Green Action Property Owners Can Take to Reduce Stormwater Runoff on Planet Earth

Lee R. Skabelund, PLA, ASLA, Associate Professor
Dept. of Landscape Architecture and
Regional & Community Planning
College of Architecture, Planning & Design
Kansas State University

20 July 2019

Two Key Ideas:

Disconnect your rooftop and pavement from downstream areas.

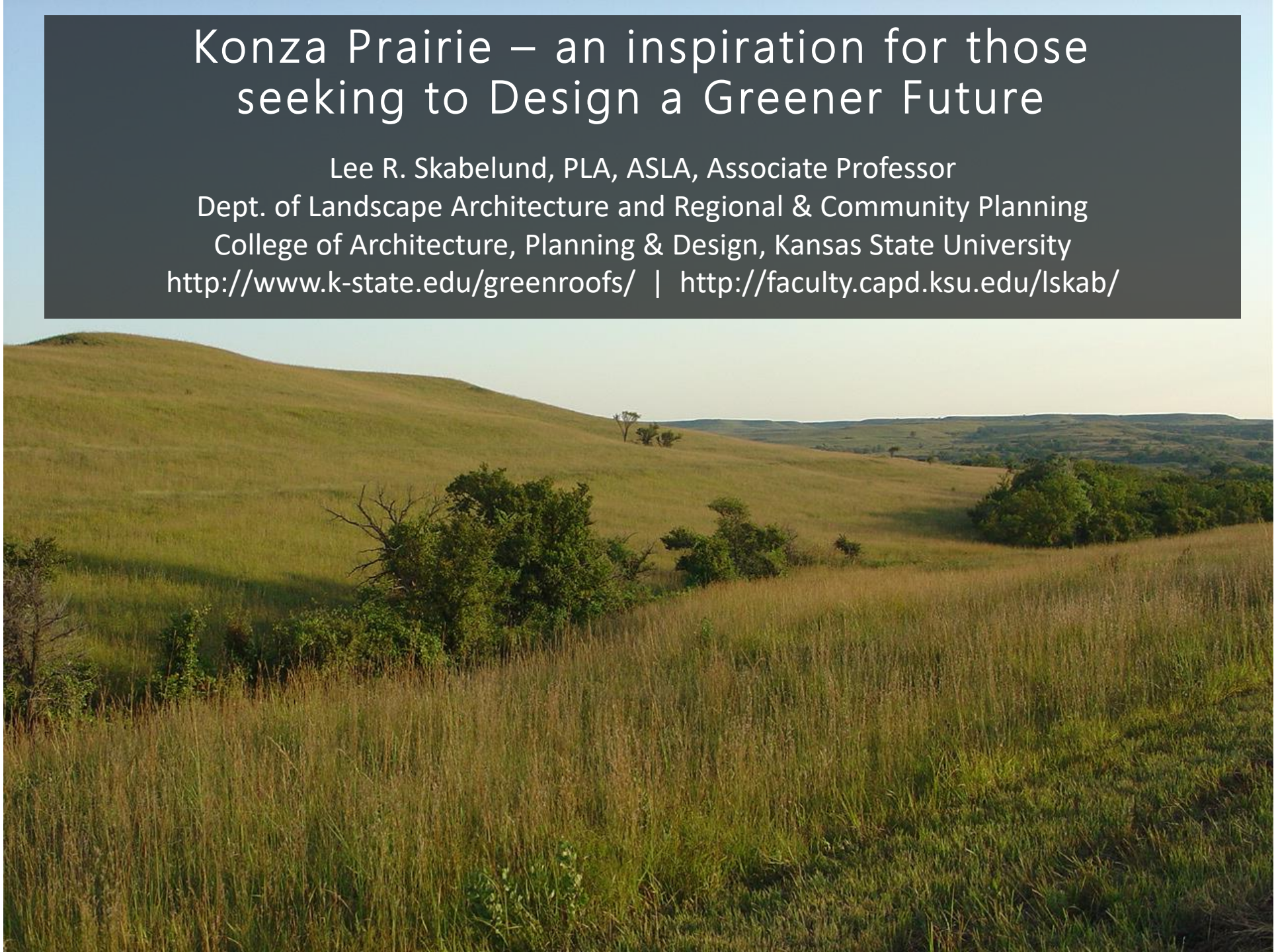
(Safely slow, hold & infiltrate precipitation!)

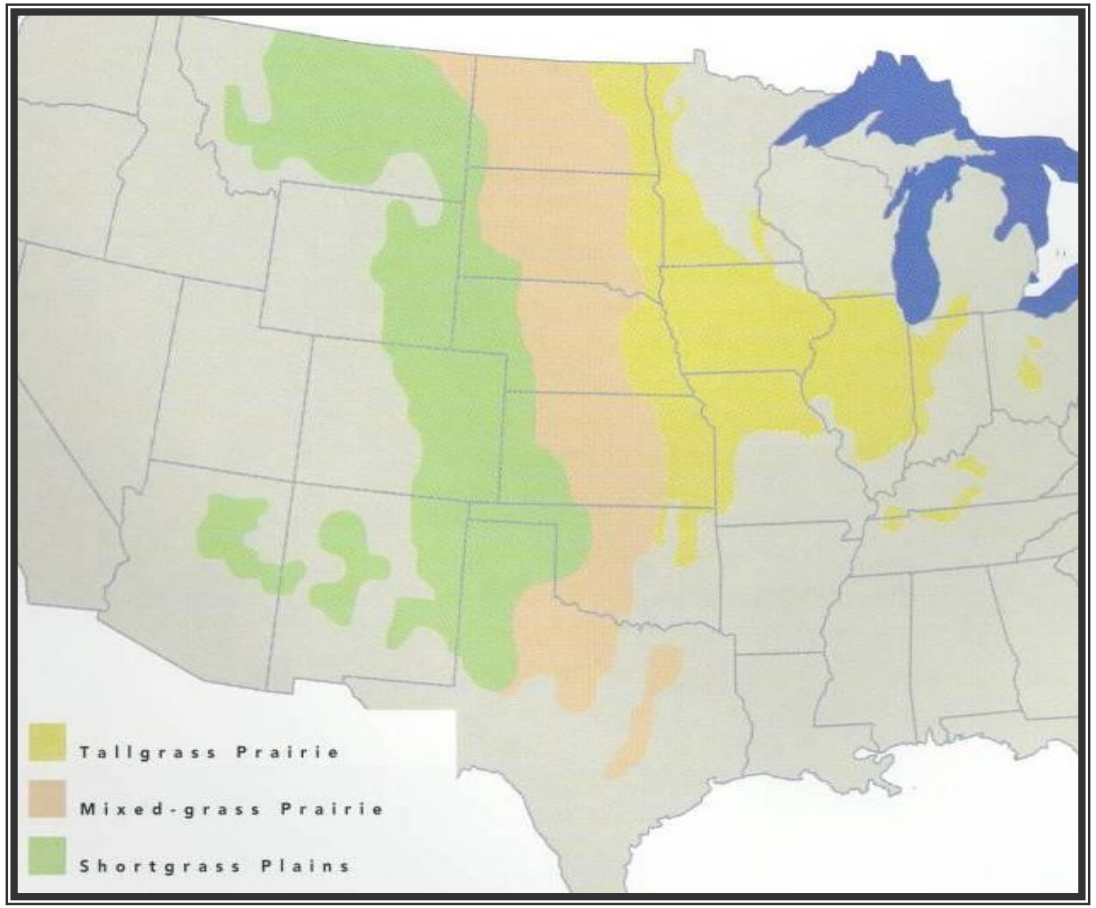
Create low-input landscape systems that support short- and long-term societal and ecological health.

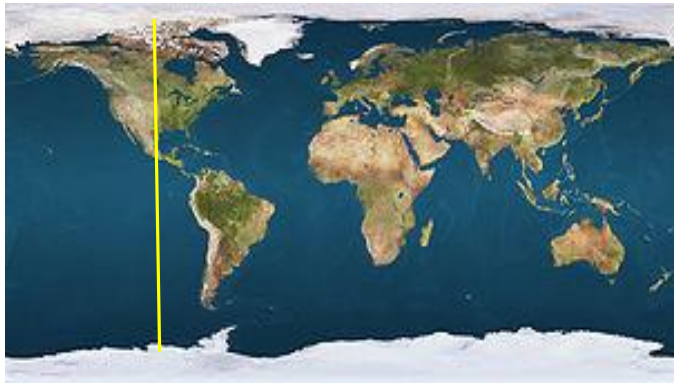
(Fit with site, surroundings & ecoregion!)

Konza Prairie – an inspiration for those seeking to Design a Greener Future

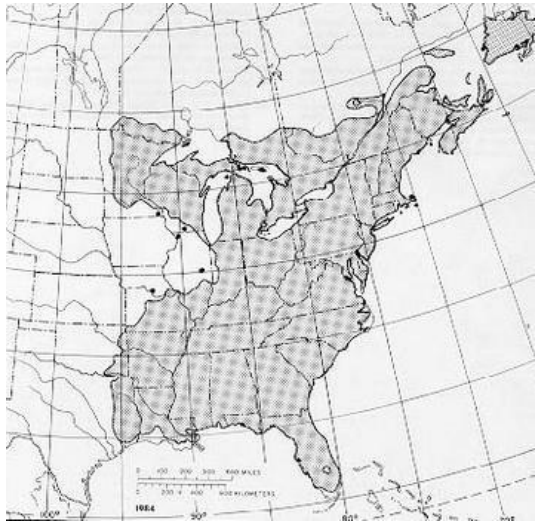
Lee R. Skabelund, PLA, ASLA, Associate Professor
Dept. of Landscape Architecture and Regional & Community Planning
College of Architecture, Planning & Design, Kansas State University
http://www.k-state.edu/greenroofs/ | http://faculty.capd.ksu.edu/lskab/







Red Maple Range



Note: images to left & text provided by KSU Professor of Biology Dr. John Blair

- Tallgrass prairie is the most mesic of Great Plains grasslands, but water limitations are very important
- Flint Hills - located at dry edge of the original tallgrass range on shallow soils; highly responsive to precipitation variability

Konza Prairie plant communities

Dominated by warm-season C_4 grasses

63 native grasses (75% perennial), 21 introduced species.

C4 grasses are adapted to warmer, drier conditions.

Grasses make up ~90% of plant productivity on the prairie.

Andropogon gerardii

Sorghastrum nutans

Schizachyrium scoparium

Konza Prairie plant communities

Forb species comprise the bulk of plant biodiversity

In total, 575+ species of vascular plants have been observed at Konza…

Forbs are vital in regards to ecosystem diversity.

Spring burns and frequent burns tend to favor grasses and minimize woody plant invasion into prairie ecosystems/plant communities

https://keep.konza.k-state.edu/prairieecology/fire.html

Konza Prairie – Kings Creek (7/1/2010)

Konza Prairie – buffalo wallow
(5/24/2007)


consider the lowly
buffalo wallow

Konza Prairie – former
buffalo wallow (10/25/2005)

Konza Prairie - intermittent stream (10/25/2005)

Wildcat Creek Corridor near Scenic Drive Bridge – 10/20/2005

What can we learn from the Konza Prairie about how to manage stormwater runoff?

Wildcat Creek Corridor north of Scenic Drive – 10/20/2005

Clearly we need to improve our operating standards!!!

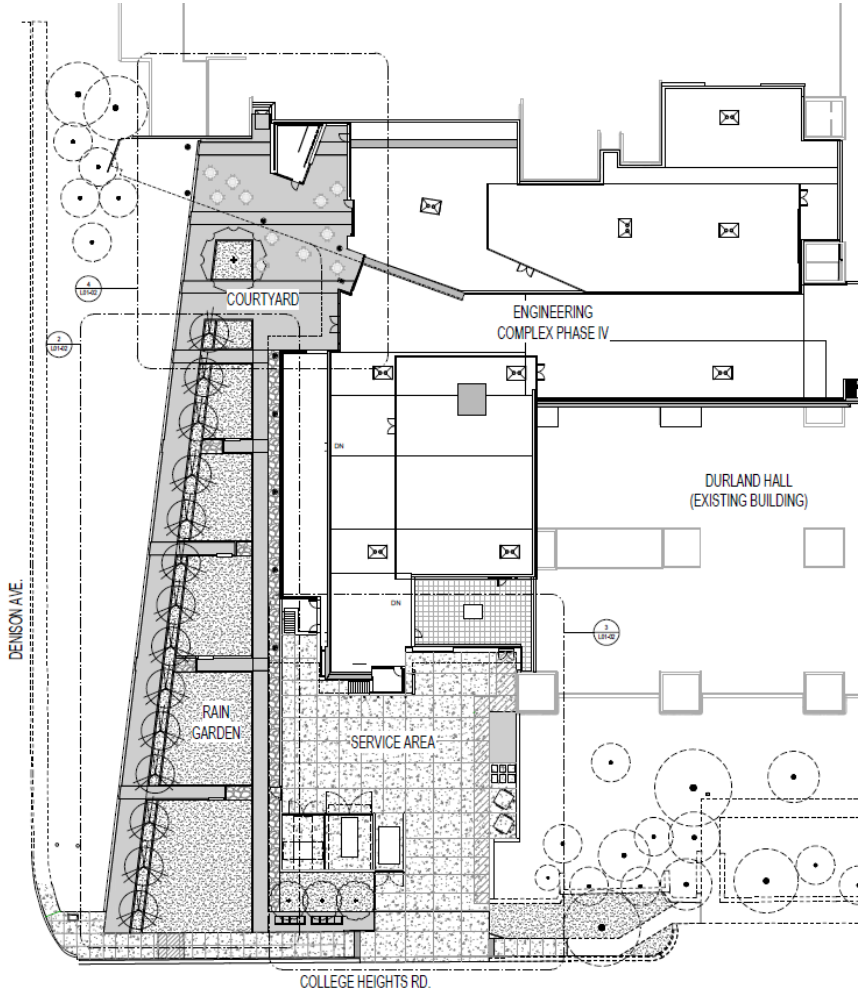
Development north of Scenic Drive – 5/8/2007

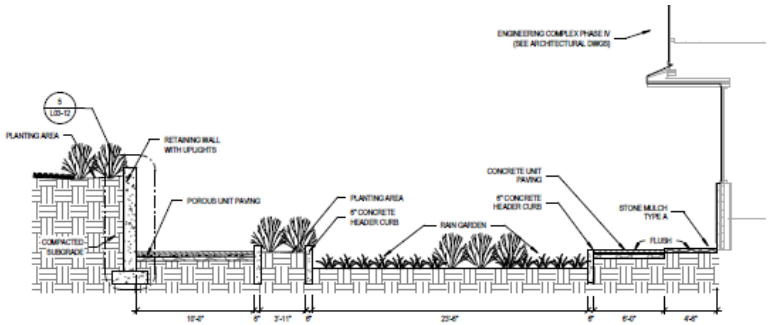
Wildcat Creek at Garden Way Apartments – 6/2/2011

Stormwater Management at Fort Riley – 11/18/2011

Large bio-retention areas were constructed in 2011 and 2012 as an attempt to mitigate the large areas of impervious paving at Fort Riley, KS.

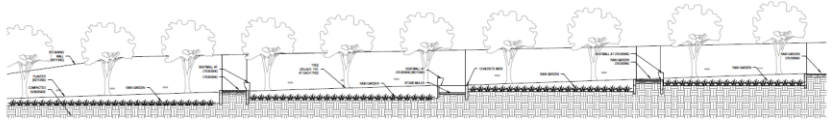
These systems seek to slow and infiltrate stormwater runoff in order to prevent or reduce gulley erosion on the military base (which can cause accidents as vehicles drive across the prairie for training).





④ E-W RAIN GARDEN SECTION
3/16" = 1'-0"

SW Engineering Rain Garden - 21 Oct 2015



③ N-S RAIN GARDEN SECTION, TYP.

The Engineering Rain-Gardens (three species within concrete bounded bio-retention cells in this southwest courtyard) were constructed in 2015 – designed by engineers and designers from two private multi-disciplinary firms.

Anderson Road – vegetated swale (10/25/2005)

June 2016

Taking a few ideas from several EPA Rainworks projects the 17th Street Pedestrian Corridor Rain Gardens (bio-retention cells and swales bounded by heavy clay soils) were created in 2015-2016.

Sep 2016

Bio-retention areas along 17th Street seek to reduce the impacts of impervious paving and thus slow and infiltrate stormwater runoff.

Students in my LAR Planting Design Studio made proposals for permeable paving and rain-gardens along 17th so it was very good to see the university and private firms propose and design these!

17th Street Bio-retention

11 Sep & 10 Oct 2015

Filled with engineered soils these areas now function reasonably well, although wetland plants are needed in some locations.

29 Jun2017

Kansas State University
17th Street Bio-retention

29 Jun 2016

Creating a naturalized basin to slow and infiltrate stormwater at KSU…
The idea was great but the design & implementation were not so great.

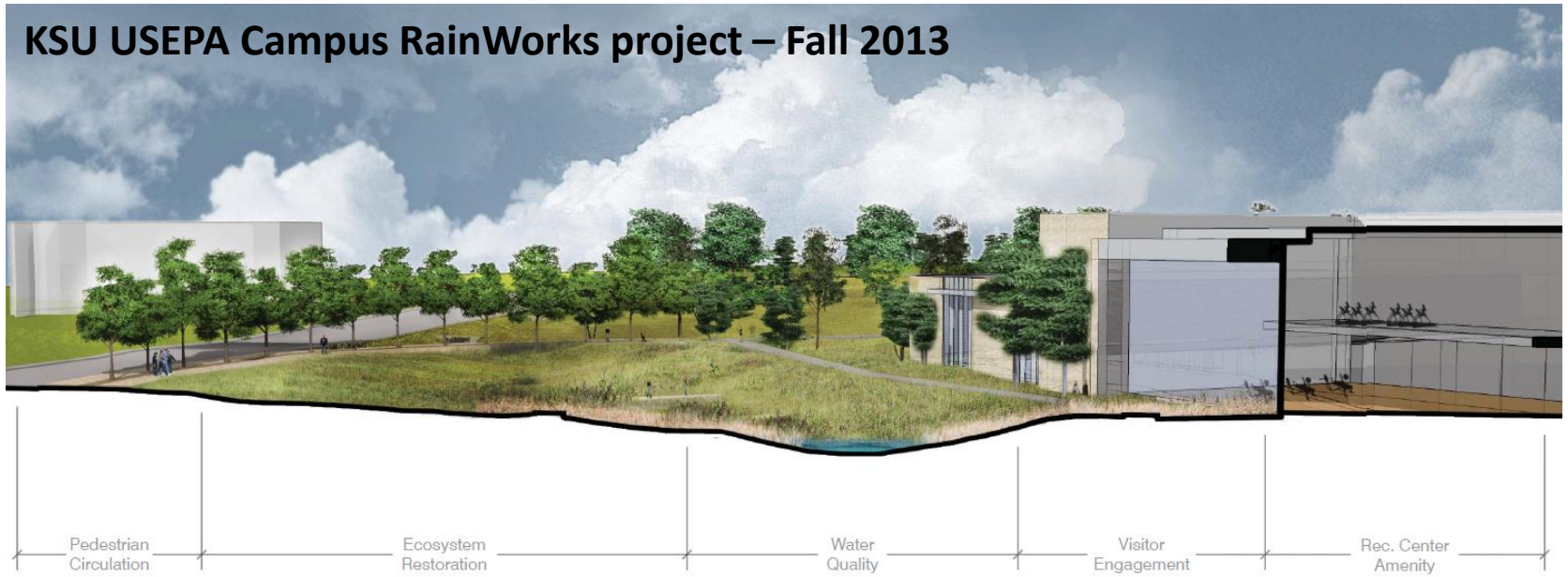
Green infrastructure designs on campus have not always been well-designed, implemented or maintained.

This was true for the infiltration (naturalized detention basins) near the Peters Recreation Building.

Green infrastructure needs to be well-thought out – and then successfully integrated into the larger landscape (accounting for high runoff rates from impervious surfaces that feed into them).

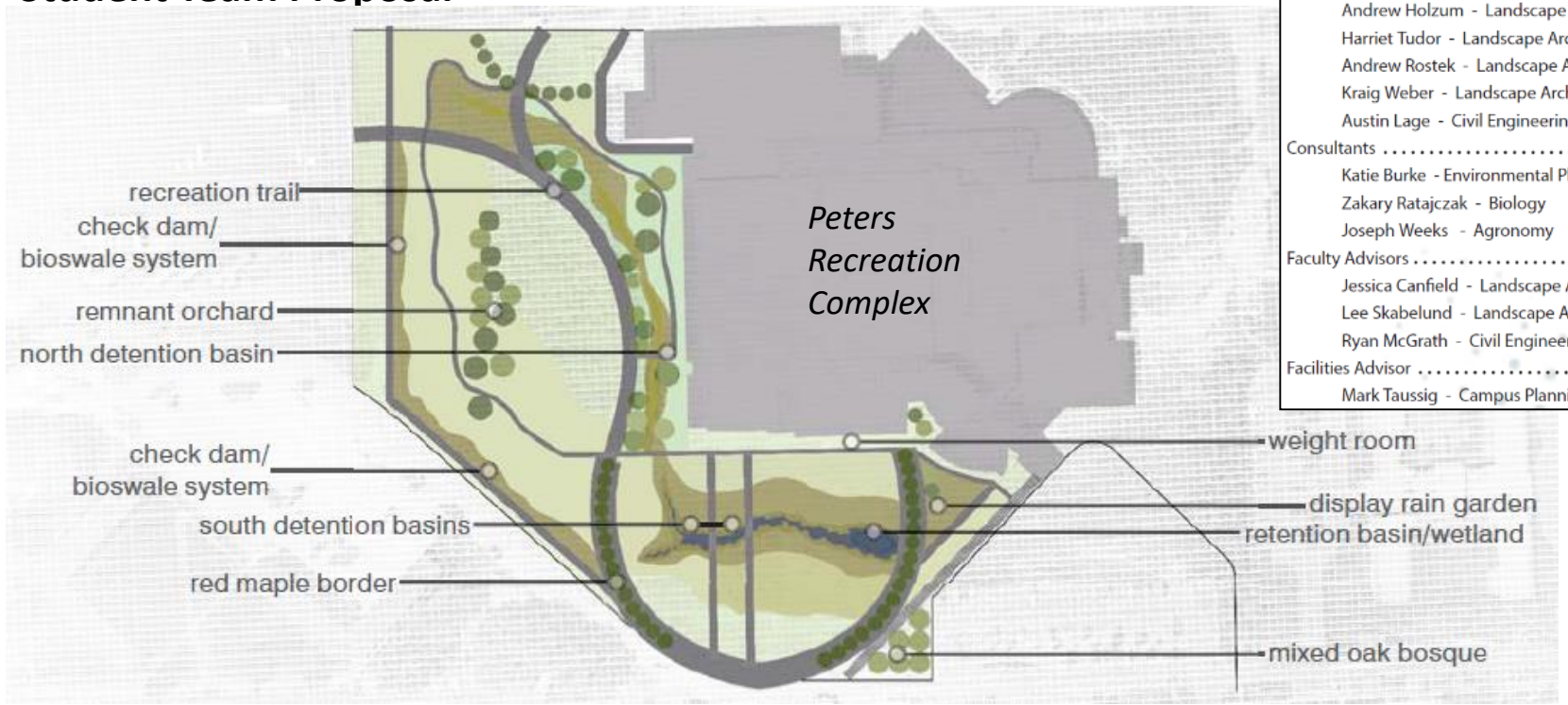
Way too much water has been eroding slopes and soils east of the football stadium parking lots…

KSU USEPA Campus RainWorks project – Fall 2013



Existing Condition

Student Team Proposal



Team Members
- Andrew Holzum - Landscape Architecture
- Harriet Tudor - Landscape Architecture
- Andrew Rostek - Landscape Architecture
- Kraig Weber - Landscape Architecture
- Austin Lage - Civil Engineering

Consultants
- Katie Burke - Environmental Planning and Design
- Zakary Ratajczak - Biology
- Joseph Weeks - Agronomy

Faculty Advisors
- Jessica Canfield - Landscape Architecture/ Regional & Community Planning
- Lee Skabelund - Landscape Architecture/ Regional & Community Planning
- Ryan McGrath - Civil Engineering

Facilities Advisor
- Mark Taussig - Campus Planning and Facilities Management

EPA Campus Rainworks project that sought to address concerns at the Peters Recreation Complex.

Campus Creek (6/3/2011)

USEPA RainWorks Competition (1st Place Nationally) – Fall 2016 project with Bruns, McDonough, Skabelund, Moore, et al.

Section 1-1

STRONGER QUINLAN

D6

Connecting the Strong Complex and the Quinlan Natural Area Through Green Infrastructure

A Large Rainwater Cisterns
Three 10,000 gallon rainwater harvesting cisterns capture the runoff from the Strong Complex rooftops. A stormwater analysis revealed that the three buildings in the Strong Complex - Boyd, Van Zile, and Putnam - contribute 30,000 gallons of runoff during a 1.1" water quality storm event. Currently, the downspouts lead directly to Campus Creek, exacerbating the problems of flooding and erosion. This design solves part of that problem by capturing the stormwater at the source, storing it, and then releasing it slowly for irrigation of the lawn areas and bioretention cell (G).

C Table Cisterns
Six "Table Cisterns" adorn the small corner plazas along the main path in the center of the Strong Complex courtyard. Each of the Table Cisterns functions as a rain barrel, and utilizes a funnel-shaped shade structure to draw rainwater into a central basin. Each individual unit has the capacity to hold 45 gallons of water, about the size of a small bath. If full, the overflow is directed into a runnel which is connected to the bioretention cell.

D Gabion Seat Walls
Concentric rings of seat walls constructed in the form of gabions allow visitors to look out towards the Quinlan Natural Area and contemplate nature. Additionally, the space doubles as a study area and performance venue for residents of the Strong Complex and greater community.

F Permeable Plaza
A circular permeable paving plaza is situated at a central node of activity. It serves as a nexus between the converging pathways of the Strong Complex, and a heavily trafficked route called Petticoat Lane. The permeable paving replaces an existing asphalt roadway, thus promoting infiltration and storage.

G Bioretention Cell
The primary green infrastructure component of the proposed design is a bioretention cell, which is nested within a detention basin. Stormwater from the Strong Complex throughout the watershed is collected and stored in the bioretention cell, where natural hydrologic mechanisms promote infiltration and groundwater recharge.

J Preserved Woodland
A mature riparian woodland contributes to the picturesque quality of the Quinlan Natural Area. The quiet, shaded reprieve is traversed by hundreds of students and faculty each day. *Stronger Quinlan* strives to maintain this inherent character of the site, while honoring it's unique history.

K Campus Creek
Campus Creek is a degraded ecosystem, which is evidenced by the stream bank scour, the lack of biodiversity, and the frequent flash flooding events. The design helps alleviate these issues by capturing stormwater runoff at the source and reducing the volumetric load of water entering the creek.

Project Statement

Stronger Quinlan is a green infrastructure and campus beautification project which aims to promote sustainable stormwater management and resiliency in the Midwestern United States. The campus community will benefit from these six green infrastructure techniques:

1. Downspout Disconnection
2. Rainwater Harvesting Cisterns
3. Permeable Paving
4. Bioretention Cell & Detention Basin
5. Urban Tree Canopy
6. Native Vegetation & Restoration

Objectives

#1 Help restore natural hydrologic regime and mitigate the recurrent flash flooding of Campus Creek .

#2 Increase the capacity of the site to be resilient and adaptive to climate change, campus development, and community use.

#3 Enhance the ecosystem services of the site by incorporating native plant communities and minimizing areas of irrigated turfgrass.

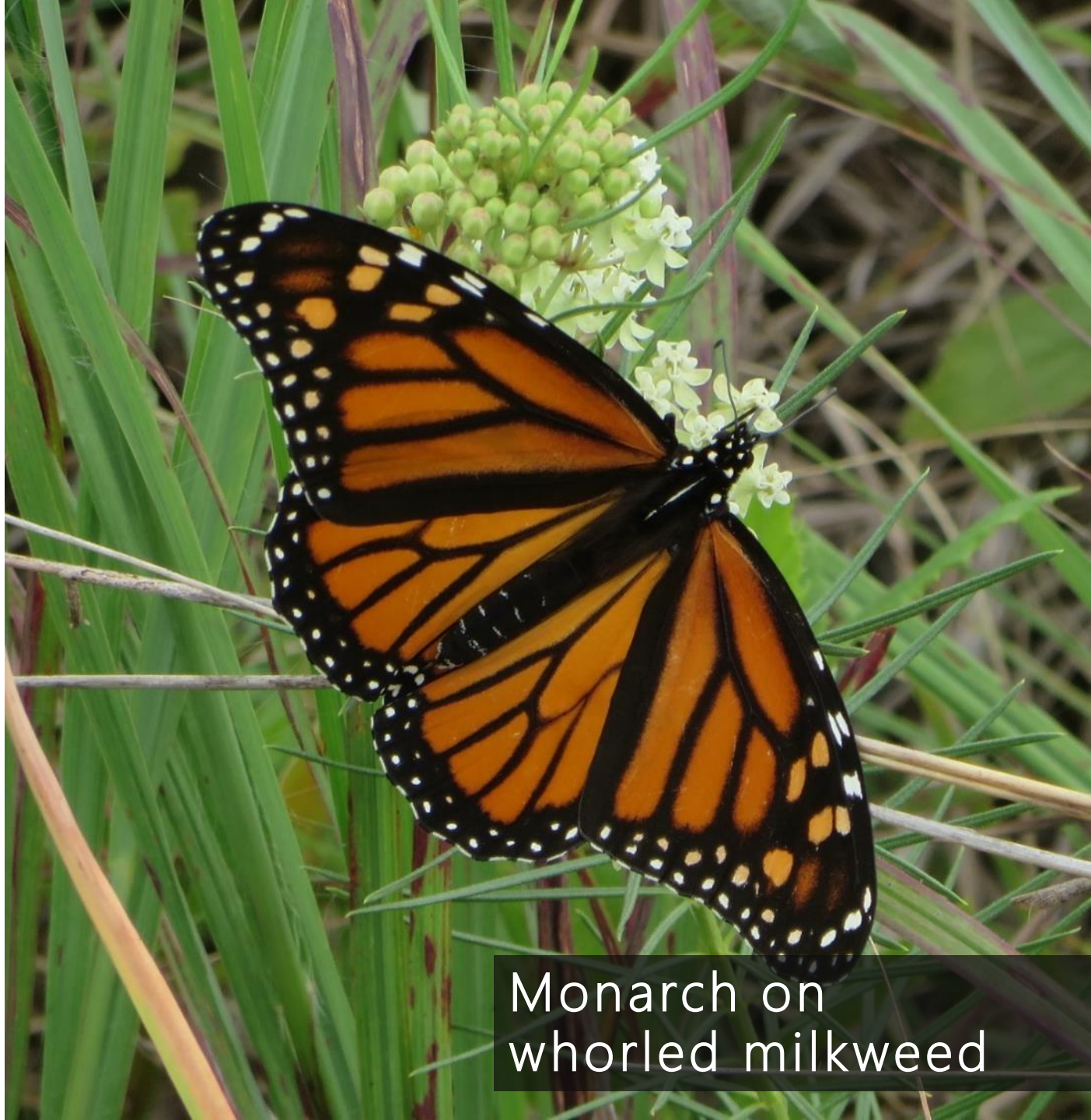
#4 Engage the campus community in a meaningful way through education, research, and an eco-revelatory design approach.

Natalie Creek, a tributary to Wildcat Creek (10/25/2005)

Humanity has wiped out 60% of wildlife populations since 1970 (*WWF, 2018*)

Pollinator populations declining in North America (*Potts et al, 2010*)

Monarch butterfly at risk of quasi-extinction in 20 years (*Semmens et al, 2015*)



Monarch on whorled milkweed

One driver for pollinator decline is urbanization

Photo by Pam Blackmore

Checkered skipper on Black-eyed Susan

What can you as a designer or homeowner do?

- 70% minimum native vegetation
- Plant caterpillar gardens
- Leave native vegetation intact
- Make friends with an "ologist"

Grass Skipper on Tall Gayfeather

Photo and text by Pam Blackmore

Less impactful, sustainable designs are good, but protecting native areas is much better!

Photo and text by Pam Blackmore

Regal Fritillary on Tall Thistle

Sustainable Green Infrastructure

Lee R. Skabelund, ASLA, PLA – Associate Professor, Kansas State University Landscape Architecture

KSU Faculty Members & Affiliations: **1) Lee Skabelund, Jessica Canfield, Katie Kingery-Page & Tim Keane, KSU-LARCP; 2) Stacy Hutchinson, Trisha Moore & Ajay Sharda, KSU-BAE, 3) Mary Knapp & Mary Beth Kirkham, KSU-Agronomy; 4) Carol Blocksome & Dale Bremer, KSU-HORT; 5) Deon van der Merwe, KSU-VetMed; 6) Thomas Phillips, KSU-Entomology.**

KSU Student Affiliations: **7) Elizabeth Musoke & Allyssa Decker, KSU-EDP; 8) Ryan Peters & Kyle Koehler, KSU-HORT; 9) Priyasha Shrestha, Pam Blackmore, Conner Bruns, M. Aleman, R. Prudenti, E. Lanning, C. Finck & G. Mader, KSU-LARCP; 10) Kelsey McDonough, KSU-BAE; 11) Zak Ratajczak & Ellen Welti, KSU-Biology; 12) Chyna Pei, KSU-Entomology. +**

KSU Staff & External Affiliations: **13) Dea Brokesh, LDB; 14) Mark Taussig & Joe Myers, KSU Facilities; 15) Jeffrey L. Bruce & Chuck Dixon, JBC.; 16) Rod Harms & Larry Erickson; 17) Jialin Liu, Green Infrastructure Researcher; and many others….**

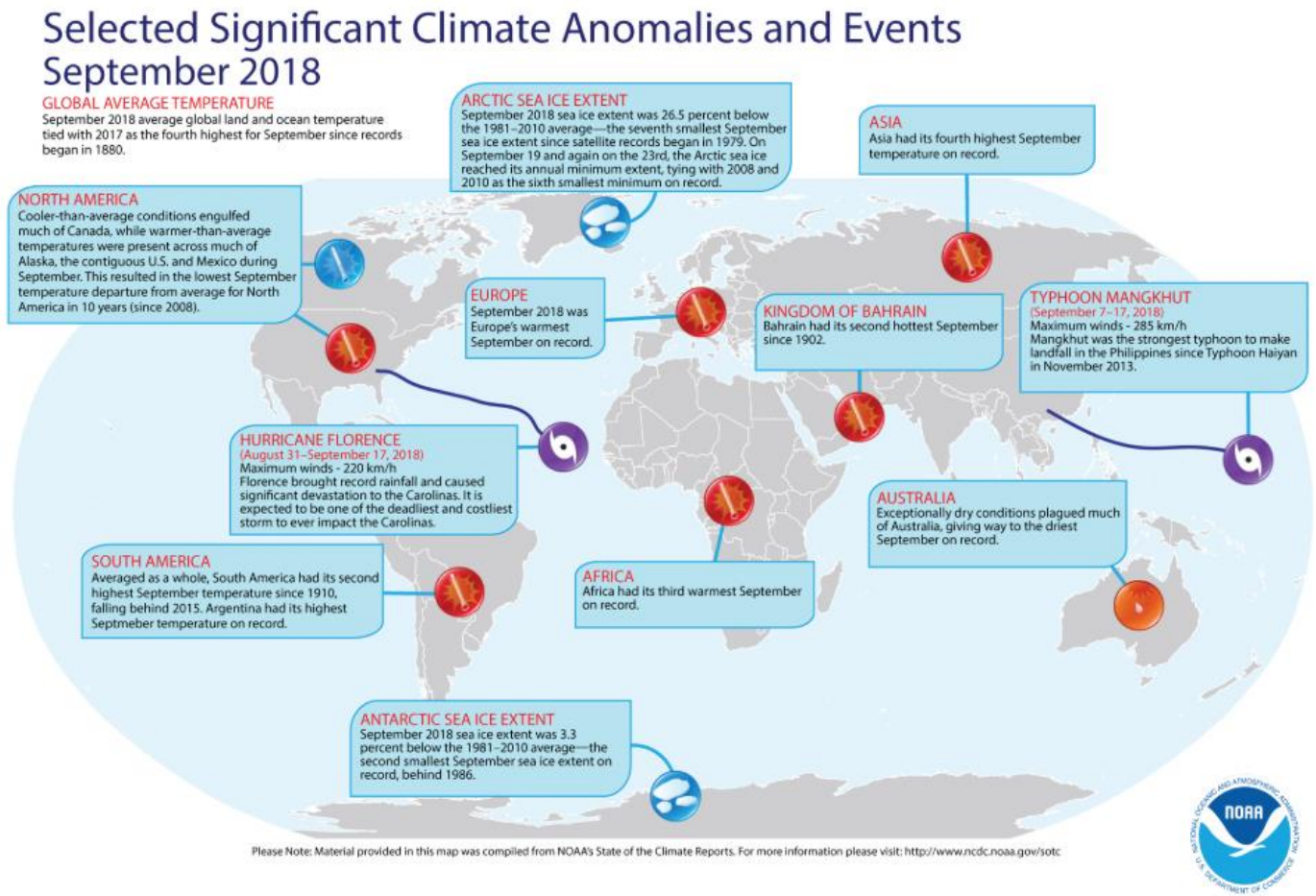
1) Associate Professors, KSU, Dept. of Landscape Architecture and Regional & Community Planning (LARCP);
2) Professor and Assistant Professors, KSU, Dept. of Biological & Agricultural Engineering (BAE);
3) Associate Agronomist, KSU, Dept. of Agronomy; 4) Professor, KSU, Horticulture & Natural Resources;
5) Associate Professor, KSU, Veterinary Diagnostic Lab; 6) Professor, KSU, Entomology;
7) PhD Students, KSU, College of Architecture, Planning & Design, Environmental Design & Planning;
8) Undergraduate Student, KSU, Dept. of Horticulture & Natural Resources; 9) KSU-LARCP students;
10) PhD Student, KSU, BAE; 11) PhD Students, KSU, Biology; 12) Graduate Student, KSU, Entomology;
13) LDB Landscape Architecture & Engineering LLP | Former KSU Landscape Architect;
14) Staff Members, KSU Facilities (Planning & Grounds); 15) President, Jeffrey L. Bruce & Company, LLC.
16) Community Organizers for the Wildcat Creek Watershed; 17) Visiting Scholar, Southwest University, China

Why is green infrastructure design important?

- Well designed & managed green roofs & other green infrastructure can serve as essential parts of interconnected and regenerative community open space networks.
- Biodiverse patches of vegetation (very small ecosystems within the larger landscape) can make a difference.
- Improving species selection, irrigation, and management practices make green roofs more resilient & sustainable *and* minimize non-essential resource use and costs.
- Humans are part of wider communities; landscape conservation and resilient urban systems are vital to human health, and to the well-being of ecosystems and other organisms.

https://www.noaa.gov/news/september-2018-and-year-to-date-were-4th-hottest-on-record-for-globe

The year-to-date average global temperature was 1.39 degrees F above the average of 57.5 degrees. This is the fourth highest on record for the January-through-September period (YTD) and 0.43 of a degree lower than the record high set in 2016 for the same period.



An annotated map of the world showing notable climate events that occurred in September 2018. For details, see the bulleted list below in our story and on the Web at http://www.ncdc.noaa.gov/sotc/global/2018/09.

Notable climate facts & stats (NOAA)

•**Land and seas warming continued**:
The globally averaged land-surface temperature was 6th highest on record for September 2018 and 4th highest for the YTD.
The globally averaged sea-surface temperature was 4th highest on record for September 2018 and 4th highest for the YTD.

•**Record-warm continents**: Parts of the Atlantic and Indian Oceans, North & South America, Europe, Africa & Asia experienced record warmth. Temperatures were at least 3.6 degrees F above average across southern South America, Alaska, southwestern & eastern U.S., much of Europe, the Middle East, and parts of Russia.

•**Sea ice coverage remained smaller than average at the poles**:
The average *Arctic sea ice coverage* (extent) in September was 26.5% below the 1981-2010 avg., the 7th-smallest extent for September on record.
The *Antarctic sea ice extent* last month was 3.3% below avg., the 2nd smallest for any September on record.

NEIL CHAMBERS, AUTHOR OF *URBAN GREEN*

"…the truth is that **climate change and many other issues would disappear if we adhered to the ecological principles that govern nature and ecosystems**.

…old growth forests, estuaries, and **prairies**…**sequester carbon, modulate temperature, manage stormwater, reduce flooding, and purify water better than any technology known to humans**.

…projects that have re-established habitat and natural lands…provide incredible amounts of clean water, habitat, and better quality of life to people.

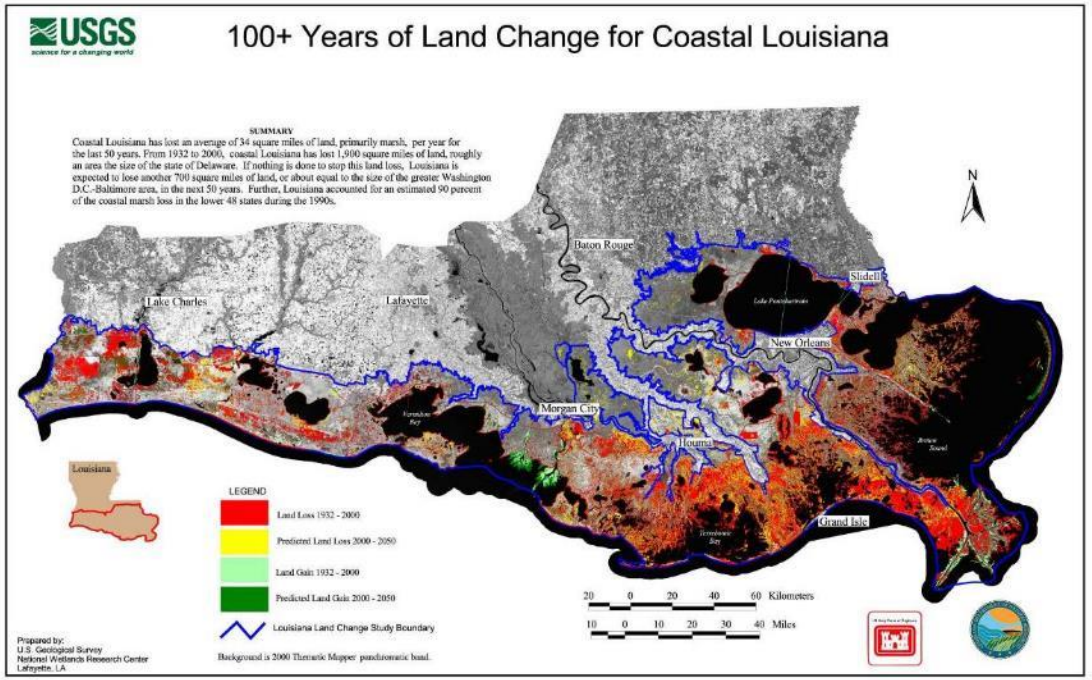
…**Ecological solutions cost a fraction of what technological solutions cost**, and need far less maintenance than the new green gadgets and gizmos being pushed as the great hope for our future."

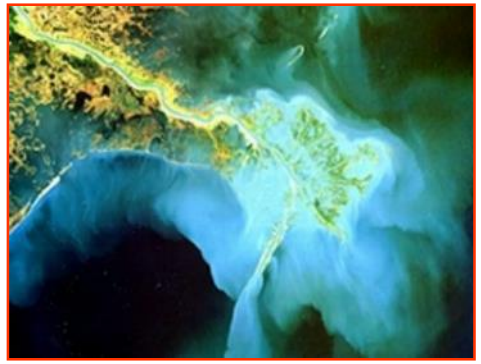
Source: https://www.asla.org/ContentDetail.aspx?id=32550 [emphasis added by lrs]
See also - https://www.amazon.com/Urban-Green-Architecture-Neil-Chambers/dp/023010763X

We need to Make Connections as we Plan, Design, Develop & Manage

One of our primary needs is to understand how we can avoid passing flooding and water quality problems downstream—and do so in ways that work with our bio-region's flora and fauna.



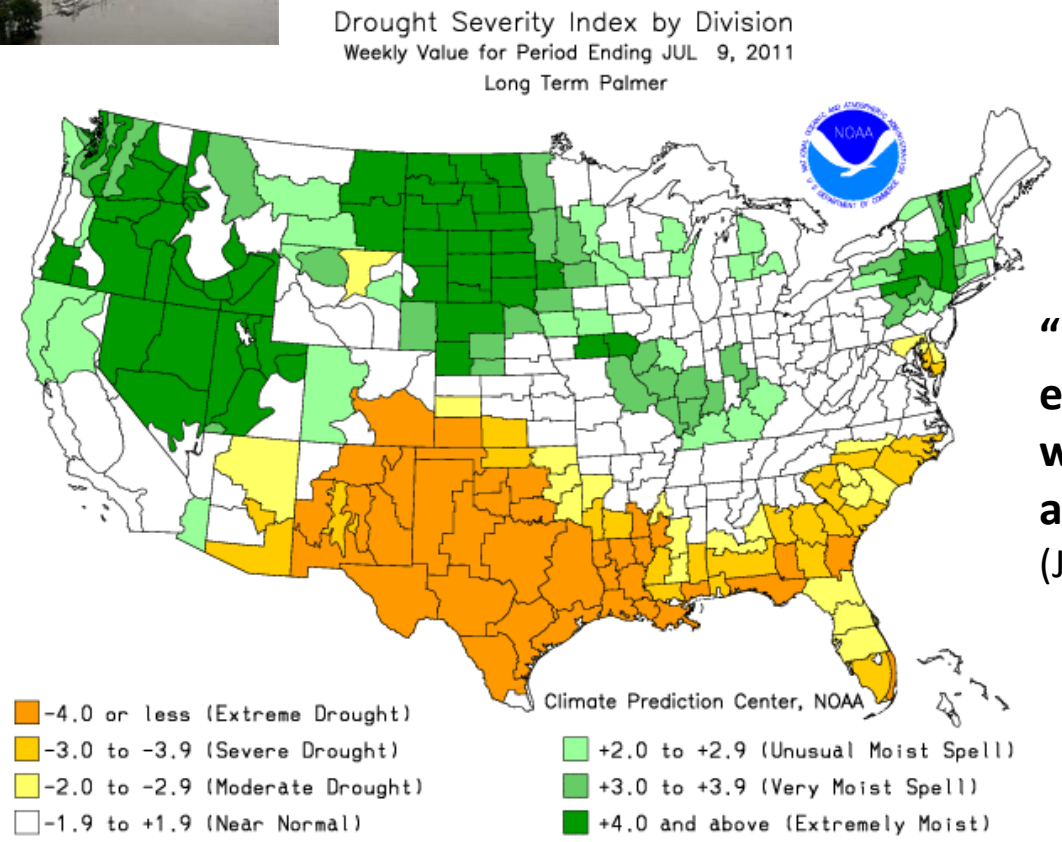


~160 million tons of sediment per year delivered to the continental shelf—with way too many pollutants …

Green infrastructure must respond to dynamic and often repeating weather patterns – floods & drought…

Residents recall 1993 Missouri River flood; hope history doesn't repeat…
By MATT PEARCE, *The Kansas City Star*

Flooding Rains Prompt Evacuations In Manhattan (6/2/2011)
Authorities evacuated three apartment complexes in Manhattan, KS due to flooding along Wildcat Creek.



"Drought conditions are expected to persist or worsen into the summer across Southeast Texas."
(July 2011)

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/palmer.gif

Causes of the Sep 3, 2018 Wildcat Creek flood event:

Ongoing upstream land use & development increases runoff…

Past narrowing/filling and development of the floodplain along Wildcat Creek…

Climate change - regional storm curves are changing;
increased frequency & magnitude of intense rain events and floods
(think Harvey & Florence, and many other places in the past 5-10 years)…

secure | themercury.com/news/local/some-residents-evacuated-in-keats-manhattan-after-late-night-rain/article_2dc3e20a-af83-11e8-abfc-2bd055a1c6b4.html

NEWS OBITS OPINION FEATURES SPORTS K-STATE SPORTS CALENDAR MULTIMEDIA MARKETPLACE CONTESTS SPECIAL SECTIONS CLASS

Some residents evacuated in Keats, Manhattan after late-night rain leads to flooding

Staff reports Sep 3, 2018

Development adjacent to (and fill placed within) the Wildcat Creek floodplain & floodway - October 2005 (near Scenic Drive)

For info on the June 2011 flood, see https://www.kstatecollegian.com/2011/06/08/rising-waters/

Not secure | www.arcgis.com/home/webmap/viewer.html?url=https://services.arc

ArcGIS My Map

Details | Basemap

About | Content | Legend

Legend

August2014DFIRM - Flood Hazard Areas

- 0.2% Annual Chance
- 1% Annual Chance Under Future Conditions
- 1% Annual Chance
- Protected by Levee

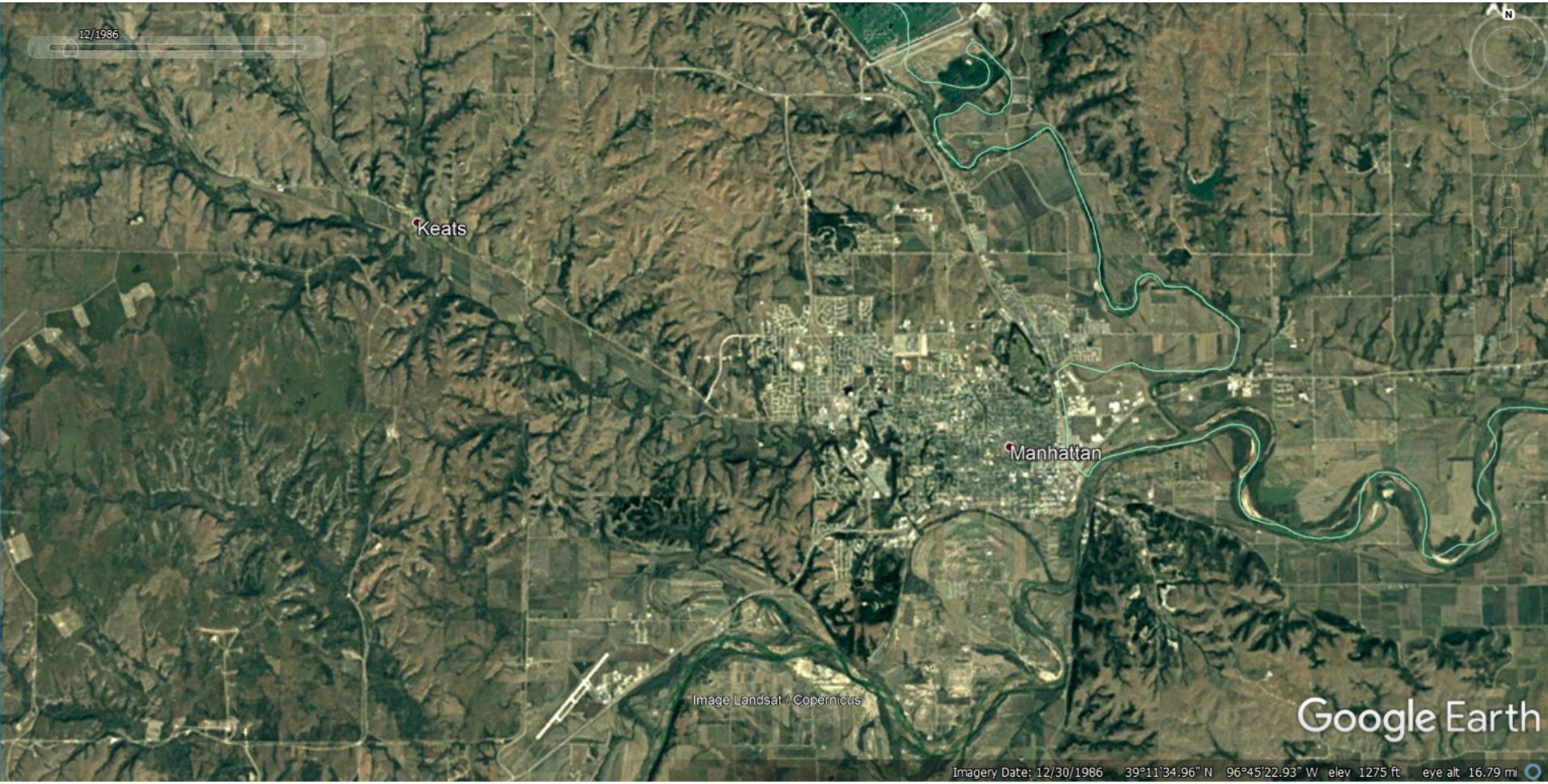
Anderson Ave
Wildcat Creek Rd
Kimball Ave
Hudson Ave
Wreath Ave
Dickens Ave
Laflin Rd
Kerr Dr
Platt St
College Heights Rd
Stone Dr
N Scenic Dr
Highland Ridge
Wildcat Creek Golf & Fitness
Amherst Ave
Sunset Cemetery
Sunset Park Zoo
Pierre St
S Seth Child Rd
S Wreath Ave
Warner Memorial Park
Warner Park Rd
Miller Pkwy
Riley Blvd
Stagg Hill Rd
Davis Rd
Cico Park
Center

0 0.2 0.4mi

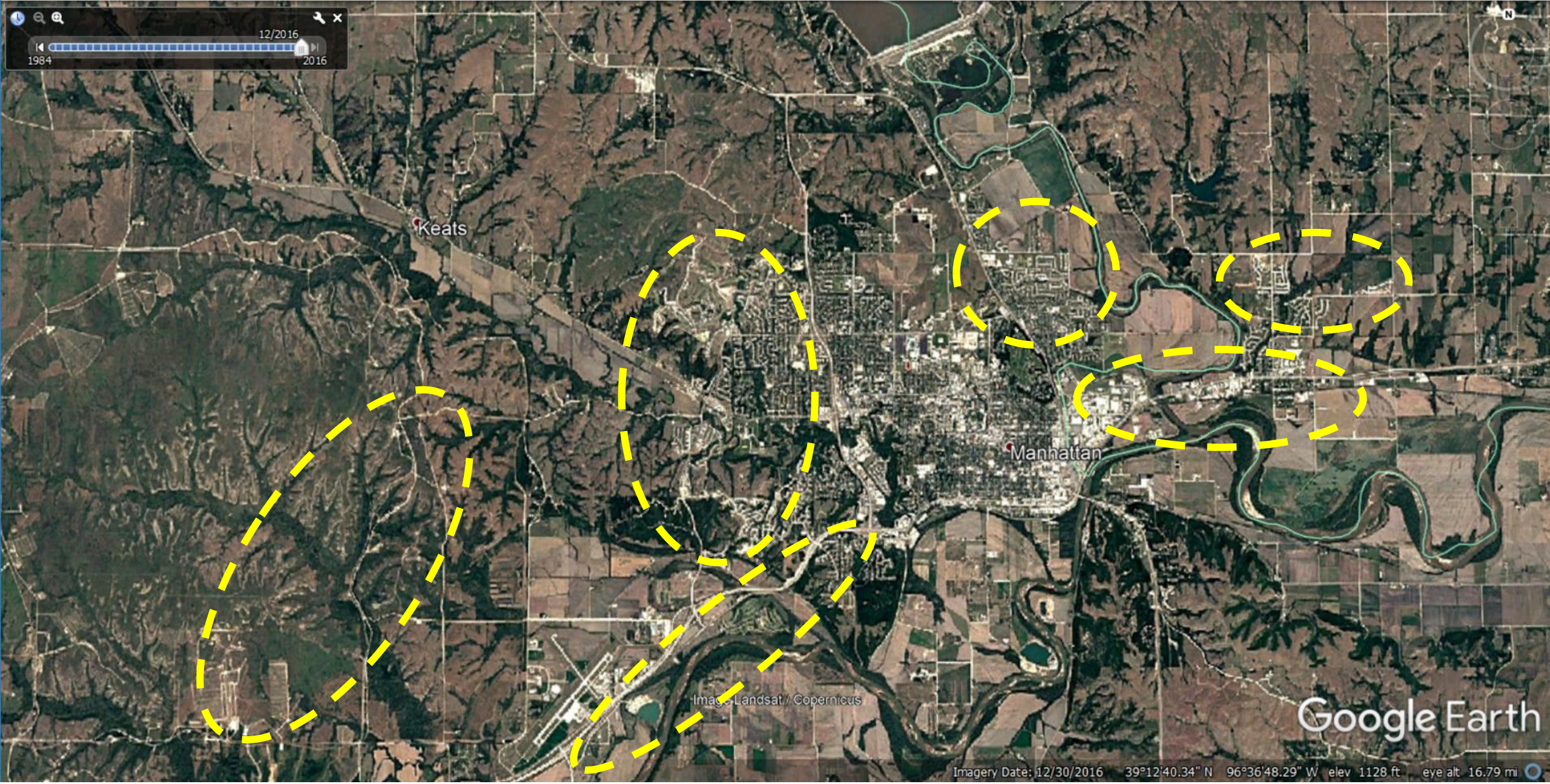
Esri.com . Help . Terms of Use . Privacy . Contact Esri . Report Abuse

County of Riley, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, EPA, USDA

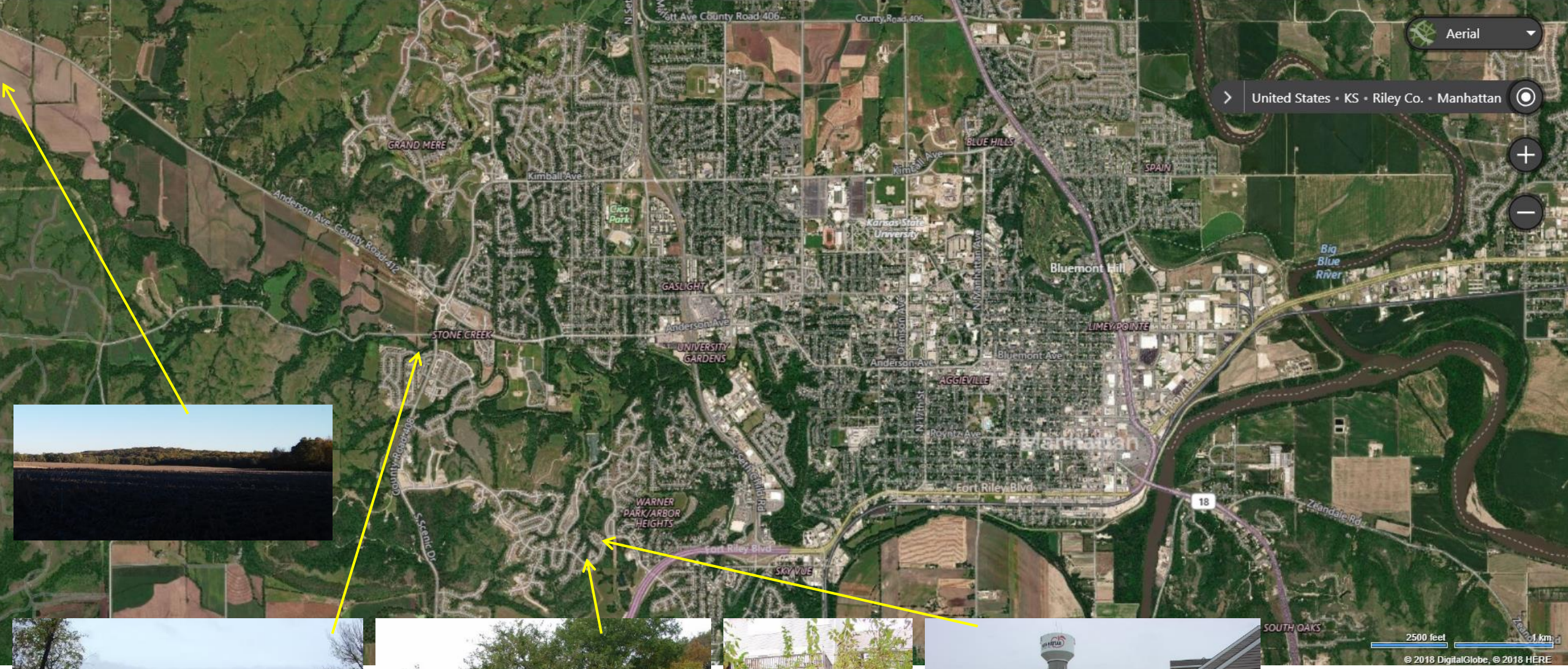
POWERED BY esri



Dec 30, 1986 – no Scenic Drive, no Colbert Hills development, no development directly west of Warner Park…



Dec 30, 2016 – lots more impervious surfaces, less prairie, similar amounts of cultivated farmland…


Aerial
United States • KS • Riley Co. • Manhattan
GRAND MERE
Kimball Ave
Anderson Ave County Road 412
Cico Park
Kansas State University
BLUE HILLS
SPAIN
Bluemont Hill
Big Blue River
GASLIGHT
STONE CREEK
Anderson Ave
UNIVERSITY GARDENS
LIMEY POINTE
Bluemont Ave
AGGIEVILLE
Poyntz Ave
Fort Riley Blvd
WARNER PARK/ARBOR HEIGHTS
SKYVUE
18
Zeandale Rd
SOUTH OAKS
2500 feet
1 km
© 2018 DigitalGlobe, © 2018 HERE

Wildcat Creek Park
Oct 20, 2005

Wildcat Creek near Scenic Drive
Oct 20, 2005

Highland Ridge Jun 16, 2010

Scenic Drive Jun 16, 2010

Annenburg Park Jun 16, 2010

Rod Harms photos






Wildcat Creek east of Scenic Drive Nov-Dec 2010

Lee Skabelund photos

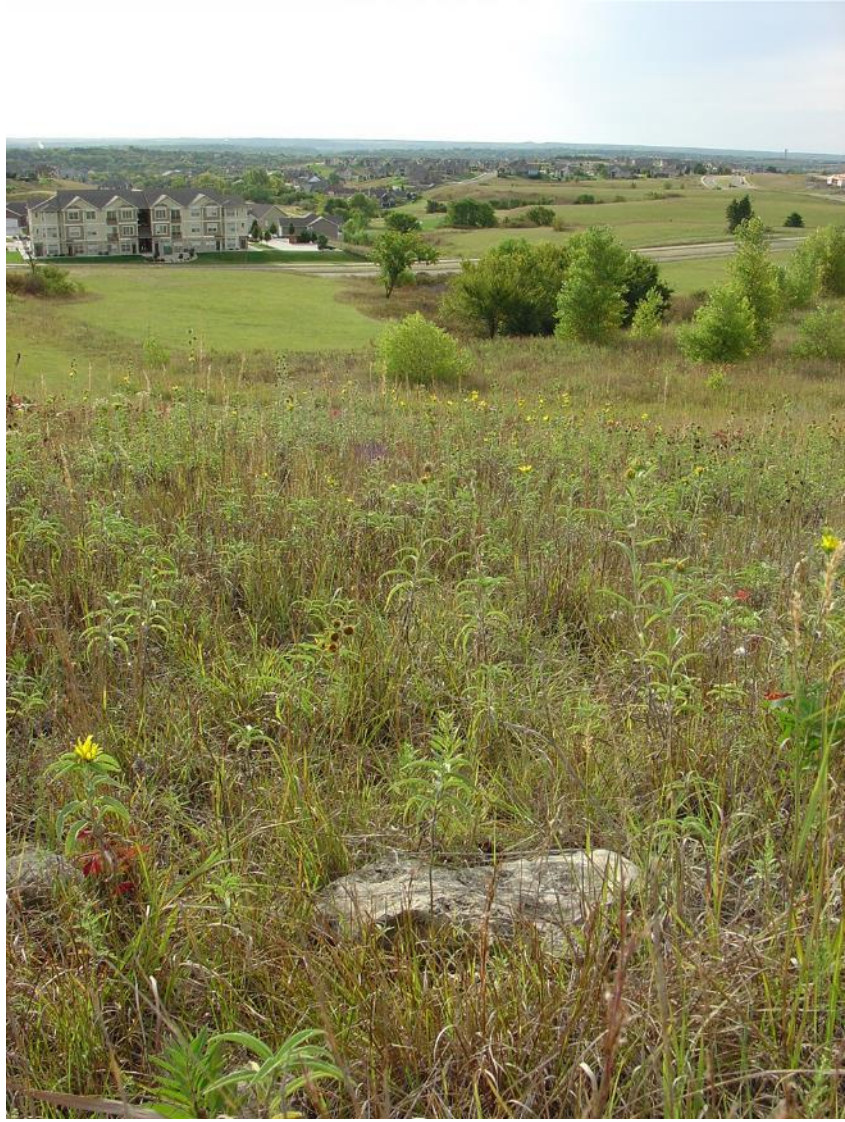
Kings Creek Jun 2, 2011
(Konza Prairie)

Wildcat Creek Floodplain Jun 2, 2011
(south of Anderson; east of Seth Child)

Wildcat Creek Floodplain Jun 2, 2011
(from Manhattan Avenue Bridge)

KSU ISC Rain Garden
and
Campus Creek
Jun 3, 2011

Aerial
United States • KS • Riley Co. • Manhattan
Keats
Anderson Ave
County Road 412
W 60th Ave
60th St
W 62nd Ave
County Road 412 - Anderson Ave
Wildcat Creek Rd
6800 Rd
Colbert Hills Golf Course
GRAND MERE
Washington Marlatt Memorial Park
Marlatt Ave
Prairie Star Dr
Marque Hill Rd
Kauffman Dr
Sunnyside Dr
N Seth Child Rd
Gary Ave
Kimball Ave
Cico Park
Dickens Ave
Claflin Rd
GASLIGHT
HYLTON HEIGHTS
Anderson Ave
College Heights Rd
UNIVERSITY GARDENS
Wildcat Creek Golf & Fitness
ALLINGHAM
MILLER RANCH
Warner Memorial Park
TOWN WEST
Sunset Cemetery
Sunset Park Zoo
Mercy Regional Health Center
Kansas State U
Jardine Dr
Kerr Dr
College Ave
Denison Ave
Hillcrest Dr
Virginia Dr
Casselli Rd
Avery Ave
Little Kitten Ave
Kings Rd
Highland Ridge Dr
County Road 408
N Scenic Dr
2000 feet
500 m
© 2018 DigitalGlobe, © 2018 HERE

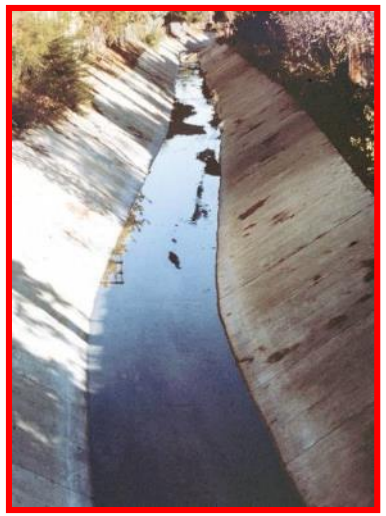


Colbert Hills, Manhattan, KS - Fall 2005

Colbert Hills, Manhattan, KS - 2018

We must employ and reveal natural processes…

this ?



or

this !

Key Q: How can we use low-cost, existing assets to create more sustainable communities?

Low-cost strategies can save water and manage stormwater:

Per David Dods (URS) runoff moving from rooftop to gutter can take less than 20 seconds; from top to bottom of an impervious 50 to 100 foot driveway may take 20-60 seconds (depending on the slope of the driveway).

Water moving across a lawn to a streetside gutter can take about 1 hour. Water traveling through a rain-garden can take several hours or more (depending on the size, type, age/management of the garden, and storm event).

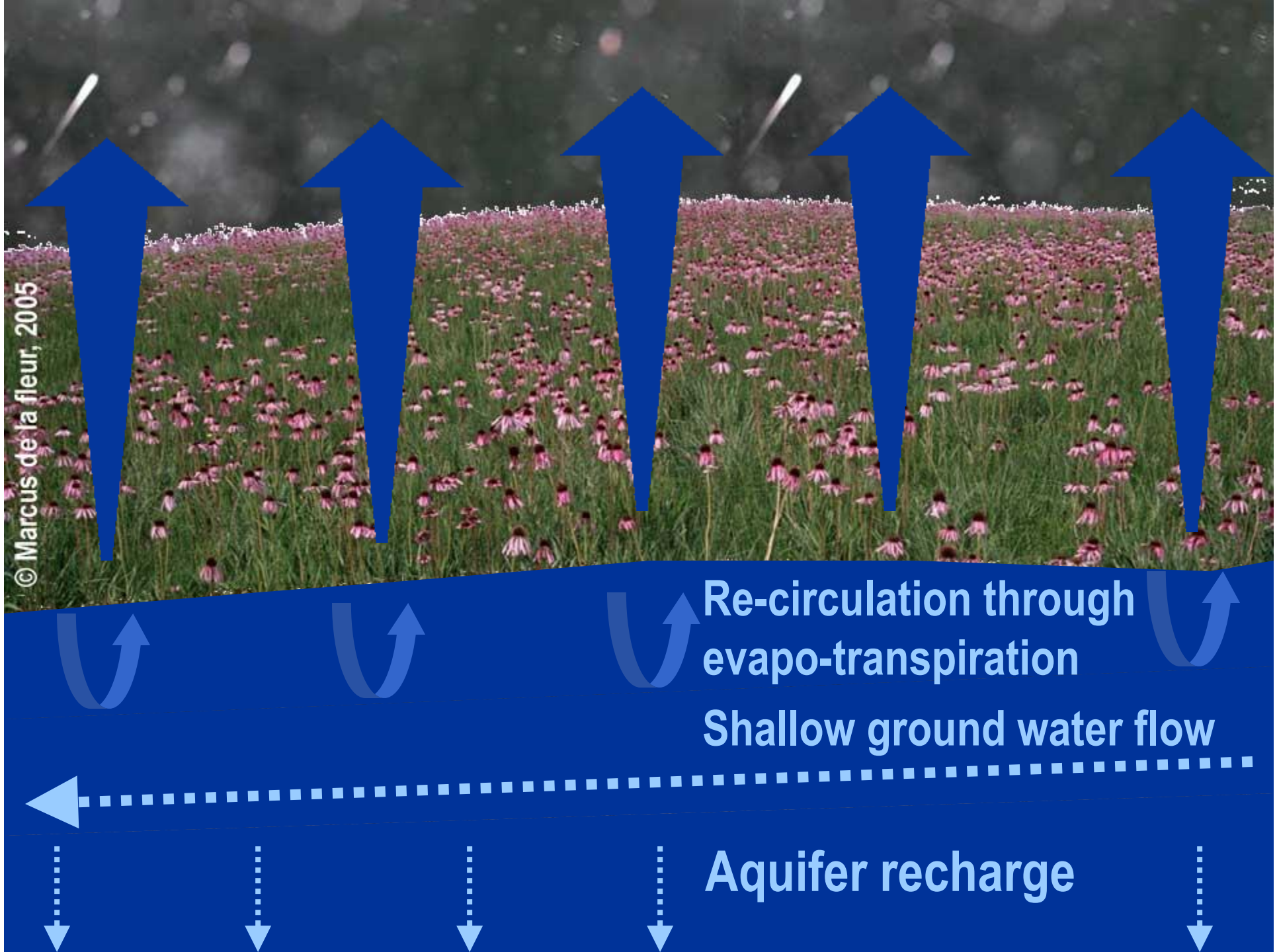
Source: http://texaslid.org/pdfs/DFW_Dods_Raingardens.pdf

See also: http://www.slideshare.net/Sotirakou964/david-dods-blue-thumb-guide-to-rain-gardens-brochure

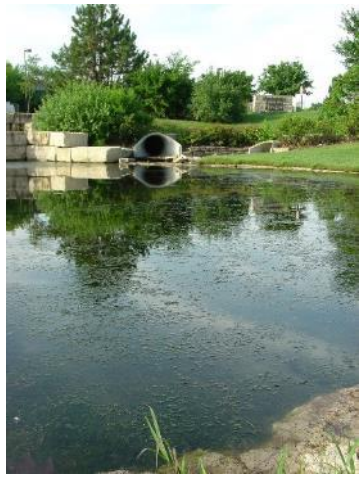
Campus Creek (KSU)

Kings Creek (Konza Prairie)

June 2, 2011 photos

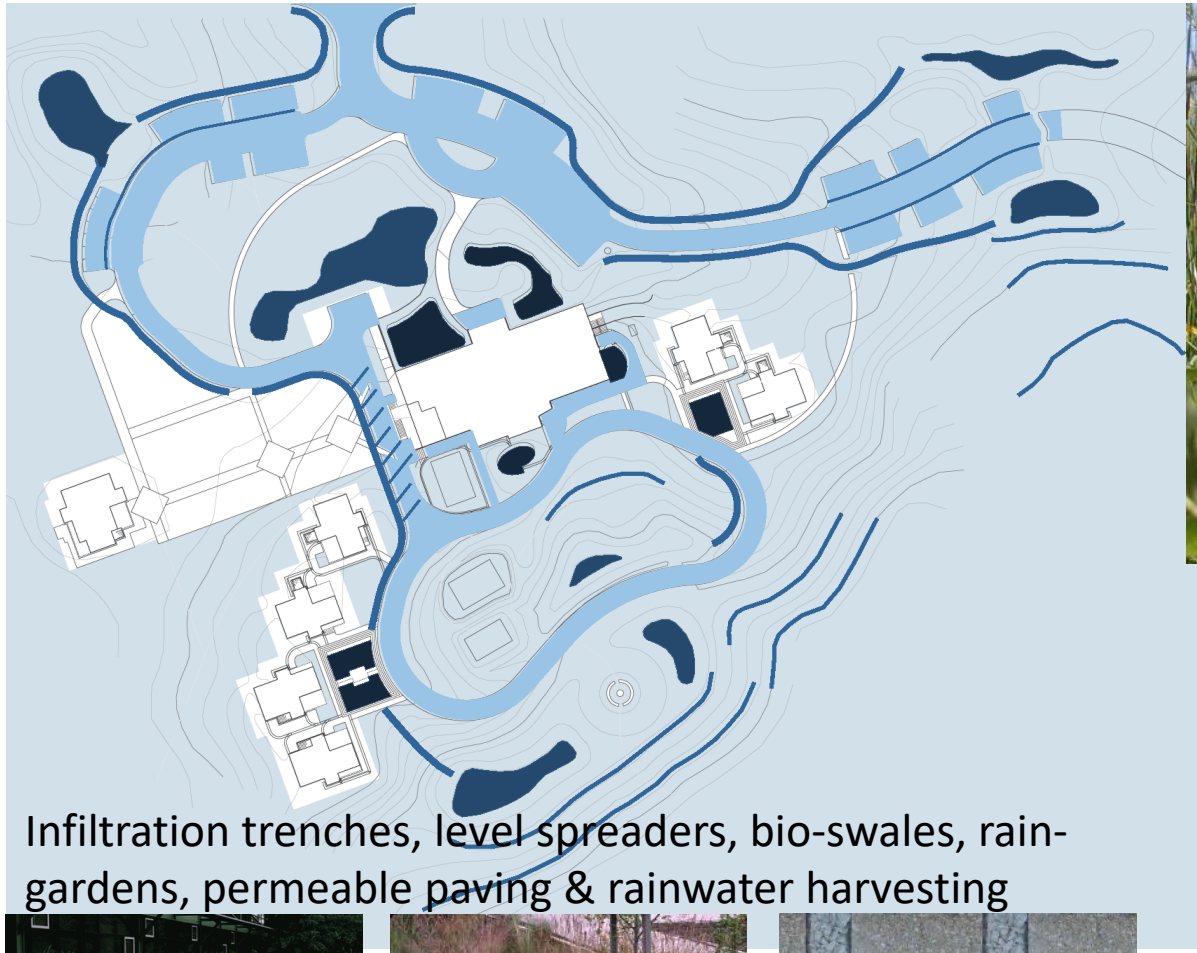

© Marcus de la fleur, 2005
Re-circulation through evapo-transpiration
Shallow ground water flow
Aquifer recharge

Examples of traditional stormwater management in Manhattan, Kansas



Photos by Lee Skabelund – June 2014

Maximizing Retention Capacities – many options!



Native Landscape

Infiltration trenches, level spreaders, bio-swales, rain-gardens, permeable paving & rainwater harvesting

Merry Lea Environmental Training Center
Goshen College, Indiana

Slide courtesy of
Conservation Design Forum

Water-sensitive site planning/design project

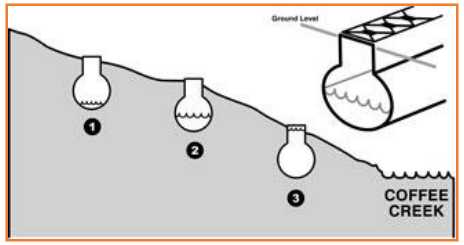
Coffee Creek, Chesterton, Indiana

www.coffeecreekwc.org (photos)
www.coffeecreekcenter.com/ (text & drawings)
www.cdfinc.com **(2001 Merit Award of Design, Illinois ASLA)**

Employing Environmental Engineering

Restoration of the Coffee Creek corridor was initiated at the outset of developing this mixed-use community, w/guidance from biologists who understand the regional landscape. Level spreaders and vegetation infiltrate water into the soil. The project employs civil engineering *without* traditional expensive and destructive stormwater drainage systems – and provides a wide range of shared community open space within a 167-acre preserve.

Level Spreader
slows runoff



Wetland Cell
treats sewage

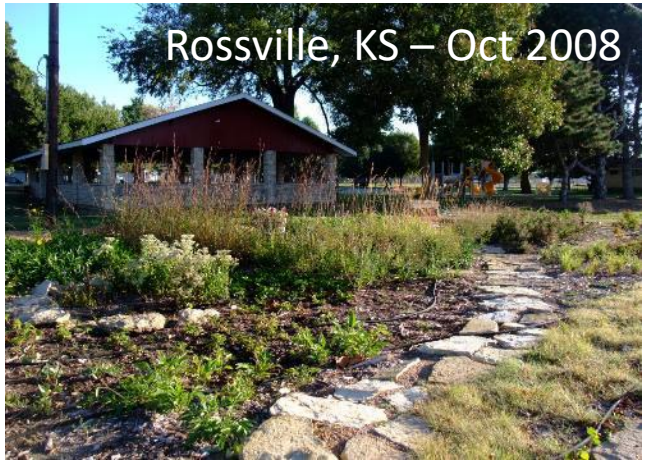
Greenroof

Restoring Native Ecosystems and Habitats

"Unbuilt areas are being restored to a pre-settlement landscape to minimize soil erosion and rebuild soil integrity, re-establish native plant & animal communities, and encourage increased bio-diversity."

Bio-Retention Areas in Kansas, Nebraska & Missouri

photos by Lee R. Skabelund



What can residents do to help? Visit 2027 Meadowmere Ct. 66502 to see a few features…

Stormwater entered our basement too many times, so I designed and had implemented a permeable driveway, vegetated swales, and rain gardens – with disconnected downspouts moving water onto our lawn (warm season grass that needs minimal water & mowing).

Permeable paving with underground storage & rain-gardens help slow in infiltrate H2O…

Recognize the many ways to slow, hold, filter and/or infiltrate stormwater, including:

Conserve and restore or create **well-functioning prairies, woodlands, meadows, riparian corridors & wetlands.**

Create **bio-retention areas, rain-gardens, and green roofs.**
Use **cisterns** (above or below ground) and/or **rain barrels.**
Construct **dry wells, porous pavement & other LID features.**

bio-retention cells (areas typically having a combination of **engineered soils**, plants and mulch – and when necessary an under-drain).

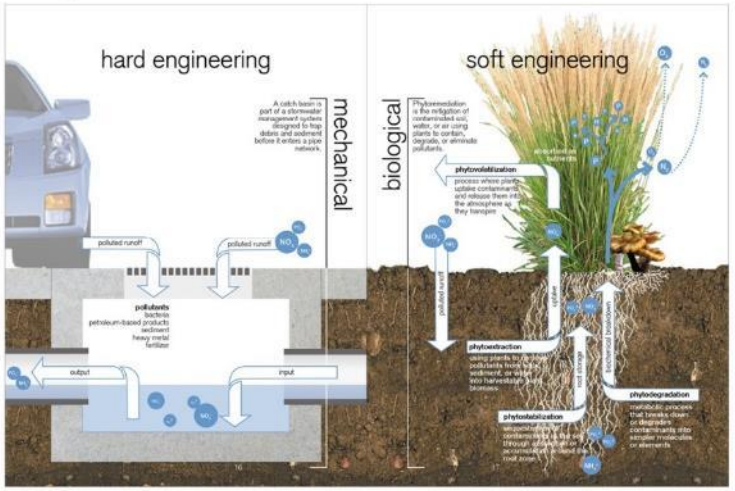
Bio-retention areas are typically much more expensive than rain-gardens and are often designed/engineered to meet a specified infiltration rate.

rain-gardens (shallow depressions that collect water from nearby impervious surfaces and then infiltrate the water into **existing, plant-mediated soils**).

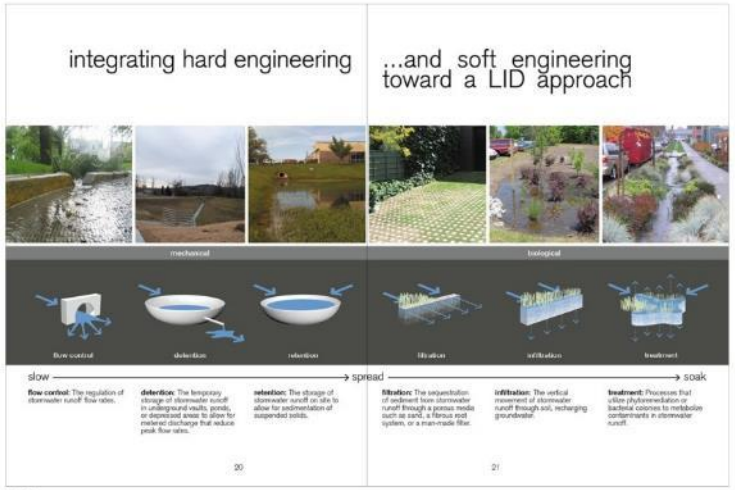
Rain-gardens can be created on nearly any property at a very modest cost!
Design rain gardens to be dry - http://stormh2o.com/SW/Articles/2188.aspx
Rain Gardens in every City - www.theatlanticcities.com/technology/2012/01/why-you-should-care-about-rain-gardens/975/

Substitute ecological engineering for conventional civil engineering to deliver ecological services in urban infrastructure.

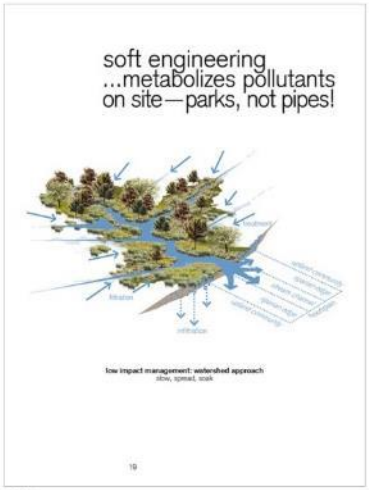
p12-13



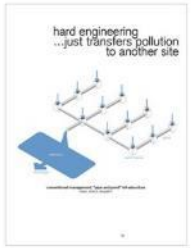
p16-17



p20-21

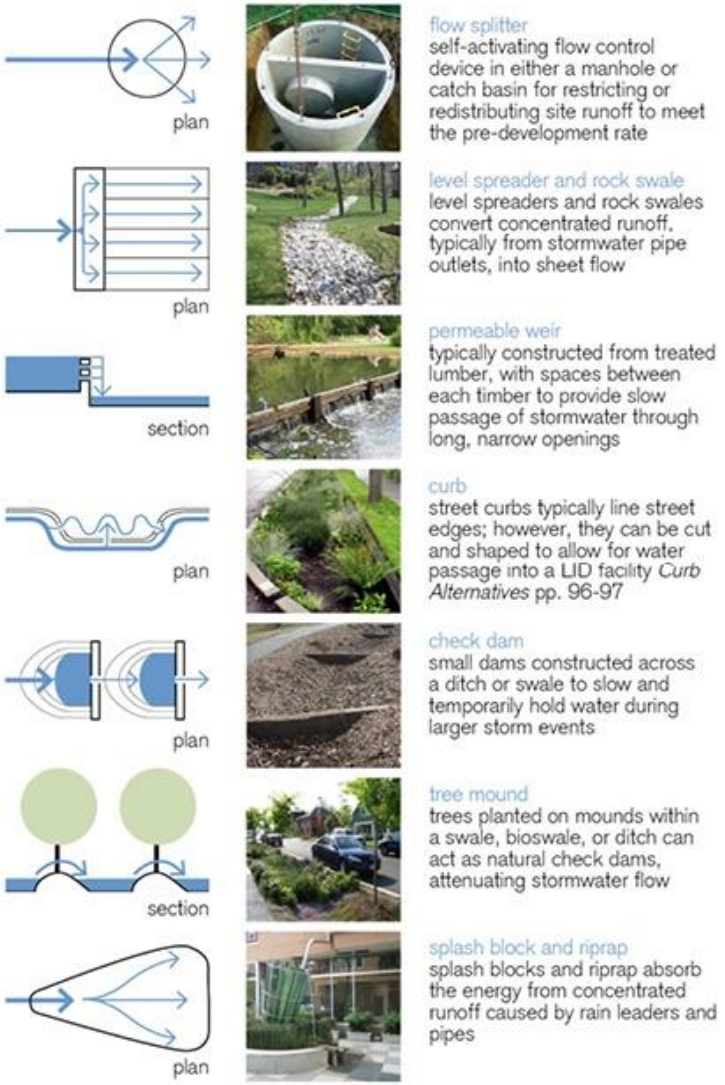


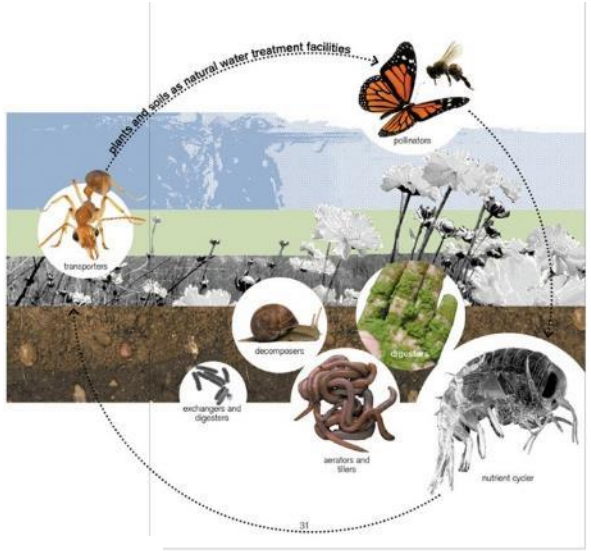
p19



p18

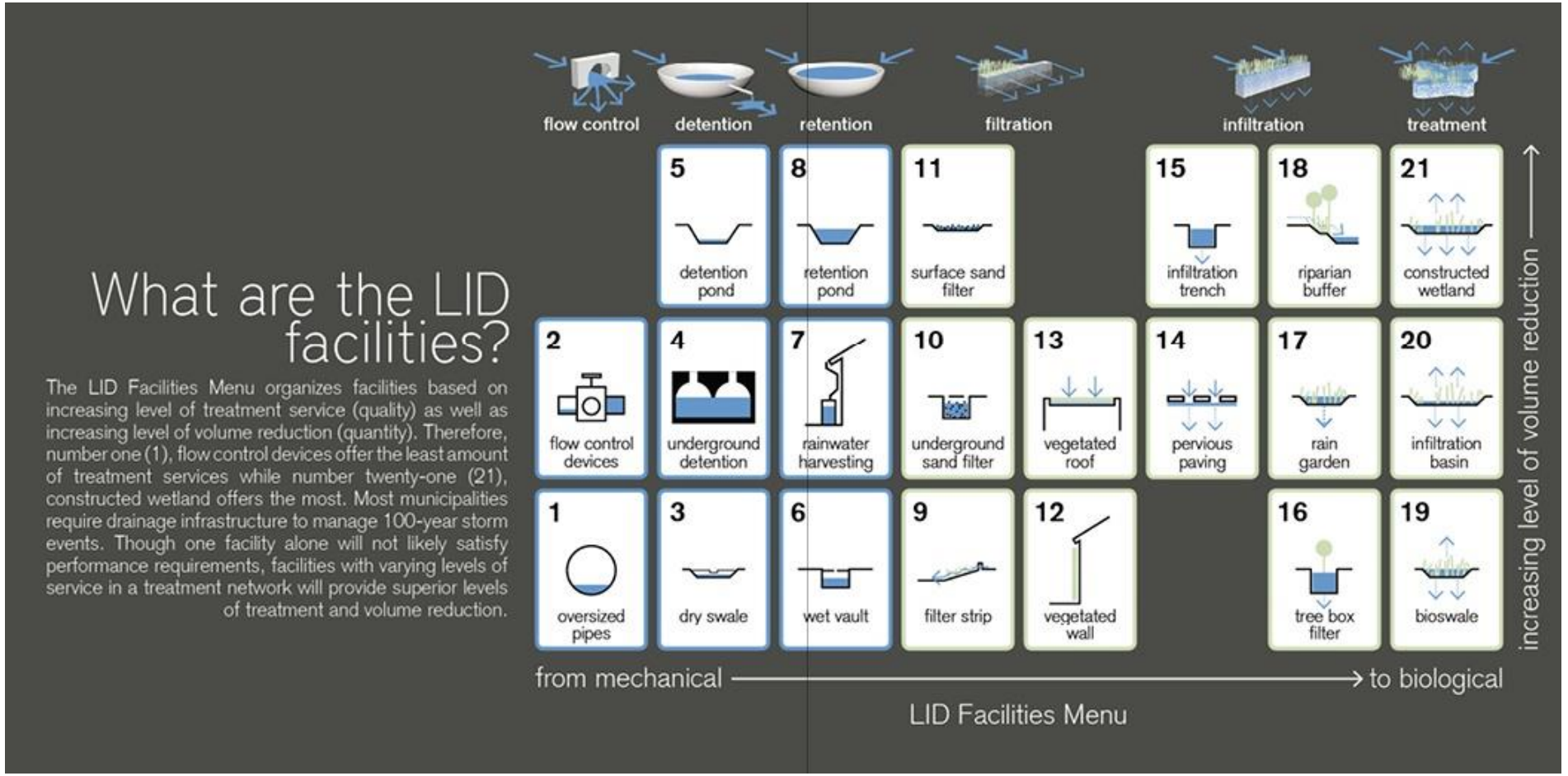
Source: ***LID Low Impact Development: A Design Manual for Urban Areas***
University of Arkansas Community Design Center
http://www.asla.org/2011awards/images/largescale/184_02.jpg





LID remediates polluted runoff through a network of treatment landscapes, with distributed, redundant, and resilient properties.

Source: ***LID Low Impact Development: A Design Manual for Urban Areas***, p 149
Univ. of Arkansas Community Design Center
http://www.asla.org/2011awards/images/largescale/184_12.jpg
http://www.asla.org/2011awards/images/largescale/184_03.jpg



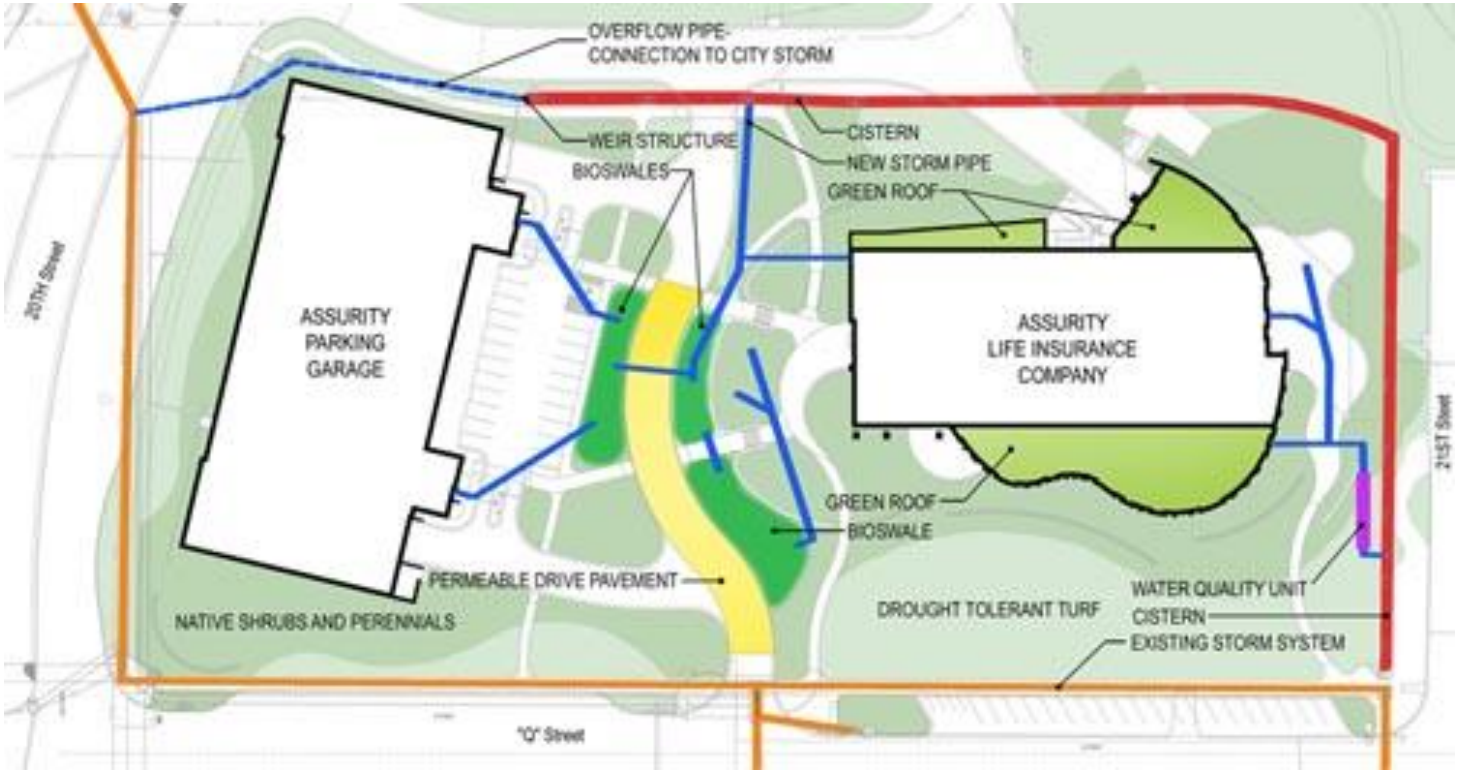
Source: ***LID Low Impact Development: A Design Manual for Urban Areas***, p 142-143
Univ. of Arkansas Community Design Center
http://www.asla.org/2011awards/images/largescale/184_12.jpg

Chicago, Lincoln, NYC, Seattle, Portland Minneapolis

Selected Examples of Green Infrastructure

The website **‘One Drop at a Time’** http://www.delafleur.com/168_Elm/ discusses accessible, in-the-ground examples of sustainable landscape solutions at 168 Elm Avenue, such as the green roof and rain-garden. (Photos: Marcus de la fleur)

http://www.asla.org/2009awards/298.html



Green (living) roofs, bio-swales & rain garden;
Three existing stormwater structures were repurposed as cisterns to capture, store and recirculate rainwater for irrigation.
Pervious site pavement allows stormwater to seep into the ground, reducing runoff;
Drought-tolerant native & naturalized plant species minimize need for irrigation while creating habitat within the city.

In 2010 the Assurity Center in Lincoln, Nebraska was selected by the Sustainable Sites Initiative™ (SITES™) as one of the first pilot landscapes involved in an international rating-testing program for green landscape design, construction, and maintenance.

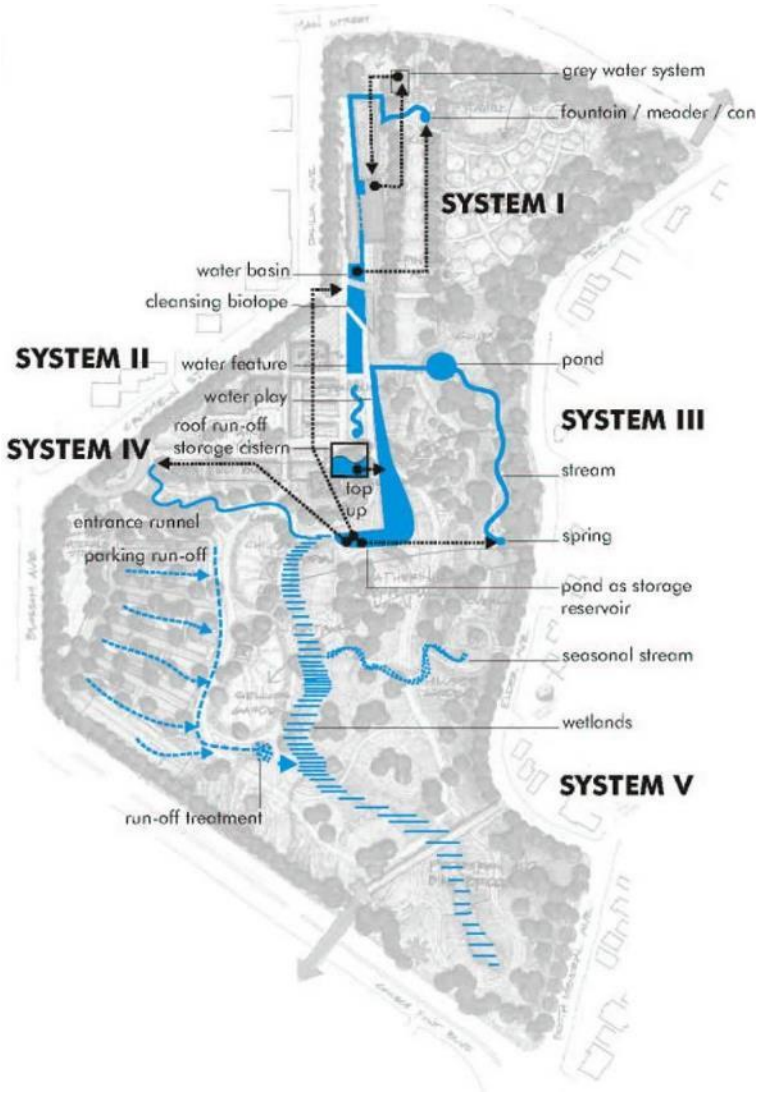
https://www.assurity.com/panel/community.html

https://www.assurity.com/gallery/sustainability.html

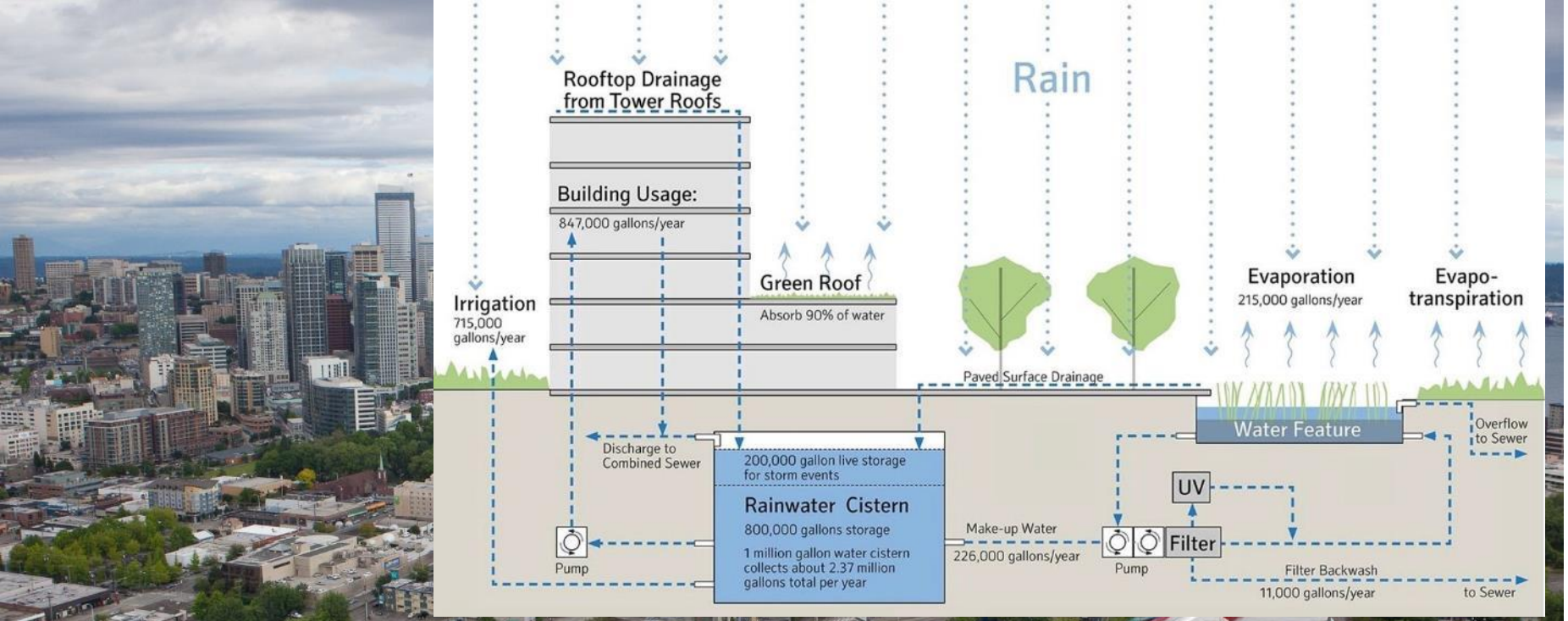
See also: http://www.sustainablesites.org/projects

Queens Botanical Garden

create an integrated system of stormwater management



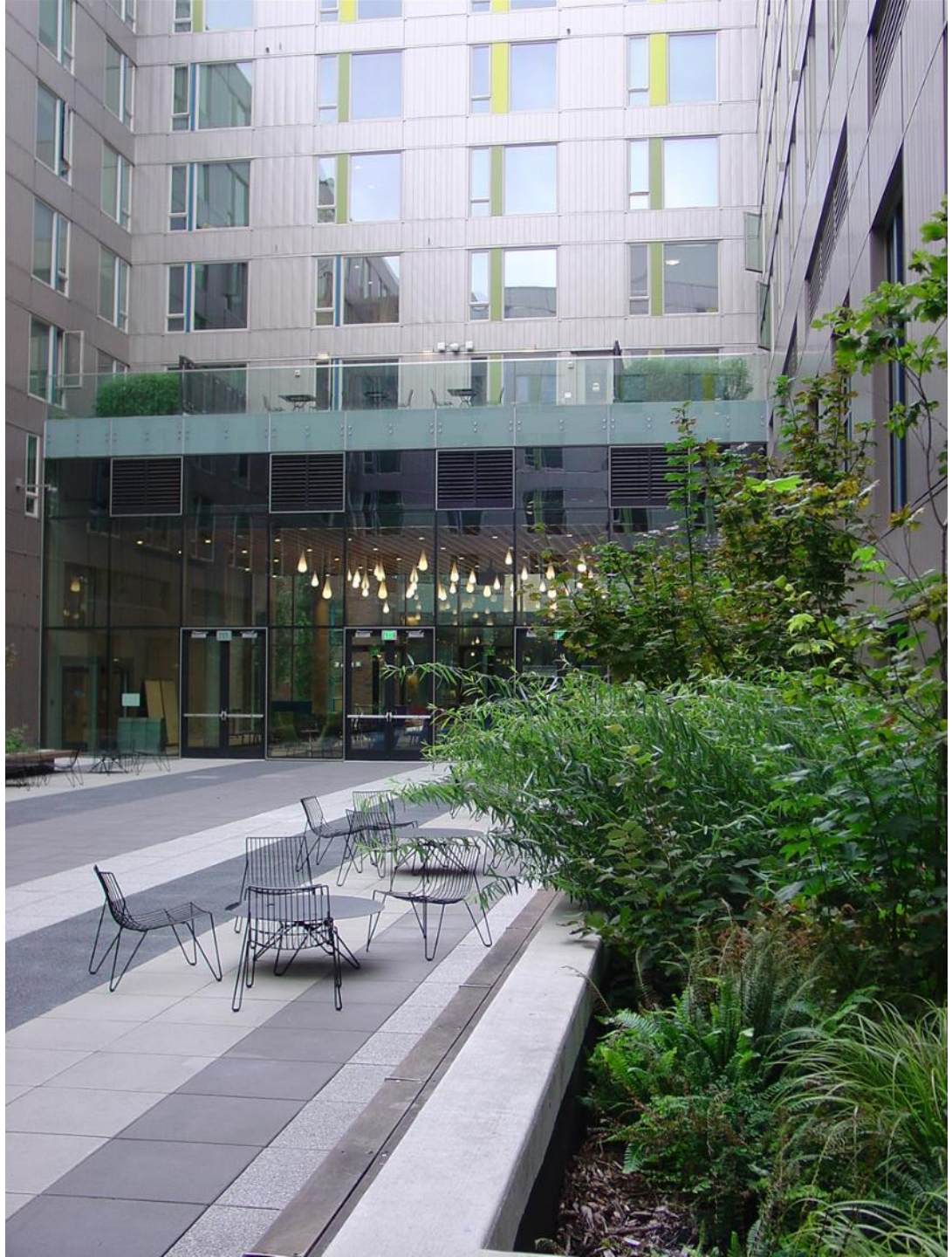
Slide courtesy of Conservation Design Forum - www.cdfinc.com



Project Name: Bill & Melinda Gates Foundation & Seattle Center 5th Ave North Parking Garage
Year: 2008-2011
Type of GR: Extensive
Size: 87,120 sq.ft.
Slope: 7%
Designers, Engineers & Manufacturers of Record:
Architect: NBBJ
GR System: American Hydrotech
GR Plant/Ecology Consultant: Rana Creek
Engineering Services: Arup
General Contractor: Sellen
Irrigation/Soils: Jeffrey L. Bruce & Co.
Landscape Architect: GGN (Gustafson Guthrie Nichol)
Landscape Installation: Mike Brandvold, Pacific Earth Works, Inc.

Harvests 3.3 million gals. RW/year

Source: www.greenroofs.com/projects/pview.php?id=995

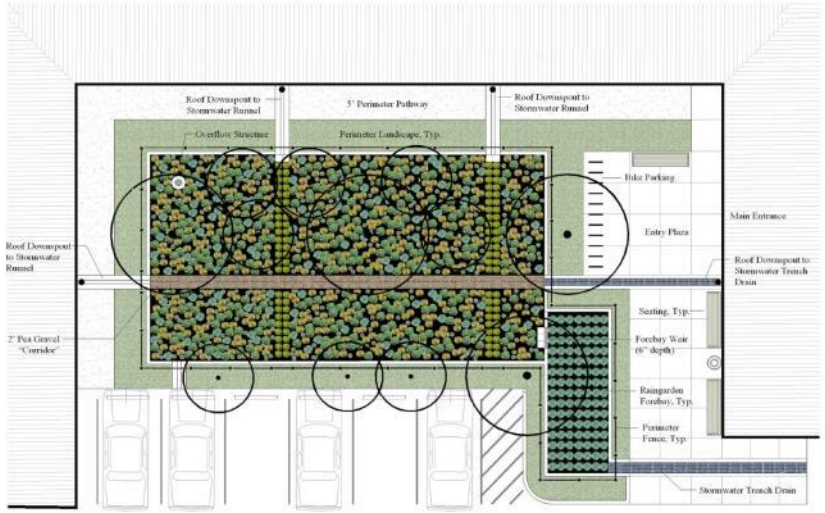


U. Washington, Seattle (Sep. 2017 lrs)

U. Washington, Seattle (Sep. 2017 lrs)

~ *Mount Tabor Middle School Raingarden* ~

Portland, Oregon



Illustrative Site Plan

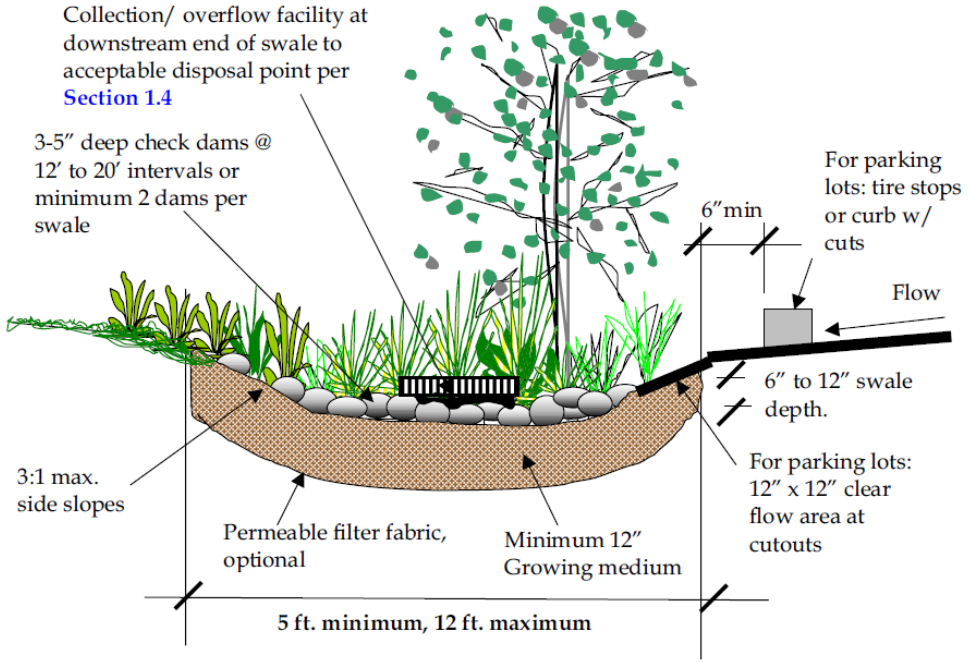
How the Rain Garden Works

Runoff from surrounding impervious surfaces – almost three-quarters of an acre of roof and asphalt – drains to the rain garden. Entering runoff spreads through low areas planted with sedges & rushes. Sediment drops out and pollutants and nutrients are removed through a number of natural processes. The runoff gradually soaks into the ground. The system is designed to dry out within a day of a storm event. An overflow standpipe guarantees a max. pond depth of six inches.

Source: http://www.asla.org/awards/2007/07winners/517_nna.html

Mount Tabor Middle School Rain Garden, Portland, Oregon (constructed in Summer 2006)
Kevin Robert Perry, ASLA, Portland, Oregon
Brandon Wilson, City of Portland Environmental Services
Client: City of Portland, Sustainable Stormwater Management Program
Source: http://www.asla.org/awards/2007/07winners/517_nna.html

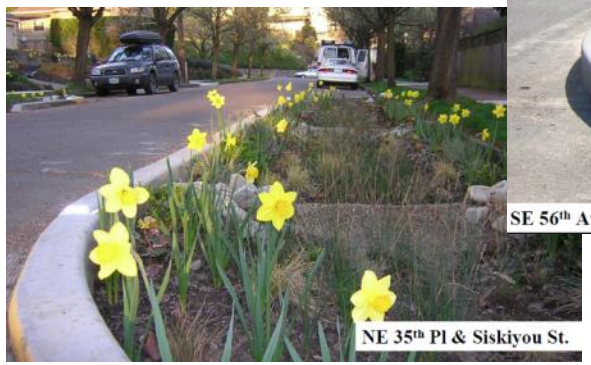
Vegetated Swale




PCC Annex (SE Water Ave.)

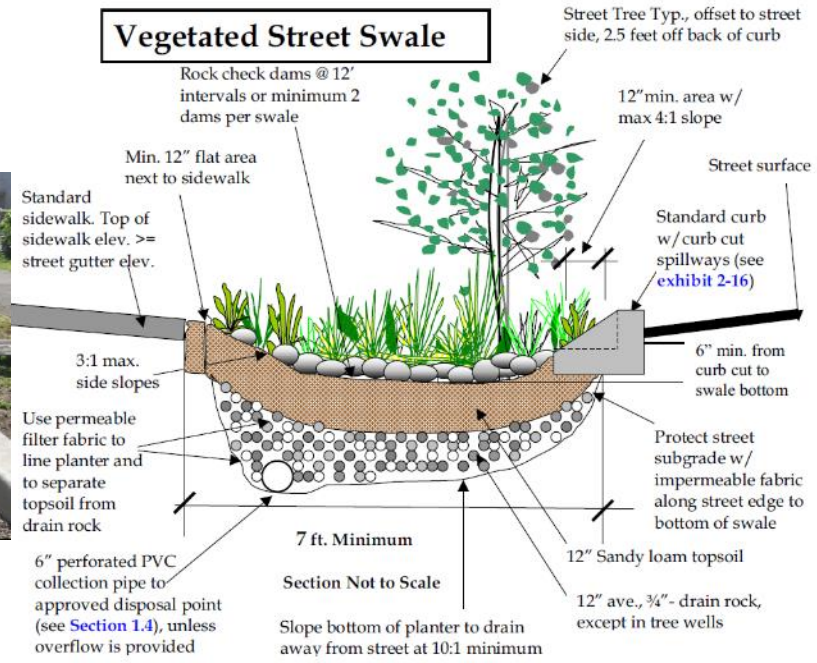
Source of sections and photos: Portland, OR
www.portlandonline.com/bes/index.cfm?c=35122&a=55791
www.portlandonline.com/bes/index.cfm?c=35122&a=55846
www.portlandonline.com/bps/index.cfm?a=115328&c=42113


SE 56th Ave. & Ankeny St.


NE 35th Pl & Siskiyou St.

Street Swales

Vegetated Street Swale

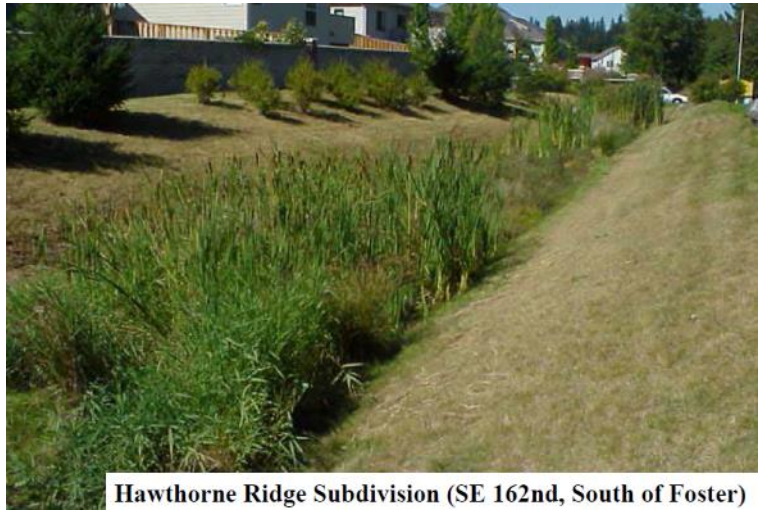


OMSI (1945 SE Water Ave)

BES Water Pollution Control Lab (6543 N. Burlington)

Vegetated Swales *or* Bioswales

more and less formal…



Hawthorne Ridge Subdivision (SE 162nd, South of Foster)

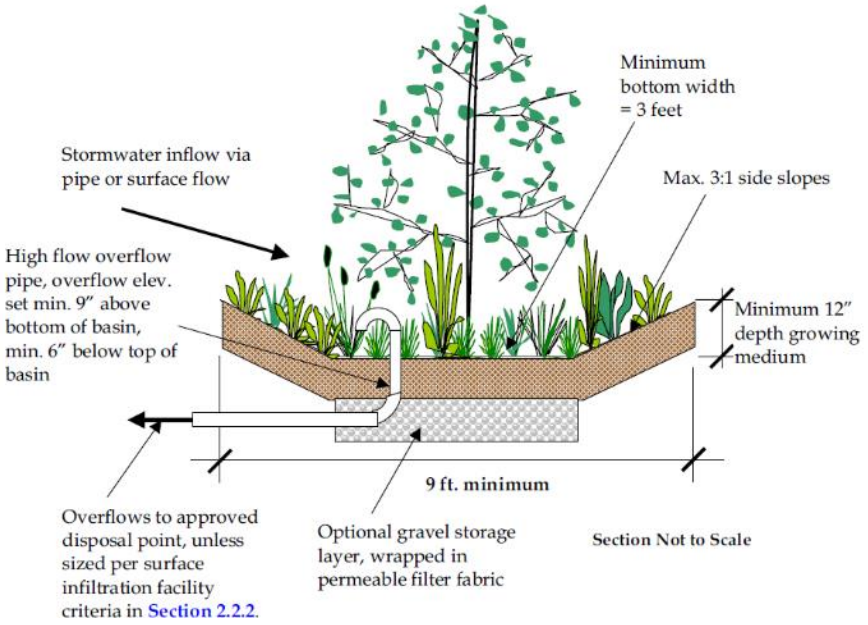
Source of photos: Portland, OR
www.portlandonline.com/bes/index.cfm?c=35122&a=55846

Vegetated Infiltration Basins

design in creative ways based on site, context and budget…

Buckman Heights courtyard infiltration basins (430 NE 16th Ave.)

Vegetated Infiltration Basin



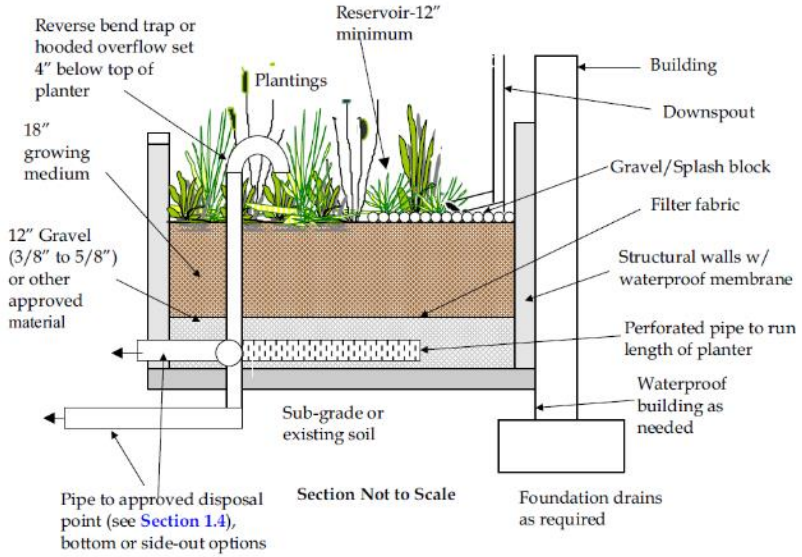
Wattles Boys and Girls Club (9330 SE Harold)

Macintyre Estates Subdivision (SE 139th & Steele)

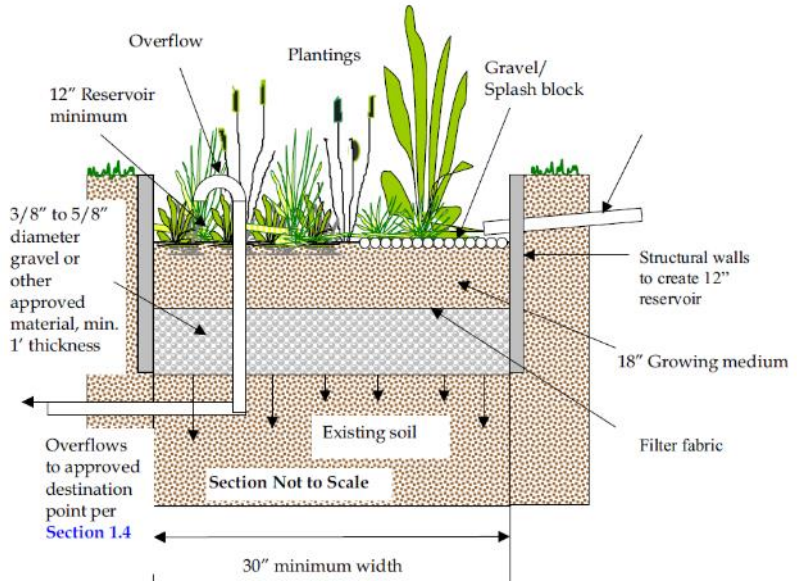
Glencoe Elementary School (825 SE 51st)

Source of sections and photos: Portland, OR
www.portlandonline.com/bes/index.cfm?c=35122&a=55846
www.portlandonline.com/bps/index.cfm?a=115328&c=42113

Flow-Through Planter



Infiltration Planter




Liberty Center Parking Garage (650 NE Holladay)

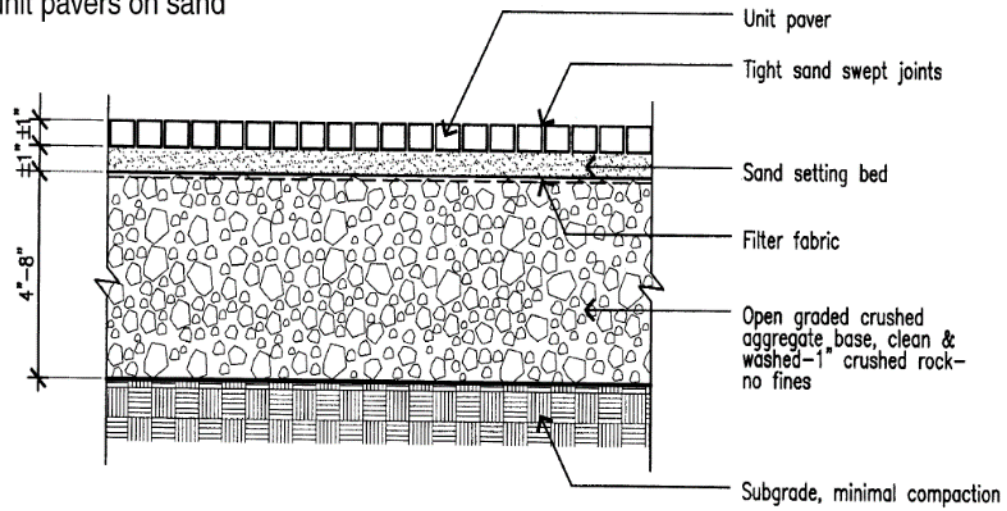

Liberty Center Parking Garage (650 NE Holladay)

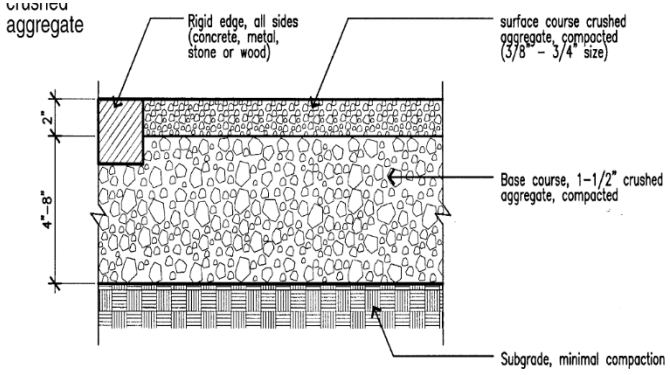

Buckman Terrace Apartments (303 NE 16th Ave.)


Wattles Boys and Girls Club (9330 SE Harold)

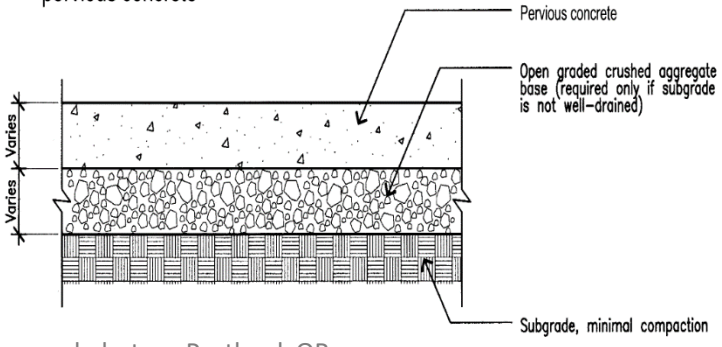
Source of sections and photos: Portland, OR
www.portlandonline.com/bes/index.cfm?c=35122&a=55846
www.portlandonline.com/bps/index.cfm?a=115328&c=42113

unit pavers on sand





pervious concrete



Source of drawings and photos: Portland, OR
www.portlandonline.com/bes/index.cfm?c=35122&a=55846
www.portlandonline.com/bes/index.cfm?c=35122&a=55836

Pervious pavers at ONRC (5825 N. Greeley)

Installation of Eco-Loc Paver Parking Lot in Washington

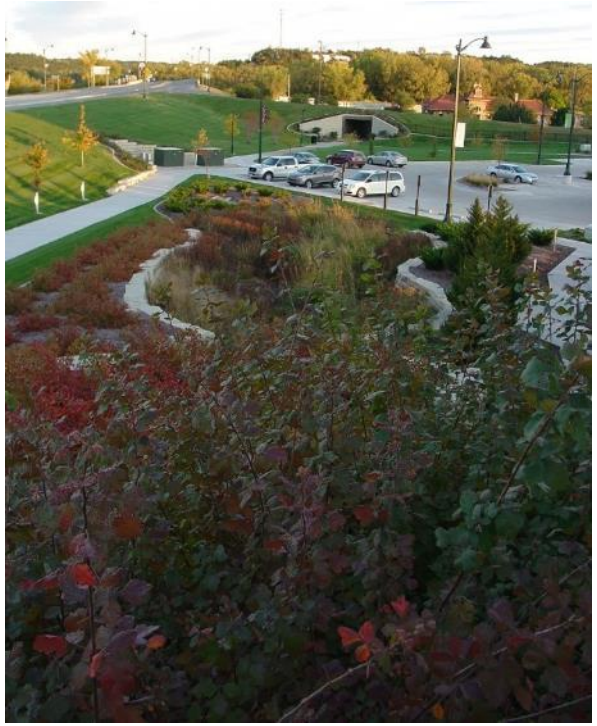
Pervious concrete installation at NE 94th & Broadway pump station site

Raingardens near Powderhorn Lake, Minneapolis (MN)

http://www.facebook.com/pages/Metro-Blooms/218582921584

Raingardens near Powderhorn Lake, Minneapolis (MN)

http://www.facebook.com/pages/Metro-Blooms/218582921584



Water-sensitive site planning/design project

ASLA 2004 award winner

Roof water is collected in carved stone basins, then drains into a grated channel before cascading over a five-foot stone-faced retaining wall.

The learning lab and auditorium buildings expand onto the courtyard, with tile artifacts historically manufactured in the watershed.

Surrounding forest and meadows are pulled into the courtyard and onto building roofs.

Design by Jones & Jones – Planners, Architects & Landscape Architects

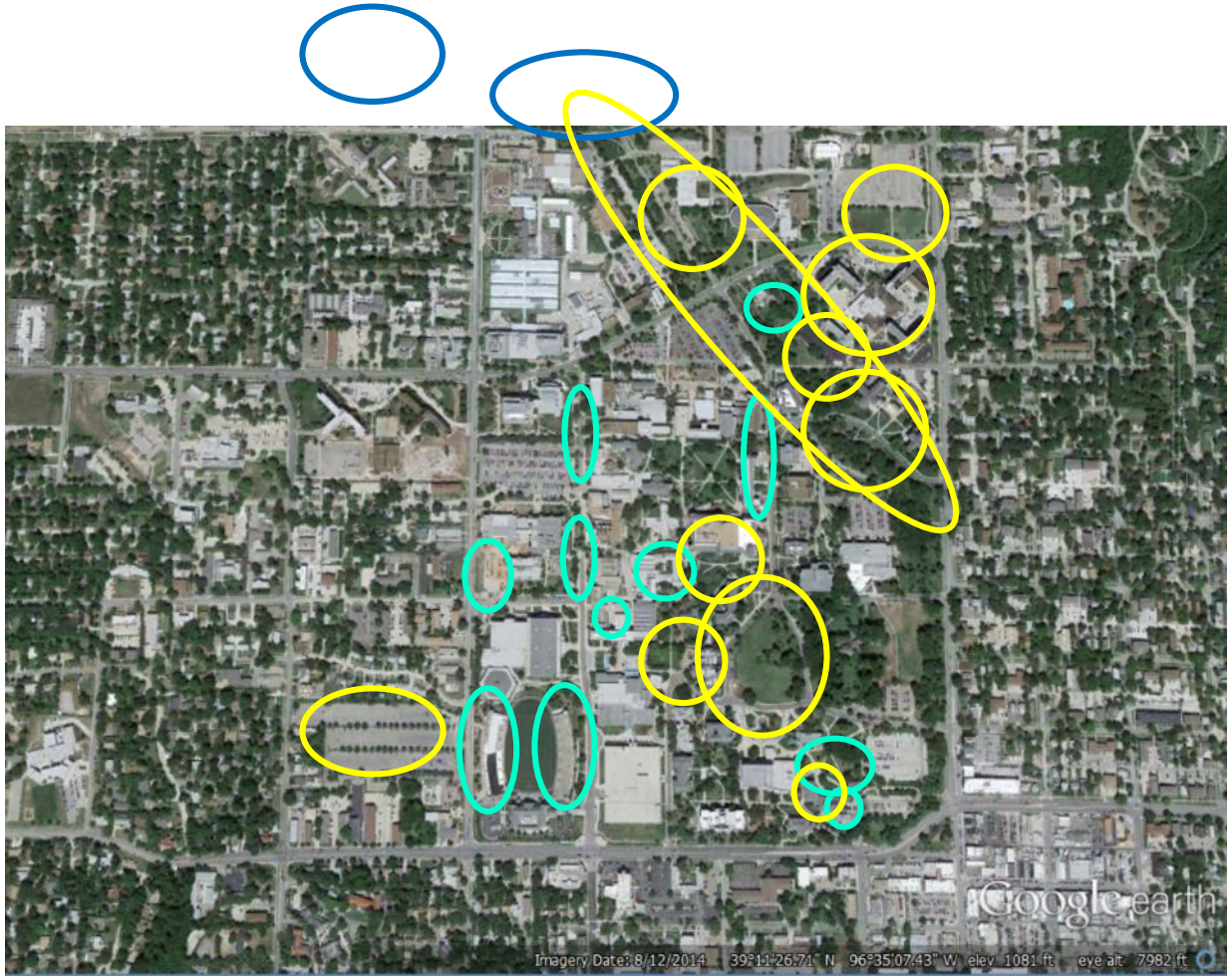
Cedar River Watershed Education Center - Seattle, WA

Source: www.asla.org

Manhattan Kansas

Selected Examples of Green Infrastructure

KSU campus – August 2005 (Google Earth)



KSU campus – August 2014 (Google Earth)

When I arrived in Manhattan, KS in late July 2005 there were no rain-gardens, green roofs, nor bio-retention areas on campus. Facilities staff were skeptical that they would work given our heavy clay soils.

Over the past 12 years more than 10 green infrastructure features have been implemented on campus (green), and many others (blue and yellow) proposed by students I taught…

Green Infrastructure Demonstration and Training:

Monitoring and Interpreting Two Sites on the Kansas State University Campus

Prof. Jessica Canfield, Kansas State University KSU-Landscape Architecture and Regional & Community Planning (LARCP)

Dr. Stacy Hutchinson, KSU-Biological & Agricultural Engineering (BAE)

Prof. Katie Kingery-Page, KSU-LARCP

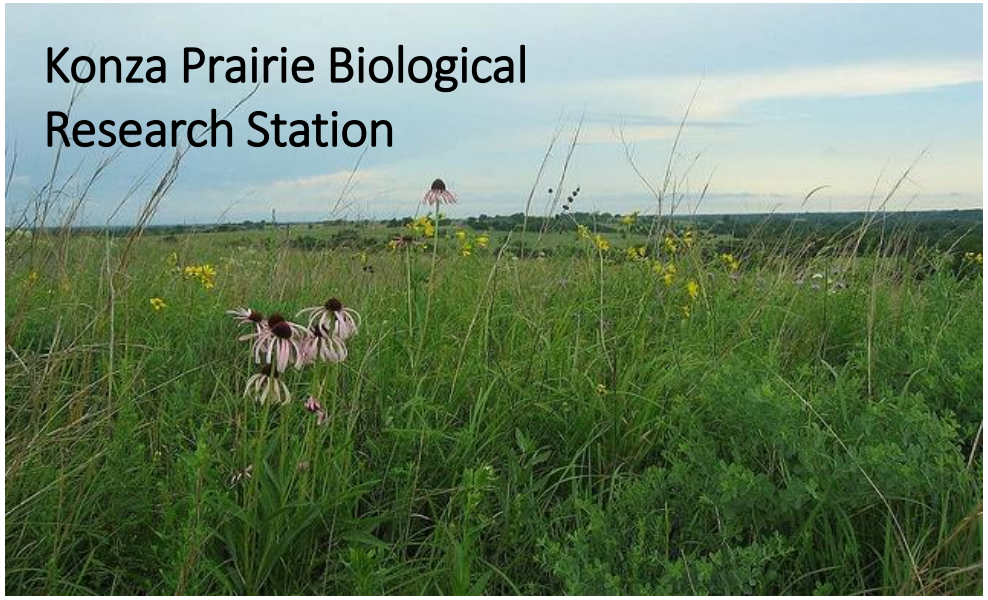
Prof. Lee R. Skabelund, KSU-LARCP

$20,000 from USEPA; $16,400 KSU cost-share (began Sep. 2015; completed in June 2018)

International Student Center Raingarden

The Meadow

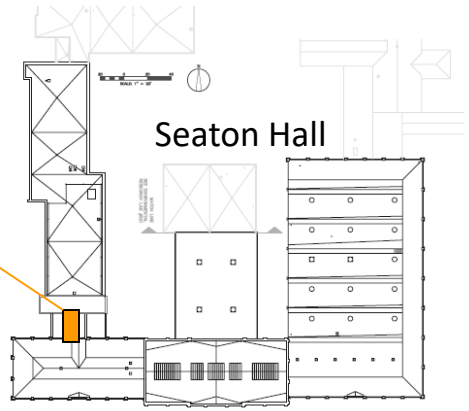
EPA Campus RainWorks Award Winner

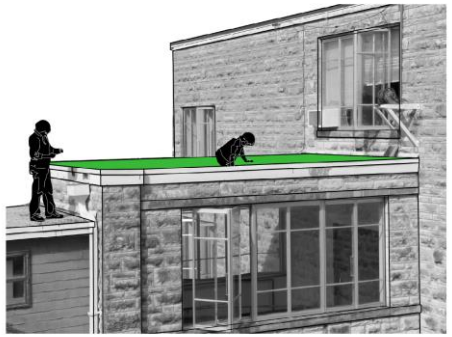


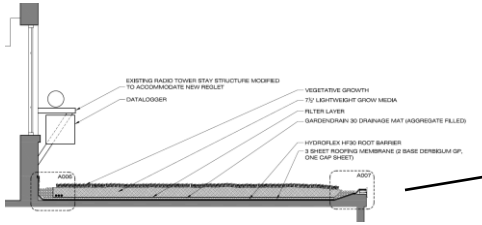
- **Native plants are adapted to local climates, many require no supplemental irrigation, and nearly all support local fauna.**
- Many native plants have evolved to survive periodic droughts using a variety of different mechanisms, although they wax & wane.

- **Identifying native plant species capable of surviving on rooftops & other urban settings is crucial if we are to provide habitat for local fauna while also meeting other important needs when green roofs are implemented.**
- Such needs include aesthetics and reasonable costs for implementation & management.

Upper Seaton Hall Green Roof – Manhattan, KS

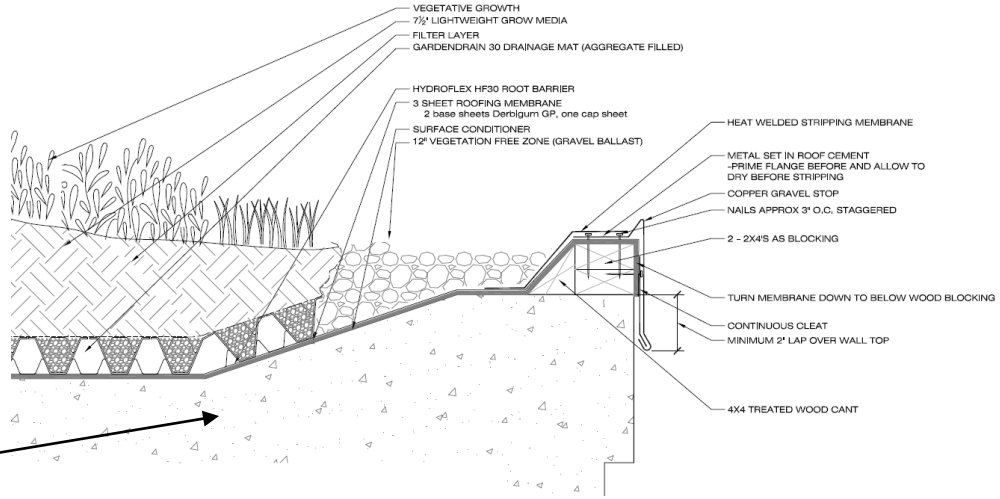






Seaton Green Roof
exposed upper rooftop

Structural calculations by Jessica Wiles & Dr. Sutton Stephens (Arch. Engineering). Details by Michael Knapp & Mark Neibling, with guidance from professors Todd Gabbard, Lee Skabelund, KSU Facilities, Greg Pfau (BNIM), and others. Monitoring support from Stacy Hutchinson (BAE), Mary Knapp & Carol Blocksome (Agronomy), and Rhonda Janke (Hort). Materials and labor donated by KSU-Facilities, Derbigum, Danker Roofing & American Hydrotech.



Upper breezeway roof – 305 sf; can hold ~64 lbs/sf

Low roofs to east & west – each ~350 sf; can hold ~51 lbs/sf

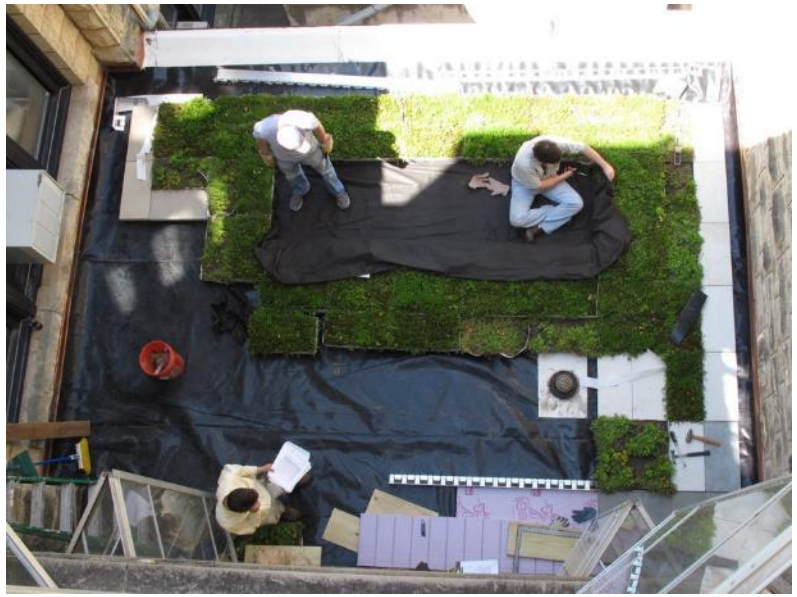
Upper Seaton Hall Green Roof

Seasonal Changes & Aesthetics – Spring 2010

5/31/10

Seaton Hall Green Roof

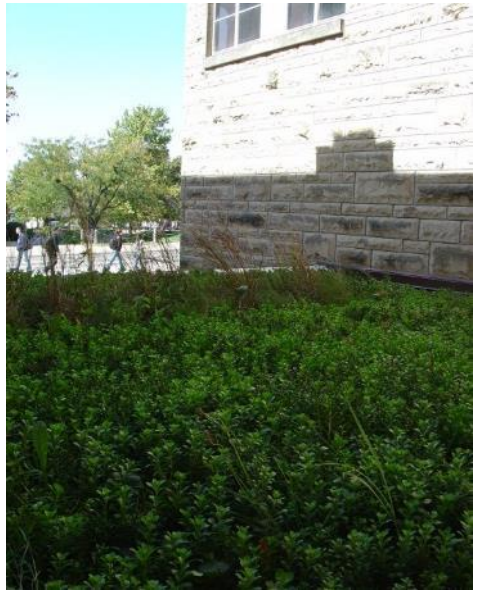
Lower Seaton Hall Green Roof – Manhattan, KS



5/8/12 installation photos by Chip Winslow

5/16/12

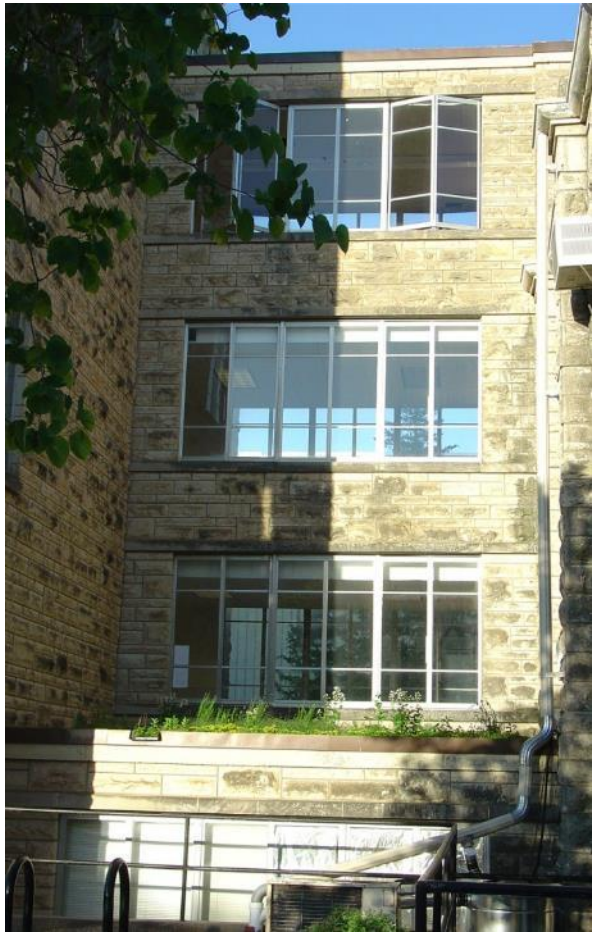
8/22/12



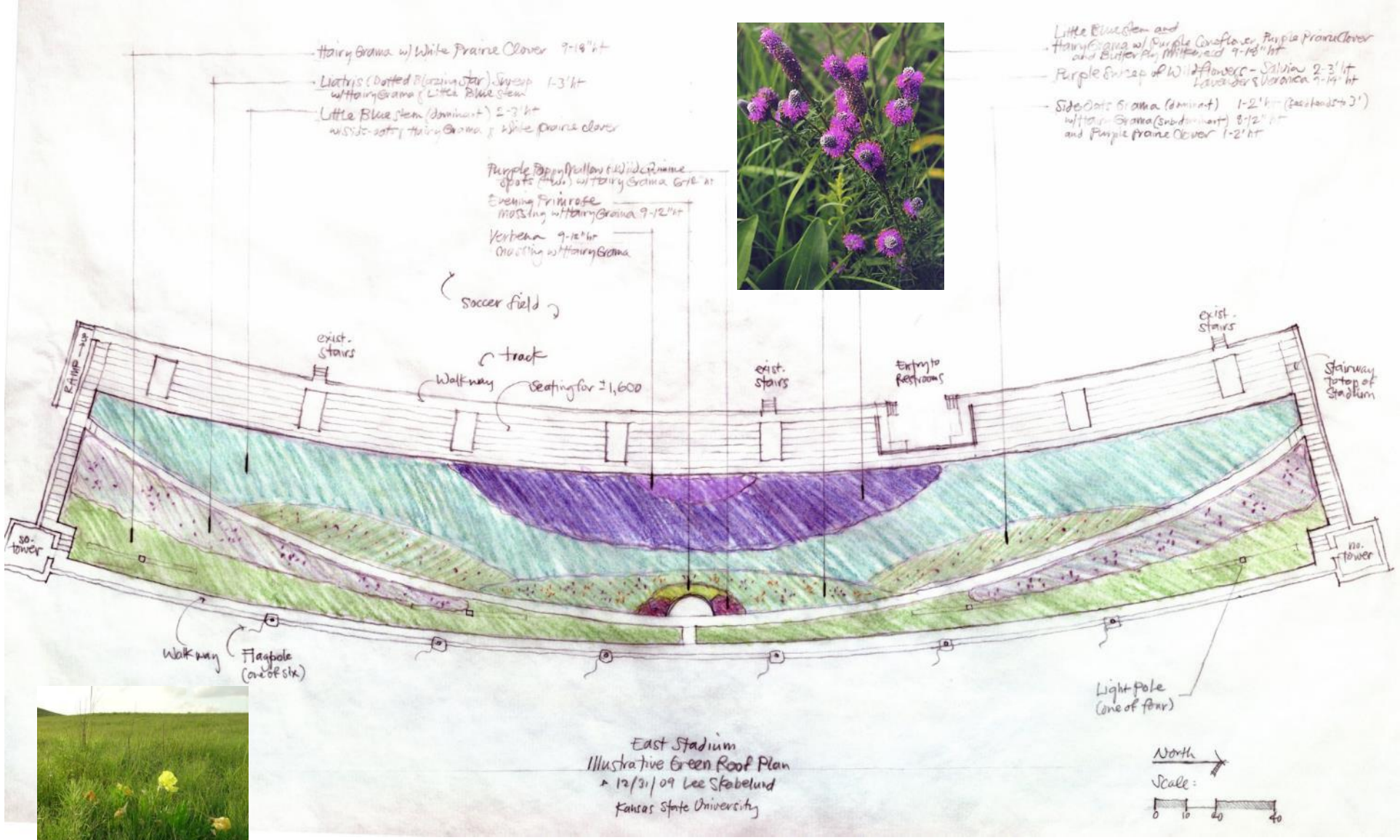
10/10/12

Lower Seaton Hall Green Roof – Manhattan, KS

6/3/14



5/30/13

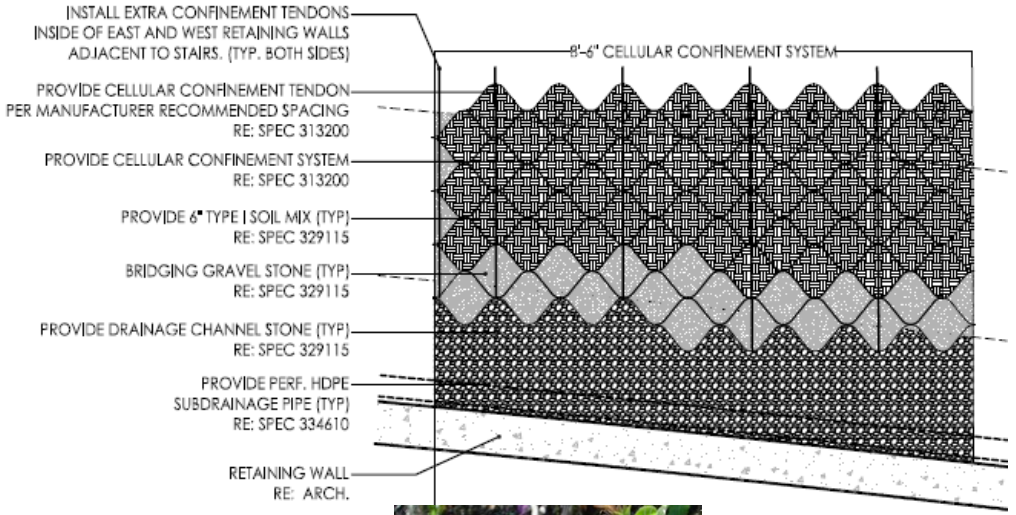


Konza Prairie Primrose - Irs

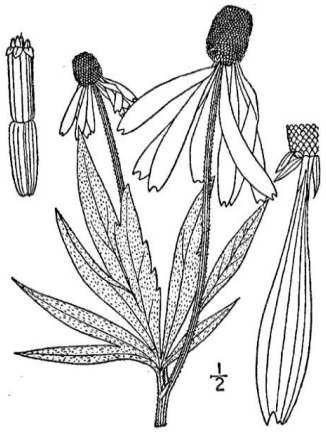
East Stadium Living Roof Concept
Lee Skabelund, Dec 2009

Purple Prairie Clover photo:
www.kswildflower.org/index.php

West Stadium Green Roof CDs
JBC, July 2013



Ratibida columnifera

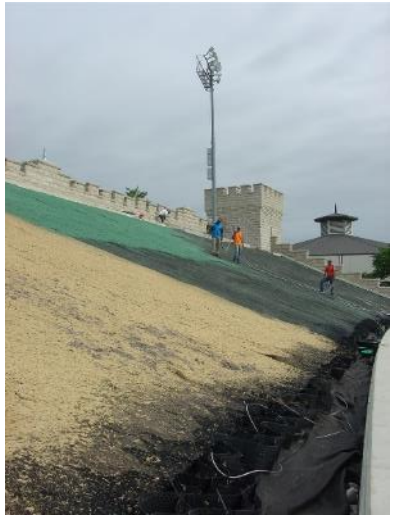


Ratibida pinnata

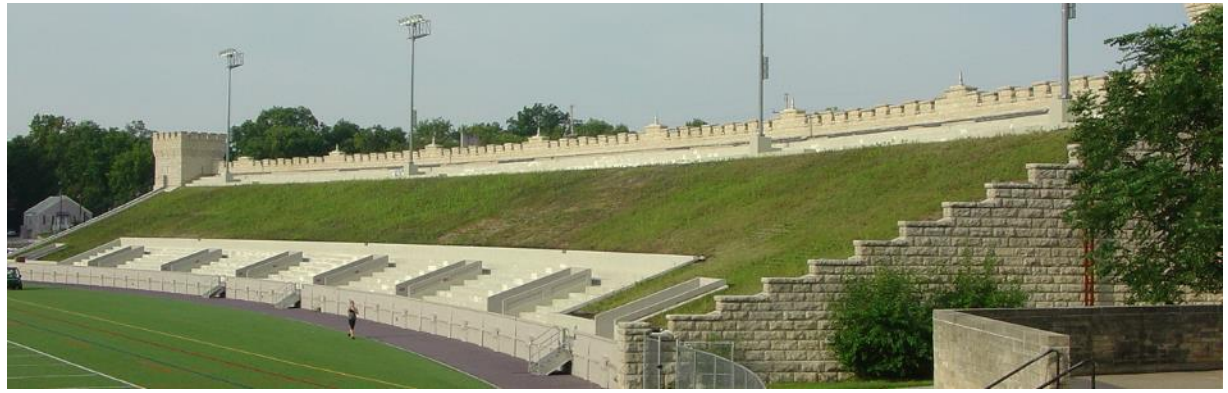
Penstemon cobaea

Dalea purpurea

Penstemon digitalis



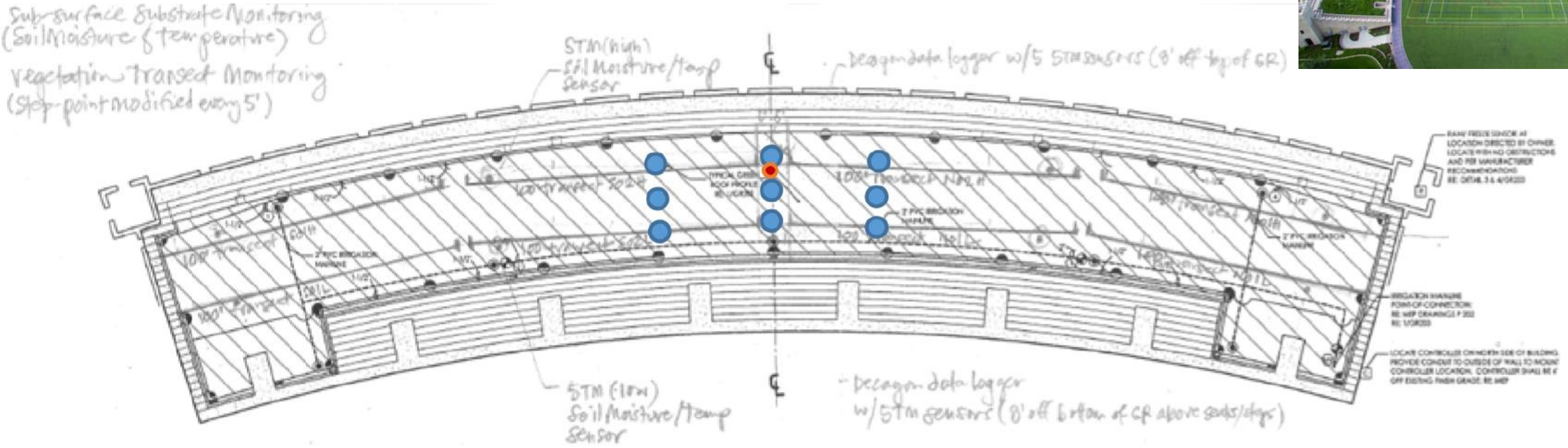
Memorial Stadium
Green Roof Observations
Summer 2015



Regular photographing MS-GR progress in 2015 led me to propose new research opportunities…







On June 20, 2016 we installed 9 Decagon 5TM Soil Moisture/Temperature sensors 3 inches below the surface to better understand changing conditions on the West and East MS Green Roofs; we plan to compare our initial data with plant coverage (using UAS aerials) and species richness (using transects) over a multi-year period.

KSU Memorial Stadium Green Roofs - Design & Implementation, Monitoring & Management (West Memorial Stadium 2015)

Seeding, planting & fertilizing by Blueville Nursery; weed management by Blueville & KSU…

KSU West Memorial Stadium Green Roof

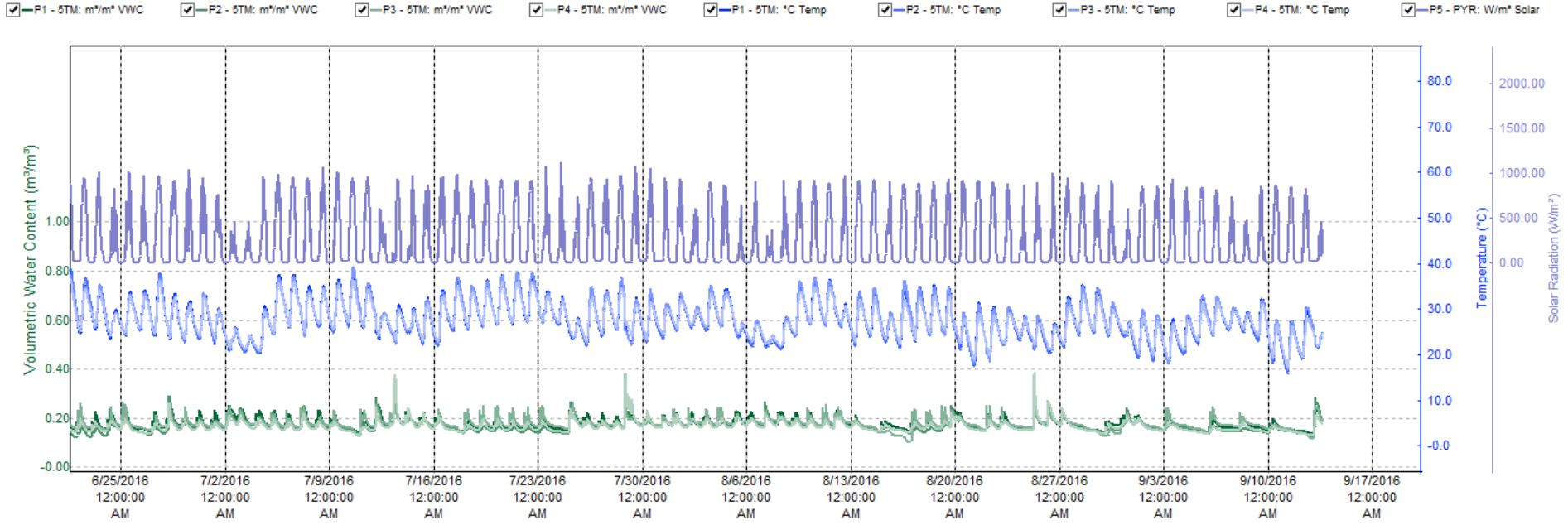
July 24, 2018

KSU East Memorial Stadium Green Roof

May 7, 2016

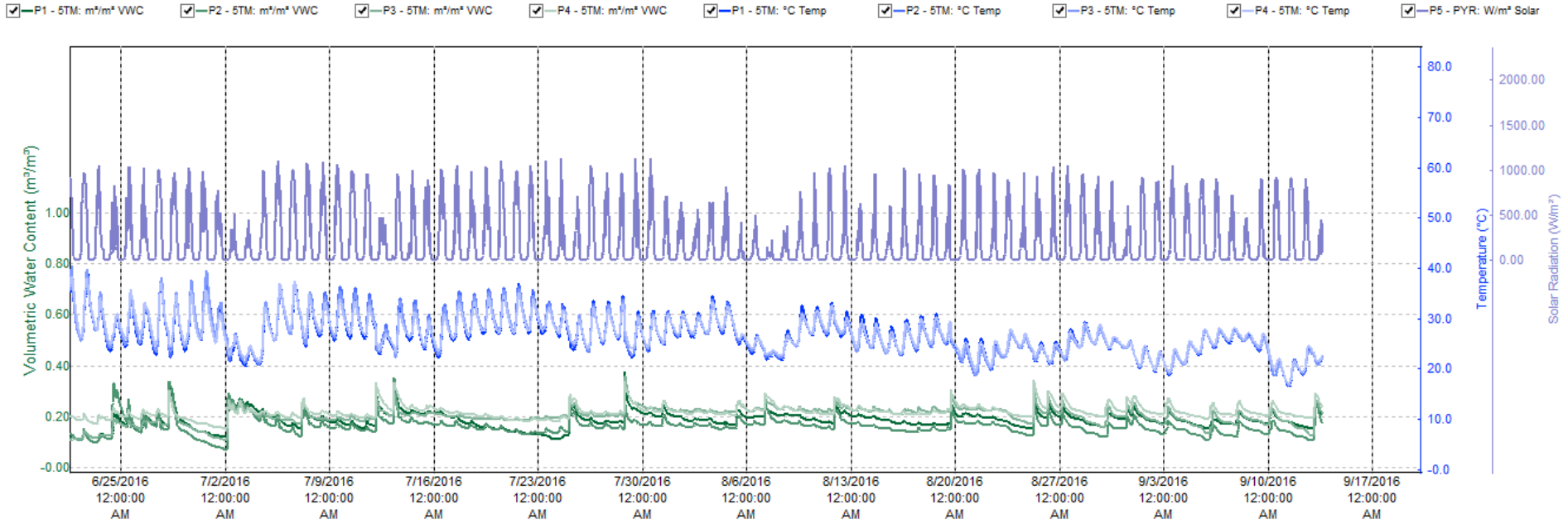
Sep 3, 2018

WMS-GR: PYR (solar radiation) and 3 high & 1 mid-level Decagon 5TM soil moist/temp sensors



Photos by LRS – taken during plant ID work along 100-foot transects…

EMS-GR: PYR (solar radiation) and 3 high & 1 mid-level Decagon 5TM soil moist/temp sensors



Memorial Stadium Green Roofs – 2016-2017 Vegetation Assessments

Intentionally seeded & planted native Kansas species were more dominant on both the WMS-GR & EMS-GR along MS-GR transects in late June 2017. However, agricultural weeds were very abundant on the EMS-GR.

WMS-GR - 28 Jun 2016 – Lower North 100-foot Transect

In late June 2016, dominant native plants on the WMS-GR were blue & hairy grama, little bluestem, Louisiana sage, prairie coneflower, yellow coneflower, and stiff goldenrod.

EMS-GR - 29 Jun 2016 – Upper South 100-foot Transect

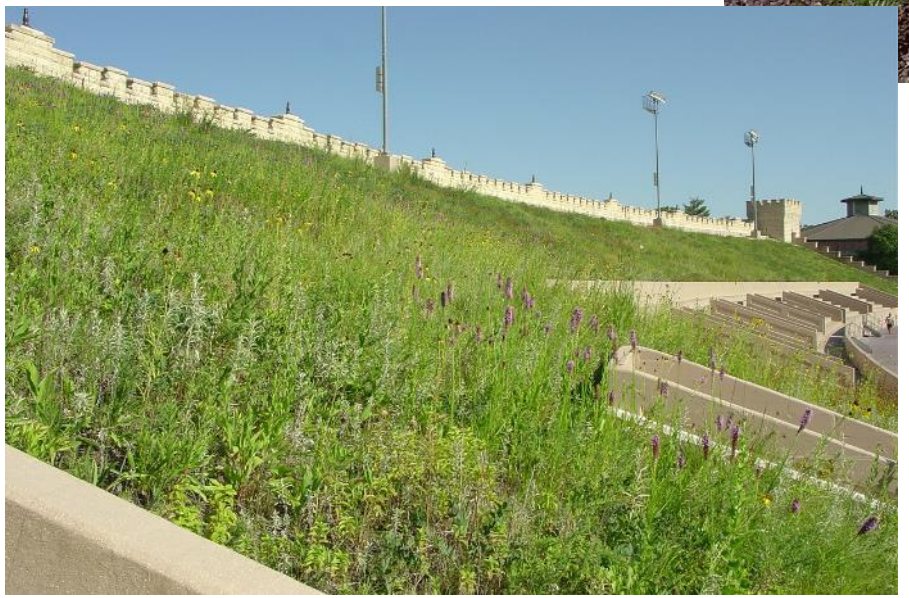
In late June 2016, dominant native plants on the EMS-GR were Indian grass and Louisiana sage. Foxtail, pigweed species, wild sweet clover, and lambsquarters were among a large variety of agricultural weeds very abundant on the EMS-GR.

Butterfly on KSU's Memorial Stadium Green Roof

Photo by Pam Blackmore

KSU West Memorial Stadium Green Roof

May 30, 2016



KSU West Memorial Stadium Green Roof

July 20, 2017

KSU East Memorial Stadium Green Roof

Sep 25, 2018

Sep 21, 2018

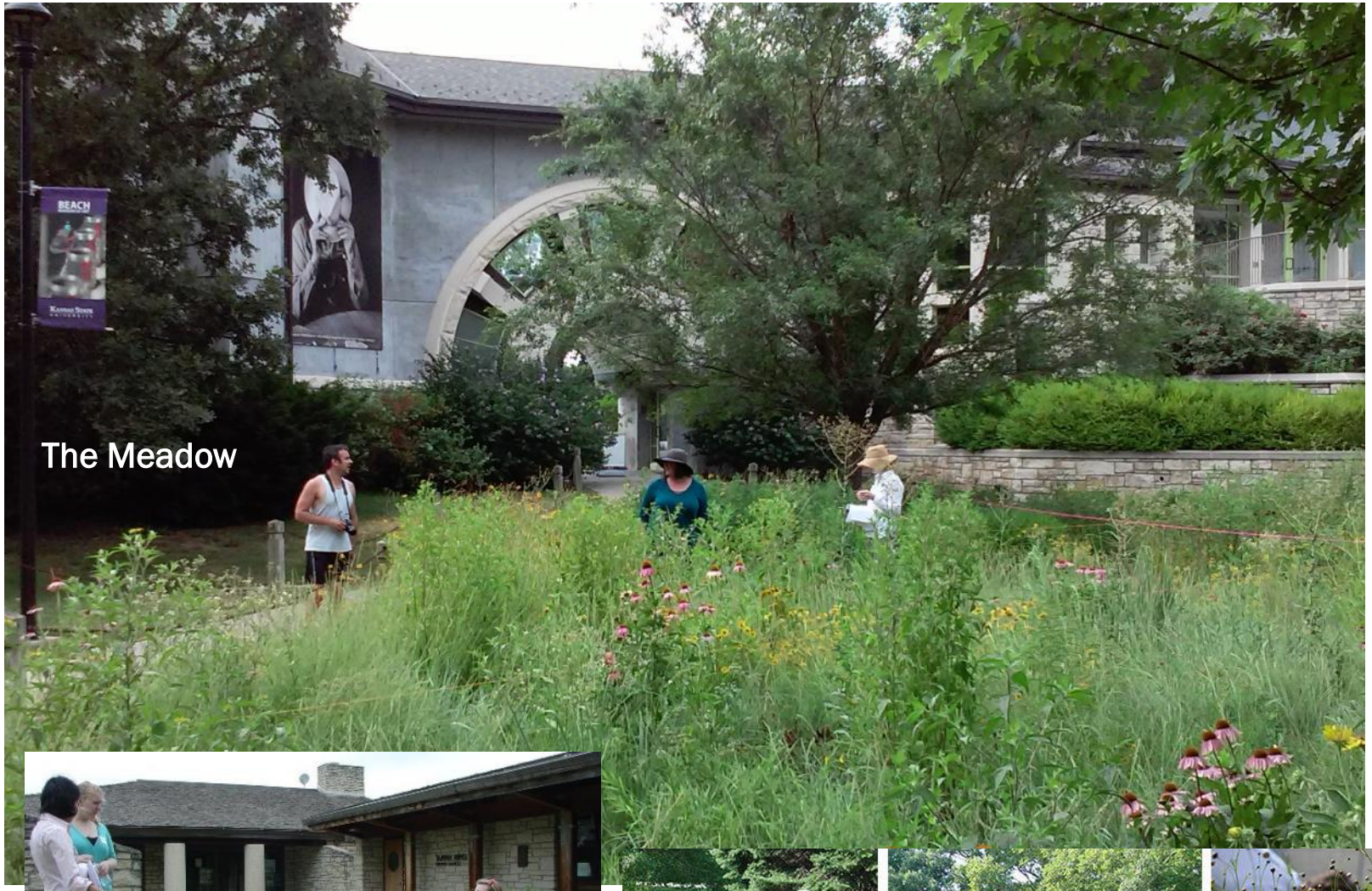
What is most important to know about green infrastructure implementation:

How and why vegetation within green infrastructure systems changes over time:
Depends on unique soil, hydrologic, micro-climatic, maintenance & contextual conditions.

Type and amount of maintenance required to retain viable stands of non-invasive & diverse vegetation on green roofs and in rain-gardens:
Requires intelligent & regular management. One must determine what to remove and how to do so to minimize soil disturbance and invasive/undesirable species.

Ecosystem services provided by these eco-design features:
Stormwater management close to where precipitation falls.
Movement of rainfall into healthy, living soils.
Reduced water and energy use.
Vibrant pollinator habitat.
Carbon sequestration.
Species diversity.

Examples of how green infrastructure makes an impact in our community…



KSU-LARCP faculty and students have led work on many projects & are learning from others…

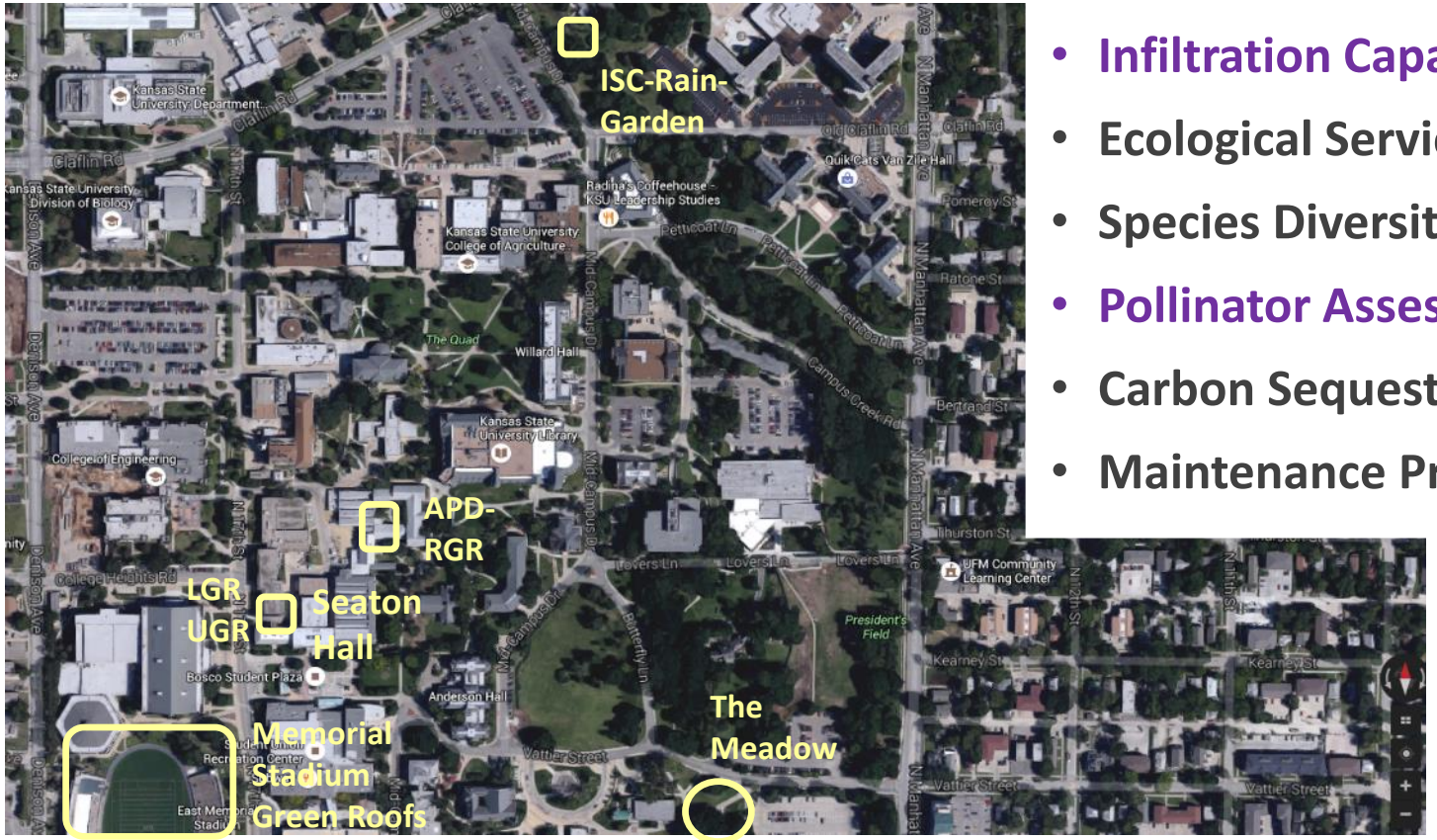
KSU-ISC Rain-Garden – May 31, 2013

Sunset Zoo Rain-Gardens

Sunset Zoo Rain-Gardens

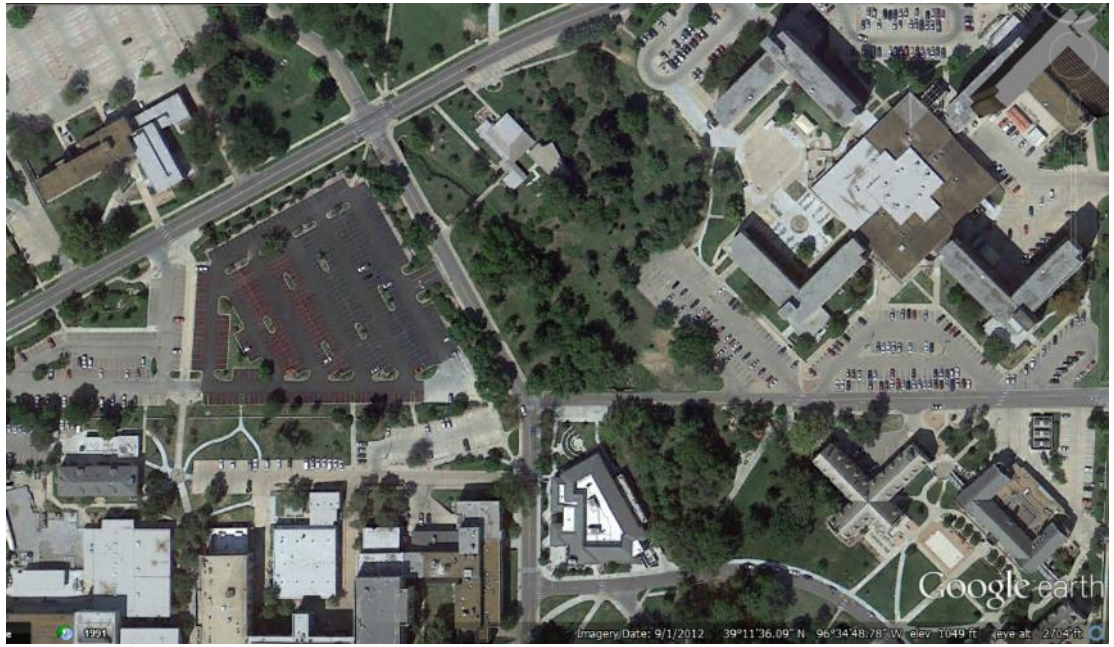
Sunset Zoo Bio-Retention Area – July 14, 2012

KSU Central Campus Green Infrastructure



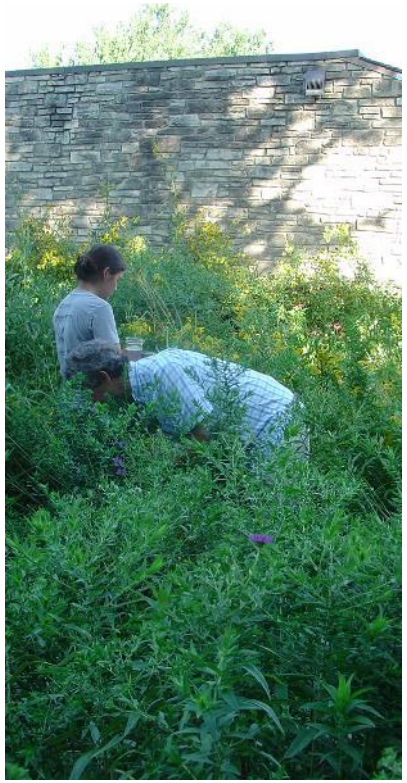
- Stormwater Runoff Analysis
- Water Quality Assessment
- **Infiltration Capacity Testing**
- Ecological Services/Health Assessment
- Species Diversity Assessment
- **Pollinator Assessment**
- Carbon Sequestration/Biomass Estimate
- Maintenance Procedures Assessment

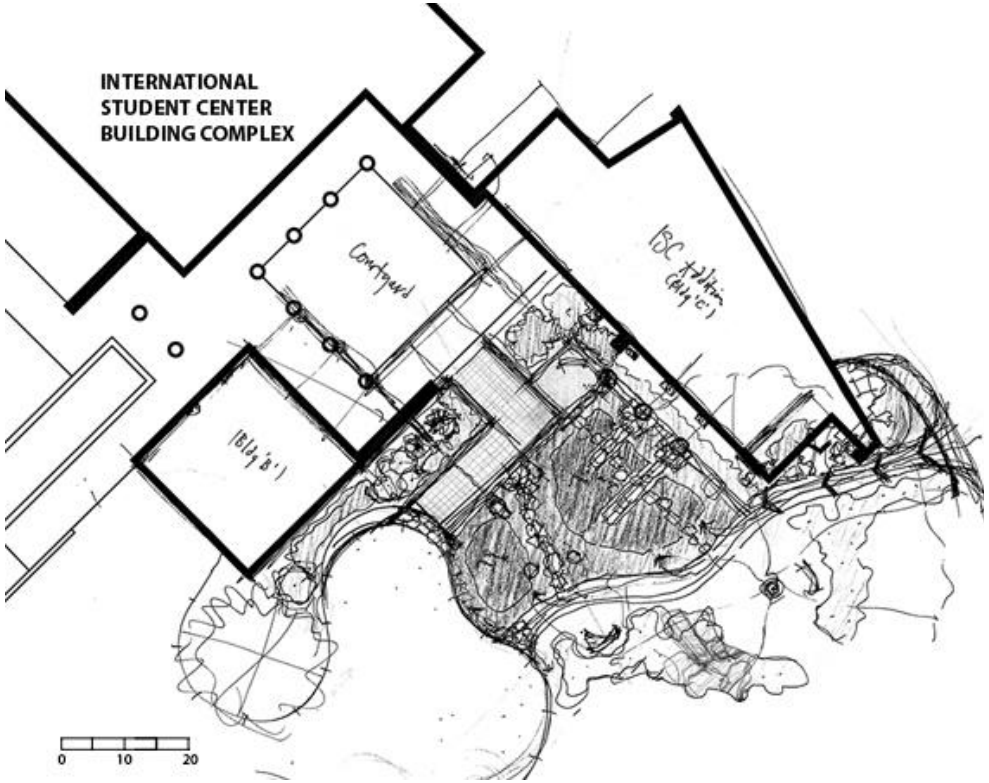
For the dual purposes of **expanding student training/learning** and **advancing community outreach**—this project is utilizing the International Student Center (ISC) Rain-Garden, Beach Meadow, and other sites as living laboratories, where faculty, staff, students, community members, and visitors monitor, learn from, and interpret the multi-faceted performance benefits of green infrastructure.



KSU ISC Rain-Garden Sep 2012 (Google Earth)

KSU Campus Mar 2006 (Google Earth)





ISC Rain-Garden Design, Implementation, Monitoring, Management & Outreach

Project Director/Lead Designer:
Lee R. Skabelund

Project Completion (Construction):
March-June 2007 (gardens and pathways);
May 2008 (rain-bowls)

Pre-existing Land Use Type:
Turfgrass

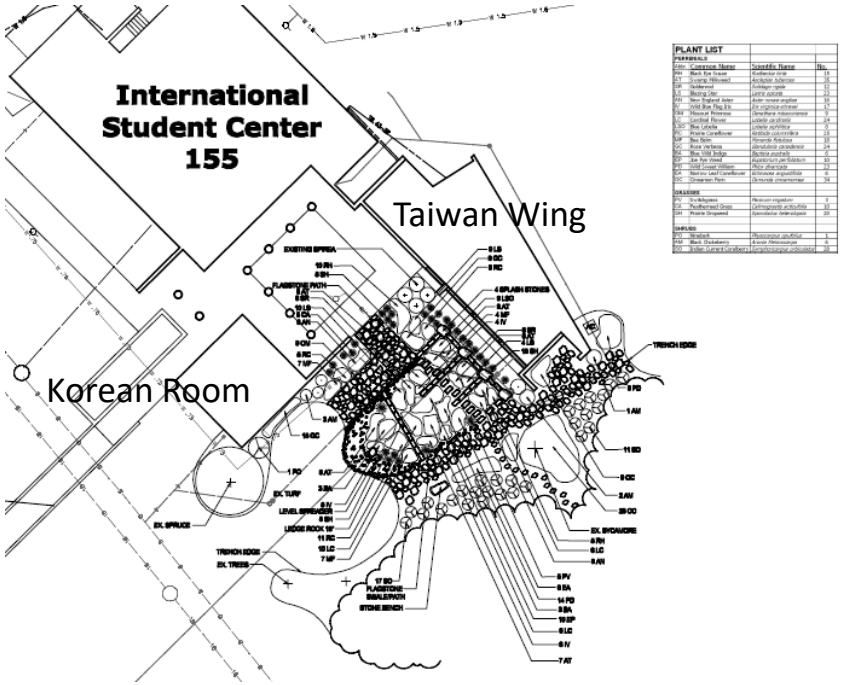
Project Funding/Support:
USEPA, KDHE, WaterLINK, KSU,
and many partners

Size:
Approx. 3,000 square feet

turfgrass to garden; pipe to non-pipe

Restoring Hydrologic Processes along Campus Creek

The KSU International Student Center Design/Build Rain-Garden Demonstration Project



Planting Plan (Cary Thomsen, KSU-MLA)

Planting & Setting Level-Spreader (4/28/07)

In-process rain-garden photos taken on 5/16/07, 6/2/07, 6/22/07, and 7/16/07

Interweaving Art and Science

K-State's International Student Center Rain-Garden

Interweaving Art and Science

K-State's International Student Center Rain-Garden

KSU-ISC Rain-Garden – April 30, 2010

KSU-ISC Rain-Garden – February 22, 2013

KSU-ISC Rain-Garden – April 17, 2013

Held an estimated 5,000 gallons; very little H2O went over the level-spreader/dam)

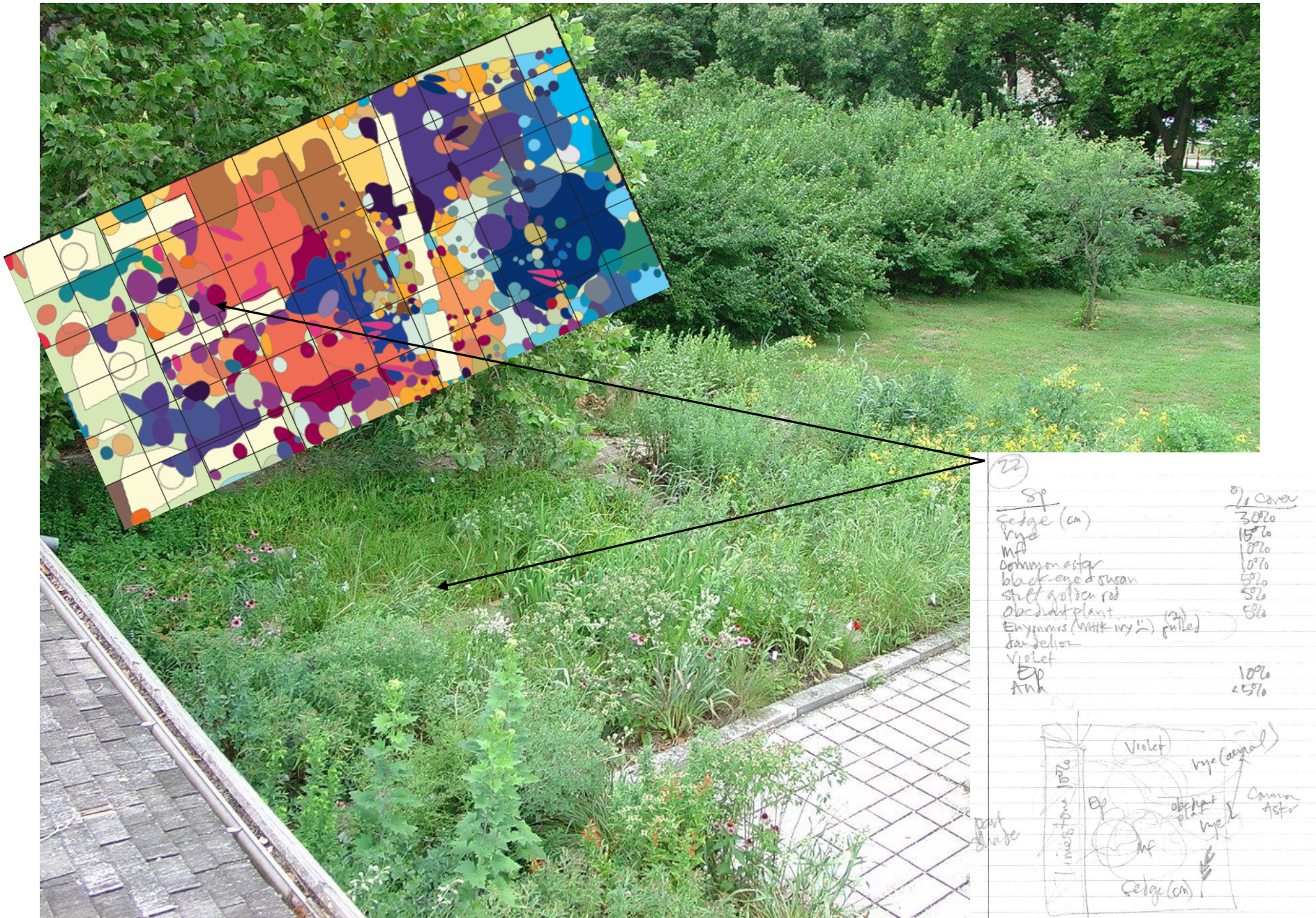
KSU-ISC Rain-Garden – July 11, 2013

KSU-ISC Rain-Garden – August 5, 2013

KSU-ISC Rain-Garden – November 11, 2016

KSU-ISC Rain-Garden – December 11, 2016

KSU-ISC Rain-Garden Plant Species Diversity – July 8, 2016




KSU-ISC Rain Garden – July 8, 2016

KSU ISC Rain-Garden Sep. 13-14, 2016 Natural Infiltration: Observations & Notes – lrs (14 Sep 2016)

Lee R. Skabelund, KSU-LARCP

Approximate rainfall at Seaton Upper Green Roof 13-14 September 2016 – 1.60" (9/13am) and 0.97" (9/14am). Both pools filled and overtopped between 5:35-5:50am on Sep 14; rain largely stopped around 6:30am—the estimated time when water in the two pools began to actively dissipate via infiltration and/or evapo-transpiration.

Based on direct measurements, water levels in the ISC Rain-Garden reached approximately 22cm at the deepest point of the rain-garden before water moved over the level spreader on 9/14 (~5:45am).

Overcast and fog/mist conditions continued between 6:30am-1:00pm. Air temperatures were between 61-67F through early afternoon, and reached the low 70s by late afternoon (with part sun conditions after 3:00pm).

LRS observed a water level depth of 11.5cm at 2:30pm in upper pool of the ISC Rain-Garden.
Measurements were taken as follows (see LRS photographs* for supporting visual evidence):
9/13/2016 – 1:45pm – water level approx. 4.0"/10cm depth in both pools (based on clearly direct measurement)
9/13/2016 – 5:45pm – approx. 1.75"/4.5cm depth in east pool; no water in west pool
9/13/2016 – 8:30pm – no water in east pool

9/14/2016 – 5:50am – water level approx. 8.0"/21cm depth in east pool; approx. 7.5"/19cm depth in west pool
9/14/2016 – 12:05pm* – approx. 4.5"/11.5cm depth in east pool; approx. 4.0"/10cm depth in west pool
9/14/2016 – 3:50pm – approx. 3.5"/9cm depth in east pool; approx. 2.5-3.0"/6.5cm depth in west pool
9/14/2016 – 6:05pm – approx. 2.5"/6.5cm depth in east pool; approx. 1.5"/4cm depth in west pool
9/14/2016 – 8:30pm – approx. 0.25"/0.5cm depth in east pool; no water in west pool
Estimate that no surface water remained in the east pool at 8:50pm; thus water infiltrated in less than 15 hours.

ISC-RG East Pool – 14 Sep 2016 mid-day

ISC-RG West Pool – 14 Sep 2016 mid-day

ISC Rain-Garden – 14 Sep 2016 mid-day

Sample_ID	Total_N_ppm	Total_P_ppm	NH4-N_ppm	NO3-N_ppm	Ortho_P_ppb	Zn_ppm	Cu_ppm
SH GR RW	0.40	0.02	0.21	0.14	2	N/A	N/A
SH UGR (drainage)	1.52	0.14	0.17	0.12	111	0.16	0.01
SH RW Dsp	0.98	0.05	0.22	0.21	32	0.01	0.38
SH LGR scupper	2.44	0.25	0.20	1.06	193	0.01	0.02
SH LGR cistern	0.44	0.06	0.16	0.30	45	0.00	0.14
ERG bypass	0.42	0.04	0.15	0.23	26	0.00	0.00
ERG pool	0.72	0.09	0.32	0.01	54	0.00	0.02
ISC RG mid scupper	1.71	0.31	0.33	0.02	218	0.07	0.05
ISC RG mid rain-bowl	1.26	0.2	0.22	0.09	117	0.26	0.05
EMS GR N2 scupper	1.28	2.39	0.19	0.05	2216	0.11	0.01
WMS GR center scupper	0.9	0.04	0.17	0.01	28	0.06	0.01
Campus Creek below LS	1.41	0.15	0.22	0.75	116	0.01	0.02












April 29, 2016

July 19, 2016

June 26, 2009

KSU-ISC Rain-Garden – June 26, 2009

Sunset Zoo Rain-Gardens – Manhattan, KS

Within one good growing season small, live native species can take hold.

Sunset Zoo Kansas Plains Prairie Rain Gardens

Maintenance Question:

How do we best manage for people (safety & aesthetics), for stormwater management, pollinators, and other ecological services?

Sunset Zoo Bio-Retention Area – Manhattan, KS

Sunset Zoo Bio-Retention Area – Manhattan, KS

Sunset Zoo Bio-Retention Area – May 30, 2014

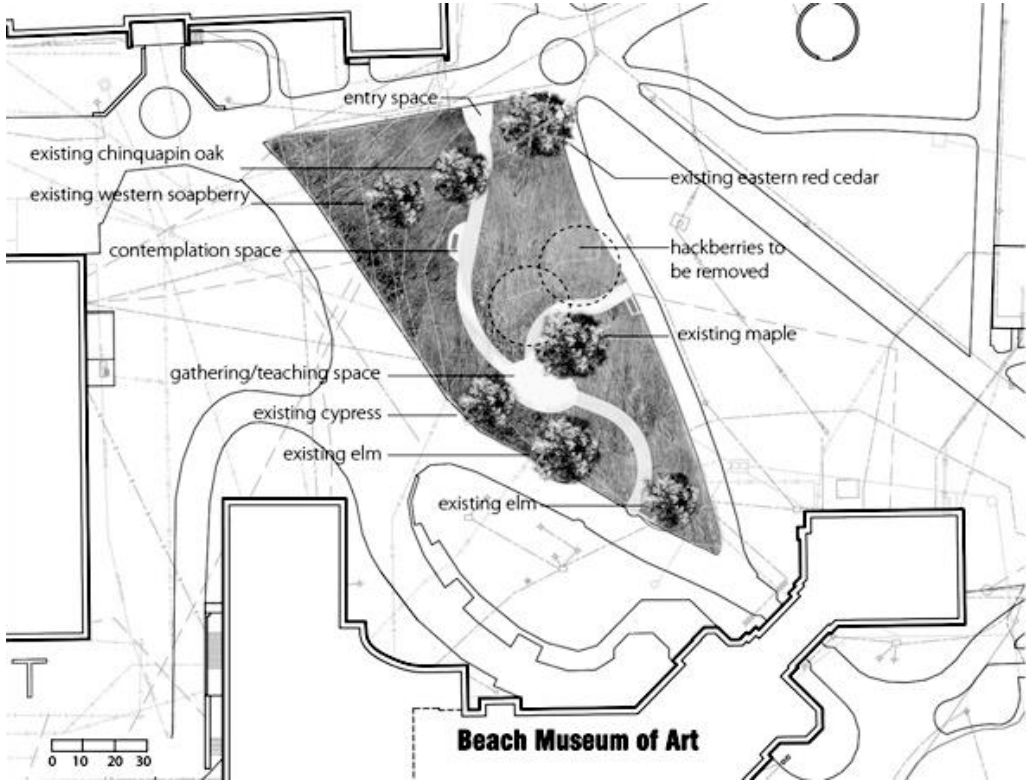
Sunset Zoo Bio-Retention Area – May 30, 2016

Sunset Zoo Bio-Retention
(May 30, 2016)

Sunset Zoo
Bio-Retention
(July 2018)

Sep 2012 (Google Earth)

KSU Meadow & Beach Museum – August 2014 (Google Earth)



The Meadow Design, Implementation, Monitoring, Management & Outreach

Project Director/Designer:
Katie Kingery-Page

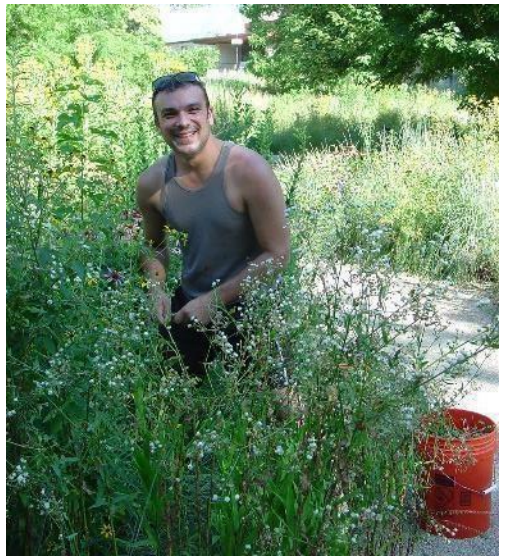
Project Completion (Construction):
Summer 2013 (seeding, pathways, benches);
June 2015 additional planting

Pre-existing Land Use Type:
Turfgrass

Project Funding/Support:
Hummel Family Memorial Fund, KSU,
and many partners

Size:
Approx. one half acre (21,000 square feet)

turfgrass to prairie-like meadow



The Meadow near Beach Museum

http://apdesign.k-state.edu/larcp/researchandcreativeactivity/la/the_meadow/prairie_roots_run_deep.html

Beach Museum Meadow
Katie Kingery-Page, et al.

Maintenance Questions:

What are the differences in the ways larger natural landscape systems are perceived and managed as compared to smaller gardens?

What influence do educational, artistic and social interventions have on maintenance decisions?

The Meadow – KSU Beach Museum (June 1 to July 8, 2015 photos – lrs)

Plant native flowering perennials….

particularly larval host plants.

ASSESSING MIXED SPECIES PERFORMANCE & PLANT HEALTH ON THE APD-RESEARCH GREEN ROOF

LR Skabelund – 12 Oct 2017

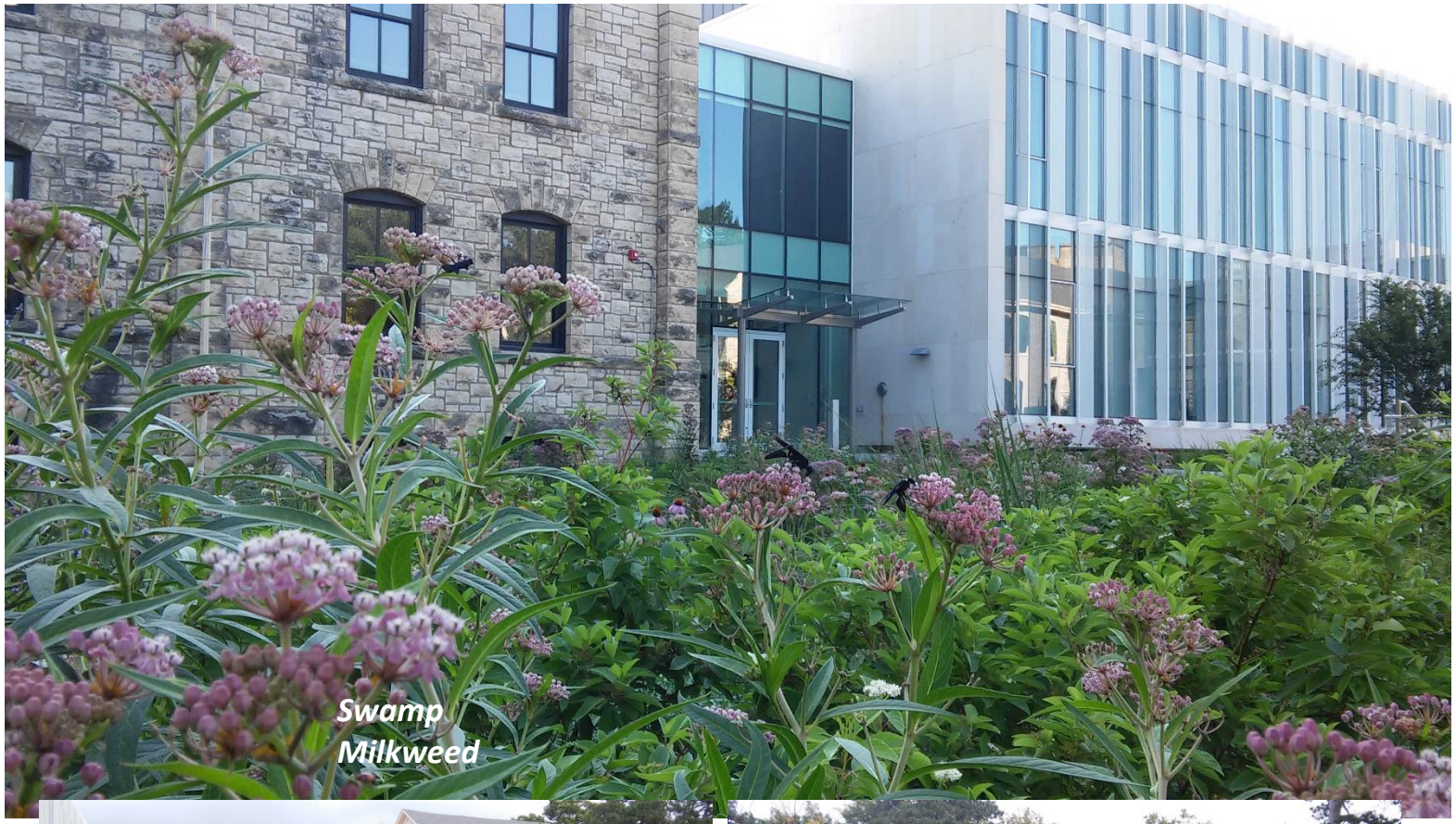
Sep 3, 2018

Oct 12, 2018

Oct 15, 2018

KSU APDesign Experimental Green Roof

POLLINATOR USE of the APD RAIN GARDENS



July 21, 2018

Sep 13, 2018

POLLINATOR USE of the APD RAIN GARDENS and Calamint (native to Europe, North Africa & Asia)

Green infrastructure can help urban stakeholders better understand natural systems

http://apdesign.k-state.edu/larcp/researchandcreativeactivity/la/the_meadow/prairie_roots_run_deep.html

Manhattan Area Green Infrastructure

Loosening existing heavy clay soils, the ISC rain-garden was created in Spring 2007, the first formally designed green infrastructure system on the K-State campus. Pocket rain-gardens and a bio-retention area were created at Sunset Zoo in 2009 and 2011. Each of these systems include more than 20 species of native plants and support many butterflies, bees & other pollinators. Engineering Complex Expansion designers & engineers created a series of highly engineered bio-retention cells employing three plant species.

KSU International Student Center Rain Garden

KSU Engineering Rain Garden

Sunset Zoo

Fall 2017 project by Grace Mader (with L. Skabelund & J. Canfield)

2018 Central States ASLA Awards

Design Unbuilt

Project Name: Roots of McCall

Again: Why this work is important:

- Green infrastructure can serve as essential parts of interconnected open space networks.
- Biodiverse patches make a difference.
- Landscape conservation and resilient urban areas are vital to human health, and to the well-being of ecosystems and other organisms.

Charlotte Sawyers Natural Area

August 2018
KSU-LAR
Site Visit

Charlotte Sawyers Natural Area

August 2018
KSU-LAR
Site Visit

THE FOREST SCHOOL

Platte Land Trust - Charlotte Sawyers Natural Area

Spencer Sanders | LAR 410: Planting Design Studio | Prof. Lee Skabelund | Kansas State University | Fall 2018

Conceptual Plan

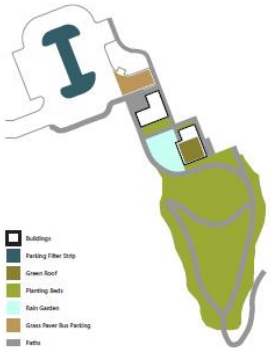
0 50 100 150 200 feet
1" = 50'
NORTH

Concept Statement

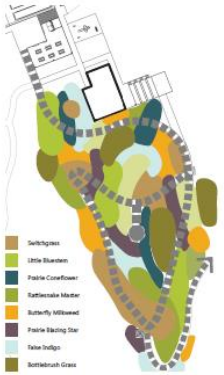
The goal of the Forest School design is to educate visitors about how versatile native plants can be through restoring native biodiversity, controlling storm water, and improving aesthetics. The site contains multiple elements of ecological design such as a rain garden, green roof, filter strips, restored prairies, and grass pavers that help control runoff from storm water. As visitors walk through the site native plants and ecological design elements will be explained by signs and markers. Then whenever people use the trail systems to explore the rest of the site they can see native plants working in natural systems similar to how they are use in this design.

Bioretention (BR) is beneficial for the environment since it reduces the amount of run-off water that leaves the site. Uncontrolled run-off can increase erosion and degradation of natural environments. As people visit the Charlotte Sawyers Natural Area they will be inspired to use similar methods with native plant to properly manage existing natural resources.

A. Nature Center Rain Garden



Infiltration Areas



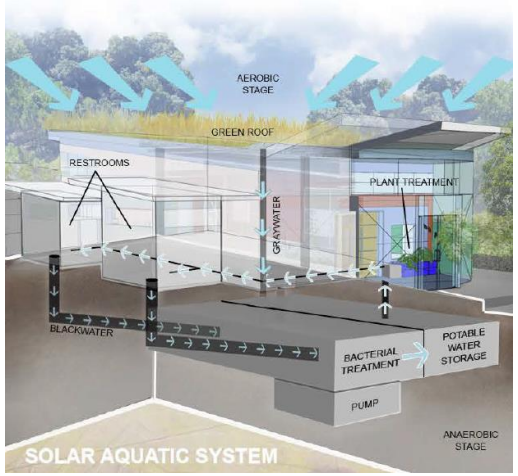
Educational Prairie

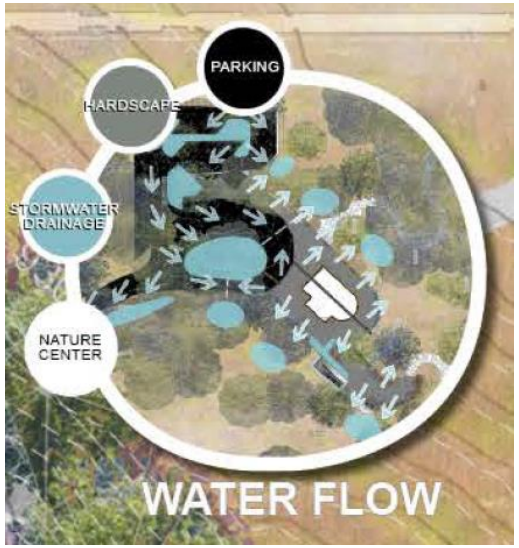
B. Visitors Enjoying the Educational Prairie

C-C'. Section Through Nature Center Scale: 1" = 10'

James Ryan's Vision:

Treat stormwater, graywater & blackwater to create fully functioning closed-loop systems for this new nature center.





An excerpt from Wendell Berry's "A Poem on Hope"

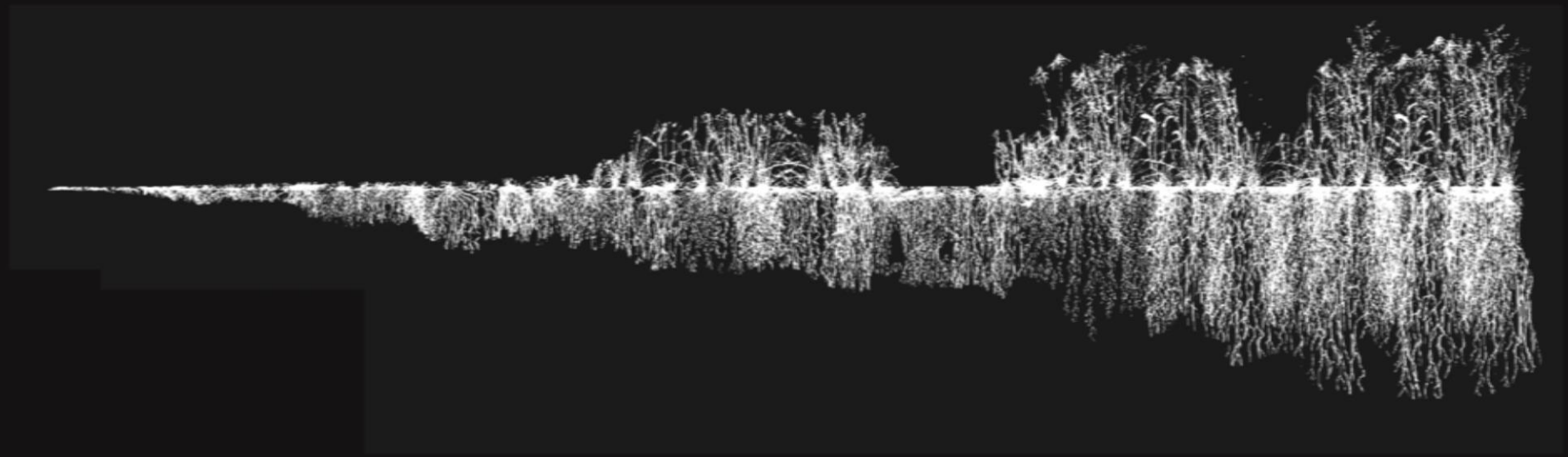
Find your hope, then, on the ground under your feet.
Your hope of Heaven, let it rest on the ground underfoot.
The world is no better than its places. Its places at last are no better than their people while their people continue in them.

–Wendell Berry (see **https://vimeo.com/75871831**)
See also: https://vimeo.com/75871177

Manhattan Green Infrastructure – inspiring those seeking to Create a Greener Future

Lee R. Skabelund (KSU-LARCP)
lskab@ksu.edu

Stormwater Benefits of Native Plants



Urban Native Plants

You are standing near a landscape that re-introduces native plants to an urban area. Many native grassland plants have deep, fibrous roots which help the soil act like a giant sponge for holding rainwater.

Stormwater Infiltration

In the stormwater infiltration process, most rainfall is absorbed by a healthy plant-and-soil system. Rainwater which is not absorbed is called runoff.

Reducing Flooding

Runoff can cause soil erosion, flooding, and water pollution. Adding native plants to a landscape can help decrease these problems.

Kyoto Japan

Selected Examples of Green Infrastructure

Takase River – Kyoto, Japan

Shoren-in Temple area – Kyoto, Japan

Savory rooftop garden – Kyoto, Japan

Savory rooftop garden – Kyoto, Japan

“The California Academy of Sciences hosts a LEED® Platinum Museum in San Francisco’s Golden Gate Park.
Rana Creek Living Architecture worked with Renzo Piano Building Workshop, Chong and Partners Architecture, SWA Group, ARUP Engineering, and the Academy to create a living roof that covers 160,000 square feet of roof with four steeply sloped domes replicating the surrounding rolling hills.

The roof is planted with over 50 [now 100] plant species native to San Francisco. The three-year research period during which Rana Creek Living Architecture designed, built and monitored a series of living roof mock-ups, informed this diverse assemblage of indigenous plants, as well as the soil retention and drainage techniques ultimately chosen for the project. The California Academy of Sciences is unique amongst natural history museums in its dedication to combining research and education under one roof.

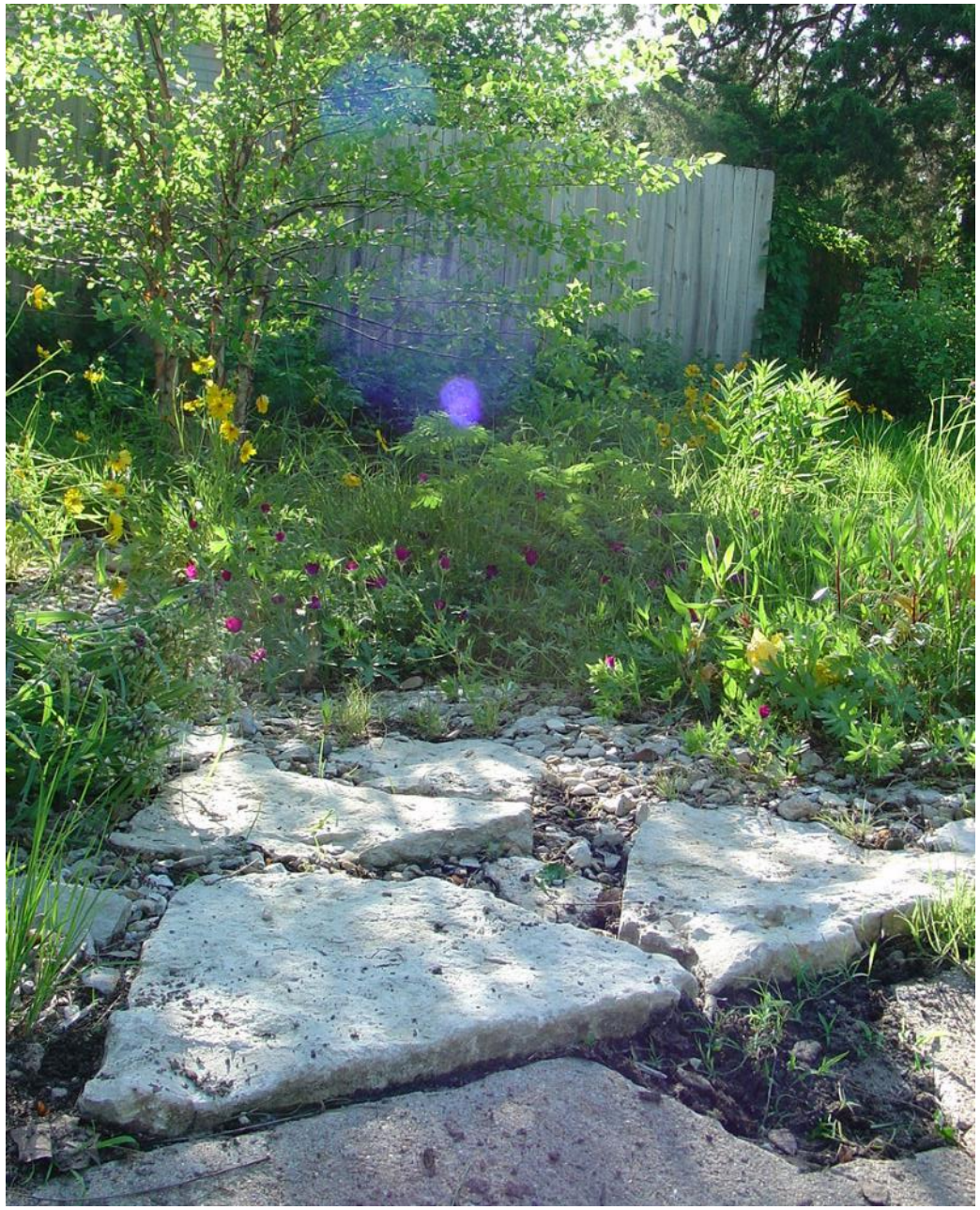
www.ranacreekdesign.com/projects/california-academy-of-sciences

Inside the Rana Creek Design Studio (ASLA 2016)
https://vimeo.com/album/2379119/video/200686969

What is most important to know about green infrastructure implementation?

Green roofs, rain-gardens, bio-retention areas, and other designed green infrastructure features have the potential to be vital parts of interconnected and regenerative community open space networks.

Poorly designed, implemented and/or managed green infrastructure projects increase resource demands by creating untenable conditions for selected vegetation (which dies out or is out-competed by undesired plant species)—leading to the need for or expectation that vegetation (or the entire system) be replanted or replaced.



Sunset Zoo Bio-retention Area

Important Maintenance Questions:

What are the best ways to manage invasive non-native and aggressive native species in this garden that acts as a sink for water and critters?

How do we effectively transmit management ideas for complex ecosystems to zoo staff and community volunteers?

Rain-Garden Maintenance:

Key Ideas to Remember:

1) **Rain-Gardens need to be maintained** (there is no "free lunch" when it comes to maintaining gardens and other modified landscapes).

2) Weeding **is essential** (although a good hardwood mulch can reduce the number of weeds & make weeding easier).

Fertilizing is not needed if you use plants adapted to the region & site. **Pruning is rarely needed** – though you will likely want to clip back perennials before spring (and transplant & water in seedlings and/or remove "aggressive" perennials if they begin to dominate).

Well designed and maintained rain-gardens infiltrate water within 24-hrs and do not breed biting mosquitos.

Rain-Garden Maintenance:

Key Ideas to Remember:

3) **Watering during the first growing season is vital** (try to strike a balance between providing too much & too little water). If you **choose plants well-adapted to your eco-region and specific site**, no watering should be needed once the plants are established.

4) Check for exposed soil and erosion and cover with an organic weed-free mulch. **If too much sediment is flowing into the garden find the source and stabilize the area**.

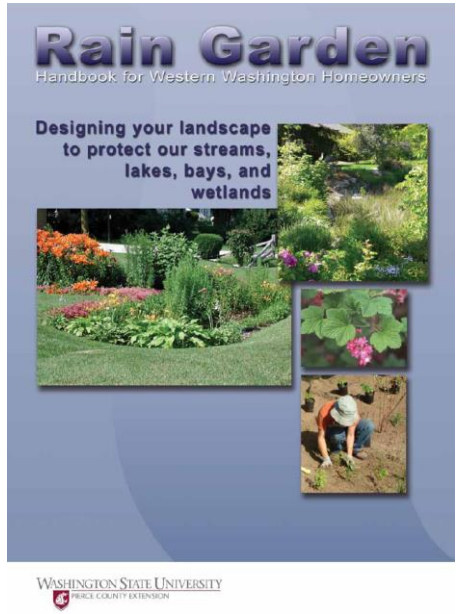
As needed, reduce volume and/or intensity of stormwater flowing into the garden.

5) **Draw upon the experience of others**, including folks on the east coast, mid-west, Rocky Mountains & west coast.

Ref: *http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm*

There are many great videos online, including at:

http://bluethumb.org/raingardens/



Manhattan (ISC & Sunset Zoo) rain-garden findings:

- **Aesthetic values influenced by knowledge and how one views the natural world, built environment & people**
- **Soils matter; need to fit plants to soils/soil moisture & sun-shade requirements**
- **Some irrigation is needed during dry periods to retain vegetative coverage and healthy plants during establishment but little to no irrigation is needed after establishment if appropriate plants are used**
- **Vegetative cover type matters in protecting soils and helping infiltrate and cleanse & cool stormwater**
- **A number of native Missouri plants can survive in our climate in part-shade conditions**
- **Most stormwater can be infiltrated into the heavy clay and loamy soils at the ISC and Sunset Zoo rain-gardens within 8-24 hours; the ISC Rain-Garden can typically capture a 1- to 2-inch rain event (depending…)**
- **Many pollinators and birds frequent the ISC and Sunset Zoo rain gardens**
- **Regular volunteer (and/or paid) work is vital to manage weeds & invasive species and improve aesthetics**
- **Hands-on management provides great opportunities for observation and learning**
- **Seed-head removal influences species dominance & composition**
- **Vegetative composition is dynamic (responding to drought periods and abundant rainfall)**
- **Frequent monitoring is vital to observe invasive species and woody plants to be removed while young, and to make corrections and repairs following very heavy rain events (if there is erosion & sedimentation)**
- **Clipping vegetation is needed to maintain a pleasing – not "too wild or weedy" look…**
- **As with the green roof projects, many, many people and organizations contributed. Thank you!!!**

Manhattan (Seaton & Memorial Stadium) green roof findings:

- **Perception of aesthetics influenced by knowledge, and how one views the natural world & built environment**
- **Substrate types matter; lighter (EMS-GR) soils dry out more quickly and have a wider range of moisture levels**
- **Roof slopes matter; steep sloped green roofs need more supplemental irrigation (typ. more than once a week)**
- **Some irrigation is needed during dry periods to retain vegetative coverage and healthy plants**
- **Vegetative cover matters in tempering heat loads & retaining moisture; plant survival/health is dynamic…**
- **Irrigation is needed to insure near-to-full surface coverage by living plants, but is not needed every day**
- **Too much irrigation is not helpful (from a water conservation perspective, and for some native plants)**
- **A number of native plants can survive in our climate; supplemental water & management are important**
- **EMS-GR plants look lush (due to abundant first-year irrigation), but contain lots of agricultural "weeds" +**
- **WMS-GR plants look less abundant (than the EMS-GR), but contains a strong matrix of native grasses**
- **Many pollinators and birds (incl. WMS meadowlark) frequent the Memorial Stadium & Seaton Hall green roofs**
- **Lack of contractor experience in the region influences implementation & establishment practices**
- **Specifications are not always followed and implementation requires active oversight/engagement/dialogue…**
- **Time will tell how lack of weed seed-head removal will influence species composition and veg. coverage…**
- **There are loads of volunteer plants to consider (and potentially clip or remove) in urban & former ag settings**
- **Many people are surprised at how well the plants are doing on the steep sloped MS-GRs**

Per Tom Jacobs (Mid-American Regional Council in Kansas City) the following stormwater management and sustainable design/development activities are notable in the KC Metro Area—which others can learn from.

1 - Kansas City Missouri Water Services Dept. is engaging more deeply on **green infrastructure solutions for their combined sewer program**. The Marlborough neighborhood has three parks retrofitted with **stormwater BMP tied to recreational facilities**. **~150 bio-retention cells & rain gardens in the road right-of-way** help catalyze neighborhood revitalization efforts.

2 - Many people are working to **restore (heal) vacant lots** in the urban core of Kansas City (Kansas & Missouri) with green infrastructure—including orchards, urban agriculture, rain gardens, and other amenities.

3 - The **Johnson County stormwater program** completed its strategic plan—to use a watershed-based approach for future planning & investment. There is a strong emphasis on water quality, asset management & flood risk reduction.

4 - Several nonprofits [including the Platte Land Trust] are involved in **ecosystem restoration** efforts which involve large numbers of volunteers, including urban forestry, invasive species removal in natural areas [like CSNA!!!], and wetland restoration at the Brush Creek & Blue River confluence.

5 - MARC is nearing the completion of a feasibility study to assess the potential of implementing an **integrated watershed management approach for the Blue River**. The study is integrating stormwater and waste/sewer water.

6 - MARC is working with Stacy Hutchinson & Kelsey McDonough (KSU-BAE) on a Federal Highways climate resilience grant. Kelsey is using ecosystem services & continuous hydrologic simulation models to assess the potential impacts of climate change on critical transportation infrastructure in the Blue River Watershed, and they are evaluating potential **green infrastructure-based mitigation strategies as proactive ways to plan ahead**.

Edited October 2018 email to Lee Skabelund

Minnesota Stormwater Manual

https://stormwater.pca.state.mn.us/index.php

People who use effective stormwater management practices on their properties can apply to receive reductions in their stormwater utility fee.
http://www.ci.minneapolis.mn.us/publicworks/stormwater/fee/index.htm

Minnesota Stormwater Manual – Infiltration BMPs

Infiltration Best Management Practices (BMPs) treat urban stormwater runoff as it flows through a filtering medium & into underlying soil, where it may eventually percolate into groundwater.

The filtering media is typically coarse-textured and may contain organic material, as in the case of bioinfiltration BMPs. These BMPs are sites ranging from small to relatively large. They are primarily designed for removal of stormwater runoff volume and pollutants in that runoff.

They are effective at removing total suspended solids (TSS), particulate phosphorus, metals, bacteria, nitrogen, and most organics. Soluble pollutants such as chloride and nitrate typically through these BMPs and into underlying groundwater.

https://stormwater.pca.state.mn.us/index.php?title=Stormwater_infiltration_Best_Management_Practices
https://stormwater.pca.state.mn.us/index.php?title=Stormwater_infiltration

Tributary to Wildcat Creek
(5/8/2007)

Wildcat Creek (5/8/2007)
at Waterbridge Road

Green roofs, rain-gardens, bio-retention areas, and other designed green infrastructure features have the potential to be vital parts of interconnected and regenerative community open space networks (see Rouse & Bunster-Ossa 2013 - *Green Infrastructure: A Landscape Approach*).

Too often, green infrastructure projects increase resource use by creating untenable conditions for selected vegetation (which dies or is out-competed by undesired plant species)—leading to the expectation that vegetation (or the entire system) be replaced.

Monitoring green infrastructure over the long-term is vital to improve design, implementation & management of green roofs, rain gardens, bio-retention areas, and other multifunctional systems that we can create healthy, resilient & biologically diverse urban areas.

Sustainable Green Infrastructure Implementation, Monitoring, Management, Outreach & Research

We seek to……
1) engage in-depth research opportunities on campus;
2) develop focused monitoring programs for assessment of landscape and ecosystem functions related to green infrastructure systems;
3) generate empirical data to demonstrate the benefits of green infrastructure sites;
4) strengthen institutional and community understanding of green infrastructure benefits—including their role in enhancing ecosystem services & restoring watersheds;
5) inspire, inform, and guide future implementation of landscapes on the campus *and* within the community and region.

Ultimately our work aims to cultivate and disseminate new knowledge about the performance, while offering faculty, students & community members an opportunity to become skilled in green infrastructure implementation *and* landscape monitoring, assessment & management.

Manhattan (Seaton & Memorial Stadium) green roof research:

Selected Initial (2016) Research Activities, Findings & Outcomes –

Spent approx. one month calibrating Decagon 5TM sensors and learning about data-logger operations – w/BAE fac/students
BAE collaborators (S. Hutchinson & T. Moore) determined that Decagon's pre-established calculations were adequate.

Weeded the MS-GRs for approx. 16 hrs (took LRS ~14 hrs to weed approx. two-thirds of the EMS-GR late May/early June 16')
Found numerous agricultural weeds and other volunteers (some choking out live plants and many beginning to dominate the roof in terms of above-ground biomass); encouraged contractor to week prior to setting of seeds and to selectively clip or weed to minimize impacts to native plants.

Placed 18 Decagon 5TM Soil Moisture & Temperature sensors on each green roof (3 high, 3 mid-level, 3 low) – LRS/DB
Placed a PYR Solar Radiation sensor adjacent to the two 5-port Decagon data-loggers on each green roof
Regularly reviewed and downloaded SM/T & PYR data and shared important trends with contractor and KSU staff.
On several occasions irrigation systems were shut off for a time to allow storm events to water the roof, and to allow for monitoring of the two roofs under natural weather conditions.

Completed plant ID along MS-GR 18 transects (4 high elevation; 4 low elevation) in late June 2016 – LRS/RP/EM + MM/KK
Found that Louisiana Sage (*Artemisia ludoviciana*) was the most common plant along the EMS-GR transects.
Found that blue, hairy and side-oats grama (*Bouteloua spp*.) were most common along WMS-GR transects.

Clipped all volunteer plants in 4 ~1-meter-square area (at high elevations, north & south on both MS green roofs) - LRS
Volunteers were dominant (in terms of total biomass and seed-head production) on the EMS-GR; natives on the WS-GRs.

Flew UAV with infrared and thermal cameras to document veg. coverage & active plant growth, and sensed temperatures.
Led by Deon ven der Merwe & Ajay Sharda, supported by Dale Bremer & Lee Skabelund (with student assistance)

22 July 2015

25 July 2016

During 2015 an influx of Marestail invaded the UGR and I decided that it should not be allowed to go to seed, so clipping was done during Aug & early Sep.
In late 2015 and early 2016 I added seed from local prairies and meadows, and in early April I added a broken branch to provide some shade and structure.

Marestail did not re-appear in 2016, but prostrate sandmat covered a good portion of the roof. I have not weeded the spurge.

KSU Green Roof Implementation & Monitoring

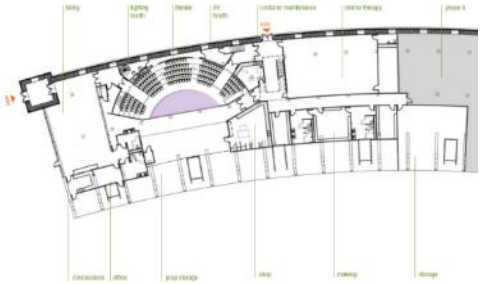
Lee R. Skabelund, Associate Professor of Landscape Architecture; Pam Blackmore, MLA Student;
Allyssa Decker, PhD Student; Priyasha Shrestha, MLA Student
College of Architecture, Planning & Design

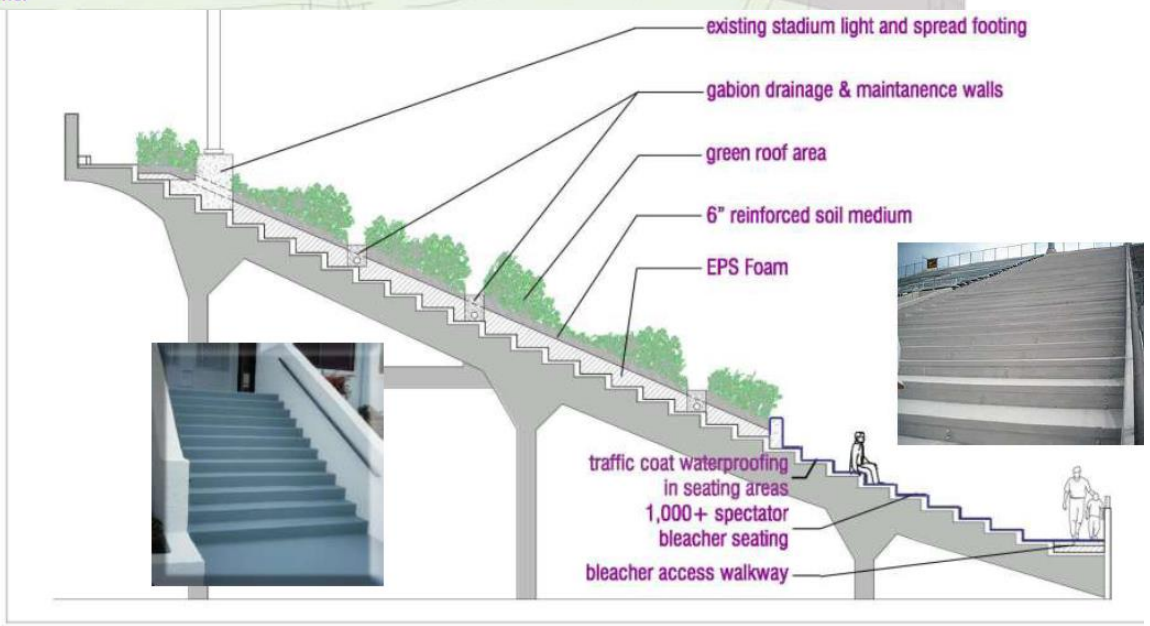
Collaborators & Affiliations:

1) Lee R. Skabelund, KSU-LARCP; 2) Deon van der Merwe, KSU-VetMed; 3) Stacy Hutchinson, Ajay Sharda & Trisha Moore, KSU-BAE, 4) Mary Knapp, KSU-Agronomy; 5) Dale Bremer, KSU-HORT; 6) Elizabeth Musoke & Allyssa Decker, KSU-EDP; 7) Ryan Peters, KSU-HORT; 8) Priyasha Shrestha, Pamela Blackmore & Kyle Koehler, KSU-LARCP; 9) Devon Bandad, KSU-BAE; 10) Mark Mayfield, KSU-BIOL; 11) Jeffrey L. Bruce, JBC.

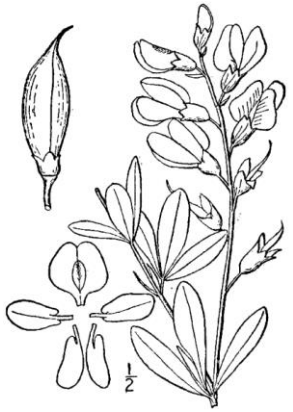
West Stadium Living Roof Concept
JBC, March 2012

Concept Plan

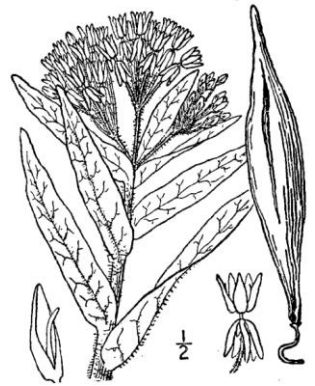




Section A



Baptisia australis



Asclepias tuberosa

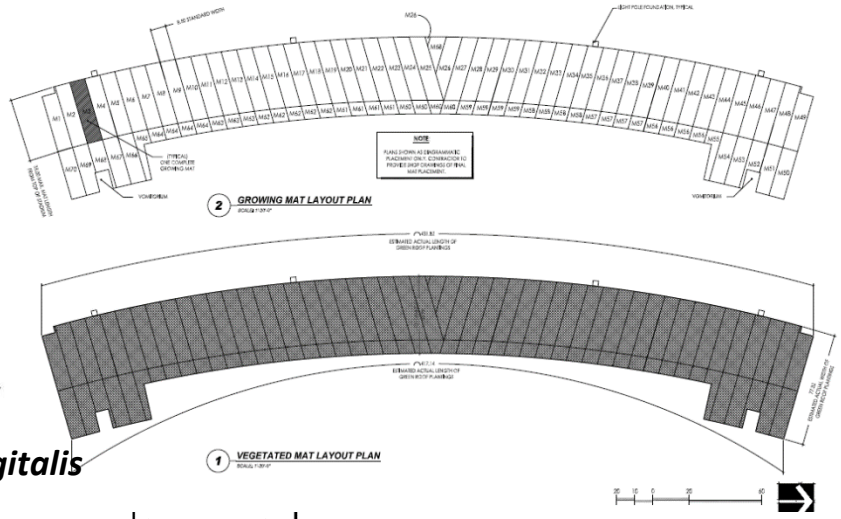
West Stadium Green Roof CDs
JBC, July 2013

Aster novae-angliae

Aster ericoides

Penstemon cobaea

Penstemon digitalis

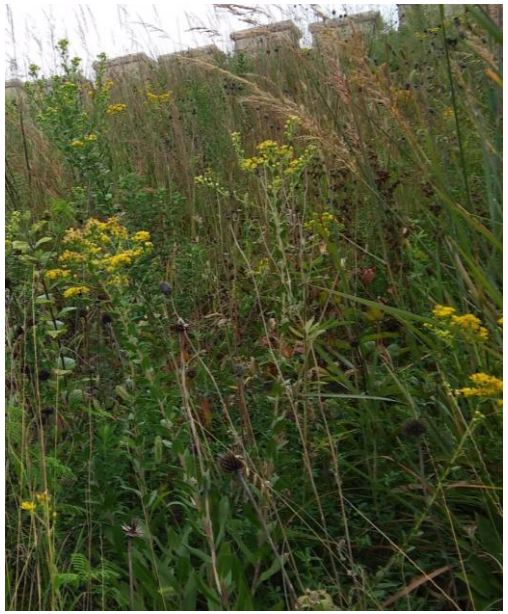


Solidago rigida

Monarda fistulosa

Sorghastrum nutans

Bouteloua curtipendula



Bouteloua gracilis

PLANT MATERIAL SCHEDULE

QUANTITY	KEY	BOTANICAL NAME	COMMON NAME	SIZE & REMARKS
BASE		PLUGS (PERENNIALS)		
873	MF	Monarda fistulosa	Bee Balm	12" O.C.
873	LA	Liatris aspera	Tall Blazing Star	12" O.C.
873	LP	Liatris pycnostachya	Tall Blazing Star	12" O.C.
873	SN	Aster novae-angliae	New England Aster	12" O.C.
873	EP	Echinacea pallida	Pale Purple Coneflower	12" O.C.
873	DP	Petalostemum purpureum 'Kaneb'	Purple Prairie Clover	12" O.C.
873	SP	Salvia pitcheri 'Nekan'	Pitcher Sage	12" O.C.
873	PG	Penstemon grandiflora	Large Beardstongue	12" O.C.
873	PD	Penstemon digitalis	Foxglove Beardtongue	12" O.C.
873	AT	Asclepias tubevosa	Butterfly Milkweed	12" O.C.
873	AM	Achillea millefolium	Common Yarrow	12" O.C.
BASE		PLUGS (GRASSES)		
4798	SC	Schizachyrium scoparium	Little Bluestem	12" O.C.
4798	SH	Sporobulous heterolepis	Prairie Drop Seed	12" O.C.
4798	SN	Sorghastrum nutans 'Osage'	Osage Indian Grass	12" O.C.
		SEED (PERENNIALS) RE: SPEC 329115 FOR SEED RATES		
	SL	Scutellaria leonardii (seed)	Small Skullcap	n/a
	RP	Ratibidia pinnata (seed)	Greyheaded Coneflower	n/a
	RC	Ratibida columnifera (seed)	Upright Coneflower	n/a
	CG	Carex glauca (seed)	Blue Sedge	n/a
	BA	Baptisia australis (seed)	Blue Wild Indigo	n/a
	AS	Allium stellatum (seed)	Autumn Onion	n/a
	CS	Camassia scilloides (seed)	Wild Hyacinth	n/a
	SS	Symphyoctrichum sericeum (seed)	Western Silver Aster	n/a
	TO	Tradescantia occidentalis (seed)	Prairie Spiderwort	n/a
	AE	Aster ericoides (seed)	Heath Aster	n/a
	AL	Artemisia ludoviciana (seed)	White Sagebrush	n/a
	SR	Solidago rigida (seed)	Stiff Goldenrod	n/a
		SEED (GRASSES) RE: SPEC 329115 FOR SEED RATES		
	BC	Bouteloua curtipendula (seed)	Side Oats Grama	n/a
	BG	Bouteloua gracilis (seed)	Blue Grama	n/a
	BH	Bouteloua hirusta (seed)	Hairy Grama	n/a

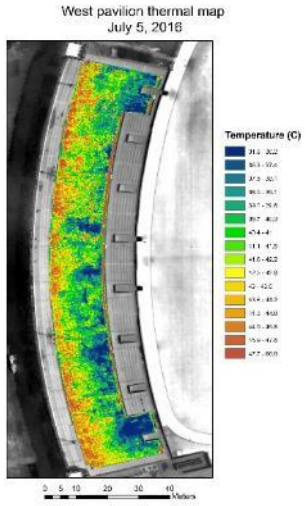
LANDSCAPE NOTES:

1. LANDSCAPE CONTRACTOR SHALL COMPLY WITH ALL PROVISIONS AND SECTIONS OF THE SPECIFICATIONS.
2. THE LANDSCAPE CONTRACTOR SHALL VERIFY CONTOURS AND SITE CONDITIONS BEFORE PROCEEDING WITH WORK.
3. CONTRACTOR IS RESPONSIBLE FOR VERIFYING QUANTITIES OF PLANT MATERIALS AND IMPROVEMENTS SHOWN.
4. THE LANDSCAPE CONTRACTOR SHALL COORDINATE WORK WITH ALL OTHER TRADES.
5. THE LANDSCAPE CONTRACTOR SHALL TAKE NECESSARY PRECAUTIONS TO PREVENT DAMAGE TO GREEN ROOF SYSTEM.
6. CONTRACTOR SHALL NOTIFY OWNER'S REP OF ANY DISCREPANCY WITH EXISTING CONDITIONS OF LANDSCAPE PLANS/DETAILS BEFORE INSTALLATION.

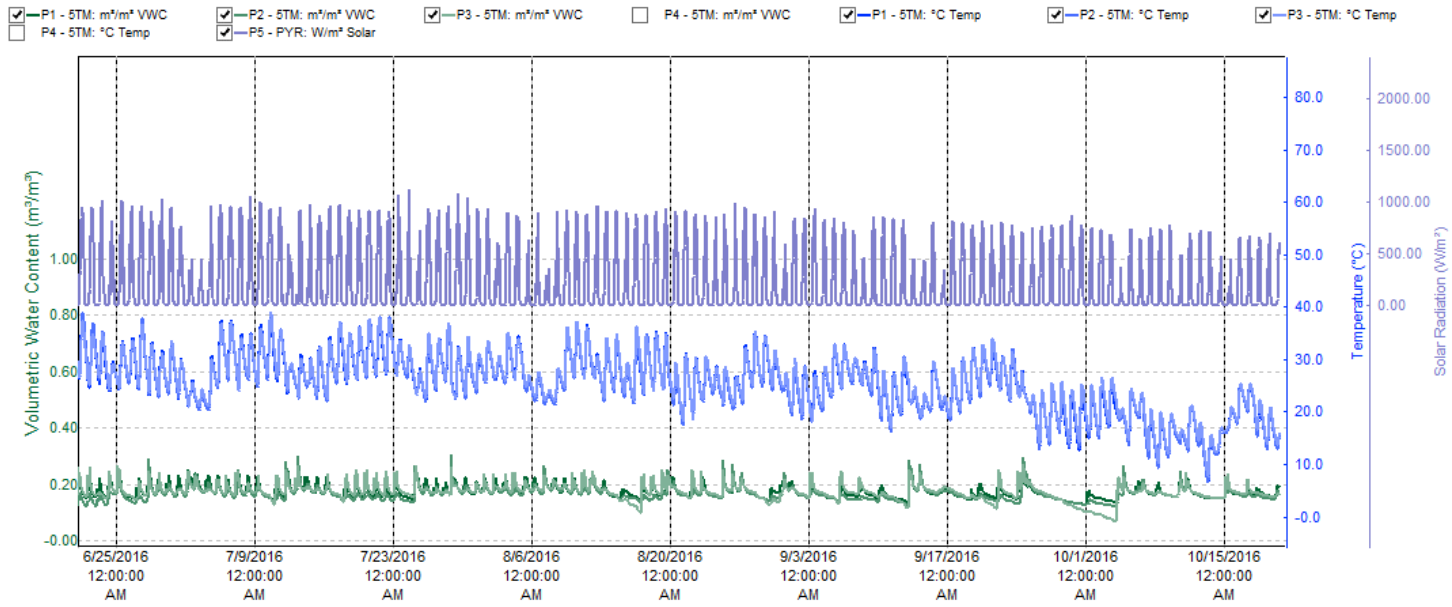
GENERAL NOTES:

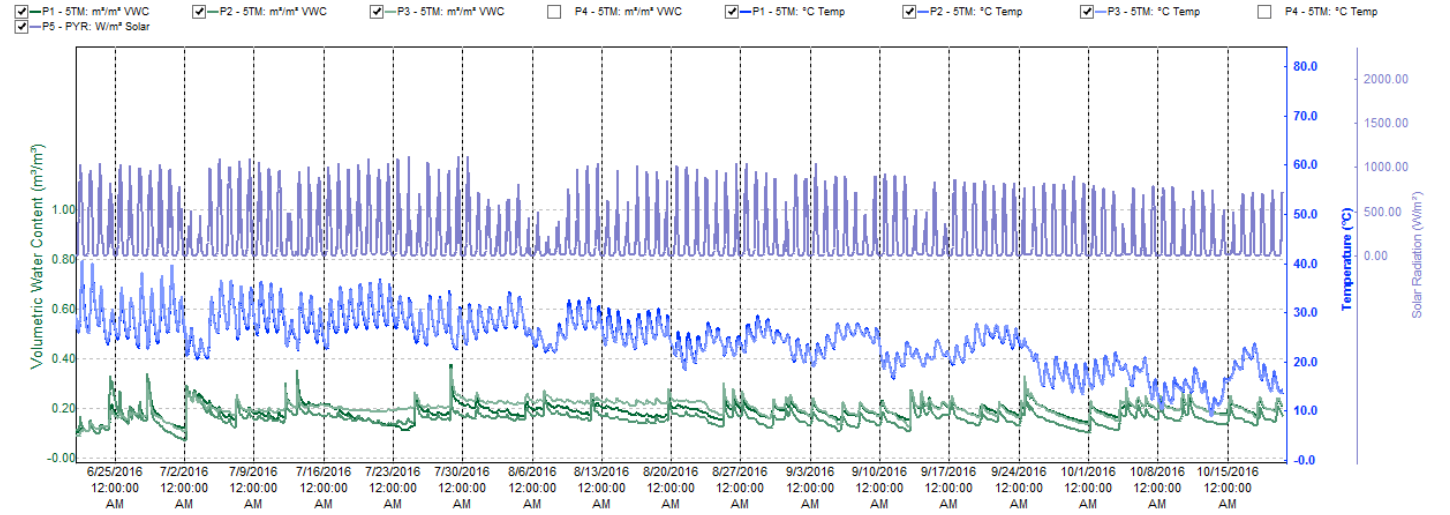
1. ALL SITE AND UTILITY INFORMATION SHOWN IS BASED UPON INFORMATION SUPPLIED TO THE LANDSCAPE ARCHITECT AT THE TIME OF DESIGN. VERIFY ALL SITE CONDITIONS, ELEVATIONS, UTILITY LOCATIONS AND DIMENSIONS SHOWN ON THE PLANS PRIOR TO COMMENCEMENT OF WORK. NOTIFY OWNER OF ANY DISCREPANCIES OR IRREGULAR CONDITIONS.
2. CONTRACTOR SHALL PROTECT ALL SITE IMPROVEMENTS AND UTILITIES. DAMAGE OCCURING DURING AND AS A RESULT OF CONSTRUCTION SHALL BE REPAIRED/REPLACED BY THE CONTRACTOR AT NO ADDITIONAL COST TO THE OWNER.
3. ALL WORK PERFORMED IN THIS CONTRACT SHALL COMPLY WITH THE CURRENT MANHATTAN, KANSAS STANDARDS FOR CONSTRUCTION AND SHALL COMPLY WITH ALL STANDARDS, LAWS, AND REGULATIONS SET FORTH BY CITY OF MANHATTAN AND THE STATE OF KANSAS.
4. ALL DIMENSIONS SHOWN ARE REPRESENTED USING U.S. SURVEY DIMENSION STANDARDS.

KSU Memorial Stadium Green Roofs Design & Implementation, Monitoring & Management



Solar radiation and sub-surface temperature & soil moisture readings on each MS-GR





KSU Memorial Stadium Green Roofs – 2016-2017 Vegetation Assessment along transects, the periphery, etc.

Roof	Time period	Graminoid	Forb/herb	Shrub/tree	Vine	Species Richness	Remarks
WMS-GR	June 2016-Aug 2017	13	48	9	0	70+	Approximate
EMS-GR	June 2016-Aug 2017	28	71	13	1	113+	Approximate

WMS-GR - 28 Jun 2016 – Lower Middle-South 100-foot Transect
30 Jun 2016 – Plant & Pollinator photos

EMS-GR - 30 Jun 2016 – Plant & Pollinator photos

Per June-September 2016 field work, total plant species counts on the WMS-GR: 7 grasses, 1 sedge, 32 forbs, 1 woody plant.

Per June-September 2016 field work, total plant species counts on the EMS-GR: 12 grasses, 1 sedge, 49 forbs, 3 woody plants.



EMS-GR – 11 & 14 July 2017



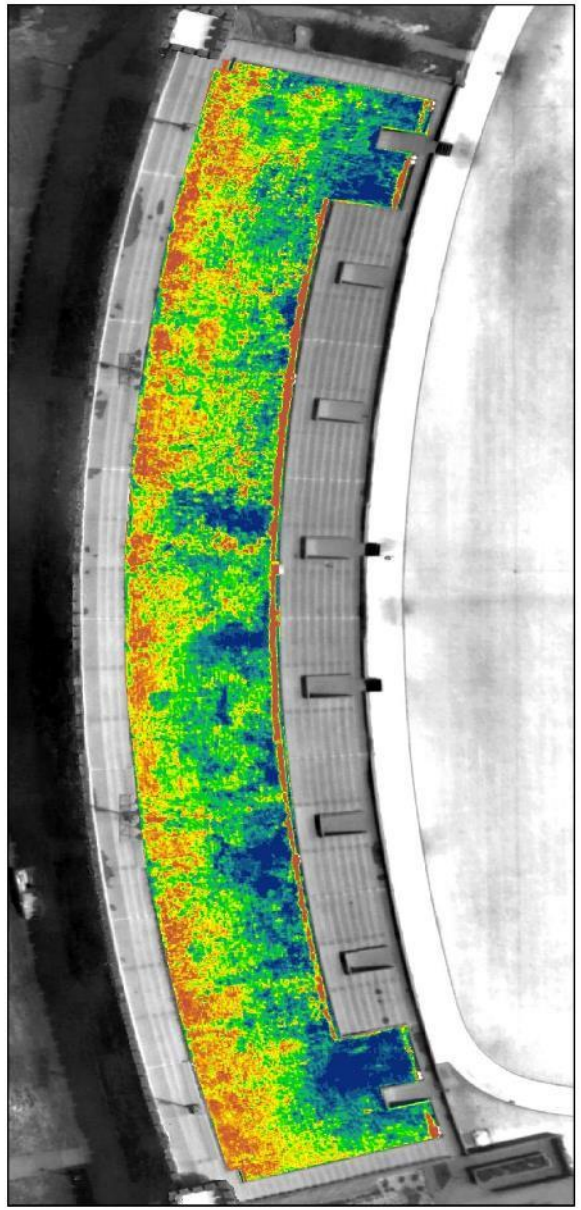
EMS-GR – 28 July 2017

EMS-GR – 21 August 2017


Over two months 18,000+ marestail (*Conyza canadensis*) pulled or clipped on EMS-GR.

As of 9/1/2017 ~10,000 remained.

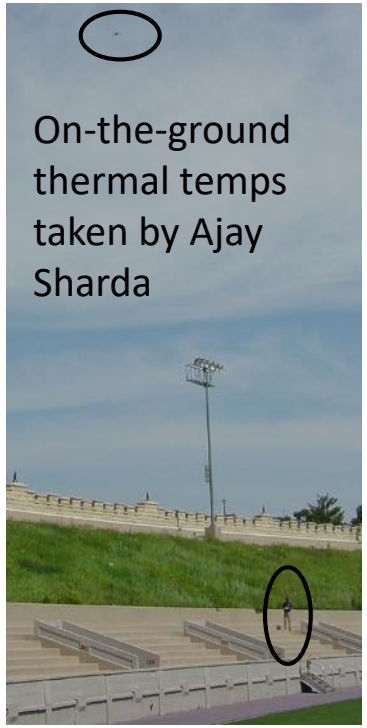
West pavilion thermal map
July 5, 2016



Imagery stitched together by Deon van der Merwe

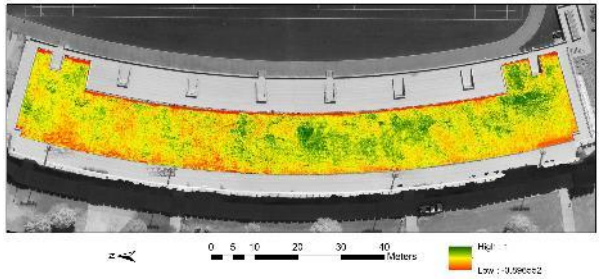
Temperature (C)

31.8 - 36.2
36.3 - 37.4
37.5 - 38.4
38.5 - 39.1
39.2 - 39.6
39.7 - 40.3
40.4 - 41
41.1 - 41.5
41.6 - 42.2
42.3 - 42.9
43 - 43.5
43.6 - 44.2
44.3 - 44.8
44.9 - 45.8
45.9 - 47.6
47.7 - 66.9

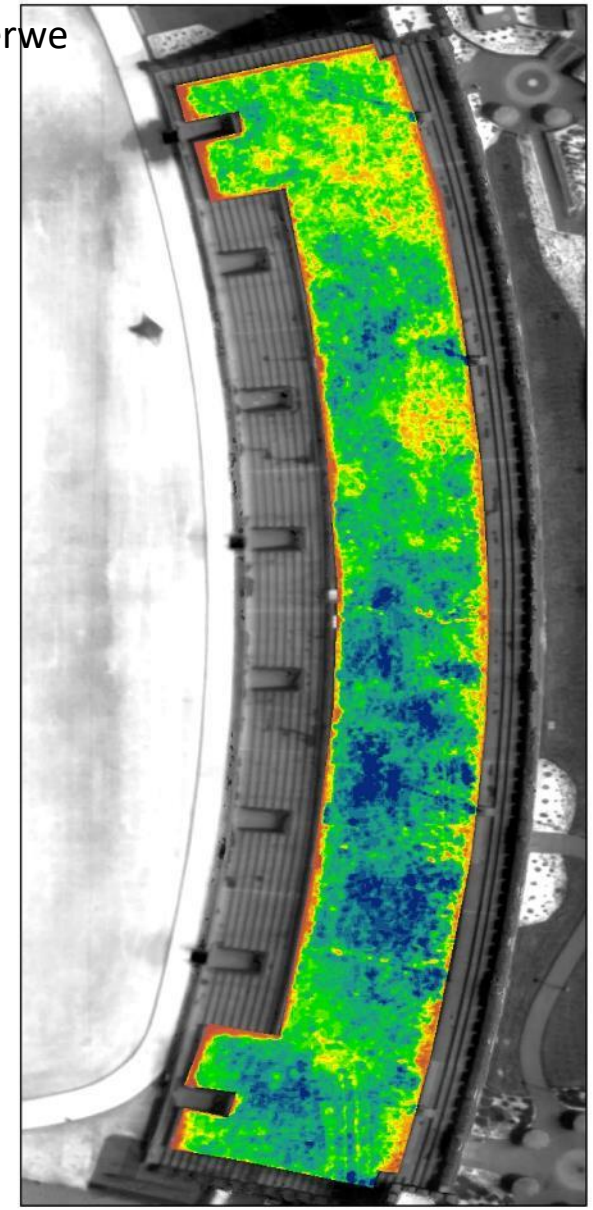


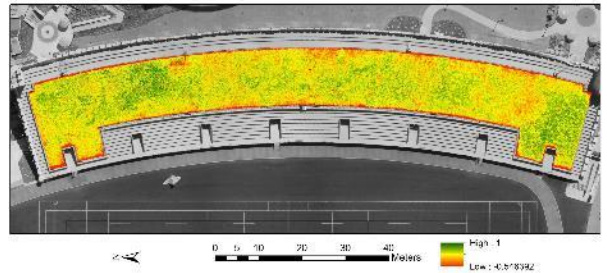
On-the-ground thermal temps taken by Ajay Sharda

WMS-GR BNDVI



East pavilion thermal map
July 5, 2016





Temperature (C)

25.2 - 26.5
26.6 - 26.9
27 - 27.2
27.3 - 27.6
27.7 - 27.9
28 - 28.3
28.4 - 28.6
28.7 - 29.1
29.2 - 29.4
29.5 - 29.8
29.9 - 30.1
30.2 - 30.8
30.9 - 31.5
31.6 - 32.5
32.6 - 35.1
35.2 - 61.7

EMS-GR BNDVI & Mosaic