A VISIBLE SOLUTION

Team Registration Number: D33

Institution: Purdue University West Lafayette

Design Team:

Chris Curnell - Landscape Architecture and Horticulture
Ethan Fleig - Landscape Architecture and Horticulture
Harland Nadeau - Landscape Architecture and Environmental Science
Jeffery Tseng - Landscape Architecture and Horticulture

Faculty Advisor:

Yiwei Huang, Ph.D., ASLA - Assistant Professor of Landscape Architecture

Facility Advisors:

Adam Keyster - Civil Engineer, Physical Facilities, Purdue Technology Center Aerospace
Camille Shoaf - Campus Planning and Sustainability, Purdue University
Marcus Smith – Civil Engineer, Physical Facilities, Purdue Technology Center Aerospace

Advising Team:

Aaron W. Tompson - Assistant Professor of Landscape Architecture
Kuang Xin - PLA and LEED AP ND at Design Workshop in Chicago
Nathan Frazee - Stormwater Management Expert and PLA at Boston Parks and Recreation
Paul C. Siciliano Jr. - Professor of Horticulture and Landscape Architecture
Sean M. Rotar - Associate Professor of Landscape Architecture, Program Chair

Abstract:

Resting on the banks of the Wabash River in West Lafayette, Indiana, Purdue University drains almost all its runoff into a highly engineered stormwater management system of pipes and lines. The Wabash is currently listed as an impaired waterway under the Clean Water Act and experiences roughly a dozen combined sewer overflows, or CSO(s), every year. These events cause havoc on the natural ecosystems that once thrived along the river's banks. Agriculture Mall sits on the southside of Purdue's campus and serves as a large un-programed and underutilized space, used primarily for students and faculty passing through during class breaks. Like many of the other malls on campus, Ag Mall is made up of about 56 percent completely impermeable surfaces like concrete and asphalt. Much of the runoff from Ag Mall's impermeable surfaces drains into the combined sewer, contributing to these CSO events. The underutilization of the mall and lack of proper stormwater management makes Ag Mall a prime site for redesigning and implementing green infrastructure (GI) technologies. This visible and interactive solution creates new spaces that not only better cater to pedestrian flow and education of sustainable stormwater management but will also support Purdue's goals in the 50-year master plan, set to take campus completely off the combined sewer system, eliminating its contribution to CSO events. *A Visible Solution's* design demonstrates a network of relevant green infrastructure technologies, showcasing the benefits of local sustainable stormwater treatment and allowing for education through interaction of the GI(s) and its ecological impact.

Regional Context:

The Midwest portion of the United States is known for being one of the largest agriculturally dense areas in the country. This is due to the deep rich soils, a nice, even climate for growing, and the lack of much topography change. In its current state, Indiana is nearly two-thirds covered by agriculture, with 74 of its 90 counties having a majority of their land covered by farmland (IBR). Indiana was not always primarily cropland, however, in the days of its statehood in 1816 Indiana had an estimated 22.4 million acres of woodland. By 1917 the state was down to less than 2 million acres of forests and it was predicted that Indiana would be completely bare of the natural woodlands by 1932. Preservation measures were installed, and the Indiana Forest Classification Act was enacted in 1921. Now Indiana has around 4.2 million acres of woodland, a mere 19 percent of the original woodlands that dominated Indiana's original landscape (Indiana Division of Forestry). The issue that arises from having large woodland areas and cropland in close proximity is that the runoff from the heavily cultivated farms starts to degrade the ecosystems and natural processes in those edge landscapes.

On a smaller scale, the Wabash River watershed, in which Purdue is located, has been, and continues to be, contaminated by large amounts of pollutants brought into the river system by stormwater runoff. A study by the Wabash River Enhancement Corporation published in 2011, reports levels of phosphorus, nitrogen, nitrate-nitrogen, and even E. coli that regularly exceed Indiana state standards. Pesticide monitoring that has taken place in multiple areas of the watershed have also reported unacceptable levels of chemicals, especially atrazine, reported at levels as high as 10 mg/L. Furthermore, tests conducted on the average suspended sediment concentration within the river in Lafayette reported an average of 714 tons of suspended sediment moving through the river each day. These factors, and many more, have caused a rapid and steady decline of the river's natural habitat. Species diversity in the river has also been on a steady decline due to increased pollution levels and severely reduced water clarity. More sensitive vulnerable species within the river have declined and given rise to common carp and freshwater drum fish species dominating the Wabash river outcompeting native species. Reports like this clearly demonstrate the dire need for green infrastructure and sustainable stormwater management strategies to increase the ecological health of the Wabash River and the surrounding communities of Lafayette, West Lafayette, and Purdue University.

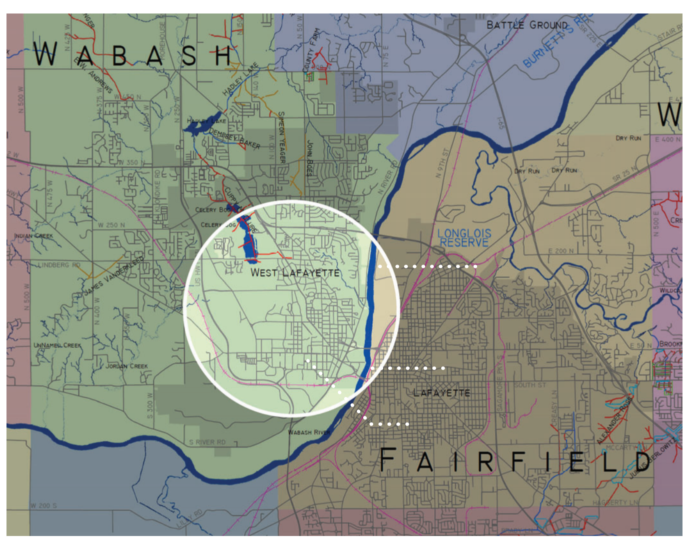

Figure 1: Watershed map showing the relationship between the Wabash watershed, Agriculture Mall, and the CSO outlet pipes that lead to pollutants from Agriculture Mall being dumped into the Wabash River after major storm events occur

Site Description:

Agriculture Mall is located on the southernmost end of campus less than a five minute walk from the heart of Purdue's main campus. Ag Mall faces many of the same stormwater management challenges inherent to any urban site. The site is unique in its stormwater divide between the combined sewer drains and the inlets that pipe a portion of the site's runoff to a retention pond just off campus. Conversations with campus master planners and civil engineers revealed Purdue's 50-year master plan, designed by Sasaki, includes plans to renovate Ag Mall and adjacent Marstellar Street to become fully pedestrian, as well as rebuilding the Forestry Building on site. This master plan would solve the traffic and pedestrian conflicts on the site but does not address the stormwater problem or lack of program in the space (Figure 3). This planned campus wide renovation creates a timely opportunity for our design intervention.

The mall's location, surrounded by both academic and residential buildings, makes this site a major bike and pedestrian route connecting south campus up to the north parts of Ross-Aid stadium. Situated less than a mile from the banks of the Wabash River, Ag Mall has the opportunity to use deliberate and thoughtful design to enhance pedestrian and cyclist experiences, while visibly dealing with the stormwater runoff in a collaborative and educational setting that shows how stormwater should and can be treated locally.

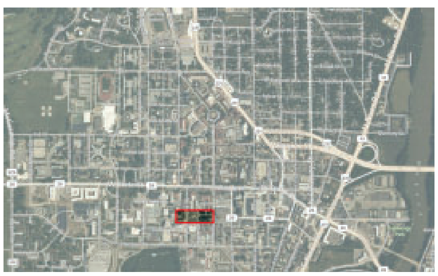

Figure 2: Satellite image showing Agriculture Mall, in relation to campus

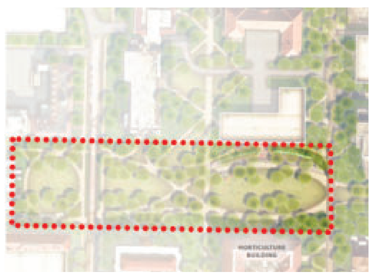

Figure 3: Rendering from Sasaki's 2009 Purdue Master Plan

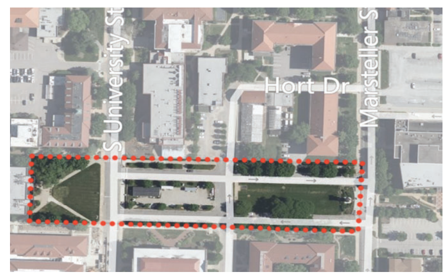

Figure 4: Satellite Image of Agriculture Mall's Existing Conditions

Site Inventory and Analysis:

Soils: Purdue's campus is situated on the Wabash floodplain and is composed of a mixture of minerals in the sand, silt, and clay soil fractions. The parent material of the site's soil is a loamy glacial till, moderately permeable but somewhat poorly drained with a seasonal high-water-table of 60–100 cm. This concludes that stormwater runoff can be expected to drain within 48 hours after a rain event. (sciencedirect) (IN gov. DNR)

Existing Vegetation: Currently, 80 trees exist on the site, many of which have been damaged by recent construction (n=20) along S. University Street and Agriculture Mall Drive. Most of the existing trees are not fully mature and range between 15 and 25 feet tall. The few mature trees on site include the eight Honey Locust (*Gleditsia triacanthos*) trees that are situated along Agriculture Mall Drive, in front of the Horticulture Building (n=10). These Honey Locusts are past their peak and are nearing the end of their lifespan in this harsh urban environment. The dominant tree species throughout the site are the Red Maple (*Acer rubrum*) (n=20) and White Oak (*Quercus alba*) (n=20), although there are several evergreen species such as White Pine, Norway Spruce and others that are present on site as well. While these trees should be taken into consideration, it is important to note that none of the trees on site are particularly worth keeping, as many have damaged root systems or are well past their peak.

Water Flow and Drainage: Water draining to the northeast portion of the site is directed into drain inlets that contribute to the combined sewer, meaning that the four drains on that side of the site contribute to roughly a dozen CSO events into the Wabash River every year. The remaining ten drain inlets on the site direct water to Harrison Pond, Purdue's retention pond that is situated just south of campus. The current conditions of the site's drainage are engineered to immediately concentrate all the stormwater runoff from the sidewalks and streets including: S. University Street, Agriculture Mall Drive, Marstellar Street, and all adjacent building roofs. Once concentrated, the water is piped underground to either the Wabash River or Harrison Pond. This highly engineered system allows for zero minutes of visible water treatment and interaction.

Pedestrian and Vehicular Circulation: Agriculture Mall's existing conditions offer many conflicts and areas of injury concern between walkers, cyclists, and vehicles . S. University Street is a main route for busses and other traffic turning off from State Street. Agriculture Mall Drive, the street that cuts directly through the site, is the main concern of Ag Mall. The way in which cars parallel park along Agriculture Mall Drive obstructs the view of oncoming traffic from pedestrians. To make matters worse, there is no dedicated bike lane on the site. This creates many challenges for the mall's visitors, requiring that they keep an eye out for oncoming vehicles, bikes, joggers, or fellow visitors at all times.

Strengths: Some of the only strengths Agriculture Mall offers are in its location on campus. The site is surrounded by educational and research buildings, as well as apartments for student living. The open lawn panel in the center of the current site provides a space for the College of Agriculture Olympic games annual hog roast. This lawn also serves as an informal recreation space for students living in the nearby apartments to use as a community backyard space. It is a prime location for students to play with their pets, throw a frisbee, or enjoy a game of Spikeball with friends (Figures 5 and 6). The proximity of this site to Purdue's vet school means that there are frequent dog walkers that pass through the space daily. Pedestrian flow on the site is optimized for efficiency, allowing students and faculty to easily move through the site to and from classes.

Figures 5 and 6: Photos of Agriculture Mall's Existing Lawn Pannel

Weaknesses: The existing site conditions present both a number of problems, as well as a number of opportunities for great improvement. The problems lie in the way stormwater is handled, as well as major issues with the overall current design of Agriculture Mall. These stormwater challenges can be described in three key terms: invisibility, underutilization, and lack of identity. The existing conditions of Ag Mall, as far as green infrastructure goes, is miniscule. The only examples being some poorly maintained pervious pavers in front of a couple of the buildings and one system of rills and swales around the Horticulture Building which lead to a small, insignificant rain garden. Other than those meager green systems, the 7.8-acre site is filled with three core materials: impervious hardscapes, lawn panels, and small areas of planted vegetation constricted to the areas immediately around some buildings.

Engineered Invisibility: The current stormwater management system that Purdue uses is a massive network of pipes that directs stormwater immediately into drain inlets, leaving the water to be dealt with out of sight (Figure 7). Much of Agriculture Mall contributes to this network of underground pipes. The mall, along with much of Purdue's campus, is almost completely devoid of any visual or physical acknowledgement of the nearly 40 inches of average annual precipitation in northern Indiana (EPA). The only interactions a visitor may have with stormwater management are the unsightly drain inlets, piping much of the mall's contaminated and largely untreated water into the Wabash River.

Figure 7: Photo of an Agriculture Mall drain inlet that leads to the combined sewer system

Underutilization: Agriculture Mall is an area of Purdue's campus that is severely underutilized. The overall design of the mall creates many pedestrian conflict points, especially with the vehicles largely dominating the site. This negative effect the vehicles have on the site is compounded by street side parking. It creates a site that reads as a network of roads, dividing the site into two island lawn panels that feel dead, uninviting, and unprogramed. The design of the current site caters heavily toward the convenience of vehicular travel, making Agriculture Mall extremely unattractive to any user or passer-by. The mall also feels disconnected from the greater campus due to its placement on the far south side of campus. The mall's lack of visual attractiveness, coupled with its lack of programed spaces or supporting elements create a space that is void of students or faculty to populate the site to draw people in and make them want to stay.

Figures 8 and 9: Photos of open, underutilized spaces in Agriculture Mall

Lack of Identity: Agriculture Mall's weaknesses provided *A Visible Solution* with a blank slate in which to design a space that transforms Ag Mall into a campus open space that connects the south side of Purdue's campus to the other existing beloved outdoor malls and gathering spaces on campus. Whether hammocking in the cool mist of Engineering Fountain during the warmer months (Figure 10), or studying in the outdoor plaza in front of Purdue's Wilmeth Active Learning Center (Figure 11), Purdue has a number of large outdoor spaces that have been given an identity on campus. Using these existing spaces on campus as inspiration we set out to design a site that has a unique identity and provides beautiful gathering areas in the previously barren mall. *A Visible Solution* brings people closer to a sustainable stormwater management system and educates the visitors on the importance of local water treatment through green infrastructures.

Figure 10: Image shows existing opportunities for hammocking on Purdue's campus (Purdue University Website)

Figure 11: Photo of WALC's outdoor seating and studying opportunities with a cafe area inside (Purdue University Website)

Inspiration and Idea Evolvement:

Our design was influenced by the transition that has been so dramatic in much of Indiana. The state has transitioned from a land that grew primarily old growth deciduous forests, to a land that has been almost entirely dedicated to large scale production agriculture. Five of the state's counties have more than 90% of their land area in crop fields. Nearly two-thirds of Indiana 23 million acres is farmland (Indiana Division of Forestry). We thought it was critical to design Agriculture Mall to acknowledge what the state has become, while also harkening back to how this land was used historically.

Within our design, there is a stark contrast between the rigid geometries that make up the plaza spaces within the mall. These plazas are formed by rectangular geometries, reinforced by rectangular planters and thin lawn panels. These spaces are designed to represent the long linear rows of corn and soybean fields that sprawl across much of the state. These plaza spaces therefore represent what the landscape within Indiana has become.

The main pedestrian pathway that cuts through the mall in a curved diagonal serves as the dividing line, drawing the boundary between the modern agricultural Indiana landscape and the historical natural forest landscape. The rain gardens within the mall were designed to show the historic Indiana landscape with prairies, wetlands, and dense forest. The curvilinear forms that make up the rain gardens' boundaries and paths within the mall, minimic forms that can be found in nature. Visitors are meant to interact with both design languages within the site and become better educated on how they juxtapose each other. More importantly, visitors will be educated on how both disparate landscapes can and should coexist with one another (Figure 12).

Figure 12: These are some early studies to develop a form and concept for the Agriculture Mall design

Community Engagement:

"The viewpoints of stormwater have changed a lot over the last 100 years, through an evolution we reach to modern day where there is much more a green infrastructure approach."
- Adam Keyster, Lead Purdue Civil Engineer

"Peel back the infrastructure, show people how water flows downhill, anything that you can do to turn it into a living laboratory. Reach into some of these other surrounding programs and pull some learning exhibits into the space."
- Aaron W. Tompson, Assistant Professor of Landscape Architecture

Community engagement is an important piece of the development and overall implementation of the proposed design. Our team found it very valuable to reach out to students and faculty within the College of Agriculture and beyond that regularly use the space, asking for their input. The idea of an outdoor living lab, designed with the intent of education and beautification of the mall was the resounding comment from both groups. Our team reached out in the early stages of our conceptual design process, to ensure we incorporated their ideas into our final design.

This project is designed to celebrate and utilize the many benefits of stormwater treatment through green infrastructure. The academic setting manifests itself into a project goal of turning Agricultural Mall into a living laboratory for the diversity of academic programs within the College of Agriculture. We envision this redesign as a space for Purdue students and researchers. In addition, the design will engage community members from the surrounding Lafayette and West Lafayette towns with the mall's green infrastructure and become better informed about the health of local ecology and the importance of treating stormwater with green infrastructure intervention locally.

Students from Purdue's Urban Forestry program can conduct performance monitoring and testing of tree species on the site. Horticulture and Landscape Architecture students could perform vital water quality testing of the green infrastructure design and aid in the maintenance process, crucial to the long-term health of each technology, which is often overlooked and under budgeted. Yearly plant and wildlife surveys can be conducted by Purdue's biology and environmental science students, monitoring the health of the plants and studying the importance of these habitat benefits in an urban setting. Researchers from the Turf Management program will have the opportunity to study the effectiveness of different kinds of turf and turf substrate on water quality and drainage in the linear planter, like those in the plaza. Photo monitoring signage can be set up with QR codes linked to a social media account. Students, researchers, and community members would easily be able to track the progression of the site and its general health from season to season or over years. The installation of educational signage, with the addition of QR code animation, will inform visitors from the larger community about the benefits provided by the site's green infrastructure technologies, even when the site is dry.

Design Goals:

This elegant design for Agriculture Mall combines the importance of showing users the impact stormwater treatment can have on the ecology and how that same green infrastructure can serve as a treatment buffer for Indiana's harsh agricultural runoff. The space that Ag Mall fills now is perfect to create a unique character for the agricultural part of campus that fills up most of the southern campus. The identity we designed is one that deviates away from the highly engineered water system and instead spotlights the stormwater flowing through the site and how it can be treated. The mall will be utilized as a learning experience by using the green infrastructure to show how the treatment of the monoculture's runoff can lead to a cleaner, more natural solution by treating water locally with green technologies. The large paths and plaza spaces create a clear flow for pedestrians, bikers, and maintenance vehicles, while still allowing the users to feel immersed in the site. By focusing all the water onto the site during a storm event, we limit the amount of water that goes to the combined sewer system, leading to less overflow occurrences and improving the water quality locally as well.

Spotlighting the Stormwater: Carrying water from the two main transportation ways, University and Marsteller Streets, the system of rills and swales directs all of the roads' runoff onto the site to be treated. The detention pond serves as a permanent water feature, drawing people in, as well as providing a large-scale retention area for overflow stormwater. A system of rain gardens and basins take water from all other parts of the site,using dense plantings to treat and recharge the water table.
Creating Identity Through Program: *A Visible Solution* provides spaces for people to relax and enjoy the natural and open outdoor spaces created while accommodating the newly built cafés with outdoor seating opportunities as well. Separating the main pedestrian and bike paths from the more secluded paths allows for heavy pedestrian traffic to flow without conflicting with those in more secluded spaces. By creating a permanent water feature in the mall, the design allows for an enjoyable microclimate and connects Agriculture Mall with the other landmarks of Purdue's campus, specifically the existing water features and fountains. Easily accessible green infrastructure technologies give opportunity for living laboratories and other learning spaces, to educate the public and students on the importance and construction of technologies like bioswales and rain gardens. The designed open green spaces are meant to serve the existing demographic that uses the lawn to gather, play, and relax. The eastern-most lawn serves as a large detention basin that can hold excess water from the forested infrastructures during particularly heavy rain events.

Design Solution:

The primary goal in populating Agricultural Mall with so much green infrastructure was to eliminate the stormwater runoff that flows into the combined sewer. The technologies also daylight stormwater to create a visual and interactive outdoor laboratory, while also reducing runoff pollutants that flow from Ag Mall into the Wabash River. The system of green infrastructure technologies work together to collect stormwater runoff, bring it onto the site, and treat it with green processes. This yields a design that maximizes a variety of ecosystem services, including improved habitats for birds, and pollinators; increased native plant biodiversity and carbon sequestration; reduced energy usage and air pollution; while expanding the opportunities for outdoor recreation and education. All of this provides the mall with an identity that it so desperately needs to secure its title as one of Purdue's many great outdoor plazas and recreation areas. This project incorporates a variety of green infrastructure interventions including: green roof, rain garden, detention basin, bioswales, curb cuts and permeable pavement. Each element of the design was intentionally selected and used to manage stormwater, as well as providing learning opportunities for students and the surrounding community. The mall allows for the public to engage with a diversity of stormwater management technologies and gain an appreciation for the variety of benefits that these natural systems can provide when designed with alternative and sustainable stormwater management as the focus.

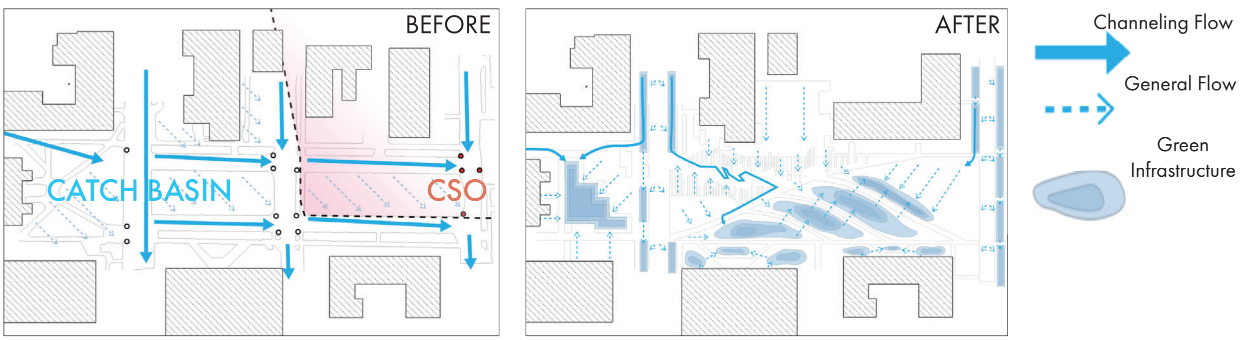

Figure 13: Diagrams show the before and after flow maps for stormwater runoff for the greater Agriculture Mall area

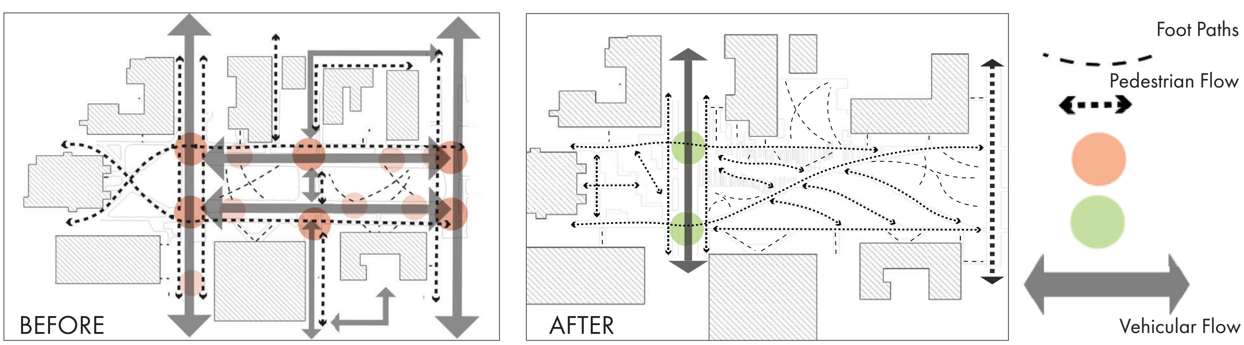

Figure 14: Diagrams show the before and after flow maps for pedestrican and vehicular traffic for the greater Agriculture Mall area

Green Infrastructure and Green Design Solutions:

Canopy Plantings: Trees provide a multitude of benefits including precipitation interception, carbon sequestration, air pollution reduction, and energy savings. Shaded spaces within our design are crucial for continued use of the site on hot summer days. Large canopy trees, noted in our plant palette table, help create a microclimate, decreasing the heat island effect on campus.

Green Roof: As per Purdue's 50-year master plan (Purdue University Website, 2020), the forestry building will be completely redesigned as LEED certified. As a part of this rebuild, the building will incorporate a green roof capable of reducing runoff from the building to near zero.

Lawn Space/Detention Basins: Some of the largest open spaces of the newly designed Agriculture Mall are the two lawn features that each serve different purposes in both green infrastructure and in the program they serve. The largest lawn area in the design serves as both a green infrastructure stormwater management facility and an open recreation area. This space is designed to accommodate larger gatherings and informal recreation. This new lawn space also doubles as an overflow detention basin, capable of holding a ten year storm event.

Permeable Paving/Curb Cuts: By replacing the current impervious asphalt with permeable pavers, the water will be able to slowly infiltrate into the ground or transition into one of the swales on either side of the roadway during a larger storm event. Curb cuts along S. University Street will allow for storm water to drain into bioswales on the roadside, directing the runoff into Ag Mall.

Permeable Walkways/Plazas: Areas of intense use from heavy vehicular traffic such as S. University Street will remain impervious asphalt. However, plaza spaces and walking paths within our design will utilize permeable paving systems to further decrease runoff, lowering the total impervious surface area by 43 percent (ESRL and NCDC).

Retention Pond: The retention pond is located outside of Hansen Life Sciences Building on the western most part of Ag Mall. During a storm event, all the stormwater runoff west of S. University Street flows into the pond, raising the water level up into the wet rooted vegetation where it is treated and allowed to infiltrate the ground until the pond returns to pre-storm levels. This focal point acts as a connection to Purdue's popular water features such as the Engineering and Loeb Fountains.

Swales: The swale system that our design employs is the first step in daylighting the process of stormwater runoff treatment. Students and other visitors are able to see the journey the stormwater takes before infiltration. Swales on either side of the vehicular and pedestrian streets, S. University and Marstellar Streets respectively, designed with a 2 percent grade, concentrate and direct runoff that then flows through a system of bioswales into Ag Mall where it is held and treated before infiltration.

Terraced Floodable Garden: The terraced floodable gardens are some of the most important pieces of the green infrastructure technologies in our design. With the average depth of the terraced rain gardens being around 12 inches and a total volume of 51,415 cubic feet of floodable gardens, these large gardens serve as major stormwater detention and treatment areas. These gardens were designed to capture 100 percent of 1 inch of stormwater runoff from the entire site and could catch 196,690 gallons (ESRL and NCDC). The immersive design allows for students and other visitors to be surrounded by natural processes and become better educated on the importance of sustainable design in every aspect of their lives. Each garden terrace is designed to fill up and spill over into the next terrace through an interactive walkway weir system. This demonstrates how natural systems can be beautifully mimicked in design to create functional, interactive, and aesthetically pleasing spaces that support a rich teachable setting for all disciplines of study in the College of Agriculture and beyond. The elevation change between each of the four garden terraces educate the visitors on the level of storm events based on how many of the terraces were utilized during and after a storm event, for up to 48 hours. The highest garden terrace is designed for the smallest rain event and is the first to fill. The lowest garden, nearest to Marstellar Street, is the last terrace to be filled. Elevation changes between each terraced garden are further reinforced by a change in both intensity and type of vegetation. Each garden terrace increases in density of vegetation from solely grasses and perennials in the highest terrace, designed to minimic Indians native primary style wetlands, to a dense forest planting within the lowest terrace, mimicking Indiana's native deciduous forests. These rain gardens will also serve as a key piece in the overall design aesthetic to show the contrast and connection between Indiana's woodlands and its intense production of agricultural land.

Proposed Plant Palette:

	Common Name	Latin Name	Native/Non-Native	Rain Garden Zone
Trees	River Birch	*Betula nigra*	Native	Zone 1 (Wet Zone)
	American Sweetgum	*Liquidambar styraciflua*	Non-Native	Zone 2 (Middle Zone)
	Shadblow Serviceberry	*Amelanchier canadensis*	Native	Zone 2 (Middle Zone)
	Pin Oak	*Quercus palustris*	Native	General Use (Any Zone)
Shrubs	Elderberry	*Sambucus canadensis*	Native	Zone 1 (Wet Zone)
	Inkberry	*Ilex glabra*	Native	Zone 2 (Middle Zone)
	Redosier Dogwood	*Cornus sericea*	Non-Native	Zone 2 (Middle Zone)
	Oakleaf Hydrangea	*Hydrangea quercifolia*	Non-Native	Zone 3 (Transition Zone)
Perennials/ Grasses	Swamp Milkweed	*Asclepias incarnata*	Non-Native	Zone 1 (Wet Zone)
	Tussock Sedge	*Carex stricta*	Non-Native	Zone 1 (Wet Zone)
	Boltonia	*Boltonia asteroides*	Non-Native	Zone 2 (Middle Zone)
	Purple Coneflower	*Echinacea purpurea*	Native	Zone 3 (Transition Zone)

Figure 15: Proposed native plant selection curated with reference to the Indiana Wildlife Federation

Design Preformance:

The required volume capture from 1 inch of runoff from the entire site's area is **28,216 cubic feet**. This 1 inch rainfall depth is often used to calculate the recommended sizing of green infrastructure technologies to treat around 90 percent of all rainfall runoff that occurs during a year of average precipitation. In the case of *A Visible Solution*, the green infrastructure used allows for **58,397 cubic feet** of runoff capture. This means that at maximum performance, *A Visible Solution* can capture and treat **100 percent of 2.07 inches of runoff** before it has to start draining off-site to the Harrison Pond detention infrastructure, where it is treated naturally. Along with the amount of water the site can capture, the amount of runoff from the site has been reduced with a **43 percent decrease** in the total impervious surfaces area. The amount that each of the green infrastructure technologies can seize and treat is shown in the table below (Figure 16).

Types of Green Infrastructure	Volume (cubic feet)
New Green Roof for Forestry Building	1,647
Tree Boxes Filter	448
Terraced Floodable Rain Gardens	51,415
Roadside Swales	2,220
Permeable Pavement on Plaza and Sidewalks	2,667

Figure 16: This table shows the relationship between the types of green infrastructure technologies and the amount of water they can capture and treat (ESRL and NCDC)

Maintenance:

*Maintenance of all aspects of design will be performed by Purdue Grounds Department, supplemented by Purdue Arboretum staff and volunteers, as well as by students in the Horticulture and Landscape Architecture programs. In order to optimize the operation and maintenance planning for *A Visible Solution's* design, a schedule was made to map out the times for needed maintenance (Figure 17).

	Activity	Schedule
Vegetation	Weed/Pest Control, Dead Headings	Monthly
	Plant Replacement, Tree Pruning, Shrub Pruning	As Needed
Irrigation	Emitter Head Adjustments	Monthly
	Leak Tests	Semi-Annual
	Tree Emitter Adjustments	Yearly
Grounds	Debris Removal	Monthly
	Fine Grade Adjustments (ensure proper deainage), Sediment Removal	As-Needed (After Storms)
Permeable Paving	Sediment Removal, Preformance Test, Durability Test	Semi-Annual

Figure 17: This diagram shows the maintenance schedule from the inital construction of *A Visible Solution's* design, deturmining whether it should be managed monthly, yearly, semi-annually, or as-needed in some cases

Cost Estimates and Calculations:

Construction Costs: The estimated construction cost of *A Visible Solution*, calculated and researched extensively from numerous different sources, is **$1,267,841**. This breaks down to approximately **$3.98 per square foot** of designed installations, the specific cost analysis breakdown of each feature can be seen in the table below (Figure 18).

Item	Qty.	Unit	Unit Cost ($)	Total ($)
Site Prep and Tree Protection				
Mowing and Cleaning	318,215	sq.ft.	0.005	1,591
Subtotal				**1,591**
Grading				
Fine Grading and Soil Preparation	261,485	sq.ft.	0.05	13,074
Rough Grading	1,618	cu.yd.	7.00	11,326
Subtotal				**24,400**
Furnishing				
Tables and Chair Sets	12	ea.	3,000	36,000
Benches	6	ea.	1,500	9,000
Trash and Recycling Receptacles	8	ea.	1,250	10,000
Subtotal				**55,000**
Green Infrastructure Components				
Permeable Pavement - Porous Concrete	20,393	sq.ft.	6.00	122,358
Terraced Rain Gardens	43,709	sq.ft.	16.00	699,344
Vegetated Area/Meadow	63,543	sq.ft.	0.13	8,261
Lawn	9,631	sq.ft.	0.21	2,023
Water Retention Basin	30,408	cu.ft.	0.60	18,245
Planter Boxes	4,552	sq.ft.	8.00	36,416
Concrete Trail - 5′	22,593	sq.ft.	6.50	146,855
Subtotal				**1,033,502**
Planting				
Structural trees - 100 gal.	4	ea.	950.00	3,800
Structural Trees - 65 gal.	6	ea.	600.00	3,600
Structural trees - 30 gal.	24	ea.	275.00	6,600
Bottomland trees - 15 gal.	16	ea.	175.00	2,800
Shrubs	16	ea.	120.00	1,920
Mixed soil for shrubs, GC, and annuals	32	cu.yd.	55.00	1,760
Ornamental Grasses (24″ O.C.)	64	ea.	8.50	544
Annuals	32	ea.	2.50	80

Item	Qty.	Unit	Unit Cost ($)	Total ($)
Bottomland seed mix	31,900	sq.ft.	0.10	3,190
Wetland Mix @ aquatic shelf	10,136	sq.ft.	1.15	11,656
Sod strip	1,200	sq.ft.	0.45	540
Hydroseeded bermuda grass	32,000	sq.ft.	0.05	1,600
Subtotal				**38,090**
Total				**1,152,583**
General Conditios, Bonds, etc.				**115,258**
Grand Total				**1,267,841**
Cost Per sq. ft.				**3.98**

Figure 18: This table details the costs of each component that went into making *A Visible Solution* by calculating the quantity, unit, unit cost, and total cost together to get the grand total and cost per sq. ft. of the site's construction (ESRL and NCDC)

Maintenance Costs: The maintenance costs that were calculated alongside the construction costs come out to about **$30,583** annually. This value was gathered from the Earth System Research Laboratory and the National Climatic Data Center and can be broken down into individual elements as seen in the table below (Figure 19).

Item	Annual Maintenance Cost ($)
Curbs and Gutters	174
Green Roof	494
Permeable Pavement	1,900
Lawn	9,257
Native Plants	7,714
Trees	400
Roadside Swales	144
Retention Pond	1,800
Terraced Rain Gardens	8,700
Total	**30,583**

Figure 19: Table shows the breakdown of some of the site pieces and green infrastructures that need funding to be maintained

Project Values and Benefits:

Reduced Air Pollution: The annual cost benefits gathered from the amount of air pollutants reduced is **$4** and the life cycle cost benefit amounts to **$115** (ESRL and NCDC). A study from Million Trees NYC showed that just one tree can remove up to **26 pounds of carbon** from the atmosphere each year. With the implementation of the proposed **50 new trees** in the design, the site will be able to remove an extra **1,300 pounds of carbon** which is a huge benefit to the entire Purdue campus environment.

Carbon Dioxide Sequestration: The cost benefits for the amount of CO2 sequestration the site performs is **$2** annually and **$76** as a life cycle cost benefit with each tree giving back **$0.12** annually as well (Syracuse)(ESRL and NCDC).

Tree Value: The annual cost benefits coming from the compensatory value of trees is **$5,500** and the life cycle benefit is around **$174,282** (ESRL and NCDC).

Groundwater Recharge: The annual and life cycle cost benefits for the replenishment and recharge of groundwater come out to **$75** and **$2,366** respectively (ESRL and NCDC). Research from EPA has shown that the amount of money replenished from groundwater recharge in Indiana is about **$90 per acre-foot of recharge**.

Additional cost benefits that were calculated in the sources used include reduced energy cost, reduced treatment benefits, and others. A rough calculation estimates the annual return in cost benefits is around **$9,180**, and when the total is calculated for the life cycle benefits the number comes out to around **$290,884** in return from life cycle green benefits (ESRL and NCDC). These numbers can be presented and will be important for stakeholders to understand the return in their investment and encourage potential buy-ins for the project.

Phasing and Funding Opportunities:

There are many extensive and flexible funding opportunities available for funding a project such as this due to the multifaceted goals and approach of our design. The total cost of our design implementation on Purdue University's Agricultural Mall campus will be approximately **$1.27 million**. In sticking with Purdue's 50-year master plan, renovating the site by removing vehicular traffic, and transforming Marstellar and S. University Streets to include swales and other green infrastructure technologies, the first phase of our design would be to implement curb-cuts and bioswales along these nodes of circulation. This first phase serves as a demonstration project to the university, showing the importance of sustainable stormwater management on campus. Funding for this initial phase would most likely be sourced from loan and or grant funding opportunities available through the school as a part of Purdue's 150 years of Giant Leaps initiative. This program aims at **planting 3,738 trees on campus over the next seven years**. Grant opportunities are available through this green initiative to apply for the total, or partial cost of our planting budget. Additional Purdue granted funding could potentially come from The Student Organization Grant Allocation Board (SOGA), providing upwards of **$15,000** for student-driven programs and initiatives that aim to better the campus experience for every undergraduate student.

The second phase of our design, scheduled to come three to four years after the construction of the initial phase, would be the implementation of the terraced gardens, complete with weir structures and lawn detention basin. This being a keystone element of our overall design, the funding will come from a portion of the adjacent Forestry Building's renovation budget, allocated specifically for the redesign of the surrounding landscape. Purdue's campus planning department is currently in the beginning stages of budget talks for the planned renovating of the Forestry Building, positioned in the northeast corner of Agriculture Mall. These early talks have produced an estimated total budget of approximately **$20 million, $2 million** of which will be allocated to improving the surrounding landscape design within Agriculture Mall. Interviews with Purdue campus planners have confirmed this proposed budget.

The third phase of construction, scheduled to come five to six years after the construction of the initial phase, would be focused on the retention pond and plaza space located on the west side of S. University Street, in front of Hansen Life Sciences Research Building. Any additional funding needed to complete this third and final phase of the project, could come from additional grant opportunities that include the National Fish & Wildlife Foundation's Five Star Urban Waters Restoration Program, providing funding for a wide range of projects that provide water quality enhancements, along with increased species habitat benefits. Due to the educational focus of the design, grant opportunities exist with other organizations such as the Urban Waters Small Grants, or the U.S. Department of Transportation's Transportation Alternatives Set-Aside Program, providing funding to install shade trees or permeable pavements near roadways and can be used to plan, design, or construct comprehensive streetscapes that incorporate trees and other plants, to create more pedestrian-friendly (and cooler) streets if they result in safer streets for non-drivers.

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THANK YOU