Waller Creek Corridor Framework Plan

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COVER LETTER

The Creek Corridor Framework Plan is a critical step towards the restoration and revitalization of the lower reach of Waller Creek and the surrounding public space in a rapidly changing urban context. As we reverse decades of neglect and build back a new thriving ecosystem in downtown Austin, we recognize that this ecosystem must embrace both the natural processes of a healthy creek and the sustainable human engagement of it. Therein lies both the challenge and the enormous opportunity for Austin — the ability to bring nature into the heart of the city where it can be appreciated and enjoyed by the greatest number of people. This document identifies the foundational technical and spatial strategies for achieving that ambitious vision.

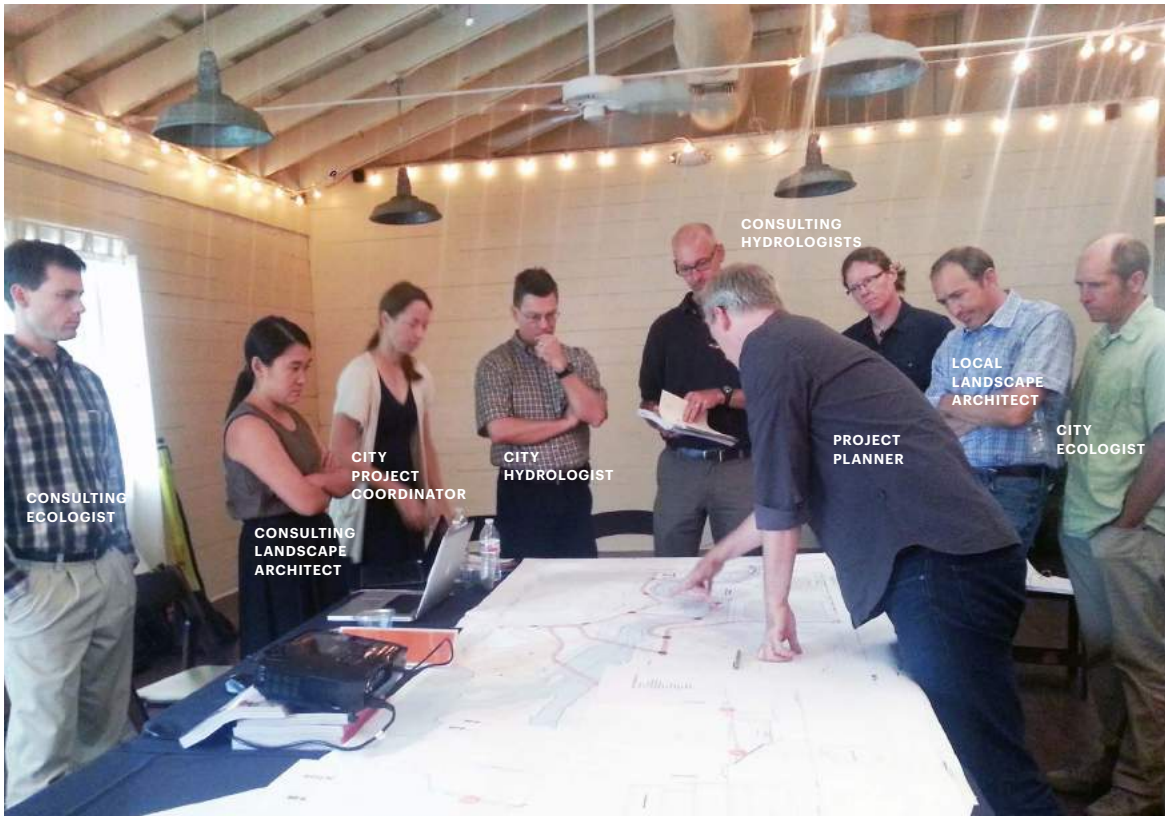
The plan is the result of over a year of in-depth analysis and data collection, examining the project at a high level and diving into some of the important minutia of a complicated 1.5 mile stretch of the urban core. Overlapping jurisdictions, numerous property owners, a tangled web of utilities, and upgrades to a flood prone and polluted water system are all significant challenges that have been addressed as part of this planning effort.

This document is also a testament to innovative and effective public-private partnership. The Waller Creek Conservancy and City of Austin came to the table with interdisciplinary teams of experts in diverse disciplines, including landscape architecture, stormwater management, biology, park operations, lighting design, and more. This final product represents the combined efforts of these talented individuals working collectively as a team. It serves as a model for working with flattened hierarchies in a collaborative setting to create a comprehensive framework tool for a complicated project.

We are grateful for the passion and the commitment that the team brought to this effort. Equipped with this versatile new tool, we look forward to making the renewed Waller Creek a reality.

Peter Mullan
CEO
Waller Creek Conservancy

CREEK CORRIDOR FRAMEWORK PLAN: DESIGN PRIORITIES



JOINT DEVELOPMENT AGREEMENT

The Joint Development Agreement is the charter that governs the cooperative and beneficial working relationship between the City of Austin and the Waller Creek Conservancy. The agreement defines the roles and responsibilities of each party to achieve the common goals of preserving, restoring, managing, and operating the Waller Creek District, a unique cultural district in the City of Austin.

The City of Austin and Waller Creek Conservancy formed a public-private partnership to strategically plan, coordinate and deliver projects for the district. This effort is a systematic and highly intentional strategy to knit together infrastructure improvements, open space and private developments along Waller Creek to create a connected and cohesive space for the citizens of Austin.

The Waller Creek Tunnel is the substructure for the district improvements. The City of Austin invested in the flood control tunnel to remove 28 acres of property from the 100-year floodplain, facilitating the District redevelopment. Additionally, the City has dedicated Bond and Drainage Utility Funds for construction of park, stream, and trail infrastructure within the District.

DESIGN PRIORITIES

Design Priorities are a set of common goals for the project team to achieve while developing the Framework Plan. Complex urban streams such as Waller Creek present unique design challenges based on the intensity of development, utility locations, and environmental features within each block of the creek. Solutions must

adapt to the unique nature of the creek corridor while still achieving the common goals for the project — to connect, protect, and restore Waller Creek.

Foundation for Design Priorities

The Design Priorities are grounded in the set of principles presented during the Waller Creek design competition. The Design Principles were the following:

Principle 1: Establish an Armature for an Urban District

Principle 2: Connect Downtown and East Austin

Principle 3: Encourage Redevelopment

Principle 4: Engage the Creek

Principle 5: Provide Access

Principle 6: Manage Sound

Principle 7: Maximize Non-exclusionary Uses

Principle 8: Create a Sustainable District

Principle 9: Create, Reclaim and Restore Parkland

Principle 10: Protect and Enhance Ecological Diversity

Innovatively, the Design Priorities are founded on functional criteria that define a healthy stream in Austin. The criteria is traditionally viewed as an assessment tool for stream health but the project team progressively took the next step, to use the criteria as a standard for design. By focusing on the health of the creek and the riparian area, the Design Priorities embrace the concept of creating an armature for valuing nature within a public district.

Design Priorities Categories

Design Priorities are the foundation for design while advancing design concepts for the Framework Plan. The Design Priorities are categorized as the following:

- **Access/Connectivity** (Principles 1, 2, 5, 7)
- **Protect and Enrich Ecology** (Principles 4, 10)
- **Preserving and Restoring Parkland** (Principle 9)
- **Redevelopment** (Principle 3)
- **Education** (Principle 8)
- **Operation and Maintenance** (Principle 8)

Within each category, the project team developed a list of common goals to guide the discussion, collaboration, and deliverable for the Framework Plan. The Design Priorities and the related common goals are the following:

ACCESS/CONNECTIVITY

The human experience is integral to successfully integrating the restoration of Waller Creek into the urban fabric of the city. Access and connectivity will provide network of trail systems for the human experience and therefore the following common goals should be achieved as part of the Framework Plan:

- Connected trail system from Lady Bird Lake to Waterloo Park.
- Trail system that maximizes opportunities to connect to the non-vehicular network of walkways and bike trails at street level.
- Trail system designed within scale of the creek system.
- Trail system should consider public safety by having open sightlines.
- Trail system should consider public safety from flood events (i.e. ingress/egress, level of inundation.

PROTECT AND ENRICH ECOLOGY

Ecological resilience is essential to successfully restoring Waller Creek and creating an armature for valuing nature within a public district. Informed by the local geology, hydrology, geomorphology, and ecology, the following common goals should be achieved as it relates to stream function, channel stability, water quality, vegetation, and habitat:

Stream Function

- Design concepts should achieve at least a 'Good' rating based on the City of Austin Zone 3 — Functional Assessment of Floodplain Health.

Channel Stability

- Create a stable stream system with natural materials such as native vegetation and rock.
- Design should first consider using native vegetation for channel stability.
- Design should be informed by local hydrology and sediment supply.
- Design should consider changes in hydraulics due to intervening flows.
- Design should consider local scour protection at storm drain outfalls.

Water Quality

- Consider end of pipe, water quality treatment opportunities. Opportunities include daylighting pipe and designing a vegetated/rock swale to control flows to the creek.
- Consider upland water quality treatment opportunities such as inlet-based treatment devices, and street level, pocket rain gardens.

CREEK CORRIDOR FRAMEWORK PLAN: DESIGN PRIORITIES

Vegetation

- Increase coverage, diversity, and complexity of vegetative plant communities.
- Vegetation selection should consider resiliency and urban context, with a particular consideration given to long-term maintenance and sustainability.
- Vegetation selection should consider plants native to Waller Creek and the Balcones Fault/Transition Zone
- Plant selection should consider sense of place for the human experience.
- Plant selection should consider the perception of public safety issues with closed sight lines.

Aquatic Habitat

- Increase habitat complexity by adding permanent log structures or other carbon sources to the stream system.
- Provide the four flow regimes with the stream system.
- Where stability allows, use cobble/gravel substrate material for habitat complexity.

PRESERVING AND RESTORING PARKLAND

Parkland preservation and restoration opportunities will create the unique 'Chain of Parks' within the Waller Creek District. The concept designs for the Framework Plan should consider the following common goals:

- The design should consider opportunities to make the existing parkland a public amenity.
- The design should consider opportunities to create new parkland within the Waller Creek District.
- The design should aim to foster the greatest degree of connectivity between the developing urban fabric and existing parkland parcels, restoring a healthy relationship between the parkland and the city.
- The design of new parkland should aim to be highly inclusive and inviting to the public — this is critical in order to prevent the creek corridor from presenting itself as a semi-private enclave serving developments that will emerge along the banks of Waller Creek
- The design should take special consideration towards restoring park program that targets use by families and children.

REDEVELOPMENT

Waller Creek is the common thread tying together redevelopment of the Waller Creek District and as such, the following common goals should be achieved:

- Redevelopment to create an armature for valuing nature and public spaces.
- Encourage positive adjacent uses of redevelopment (through development guidelines)

EDUCATION

Waller Creek is an integral part of Austin's history and future. Opportunities to educate the community about the cultural and natural history of Waller Creek in Austin as well as the natural science of Waller Creek should be considered through the following common goals:

- Consider passive education opportunities such as providing access to the creek or locations to sit along the trail system.
- Consider opportunities for signage, visual education, and place making experiences (i.e. access to bedrock outcroppings to learn about the local geology; plant selection to attract specific fauna to identify along the trail; and lake backwater as an opportunity to learn about the history of the Colorado River).
- Consider opportunities to educate community about watersheds and connection to the watershed.
- Consider opportunities to educate community about good and bad water quality indicators.
- Consider human stewardship opportunities.

OPERATION AND MAINTENANCE

- Landscape plan should minimize long term maintenance within the creek corridor.
- Design should calibrate operations and maintenance needs to available resources, especially in highly programmed parks.

ACHIEVING DESIGN EXCELLENCE

Waller Creek achieves design excellence by establishing Design Priorities that consider the creek in a highly urban context. Design excellence is defined as integrating multiple priorities for design into a project and emphasizing the need for collaboration and coordination to achieve excellence, so the Waller Creek District is both a model for urban ecological restoration as well as a model of successful public space design.

Kristin K. Pipkin, PE, CPESC
Waller Creek District Redvelopment Project Manager
City of Austin Watershed Protection Department

TEAM FIELD WORK

Monthly workshops incorporated on-site observation, discussion & documentation.

THE FRAMEWORK PLAN

A Framework Plan is a planning tool that prioritizes strategic thinking over the more prescriptive and programmatic approach of a traditional Master Plan. This is an important distinction within a complex planning environment like the Waller Creek Corridor as the recommendations of a Master Plan can be more easily rendered obsolete in the face of new urban developments, shifts in policy, and other unforeseen changes. The objective of a Framework Plan is to maintain a level of coherence in the face of the indeterminacy that necessarily exists in complex urban environments.

The Waller Creek Corridor Framework Plan is a critical piece for the rapidly emerging puzzle of downtown Austin. The Environmental Assessment for Interstate 35, the expansion of the chilled water infrastructure and a downtown reclaimed water system, the Sabine Street Promenade, the expansion of Metro Rail, the Waller Creek Tunnel Project and the large amount of developer activity now occurring within the District all add up to a significant transformation of downtown Austin. The creek landscape will hold a special place in the midst of all of this concurrent planning and development—it will be the physical glue that connects these new city-building activities with the historic assets and the institutions that exist alongside the creek. The creek landscape is also the means by which some form of continuity will be preserved in this wave of urban redevelopment. In one of the fastest-growing cities in country, the presence of nature is a powerful factor that links communities across the city and provides a precious connection to the Austin population that is experiencing change at an unprecedented speed and scale.

In 2011, the City of Austin approved the design of an underground flood control tunnel that would divert almost all the waters of Waller Creek at Waterloo Park to Lady Bird Lake. The tunnel, which represents an unprecedented overlap of municipal, state and federal waterway jurisdictions, also conveys aerated Lady Bird Lake water back upstream to Waterloo Park. This extreme engineering solution removes the threat of floodwaters on 28 acres of downtown, garners many water quality improvements, and creates a central amenity to anchor the value of the adjacent redevelopment opportunities—all of which contribute to the economic structure created to pay back the bonds for the tunnel construction through a tax increment financing formula (TIF).

The tunnel going "on-line" in mid-2015 marks a major milestone in opening up quantitative improvements for the District—new developable areas, measurable water quality improvements, new public space opportunities, and building a revenue stream for the City. However, the construction contracts of the Tunnel Project do not holistically address the numerous qualitative and functional aspects of the creek corridor. This Framework Plan explores this vital dimension of the creek corridor by a careful examination of the layering and mixing of pre-tunnel and post-tunnel conditions — what changes and what remains?

Beginning with an assessment of changes in the creek hydrology and the physical circumstances in the contiguous public rights-of-way (trails, parkland, streets, easements, etc.) the result is a three-part plan: The Waller Creek Corridor Framework Plan (the "white book") that describes the strategic approach towards each functional layer of the creek landscape in its entirety, The Block-by-Block Enlargements (the "blue book") that succinctly describes how these strategic approaches play out in the varied conditions found block-by-block along the creek, and the Waller Creek Corridor Framework Plan Appendix (the "yellow book") that catalogs all of the supporting technical memos, studies, backgrounds, and modeling.

The recommendations and guidelines of this plan are tailored to analytic and technical criteria in order to find 'footholds' for working within the dynamic complexity of the creek environment. With respect to the methodology that guided Framework thinking, however, there were three basic qualitative motivations that underlay each and every encounter with the creek corridor's indeterminacy: to connect, to green, and to build.

WALLER CREEK AND CHAIN OF PARKS

The Framework Plan establishes a network that "pre-wires" the potential 10-12 million SF of development that can be accommodated along the flood-protected creek. This level of development could translate into as much as a 50% increase in the downtown population.

CONNECTING

The plan reflects a commitment to the realization of a universally accessible, safe, and innovative trail network. The trail has been developed to incorporate as many points of access as possible, and the resulting abundance of access and circulation will contribute significantly to the perception of feeling safe in a intensely urban environment. The trail system has also been shaped to afford long sight lines and to eliminate as many blind corners as possible — another important factor in building a safe-feeling environment.

With all of these criteria informing the alignment and elevations of the trail, the resulting network promises to foster something new for Austin — a walkable district. A four to eight block walk from any point on the creek provides access to a tremendous range of downtown destinations and activities. With the development of new residences, diversified ground floor program opportunities and a new collection of park areas, the trail network will provide a rich pedestrian experience.

GREENING

Creating a positive experience for visitors is crucial for the transformation of Waller Creek. The episodic beauty of the existing creek landscape is very delicate but is often compromised by the myriad of urban pressures. Because the creek is cut into the adjacent city blocks and is often constrained in width, holding back slopes with walls or revetment structures has been a common practice along Waller Creek. A goal of the plan is to remove as many wall structures and to employ as many green slope stabilization methodologies as possible. This is critical in offsetting the intensity of development (buildings, widened rights-of-way, etc.) with planted areas to convincingly evoke a central Texas waterway. The presence of a robustly green landscape in this location will also offer environmental benefits for pedestrian comfort—including shade, water quality improvements, beneficial wildlife, the offsetting of heat island effect, transpiration and natural cooling.

BUILDING

The Waller Creek District will include millions of square feet of new development in the adjacent blocks along of the creek. This development should support a mixture of uses and an approach that seeks out ways to carefully engage the creek landscape. The new creek landscape adds tremendous value; it enhances and is enhanced by good development. Nevertheless, interface will be an ongoing challenge given the complex topography and changing character of the banks of the creek. The landscape spine of the creek offers a remarkable potential to tie all these projects together and add enormous economic, social and environmental value. Handled skillfully, what happens at the thresholds between the creek landscape and urban fabric surrounding it has the potential to create some of the most unique and vibrant environments in the city. A creative dialogue between Waller Creek design team and the individual projects that will line and frame it will be essential to optimizing this decidedly unique opportunity for the positive integration of city and creek.

THE WALLER CREEK CORRIDOR AS INFRASTRUCTURE

Iterative testing of these basic imperatives (connecting, greening, and building) in relation to the many varied conditions encountered alongside of the creek reveals that Waller Creek Corridor is in fact a critical piece of infrastructure serving the City of Austin. This is an important aspect to understand and communicate about the Creek Corridor, as there is a tendency in public perception and in municipal contexts to see projects that appear natural as having a focus on aesthetic improvements. In truth, however, the Waller Creek Corridor Project is poised to play a key role in resilient city-building and presents multiple opportunities for positively transforming infrastructure, shaping already planned infrastructure, building new infrastructure, and establishing nature as a new infrastructure of sorts.

WALLER CREEK

EXISTING URBAN PARKS & WALLER CREEK DISTRICT

Transforming Infrastructure

With the historic build up of downtown Austin, the infrastructural function of the creek corridor became entirely oriented towards the accommodation of utilities and the immense diversion of stormwater from the surrounding impervious areas of the developing city. During the time of the Framework Plan effort, relatively minor storm events generated formidable pulses of water through the creek channel, flooding properties, causing severe erosion, compromising utilities and structures, and contributing to collapsed earthen banks. The post-tunnel creek channel will still have work to do relative to the conveyance of stormwater, but the contribution of the watershed to this reach of the creek will be dramatically reduced, looking and feeling much more like the flow of water that one would expect to experience in a natural stream system. This change opens the door for the creek corridor to transform and take on a new role in its central position in downtown Austin. The tax-increment financing (TIF) plan to pay back the bonds for the tunnel construction shifts the infrastructural focus of the project to serve the forthcoming development lining the creek and the larger public need for open space within what will be a dense urban core.

The creation of highly accessible and walkable trail infrastructure that serves the District is not only critical to this city building effort, it will also create a unique opportunity to offer Austin a new model for development in the 21st century. A successful pedestrian trail network will also provide a visible juxtaposition to the almost constant traffic overload that the city currently experiences one block away on I-35.

Shaping Planned Infrastructure

While it would have been perhaps much simpler to treat the creek restoration as a singular technical project of accommodating the post-tunnel flow regime, the creek project is unavoidably interlaced with other concurrent infrastructure

CHAIN OF PARKS & CREEK RESTORATION

A WALKABLE DISTRICT

development — much of which was already being planned within the District prior to the Waller Creek Corridor project. What the Framework Plan process has inspired is the integration of several infrastructure initiatives that were being developed not only independent of the creek restoration, but also in isolation of one another.

This interaction of the Framework Team with developers, City staff, and critical stakeholders has led to several shifts in scope, direction and funding priorities. These include: changes to the construction contract scopes for the Waller Creek Tunnel inlet structures, a new direction for the downtown water quality improvement plan, the planning and preliminary design for the Sabine Promenade, the anticipation of future utility needs in relation to the expansion of the Capitol Metro Rail system, the integration of park programming for Waterloo and Palm Parks, the coordination of multiple bikeway initiatives, and the shaping of many developer site plans and parkland contributions at the creeks edge.

Building New Infrastructure

With the proposition of a highly connective trail network at Waller Creek comes a multitude of small support elements that are critical to managing the large constituency that the project anticipates drawing into the space of the creek. These individual site elements may not, in and of themselves, represent traditional urban infrastructure, and as such cannot draw from existing City standards. New standards need to be developed and tailored to the scale of the creek and the sensitivity of the creek habitat. This collection of trail components represents a new infrastructure that will enable the user's interface with the creek. Such as: garbage collection, lighting standards, wayfinding systems, and safety rails. This system has significant implications for the accommodation of crowds, for the level of effort involved in maintaining creek trails and landscapes, and for the identity of the emerging creek district.

Establishing Nature as Infrastructure

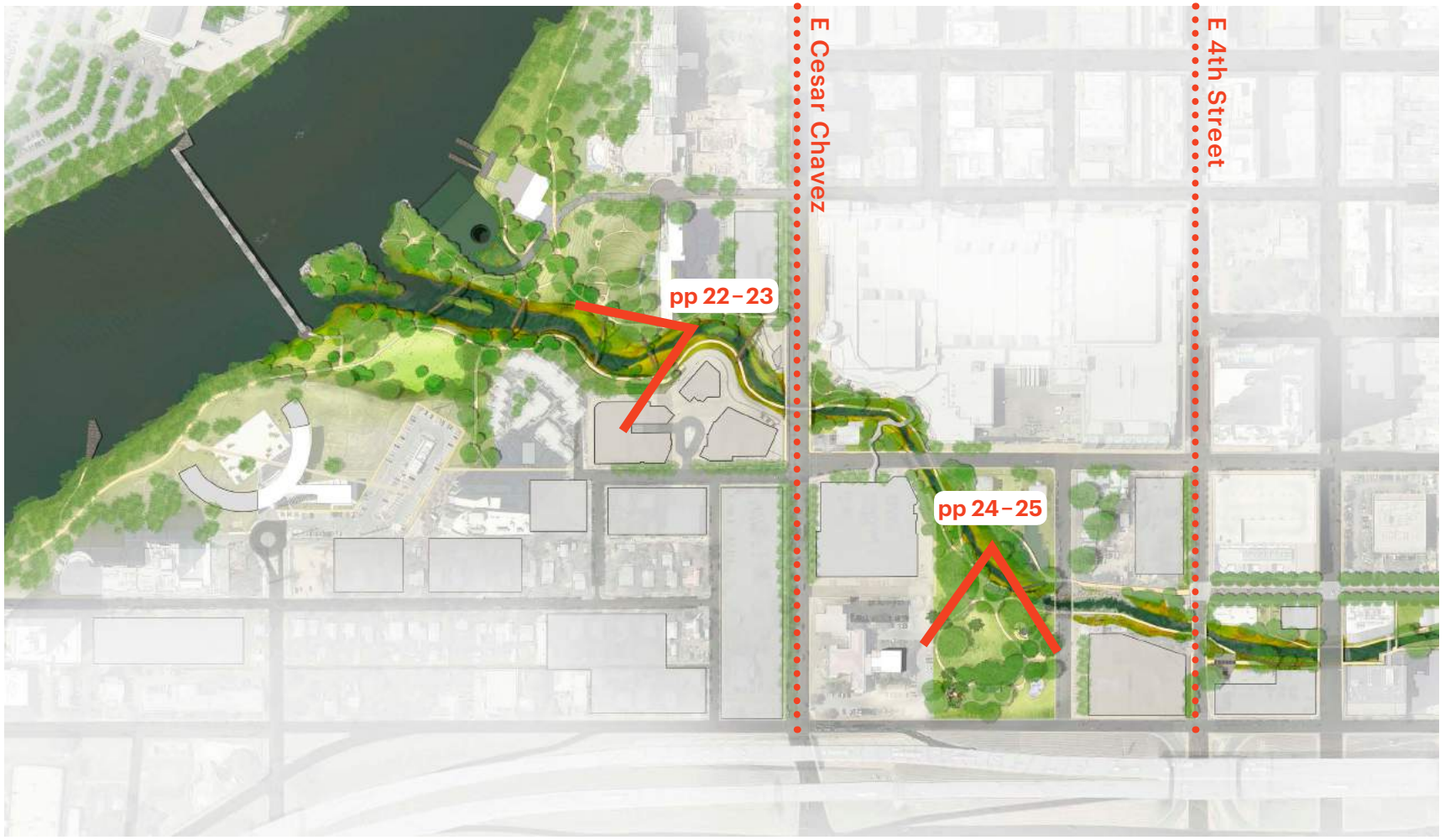
In western culture, conquering nature has been a necessary consequence of city building. However, this conceit is beginning to erode as a scientific understanding of climate change, sea level rise, ecological succession, soils, forestry, and hydrological systems is quickly changing the basic tenets of city-building. The planning and design community is currently producing tremendous amounts of new data, models and documentation of how natural systems can play a critical role in the environmental performance of cities. This more nuanced understanding of the city/nature interface has also given rise to a new kind of accounting that recognizes the good business sense of a collaborative relationship with nature. Taken together, these reveal the need for a new idiom of resilient city-building and a lens for understanding natural systems as city infrastructure.

With the imminent completion of the Waller Creek Tunnel project, the unnatural manipulation of the flood-prone creek catalyzes a new role for urban nature of an immense scale amidst dense new development. This is a situation where the investment in rebuilding natural systems in the city will convey benefits quite beyond superficial aesthetic improvements — including the capacity to ameliorate a broad range of social and environmental stresses such as: heat island effect, flooding, declining ecological diversity, poor water quality, traffic and congestion, urban health issues, individual stress, and the lack of social cohesion.

But if one were to simply leave the creek alone after the completion of the tunnel, it would take decades, if not longer, to find its stable form as a landscape system. Eroded slopes would continue to degrade until colonized by early successional species, and root masses and soil dynamics find balance. Large areas would become dominated by invasive species, reaching an apparent successional dead end, and the interruption of sediment sources by the 12th Street dam could contribute to a nutrient-starved biological system. Add to this picture the entire top-of-bank condition along Waller Creek being ripped up and rebuilt by adjacent developers and city infrastructure projects. In essence, nature cannot simply "run its course" in this context.

Heavily impacted waterways such as Waller Creek have a tendency to degrade into simple landscapes that lack variety in habitat and aquatic life. Moreover, the introduction of trails for people tends to exacerbate the stresses on natural water systems. The Waller Creek project is quite ambitious as it is both a public space infrastructure and an infrastructure for nature. While the trail network project is to create and maintain a range of inclusive-feeling environments for all, the parallel project is to manage the succession of a blighted waterway into a robust landscape that promotes a diversity of habitat types. Both projects require careful study during design but also require a commitment to maintenance and iterative assessment as the city and the creek landscape grow.

THE FRAMEWORK PLAN — PROPOSED IMPROVEMENTS




E 7th Street
E 10th Street
E 12th Street
pp 26–27
pp 28–29

PROPOSED IMPROVEMENTS

Development site will demolish existing creek bank

Existing monolithic stone wall to be preserved

Existing gabions and concrete revetment failure

Floodwater erosion has undercut bank below existing grove of valuable canopy trees

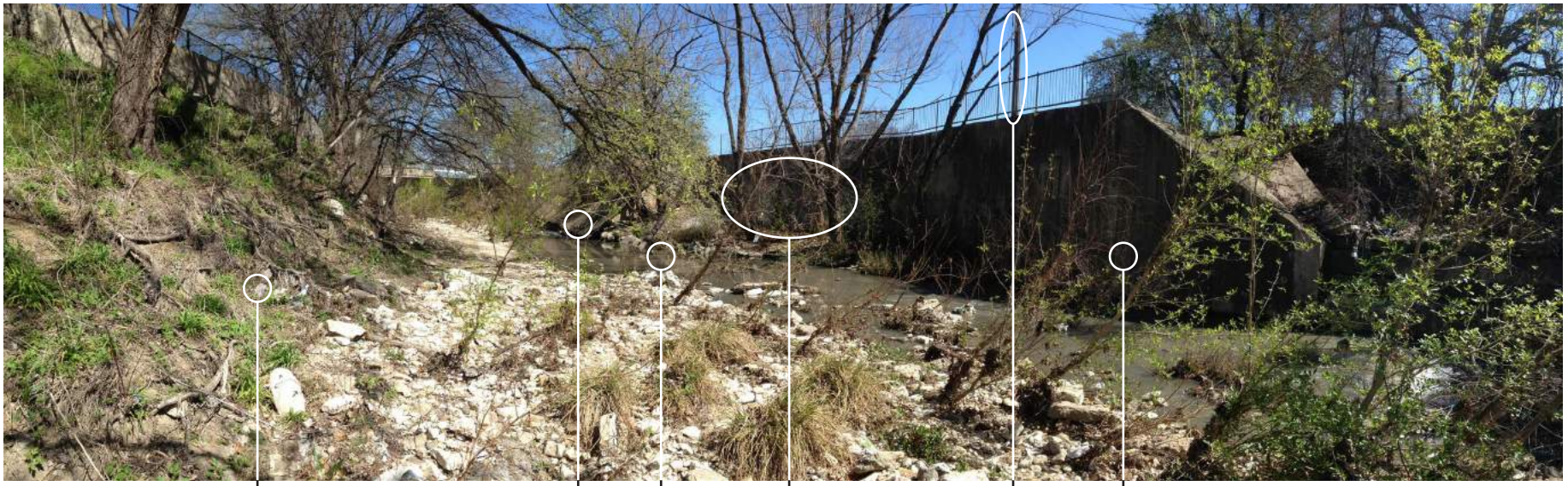
Path width pinched between building and failing revetment

BUILDING A PUBLIC THOROUGHFARE TO THE LAKE

Currently the mouth of the creek can easily be mistaken as a cove at the edge of Lady Bird Lake, offering no cue that the creek channel winds its way up into the intensely urban east side of Austin. Moreover, the existing creek channel presents itself as a significant obstacle to east-west connectivity along the lakefront. The Waller Creek landscape, under the conditions of the post-tunnel hydrology, will become a demonstration of a robust Texas creek ecology, but it will also importantly announce a much-needed public thoroughfare between downtown Austin and the lake.

Longitudinal trails on either bank are joined together by a series of pedestrian trail bridges to form a ladder, or lattice of movements, that will open up an unambiguously public-feeling threshold through the intensity of private development currently being planned or implemented on the lakefront. The new trail system set high above the waterway will foster intuitive way-finding along and across the creek channel while simultaneously highlighting the sensory impacts of the rejuvenated riparian landscape below. This elevated right-of-way to the lakefront will offer a thrilling experience at the junction of the lake and the Waller Creek District.

PROPOSED IMPROVEMENTS



Lower bank below canopy trees showing signs of erosion and invasive species

Wall failure and slope destabilization

Creek bed gabion repairs are exposed from floodwater scour

Existing Black Willows at creek bed to be preserved

Overhead utilities along creek edge to be re-routed

Retaining wall to be replaced with a gentle slope connecting park to creek

ACTIVATING THE CONNECTION TO THE LAKE

Since the construction of I-35 over 50 years ago, Palm Park has been cut off from any meaningful street-level connections and, with the increased frequency of creek flooding, has been severed from the channel by a block-long retaining wall and other slope stability solutions. This isolated park space is re-envisioned as an annex to the creek landscape by laying back the park-side bank in order to create a visual connection between the park and the new trail system. As such, the park will serve as a hub of new street-to-creek connections between the historic downtown core and the lake.

These interchanges will be increasingly important as the intense wave of redevelopment occurs along the creek, as they will reserve an inclusive-feeling public space, a mix of residents and visitors of Austin, and imbue the creek with a new role as the passage to the lake. Beyond its importance as a hub of connectivity, the park is planned as a multi-use and family-friendly open space that serves residents of East Austin, downtown and creek trail-goers.

PROPOSED IMPROVEMENTS

REDISCOVERING BEAUTY IN WALLER CREEK

Immediately downstream of the 11th Street Bridge, a massive heritage live oak tree, a limestone pedestrian bridge, intact stone-paved trails, and an exposed bedrock channel offer an iconic experience of Waller Creek. However, this moment of calm and beauty is short-lived in the context of adjacent areas, which are characterized by poor connectivity to the street, incompatible land uses, and the heavy presence of stormwater overflow infrastructure that will be obsolete in the post-tunnel creek hydrology.

By redeveloping the open space character of the adjacent city-owned properties and selectively modifying the circulation and stormwater infrastructure, moments like this can be elevated significantly in terms of their overall experience of place by evolving into a park-like environment. An alteration to the 11th Street Bridge will also produce a more inviting threshold to Symphony Square, better sightlines, a much-needed maintenance store, and an important new stair connection to Red River. This sort of strategic improvement along the entirety of the creek will add up to a substantive transformation of place from a stormwater spillway into an urban park system.

PROPOSED IMPROVEMENTS

CELEBRATING A VESTIGE OF THE UNTAMED WALLER CREEK

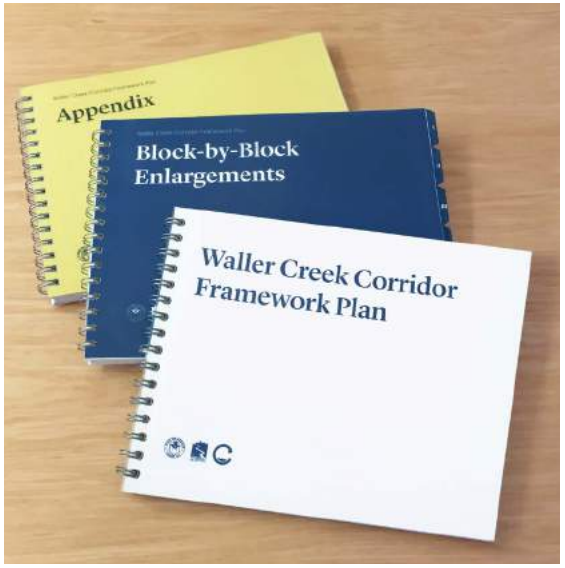
Within the scope of this project, the existing riparian banks between 14th and 15th Streets will be the only post-tunnel creek landscapes still subject to significant flash flooding. They are also located within parkland that possesses several dead ends and compromised trail segments including stairs and tunnel passages that lead nowhere — remnants of previous attempts to develop a recreational experience for this reach of the creek.

Despite the poor circulation network in this location, the existing landscape supports a fairly high-functioning riparian ecology. Re-engineering these slopes will simultaneously bolster the resilience of these systems and create informal invitations to explore this still-untamed creek landscape. The primary way to experience this landscape, however, is from the proposed serpentine walk that hovers over the more frequently flooded zones. The meander of this path will also accommodate a much-needed accessible connection to the corner of 15th and Red River Streets.

THE STRUCTURE OF THE FRAMEWORK PLAN

Three-part Plan

Beginning with an assessment of changes in the creek hydrology and the physical circumstances in the contiguous public rights-of-way (trails, parkland, streets, easements, etc.) the result is a three-part plan: the Waller Creek Corridor Framework Plan (the "white book") that describes the strategic approach towards each functional layer of the creek landscape in its entirety, The Block-by-Block Enlargements (the "blue book") that succinctly describes how these strategic approaches play out in the varied conditions found block-by-block along the creek, and the Waller Creek Corridor Framework Plan Appendix (the "yellow book") that catalogs all of the supporting technical memos, studies, backgrounds, and modeling.



The Framework Plan dissects the new creek landscape in three ways: functional layers, distinct and implementable segments, and serial cross-sections. The functional layers are oriented to the development of the plan relationships and documenting extensive amounts of research, data-collection and on-site investigations. Consistent with the original Waller Creek Design Plan from the 2012 competition, the definition of implementable segments has been an instrumental means for coalescing the gradient of site issues along the length of the creek into tangible drivers for the essential character to these locales. Providing a different window into a range of conditions, the metered cutting of sections along the length of the creek provides an armature for testing the feasibility of planning concepts, as well as the basis for numerous technical assessments.

Framework Plan Segments

The Framework Plan subdivides the Creek Corridor into six distinct project segments:

I Lady Bird Lake to Cesar Chavez (Creek Mouth)

II Cesar Chavez to 4th Street (Palm Park)

III 4th Street to 7th Street (The Narrows)

IV 7th Street to 10th Street (The Refuge)

V 10th Street to 12th Street (Symphony Square)

VI 12th Street to 15th Street (Waterloo Park)

Functional Layers of the Framework Plan

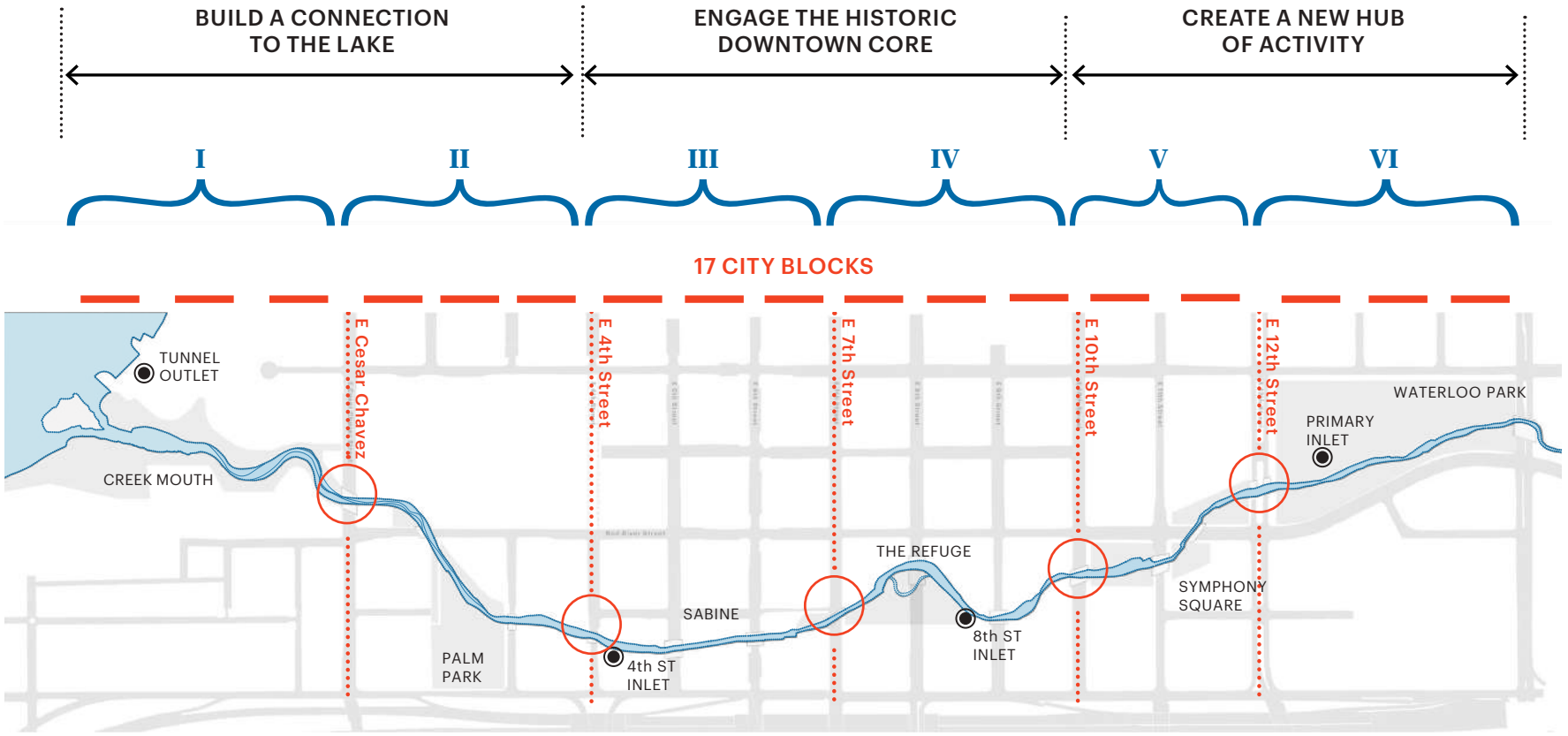
The Framework Plan describes new interactions between the city and the creek in the build-up of functional layers. The Plan begins with the structuring elements, such as trails and connections to rights-of-way, that will link civic activities and a multitude of existing and future destinations. Subsequent layers address the systemic tangle of the creek's natural systems and the city's infrastructural systems that have made extensive use of the creek corridor. The Framework Plan concludes with the description of the creek hydrology as the due diligence for shaping the new flood plain, but also as it relates to stewardship of the creek corridor landscape in the post-Tunnel context.

The functional layers of the Framework Plan are:

- Trail Network
- Utilities
- Heritage Trees
- Riparian Slopes
- Aquatic Habitat
- Stormwater Retrofits – Landscape
- Stormwater Retrofits – Inline
- Stormwater Retrofits – Sewershed
- Stewardship, Maintenance & Operations
- Hydraulics & Hydrology

Block-by-Block and Cross-Sections

For each block in the urban grid (approximately 276') from Lady Bird Lake to 15th Street, the Framework Plan provides a minimum of two-cross sections. These 43 cross-sections synthesize and spatialize the findings of the functional layers above along with an updated HEC-RAS model (which identifies preliminary baseflow and flood elevations).



FRAMEWORK PLAN SEGMENTS AND CROSS-SECTIONS

TRAIL NETWORK

First and foremost, the Waller Creek Corridor Framework Plan is organized around establishing a trail network that will foster recreational uses such as jogging and biking, as well as support the pedestrian community that will emerge from development adjacent to the Creek. It is critical that this network fosters a walkable and inclusive feeling district while also structuring the experience of the revitalized creek landscape. In short, the trail network is the "frame" of the Framework Plan. This prioritization of the experience of connectivity and access is consistent with the primary Waller Creek Design Competition goal of creating an "armature for an urban district" and the design priorities established at the beginning of the Framework Planning process.

The proposed trail network has been tested in a highly iterative manner against the existing and emerging conditions in the Waller Creek District, including: COA trail standards, idiosyncratic physical and jurisdictional circumstances, private developments, the surface components of the Waller Creek Tunnel, planned program changes within the city rights-of-way (rail, vehicle, bikes), entwined infrastructures, necessary utility upgrades, street bridges, historic assets, and easement obligations. As such, the firmness of the network alignment reflects the deep collaboration of the City and the Waller Creek Conservancy in the context of the Joint Development Agreement and the endorsement of the Technical Advisory Committee and the Waller Creek Board of Trustees.

The construction of the trail network will be phased over many years; project areas for construction must carefully consider tie-in points to existing trails and sidewalks. Trails should never dead-end, and phasing may require temporary access and egress points.

PRINCIPLES IN DEVELOPING THE WALLER CREEK TRAIL NETWORK

Trail Network Alignment

- Sloped walks should not exceed 5% grade
- Avoid use of switchback ramps or elevators for creek access
- Evaluate trail width against impact to the creek environment (construction impacts and overwhelming the creek channel with an inappropriately sized trail)
- Foster multiple points of egress and long sightlines for an improved sense of safety at the creek level trails
- Consider the advantages and disadvantages of aligning new trails to areas with already planned bank and upland construction.
- Maximize the scale of areas for restoration and preservation along the creek
- Trail structures should be perceived as independent from municipal structures and privately-owned structures
- Encourage strategic redundancy of the trial and bike facilities rights-of-way to prevent congestion and overloading of the creekside trail network

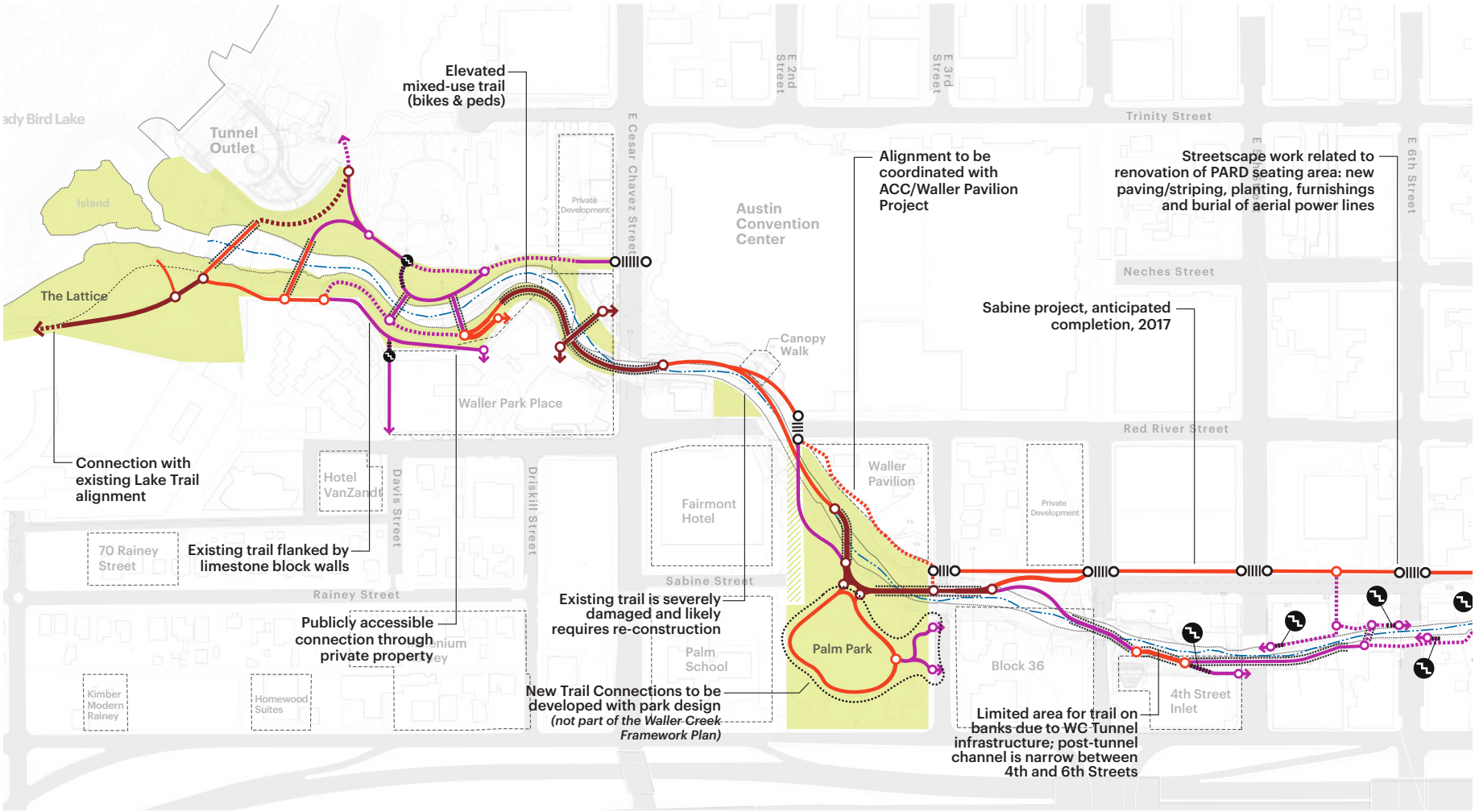
Trail Width

- No less than 8 ft. width, ideally with 2 ft. creekside shoulder
- When the trail is located on structure, 14 ft. wide is preferred
- Width of path is most likely to fluctuate due to the constraints found in the varied creek environment
- Prioritize wider trails between Lady Bird Lake Hike & Bike Trails and the Sabine Street Promenade
- The secondary creekside trail branch between 4th and 7th Streets should prioritize pedestrian movement; bike traffic will be directed on the Sabine Promenade

GUIDELINES FOR TRAIL MATERIALITY AND DESIGN

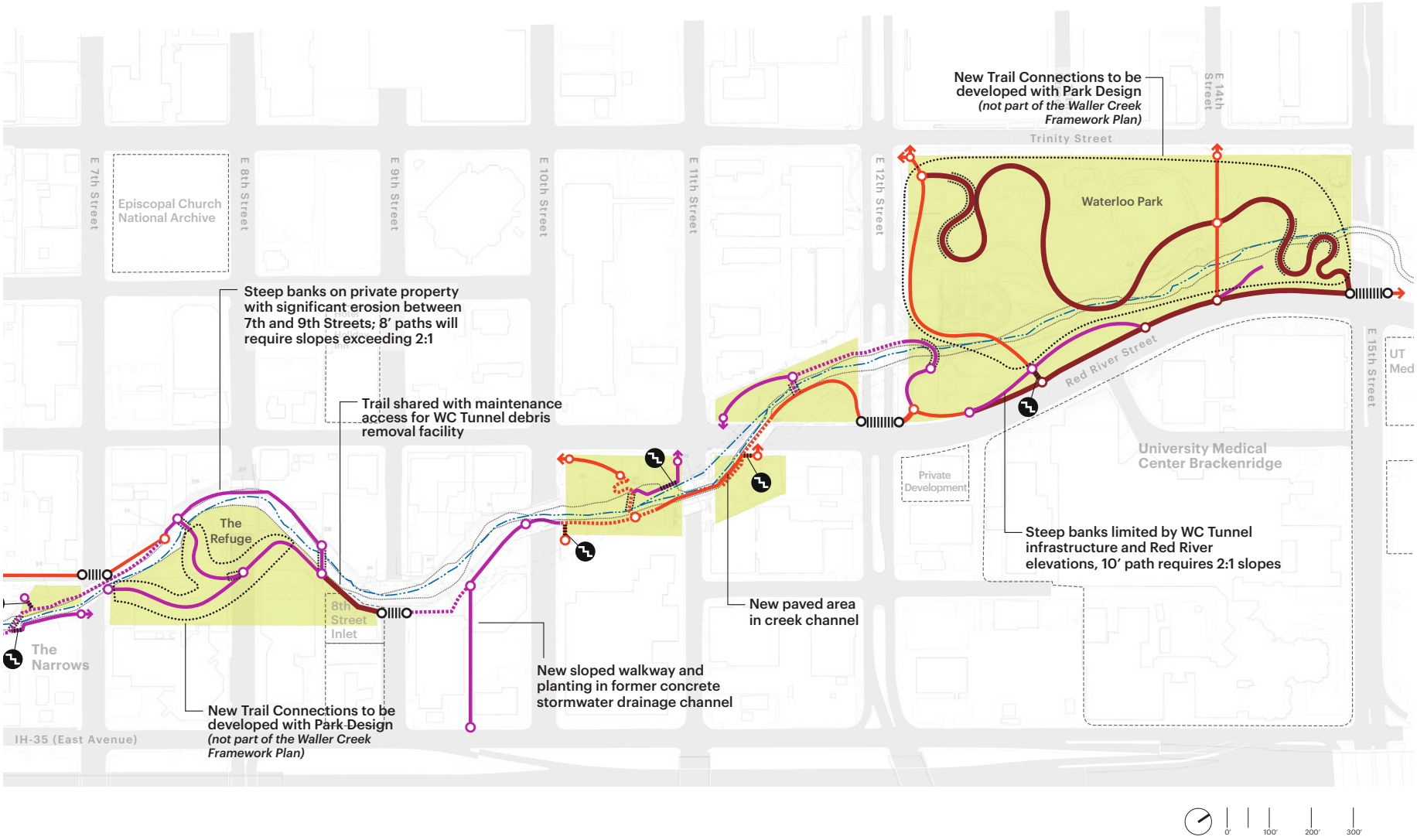
- Trail elevations should be designed above the post-tunnel Waller Creek 100-year flood plain. Within the influence of the higher Lady Bird Lake flood plain, the Waller Creek 100-year flood elevation supersedes as design criteria.
- Concrete pavement on grade and planks on structure are preferred (wood boardwalks to be avoided
- Exceptions to trail surfaces above may include metal grating walkway surfaces for transmission of water and light to landscapes below, or for featuring unique conditions relating to the tunnel infrastructure
- Broom finish or alternative for a firm, stable, and slip-resistant surface
- Guardrails provided at locations with vertical drops over 30” and without landscape barriers
- Standard guardrail heights of 42”, potentially including a rub rail where bicycle use is anticipated
- Trailheads at or near street level should be sufficiently sized to accommodate standard-sized trash and recycling receptacles and signage for the trail network
- Trailheads at or near street level should be coordinated with streetscape lighting to create a focus at creek access points
- Within the creek corridor, integrate site elements (e.g. waste receptacles, signage, lighting) into the design of the railings and trailheads
- Site elements and wayfinding should not encroach upon the clear path width
- Minimize wayfinding signage and emphasize intuitive spatial design to guide visitors between street level and the creek
- With the exception of the Sabine Street Promenade, no lane demarcation will be required on the trails
- Design elevated trail components for ease of replacement and repair, with the goal of minimizing damage to landscape areas
- Consider design of trail structure below roadway bridges to include fittings for temporary covers, which would protect pedestrians from repair or reconstruction activities on these bridges
- Applicable code and guideline references: AASHTO, TAS, ADAAG
- Plan for inevitable interim conditions where compliant trails will transition to non-compliant trail segments

TRAIL NETWORK



MAP KEY

- Creek Centerline
- 8′ wide Existing Trail
- 10′ wide Existing Trail
- 14′ wide Existing Trail
- 8′ wide Proposed Trail
- 10′ wide Proposed Trail
- 14′ wide Proposed Trail
- Elevated Trail
- Ped/Bike Street Crossing
- Stair Connection to Street
- Trail Junction
- Trail Connection to Existing Path/Sidewalk


New Trail Connections to be developed with Park Design
(not part of the Waller Creek Framework Plan)
E 14th Street
Trinity Street
E 7th Street
Episcopal Church National Archive
E 8th Street
E 9th Street
E 10th Street
E 11th Street
E 12th Street
Waterloo Park
Steep banks on private property with significant erosion between 7th and 9th Streets; 8′ paths will require slopes exceeding 2:1
Trail shared with maintenance access for WC Tunnel debris removal facility
Red River Street
E 15th Street
UT Med
University Medical Center Brackenridge
Private Development
The Refuge
Steep banks limited by WC Tunnel infrastructure and Red River elevations, 10′ path requires 2:1 slopes
8th Street Inlet
New paved area in creek channel
The Narrows
New sloped walkway and planting in former concrete stormwater drainage channel
New Trail Connections to be developed with Park Design
(not part of the Waller Creek Framework Plan)
IH-35 (East Avenue)
0′
100′
200′
300′

SITE ELEMENTS MATRIX

Waller Creek will be one of the largest urban creeks in the U.S. to undergo such dramatic transformation. The creek corridor is characterized by constant interaction with urban systems and civic activities. As such, there will be an implicit demand to provide a legible identity for the moments when a visitor has a direct interface with the new urban creek landscape — the benches, railings, and trash receptacles common to Austin's streets may not be appropriate or even functionally feasible within the creek landscape. Site elements need to be tailored to the creek experience as well as the regime of maintenance that will operate there. In addition to the observation that there will be a distinction between street-level elements and creek-level elements, a complementary axis distinguishing furnishings from infrastructure produces a matrix of urban landscape treatments. This matrix locates types of needed furnishings and pedestrian site elements within four zones of this new urban landscape, each with different scalar sensibilities and potential to inform the identity of this project.

I. Street Furnishings Zone
Many of Austin's City Standards can be employed in this zone; however, street-level environments associated with this project, such as Palm Park and Waterloo Park, will likely be encountering higher levels of use than most urban parks in downtown Austin. The program for site elements in this zone should anticipate larger numbers of daily and event-based visitors, the incremental growth of the creek corridor park system and development should characterize

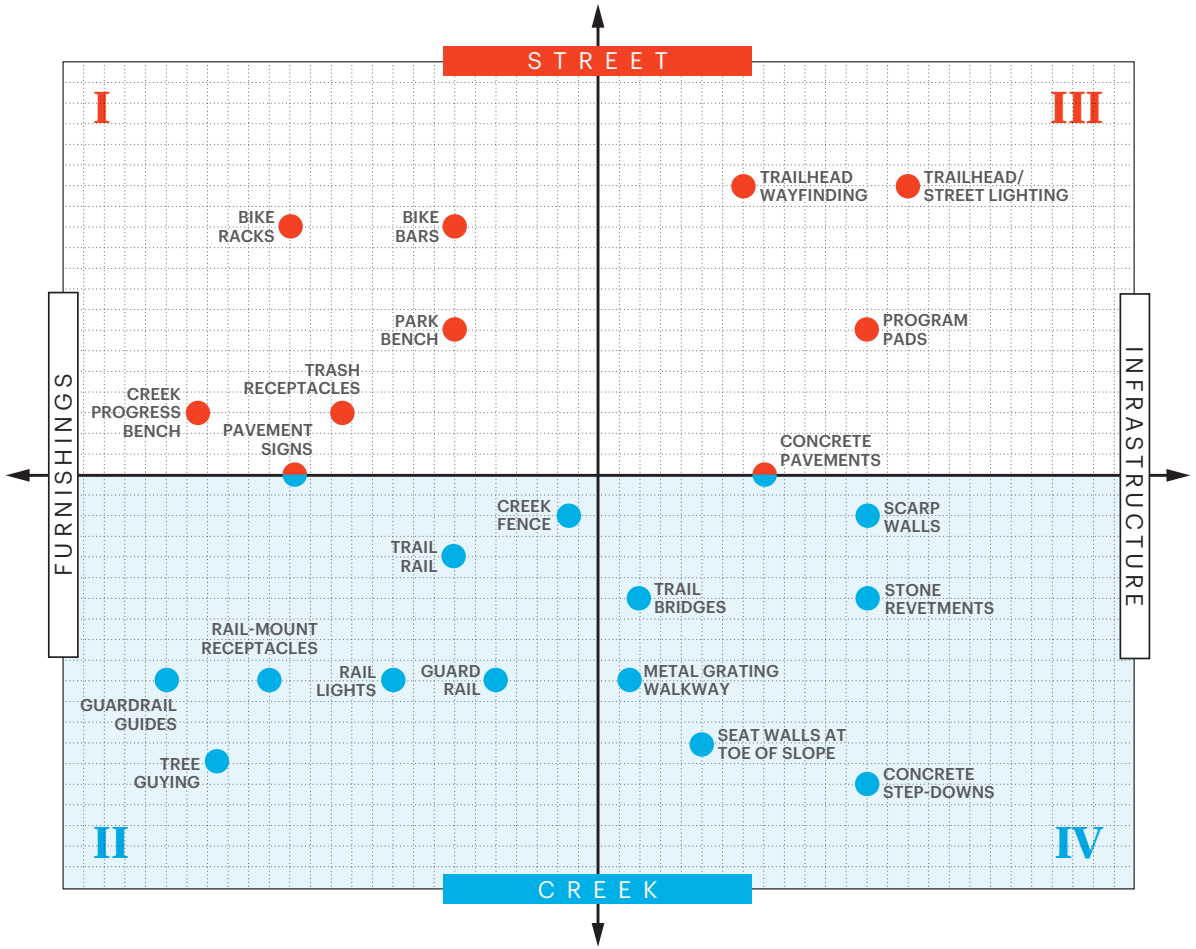
II. Creek Furnishings Zone
The standard scale and frequency of site elements found at street-level — signage, light poles, and trash receptacles etc.— would easily overwhelm the delicate naturalism of the creek landscape. This zone should consider every effort to incorporate site elements into the architecture of the trail so that the creek can constitute the primary experience.

III. Street Infrastructure Zone
Many of Austin's emerging City "systems" can be incorporated into this zone, such as many of the components of the Great Streets program. The implementation of these systems, however, should consider minor adjustments where they meet the Waller Creek corridor, and also to anticipate different patterns of use than one might expect in a street right-of-way. Lighting and wayfinding elements will be critically important to tailor at the street-level entry points to the creek corridor, and infrastructure that supports a heavier regime of programming should be considered in this zone.

IV. Creek Infrastructure Zone
Decades of degradation of the riparian creek banks and aquatic habitat now require that the geomorphology of the creek depend upon "infrastructural" support. Highly eroded near-vertical earthen banks cannot simply regenerate on their own, and urban runoff places additional stresses to natural systems. This artificial infrastructure of stabilizing creek channels and slopes with integrated bioengineering and geotextile techniques can also sponsor a more refined and high-functioning program of natural processes.

IDENTITY FOR THE DISTRICT

The success of the Waller Creek District in the public imagination is closely related to its legibility in the urban realm. While the variety of the creek is part of what makes it a special place, Waller Creek must be easily recognizable as a destination and an intuitively navigable part of Austin's circulation network. Through outreach to private and public development projects and continued collaboration between the Waller Creek Conservancy and the City of Austin, the full promise of the District can be realized by upholding district-wide standards for trail criteria and development.



TRAIL NETWORK – SITE ELEMENTS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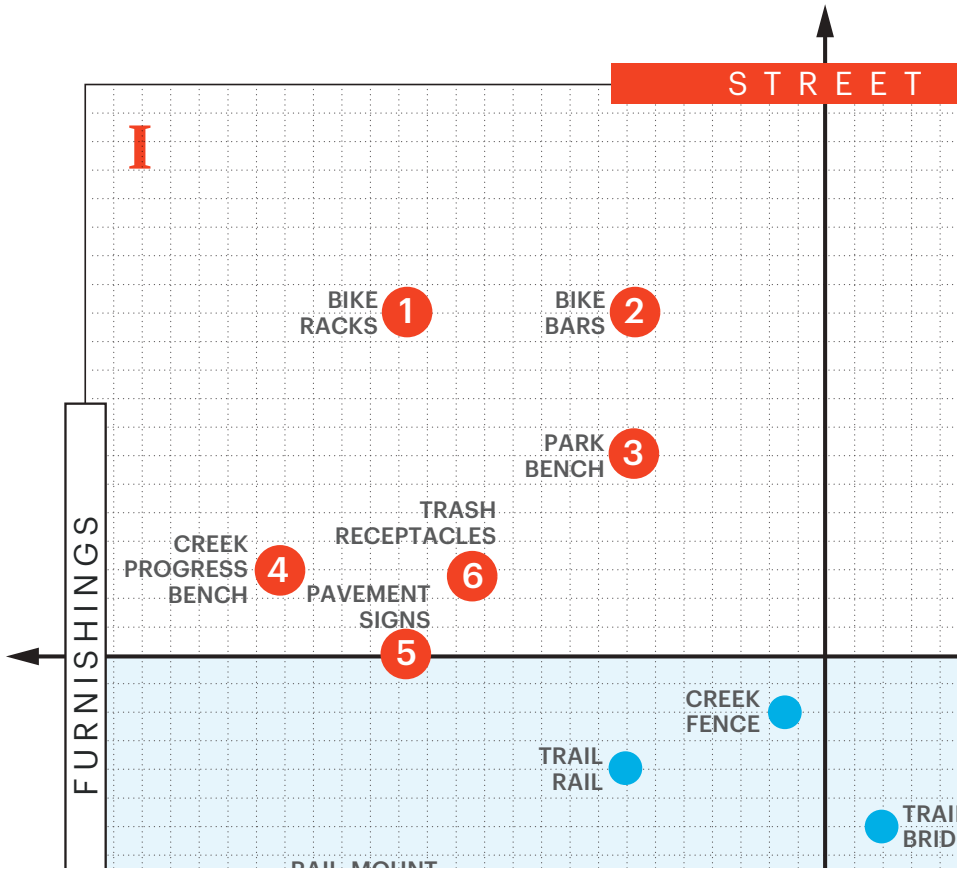

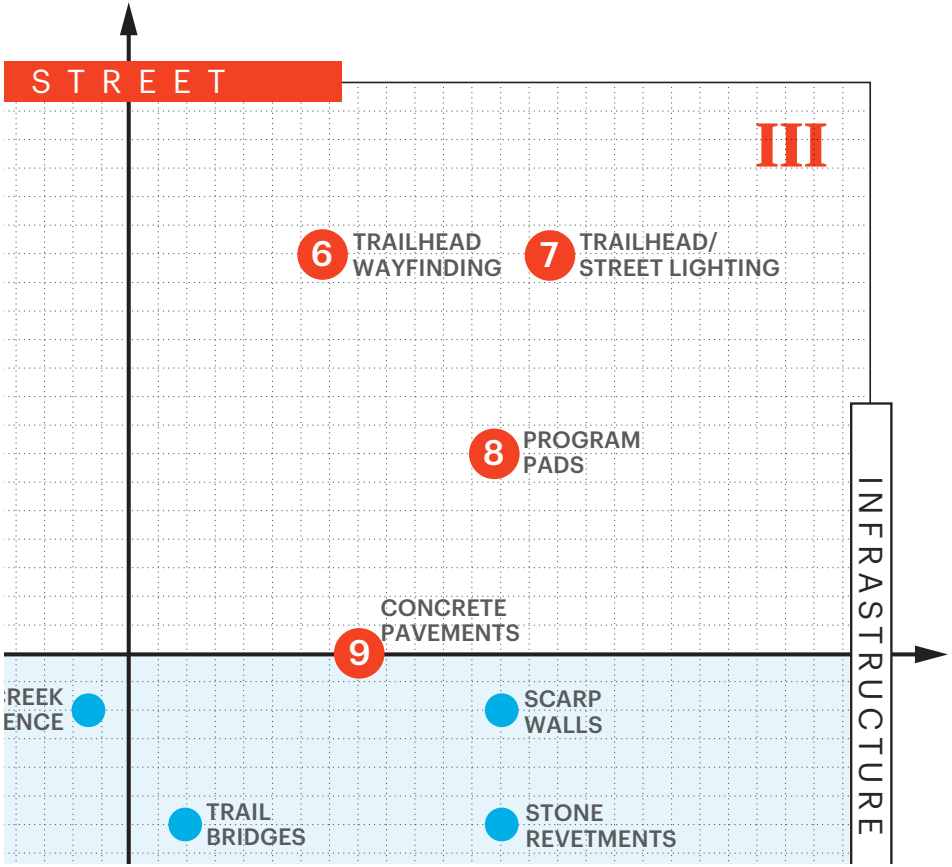
STREET
III
6 TRAILHEAD WAYFINDING
7 TRAILHEAD/ STREET LIGHTING
8 PROGRAM PADS
INFRASTRUCTURE
9 CONCRETE PAVEMENTS
REEK ENCE
SCARP WALLS
TRAIL BRIDGES
STONE REVETMENTS

6

7

8

9

TRAIL NETWORK – SITE ELEMENTS

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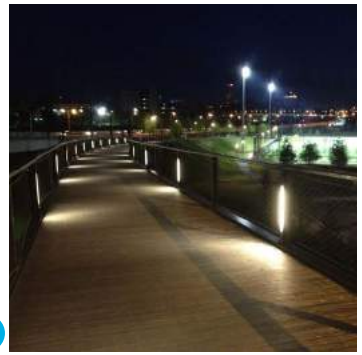

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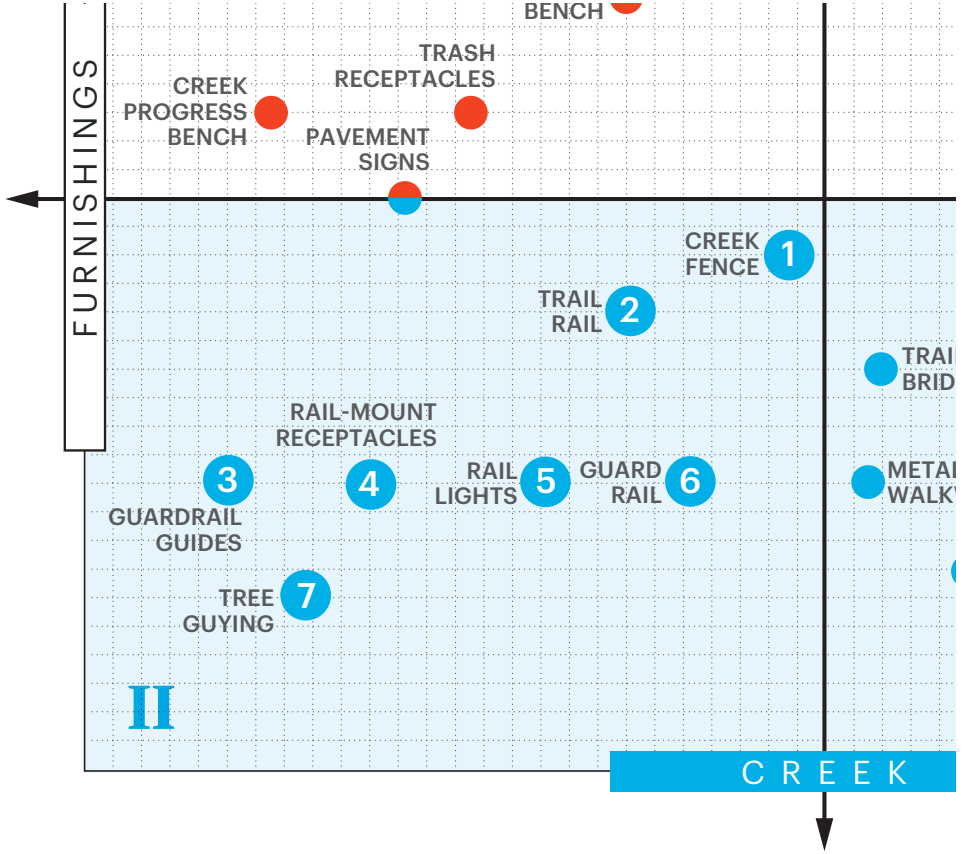

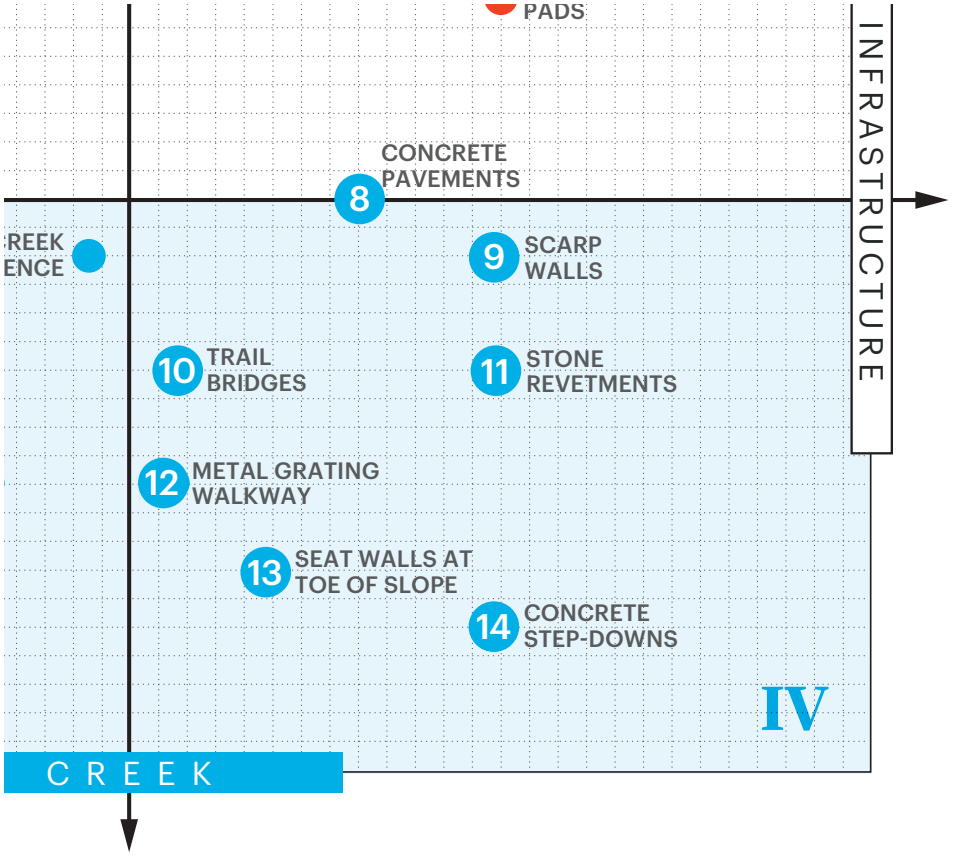


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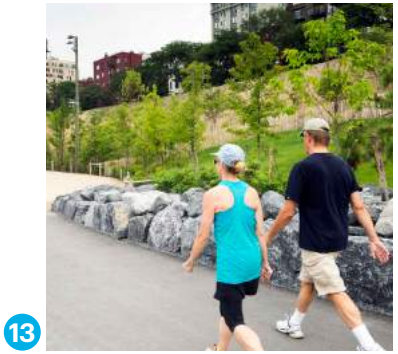
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UTILITIES

The Framework Plan has to be selective and strategic in its engagement with City of Austin utility agencies as there are many potential futures to development and city infrastructure in the rights-of-way. These changes could affect the holistic picture of how utilities are organized in the city grid. While the priority of COA planning is, by necessity, on the capacity, configuration and sequencing of utility service, the focus of this Framework Planning effort has been limited to the identification what infrastructure currently exists or is planned that would impede the development of the trail system or other critical continuities for the creek restoration project. Nevertheless, in the context of the large number of parallel planning efforts currently underway in the downtown area, there are also critical overlaps of that are identified in the Plan as opportunities for integrated utility planning that could mutually benefit the city systems and reduce the burden of urban utility impacts on the creek landscape.

OVERHEAD UTILITIES

The most common utility issue present along the creek is that a significant number of power, data, and telephoneaerial creek crossings and overhead lines adjacent to parks. These lines have not been buried per the current City standards because of the lack of redevelopment along the corridor for the last several decades. In many cases, resolving this issue will be required in the site plan approvals process for developers along the creek. However, because burying aerial lines that cross the creek will require boring through limestone and could have potential impacts to the creek banks, this plan seeks to identify some preliminary guidelines for how lines could find alternate routes. The majority of these overhead crossings are located in the existing alley rights-of-way held by the City. In many circumstances, however, the alleys have been vacated, which underscores the importance of effective coordination with private developers along the creek.

One critical area of utility conflict is at Palm Park and the creek crossing at 3rd Street. Here, the intersection of several branches of overhead lines must be dealt with before the development of the creek trail, the renovation of Palm Park, and the connection to the Sabine Street Promenade.

WASTEWATER, WATER, AND RECLAIMED WATER

Wastewater lines represent the greatest physical impact on the development of pedestrian and bike facilities along the creek, particularly at street crossings. Due to the limited range of feasible depths for this utility, these lines are commonly visible passing through the abutments or archways of existing bridges.

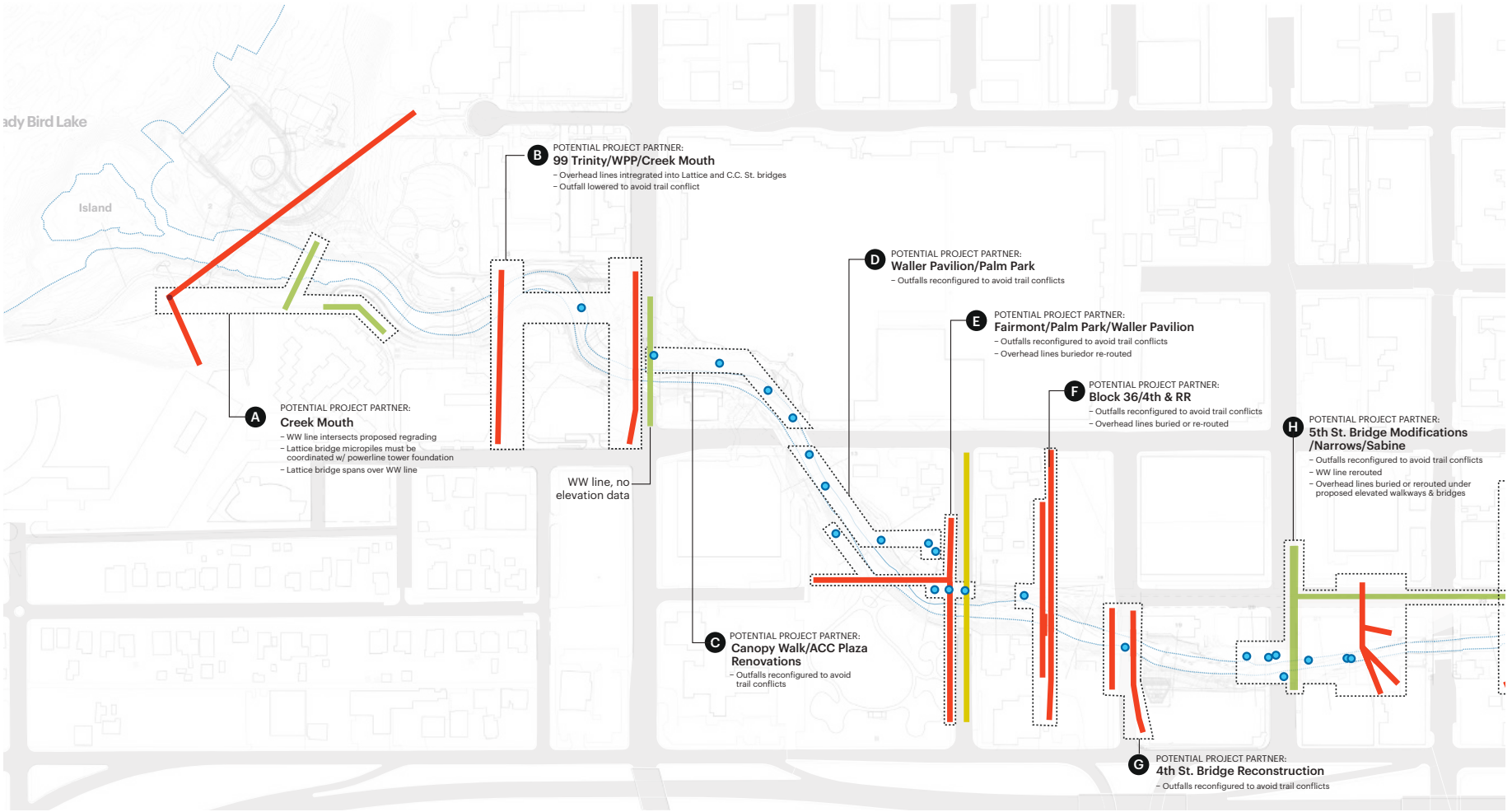
Additionally, water lines and the currently planned reclaimed water system present similar obstacles for minimum clearances along the creek trail. The Framework Plan has identified that the Texas Accessibility Standards state a minimum of 80" for vertical clearance on an urban trail. City of Austin guidelines recommend a minimum of 8'-0" clearance along trails, with a highly preferred clearance of 10'-0", especially south of 4th Street where higher bike traffic is anticipated. Critical sites for system modifications are the wastewater line crossing the creek at 5th Street and the planned reclaimed water line at Red River between 11th and 12th Street.

STORMWATER

The Framework Plan has been developed more extensively in regard to this utility service because of its direct impact on water quality and flood level flows in the creek. Beyond performance recommendations, there is also a need to address the physical encumbrance of this infrastructure on the creek landscape. There are 66 functioning end-of-pipe conditions and dozens of other abandoned pipe ends along the creek corridor.

This plan has identified strategies for mitigating the end-of-pipe relative to flow and quality but in the instances of a storm larger than a 5-year event, the creek landscape will still experience high velocity inputs form these pipes. This condition is a maintenance burden for the planned landscape in the form of erosion and trail conflicts. Development along the creek should prioritize stormwater measures with minimal impact on the creek landscape and those that result in the removal of abandoned end of pipes. Additionally, end-of-pipe conditions that frequently appear in the public rights-of-way should be retrofitted with devices, such as flap-gates, that reduce the velocity of stormwater and mitigate the risk of public safety hazards.

UTILITIES

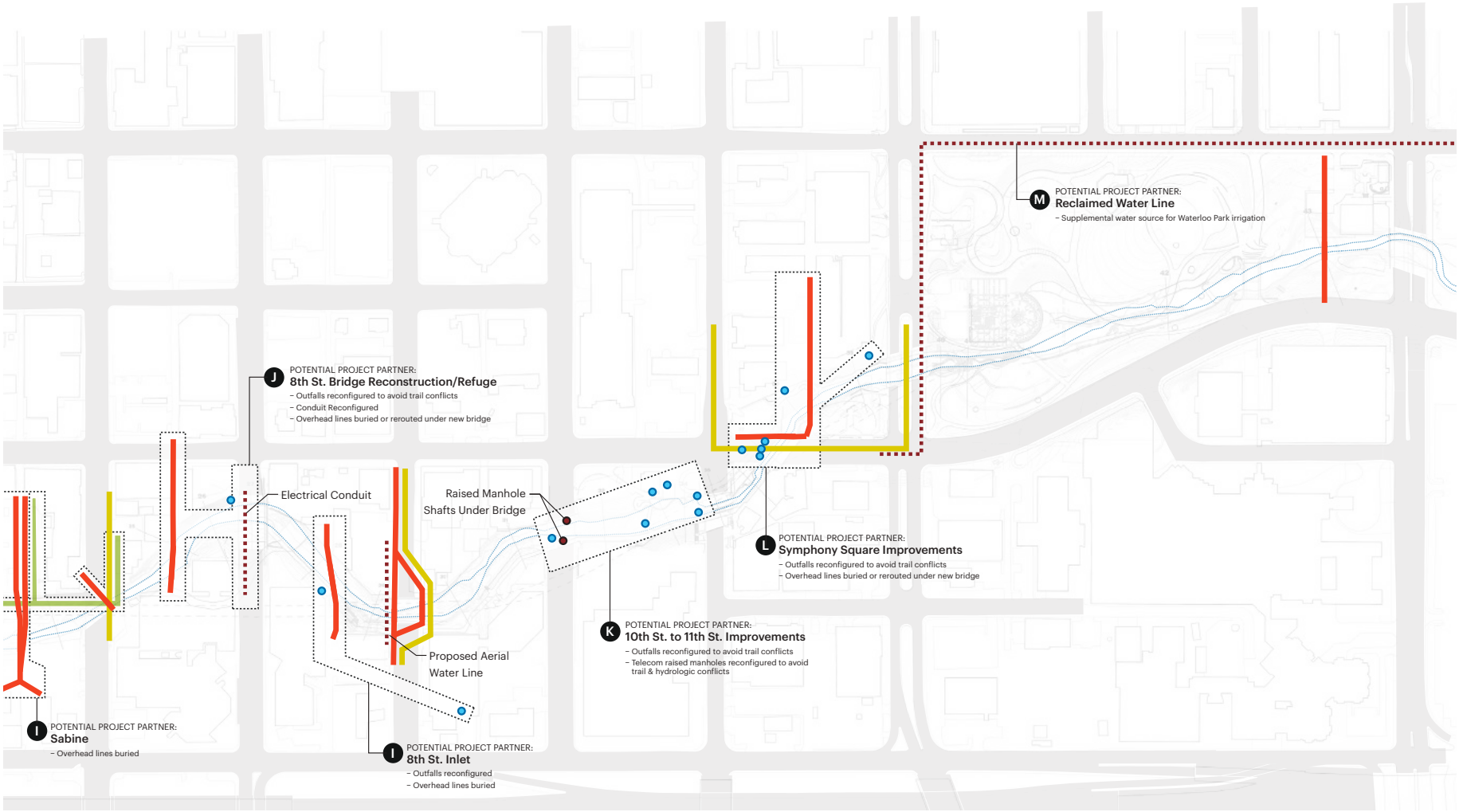


MAP KEY

Potential Utility Renewal Project

POTENTIAL UTILITY CONFLICTS

- **Stormwater Outfall** — To be relocated or reconfigured when feasible
- **Wastewater** — Limit reconfiguration unless necessary for trail passage
- **Overhead Utility** — To be buried when feasible
- **Gas** — Avoid relocation
- **Other Utility** — Assumed impact – to be relocated when feasible


M
POTENTIAL PROJECT PARTNER:
Reclaimed Water Line
– Supplemental water source for Waterloo Park irrigation
J
POTENTIAL PROJECT PARTNER:
8th St. Bridge Reconstruction/Refuge
– Outfalls reconfigured to avoid trail conflicts
– Conduit Reconfigured
– Overhead lines buried or rerouted under new bridge
Electrical Conduit
Raised Manhole
Shafts Under Bridge
L
POTENTIAL PROJECT PARTNER:
Symphony Square Improvements
– Outfalls reconfigured to avoid trail conflicts
– Overhead lines buried or rerouted under new bridge
K
POTENTIAL PROJECT PARTNER:
10th St. to 11th St. Improvements
– Outfalls reconfigured to avoid trail conflicts
– Telecom raised manholes reconfigured to avoid trail & hydrologic conflicts
Proposed Aerial
Water Line
I
POTENTIAL PROJECT PARTNER:
Sabine
– Overhead lines buried
I
POTENTIAL PROJECT PARTNER:
8th St. Inlet
– Outfalls reconfigured
– Overhead lines buried
0'
100'
200'
300'

HERITAGE TREES

The 2010 City of Austin Ordinance No. 20100204-038 defines Heritage Trees as trees of a species prevalent to the climate and landscape of Central Texas that are greater than 24" in diameter. The 2013 Central Business District Tree Inventory identifies 100 Heritage Trees along Waller Creek, with a significantly higher percentage of bald cypress and Durand oaks than typically distributed throughout the urban forest, although the number of cypress south of 12th Street is minimal.

The 2013 report also includes an excerpt from the 2010 Canopy Coverage Study, which reveals that the tree canopy along the creek represents almost the entirety of the canopy coverage for the Waller Creek District. This is in part due to the challenging utility and subgrade conditions for supporting street trees in this part of downtown. City infrastructure improvement programs, such as the chilled water line expansion, the reclaimed water line and the Great Streets program, will continue to have varying impacts on canopy coverage downtown in the public rights-of-way and make the Creek Corridor canopy increasingly important to downtown tree canopy.

Ultimately, the Waller Creek Framework Plan looks to add to the tree canopy coverage along the creek; as significant shade providers, these trees will create destination microclimates for daily users of the trail. However, planting the next generation of Heritage Trees may first involve removing a significant number of invasive or ailing trees to make room for a higher quality tree canopy. The Riparian Slope section of this document indicates which areas will have greater or lesser impacts to the existing tree canopy.

Based on the COA-commissioned 2012-2013 ArborPro survey, the Framework Plan has documented and acknowledged Heritage Trees throughout the analysis and alignment of the trail network. Heritage Trees identified in "poor condition" by the ArborPro survey are recommended for removal if they coincide with a slope reconstruction area recommended in this plan. Others need not be removed immediately but are documented should a conflict emerge in the design process.

This Framework Plan looks at the topic of the tree canopy in a layered manner, starting with the feasibility of the trail network relative to conflicts with existing Heritage trees. The trails are planned in such a way as to have no impact on any Heritage Tree on the creek with one notable exception — at the intersection of the creek with the alleyway between 7th and 8th Street. In this location, a Heritage-sized American Elm is in direct conflict with the connection between the Sabine Promenade and the northbound continuation of the trail. The Framework Team has inspected the tree with a COA arborists and made the preliminary determination that this tree is in such a deteriorated condition that it is unlikely to be an obstacle during the design and permitting process to establishing this critical connection for the network.

The trail network was also planned with consideration of 54 documented future heritage trees that are less than 24" diameter but are assessed in 'good' condition or better. These champion trees have already demonstrated their resiliency through the stressful drought conditions of the past decade and will become key features in the evolution of the Creek landscape. Lastly, the Framework Plan identifies Heritage Tree zones where same-species Heritage Tree might be grouped to provide legacy trees for future generations. The creation of these zones is conceived as a way to raise awareness of the value of these trees in the community by presenting the impressiveness that same-species groves afford. In most cases this is suggested primarily in park locations located outside of the creek corridor, but it may also be incorporated into the design of adjacent creek areas.

HERITAGE TREES

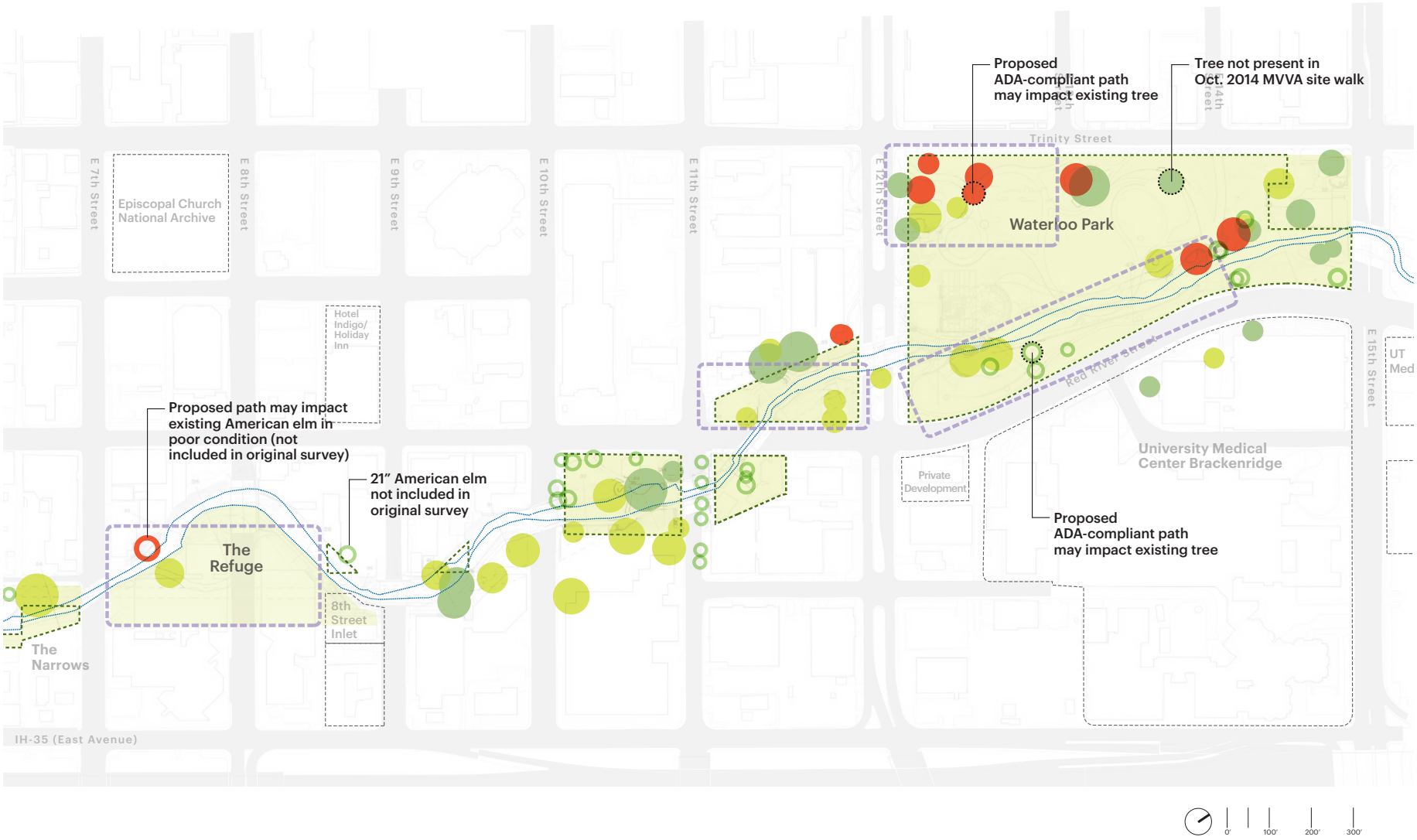
MAP KEY

ASSESSMENT RATINGS KEY: (Heritage Trees)

- **Good-** No Apparent Problems
- **Fair-** Minor Problems
- **Poor-** Major Problems
- **12"-24" Good**

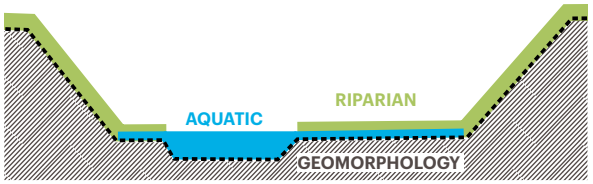
SOURCE: 2012-2013 ArborPro survey & 2014 dwg graphic conversion.
Evaluation based upon an adaptation of the Council of Tree and Landscape Appraisers (CTLA) tree appraisal standards (CTLA, 2000 Guide for Plant Appraisal, 9th Ed.)

- **Park Destination**
- **PARD Property (GIS)**
- **Recommended Heritage Tree Zone**


Proposed
ADA-compliant path
may impact existing tree
Tree not present in
Oct. 2014 MVVA site walk
Trinity Street
E 7th Street
E 8th Street
E 9th Street
E 10th Street
E 11th Street
E 12th Street
E 14th Street
E 15th Street
Episcopal Church
National Archive
Waterloo Park
Hotel
Indigo/
Holiday
Inn
Red River Street
UT
Med
University Medical
Center Brackenridge
Private
Development
Proposed path may impact
existing American elm in
poor condition (not
included in original survey)
21" American elm
not included in
original survey
The
Refuge
8th
Street
Inlet
The
Narrows
Proposed
ADA-compliant path
may impact existing tree
IH-35 (East Avenue)
0'
100'
200'
300'

RIPARIAN SLOPES

Developed in tandem with the trail network, the most critical layer in this Framework Plan is the character and construction of the creek's sloped banks — the riparian zone between the top of bank and the edge of the waterway. There is a substantial amount of failed or failing slopes throughout the corridor that need to be stabilized, rebuilt, or reinforced. Significant lengths of the creek are flanked by architectural edges with transitions to vegetated slopes often representing key points of vulnerability in the creek landscape. With the Waller Creek Tunnel coming online, the existing banks will no longer be subject to the erosive floodwaters that shaped the current condition of the creek banks. However, anticipating the future pressures of public and private infrastructure and development presents a considerable challenge, including impacts from adjacent construction activity, changes to neighboring land uses, and the effects of stormwater flows that are not mitigated by the tunnel (e.g. overland runoff). Despite these new exterior challenges, this portion of the Framework Plan is crucial to steering the overall character of the creek channel, and privileges vegetated slopes over hard-structured engineering solutions (walls and masonry revetments).



PRESERVATION, RESTORATION, RECONSTRUCTION

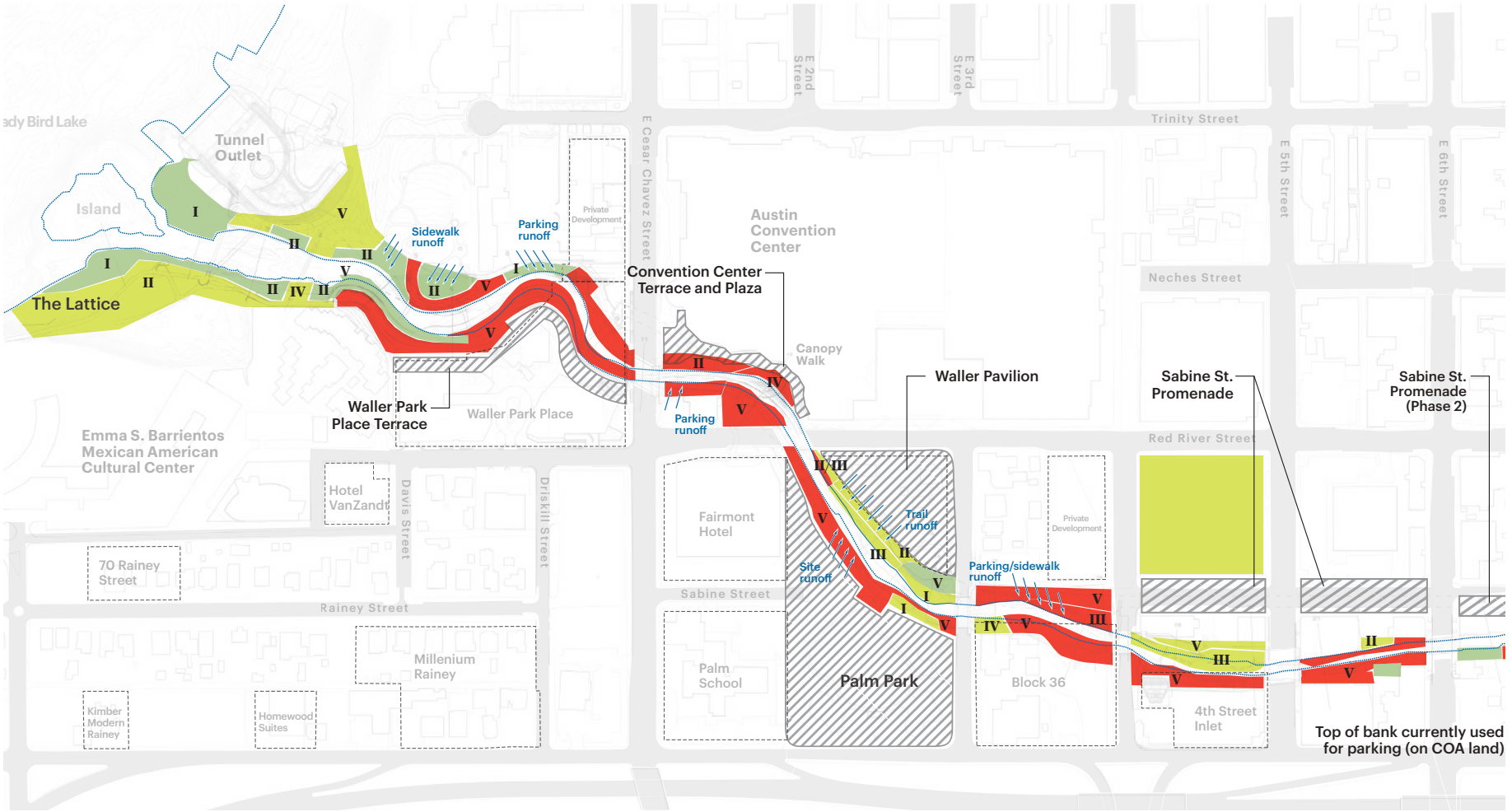
Promoting diversity and stability in Waller Creek's riparian slopes is critical to improving the corridor's ecological health and elevating its value as a green corridor in the city. The Waller Creek Tunnel practically eliminates the possibility of catastrophic flash floods, which allows for greater channel and streambank stability. However, nearly 100 years of urban development along the banks of Waller Creek require careful and site-specific consideration of the capacity or necessity for change. This evaluation, borne out of the trail alignment plans and a number of MVVA team and COA site walks in 2014, designates the riparian slopes as areas for preservation, restoration, and reconstruction.

First, areas slated for preservation typically represent healthy and high-functioning riparian slopes, ranging from 1:1 to 3:1 in steepness. The vegetation is multi-layered — stable groundcover, understory, and canopy — and can support a diverse wildlife community. Groundcover with deep fibrous root growth, such as provided by perennial grasses and sedges, contributes to stable creek banks and slopes, and adds organic material to the soil, thus improving soil productivity and stability. The understory and canopy shade the creek, deposit organic matter needed by macroinvertebrates and other life in the stream, and create habitat. Organic matter — including tree trunks, branches, and leaves — provides both nutrients and habitat in the form of large woody debris.

Areas identified for restoration have the capacity to host the multi-layered environment described above, but suffer from external factors that have compromised slope stability. These factors include: erosion from flood events, overbank runoff, impacts of adjacent land uses, failing stabilization structures, and unsustainable vegetation (such as highly invasive species or high-maintenance turf). The restoration of these slopes must include correction of the causal factor behind slope failure as part of the design and engineering.

Finally, riparian slopes designated as reconstruction areas have a wide variety of underlying circumstances that influence their future conditions. Some are to be reconstructed as part of the Waller Creek Tunnel project infrastructure. This infrastructure effectively rebuilds a pre-existing slope onto a constructed flood-control device. Similarly, reconstructed slopes related to private development are typically on privately owned land, and may even re-align the channel itself in order to accommodate new structures. Other slope reconstructions coincide with the construction of a new trail. These areas may include bridge abutments, new masonry mechanically stabilized earth (MSE) walls, and structural supports for elevated trails. These elements substantially alter existing habitats, but the objective of the design team is to achieve the qualities of "preservation zones" through reconstruction wherever possible, and to integrate these newly constructed areas with riparian slopes and aquatic habitat.

RIPARIAN SLOPES



MAP KEY

PROJECT TYPE

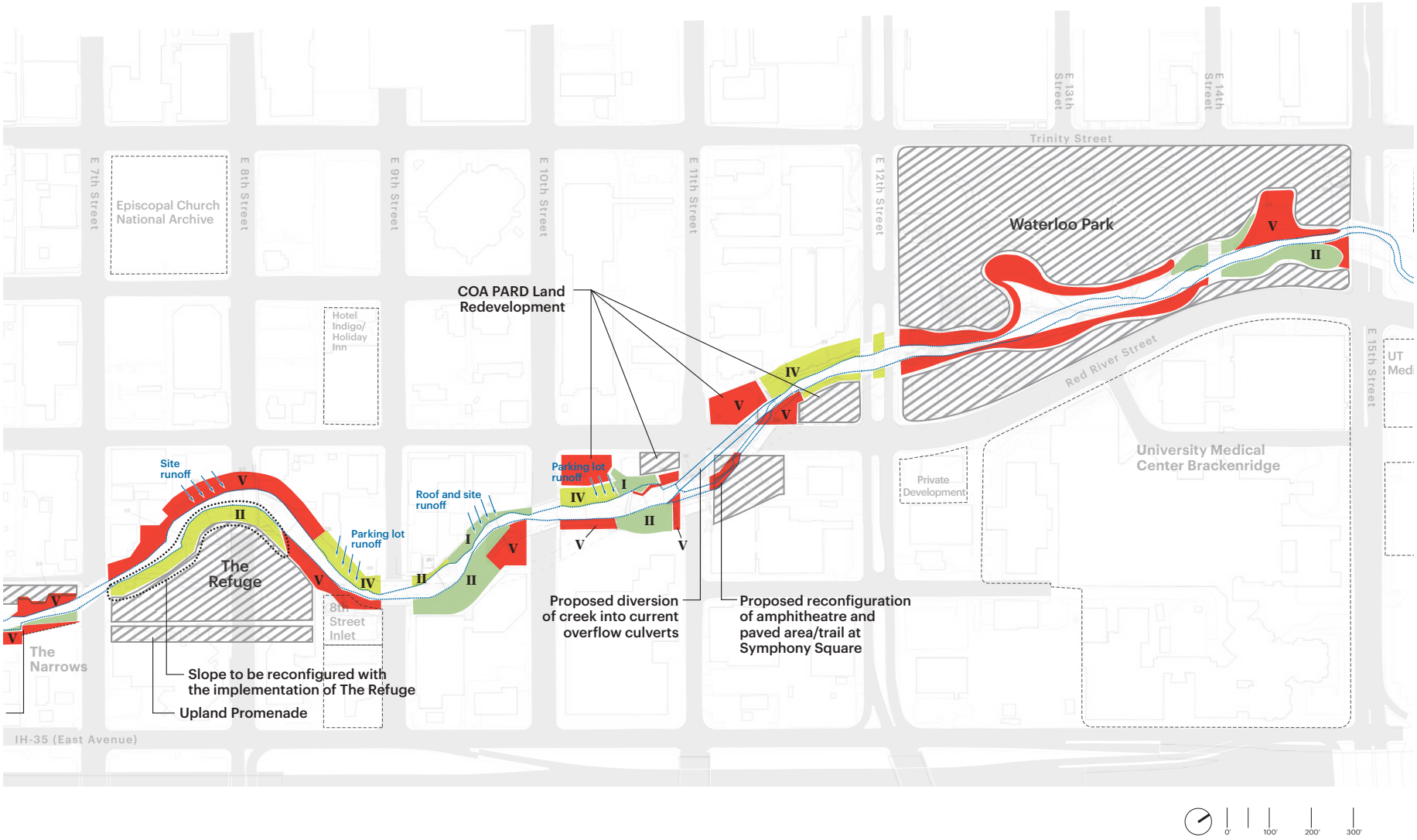
- Do Nothing
- Preservation
- Restoration
- Reconstruction

VEGETATION CLASS

- I Problem Species Removal/Reseed
- II Removal/Reseeding/Replanting
- III Rescue and Salvage Plant/Seed
- IV Significant Removal/Reseeding/Replanting
- V Complete Replacement

Adjacent Public Space Improvements
(outside of Framework Plan scope)

Overbank runoff
(As observed by MVVA team)


E 7th Street
E 8th Street
E 9th Street
E 10th Street
E 11th Street
E 12th Street
E 13th Street
E 14th Street
E 15th Street
Trinity Street
Red River Street
Episcopal Church National Archive
Hotel Indigo/ Holiday Inn
Waterloo Park
University Medical Center Brackenridge
Private Development
UT Medi
COA PARD Land Redevelopment
Site runoff
Parking lot runoff
Roof and site runoff
Parking lot runoff
The Refuge
8th Street Inlet
The Narrows
Slope to be reconfigured with the implementation of The Refuge
Upland Promenade
Proposed diversion of creek into current overflow culverts
Proposed reconfiguration of amphitheatre and paved area/trail at Symphony Square
IH-35 (East Avenue)
0'
100'
200'
300'

RIPARIAN SLOPES

VEGETATION CLASSES

This plan describes the creek vegetation restoration program separately from the description of construction impact on the sloped banks. The emphasis of this programmatic layer highlights the type of re-vegetation that should occur on the slopes. This is broken into five categories, ranging from complete replacement of the slope vegetation to selective removal of problem species and reseeding:

Class I

Class I denotes areas where individual invasive or undesirable plant species are to be removed without significant disturbance to the existing plant community. Class I has the least impact to the existing ecology, and occurs primarily in restoration areas.

Class II

Class II will require some thinning and removal of biomass and minimal soil restoration — working with present soils followed by reseeding and replanting.

Class III

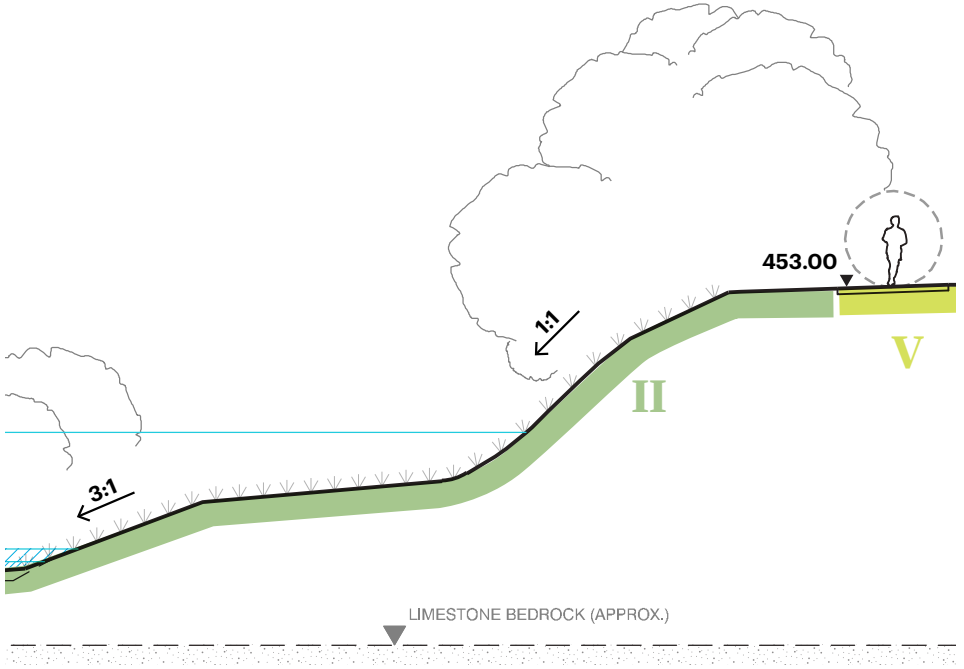
Class III indicates that desirable existing species are to be salvaged from the site, stockpiled, and replanted with additional seeding and new plantings as necessary.

Class IV

Class IV denotes construction — intensive areas, where significant removal, reseeding and replanting will follow changes to soil composition.

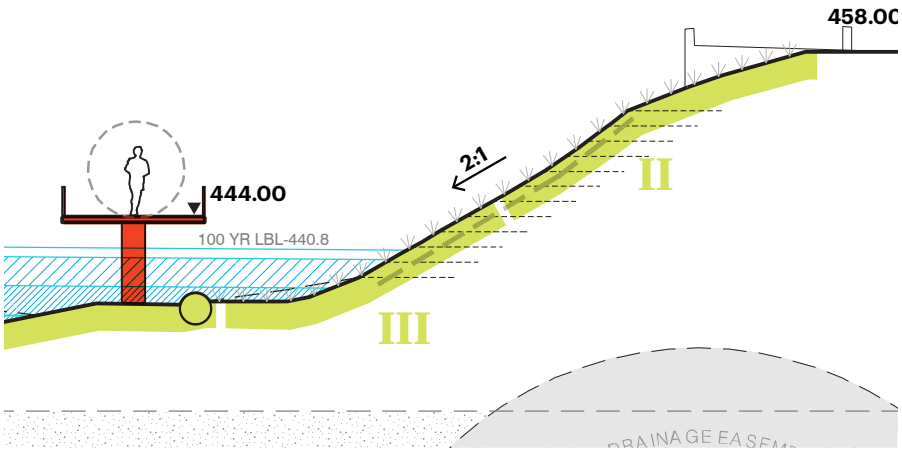
Class V

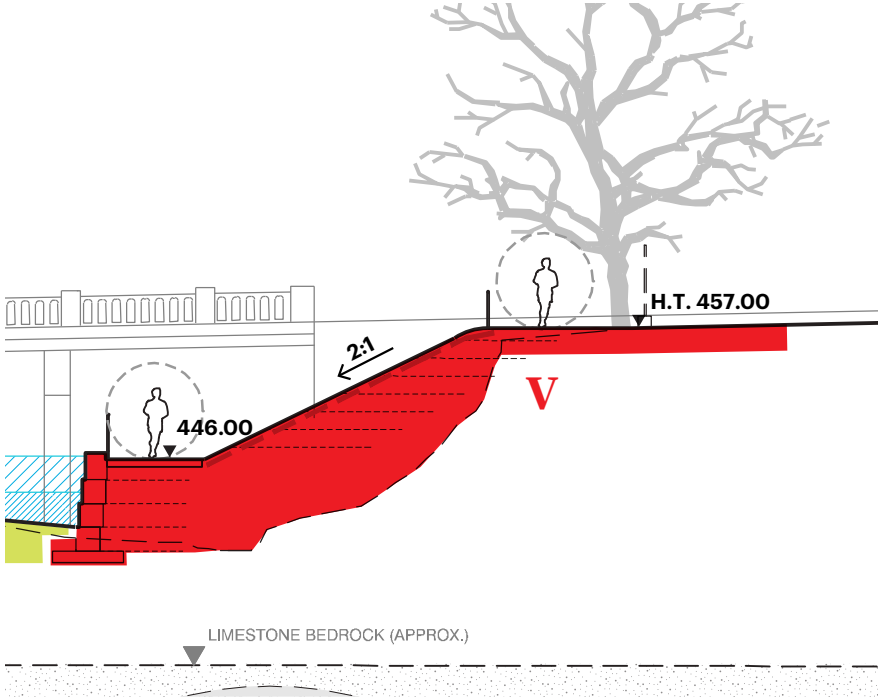
Class V indicates a full-scale replacement of vegetative cover following reconstruction of the underlying structure and soil composition. Class V has the most impact to the existing ecology.



PRESERVATION

Areas of preservation are intended to maintain and enhance natural existing characteristics of the creek environment. This will involve only minimal changes to existing grades and selective removal of invasive vegetation and vegetation that poses safety hazards. Strategic planting will be implemented to improve slope stability, habitat and diversity.





RESTORATION

Areas of slope restoration are intended to reestablish riparian slopes and native plant communities. These areas may require moderate rebuilding of slopes. Through slope restoration, the project will build up these areas to eventually become Waller Creek's future preservation sites.

RECONSTRUCTION

Areas of slope reconstruction are intended to establish more positive and novel plant communities. This will require a complete reconstruction of slope from sub-soils to vegetation. By implementing slope reconstruction, urban programs along the creek can be integrated into a more stable creek environment.

RIPARIAN SLOPE RESTORATION

F HYDROMULCHING/SEEDING
Applied above baseflow with fast-growing, deep-rooted perennial natives & cover

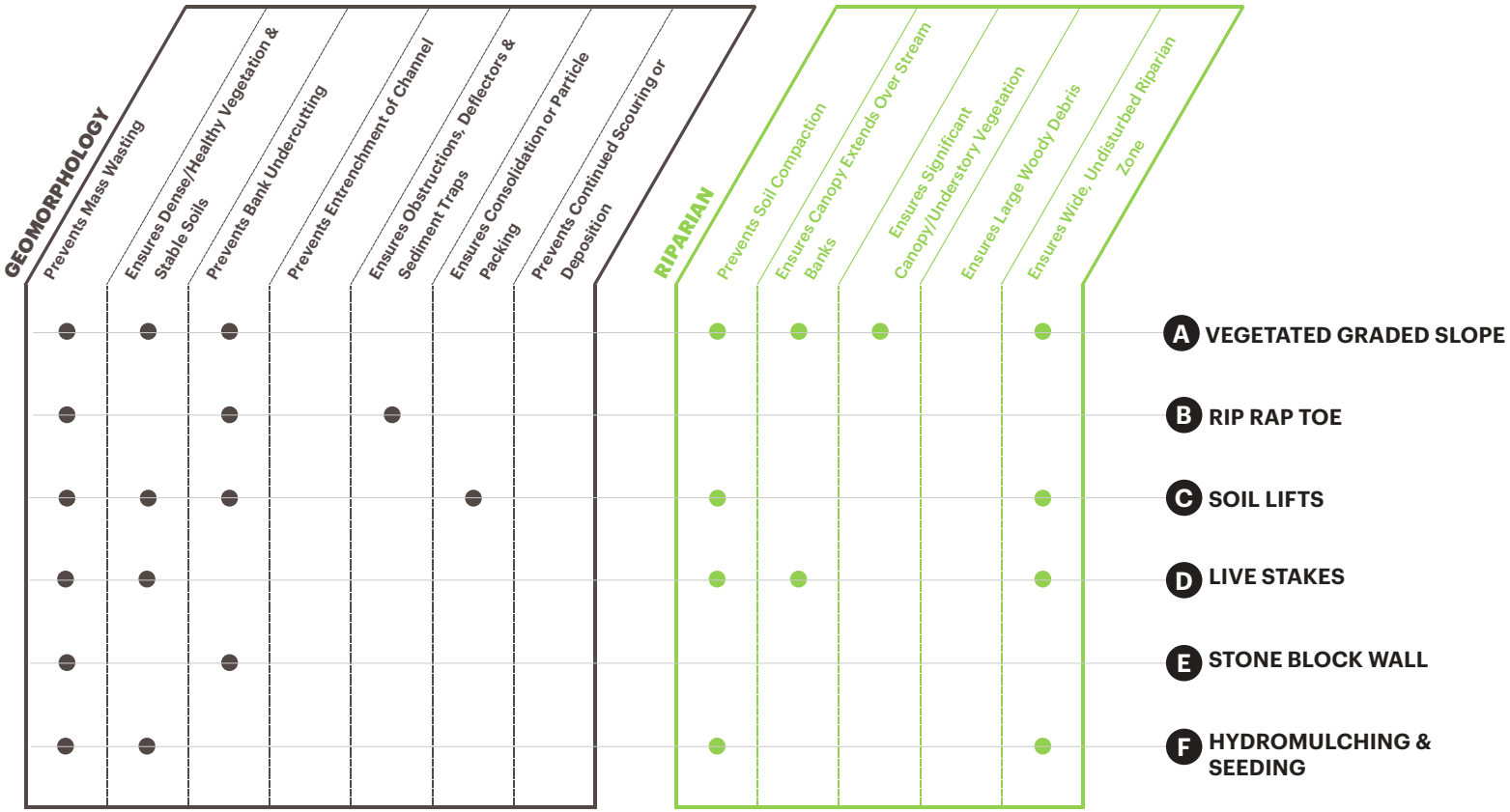
A VEGETATED GRADED SLOPE
Re-worked native soils graded to 2.5:1 or flatter (where feasible) and planted with groundcover, understory and upper story vegetation (see right)

E STONE BLOCK WALL
Locally quarried or salvaged, can be used in place of rip rap and for growth of vines, ferns, moss, and other herbaceous plants

C SOIL LIFTS
6"-12" nondegradable geotextile planted with aggressive native mix. Composed of re-worked native and/or engineered soils

D LIVE STAKES
0.5"-3" diameter, 1.5'-5' long, locally harvested, 2-5 yr old branches installed so tip reaches very moist or wet soil . Recommended downstream of Cesar Chavez only.

B RIP RAP TOE
Natural or salvaged, angular boulders 18" - 24" with a specific gravity of ≥2.4



FUNCTIONAL LIFT

Slope restoration design in the Waller Creek corridor should aim to improve and enhance existing geomorphic and riparian/biologic conditions. At left is an illustration of the components of a robustly planted slope; the table above describes how these components contribute to positive ecological improvements.

PLANT SPECIES RECOMMENDATIONS

Native Planting and Analog Niches

The Waller Creek Framework Plan features an approach to restoring and generating ecological function along the creek corridor, which will provide important environmental and sociological services to the public.

Ecosystem services provided by healthy riparian systems include stabilizing stream banks, cleaning water, providing diverse habitat, and recharging groundwater. Restoring or generating ecological function at Waller Creek will provide many of these services for the immediate corridor, as well as for downtown and for the larger region, as ecosystem services extend beyond human-designated boundaries.

Central Texas is a region where eastern deciduous forests, the Edwards Plateau ecoregion and Chihuahuan desert elements all meet –it is one of the country's highest areas of plant diversity and available plant material. For preservation and restoration projects such as this one, this system provides a broad palette of species adapted to a large range of soil, light and climatic conditions. A focus on native plant species, whose ecological function is adapted to current and forecasted Central Texas conditions, and their analog niches will shape the approach to plant selection for Waller Creek.

Responding to Climate Change

In addition to the provision of ecosystem services, the Waller Creek Corridor will be designed as a resilient system that is able to respond to changing conditions of the area and region. In terms of ecology, resilience is the ability of an ecosystem to recover from disturbance before the system fails or changes structure. Accordingly, vegetation for Waller Creek will meet the demands of use and aesthetics but also be hardy and capable of adapting to changing conditions, whether climatic or patterns of management.

Opportunistic individual species and whole plant assemblages should be managed appropriately to optimize ecological and hydraulic function, and to minimize both resources for establishment and long term maintenance. The goal is to create a system robust enough to survive the localized effects of climate change, which are modeled to be the extremes of prolonged drought and excessive flooding events for the Central Texas region.

Planning vs. Design

The Waller Creek Framework Plan provides a set of priorities and principles that the will guide subsequent design phases. Similarly, the approach to ecological resilience outlined here, focusing on biodiversity, habitat complexity and function, will eventually guide planting design. Plant assemblages and communities of the Central Texas region from which the Waller Creek projects may draw include dry riparian, wet riparian, midgrass prairie, tallgrass prairie, bottomland hardwood forest, juniper oak savanna, and limestone cliff and seep communities.

Healthy mesic riparian plant communities have an overstory of bald cypress, sycamore, cottonwood, pecan, black willow, box elder, cedar elm and American elm, a midstory layer including mustang grape, hackberry, dogwood, red bud, hawthorn, ash, possum haw, mulberry, buttonbush, elderberry and turk's cap, and a groundcover of yellow columbine, Drummond's wild petunia, eastern red columbine, cardinal flower, giant coneflower, beaked spikebrush, big muhly, inland seaoats, Virginia wildrye and creek sedge. Drier, more xeric plant assemblages on the upper bank would have alternative overstory dominant such as mesquite, hackberry, live oak, huisache and cedar elm. Many of these species and assemblages already exist along the creek corridor, and would be suited to Preservation and Restoration areas with Class I and Class II vegetation.

Midgrass and tallgrass prairie communities, which occur in areas of less shade, consist of assemblages of native grasses and forbs including little bluestem, Indiangrass, sideoats grama, switchgrass, big bluestem, eastern gamagrass, bushy bluestem, green sprangletop, prairie wildrye and purple threeawn, with wildflowers such as Maximillian sunflower, goldenrod, partridge pea, bundleflower, cone flower, indian blanket, coreopsis, standing cypress and many others. Prairie assemblages would also be appropriate for bank stabilization in Restoration and Reconstruction areas.

The juniper-oak savannas are characteristic of the Edwards Plateau, and the overstory is dominated by

live oaks, deciduous oak species (e.g. red oak) and Ashe juniper, while understory vegetation can consist of the prairie species listed above.

Texas limestone cliff and seep communities consist primarily of rock-face dwelling ferns such as maidenhair fern, cliff brake fern and fairy swords, and seep species including beargrass, various muhly species and nimblewill. These communities would be appropriate for preserved and new constructed limestone embankments and vertical planting elements.

These central Texas native communities and mixed custom assemblages will strategically enhance preserved healthy vegetation throughout the creek corridor. This wide palette of species and assemblages provides opportunities for an array of vegetative cover and function, and has the capacity to fundamentally alter the experiences and views along and within Waller Creek.

PLANT COMMUNITIES OF THE CENTRAL TEXAS REGION:

1. Dry Riparian
2. Wet Riparian
3. Midgrass Prairie
4. Tallgrass Prairie
5. Bottomland Hardwood Forest
6. Juniper Oak Savanna
7. Limestone Cliff
8. Seep

AQUATIC HABITATS

The Waller Creek Tunnel and subsequent urban redevelopment will have a wide range of effects on the aquatic zone, which is the area of the creek directly in the waterway. Whereas many of the riparian slopes will need to be reconstructed for trails, slope stabilization, and new urban redevelopment, this Framework Plan seeks to celebrate, preserve, and restore the unique aquatic habitats of Waller Creek wherever possible. Furthermore, Waller Creek's altered post-tunnel hydrology will generate new possibilities for aquatic habitat. Future projects should design areas of intervention in the aquatic zone to prioritize ecological diversity and adaptability to a rapidly changing urban environment.

EXISTING AQUATIC HABITAT

Over many years, Waller Creek experienced a variable flow regime that consisted of high flood volumes and frequency. While Edwards Plateau bedrock streams are known for highly variable and flashy flood flows, the watershed and hydrologic changes brought about by urbanization have had an appreciable limiting effect on Waller Creek's channel form and in-stream habitat.

Striking white "Austin chalk" bedrock exposures create shallow, often turbulent flow, which incorporates oxygen into the water. The bedrock also prevents the creek from cutting down into its bed (entrenchment),

and in some places stabilizes the banks. Repeating pool-riffle-run sequences are found throughout the creeks' lower reaches. Pools typically form when high flows scour deep pockets in the creek bed. Water in this cooler habitat moves fairly slowly; silt, leaves, and other organic material tend to accumulate here. Riffles appear as shallow water with a rough, turbulent surface caused by water flowing over boulders, corrugated bedrock surfaces, cobbles, and gravel; this mixing of air and water incorporates oxygen into the creek. Runs are moderately deep, free-flowing sections of the creek, often in relatively straight reaches. The pool-riffle-run arrangement establishes a variety of water depths and flow regimes, which create habitat for a wide array of aquatic wildlife, including many species of amphibians, fish, and aquatic macroinvertebrates. Within the pool-riffle-run sequences, features such as solitary boulders, submerged rock clusters, and large debris provide places for aquatic vegetation to anchor, habitat for aquatic macroinvertebrates, and refuges for fish and amphibians.

Delta habitat at the mouth of Waller Creek has formed because the creek flows slow upon entering the relatively stable water level of Lady Bird Lake. Sediment carried by the creek settles out here, creating various depositional features. This delta habitat includes both shallow and deeper areas, exposed sand bars, emergent islands, forested islands, and complex gradients of both water velocity and water quality. The resulting variety of aquatic habitats and plant communities attracts many species of wildlife, including fish, turtles, shorebirds, and wading waterbirds.

EXISTING WATER QUALITY CONDITIONS

Prior to the completion of the Waller Creek Tunnel, periodic large magnitude and high frequency floods contributed to a number of ecologically beneficial processes. Excessive algal growth, which is both visually unappealing and potentially harmful to water quality, is curtailed by flushing events. Higher flows also aid in the delivery of large woody debris for organic matter inputs and habitat, as well as provide sediment transport. Coarse particles mobilized by higher flows provide spawning habitat, define channel morphology, and add substrate diversity. Finally, many native organisms depend on the variability of seasonally-derived flows for reproduction cues.

Despite the adaptations that the creek's biota have made throughout the process of urbanization, massive floods and periods of low to no flow were never a part of the historical and natural seasonal trends of Waller Creek. The altered watershed and resulting volatile water levels created environmental conditions detrimental to some aquatic life and a healthy ecosystem. Excessive fine-grained sediment, released into the water by high rates of erosion, can inhibit proper gill function of fish and filter feeding invertebrates, limit biodiversity by favoring species tolerant of turbid (murky) conditions and fine sediment, and degrade existing habitat. High nutrient inputs encourage excessive algal growth, which in turn can lower dissolved oxygen as algal biomass decomposes.

High rates of pollutant loading from the surrounding watershed will continue to affect the creek, even after the completion of the tunnel. Nutrients (from fertilizer and wastewater leakage), chemical pollutants (from urban runoff), and thermal pollution (runoff from hot roads and roofs), can be toxic to aquatic organisms by fatally interrupting biochemical processes or compromising reproductive success.

ANTICIPATED IMPACTS OF THE WALLER CREEK TUNNEL

As the Waller Creek Tunnel comes online, it will undergo an extended process of calibration for flood control, debris removal, and pumping rates. The design efforts for the preservation and creation of aquatic habitats throughout the Waller Creek corridor will need to be in a continuous feedback loop with this system. One key issue will be the availability of coarse sediment bedload. Although storm events will still encourage some sediment transport, coarse sediment supply to

the system will be essentially cut off at the tunnel inlet in Waterloo Park. The greater bank stability enabled by the tunnel will also limit the supply of sediment from the channel itself. This may result in the lower creek being depleted of coarse sediment, which can degrade some habitats. Ongoing monitoring of sediment supply will inform if and how future design efforts should incorporate mechanisms for "seeding" Waller Creek with new coarse sediment.

At the Inlet Facility in Waterloo Park, the new "headwater" of the post-tunnel Waller Creek will have its source from pumped water from Lady Bird Lake. This supply of relatively higher quality water will continuously seed the creek with algae, microbes, and organic matter. Lower flows and reduced flood events may also reduce nutrient transport into and out of the benthic (bottom) zone.

Following flow stabilization, projects can provide improvements to the aquatic zone by encouraging resilient plantings of streamside vegetation, which shades against extreme temperature fluctuations and contributes organic matter to the stream. Also, wherever feasible, future design should increase the amount and variety of riparian habitat by creating flood bench wetlands and flood bench channels with integrated habitat features.

IMPACTS OF URBAN DEVELOPMENT IN THE AQUATIC REALM

New development enabled by the Waller Creek Tunnel will have considerable impacts to the aquatic environment. The cumulative impacts of private and public development should be considered longitudinally, both upstream and downstream, and not just at the limits-of-work.

High-rise buildings will change the available sunlight reaching the creek. Although the shade created by buildings can provide cooling opportunities where vegetative shade is not available (e.g. the Narrows), it can also reduce stabilization of bank vegetation where inadequate light is available for growth. Wherever possible, creek improvement projects should consider not only present conditions, but the future development capacity and allowable height of adjacent parcel; similarly, district-wide review of new development should evaluate the potential effects of new structures on available light to the creek.

Redevelopment sites within the Waller Creek watershed will be required to meet the City's standards for stormwater management. Compliance with these standards will reduce the sediment and pollutants discharged to Waller Creek from the landscape, which should improve aquatic habitat conditions.

Construction projects associated with redevelopment will expose bare soil within the project limits. The exposed bare soil will temporarily increase sediment discharge to the creek in general, and increase the risk of large sediment discharges to Waller Creek if storm events exceed the design thresholds of the construction site erosion control plans.

CREATING AND SUSTAINING AQUATIC HABITAT

The following project type map, which shows areas of preservation/restoration/reconstruction, was generated from a series of field walks with WPD, MVVA, AES, LimnoTech, and LBJWC Ecosystem Design Group in 2014 and 2015. Significant existing aquatic features and opportunities were documented in plan and overlaid with known areas of bank and channel reconstruction by Waller Creek Tunnel infrastructure and private development. The aquatic habitat features and augmentations include:

Preserve

- Preserve structures that provide channel stability and refuges for aquatic organisms; if these structures are made of urban debris, they should be removed only if they present a significant aesthetic nuisance.
- Protect exposed bedrock during construction

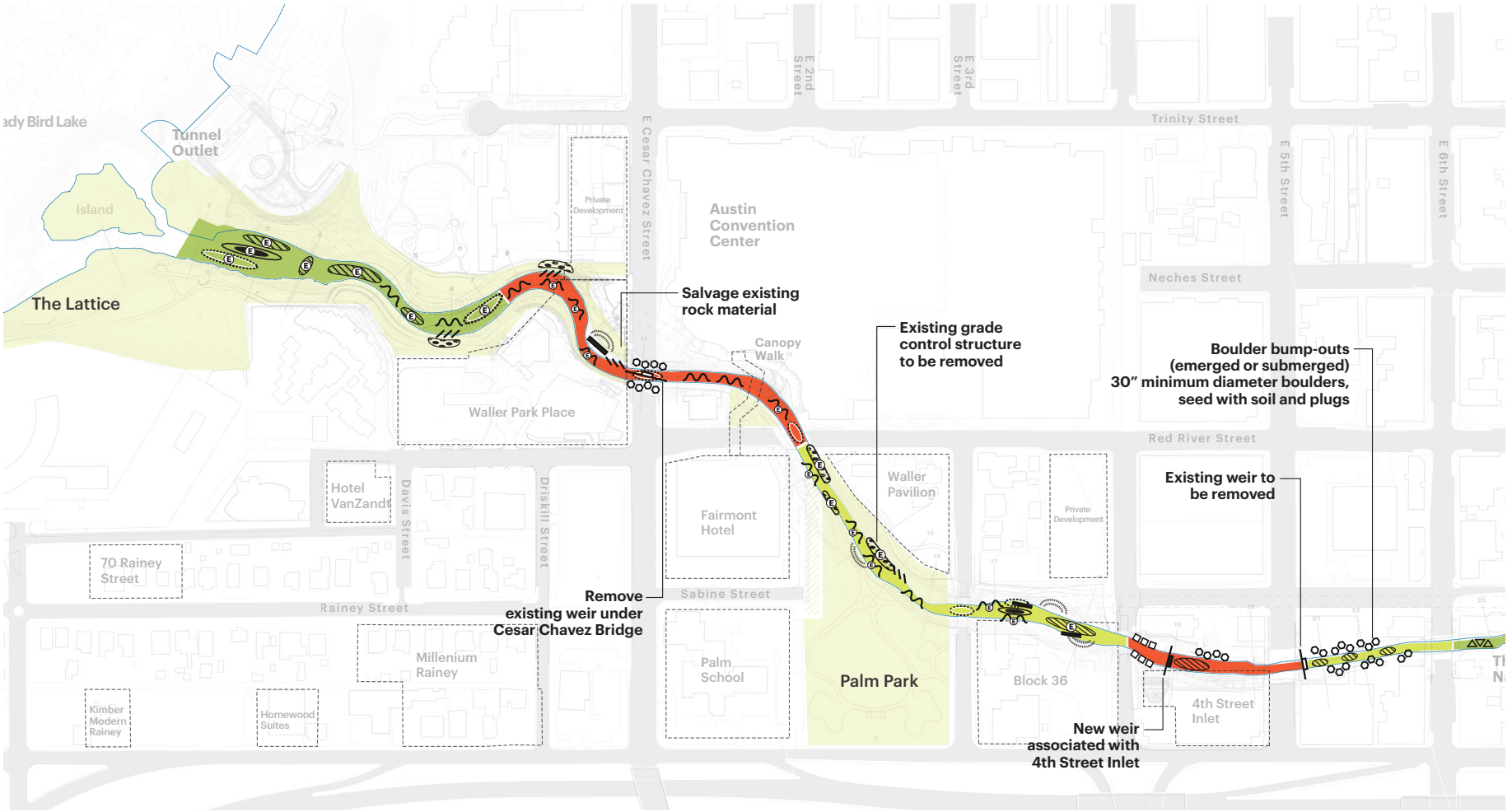
Restore

- Restore pools, riffles, runs, and islands that are consistent with the design of post-tunnel creek and make improvements through augmentation.
- Evaluate opportunities for "sediment seeding" to establish and maintain a desirable level of bedload transport necessary to support aquatic habitat in the creek and at the delta.
- At locations warranting channel redirection, cross vanes can be used to direct flow, protect banks, and sustain desired channel geometry.
- Install in-stream habitat features such as lunkers, boulder clusters, and submerged logs

Reconstruct

- Increase aquatic habitat diversity by creating self-sustaining pools, riffles, runs, and islands.
- Install in-stream habitat features such as lunkers, boulder clusters, and submerged logs
- Salvage boulders, cobbles and gravel from the streambed and replace it in the reconstructed channel or other appropriate locations.

AQUATIC HABITATS



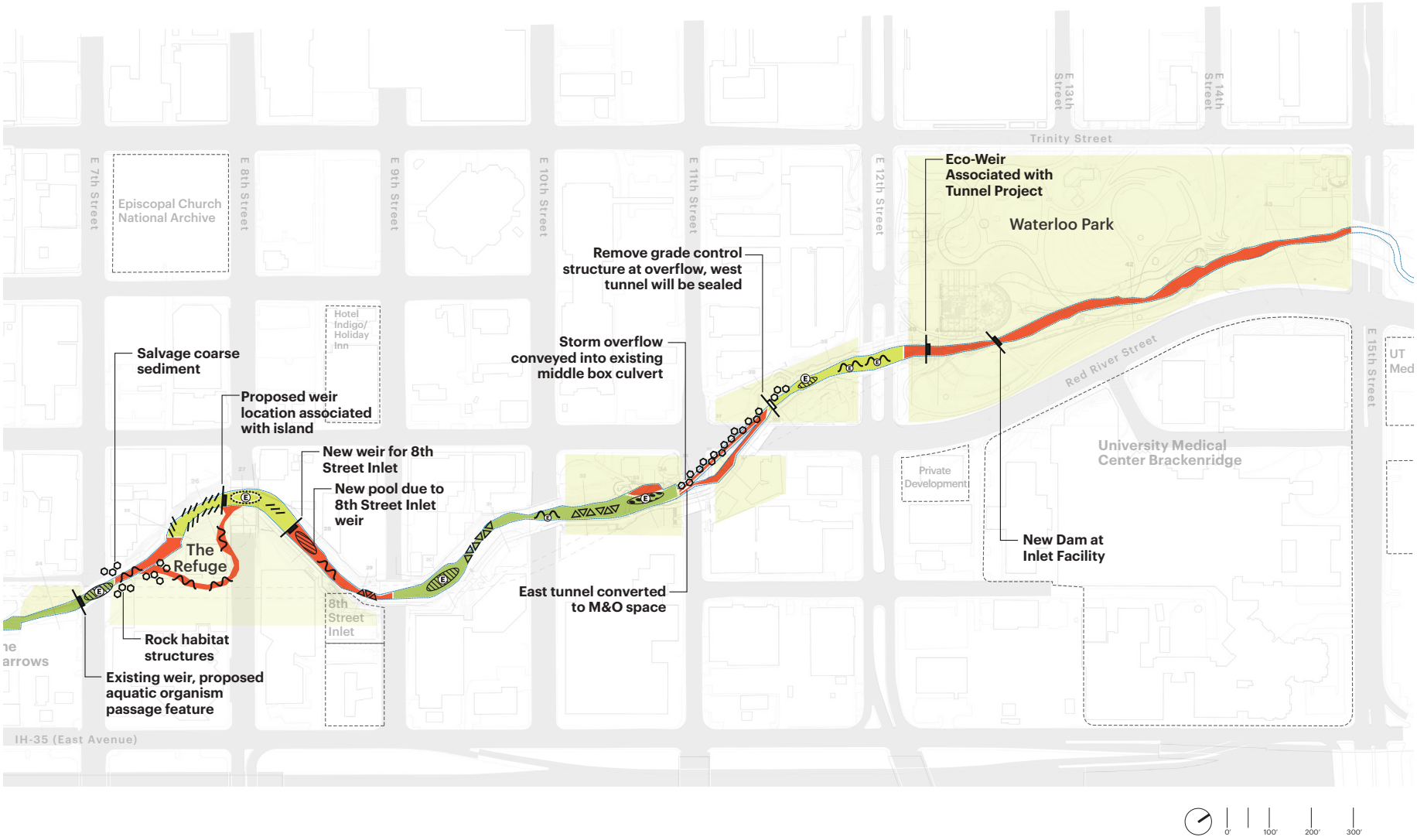
MAP KEY

PROJECT TYPE

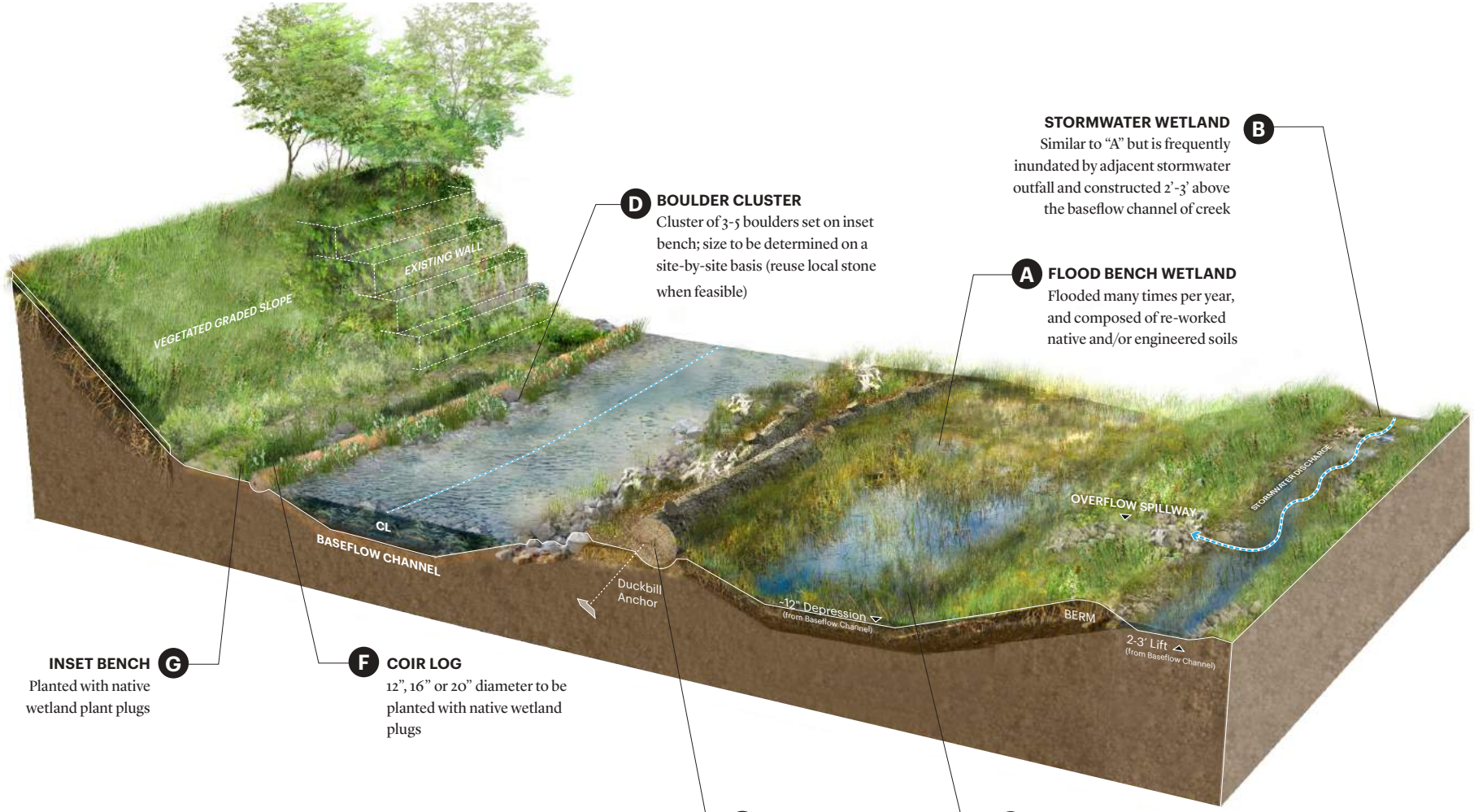
- Do Nothing
- Preservation
- Restoration
- Reconstruction

IN-CHANNEL FEATURES

- Existing Feature
- Deep Pool
- Cooling Pool
- Wetland Bench
- Proposed Woody Debris
- Boulder Cluster
- Riffle/Pool Complex
- Cross Vane
- Bank Lunker
- Perm. Island
- Gravel Bar
- Existing Exposed Bedrock
- Weir


Eco-Weir
Associated with
Tunnel Project
Waterloo Park
Remove grade control
structure at overflow, west
tunnel will be sealed
Storm overflow
conveyed into existing
middle box culvert
Salvage coarse
sediment
Proposed weir
location associated
with island
New weir for 8th
Street Inlet
New pool due to
8th Street Inlet
weir
The
Refuge
East tunnel converted
to M&O space
New Dam at
Inlet Facility
Rock habitat
structures
Existing weir, proposed
aquatic organism
passage feature
Episcopal Church
National Archive
Hotel
Indigo/
Holiday
Inn
8th
Street
Inlet
Private
Development
University Medical
Center Brackenridge
Red River Street
Trinity Street
E 7th Street
E 8th Street
E 9th Street
E 10th Street
E 11th Street
E 12th Street
E 13th
Street
E 14th
Street
E 15th Street
IH-35 (East Avenue)
0'
100'
200'
300'

CROSS SECTION: RIPARIAN AREA, FLOOD BENCHES & AQUATIC HABITAT



STORMWATER WETLAND B
Similar to "A" but is frequently inundated by adjacent stormwater outfall and constructed 2'-3' above the baseflow channel of creek

D BOULDER CLUSTER
Cluster of 3-5 boulders set on inset bench; size to be determined on a site-by-site basis (reuse local stone when feasible)

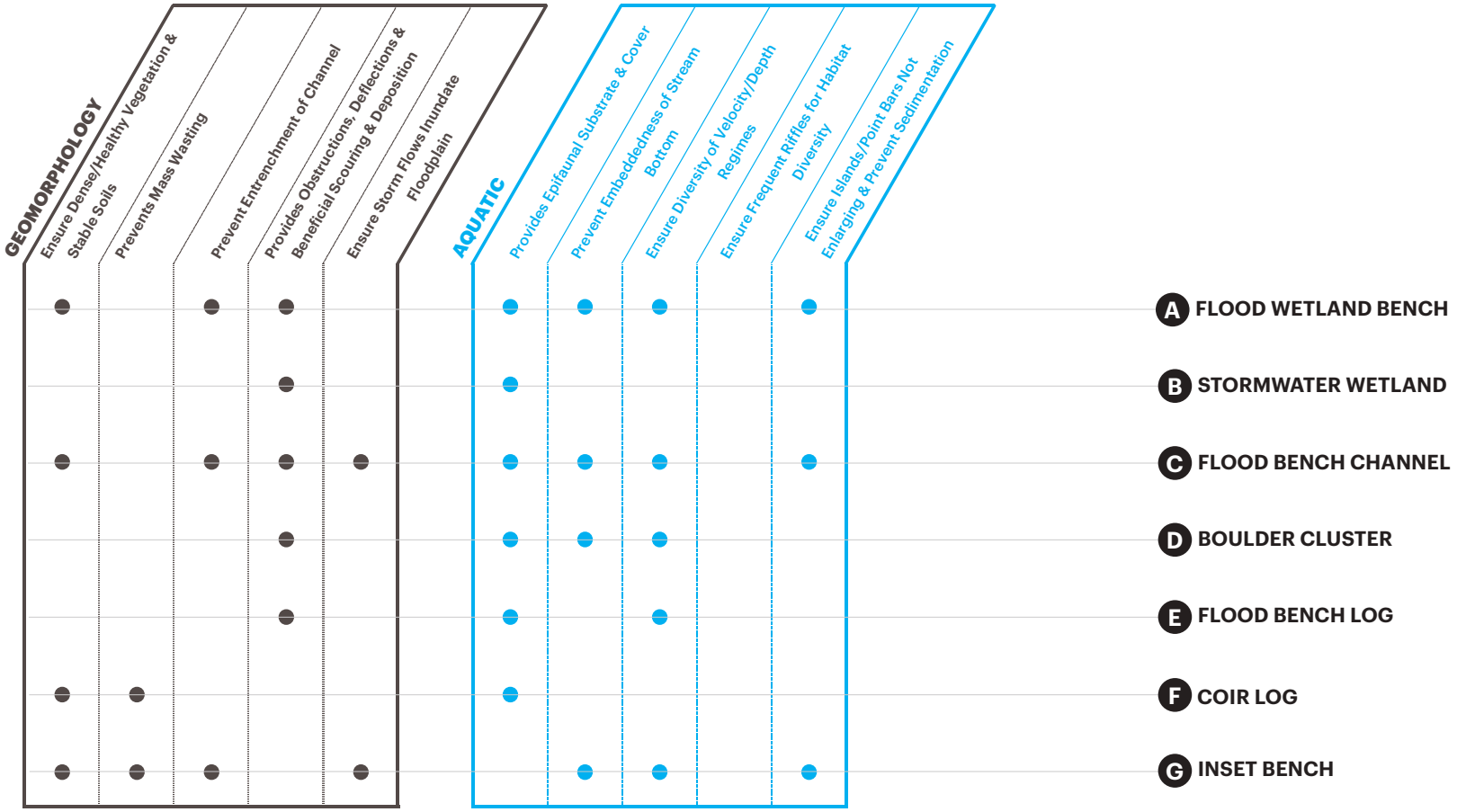
A FLOOD BENCH WETLAND
Flooded many times per year, and composed of re-worked native and/or engineered soils

INSET BENCH G
Planted with native wetland plant plugs

F COIR LOG
12", 16" or 20" diameter to be planted with native wetland plugs

E FLOOD BENCH LOG
Cluster of 2-5 anchored logs, minimum 12" diameter bole (reuse local trees when feasible)

C FLOOD BENCH CHANNEL
Half the width of main channel, flows many times per year, and composed of re-worked native soils



FUNCTIONAL LIFT

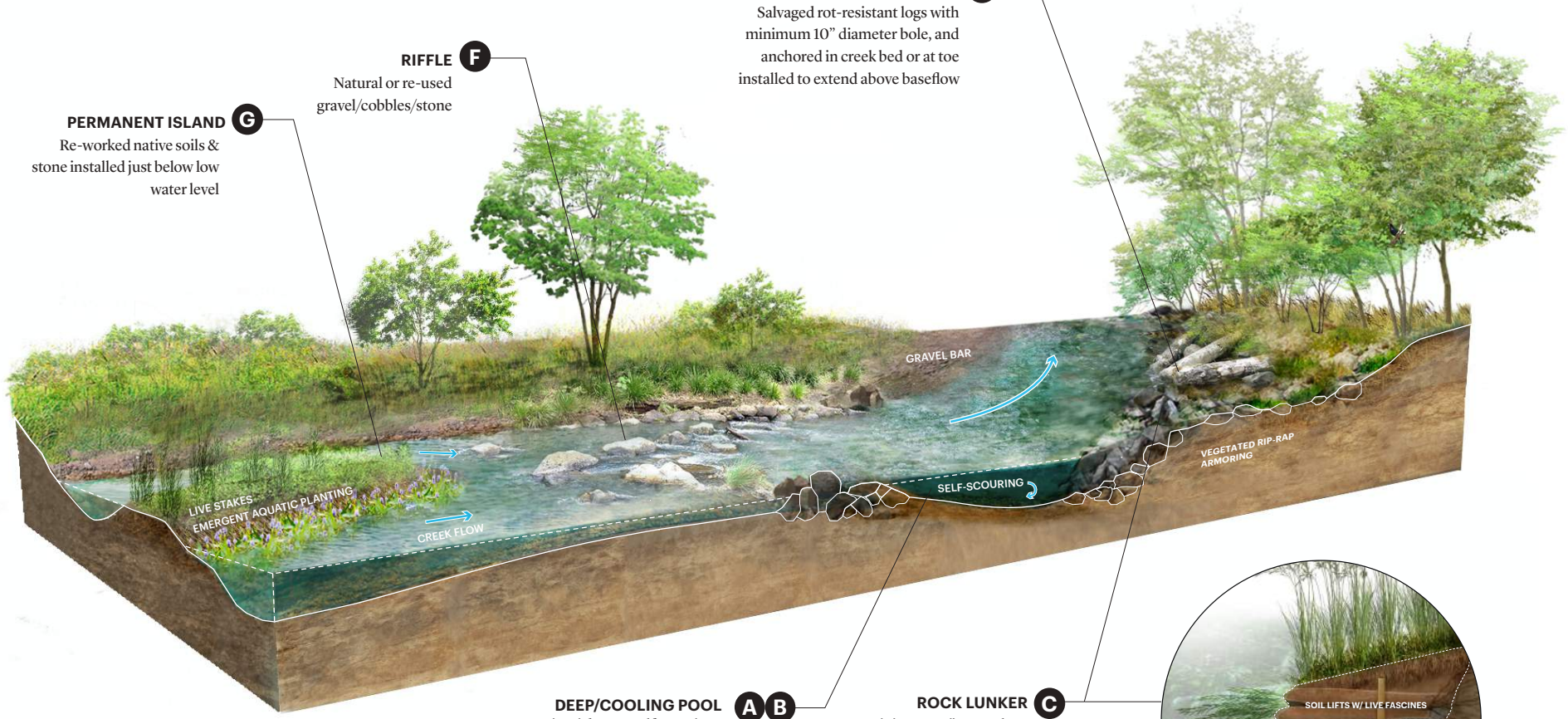
Aquatic zone and channel restoration design in the Waller Creek corridor should improve and enhance existing geomorphic and aquatic/biologic conditions. At left is an illustration of a cross-section through a restored two-stage creek channel, with a baseflow channel and adjacent flood bench at a higher elevation. The table above describes how these components contribute to positive ecological improvements.

LONGITUDINAL SECTION: IN-CHANNEL RESTORATION & AQUATIC HABITAT

EMERGENT LOG E
Salvaged rot-resistant logs with minimum 10" diameter bole, and anchored in creek bed or at toe installed to extend above baseflow

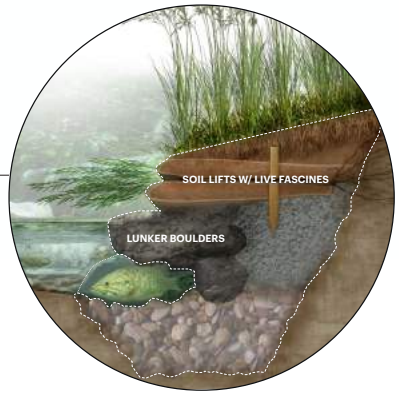
RIFFLE F
Natural or re-used gravel/cobbles/stone

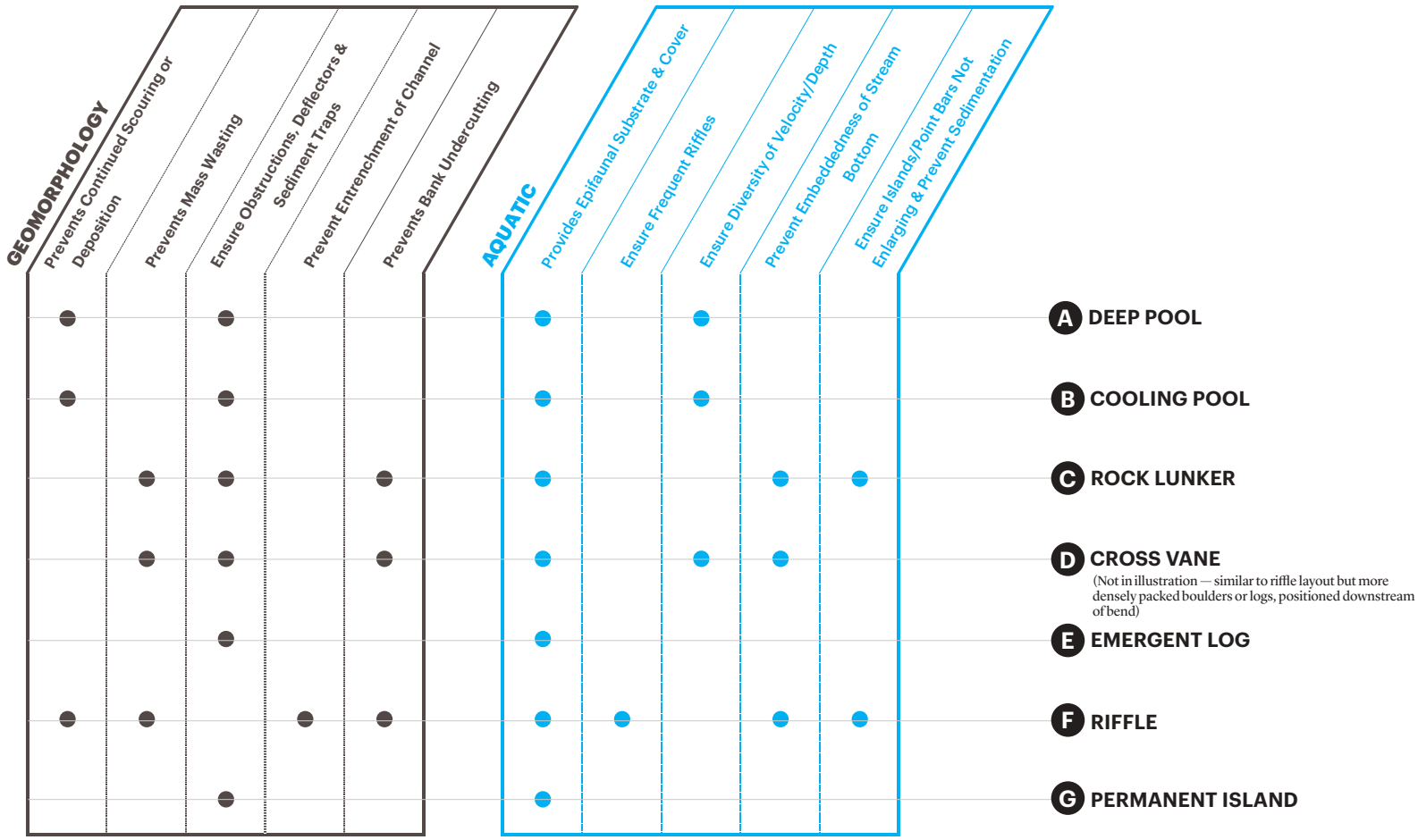
PERMANENT ISLAND G
Re-worked native soils & stone installed just below low water level



DEEP/COOLING POOL A B
Min. 3' deep & self scouring and composed of re-worked native soils

ROCK LUNKER C
Minimum 24" natural or re-used slab boulders installed just below LWL to create submerged void habitats (see illustration enlargement at right)

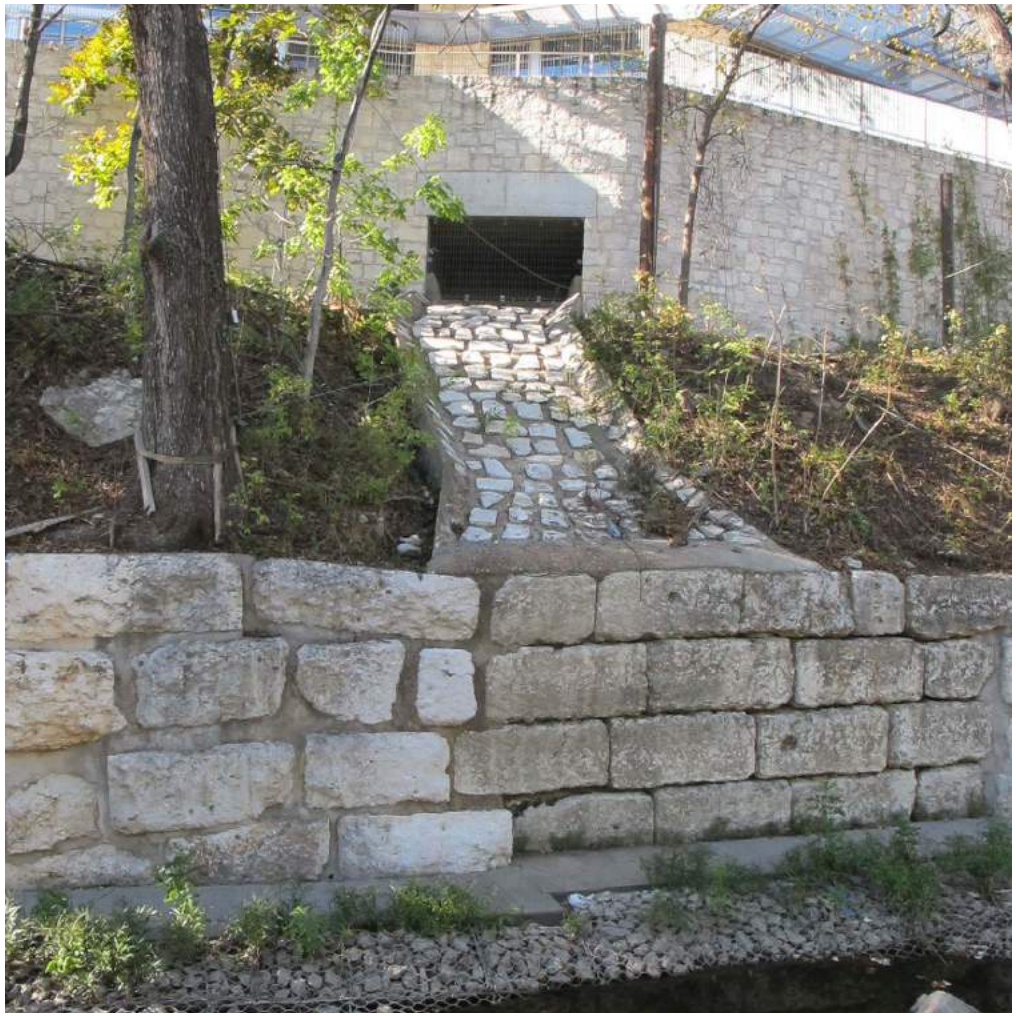




FUNCTIONAL LIFT

At left is an illustration of a longitudinal section through a pool/riffle sequence. These complexes already exist in Waller Creek and will be protected, preserved, and used as templates for new aquatic habitat creation. The table above describes how these components contribute to positive ecological improvements.

STORMWATER RETROFITS



INTRODUCTION

Over the last 100 years, the Waller Creek watershed has transformed from a Hill Country grassland to an area dominated by urban land use with more than 50% impervious cover. Consequently, this urban stream has been the primary conveyor of stormwater for 28 acres of downtown Austin and a critical component of urban drainage infrastructure.

The Waller Creek Tunnel will dramatically reduce stormwater contributions to lower Waller Creek from upstream of 12th Street, but this does not affect the influence of the contributing sub-watersheds which discharge directly into the creek. These outfalls are a familiar presence along the creek corridor; in some instances, they are stormsewer pipes integrated into retaining walls and buildings, but in dozens of locations, their unconsidered placement is a reminder of Waller Creek's historic role as a utility for the conveyance of water, rather than a natural amenity.

As a new trail system and open space network is envisioned for Waller Creek, the intersections of new public access and existing stormwater infrastructure must be coordinated to respond to a variety of different conditions and accomplish a number of goals:

First, many stormwater outfalls are structurally incompatible with existing and proposed

improvements. Water and debris from outfalls can intersect with the trail, creating both an unpleasant experience and public safety hazard with slippery surfaces and open cavities that collect trash. Also, existing outfalls have created severe erosion problems as periodic blasts of stormwater have destabilized unprotected slopes. New improvements seek to mitigate hazards while creating resilient and green slopes where possible.

Second, the source of water for these outfalls is poor quality runoff from active roadways and other urban impervious surfaces. This Framework Plan has identified specific outfalls that can be retrofitted to improve water quality in the creek, fostering a healthy, thriving riparian system appropriate to a radically transformed new post-tunnel hydrology. These Waller Creek specific goals differ from those centered on local site development, and therefore require unique stormwater management strategies that extend beyond local codes.

Lastly, these improvements must be opportunistic, strategically allocating limited funding resources and prioritizing sites of size and configuration that can maximize improvements to the public realm and to water quality. The consideration of capital costs and long-term maintenance costs as an integral part of a particular treatment's overall benefit is key.

METHODOLOGY

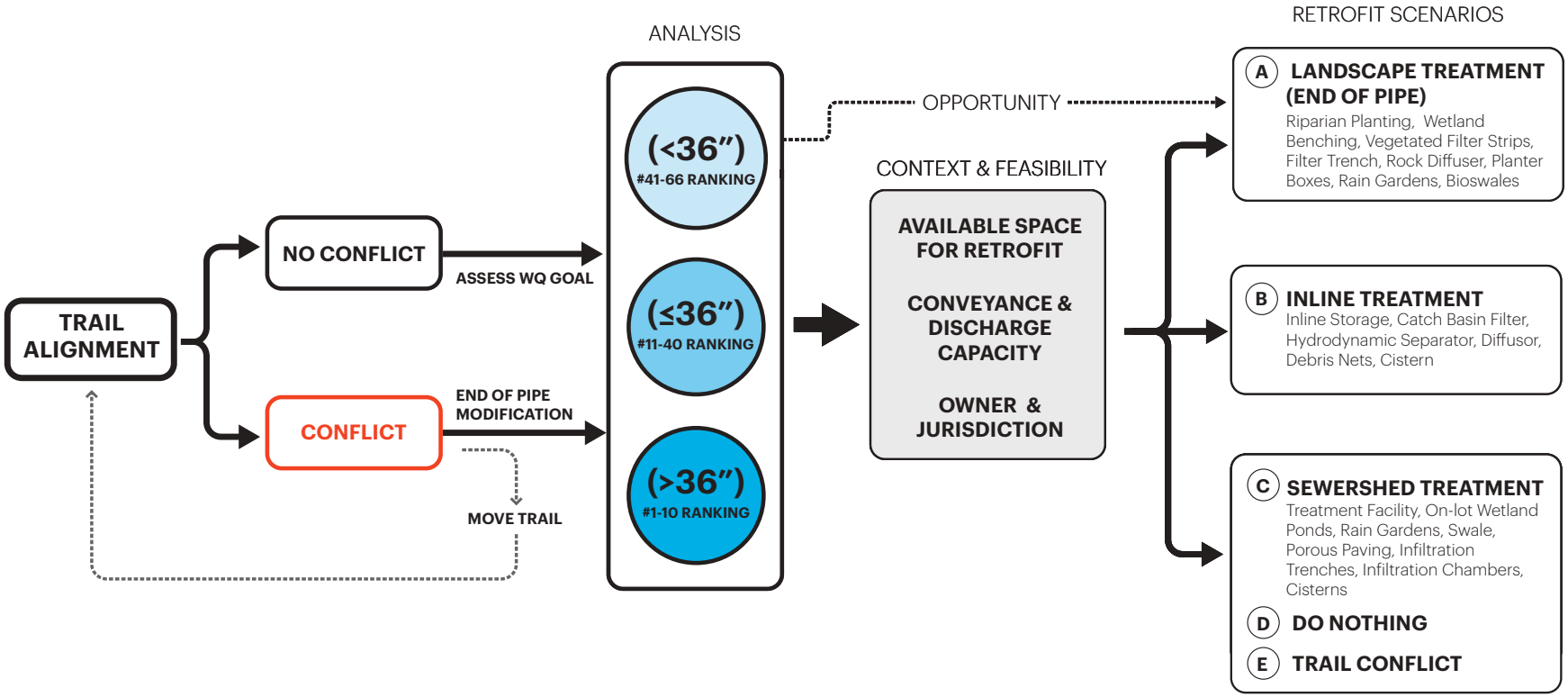
Based on GIS, HEC-HMS, and StormCAD data provided by COA, LimnoTech assembled a ranking of outlets based on pipe size, discharge capacity, and trail conflicts. These rankings were primarily designed to inform the three main categories of stormwater management opportunities: creek side landscape treatment, inline treatment, and sewershed treatment [See flowchart on following page].

Pipes that convey relatively low volumes of water are good candidates for landscape-based treatments. Such pipes provide the best opportunities since features such as constructed wetlands and step pools might be destroyed by heavy flows and would be unable to perform effective treatment during high-flow storm events. Landscape treatment areas can be integrated into the re-building of slopes and the creation of aquatic features and habitat, as well as offer opportunities to educate the public about urban water quality.

Pipes that convey moderately high volumes of water are good candidates for inline treatment. Inline treatment employs a sub-grade mechanical device that removes floatable debris (solid trash such as disposal cups, cigarette butts, etc.) and total suspended solids ("TSS", which are inorganic and organic materials suspended in the water that can diminish water quality at elevated concentrations). This study focused on inline treatment options in candidate areas in close proximity to the Waller Creek Corridor itself.

Larger pipes – typically greater than 36 inches – which convey the highest volumes of water will flow at rates too great for either landscape-based solutions or inline treatments. Typically, these pipes are best treated using sewershed methods. However, it may not be feasible or cost-effective to implement sewershed methods in some locations. For example, pipes with very small discharges also fall into this category as their contributions too small to have a cost effective impact on global water quality.

STORMWATER RETROFITS — DECISION PATHWAY

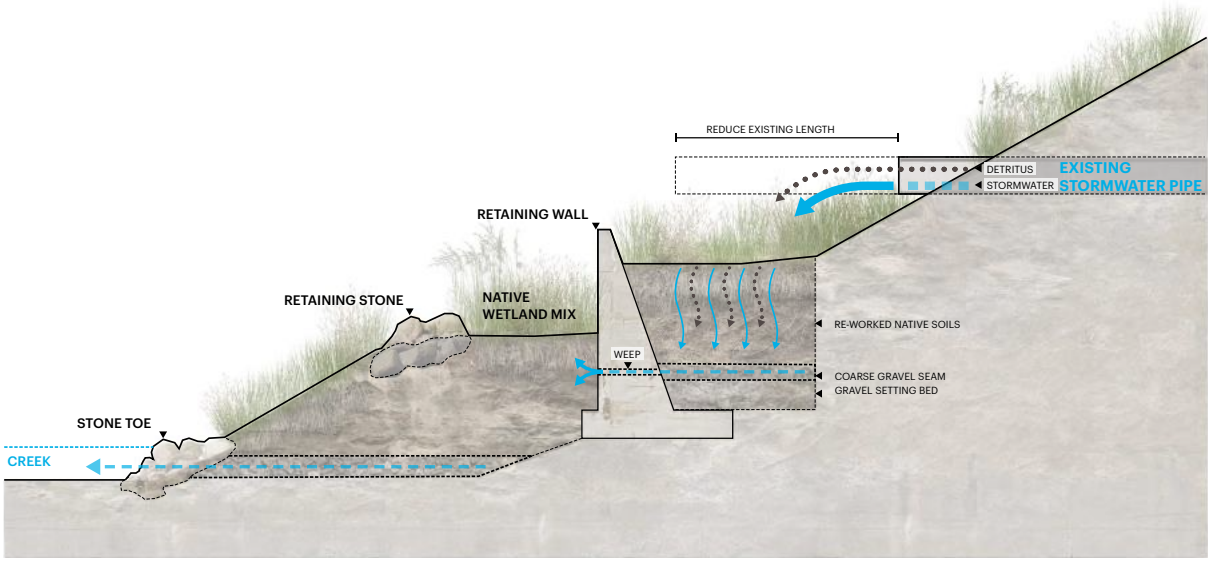


STORMWATER RETROFITS — LANDSCAPE TREATMENT

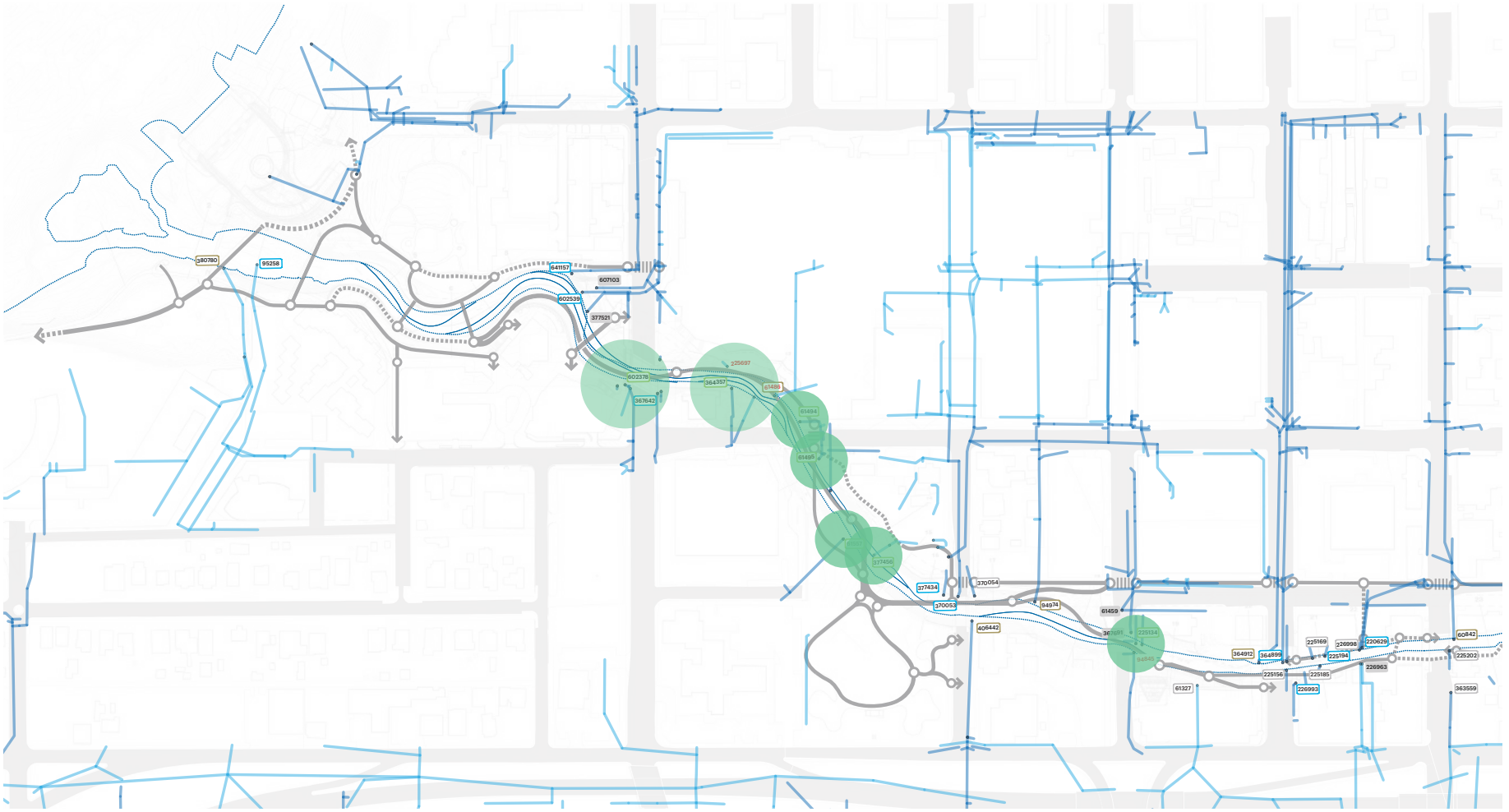
The reinvented Waller Creek will be an ecologically rich vein through the city. In order to maximize its benefits, it must also be carefully calibrated with adjacent urban infrastructure. Landscape-based treatment at the "end-of-pipe" is an important opportunity for the integration of water quality and the experience of the public realm.

In order to capture water and sustain planting, landscape treatments require sufficient horizontal area and the appropriate elevational relationships between the end-of -pipe and the creek itself. Because Waller Creek is characterized by a narrow channel (often lined with existing buildings and walls) and steep banks, not every site potentially eligible for landscape treatment is necessarily an appropriate site.

The analysis of pipe size, discharge capacity, and trail conflicts yielded 12 potential areas for landscape treatments. Field verification of these areas revealed 9 as good candidates. In several cases, there is sufficient space for robustly planted and highly visible treatment systems such as constructed wetlands and step pools. Some of these sites, when combined with the reconstruction of banks to reduce steep grades, can treat both stormsewer runoff and site runoff.



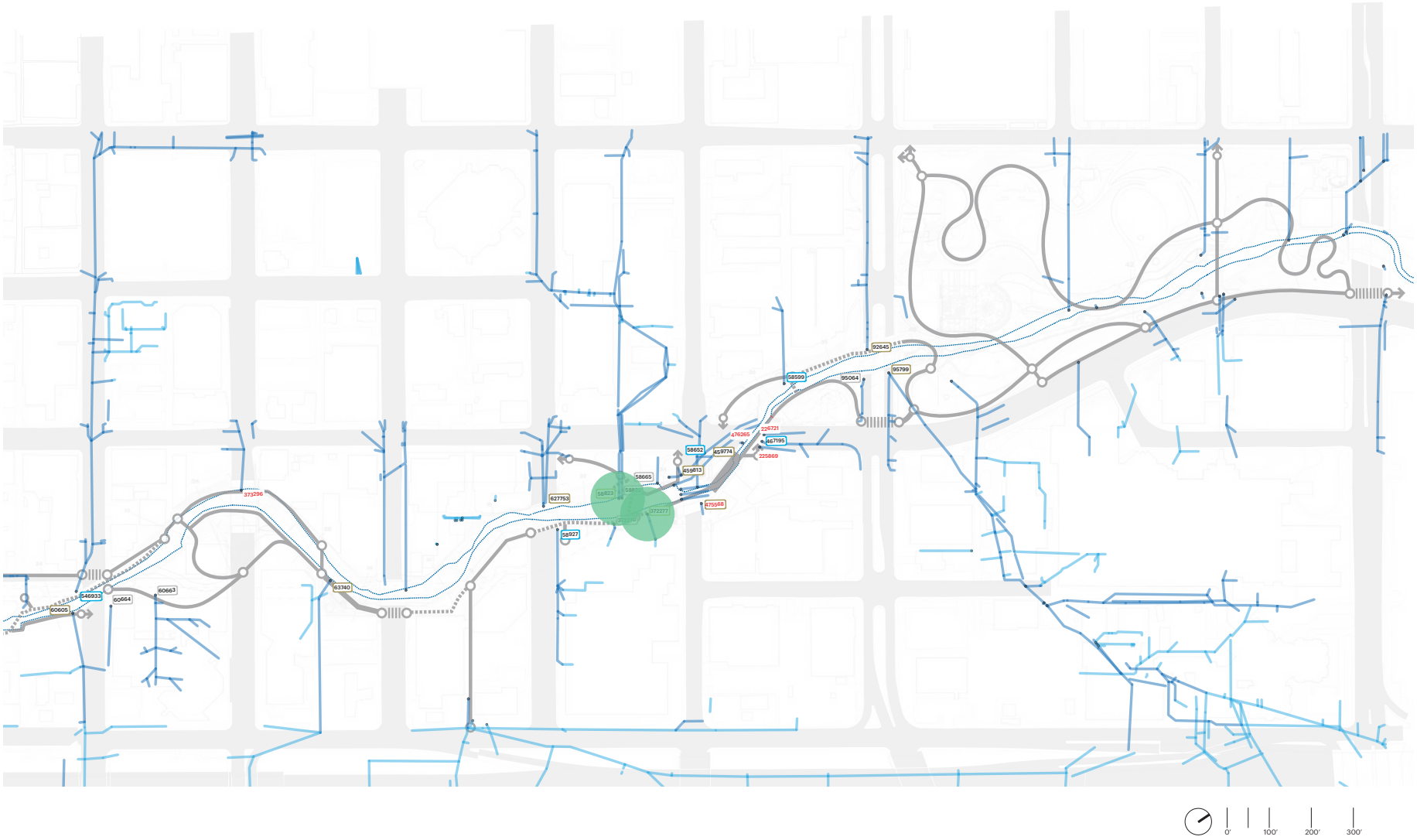
STORMWATER RETROFITS — LANDSCAPE TREATMENT



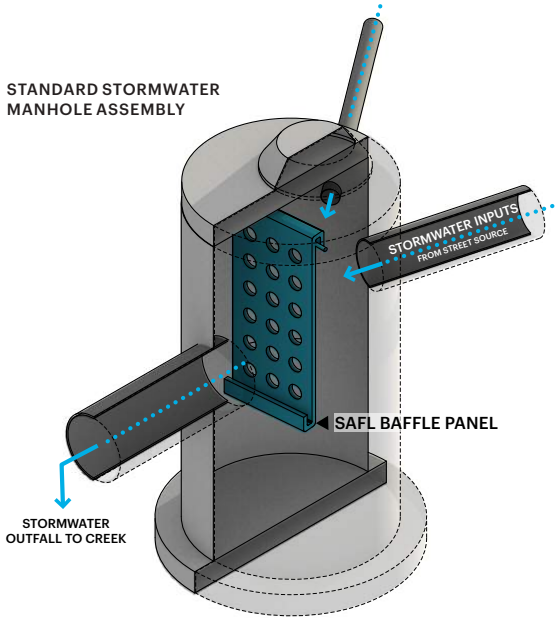
MAP KEY

LEVEL OF CONTRIBUTION

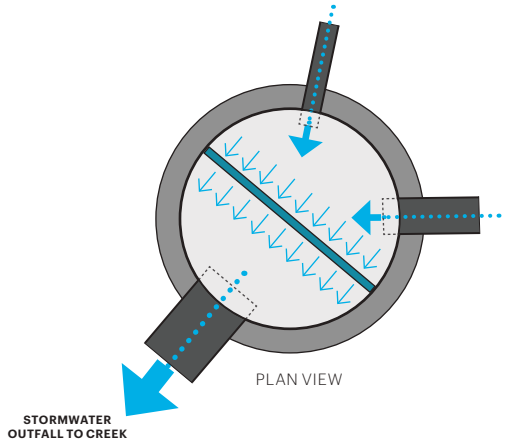
High (N/A) Medium Low


92645
95799
58599
95064
476265
226721
467195
225869
58652
459774
459813
58665
58823
627753
475568
372277
58927
373296
546933
60605
60664
60663
63740
0'
100'
200'
300'

STORMWATER RETROFITS — INLINE TREATMENT



AXONOMETRIC VIEW



PLAN VIEW

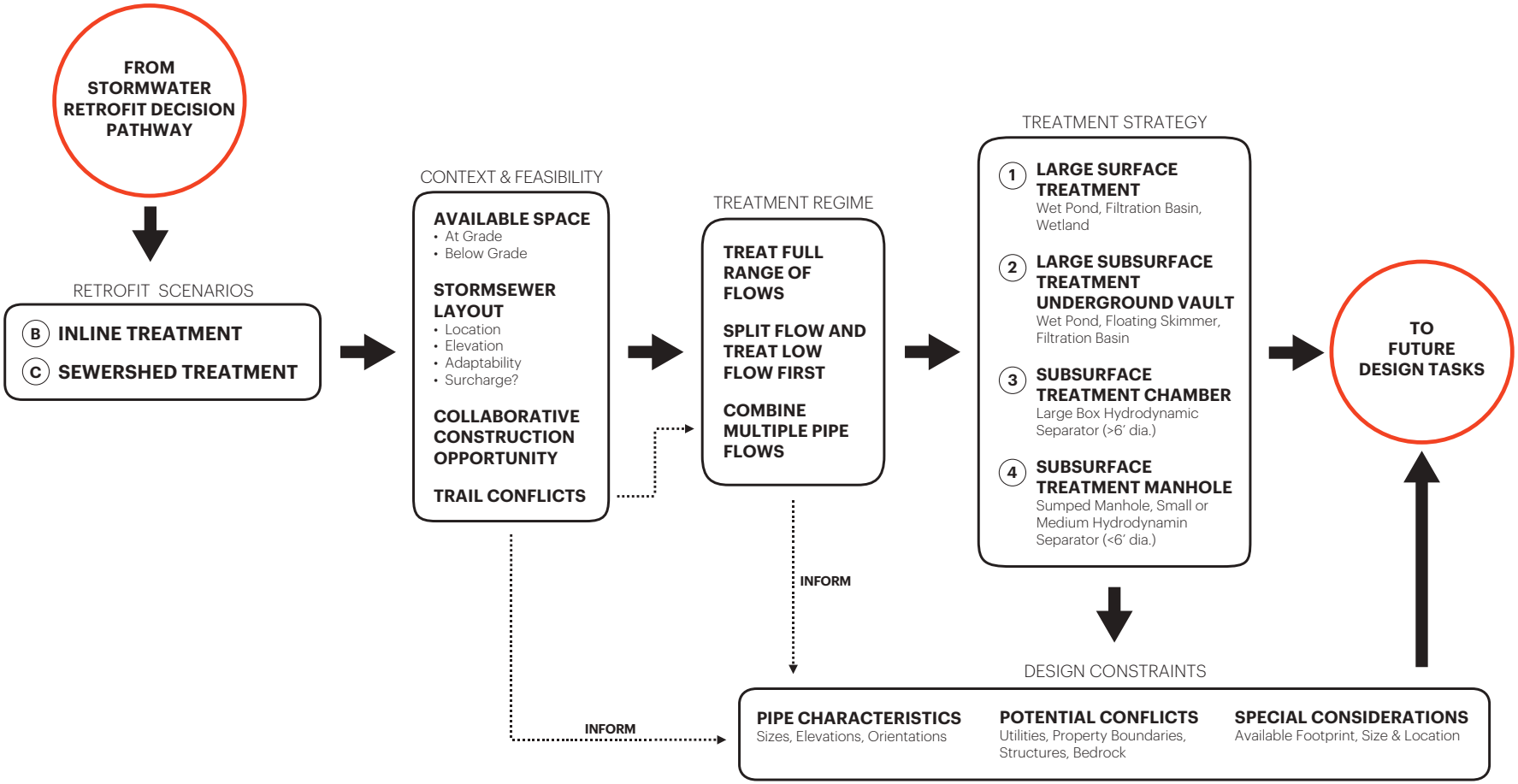
The flowchart at the right describes a decision pathway for the mid-range pipes which were identified as potential candidates for inline treatment. Where there is available space and suitable configuration of stormsewer infrastructure, inline treatment devices can be sited just before a pipe outfalls into Waller Creek; these devices are effective ways of improving water quality within the physical boundaries of the creek corridor.

It is possible to capture floatable debris upstream in the sewershed; a current pilot project captures disposable cups and plates, cigarette butts, etc., from roadway drains in several heavily used downtown blocks of 6th Street before this material reaches Waller Creek. However, with the anticipated densification of downtown Austin, the installation of such devices in roadways could become a costly undertaking, both for initial capital costs and ongoing maintenance. Furthermore, despite their direct hydrological connection to Waller Creek in terms of water quality, these roadway drains are well outside of future project boundaries.

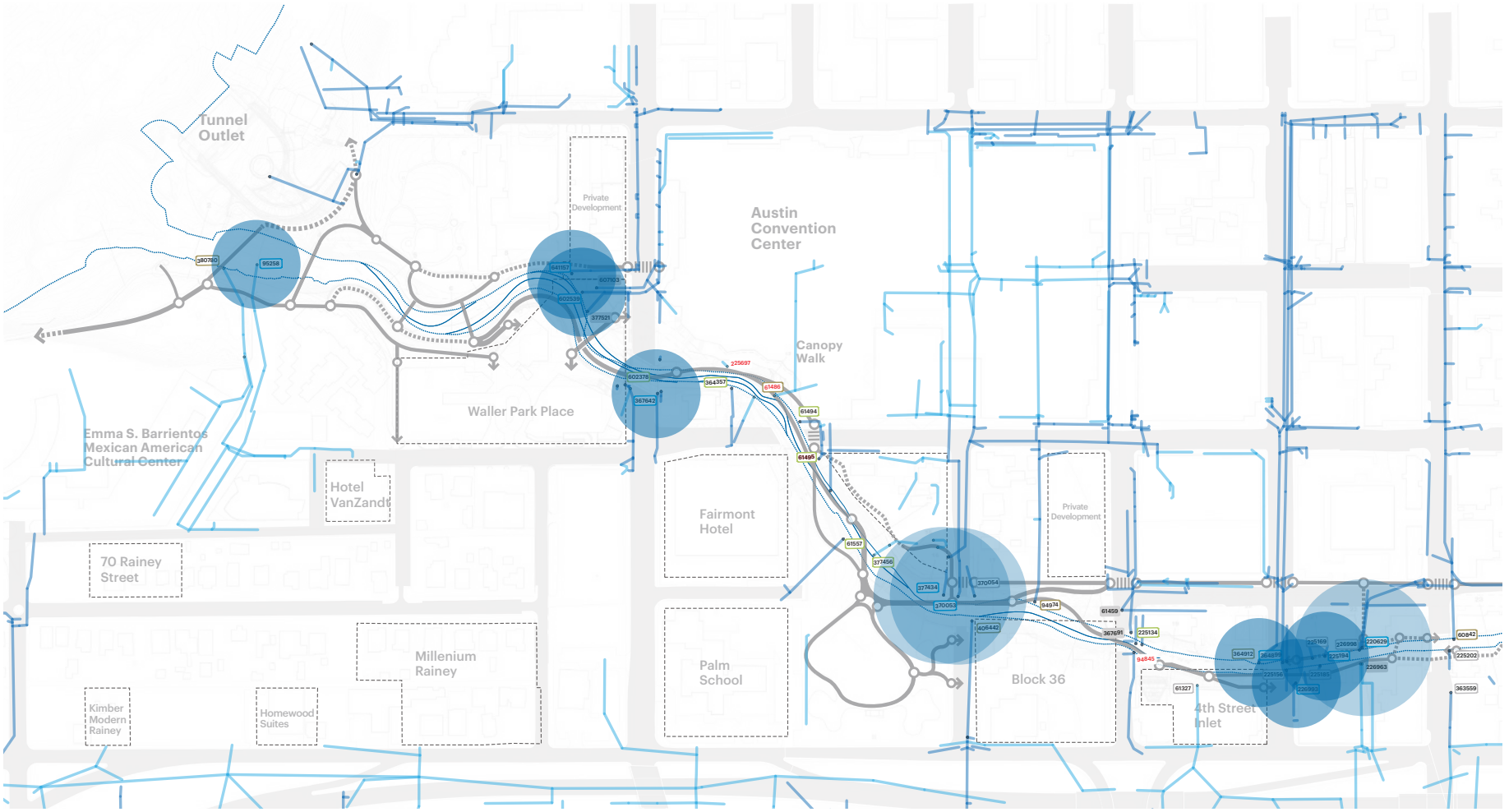
Underground treatment devices, such as the "SAFL Baffle" (depicted to the left) combined with a floatables skimmer, intercept floatable debris and suspended solids just before they enter the creek system. As a result, these flows contain much of the accumulated debris from upstream. With regular maintenance to ensure a high level of performance, the strategic placement of these devices could capture a great deal of the unwanted material entering Waller Creek, using only limited resources.

These inline treatment devices can fit inside manholes ranging from 4'-8' in diameter. These manholes need to be cleaned out with a vactor truck at least once per year, and potentially more frequently in areas prone to trash accumulation. The framework plan makes recommendations for potential sites for these inline devices, based on the apparent availability of subsurface area and proximity to a right-of-way for maintenance access.

INLINE STORMWATER TREATMENT DECISION PATHWAY



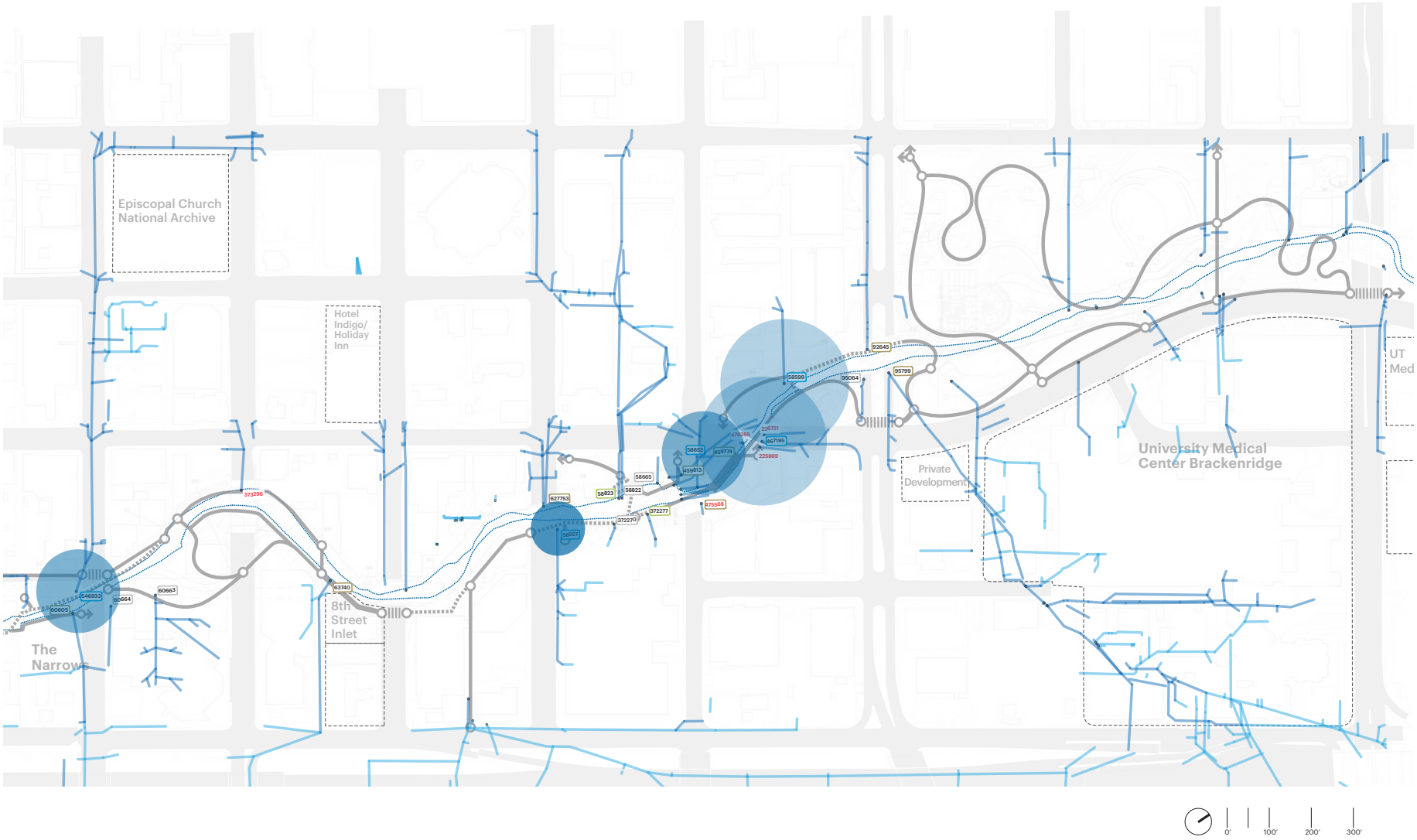
STORMWATER RETROFITS — INLINE TREATMENT



MAP KEY

LEVEL OF CONTRIBUTION

High Medium Low


Episcopal Church
National Archive
Hotel
Indigo/
Holiday
Inn
8th
Street
Inlet
The
Narrows
Private
Development
University Medical
Center Brackenridge
UT
Med
0'
100'
200'
300'

The sub-watersheds that contribute to Waller Creek are anticipated to undergo a high level of redevelopment over the next decade, which will have an impact on water quality in the creek itself. In many instances, the volume of water or the physical conditions around an outfall preclude the deployment of inline or landscape treatments as described above. For these pipes, the framework plan looks to address water quality at the sub-watershed level.

First, stormwater management infrastructure can be deployed within right-of-way, through inlet devices in the roadway that capture debris, as well as features such as rain gardens on sidewalks. Best-practices as required for public and private upland redevelopment will hold and treat stormwater on-site before it enters Waller Creek. Collectively, these efforts can contribute to improved water quality within Waller Creek. Below is a description of potential strategies specific to each of these sub-watersheds.

WLR 28

- Contains high contributors that cannot be treated with inline devices within creek corridor

WLR 30

- Concentrated area of emerging private development
- Relationship to Waller Creek Tunnel 8th Street side inlet

WLR 31

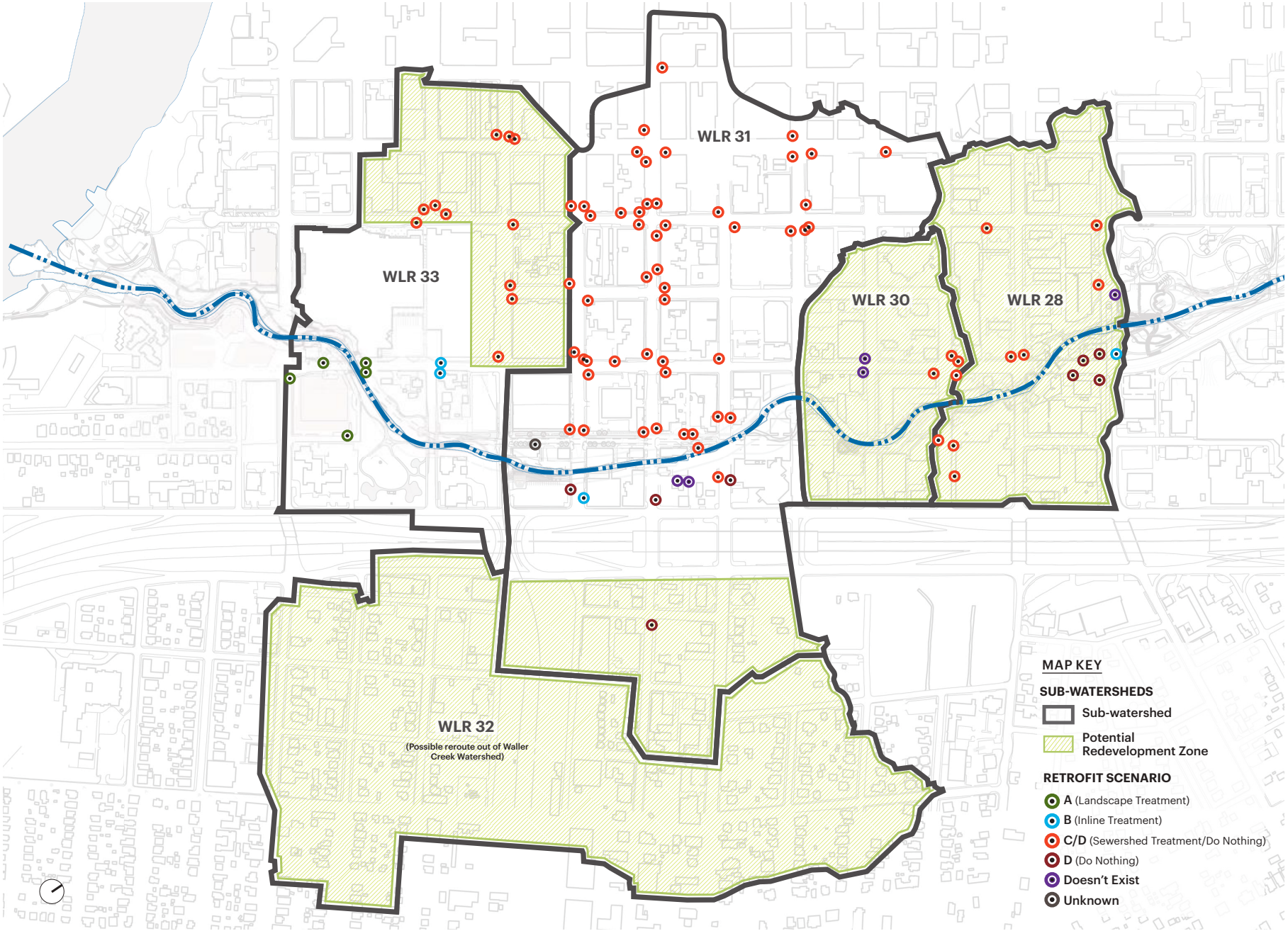
- Core downtown area receives a large amount of floatable debris that ends up in Waller Creek
- Historic core with small parcels that are unlikely to be redeveloped and present few opportunities for site-based treatment
- Recommended inlet filters shown in red
- Potential for large inline treatment devices which threat runoff from multiple inlets

WLR 32

- Covers a significant portion of East Austin - many residents and property owners likely unaware that there is a direct hydrologic connection to Waller Creek
- Potential reconstruction of I-35 through downtown may radically alter relationship to Waller Creek

WLR 33

- Recommended inlet filters shown in red


WLR 31
WLR 33
WLR 30
WLR 28
WLR 32
(Possible reroute out of Waller Creek Watershed)
MAP KEY
SUB-WATERSHEDS
Sub-watershed
Potential Redevelopment Zone
RETROFIT SCENARIO
A (Landscape Treatment)
B (Inline Treatment)
C/D (Sewershed Treatment/Do Nothing)
D (Do Nothing)
Doesn't Exist
Unknown

MAINTENANCE AND OPERATIONS

The programmatic layers of this Framework Plan culminate in the topic of maintenance and operations. Assessment of maintenance and operations is a critical at each step in implementing the individual creek segments for the purposes of funding and establishing operations budgets as outlined in the Joint Development Agreement between the City and the Waller Creek Conservancy, but also as a design tool for developing a resilient model for this new piece of public infrastructure. The fact that this project involves both creek restoration practices and new recreational programming suggests the need for grounding this topic with spatial principles that frame how a maintenance regime should be conceived in this context.

CLEANING AND DEBRIS COLLECTION

Cleaning and maintenance operations in public spaces often come with a regime of devices and practices (power-washing, chemical cleaners, removal of thatch and dead vegetative material) that limits the ecological production of riparian areas along a stream. Within the district, cleaning operations should consider the sensitive nature of riparian areas, and be deployed sparingly to address graffiti and staining on the trail architecture or adjacent walls and abutments. Cleaning operations should consider best management practices as to not discharge pollutants or disturb

plant and soil communities. While foreign trash and non-biodegradable debris may be removed as part of the debris collection operations, not all kinds of debris are detrimental. For example, fallen branches, logs and leaf-litter should be considered for their critical role in the creek and riparian ecology and left in place where feasible (or relocated in and around the same area), emulating a natural distribution of this beneficial material.

EDGES AND FACILITIES

The blending of hard infrastructural or architectural elements and natural landscape systems will inevitably invite unplanned conditions: as healthy plant communities encroach into joints and seams, they can potentially damage structures or degrade architectural elements. However, not all of these conditions are at equal risk for destabilization. The impulsive removal of plant and soil communities in riparian areas should be discouraged; every effort should be made to evaluate the specific areas at risk for both long-term vegetative health and structural integrity.

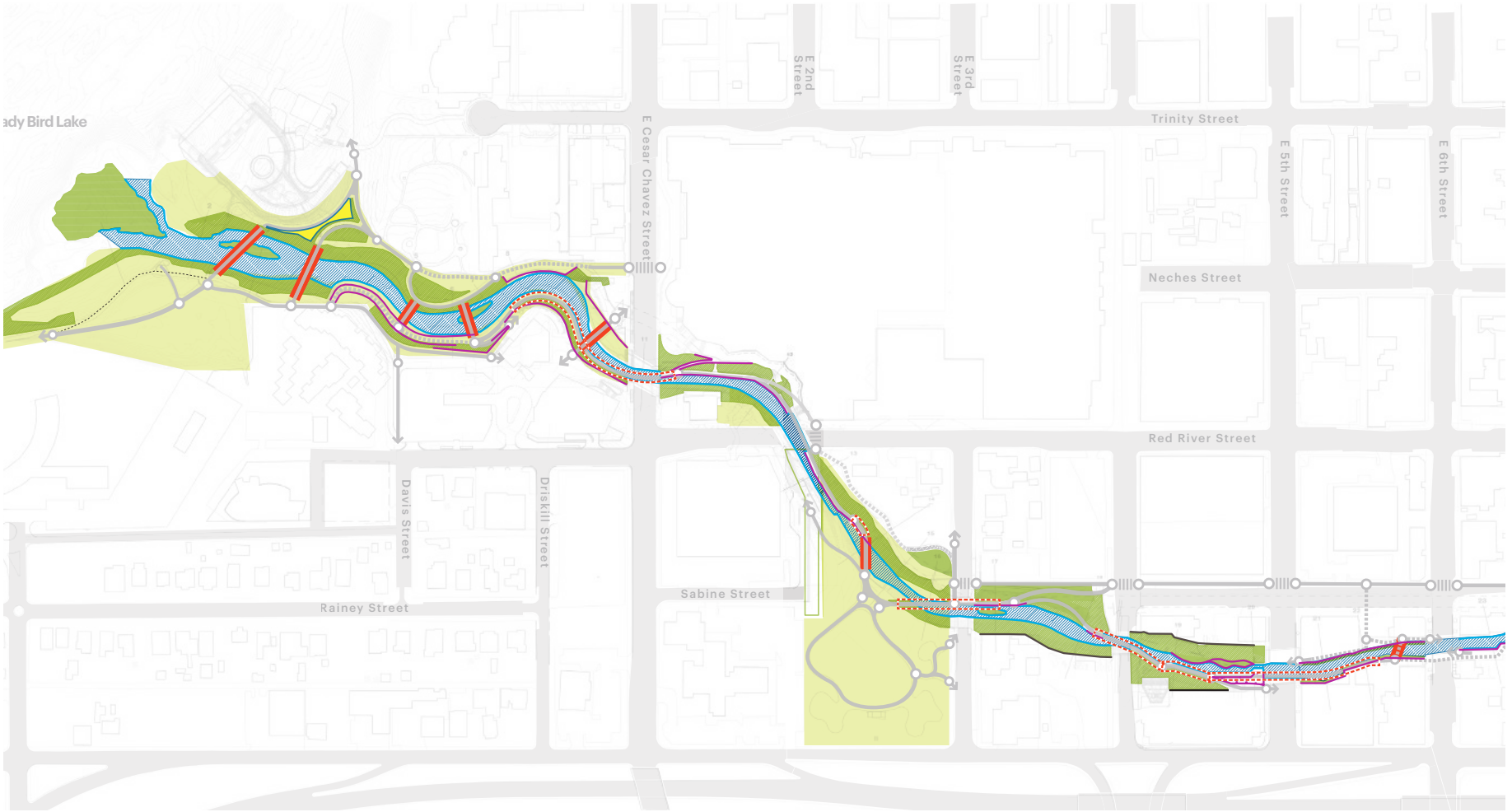
REOCCURRING VS ADAPTIVE MAINTENANCE

To balance the workforce available between recurring and more unpredictable responsive tasks, monitoring will be a critical part of the upkeep and stewardship of the creek system. Monitoring will be used to direct the level of recurring and responsive work. If adaptive tasks attempting to correct chronic problems identified through the monitoring process repeatedly fail to solve the problem, then a new recurring task may be identified for a specific area or plant community. For example, if spot or manual methods of removing invasive species does not appear to be making progress, a larger scale, longer term approach to the problem may be warranted. In either case, the stability of the creek system should be established through the understanding of how dynamic systems experience disturbance and find equilibrium on their own. However, due to the highly urban and modified nature of this creek corridor, a combination of natural stream processes and active stakeholder stewardship will be necessary to achieve the goals of the Waller Framework Plan.

MAINTENANCE MODEL

Quantifying a level of effort for maintaining the fully-built out landscape program described herein is achieved by separating out several landscape types areas and assigning each with a regime of maintenance activity. These types are described in general in this section and are represented in the graphic plan, and further details for the level of effort quantification is included in the Appendices Book. The area breakdown by types and by segment is summarized below.

STEWARDSHIP, MAINTENANCE, & OPERATIONS



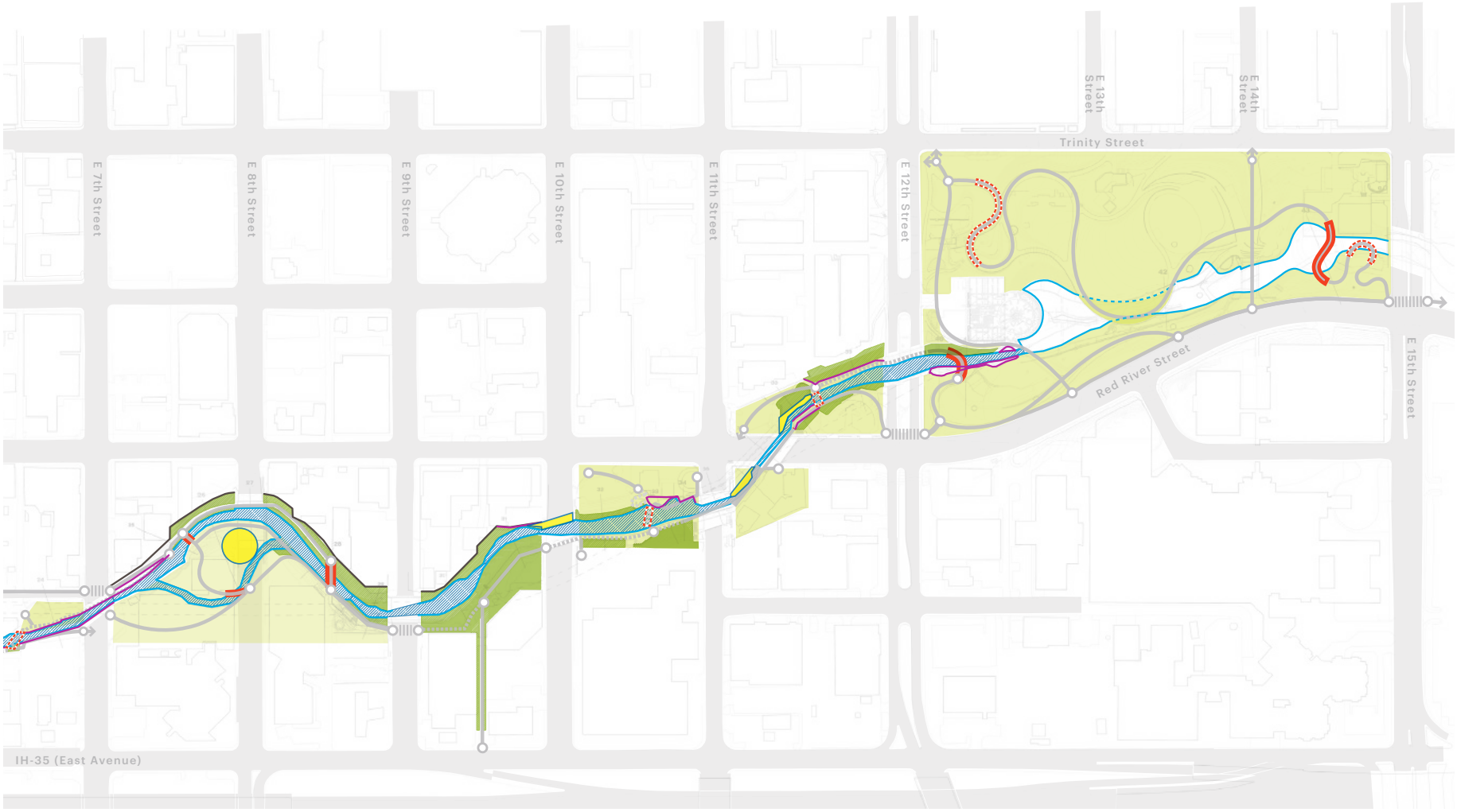
MAP KEY

LANDSCAPE TYPE

- Riparian Slope
- Parkland
- Stormwater Management
- Creek Channel
- Vertical Slope
- Creek Edge
- Upland Corridor Edge

TRAIL TYPE

- Trail
- Trail on Structure
- Bridge


E 7th Street
E 8th Street
E 9th Street
E 10th Street
E 11th Street
E 12th Street
E 13th Street
E 14th Street
E 15th Street
Trinity Street
Red River Street
IH-35 (East Avenue)
0'
100'
200'
300'

STEWARDSHIP AREA TAKE OFFS

Segment I	
Parkland	257,500 SF
Riparian Slopes	87,000 SF
Slopes Near Vertical	1,700 LF
Upland Corridor Edge	N/A
Stormwater Management	2,300 SF
Creek Channel	61,800 SF
Trail	3,500 LF

Segment II	
Parkland	153,100 SF
Riparian Slopes	50,400 SF
Slopes Near Vertical	1,000 LF
Upland Corridor Edge	300 LF
Stormwater Management	N/A
Creek Channel	33,000 SF
Trail	2,800 LF

Segment II	
Parkland	7,600 SF
Riparian Slopes	20,400 SF
Slopes Near Vertical	1,600 LF
Upland Corridor Edge	430 LF
Stormwater Management	N/A
Creek Channel	24,100 SF
Trail	700 LF

Segment III	
Parkland	64,500 SF
Riparian Slopes	49,200 SF
Slopes Near Vertical	600 LF
Upland Corridor Edge	1,100 LF
Stormwater Management	5,100 SF
Creek Channel	36,700 SF
Trail	2,400 LF

Segment V	
Parkland	104,800 SF
Riparian Slopes	18,800 SF
Slopes Near Vertical	500 LF
Upland Corridor Edge	N/A
Stormwater Management	3,400 SF
Creek Channel	23,400 SF
Trail	1,700 LF

Segment VI	
Parkland	460,400 SF
Riparian Slopes	3,800 SF
Slopes Near Vertical	400 LF
Upland Corridor Edge	N/A
Stormwater Management	N/A
Creek Channel	27,000 SF
Trail	3,500 LF

TOTALS	
Parkland	**1,047,900 SF**
Riparian Slopes	**229,600 SF**
Slopes Near Vertical	**5,800 LF**
Upland Corridor Edge	**1,830 LF**
Stormwater Management	**10,800 SF**
Creek Channel	**206,000 SF**
Trail	**14,600 LF**

For many years, Waller Creek suffered for the lack of a constituency and its minimal maintenance was fragmented among public and private entities. The partnership between the Waller Creek Conservancy and the City of Austin forms a strong foundation for better stewardship of the reinvented Waller Creek corridor. Long term management for landscape ecology will be closely intertwined with increased activities in the creek channel and in restoration areas. The categories below subdivide creek improvements by their respective maintenance needs.

Restoration Areas (Riparian Slopes)

Restoration areas are native planting landscapes with slopes ranging from nearly flat to 2:1. These areas do not include trails and are not intended for frequent use by park visitors, although some litter clean-up will be needed. Vegetation includes trees, shrubs, groundcovers, and meadow planting. Depending on the species mix, the restoration areas may require care of vegetation, erosion control, annual mowing, and debris removal. Regular inspection for erosion and repair will also be performed.

Constructed Embankments (slopes near vertical)

Constructed embankments include nearly vertical slopes such as retaining walls (proposed and existing) and mechanically stabilized earth embankments with slopes steeper than 1:1. These areas do not include trails and are not intended for frequent use or public access. Vegetation, where present, includes vines, grasses and forbs. Erosion control in these areas will

be critical. Depending on the species mix, constructed embankments may require limited clearing or annual mowing. Litter is expected to be minimal, however maintenance will be more time consuming as access to these areas may be difficult.

Trails

Trails provide the primary means for park visitors to move through the Creek Corridor. Typically constructed of concrete, trails will range from 8' to 14' in width. Lighting and seating are located along the trails and railings are likely to be on the creek-side edge. Regular maintenance includes sweeping and stain removal. Periodic patching and repair of integrated furnishings/fixtures will also be needed.

Trails on Structure

Trails on structure are supported by piers, pilings or footings. In some cases these trails are integrated into larger structures such as the Waller Creek Tunnel side-flow inlets. This category also includes small foot bridges at creek-level and the areas under these bridges. Trails on structure have similar amenities and maintenance requirements as normal trails, but in some cases railings may be required on both sides. Site furnishing will be bolted onto the railings to conserve space. On average, these trails are 10' wide.

Bridges

Bridges are integrated into the circulation network, but differ from trails on structure in that they span greater distances. Bridges consist of different materials such as cable, wood/composite decking, concrete, or steel and are an average of 14' wide. In most cases they connect trails well above creek-level. Bridges will need regular safety and structural inspections, and all repairs must be done immediately. Additionally, these structures will need to be inspected for graffiti and debris removal.

Upland Corridor Edge

The Upland Corridor Edge is the boundary between the publicly-accessible creek corridor and adjacent properties. Use of the edge itself will be limited, but a fence or other boundary structure will be needed to define recreational and restoration areas. The fence may be planted with vines or plantings for added screening. Vegetation will need regular upkeep and litter that gets caught in the fence will need to be removed. The fence may have graphic information that will need to be maintained and periodically updated. Invasive species will need to be removed from the ground plane and some reseeding/replanting may be necessary. Erosion control may be needed, and should be coordinated with adjacent property owners.

Creek Edge

The creek edge is where the water's edge meets upland areas, particularly trails and retaining walls. The edge will receive limited use. Debris, litter and floatables are expected to collect along the water's edge and where it can be accessed from landside it may be removed. Some vegetation at the water's edge will require maintenance.

Creek Channel

The creek channel is the area of moving water. This includes floodplain benches, riffles, pools, and other aquatic features, both existing and proposed. These areas will get little or no public use, therefore maintenance will be minimal. After storms and severe weather events, debris may accumulate and will need to be removed.

Stormwater Management

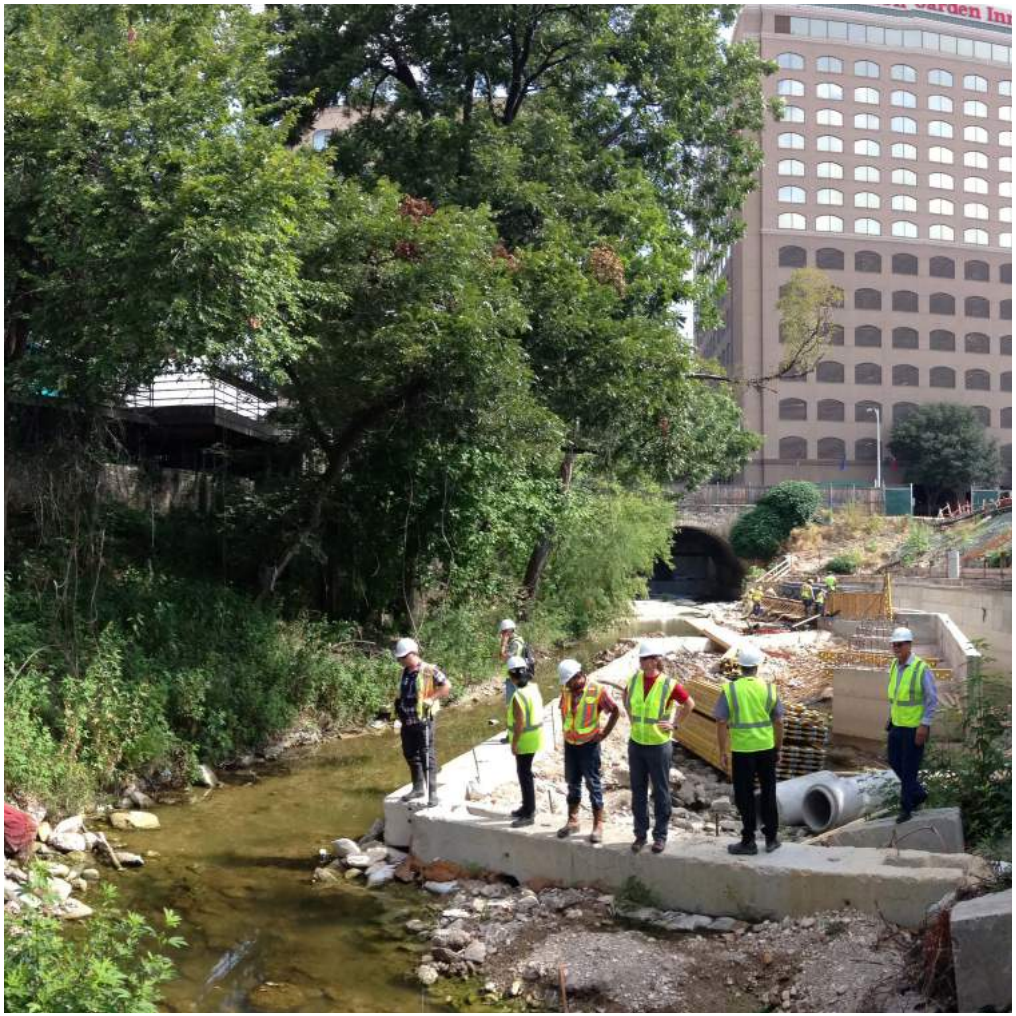
Stormwater management includes rain gardens, outfalls, overbank, and other features that help manage stormwater runoff. Since these areas will get little or no public use, maintenance will be minimal. However, rain gardens will require regular horticultural maintenance. Most stormwater management features will require regular inspections before and after storm or rain events.

Parkland

Parkland includes areas which receive regular use by the general public. Both passive activities and heavily programmed public events will occur in parkland. In some cases trailheads and other more intensely planted or used areas within the creek corridor are also considered to be parkland. These areas will require regular trash removal, horticultural maintenance and site furnishing maintenance.

Restrooms

Restrooms will be accessible by the public year-round. Facilities will require regular cleaning and restocking, periodic material replacement and repairs, and graffiti removal as needed.



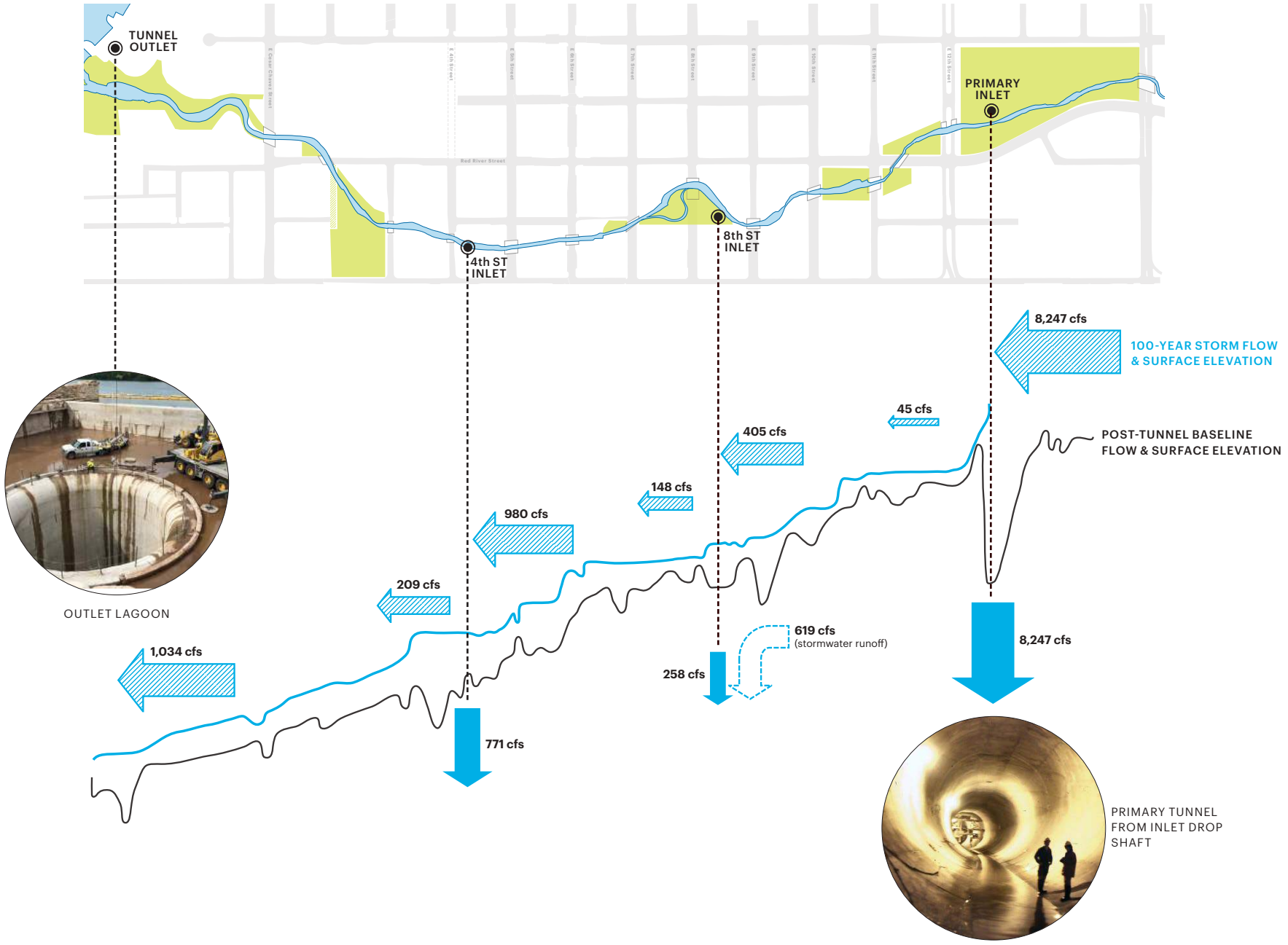
THE TUNNEL CONTEXT

The hydrology of the downstream reaches of Waller Creek that are the focus of the Framework Plan will be dramatically altered with the completion of the Waller Creek Tunnel. The tunnel will route a significant portion of all rain events through a mile-long tunnel with an average diameter of 22 feet. As the tunnel goes online, the size of the 100-year floodplain will decrease by approximately 28 acres (Moody 2009), resulting in a new 100-year event condition that will be contained entirely within the narrow Waller Creek channel corridor as it runs from 12th Street to the mouth, and protecting most developed lands from flooding under conditions up to the 500 year event.

The tunnel entry is configured as a circular inlet weir and drop shaft, which allows storm water flows to drop 70 feet to the tunnel invert and then through the tunnel to the outlet riser on the west side of the creek mouth. Additional diversion of stormwater flows to the tunnel is managed via creek side inlets located at 8th Street and 4th Street. Flows to the side inlets are managed by control weirs located just downstream of each inlet, which provide a local control on creek elevations and direct elevated flows and trash and debris to the tunnel drop shafts.

The effect of the tunnel diversion on the flow regime of the lower Creek is dramatic, for both the 100-year design event and for the range of smaller, more frequent events that shape the hydrology of lower Waller Creek. Under the 100 year event, flows of approximately 8,250 cubic feet per second (cfs) enter Waterloo Park and will be diverted almost entirely to the tunnel via the morning glory inlet, with a small portion of flows (approximately 45 cfs) diverted through the 12th Street Dam via a 42" orifice and outlet to the creek. Additional stormwater enters the system downstream of Waterloo Park, resulting in an increase in flow from 45 to 400 cfs between 12th and 8th streets, followed by a diversion of 250 cfs at 8th street and a corresponding decrease in creek flow. Stormwater inputs then create a rise in flow to 1000 cfs just upstream of the 4th street inlet, diversion of 800 cfs to the tunnel at the inlet, and a final increase in flows from 200 cfs downstream of 4th Street to over 1000 cfs at the mouth. As with the 100 year event, flows are similarly variable under the more frequent events that will characterize the typical annual behavior of the creek.

Beyond the primary goal of the tunnel project to manage floodwaters in downtown Austin, a secondary goal is to provide a significant improvement in the quality of Waller Creek waters through circulation of waters diverted from Lady Bird Lake and the Colorado River. Under its normal operating condition, the Waller Creek Tunnel is full of water because its elevation is well below the normal pool elevation of Lady Bird Lake. During dry weather periods, Waller Creek base flows will be maintained by pumping of tunnel water at Waterloo Park and releasing flow to the creek. Pumping will be conducted to serve two purposes: to allow for continuous flushing of the tunnel water to provide high water quality in the tunnel itself, and also to ensure a consistent and high quality base flow for the creek. The primary water quality objective of tunnel flushing is to maintain acceptable dissolved oxygen levels by limiting the residence time of waters in the tunnel, and consequently limiting the amount of time during which biological and sediment oxygen-demanding processes in the tunnel can negatively effect the relatively high quality waters of the Colorado River.


TUNNEL OUTLET
PRIMARY INLET
4th ST INLET
8th ST INLET
8,247 cfs
100-YEAR STORM FLOW & SURFACE ELEVATION
45 cfs
405 cfs
148 cfs
980 cfs
209 cfs
1,034 cfs
771 cfs
258 cfs
619 cfs
(stormwater runoff)
8,247 cfs
POST-TUNNEL BASELINE FLOW & SURFACE ELEVATION
OUTLET LAGOON
PRIMARY TUNNEL FROM INLET DROP SHAFT

MANAGED URBAN HYDROLOGY

As described above, the construction of the stormwater bypass tunnel creates a dramatic change in the flows passing through the lower reach of Waller Creek, greatly decreasing flow under the range of wet weather conditions, and increasing flow during dry weather when tunnel flushing will result in a double to triple increase over current base flow conditions in the creek. These changes amount to a shift in the apparent hydrology of the creek and a fundamental shift in the frequency, duration and intensity of flows experienced by the creek.

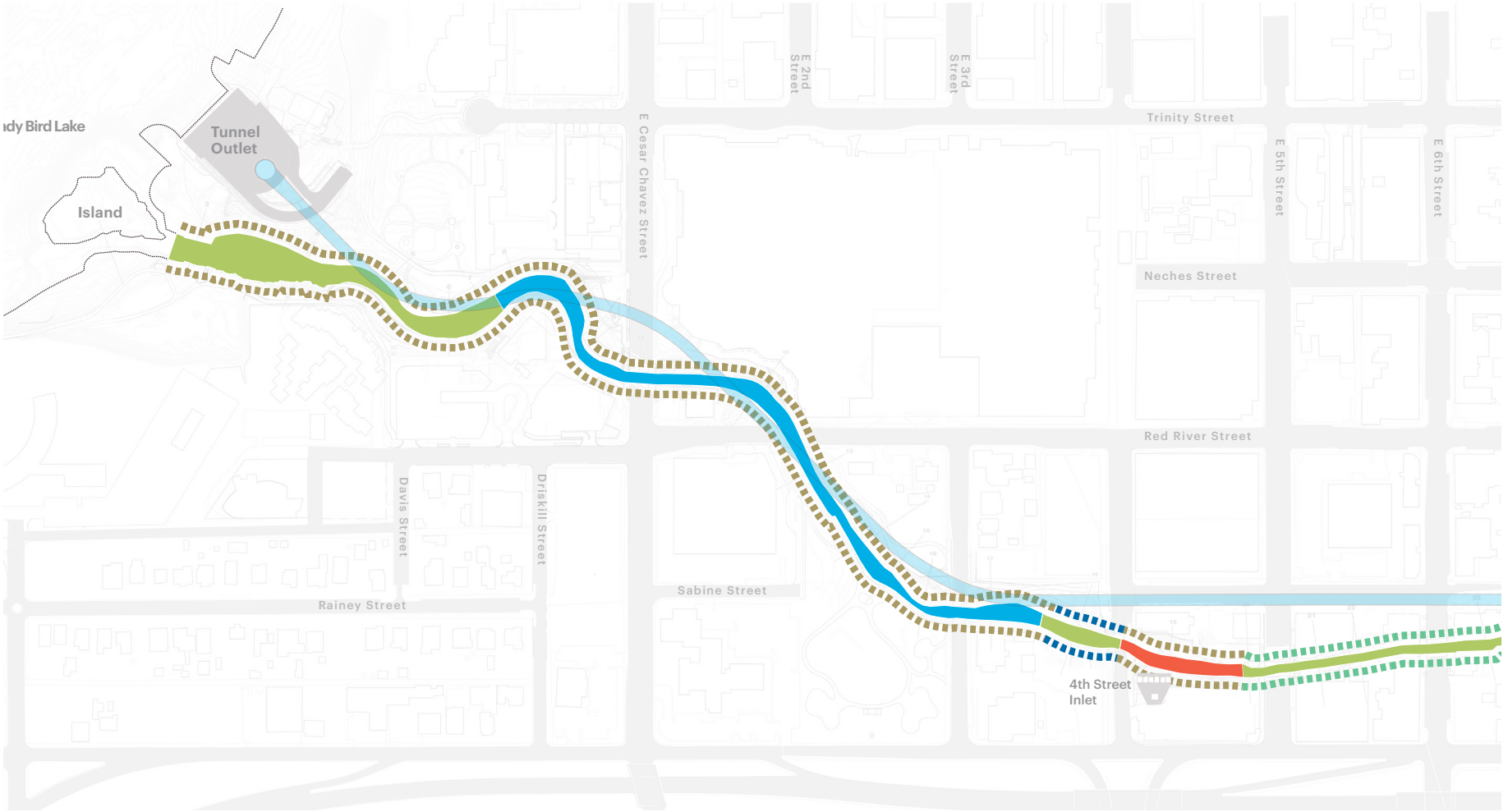
This hydrologic shift has profound implications for all aspects of creek function. Hydrology acts as a fundamental process upon which most other physical, chemical and biological functions of the creek depend. Altered hydrology results in changed hydraulics of flow at all scales, meaning that the velocities and associated stresses imparted by water on the creek bed are changed under all weather conditions. These changes in water velocities and stresses affect the basic geomorphology of the creek – channel form in profile, plan, and cross-section are all dependent on the range of stresses that deliver sediment, scour the bed and banks, and create channel shape and profile.

Hydrology, hydraulics and channel form combine to create the conditions for the water quality and biological functions of the waterway as well. Baseflow and periodic high flow events move water and nutrients through the system, maintain high dissolved oxygen levels, and scour away decaying plant matter and accumulated biofilms. Periodic flood and drought periods provide necessary sediment and nutrients to floodplain vegetation, but also enhance biogeochemical processes which control nutrient concentration in flowing waters. Natural variability in flows tends to favor productivity in wetlands and vegetated riparian zones and is a critical part of a thriving creek ecosystem.

The altered hydrology of Waller Creek has aspects that are not common to most natural systems. The system as currently envisioned will have very consistent baseflow, no periods of drought, significant variability in stormwater flow due to localized stormwater inputs, and varying water quality: high quality base flow waters originating from Lady Bird Lake, and lower quality urban stormwater inputs under all event conditions.

Ultimately, the effects of the tunnel will be mixed: a strongly beneficial effect of reduced flooding pressure counteracting years of urbanization and impervious runoff conditions, and a beneficial input of high quality lake water, alongside the potentially negative effects of eliminating much of the natural variability of the system, particularly at the lower and middle range flows of the new hydrology. The hydrologic and water quality changes will likely register as a net benefit under the City of Austin's Environmental Integrity Index, which characterizes a stream in terms of water quality, sediment quality, contact recreation potential, non-contact recreation aesthetic considerations, habitat quality and aquatic life. Of these, the habitat and aquatic life considerations are the most difficult to improve, and are the most likely to be affected by the altered variability of the system.

HYDRAULICS & HYDROLOGY



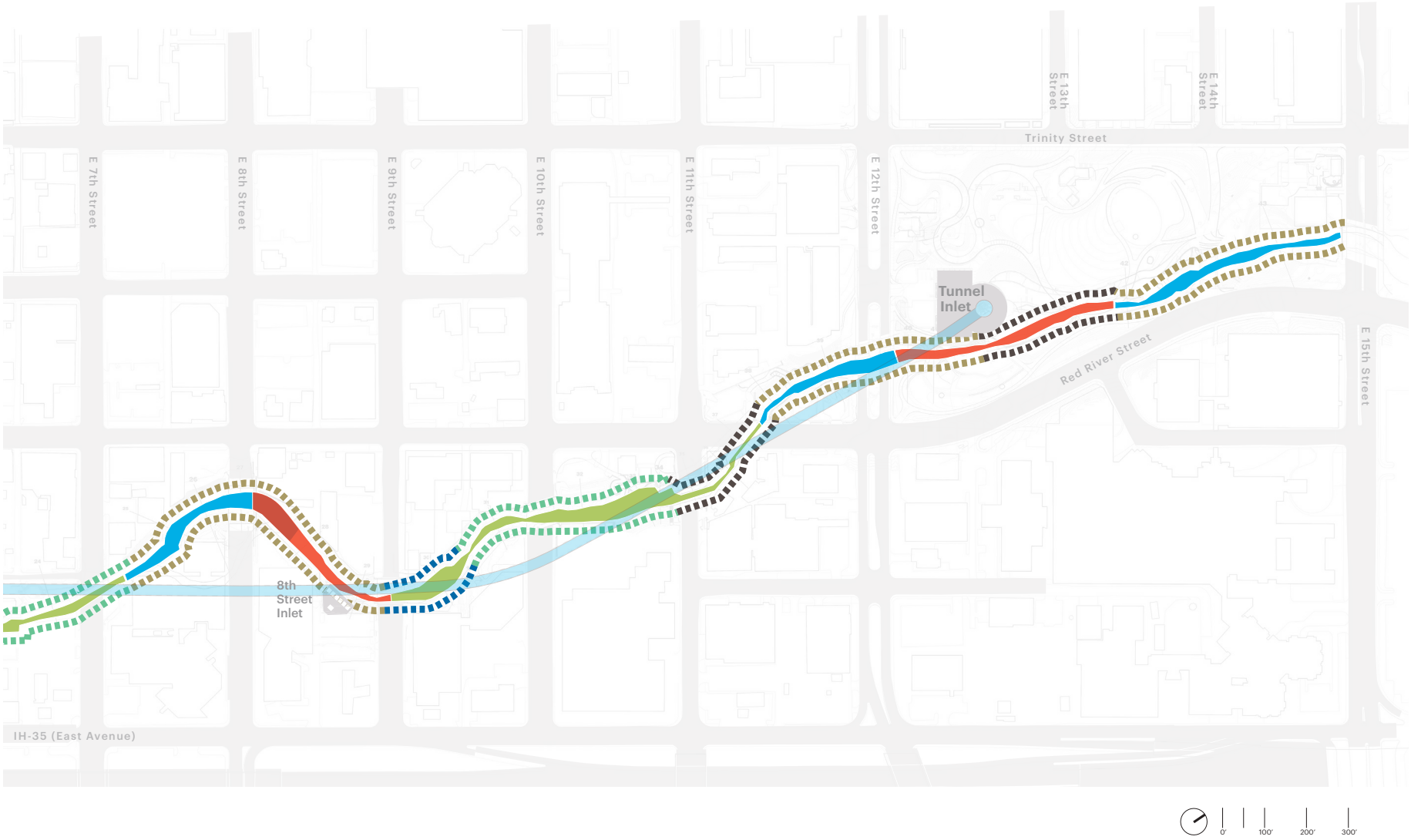
MAP KEY

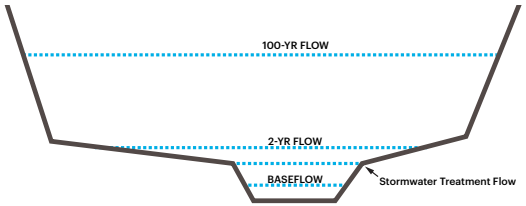
POTENTIAL PROJECT TYPE

- Tunnel Project
- Habitat Improvements Only
- Restored Channel Form (With Pool & Riffle Sequences)

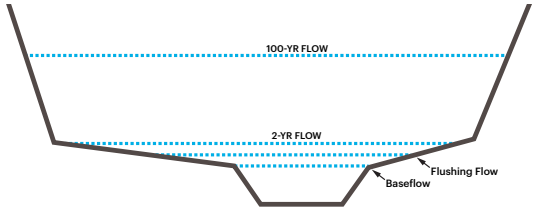
HYDRAULICS & GEOMORPHOLOGY

- Sand, Gravel, Cobble Bed
- Deep Pool
- Rock Bed
- Concrete Bed
- Waller Tunnel

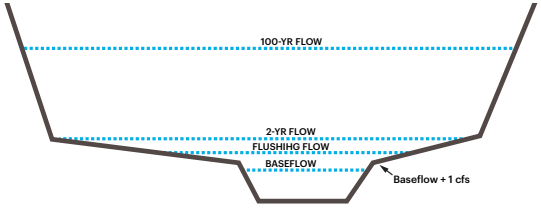

E 13th Street
E 14th Street
Trinity Street
E 7th Street
E 8th Street
E 9th Street
E 10th Street
E 11th Street
E 12th Street
Tunnel Inlet
Red River Street
E 15th Street
8th Street Inlet
IH-35 (East Avenue)
0'
100'
200'
300'



A. TARGET STORMWATER TREATMENT FLOW IN THE LOW-FLOW CHANNEL



B. BASEFLOW IN THE LOW-FLOW CHANNEL



C. BASEFLOW JUST BELOW THE LOW-FLOW CHANNEL

CHANNEL FORM

As described in the previous section, the highly modified hydrology of Waller Creek will provide a basis for the evolution of the new channel form adapted to the range of flows, velocities, channel stresses and sediment loads delivered by the new system. The channel form is the critical means by which the modified hydrology is translated into characteristics that support of habitat, biota and vegetation on the creek: inundation frequency and duration, deposition of solids and solids-associated nutrients, and hydraulic scour and removal of decayed vegetation and biofilms.

A natural channel system with a history of channel evolution and natural adaptation may contain a wide variety of geomorphological elements: a sloped upland edge, terraces or abandoned floodplains, active floodplains, natural levees, inset channels, sub inset channels, and many other features specific to the region, channel gradient, and character and supply of the sediment load. In Austin, many channels are entrenched into a well-defined floodway or valley that contains an inset floodplain and channel. The configuration of the inset channel is of critical importance for the hydrologic, water quality and biological functions of the waterway, as the boundary of the inset channel is the elevation that controls access to the riparian floodplain.

Because of the relative simplicity of the Waller Creek system, a simplified version of the channel cross-section and profile is envisioned that integrates the slope of the upland edge with existing uses and land ownership along the creek corridor, and creates a defined inset channel with a top elevation corresponding to the 1-month to 1-year event. The relatively high and regular base flow planned for the system may result in the formation of a sub inset channel in some locations, which would be a desired condition that would best be allowed to form naturally, or possibly influenced with the use of channel training structures, as opposed to explicitly constructed.

In places where construction or modification of the inset channel is desired, the specific strategies available for creating and maintaining the channel depends in part on the sediment transport environment, and the availability of sediment load. When a continuous feed of sediment load is available that allows for channel migration and adaptation in response to changing hydrologic conditions, it is possible to construct a dynamic creek morphology that allows for continuous migration within boundaries defined by armoring at the edges of the floodplain boundary (A). In contrast, a sediment-limited system requires a more static creek morphology, in which the channel form is more rigidly constructed and armored to resist scour (C). For Waller Creek, a recommended middle condition (B) would allow for more limited channel migration within a pool-riffle sequence, sustained either by solids delivered by

existing stormwater inputs, or in the case of inadequate sediment inputs, by seasonal feeding of sediments through seeding of eroding banks at strategic locations in the system.

The degree of intervention and desired channel forms will vary along the creek. In areas of the creek not dominated by bedrock outcrops, sequences of pools and riffles are generally desirable. Pool and riffle sequences of this type are already naturally occurring in Waller Creek downstream of Cesar Chavez. The majority of the creek from Cesar Chavez up to Waterloo Park is dominated by creek runs and pools; however, these pools are the consequence of weirs and not natural processes. The best opportunities for restoring natural pools and riffles is downstream of 4th Street and in the vicinity of the proposed 8th Street island. Pool and riffle sequences will need to opportunistically take advantage of existing topographical variability in order to minimize construction costs while still achieving geomorphic, physiochemical, and biologic goals.

ADAPTIVE MANAGEMENT OF FLOWS

The channel forms described in the previous section will be designed to make the most of the range of flows expected along each reach of the creek corridor. This will result in a variety of cross-sectional forms that reflect the local hydrology, as affected by the stormwater inputs unique to each reach. Work is also being done to identify ways to attenuate the intensity of stormwater flows using a combination of end-of-pipe landscape treatments, inline engineered storage and filtration elements, and recommended treatment further up in the sewershed when local treatment is not possible.

Additionally, the lower range of flows can be manipulated to provide enhanced performance of the system with greater variability of flow. Pumped flows, which contribute to base flow, are constrained by a number of considerations including: the need for continuous flushing of the tunnel, the need for elevated rates of flushing after a storm event, the limited range of pumping rates of the pumps at Waterloo Park, and the limits of the LCRA water use agreement which caps annual recirculated water. However, even with these recognized constraints, there are significant opportunities to create flow variability that could include periods of lower than normal flow, periods of elevated flow, post-storm event receding flows that simulate natural systems, and even periods of simulated drought that could be coordinated with periods of tunnel maintenance. The specific opportunities for flow variability are closely tied to the need for maintaining high water quality in the tunnel, and consequently will require further analysis to identify opportunities and potential benefits.