



North Central Texas
Council of Governments

Integrating Transportation and Stormwater Infrastructure

Green Stormwater Infrastructure and Nature Based Solution Memo

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Integrating Transportation and Stormwater Infrastructure (TSI)

Green Stormwater Infrastructure and Nature-Based Solutions Memo

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1 Background

In the face of escalating climate change and rapid urban development, cities worldwide are increasingly vulnerable to flooding. Climate change is leading to more frequent and intense rainfall events, which overwhelm existing drainage systems and overflowing streambanks, contributing significantly to more flooding issues. As cities expand, natural landscapes are replaced with impervious surfaces such as parking lots and buildings. These surfaces prevent water infiltration, increasing surface runoff and the potential for flooding. Moreover, the high demand for the development of extensive transportation networks, such as roads, highways, and bridges, further increases impervious areas percentages, channeling large volumes of stormwater into urban drainage systems. The integration of green stormwater infrastructure (GSI)/nature-based solutions (NBS) presents a promising strategy to mitigate these risks, offering a dual benefit of protecting the conventional transportation infrastructure and reducing flooding frequency in downstream communities (Figure 1). This memo was prepared to help better understand the role GSI and NBS play in stormwater management and to learn from these experiences for potential application in the integrating Transportation and Stormwater Infrastructure (TSI) project.

From the local perspective, recent flood events in Texas have brought to the attention of the State the need for more comprehensive planning in urban areas. This is particularly important in the upstream portions of the Trinity River watershed where urban growth and development is expected to continue, and unmanaged growth will have strongly negative consequences on downstream communities like the cities of Dallas and Fort Worth. The North Central Texas region has a distinct window of opportunity to proactively engage in comprehensive planning efforts that integrate its transportation, environmental, and stormwater needs to address the health, safety, and welfare concerns of the region while helping local governments manage their growth and development in a cost-effective manner. (NCTCOG, n.d.-e)

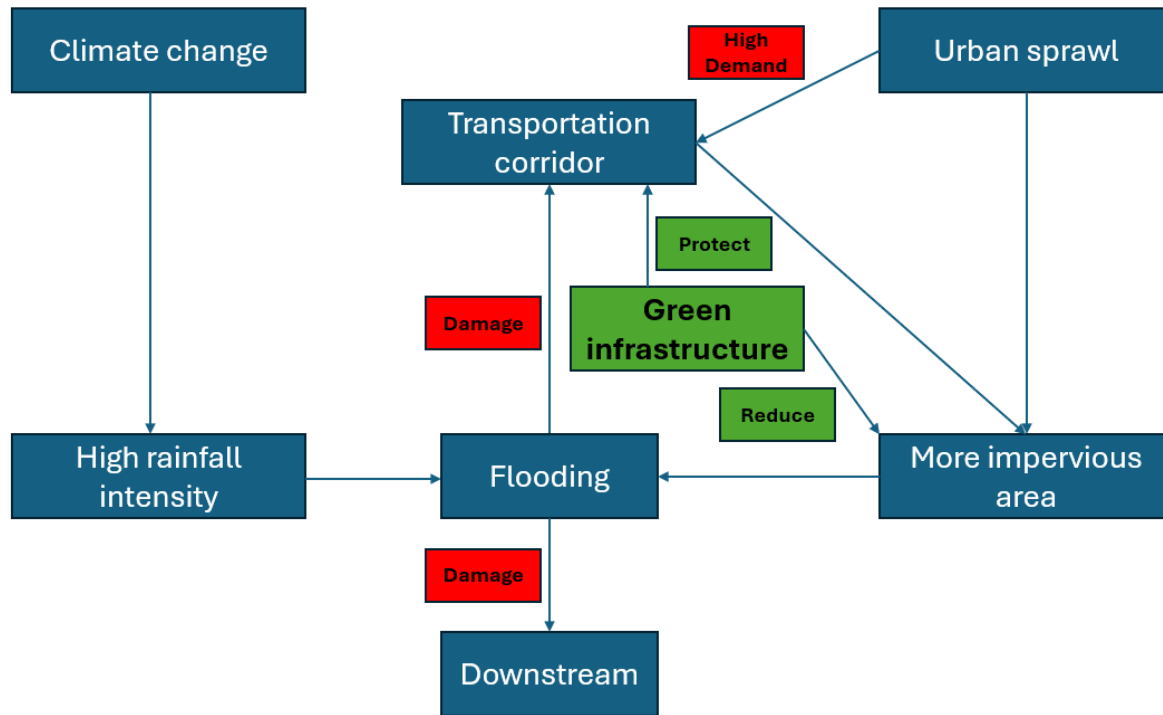


Figure 1. Transportation-Stormwater-Infrastructure Nexus

2 Projects/Programs Summary

The TSI study will identify projects to reduce future flood risk and potential funding sources to implement those projects. The study also will generate:

- Maps and models of future flood risk
- Policy recommendations related to development and floodplain management (NCTCOG, n.d.-e)

As part of the TSI study, regional projects across the U.S. that integrate GSI or NBS were reviewed. Thirteen projects or programs have been found and are summarized as follows. It is worth noting that some projects/programs may not be transportation-related, but their inclusion in this memo is still beneficial to the TSI study.

2.1 Atlanta, Georgia

Program Name: City of Atlanta's Environmental Impact Bond for Green Infrastructure

Agencies Involved: City of Atlanta Department of Watershed Management (DWM)

Start Year: January 3, 2019 **End Year:** November 1, 2024 **Duration:** 5 years

Problem: DWM receives about 1,300 complaints about stormwater issues every year including damaged infrastructure, street flooding, and water quality issues, etc.

Target Area: Upper Proctor Creek Watershed Neighborhoods

Source of Funding: \$14 million Municipal Environmental Impact Bond to fund six GSI projects

Program Goals: Provide a total of 6.4 million gallons of stormwater storage capacity, resulting in a reduction of 56 million gallons in annual stormwater runoff; add multiple co-benefits, such as to improve water and air quality, enhance wildlife habitat, provide access to green space, safeguard public health, educate, create jobs for residents, etc.

Program Progress: The six EIB-funded GSI projects were identified at the start of the program, but it is unclear if they have been fully implemented.

Public Engagement: DWM partnered with the Water Equity Task Force, comprised of cross-sector Learning Teams from cities across the U.S., and participated in community meetings to advance the EIB program and gather feedback on EIB projects and outcomes.

Transportation-related: The projects will reduce street flooding during storms thereby increasing road accessibility during precipitation.

Applied GSI: Bioretention along streetscapes and in city parks, stream and floodplain restoration, constructed wetlands (Figure 2)



Figure 2. Project types (left to right: stream restoration, constructed wetlands, bioretention area)

Technical Approach: N/A

Modeling: N/A

(Quantified Ventures, n.d.; City of Atlanta, 2019; City of Atlanta, n.d.; U.S. Water Alliance, n.d.)

2.2 Berkeley, California

Program Name: City of Berkeley Green Infrastructure Plan 2019

Agencies Involved: City of Berkeley

Start Year: 2019

End Year: 2040

Duration: 21 years

Problem: Polluted stormwater runoff entering the Bay is a concern, particularly polychlorinated biphenyl and mercury.

Target Area: City of Berkeley (Piedmont Avenue, Woolsey, Tremont, Potter Watershed, Gilman Watershed, etc.)

Source of Funding: The estimated cost for constructing the 11 priority sites identified in the Plan is \$1.7 million, with ongoing maintenance adding \$100,000 per year. The city's Clean Stormwater Fee funds may be used, but additional sources of funding will need to be identified.

Program Goals: Develop a tool to prioritize areas for potential GSI projects and to track completed GSI projects; retrofit impervious surfaces by target dates 2020, 2030, and 2040; update city planning documents to include GSI requirements

Program Progress: As of 2020, about 41 acres of impervious surface have been retrofitted. The Plan intends to convert about 224 acres into green infrastructure by 2040.

Public Engagement: The city's stormwater department collaborated with other departments such as the San Francisco Bay Area Metropolitan Transportation Commission when developing the Plan.

Transportation-related: The San Francisco Bay Area Metropolitan Transportation Commission is incorporating GSI projects in its operations.

Applied GSI: Permeable pavements, bioswales, rain gardens, green roofs, cisterns and flow-through planters (Figure 3)





Figure 3. GSI applications in Berkeley (left to right, top to bottom: bioswales, permeable pavements, flow-through planters, green roofs)

Technical Approach: Created a Multi-Benefit Prioritization Tool and Micro-Watershed Tool

- **Multi-Benefit Prioritization Tool:** A quantitative metrics-based way to evaluate publicly owned parcels and public right-of-way blocks using an automated GIS process. Scoring metrics include location slope, infiltration feasibility, pollutant load reduction potential, water supply augmentation potential, flood control co-benefit, re-establishment of natural drainage systems, restoration of habitat or open space, public use/community involvement benefits, and trash capture co-benefit. (Figure 4)

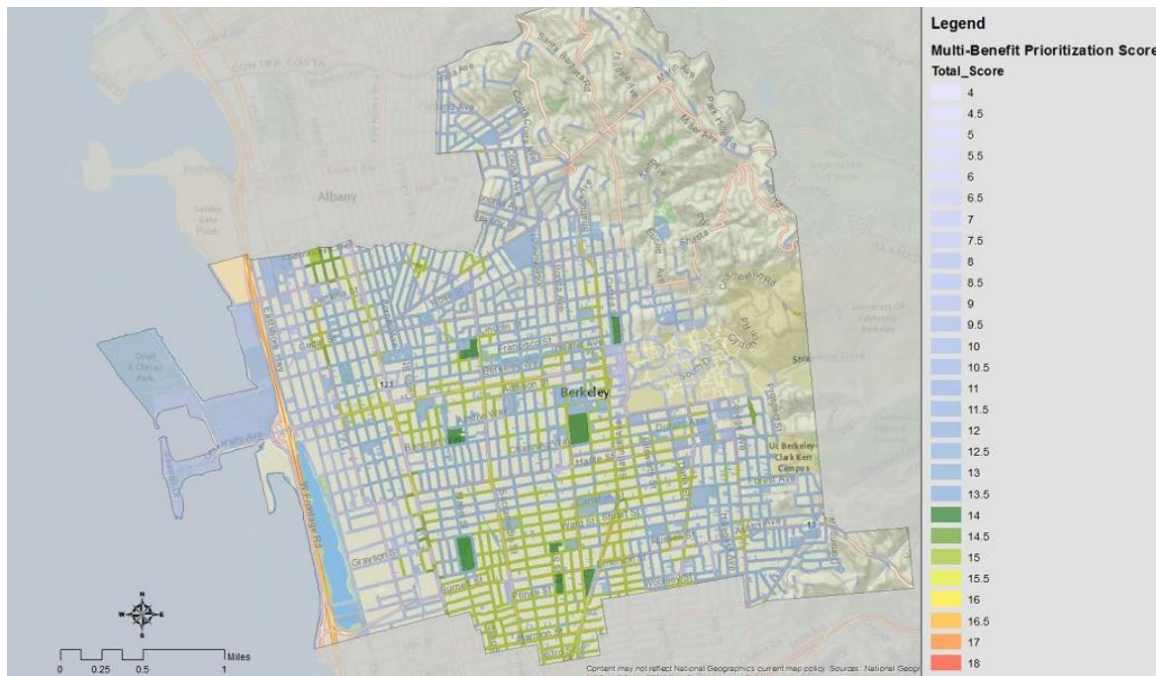


Figure 4. Multi-Benefit Prioritization Tool

- **Micro-Watershed Tool:** A land use-based micro-watershed pollutant load estimation tool was developed by digitizing the city's surface drainage maps in ArcGIS, creating GIS polygons for the drainage area of each storm drain inlet in the city (micro-watersheds), overlaying the micro-watersheds with the Historical Land Use Layer and calculating the amount of each category of land-use within each micro-watershed, and calculating a pollutant reduction potential value for each micro-watershed based on the Bay Area Stormwater Management Agencies Association Interim Accounting Methodology for TMDL Loads Reduced. (Figure 5)

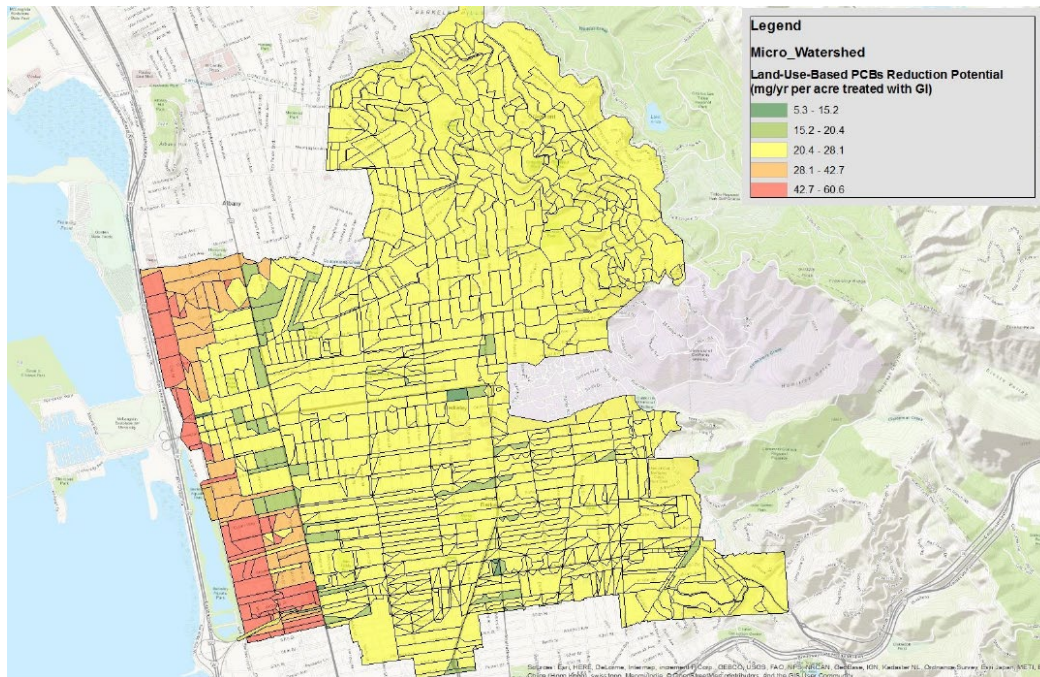


Figure 5. Micro-Watershed Tool

Modeling: Micro-watersheds were created in ArcGIS based on the drainage area to each storm drain inlet. The Multi-Benefit Prioritization Tool also relied on an automated GIS process. Additionally, a regional ArcGIS online GSI tracking tool was developed.

(City of Berkeley, 2019)

2.3 Bloomington, Indiana

Program Name: Stormwater Program Master Plan

Agencies Involved: City of Bloomington Utilities Department (CBU)

Start Year: 2022

End Year: 2028

Duration: 6 years

Problem: The city does not have a long-term strategy to maintain the public stormwater system and community growth. This combined with stronger and more frequent storms are overwhelming the stormwater system.

Target Area: Bloomington city limits

Source of Funding: CBU allocates funds annually from its stormwater utility fee to implement the Plan's recommendations over the 6-year period, amounting to a total of \$1.88 million. Ongoing annual costs of at least \$300,000 after 2028 are expected to be needed to support ongoing activities such as maintenance and minor repairs.

Program Goals: To address existing water quality and quantity problems and prevent future problems; place the city in an opportune position to continue its compliance with Indiana's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System permit now and well into the future, especially when considering the use of innovative GSI practices; better align the city's stormwater management program with the goals, objectives, and vision established in the city's comprehensive plan and sustainability action plan

Program Progress: CBU completed the planning phase and is now in the implementation phase.

Public Engagement: The planning phase of the Plan included meetings and interviews with CBU staff and a city staff focus group comprised of representatives from nine city departments. The implementation phase will include a strategy to engage external stakeholders for relevant strategies. (Figure 6)



Figure 6. Stakeholder engagement process for development and implementation of the city's Stormwater Master Plan

Transportation-related: The transportation plan, adopted July 17, 2019, established new street typologies that incorporate green streets in construction works. Construction site runoff control and post construction stormwater control are also considered.

Applied GSI: Rain gardens, bioretention area, green roofs, cisterns, permeable pavement, etc.

Technical Approach: Identification of suitable sites to install GSI; flood prone areas have been identified and GSI is being installed

Modeling: Spatial analysis tools

Notes: The GSI applications mentioned above are projected targets, but the exact ones being developed are unknown. Moreover, the program has a vision on designing through the lens of climate change; however, no details on implementation are provided.

(City of Bloomington, 2022; WEIS, Inc. and Empower Results, 2022)

2.4 Cleveland, Ohio

Project Clean Lake is a 25-year program that will reduce pollution in Lake Erie by 4 billion gallons per year. A combination of large tunnels, treatment plant improvements and expansion, and GSI is reducing the volume of combined sewer overflow discharging to the Great Lake. Northeast Ohio Regional Sewer District (NEORSD) developed six programs as follows to implement GSI under the circumstances of Project Clean Lake.

- Program 1: Capital Improvement and Operation and Maintenance Program
- Program 2: Green Infrastructure Grants Program
- Program 3: Member Community Infrastructure Program
- Program 4: Water Resources Restoration Sponsorship Program
- Program 5: NEORSD Code of Regulations Titles III and IV Community Discharge Permit Program
- Program 6: NEORSD Code of Regulations Title V Regional Stormwater Management Program

Only “Program 2: Green Infrastructure Grants Program” has detailed information about GSI projects. Information on this program is presented as follows.

Program Name: Green Infrastructure Grants Program

Agencies Involved: NEORSD

Start Year: 2014

Duration: In-progress

Problem: Combined sewer overflow control

Target Area: A combined sewer area in Cleveland by Lake Erie (Figure 7)

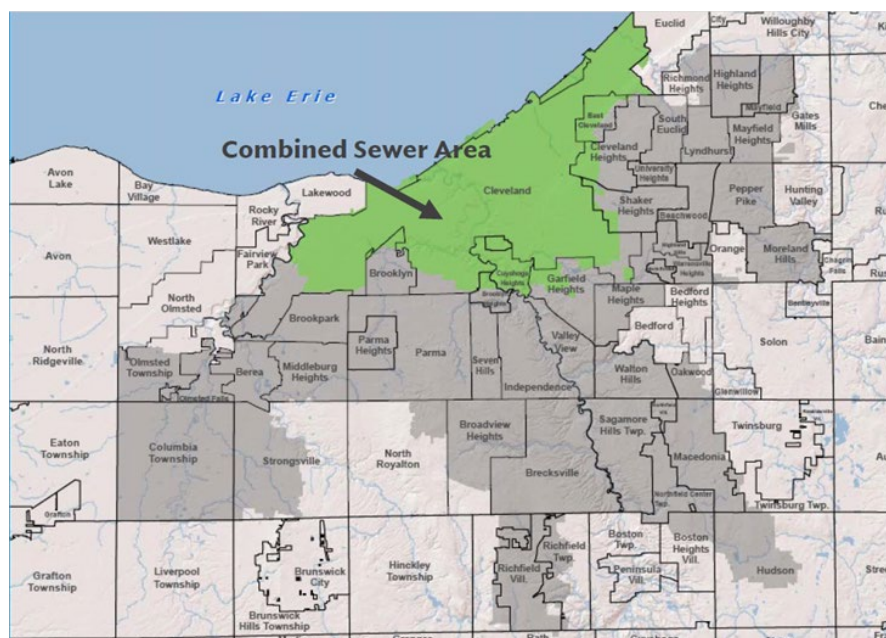


Figure 7. Combined sewer area in Cleveland

Source of Funding: This program is a reimbursement grant to financially support GSI projects in the area of interest.

Program Goals: The funded projects are expected to prevent the post-development average annual runoff from exceeding the pre-development (i.e., undeveloped) average annual runoff, as determined by the U.S. Environmental Protection Agency Stormwater Calculator; Green Infrastructure Grants projects are expected to manage over 16.3 million gallons of stormwater per year.

Program Progress: The program has developed eight rounds of funding since 2014 with a total grant of \$12,728,824 and a total runoff reduction of 35,066,342 gallons. In 2024, \$1,625,000 was spent to reduce 2,904,305 gallons of runoff. (Figure 8)

Funding Round	Award Recommendations Total	Runoff Reduction gallons/year Total
2014 – 2023 GIG PROGRAM	\$12,728,824	35,066,342
2024 GIG PROGRAM	1,625,000	2,904,305
GRAND TOTAL	\$14,353,824	38,266,308

Figure 8. Program progress (investment and runoff reduction)

Public Engagement: The program encourages community engagement and collaboration. For example, a project which organizes a public design charette or conducts surveys to generate ideas in the early stages of design will earn one point as the project's co-benefits are evaluated. Moreover, a project during construction phase which includes selling engraved paver bricks or organizing a planting party, etc. will earn one point. During the maintenance phase, a project

which partners with an established garden club to maintain the landscaping of a bioretention cell will earn one point.

Transportation-related: N/A

Applied GSI: Bioretention cells, bioretention planters, tree vaults, permeable pavement

Technical Approach:

- The reduced runoff volume by GSI from the combined sewer system was determined by comparing post-development average annual runoff with all GSI applications to the average annual runoff of existing conditions and considers the project size in acres.
- The runoff volume is expected to be brought back to the level where area is undeveloped. To mimic an undeveloped pre-development condition, all existing impervious areas must be accounted for as “lawn”.
- A social vulnerability index (SVI) map was introduced as one of the criteria to score the proposed projects, thus, deciding which projects should be funded. This consideration helps to facilitate the GSI application in vulnerable communities which have low-income, lack of access to transportation, and crowded housing, etc.
- A priority urban heat resilience map was introduced to evaluate the co-benefits of proposed projects to alleviate heat island effect brought by impervious surfaces.

Modeling: N/A

(NEORSD, n.d.)

2.5 Kansas City, Missouri

Program Name: Green Infrastructure Framework and Smart Sewer

- Green Infrastructure Framework is a design program covering nine counties focusing on data collection, mapping, and policy recommendations.
- Smart Sewer is an implementation program aimed at reducing and preventing sanitary sewer overflows.

Agencies Involved: Mid-America Regional Council, Kansas Department of Transportation, Kansas City Water Services Department

Start Year: Unknown **Duration:** In-progress

Problem: Stormwater management and combined sewer system control

Target Area: Greater Kansas City Region (Figure 9)

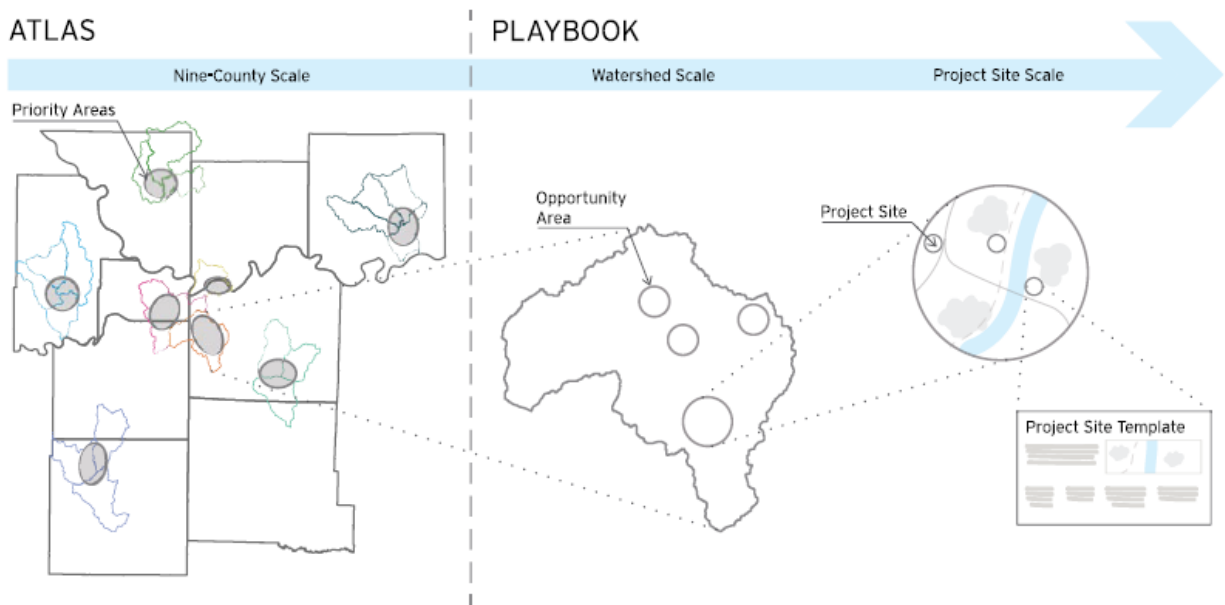


Figure 9. Target area

Source of Funding: Funding is not currently committed or available.

Program Goals: Improve health of rivers and streams; connect people to water (education, advocacy, and access); improve quality of life with green infrastructure amenities; improve local habitats; establish conservation priorities; regulate the microclimate with living systems; improve air quality; reduce combined sewer system overflows

Program Progress: The phase of data collection and analysis is complete. Thirteen GSI projects have been implemented, and four projects are in the design phase under the program called “KC Smart Sewer” to mitigate combine sewer overflow. (Figure 10)



Figure 10. Snapshot of a complete project

Public Engagement: Regional workshops are held with participants from environmental organizations and Kansas City municipal council departments.

Transportation-related: Metro-green planning and smart-moves transit plan focus on integrating GSI in construction works. Moreover, transportation corridors like major roads with a 100-meter buffer have been utilized in GIS analysis to create an ecological value map.

Applied GSI: Permeable pavers, pervious concrete, bioswales, rain gardens, green roofs, bioretention basins, infiltration trenches, wetlands, etc.

Technical Approach: Collect and evaluate the current datasets underlying the region's environmental and transportation plans, programs, and policies. So far, data has been collected from 500 city projects. This is intended to help in the identification of flood prone areas where suitable GSI would be installed.

Modeling: GIS for data (environment, transportation and infrastructure, land use, demographic, health, employment) collection and analysis

Notes: Kansas City has a comprehensive plan associated with GSI applications from conception to design and implementation. A Technology Fact Sheet is provided for each type of GSI to introduce how it works. The city's Green Stormwater Infrastructure Manual is a detailed design guide for each type of GSI, including storage and sizing calculations, design considerations, and some key components.

(City of Kansas City, n.d.; MARC, n.d.)

2.6 Miami, Florida

Program Name: City of Miami's Comprehensive Stormwater Master Plan (B-30632A)

Agencies Involved: City of Miami

Start Year: 2021 **End Year:** 2061 **Duration:** 40 years

Problem: Local and regional flooding due to changes in land use from redevelopment, increase sea level rise, and extreme rainfall events

Target Area: City-wide project; first phase focuses on Biscayne Bay

Source of Funding: Funded by a portion of the 2017 Miami Forever General Obligation Bond Program which is intended to build a stronger and more resilient future for Miami through alleviating existing and future risks to the residents, economy, and tourism, and by protecting the city's legacy. The estimated budget is \$5.4 billion.

Program Goals: Mitigate flooding, protect and enhance water quality in the Biscayne Bay, and strengthen the shorelines from tidal storm inundation and improve coastal resiliency

Program Progress: Phase 1 of the project is near completion while phases 2 to 4 are yet to kick off.

Public Engagement: Stakeholder workshops were organized through a public information program and community awareness and outreach plan were developed and implemented at the start of the project. In person meetings and presentations to neighborhood associations and other civic groups were held to keep the public informed of the project and goals.

Transportation-related: N/A

Applied GSI: Exfiltration, recharge wells, bioswales, pervious pavement, coastal features-grassed levees, sea grasses, mangroves, green roofs, tree vaults, etc.

Technical Approach: To identify flood prone areas and determine what type of GSI is suitable for the city

Modeling: Storm Water Management Model (SWMM) covers the city's eight drainage basins. The stormwater model was developed at a neighborhood scale and was used to simulate rainfall, infiltration, runoff, and flows and stages in pipes, exfiltration systems, channels, rivers, wells, outfalls, and pump systems for design storm rainfall events and various tidal and sea level rise conditions. The models were validated to actual conditions for historic storms and then were used to predict existing and future sea level condition flood flows, depths, and durations for South Florida Water Management District-required design storms to determine the causes of the flooded areas and to evaluate alternatives of mitigative capital improvement projects. (Figure 11)

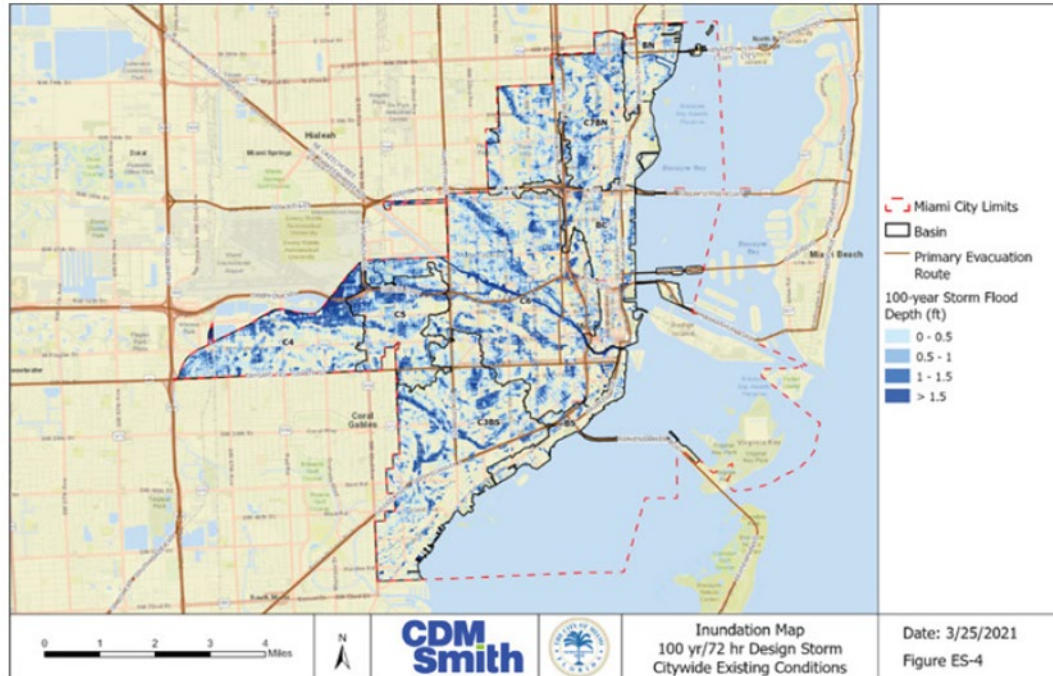


Figure 11. SWMM modeling: existing conditions 100-year predicted storm inundation map

Notes: This is a multi-phase project with \$545 million allocated for phase 1 (group 1 project as the report calls it) and \$5.4 billion for groups 2 to 4. This project was launched to mainly combat coastal flooding rather than riverine (fluvial) flooding or stormwater flooding.

(CDM Smith, n.d.; CDM Smith, 2021)

2.7 New Orleans, Louisiana

Program Name: Green Infrastructure Plan (Plan for the 21st Century: New Orleans 2030)

Agencies Involved: Sewerage and Water Board of New Orleans (SWBNO), City of New Orleans

Start Year: 2014 **End Year:** 2030 **Duration:** 16 years

Problem: The city seeks to explore and pursue including GSI to fulfill the Second Modification of the Consent Decree entered on April 24, 2013 for stormwater management.

Target Area: New Orleans city limits (Figure 12)

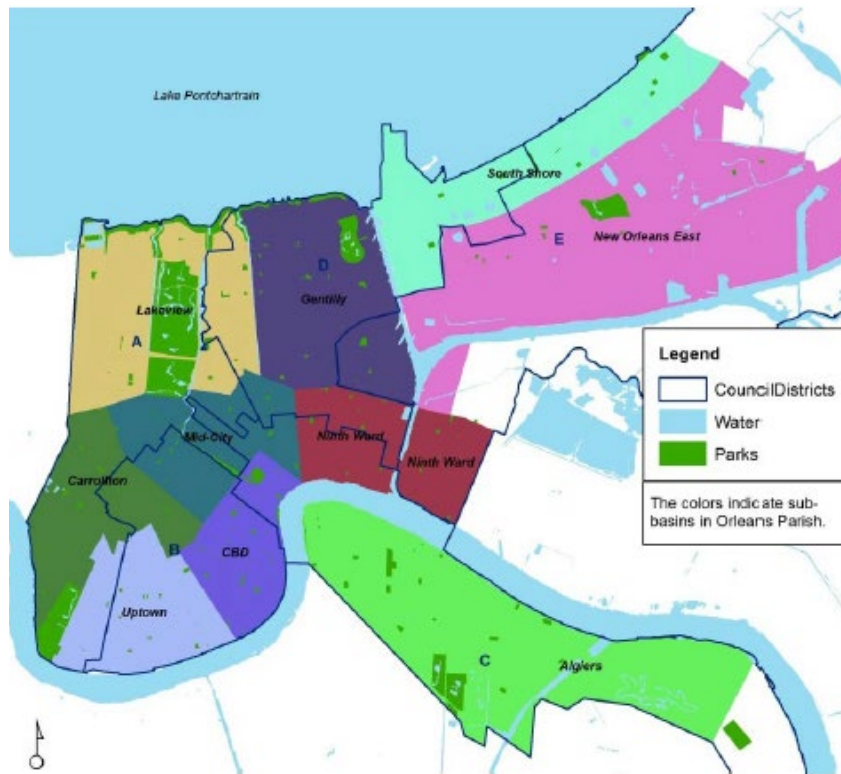


Figure 12. New Orleans east bank sewer service basins

Source of Funding: Funded by SWBNO with \$500,000 each year for the first five years; \$2.5 million to be subsequently used for GSI projects and activities carried out pursuant to the plan

Program Goals: Implement best management practices to retain, reuse, and delay stormwater while simultaneously improving water quality, mitigating flooding, and lessening the burden on the drainage system; create rain gardens and small-scale water management infrastructure to reduce runoff and increase the permeability of the urban landscape; retrofit existing public buildings with green roofs that can help retain stormwater on site rather than adding to runoff

Program Progress: The Plan is still in progress

Public Engagement: Community outreach included public meetings to present and receive comments on preliminary/conceptual design, final designs, and neighborhood concerns, and brochures or signage that illustrate, educate, and promote stormwater management through GSI.

Transportation-related: New stormwater infrastructure would help mitigate and reduce flooding, thereby improving mobility during and after storm events.

Applied GSI: Rain gardens, bioswales, green roofs, tree planting, etc.

Technical Approach: To identify flood prone areas and determine what type of GSI is appropriate for the city

Modeling: A cost-benefit analysis is used in this project and references an online stormwater calculator (EPA, 2024). A stormwater retention analysis is also used, and calculations shall be made for all proposed projects, including a no-build option for the specific sites (pre- and post-construction). Soil and hydrologic testing must be conducted. All GSI installations should be designed to retain, detain, and filter the first one inch of stormwater runoff during each rain event.

(SWBNO, 2024)

2.8 Philadelphia, Pennsylvania

Program Name: Green City, Clean Waters

Agencies Involved: Pennsylvania Department of Environmental Protection, Philadelphia Water Department

Start Year: 2011 **Duration:** 25 years

Problem: Combined sewer systems overflow issue (60 percent of the city) (Figure 13)

Target Area: Fully developed urban area (over 9,000 acres of impervious surface)

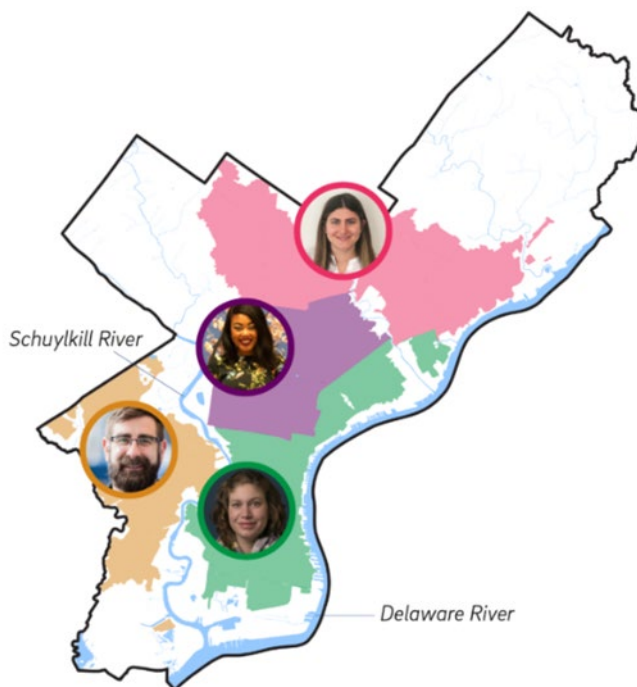


Figure 13. Combined sewer system in Philadelphia (colored area)

Program Goals: Meet the U.S. Environmental Protection Agency's mandated goal to reduce the amount of polluted stormwater overflows discharging into creeks, streams, and rivers in and

around the city by 85 percent by 2035 through GSI and investments in traditional infrastructure, such as treatment plants

Program Progress: Installed more than 2,800 green tools at nearly 800 sites throughout the city keeping more than 3 billion gallons of polluted water out of local rivers annually

Public Engagement: Nearly half of surveyed residents are willing to pay more on their water bills if the money is used directly for priority issues like clean water and climate change.

Transportation-related: Pennsylvania Department of Transportation is reconstructing Interstate 95 (I-95) in Philadelphia while installing GSI in the public right-of-way.

Applied GSI: Cistern, green roof, permeable pavement, infiltration trench, rain garden, bioswale, constructed wetland

Technical Approach: N/A

Modeling: N/A

Notes: A heat exposure map was considered in the process of placement of GSI applications. (Figure 14)

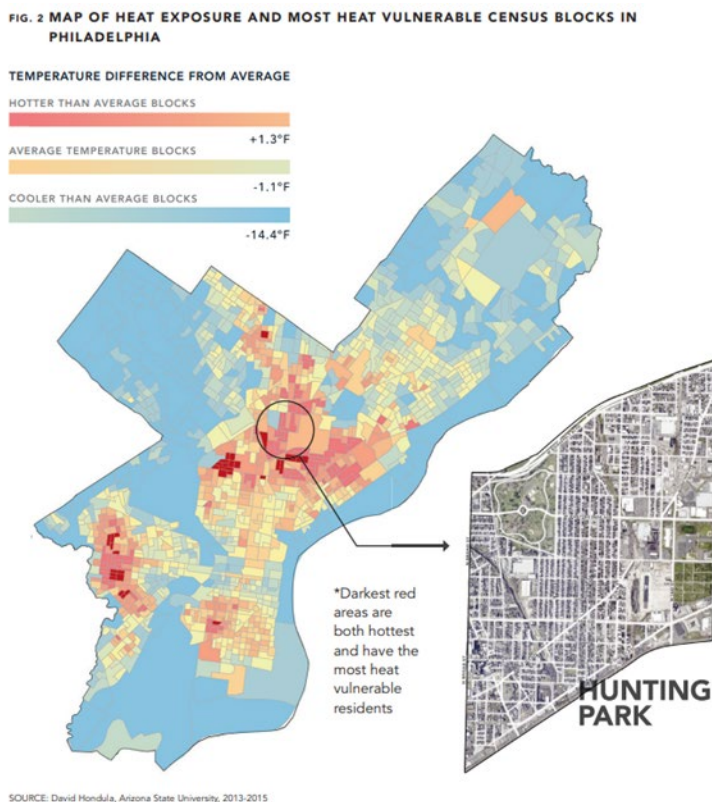


Figure 14. Heat exposure map

(City of Philadelphia, 2021)

Progress: Twelve projects have been funded that were either a feasibility study and/or planning for a blue-green-gray project or are ready for construction/implementation. See Appendix A for more information on the six projects that utilize green stormwater infrastructure components.

Public Engagement: N/A

Transportation-related: Promote land use-transportation connections

Applied GSI: Rain garden (Figure 16), bioswale, stormwater detention, biofiltration, incorporating GSI in development processes



Figure 16. City of Watauga rain garden design (City of Watauga. 2022)

Technical Approach: N/A

Modeling: N/A

(NCTCOG, n.d.-a)

2.10 North Central Texas

Program Name: Sustainable Development Funding Program

Agencies Involved: NCTCOG

Start Year: 2001 **Duration:** 4 cycles of funding to date (2001, 2006, 2010, 2018)

Problem: Air quality, congestion, and quality of life issues are escalating

Target Area: Land use and transportation practices that promote economic development and efficient use of resources to reduce vehicle miles traveled and increase the viability of alternative transportation modes within the 12-county Metropolitan Planning Area (Figure 17)

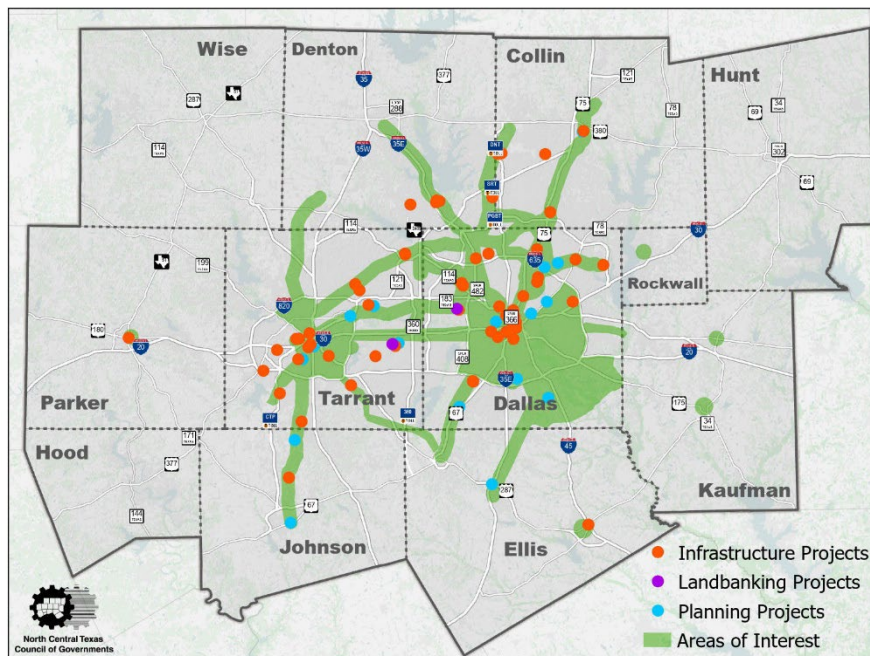


Figure 17. Sustainable development areas of interest and funded project locations

Source of Funding: NCTCOG's Transportation Department through the Regional Transportation Council funds eligible projects and applicants through a competitive selection process

Program Goals: Encourage planning and foster growth and development in and downtown areas, infill areas, and along passenger rail lines and at stations

Progress: More than 50 projects have been funded with three utilizing green infrastructure components (Figures 18 and 19). See Appendix A for more details on the three projects.



Figure 18. College Town low impact development elements



Figure 19. Gus Thomasson Road corridor design

Public Engagement: N/A

Transportation-related: Supports sustainable development throughout the region

Applied GSI: Bioswales, bioretention, trees, pervious pavement, etc.

Technical Approach: N/A

Modeling: N/A

(NCTCOG, n.d.-d)

2.11 North Central Texas

Program Name: integrated Stormwater Management (iSWM) Program

Agencies Involved: NCTCOG

Start Year: 2009 **Duration:** Ongoing

Problem: North Central Texas is a rapidly growing urbanizing region, resulting in increased pervious surfaces, such as concrete and asphalt. This increase in surface water runoff and reduced water infiltration causes water quality and flooding concerns.

Target Area: North Central Texas 16-County Region (Figure 15)

Source of Funding: General program is funded by the NCTCOG's Public Works Program; implementation is locally funded

Program Goals: Assist cities and counties with achieving their goals of water quality protection, streambank protection, and flood mitigation, while also helping them meet their construction and post-construction obligations under state stormwater permits; encourage the use of holistic site designs that integrate green and gray infrastructure

Progress: Many projects have been planned or implemented locally using iSWM principles. (Figure 20)



Figure 20. Curb cuts at Rayzor Ranch

Public Engagement: N/A

Transportation-related: A Transportation Integrated Stormwater Management (TriSWM) Appendix is included to provide planning and design guidance and a framework for incorporating effective and environmentally sensitive stormwater management practices into the street and roadway project development process

Applied GSI: Curb cuts, bioretention, pocket wetland, parking low islands, rainwater harvesting, vegetated swales

Technical Approach: N/A

Modeling: N/A

(NCTCOG, n.d.-c)

2.12 North Central Texas

Program Name: Greenprinting Projects

Agencies Involved: NCTCOG, Trust for Public Land

Start Year: 2010 **End Date:** 2015

Problem: Increasing urbanization in North Central Texas watersheds can impact the quality of water entering local streams, jeopardizing regional drinking water reservoirs

Target Area: Lake Arlington, Lewisville Lake East, and Lake Worth watersheds

Source of Funding: NCTCOG's Water Resources Program and grants from the U.S. Environmental Protection Agency through the Texas Commission on Environmental Quality

Program Goals: Three watersheds were selected (Lake Arlington, Lewisville Lake East, and Lake Worth) to identify land areas through a GIS analysis technique known as "Greenprinting",

developed by the Trust for Public Land, that offer a significant benefit for water quality protection and other program goals (e.g., recreation enhancement in the Lake Worth Watershed).

Progress: The project reports were finalized in 2011 for the Lake Arlington and Lewisville Lake East watersheds and in 2015 for the Lake Worth watershed. The Lake Arlington and Lewisville Lake East watershed greenprints recommend maintaining land areas as undeveloped based on land use with natural vegetated cover; proximity to streams, the reservoir, ponds, and wetlands; water erosion potential; and floodplains. In general, the protection of open space, especially riparian corridors, offer the best water quality protection based on these priorities. (Figure 21)

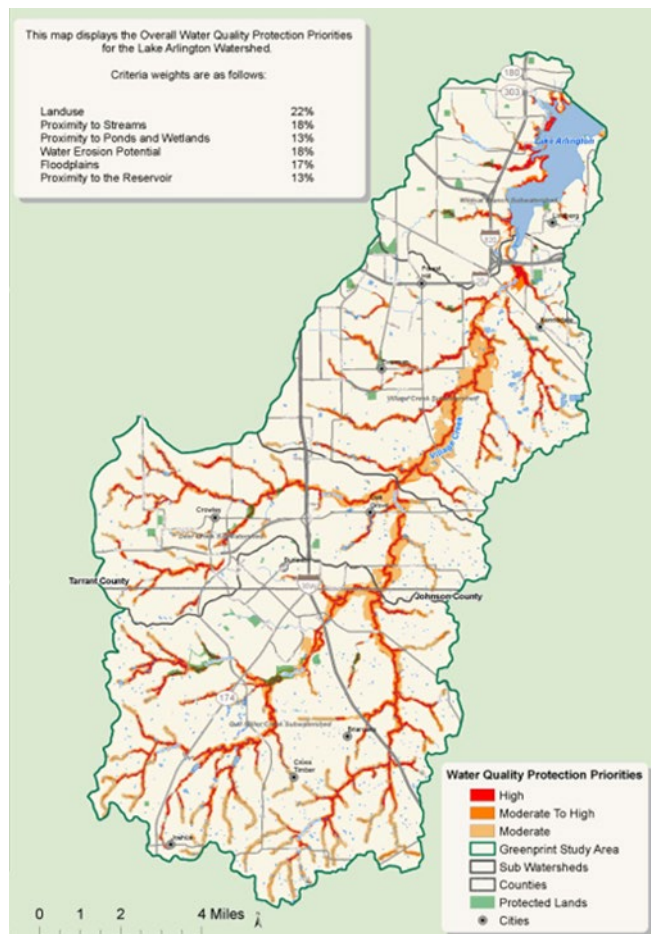


Figure 21. Lake Arlington Watershed Greenprint analysis

Public Engagement: The process involved a diverse stakeholder group including local governments, special districts, large businesses, property owners, homeowner associations, and others interested in watershed and water quality. Stakeholder workshops were conducted in each watershed study area.

Transportation-related: N/A

Applied GSI: Protection of riparian corridors, open space protection, conservation easements

Technical Approach: GIS data and conservation value methodology, developed by technical advisors, were used to translate the watersheds' priorities into criteria maps.

Modeling: N/A

(NCTCOG, n.d.-b; TPL, 2011)

2.13 North Central Texas

Program Name: Fort Worth Open Space Conservation Program

Agencies Involved: City of Fort Worth, Trust for Public Land

Start Year: 2020 **Duration:** Ongoing

Problem: Fort Worth is growing and developing at a rapid pace and loses roughly 50 acres of natural open space per week to development (Zakalik, 2020).

Target Area: Fort Worth city limits

Source of Funding: One-time distribution from the General Gas Lease Fund and Water Gas Lease Fund, as well as Fort Worth's 2022 Bond (will pursue funding from the 2026 Bond)

Program Goals: The online prioritization mapping tool to prioritize areas for open space conservation considers seven goal areas – ecosystem preservation; stream, river, and lake health; community health; recreation; flood control; equitable access to open space; and economic development. (Figure 22)

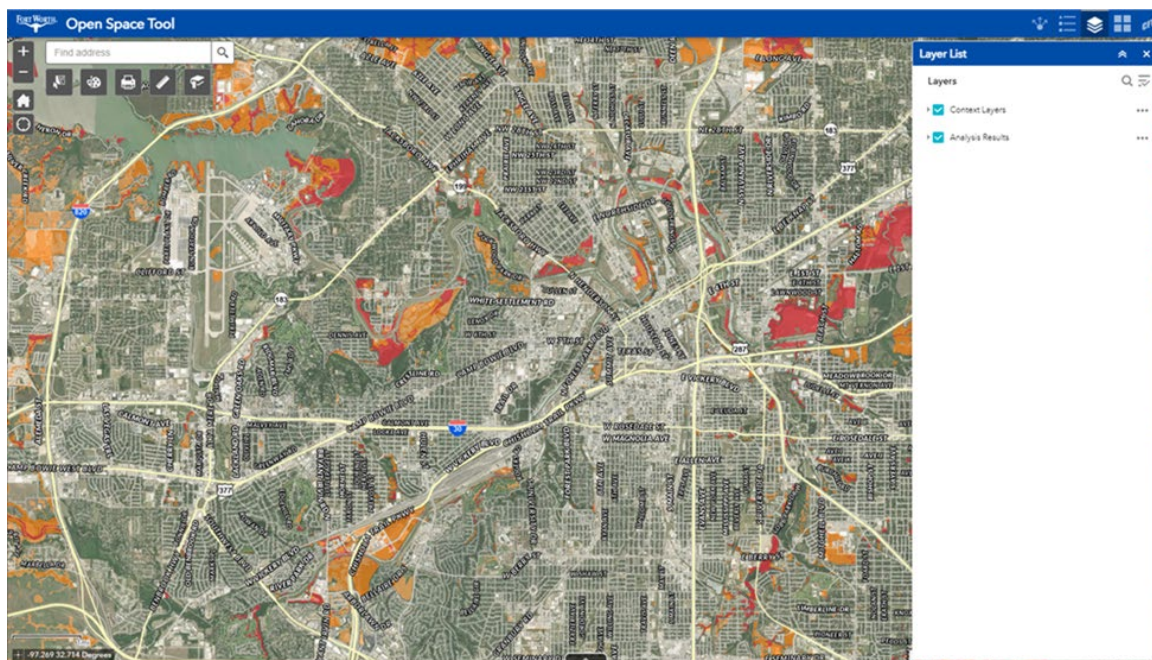


Figure 22. Open space prioritization tool

Progress: As of October 2024, the city has acquired 311.85 acres of open space with an additional 288.91 acres in progress.

Public Engagement: City staff hosted several public and stakeholder meetings to guide the direction of the prioritization tool, strategy report, and associated policy recommendations.

Transportation-related: N/A

Applied GSI: Open space preservation

Technical Approach: To determine the highest-priority areas for open space conservation, a GIS-based online mapping tool using dozens of data sets was developed.

Modeling: N/A

(City of Fort Worth, n.d.)

3 Key Takeaways

After the review of existing or completed regional stormwater projects, The key takeaways from this analysis were:

- While most of the projects/programs mentioned climate change and land use change in the future, they still only focus on the existing conditions. There are few previous studies that applied projected climate conditions and future land use information when they explored the hydrological impact with or without incorporating GSI.
- Most studies targeted completely or near completely developed areas, with some retrofit work, rather than planning it ahead of development.
- More than 1/3 of the projects/programs cited outside of Texas considered GSI as one of the solutions to specifically combat combined sewer system overflow issue (which is not the case for TSI).
- Identifying flood-prone areas using spatial analysis approaches (i.e. ArcGIS) is a common technical approach.
- While some studies mentioned the identification of suitable sites for GSI applications, there is a lack of detailed information on the selection and placement of various GSI applications.
- Social vulnerability index mapping was used in some of the studies and could be considered in the TSI study in terms of flood-prone area identification.
- Since most studies found in this memo targeted completely or near completely developed areas, the Storm Water Management Model (SWMM) was utilized to simulate the hydrological response with or without GSI. However, SWMM may not be applicable to

the TSI study due to a lack of fully developed drainage network information. Other hydrological models such as the Soil and Water Assessment Tool (SWAT) could be an alternative option.

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Green Stormwater Infrastructure and Nature-Based Solutions Memo

Appendix A

NCTCOG: Shawn Conrad, Kyle Hoener

1 NCTCOG Transportation Department-Funded Projects Incorporating GSI and NBS

Transportation systems make up a significant portion of the built environment impervious surfaces. In large cities like Dallas and Fort Worth roadways can cover up to a third of the total city surface. In rural areas, major roads are often already developed long before subdivisions or other developments are proposed. The design and management of roadways play a crucial role in urban stormwater control, necessitating a collective approach to mitigate flooding and water pollution.

Roadways serve as an inherent conveyance system for stormwater. Historically the primary objective of roads has been to move traffic, and stormwater control has been considered secondary. The most accepted approach to managing stormwater on roadways is to move water off the roads, typically by directing the water to an underground drainage system as quickly as possible to avoid roadway pooling.

Upstream exurban areas in the Dallas-Fort Worth metroplex are developing at a rapid rate, placing more strain on stormwater systems in downstream areas. Downstream cities, which are typically older, are fairly built out. These older cities have less flexibility in managing the increased flow of stormwater.

The NCTCOG Transportation Department, as the Metropolitan Planning Organization for the 12-county Metropolitan Planning Area, has had the opportunity to fund and/or plan transportation projects incorporating Green Stormwater Infrastructure (GSI) or Nature-Based Solutions (NBS) to help address these challenges (Table 1-1). The summary below includes transportation activities that have been recently funded or conducted by the Transportation Department and that use GSI or NBS.

1.1 Southlake Bio Pod Burney Lane Reconstruction

- Agencies Involved: City of Southlake
- Start Year: 2017
- End Year: 2019
- Duration: 2 years

- Project Type: Blue-Green-Grey Funding Program
- Stormwater Management: Filtration
- Project Description: The City of Southlake implemented a prefabricated Bio Pod Biofiltration system as a part of the storm drain. This system includes water testing and recording results to ensure its effectiveness. The City has seen a decrease in pollutants since the Bio Pod installation.
- Website: [BGG_Southlake_Report.pdf](#)

1.2 Project Name: Micro-Detention Project for University Park

- Agencies Involved: The City of University Park and Huitt – Zollars, Inc.
- Start Year: 2017
- End Year: 2020
- Duration: 3 years
- Project Type: Blue-Green-Grey Funding Program
- Stormwater Management: Filtration and Flood Control
- Project Description: The City of University Park experienced flooding due to limited inflow capacity of storm drains, and redevelopment that resulted in an increase in impervious surfaces in a city that was almost fully built out. They applied a micro-detention storage system (MDSS) underneath driveways, sidewalks and parking areas to divert runoff from surface flooding. This system is scalable, affordable and was intended to become a design standard for the city.
- Website: [BGG_UniversityPark_Report.pdf](#)

1.3 Project Name: Hightower Rain Garden Project for Watauga

- Agencies Involved: City of Watauga and Burgess & Niple, Inc.
- Start Year: 2018
- End Year: 2022
- Duration: 4 years
- Project Type: Blue-Green-Grey Funding Program
- Stormwater Management: Nature-Based Solution, Filtration and Flood Control
- Project Description: The City of Watauga retrofitted a rain garden on a storm drain inlet on Hightower Drive. The inlet directed water to a rain garden to filter pollutants before going into the drain system.
- Website: [BGG_Watauga_HightowerRainGarden.pdf](#)

1.4 Project Name: Bottom District Neighborhood Beautification and Green

Infrastructure – The Bottom Rain Garden

Agencies Involved: University of Texas-Arlington, The Golden S.E.E.D.S. Foundation, C-Suite Consulting, Design Jones, and the City of Dallas

- Start Year: 2021
- End Year: 2024
- Duration: 3 years
- Project Type: Blue-Green-Grey Funding Program
- Stormwater Management: Nature-Based Solution, Filtration and Flood Control
- Project Description: The Bottom is a historically underserved neighborhood located in a FEMA floodplain. The pilot project used community engagement to design a plan to increase neighborhood aesthetics and manage flood risks by creating green spaces and placing green infrastructure. The project included construction of a demonstration rain garden and development of a how-to guide for other entities interested in implementing rain gardens.
- Website: [BGG_BottomDistrict_10-02-2024.pdf](#)

1.5 Project Name: UTA Testing of Engineered Media for Biofiltration Swales

- Agencies Involved: University of Texas – Arlington
- Start Year: 2021
- End Year: 2023
- Duration: 2 years
- Project Type: Blue-Green-Grey Funding Program
- Stormwater Management: Nature-Based Solution, Filtration and Flood Control
- Project Description: This study researched bioswale infiltration as an alternative method to remove pollutants from runoff by assessing different soils and the potential of engineered shale. This research provided insights into improving stormwater filtration practices.
- Website: [BGG_LabTesting_Biofiltration_UTA.pdf](#)

1.6 Project Name: Median Bioswale Retrofit on Parkwood Boulevard

- Agencies Involved: City of Frisco
- Start Year: 2024
- End Year: 2027 (Estimated)
- Duration: 3 years

- Project Type: Blue-Green-Grey Funding Program
- Stormwater Management: Nature-Based Solution, Filtration and Flood Control
- Project Description: This project will retrofit a roadway median to function as a bioswale and help manage stormwater runoff. This innovative approach not only enhances the aesthetic appeal of the roadway but improves water quality by filtering pollutants and reducing flood risks.
- Website: N/A

1.7 Project Name: Klyde Warren Park Phase 1

- Agencies Involved: City of Dallas, Texas Department of Transportation
- Start Year: 2006
- End Year: 02/2013
- Duration: 7 years
- Project Type: Sustainable Development Funding Program
- Stormwater Management: Nature-Based Solution, Filtration, and Flood Control
- Project Description: This urban greenspace, located above the recessed Woodall Rogers Freeway in downtown Dallas, features native plants and innovative flood-reducing landscapes. It uses stormwater drainage systems including Silva Cells to capture runoff and prevent flooding of the recessed highway.
- Website: [NCTCOG - Dallas - Klyde Warren/ Woodall Rodgers](#)

1.8 Project Name: College Town

- Agencies Involved: University of Texas-Arlington
- Start Year: 2006
- End Year: 04/2012
- Duration: 6 years
- Project Type: Sustainable Development Funding Program
- Stormwater Management: Nature-Based Solution, Filtration, and Flood Control
- Project Description: This award-winning mixed-use development includes The Green at College Park, a three-acre park that was among the first three projects in the world to receive the Sustainable Sites Initiatives (SITES) Certification for landscape site development, as well as other awards. The Green incorporates low-impact development strategies, including bioswales and permeable pavement, to mitigate flooding. The overall project enhances pedestrian amenities and landscaping, creating a pedestrian environment that connects the University of Texas – Arlington to downtown Arlington.
- Website: [NCTCOG - Arlington - College Town](#)

1.9 Project Name: Thomasson Square

- Agencies Involved: City of Mesquite
- Start Year: 2010
- End Year: 09/2022
- Duration: 12 years
- Project Type: Sustainable Development Funding Program
- Stormwater Management: Nature-Based Solution, Filtration, and Flood Control
- Project Description: This roadway project enhances the street with pedestrian improvements, traffic signalization and landscaping to support mixed-use development. It has bioswales with native plants in the median to capture and filter runoff. Green spaces between roadways and sidewalks function as a permeable surface and a pedestrian safety feature.
- Website: [NCTCOG - Mesquite - Thomasson Square](#)

Table 1-1. The NCTCOG Transportation Department has had the opportunity to fund and/or plan green stormwater infrastructure projects.

Project Name	Start Date	Type of GSI	Funding Source	Study Area
Klyde Warren Park	2006	Nature-Based Solution, Filtration and Flood Control	Sustainable Development Funding Program	No
College Town	2006	Nature-Based Solution, Filtration, and Flood Control	Sustainable Development Funding Program	No
Thomasson Square	2010	Nature-Based Solution, Filtration, and Flood Control	Sustainable Development Funding Program	No
Southlake Bio Pod Burney Lane Reconstruction	2017	Filtration	Blue-Green-Grey	North
Micro-Detention Project For University Park	2017	Filtration and Flood Control	Blue-Green-Grey	No
Hightower Rain Garden Project For Watauga	2018	Nature-Based Solution, Filtration and Flood Control	Blue-Green-Grey	No
Bottom District Neighborhood Beautification and Green Infrastructure	2021	Nature Based Solution, Filtration and Flood Control	Blue-Green-Grey	No
UTA Testing of Engineered Media for Biofiltration Swales	2021	Nature-Based Solution, Filtration and Flood Control	Blue-Green-Grey	No
Median Bioswale Retrofit on Parkwood Boulevard	2024	Nature-Based Solution, Filtration and Flood Control	Blue-Green-Grey	No