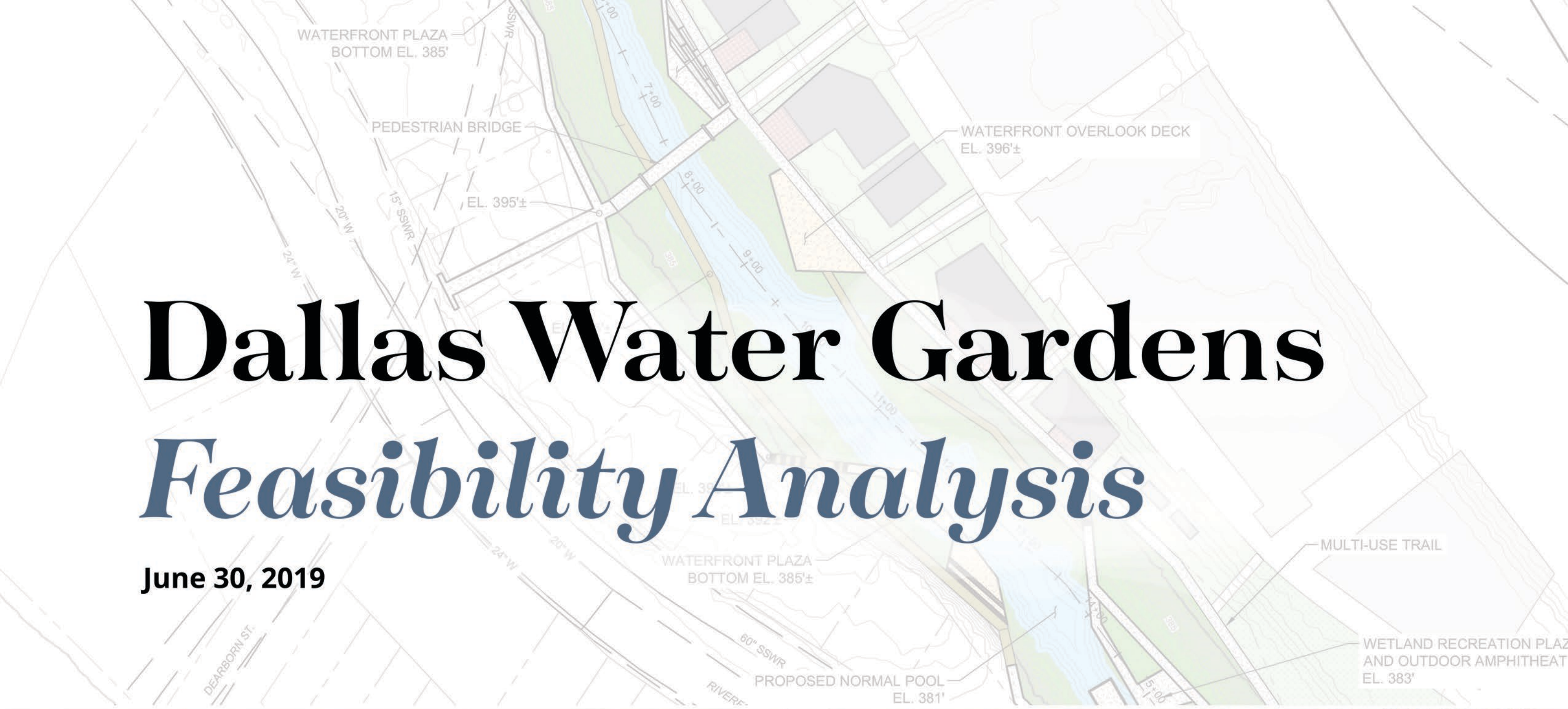

Dallas Water Gardens

Feasibility Analysis

June 30, 2019

North Central Texas
Council of Governments

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Pond 8 looking northwest toward downtown Dallas

Acronyms

BOD5	5-day Biochemical Oxygen Demand
DO	Dissolved Oxygen
GI	Green Infrastructure
HSG	Hydrologic Soil Group
NCTCOG	North Central Texas Council of Governments
NOAA	National Atmospheric and Oceanographic Administration
NOX	Nitrate + Nitrite Nitrogen
NRCS	Natural Resources Conservation Service
SSURGO	Soil Survey Geographic Database
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USDA	US Department of Agriculture
USGS	US Geological Survey

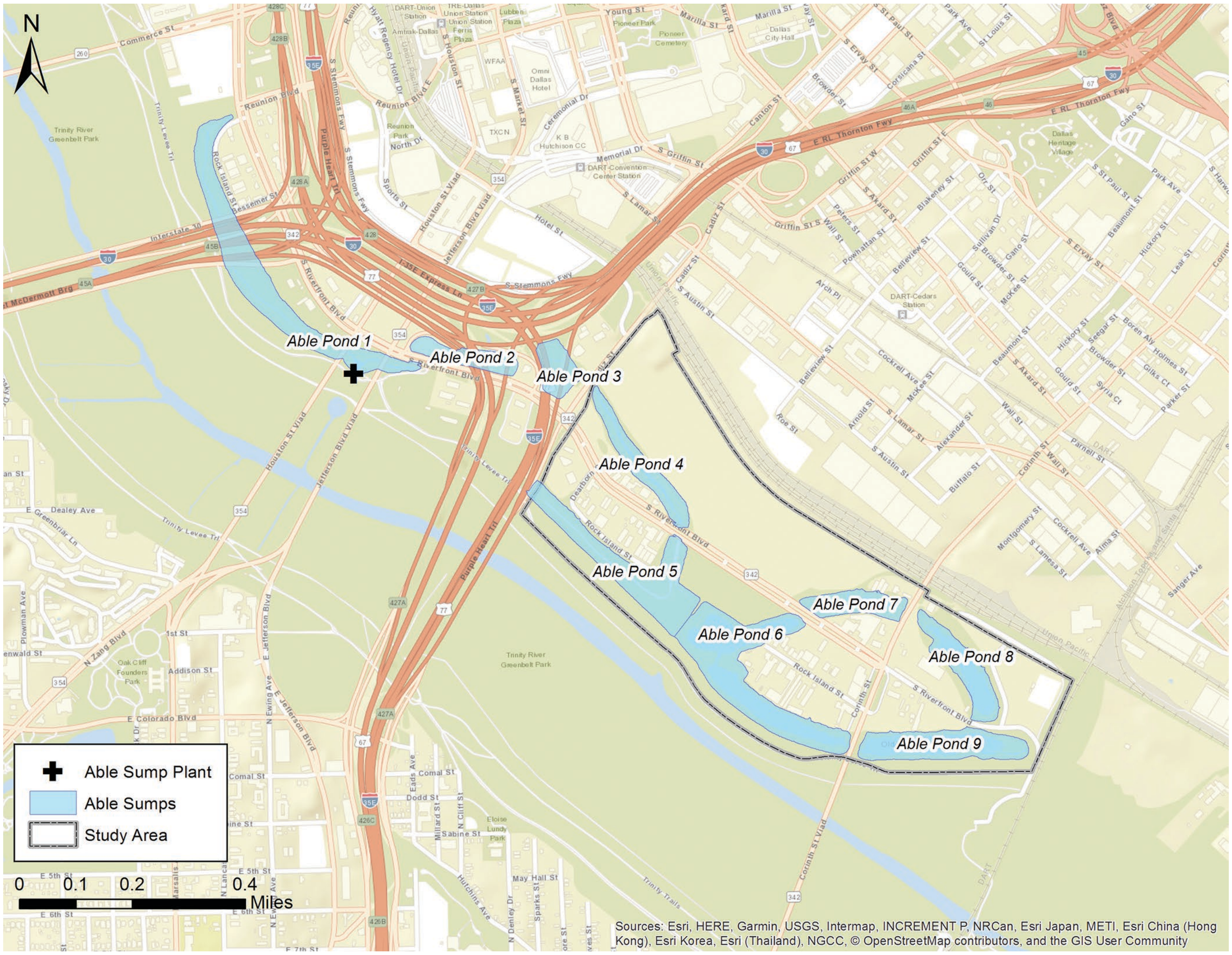
Pond 5 looking southeast

Executive Summary

The Dallas Water Gardens (Water Gardens) is a project planned south of downtown, along the forgotten path of the Trinity River where it meandered before levees were built to contain it early in the 20th Century. The impetus for the Dallas Water Gardens grows out of the storied past of the Trinity River's history and is nurtured by both the continued necessity of flood and drought control, as well as the City's enthusiasm for public green spaces.

Nine separate ponds are currently utilized by the City of Dallas to store floodwater. The ponds ("Sumps #1 through #9") are drained into the Trinity River via the Able Pump Station (Figure 1). The Dallas Water Gardens aspires to link the separate water holding areas in order that the newly enhanced ponds will embody both smart water engineering and natural wetland infrastructure to provide a hybrid city amenity. The project proposes to focus on the conversion of Ponds 4 through 9 into active wetlands.

Pond 9 looking east toward levee and Commuter rail



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community

Figure 1. Study Area for the Feasibility Analysis

Within the future of this modern urban water remediation and garden system lies an opportunity to help shift historical, physical, economic and ecological gaps in Dallas. The Dallas Water Gardens and its wetlands are to become a tranquil southern connectivity point to downtown.

The North Central Texas Council of Governments contracted Tetra Tech to perform a feasibility analysis of the proposed Water Gardens project. The feasibility study included an inventory of ongoing and proposed infrastructure projects in the study area, evaluation of soil properties, groundwater and surface water quality evaluations, hydraulics and hydrology modeling, water quality modeling, and concept schematic and ecological designs. The feasibility analysis consisted of evaluating several alternatives for mitigation of increased flood risk due to the conversion of upper ponds (4 through 7) to active wetlands. The evaluated mitigation options included capacity increase of the upper ponds via lateral expansion and excavation, using a gated structure to release water before a major storm and adding underground storage features. Each option was evaluated for flood risk, water quality impacts,

Pond 3 main stormwater outfall

impacts to the local economy, habitat creation, connection to the Trinity River, visual appeal, mitigation of urban environmental impacts, and opportunities for active recreation and wellness. The alternative presented in this document proposes a weir between Ponds 3 and 4 as the primary water impoundment structure, and recommends increasing the capacities of Ponds 5, 7 and 8 through a combination of lateral expansion and excavation for flood risk mitigation. Analysis of long-term watershed and pond hydrology and water quality, and ecological and schematic designs are based on this proposed alternative.

The Dallas Water Gardens is not a part of the Trinity River Corridor Project even though it will contribute to the Trinity River Water Management infrastructure of the City of Dallas.

The Dallas Water Gardens...

*...is a **public private enterprise** adjacent to the original path of the Trinity River south of downtown Dallas.*

*...will **filter an average of 2 billion gallons** of storm water runoff a year, providing a practical and natural way to remediate water for the city and the state of Texas.*

*...will **provide park spaces** to the City of Dallas Parks and Recreation Department, increasing the acreage of open land within the central city area.*

*...will be a **leading project in blue/green/gray infrastructure for the U.S.** due to its central urban location and natural hydrology enhanced by extensive engineering.*

*...will demonstrate the **water efficiencies and technologies** necessary for future flood and drought control.*

*...will be a **living classroom** enhanced by interactive curriculum for all students, residents and visitors of every age.*

*...will be a **working lab for engineers** exploring ways to meet the water needs of an increasing urban population.*

*...will **expand conservation opportunities** by amplifying the cleansing nature of urban wetlands and ponds.*

...will enhance much of the ***historic bed of the Trinity River*** *near downtown.*

...will provide opportunities for ***urban forestation and native plants*** *for beautification and water filtration.*

...will become a ***place of respite*** *in the heart of a busy city, blocks from the Convention Center, City Hall and the Dallas Police Headquarters.*

...will further ***connect downtown to neighboring communities*** *such as the Cedars, South Dallas, Fair Park, the Design District, and Oak Cliff through hike and bike trail connections.*

...will ***stimulate economic development*** *south of downtown and create a meaningful green pathway between Southern Dallas and the Central Business District.*

...will have a ***stream of maintenance funding*** *provided by a nearby Public Improvement District.*

...is ***managed by the Dallas Wetlands Foundation****, a 501c3 created to work in conjunction with the North Texas Council of Governments, City of Dallas, Army Corps of Engineers, non-profits, and corporations.*

...has ***enthusiastic support*** *from all levels of local, state, and federal officials as well as the surrounding neighborhoods.*

Figure 2. Base Map–Site Scale

Pond 8 looking northwest toward downtown Dallas

🟥 *Study Area*

.5 Miles

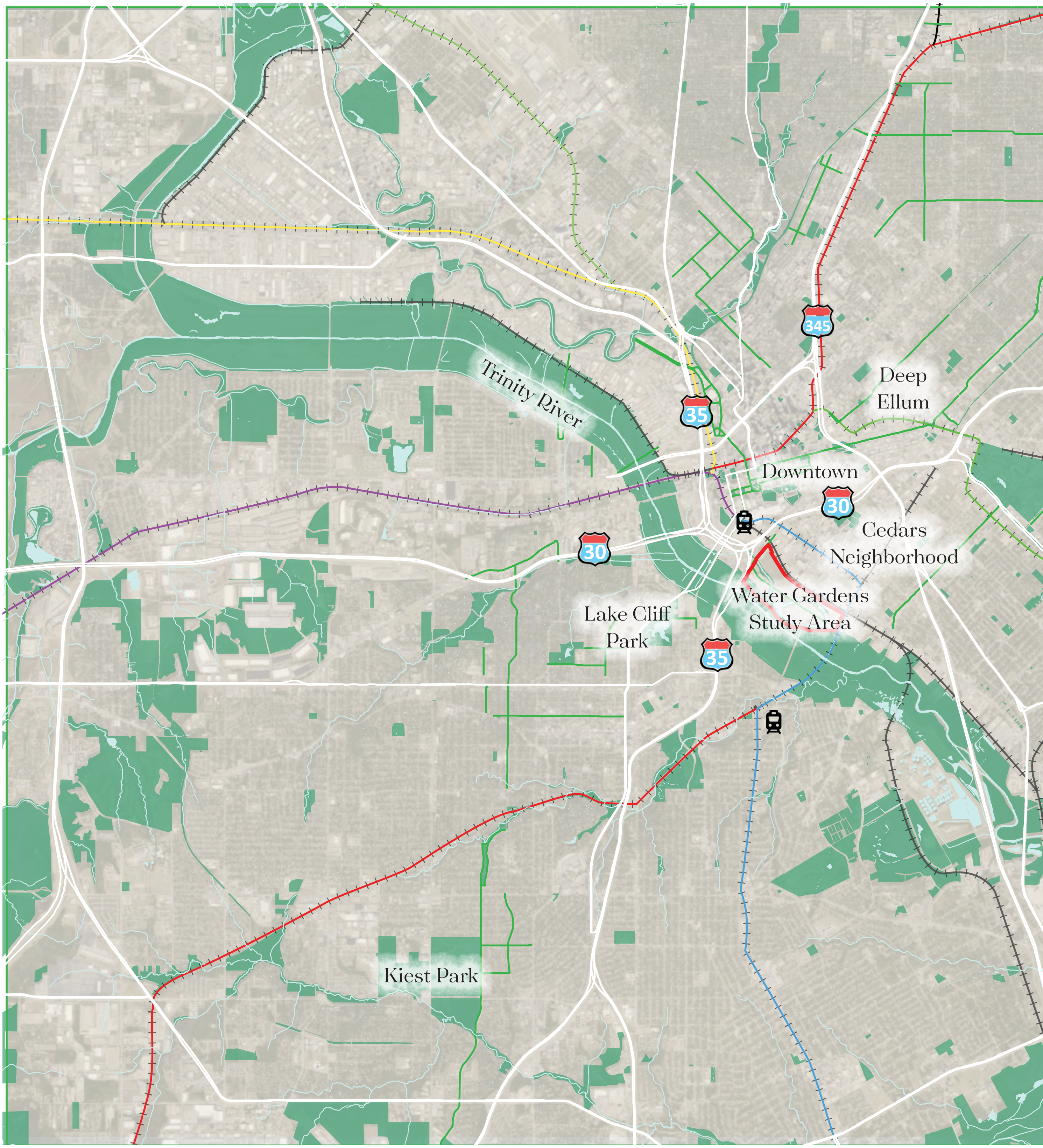
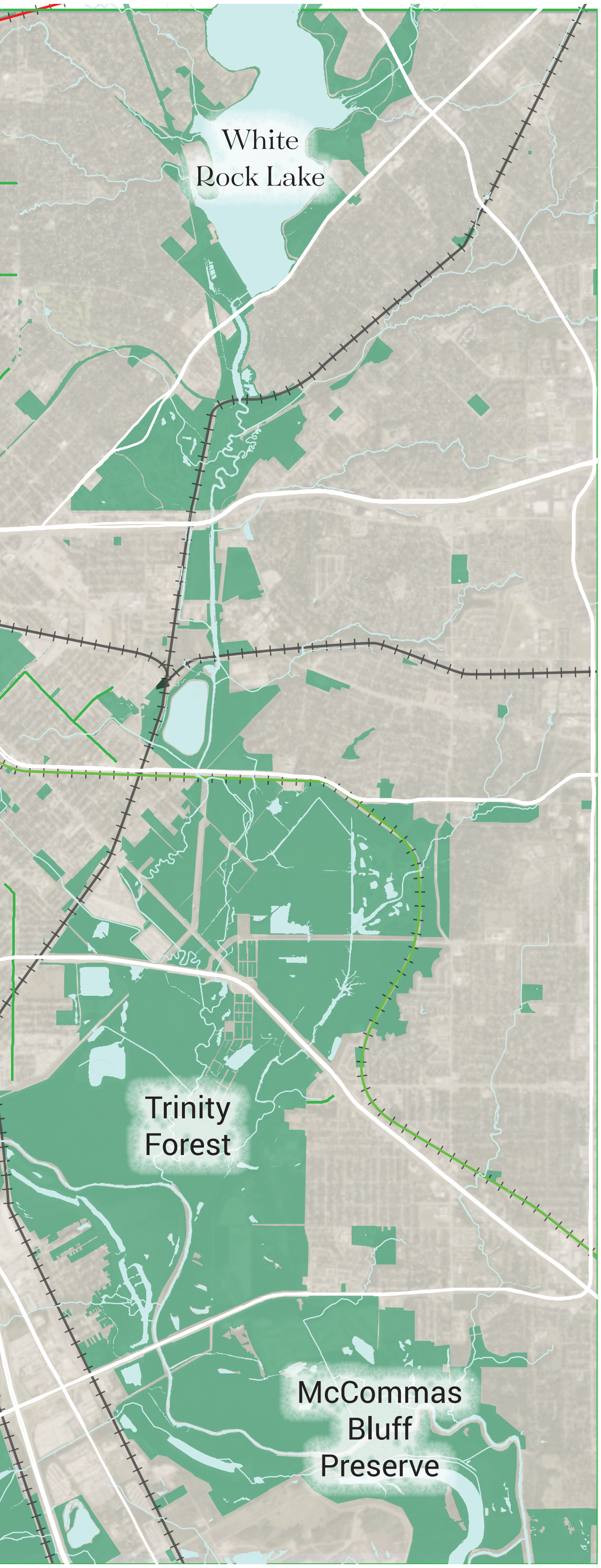


Figure 3. Base Map–Context Scale



🟥 *Study Area*

3.5 Miles


Pond 3 looking northwest toward downtown Dallas

Pond 7 looking west towards Riverfront Boulevard

1. Hydraulic and Hydrology Modeling

Existing Conditions

Able 3 Pump Station

In spring 2018, the Small Able and Large Able pump stations established in 1932 and 1957 respectively were replaced with the Able 3 Pump Station. The Able 3 Station is comprised of four (4) main pumps each with a capacity of 220,000 gallons per minute (gpm) and two (2) low flow pumps each with a capacity of 12,500 gpm. The new station has a total pumping capacity of approximately 905,000 gpm which quadruples the previous pumping capacity of the Small Able and Large Able pump stations.

Able Sump Connectivity

The Able Sump system is comprised of nine (9) interconnected ponds flowing from southeast to northwest from Pond 9 to Pond 1 as shown in

Pond 3 connection to Pond 4

Figure 4. The system is divided by the Bellevue Pressure Sewer due to the berm it creates that prevents low flow connectivity from Pond 6 to Pond 5. Because of the Bellevue Pressure Sewer flow restriction, a single barrel of 36" reinforced concrete pipe (RCP) connecting Ponds 4 and 7 is the only conduit by which the upper ponds drain under normal low flow conditions. Note that 1932 City of Dallas Bellevue Pressure Sewer as-built plans show the connection between Pond 4 and 7 crossing through the center of pressure sewer and the modeled 36" RCP was kept consistent with this alignment. During high volume events, the Bellevue Pressure Sewer berm acts as a weir and is overtopped.

With the implementation of the Able 3 Station, Ponds 1 through 4 will be dry during normal existing conditions with the modeled Cadiz Bridge improvement. Due to flowline restrictions at the upper pond connections, Ponds 5 through 9 will have a higher initial water surface elevation (WSEL) and depth than the lower ponds. A summary of starting conditions is shown in Table 1.

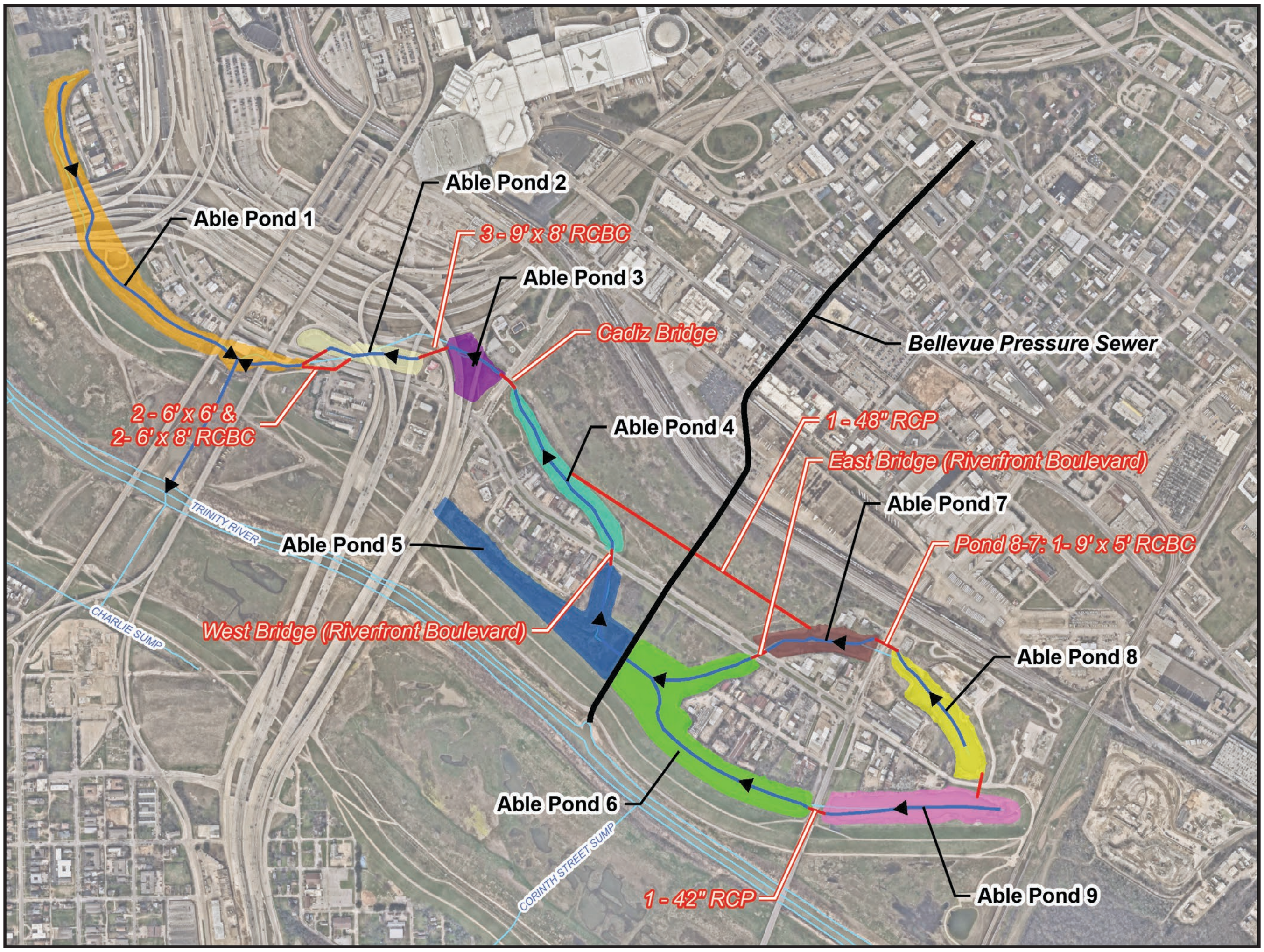


Figure 4. Study Area for the Proposed Dallas Water Gardens

Table 1. Initial Pond Conditions

Pond	Starting Condition	Initial Depth (ft)	Initial WSEL (ft)
Able Pond 1	Dry	0.0	375.0
Able Pond 2	Dry	0.0	375.4
Able Pond 3	Dry	0.0	375.4
Able Pond 4	Dry	0.0	376.6
Able Pond 5	Wet	1.0	377.0
Able Pond 6	Wet	4.0	380.0
Able Pond 7	Wet	2.7	380.0
Able Pond 8	Wet	0.6	380.0
Able Pond 9	Wet	2.3	380.0

Existing and Future Pond Connections

As a basis for existing conditions, several pond connections were updated with future bridge improvements as requested by the City of Dallas. The existing culvert for Pond 4 to 3 was updated with the proposed Cadiz Street 30% bridge design plans dated September 2015. Similarly, the Pond 7 to 6 and Pond 5 to 4 culverts were replaced with the Riverfront Boulevard 65% bridge design plans dated August 2017. A summary of the modeled pond connections is shown in Table 2.

Able Sump Pond Interaction and Sensitivity

The sump system features significant flow exchanges during periods of high flow. Water backs up towards Pond 9 during all storm events due to the 36" RCP connection between Ponds 4 and 7. Most notably, the Bellevue Pressure Sewer crossing weir allows backflow from Pond 5 to Pond 6 during periods of high rainfall. During the peak of these events, the upper ponds act as additional storage allowing the system to slowly drain through the 36” RCP after the peak has passed. Because of the interconnected nature of the Able Sump system, adjustments to any pond footprint/volume or pond connection result in peak WSEL changes for all ponds.

Overflow runoff from the Dallas Branch Pressure Sewer to the northwest of the Able Sump system and Mill Creek basin to the north have also been included in the Able Sump analysis based on best available data discussed in Appendix A. Overflow runoff from the Mill Creek basin assumes that the Mill-Peaks Tunnel, currently under construction, has been constructed and in service. Figure 5 depicts the overflow locations in relation to the Able Sump system.

Table 2. Pond Connections

Location	Existing Connection	Modeled / Future Connection[1]
Pond 9-6	1 - 42" RCP	1 - 42" RCP
Pond 9-8	1 - 48" RCP	1 - 48" RCP
Pond 8-7	1 - 9' x 5' RCBC	1 - 9' x 5' RCBC
Pond 7-4	1 – 36" RCP	1 - 4' x 4' RCBC
Pond 7-6	1 – 6’ x 6’ RCBC	Proposed Riverfront Boulevard East Bridge
Pond 6-5	Bellevue Pressure Sewer acts as a weir	Bellevue Pressure Sewer acts as a weir
Pond 5-4	2 – 6' x 6' RCBC	Proposed Riverfront Boulevard West Bridge
Pond 4-3	1 – 9' x 8' RCBC	Proposed Cadiz Bridge
Pond 3-2	3 - 9' x 8' RCBC	3 - 9' x 8' RCBC
Pond 2-1	2 - 6' x 8' and 2 - 6' x 6' RCBC	2 - 6' x 8' and 2 - 6' x 6' RCBC

[1] The modeled/future connections have been incorporated into the existing conditions analysis and will need to be constructed prior to or in conjunction with the Dallas Water Gardens in order to meet City drainage criteria.

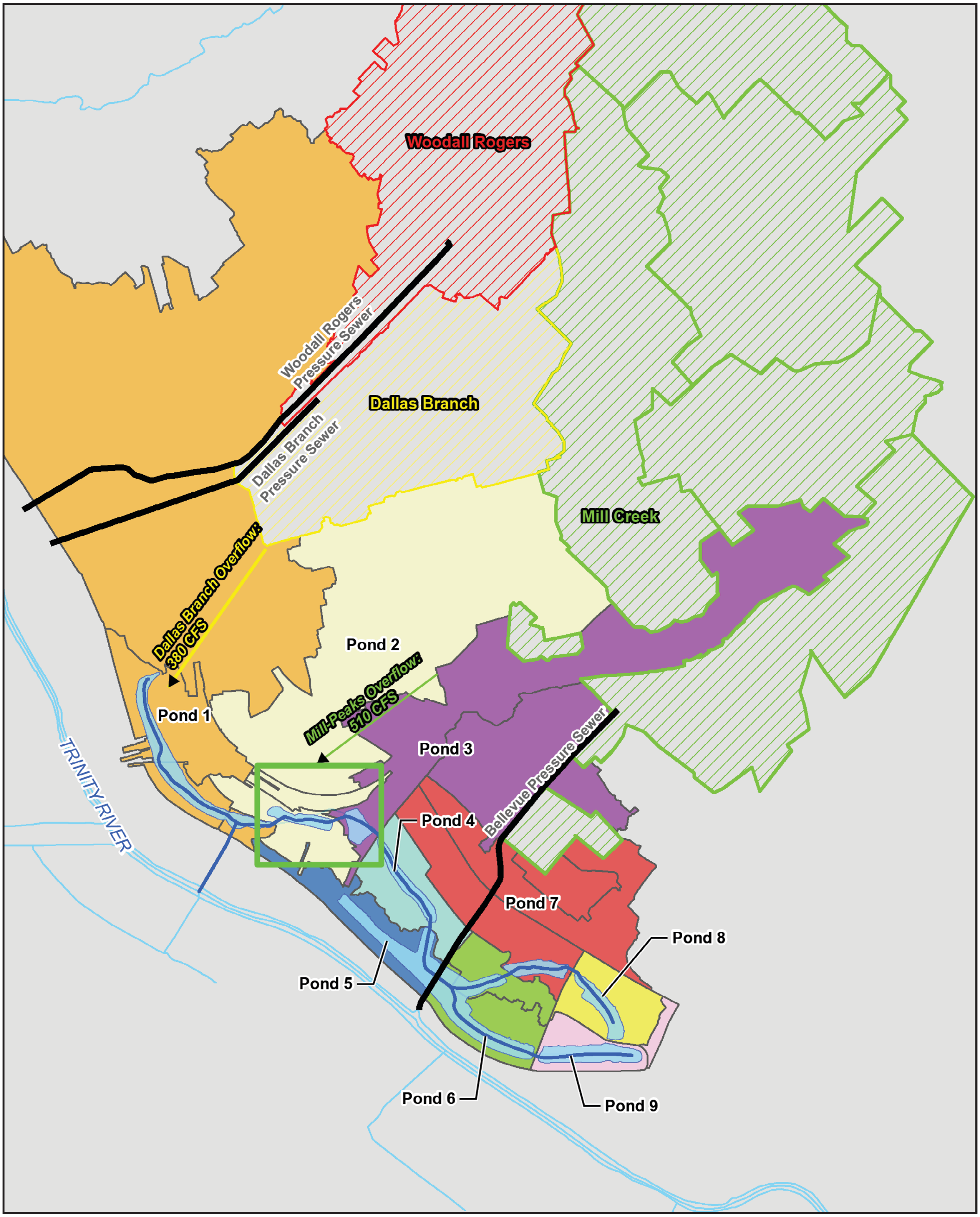


Figure 5. Able Pump Overflow

Pond 4. Top: looking south towards Riverfront Boulevard; Bottom: looking north-northwest towards downtown

Able Sump 100-Year Floodplain

The existing 100-year floodplain for the Able Sumps system is well-contained within the existing pond footprints of all ponds except for some slight spill along Riverfront Boulevard. The floodplain limits in relation to the Dallas Water Gardens project site is shown in Figure 6.

Figure 6. 100-year floodplain (yellow) at project site

Proposed Water Gardens

Proposed Hydraulic Design

The proposed Dallas Water Gardens conceptual design features a weir at Cadiz Street between Ponds 3 and 4 that establishes normal pool conditions that support the ecologic design and schematic of the Dallas Water Gardens project.

The Able Sump modeling demonstrated that implementing a weir at Cadiz Street would require floodplain mitigation measures to meet the City of Dallas drainage design criteria. The floodplain mitigation features include improvements to the existing 36" RCP connection between Ponds 4 and 7 and excavation to increase the capacities of Ponds 5, 7, and 8 as described below.

Another floodplain mitigation measure that was considered would allow Ponds 4 and 5 to drain through a mechanical or user-operated gate located at the bottom of the proposed weir when a significant rain event is predicted. This alternative would have the benefit of using the existing storage in Ponds 4 and 5 for storing floodwaters without additional excavation. However, this system has challenges. In the event where a predicted rain event does not occur, water may need to be replenished in order to reestablish normal pool ecological conditions along the proposed terraced pond edge. Additionally, the gate operations require lead time to empty Ponds 4 and 5 before the predicted rain event, which could otherwise result in hazardous conditions along Riverfront Boulevard. For these reasons, the gate control alternative was not further pursued. By addressing the volume needs through excavation in Ponds 5, 7, and 8, the gate would not be necessary.

Initial Condition Changes due to Proposed Project

The proposed weir has a crest elevation of 381.0 feet, will be approximately 100 feet in length, and is located on the north side of Cadiz Street as shown on Figure 7. The weir will establish a normal pool in the upper ponds that supports the ecological conditions along Pond 4. Additional storage will be needed to offset the volume of water needed to create the water gardens. Changes in initial pond conditions are shown in Table 3. During an existing conditions storm event, Pond 4 was considered to begin dry and Pond 5 had 1.0 foot of depth due to the Riverfront Boulevard bridge flowline. Under proposed conditions, the ponds begin with 4.4 feet and 5.0 feet of water depth respectively.

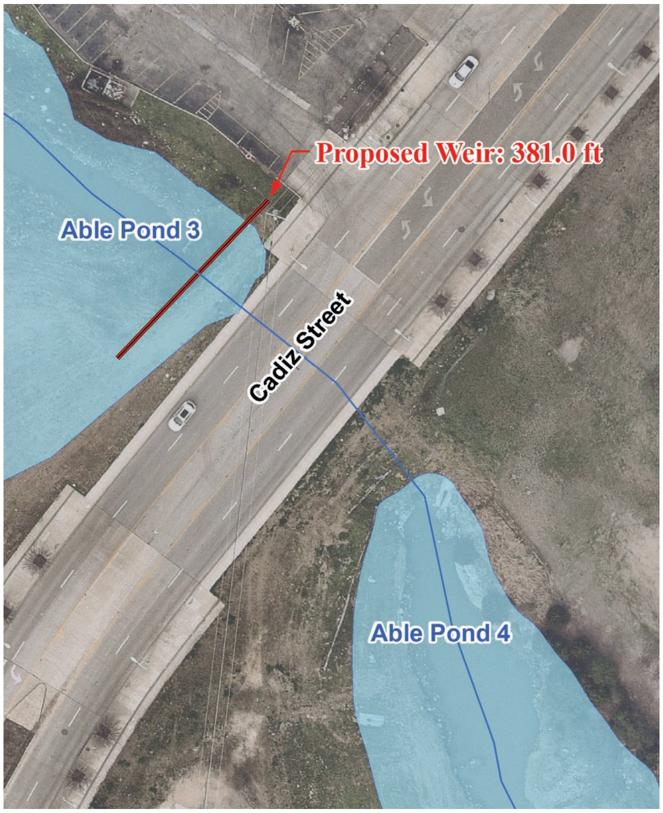


Figure 7. Proposed weir location

The increase in normal pool elevation for the Able Sump system results in a loss in available storage volume that will be addressed with excavation in key areas to be discussed below.

Table 3. Proposed Pond Initial Conditions

Pond	Starting Condition	Existing Initial Depth (ft)	Proposed Initial Depth (ft)	Existing Initial WSEL (Ft)	Proposed Initial WSEL (Ft)
Able Pond 1	Dry	0.0	0.0	375.0	375.0
Able Pond 2	Dry	0.0	0.0	375.4	375.4
Able Pond 3	Dry	0.0	0.0	375.4	375.4
Able Pond 4	Wet	0.0	4.4	376.6	381.0
Able Pond 5	Wet	1.0	5.0	377.0	381.0
Able Pond 6	Wet	4.0	5.0	380.0	381.0
Able Pond 7	Wet	2.7	3.7	380.0	381.0
Able Pond 8	Wet	0.6	1.6	380.0	381.0
Able Pond 9	Wet	2.3	3.3	380.0	381.0

Pond 7 connection to Pond 8

Proposed Excavation in Able Ponds 5, 7, and 8

The City of Dallas regulates the 100-year floodplain such that rises to the nearest hundredth of a foot are prohibited on adjacent property owners. In order to satisfy City criteria, the minimum amount of excavation needed to provide adequate storage mitigation is provided in Table 4. The excavation in Ponds 5, 7, and 8 will increase the volume of the Able Sump system by approximately 28 acre-ft. The volume adjustment to Able Pond 7 can be achieved within City owned property and will not require additional land. The Pond 5 and 8 excavations will require an additional combined area of approximately 2 acres if the excavation is horizontal and does not lower the pond flowlines. The City of Dallas owns approximately 3 acres of land surrounding the ponds as shown on Figure 8.

The required excavation does not consider volume loss due to potential proposed boardwalks, piers, retaining walls, or other features that require fill that could be incorporated into the Dallas Water Gardens final design at a later date. As the project progresses and these features are designed, modifications to the amount of excavation may be necessary to meet City criteria.

Table 4. Proposed Storage Change for Water Gardens

Location	Footprint Increase (ac)	Volume Increase (ac-ft)
Able Pond 5	1.3	11
Able Pond 7	0.0	11
Able Pond 8	0.5	6
Total	**1.8**	**28**

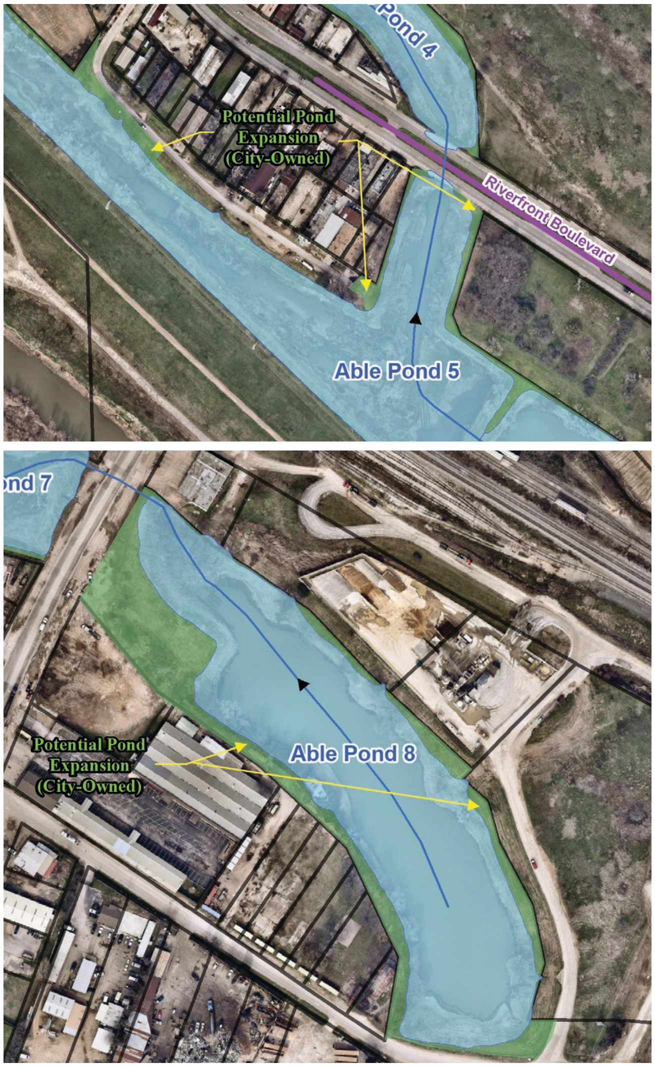


Figure 8. Potential pond expansion in Ponds 5 and 8

Realignment of Pond 4 and 7 Connection

The City of Dallas has expressed their support to remove and replace the current Pond 4 to Pond 7 connection. A replacement connection was established to work in conjunction with the Dallas Water Gardens weir design and meet City drainage criteria. The existing 36" RCP is proposed to be replaced with a 4-foot by 4-foot RCB relocated along the north side of Riverfront Boulevard (Figure 8). Note that the 4-foot by 4-foot RCB replacement would require crossing through the center of the Belleview Pressure Sewer similar to the existing 36" RCP alignment. An alternative replacement connection is a 36" RCP siphon under the pressure sewer with drop structures on either side to maintain the normal pool in Ponds 5 and 6. The added capacity and shorter culvert lengths in the replacement connections allow for better balance of flow with the upper ponds during all storm events and faster drainage from the upper ponds when the storm event has passed. Replacement of the existing 36" RCP is also recommended because it is difficult to maintain.

The hydraulic models show that a combination of pond excavation, replacement of the Pond 4 to 7 connection, and installation of the weir will not cause increases in water surface elevation on adjacent properties during the 100-year storm event.

2. Watershed and Pond Hydrology and Water Quality

Existing Conditions

A watershed modeling approach was adopted to simulate the hydrological processes and behavior of pollutants in the Able system under existing conditions and the proposed Water Gardens scenario. Continuous simulation modeling was carried out from 1/1/2009 to 4/30/2019 using XPSWMM. The hydraulic details in the continuous simulation XPSWMM model were identical to those in the event-based model discussed above.

Precipitation data in the model is based on sub-hourly observations reported for the Dallas Love Field (WBAN ID - 13690) acquired from the National Oceanic and Atmospheric Administration (NOAA). This station is very close to the study area and NOAA reports 100% data coverage (i.e., no data-gaps). Precipitation in the Dallas-Fort Worth metroplex shows seasonal trends with lowest amounts reported for the summer months. The reported average air temperatures are also the highest during these months, suggesting a potential for high evaporative losses during these months (Figure 9).

Pond watershed characteristics including landuse and imperviousness fractions were based on local landcover data. According to the Soil Survey Geographic (SSURGO) database, soils in the watersheds generally belong to the D hydrologic soil group (HSG), indicating poor infiltration capacity and high runoff potential. The US Department of Agriculture (USDA) National Resources Conservation Service (NRCS) classifies soils into four HSGs based on infiltration characteristics. Soils classified as A or B have high to moderate infiltration capacities and low runoff potential while C or D soils have poor infiltration capacities and high runoff potential. The poor infiltration capacity of the soils in the study area is also supported by the geotechnical analysis, as summarized in the *Technical Memorandum*.

Simulated average annual outflow and water quality loads were verified against site-specific data and local studies. The total average annual runoff simulated by the XPSWMM model over a period of 10 years was comparable to the observed

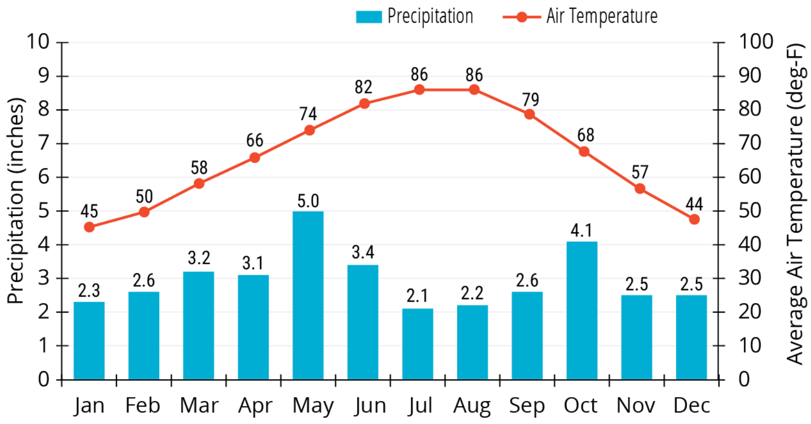


Figure 9. Average monthly precipitation and range (25th - 75th percentile) and average monthly air temperature reported for the Dallas-Fort Worth metroplex (1975-2018).
Source: National Weather Service

streamflow reported by the US Geological Survey for the Turtle Creek, a watershed with similar landuse characteristics and close to the study area. The range of water depths in Pond 1 simulated by the model were comparable to the reported stage over the past 3 years. The long-term simulated water balance for the pond watersheds is shown in Figure 10. Bulk of the simulated evapotranspiration is from the subsurface store (upper and lower zone soil evapotranspiration). The average annual runoff simulated by the model over the simulation time-period is 25.24 inches. The watersheds for Ponds 1, 2 and 3 (lower ponds) have large areas and have more impervious cover than the other ponds. The bulk of the total runoff (~83%) is therefore associated with the lower pond watersheds (Figure 11).

Water quality simulations were carried out for total suspended solids (TSS), total nitrogen (TN)

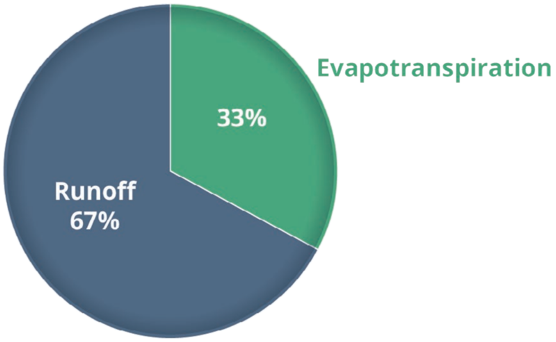


Figure 10. Simulated long-term water balance for the pond watersheds

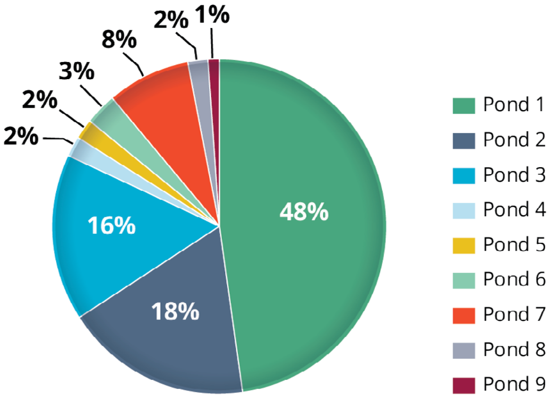


Figure 11. Proportion of total system runoff generated by the different pond watersheds

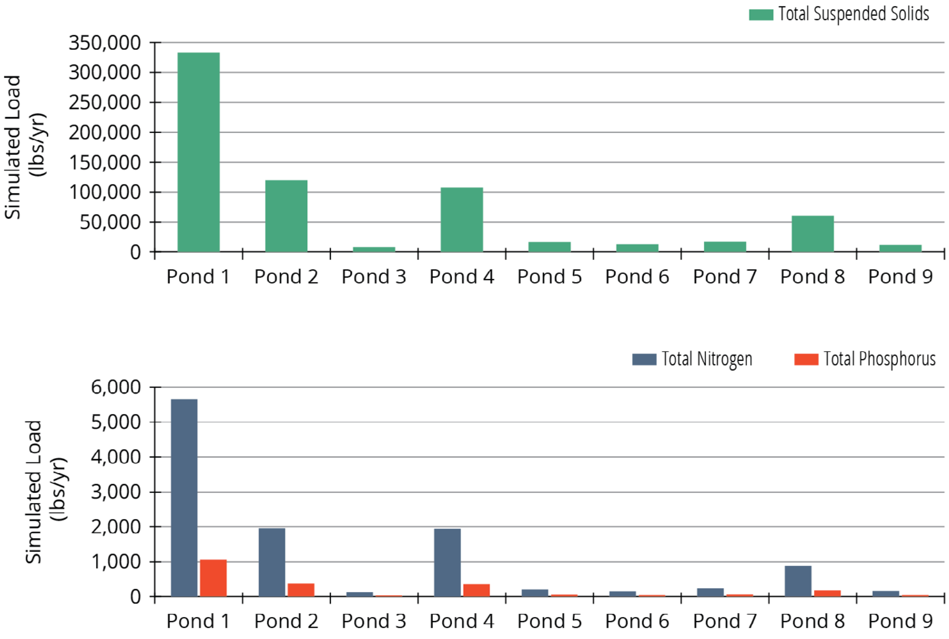


Figure 12. Simulated average annual sediment and nutrient loads for the pond watersheds

and total phosphorus (TP) using the XPSWMM model. Simulated unit area pollutant loading rates generated by the model were comparable to the estimates reported by US Geological Survey study for small commercial, industrial and residential watersheds in the Dallas-Fort Worth metroplex. Consistent with the hydrology simulation, the bulk of the pollutant loads are generated in the upper pond watersheds (Figure 12). Approximately 67% and 68% of watershed sediment and nutrient loads, respectively, are generated in the watersheds for ponds 1, 2 and 3. Simulated flow-weighted concentrations and loads of TSS, TN and TP in Ponds 4 and 1 outflow are shown in Table 5. The model simulated very little removal of sediment and nutrients in Pond 4. Removal is simulated in the remaining upper ponds (5 through 9) since they already hold some water under existing conditions.

Table 5. Concentrations and Loads of Sediment and Nutrient Outflow from Pond 4 and 1 under Existing Conditions

Pond	Constituent	Concentration (mg/L)	Load (lbs/yr)
Pond 4	TSS	30.865	32,793
	TP	0.127	135
	TN	0.770	818
Pond 1	TSS	50.812	581,404
	TP	0.169	1,929
	TN	1.348	15,421

Purple-brownish coloration of Pond 4 water on December 11, 2018

Proposed Water Gardens Scenarios

The Water Gardens scenario consisted of evaluating the long-term hydrology and water quality characteristics of the system due to the conversion of Ponds 4 to 7 to a wetland system. The key considerations were the ability of the system to improve water quality while ensuring that the primary flood control goal of the Able system was satisfied. This scenario consisted of maintaining a permanent pool at 381' throughout the upper ponds (see Figure 13 for depth-duration curve for Pond 4). This is equivalent to a normal pool depth of 4 to 5' in most ponds. Ponds 7 and 8 have higher invert elevations than the other upper ponds and therefore a normal pool elevation of 381' results in lower average depths.

The water quality simulation for the proposed Water Gardens scenario suggests a net reduction in sediment and nutrient concentrations and loads transported out of Pond 4 and Pond 1 compared to existing conditions (Table 6). The results suggest that the Water Gardens improve the water quality in the upper ponds and also reduce the transport of sediment and nutrient to the Trinity River.

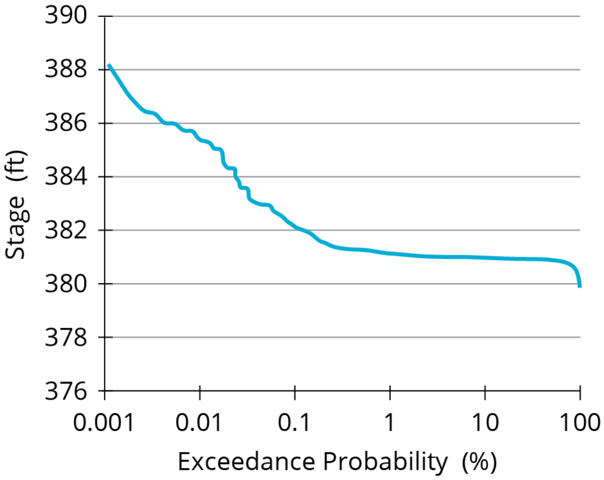


Figure 13. Stage-duration curve for Pond 4

Table 6. Concentrations and Loads of Sediment and Nutrient Outflow from Pond 4 and 1 under the Proposed Water Gardens Scenario

Pond	Constituent	Concentration (mg/L)	Load (lbs/yr)
Pond 4	TSS	18.787	19,879
	TP	0.105	111
	TN	0.596	630
Pond 1	TSS	49.652	568,283
	TP	0.166	1,904
	TN	1.330	15,224

Relative to existing conditions, the average velocities reduce while the residence times increase, which promote settling of solids and uptake of nutrients. There is a potential for an increase in sediment accumulation in the upper ponds under the Water Gardens scenario due to increased settling. Accumulated sediment can also exert an oxygen demand on the pond water column. Stormwater best management practices (BMPs), such as sediment forebays and green infrastructure (GI), are therefore recommended to reduce sediment accumulation and improve water quality in the upper ponds.

Pond 4 was periodically sampled for bacteria, specifically Escherichia coli (E. coli). The geometric mean (GM) and statistical threshold value (STV) for E. coli based on the limited number of samples collected in Pond 4 are 136 and 802 cfu/100mL, respectively. The US Environmental Protection Agency's (USEPA) Recreational Water Quality Standards requires the GM and STV for E. coli at 120 and 410 cfu/100mL, respectively. The USEPA also stipulates that the GM should not exceed the threshold in any 30-day interval and only 1 in 10 samples may exceed the STV. Pond 4 therefore does not pass the USEPA's criteria for primary contact under existing conditions.

The modeling indicates removal (die-ff) of bacteria in the upper ponds under existing conditions. The fraction removed increases substantially under the proposed Water Gardens scenario. However, in the absence of adequate sampling data the modeling results are largely unverified. Primary contact in Pond 4 is therefore not recommended.

A detailed three-dimensional (3D) computation fluid dynamics (CFD) model for Pond 4 was developed using Flow3D to evaluate shear stresses under the proposed Water Gardens scenario and inform the need for protective measures to reduce scour. The CFD model was configured for the backflow conditions during a 100-year storm with the boundary conditions informed by the XPSWMM model. Limited bathymetry data based on the available LiDAR data was used to configure the model. The results suggest that excessive shear may be a concern in some parts of Pond 4. The accuracy of the bathymetry used in the CFD model has a significant impact on the modeling results. Note that the bathymetry for Pond 4 based on LiDAR stops at an elevation of 381'. The bathymetry contours below 381' (Pond 4 invert is at 376') are estimated. The CFD modeling results should therefore be considered preliminary.

3. Ecological Analysis and Proposed Design

Existing Conditions

The stakeholders in the project area will dictate the ultimate design of the wetland ecosystem. The goal of this study was to use both discrete planting strategies as well as broader landscape concepts to integrate the project with surrounding human and natural communities (Figure 14). To this end, the evaluation considered the historic context of the study area and assessed the wildlife interface, land use and landcover, topography, pollution risk and urban heat islands. See Figures 15–23. Existing data and the modeling were used to inform the planting design and ensure that the project site successfully functions ecologically while also providing equitable public access and universally accessible opportunities to interact. Strategies for adaptive management plans that focus on managing sites as ever-changing and evolving systems were investigated to ensure expectations are met.

Pond 9 looking west toward the river levee

Guiding Principles

The Dallas Water Gardens Plant Community Structure Vision presents an incredible opportunity to integrate ecological function, aesthetic design, recreation planning, and educational programming to create an attraction with social and economic value for local and regional residents. The schematic design for the site was guided by eight principles in the interest of these goals.

Connect to the Trinity River

The Trinity River is the primary waterway of the Metroplex. The river and its West and Elm Forks connect Fort Worth, Arlington, Grand Prairie, Irving, Lewisville, Carrolton, and Dallas, and anchor dozens of parks, golf courses, and other greenspaces. Dallas Water Gardens provides a new opportunity for connection to the river on which the Metroplex was built with wetlands that speak to and respect the native physiography.

Enhance Visual Interest

Careful grading, a well-selected plant palette, and intentional planting design can create a stormwater wetland that is not only functional, but beautiful as well. With proper design, Dallas Water Gardens has the potential to be an asset for the neighboring community and an attraction for the City as a whole.

Absorb Storm Events

Stormwater wetlands are designed to receive and accommodate runoff from surrounding impervious surfaces during a storm event, and to slowly release it downstream in the days following. In doing so, they minimize the risk of flooding to nearby homes, businesses, roads, and infrastructure.

Mitigate Urban Environmental Impacts

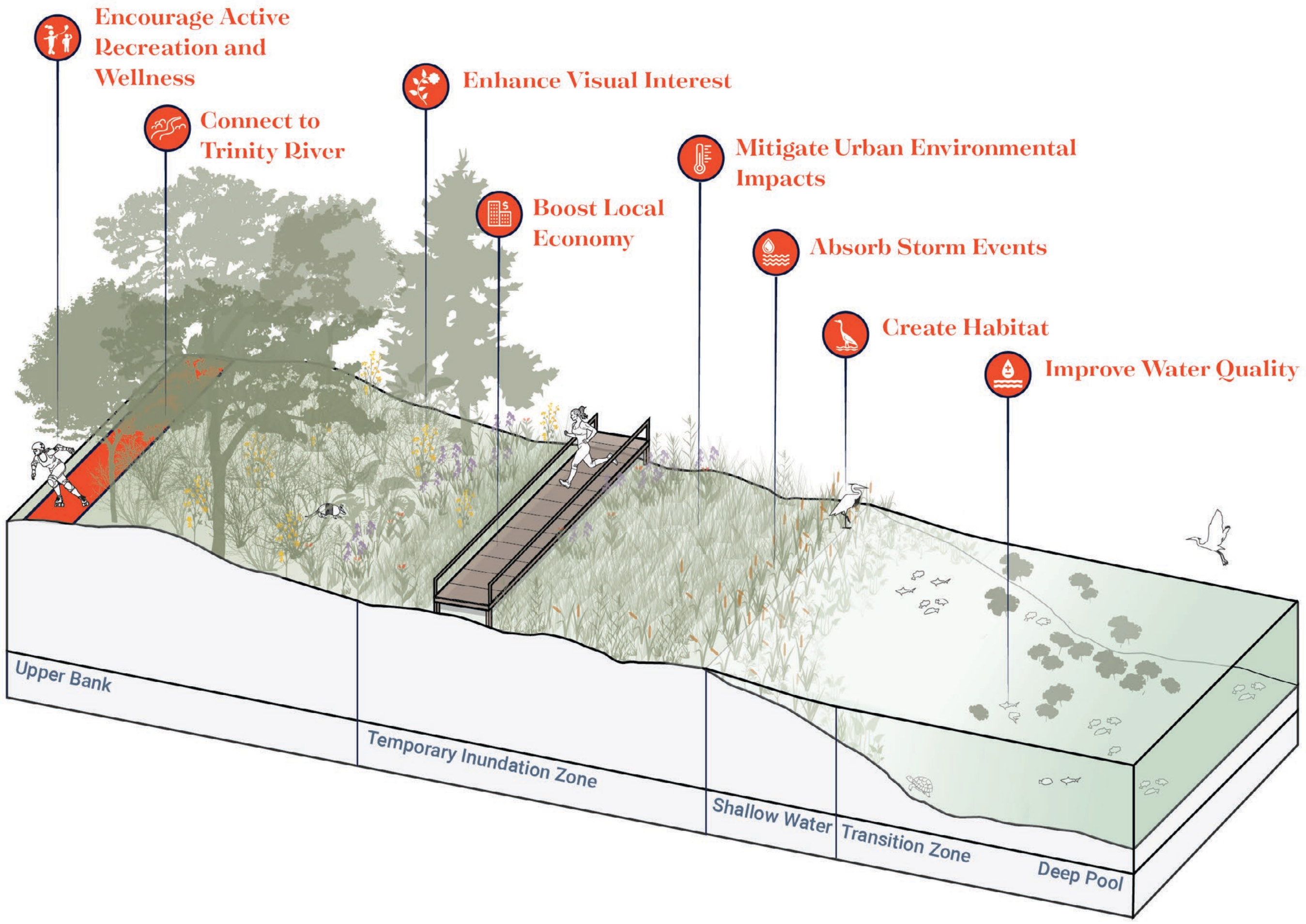
With both aquatic and terrestrial components, stormwater wetlands provide counterbalance to their harsher urban surroundings. As a rich and dynamic ecosystem, Dallas Water Gardens will have the capacity to mitigate heat island effect, reduce air pollution, and capture atmospheric carbon for the adjacent neighborhood.

Improve Water Quality

Stormwater wetlands are one of the most effective ways to reduce pollutant levels in urban runoff. Proper design and planting can create an ecosystem that can help remove suspended solids (sediment), nitrate and ammonia forms of nitrogen, phosphate and phosphorus, and some heavy metals.

Encourage Active Recreation and Wellness

Stormwater wetlands are dynamic, aesthetically and topographically interesting green spaces that can be highly desirable places for outdoor recreation in an urban context. Boardwalks and paths can provide opportunities for casual or active exercise, as well as access to the nature that calls the wetland home.



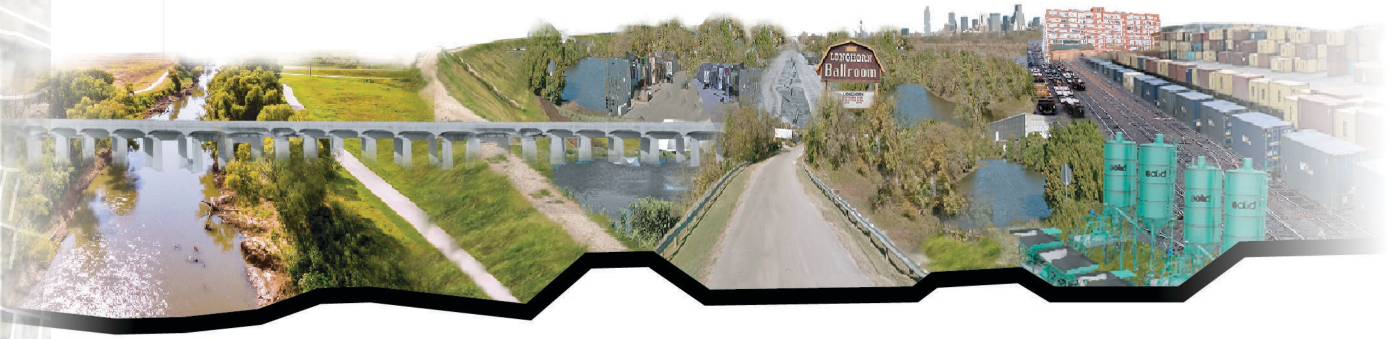
Create Habitat

Healthy, functioning wetlands with a variety of plant material and microenvironments attract and support diverse communities of mammals, birds, fish, and insects. They also serve a significant seasonal function as places for migratory species places to rest and refuel.

Boost Local Economy

A stormwater wetland that is also a vibrant, attractive recreation and education destination will draw visitors from the surrounding community, the city and beyond. These visitors will patronize local businesses, and possibly spur the creation of new ones, providing a new source of income in the local economy.

Figure 14. Site Sections


LONGHORN
Ballroom
solid

Eastern Pondhawk

These dragonflies are common near bodies of water, where they hunt and mate among the riparian vegetation. The Pondhawks maintain insect populations through predation, and are important prey for frogs, reptiles and small mammals.

Coopers Hawk

These medium sized hawks are well adapted to urban environments, using buildings as vantage points to launch surprise attacks on smaller birds, their primary prey. Coopers Hawks maintain pigeon and other nuisance bird populations.

Western Ribbon Snake

A type of garter snake, these semi-aquatic snakes are found in riparian ecosystems where they prey upon small insects, frogs and reptiles. They are harmless to humans and serve as prey to larger snakes, birds and mammals.

Yellow Crowned Night Heron

The Yellow Crowned Night Heron can be found stalking its prey of crustaceans and other small creatures in the shallow waters of creeks and marshes. These birds have few predators but are under threat from habitat loss.

Figure 15. Wildlife Sightings

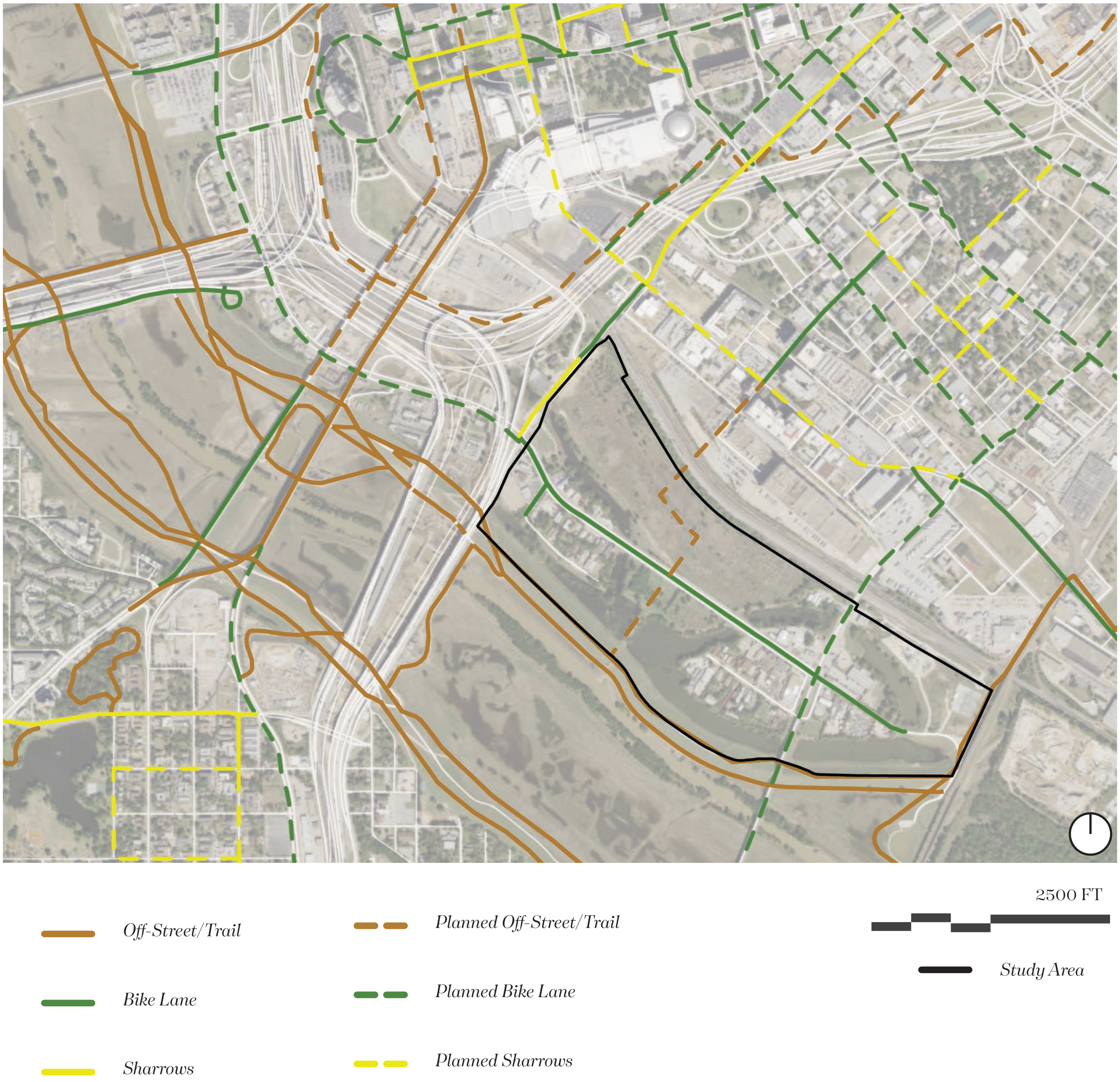
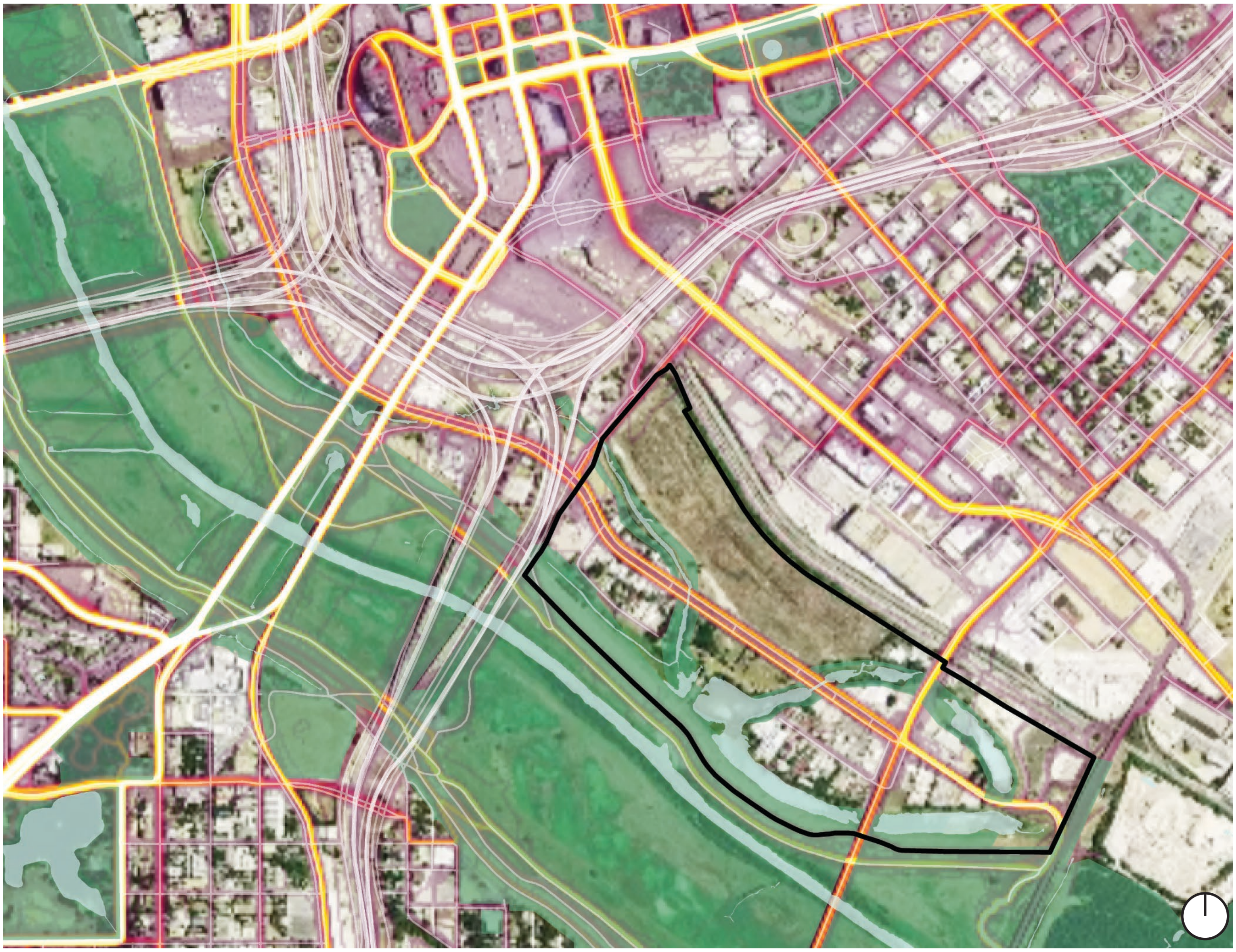


Figure 16. Bicycle Facilities



Strava is a GPS tracking platform that allows users to record their cycling, walking, and other activities and compare them with other users. Strava has since aggregated this data into a publicly accessible "Heat Map" that allows users to view the most heavily trafficked corridors for their particular mode.

Figure 17. Strava Heat Map

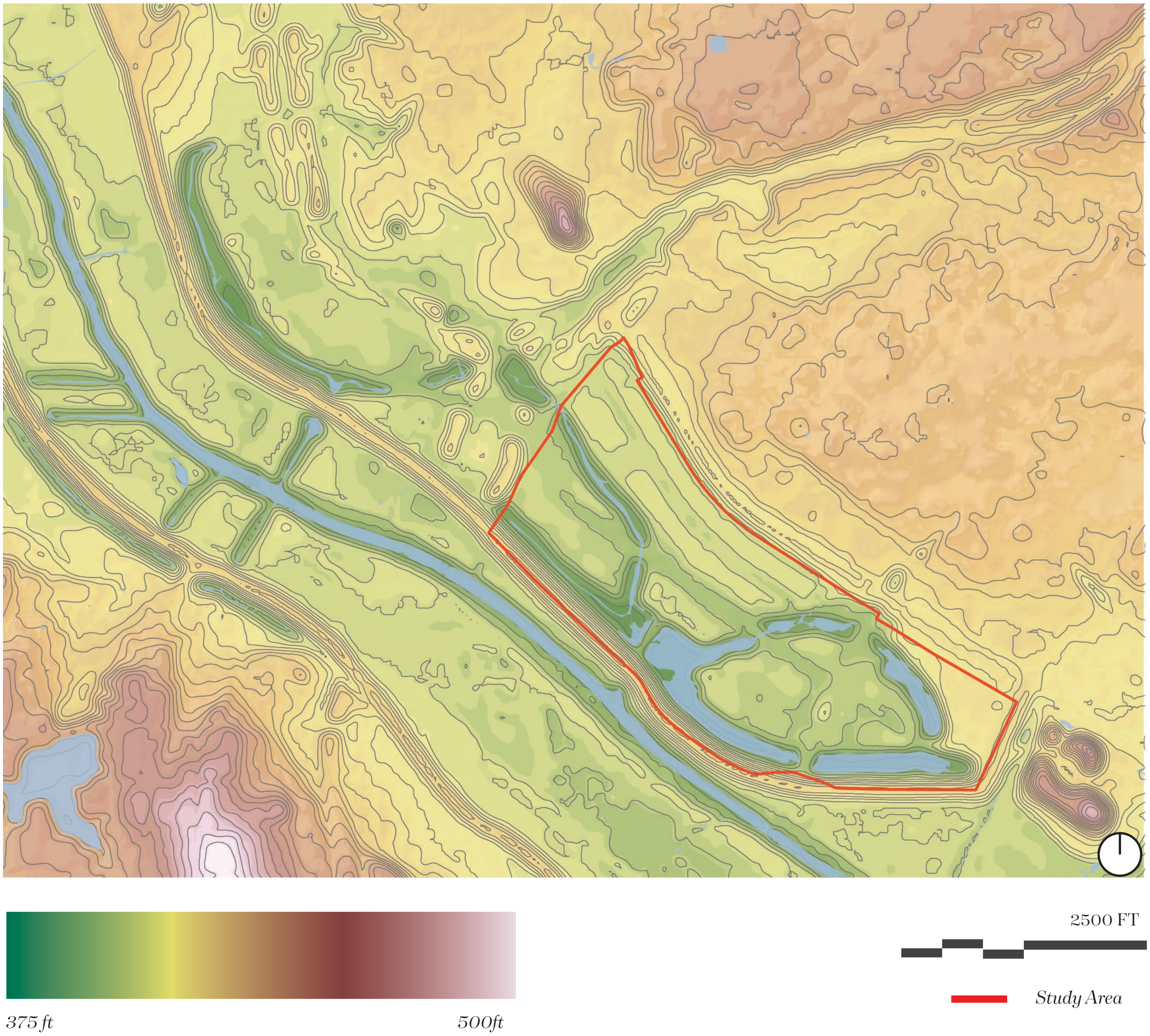


Figure 18. Topography

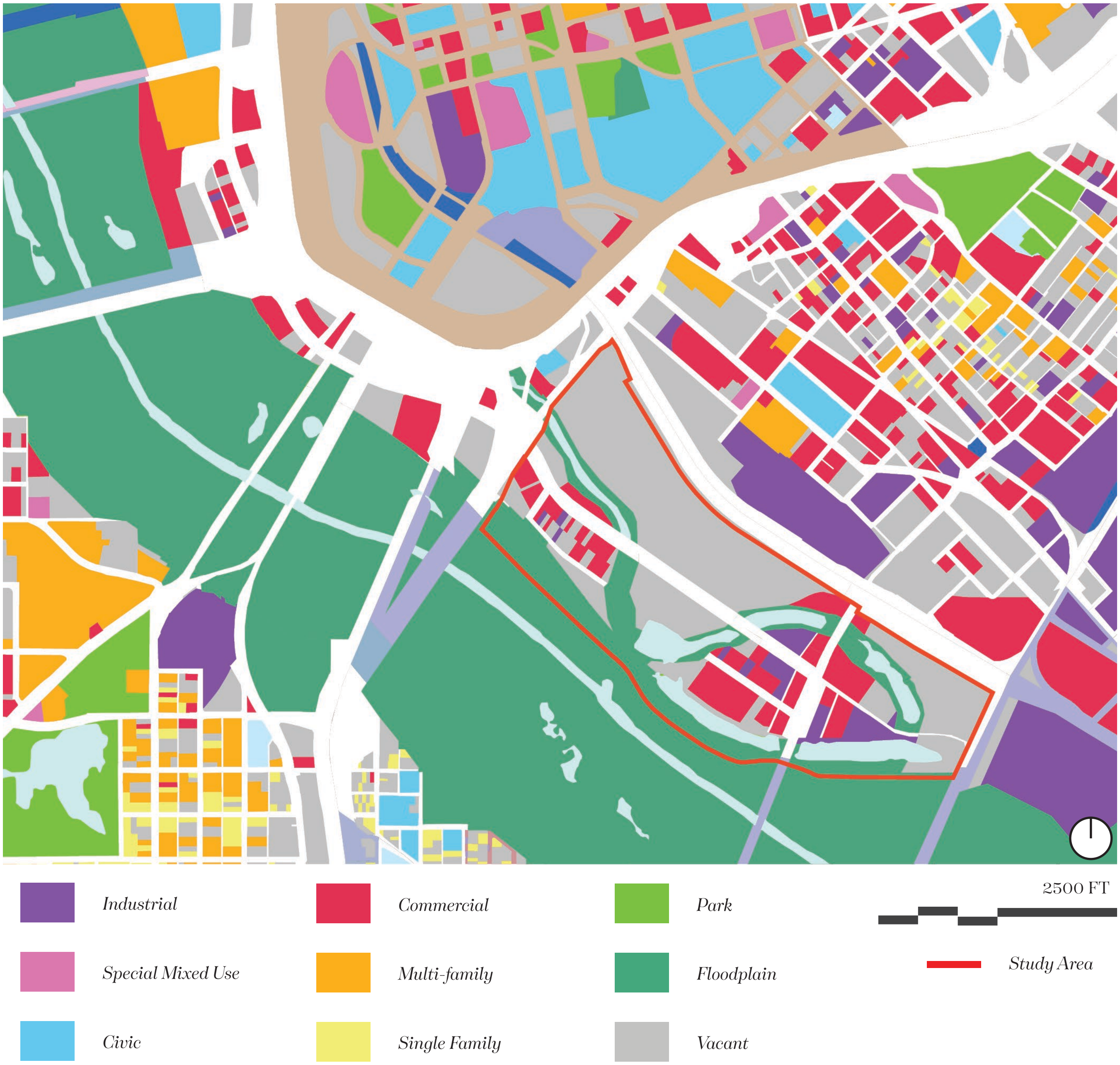
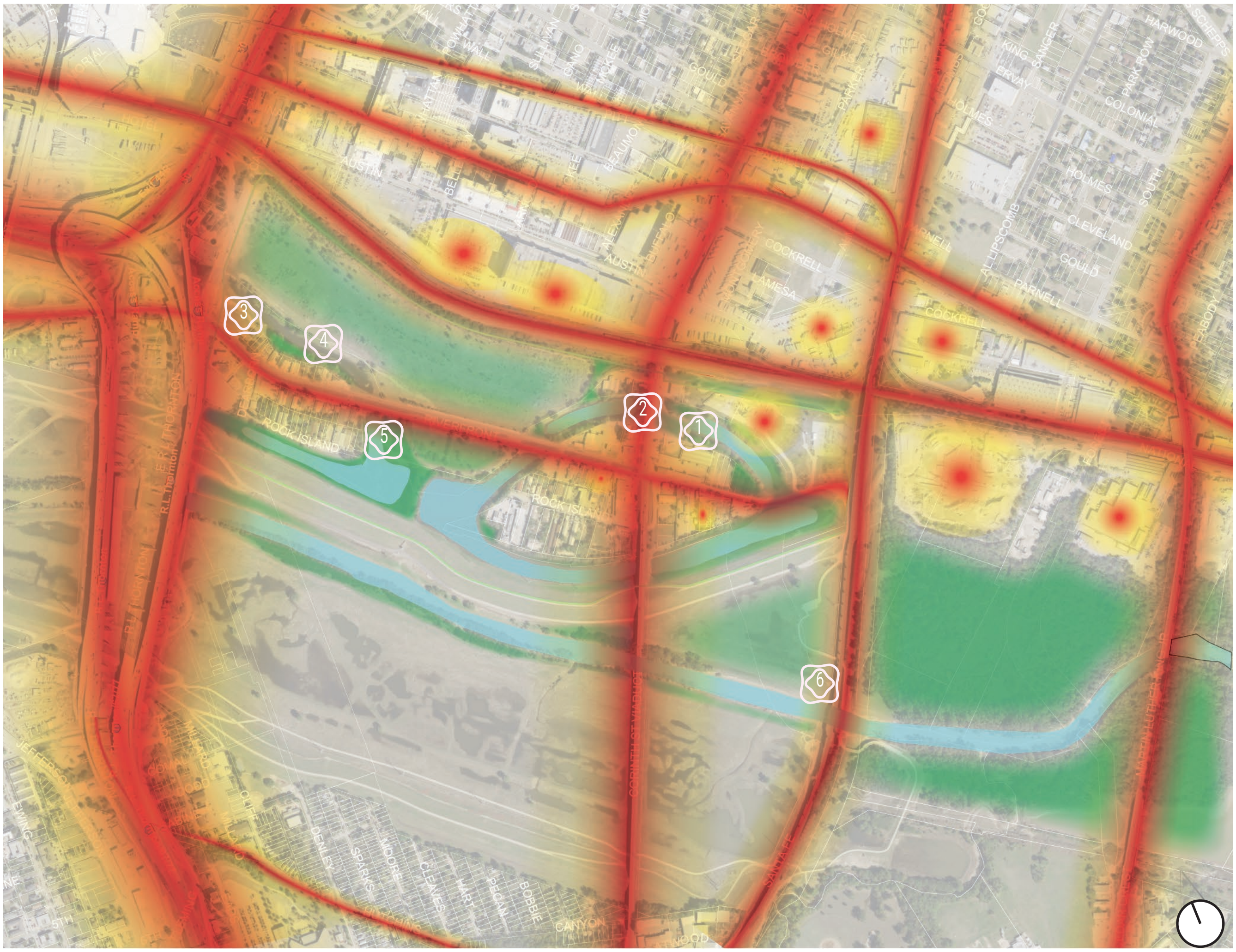


Figure 19. Land Use



2500 FT

Noise Pollution is an often overlooked source of pollution that is proven to negatively impact both people and wildlife. People who spend most of their time in high noise environments are shown to have increased rates of stress-related health problems such as hyper-tension and poor mental health.

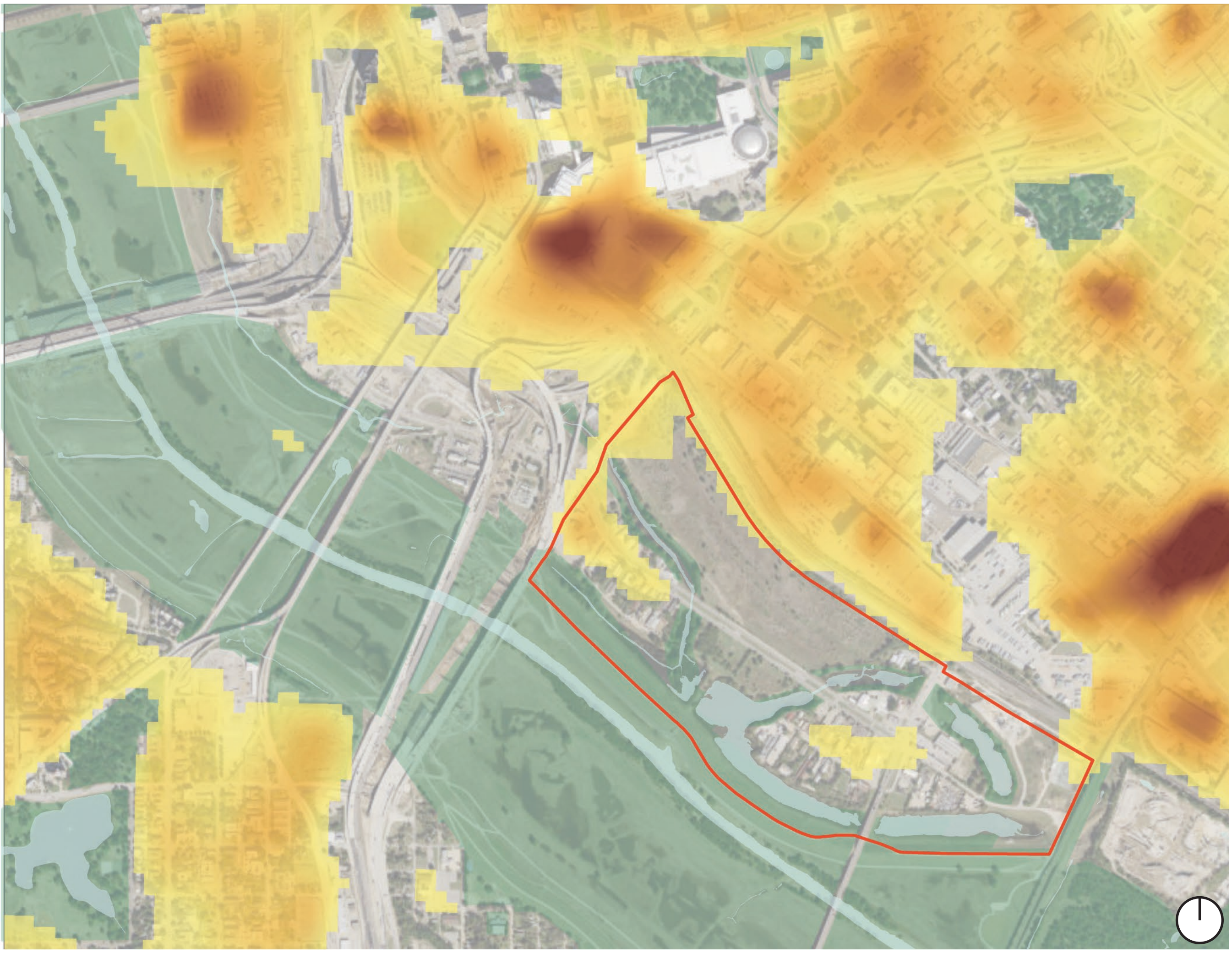
Noise pollution also affects wildlife, typically by disrupting the ways in which animals communicate, find mates, or hunt for food. Predatory birds are particularly sensitive to noise pollution. Often a noisy site may be ecologically suitable for nesting, but because of lower hunting success they may not reproduce successfully or abandon the nest all together.

The above map illustrates likely sources of noise pollution, including busy roads, highways, rail lines, and industrial areas. The map also illustrates potential noise sinks, which are largely the vegetative areas around the ponds and the Trinity Forest.

Using a decibel Meter, our team of consultants took six readings across the Water Garden Site to get a sense of the sound conditions on the ground. Sound was typically higher around the busy roads, however the highest reading (5) was unexpectedly in a vegetated area, likely due to a high presence of loud birds such as grackles.

1	75 dB
2	71 dB
3	68 dB
4	64 dB
5	84 dB
6	63 dB

Figure 20. Noise Pollution



Urban Heat Islands (UHI) are areas within urban areas that have a higher temperature than the surrounding environment. Impervious areas such as parking lots, industrial zones, and roads with heavy traffic are all examples of areas where UHIs can occur.

UHIs impact the urban environment in the following ways:

- *Dangerous outdoor conditions for residents*
- *Increased Energy Demand*
- *Increased Air and Greenhouse Gas Pollution*
- *Reduced Water Quality*

UHI's can be mitigated through green infrastructure such as improved tree canopy cover, as well as structural changes such as repainting roofs white.

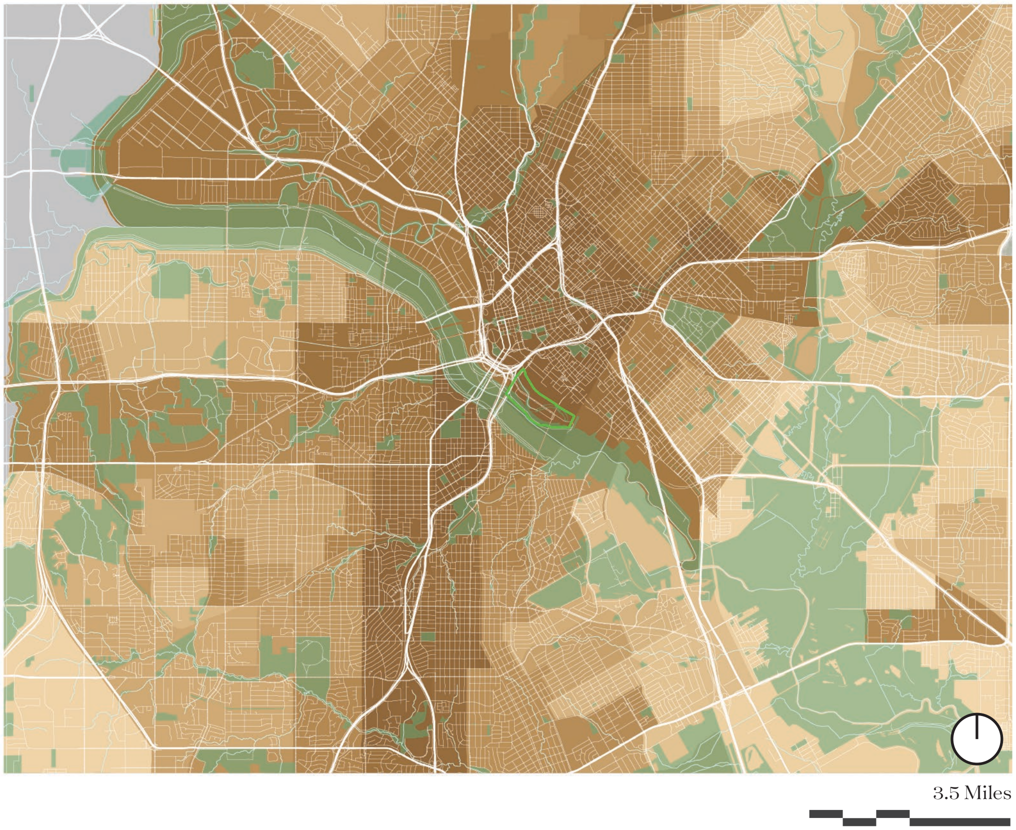
The above map was created by analyzing remotely sensed thermal data to display areas which show a higher than the regional average temperature. This particular image was taken at 5 PM on March 22, 2018, when the average temperature in the Dallas area was 75 °F.

The map illustrates that areas with high industrial activity or significant impervious cover exhibit temperatures over 10 °F above average, while the vegetated floodplain and other green spaces exhibited lower than average temperatures.

Figure 21. Urban Heat Islands

NATA Diesel Particulate Matter in Air

A mixture of particles that is a component of diesel exhaust. USEPA lists diesel exhaust as a mobile-source air toxic due to the cancer and non-cancer health effects associated with exposure to whole diesel exhaust. (USEPA)



NATA Cancer Risk

The probability of contracting cancer over the course of a lifetime, as risk per lifetime per million people and assuming continuous exposure (assumed to be 70 years for the purposes of NATA risk characterization). (USEPA)

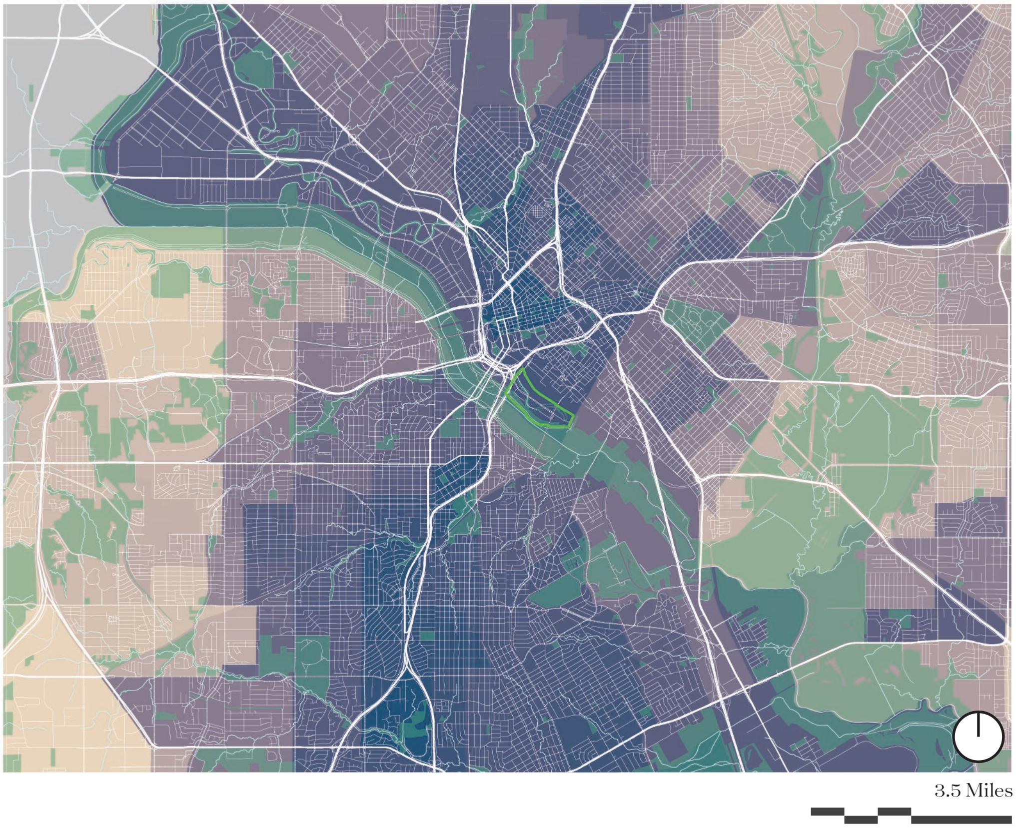
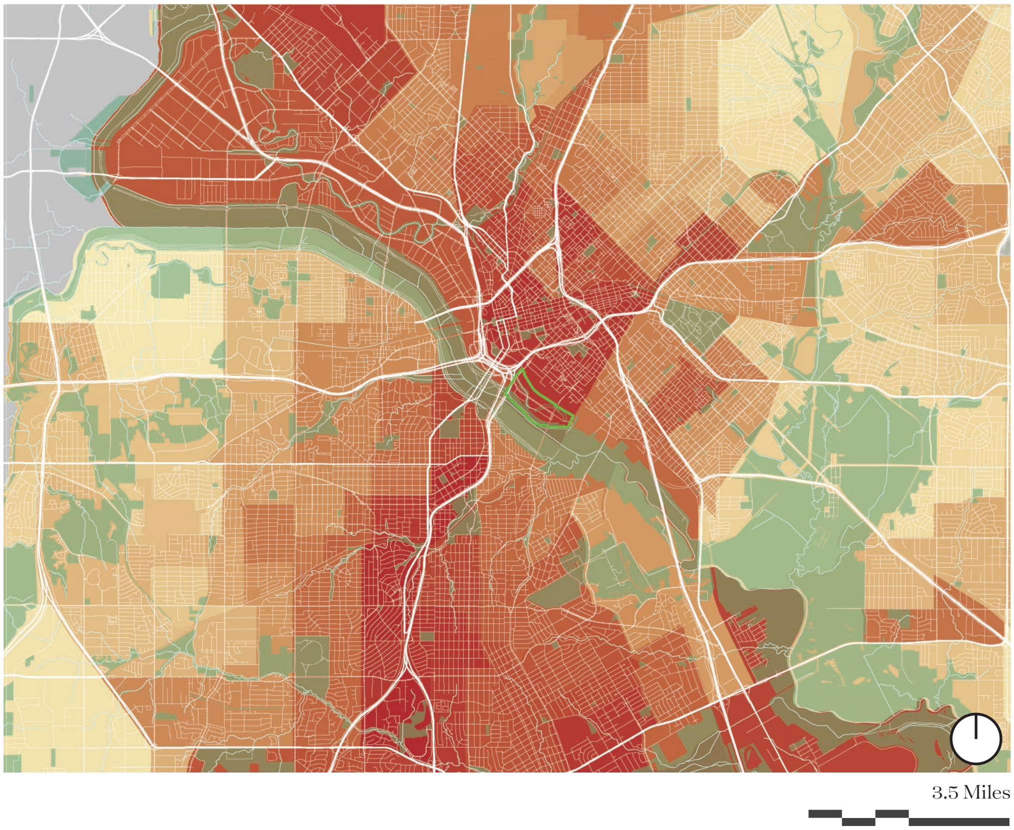


Figure 22. Pollution Risk 1

NATA Respiratory Hazard Index

The sum of hazard indices for those air toxics with reference concentrations based on respiratory endpoints, where each hazard index is the ratio of exposure concentration in the air to the health-based reference concentration set by USEPA. (USEPA)



Traffic Proximity

Count of vehicles per day (average annual daily traffic) at major roads within 500 meters (or nearest one beyond 500 m), divided by distance in meters. Calculated from U.S. Department of Transportation National Transportation. (USEPA)

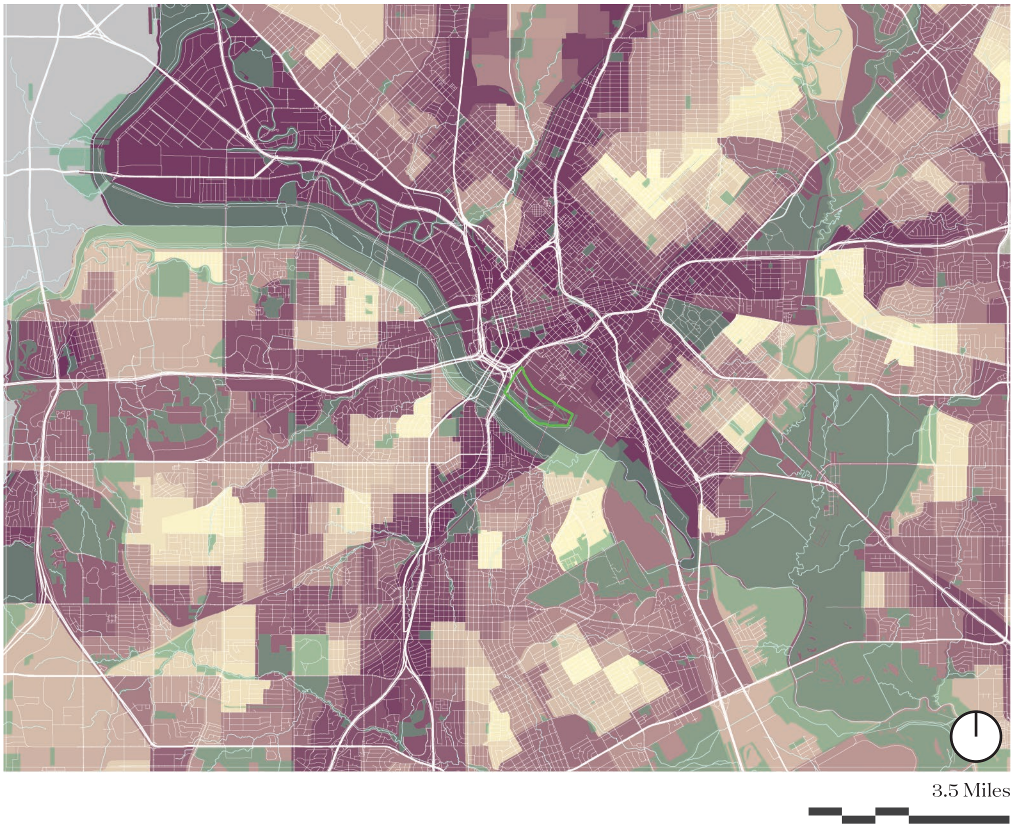
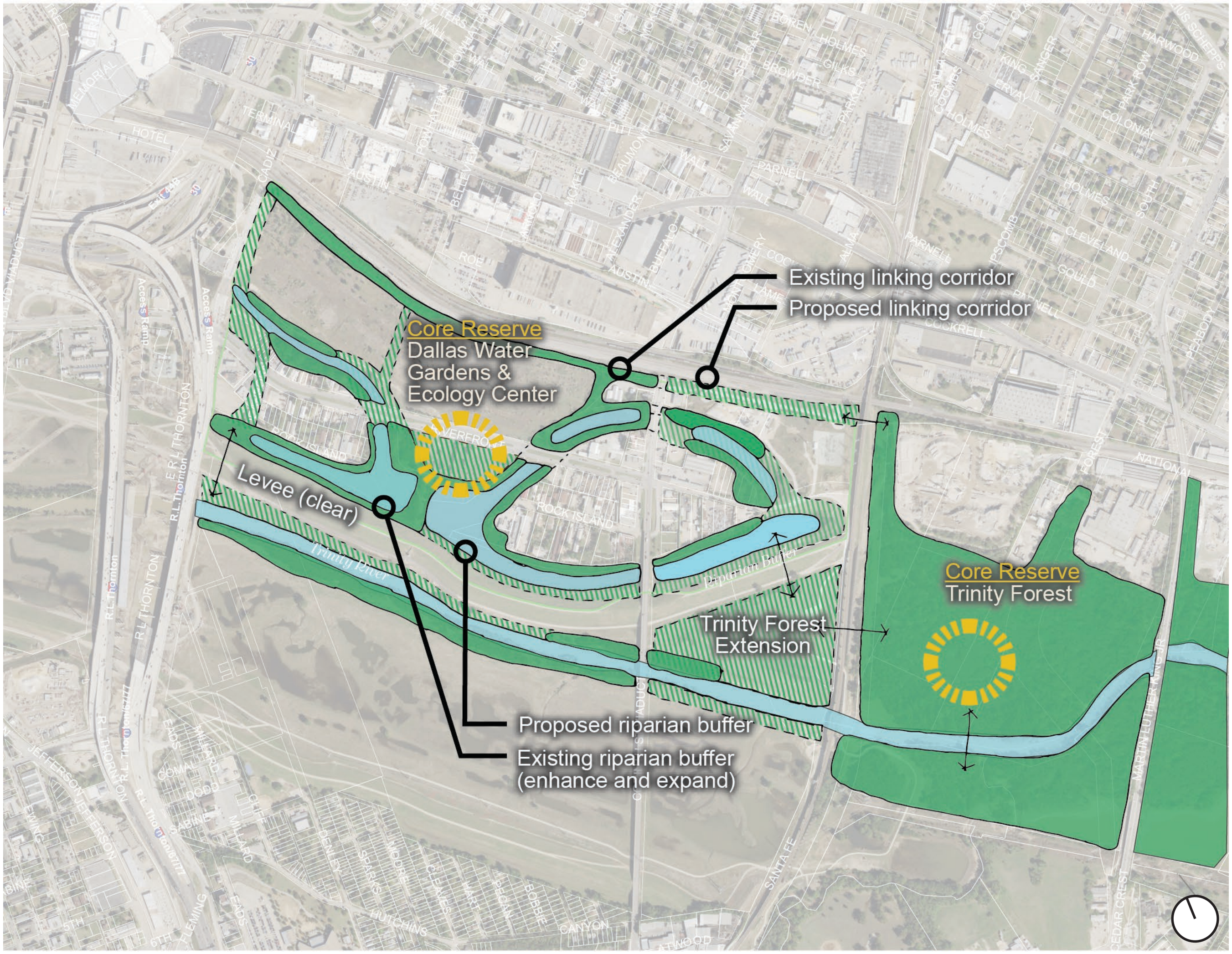


Figure 23. Pollution Risk 2

Pond 5 looking northwest toward IH-35 bridges

Plant palettes and tailored planting strategies for terrestrial and wetland sites were developed to maximize the multi-functionality of those systems. The new plant communities are designed to provide ecosystem services including infiltration, stabilization, water quality, habitat creation, carbon sequestration, air pollution mitigation, and simultaneously provide cultural value (Figure 24). The distribution of species and plant communities within the wetland vary primarily as a function of water depth, under wet, normal and dry seasonal conditions (Figure 25). Results of the seasonal/annual water balance evaluation (see previous section) were used to ensure that the contributing watershed supply adequate flows to ensure that the pool level is maintained as required by the vegetation at various depths in the wetlands. The modeling was used to predict the range of system flows and to support development of a palette of vegetation types that can be maintained in the constructed wetlands. This analysis includes the development of an ecological framework for the site that accounts for all potential ecosystem services that can be met in the site design.



The Water Gardens Site is directly adjacent to the Great Trinity Forest (seen below) a large riparian forest reserve in the heart of Dallas. The Gardens can improve the forest's connectivity with urban canopies by restoring habitat corridors through the site, connecting the patchwork of existing habitat into a landscape mosaic.

This improved connectivity would facilitate improved ecosystem services such as:

- *Increased Wildlife Habitat*
- *Improved Flood Prevention*
- *Improved Water Quality*
- *Lower Ambient Temperature*
- *Increased Recreation*
- *Increased Biodiversity*

2500 FT

🟦 *Water*

▨ *Proposed Habitat Enhancement*

🟩 *Existing Forested Habitat*

Figure 24. Ecological Priorities

Stormwater wetlands are comprised of contiguous vertical zones that mimic the structure and function of natural wetlands. Zones are defined by relationship to permanent water level, frequency of inundation, water depth, and/or slope. Different zones provide different ecological services, including but not limited to pollutant removal, habitat provision, and erosion control.

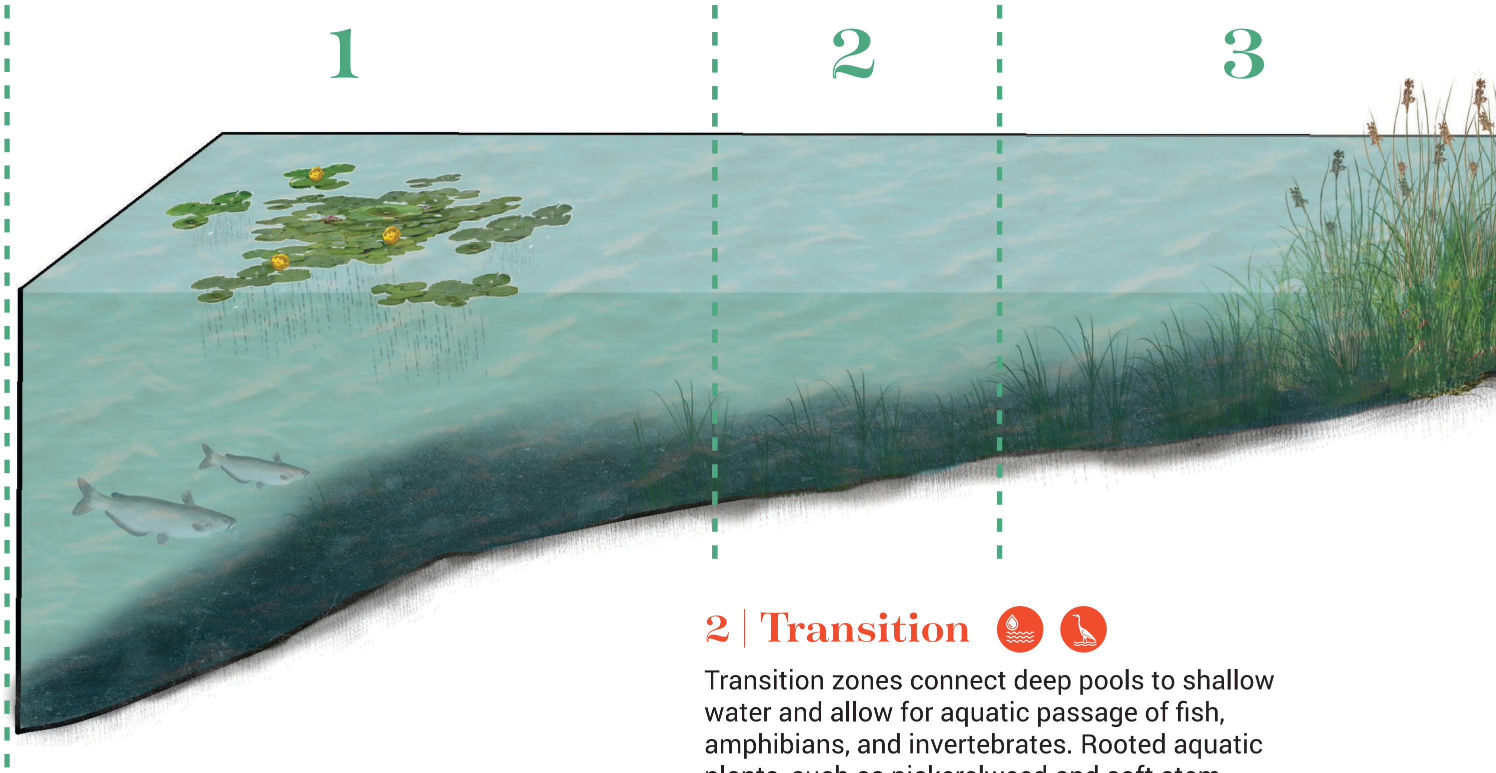


Figure 25. Stormwater Wetland Zones

1 | Deep Pool

Deep pools provide refuge for aquatic organisms during dry periods and an anaerobic environment for enhanced nitrate treatment. Floating and submerged plants grow here, but rooted plants do not. Deep pools are at least 24" below the permanent pool level and can be as deep as 40". They represent 20-25% of the total wetland surface area.

2 | Transition

Transition zones connect deep pools to shallow water and allow for aquatic passage of fish, amphibians, and invertebrates. Rooted aquatic plants, such as pickerelweed and soft stem bulrush, grow here and support the nitrification and denitrification of stormwater. Transition zones are 6-9" below permanent pool level, with a maximum slope of 1.5:1. They represent a nominal percentage of the total wetland surface area.

3 | Shallow Water

Shallow water is the wheelhouse for pollutant removal of a stormwater wetland. High oxygen levels in this zone enable the rooted aquatic plants that grow here to capture oxygen in the root zone for nitrification processes that occur there. Shallow water zones are 0"-4" below permanent pool level. They represent approximately 40% of the total wetland surface area.

4 | Temporary Inundation Zone

The temporary inundation zone is only underwater during and immediately after storm events; the rest of the time it is dry. This dynamic zone supports a large variety of plant species, which in turn provide habitat diversity for aquatic and terrestrial species. The temporary inundation zone is 0-15" above permanent pool level. It represents 30-45% of the total wetland surface area.

5 | Upper Bank

The upper bank zone is never regularly submerged; accordingly, its primary use is recreation and wetland observation. A variety of non-wetland plants, including trees and shrubs, grow here. The upper bank zone starts 15" above permanent pool level. It is not counted in the total wetland surface area.

Resources:

NCDENR (North Carolina Department of Environment and Natural Resources). "Stormwater best management practices manual." (2009).

Brown, Robert A., and William Frederick Hunt. "Improving Exfiltration from BMPs: Research and Recommendations. North Carolina Cooperative Extension" (2009).

Proposed Design

Opportunities for linking the site with adjacent existing communities and areas of anticipated development were explored in this analysis. The proposed bridge crossings on Riverfront Boulevard and Cadiz Street were evaluated to incorporate pedestrian access and improve connectivity through the wetland/pond system (Figure 26). A perspective rendering of Pond 4 with the proposed connections and water observation points is shown in Figure 29.

The schematic design provides a detailed physical layout of the proposed Water Gardens. The design documents have been created using AutoCAD and supplemented with ArcGIS data and exhibits (Figures 30-34). The documents include property ownership as identified in public records, topographic information from available sources, streets, known utilities, and location and dimensions of major features of the project (see *Technical Memorandum* for GIS Exhibits). Profiles and sections showing dimensions of the features (for Pond 4 only) have been included to provide clarity on the arrangement of features within the site (see *Technical Memorandum* for Proposed Schematic Design).

An opinion of probable construction costs has been developed based on the schematic design of Pond 4, and requirements for land acquisition and excavation in Ponds 5, 7 and 8 (as summarized in Table 4 on page 18).

Table 7. Summary Opinion of Probable Costs

ITEM NO.	DESCRIPTION	TOTAL AMOUNT*
1	Clearing, Stockpiling Topsoil	$9,000
2	Weir Control Structure; Formed Weir Channel Manual with Approach & Spillway Largely Under Cadiz Bridge	$160,255
3	Pedestrian Bridge - 15' Wide X 150' Length	$2,030,634
4	Sidewalk Connections at Existing Streets	$15,000
5	Concrete Water Access Point	$136,654
6	Concrete Water Access Point	$402,290
7	Boardwalks, 10’ & 6’ Widths	$1,343,000
8	Concrete Walks on Grade	$132,880
9	Concrete Walks Along Slope	$225,775
10	Concrete Stairway	$16,500
11	Water Cascade Plaza	$360,386
12	Decorative Overlook Deck	$342,790
13	Park/Wetland Seeding	$75,188
14	Forested Trees	$57,000
15	Surface Pond Aerator	$32,000
16	Performance Stage Island and Bridge Approach	$208,990
17	Excavation and Disposal (Ponds 5, 7 and 8)	$1,068,335
18	Property Acquisition (Ponds 5, 7 and 8)	$4,704,480
19	Removal of Existing Storm Drain Connecting Ponds 4 and 7	$46,890
20	Addition of New Storm Drain Between Ponds 4 and 7	$512,494
	CONSTRUCTION SUBTOTAL (Exclude Property Acquisition)	**$7,176,060**
	ESTIMATING SUBTOTAL (Exclude Property Acquisition)	**$8,970,075**
	E, D + C SUBTOTAL (Exclude Property Acquisition)	**$11,462,594**
	TOTAL ESTIMATED PROJECT COST	**$19,411,375**

* All costs are in US dollar and current as of May 2019

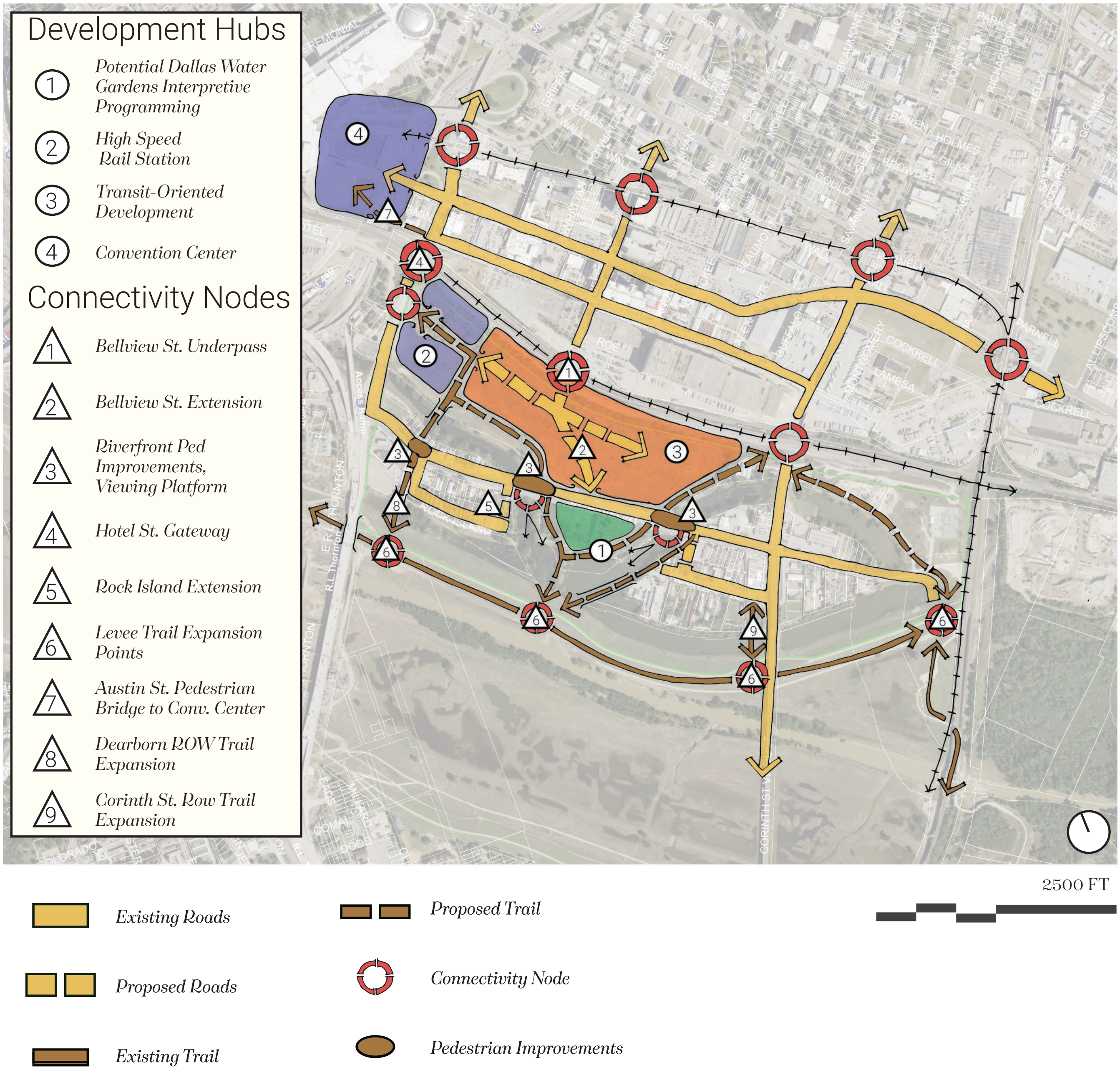


Figure 26. Connectivity Priorities

Robust and healthy wetland vegetation plays a critical role in the success of stormwater wetlands. Wetland plants provides pollutant filtration, aids in sedimentation, and provides critical forage and habitat for aquatic wildlife. The location of stormwater wetland vegetation species are determined by wetland zone.

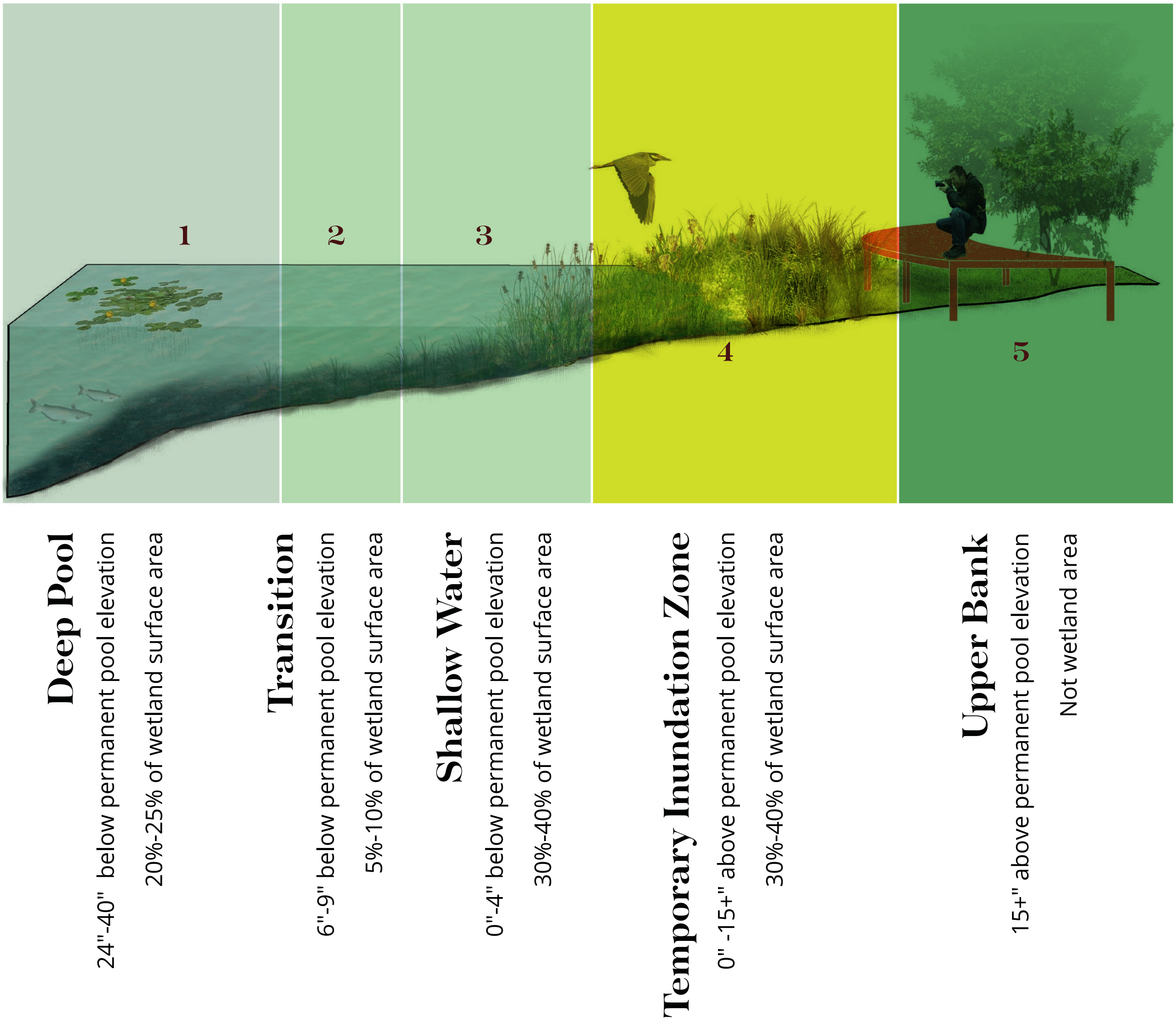


Figure 27. Planting Palette

	Key	Common Name	Latin Name	Plant Type	Sun Needs	Growth Rate	Urban Adaptability*
DEEP POOL 24-40" below	1	Needle Spikerush	*Eleocharis acicularis*	Grass	☼	Moderate	● ● ●
	2	American Lotus	*Nelumbo lutea*	Floating Aquatic	☼	Moderate	● ●
	3	Yellow Pond Lily	*Nuphar lutea*	Floating Aquatic	☼ ◐	Slow	● ●
	4	White Water Lily	*Nymphaea ordorata*	Floating Aquatic	☼ ◐	Moderate	● ●
TRANSITION 6-9" below	5	Bigfoot Water Clover	*Marsilea macropoda*	Fern	☼ ◐	Rapid	● ●
	6	Softstem Bulrush	*Schoenoplectus tabernaemontani*	Grass	☼	Rapid	● ●
	7	Pickerelweed	*Pontederia cordata*	Herbaceous	☼ ◐	Moderate	● ● ●
	8	Green Arrow Arum	*Peltandra virginica*	Herbaceous	☼ ◐ ●	Slow	● ● ●
SHALLOW WATER 0-4" below permanent pool elevation	9	Virginia Iris	*Iris virginica*	Herbaceous	☼	Moderate	● ●
	10	Lamp Rush	*Juncus effusus var. solutus*	Rush	◐	Moderate	● ●
	11	Broadleaf Arrowhead	*Sagittaria latifolia*	Herbaceous	☼ ◐	Moderate	● ●
	12	Sweet Flag	*Acorus calamus*	Herbaceous	☼	Moderate	●
	13	Bulltounge Arrowhead	*Sagittaria lancifolia*	Herbaceous	☼	Rapid	●
	14	Lizard's Tail	*Saururus cernuus*	Herbaceous	☼ ◐	Slow	● ●
	15	Branched Bur-reed	*Sparganium androcladum*	Herbaceous	☼ ◐	Moderate	● ●
TEMPORARY INUNDATION ZONE 0-15" above permanent pool elevation	16	Woolgrass	*Scirpus cyperinus*	Grass	☼	Moderate	● ● ●
	17	Purple Three Awn	*Aristida purpurea*	Grass	☼	Rapid	● ● ●
	18	Swamp Milkweed	*Asclepias incarnate*	Herbaceous	☼	Slow	● ● ●
	19	Sedge	*Carex spp.*	Grass	☼ ◐	Rapid	● ● ●
	20	Buttonbush	*Cephalanthus occidentalis*	Shrub	☼ ◐	Moderate	● ● ●
	21	Cardinal Flower	*Lobelia cardinalis*	Herbaceous	☼ ◐	Moderate	● ● ●
	22	Sweet Pepperbush	*Clethra alnifolia*	Shrub	☼ ◐	Moderate	● ●
	23	Red Chokeberry	*Aronia arbutifolia*	Shrub	☼ ◐	Slow	● ●
	24	Joe-Pye Weed	*Eupatoriadelphus fistulosus*	Herbaceous	☼ ◐	Moderate	● ●
	25	Swamp Rose Mallow	*Hibiscus grandiflorus*	Shrub	◐	Rapid	● ●
	26	Crimson Rose Mallow	*Hibiscus moscheutos*	Herbaceous / Shrub	☼	Rapid	● ●
	27	Inkberry	*Ilex glabra*	Shrub	☼	Slow	● ●
	28	Virginia Sweetspire	*Itea virginica*	Shrub	☼ ◐	Slow	● ●
UPPER BANK 15+" above	29	Southern Lady Fern	*Athyrium asplenioides*	Fern	◐ ●	Rapid	● ● ●
	30	Woodoats	*Chasmanthium latifolium*	Grass	☼ ◐	Moderate	● ● ●
	31	Sycamore	*Platanus occidentalis*	Tree	☼	Rapid	● ● ●
	32	Water Oak	*Quercus nigra*	Tree	☼	Rapid	● ● ●
	33	Red Maple	*Acer rubrum*	Tree	☼ ◐	Rapid	● ●
	34	Southern Wax Myrtle	*Morella cerifera*	Shrub / Tree	☼ ◐	Moderate	● ●

Sun Needs	☼	Sun
	◐	Part Shade
	●	Shade
Urban Adaptability	●	Mildy Adaptable
	●●	Adaptable
	●●●	Highly Adaptable

*Urban adaptability is a measurement of a plant's ability to withstand higher disturbance levels anticipated in urban environments.

Resources:

NCDENR (North Carolina Department of Environment and Natural Resources). "Stormwater best management practices manual." (2009).

Brown, Robert A., and William Frederick Hunt. "Improving Exfiltration from BMPs: Research and Recommendations. North Carolina Cooperative Extension" (2009).

John DePhillipo, Director, John Bunker Sands Wetland Center (personal communication, November, 2018)

Plant Community Structure Vision

1 | Deep Pool	2 | Transition	3 | Shallow Water	4 | Tempo Zone
24"-40" below permanent pool elevation	6"-9" below	0"-4" below permanent pool	0"-15+" above pe

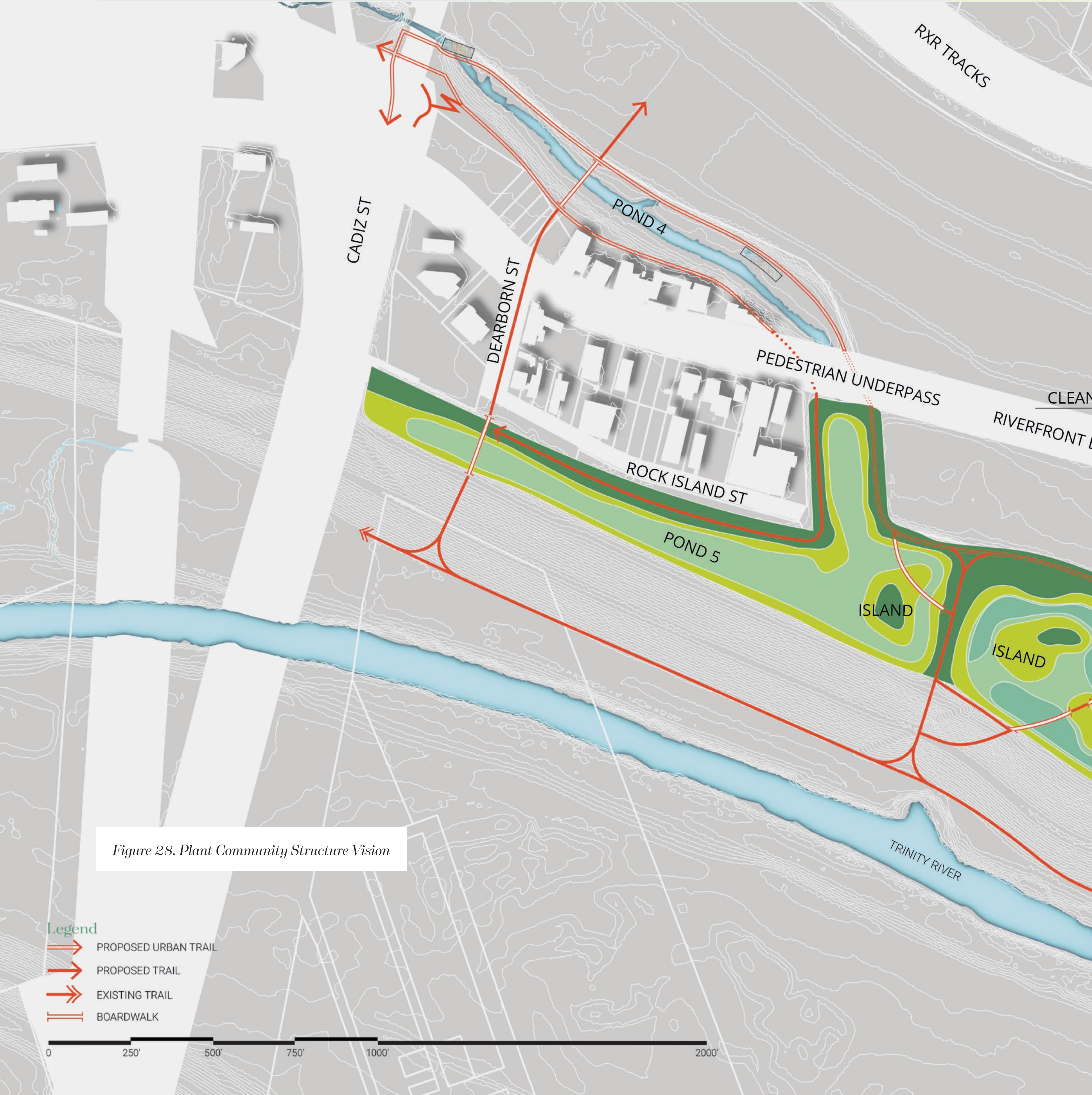


Figure 28. Plant Community Structure Vision


rary Inundation
ermanent pool elevation
5 | Upper Bank
15+” above permanent pool elevation
NSING/ POLISHING WETLANDS
BLVD
POND 7
PEDESTRIAN UNDERPASS
ISLAND
POND 8
ROCK ISLAND ST
CORINTH ST
POND 9
POND 6

Figure 29. Perspective rendering of the Water Gardens

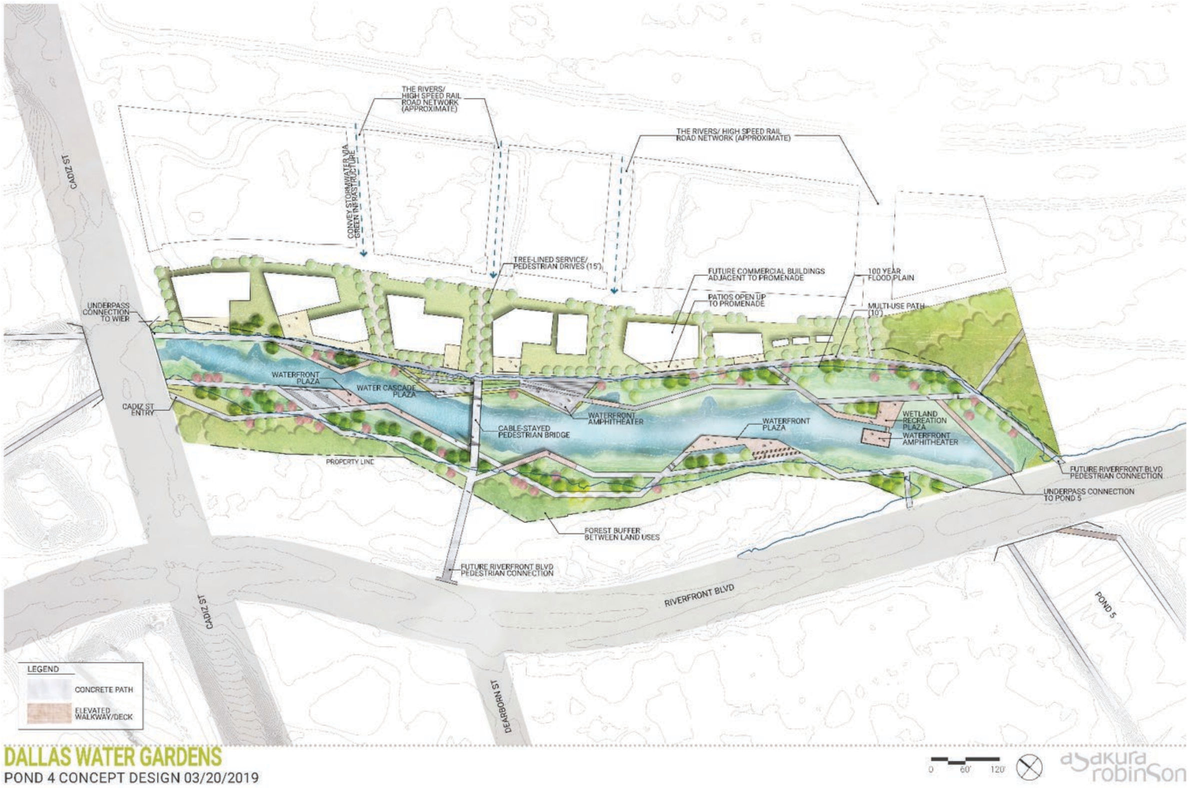


Figure 30. Concept design

Figure 31. Ecological design

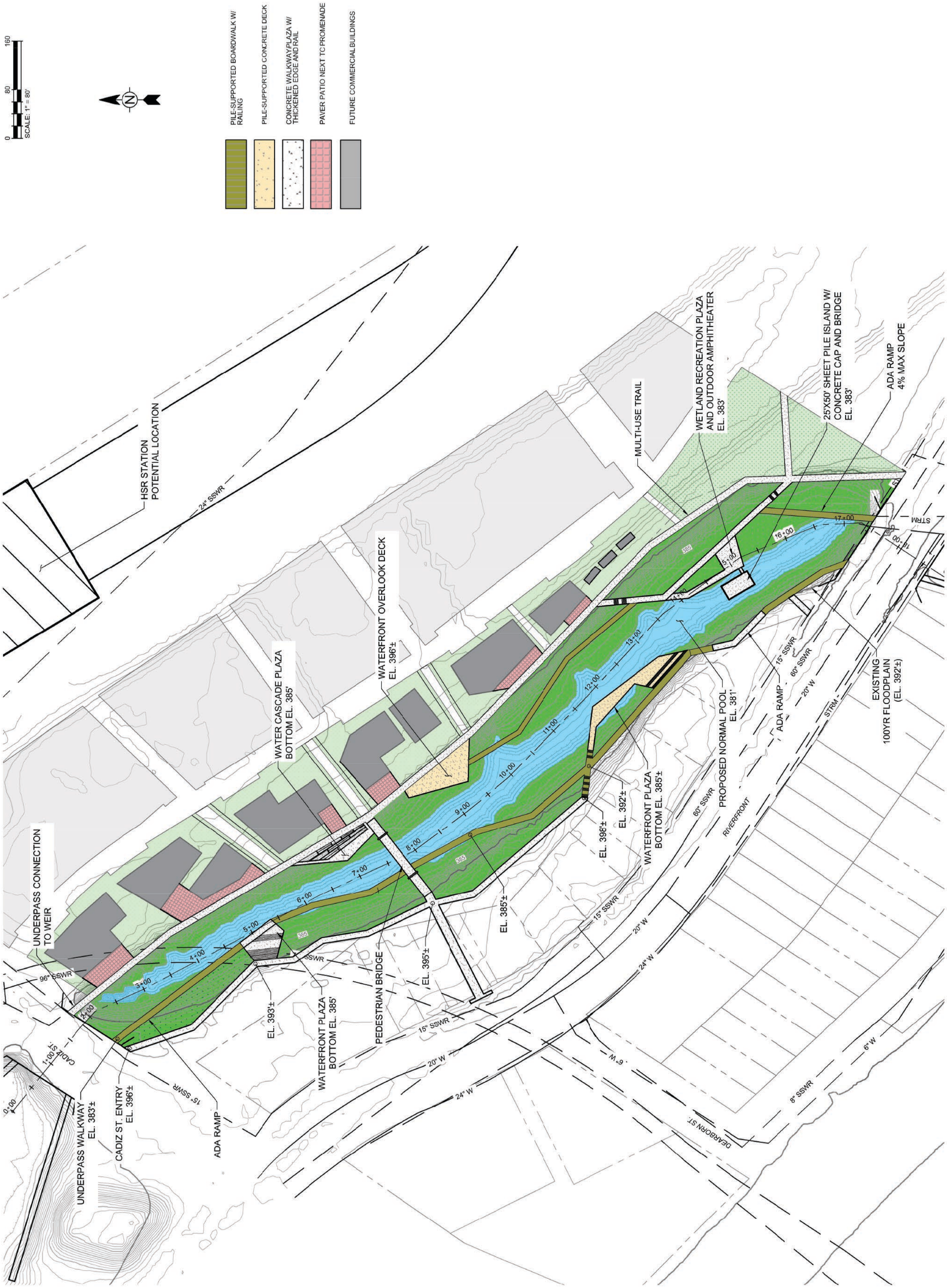


Figure 32. Concept Plan Pond 4

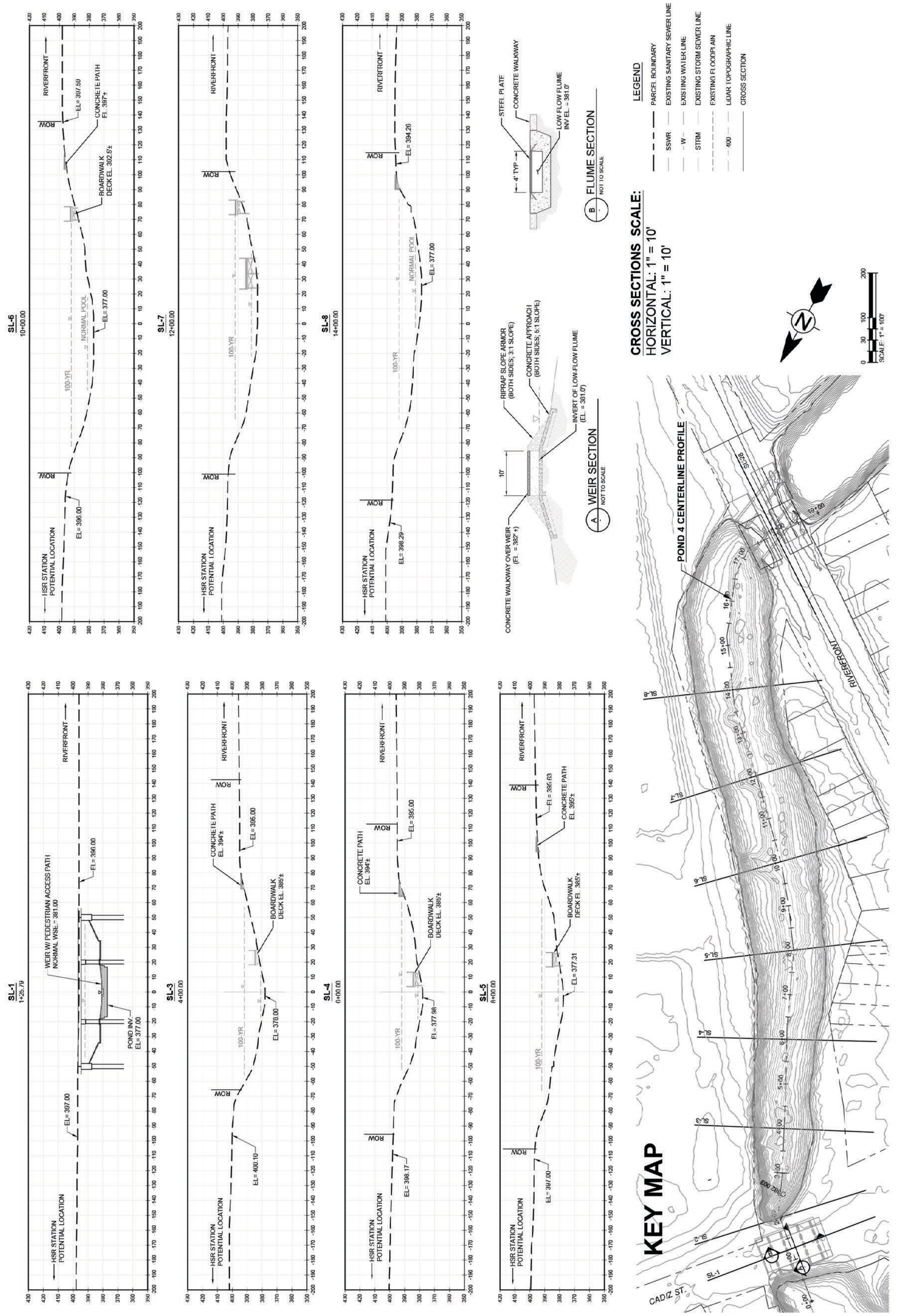


Figure 33. Sections Pond 4

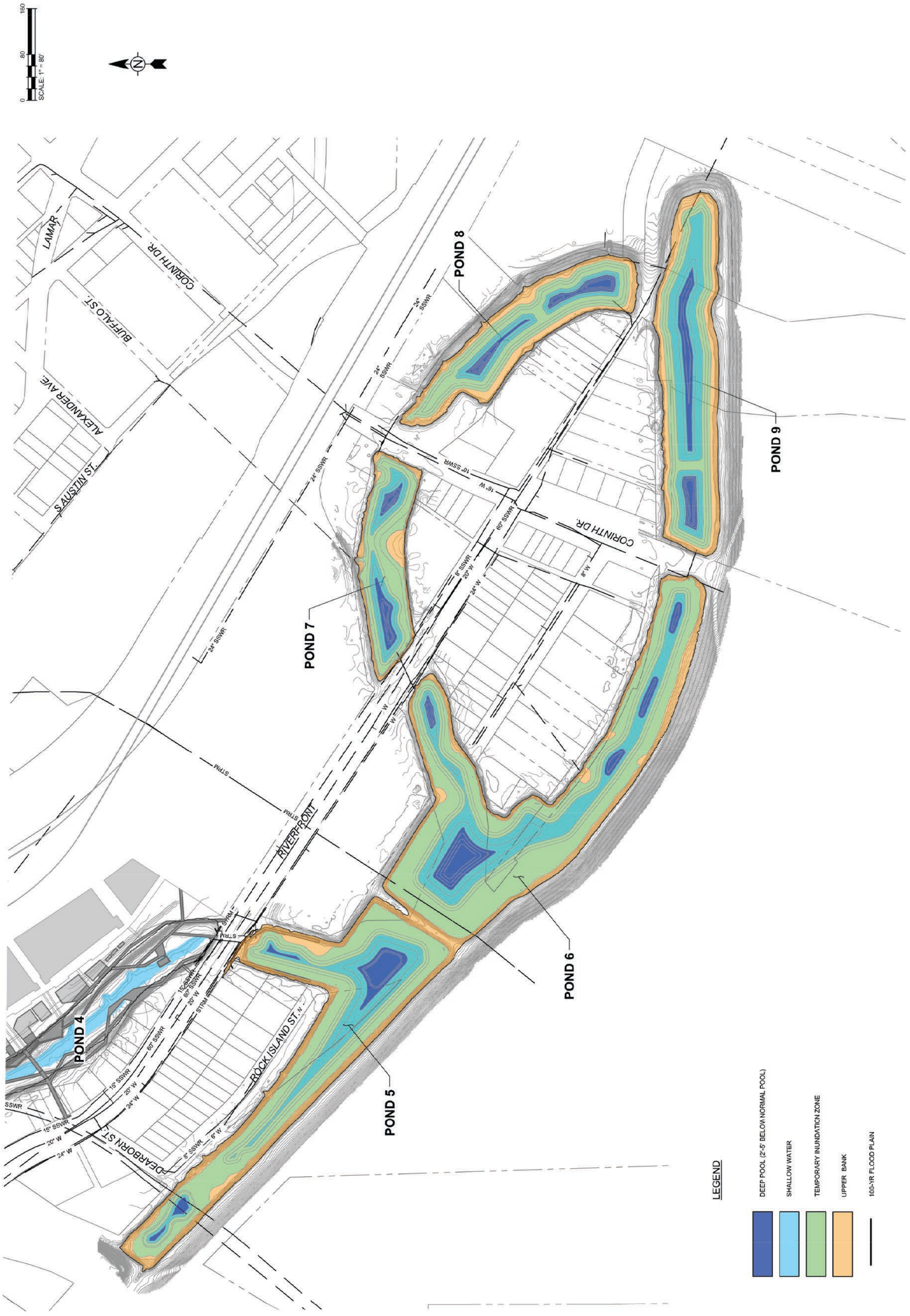


Figure 34. Concept Plan Ponds 5 to 9

4. Conclusions and Future Direction

The objective of this analysis was to assess the feasibility of converting six of the nine stormwater ponds in the Able Sump system to active wetlands while ensuring that the primary flood control objective of the Able Pump station was achieved. The alternatives explored included use of active controls to manage water levels in the upper ponds, deepening or increasing the footprints of the upper ponds, and underground storage systems. The feasibility analysis presented here converts the upper ponds into wetlands while meeting the additional volumetric capacity requirement. This alternative meets the City's floodplain criteria while providing the ecosystem benefits associated with a wetland system.

Design and Construction of Cadiz St. and Riverfront Blvd.

The Dallas Water Gardens design is dependent on the construction of the future Cadiz Street and the East and West Riverfront Boulevard bridges. The design of the Cadiz Street bridge is considered 30% complete and the Riverfront bridges are considered 65% complete. All designs are being developed by Halff Associates, Inc. and are currently under review with the City of Dallas.

Subsurface Utility Engineering for Adjacent Utilities

It is recommended that Subsurface Utility Engineering (SUE) be completed for the surrounding area of the Dallas Water Gardens project to locate any adjacent utilities that could interfere with design implementation. The presence of additional utilities could complicate construction schedules and costs.

Survey of the Upper Ponds

Survey of ponds 4 through 9 is required to determine the bathymetry contours below the water surface.

Forebay or Green Infrastructure to Prevent Pond Sedimentation

The final design considerations should include a forebay in Pond 4 and/or green infrastructure (such as bioretention) to prevent increased pond sedimentation caused by known future development surrounding the Water Gardens.

City Review and Acceptance of H&H Modeling

The Able Sump hydrologic and hydraulic modeling will require a formal review and acceptance by the City of Dallas. The review will demonstrate no negative floodplain impacts due to the project and that the City of Dallas 10-point floodplain criteria are met.

USACE Permitting

The old channels of the Main Stem of the Trinity River and borrow ditches created during levee construction are part of the original sump network of the Dallas Floodway (Floodway). The Floodway is a USACE civil works project, the modification of which is subject to USACE review. The authority to grant permission for temporary or permanent alterations to USACE civil works projects is codified in 33 USC 408 (Section 408). Section 408 authorizes the USACE to grant permission to alter a Civil Works project upon a determination that the proposed alteration will not be injurious to the public interest and will not impair the usefulness of the project.

Policy and procedural guidance for Section 408 requests is provided in EC 1165-220. As verified by the USACE Fort Worth District, the project will also require regulatory authorization under Section 10 of the Rivers and Harbors Act (Section 10) and Section 404 of the Clean Water Act (Section 404). Regulatory authorization requires an evaluation of the project's compatibility with the purposes of the federal project, and the Section 408 analysis informs the compatibility with the purposes of a federal project for Regulatory purposes. Therefore, all necessary information to support the Section 10/404 approval will be included in the Section 408 request submittal to facilitate concurrent and efficient review. Mr. Jason Story is the USACE Fort Worth District Section 408 coordinator; the project is included in NCTCOG's Section 214 program and has been assigned to Mr. Barry Osborn as the Regulatory manager.

Components of a complete Section 408 submittal include the following:

- **Technical Analysis and Design**

  USACE Fort Worth District has stated that initiation of review should begin with a minimum of 60-65% design. A hydraulic and hydrology analysis will be required, and the scope of analysis should account for velocities when the Able Pump Station is operating at full capacity.

- **Environmental and Cultural Resources Compliance**

  The USACE Fort Worth District utilizes an existing programmatic NEPA document which requires demonstrations that the project meets certain requirements pursuant to Section 7 of the Endangered Species Act (ESA) and Section 106 of the National Historic Preservation Act. This also includes a demonstration that the project may be authorized under Section 404 by either nationwide or regional permit. A formal delineation of Waters of the United States within the proposed project corridor has not been performed at this early phase in the project schedule. However, the old channels were included in the Approved Jurisdictional Determination (AJD) of the Dallas Trinity River Floodway for the City of Dallas, which was most recently extended through March 24, 2021 (USACE 2011-00049). Additional delineation information will be provided in the Section 408 submittal if field investigations warrant updates to the AJD.

- **Real Estate Requirements**

  A description of the real property required to support the proposed alteration must be provided. Maps depicting both existing real property and the additional real property required must be provided.

- **Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R)**

  The submittal must include any projected requirements for OMRR&R needed throughout the life of the proposed alteration and the responsible entity.

The *Dallas Water Gardens: Feasibility Analysis | Technical Memorandum* is available separately.