Design for Resilience in Brattleboro's Lower Whetstone Brook Corridor

United States Environmental Protection Agency

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US Environmental Protection Agency

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Whetstone Brook is a tributary of the Connecticut River and its confluence with that river led to the settlement of Brattleboro, Vermont. As the town grew over the past 263 years, the core of the downtown commercial, industrial, and residential uses clustered around the brook, taking advantage of the opportunities for water power and waste disposal. Throughout its history, the downtown has been subject to flooding from the Whetstone. Most recently, Tropical Storm Irene in 2011 caused a major flood that inundated parts of the Whetstone corridor.

Since that flood, the town of Brattleboro has embarked on a series of initiatives to reduce the impacts of flooding and to create plans, policies, and projects that will result in a more resilient downtown. In 2016, the town received technical assistance from the U.S. Environmental Protection Agency (EPA) under its "Making a Visible Difference (MVD) in Communities" initiative. The goals of this assistance were to identify design solutions for the lower Whetstone Brook that would reduce flood damage, manage stormwater runoff, envision infill development, and reconnect the brook to the surrounding neighborhoods as a recreational amenity.

In April 2016, EPA and its consultant team met with Brattleboro officials and visited the Whetstone corridor, noting areas that were channelized and exacerbating flood damage; areas adjacent to the brook that were underutilized or paved over; and areas that were well suited for restoration and flood storage. Then, through a public design charrette held in June 2016, the team identified a series of designs and strategies to reduce stormwater runoff, increase flood storage, provide infill development opportunities, and create visual and physical access to the brook.

The design options created at the charrette and modified in response to public input and agency comments demonstrate how and where these resilience strategies could be applied in the study area. The design options include:

- Conversion of the Preston parking lot into a park
- Provision of pedestrian and bicycle paths along both sides of the brook
- Removal of some vertical channel walls along the brook and replacement with terracing elements to increase flood storage
- Creation of a mixed use neighborhood on existing underutilized industrial land
- Creation of a major flood storage and stormwater management facility on a 12 acre site upstream from the downtown
- Widespread use of green infrastructure to control stormwater and improve water quality in the brook

These design options are woven together with a comprehensive network of paths and recreational areas to create new access to the brook and transform it into a robust public amenity for the town. In addition to the designs, the project report includes a stormwater mitigation toolkit, a flood mitigation toolkit, case studies, implementation strategies, and potential local, state, and federal sources of funding.

The Whetstone Brook watershed drains nearly 18,000 acres, of which over 69 percent (or 12,420 acres) lie in Brattleboro, Vermont. The study area for this report is the lower Whetstone Brook, which is a short distance from the confluence of the brook and the Connecticut River, and is the most intensively developed area of the watershed. Like much of New England, Brattleboro's downtown is located in a flood hazard area due to the historic settlement pattern which exploited waterways for power, transportation, and waste conveyance. The flood plain in the downtown covers 43.6 acres, of which all but 10 acres are developed. This dense, historic built form is now appreciated for its potential for redevelopment into compact, walkable neighborhoods. The purpose of this report is to guide the refashioning of this historic mixed use settlement pattern into a resilient 21st century community.

To achieve this more resilient future, Brattleboro must overcome demographic, socioeconomic, and climate change challenges. This report responds by envisioning redevelopment in three distinct zones to reconnect the community with the brook; enhance and expand walkable neighborhoods adjacent to downtown; foster mixed use development; and implement trail developments that complement new public open spaces. These new open spaces would incorporate ecological services such as stormwater treatment and flood hazard management strategies.

Brattleboro is a member of the National Flood Insurance Program (NFIP) Community Rating System (CRS), and since the mid 1980s has regulated development in the Special Flood Hazard Area (SFHA), also known as the 100 year flood plain. The planning process documented in this report is the latest example of Brattleboro's efforts to employ a science informed, multidisciplinary planning approach to flood resilience. These efforts intensified after Tropical Storm Irene but the priorities have remained the same. The most important work has been to remove residential units from the floodway through relocation, FEMA buyouts, or implementation of the Special Flood Hazard regulations. The majority of these structures are found in West Brattleboro, where the Whetstone Brook descends from steep slopes into a relatively wide flood plain. The dominant land use in this area is low density residential and highway commercial development dating from the 1960s that was built with little regard for flood threat or ecological function. Here the strategy has been to allow the brook to regain access to the flood plain, remove encroachments (including homes) and let the stream reestablish equilibrium through channel migration by reducing conflicts with structures, including public infrastructure. Future work may entail excavation of filled material in the flood plain, which would increase flood storage and reduce flooding downstream.

The town has partnered with major stakeholders including local affordable housing organizations, the Vermont Department of Environmental Conservation (DEC), the Vermont Department of Housing and Community Development (DHCD), and the U.S. Environmental Protection Agency (EPA). The experience of Tropical Storm Irene underscored the need for a complete rethinking of the land use regulations the town used to guide development. The preparation of the new land use regulations benefited directly from the stream geomorphic assessment study of the Whetstone Brook undertaken by DEC in 2008 and the EPA Sustainable Communities Building Blocks workshop that helped the town explore best practices for conservation subdivisions. In the more rural, low density sections of town to the west (which drain into the Whetstone) new development now must respond to specific criteria to minimize the impact on watershed function and flood hazard, including controls for steep slope development, riparian buffers and inventorying natural assets.

Subsequent, more focused work included participating in the 2014 DHCD funded Vermont Downtown Action Team (VDAT) analysis of Brattleboro's downtown, funded through the Community Development Block Grant (CDBG) Disaster Recovery program of the U.S. Department of Housing and Urban Development. This VDAT report provided market analysis and implementation strategies for improved management of key public assets to spur private reinvestment. This work helped the town to consider how to transition to a more resilient downtown.

In 2015, Brattleboro partnered again with DHCD on the Vermont Economic Resiliency Initiative (VERI) funded through the Economic Development Administration (EDA) of the U.S. Department of Commerce. This work examined the economic and social impact of flooding on Brattleboro and made recommendations to minimize this hazard. This work updated the data from the 2008 stream geomorphic study and again directed the town's attention to a segment of the Whetstone Brook where access to the flood plain could be reestablished on a large open site at the western end of the study area (see Natural Zone description, below). The VERI report also recommended lowering the elevation of this area to further increase flood storage and restore natural infrastructure.

The work contained in this report is a continuation of Brattleboro's commitment to fostering an appreciation for the waterway that defines the town. The emphasis on design responses reflects the predominantly urban stream characteristics of the study area. The intent is to bring the community into closer, more frequent (but respectful) contact with the brook, which will be treated as an amenity, not a vestige of an early industrial landscape, currently neglected. The town will continue to work with its state and federal partners to make Brattleboro vibrant, safe, and resilient.

In 2015, the town of Brattleboro, Vermont applied for technical assistance from the U. S. Environmental Protection Agency (EPA) under its "Making a Visible Difference (MVD) in Communities" initiative. The town was eager to pursue design solutions that respond to climate change by creating resilient redevelopment and recreational opportunities within flood prone areas of the town while protecting water quality and connecting people with the Whetstone Brook.

The town's specific goals for the project included:

- Reduce the potential for damage from future flooding.
- Protect water quality with green infrastructure to capture and filter stormwater.
- Identify opportunities for infill development and redevelopment.
- Connect residents and visitors to the Whetstone Brook through a series of open spaces that provide recreational opportunities.

Based upon those goals, EPA formed a planning team of urban designers, landscape architects, and watershed consultants to facilitate a public process to develop a vision for the lower Whetstone Brook corridor. During a design charrette hosted by the town of Brattleboro between June 6 and 8, 2016, the team engaged residents, stakeholders, elected officials, and representatives from local, regional, state, and federal agencies in discussing and developing design options that could address the town's goals.

During the first day the team met with local officials and other stakeholders, including focus group meetings with community groups, neighbors, and business owners.

In the evening of the first day of the charrette, the design team presented conceptual strategies and design solutions for responding to climate change in Brattleboro's lower Whetstone Brook corridor at an open house held at the Latchis Theater in the heart of downtown Brattleboro.

On the following day, part of the design team participated in a focus group discussion with local, state, regional, and federal partners to discuss project phasing, potential funding opportunities, partnerships, and policy or regulatory approaches to achieve the goals for the Whetstone Brook corridor set by the town of Brattleboro. The rest of the planning team modified the proposed design solutions based on community input, comments, and feedback heard throughout the first day. The design team then incorporated changes based on comments and feedback from the agencies in order to create cohesive design solutions that correspond to local and state codes and regulations. At the end of the second day the design team provided a progress update that was open to the public.

In the morning of the third day, the design team finalized modifications and revisions to the existing design while also creating new graphics to better communicate the proposed concepts and to address interests and concerns heard throughout the first part of the charrette. The team held an open house at noon that day to share how the designs evolved and to discuss revisions and modifications from the original plans.

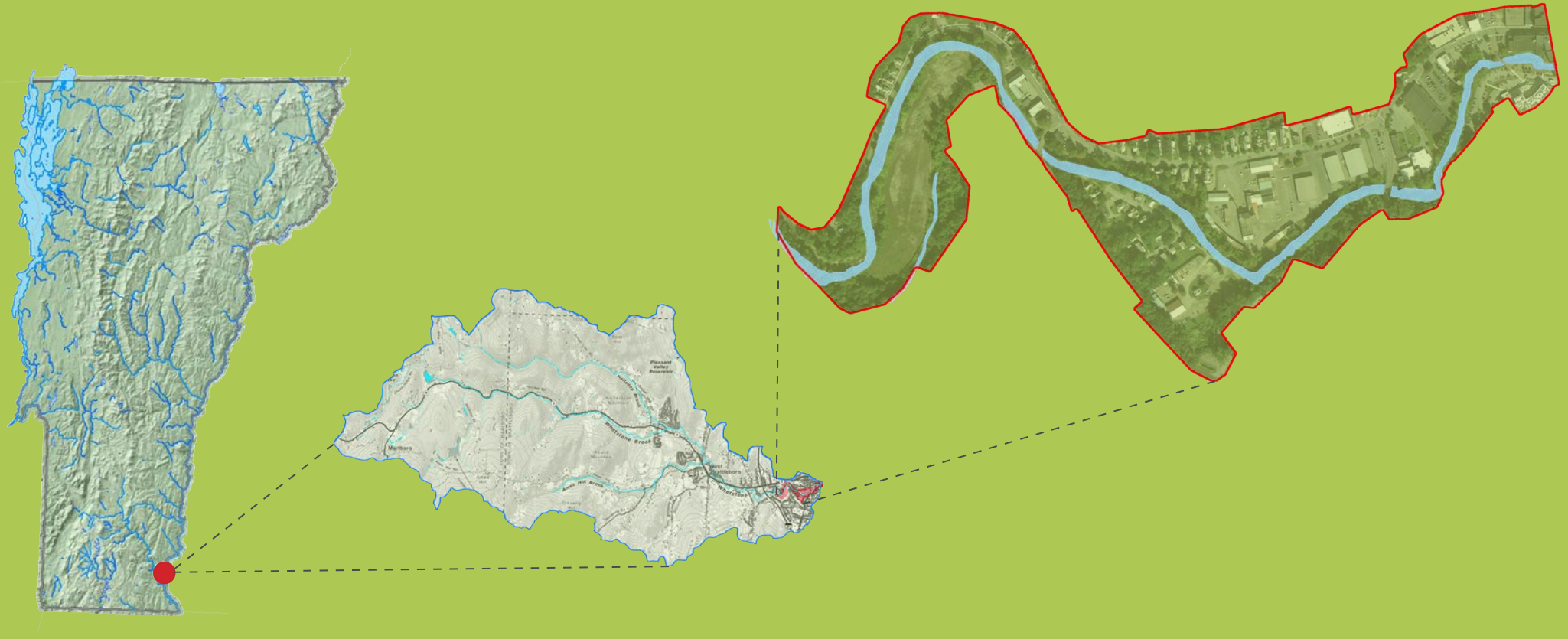
The following plans, graphics, and views illustrate the options Brattleboro can consider for the lower Whetstone Brook corridor.

The design concepts demonstrate solutions for flood resilient landscapes created in environmentally and culturally sensitive ways that address Brattleboro's vision and concerns.

This vision for the corridor can be implemented incrementally over time and could result in improvements in the health and wellbeing of its residents and visitors, as well as in water quality of the Whetstone Brook.

We note that the designs contained in this document are conceptual in nature and are likely to change over time in response to market conditions, site constraints, and regulatory requirements. Many, if not most, of the designs would need to receive permits from the Town and the State of Vermont, through normal regulatory processes such as Act 250, the River Corridor Rule, and FEMA requirements for development in Special Flood Hazard Areas.

Lower Whetstone Brook Corridor



STATE OF VERMONT

WHETSTONE BROOK WATERSHED

STUDY AREA: LOWER WHETSTONE BROOK

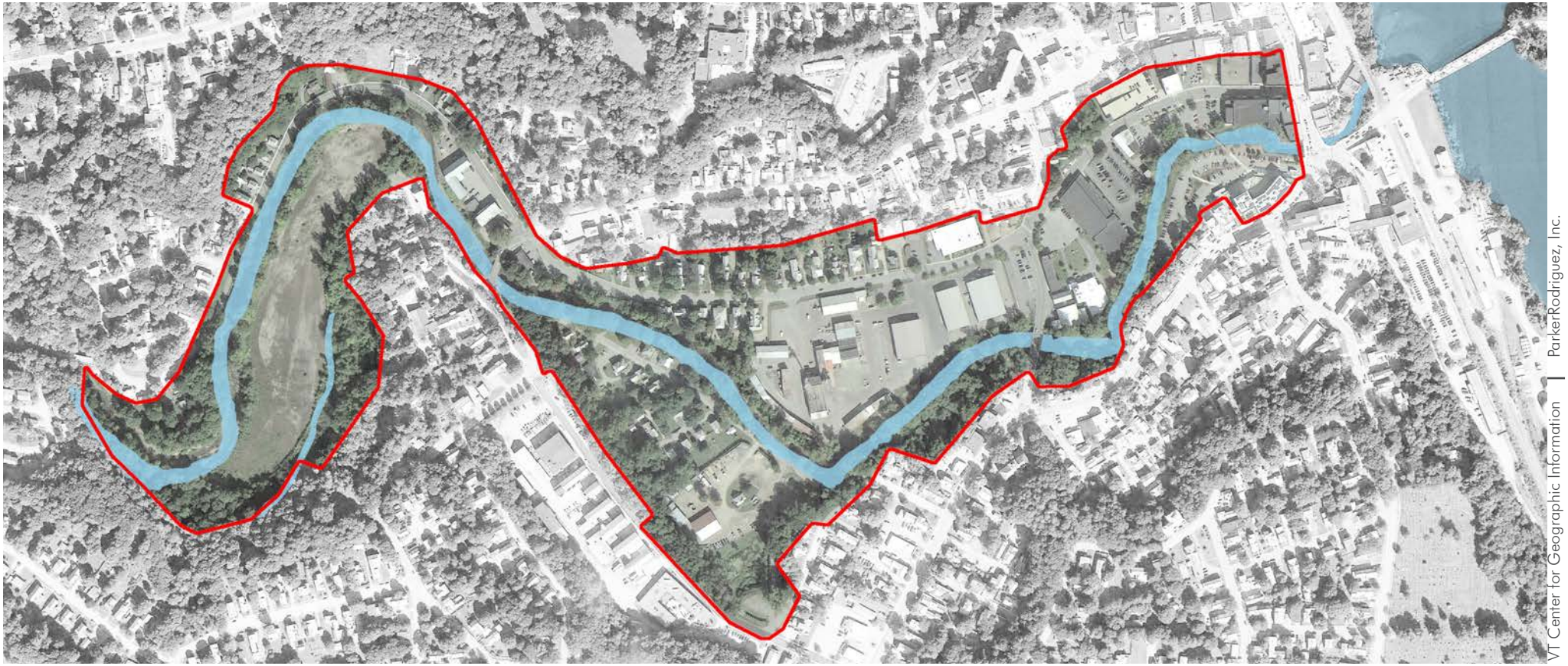


FIGURE 1. Overall site aerial

The study area encompasses the portion of the lower Whetstone Brook corridor that stretches one mile east from the West Street Bridge to Main Street and is within walking distance of downtown. The study area extends on both sides of the brook to the upland edge of the parcel boundary or to the boundary of the Special Flood Hazard Area.

Many of the properties in the lower Whetstone Brook corridor are located in the National Flood Insurance Program's (NFIP) Special Flood Hazard Area (SFHA). The low-lying structures and public infrastructure have been flooded in the past, most recently during Tropical Storm Irene in 2011.

Water quality in the Whetstone Brook is impaired with bacteria, and local and regional partners are taking action to control high levels of bacteria in the brook.

The current regulatory framework for minimizing flood hazards (through the National Flood Insurance Program) has been mapped onto a pre-existing, historic built form. High proportions of impervious surfaces in addition to adjacent steep slopes minimize rainwater infiltration near the brook and contribute to potential flood risk.

TOPOGRAPHY

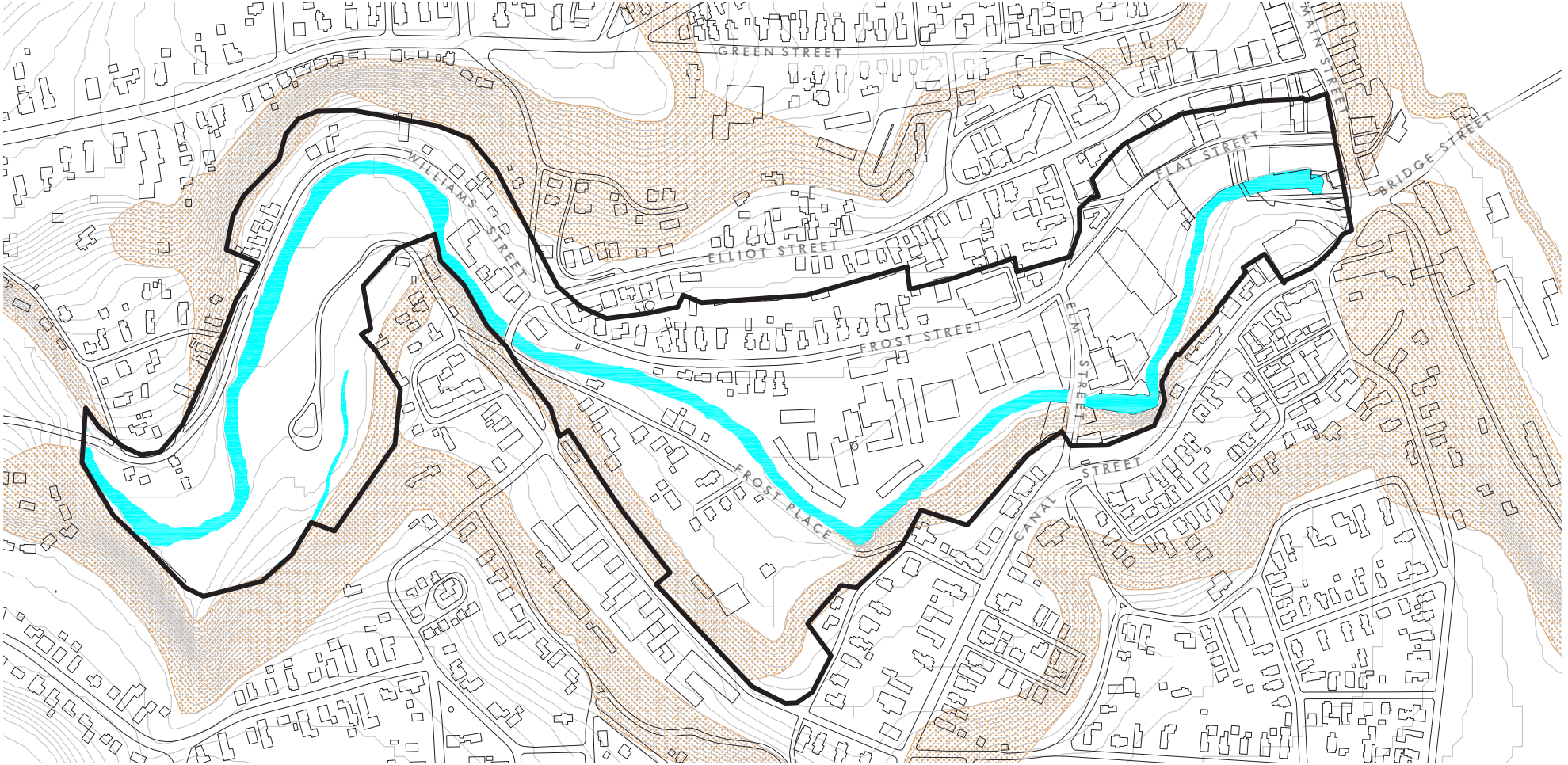


FIGURE 2. Topography showing contours at 5 feet intervals

LEGEND

Steep slopes (>15%)

Steep slopes are characteristic along the banks of the Whetstone Brook and have influenced vegetation and development patterns. Low lying areas within the flood plain provide access to the brook and shaped historic development patterns.

FLOOD PLAIN

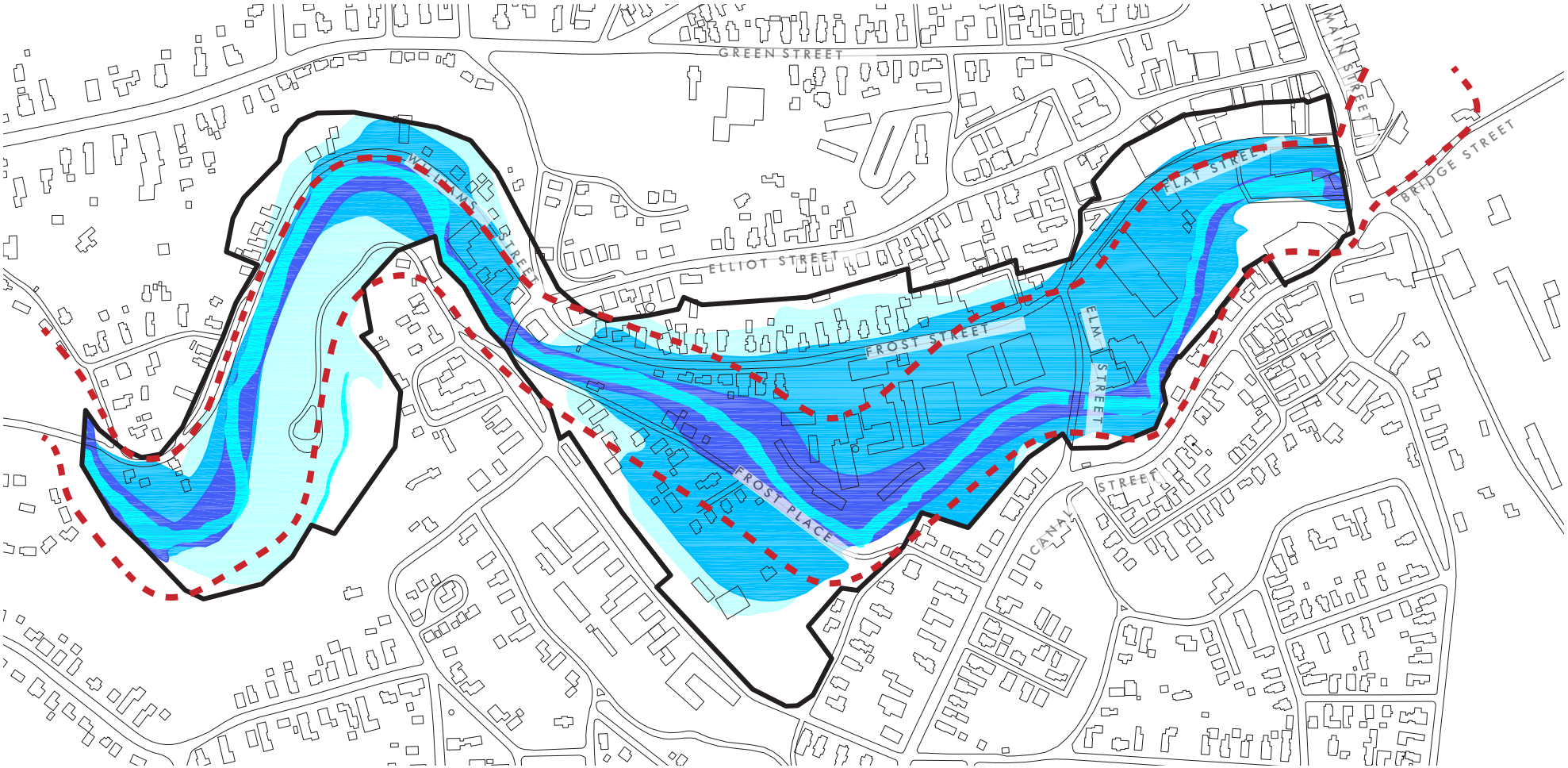


FIGURE 3. Hydrology

LEGEND

- Floodway
- 100-year flood plain
- 500-year flood plain
- River corridor

Many of the residential, light industrial, and commercial properties along this stretch of the Whetstone Brook lie within the 100 year flood plain. In 500-year flood events, the adjacent residential areas would also be impacted.

WETLANDS AND VEGETATION

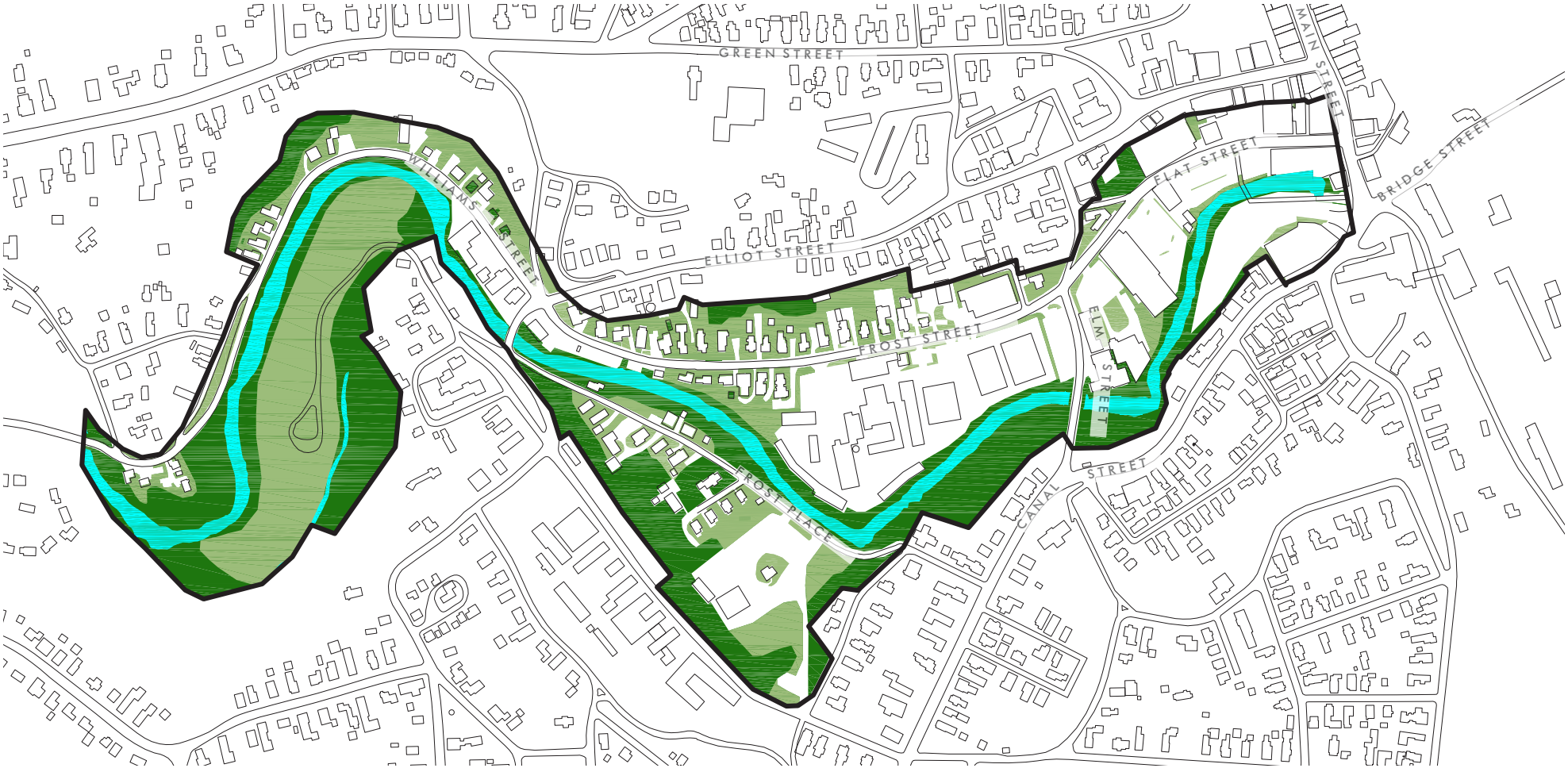


FIGURE 4. Vegetation

LEGEND

- Forest and tree cover
- Permeable surface

Long and contiguous areas of the riparian corridor are characterized by mature deciduous trees. The tree cover largely corresponds to locations of public land and slopes too steep for development. This vegetation helps to slow runoff and minimize erosion. No wetlands exist within the project area.

SOILS

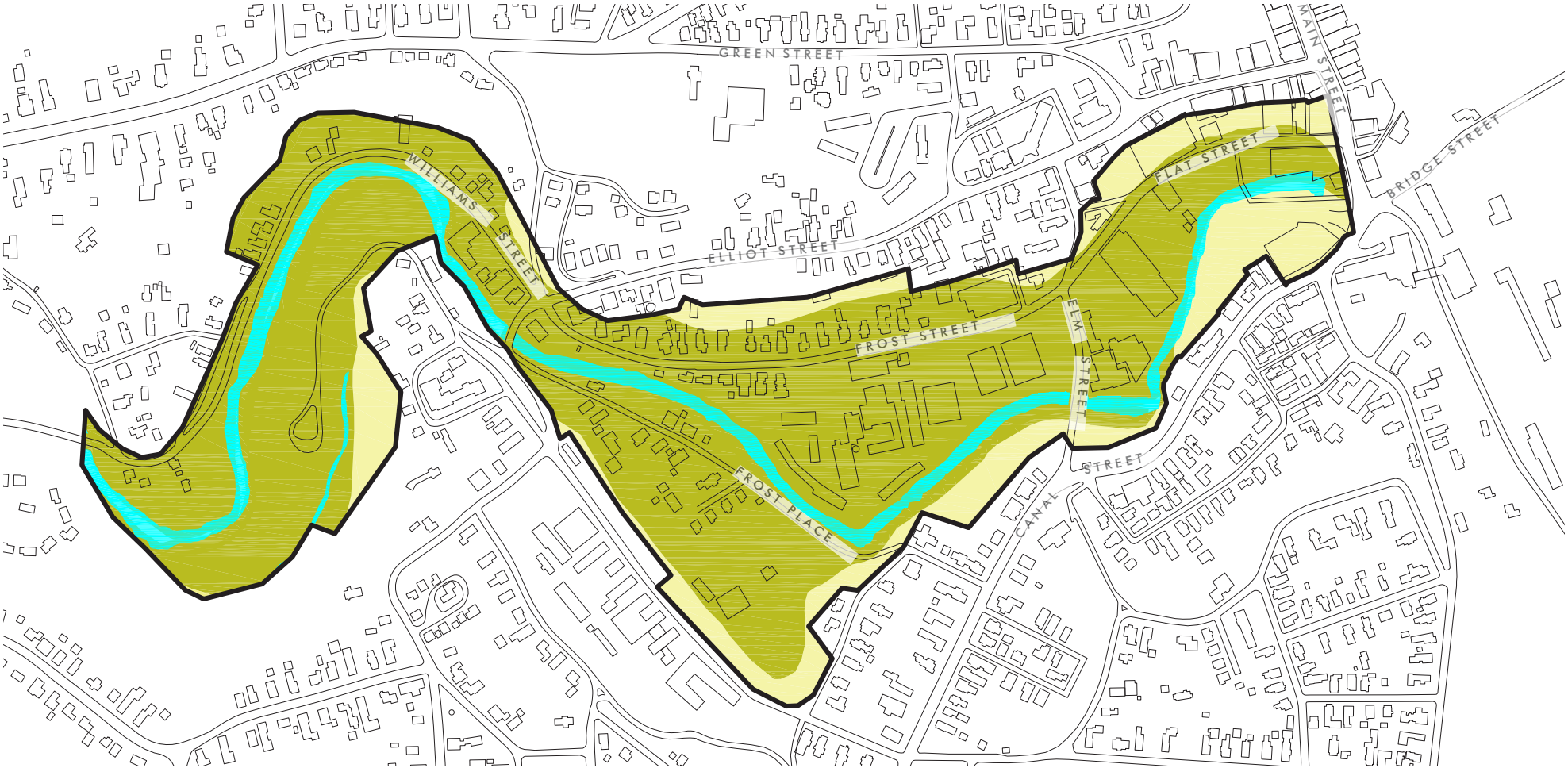


FIGURE 5. Soils

LEGEND

- Quonset & Warwick soil (25-70% slope)
- Podunk fine sandy loam (shallow slope)

Native soils underlying the study area are well suited for infiltration. Opportunities exist to increase infiltration by incorporating stormwater control strategies into public lands, along roadways, and in new development to improve water quality in the brook.

LAND USE

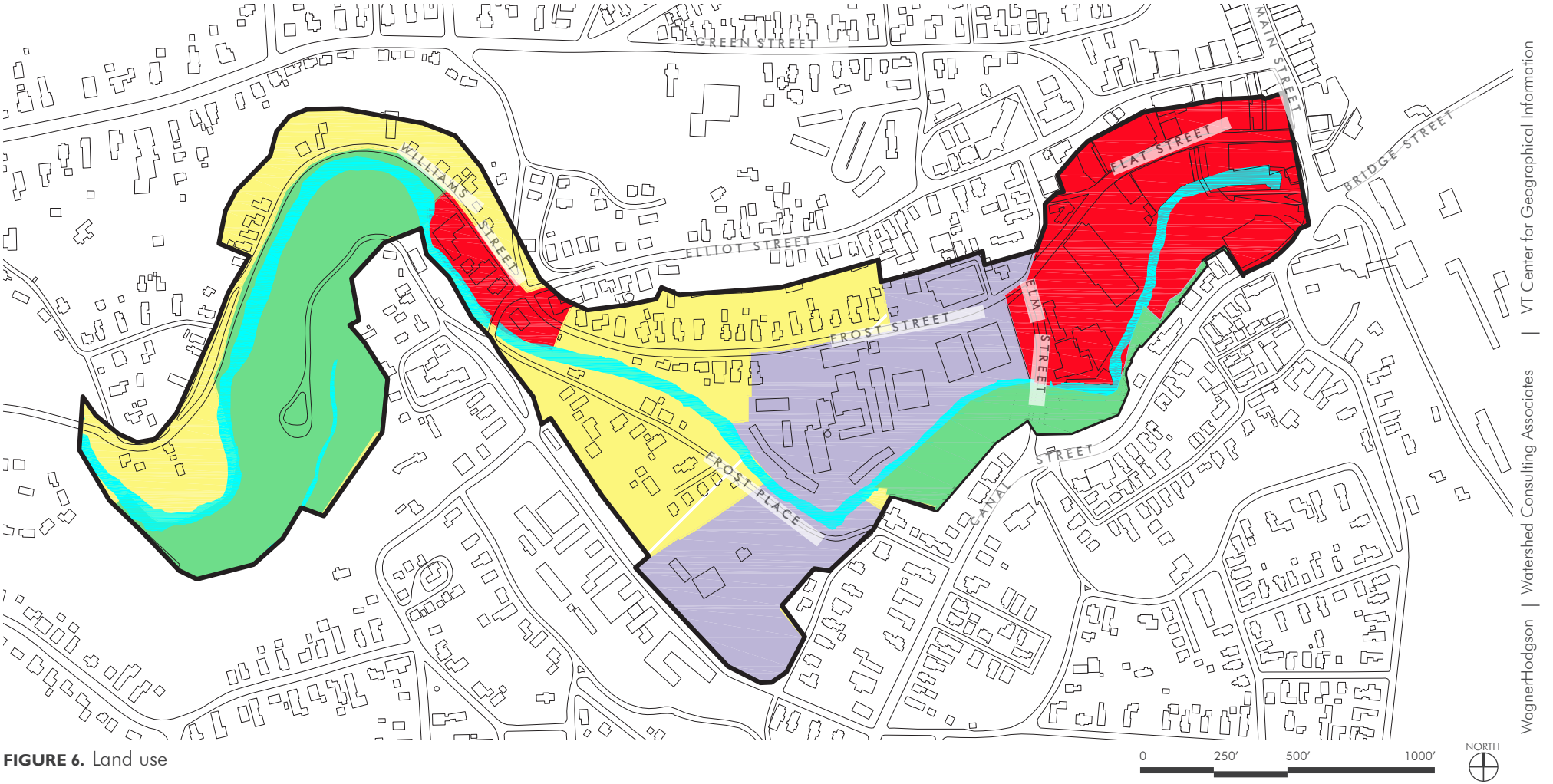


FIGURE 6. Land use

LEGEND

- Commercial
- Industrial
- Residential
- Undeveloped land

Land use within the study area quickly transitions from a filled flood plain to neighborhoods, mixed use, and urban development.

PUBLIC VS PRIVATE

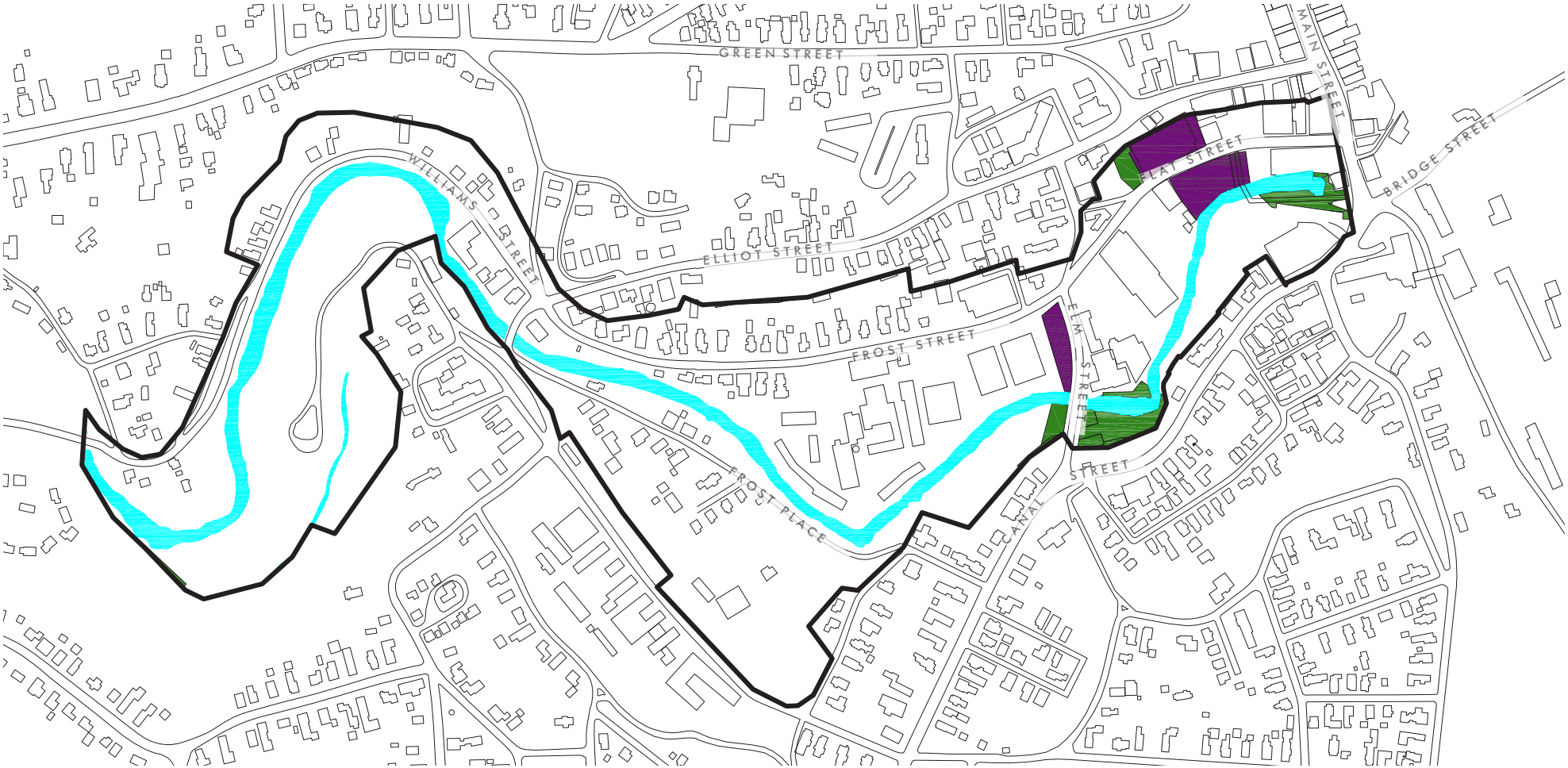


FIGURE 7. Land ownership

LEGEND

- Public land - green space
- Public land - public parking
- Private land

Parcels of public land within the brook's corridor are disconnected from each other. A large parcel of public green space near the Elm Street bridge is not accessible by pedestrians or bicyclists.

ROADWAYS | BICYCLE | PEDESTRIAN

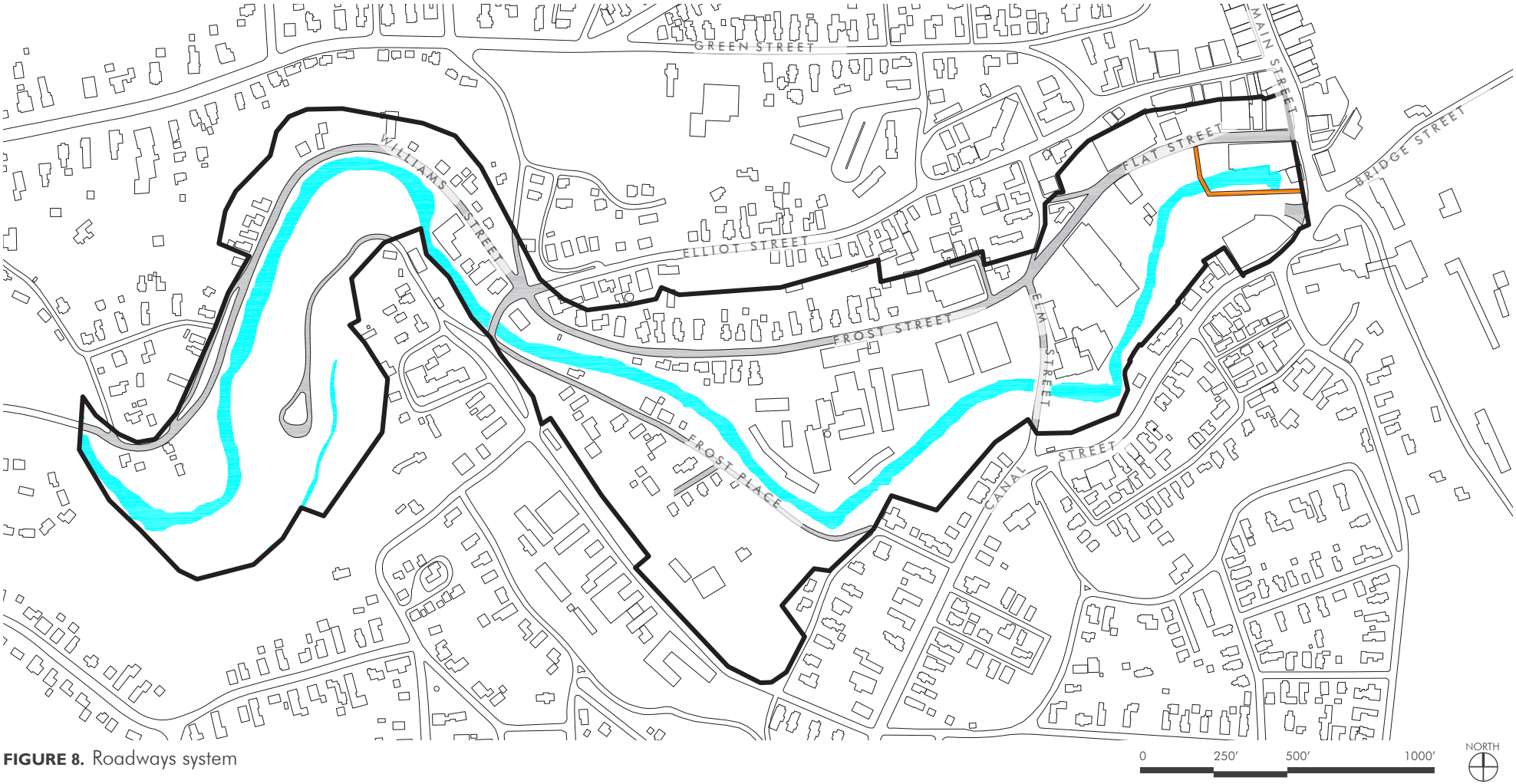


FIGURE 8. Roadways system

LEGEND

- Town roadways
- Whetstone pathway (pedestrian and bicycles only)

Pedestrians and bicyclists use the town roadway network, along with vehicles.

The existing Whetstone Pathway, the only path designated for pedestrians and bikes, connects the Preston parking lot on Flat Street with the Brattleboro Food Co-op, and crosses the Whetstone Brook to the Main Street bridge.

FIGURE GROUND STUDY

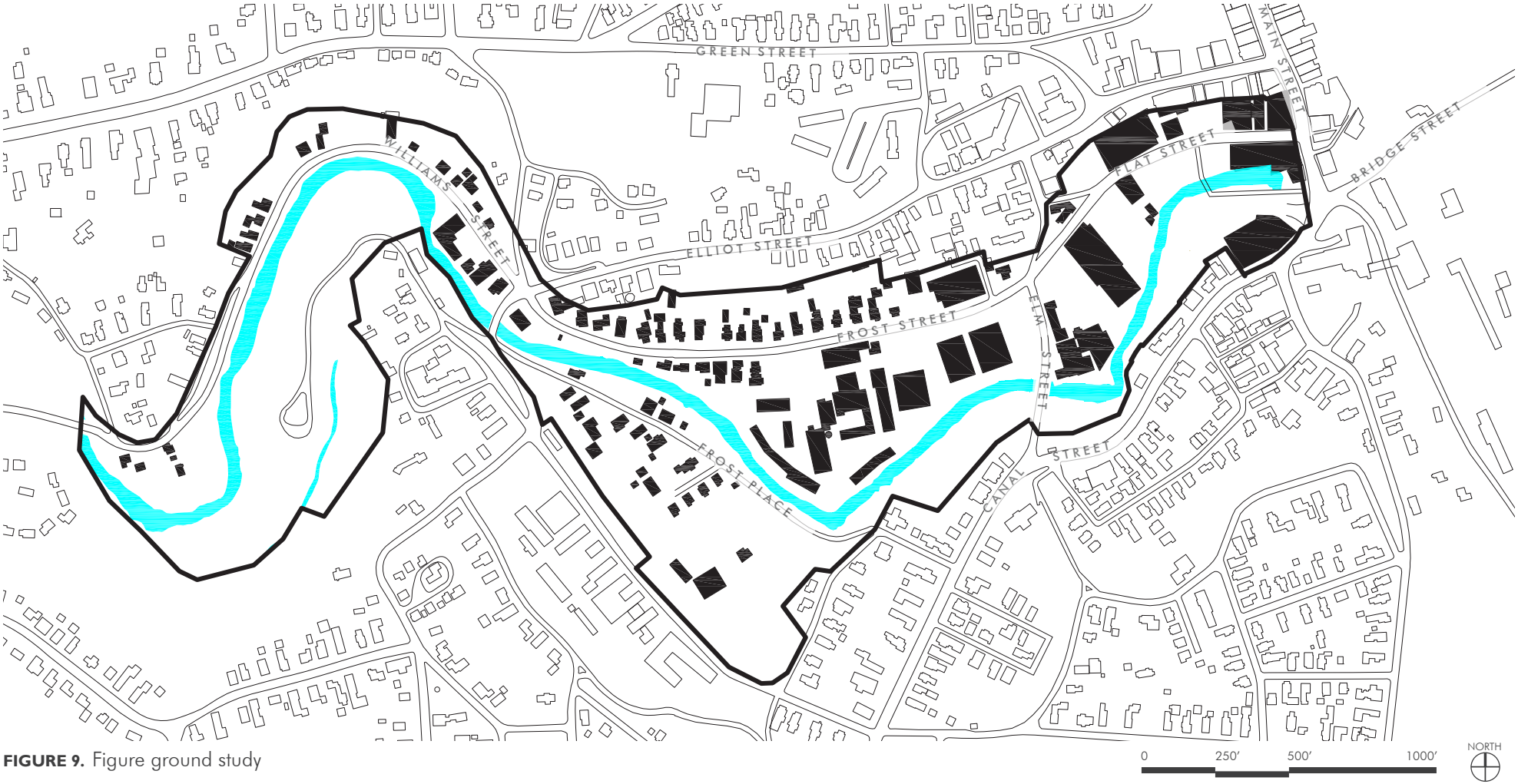


FIGURE 9. Figure ground study

LEGEND

Building footprints

Moving downstream along Whetstone Brook, there is a change from a natural riparian corridor to residential neighborhoods that transition quickly into larger light industrial and commercial scale buildings near downtown.

IMPERVIOUS SURFACE

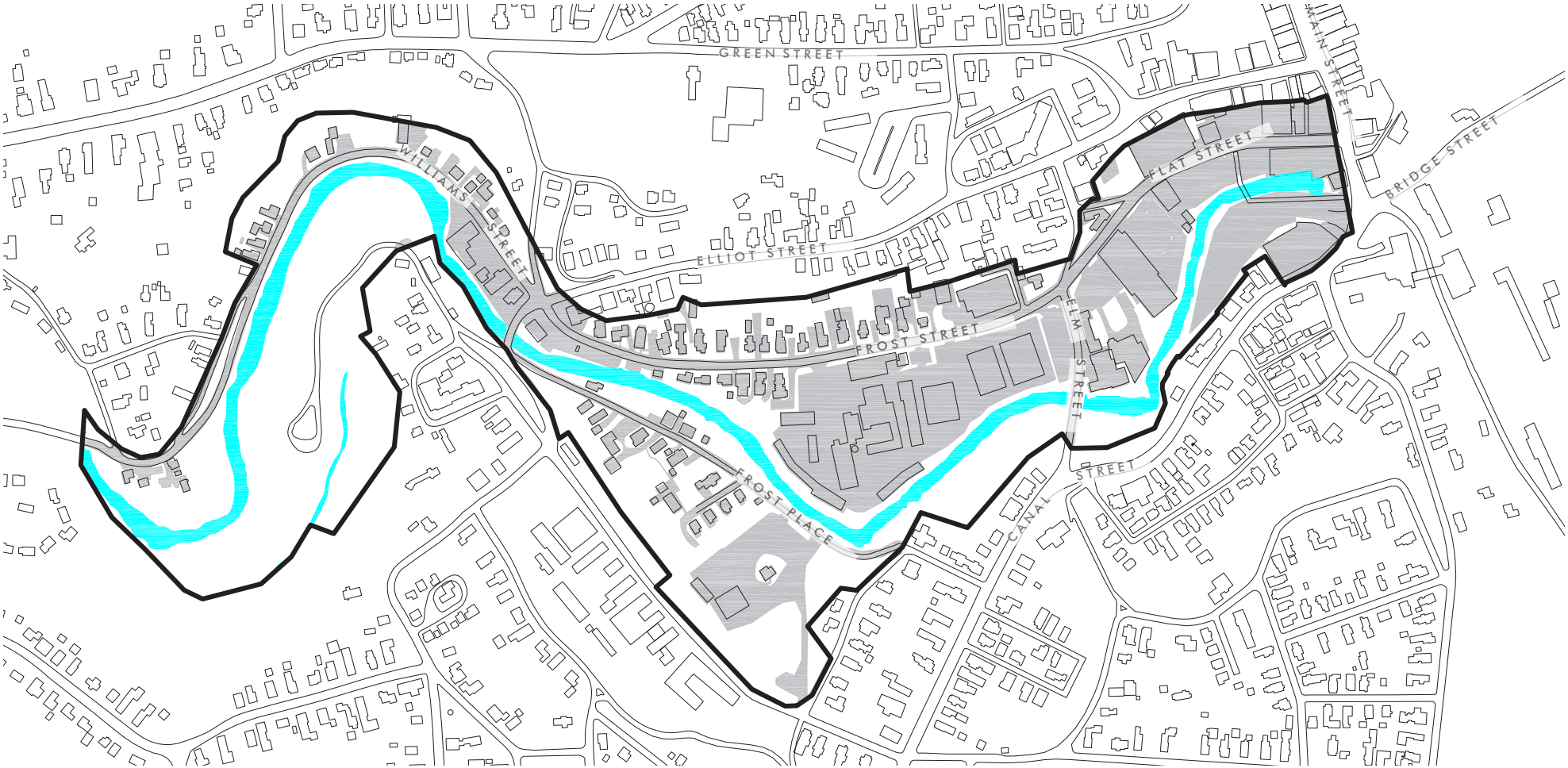


FIGURE 10. Impervious surface

LEGEND

Impervious surfaces

There is a significant increase in impervious surfaces (e.g., rooftops, driveways, and roads) from the west to the east toward the outlet of Whetstone Brook into the Connecticut River. Because stormwater can't sink into the ground, these impervious surfaces exacerbate the flooding potential in downtown Brattleboro during storm events.

STORMWATER SYSTEM | SANITARY

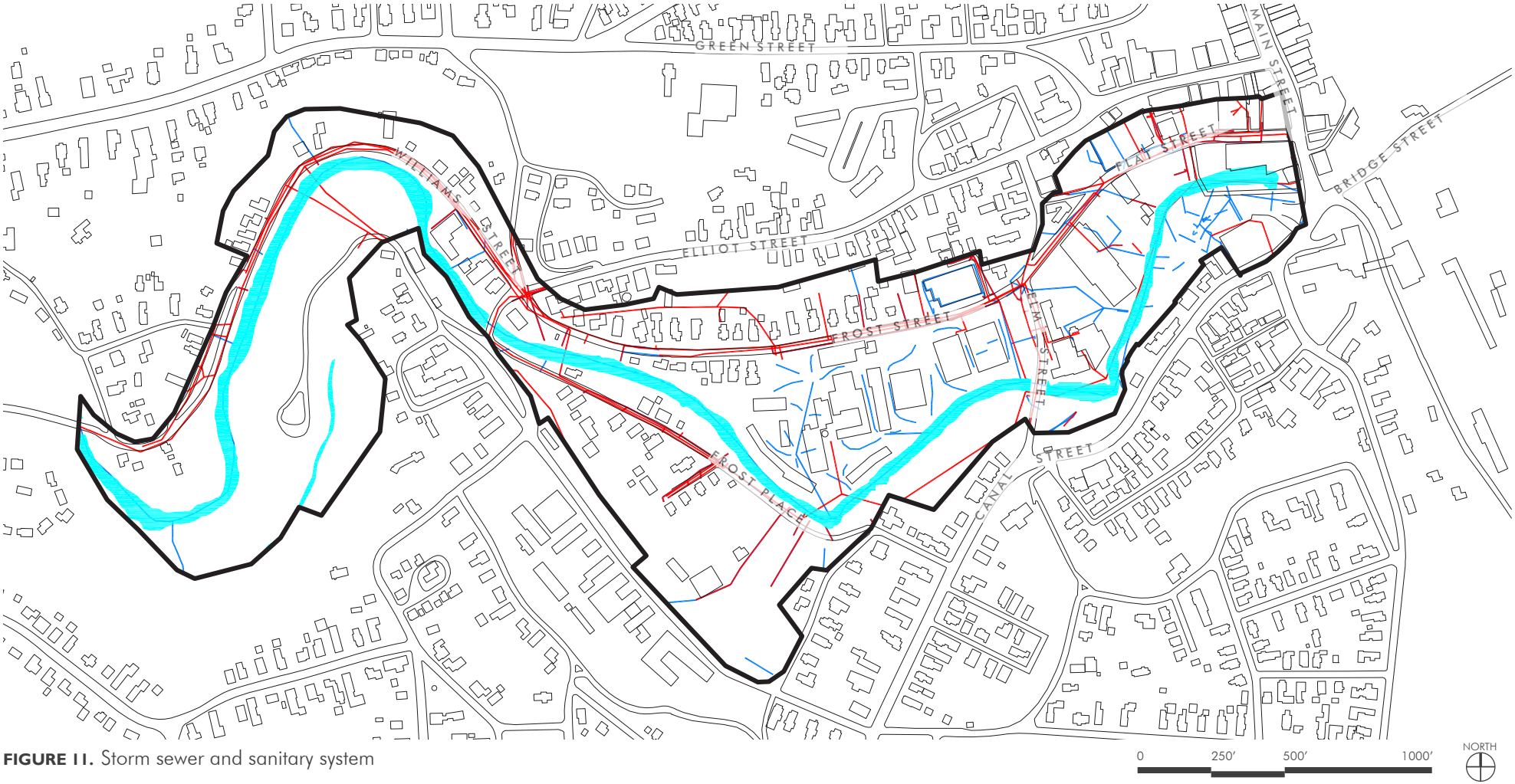


FIGURE 11. Storm sewer and sanitary system

LEGEND

- Storm sewer
- Sanitary sewer

Most of the pipes and other infrastructure that convey either stormwater or sewage within the study area are located in the area that is inundated in a 100 year storm event, and some are vulnerable to damage during storms. In addition, many stormwater outfalls discharge directly to the Whetstone Brook.

SITE SYNTHESIS

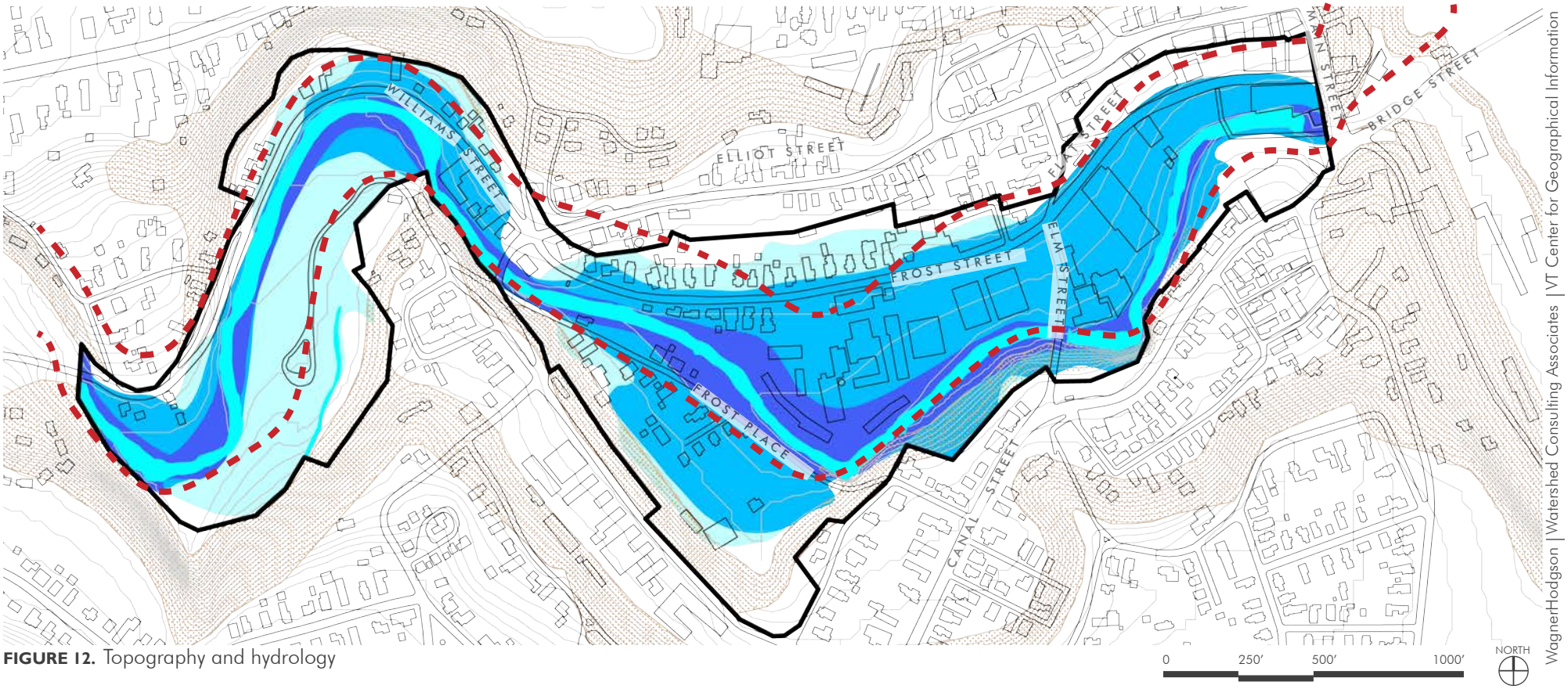


FIGURE 12. Topography and hydrology

The vast majority of the study area is within the Special Flood Hazard Area (SFHA), especially approaching the brook's lower reaches near downtown. The SFHA, also known as the 100 year flood plain, is defined as the area with a 1% chance of flooding in any given year. High proportions of impervious surfaces, such as pavement and rooftops, in addition to adjacent steep slopes minimize rainwater infiltration near the brook and contribute to its flood potential. Parcels controlled by Vermont Act 250 land use permits are additionally reviewed under Vermont Department of Environmental Conservation (VT DEC) River Corridor rules. The "no adverse impact" standard applies to (re)development of subject parcels and is in addition to locally enforced Special Flood Hazard Area requirements.

River corridors represent the area around a river most likely susceptible to fluvial erosion, channel evolution, and down-valley meander migration. VT DEC implements the river corridor concept to manage Vermont's rivers towards equilibrium conditions.

The steep slope designation is based on local land use regulation.

URBAN CHANNEL

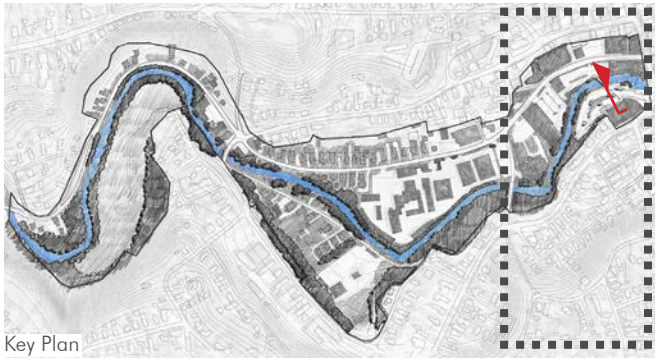


FIGURE 13. The channelized portion of Whetstone Brook between the Brattleboro Co-op and the Preston parking lot

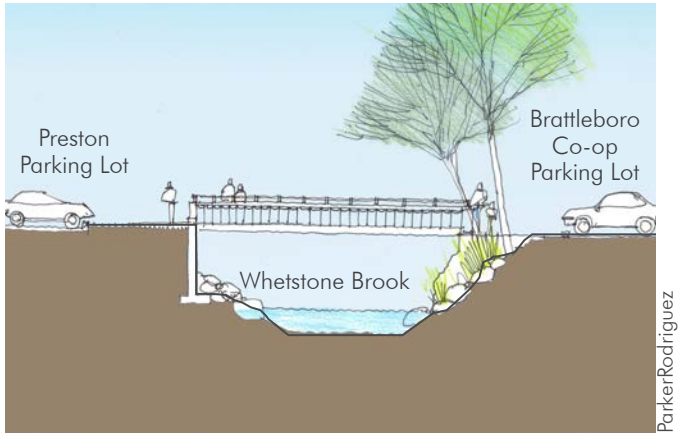


FIGURE 14. Existing section enlargement of channelized brook

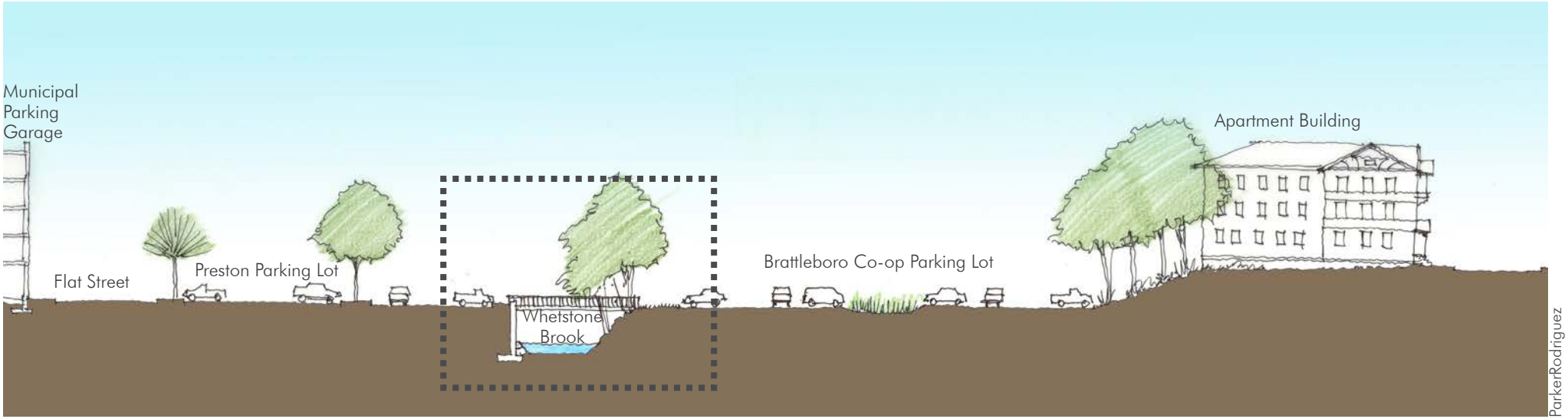


FIGURE 15. Existing cross-section

This area is defined by the Flat Street to the north, the Brattleboro Co-op and wooded hillsides to the south, Main Street to the east, and the Elm Street bridge to the west.

This portion of the site is located in Brattleboro's downtown urban core where the natural brook has been altered and contained by concrete walls.

INTERMITTENT ARMORING

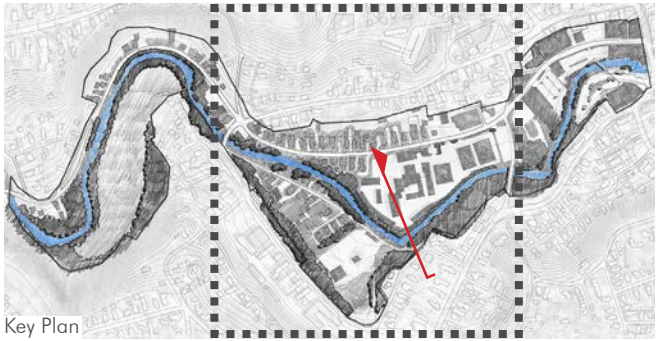


FIGURE 16. Armored steep embankment of Whetstone Brook

FIGURE 17. Existing section enlargement

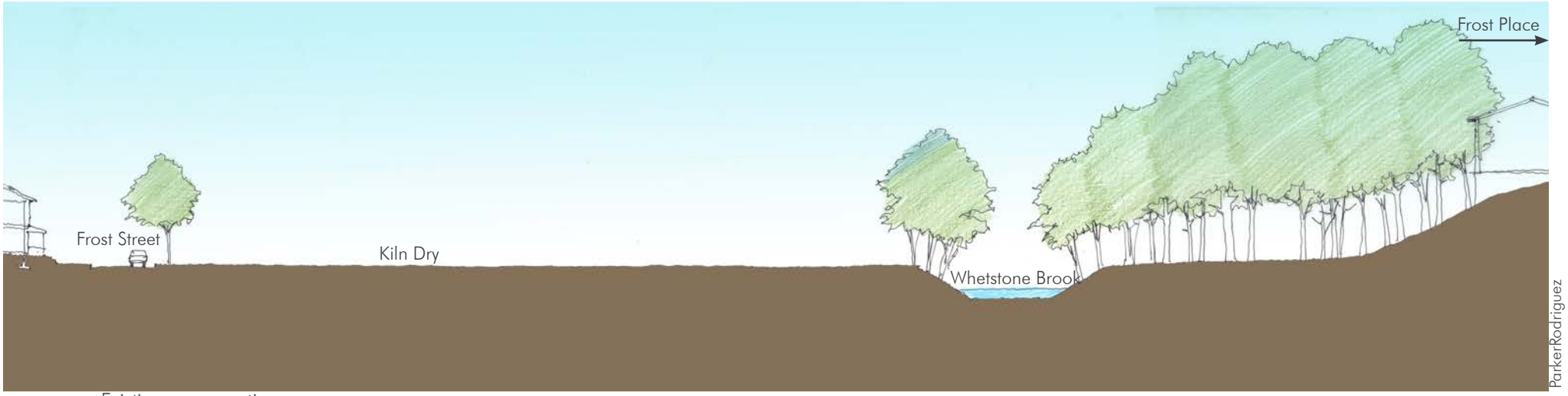


FIGURE 18. Existing cross-section

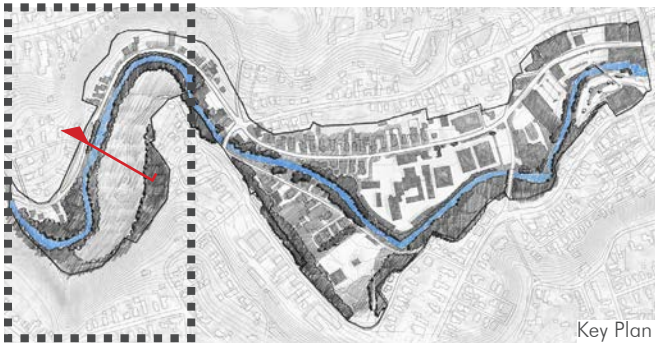
This area is defined by Frost Street to the north, the Elm Street bridge to the east, Frost Place to the south, and Elliot Street bridge to the west.

This portion of the brook is characterized by rip rap armoring in combination with concrete walls to hold the steep embankments and prevent erosion, especially on the south side of the brook.

The brook makes an unusually sharp bend in this portion of the study area as it moves downstream, towards the urban core.

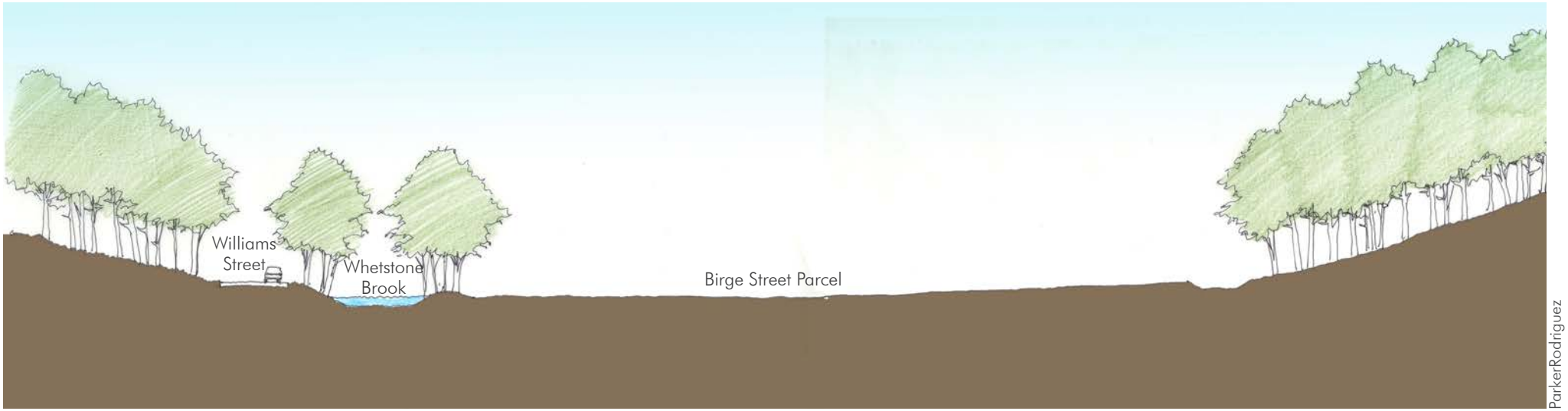
The site is dominated by the extensive impervious surface of the existing Kiln Dry site, immediately adjacent to the brook.

FLOODPLAIN



WagnerHodgson

FIGURE 19. Flat, undeveloped flood plain at Birge Street parcel



ParkerRodriguez

FIGURE 20. Existing cross-section

This area, called the Birge Street parcel, is defined by Williams Street to the north and west, and steep wooded hillsides to the east and south.

The Whetstone Brook formed a new channel when an upstream berm was breached during Tropical Storm Irene and the Birge Street parcel was flooded.

This portion of the study area is characterized by flat, undeveloped flood plain that presents an opportunity for additional flood water and sediment storage thus dissipating the erosive energy from the brook during high water flows, and minimizing downstream flooding.

PROPOSED OVERALL SITE PLAN

NATURAL ZONE

flat open floodplain at the foothill of a steeply wooded hillside

NEIGHBORHOOD ZONE

steep embankment on one side, with intermittent rip-rap and vegetation

URBAN ZONE

predominantly channelized brook with concrete retaining walls, rip-rap embankments, and historic foundations

FIGURE 21. Proposed plan

The plan is divided in to three zones based on the existing stream typology for each area.

This plan for the lower Whetstone Brook corridor identifies opportunities to protect existing infrastructure downtown and along the brook, reduces the potential for damage from future flooding events, and protects water quality by integrating green infrastructure into the public right-of-way and proposed development near the brook. Concurrently, this plan shows opportunities for infill development that creates a more cohesive, walkable community, and promotes neighborhood connections and recreational opportunities between neighborhoods and downtown along the brook.

The narrative below follows the plan from east to west, moving upstream from downtown Brattleboro to neighborhoods and natural areas.

Urban Zone

The transformation of the Preston municipal parking lot into a public park would create a central green space that anchors downtown Brattleboro. It is directly across the Whetstone Path pedestrian bridge from the Brattleboro Food Co-op and opposite the Transportation Center. It would become the heart of existing and proposed recreational connections, promote access to the brook, and provide treatment and storage for stormwater and flood waters. An extended Whetstone Path running through the new Preston Park and west along the brook would connect downtown to the New England Youth Theater (NEYT) and adjacent neighborhoods upstream. A second pedestrian bridge could connect the western edge of the Co-op parking area directly to the NEYT. The Whetstone Path could extend west along both sides of the brook, connecting to the existing pedestrian bridge near the Co-op to create a neighborhood path network.

Existing rip rap embankments, retaining walls, and historic foundations that constrict flow could be softened by widening areas of the existing riverbank. Both at the proposed Preston Park and east of the NEYT, a series of proposed stone terraces designed to withstand flooding pull back the brook's banks, which would help to protect the existing floodway from erosion and scour while creating outdoor performance and flexible public space. Intermittent planted areas between the terraces would increase infiltration and buffer the brook's storm event velocity and flood water volume. Beneath the new Preston Park, subsurface cisterns could capture stormwater and flood water for temporary storage and treatment. Removal or transformation of rundown existing structures near the brook would reduce encroachment in the flood plain and provide minor improvement to flood storage. Such sensitive redevelopment will improve pathway connections, and create opportunities for retail or restaurant space to face the brook along the northern streambank.

Neighborhood Zone

The designs for this zone are intended to better connect residential neighborhoods with the downtown and with the brook. They are intended to allow for flood-resilient residential development that complies with local and state regulations. Replacing the existing public parking lot at the corner of Frost and Elm Streets with mixed use development would provide first floor retail and upper level residential units. Across Elm Street from the NEYT, the mixed use development could provide a retail anchor to this busy intersection and create a transition from downtown to adjacent neighborhoods in both use and scale. Townhomes adjacent to the mixed use building, developed on the large (currently active) parcel would wrap around a central shared parking area to create desirable units that front public green space or the street. To the west, groups of 2-3 unit townhome buildings could be oriented perpendicular to the brook, promoting neighborhood pedestrian and bicycle access to the extended Whetstone Path. A seamless link between downtown and the existing, adjacent, pre-war residential neighborhoods could be created by transitioning from townhomes into single family homes.

The extended Whetstone Path could pass under the Elm Street bridge and along the brook's winding stone rip rap and vegetated slopes, creating a walkable connection to downtown from proposed infill and existing neighborhoods. Park-like pedestrian corridors through the townhome area and a green boulevard with a play area between new single family homes would create numerous access points to the brook, improve stormwater infiltration, and provide increased flood water storage area during heavy rain events. A vegetated swale would provide an expanded fluvial channel for increased flood storage capacity, and create recreational green space and habitat for riparian species. Pedestrian bridges could cross to the south side of the brook, linking to the Frost Place neighborhood and back east along the brook to the Co-op. These pedestrian bridges could be constructed with a 'break away' feature. Tethered on one end, this break away feature would allow the bridge to swing harmlessly out of the way during flood events, so that it does not obstruct flood waters or debris, and can be reattached after the flood is over. The Frost Place neighborhood would include additional single family housing, a stormwater treatment area, and pedestrian connections up to Birge and Canal Streets.

Natural Zone

Farthest upstream within the study area, the Whetstone Brook enters a broad open flood plain just east of the Williams Street bridge, surrounded by steeply wooded hillsides, before meandering through residential areas toward downtown. At the edge of the undeveloped open flood plain, a gravel wetland could be constructed to treat stormwater from existing uphill development, and the open area designed with a network of recreational trails and planted meadows that would help to slow and store water from storm events. A pedestrian bridge crossing the brook, connecting this recreational area to Williams Street and upstream, could be built upon existing former rail bridge footings, and be designed with a break away feature, as described above.

PLAN


Key Plan

The Whetstone Brook is largely channelized in the urban zone, its boundary defined either by tall retaining walls, actual building foundations or stone rip rap embankments. In addition, the cross section of the brook gets narrower as it approaches Main Street. This portion of the brook constricts flow and changes fluvial dynamics during heavy rain due to these characteristics. Buildings and paved parking areas occupy the majority of the brook's edges, but strategic softening and widening of the edges can help to buffer velocity and volume of storm events and provide recreational opportunities accessible from adjacent neighborhoods and public spaces.

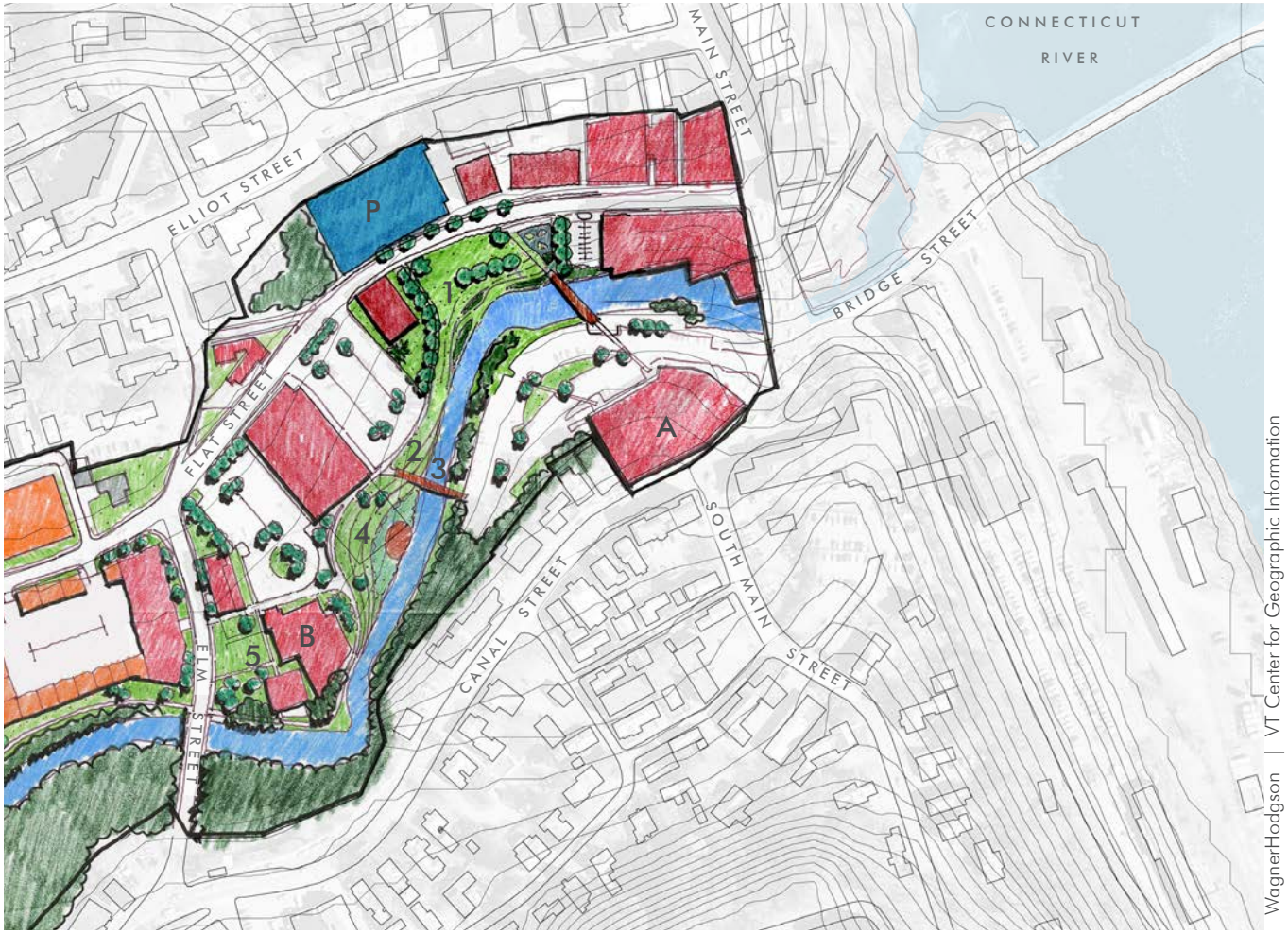


FIGURE 22. Proposed plan enlargement

EXISTING ELEMENTS

- A Brattleboro Co-op
- B New England Youth Theater
- P Municipal Transportation Center

PROPOSED ELEMENTS

1. Preston Park
2. Extended Whetstone Pathway
3. Future pedestrian bridge
4. Terraced outdoor seating
5. NEYT outdoor amphitheater

SECTIONS

The existing conditions show the channelized portion of the Whetstone Brook. The impervious surface of the Preston parking lot contributes runoff to the brook during storm events.

The proposed design concepts suggest converting the parking lot into a park, and accommodating the displaced parking in the adjacent municipal parking garage and elsewhere. This design would not only eliminate large amounts of impervious surface, but would also allow for more water volume storage during large storm events through terraced flood walls. The flood walls would provide recreational opportunities for the community during dry weather.

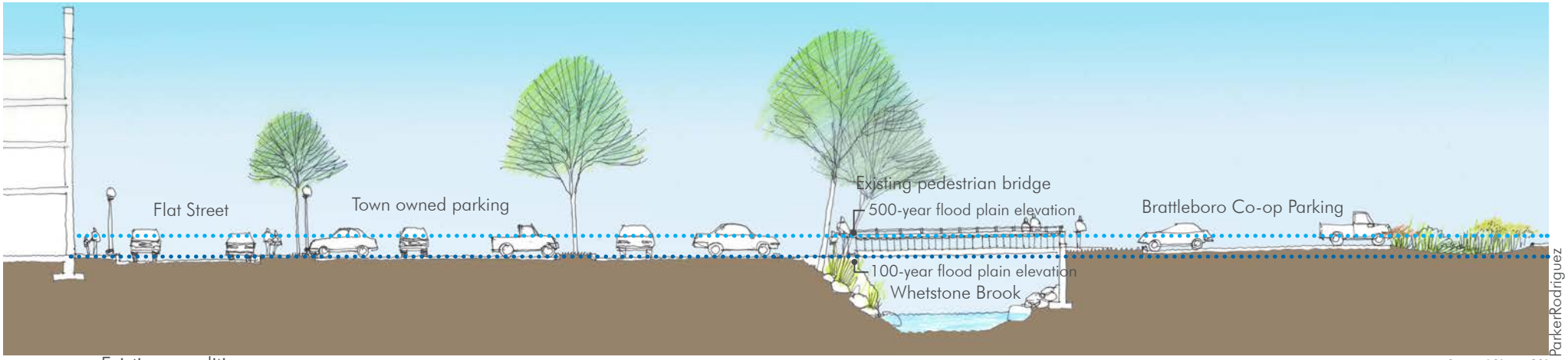


FIGURE 23. Existing conditions

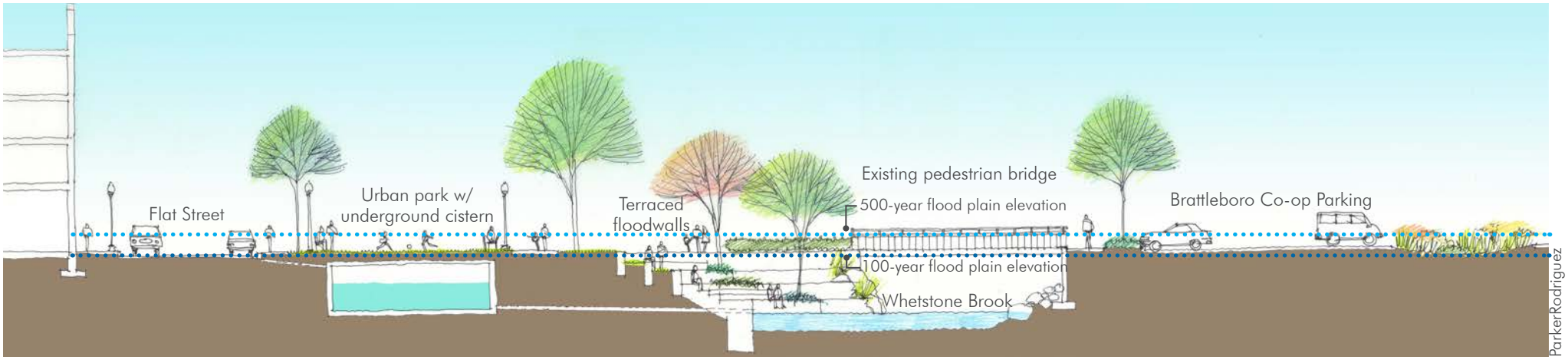


FIGURE 24. Proposed conditions

ISOMETRIC

Currently, the Preston parking lot extends to the edge of the brook, which leads to untreated stormwater entering the brook. The current land use also limits the outdoor recreational opportunities and community public use.

The proposed terraced seating allows for an amenity area with flexible outdoor space. The terraced area could be used for outdoor movies, and the open lawn could become the area for neighborhood games, picnicking, community gatherings, and fairs within the heart of Brattleboro, while providing access to the brook (see the Guadalupe River Park case study in Appendix B). This design responds to community interests expressed during the charrette, especially the need for space for special events.

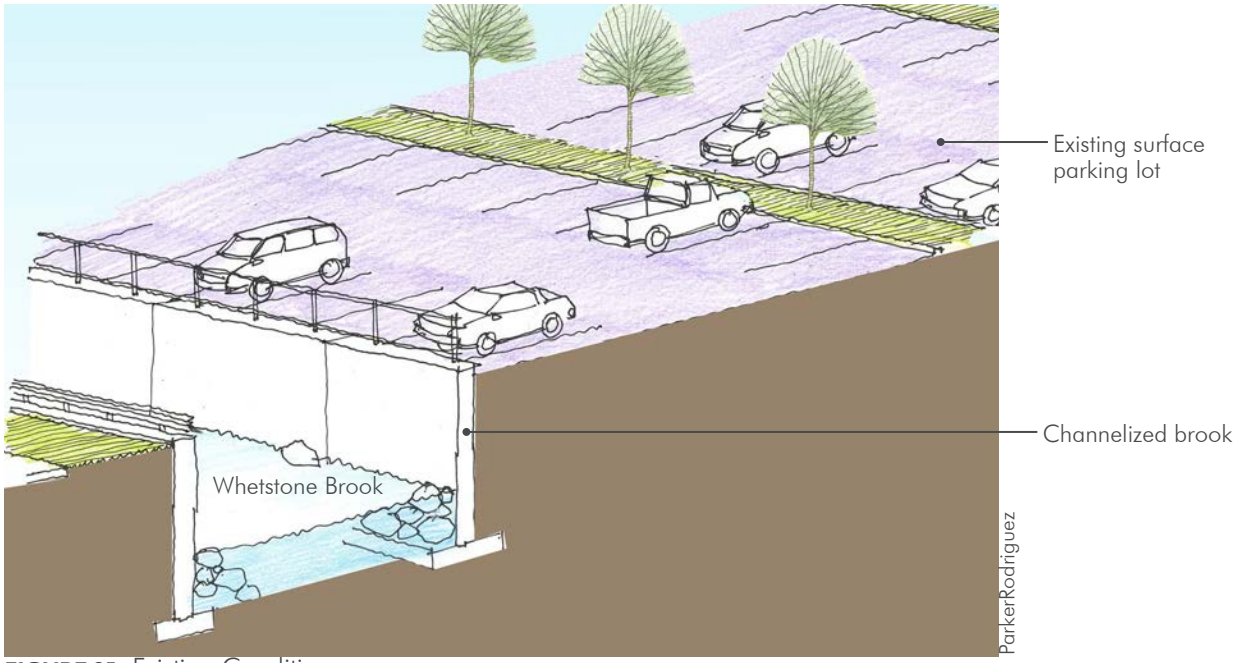


FIGURE 25. Existing Conditions

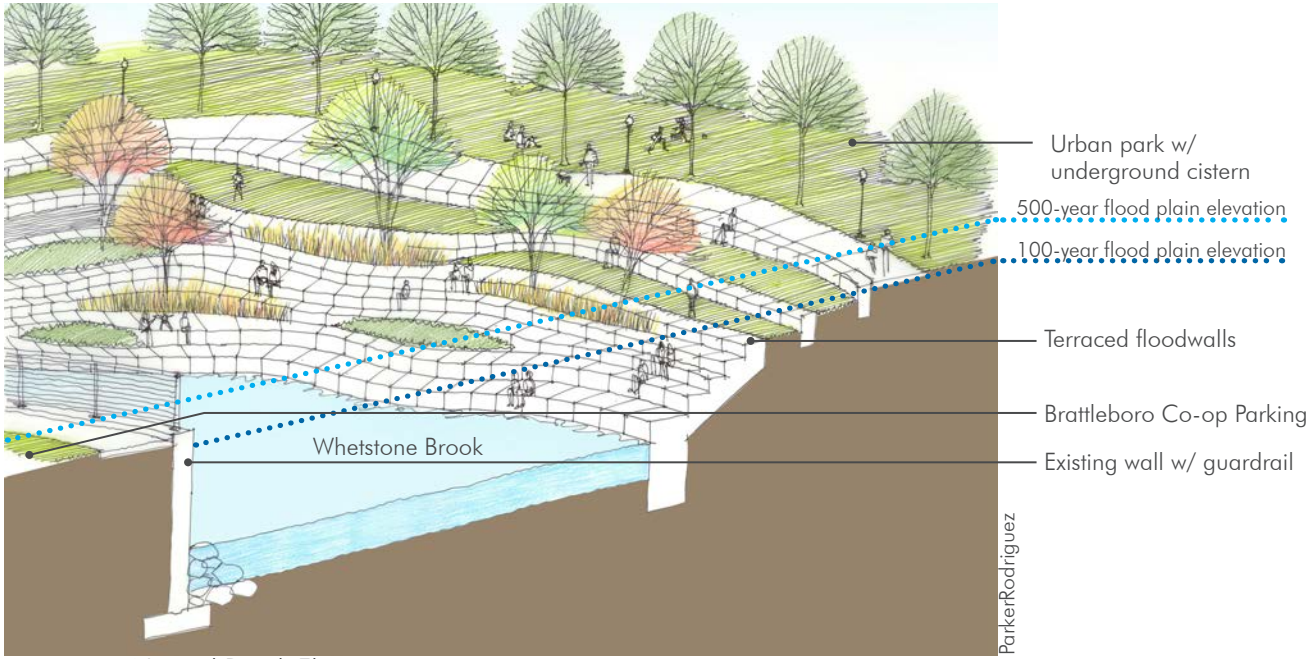


FIGURE 26. Normal Brook Elevation

ISOMETRIC


Key Plan

This stretch of the brook is channelized, thus limiting the water volume capacity during storm events.

The stormwater runoff from Preston parking lot contributes to the increased water volume during storm events.

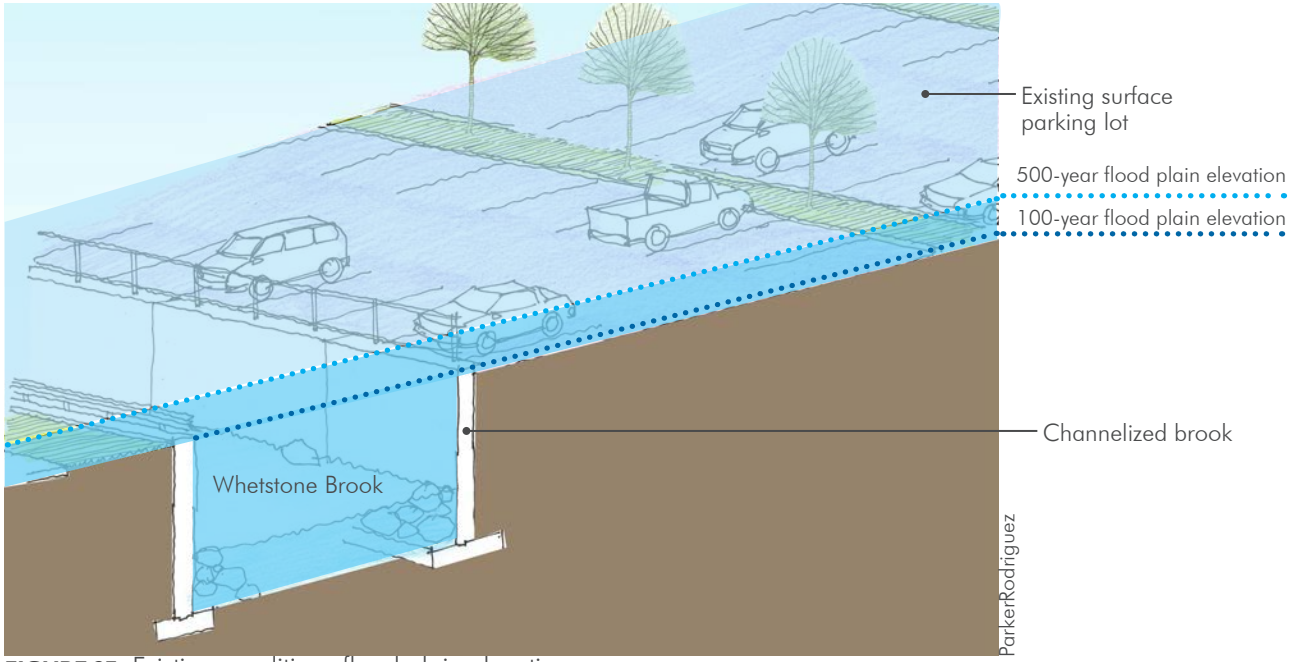


FIGURE 27. Existing conditions flood plain elevation

The terraced embankment would allow for additional flood volume storage during storm events. The planting within the floodwall terraces would be suited to withstand inundation and would improve the water quality of the brook by providing some level of infiltration.

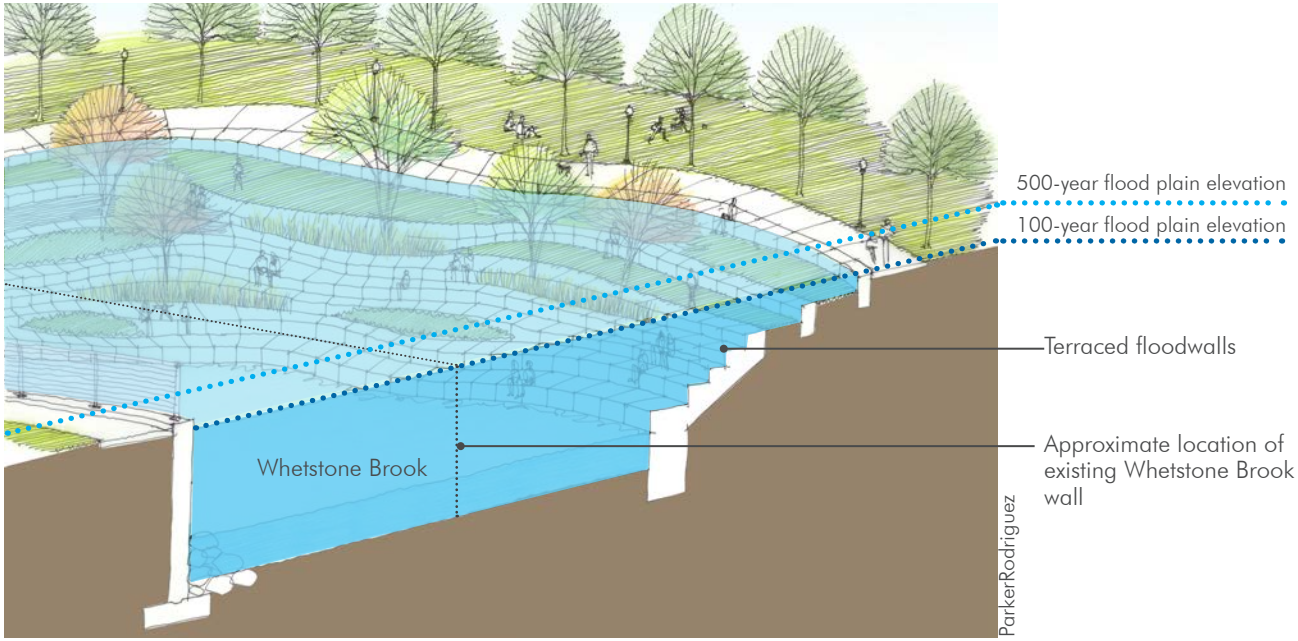


FIGURE 28. Proposed conditions flood plain elevation

PERSPECTIVE


Key Plan

The impervious surface of the Preston parking lot contributes to additional water volumes during storm events.

The parking lot could be transformed into an urban park in the heart of downtown Brattleboro and allow for community events and gatherings.


ParkerRodriguez

FIGURE 29. Existing view


ParkerRodriguez

FIGURE 30. Proposed view

SECTIONS

The existing section shows the steep embankments of the brook in this segment of the study area, and the banks reinforced with rip rap. There is no public access to the Whetstone Brook, which remains hidden within the thick vegetation.

The proposed design suggests complete transformation of the space by introducing outdoor, terraced seating overlooking the brook and taking advantage of this incredible amenity. The proposed design also creates pathways on both sides of the brook that connect the neighborhoods, create recreational opportunities for walking and biking, and allow for direct interaction with the Whetstone Brook.

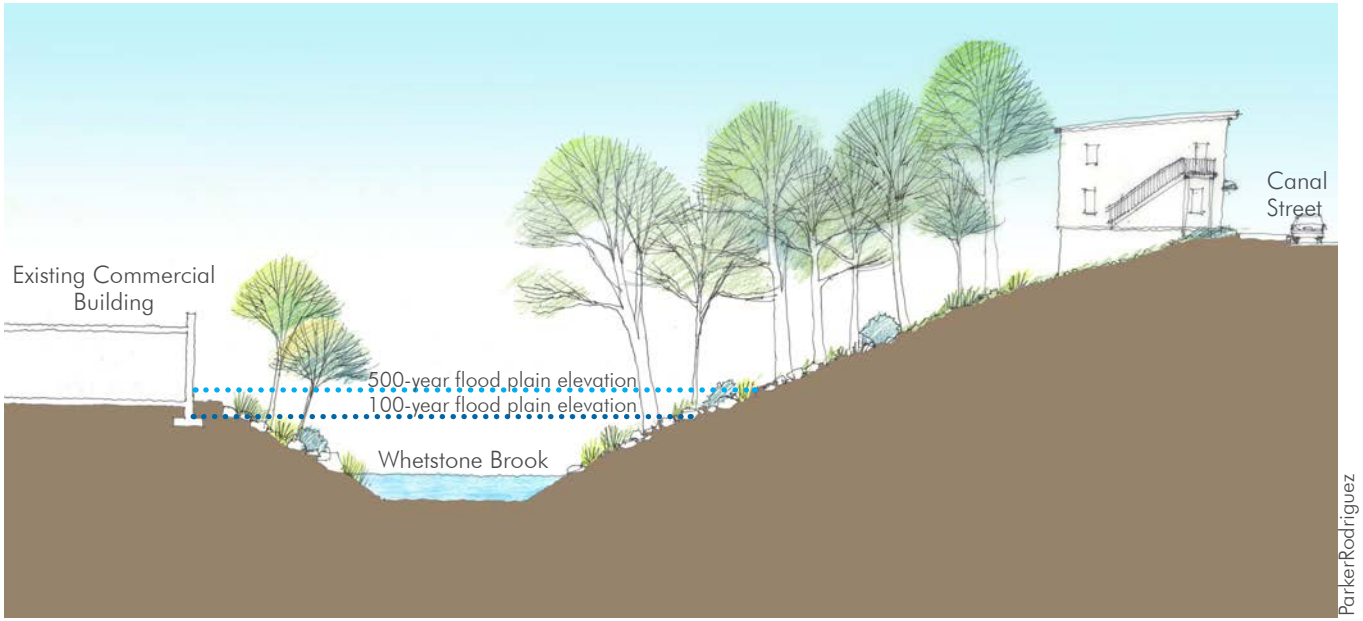


FIGURE 31. Existing conditions

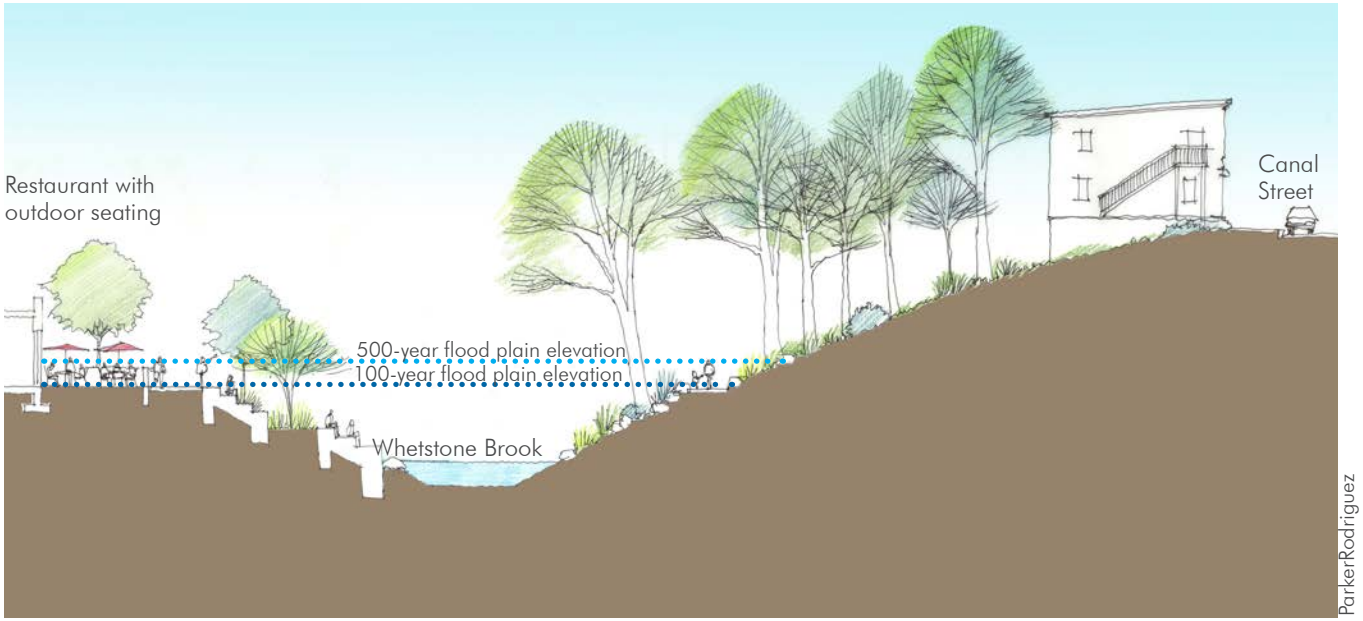


FIGURE 32. Proposed conditions

PERSPECTIVE


Key Plan

The Whetstone Brook remains hidden within the overgrown surrounding vegetation, with no formal public access.

The proposed design takes advantage of the Whetstone Brook. The design concept introduces public access to the brook for pedestrians and cyclists. The design further improves connectivity by adding a pedestrian bridge from the south to the north embankment at the New England Youth Theater (NEYT) to improve connections between the two sides of the brook and to allow for easy movement within the downtown and surrounding neighborhoods.


ParkerRodriguez

FIGURE 33. Existing view


ParkerRodriguez

FIGURE 34. Proposed view

PLAN


Key Plan

This winding section of the Whetstone Brook is bound by stone rip rap and on one side by steep vegetated slopes, and it flows between traditional pre-war residential neighborhoods and a large industrial use parcel. The proposed housing density transitions gradually between the downtown area and adjacent neighborhoods.

Proposed mixed use, townhome, and single family homes on the industrial parcel face the brook, and common green spaces provide pedestrian access to, along, and across the brook. A vegetated swale would provide an expanded fluvial channel for increased flood storage capacity, and would create recreational green space and habitat for riparian species. Pedestrian bridges could cross to the south side of the brook, linking to the Frost Place neighborhood and back east along the brook to the Co-op. These pedestrian bridges could be constructed with a 'break away' feature that would allow them to be reattached after the flood is over. The Frost Place neighborhood would include additional single family housing, a stormwater treatment area, and pedestrian connections up to Birge and Canal Streets.

FIGURE 35. Proposed plan enlargement

PROPOSED ELEMENTS

1. Mixed use development
2. Neighborhood pedestrian corridor
3. Duplex/triplex
4. Single family
5. Extended Whetstone Pathway
6. Pedestrian bridge connections
7. Vegetated swale
8. Low-water crossing
9. Stormwater pond

SECTIONS


Key Plan

The Kiln Dry industrial operation occupies a large portion of the Whetstone Brook study area. Its extensive industrial buildings and vast amounts of asphalt dominate the north embankment of the site in this area. The property bisects the single family neighborhood from the downtown urban core.

The proposed section demonstrates the transformation of the site and the introduction of a multifamily apartment building with ground floor retail and structured parking below. The residential portion above will be flood resilient with livable space above the 500 year flood plain. The below grade parking garage would be dry floodproofed. Dry floodproofing is a combination of measures that result in a structure, including the attendant utilities and equipment, being watertight with all elements substantially impermeable and with structural components having the capacity to resist flood loads. It will also be important for a developer to check in advance with the National Flood Insurance Program to ensure that their design will enable the property owner to qualify for flood insurance credits for dry floodproofing.

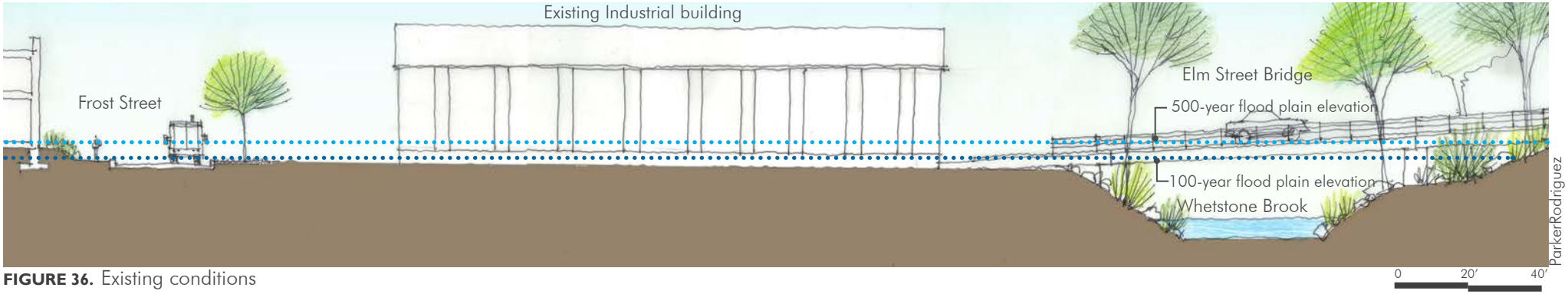


FIGURE 36. Existing conditions

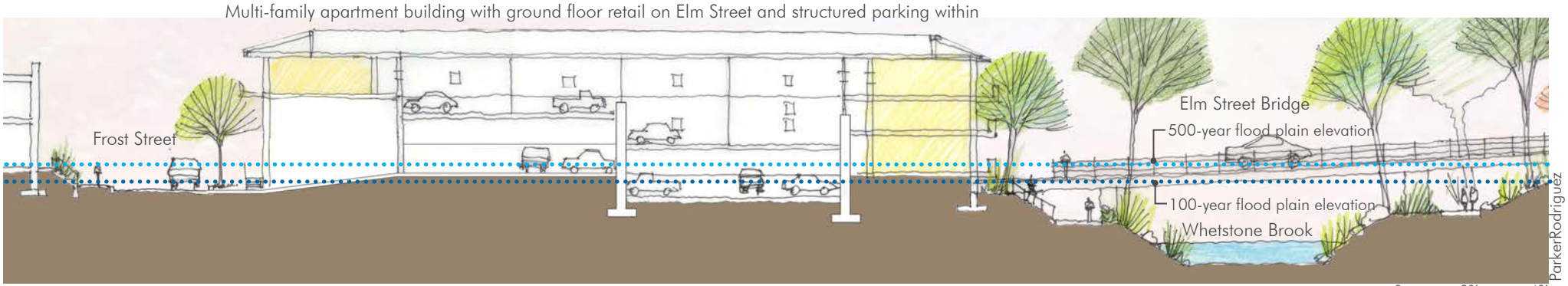
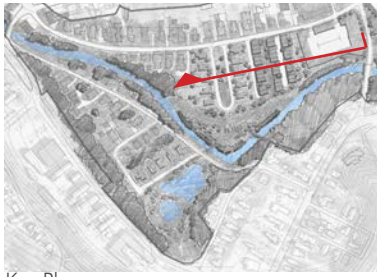


FIGURE 37. Proposed conditions

SECTIONS


Key Plan

The proposed design explores a smoother transition from urban to residential by introducing mixed use, townhome, and single family homes on the industrial parcel, facing the brook and taking advantage of views of the water.

Furthermore, the design suggests how residential development could be accommodated within the flood plain so long as the living space is above the 500 year flood plain, and the designs meet local and state regulatory requirements.

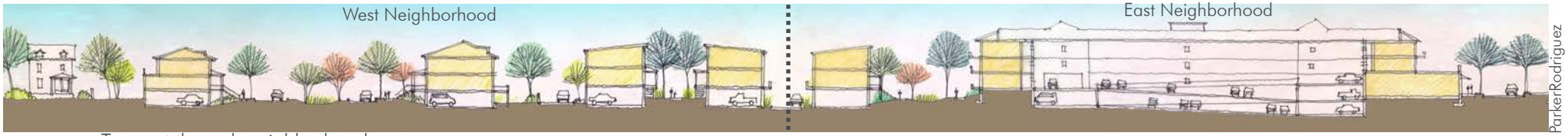


FIGURE 38. Transect through neighborhood

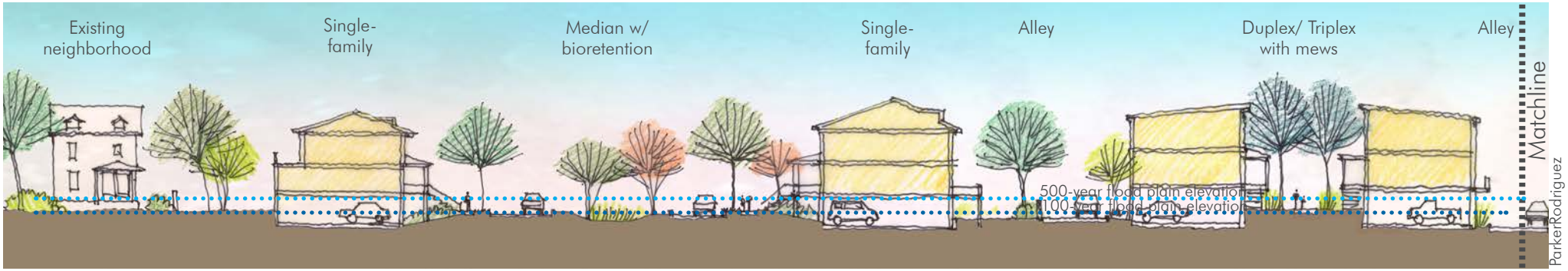


FIGURE 39. West neighborhood

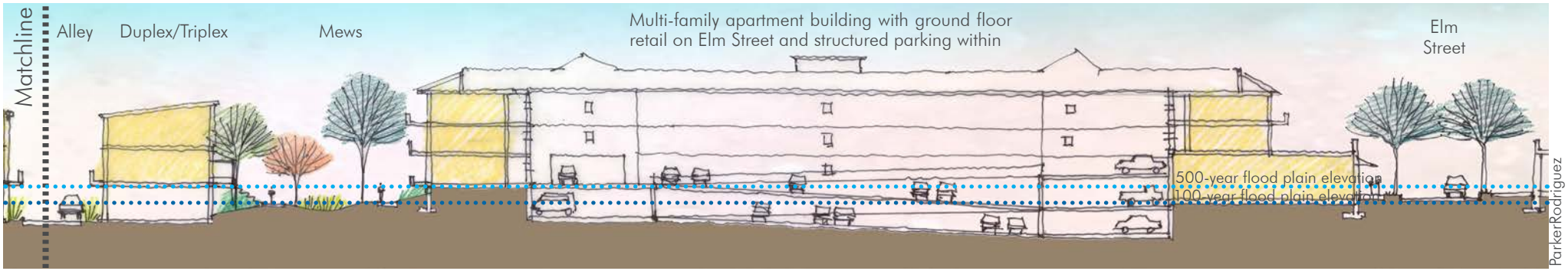


FIGURE 40. East neighborhood

SECTIONS

The extensive amount of impervious surface exacerbates flooding downstream and pollution of the brook as it brings large volumes of runoff during storm events.

The proposed section shows the single family neighborhood zone with a recreational area adjacent to the brook, and pedestrian paths and bridges that allow access to the brook and connect the downtown urban core with the neighborhood. The recreational area bounded by the brook and the vegetated swale could become an ideal site for environmental education and permaculture (perennial agriculture). It would be created by carving a swale that would be dry during low flow periods, but would allow additional water storage when flows in the brook are high.

Furthermore, bioretention cells within the neighborhood streets will slow down the release of rain water to the brook.

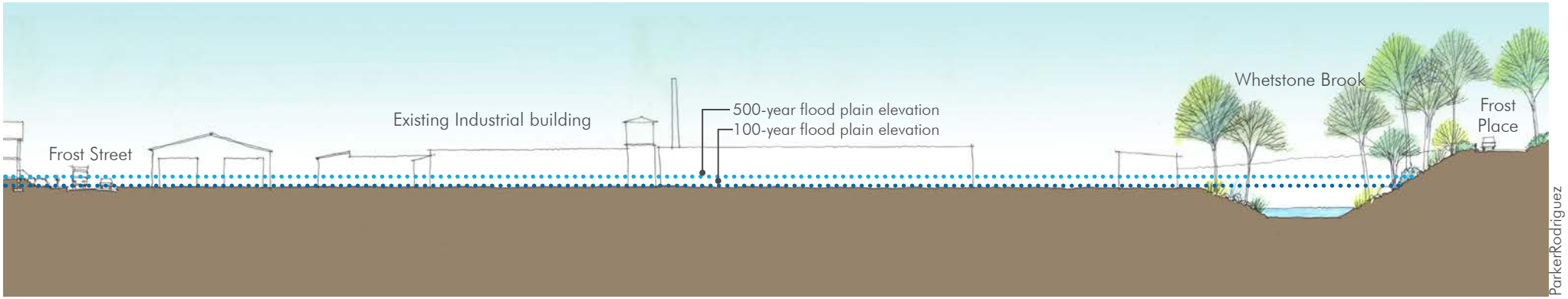


FIGURE 41. Existing conditions through industrial facilities

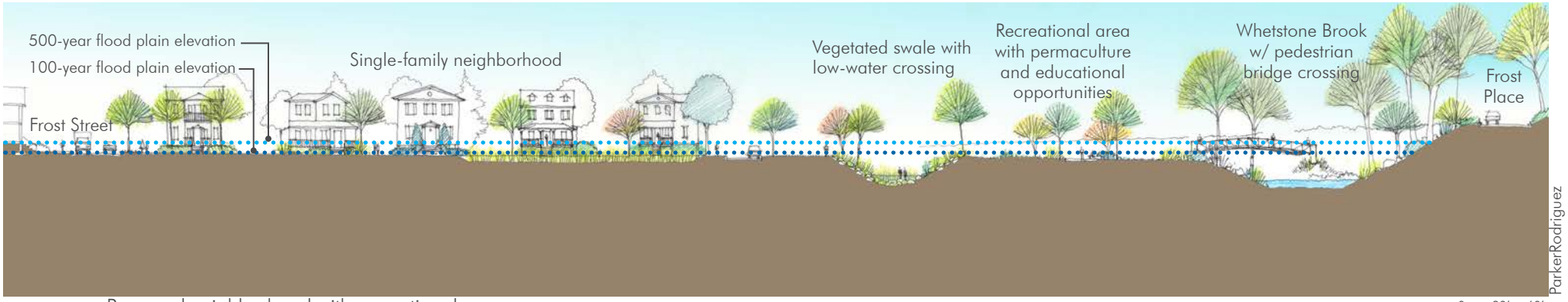


FIGURE 42. Proposed neighborhood with recreational area

PERSPECTIVE


Key Plan

This photograph shows the existing conditions at the corner of Elm and Frost Streets with surface parking and large industrial buildings. This is the edge of the urban area where the downtown area transitions into the surrounding neighborhood.

The proposed design concept introduces a multifamily residential apartment building with retail underneath to activate the corner, create a smoother transition from the downtown area into the neighborhood zone, and to allow for residential units above the flood plain. In this way, this portion of Whetstone Brook will become publicly accessible and the neighborhood would be able to take advantage of this recreational asset on daily basis. Retail will animate the space along the street while residential units will be elevated above the 500 year flood plain.


ParkerRodriguez

FIGURE 43. Existing view


ParkerRodriguez

FIGURE 44. Proposed view

PERSPECTIVE

Key Plan

The existing Kiln Dry site is dominated by large industrial buildings and an extensive amount of impervious pavement.

The proposed design introduces housing, with parking underneath and living space above the 500 year flood plain. The areas in between the homes and the edges of the central lawn could incorporate green infrastructure strategies to prevent stormwater runoff from entering the brook during periods of peak water discharge.

ParkerRodriguez

FIGURE 45. Existing view

ParkerRodriguez

FIGURE 46. Proposed view

PERSPECTIVE


Key Plan

The compacted soil at the existing contractor's yard on Frost Place reduces infiltration rates and thus increases stormwater runoff.

The proposed Frost Place neighborhood includes single family housing, a stormwater treatment area, and pedestrian connections up to Birge and Canal Streets. The stormwater treatment area would catch the stormwater runoff from the steep surrounding neighborhoods, which would slow down the release and cleanse the water before it enters the brook.


WagnerHodgson

FIGURE 47. Existing view


ParkerRodriguez

FIGURE 48. Proposed view

RESILIENT HOUSING CONFIGURATION

The proposed design reflects the New England vernacular while allowing for limited residential use within the flood plain, with all living space elevated above the 500 year flood plain.

The entire structure would be above grade and two masonry walls on each side of the unit would support the home with parking and storage underneath. These masonry walls would be parallel to the flow of the brook and would allow the free flow of water during flood events.

The homes nearest to Frost Street would need to have a deeper excavation underneath them to accommodate parking space headroom, as their finished floor elevation may only be 4 feet above grade. The units closer to the brook, while with the same finished floor elevation, would require less excavation for the parking headroom because the grade beneath is falling away. This excavation will increase flood storage in the flood plain. A Hydrologic & Hydraulic (H&H) study along the mid and lower Whetstone Brook would determine whether such a design, along with potential upstream improvements in flood storage, would meet the state's No Adverse Impact Standard (NAI) in the Flood Hazard Area and River Corridor Protection Procedures and Act 250 Criterion 1(D). The H&H study would provide an assessment of flood water depth and velocity for different development and flood plain restoration scenarios.

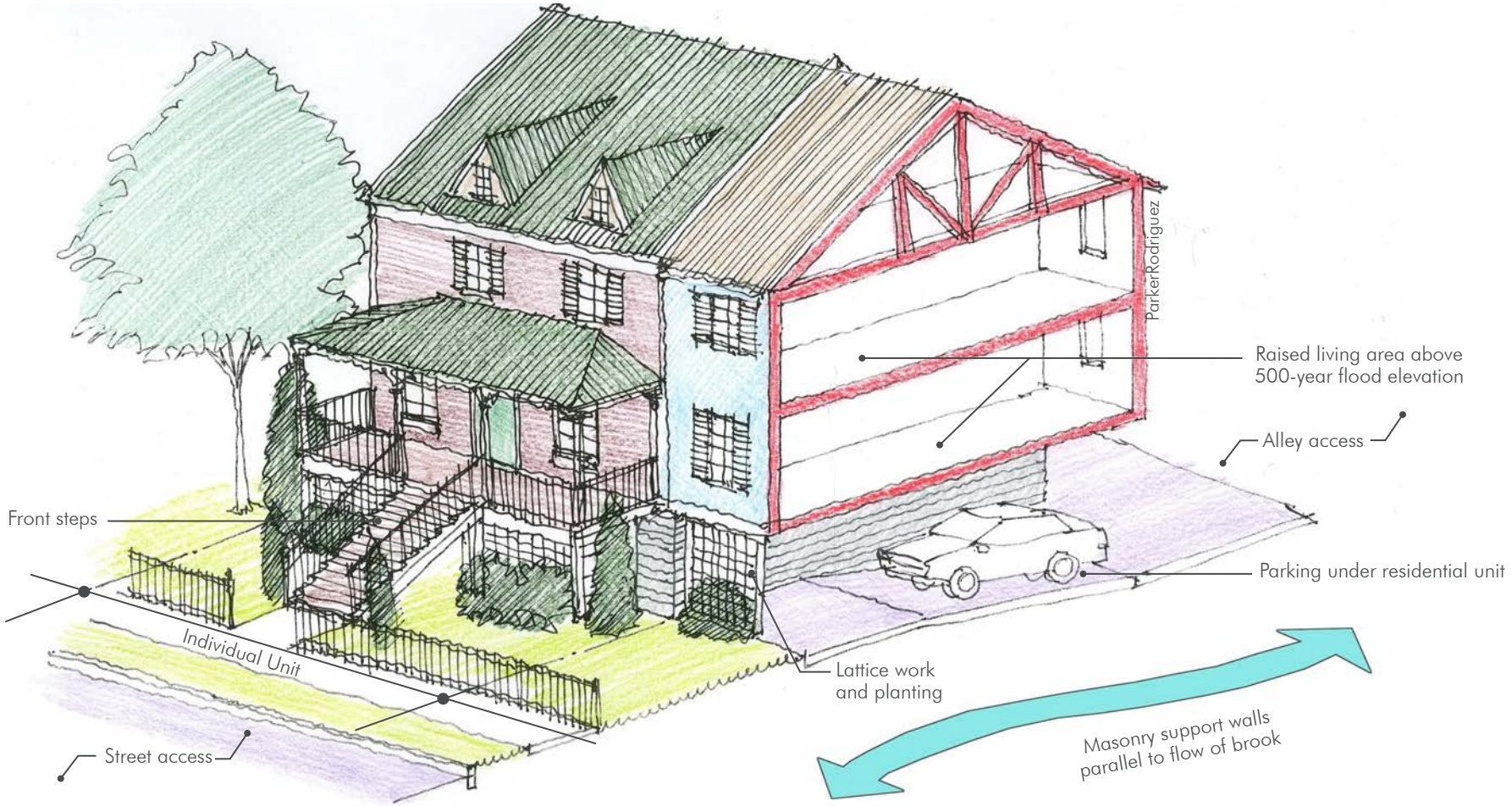


FIGURE 49. Proposed resilient housing configuration

SITE DIAGRAMS

Currently, the extensive impervious surface area of the Kiln Dry site conveys significant runoff to the brook during storm events.

The proposed design significantly reduces the impervious surface by introducing smaller building footprints, increasing the pervious surfaces, and incorporating bioretention areas. These strategies would slow the water flow and minimize the volume of stormwater discharge at peak flow, thus reducing the impact on the brook.

Given the history of high flood depths and velocities in this segment of the Whetstone Brook and the imperative to protect public safety, the state will evaluate whether new residences in the Neighborhood Zone would cause or contribute to a flood or fluvial erosion hazard as a part of the No Adverse Impact evaluation. Projects that increase flood storage and demonstrate a substantial reduction in flood heights and velocities should help to support a finding of No Adverse Impact.

The flood storage diagram demonstrates how the proposed redevelopment could provide additional water storage in this area.

The parking areas under the proposed structures could be excavated to different depths, depending on existing grades, to accommodate additional water storage. These parking areas will have two openings on each side, parallel to the water flow of the brook. In addition, the vegetated swale could release the pressure in the main channel by accepting some water during the brook's high flow periods, and the recreational area between the brook and the swale could be slightly depressed and serve as additional water storage during flood events.

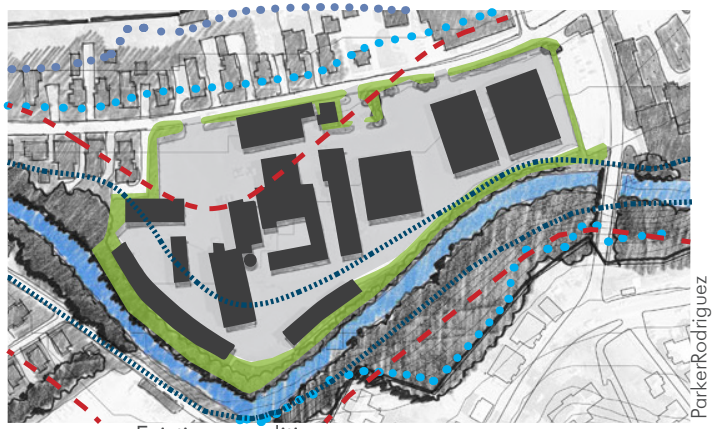


FIGURE 50. Existing conditions

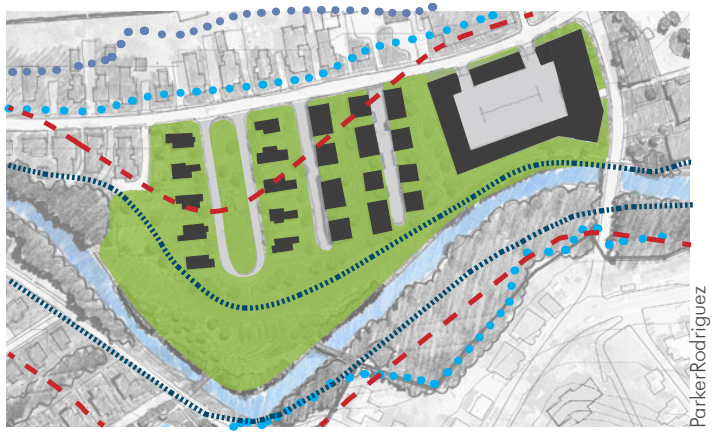


FIGURE 51. Proposed concept

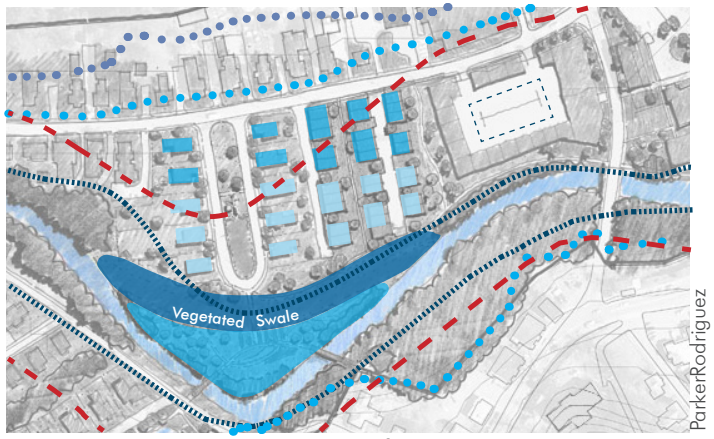
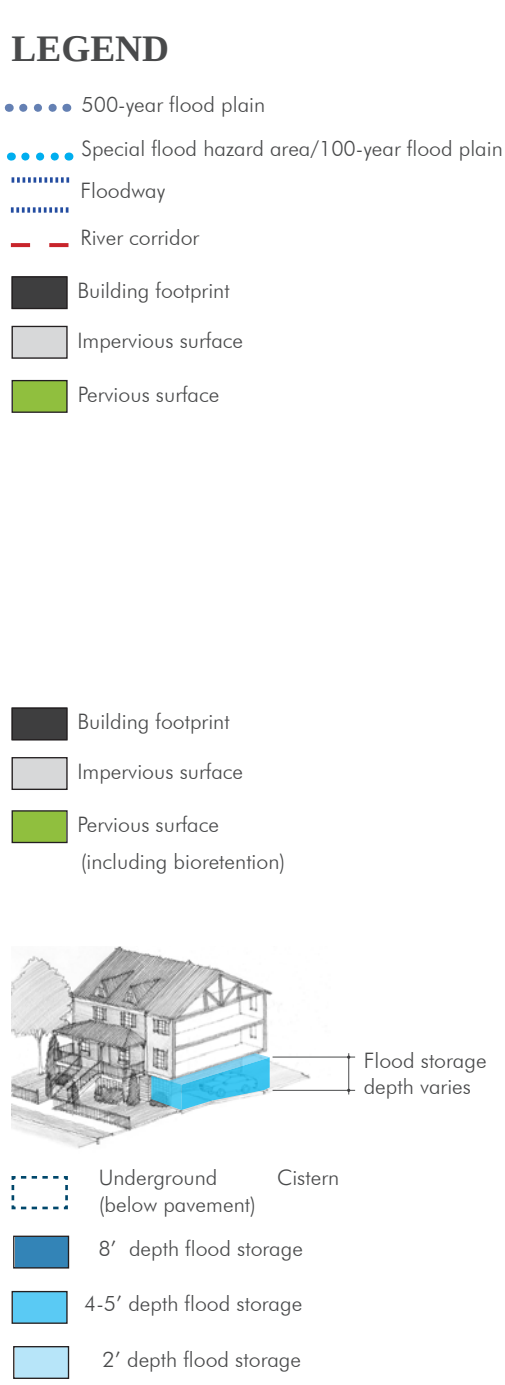


FIGURE 52. Proposed conditions - flood storage diagram



PLAN

This zone is primarily comprised of open space, with residential and forested sections on the edges. Outside of the study area, the zone is bounded on the south, west, and east sides by steep and heavily wooded slopes. This largely undeveloped area offers the best opportunity in the study area for a significant flood plain restoration project that would provide flood storage, reduce flood energy, and allow for settling of sediments and other pollutants. Additionally, runoff that is currently entering the brook from a large untreated stormwater outfall could be rerouted and the stormwater treated in a constructed gravel wetland on the edge of the flood plain.

These two improvements (excavation of fill materials and construction of a gravel wetland) would make significant progress in increasing the ecological health of the Whetstone Brook, and, in addition to these benefits, this zone could present recreational opportunities including walking, running, bicycling and cross country skiing.

FIGURE 53. Proposed plan enlargement

PROPOSED ELEMENTS

1 Meadow planting
2 Pedestrian path
3 Potential pedestrian bridge
4 Constructed gravel wetland

The design options shown in this report present a holistic approach for addressing Brattleboro's goals for the lower Whetstone Brook corridor. The table on the following pages shows how the Town could potentially divide the overall plan into smaller projects to achieve their goals incrementally, as funding, public support, and other considerations allow. In this way, small portions of the proposed design could target different funding sources at the same time.

The near term strategies (2016-2018) include projects that the Town of Brattleboro has direct control over, some of which they have already started working on, such as partnering with the Vermont River Conservancy as they work to acquire the Birge Street parcel.

As work progresses on the near term strategies, the Town could begin the negotiation process for the mid-term strategies (2018-2020) that would require much longer time to gain authority and ability to execute, as well as more funding to implement.

The long term strategies (2020-2025) include the most complex projects that would require the longest coordination, initial preparation, and negotiation, such as redevelopment of the Kiln Dry site.

NEAR TERM (2016-2018)

PROJECT	DESCRIPTION	FUNDING SOURCES
Complete Birge Street parcel flood plain restoration project	Continue working with the Vermont River Conservancy to acquire the property and restore flood plain. Given past industrial use of the property, historical contamination should be characterized. Engineering design and feasibility study of flood plain restoration project will provide adequate information to raise funds for implementation.	• FEMA Pre-Disaster Funds • Vermont Clean Water Fund • Vermont Watershed Grants • Vermont Housing & Conservation Board (VHCB) • Windham Regional Commission (WRC) Brownfields Revolving Loan Fund Program • High Meadows Fund • Lintilhac Foundation
Complete Birge Street parcel stormwater mitigation project	Reroute untreated stormwater from the Birge Street neighborhood away from an existing outfall to the brook to a gravel wetland adjacent to the flood plain on the Birge Street parcel.	• FEMA Pre-Disaster Funds • Vermont Clean Water Fund • Vermont Watershed Grants • High Meadows Fund • Lintilhac Foundation
Create a downtown trails plan	Study potential trail alignments and connections throughout the downtown. Conduct public outreach including private landowners from whom the town would seek use easements for trails.	• HUD Community Development Block Grant (CDBG) Program Funds • National Park Service Federal Rivers, Trails & Assistance Program • Department of Transportation's Federal Highway Administration (FHWA) Recreational Trails Grant Program • Vermont Municipal Planning Grant program (MPG) • VTrans Transportation Alternatives (TA) program • Vermont Trails & Greenways Council • VHCB • Town of Brattleboro

NEAR TERM (2016-2018)

PROJECT	DESCRIPTION	FUNDING SOURCES
Parking needs assessment for downtown/ Preston Park	Secure funding for a downtown parking assessment and conceptual plans for Preston Park, replacing surface parking with public open space that can serve as flood water storage and improved access to brook as asset.	• USDA Rural Development • Vermont MPG
Infill development opportunities	Initiate discussions with the owners of the Kiln Dry and 103 Frost Place sites on the viability of a public/ private partnership.	
Feasibility study: Temporary flood protection	Study the cost and feasibility for the application of temporary measures of flood protection, including such elements as stop logs and inflatable dams. Analyze which public and private properties could benefit from protection. Educate private property owners about their own mitigation options.	• USDA Rural Development • Vermont MPG
Complete Hydrologic & Hydraulic (H&H) modeling for the study area	Model stream conditions to identify downstream benefits of creating significant flood storage capacity at the Birge Street parcel and Kiln Dry sites. Versions of the model can then be used as a redevelopment tool to evaluate proposals to ensure regulatory compliance with Act 250, the VT Flood Hazard Area and River Corridor Protection Procedure, and local and federal permitting requirements. Public funding for this scientific analysis will make redevelopment more cost competitive and less uncertain. A continuous H&H model of the Whetstone Brook from West Brattleboro to the confluence with the Connecticut River will create a useful tool that can guide redevelopment designs and underpin regulatory amendments (extent of the Special Flood Hazard Area) effected through a Letter of Map Revision submitted to FEMA. Extensive modeling of an upstream segment has already been completed.	• EPA Brownfields Assessment • Vermont Ecosystem Restoration Program • FEMA Pre-Disaster Mitigation Funds • Town of Brattleboro

MID TERM (2018-2020)

PROJECT	DESCRIPTION	FUNDING SOURCES
Implement Preston Park	Secure funding for final design, engineering, and construction.	• VHCB • Town of Brattleboro Capital Improvement Funds • Town of Brattleboro Public Parking Funds • Local philanthropy
Extend the Whetstone Path	Design and construct extensions to the Whetstone Path. Secure easements for public access.	• HUD CDBG Program Funds • National Parks Service Federal Rivers, Trails & Assistance Program • FHWA Recreational Trails Grant Program • VTrans TA program • Downtown Transportation Fund • Vermont Trails & Greenways Council • VHCB • Town of Brattleboro
Implement green infrastructure strategies for stormwater	Identify potential green infrastructure projects in the Urban Zone. Implement these practices as funding or opportunities allow.	• USDA Rural Development • Vermont Clean Water Fund • Vermont Watershed Grants
Infill development public/private partnerships	The public sector can assume the role of developer for infrastructure, making land available for new residential and retail uses. The objective would be to bring to market sites affordable enough for individuals to build homes and a developer to build the multifamily/retail building.	
Create architectural guidelines for resilient buildings	Develop a set of guidelines for building design within the flood plain that reflect legal and insurable thresholds of construction practice and practices in architectural design within the context of the historic fabric of the town.	• Resilient Vermont

LONG TERM (2020-2025)

PROJECT	DESCRIPTION	FUNDING SOURCES
Redevelop the Kiln Dry site into flood resilient residential and retail development	If the owner of the Kiln Dry property decides to sell, the town facilitates site cleanup through regional and/or Vermont brownfield program resources, and develops a master plan for the site (including subdivision, creation of new frontage with additional streets and utility infrastructure).	• HUD CDBG Program Funds • Resilient Vermont • WRC/ brownfield revolving loan program • Private development • Town of Brattleboro's Capital Improvements Plan (roads and utilities)
Redevelop 103 Frost Place (contractors' yard)	If the owner of the property at 103 Frost Place decides to sell, the town could help facilitate new residential infill development. Six single family home sites could be developed along the northern edge of the property. The remainder could be used for stormwater management ponds and flood storage.	• HUD CDBG Program Funds • Resilient Vermont • WRC/ brownfields revolving loan program • Private development • Town of Brattleboro's Capital Improvements Plan (roads and utilities)
Reconnect neighborhoods to Whetstone Brook by providing multi-functional open space and public access to the brook	Infill development within the Neighborhood Zone could provide many opportunities for publicly accessible open space and recreational areas. One central area could be the southern quarter of the Kiln Dry site, an area that lies within the floodway and thus cannot be developed. The concept illustrates the potential to carve a flood spillway along the line of the floodway. The land south of the spillway can become a natural area, connected to the north by a low water crossing, but able to absorb flood water during a storm event.	• HUD CDBG Program Funds • National Parks Service Federal Rivers, Trails & Assistance Program • Vermont Watershed grants • VHCB • Lintilhac Foundation

FUNDING SOURCES

FEDERAL SOURCES

U.S. Department of Housing and Urban Development Funding supports urban housing and community development. There are multiple funding opportunities including the Community Development Block Grant Program Funds, which must benefit low- to moderate-income residents. (http://portal.hud.gov/hudportal/HUD?src=/topics/grants)

The National Parks Service Federal Rivers, Trails & Assistance Program provides funding to expand public access to water resources including pedestrian walkways, enhance connections to the local community, and other projects that focus on recreation and conservation. (https://www.nps.gov/orgs/rtca/apply.htm)

The FEMA Hazard Mitigation Fund provides funds to reduce or eliminate long term risk to people and property from natural disasters. Part of this program, FEMA Pre-Disaster Funding, is designed to reduce risk from future events and prevent future disasters through preventative management. (https://www.fema.gov/hazard-mitigation-assistance; http://www.fema.gov/pre-disaster-mitigation-grant-program)

The Department of Transportation's Federal Highway Administration Recreational Trails Grant Program provides funding for the construction, design, maintenance, or restoration of recreational trails. (http://fpr.vermont.gov/recreation/grants/rtp)
USDA Rural Development provides funding for community facilities, business development, infrastructure, and other activities. (http://www.rd.usda.gov/)

The US Environmental Protection Agency provides funding for a variety of activities, including assessment and cleanup of brownfields sites. (https://www.epa.gov/brownfields/types-brownfields-grant-funding)

STATE SOURCES

The Vermont Clean Water Fund provides state funds to help municipalities implement projects that will reduce pollution to Vermont's surface waters. (http://dec.vermont.gov/watershed/cwi/cwf)

The Vermont Housing & Conservation Board funds projects that provide recreational opportunities, preserve public access to natural resources, conserve wildlife habitat, protect water quality, and enhance flood resiliency. (http://www.vhcb.org/conservation.html)

The Vermont Municipal Planning Grant program provides grants to assist with planning-related research, mapping, capacity studies, outreach, or can be used to pay consultants or other fees associated with a project. Funding can also be used to purchase easements or titles of properties for housing and conservation purposes or to acquire needed materials. (http://accd.vermont.gov/strong_communities/opportunities/funding/overview/municipal_planning_grants)

The VTrans Transportation Alternatives (TA) program provides funding for the planning, design, and construction of transportation infrastructure for non-motorized transportation. (http://vtrans.vermont.gov/highway/local-projects/transport-alt)

Vermont Watershed Grants offers grants to restore or protect water quality, reduce phosphorus and sediment pollution in waterways, enhance recreational use of water resources, provide watershed education, or a number of projects that protect and enhance water quality. (http://dec.vermont.gov/watershed/cwi/grants/watershed-grants)

The Downtown Transportation Fund supports public capital projects such as improvements to the pedestrian network and streetscape. (http://accd.vermont.gov/strong_communities/opportunities/funding/downtown_transportation_fund)

Vermont Trails and Greenways Council seeks to ensure that people will always have access to adequate land and water-based trails and greenways.

FUNDING SOURCES

LOCAL SOURCES

Windham Regional Commission brownfield revolving loan program provides loans and grants to facilitate the cleanup of brownfields properties. (http://www.windhamregional.org/brownfields)

With guidance from the town, private development could help to move several projects forward. This relationship would be particularly important in the Neighborhood Zone.

Local non-profit organizations may have available funding to assist with certain projects depending on the focus of the non-profit organization.

The town of Brattleboro could explore partnerships with local individuals or groups for the construction or maintenance of green stormwater infrastructure or other small scale projects.

A Capital Improvement Plan, which is a planning tool to identify and plan for expenses associated with improvement projects in the short term (4-10 years), could be utilized to plan for future expenditures.

Local philanthropy could play an important role in funding projects that would otherwise not be funded.

High Meadows Fund supports projects that seek to help Vermont adapt to the changing climate. Their initiatives include promoting "land use that supports resilient communities, healthy soil, and clean water".
(http://www.highmeadowsfund.org/)

The Lintilhac Foundation funds projects focused on water quality, specifically stream corridor management and water quality monitoring. (http://www.lintilhacfoundation.org/)

Public parking funds could be used for improvements to public parking in the downtown area.

Watershed Consulting Associates

FIGURE 54. Bioretention cell

Urban Rain Design

FIGURE 55. Green gutter

Watershed Consulting Associates

FIGURE 56. Underground storage

Watershed Consulting Associates

FIGURE 57. Filter strip

Watershed Consulting Associates

FIGURE 58. Gravel wetland

ParkerRodriguez

FIGURE 59. Pervious paving

BC **Bioretention cell**
Bioretention practices use shallow, depressed, vegetated areas that collect and treat runoff from impervious surfaces using native vegetation. Examples include rain gardens and stormwater planters. These features can be designed to either detain, slowly release (via an underdrain), or infiltrate stormwater runoff and use a variety of native plants. Bioretention practices can range in size based on the particular drainage area and available space.

GG **Green gutter**
Green gutters collect and treat stormwater from roadways via filtration and infiltration. Runoff reaches these narrow, landscaped strips through curb cuts and is slowed down by the plants. Check dams can be installed in between plantings along the gutter to further slow stormwater. This feature is aesthetically pleasing and is a good practice to integrate in constricted urban areas where open space is limited.

US **Underground storage**
Underground storage in constrained areas where it is necessary to keep existing impervious surfaces. These systems redirect stormwater runoff from the ground surface to underground storage pipes or chambers. Stored water is then slowly released into waterways to reduce peak flows during storms or infiltrated. Underground storage that does not provide infiltration does not treat stormwater but there are optional pre-treatment techniques that can improve water quality at the system's inlet.

FS **Filter strip**
Filter strips are vegetated areas that can be planted along waterbodies where there is no riparian buffer. Permanent, native vegetation in these filter strips helps to slow stormwater runoff and filters out pollutants while increasing bank stability and preventing erosion. These features should be moderately wide (≥100') in order to effectively promote healthy waterways.

GW **Gravel wetland**
Gravel wetlands are constructed treatment systems that utilize native plants to filter and slow stormwater. The wetland includes a series of horizontal flow-through treatment cells. Their gravel substrate creates a microbe rich environment that has very high nutrient removal rates. Gravel wetlands also increase wildlife habitat and aesthetics onsite.

PP **Pervious paving**
Pervious paving decreases runoff by allowing stormwater to pass through the pore space in the paving material. A stone bed under the pavers filters the stormwater, which can then be infiltrated or slowly released via an underdrain. Pervious paving can be used in place of traditional impervious materials and allows for the treatment of stormwater without utilizing additional space.

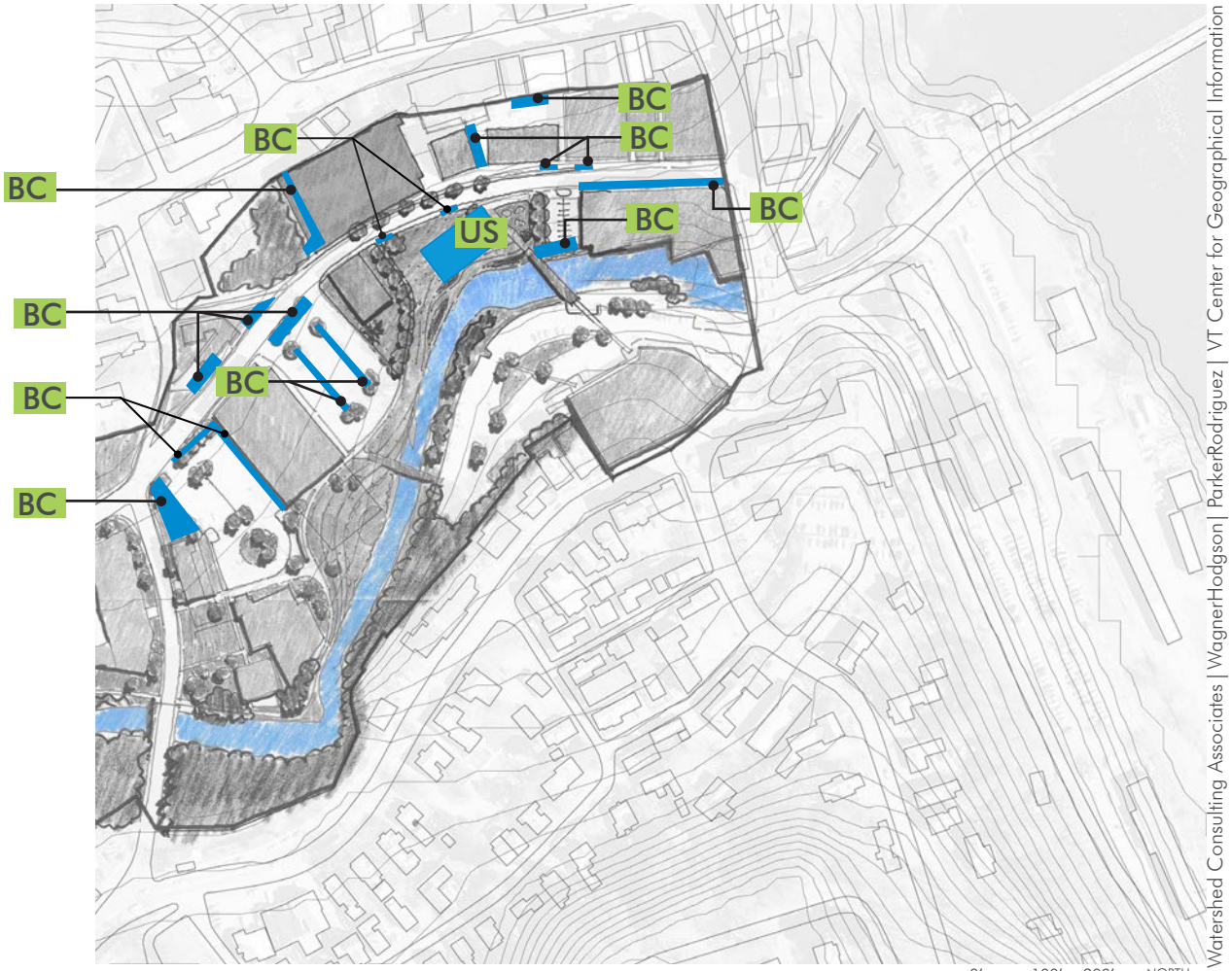
URBAN ZONE

Watershed Consulting Associates

BC **FIGURE 60.** Bioretention cell

Watershed Consulting Associates

US **FIGURE 61.** Underground storage



Watershed Consulting Associates | WagnerHodgson | ParkerRodriguez | VT Center for Geographical Information

FIGURE 62. Potential stormwater mitigation locations

Downtown Brattleboro is largely covered with impervious surfaces, including buildings, roads, and parking lots. Breaking up this impervious cover with a diverse group of stormwater management elements could greatly improve water quality in the Whetstone Brook, slow stormwater discharge into the brook, and create opportunities for public education about stormwater.

Bioretention cells along the edge of the Transportation Center would help to slow water from steep slopes above from entering the garage, and could create an opportunity for an educational display about stormwater at the busy corner of Flat and Elm Streets. Bioretention cells along Flat Street and within large parking areas maximize the opportunity for infiltration while allowing for traffic and winter maintenance.

Underground storage beneath what is now the Preston parking lot, and is envisioned as a future park, could quickly contain runoff and maximize stormwater storage and infiltration while maintaining an active public space above.

Filter strips along the brook could capture and filter roof water from buildings immediately adjacent to the brook.

NEIGHBORHOOD ZONE

ParkerRodriguez

PP **FIGURE 63.** Pervious paving

Watershed Consulting Associates

BC **FIGURE 64.** Bioretention cell

Urban Rain Design

GG **FIGURE 65.** Green gutter

Watershed Consulting Associates

US **FIGURE 66.** Underground storage

Watershed Consulting Associates

FS **FIGURE 67.** Filter strip

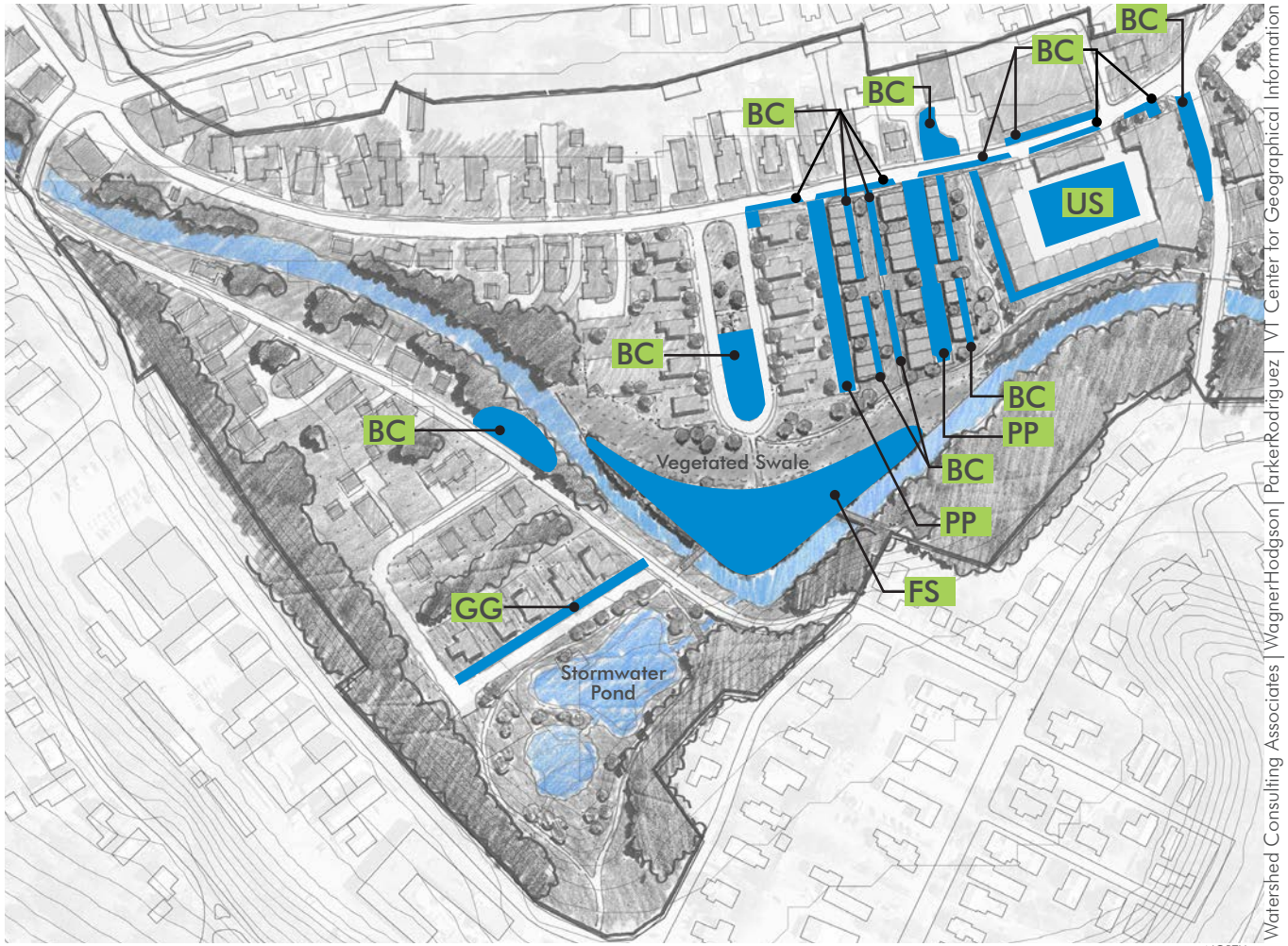


FIGURE 68. Potential stormwater mitigation locations

In the neighborhood zone, permeable pavers can be used in driveways to allow for infiltration.

Bioretention cells across the neighborhood zone capture and filter stormwater from larger paved areas. Along Frost Street and townhome units they maximize the opportunity for infiltration in paved, constricted areas.

Green gutters along quieter, non-curbed streets also allow for infiltration.

Underground storage beneath the mixed use central parking area could quickly contain runoff and maximizes stormwater storage and infiltration.

The recreational island could serve as filter strip to slow stormwater runoff and filter out pollutants.

NATURAL AREA

Watershed Consulting Associates

BC **FIGURE 69.** Bioretention cell

Urban Rain Design

GG **FIGURE 70.** Green gutter

Watershed Consulting Associates

GW **FIGURE 71.** Gravel wetland

FIGURE 72. Potential stormwater mitigation locations

In the natural zone, bioretention cells and green gutters capture sediments and filter stormwater from steep slopes and along non-curbed streets.

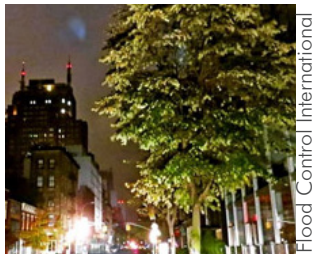
A large gravel wetland along the eastern side of the Birge Street parcel is a flow through system that captures sediment and allows stormwater to be filtered through gravel treatment cells that host a diverse wetland plant community.

ParkerRodriguez

FIGURE 73. Terraced floodwall

TF Terraced floodwall

A terraced floodwall is a partially hardened and partially vegetated slope adjacent to a waterbody. The terraces are constructed of stone or other hard materials and they resist erosion during floods. The vegetated areas within the terraces improve water quality as each step slows stormwater runoff from upland sources and allows for filtering and infiltration. A terraced floodwall also provides some flood storage during storms, and a recreational amenity for the public during dry weather.



Flood Control International

FIGURE 74. Stop logs

SL Stop logs

Stop logs are removable flood barriers that stack on top of each other to form impervious wall structures that prevent floodwater from entering buildings or reaching other vulnerable areas. They are simple to install, are completely removable, and be used on most surfaces including slopes of up to 20°.

Smart Vents

FIGURE 75. Smart vent

SV Smart vents

Smart vents offer a unique method of flood protection by allowing flood waters to pass through enclosed spaces such as basements that are below the base flood elevation. The vent stays closed until it comes in contact with floodwater. Rotating open, the vent allows water to pass through the space which alleviates pressure on the building's foundation.

Mara Williams

FIGURE 76. Flood gates

FG Flood Gates

Flood gates are removable flood barriers that can be used on residential or commercial buildings. Tracks are installed on each side of the door frame and then in advance of a storm, aluminum sheets slide into the tracks to form a watertight seal, and are easily removed once floodwaters recede. These structures were used successfully to prevent flooding of the New England Youth Theatre during Irene, as shown on figure 76.

Layfield Environmental

FIGURE 77. Inflatable dams

ID Inflatable dams

Inflatable dams can be used as a method of flood control by diverting flood waters, creating temporary reservoirs, and augmenting embankment shapes. Easily set up and removed, these dams are designed for flexibility, durability, and strength, and can work on a variety of surfaces and slopes. In the case that the dam is breached or overtopped, it will no longer serve as an effective method of flood control, however.


Gabion 1

FIGURE 78. Gabions

GB Gabions

Gabions are stone filled, wire mesh baskets utilized for erosion control and stabilization purposes in areas like stream banks. Gabions are most effective in areas where previous stabilization attempts have failed and where erosive forces are such that vegetated solutions will likely fail. They have high permeability, which allows water to drain easily when waters recede.


Town of Waitsfield

FIGURE 79. Armored banks

AB Armored banks

Reinforcing river banks with rip rap (a layer of large, angular stones) mitigates erosion by increasing the structural stability of the slope and holding the soil in place. This method is particularly effective in areas where erosive forces prohibit the establishment of vegetation.


Watershed Consulting Associates

FIGURE 80. Bioengineered embankments

BE Bioengineered embankments

Bioengineered embankments incorporate the use of vegetation and construction materials for erosion control and soil stabilization of river banks. A variety of plants are used throughout these areas with grasses in the lowest "splash" zone, smaller shrubs and woody plants in the middle "bank" zone, and larger shrubs and trees in the upper "terrace" zone. Plant species include those native to the local stream environments and provide habitat for fish and wildlife.


Salix Ltd, UK

FIGURE 81. Stream spillway

SS Stream spillway

Spillways are channels for diverting flood waters and serve as a method of flood protection and control. Redirecting water from the main river system lessens the impact of flooding on the river as well as effectively reducing the flood stage. These channels, also known as floodways or flood bypass channels, consist of low lying vegetated areas that can be utilized for recreation and wildlife habitat when not submerged.

URBAN ZONE

ParkerRodriguez

TF **FIGURE 82.** Terraced floodwalls

Flood Control International

SL **FIGURE 83.** Stop logs

Mara Williams

FG **FIGURE 84.** Flood gates

Layfield Environmental

ID **FIGURE 85.** Inflatable dams

Gabion 1

GB **FIGURE 86.** Gabions

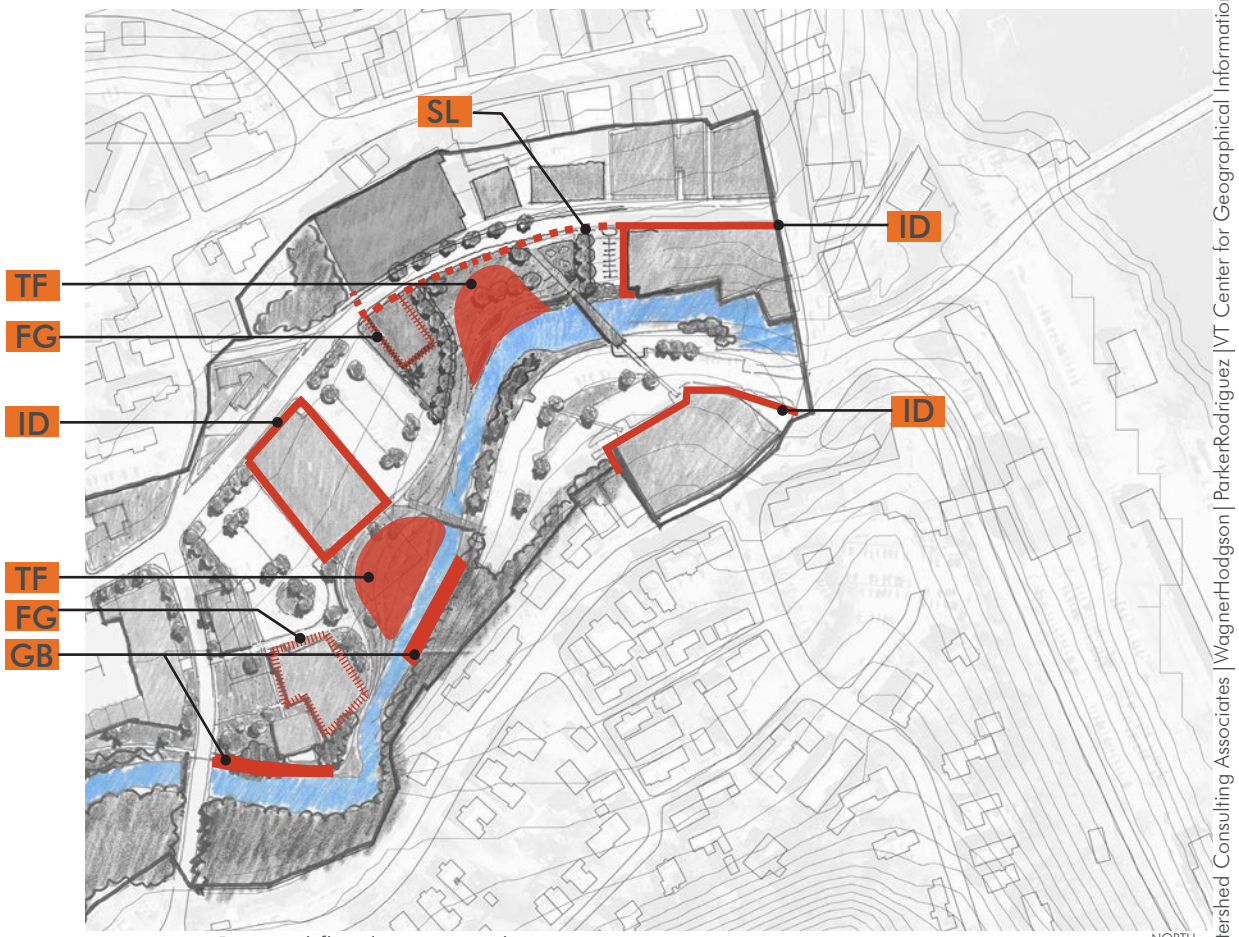


FIGURE 87. Potential flood mitigation locations

To reduce the potential for flood damage in Brattleboro's urban core, a diverse group of temporary and permanent flood mitigation elements could help greatly during heavy precipitation events, lessen the rate of flood water discharge into the Whetstone Brook, and help to protect downtown's historic buildings, roads, and infrastructure.

A series of terraced floodwalls in Preston Park could help to anchor the cutbank while widening the channel and providing flood storage.

A series of stop logs along Flat Street could prevent flooding of the street, thereby allowing vehicular access between Main Street and the Transportation Center.

Inflatable dams filled with water could be mobilized to protect buildings or critical circulation routes.

Gabions installed along the brook's banks could help to protect the brook corridor from scouring and erosion during flood and high water events.

NEIGHBORHOOD ZONE

Watershed Consulting Associates

BE **FIGURE 88.** Bioengineered embankment

Salix Ltd, UK

SS **FIGURE 89.** Stream spillway

Town of Waitsfield

SS **FIGURE 90.** Armored banks

Gabion I

GB **FIGURE 91.** Gabions

Smart Vents

SV **FIGURE 92.** Smart vents

FIGURE 93. Potential flood mitigation locations

In the neighborhood zone, densely planted bioengineered embankments placed along the depositional side of the brook could protect the banks from erosion and help to slow high energy flow during flood events.

A stream spillway upstream of the brook's bend, could divert flood waters into a secondary storage corridor with armored banks, providing flood volume storage and stabilized slopes to help dissipate the flood water's energy.

Gabions could help to protect the brook's slopes that are susceptible to erosion and scour.

Smart vents could be incorporated as appropriate in existing development within the flood plain.

NATURAL AREA

Watershed Consulting Associates

BE **FIGURE 94.** Bioengineered embankment

Town of Waitsfield

AB **FIGURE 95.** Armored banks

Watershed Consulting Associates | WagnerHodgson | ParkerRodriguez | VT Center for Geographical Information

FIGURE 96. Potential flood mitigation location

In the natural zone, densely planted bioengineered embankments placed along the depositional side of the brook and along the slopes of the gravel wetland could protect the banks from erosion and help to slow high energy flow during flood events.

Armored banks on the cutbank side anchor the brook's edges that are susceptible to erosion and scour during high energy flooding events.

Communities around the country are looking to get the most from new development and to maximize their investments. Frustrated by development that gives residents no choice but to drive long distances between jobs and housing, many communities are bringing workplaces, homes, and services closer together. Communities are examining and changing zoning codes that make it impossible to build neighborhoods with a variety of housing types. They are questioning the fiscal wisdom of neglecting existing infrastructure while expanding new sewers, roads, and services into the fringe. Many places that have been successful in ensuring that development improves their community, economy, and environment have used smart growth principles to do so (see box). Smart growth describes development patterns that create attractive, distinctive, and walkable communities that give people of varying age, wealth, and physical ability a range of safe, convenient choices in where they live and how they get around. Growing smart also means that we use our existing resources efficiently and preserve the lands, buildings, and environmental features that shape our neighborhoods, towns, and cities.

This work in Brattleboro was conducted under the U.S. Environmental Protection Agency's (EPA) "Making a Visible Difference (MVD) in Communities" initiative. This initiative coordinates technical assistance and other resources across EPA programs with states, tribes, local governments, and other federal agencies to support communities as they pursue environmental improvements that enhance economic opportunity and quality of life.

For more information about EPA's "Making a Visible Difference in Communities," visit www.epa.gov/smartgrowth/making-visible-difference-communities<http://www.epa.gov/smartgrowth/making-visible-difference-communities>.

Smart Growth Principles

Based on the experience of communities around the nation, the Smart Growth Network developed a set of 10 basic principles:

- Mix land uses.
- Take advantage of compact building design.
- Create a range of housing opportunities and choices.
- Create walkable neighborhoods.
- Foster distinctive, attractive communities with a strong sense of place.
- Preserve open space, farmland, natural beauty, and critical environmental areas.
- Strengthen and direct development towards existing communities.
- Provide a variety of transportation choices.
- Make development decisions predictable, fair, and cost effective.
- Encourage community and stakeholder collaboration in development decisions.

Source: Smart Growth Network. "Why Smart Growth?" http://www.smartgrowth.org/why.php.

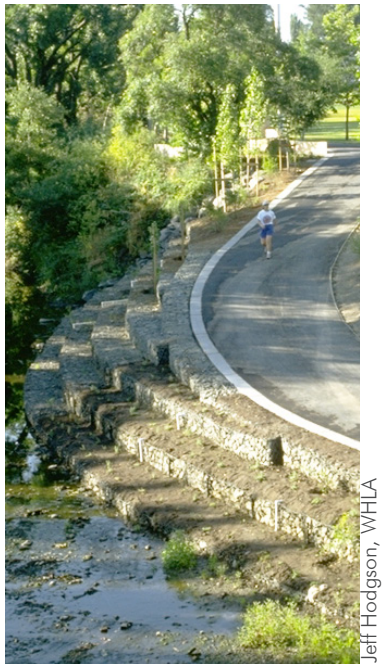
GUADALUPE RIVER PARK
SAN JOSE, CALIFORNIA

Guadalupe River Park is a three-mile ribbon of park land that runs along the banks of the Guadalupe River through the heart of downtown San Jose.

In the early 1990s, the City of San Jose formed a team of landscape architects, engineers, hydrologists and city officials to develop an alternative flood control protection solution that met requirements of the US Army Corps of Engineers while keeping the river accessible to the public. The design peeled back the banks of the river to accommodate seasonal flooding while providing river access points at the major bridges through downtown. The river walk follows the top of the riverbank except at vehicular bridge locations where it dips below the bridges to avoid pedestrian and vehicular conflicts. Riparian habitat was restored through much of the river and three major parks were designed within the River Park to accommodate the city's large festivals.

Jeff Hodgson, WHLA

FIGURE 97. Stone stadium seating provides streambank stabilization, and interspersed riparian planting slows and filters storm water while providing a shady urban respite in the heart of downtown.



Jeff Hodgson, WHLA

FIGURE 98. Gabions (rock-filled cages) anchor the meandering river and provide informal seating.


ELLIOT STREET
CANAL STREET