 Watershed Cycles and Processes class.

Signage

Preliminary text and locations for signs were developed to help identify various features in the Swale to the general public. With the assistance of Dr. Gaboury Benoit and Colleen Murphy-Dunning, the following features were chosen to be highlighted with signs:

- Trail head
- Rain gauge and MET station
- Groundwater wells
- Inlet YSI station
- Outlet YSI station
- Vegetation
- Boardwalk
- Bird habitat
- Sampling sites

We met with David Heissler and Richard Kissel from the Yale Peabody Museum of Natural History to discuss sign writing, designing, and constructing in accordance with the University signage guidelines. Currently, sign text has been created and the Yale Peabody Museum is adding graphic design elements and Yale University approved logos to be incorporated in the final design for each identified sign. Once individual signs have been approved, the signs will be installed.

Courses

In Spring 2014, a new course entitled FES 724 Watershed Cycles and Processes was offered. Co-taught by Dr. James Saiers, Dr. Peter Raymond and Dr. Gaboury Benoit, this course offered students an opportunity to conduct independent hydrologic research projects using the Swale as a study site. A majority of students completed research projects on the Swale. Topics ranged from effects of road salt on water quality, watershed modeling, and flooding risks in the Swale watershed (Table 4). The final presentations from each project can be found on the URI server. Several student teams used hydrologic modeling, including the SWAT, TOPMODEL, and Kirchener to model the Swale system. These models could be useful for future interns to develop conservation scenarios or to test the response of the Swale under different climate scenarios.

1	Characterizing and Measuring DOC and POC in the Yale Swale
2	Road Salt Effects on Yale Swale soil and water composition
3	Detection of Sanitary-Sewer Leakage in the Yale Swale Watershed
4	Evaluating Transport and Transformation of DOM at Yale Experimental Watershed
5	Assessment of potential flooding in a small urban catchment
6	Greenhouse Gas Evasion from the Yale Swale
7	Groundwater Flow in the Yale Swale
8	Test of Scale for the Soil & Water Assessment Tool (SWAT)
9	Developing a Green Infrastructure Pilot Program in the Yale Swale Watershed

Table 4. Final presentation titles for FES 724

DATA MANAGEMENT

As part of the effort to improve the yearly transmission of past research to new interns and outside parties, our team undertook the large organizational project of restructuring the Swale database on the URI server. As part of this effort, we reached out to Carla Heister and Kristen Bogdan at the Center for Science and Social Science Information (CSSSI) for advice on database management. We also met with Stacey Maples, the campus geospatial analyst, in order to organize spatial data while preserving the integrity of previously developed geodatabases. After these consultations, the Swale research folders were reorganized to reflect a more intuitive and universal structure.

RECOMMENDATIONS

Based on current and previous fieldwork at the Swale, we recommend future interns to continue work in these following categories.

Research:

- Continue soil testing. All remaining soil samples should be tested for lead. Samples with significant levels of lead should be further tested for mercury.
- As part of FES 724, Uma Bhandaram and Dave Jaeckel worked on a green infrastructure report with support from the Office of Facilities and an engineering consulting

firm. Construction of the green infrastructure strategies recommended in this report should be carried out next year.

- Improve estimation of evapotranspiration using sap flow measurements.
- Continue long term integrated monitoring of the hydrologic balance using telemetry stations.
- Install soil moisture monitors and on-site weather station.

Management:

- Continue website development and data management of the URI server. Create spaces to publicly host student research and reports.

Outreach:

- Integrate Swale site into the MODS Curriculum, possibly through invasive species removal or further vegetation surveying.
- Construction of a trail to enhance Swale accessibility for researchers and the Yale community at large.
- Continue work with the Peabody museum to finalize interpretive signage to be placed in the Swale.

APPENDIX A: Lead Digestion Procedure

Equipment

- Soil samples
- Scale
- Filter paper
- Falcon tubes
- Vessels (for microwave digestion)
- Pressure release membranes
- 2 pipettes
- Gloves
- 10% HCl solution
- 10% HNO3 solution
- Deionized (DI) water

Prep

1. Get falcon tubes from the stock room or over by shelves
2. Soak the falcon tubes in the acid bath for 30 minutes and rinse with DI water 4 times each
3. Clean vessels

a. Soak in acid bath. Do not put pressure release cap or sleeve in acid bath.

b. Rinse with DI water 4 times

4. Change pressure release membranes

Procedure

1. Place filter paper on scale.
2. Tare Scale.
3. Weigh out 0.25 grams of your sediment sample

a. Scale can be sensitive to static from gloves or leaning on counter.

4. Put sample into vessel. Make sure none of the sample is above the line made by the lid on the inside of the vessel. Also make sure to get as much as the sample as possible off the filter paper. A thin mist is fine.
5. Finish weighing out all the samples.
6. Move the tray over by the hood. Get out the two bottles of 10% HCl and 10% HNO3.
7. Get the pipettes out of the drawer and put on the appropriate tips. Make sure not to touch the tips while you are doing this. Measure out 3ml on the pipette for HCl and 9ml for HNO3.
8. Put your vessel under the hood. Open up the HNO3 botte. Use the pipette the transfer 9ml into the vessel, washing down any sediment on the sides but being careful not to touch the sediment with the pipette tip. Cap the HNO3 bottle.
9. Open up the HCl bottle. Pipette 3ml into the sample vessel, again being careful not to touch the tip to the contents of the vessel. Cap the HCl bottle.
10. Cap the vessel and put it into the carousel. Place pressure cap on and twist until a click is heard. Use wrench if necessary.

a. Note that the monitoring tube goes in slot #1. Start placing samples from slot #2.

11. Repeat steps until carousel is full. Check to ensure that the right sample is in the right spot – vessels are not numbered but the carousel is. Use a lab notebook to note which sample is placed in which carousel slot.

12. Place carousel in the microwave. Check to make sure it is plugged in and that the hood is attached. Turn it on. Settings are pre-programmed.

a. Periodically check to see if pressure and temperature settings are right.

13. Let it cool for 30 minutes before you remove the carousel from the microwave.

14. Place carousel on table next to the fume hood. Remove each vessel by unscrewing the pressure cap (use wrench). Point the release valve away from you and slowly unscrew.

15. Pour the contents of each vessel in a 50ml falcon tube and label clearly.

16. Repeat for all vessels.

17. Clean up.