

Conceptual Design and Implementation Memorandum NCLWF Mud Creek Restoration Planning

Prepared for: City of Hendersonville

Project Title: Mud Creek Stream and Wetland Restoration Planning Project

Wildlands Project No: W20371

Subject: Conceptual Design and Implementation Tasks (6, 7, and 8)

Date: April 30, 2023

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INTRODUCTION

The purpose of this memorandum (memo) is to summarize project findings and deliverables associated with the following design and implementation planning tasks conducted under the Mud Creek Stream and Wetland Restoration Planning Project:

Task 6: Hydraulic Modeling

Task 7: Property and Easement Acquisition Evaluation

Task 8: Restoration Concept Development

This memo documents analysis and conclusions from modeling, acquisition opportunities assessment, and project opportunities concept development. Modeling and project potential was focused on three City-owned properties identified for this planning project: the Wilson Site, the Brevard Church Site, and the Dog Park Site. During the project process, a fourth site, consisting of three acquisition parcels under one owner (the "Acquisition Site") was incorporated into concept plan development as well. The Project Area Map in Appendix A depicts these sites. The other planning task, to identify potential acquisition



parcels of interest, looked at adjacent and nearby parcels within the mainstem and tributary stream corridors.

TASK 6: HYDRAULIC MODELING

Wildlands completed hydrologic and hydraulic evaluation of the project sites to understand opportunities and considerations for stream and floodplain restoration and stormwater management opportunities. The hydrologic characteristics of tributaries and stormwater networks were considered for stormwater management considerations, with focus on the 1" rainfall for the purposes of water quality planning.

Mud Creek and two of the contributing urban tributaries (UT1 & UT2) were studied to evaluate their flood magnitudes in order to understand and evaluate the influence of historic berms still present on the sites, the behavior around breached areas of these berms, and other considerations as related to floodplain activation, flow vector fields during large events, and flood storage.

Tributary and Local Stormwater Hydrology for Stormwater Management

Several tributaries to Mud Creek or Johnsons Ditch enter into, or originate and flow from, the three project sites and the Acquisition Site. The subwatersheds for these drainages were delineated using the USGS StreamStats application, with results and regional curve bankfull geometry predictions presented in the Assessment Memorandum. Appendix B provides a map of the subwatersheds for the six urban drainages (UT1 – UT6) that contribute to the project area. These tributaries range in size from approximately 30 to 160 acres, with most characterized by high impervious land use cover.

In addition, other local stormwater drainage enters project or acquisition sites, or is flowing adjacent to the sites. These piped or open channel conveyances are candidates for diversion to treatment. The City's stormwater database, site reconnaissance as well as development plans from adjacent parcels, where available, were used to evaluate outfalls for opportunity assessment.

Runoff estimates from UT1, UT2, UT4 and two stormwater outfalls on the Acquisition Site were prepared using the Simple Method (Shuler, 1987) to estimate runoff coefficients based on land use for the purpose of planning and design feasibility evaluation for stormwater management opportunities. The anticipated typical treatment concept for sites is to use offline wetlands for jurisdictional features or online wetlands for stormwater outfalls to treat first flush stormwater flows. The following table presents first flush runoff estimates and required treatment ponding depths based on the potential area available for treatment.

Stormwater Management Runoff and Treatment Area Estimates for Evaluated Opportunities

ID	Site/Stream	Drainage Area (acres)	% Impervious	Runoff Coefficient (Rv)	Volume 1" Rainfall Event (cu ft)	Approximate Storage Area Available (acres)	Ponding Depth Required (ft)
1	Wilson / UT1	130	21%	0.28	132,000	3.7	0.8
2A	Brevard Church / UT2	100	40%	0.40	145,100	7.9	0.4
3A	Acquisition Site / UT4	86	50%	0.46	143,400	13.7	1.1
3B	Acquisition Site / Stormwater Outfall East Side	35	50%	0.46	58,400	13.7	0.1



These and other investigated and uninvestigated opportunities are mapped on the Stormwater Management Opportunities figure in Appendix C and further described in the Task 8 section of this memo in the Stormwater Management Opportunities table.

Mud Creek Hydrology

In recent years, the City of Hendersonville prepared hydrologic data and floodplain mapping based on HEC-HMS evaluation of the Mud Creek watershed above Wash Creek. HEC-HMS output higher frequency flow event estimates that were added to the effective FEMA (1-d) hydraulic model to calculate water surface profiles. Profiles were used to complete floodplain inundation area mapping, such as for the 2-year event included in Appendix B as an example.

Hydraulic Modeling

FEMA 1-d Hydraulic Model

For the mainstem of Mud Creek (23.5 square miles drainage area below Wash Creek), Wildlands obtained the effective FEMA HEC-RAS model from the online from NC Floodplain Mapping Program's Flood Risk Information System (NC FRIS) and reviewed model setup and results. The model is not set up to account for split flow which occurs at the Wilson Site, where a portion of high flow is diverted from Mud Creek (and UT1) into the parallel Johnsons Ditch conveyance channel. The original model only contains the 100-year flow event but was updated using City HEC-HMS flow data. In some cases, such as at South Grove Street, multiple relief structures are present but are missing from the model, further affecting the accuracy of results. Rather than try to correct and setup a functional 1-d hydraulic model, it was judged that for future design and implementation a 2-d hydraulic model such as HEC-RAS and/or PC SWMM should be employed to more accurately assess existing and design conditions in this hydraulically complex setting.

Preliminary 2-d Hydraulic Model

For this planning study, a preliminary 2-d hydraulic model was set up for Mud Creek and Johnsons Ditch using a combination of 1-d model input, field data collection and measurement, and QL1 LiDAR from North Carolina Floodplain Mapping Program (NCFMP). Wildlands used this preliminary 2-dimensional model of the corridor in order to evaluate questions about how Mud Creek, Johnsons Ditch and other streams and floodprone areas interact during high flows. The preliminary model was not refined based on the gaging data available from assessment (see Assessment Memorandum) under this scope. However, both gage and model data can be used to inform interpretation of storm event behavior and guide detailed design. A more extensive network of gaging has been recommended to help support 2-d model refinement and validation which is proposed to guide design decision making, as well as potentially being a resource for floodplain permitting.

2-d modeling is available for future use and will require refinement with improved structure and topographic data, and greater distinction of land use/land cover for assignment of Manning's n-values for design-phase analyses. Refer to Appendix B for the Preliminary Mud Creek Hydrology and Hydraulics Report prepared in support of the fall 2022 LWF flood reduction grant application.

Some interesting results from the 2-d modeling include:

- Water surface differences visible in Figures 5A – 7A of the referenced report show higher water levels in Mud Creek than in the adjacent floodplain and in Johnsons Ditch for the modeled 1-year flows. This suggests flood storage potential on the floodplain, and the potential for additional flow routing to areas of underutilized flood storage using Johnsons Ditch and other hydraulic modifications to route and store flows (Figure 10 shows actual elevation data where the storage



potential can be estimated). This hydraulic behavior was confirmed by the gage data from the assessment activities.

- The primary flow onto the floodplain for the 1-Year flow event is through breached segments of existing berms, short segments that are likely the results of berm failure during prior flooding. Breached opening areas are small enough to contract flow and create high velocity fields on the floodplain, and also to be prone to debris jams and clogging. The berm heights on Mud Creek through the Acquisition Site are particularly high as evidenced from inundation plots for the 5-Year flow event on which the top of berm is still visible along much of its length.
- Significant storage potential exists downstream of the project area in Jackson Park along floodprone areas adjacent to Johnsons Ditch. Further discussion of this potential with the County could provide mutual benefit, as the Park experiences flooding to infrastructure while natural floodplain storage areas go underutilized.

TASK 7: PROPERTY ACQUISITION RECOMMENDATIONS

The purpose of reviewing acquisition potential in the corridor is to identify parcels that would provide additional benefits along the lines of those being pursued on the project sites, and/or other community and environmental benefits.

The majority of undeveloped parcels in the corridor are low-lying, within the floodway and floodplain of Mud Creek, and under existing conditions provide flood storage, stormwater management, habitat and other benefits. Many of these parcels are undevelopable, or marginally developable requiring fill of natural floodplains, streams and wetlands to be made acceptable for such purpose. While modern construction methods and permitting may allow for such activities to occur, sites provide valuable environmental services, including scarce habitat for wildlife with connectivity to the Jackson Park Wetlands, a state Natural Heritage Area, within the urban core of Hendersonville.

In addition, property acquisition may support community open space or greenway development and expand and enhance connectivity and public recreational and educational uses within the corridor. The City and other entities are engaged in the development of recreational and open space access opportunities, including the development of the Above the Mud Greenway Connector, which will connect the Ecusta Trail to the west and the Oklawaha Greenway through Jackson Park to the east. In addition, a planned sidewalk along S. Grove Street will also connect adjacent neighborhoods to the project area. Projects and acquisition have potential to benefit minority and low-income communities based on the NCDEQ Community Mapping System (Appendix C) and outreach to these communities as stakeholders in the development process is encouraged.

The following considerations were reviewed in the assessment of potential acquisition site recommendations:

- Flood inundation areas and depths,
- Stream, floodplain and/or buffer restoration opportunities,
- Stormwater management opportunities, and
- Adjacency to public lands or corridors,

A map and table of potential sites of interest for acquisition was prepared. The table is presented below with the accompanying map in Appendix C.



Potential Sites of Interest for Acquisition

Site ID	# Parcels	# Owners	Approximate Acreage	Rationale/Comments
1	3	1	24.9	Restoration opportunities, flood storage, proposed future greenway corridor.
2	7	2	5.9	Contiguous and hydrologically connected to Brevard Church. Stormwater and floodplain restoration opportunities. Protect investment in vegetation management on Brevard Church Site. Potential connectivity to Hwy 176 via NCDOT acquisition.
3	1	1	5.8	Contiguous to Dog Park. Stream restoration potential. Would complement invasives vegetation management on Dog Park Site. Conceptual greenway alignment (Oklawaha) with neighborhood connections to greenway and park. Structures on site were excluded.
4	1*	1	2.3	Hydrologic connectivity to Brevard Church Site, other streams running through site, potential for stormwater retrofit to treat Harris Teeter parking or street runoff.
5	1*	5	8.5	Buffer restoration, potential flood benefits although would need close coordination with agricultural activities, proposed future greenway connection through parcel.
6	multiple*	2 or more	4.5	Limits of proposed acquisition may vary. Purpose is maintenance and/or public access to City-owned Wilson Site. Hydrologic connectivity along Johnsons Ditch, large ponding wetland area.
* See mapping – site consisting of partial parcel, or multiple partial parcels.				

TASK 8: PROJECT OPPORTUNITIES – CONCEPT DEVELOPMENT

During the course of the project, unique funding opportunities for stream and wetland restoration, stormwater management and flood reduction became available via state grant funding programs. In response to this, the project concepts were developed in two phases. The first grant focus was green infrastructure restoration for stormwater management for which reestablishing stream, wetland and floodplain connectivity on the interior of the Wilson and Brevard Church project Sites was proposed. (Note: Due to prior use as a pre-regulatory landfill (see Assessment Memorandum), the Dog Park Site was excluded from these funding pursuits and from opportunity design development in general.) The Proposed Project Map for the Lower Mud Creek Floodplain Restoration depicting these activities is provided in Appendix C.

The conceptual design plan for the sites is to realign UT1 & the combined UT2/Johnsons Ditch channel through the interior of their respective sites by removal of existing berms, reconfiguring channels to reduce their cross-sectional area, promoting sand transport within the low flow channels and frequent overbank access from storm events. This will allow storm flows to access the broader floodplain and wetland areas within site interiors. Stormwater benefits are anticipated to be realized by allowing storm flows to spread out into these areas. Vegetation management is planned in the buffer and wetland areas and the stream alignments were selected to coincide with more disturbed areas of the sites with less favorable riparian and wetland vegetation conditions. A third stream (likely a historic agricultural



ditch) originating on the Brevard Church Site, UT3, is also being proposed for restoration to reduce erosion and treat non-native invasive species proliferating on its banks. Potential improvement of the alignment and flows through the downstream culvert under South Grove Street is a secondary target activity.

Considerations addressed by the planning and preliminary design completed under the current scope of the work include:

1. **Adequate Sizing** – As provided in the earlier section on Tributary and Local Stormwater Hydrology, floodplain infiltration areas are of commensurate size to handle 1" rainfall volumes from their respective watersheds. Some refinement of ponding limits, and corresponding grading and shaping of storage areas, is proposed to provide maximum treatment potential. Further evaluation of soils and water table elevations is recommended to refine proposed grading.
2. **Recommendations for Preliminary Maintenance Considerations** – The stream, wetland and stormwater infiltration areas will be planned to consider vegetation, sediment & debris and other potential maintenance. On the Wilson site, access will be a primary consideration that must be addressed early in the design process. Maintenance of existing facilities such as sanitary sewer, other utilities, and potential future greenways, bridges or other infrastructure should also be considered. The implementation grant proposal included post-project invasive species management as well as operation and maintenance plan development.
3. **Permitting Considerations** – 404/401, erosion control and floodplain development permitting through no-rise will be required. No 404/401 cultural or species constraints have been identified based on preliminary review. However, the project will require that agency scoping letters and formal field reviews and writeups be completed to ensure that all National Historic Preservation Act and Endangered Species Act requirements are met. For floodplain permitting, while an iterative no-rise modeling process is anticipated, most activities are targeted to affect higher frequency, smaller flows and to maintain high flow capacity for large events. Flood modeling will demonstrate no-rise for the base flood while increasing storage for more frequent storms in order to achieve targeted flood reduction and stormwater treatment. 1-d modeling may have limitations in depicting hydraulic behavior in the corridor and a more robust modeling effort may be required for the demonstration of a no-rise condition.

The second grant focus was flood reduction. For this, flood reduction concepts were developed to overlay and complement the previously proposed stormwater and natural infrastructure restoration techniques. The primary focus of flood reduction concepts was to enhance streambank and existing berm treatments to facilitate floodplain activation and flood storage under lower magnitude higher frequency flood events. Opportunities that were layered onto the restoration plan include storage of UT1 floodwater on the Wilson Site by using the proposed greenway path through the site and proposed Johnsons Ditch outlet modifications as restrictive points for management of high frequency flow events. In addition, multiple bank restoration sites were identified on the Wilson, Brevard Church and Acquisition Sites. Activities will include regrading of eroding banks and selective berm removal or lowering of the berm heights to facilitate floodplain activation and flood routing goals and objectives, to be further refined and determined by more detailed hydraulic modeling evaluation. The proposed activities are depicted in Appendix C on the figure for Lower Mud Creek Floodplain Restoration and Flood Reduction, and include implementation of flood control structures which may consist of ditch plugging, low flow outlet control weirs or other simple devices to enhance flood storage under low magnitude high frequency storm events. In addition, the proposal for the flood reduction grant included



additional invasives treatment in other flood storage areas and along mainstem bank restoration areas that were not included under the first grant proposal. Site existing conditions photos and proposed treatment captions are presented in the Appendix C Lower Mud Creek Photo Log. This grant also included a request for funding for purchase of the Acquisition Site downstream of South Grove Street, and consideration and modeling of additional flood storage potential on the Dog Park Site as well as in the downstream Jackson Park adjacent to Johnsons Ditch.

On the Acquisition Site, future phase 2 implementation work may incorporate more elaborate outlet control modification of relief structures which consist of aging corrugated metal pipes, potentially in need of replacement. Significant flood storage potential exists provided that backwater for lower magnitude events can be limited to acceptable levels and adequately controlled with reliable and maintainable outlet control works.

As discussed under the property acquisition section, multiple ongoing open space planning initiatives are underway in the corridor. These opportunities will be enhanced through improvements to water quality and through benefits of more controlled flood management. Consideration of trail and amenity siting is necessary as part of future project design and development of hydrologic restoration activities in order to avoid future rework to project improvements. Additionally, the City is designing the Mud Creek Interceptor sewer realignment project through the corridor to upgrade aging sanitary sewer infrastructure. Preliminary proposed sewer design has been reviewed, but final design information should be reviewed and used to inform the design of proposed hydrologic restoration activities.

Stormwater Management Opportunities

In addition to the restoration and flood reduction concepts prepared for funding, stormwater management opportunities were reviewed and documented in the table below and on the Stormwater Opportunities Map in Appendix C. Some of these concepts, such as 1 & 2A, are concepts proposed for the aforementioned funding. Opportunities 3A & 3B are primary opportunities for design and implementation on the Acquisition Site (phase 2 of the proposed overall project, for which Goldenleaf grant funding is being pursued). The table below provides a list of potential stormwater management opportunities, with numbers corresponding to Appendix C map.

Mud Creek Stormwater Management Opportunities

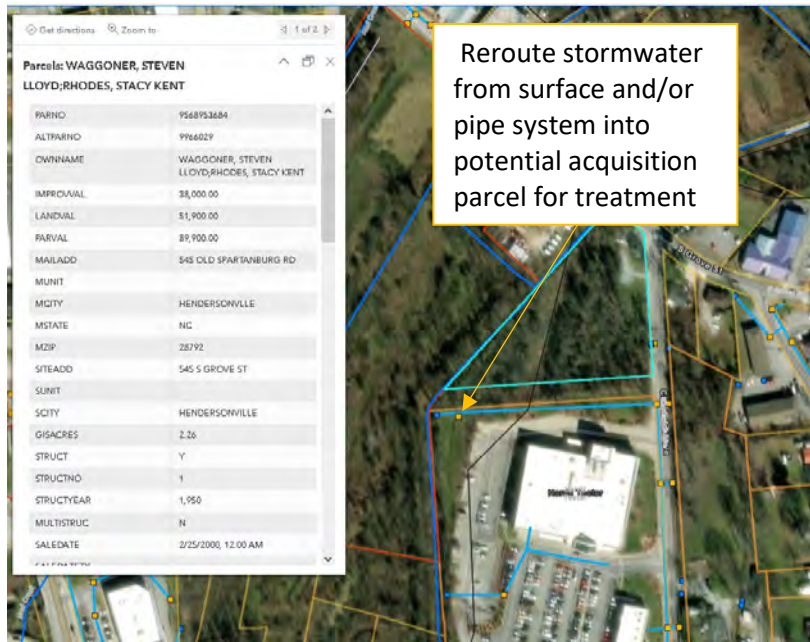
ID	Location	Concept
1	UT1 at Wilson Site	Breach berm on UT1 side of Wilson Site and route stream through floodplain, rather than around site. Design stream with slight perch above adjacent floodplain allowing overtopping storm flows to access adjacent lower lying ponding/storage areas as offline wetland treatment areas. Retrofit Johnsons ditch to provide treatment area during lower flows and only overtop and outflow to maintain outlet flood capacity during larger events.
2A	Johnsons Ditch/UT2 at Brevard Church Site	Breach berm along Brevard Church Site and route stream into interior of site using an area of heavy invasive overgrowth as the target alignment for the stream corridor through the floodplain. Evaluate potential modifications to the two outflows (to Johnsons Ditch and to another UT3) in order to enhance residence time and treatment. Design stream with slight perch above adjacent floodplain allowing overtopping storm flows to access adjacent lower lying ponding/storage areas as offline wetland treatment areas. Retrofit Johnsons



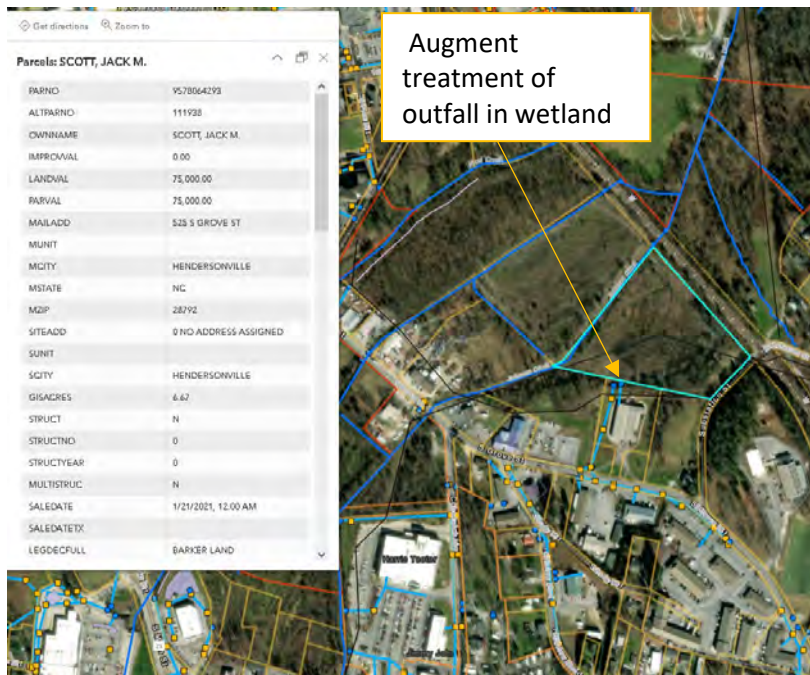
		ditch to provide either treatment, or potential forebay-like, functions. Explore options to expand treatment via opportunity 2B.
2B	Potential Acquisition Site or Footprint of Johnsons Ditch east of Brevard Church Site	Parking lot flow from Harris Teeter enters a grassed area and outflows into Johnsons Ditch. The existing grassed area, or the downstream acquisition parcel 4 on the right floodplain of Johnsons Ditch, or the footprint of Johnsons Ditch with flow relocated to the interior of the Brevard Church Site, could all be suitable retrofit locations for stormwater management. A piped outfall is also shown on City GIS mapping although the outfall was not apparent during field reconnaissance. This opportunity was not evaluated in detail.
3A	Stormwater Outfall East Side Acquisition Site	UT4, flowing through the potential acquisition site 4 discussed under 2B, subsequently flows into Johnsons Ditch and the Acquisition Site below South Grove Street for which funding has been obtained. The Acquisition Site has a ditch that routes flows from the combined UT4 and Johnsons Ditch under the railroad embankment. Modification of the outlet structure and or ditch could provide treatment and flood storage of this 86-acre watershed.
3B	Stormwater Outfall East Side Acquisition Site	Local stormwater runoff from roadways and commercial and residential parcels flows in a pipe network into the funded Acquisition Site. Some level of treatment is already provided as the outflow is into a natural wetland area. Further evaluation of the existing storage volume available in this area relative to the contributing 3A and 3B watersheds should guide opportunity development.
4	City-owned Parcel upgradient of Ingles	Not evaluated under this scope, but identified as a site with potential for stormwater management or watershed enhancement (e.g. streambank or vegetative work). Site could be planted and serve as a pocket park for local neighborhood.
5	Adjacent to CVS and Potential Acquisition Parcels	The outfall elevation of the stormwater pipe draining Hwy 25 runoff is higher than the elevation on the Mud Creek floodplain on the proposed adjacent acquisition site 2, multiple low-lying parcels between CVS and the Brevard Church Site. It may be feasible to reroute stormwater from the end of pipe and/or the outfall of the CVS stormwater control measure to site 2. The pipe system is prone to backwater from Mud Creek and this condition may be improved by routing the pipe system into the currently less floodprone floodplain areas. This backwater is a potential contributor to flooding at the intersection of Hwy 25 / Hwy 176. This concept was not thoroughly investigated.
6	Hwy 176 and Proposed Acquisition Parcels	Similar to opportunity #5, it may be feasible to reroute pipe systems or inlets into the Brevard Church site via acquisition site 2. The potential NCDOT ROW acquisition parcel(s) could play a role in this concept. This concept was not thoroughly investigated.
7	Dog Park Site	Offline treatment areas existing adjacent to UT5 & 6 but work in the area may be constrained by historic dumping in the area.



Opportunities 2B, 3B, 5 & 6 are shown below to document the intended location of stormwater outfall interception and treatment.

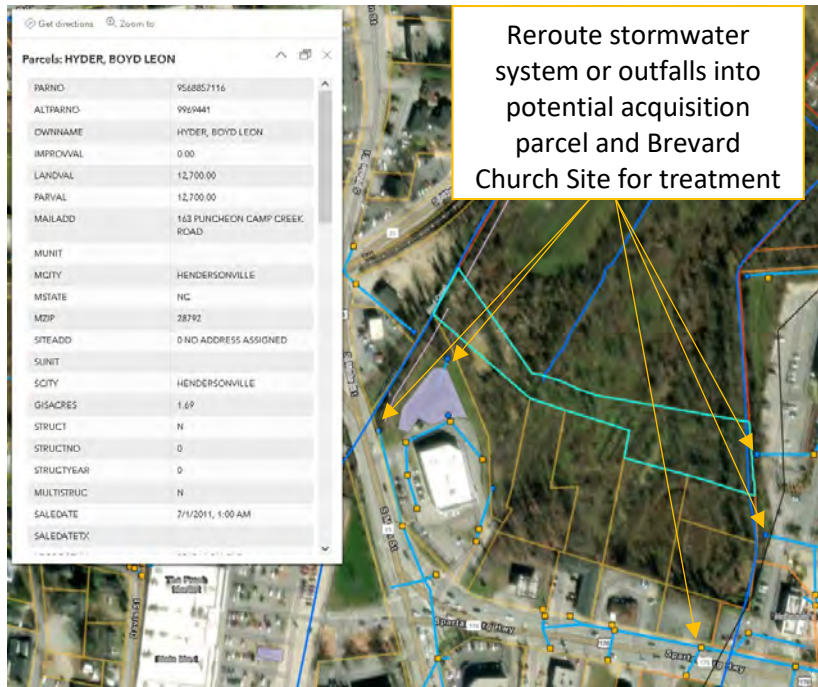


Stormwater Opportunity 2B on Potential Acquisition Site 4



Stormwater Opportunity #3B on Acquisition Site 1





Stormwater Opportunities 5&6 on Potential Acquisition Site 2 and Brevard Church Site



Cost Estimates

In order to support grant requests previously discussed, the following project cost estimates were prepared for the Wilson and Brevard Church Sites reflecting the magnitude and relative level of effort on the sites. Actual costs may vary, but this budget should be used as a baseline to guide proposed efforts. Funding constraints will include match dependent allocations, as well as allocations that pertain to restoration and stormwater-focused grant activities versus those pertaining to flood reduction. Grant narrative and relative information should be reviewed prior to and during project execution at milestones to evaluate compliance with target grant deliverables.

Wilson Site Cost Estimate

Wilson Site Construction Estimate	
Stream, Wetland and Floodplain Restoration	
Contractor Overhead	\$ 68,900
Earthwork Costs (<i>Cut/Fill, tree removal</i>)	\$ 383,000
Erosion and Sediment Control (<i>including matting, pump around where required, and typical ESC</i>)	\$ 55,000
In-stream Structures	\$ 81,000
Stream and Buffer Planting	\$ 61,000
Invasive Species Management	\$ 35,000
Flood Reduction Strategies	\$ 160,050
Construction Oversight	\$ 35,000
Contingency (~10%)	\$ 87,000
Construction Subtotal	\$ 965,950
Soft Costs	
Design & Permitting	\$ 181,500
Survey	\$ 37,800
Grant Management	\$ 49,500
Educational Materials	\$ 4,500
Monitoring & Stewardship	\$ 22,500
Total Soft Cost	\$ 295,800
Total Project Costs	\$ 1,261,750



Brevard Church Site Cost Estimate

Brevard Church Construction Estimate	
Stream, Wetland and Floodplain Restoration	
Contractor Overhead	\$ 76,000
Earthwork Costs <i>(Cut/Fill, tree removal)</i>	\$ 398,000
Erosion and Sediment Control <i>(including matting, pump around where required, and typical ESC)</i>	\$ 55,000
In-stream Structures	\$ 72,000
Stream and Buffer Planting	\$ 59,000
Invasive Species Management	\$ 31,000
Flood Reduction Strategies	\$ 150,800
Construction Oversight	\$ 28,000
Contingency (~10%)	\$ 86,000
Construction Subtotal	\$ 955,800
Soft Costs	
Design & Permitting	\$ 177,000
Survey	\$ 37,700
Grant Management	\$ 49,000
Educational Materials	\$ 4,500
Monitoring & Stewardship	\$ 22,500
Total Soft Cost	\$ 290,700
Total Project Costs	\$ 1,246,500

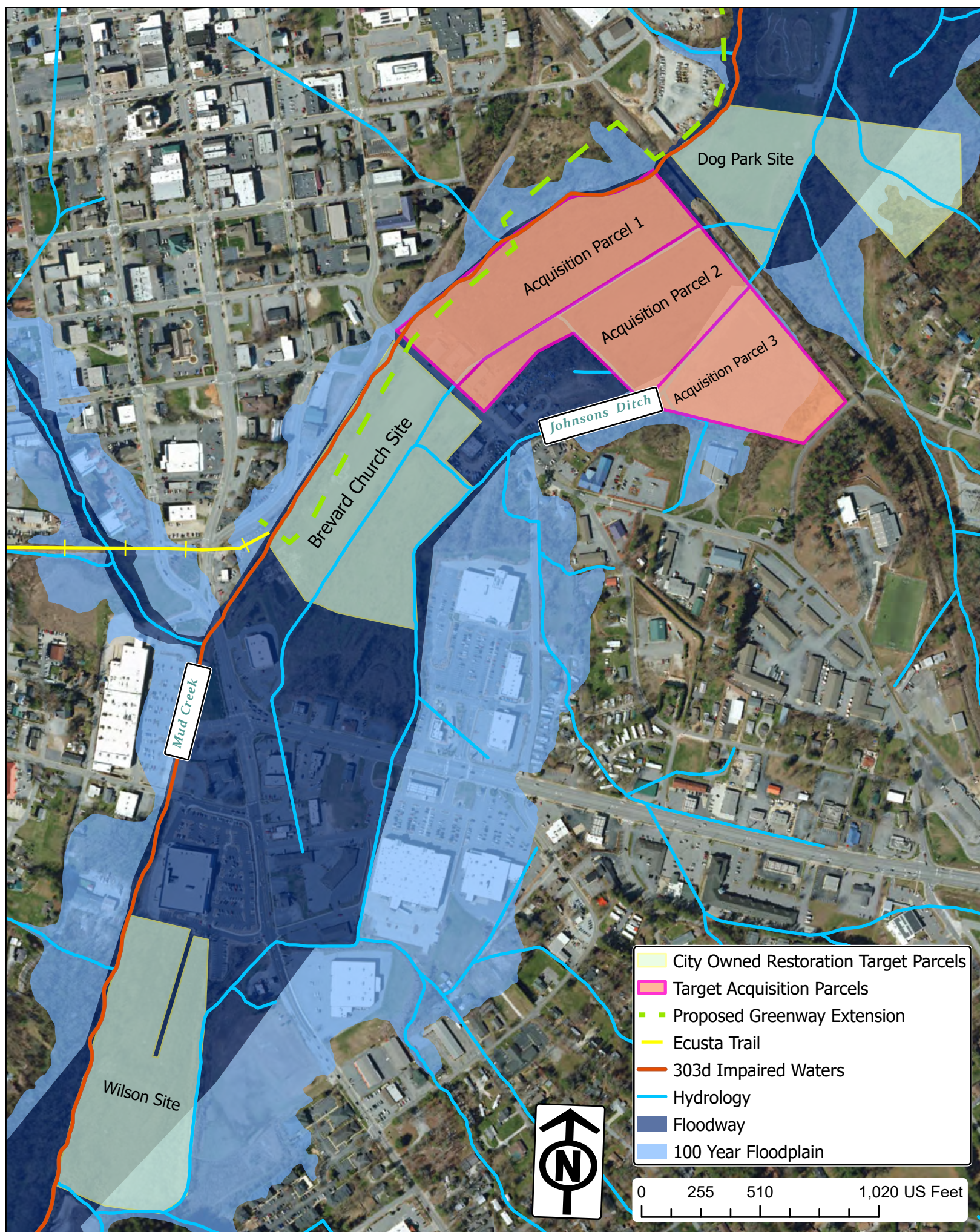


Appendix A.

Project Area Map



2022 NCLWF - Project Area Map



Appendix B.

Hydrologic & Hydraulic Data

Watershed Map

Flood Risk Summary Maps

Preliminary Mud Creek Hydrology and Hydraulics Report



MUD CREEK FLOOD STUDY SOUTHSIDE AREA

STORM PROBABILITY: ONCE EVERY 2 YEARS

KEY FOR BUILDING OUTLINES
(FEMA CALCULATED PROBABILITY OF
FLOODING IN 30 YEAR PERIOD)

<div></div>	<10%
<div></div>	25-50%
<div></div>	75-90%
<div></div>	>90%

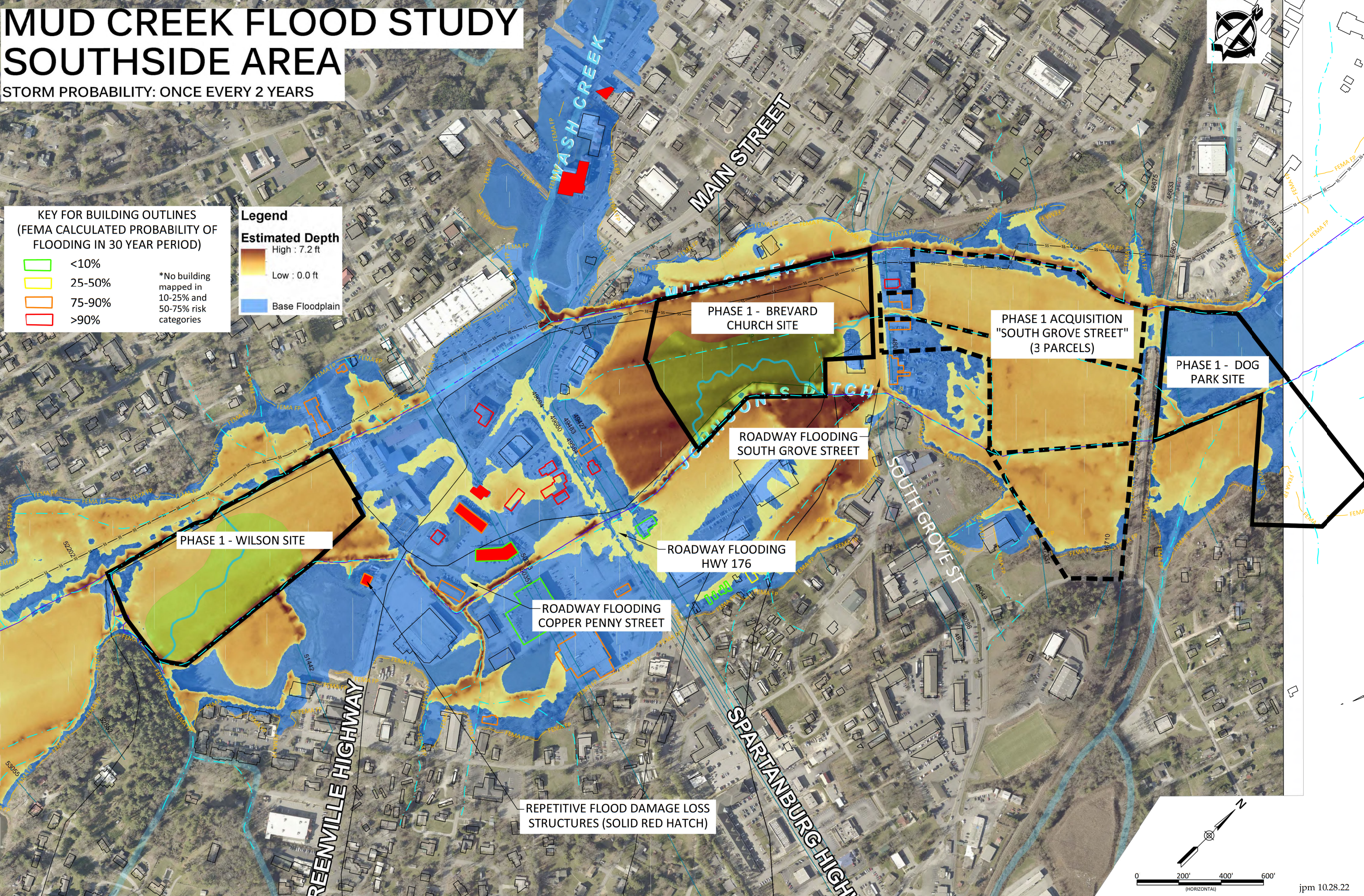
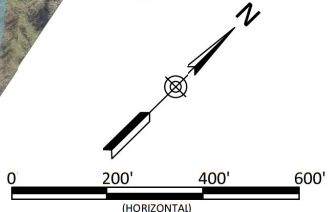
*No building mapped in
10-25% and
50-75% risk
categories

Legend

Estimated Depth

<div></div>	High : 7.2 ft
<div></div>	Low : 0.0 ft

Base Floodplain



Preliminary Mud Creek Hydrology and Hydraulics (H&H) Report
April 27, 2023

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Note About Report

Two-dimensional modeling was prepared to understand the range of flow condition behavior that occurs within this complex setting where the existing one-dimensional FEMA model cannot accurately predict split flow and other complex flow interactions between channels, levies, floodplains and infrastructure. The modeling prepared is based on best available data at the time of this study (LiDAR, GIS and field measurements but has not undergone calibration and quality control checks that will be required during subsequent design efforts. All results should be considered preliminary and are only suitable for preliminary planning and project scoping and should not be used to guide final design or construction.

Wash Creek DA=2.3 sq mi	
Return Interval	Qrural (cfs)
1-yr	50
2-yr	100
5-yr	170
10-yr	220
25-yr	280
50-yr	330
100-yr	390

Mud Creek DA=21.1 sq mi	
Return Interval	Qrural (cfs)
1-yr	470
2-yr	1180
5-yr	2050
10-yr	2720
25-yr	3620
50-yr	4270
100-yr	5060

Tables 1 & 2. Preliminary Hydrology – Mud and Wash Creek Discharges
(Streamstats USGS 1-, 2-, 5-, 10-, 25-, 50-, and 100-Year)

UT2 DA=0.2 sq mi	
Return Interval	Qurban (cfs)
1-yr	30
2-yr	84
5-yr	153
10-yr	207
25-yr	326
50-yr	380
100-yr	433

UT1 DA=0.2 sq mi	
Return Interval	Qurban (cfs)
1-yr	30
2-yr	53
5-yr	105
10-yr	149
25-yr	248
50-yr	298
100-yr	350

Tables 3 & 4. Preliminary Hydrology – Urban Tributary Discharges UT1 & UT2
(Streamstats USGS 1-, 2-, 5-, 10-, 25-, 50-, and 100-Year)

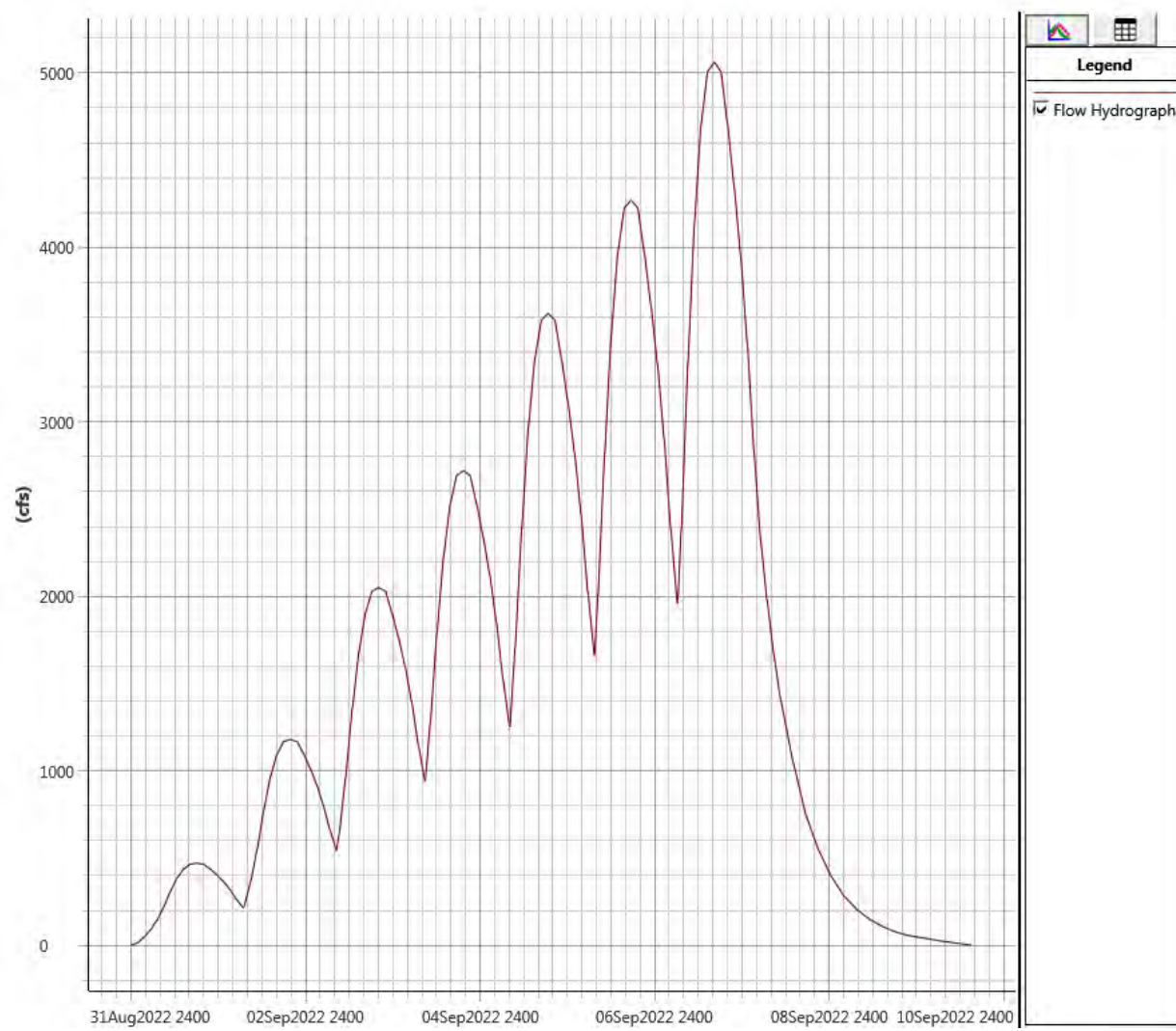


Figure 1. Mud Creek Hydrograph for HECRAS 2-D Modeling
(1-, 2-, 5-, 10-, 25-, 50-, and 100-Year)

Figure 2. UT1 & UT2 Combined Hydrograph for HECRAS 2-D Modeling
(1-, 2-, 5-, 10-, 25-, 50-, and 100-Year)

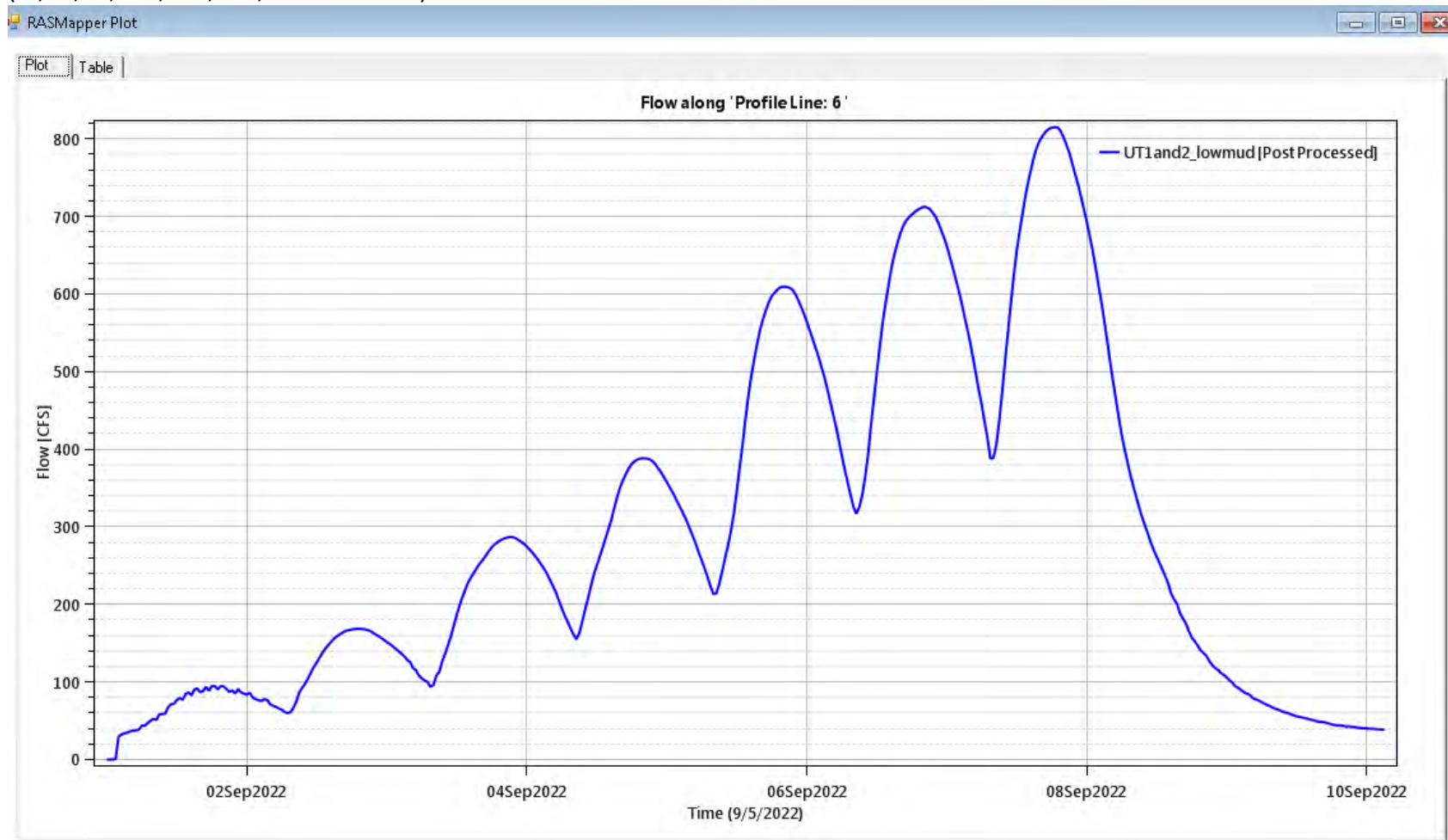


Figure 3 depicts the distribution of flood storage (in blue) in the Mud Creek and Johnsons Ditch watershed for the Mud Creek 1-Year Flood. Project sites are highlighted yellow.

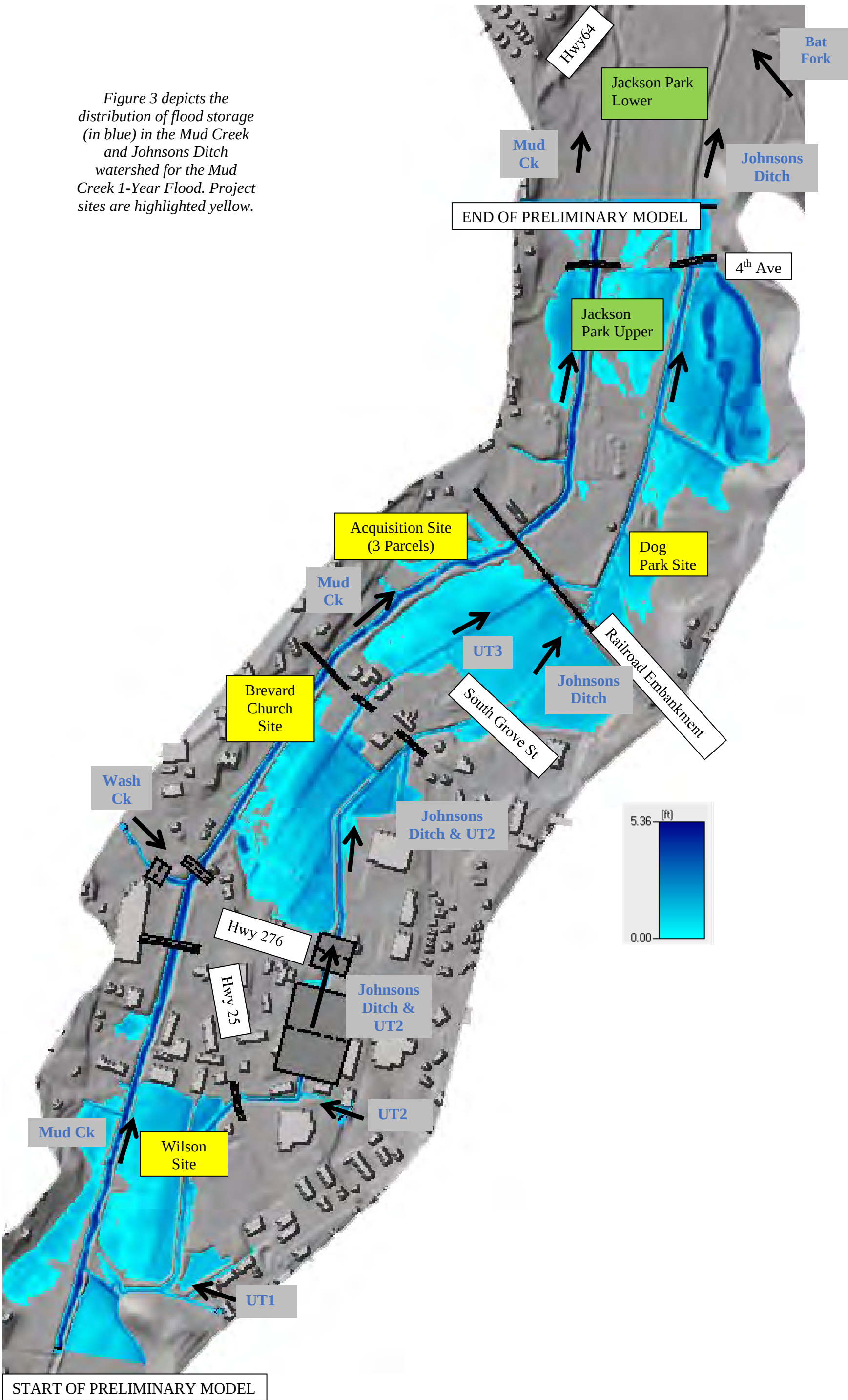


Figure 3. Flood Storage in the Mud Creek / Johnsons Ditch Watershed
Mud Creek Based on Inundation Area for Mud Creek 1-Year Discharge

Figure 4 was data was used to evaluate current hydraulic connections between Mud Creek, Johnsons Ditch and their shared floodplain. Most connections appear to be the result of historic breaches of levy (berm) features.

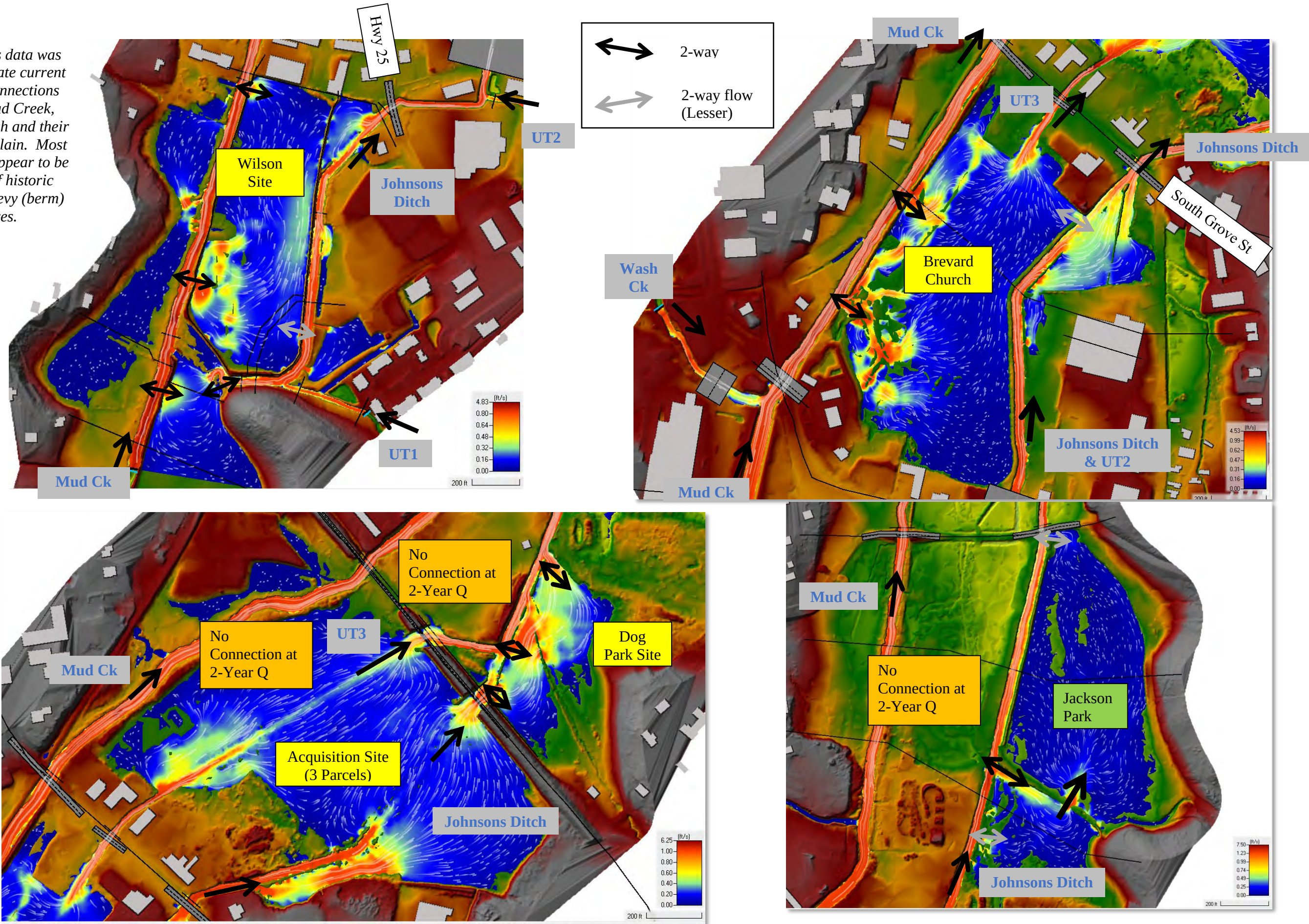


Figure 4. Flow Paths and Existing Levy (Berm) Breaches – Velocities and Flow Paths are for Mud Creek 2-Year Discharge

Figure 5A. Water Surface Elevations for Mud Creek 1-Year Discharge in Vicinity of Wilson Site

Wilson Site Storage Explanation:
For the Mud Creek 1-Year flow event, approximately 6 acre-feet of storage can be added through berm removal activities to raise the WSE from 2086.3 to 2087.0' or greater, and approximately 4-6 additional acre-feet of excavated storage is planned to be incorporated into the Wilson Site design as part of the priority 2 stream restoration of UT1 and associated wetland restoration grading.

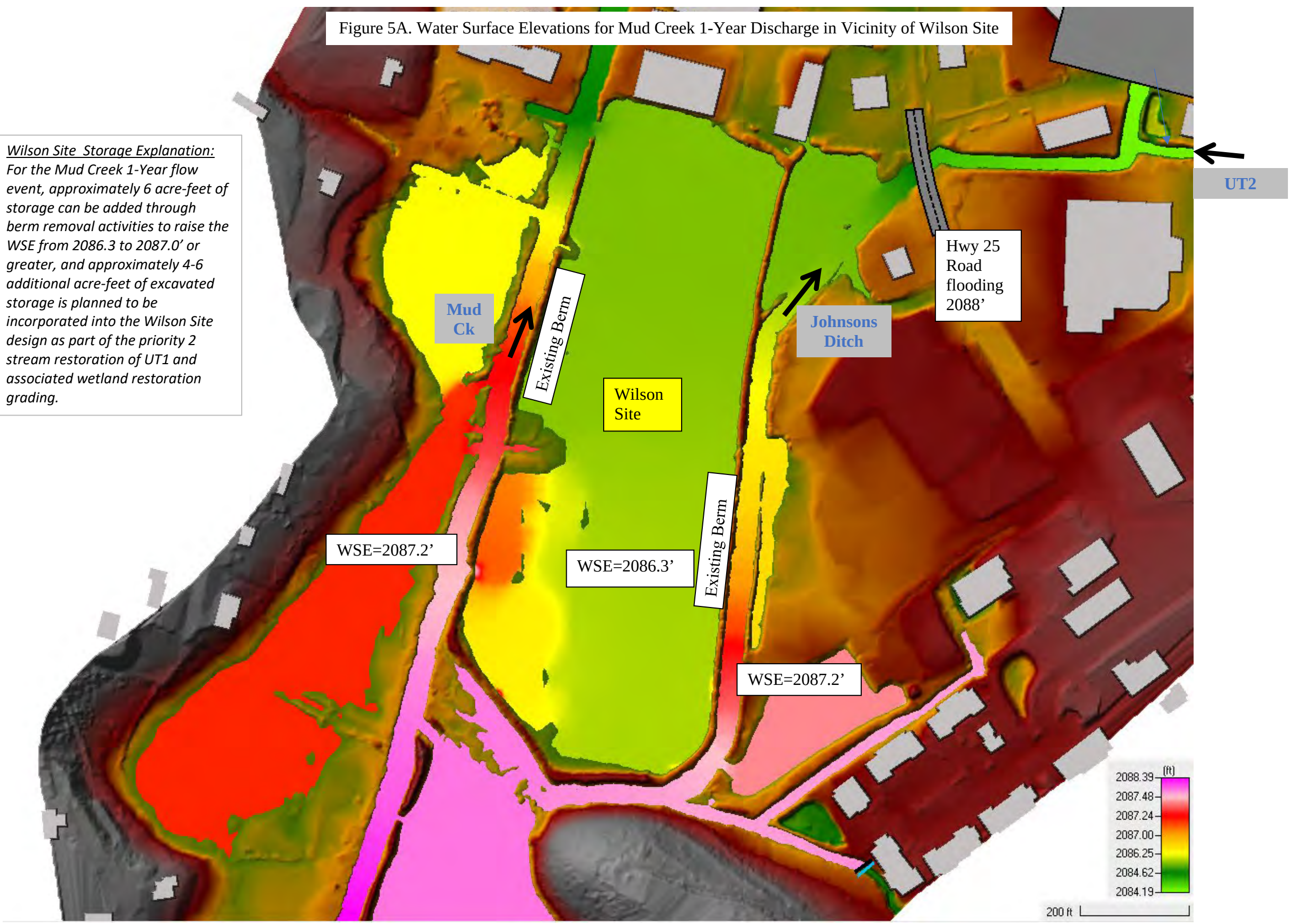


Figure 6A. Water Surface Elevations for Mud Creek 1-Year Discharge in Vicinity of Brevard Church Site



South Grove Acquisition Site (3 Parcels) Storage Explanation:
For the Mud Creek 1-Year flow event, approximately 40 acre-feet of storage can be added through berm removal activities and flow routing efforts on upstream parcels that increase flow and water surface equilization between Mud Creek and Johnsons Ditch in order to raise the elevation of the Acquisition Site WSE from 2081.3 to 2083', or higher. No additional grading is proposed on the Acquisition Site as part of Phase 1 activities.

Figure 7A. Water Surface Elevations for Mud Creek 1-Year Discharge in Vicinity of South Grove Street Proposed Acquisition Parcels (3)

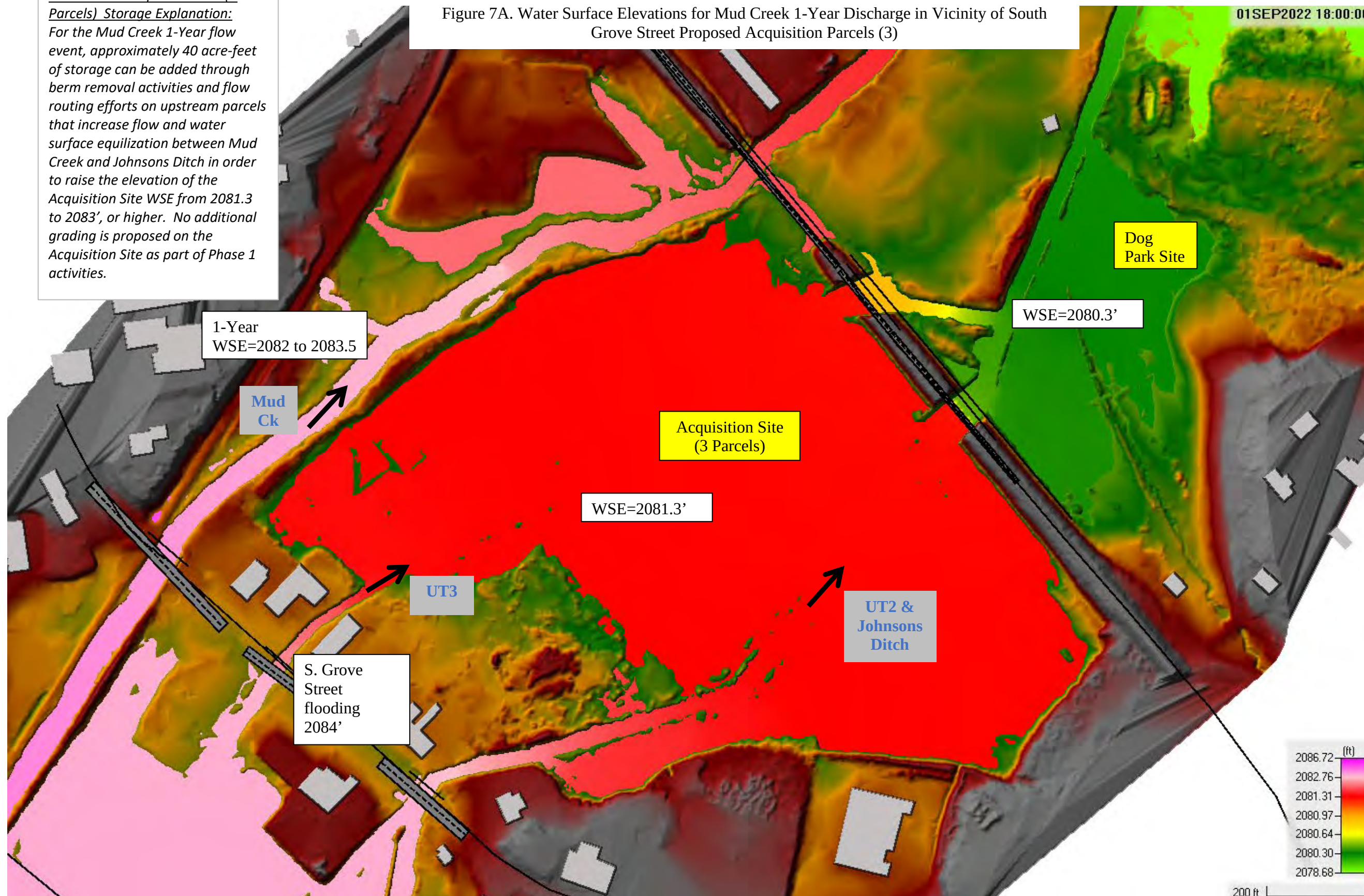


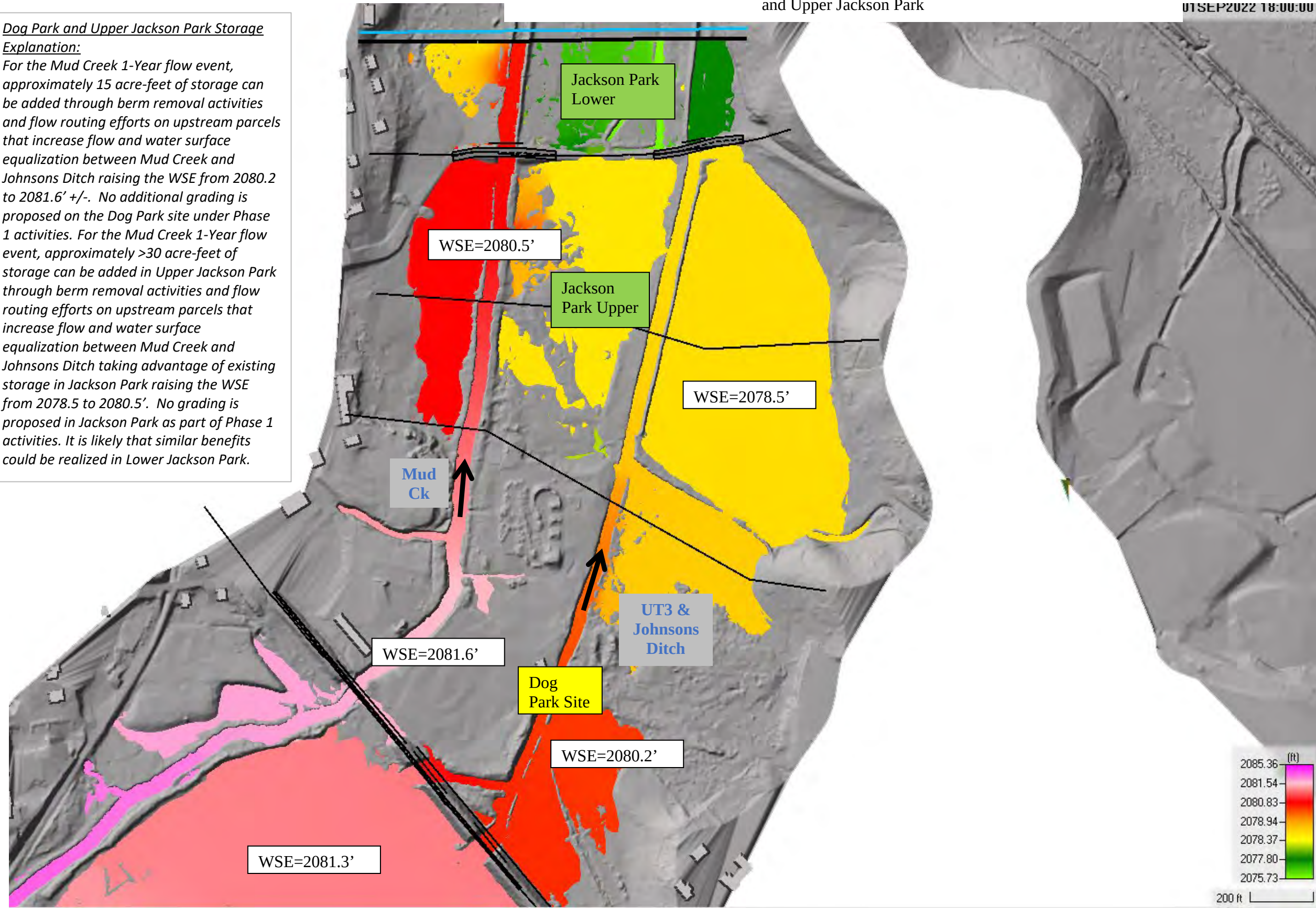
Figure 8A. Water Surface Elevations for Mud Creek 1-Year Discharge in Vicinity of Dog Park and Upper Jackson Park

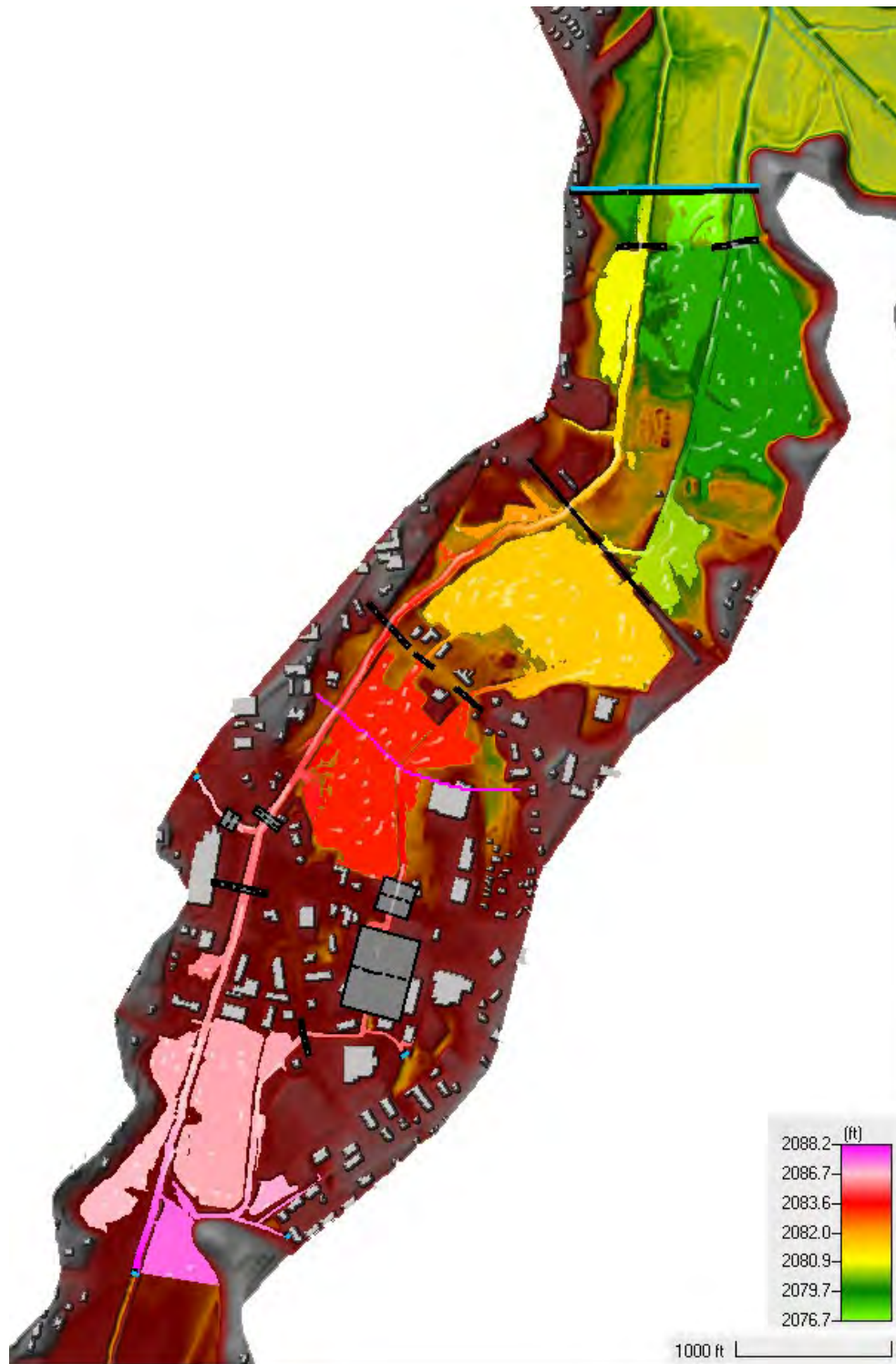
01SEP2022 18:00:00

Dog Park and Upper Jackson Park Storage

Explanation:

For the Mud Creek 1-Year flow event, approximately 15 acre-feet of storage can be added through berm removal activities and flow routing efforts on upstream parcels that increase flow and water surface equalization between Mud Creek and Johnsons Ditch raising the WSE from 2080.2 to 2081.6' +/- . No additional grading is proposed on the Dog Park site under Phase 1 activities. For the Mud Creek 1-Year flow event, approximately >30 acre-feet of storage can be added in Upper Jackson Park through berm removal activities and flow routing efforts on upstream parcels that increase flow and water surface equalization between Mud Creek and Johnsons Ditch taking advantage of existing storage in Jackson Park raising the WSE from 2078.5 to 2080.5'. No grading is proposed in Jackson Park as part of Phase 1 activities. It is likely that similar benefits could be realized in Lower Jackson Park.





Mud Creek 1-Year Flow – 620 cfs
Water Surface Gradients



Mud Creek 5-Year Flow – 2200 cfs
Water Surface Gradients

Figure 9. Comparison of Water Surface Gradients for 1-Year and 5-Year Mud Creek Flows

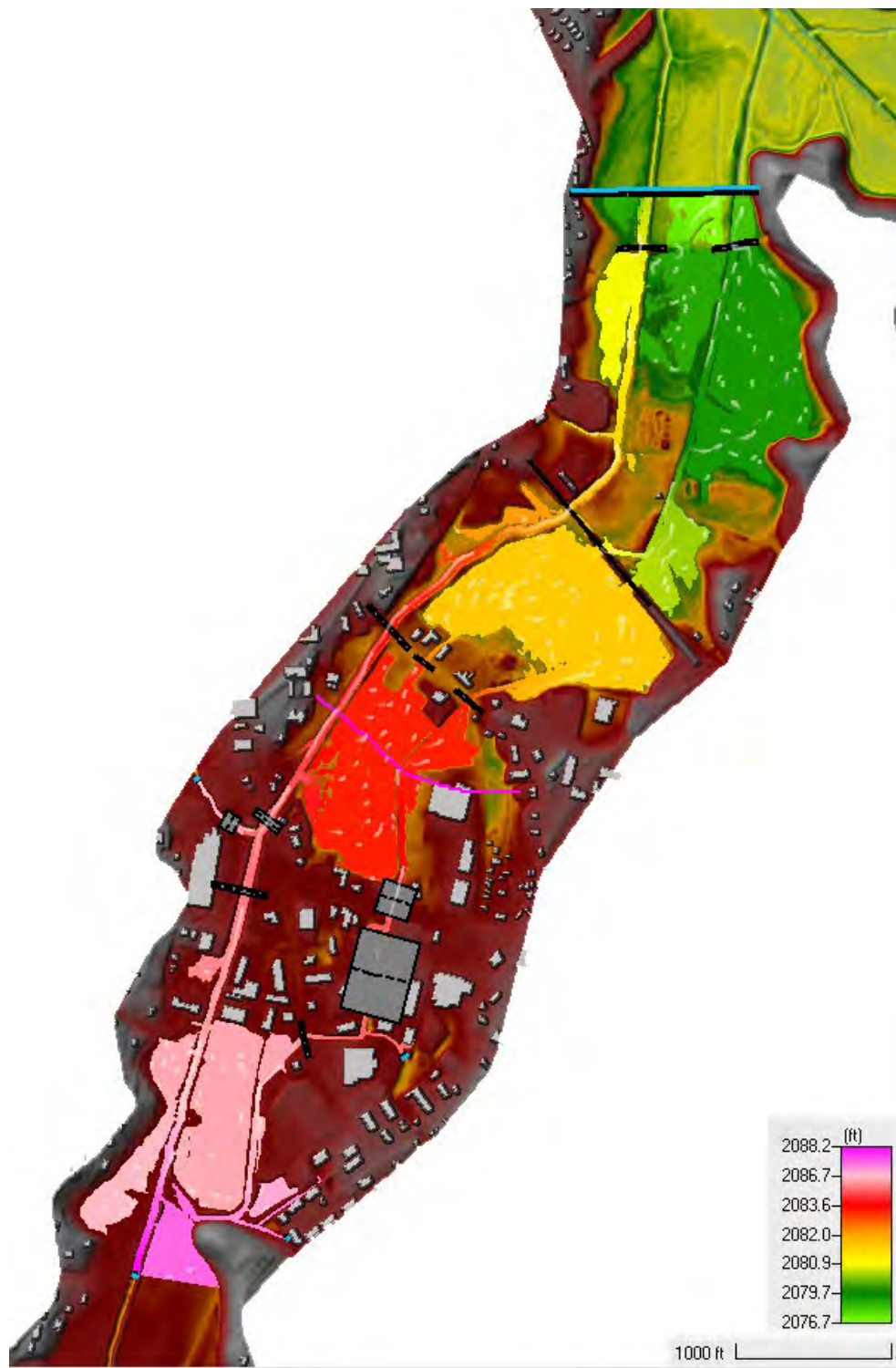


Mud Creek 1-Year Flow – 620 cfs
Water Surface Gradients



Mud Creek 5-Year Flow – 2200 cfs
Water Surface Gradients

Figure 10. Comparison of Water Surface Gradients for 1-Year and 5-Year Mud Creek Flows with Water Surface Labels



Mud Creek 1-Year Flow – 620 cfs
Water Surface Gradients



UT1 & UT2 100-Year Flow – 810 cfs
Water Surface Gradients

Figure 11. Comparison of Water Surface Gradients for 1-Year Mud Creek Flow and 100-Year UT1 & UT2 Flow

Appendix C.

Acquisition and Concept Design

NCLWF Sites of Interest for Acquisition

NCDEQ Community Mapping System Lower Mud Creek

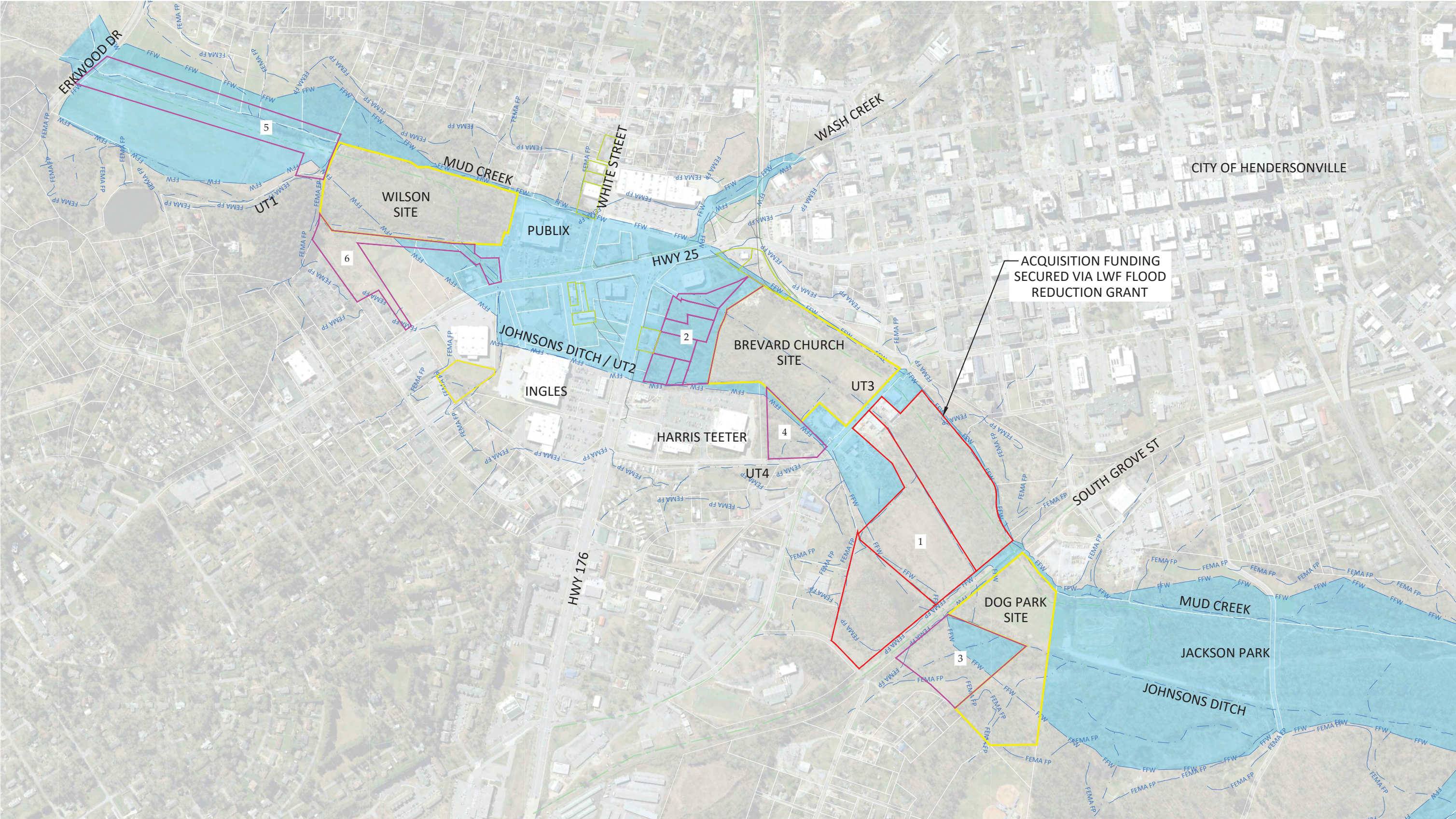
Floodplain Restoration Project Map

Lower Mud Creek Floodplain Restoration and Flood Reduction

NCLWF Stormwater Management Opportunities

Photo Log





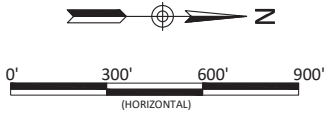
2022 AERIAL

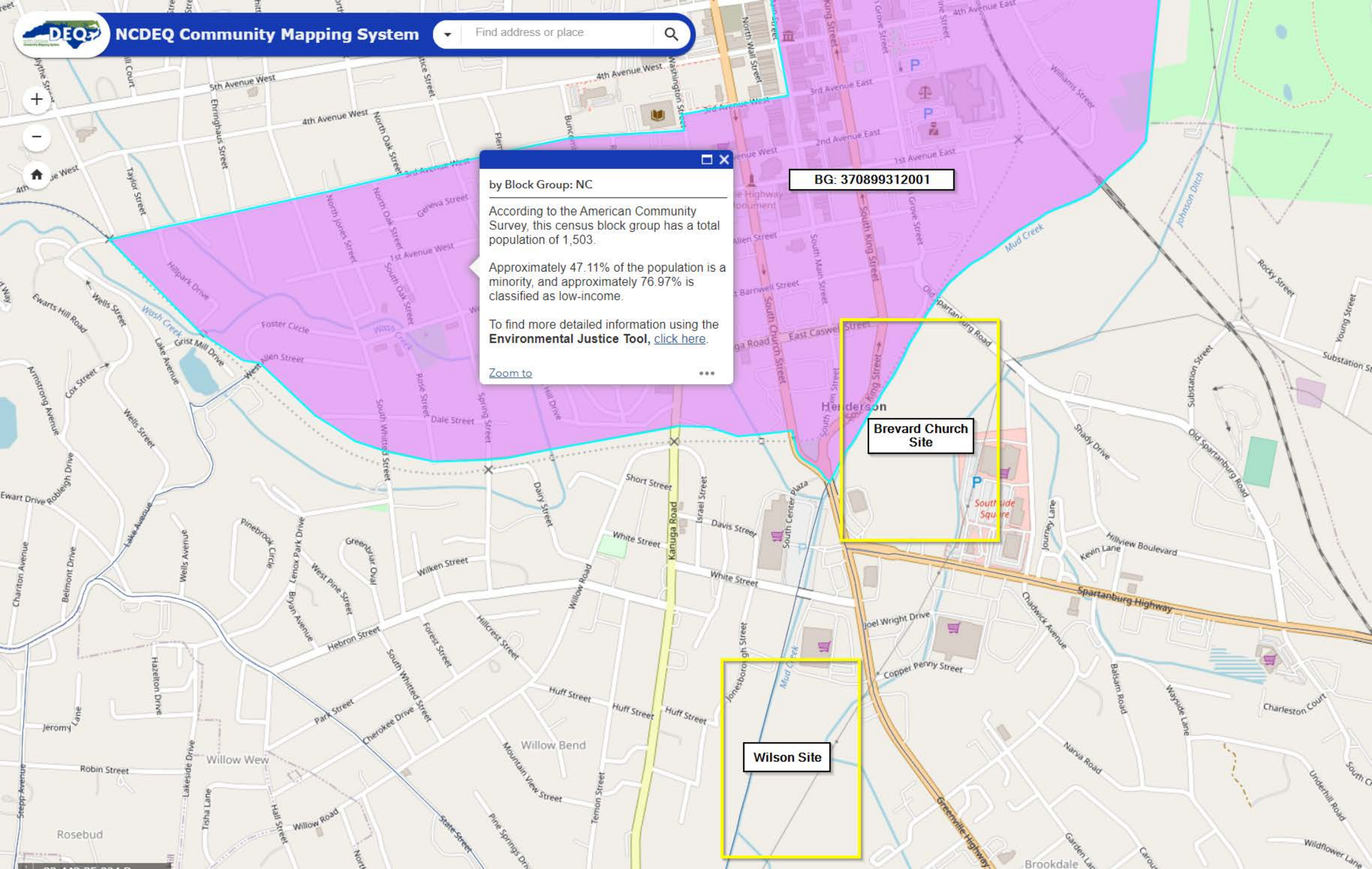
- FEMA FP —
- FFW —
- EXISTING FLOODPLAIN/FLOODWAY (FLOODWAY SHADING NOT SHOWN ON CITY PARCELS)
- EXISTING STREAMS OR FLOW PATHS (NHD)
- PROPOSED GREENWAYS
- CITY PARCELS (IN CORRIDOR)
- PHASE 1 ACQUISITION (FUNDED)
- ACQUISITION PARCEL OF INTEREST
- POTENTIAL ACQUISITION NCDOT (FOR ROW)

- Note:**
1. Landowners identified on this plan have generally not been contacted. Identified sites are preliminary and primarily for the purposes of watershed restoration efforts (stream buffers, floodplain resotration, streambank restoration) or sometimes for additional recreational accses and connectivity based on future anticipated greenway alignments and public open space.
 2. Parcel numbers are referenced in planning project Design Memo.

NCLWF MUD CREEK RESTORATION PLANNING

POTENTIAL SITES OF INTEREST FOR ACQUISITION





by Block Group: NC

According to the American Community Survey, this census block group has a total population of 1,503.

Approximately 47.11% of the population is a minority, and approximately 76.97% is classified as low-income.

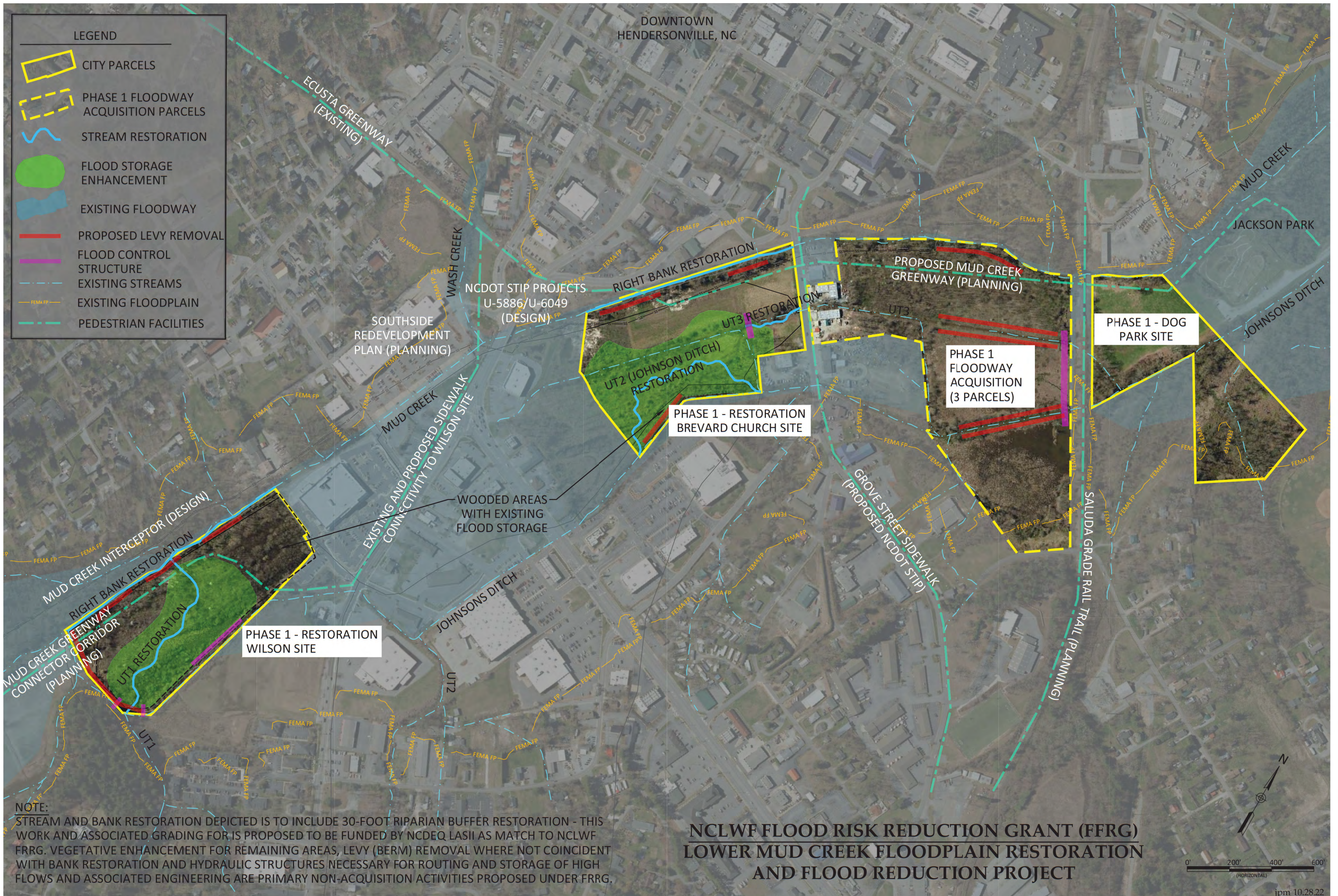
To find more detailed information using the **Environmental Justice Tool**, [click here](#).

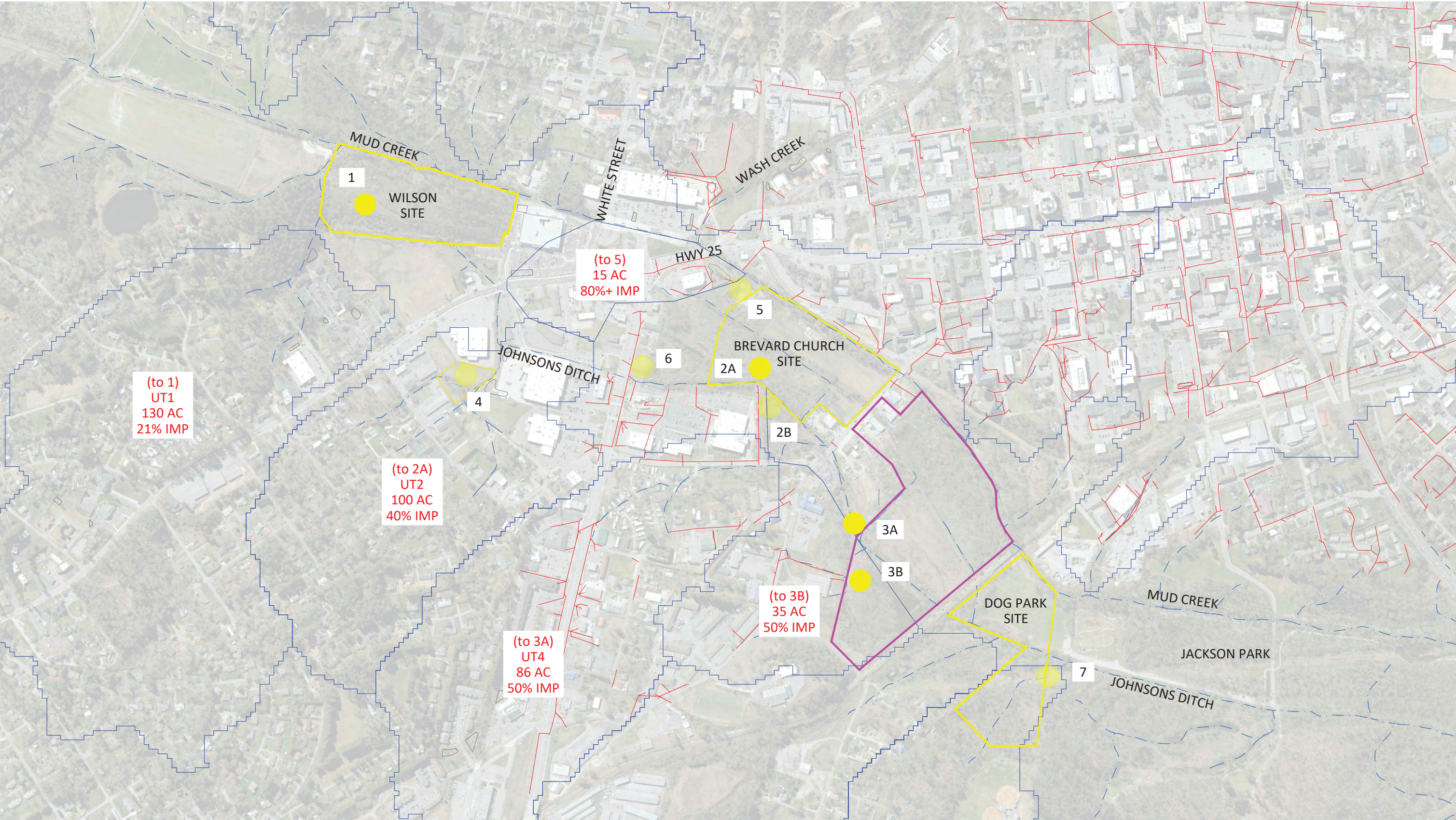
Zoom to

BG: 370899312001

Brevard Church Site

Wilson Site





2022 AERIAL

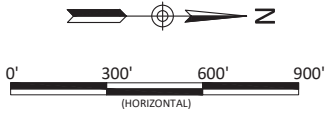
- EXISTING FLOW PATHWAYS (NHD)
- CITY STORMWATER PIPES (GIS)
- CITY PARCELS (IN CORRIDOR)
- ACQUISITION PARCEL
- APPROXIMATE DRAINAGE DIVIDES
- 1 OPPORTUNITY NUMBER (SEE NOTE 3)
- EVALUATED OPPORTUNITY
- OTHER POTENTIAL OPPORTUNITY (NOT EVALUATED)

Notes:

1. Impervious acreages are from Streamstats or visual estimates for planning purposes only.
2. Drainage delineations are approximate based on streamstats and LiDAR topography as well as GIS stormwater mapping.
3. Stormwater opportunity numbers are referenced in planning project Design Memo.

NCLWF MUD CREEK RESTORATION PLANNING

STORMWATER MANAGEMENT OPPORTUNITIES



Lower Mud Creek Floodplain Restoration Photo Log



Photo 1 – Mud Creek – right bank to be graded



Photo 2 – Mud Creek – right bank invasives removal and buffer reestablishment



Photo 3 – UT1 - historically ditched with heavy sand deposition to be restored



Photo 4 – Northern end of site is forested and serves as reference for restoration



Photo 5 – Remove invasives reestablish riparian buffer and forested wetlands



Photo 6 – Invasives will be treated on Johnson Ditch and UT1/Mud Ck Floodplain



Photo 7 – UT2 (also Johnson Ditch) near beginning of restoration reach



Photo 8 – Looking upstream at UT3 restoration reach (across road)



Photo 9 – A smaller channel will replace slough conditions on Johnson Ditch (UT2)



Photo 10 – The restoration will remove invasives and create stable wood features rather than unstable brush jams



Photo 11 – Mud Creek – invasives removal and buffer reestablishment



Photo 12 – South Grove Street sidewalks will connect community to the site



Photo 13 – Aerial of Wilson Site looking north



Photo 14 – Aerial of Brevard Church Site looking north