



**North Central Texas  
Council of Governments**

# **Integrating Transportation and Stormwater Infrastructure**

## **Benefit-Cost Analysis and Return-on-Investment Considerations**

*September 2026*



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# Upper Trinity River Basin Transportation–Stormwater Infrastructure Plan

## Economics Appendix

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### 1 Executive Summary

This appendix summarizes the approach and results of an economic analysis of the Upper Trinity River Basin Transportation - Stormwater Infrastructure Plan, also known as the integrating Transportation Stormwater and Infrastructure (TSI) study or project. This memo documents findings from the first phase of the study, focused on the TSI West project area. The economic analysis estimates the flood damages to structures and roadways based on results from the hydrologic and hydraulic modeling conducted for each watershed in the TSI project area.

Flood damage is projected to rise in the West study area over the next fifty years with continued population growth, development, and associated increase in runoff volumes (from increased impervious area) and increased number of structures at risk.

Following an introduction in Section 2, Section 3 describes existing infrastructure and lands at risk from flooding. Section 4 describes population growth and development anticipated in the region, including a summary of newly constructed structures that may be at risk of flooding based on projected TSI West population growth and development.

Section 5 estimates the costs of inaction, which are estimated based on the damages associated with flooding of structures and roadways under existing conditions and future 2070 conditions without investment in stormwater infrastructure. Section 6 provides a benefit-cost analysis of investments of regional detention projects to store stormwater runoff in regional detention facilities integrated with transportation infrastructure, based on hydrologic and

#### Key Terms

**Storm Event:** Storm defined by the likelihood of an event of its magnitude being equaled or exceeded in any given year. For example, a 100-year storm event is an event with a 1 in 100 chance of occurring in any given year. Five storm events were modeled in this analysis.

**Scenarios:** Each scenario specifies different flow conditions with different levels of flooding for a given storm event. This analysis includes four scenarios.

**Analysis Period:** Period over which costs and benefits are evaluated, the analysis period is defined at 50 years (2027 to 2076).

**Expected Annual Damage:** Average damage that is expected in any given year based on the magnitude of damage from each storm event and the probability of each storm event.

**Discount Rate:** Annual rate to convert values from future years to present year dollars due to society's preference for value today; the discount rate is 3.25%, which means that \$1 year from now is equivalent to \$0.975 this year.

**Annualized Average Damage:** Average annual damage over the period of analysis expressed in current year dollars after discounting of future costs and benefits.

hydraulic (H&H) modeling. Section 7 provides results of a case study buy-out analysis of structures at high risk of flooding in the Mary's Creek watershed. Section 8 discusses the benefits and costs of alternative methods, including floodplain buyouts, nature-based solutions, and green stormwater infrastructure (GSI) to manage (i.e., store or infiltrate) stormwater runoff.

The economic findings are based on the number and type of structures at risk from flooding under different flow conditions and storm events. Five storm events were modeled: 2-year, 10-year, 50-year, 100-year, and 500-year events. Two flow conditions were modeled in the H&H analysis: flows in 2020 and projected increased flows in 2070 (due to additional development in the floodplain and increased runoff from increased impervious cover associated with development). Each of these two flow conditions was modeled under two conditions: no project condition (i.e., no storage of increased runoff and flows), and with project condition (i.e., storage of increased runoff), resulting in four flow scenarios.

1. 2020 Flows, Existing Conditions.
2. 2070 Flows, Future Development Conditions (No Storage of Increased Runoff).
3. 2020 Flows, Existing Conditions with Regional Detention Projects to Store Runoff.
4. 2070 Flows, Future Development Conditions with Regional Detention Projects to Store Runoff.

Two key modeling assumptions drive the results of the H&H analysis and associated economic analysis of flood damage: 1) development continues in and around the floodplain in the TSI West study area based on forecasted land use change associated with population growth and development, and 2) development is not required to store stormwater runoff or offset floodplain fill. To the extent that development is excluded from the floodplain or is offset with compensatory floodplain and stormwater runoff storage, the increased damage over time would be less than projected in this analysis.

#### **Key Modeling Assumptions**

##### **Unrestricted floodplain**

**development:** Development continues in and around the floodplain in the TSI West based on forecasted land use due to population growth and development, and development is not required to store stormwater runoff or offset floodplain fill.

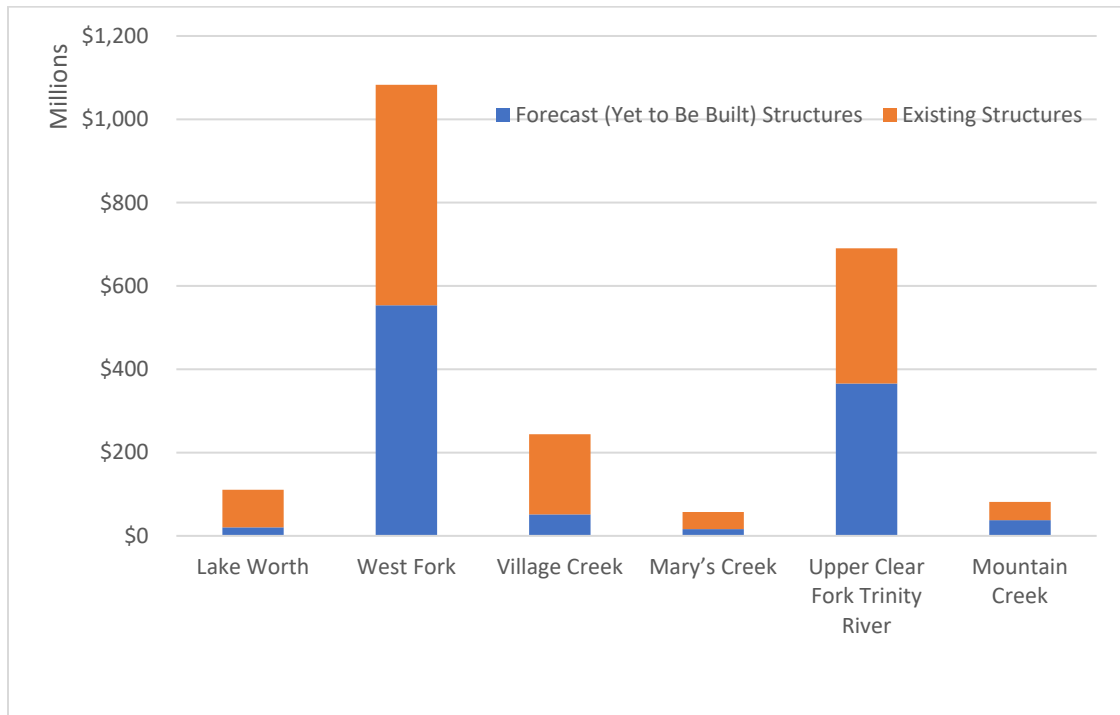
**No mitigation of floodplain fill or stormwater runoff:** The analysis estimates stormwater flow impact of development without mitigation.

Key conclusions include the following:

- **Development in the floodplain will lead to high flood damage costs, even with significant investments to manage stormwater and maintain flows at 2020 levels.** Population in the eight counties in the TSI West study area is projected to grow 76% by 2070 from under 5.3 million people in 2019 to over 9.2 million people in 2070. Over 2,000 structures are projected to be constructed within the existing 100-year floodplain in the TSI West study area. Even if flows are maintained at 2020 levels, expected *annual* flood damage to forecasted structures projected to be built by 2070 total \$585.7 million in the year 2070. In addition to incurring flood damage directly, new structures in the floodplain will also contribute to downstream flooding by decreasing floodplain capacity and increasing stormwater runoff.

- **Without restrictions on floodplain development and storage of stormwater runoff from developed areas, expected annual flood damage in the TSI West study area is modeled to total approximately \$1.4 billion annually by 2070 (projected 2070 flow conditions).** If development proceeds as forecast and investments are not made in stormwater storage, then flood damage to forecasted structures will total \$797.5 million by 2070. This is almost 25 percent more than the annual expected flood damage by 2070 to existing structures: \$640.8 million.
- **Increased flows may result in limited additional flooding of roadways.** Modeling projects by that by 2070, there would be 13 additional locations on average annually that would require road closures, and there would also be approximately 13 additional lane miles (for example, 6.5 miles of a two-lane road) affected by flooding. The costs of this flooding and road closures are expected to be relatively minor, both due to the relatively small number of locations and the fact that the increased road flooding will not occur until later in the analysis period (as discounting of future costs results in a smaller value in today's dollars).
- **Allowing floodplain development but investing in stormwater storage to maintain flows at 2020 levels is modeled to reduce flood damage by \$311.3 million by 2070 (compared to projected 2070 flow conditions).** The value of investing in storage to reduce flows and flooding during storm events rises from \$0 in 2020 to \$536 million in 2076; over the next 50 years the annualized expected value of maintaining 2020 flows is estimated at \$92.2 million, or \$2.27 billion cumulatively (present value) across the 50-year period. This indicates that from a flood risk management perspective (and not accounting for other potential benefits), a maximum of \$2.27 billion could be economically justified for investments today in stormwater management in the TSI West study area to maintain flows at 2020 levels. The distribution of these \$2.27 billion of damage across watersheds and across existing and forecasted future structures is presented in Figure ES-1 and Table ES-1. As shown in the Figure, nearly half of all damages are to forecasted (yet to be built) structures. Increased flood damage is modeled to be particularly high in the West Fork watershed and the Upper Clear Fork Trinity River watershed; together these two watersheds account for approximately 78 percent of all forecasted flood damage in the TSI West study area.

**Figure ES-1: Present Value of Increased Damages from 2027 to 2076 due to Increasing Flows, 2026\$**



- Maintaining flows at current levels in Mary's Creek watershed are particularly beneficial for reducing flood damage in areas downstream of the TSI study area.** Effects of flows from the TSI West and North study areas on downstream areas is limited to analysis of the 500-year storm event. Due to the low probability of a 500-year event, the expected annual benefit measured in this analysis of maintaining flows at 2020 levels across the TSI West and North study areas is low (approximately \$0.5 million by 2070). However, the analysis indicates that approximately three-quarters of the benefits to downstream areas are from maintaining flows at 2020 levels in the Mary's Creek watershed. Further analysis of downstream benefits (i.e., analysis of reduction in flooding in all storm events) may indicate a substantial, additional benefit of storage in the Mary's Creek watershed above the findings in this analysis.

**Table ES-1: Increased Expected Annual Damage from 2027 to 2076 in TSI West Study Area from Flow Increase**

| <b>Year</b>                                | <b>Lake Worth</b>    | <b>West Fork</b>       | <b>Village Creek</b> | <b>Mary's Creek</b> | <b>Upper Clear Fork Trinity River</b> | <b>Mountain Creek</b> | <b>Total, Modeled TSI West Study Area</b> |
|--------------------------------------------|----------------------|------------------------|----------------------|---------------------|---------------------------------------|-----------------------|-------------------------------------------|
| 2020 (H&H Modeled Year)                    | \$0                  | \$0                    | \$0                  | \$0                 | \$0                                   | \$0                   | \$0                                       |
| 2027                                       | \$1,000,000          | \$5,900,000            | \$2,100,000          | \$400,000           | \$3,400,000                           | \$500,000             | \$13,300,000                              |
| 2050                                       | \$4,600,000          | \$34,900,000           | \$10,000,000         | \$2,200,000         | \$21,300,000                          | \$2,800,000           | \$75,800,000                              |
| 2070 (H&H Modeled Year)                    | \$11,400,000         | \$154,200,000          | \$25,900,000         | \$6,700,000         | \$102,000,000                         | \$11,100,000          | \$311,300,000                             |
| 2076                                       | \$16,200,000         | \$268,800,000          | \$38,100,000         | \$10,300,000        | \$183,700,000                         | \$18,900,000          | \$536,000,000                             |
| Average Annualized Damage, 2027-2076       | \$4,500,000          | <b>\$44,100,000</b>    | \$9,900,000          | \$2,300,000         | \$28,100,000                          | \$3,300,000           | \$92,200,000                              |
| <b>Present Value Damages, 2027 to 2076</b> | <b>\$110,700,000</b> | <b>\$1,082,900,000</b> | <b>\$244,100,000</b> | <b>\$57,300,000</b> | <b>\$690,200,000</b>                  | <b>\$81,600,000</b>   | <b>\$2,266,800,000</b>                    |
| <b>Present Value % by Watershed</b>        | <b>5%</b>            | <b>48%</b>             | <b>11%</b>           | <b>3%</b>           | <b>30%</b>                            | <b>4%</b>             | <b>100%</b>                               |

Source: Highland Economics analysis of H&H modeling results.

1/No benefits estimated for 2020 as flow conditions in all scenarios are the same in 2020.

- **Of ten regional detention projects modeled in TSI West, preliminary cost benefit analysis indicates that** five projects may provide sufficient avoided flood damage benefits to justify construction. These five projects have benefit-cost ratios at 0.8 or above, with at least one project in each of the following four watersheds: Mary's Creek, Mountain Creek, Upper Clear Fork Trinity, and Village Creek. Table ES-2 provides summary cost and benefit (avoided flood damage) results for each modeled project. Projects may be designed to provide other benefits, particularly recreation, aesthetics, habitat, urban heat island mitigation, and other open space benefits.<sup>1</sup> As discussed in the TIS economic literature review, these types of benefits may be significant, particularly if the project design includes restoration of vegetation and aesthetic or recreation elements.

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<sup>1</sup> Due to the types of soils and depth of aquifers used for water supply in the region, without additional investment in such systems as aquifer storage and retrieval (ASR) there are not expected to be measurable waters supply benefits from groundwater recharge at regional detention projects. Further, there may be pedestrian or cycling transportation benefits if trails along the river corridor are included and connected to existing trail networks as part of the regional detention project design.

**Table ES-2: Summary of Modeled Regional Detention Project Benefits and Costs**

| Project Name                                           | TSI Incremental Project Cost <sup>a</sup> | Buyout Cost (Structures with Induced Flooding) | Estimated Total Cost | Modeled Reduced Flood Damage, Present Value | Benefit Cost Ratio |
|--------------------------------------------------------|-------------------------------------------|------------------------------------------------|----------------------|---------------------------------------------|--------------------|
| <b>MARY'S CREEK WATERSHED</b>                          |                                           |                                                |                      |                                             |                    |
| Little Mary's Creek at FM 3325                         | \$4,800,000 <sup>b</sup>                  | \$0                                            | \$4,800,000          | \$1,600,000                                 | 0.3                |
| Mary's Creek at FM 3325                                | \$2,200,000                               | \$1,600,000                                    | \$3,800,000          | \$14,300,000                                | 3.8                |
| South Mary's Creek at IH-20                            | \$3,500,000                               | \$0                                            | \$3,500,000          | \$600,000                                   | 0.2                |
| Little Mary's Creek Tributary at FM 3325               | \$4,500,000 <sup>b</sup>                  | \$0                                            | \$4,500,000          | \$1,600,000                                 | 0.4                |
| <b>MOUNTAIN CREEK WATERSHED</b>                        |                                           |                                                |                      |                                             |                    |
| Mountain Creek at CR 616                               | \$19,200,000                              | \$2,100,000                                    | \$21,300,000         | \$4,200,000                                 | 0.2                |
| Mountain Creek at FM 2738                              | \$10,700,000                              | \$1,100,000                                    | \$11,800,000         | \$10,500,000                                | 0.9                |
| <b>UPPER CLEAR FORK TRINITY WATERSHED</b>              |                                           |                                                |                      |                                             |                    |
| Clear Fork at Sarra Ln                                 | \$21,200,000                              | \$0                                            | \$21,200,000         | \$17,700,000                                | 0.8                |
| Town Creek at Ric Williamson Memorial Highway/Bowie Dr | \$145,600,000                             | \$0                                            | \$145,600,000        | \$15,000,000                                | 0.1                |
| <b>VILLAGE CREEK WATERSHED</b>                         |                                           |                                                |                      |                                             |                    |
| Chambers Creek at Enon Ave/Forest Hill Dr              | \$52,100,000                              | \$0                                            | \$52,100,000         | \$40,300,000                                | 0.8                |
| Village Creek at FM 731                                | \$2,900,000                               | \$5,100,000                                    | \$8,000,000          | \$23,100,000                                | 2.9                |

Source: Project engineer opinion of probable costs, see Section 5 and Appendix 5. Highland Economics analysis of H&H modeling results.

a/The Incremental TSI Cost is equal to TSI Cost minus the Traditional Approach cost for bridge construction. TSI incremental cost includes the cost to purchase land that would be inundated during storm events.

b/The TSI incremental project cost of these two projects is the TSI project cost, not the incremental project cost. A traditional bridge is projected to cost more than a TSI bridge at these locations, but it is not clear if a traditional bridge would be constructed at this location, so the full TSI cost is included for these projects. The TSI incremental cost may be much lower than this cost in which case the benefit cost ratio could change significantly.

- **Site-specific factors result in a wide range in the cost-effectiveness of regional detention projects.** The ten evaluated projects vary widely in storage capacity and in their costs and benefits per AF of storage. Storage capacity at each project ranges from 16 AF to 1,487 AF; benefits range from approximately \$3,000 to over \$500,000 per AF, and costs range from approximately \$14,000 to over \$650,000 per AF (see Table 28 in Section 6).
- **Targeted floodplain buy-out programs of properties in flood-prone locations can be less costly than flood damage through time.** A case study comparing buy-out program costs to avoided flood damage benefit in six areas within the City of Benbrook indicates that there are four areas where modeled flood damage over the next 50 years far exceeds the market value of properties. For these four areas with high benefit-to-cost ratios, localized buy-out programs may significantly reduce flood damage if property owners are amenable to relocating. Relocating can be stressful to property owners and adversely affect community cohesion and social stability, and consequently homeowners may be reluctant to re-locate. These social costs are not quantified in this analysis, nor has

community interest in a buy-out program been evaluated through outreach or stakeholder engagement.

- **In many areas of the study area, floodplain and wetland preservation is likely the least-cost method to manage stormwater and mitigate flood risk.** While costs vary based on many site-specific factors, on average, gray stormwater infrastructure likely has the highest installation cost per unit of stormwater managed compared to other approaches. Furthermore, gray infrastructure does not provide environmental co-benefits as provided by the other approaches.

**Table ES-3: Costs of Different Stormwater Management Approaches (Costs for One Acre-Foot Stormwater Storage Capacity)**

| Stormwater Management Approach                               | Installation Cost <sup>a</sup> , Low | Installation Cost <sup>a</sup> , High | Necessary Land Area (acres)                          | Magnitude of Co-Benefit Over 50 Years (Present Value)                                                   |
|--------------------------------------------------------------|--------------------------------------|---------------------------------------|------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Regional Detention (TSI)                                     | \$6,000                              | \$283,000                             | 0.1 to 0.9                                           | May be substantial if vegetation/habitat is restored and public recreation access provided.             |
| Wetlands                                                     | \$42,000                             | \$474,000 (constructed wetland costs) | 0.67                                                 | ~\$560,000                                                                                              |
| Local Bioretention                                           | \$260,000                            | \$743,000                             | 0.67                                                 | ~\$155,000                                                                                              |
| Street Trees                                                 | \$374,000                            | \$1,742,000                           | 34 acres of canopy or 3 acres of tree root base area | ~\$111.6 million                                                                                        |
| Floodplain Preservation (Purchase of undeveloped floodplain) | \$5,000                              | \$97,000                              | ~2 <sup>b</sup>                                      | May be substantial if vegetation/habitat is preserved or restored and public recreation access provided |
| Gray Stormwater Infrastructure                               | \$4,331,000 <sup>c</sup>             |                                       | N/A                                                  | \$0                                                                                                     |

Sources: Highland Economics analysis of (Jack, Jaber, Heidari, & Prideaux, Green Stormwater Infrastructure for Urban Flood Resilience: Opportunity Analysis for Dallas, TX, 2021; Lofton & Porse, 2025; Lesikar, 2008). Assumes street trees have a storage capacity of 100 cubic feet with 420 square feet of canopy, bioretention and wetland has 1.5 cubic foot of storage capacity per square foot of area, and conservatively assumes natural floodplain has 0.50 cubic foot of storage capacity per square foot of area.

a/. It is important to note that life-cycle operation, maintenance, and repair (OMR) costs can be sizable for both grey and green stormwater infrastructure. OMR costs were not considered in Table 50 because of the variability by location and the fact that OMR costs for regional detention were not estimated. For evaluating cost effectiveness at any one location, life-cycle costs should be considered.

b/ Very conservatively assumes floodplain storage capacity of 0.5 acre-feet per acre; this is based on H&H modeling of Mary's Creek Watershed which indicates that the storage capacity decreases by 0.5 AF per acre across the entire watershed (i.e., the change in storage capacity divided by all acres in the watershed) due to development between 2020 and 2070 conditions. As the entire watershed is not projected to be developed by 2070 and the floodplain has greater water storage capacity than elsewhere in the watershed, the actual storage capacity per floodplain acre is likely much greater and the land cost (installation cost)

much lower per AF of storage capacity.

c/ The original cost was reported as \$10.60 per gallon from Jack et al. (2025), based on the cost to upgrade the system to handle overflow from a 100-year storm, as estimated by Dallas Water Utilities in 2020. We adjusted this cost to 2026 dollars using the RSMeans Cost Index and converted it into acre-feet. We then converted the resulting value into present-value terms using a discount rate of 3.25 percent and a period of 50 years.

## 2 Overview of Approach and Methods

This appendix summarizes the approach and results of an economic analysis of the Upper Trinity River Basin Transportation - Stormwater Infrastructure Plan, also known as the integrating Transportation Stormwater and Infrastructure (TSI) study or project. This memo documents findings from the first phase of the study, focused on the TSI West project area. The economic analysis estimates the flood damage to structures and roadways based on results from the hydrologic and hydraulic modeling conducted for each watershed in the TSI project area.

Flood damage is projected to rise in the West study area over the next fifty years with continued population growth, development, and associated increase in runoff volumes (from increased impervious area) and increased number of structures at risk.

Section 2 of this appendix provides an overview of approach and methods. Section 3 describes existing conditions and structures at risk from flooding, while Section 4 describes future conditions based on projected TSI West population growth and development. Section 5 estimates the costs of inaction, which are estimated based on the damages associated with flooding of structures and roadways under existing conditions and future 2070 conditions without investment in stormwater infrastructure. Section 6 provides a benefit-cost analysis of investments of regional detention projects to store stormwater runoff in regional detention facilities integrated with transportation infrastructure, based on hydrologic and hydraulic (H&H) modeling. Section 7 provides a case study of a buy-out program in the Mary's Creek watershed.

The economic analysis estimates flood damage based on the depth and extent of flooding under different flow conditions, as estimated in the H&H analysis detailed in Section 10 and Appendix 5. The economic findings are based on the number and type of structures at risk from flooding under different flow conditions and storm events. Four flow conditions were modeled in the H&H analysis, and serve as the basis for the economics analysis:

1. 2020 Flows, Existing Conditions (No Storage Projects)
2. 2070 Flows, Future Development Conditions (No Storage Projects).
3. 2020 Flows, Existing Conditions *with Regional Detention Projects to Store Runoff*.
4. 2070 Flows, Future Development Conditions *with Regional Detention Projects to Store Runoff*.

Five storm events were evaluated for each flow condition: 2-year storm, 10-year storm, 50-year storm, 100-year storm, and a 500-year storm. With five storm events for each of four flow condition, there were twenty different flood scenarios analyzed. These twenty scenarios were analyzed at the watershed level. There are six watersheds in the TSI West study area: Mary's Creek, Village Creek, Mountain Creek, Eagle Mountain, West Fork, and Upper Clear Fork Trinity. Initial engineering and H&H analysis of those basins identified suitable locations for regional storage projects; however, no economic analysis of storage projects in the Eagle

Mountain and West Fork was completed as the low level of current development in those watersheds reduces the current flood control benefits in those watersheds (with expected relatively low benefit cost ratios for projects in those watersheds). Therefore, the economic analysis for those two watersheds is limited to evaluation of the costs of the projected changes in flow conditions through time with development.

For each scenario, the following types of flood damage within TSI West study area were estimated:

- Damages to structures, contents, and vehicles.
- Displacement costs to residents and business owners, including dislocation costs and rental costs of temporary lodging and business locations.
- Damages to roadways flooded more than 6 inches.
- Damages to structures in downstream areas located outside of TSI West study area boundaries. Downstream areas were only analyzed for the 500-year flood event, as H&H data were not available for other storm events.

No travel cost damages were estimated as there were relatively few additional road locations projected to experience flooding by 2070 compared to 2020 conditions. No damage to agricultural crops were estimated as there are relatively low average annual flood damage to crops reported in the TSI West study area counties.<sup>1</sup> The total affected daytime and nighttime populations are estimated for affected structures, but due to time and budget constraints the analysis does not estimate social or economic costs associated with public health, community cohesion, social or emotional well-being, or loss of income due to business disruptions. Further, no analysis of the social vulnerability of affected populations was included in the economic analysis.

The time horizon for the economic analysis was fifty years, 2027 to 2076 as the regional detention basins analyzed have a projected life of at least fifty years. Further, the H&H modeling was completed through the year 2070, so forecasting beyond 2076 was considered increasingly speculative. All values presented in this analysis are in 2026 dollars (as of the first quarter of 2026). Values are presented in both present value (value in today's dollars of cost and benefit streams from 2027 to 2076) and in average annualized values (average annual value in today's dollars expected across the 50 years of analysis). A discount rate of 3.25 percent,

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<sup>1</sup> Per data downloaded from the Storm Events database for the years 1990 to 2026 maintained by the National Centers for Environmental Information, part of the National Oceanic and Atmospheric Sciences Administration, accessed online at: <https://www.ncei.noaa.gov/stormevents/>. Also, per data on crop insurance indemnities for the years 1995 to 2024 from the USDA Risk Management Agency as analyzed by the Environmental Working Group, accessed at: <https://farm.ewg.org/cropinsurance.php>, which indicated that on average cross the 30-year period, there were an average annual \$69,000 in crop insurance indemnities paid related to flooding in the TSI West study area counties.

equivalent to the current 2026 federal water resources planning rate, is used in the analysis to estimate present value and average annualized value.

The analysis approach can be summarized in seven steps (see the economics replication report for more detail):

1. **Select key analysis parameters**, including timeframe of the analysis, geographic area of analysis, and discount rate.
2. **Develop with and without project conditions through the period of analysis to estimate the costs and benefits of different management actions.** This includes forecasting future development of structures to align with H&H modeling of future land use and impervious surface conditions in and around floodplain areas.
3. **Coordinate with H&H modelers** to obtain flood depths for all existing and forecasted structures and roadways in the TSI West study area under each of the four flow conditions for each of the five storm events (i.e., 20 different flood scenarios in total). As increased flows generated in the TSI West study area can increase flooding in areas further downstream as well (i.e., the Dallas-Fort Worth metroplex), coordinate with H&H analysts to obtain flood depths for downstream structures in the 2020 and 2070 flow conditions with and without projects.
4. **Estimate monetary damage from flooding of structures and roadways.**
  - a. Estimate damages for each of the 20 flood scenarios using depth-damage functions for structures, contents, vehicles, and displacement. We apply depth-damage functions (DDFs, which estimate percent of damage based on depth of flooding) specific to each structure type to each inundated structure's value to calculate total structural and content damage.
  - b. Estimate annual average expected damages in 2020 and in 2070 with and without projects based on the probability of each flood event. Each storm event has an associated probability of occurrence in any given year (e.g., 1 in 500 for a 500-year storm, or 0.2%). To estimate the total expected average annual damage, the analysis estimates the expected annual damage in storm event intervals, which represent the storm events that could occur between each of the modeled storm events. We assume that the 2-year storm event represents the minimum storm damages. Since the flood damages for the 2-year storm event is non-zero for many structures, this may underestimate total expected annual storm damages.

- c. Estimate expected average annual damages for each year between 2020 and 2076 without projects, then estimate average annual damages for each year between 2020 and 2076 *with* projects. Interpolate each year's expected average annual damages based on relatively constant projected growth and development in the TSI West study area, assume a constant growth rate and linearly interpolate expected annual damages between 2020 and 2070.
  - d. Allocate reduction in flood damages under with project conditions to specific proposed projects in each watershed. Coordinate with H&H modelers to obtain the 'zone of benefit' for each project and attribute the reduction in flooding experienced at each structure to the appropriate project.
5. **Estimate the flood-related costs of inaction (development in and out of the floodplain without stormwater storage) and the benefits of specific proposed storage projects.** Compare the flood damages from 2027 to 2076 when flows are allowed to increase from development relative to the flood damages if flows are maintained at 2020 conditions. This is the cost of no action. Estimate the reduction in damages due to projects and attribute to each project.
  6. **Compare the relative costs and benefits of regional detention projects, localize buyout, GSI, and NBS solutions to limit flood-related damages.** Evaluate and compare the menu of options for maintaining flows at the 2020 levels in the TSI West study area.

Key data sources (see replication report for more detail).

- H&H modeling results developed for the TSI study area.
- National Structure Inventory (NSI), developed and maintained by the USACE.
- Depth-Damage Functions (DDFs) from the current FEMA HAZUS flood damage estimation model that provide estimates of damages for every depth of flooding.
- Texas Parcel dataset, to obtain current market land value at proposed project locations.
- Gross Domestic Product Implicit Price Deflator, obtained from the Bureau of Economic Analysis for converting all dollar values into 2026 dollars.

### 3 Existing Conditions

This section summarizes available data on historical flooding in the TSI West study area, including reported data on property damage claims and data on crop losses. The section then provides estimated flood damage to structures under existing conditions with modeled 2020 flows.

#### 3.1 Historical Reported Flood Damages

Tables 1 and 2 summarize the available data on structural damages from flooding recorded between 1990 and 2025 in the TSI West study area counties. Table 1 presents storm event data from the National Center for Environmental Information (NCEI), a part of the National Oceanic and Atmospheric Administration (NOAA). As shown in Table 1, this data indicates that flood events (including flash flood events) during this time period have caused structural damage of at least \$619.8 million, or on average, approximately \$23.8 million annually. This dataset is based on newspaper articles and other types of reported information and is likely not a complete dataset of storm damage. Table 2 summarizes data from the National Flood Insurance Program for the same period. Claims paid by the NFIP in the TSI West study area have totaled \$143.7 million in nominal dollars (not adjusted for inflation), or approximately \$4 million annually during this period.

**Table 1: Reported Property Damages in Flood Events from 1990 to 2025**

| County  | Flood         | Flashflood   | Total         | Annual Average |
|---------|---------------|--------------|---------------|----------------|
| Dallas  | \$536,270,000 | \$23,212,000 | \$559,482,000 | \$21,518,538   |
| Ellis   | \$120,000     | \$6,416,000  | \$6,536,000   | \$251,385      |
| Hood    | \$1,752,000   | \$2,393,000  | \$4,145,000   | \$159,423      |
| Johnson | \$237,000     | \$3,481,000  | \$3,718,000   | \$143,000      |
| Parker  | \$728,000     | \$8,349,500  | \$9,077,500   | \$349,135      |
| Tarrant | \$224,000     | \$35,205,000 | \$35,429,000  | \$1,362,654    |
| Wise    | \$205,000     | \$1,254,000  | \$1,459,000   | \$56,115       |
| West    | \$539,536,000 | \$80,310,500 | \$619,846,500 | \$23,840,250   |

Source: Highland Economics analysis of National Center for Environmental Information, a part of the National Oceanic and Atmospheric Administration (NOAA), accessed at: <https://www.ncei.noaa.gov/stormevents>

**Table 2: Building and Content Damage Claims, National Flood Insurance Program, 1990 to 2025**

| County Name    | National Flood Insurance Program Claims, 1990 to 2025 |                          |                 | Per Claim Value, 2020 to 2025 |
|----------------|-------------------------------------------------------|--------------------------|-----------------|-------------------------------|
|                | Total Paid Claims                                     | Total Claim Dollars Paid | Per Claim Value |                               |
| Ellis          | 104                                                   | \$5,869,441              | \$56,437        | \$59,040                      |
| Denton         | 324                                                   | \$9,938,243              | \$30,674        | \$42,816                      |
| Dallas         | 1,878                                                 | \$61,566,198             | \$32,783        | \$65,962                      |
| Hood           | 113                                                   | \$3,411,397              | \$30,189        | \$12,433                      |
| Johnson        | 193                                                   | \$4,499,131              | \$23,312        | \$52,230                      |
| Parker         | 176                                                   | \$3,851,232              | \$21,882        | \$44,690                      |
| Tarrant        | 1,864                                                 | \$52,146,385             | \$27,976        | \$40,852                      |
| Wise           | 64                                                    | \$2,427,873              | \$37,936        | \$148,043                     |
| Total          | 4,716                                                 | \$143,709,901            | \$30,473        | \$54,384                      |
| Annual Average | 131                                                   | \$3,991,942              | \$30,473        | \$54,384                      |

Source: Highland Economics analysis of National Flood Insurance Program data, Accessed online at: <https://www.fema.gov/openfema-data-page/fima-nfip-redacted-claims-v2>.

Flooding of agricultural lands can result in several types of damage: crop loss, clean-up costs, and scouring of topsoil with adverse effects on soil fertility. Flooding can also potentially deposit rich alluvial soils that have a positive effect on soil fertility. Within the TSI West study area, including Dallas, Ellis, Hood, Johnson, Parker, Tarrant and Wise Counties, the NCEI reported no storm events (including both flood events and flash flood events) that resulted in crop damage from 1995 to 2024. However, there were crop indemnities paid through the Federal Crop insurance Program, which is a federal program to compensate farmers for declines in crop yields or revenues, including from flood losses. These are presented in Table 3 and indicate approximately \$70,000 annual on average in crop indemnities paid due to flooding in TSI West counties over approximately 30 years. Additional losses could be experienced due to flooding that do not qualify for indemnity payments, or that are not claimed by farmers.

**Table 3: Crop Indemnities Paid for Agricultural Losses from Flooding in TSI West Counties, 1995 to 2024**

| County                        | Flood Losses       | 30-Year Average Annual Flood Losses |
|-------------------------------|--------------------|-------------------------------------|
| Dallas                        | \$317,216          | \$10,574                            |
| Ellis                         | \$200,831          | \$6,694                             |
| Hood                          | \$7,001            | \$233                               |
| Johnson                       | \$0                | \$0                                 |
| Parker                        | \$2,780            | \$93                                |
| Tarrant                       | \$756,679          | \$25,223                            |
| Wise                          | \$777,870          | \$25,929                            |
| <b>TSI West County Totals</b> | <b>\$2,062,377</b> | <b>\$68,746</b>                     |

Data source: Highland Economics analysis of crop indemnity data from USDA Risk Management Agency as reported at: <https://farm.ewg.org/cropinsurance.php>.

### 3.2 Modeled Flood Damage to Structures with 2020 Flows under Existing Conditions

Table 4 summarizes TSI H&H modeling results related to the structures expected to flood under 2020 flow conditions and existing development in the TSI West study area.

**Table 4: Existing Number of Structures Modeled to Flood with 2020 Flows by Storm Event and by Watershed, TSI West**

| Watershed                            | Storm Event  |              |              |              |              |
|--------------------------------------|--------------|--------------|--------------|--------------|--------------|
|                                      | 2-Year       | 10-Year      | 50-Year      | 100-Year     | 500-Year     |
| Lake Worth                           | 140          | 240          | 370          | 420          | 470          |
| West Fork                            | 780          | 930          | 1,360        | 1,670        | 2,680        |
| Village Creek                        | 450          | 560          | 700          | 1,030        | 1,420        |
| Mary's Creek                         | 70           | 160          | 320          | 380          | 530          |
| Upper Clear Fork Trinity River       | 260          | 310          | 480          | 500          | 570          |
| Mountain Creek                       | 170          | 200          | 240          | 290          | 500          |
| <b>Total, TSI West Modeled Areas</b> | <b>1,860</b> | <b>2,390</b> | <b>3,470</b> | <b>4,270</b> | <b>6,160</b> |

Source: Highland Economics analysis of H&H modeling results.

**Table 5: Existing Population Affected by Flooding with 2020 Flows by Storm Event and by Watershed, TSI West**

| Watershed  | Nighttime Population |         |         |          |          | Daytime Population |         |         |          |          |
|------------|----------------------|---------|---------|----------|----------|--------------------|---------|---------|----------|----------|
|            | 2-Year               | 10-Year | 50-Year | 100-Year | 500-Year | 2-Year             | 10-Year | 50-Year | 100-Year | 500-Year |
| Lake Worth | 130                  | 370     | 680     | 810      | 970      | 170                | 350     | 630     | 720      | 820      |
| West Fork  | 3,000                | 14,020  | 19,790  | 22,160   | 26,050   | 1,910              | 8,610   | 11,990  | 13,420   | 15,690   |

|                                      |              |               |               |               |               |              |               |               |               |               |
|--------------------------------------|--------------|---------------|---------------|---------------|---------------|--------------|---------------|---------------|---------------|---------------|
| Village Creek                        | 280          | 600           | 990           | 1,970         | 3,050         | 2,130        | 2,340         | 2,610         | 3,180         | 3,860         |
| Mary's Creek                         | 80           | 320           | 700           | 800           | 1,150         | 470          | 650           | 910           | 970           | 1,100         |
| Upper Clear Fork Trinity River       | 120          | 290           | 770           | 900           | 1,250         | 540          | 660           | 970           | 1,070         | 1,320         |
| Mountain Creek                       | 100          | 160           | 310           | 490           | 1,110         | 1,860        | 1,900         | 1,980         | 2,080         | 2,330         |
| <b>Total, TSI West Modeled Areas</b> | <b>3,710</b> | <b>15,760</b> | <b>23,240</b> | <b>27,130</b> | <b>33,580</b> | <b>7,080</b> | <b>14,510</b> | <b>19,090</b> | <b>21,440</b> | <b>25,120</b> |

Source: Highland Economics analysis of H&H modeling results.

**Table 6: Modeled Existing Damages (Existing Structures with 2020 Flows) by Storm Event and by Watershed, TSI West**

| Watershed                            | Storm Event          |                        |                        |                        |                        | Average Annualized Damages |
|--------------------------------------|----------------------|------------------------|------------------------|------------------------|------------------------|----------------------------|
|                                      | 2-Year               | 10-Year                | 50-Year                | 100-Year               | 500-Year               |                            |
| Lake Worth                           | \$73,500,000         | \$106,600,000          | \$155,600,000          | \$175,500,000          | \$215,400,000          | \$49,700,000               |
| West Fork                            | \$328,600,000        | \$663,300,000          | \$1,026,700,000        | \$1,222,600,000        | \$1,852,400,000        | \$289,500,000              |
| Village Creek                        | \$127,200,000        | \$232,600,000          | \$323,700,000          | \$388,500,000          | \$586,400,000          | \$101,700,000              |
| Mary's Creek                         | \$1,900,000          | \$21,700,000           | \$63,800,000           | \$78,100,000           | \$120,100,000          | \$9,600,000                |
| Upper Clear Fork Trinity River       | \$88,800,000         | \$160,400,000          | \$258,600,000          | \$294,100,000          | \$394,400,000          | \$72,100,000               |
| Mountain Creek                       | \$48,200,000         | \$72,500,000           | \$100,600,000          | \$110,200,000          | \$124,400,000          | \$18,800,000               |
| <b>Total, TSI West Modeled Areas</b> | <b>\$668,200,000</b> | <b>\$1,257,100,000</b> | <b>\$1,929,000,000</b> | <b>\$2,269,000,000</b> | <b>\$3,293,100,000</b> | <b>\$541,400,000</b>       |

Source: Highland Economics analysis of H&H modeling results.

Table 7 presents the modeled flood damage that would occur through the analysis period with no new development and no increased flows. This is the baseline for the analysis – the point of comparison to estimate the costs of increased development without increased stormwater storage. As shown in Table 7, the H&H modeling of flood extent with 2020 flows overlaid with existing development and structures indicates that average annual flood damages may be approximately \$700 million annually, equating over the next 50 years to nearly \$17.2 billion in damages. More than two-thirds of this flood damage under existing conditions are modeled to be experienced in the West Fork and Upper Clear Fork Trinity watersheds.

Flows from the TSI West watersheds also affect flood risk in downstream areas in the Dallas-Fort Worth metroplex. These downstream areas were modeled in the H&H analysis only in the

500-year storm event. Table 8 summarizes the baseline damages in the modeled 500-year storm event in downstream areas under existing conditions (2020 flows). As highlighted in the table, flows from the Mary's Creek watershed play a particularly important role in determining the level of downstream damages: flows from this watershed currently contribute to over 70 percent of the damages in downstream areas.

**Table 7: Modeled Annual Damages in TSI West Study Area Through Time Without Projects, No New Development, 2020 Flows**

| Year                                       | Lake Worth             | West Fork              | Village Creek          | Mary's Creek         | Upper Clear Fork Trinity River | Mountain Creek       | Modeled TSI West Study Area |
|--------------------------------------------|------------------------|------------------------|------------------------|----------------------|--------------------------------|----------------------|-----------------------------|
| 2020 (H&H Modeled Year)                    | \$50,000,000           | \$293,300,000          | \$102,000,000          | \$9,800,000          | \$72,900,000                   | \$19,300,000         | \$547,300,000               |
| 2027                                       | \$50,300,000           | \$296,800,000          | \$102,300,000          | \$9,900,000          | \$73,600,000                   | \$19,700,000         | \$552,600,000               |
| 2050                                       | \$55,000,000           | \$349,800,000          | \$107,000,000          | \$11,800,000         | \$84,500,000                   | \$26,200,000         | \$634,300,000               |
| 2070 (H&H Modeled Year)                    | \$82,800,000           | \$670,100,000          | \$135,200,000          | \$23,400,000         | \$150,000,000                  | \$65,700,000         | \$1,127,200,000             |
| 2076                                       | \$107,200,000          | \$950,800,000          | \$159,900,000          | \$33,600,000         | \$207,500,000                  | \$100,300,000        | \$1,559,300,000             |
| Average Annualized Damage, 2027-2076       | \$59,300,000           | <b>\$390,500,000</b>   | \$113,000,000          | \$13,300,000         | \$93,200,000                   | \$30,700,000         | \$700,000,000               |
| <b>Present Value Damages, 2027 to 2076</b> | <b>\$1,455,600,000</b> | <b>\$9,587,000,000</b> | <b>\$2,775,400,000</b> | <b>\$325,800,000</b> | <b>\$2,288,100,000</b>         | <b>\$753,800,000</b> | <b>\$17,185,700,000</b>     |
| <b>Present Value % by Watershed</b>        | <b>8%</b>              | <b>56%</b>             | <b>16%</b>             | <b>2%</b>            | <b>13%</b>                     | <b>4%</b>            | <b>100%</b>                 |

**Table 8: Modeled Annual Damages in Downstream Areas, Existing Conditions (2020 Flows), 500 Year Storm**

| Year                                   | Lake Worth / West Fork | West Fork / Eagle Mountain | Village Creek | Mary's Creek    | Upper Clear Fork Trinity River | Mountain Creek | Modeled TSI West Study Area |
|----------------------------------------|------------------------|----------------------------|---------------|-----------------|--------------------------------|----------------|-----------------------------|
| 2020 (H&H Modeled Year)                | \$271,700,000          | N/A                        | N/A           | \$1,643,500,000 | \$222,900,000                  | \$140,400,000  | \$2,278,500,000             |
| Expected Annual Damage, 500-Year event | \$500,000              | N/A                        | N/A           | \$3,300,000     | \$400,000                      | \$300,000      | \$4,600,000                 |
| <b>% by Watershed</b>                  | <b>11%</b>             | <b>12%</b>                 |               | <b>72%</b>      | <b>9%</b>                      | <b>7%</b>      | <b>100%</b>                 |

### 3.3 Modeled Flood Damage to Roads with 2020 Flows under Existing Conditions

Roadways that are modeled in the H&H analysis to be flooded more than 6 inches are presented in Table 9. Roads are presumed to close with six inches of flooding as driving conditions become hazardous. Flooding at this level (or greater) thus can result in increased travel time, transportation system costs to manage closures and flood cleanup, and also potentially result in damage to pavement. Results from the analysis of flooding of roadways in four of the six TSI

West watersheds are provided in Table 9; flooding of roadways also occurs in the other two TSI West study area watersheds but have not yet been quantitatively analyzed. The data in Table 9 are for lane miles; for a two-lane road, for every mile there are two lane miles. For a four-lane road, for every mile there are four lane miles, etc.

**Table 9: Modeled Flooding of Roadways, Existing Conditions (2020 Flows), by Watershed and Storm Event, Lane Miles Flooded**

| <b>Watershed</b>         | <b>Collector</b> | <b>Freeway</b> | <b>Frontage</b> | <b>Minor Arterial</b> | <b>Principal Arterial</b> | <b>Ramp</b> | <b>Tollway</b> | <b>Total</b> |
|--------------------------|------------------|----------------|-----------------|-----------------------|---------------------------|-------------|----------------|--------------|
| <b>2-Year Storm</b>      |                  |                |                 |                       |                           |             |                |              |
| Mary's Creek             | 0.4              | 0.2            | 0.2             | 1.6                   | 0.3                       |             |                | 2.7          |
| Mountain Creek           | 4.3              | 0.9            | 6.4             | 1.2                   | 3.9                       | 0.3         | 7.6            | 24.6         |
| Upper Clear Fork Trinity | 2.7              | 0.5            | 0.6             | 1.1                   | 1.6                       | 0.1         | 0.2            | 6.7          |
| Village Creek            | 3.5              | 1.3            | 1.7             | 2.7                   | 1.8                       | 0.1         |                | 11.0         |
| 2-Year Storm Total       | 11.0             | 2.8            | 8.7             | 6.6                   | 7.6                       | 0.5         | 7.7            | 45.0         |
| <b>10-Year Storm</b>     |                  |                |                 |                       |                           |             |                |              |
| Mary's Creek             | 2.4              | 0.3            | 1.2             | 6.1                   | 2.0                       |             |                | 11.9         |
| Mountain Creek           | 8.0              | 1.0            | 8.5             | 3.7                   | 4.5                       | 0.5         | 9.7            | 35.9         |
| Upper Clear Fork Trinity | 10.6             | 0.6            | 1.0             | 4.0                   | 3.2                       | 0.1         | 0.4            | 20.0         |
| Village Creek            | 7.6              | 2.4            | 2.9             | 4.5                   | 2.8                       | 0.3         |                | 20.5         |
| 10-Year Storm Total      | 28.6             | 4.3            | 13.7            | 18.2                  | 12.5                      | 0.9         | 10.1           | 88.3         |
| <b>50-Year Storm</b>     |                  |                |                 |                       |                           |             |                |              |
| Mary's Creek             | 2.7              | 0.4            | 1.7             | 7.7                   | 2.6                       |             |                | 15.2         |
| Mountain Creek           | 10.5             | 1.1            | 10.5            | 4.9                   | 4.7                       | 0.8         | 10.5           | 42.9         |
| Upper Clear Fork Trinity | 20.6             | 0.8            | 1.4             | 8.5                   | 6.8                       | 0.1         | 0.6            | 38.8         |
| Village Creek            | 11.2             | 3.7            | 5.0             | 6.4                   | 4.7                       | 0.5         |                | 31.5         |
| 50-Year Storm Total      | 45.0             | 5.9            | 18.7            | 27.5                  | 18.8                      | 1.4         | 11.1           | 128.4        |
| <b>100-Year Storm</b>    |                  |                |                 |                       |                           |             |                |              |
| Mary's Creek             | 2.9              | 0.4            | 1.7             | 8.2                   | 2.6                       |             |                | 15.7         |
| Mountain Creek           | 11.3             | 1.1            | 11.6            | 5.5                   | 4.9                       | 0.9         | 10.9           | 46.2         |
| Upper Clear Fork Trinity | 24.7             | 0.8            | 1.6             | 10.1                  | 8.1                       | 0.1         | 0.8            | 46.2         |
| Village Creek            | 12.3             | 4.3            | 5.7             | 6.9                   | 5.5                       | 0.5         |                | 35.4         |

Economics Appendix: Upper Trinity River Basin Transportation-Stormwater Infrastructure Plan

|                             |      |      |      |      |      |     |      |       |
|-----------------------------|------|------|------|------|------|-----|------|-------|
| 100-Year Storm<br>Total     | 51.2 | 6.6  | 20.6 | 30.7 | 21.1 | 1.6 | 11.7 | 143.5 |
| <b>500-Year Storm</b>       |      |      |      |      |      |     |      |       |
| Mary's Creek                | 3.3  | 0.8  | 1.9  | 8.6  | 2.6  | 0.0 |      | 17.3  |
| Mountain Creek              | 13.2 | 2.1  | 13.1 | 7.8  | 5.5  | 1.0 | 11.5 | 54.1  |
| Upper Clear Fork<br>Trinity | 29.8 | 1.9  | 2.4  | 15.9 | 14.6 | 0.2 | 1.1  | 66.1  |
| Village Creek               | 15.2 | 7.3  | 7.2  | 9.2  | 6.9  | 0.6 |      | 46.4  |
| 500-Year Storm<br>Total     | 61.5 | 12.1 | 24.6 | 41.5 | 29.6 | 1.9 | 12.6 | 183.9 |

## 4 Forecasted Conditions

This section provides data on the forecasted population growth, new structures developed in and adjacent to the existing floodplain, and modeled damages to forecasted structures and existing structures under future flow conditions.

### 4.1 Forecasted Population Growth

The primary driver of projected changes in hydrologic conditions, land use, and associated flood damages in the TSI West study area is population growth and associated development in and around floodplains. As shown in the first two columns of Table 9, NCTCOG forecasts rapid population growth from 2019 to 2050 in the TSI West study area. Average annual population growth in the eight counties in the study area averages approximately 1.1 percent and is highest in Parker and Wise counties at 3.1 percent annual growth. Based on the assumption that each county continues to grow from 2050 to 2070 at the same annualized growth rate projected for 2019 to 2050, the second to last column in Table 9 shows the estimated 2070 population.

The final column in Table 9 presents the 2070 population as a percent of the 2019 population; in Parker and Wise counties in the TSI West study area the 2070 population may be nearly five times the 2019 population. Overall the population in the eight-county area is projected to grow 76% by 2070 from under 5.3 million people in 2019 to over 9.2 million people in 2070.

**Table 9: Population Growth in the TSI West Study Area**

| County  | NCTCOG<br>estimated<br>2019<br>Population | NCTCOG<br>Projected<br>2050<br>Population | 2019 to<br>2050<br>% Annual<br>Growth<br>Rate | 2070<br>Population <sup>1</sup> | 2070 Population as a % of 2019<br>Population |
|---------|-------------------------------------------|-------------------------------------------|-----------------------------------------------|---------------------------------|----------------------------------------------|
| Dallas  | 2,565,625                                 | 3,070,896                                 | 100.6%                                        | 3,448,500                       | 134%                                         |
| Ellis   | 187,707                                   | 442,300                                   | 102.8%                                        | 768,900                         | 410%                                         |
| Hood    | 59,955                                    | 114,156                                   | 102.1%                                        | 173,000                         | 288%                                         |
| Johnson | 174,383                                   | 369,655                                   | 102.5%                                        | 600,200                         | 344%                                         |
| Parker  | 144,355                                   | 374,523                                   | 103.1%                                        | 692,800                         | 480%                                         |
| Tarrant | 2,059,644                                 | 2,866,567                                 | 101.1%                                        | 3,548,000                       | 172%                                         |
| Wise    | 67,176                                    | 171,715                                   | 103.1%                                        | 314,600                         | 468%                                         |
| Total   | 5,258,845                                 | 7,409,812                                 | 101.1%                                        | 9,244,500                       | 176%                                         |

Source: Highland Economics analysis of NCTCOG 2050 demographic forecasts by county, [https://data-nctcog.hub.arcgis.com/datasets/4ceaa5ba01994d7aa44752374a543b9b\\_15/explore](https://data-nctcog.hub.arcgis.com/datasets/4ceaa5ba01994d7aa44752374a543b9b_15/explore).

<sup>1</sup>/Assumes annual growth rate from 2050 to 2070 is the same as from 2019 to 2050.

Population growth and development by 2070 in the TSI West study area will tend to increase flood damages for several reasons:

1. Increased developed land increases runoff from impervious pavement and results in associated increase in water volumes flowing in area streams and rivers,
2. Increased development in the floodplain (which is projected absent careful planning) means
  - a. Less capacity of the floodplain to convey and absorb water, and
  - b. More structures are at risk of flooding in storm events.

In other words, due to development there is more flow in the floodplain coupled with less capacity in the floodplain to handle the flow, which will lead to greater flood depths and flooded area for the same storm event. (The increased flows and associated flooding that is expected to occur by 2070 is described in detail in the H&H analysis in Section 12 and Appendix 5.) Further, without careful planning, development will lead to more structures being built in the floodplain that will be at risk of flooding, which will increase structural damage at any given flood level.

## 4.2 Forecasted New Structures in Floodplain

Based on the land use data used in the H&H modeling, Table 10 summarizes the associated number of new structures that are forecasted to be constructed in the 100-year floodplain (under 2070 flow conditions) by 2070 based on forecasted land use change in the TSI study area, barring restrictions on floodplain development.<sup>1</sup> These structures were forecast using the same land use data sets used for the TSI hydrology models (ICLUS 2020 and 2070 land use data and NCTCOG 2070 forecasted land use). For each land use category, the density of structures and associated dollar value of forecasted structures, contents, and vehicles were estimated based on the NCTCOG-area averages from the National Structure Inventory data. Table 10 summarizes the number of forecasted structures (if they were to be built now) that would be affected by each storm event with 2020 flow conditions. The data in Table 10 showcase that there are over 7,000 structures projected to be constructed within the existing 100-year floodplain; with a projected 1,220 structures projected to be constructed within the two-year floodplain. Table 11 summarizes the nighttime population (resident population) and the daytime population (including both residents, students, or employees) associated with the forecasted structures shown in Table 10 that are built in locations that are modeled to be affected by flooding under 2020 flows.

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<sup>1</sup> The ICLUS dataset does not restrict development in the 100-year FEMA floodplain; as that was the land use projection (and associated development and percent impervious surface) used in the hydrology and hydraulics modeling to project impervious surface and runoff, for consistency the same land use data layers was used for forecasting future structures. As such, there are many structures forecasted in the current 100-year FEMA floodplain.

**Table 10: Forecasted Number of Structures Modeled to Flood with 2020 Flows by Storm Event and by Watershed, TSI West**

| Watershed                            | Storm Event |         |         |          |          |
|--------------------------------------|-------------|---------|---------|----------|----------|
|                                      | 2-Year      | 10-Year | 50-Year | 100-Year | 500-Year |
| Lake Worth                           | 170         | 220     | 270     | 270      | 300      |
| West Fork                            | 660         | 3,300   | 4,630   | 5,160    | 6,090    |
| Village Creek                        | 90          | 220     | 310     | 360      | 430      |
| Mary's Creek                         | 20          | 100     | 170     | 190      | 220      |
| Upper Clear Fork Trinity River       | 90          | 300     | 620     | 740      | 970      |
| Mountain Creek                       | 190         | 340     | 420     | 450      | 520      |
| <b>Total, TSI West Modeled Areas</b> | 1,220       | 4,480   | 6,420   | 7,170    | 8,530    |

**Table 11: Population Affected in Forecasted Structures by Flooding with 2020 Flows by Storm Event and by Watershed, TSI West**

| Watershed                            | Nighttime Population |         |         |          |          | Daytime Population |         |         |          |          |
|--------------------------------------|----------------------|---------|---------|----------|----------|--------------------|---------|---------|----------|----------|
|                                      | 2-Year               | 10-Year | 50-Year | 100-Year | 500-Year | 2-Year             | 10-Year | 50-Year | 100-Year | 500-Year |
| Lake Worth                           | 1,800                | 2,390   | 2,870   | 2,940    | 3,210    | 1,320              | 1,770   | 2,130   | 2,190    | 2,390    |
| West Fork                            | 3,000                | 14,020  | 19,790  | 22,160   | 26,050   | 1,910              | 8,610   | 11,990  | 13,420   | 15,690   |
| Village Creek                        | 870                  | 1,930   | 2,600   | 2,830    | 3,120    | 510                | 1,040   | 1,410   | 1,550    | 1,700    |
| Mary's Creek                         | 200                  | 1,010   | 1,520   | 1,620    | 1,880    | 100                | 490     | 740     | 790      | 920      |
| Upper Clear Fork Trinity River       | 640                  | 2,450   | 5,240   | 6,190    | 8,700    | 360                | 1,330   | 3,020   | 3,620    | 5,120    |
| Mountain Creek                       | 620                  | 1,220   | 1,540   | 1,640    | 1,870    | 320                | 620     | 800     | 860      | 1,000    |
| <b>Total, TSI West Modeled Areas</b> | 7,130                | 23,020  | 33,560  | 37,380   | 44,830   | 4,520              | 13,860  | 20,090  | 22,430   | 26,820   |

### 4.3 Forecasted Damages to New Structures

As highlighted in Table 10, there are many forecasted structures in the current floodplain that are projected to sustain flood damage even under existing 2020 flow conditions. Table 12 summarizes by storm event and watershed the damage to forecasted structures projected to be built by the year 2070 if 2020 flows are maintained. Under these flow conditions, expected annual damages to forecasted structures projected to be built by 2070 damages total \$585.7

million. If flows are not maintained at 2020 levels, but are allowed to increase with development, then expected annual flood damage by the year 2070 to forecasted new structures is modeled to rise to \$797.5 million as shown in Table 13. This is the expected annual damage to forecasted new structures that could be avoided if new construction were diverted out of the current and future floodplain.

**Table 12: Modeled Damages to Structures Forecast to be Built by 2070, with 2020 Flows Maintained, by Storm Event and by Watershed, TSI West**

| Watershed                            | Storm Event          |                        |                        |                        |                        | Expected Annual Damages (2020 Flows) |
|--------------------------------------|----------------------|------------------------|------------------------|------------------------|------------------------|--------------------------------------|
|                                      | 2-Year               | 10-Year                | 50-Year                | 100-Year               | 500-Year               |                                      |
| Lake Worth                           | \$48,200,000         | \$72,500,000           | \$100,600,000          | \$110,200,000          | \$124,400,000          | \$33,100,000                         |
| West Fork                            | \$188,900,000        | \$1,025,900,000        | \$1,573,700,000        | \$1,833,600,000        | \$2,308,700,000        | \$380,500,000                        |
| Village Creek                        | \$19,300,000         | \$88,400,000           | \$137,600,000          | \$157,200,000          | \$204,000,000          | \$33,500,000                         |
| Mary's Creek                         | \$5,800,000          | \$35,600,000           | \$66,700,000           | \$76,000,000           | \$91,500,000           | \$13,800,000                         |
| Upper Clear Fork Trinity River       | \$25,000,000         | \$182,200,000          | \$432,400,000          | \$587,400,000          | \$1,107,500,000        | \$77,900,000                         |
| Mountain Creek                       | \$46,900,000         | \$117,300,000          | \$156,300,000          | \$169,600,000          | \$207,300,000          | \$46,900,000                         |
| <b>Total, TSI West Modeled Areas</b> | <b>\$334,100,000</b> | <b>\$1,521,900,000</b> | <b>\$2,467,300,000</b> | <b>\$2,934,000,000</b> | <b>\$4,043,400,000</b> | <b>\$585,700,000</b>                 |

**Table 13: Modeled Damages to Structures Forecast to be Built by 2070, with 2070 Flows, by Storm Event and by Watershed, TSI West**

| Watershed  | Storm Event   |                 |                 |                 |                 | Expected Annual Damages, 2070 Flows |
|------------|---------------|-----------------|-----------------|-----------------|-----------------|-------------------------------------|
|            | 2-Year        | 10-Year         | 50-Year         | 100-Year        | 500-Year        |                                     |
| Lake Worth | \$52,500,000  | \$83,700,000    | \$110,500,000   | \$115,900,000   | \$130,600,000   | \$37,100,000                        |
| West Fork  | \$445,300,000 | \$1,222,100,000 | \$1,807,900,000 | \$2,056,500,000 | \$2,464,900,000 | \$492,100,000                       |

|                                      |                      |                        |                        |                        |                        |                      |
|--------------------------------------|----------------------|------------------------|------------------------|------------------------|------------------------|----------------------|
| Village Creek                        | \$45,000,000         | \$106,500,000          | \$152,900,000          | \$173,300,000          | \$223,100,000          | \$43,900,000         |
| Mary's Creek                         | \$14,600,000         | \$40,400,000           | \$72,800,000           | \$81,600,000           | \$97,700,000           | \$17,000,000         |
| Upper Clear Fork Trinity River       | \$169,500,000        | \$332,900,000          | \$601,900,000          | \$745,800,000          | \$1,337,100,000        | \$152,900,000        |
| Mountain Creek                       | \$72,500,000         | \$124,400,000          | \$168,700,000          | \$185,000,000          | \$222,100,000          | \$54,500,000         |
| <b>Total, TSI West Modeled Areas</b> | <b>\$799,400,000</b> | <b>\$1,910,000,000</b> | <b>\$2,914,700,000</b> | <b>\$3,358,100,000</b> | <b>\$4,475,500,000</b> | <b>\$797,500,000</b> |

#### 4.4 Forecasted Damages to Existing Structures in TSI West and Downstream

Rising flows are also expected to lead to increased damage to existing structures in the TSI West study area and downstream areas. Table 14 shows that expected annual damage to existing structures under 2070 flow conditions is estimated at \$640.8 million across all storm event types (compared to \$541.4 million in expected annual damages under 2020 flow conditions). Damage to existing structures from a 100-year storm under 2070 conditions would be approximately \$2.48 billion (compared to \$2.269 billion under 2020 flows as presented in Table 6).

**Table 14: Modeled Damages to Existing Structures by 2070 with 2070 Flows by Storm Event and by Watershed, TSI West**

| Watershed                            | Storm Event          |                        |                        |                        |                        | Expected Annual Damages |
|--------------------------------------|----------------------|------------------------|------------------------|------------------------|------------------------|-------------------------|
|                                      | 2-Year               | 10-Year                | 50-Year                | 100-Year               | 500-Year               |                         |
| Lake Worth                           | \$83,600,000         | \$124,600,000          | \$172,300,000          | \$189,900,000          | \$229,300,000          | \$57,000,000            |
| West Fork                            | \$444,200,000        | \$728,000,000          | \$1,094,800,000        | \$1,295,000,000        | \$1,918,000            | \$332,100,000           |
| Village Creek                        | \$153,400,000        | \$264,100,000          | \$364,900,000          | \$453,100,000          | \$658,600,000          | \$117,200,000           |
| Mary's Creek                         | \$3,700,000          | \$33,200,000           | \$68,500,000           | \$83,300,000           | \$127,700,000          | \$13,000,000            |
| Upper Clear Fork Trinity River       | \$147,300,000        | \$211,200,000          | \$309,500,000          | \$355,400,000          | \$456,800,000          | \$99,100,000            |
| Mountain Creek                       | \$24,000,000         | \$51,100,000           | \$79,500,000           | \$103,000,000          | \$199,400,000          | \$22,400,000            |
| <b>Total, TSI West Modeled Areas</b> | <b>\$856,200,000</b> | <b>\$1,412,200,000</b> | <b>\$2,089,500,000</b> | <b>\$2,479,700,000</b> | <b>\$1,673,700,000</b> | <b>\$640,800,000</b>    |

In addition to flooding structures in the TSI West study area, the increase in flows in the Trinity River from the runoff in the TSI West study area will increase flooding in downstream areas in the Dallas-Fort Worth metroplex. The increased risk of flooding in downstream areas was

modeled by the USACE for the 500-year flood event (see Section 5 and Appendix 5). As this area is already well developed, no new structures were forecasted for downstream areas. Within the downstream areas, structures were geographically grouped based on which upstream watersheds in the TSI West contribute most significantly to their flood risk. As shown in Table 15, by the year 2070 with projected 2070 flows in the West Fork Trinity River and North Fork Trinity River (the entire TSI West and North study areas), nearly \$3.3 billion in damages are projected in downstream areas. The H&H modeling and associated economic analysis of flood damages indicates that nearly two-thirds of this damage is related to flows in the Mary's Creek watershed.

As shown in Table 16, by the year 2070 if 2020 flows in the TSI West and North study areas are maintained through storage of stormwater runoff and maintenance of floodplain capacity, then a 500-year storm event is projected to result in approximately \$3.0 billion in damages. In other words, by the year 2070, the benefit of maintaining valley storage and 2020 flows in the TSI study area (West and North) is approximately \$300 million in a 500-year storm event. Given that the annual probability of a 500-year storm event is one in five hundred, or 0.002, the annual expected benefit of reducing the damage of a 500-year storm is approximately \$500,000.

**Table 15: Modeled Annual Damages in Downstream Areas, 2070 Future Conditions (2070 Flows), 500-Year Storm**

| <b>Year</b>                            | <b>Lake Worth / West Fork</b> | <b>Eagle Mountain</b> | <b>Village Creek</b> | <b>Mary's Creek</b> | <b>Upper Clear Fork Trinity River</b> | <b>Mountain Creek</b> | <b>Modeled TSI West Study Area</b> |
|----------------------------------------|-------------------------------|-----------------------|----------------------|---------------------|---------------------------------------|-----------------------|------------------------------------|
| 2070 (H&H Modeled Year), 2070 Flows    | \$305,500,000                 | N/A                   | N/A                  | \$2,088,900,000     | \$310,300,000                         | \$177,400,000         | \$3,292,600,000                    |
| Expected Annual Damage, 500-Year Event | \$600,000                     | N/A                   | N/A                  | \$4,200,000         | \$600,000                             | \$400,000             | \$6,600,000                        |
| <b>% by Watershed</b>                  | <b>9%</b>                     | <b>12%</b>            |                      | <b>64%</b>          | <b>9%</b>                             | <b>6%</b>             | <b>100%</b>                        |

**Table 16: Modeled Annual Damages in Downstream Areas, 2070 Future Conditions (2020 Flows), 500-Year Storm**

| <b>Year</b>                            | <b>Lake Worth / West Fork</b> | <b>Eagle Mountain</b> | <b>Village Creek</b> | <b>Mary's Creek</b> | <b>Upper Clear Fork Trinity River</b> | <b>Mountain Creek</b> | <b>Modeled TSI West Study Area</b> |
|----------------------------------------|-------------------------------|-----------------------|----------------------|---------------------|---------------------------------------|-----------------------|------------------------------------|
| 2070 (H&H Modeled Year), 2020 Flows    | \$305,500,000                 | N/A                   | N/A                  | \$1,890,800,000     | \$285,000,000                         | \$177,300,000         | \$3,031,100,000                    |
| Expected Annual Damage, 500-Year Event | \$600,000                     | N/A                   | N/A                  | \$3,800,000         | \$600,000                             | \$400,000             | \$6,100,000                        |
| <b>% by Watershed</b>                  | <b>10%</b>                    | <b>11%</b>            |                      | <b>62%</b>          | <b>10%</b>                            | <b>7%</b>             | <b>100%</b>                        |

## 4.5 Forecasted Damages to Roadways in TSI West and Downstream

In addition to structures, roads will also be flooded with increased flows in the 2070 condition. Once flooding exceeds approximately six inches, roads are often closed and repairs may be necessary. Table 17 summarizes the total lane miles of existing roads projected to be flooded by at least 6 inches of water in the 100-year storm by watershed by 2070; note that road data were not available for Eagle Mountain or Fort-Worth watersheds. Table 17 highlights the increased number of lane miles flooded by watershed. Overall, approximately 20 additional lane miles in the TSI West study area will flood in a 100-year storm event with projected 2070 flows, or an increase of 14 percent from the 143.5 existing miles of lane (163.5 lane miles less the additional 20 lane miles flooded by 2070 flows) already flooding with 2020 flows.

**Table 17: Lane Miles Flooded Over 6 Inches, 100 Year Storm**

| <b>Watershed</b>                                                       | <b>Collector</b> | <b>Freeway</b> | <b>Frontage</b> | <b>Minor Arterial</b> | <b>Principal Arterial</b> | <b>Ramp</b> | <b>Tollway</b> | <b>Total</b> |
|------------------------------------------------------------------------|------------------|----------------|-----------------|-----------------------|---------------------------|-------------|----------------|--------------|
| <b>Total Lane Miles Flooded, 2070 Flows</b>                            |                  |                |                 |                       |                           |             |                |              |
| Mary's Creek                                                           | 3.1              | 0.5            | 1.7             | 8.3                   | 2.6                       |             |                | 16.2         |
| Mountain Creek                                                         | 11.9             | 1.1            | 12.3            | 6.3                   | 5.1                       | 1.0         | 11.1           | 48.9         |
| Upper Clear Fork Trinity                                               | 27.6             | 0.8            | 1.9             | 13.2                  | 12.9                      | 0.2         | 1.0            | 57.6         |
| Village Creek                                                          | 13.5             | 6.2            | 6.6             | 7.7                   | 6.2                       | 0.6         |                | 40.8         |
| Total, Modeled West Study Area                                         | 56.1             | 8.6            | 22.6            | 35.5                  | 26.9                      | 1.7         | 12.1           | 163.5        |
| <b>Increased Lane Miles Flooded, 2070 Flows Compared to 2020 Flows</b> |                  |                |                 |                       |                           |             |                |              |
| Mary's Creek                                                           | 0.3              | 0.1            | 0.0             | 0.1                   | 0.0                       | -           | -              | 0.5          |
| Mountain Creek                                                         | 0.7              | 0.0            | 0.7             | 0.7                   | 0.2                       | 0.0         | 0.2            | 2.6          |
| Upper Clear Fork Trinity                                               | 2.9              | 0.0            | 0.3             | 3.1                   | 4.9                       | 0.0         | 0.2            | 11.4         |
| Village Creek                                                          | 1.1              | 1.8            | 0.9             | 0.8                   | 0.7                       | 0.1         | -              | 5.4          |
| Total, Modeled West Study Area                                         | 5.0              | 2.0            | 2.0             | 4.7                   | 5.8                       | 0.1         | 0.4            | 20.0         |
| % Increase in Affected Land Miles                                      | 10%              | 29%            | 10%             | 15%                   | 27%                       | 9%          | 4%             | 14%          |

## 5 Costs of Inaction: Increased Flood Damages Over Time Without Floodplain Protections and Storage Projects

This section estimates the cost of inaction. It compares flood damage through time if flows are allowed to increase to projected 2070 levels<sup>1</sup> to the flood damages through time if flows are maintained at 2020 levels. Due to the forecasted construction of structures in the floodplain, damages rise through time even if flows are maintained at 2020 levels (as more structures flood each year with development in flood-prone areas). The economic analysis forecasts damages in each year from 2020 to 2076 with maintenance of flows at 2020 levels, and then also forecasts

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<sup>1</sup> In other words, if development proceeds as forecasted without accompanying protection of floodplain capacity and storage of stormwater flows.

damages in each year from 2020 to 2076 if flows to increase through the period of analysis. By comparing these two forecasts, the economic analysis estimates the increased damages effects of flow increases alone (separate from the effects of more structures being flooded).

## **5.1 Increased Flood Damages in TSI West Study Area**

Increased flood damages in the TSI West study area are summarized in Table 18 by watershed. The table shows how increasing flows result in increased flood-related damages that rise between 2020 and 2076 due to forecasted development and changes in land use. Damage values presented in Table 18 and through the rest of this section include losses related to physical damage of structures, contents, and vehicles, and the cost of displacement to residents and businesses. The analysis uses a fifty-year time horizon into the future (2027 to 2076) as the regional detention basins analyzed in the next section are expected to have a useful life of at least 50 years.

As shown in Table 18, expected annual damages in the TSI West study area from increased stormwater flows and associated flooding from area waterways rise from \$0 in 2020 (when flows are the same in all scenarios) to \$92.2 million in 2076. If development proceeds as forecast and flows are allowed to increase as modeled, the total flood-related costs in today's dollars across the next fifty years (i.e., the present value of damages over 50 years) will increase by \$2.267 billion across all modeled TSI West watersheds. Said differently, if development proceeds as forecast but stormwater is stored and managed such that 2020 flows are maintained, then there would be \$2.267 billion in flood damage savings. Almost half of the projected flood damage is modeled to occur in the West Fork watershed.

**Table 18: Increased Expected Annual Damage from 2027 to 2076 in TSI West Study Area from Flow Increase**

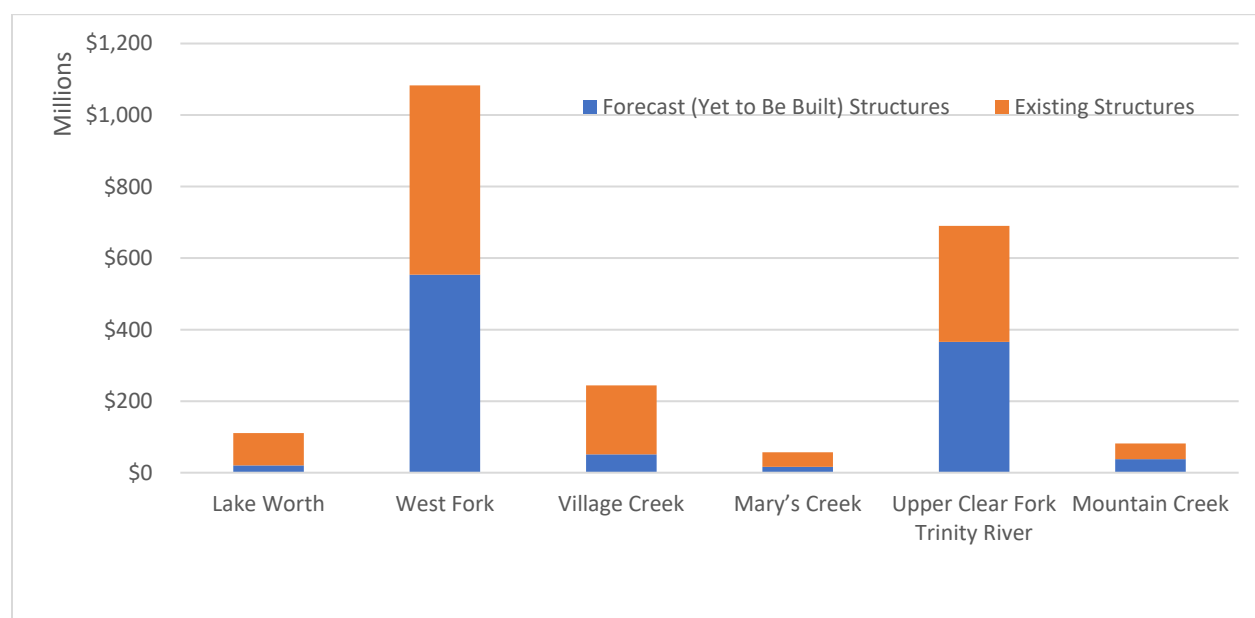
| <b>Year</b>                                | <b>Lake Worth</b>    | <b>West Fork</b>       | <b>Village Creek</b> | <b>Mary's Creek</b> | <b>Upper Clear Fork Trinity River</b> | <b>Mountain Creek</b> | <b>Total, Modeled TSI West Study Area</b> |
|--------------------------------------------|----------------------|------------------------|----------------------|---------------------|---------------------------------------|-----------------------|-------------------------------------------|
| 2020 (H&H Modeled Year)                    | \$0                  | \$0                    | \$0                  | \$0                 | \$0                                   | \$0                   | \$0                                       |
| 2027                                       | \$1,000,000          | \$5,900,000            | \$2,100,000          | \$400,000           | \$3,400,000                           | \$500,000             | \$13,300,000                              |
| 2050                                       | \$4,600,000          | \$34,900,000           | \$10,000,000         | \$2,200,000         | \$21,300,000                          | \$2,800,000           | \$75,800,000                              |
| 2070 (H&H Modeled Year)                    | \$11,400,000         | \$154,200,000          | \$25,900,000         | \$6,700,000         | \$102,000,000                         | \$11,100,000          | \$311,300,000                             |
| 2076                                       | \$16,200,000         | \$268,800,000          | \$38,100,000         | \$10,300,000        | \$183,700,000                         | \$18,900,000          | \$536,000,000                             |
| Average Annualized Damage, 2027-2076       | \$4,500,000          | \$44,100,000           | \$9,900,000          | \$2,300,000         | \$28,100,000                          | \$3,300,000           | \$92,200,000                              |
| <b>Present Value Damages, 2027 to 2076</b> | <b>\$110,700,000</b> | <b>\$1,082,900,000</b> | <b>\$244,100,000</b> | <b>\$57,300,000</b> | <b>\$690,200,000</b>                  | <b>\$81,600,000</b>   | <b>\$2,266,800,000</b>                    |
| <b>Present Value % by Watershed</b>        | <b>5%</b>            | <b>48%</b>             | <b>11%</b>           | <b>3%</b>           | <b>30%</b>                            | <b>4%</b>             | <b>100%</b>                               |

Source: Highland Economics analysis of H&H modeling results.

1/No benefits estimated for 2020 as flow conditions in all scenarios are the same in 2020.

Figure 1 presents the proportion of the present value flood damage affecting existing structures versus forecasted (yet to be built) structures. Across the modeled areas in the TSI West study area, approximately 42 percent of all projected increased damages are to newly constructed structures. This highlights the importance of avoiding development in areas with flood risk. Most of the newly constructed structures at risk of flooding are projected to be built in the Upper Clear Fork Trinity and Mountain Creek watersheds.

**Figure 1: Present Value of Increased Damage from 2027 to 2076 of Increasing Flows, Existing and Forecasted Structures, 2026\$**



As development continues, the proportion of damages to new structures built in the floodplain rises as a share of total damage. Structures built in the floodplain are not only at risk of flooding themselves but also increase damage for structures downstream as they 1) reduce floodplain capacity to convey flows, and 2) increase impervious surfaces that increase runoff. In both the West Fork and the Upper Clear Fork Trinity watersheds, newly built structures contribute over half of the total projected damage over time from 2027 to 2076. Across the modeled areas of the TSI West study area, 46 percent of projected damages are to new structures constructed in areas susceptible to flooding.

**Table 19: Increased Damage by Storm Event Through Time Without Projects, % Damages to Forecasted Structures (Excluding Existing Structures)**

| <b>Year</b>                                 | <b>Lake Worth</b> | <b>West Fork</b> | <b>Village Creek</b> | <b>Mary's Creek</b> | <b>Upper Clear Fork Trinity River</b> | <b>Mountain Creek</b> | <b>Total, TSI West Study Area</b> |
|---------------------------------------------|-------------------|------------------|----------------------|---------------------|---------------------------------------|-----------------------|-----------------------------------|
| 2020 (H&H Modeled Year) <sup>1</sup>        | N/A               | N/A              | N/A                  | N/A                 | N/A                                   | N/A                   | N/A                               |
| 2027                                        | 1%                | 5%               | 1%                   | 2%                  | 4%                                    | 4%                    | 4%                                |
| 2050                                        | 8%                | 29%              | 9%                   | 14%                 | 29%                                   | 25%                   | 24%                               |
| 2070 (H&H Modeled Year)                     | 36%               | 72%              | 40%                  | 49%                 | 74%                                   | 68%                   | 68%                               |
| 2076                                        | 49%               | 82%              | 54%                  | 63%                 | 83%                                   | 79%                   | 79%                               |
| <b>Average Annualized Damage, 2027-2076</b> | <b>18%</b>        | <b>51%</b>       | <b>21%</b>           | <b>29%</b>          | <b>53%</b>                            | <b>47%</b>            | <b>46%</b>                        |

Source: Highland Economics analysis of H&H modeling results.  
2026\$ Values, 3.25% Discount Rate.

Table 20 summarizes the increased damage by storm event across the modeled areas of the TSI West study area in Year 2070. In this year, the modeled increase in damages from increased development and associated flows is over \$500 million in every single storm event, including the 2-year storm event. In other words, development in the floodplain and surrounding areas results in a big increase in flood damage even in very frequent storm events. By year 2070, unconstrained development in the floodplain and surrounding areas without offsetting storage of storm flows is projected to result in annual average flood damage of over \$311 million annually. Note that the expected annual damages in year 2070 are higher than the expected annualized average damages from 2027 to 2076 because damages are increasing with increased development and higher flows during the analysis period.

**Table 20: Increased Damage by Storm Event: 2020 vs. 2070 Flow Conditions, Year 2070**

| <b>Storm Event</b>                                | <b>Lake Worth</b>   | <b>West Fork</b>     | <b>Village Creek</b> | <b>Mary's Creek</b> | <b>Upper Clear Fork Trinity River</b> | <b>Mountain Creek</b> | <b>Total, TSI West Study Area</b> |
|---------------------------------------------------|---------------------|----------------------|----------------------|---------------------|---------------------------------------|-----------------------|-----------------------------------|
| 500-Year                                          | \$20,100,000        | \$221,700,000        | \$91,400,000         | \$13,800,000        | \$291,900,000                         | \$44,400,000          | \$683,300,000                     |
| 100-Year                                          | \$20,100,000        | \$295,300,000        | \$80,800,000         | \$10,800,000        | \$219,800,000                         | \$29,400,000          | \$656,200,000                     |
| 50-Year                                           | \$26,600,000        | \$302,000,000        | \$56,500,000         | \$10,700,000        | \$220,500,000                         | \$22,900,000          | \$639,200,000                     |
| 10-Year                                           | \$29,200,000        | \$261,000,000        | \$49,600,000         | \$16,300,000        | \$201,500,000                         | \$12,400,000          | \$570,000,000                     |
| 2-Year                                            | \$14,400,000        | \$372,000,000        | \$51,800,000         | \$10,600,000        | \$203,000,000                         | \$33,500,000          | \$685,300,000                     |
| Expected Annual Damages in Year 2070 <sup>a</sup> | <b>\$11,400,000</b> | <b>\$154,200,000</b> | <b>\$25,900,000</b>  | <b>\$6,700,000</b>  | <b>\$102,000,000</b>                  | <b>\$11,100,000</b>   | <b>\$311,300,000</b>              |
| % by Watershed                                    | 4%                  | 50%                  | 8%                   | 2%                  | 33%                                   | 4%                    | 100%                              |

Source: Highland Economics analysis of H&H modeling results.

a/Note that the expected annual damages in year 2070 are higher than the expected annualized average damages from 2027 to 2076 because damages are increasing with increased development and higher flows during the analysis period.

Table 21 highlights that in Year 2070, 68 percent of all flood damages are to forecast (not yet built) structures. New developments in the West Fork, the Upper Clear Fork Trinity River, and Mountain Creek watersheds will suffer high damage, with between two-thirds and three-quarters of all annual damage in 2070 affecting structures not yet built.

**Table 21: Increased Damages by Storm Event: 2020 vs. 2070 Flow Conditions, % of Damages to Forecast Structures, Year 2070**

| <b>Storm Event</b>             | <b>Lake Worth</b> | <b>West Fork</b> | <b>Village Creek</b> | <b>Mary's Creek</b> | <b>Upper Clear Fork Trinity River</b> | <b>Mountain Creek</b> | <b>Total, TSI West Study Area</b> |
|--------------------------------|-------------------|------------------|----------------------|---------------------|---------------------------------------|-----------------------|-----------------------------------|
| 500-Year                       | 31%               | 70%              | 21%                  | 45%                 | 79%                                   | 33%                   | 63%                               |
| 100-Year                       | 28%               | 75%              | 20%                  | 52%                 | 72%                                   | 52%                   | 65%                               |
| 50-Year                        | 37%               | 77%              | 27%                  | 56%                 | 77%                                   | 54%                   | 70%                               |
| 10-Year                        | 38%               | 75%              | 37%                  | 30%                 | 75%                                   | 58%                   | 68%                               |
| 2-Year                         | 30%               | 69%              | 50%                  | 83%                 | 71%                                   | 76%                   | 68%                               |
| <b>Expected Annual Damages</b> | <b>36%</b>        | <b>72%</b>       | <b>40%</b>           | <b>49%</b>          | <b>74%</b>                            | <b>68%</b>            | <b>68%</b>                        |

Source: Highland Economics analysis of H&H modeling results.

In terms of the type of damage sustained, Table 22 summarizes the increased average annual damage in Year 2070 by damage category. Structural damage and content damage are the largest

damage categories, with 34 percent and 39 percent of damage respectively, while vehicle damage and displacement account for 9 percent and 18 percent of damages, respectively.

**Table 22: Increased Expected Annual Damages by Damage Category, Year 2070**

| <b>Watershed</b>                    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-------------------------------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| Lake Worth                          | \$3,900,000            | \$4,400,000           | \$600,000             | \$2,500,000         | \$11,400,000      |
| West Fork                           | \$46,300,000           | \$67,300,000          | \$8,300,000           | \$32,200,000        | \$154,100,000     |
| Village Creek                       | \$9,700,000            | \$11,700,000          | \$1,100,000           | \$3,400,000         | \$25,900,000      |
| Mary's Creek                        | \$2,500,000            | \$2,800,000           | \$200,000             | \$1,200,000         | \$6,700,000       |
| Upper Clear Fork Trinity River      | \$38,700,000           | \$32,100,000          | \$18,200,000          | \$13,000,000        | \$102,000,000     |
| Mountain Creek                      | \$3,400,000            | \$4,600,000           | \$600,000             | \$2,600,000         | \$11,100,000      |
| Total, Modeled TSI West Study Areas | \$104,500,000          | \$122,900,000         | \$29,000,000          | \$54,900,000        | \$311,200,000     |
| <b>Percent of Total</b>             | <b>34%</b>             | <b>39%</b>            | <b>9%</b>             | <b>18%</b>          | <b>100%</b>       |

Source: Highland Economics analysis of H&H modeling results.

## 5.2 Increased Flood Damages in Downstream Areas

Table 23 summarizes the modeled benefits to downstream areas in the Dallas-Fort Worth metroplex of maintaining flows in the TSI Study Area to 2020 flow levels. As shown in the table, the damage from a 500-year storm event in downstream areas in the year 2070 would be reduced by \$261.5 million. Due to the low probability of a 500-year event, the expected annual benefit in Year 2070 would be approximately \$0.5 million. Approximately three-quarters of the benefit to downstream areas is from maintaining flows at 2020 levels in the Mary's Creek watershed.

**Table 23: Increased Annual Damages in 2070 from 500-Year Flood Event, Downstream Areas (2070 flows vs. 2020 flows)**

| Year                                                                      | Lake Worth | West Fork/Eagle Mountain* | Village Creek* | Mary's Creek  | Upper Clear Fork Trinity River | Mountain Creek | Modeled TSI West Study Area |
|---------------------------------------------------------------------------|------------|---------------------------|----------------|---------------|--------------------------------|----------------|-----------------------------|
| Increased 500-Year storm damage, 2020 flows vs. 2070 flows                | \$0        |                           |                | \$198,000,000 | \$25,300,000                   | \$76,000       | \$261,500,000               |
| Increased expected <i>annual</i> damage from 500-Year storm event in 2070 | \$0        |                           |                | \$400,000     | \$100,000                      | \$0            | \$500,000                   |
| <b>% Contribution by Watershed</b>                                        | 0%         | 15%                       |                | 76%           | 10%                            | 0%             | 100%                        |

\*No data.

Source: Highland Economics analysis of H&amp;H model results.

Table 24 summarizes how flood damage from a 500-year flood event will increase in downstream areas through time if 2020 flows are not maintained. The table compares the 500-year event flood damage through time with 2020 flows compared to increasing flows through time. The analysis finds that the increased damage in downstream areas due to flows from the TSI study area rise from \$0 in 2020 to \$300.3 million in 2076. On an average annualized basis, taking into account the probability of a 500-year storm (a 1 in 500 chance, or 0.002) and discounting of damages in future years relative to damages incurred today, the average annualized benefit over the next fifty years of maintain flows in the TSI study area (north and west) is estimated at \$300,000. Considering damage prevention in a 500-year storm event alone (and not considering benefits that may accrue in other storm events), the present value of maintain flows is estimated at approximately \$6.2 million.

**Table 24: Expected Damages 2027 to 2076, Downstream Areas (2070 flows vs. 2020 flows), 500-Year Event**

| Year                                        | Flows Allowed to Increase | 2020 Flows Maintained | Costs of Flowing Increasing/Benefit of Maintaining 2020 Flows |
|---------------------------------------------|---------------------------|-----------------------|---------------------------------------------------------------|
| 2020 (H&H Modeled Year) <sup>1</sup>        | \$2,567,800,000           | \$2,567,800,000       | \$0                                                           |
| 2027                                        | \$2,658,800,000           | \$2,628,100,000       | \$30,600,000                                                  |
| 2050                                        | \$2,980,900,000           | \$2,836,500,000       | \$144,400,000                                                 |
| 2070 (H&H Modeled Year)                     | \$3,292,600,000           | \$3,031,100,000       | \$261,500,000                                                 |
| 2076                                        | \$3,392,300,000           | \$3,092,000,000       | \$300,300,000                                                 |
| <b>Average Annualized Damage, 2027-2076</b> | \$6,000,000               | \$5,800,000           | \$300,000                                                     |
| Present Value, 2027-2076                    | \$147,800,000             | \$141,600,000         | \$6,200,000                                                   |

Source: Highland Economics analysis of H&amp;H model results.

As shown in Table 23, approximately three quarters of this value, or \$4.7 million is estimated to be related to maintaining flows at 2020 levels in the Mary's Creek watershed. The optimization model that estimates storage requirements by watershed to maintain 2020 flows indicates that approximately 5,000 acre-feet (AF) of storage is required to maintain 2020 flows in the Mary's Creek watershed during a 100-year storm event. Additional storage would be required to maintain flows during a 500-year storm event. However, assuming 5,000 AF of storage in Mary's Creek would provide \$4.7 million in reduced flood damages in downstream areas over the next 50 years, each AF of storage provides approximately \$627 of present value to downstream areas. After considering the value to downstream areas of smaller storm events, this value is likely much greater.

### 5.3 Increased Flooding of Roads

Tables 25 and 26 summarize results of the analysis of roadways flooding. By the year 2070, modeling indicates that on average every year there would be an estimated 13 additional locations that would require road closures and there would also be approximately 13 additional lane miles (for example, 6.5 miles of a two-lane road) affected by flooding. The costs of this flooding and road closures are expected to be relatively minor, both due to the relatively small number of locations and the fact that the increased road flooding will not occur until later in the analysis period (as discounting of future costs results in a smaller value in today's dollars).

**Table 25: Increased Road Closure Locations by 2070 (2070 Flows vs 2020 Flows)**

| Storm Event                                             | Collector | Freeway | Frontage | Minor Arterial | Principal Arterial | Ramp | Tollway | Total |
|---------------------------------------------------------|-----------|---------|----------|----------------|--------------------|------|---------|-------|
| 2-Year                                                  | 11.00     | -       | 1.00     | 4.00           | 3.00               | 2.00 | -       | 21.00 |
| 10-Year                                                 | 6.00      | -       | 1.00     | 1.00           | 1.00               | 2.00 | -       | 11.00 |
| 50-Year                                                 | 6.00      | 1.00    | 3.00     | 3.00           | 1.00               | 1.00 | 1.00    | 16.00 |
| 100-Year                                                | 6.00      | -       | 1.00     | 2.00           | 3.00               | 3.00 | -       | 15.00 |
| 500-Year                                                | 7.00      | 1.00    | 4.00     | 4.00           | -                  | 2.00 | -       | 18.00 |
| Average Annual Increased Road Closure Locations by 2070 | 6.7       | 0.0     | 0.9      | 2.2            | 1.7                | 1.5  | 0.0     | 13.0  |

Source: Highland Economics analysis of H&H model results.

**Table 26: Increased Lane Miles Flooded by 2070 (2070 Flows vs 2020 Flows)**

| <b>Storm Event</b>                          | <b>Collector</b> | <b>Freeway</b> | <b>Frontage</b> | <b>Minor Arterial</b> | <b>Principal Arterial</b> | <b>Ramp</b> | <b>Tollway</b> | <b>Total</b> |
|---------------------------------------------|------------------|----------------|-----------------|-----------------------|---------------------------|-------------|----------------|--------------|
| 2-Year                                      | 8.6              | 0.5            | 1.9             | 5.3                   | 1.3                       | 0.2         | 1.2            | 18.9         |
| 10-Year                                     | 7.7              | 0.6            | 1.2             | 4.1                   | 2.2                       | 0.1         | 0.0            | 16.0         |
| 50-Year                                     | 6.3              | 0.8            | 1.9             | 3.7                   | 3.4                       | 0.2         | 0.6            | 16.8         |
| 100-Year                                    | 5.0              | 2.0            | 2.0             | 4.7                   | 5.8                       | 0.1         | 0.4            | 20.0         |
| 500-Year                                    | 4.5              | 2.6            | 1.5             | 3.6                   | 5.0                       | 0.2         | 0.4            | 17.8         |
| Average Annual Increased Lane Miles by 2070 | 6.1              | 0.4            | 1.3             | 3.6                   | 1.3                       | 0.1         | 0.6            | 13.3         |

Source: Highland Economics analysis of H&H model results.

## 6 Costs and Benefits of Regional Detention: Decreased Flood Damages from 2020 to 2070 With Projects

This section summarizes the estimated costs and benefits of 10 regional detention projects in the TSI West study area. These 10 projects are modeled for four of the TSI west watersheds: Mary's Creek, Mountain Creek, Upper Clear Fork Trinity, and Village Creek. Estimated project construct costs and estimated avoided flood damage benefits for each project are summarized in Table 27. As highlighted in Table 27, five of the ten projects have benefit cost ratios of 0.8 or higher; the preliminary analysis thus indicates that these projects may provide sufficient avoided flood benefits to justify construction.

**Table 27: Summary of Modeled Regional Detention Project Benefits and Costs**

| Project Name                                           | TSI Incremental Project Cost <sup>a</sup> | Buyout Cost (Structures with Induced Flooding) | Estimated Total Cost | Modeled Reduced Flood Damages, Present Value | Benefit Cost Ratio |
|--------------------------------------------------------|-------------------------------------------|------------------------------------------------|----------------------|----------------------------------------------|--------------------|
| <b>MARY'S CREEK WATERSHED</b>                          |                                           |                                                |                      |                                              |                    |
| Little Mary's Creek at FM 3325                         | \$4,800,000                               | \$0                                            | \$4,800,000          | \$1,600,000                                  | 0.3                |
| Mary's Creek at FM 3325                                | \$2,200,000                               | \$1,600,000                                    | \$3,800,000          | \$14,300,000                                 | 3.8                |
| South Mary's Creek at IH-20                            | \$3,500,000                               | \$0                                            | \$3,500,000          | \$600,000                                    | 0.2                |
| Little Mary's Creek Tributary at FM 3325               | \$4,500,000                               | \$0                                            | \$4,500,000          | \$1,600,000                                  | 0.4                |
| <b>MOUNTAIN CREEK WATERSHED</b>                        |                                           |                                                |                      |                                              |                    |
| Mountain Creek at CR 616                               | \$19,200,000                              | \$2,100,000                                    | \$21,300,000         | \$4,200,000                                  | 0.2                |
| Mountain Creek at FM 2738                              | \$10,700,000                              | \$1,100,000                                    | \$11,800,000         | \$10,500,000                                 | 0.9                |
| <b>UPPER CLEAR FORK TRINITY WATERSHED</b>              |                                           |                                                |                      |                                              |                    |
| Clear Fork at Sarra Ln                                 | \$21,200,000                              | \$0                                            | \$21,200,000         | \$17,700,000                                 | 0.8                |
| Town Creek at Ric Williamson Memorial Highway/Bowie Dr | \$145,600,000                             | \$0                                            | \$145,600,000        | \$15,000,000                                 | 0.1                |
| <b>VILLAGE CREEK WATERSHED</b>                         |                                           |                                                |                      |                                              |                    |
| Chambers Creek at Enon Ave/Forest Hill Dr              | \$52,100,000                              | \$0                                            | \$52,100,000         | \$40,300,000                                 | 0.8                |
| Village Creek at FM 731                                | \$2,900,000                               | \$5,100,000                                    | \$8,000,000          | \$23,100,000                                 | 2.9                |

a/The Incremental TSI Cost is equal to TSI Cost minus the Traditional Approach cost for bridge construction.

b/The TSI incremental project cost of these two projects is the TSI project cost, not the incremental project cost. A traditional bridge is projected to cost more than a TSI bridge at these locations, but it is not clear if a traditional bridge would be constructed at this location, so the full TSI cost is included for these projects. The TSI incremental cost may be much lower than this cost in which case the benefit cost ratio could change significantly.

The costs in Table 27 are based on an opinion of probable project costs provided by TSI study engineers; project costs are presented in more detail in Section 5 and Appendix 5. The TSI incremental costs presented in Table 27 are the estimated increased costs of a TSI approach to bridge construction (with regional detention of stormwater incorporated into the design) that exceed the cost of traditional bridge construction. Incorporated into these cost estimates are 30 percent for associated infrastructure and improvements, 30 percent contingency, and 25 percent for administration, design and survey. Operation, maintenance, and repair costs are expected to be similar for TSI approach and a traditional approach to bridge construction, so are not considered in the benefit cost analysis.

The benefits quantified in Table 27 reflect the present value of the estimated avoided flood damage from 2027 to 2076, assuming the projects are constructed immediately. The benefits are based on H&H modeling in each watershed of the decreased flows and associated flood extent that would result from implementing all of the proposed projects in each watershed. Benefits are allocated to each projects based on geographic zones of benefit for each project (i.e., the benefit of reduced flooding at structures within one benefit zone may be 100 percent allocated to one project, while the benefit of reduced flooding of structures within another benefit zone may be allocated 50 percent to one project and 50 percent to another project). While this analysis only quantifies the benefit of reduced flood damage, regional detention projects may have additional benefits not quantitatively evaluated, including benefits associated with recreation, aesthetics, habitat, urban heat island mitigation, and other open space benefits.<sup>1</sup> As discussed in the TIS economic literature review, these types of benefits may be significant, particularly if the project design includes restoration of vegetation and aesthetic or recreation design elements.

Table 28 highlights the estimated storage capacity in acre-feet (AF) of each evaluated project, as well as the avoided flood damage benefits and construction costs per AF. The projects vary in storage capacity from 16 AF to 1,487 AF. Costs and benefit per AF also vary widely – ranging from approximately \$3,000 to over \$500,000 per AF on the benefit side and ranging from approximately \$14,000 to over \$650,000 per AF on the cost side. These wide ranges illustrate the importance of site-specific characteristics that determine project costs and benefits.

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<sup>1</sup> Due to the types of soils and depth of aquifers used for water supply in the region, without additional investment in such systems as aquifer storage and retrieval (ASR) there are not expected to be measurable waters supply benefits from groundwater recharge at regional detention projects. Further, there may be pedestrian or cycling transportation benefits if trails along the river corridor are included and connected to existing trail networks as part of the regional detention project design.

**Table 28: Project Costs and Benefits per Acre-Feet of Storage**

| <b>Project Watershed /<br/>Project Name</b>               | <b>AF of<br/>Storage</b> | <b>Avoided Flood<br/>Damage<br/>Benefit Per AF<br/>of Storage</b> | <b>Construction<br/>Cost Per AF of<br/>Storage</b> |
|-----------------------------------------------------------|--------------------------|-------------------------------------------------------------------|----------------------------------------------------|
| <b>MARY'S CREEK WATERSHED</b>                             |                          |                                                                   |                                                    |
| Little Mary's Creek at FM 3325                            | 23                       | \$67,612                                                          | \$208,174                                          |
| Mary's Creek at FM 3325                                   | 238                      | \$59,988                                                          | \$15,965                                           |
| South Mary's Creek at IH-20                               | 53                       | \$11,519                                                          | \$65,245                                           |
| Little Mary's Creek Tributary at FM 3325                  | 16                       | \$97,192                                                          | \$282,938                                          |
| <b>MOUNTAIN CREEK WATERSHED</b>                           |                          |                                                                   |                                                    |
| Mountain Creek at CR 616                                  | 1,487                    | \$2,852                                                           | \$14,301                                           |
| Mountain Creek at FM 2738                                 | 945                      | \$11,108                                                          | \$12,461                                           |
| <b>UPPER CLEAR FORK TRINITY WATERSHED</b>                 |                          |                                                                   |                                                    |
| Clear Fork at Sarra Ln                                    | 1,166                    | \$15,152                                                          | \$18,165                                           |
| Town Creek at Ric Williamson Memorial<br>Highway/Bowie Dr | 917                      | \$16,353                                                          | \$158,797                                          |
| <b>VILLAGE CREEK WATERSHED</b>                            |                          |                                                                   |                                                    |
| Chambers Creek at Enon Ave/Forest Hill Dr                 | 80                       | \$504,107                                                         | \$651,288                                          |
| Village Creek at FM 731                                   | 477                      | \$48,458                                                          | \$16,706                                           |

Source: H&H study cost estimates and Highland Economics analysis of H&H modeling results.

The following sectors provide additional detail on the costs and benefits of the proposed regional detention projects.

## 6.1 Benefits of Regional Detention Projects

This section provides additional detail on the avoided flood damage benefits of regional detention projects. As noted above, detention basins may also provide other benefits that are not quantified in this analysis. This is particularly the case if projects are designed as community amenities, such as offering recreational opportunities like walking paths and fishing, while also providing valuable habitat for birds and other wildlife (Kang, et al., 2024; Minnesota Pollution Control Agency, 2022). Large, multi-use detention basins, such as those containing trails, sports fields and courts, and other park amenities, can increase nearby property values more consistently; in one study of detention basins in College Station, TX, property values decreased by about \$250 for every 10 meters further from the basin (Lee & Li, 2009).<sup>1</sup> It is well established in the literature that property values next to parks are about 8-10% higher than similar properties that are not (Crompton & Nicholls, 2020). These higher property values demonstrate the value to homebuyers of the aesthetic, recreational and flood control services

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<sup>1</sup> Adjusted to 2025 dollars from \$164 in 2006 USD using GDP Deflator.

provided by these areas. Meanwhile, green spaces can provide the financial means to maintain themselves via increased property tax revenue.

### 6.1.1 *Mary's Creek Watershed*

The modeled expected damage from 2027 to 2076 due to increased flows in the Mary's Creek watershed (see Section 7) is estimated at \$57.3 million in present value terms. Table 29 shows the estimated benefit of each proposed project in reducing these damages. Together, the four proposed projects would reduce damages by approximately \$18 million, equivalent to a reduction of 31 percent in the projected increased damages in the Mary's Creek watershed for the period 2027 to 2076. The greatest benefit is from the Mary's Creek at FM 3325 project, which also has the highest benefit cost ratio of any analyzed project.

As discussed in Section 7, Mary's Creek storage projects may also measurably affect flooding in downstream areas. Reduced damages from a 500-year event alone may provide an additional \$627 per AF of storage value (present value). This value would not measurably affect the benefit cost ratios of Mary's Creek projects. However, the value of storage in the Mary's Creek watershed may be much higher (and therefore could affect the benefit cost ratios) if storage in Mary's Creek were to also significantly reduce downstream area damages in smaller, more frequent storm events.

**Table 29: Reduced Flood Damage Due to Projects, Mary's Creek Watershed, 2027-2076**

| <b>Benefit Metric</b>                                         | <b>Little Mary's Creek @ FM 3325</b> | <b>Mary's Creek @ FM 3325</b> | <b>South Mary's Creek @ IH20</b> | <b>Little Mary's Creek Tributary at FM 3325</b> | <b>Total</b> |
|---------------------------------------------------------------|--------------------------------------|-------------------------------|----------------------------------|-------------------------------------------------|--------------|
| Existing Building Benefit Over 50 Years                       | \$1,200,000                          | \$10,900,000                  | \$600,000                        | \$1,200,000                                     | \$13,900,000 |
| Forecasted Building Benefit Over 50 Years                     | \$300,000                            | \$3,400,000                   | \$0                              | \$300,000                                       | \$4,100,000  |
| Total Benefit over 50 Years (Existing + Forecasted Buildings) | \$1,600,000                          | \$14,300,000                  | \$600,000                        | \$1,600,000                                     | \$18,000,000 |
| Average Annualized Benefit                                    | \$100,000                            | \$600,000                     | \$0                              | \$100,000                                       | \$700,000    |
| % Reduction in Damages due to Projects                        | 3%                                   | 25%                           | 1%                               | 3%                                              | 31%          |

Source: Highland Economics analysis of H&H modeling results.

### 6.1.2 *Upper Clear Fork Trinity Watershed*

The modeled expected damage from 2027 to 2076 due to increased flows in the Upper Clear Fork Trinity Watershed (see Section 7) is estimated at \$690.2 million in present value terms. Table 30 shows the estimated benefit of each proposed project in reducing these damages.

Together, the two proposed projects would reduce damage over the next 50 years by approximately \$32.7 million, equivalent to a reduction of 5 percent in the projected increased damages in the Upper Clear Fork Trinity Watershed for the period 2027 to 2076. The greatest benefit is from the Clear Fork at Sarra Lane Project, with total present value of avoided flood damage benefit estimated at \$17.7 million if development proceeds as projected.

**Table 30: Reduced flood damage due to Projects, Upper Clear Fork Trinity Watershed, 2027-2076**

| <b>Benefit Metric</b>                                         | <b>Clear Fork at Sarra Ln</b> | <b>Town Creek at Ric Williamson Memorial Highway/Bowie Dr</b> | <b>Total</b> |
|---------------------------------------------------------------|-------------------------------|---------------------------------------------------------------|--------------|
| Existing Building Benefit Over 50 Years                       | \$11,200,000                  | \$9,000,000                                                   | \$20,100,000 |
| Forecasted Building Benefit Over 50 Years                     | \$6,500,000                   | \$6,000,000                                                   | \$12,500,000 |
| Total Benefit over 50 Years (Existing + Forecasted Buildings) | \$17,700,000                  | \$15,000,000                                                  | \$32,700,000 |
| Average Annualized Benefit                                    | \$700,000                     | \$600,000                                                     | \$1,300,000  |
| % Reduction in Damages due to Projects                        | 3%                            | 2%                                                            | 5%           |

Source: Highland Economics analysis of H&H modeling results.

### **6.1.3 Mountain Creek Watershed**

The modeled expected damage from 2027 to 2076 due to increased flows in the Mountain Creek Watershed (see Section 7) is estimated at \$81.6 million in present value terms. Table 31 shows the estimated benefit of each proposed project in reducing these damages. Together, the two proposed projects would reduce damages over the next 50 years by approximately \$14.7 million, equivalent to a reduction of 18 percent in the projected increased damages in the Upper Clear Fork Trinity Watershed for the period 2027 to 2076. The greatest benefit is from the Mountain Creek at FM 2738 Project, with total present value of avoided flood damage benefit estimated at \$10.5 million if development proceeds as projected.

**Table 31: Reduced Flood Damage Due to Projects, Mountain Creek Watershed, 2027-2076**

| <b>Benefit Metric</b>                                         | <b>Mountain Creek at FM 2738</b> | <b>Mountain Creek at CR 616</b> | <b>Total</b> |
|---------------------------------------------------------------|----------------------------------|---------------------------------|--------------|
| Existing Building Benefit Over 50 Years                       | \$3,100,000                      | \$1,600,000                     | \$4,700,000  |
| Forecasted Building Benefit Over 50 Years                     | \$7,400,000                      | \$2,700,000                     | \$10,000,000 |
| Total Benefit over 50 Years (Existing + Forecasted Buildings) | \$10,500,000                     | \$4,200,000                     | \$14,700,000 |
| Average Annualized Benefit                                    | \$400,000                        | \$200,000                       | \$600,000    |
| % Reduction in Damages due to Projects                        | 13%                              | 5%                              | 18%          |

Source: Highland Economics analysis of H&H modeling results.

#### 6.1.4 Village Creek Watershed

The modeled expected damage from 2027 to 2076 due to increased flows in the Village Creek Watershed (see Section 7) is estimated at \$244.1 million in present value terms. Table 32 shows the estimated benefit of each proposed project in reducing these damages. Together, the two proposed projects would reduce damages over the next 50 years by approximately \$63.4 million, equivalent to a reduction of 26 percent in the projected increased damages in the Village Creek Watershed for the period 2027 to 2076. The greatest benefit is from the Village Creek at Enon Ave/Village Hill Drive Project, with total present value of avoided flood damage benefit estimated at \$40.3 million if development proceeds as projected.

**Table 32: Reduced flood damage due to Projects, Village Creek Watershed, 2027-2076**

| <b>Benefit Metric</b>                                         | <b>Village Creek at FM 731</b> | <b>Village Creek at Enon Ave/Village Hill Drive</b> | <b>Total</b> |
|---------------------------------------------------------------|--------------------------------|-----------------------------------------------------|--------------|
| Existing Building Benefit Over 50 Years                       | \$16,600,000                   | \$28,700,000                                        | \$45,300,000 |
| Forecasted Building Benefit Over 50 Years                     | \$6,500,000                    | \$11,700,000                                        | \$18,200,000 |
| Total Benefit over 50 Years (Existing + Forecasted Buildings) | \$23,100,000                   | \$40,300,000                                        | \$63,400,000 |
| Average Annualized Benefit                                    | \$900,000                      | \$1,600,000                                         | \$2,600,000  |
| % Reduction in Damages due to Projects                        | 9%                             | 17%                                                 | 26%          |

Source: Highland Economics analysis of H&H modeling results.

## 6.2 Costs of Regional Detention Projects

This section provides additional detail on the cost of the 10 evaluated regional detention projects. Table 32 summarizes the cost estimates for each TSI West modeled project. The table presents the estimated cost to implement the TSI approach at a bridge costing and a traditional approach. For two projects in Mary's Creek (shaded in grey in Table 32), the traditional approach costs more than the TSI approach. As a conservative approach, the entire TSI cost was used as the incremental cost in the benefit cost analysis as it is not clear if the traditional bridge would be constructed in the absence of a TSI project in these locations, or what project costs would be if traditional bridges were constructed.

**Table 32: Costs of TSI West Modeled Projects**

| Project Name                                           | TSI Cost      | Traditional Cost | Incremental Cost |
|--------------------------------------------------------|---------------|------------------|------------------|
| <b>MARY'S CREEK WATERSHED</b>                          |               |                  |                  |
| Little Mary's Creek at FM 3325                         | \$4,788,000   | \$10,271,000     | \$4,788,000      |
| Mary's Creek at FM 3325                                | \$18,290,000  | \$16,049,000     | \$2,241,000      |
| South Mary's Creek at IH-20                            | \$3,458,000   | \$0              | \$3,458,000      |
| Little Mary's Creek Tributary at FM 3325               | \$4,527,000   | \$9,570,000      | \$4,527,000      |
| <b>MOUNTAIN CREEK WATERSHED</b>                        |               |                  |                  |
| Mountain Creek at CR 616                               | \$34,284,000  | \$15,130,000     | \$19,154,000     |
| Mountain Creek at FM 2738                              | \$28,349,000  | \$17,682,000     | \$10,667,000     |
| <b>UPPER CLEAR FORK TRINITY WATERSHED</b>              |               |                  |                  |
| Clear Fork at Sarra Ln                                 | \$32,188,000  | \$11,008,000     | \$21,180,000     |
| Town Creek at Ric Williamson Memorial Highway/Bowie Dr | \$159,640,000 | \$14,022,775     | \$145,617,225    |
| <b>VILLAGE CREEK WATERSHED</b>                         |               |                  |                  |
| Chambers Creek at Enon Ave/Forest Hill Dr              | \$65,175,000  | \$13,072,000     | \$52,103,000     |
| Village Creek at FM 731                                | \$24,184,000  | \$21,302,000     | \$2,882,000      |

Source: Freese and Nichols, Inc engineering cost analysis, as provided in Section X.

a/For projects with a negative incremental cost (i.e., the traditional approach to constructing a bridge is less than the TSI approach, the TSI cost was used as it is unclear in a bridge would be constructed in the absence of TSI.

A key component of costs is land value. To support the engineering cost analysis, the economic analysis analyzed Texas parcel data to estimate land values at proposed project sites. These values are presented in Table 33. Per-acre land values across the 10 modeled projects vary from approximately \$23,000 per acre to over \$65,000 per acre. The acreage requirement per AF of storage varies from 0.1 acre per AF to 0.9 acre per AF of storage.

**Table 33: Land Costs by Project**

| <b>Project Area</b>                       | <b>Average Land Value per Acre</b> | <b>Acres (Inundation Area)</b> | <b>Land Cost</b> | <b>Acres per AF of Storage</b> |
|-------------------------------------------|------------------------------------|--------------------------------|------------------|--------------------------------|
| <b>MARY'S CREEK WATERSHED</b>             |                                    |                                |                  |                                |
| Little Mary's Creek @ FM 3325             | \$23,100                           | 10                             | \$231,000        | 10.0                           |
| Mary's Creek @ FM 3325                    | \$49,180                           | 60                             | \$2,950,800      | 60.0                           |
| South Mary's Creek @ IH 20 *              | \$23,000                           | 35                             | \$805,000        | 35.0                           |
| Little Mary's Creek Tributary @ FM 3325 * | \$23,960                           | 15                             | \$359,400        | 15.0                           |
| <b>MOUNTAIN CREEK WATERSHED</b>           |                                    |                                |                  |                                |
| Mountain Creek @ CR 616                   | \$32,020                           | 270                            | \$8,645,400      | 270.0                          |
| Mountain Creek @ FM 2738                  | \$22,818                           | 160                            | \$3,650,880      | 160.0                          |
| <b>UPPER CLEAR FORK TRINITY WATERSHED</b> |                                    |                                |                  |                                |
| Clear Fork @ Sarra Lane                   | \$26,503                           | 285                            | \$7,553,355      | 285.0                          |
| Town Creek @ RWMH, Bowie Dr               | \$40,485                           | 130                            | \$5,263,050      | 130.0                          |
| <b>VILLAGE CREEK WATERSHED</b>            |                                    |                                |                  |                                |
| Chambers Creek @ Enon Ave, Forest Hill Dr | \$65,548                           | 55                             | \$3,605,140      | 55.0                           |
| Village Creek @ FM 731                    | \$33,196                           | 140                            | \$4,647,440      | 140.0                          |

Source: H&H study cost estimates and Highland Economics analysis of Texas land parcel data and H&H modeling results.

## 7 Cost-Benefit of Local Buyout: Case Study in Mary's Creek Watershed

Flooding in and around Mary's Creek in the City of Benbrook was analyzed for potential buy-out benefits. The general study area is shown in Map 1, with the structures analyzed for buyout identified by circular points on the map. Six potential buy-out areas were identified based on geographic proximity and level of expected flood damages; detail for the geographic extent of these areas is provided in Map 2 and described in Table 34.

**Map 1: Mary's Creek Buy-Out Analysis Study Area**

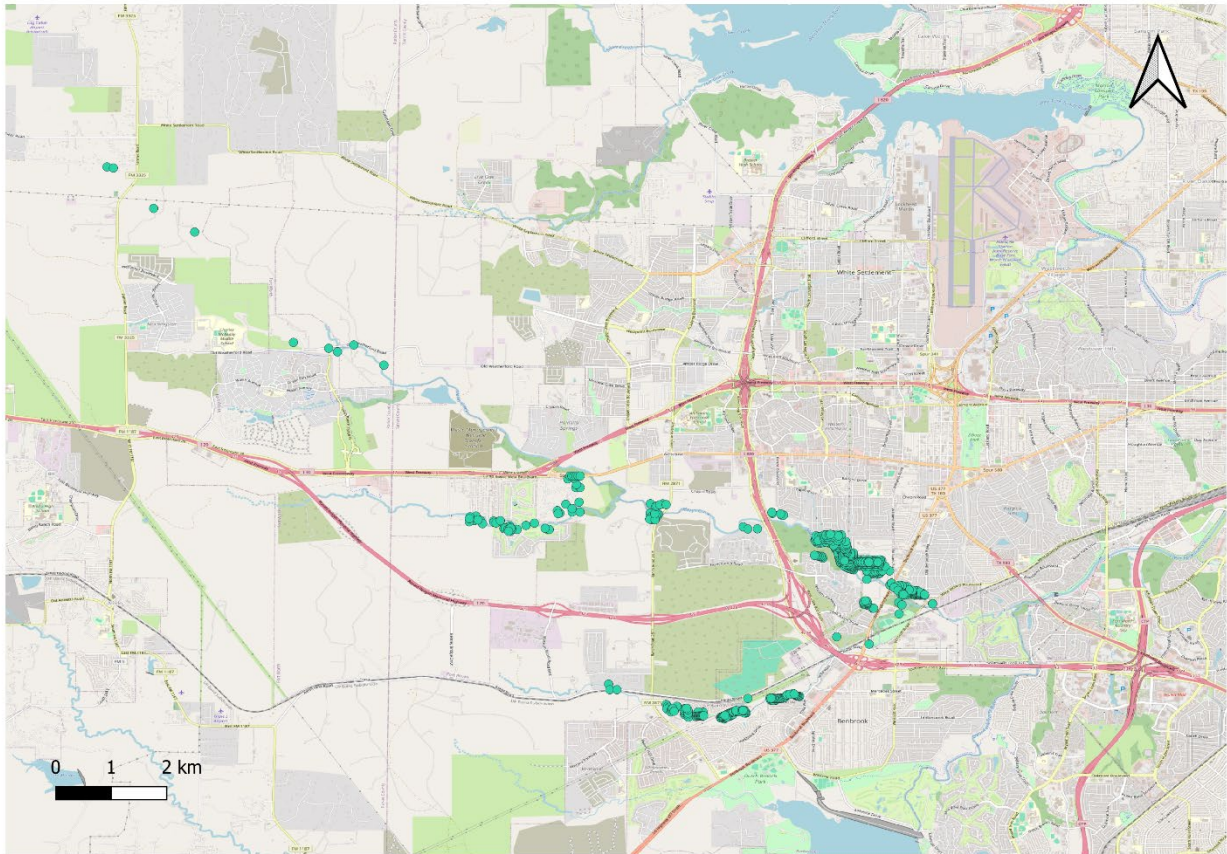


**Table 34: Definition of Potential Buy-Out Areas**

| <b>Area Name</b>        | <b>Area Boundaries</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Bowie                   | Structures between 11105 and 11255 Camp Bowie West Blvd Ste.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| East of 377             | Structures located between 5050 Benbrook Blvd east down Mary's Creek Drive to 5250 Old Benbrook Road. Includes 7615 Mary's Creek Drive.                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Mary's Creek Drive      | Bounded on the north by 4405 Mary's Creek Drive and on the south by 4405 Twilight Drive; includes all homes on north side of Mary's Creek Drive until 8600 Mary's Creek Drive. Bounded on west by homes between 4408 Mary's Creek Drive south to 8321 Mary's Creek Drive. Bounded on east by 4620 and 4625 Owendale Drive. Includes all homes on Leo Court, Gladys Court, and Wayne Court, and east on Idledell until 4537 Phillips Court. Does not include structures on east side of Mary's Creek Drive between 8600 Mary's Creek Drive and 4540 Idledell Drive. |
| North Creekside         | North side of Creekside Drive, between 9800 and 9816 Creekside Drive.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Mary's Creek Drive East | Includes all other structures in Mary's Creek Drive area, northward from 4300 and 4401 Mary's Creek Drive, northward of 4401 and 4404 Twilight Drive, including Elmwood Drive, and all of Springwood Drive. Includes structures on the east side of Mary's Creek Drive between 8600 Mary's Creek Drive and 4540 Idledell Drive, and all structures north of 4533 Phillip Ct (inclusive). Includes Owendale Drive north of 4616 (west side) and 4621 (east side) (inclusive).                                                                                       |
| All Other Structures    | Any structures not included in above boundaries that are modeled to flood in any storm event up to and including the 500-year flood. These structures are dispersed widely.                                                                                                                                                                                                                                                                                                                                                                                        |

Table 35 summarizes the findings of the buy-out analysis. Four of the six analyzed buy-out areas have a high benefit-to-cost ratio. A benefit-to-cost ratio over 1.0 indicates that the modeled flood damages to properties in these regions over the next 50 years are expected to exceed the current market value of the properties. For these four regions with high benefit to cost ratios, localized buy-out programs may significantly reduce flood damages if property owners are amenable to relocating. Relocating can be stressful to property owners and adversely affect community cohesion and social stability, and consequently homeowners may be reluctant to relocate. These types of social costs are not quantified in this analysis, nor has the community interest in a buy-out program been evaluated through outreach or stakeholder engagement.

**Table 35: Summary of Buy-Out Potential Costs and Benefits**

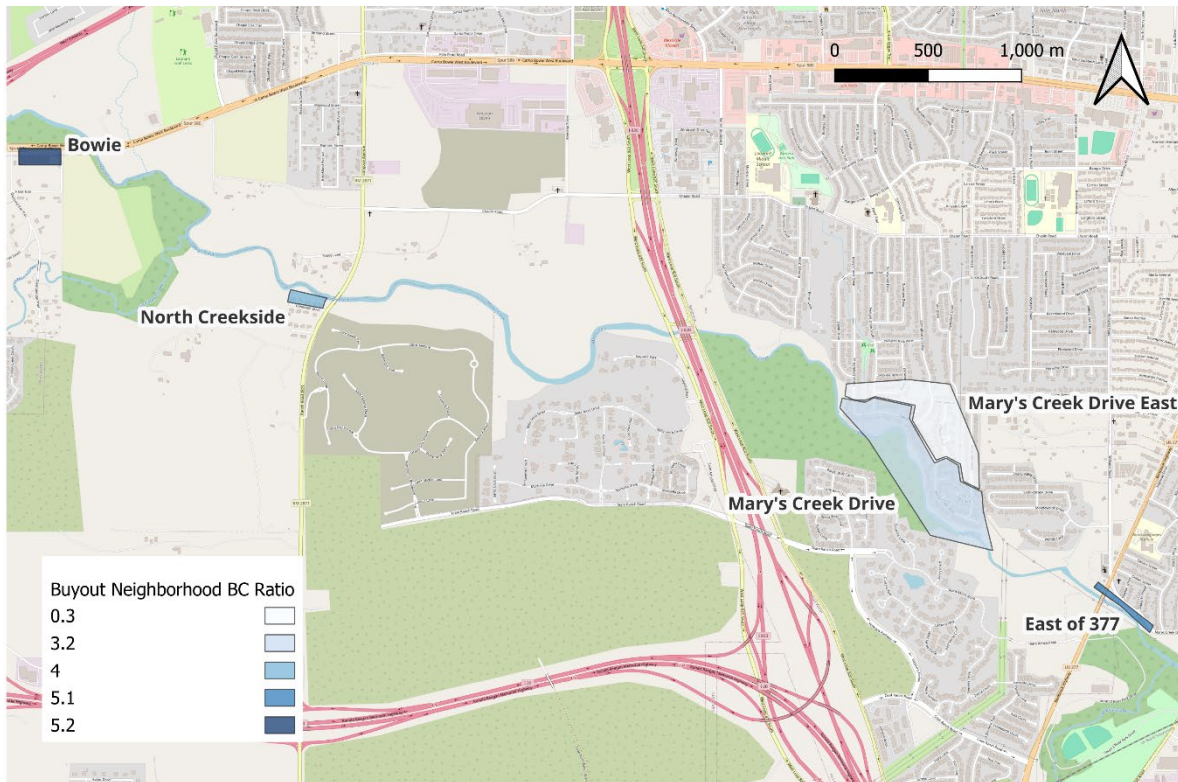
| <b>Area</b>        | <b>Total Cost Range<sup>1</sup></b> | <b>Total Benefits<br/>(Present Value of Avoided<br/>Flood Damages 2027 to 2076)</b> | <b>Benefit to Cost<br/>Ratio</b> |
|--------------------|-------------------------------------|-------------------------------------------------------------------------------------|----------------------------------|
| Bowie              | \$4,200,000 to<br>\$5,100,000       | \$24,000,000                                                                        | 4.7 to 5.7                       |
| East of 377        | \$2,000,000 to<br>\$2,400,000       | \$11,000,000                                                                        | 4.7 to 5.6                       |
| Mary's Creek Drive | \$24,700,000 to<br>\$29,700,000     | \$85,600,000                                                                        | 2.9 to 3.5                       |
| North Creekside    | \$2,100,000 to<br>\$2,500,000       | \$9,400,000                                                                         | 3.8 to 4.5                       |

|                         |                                   |               |            |
|-------------------------|-----------------------------------|---------------|------------|
| Mary's Creek Drive East | \$24,400,000 to<br>\$29,300,000   | \$7,500,000   | 0.3        |
| All Other Structures    | \$196,800,000 to<br>\$236,100,000 | \$139,900,000 | 0.6 to 0.7 |

Source: Highland Economics analysis of H&H modeling results.

1/Cost range reflects uncertainty in transaction costs associated with administration of the buy-out program and relocation costs of residents and businesses.

**Map 2: Mary's Creek Potential Buy-Out Areas**



## 7.1 Buy-Out Costs

Total costs of buy-out include the costs of purchasing land and structures, as well as transaction costs that include administration costs and relocation costs for homes and businesses. Relatively little information is available on transaction costs of floodplain buy-out programs. Several recent research efforts have identified that transactions costs can vary widely by program (Curran-Groome, Haygood, Hino, BenDor, & Salvesen, 2021) (Vegh, BenDor, & Monast, 2023). This analysis uses a range of transaction costs, of 25 percent to 50 percent of the total purchase cost for both land and structures. Buy-out costs are summarized in Table 36.

**Table 36: Buy-Out Cost by Area**

| Potential Buy-Out Area  | Cost of Structures | Cost of Land | Low Transaction Costs | High Transaction Costs | Total Estimated Cost Range     |
|-------------------------|--------------------|--------------|-----------------------|------------------------|--------------------------------|
| Bowie                   | \$3,214,000        | \$165,000    | \$800,000             | \$1,700,000            | \$4,200,000 to \$5,100,000     |
| East of 377             | \$1,212,000        | \$346,000    | \$400,000             | \$800,000              | \$2,000,000 to \$2,400,000     |
| Mary's Creek Drive      | \$18,539,000       | \$1,216,000  | \$4,900,000           | \$9,900,000            | \$24,700,000 to \$29,700,000   |
| North Creekside         | \$1,625,000        | \$74,000     | \$400,000             | \$800,000              | \$2,100,000 to \$2,500,000     |
| Mary's Creek Drive East | \$16,203,000       | \$3,331,000  | \$4,900,000           | \$9,800,000            | \$24,400,000 to \$29,300,000   |
| All Other Structures    | \$129,131,000      | \$28,284,000 | \$39,400,000          | \$78,700,000           | \$198,600,000 to \$236,600,000 |

Source: Highland Economics analysis of H&H modeling results.

## 7.2 Benefits of Buy-Out

Table 37 summarizes the average annual avoided flood damage benefits by buy-out area through time. Due to projected increases in flows, avoided damages rise through time, from approximately \$9.8 million across all evaluated structures in 2020 to \$13.7 million in 2076.

**Table 37: Avoided Flood Damage Benefits from Buy-Out, 2020 to 2076**

| <b>Year</b>                                | <b>Bowie</b> | <b>East of 377</b> | <b>Mary's Creek Drive</b> | <b>North Creekside</b> | <b>Mary's Creek Drive East</b> | <b>All Other Structures</b> | <b>Total</b>  |
|--------------------------------------------|--------------|--------------------|---------------------------|------------------------|--------------------------------|-----------------------------|---------------|
| 2020 (H&H Modeled Year)                    | \$682,000    | \$383,000          | \$2,843,000               | \$331,000              | \$278,000                      | \$4,899,000                 | \$9,416,000   |
| 2027                                       | \$744,000    | \$396,000          | \$2,980,000               | \$342,000              | \$283,000                      | \$5,062,000                 | \$9,807,000   |
| 2050                                       | \$993,000    | \$442,000          | \$3,476,000               | \$380,000              | \$300,000                      | \$5,636,000                 | \$11,227,000  |
| 2070 (H&H Modeled Year)                    | \$1,275,000  | \$486,000          | \$3,975,000               | \$416,000              | \$315,000                      | \$6,189,000                 | \$12,656,000  |
| 2076                                       | \$1,374,000  | \$500,000          | \$4,139,000               | \$428,000              | \$320,000                      | \$6,365,000                 | \$13,126,000  |
| Average Annualized Damage, 2027-2076       | \$978,000    | \$446,000          | \$3,488,000               | \$384,000              | \$306,000                      | \$5,700,000                 | \$11,302,000  |
| <b>Present Value Damages, 2027 to 2076</b> | \$24,020,000 | \$10,958,000       | \$85,643,000              | \$9,430,000            | \$7,517,000                    | \$139,935,000               | \$277,503,000 |
| <b>% Damages, 2027 to 2070</b>             | 9%           | 4%                 | 31%                       | 3%                     | 3%                             | 50%                         | 100%          |

### 7.2.1 *Bowie*

Table 38 summarizes flood damages in the Bowie area under 2020 conditions while Table 39 summarizes flood damages in the Bowie area under 2070 conditions. This damage would be avoided if all structures in this area were acquired and structures removed in a buy-out program.

**Table 38: Bowie Area Flood Damage: 2020 Existing Conditions**

| Event           | Building Damage | Content Damage | Vehicle Damage | Displacement | Total Cost  |
|-----------------|-----------------|----------------|----------------|--------------|-------------|
| 500-yr          | \$2,850,000     | \$5,670,000    | \$510,000      | \$590,000    | \$9,630,000 |
| 100-yr          | \$2,410,000     | \$4,860,000    | \$430,000      | \$530,000    | \$8,230,000 |
| 50-yr           | \$2,160,000     | \$4,260,000    | \$380,000      | \$530,000    | \$7,320,000 |
| 10-yr           | \$180,000       | \$550,000      | \$40,000       | \$150,000    | \$920,000   |
| 2-yr            | \$0             | \$0            | \$0            | \$100,000    | \$100,000   |
| Expected Annual | \$170,000       | \$390,000      | \$30,000       | \$90,000     | \$680,000   |

Source: Highland Economics analysis of H&H modeling results.

**Table 39: Bowie Area Flood Damage: 2070 Conditions**

| Event           | Building Damage | Content Damage | Vehicle Damage | Displacement | Total Cost  |
|-----------------|-----------------|----------------|----------------|--------------|-------------|
| 500-yr          | \$2,910,000     | \$5,750,000    | \$520,000      | \$590,000    | \$9,770,000 |
| 100-yr          | \$2,460,000     | \$4,990,000    | \$440,000      | \$530,000    | \$8,420,000 |
| 50-yr           | \$2,230,000     | \$4,420,000    | \$390,000      | \$530,000    | \$7,580,000 |
| 10-yr           | \$850,000       | \$1,860,000    | \$120,000      | \$500,000    | \$3,330,000 |
| 2-yr            | \$0             | \$0            | \$0            | \$100,000    | \$100,000   |
| Expected Annual | \$340,000       | \$710,000      | \$50,000       | \$170,000    | \$1,270,000 |

Source: Highland Economics analysis of H&H modeling results.

### 7.2.2 *East of 377*

Table 40 summarizes flood damages in the East of 377 area under 2020 conditions while Table 41 summarizes flood damages in the East of 377 area under 2070 conditions. This damage would be avoided if all structures in this area were acquired and structures removed in a buy-out program.

**Table 40: East of 377 Area Flood Damage: 2020 Existing Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$910,000              | \$1,790,000           | \$260,000             | \$570,000           | \$3,530,000       |
| 100-yr          | \$700,000              | \$1,500,000           | \$220,000             | \$490,000           | \$2,920,000       |
| 50-yr           | \$600,000              | \$1,240,000           | \$180,000             | \$480,000           | \$2,500,000       |
| 10-yr           | \$260,000              | \$410,000             | \$70,000              | \$190,000           | \$940,000         |
| 2-yr            | \$10,000               | \$0                   | \$0                   | \$10,000            | \$20,000          |
| Expected Annual | \$100,000              | \$180,000             | \$30,000              | \$80,000            | \$380,000         |

Source: Highland Economics analysis of H&H modeling results.

**Table 41: East of 377 Area Flood Damage: 2070 Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$920,000              | \$1,800,000           | \$270,000             | \$570,000           | \$3,550,000       |
| 100-yr          | \$710,000              | \$1,520,000           | \$230,000             | \$490,000           | \$2,950,000       |
| 50-yr           | \$630,000              | \$1,330,000           | \$190,000             | \$480,000           | \$2,640,000       |
| 10-yr           | \$350,000              | \$590,000             | \$110,000             | \$220,000           | \$1,260,000       |
| 2-yr            | \$40,000               | \$30,000              | \$20,000              | \$30,000            | \$120,000         |
| Expected Annual | \$130,000              | \$230,000             | \$40,000              | \$90,000            | \$490,000         |

Source: Highland Economics analysis of H&H modeling results.

### **7.2.3 Mary's Creek Drive**

Table 42 summarizes flood damages in the Mary's Creek Drive area under 2020 conditions while Table 43 summarizes flood damages in the Mary's Creek area area under 2070 conditions. This damage would be avoided if all structures in this area were acquired and structures removed in a buy-out program.

**Table 42: Mary's Creek Drive Area Flood Damage: 2020 Existing Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$10,780,000           | \$7,990,000           | \$1,140,000           | \$2,810,000         | \$22,720,000      |
| 100-yr          | \$8,870,000            | \$7,330,000           | \$1,020,000           | \$2,510,000         | \$19,730,000      |
| 50-yr           | \$8,180,000            | \$6,930,000           | \$920,000             | \$2,380,000         | \$18,410,000      |
| 10-yr           | \$3,310,000            | \$2,510,000           | \$220,000             | \$1,060,000         | \$7,110,000       |
| 2-yr            | \$140,000              | \$70,000              | \$0                   | \$0                 | \$200,000         |
| Expected Annual | \$1,310,000            | \$1,030,000           | \$110,000             | \$400,000           | \$2,840,000       |

Source: Highland Economics analysis of H&amp;H modeling results.

**Table 43: Mary's Creek Drive Area Flood Damage: 2070 Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$10,860,000           | \$8,010,000           | \$1,140,000           | \$2,840,000         | \$22,850,000      |
| 100-yr          | \$8,980,000            | \$7,380,000           | \$1,040,000           | \$2,540,000         | \$19,940,000      |
| 50-yr           | \$8,340,000            | \$7,030,000           | \$950,000             | \$2,420,000         | \$18,730,000      |
| 10-yr           | \$5,250,000            | \$4,390,000           | \$450,000             | \$1,670,000         | \$11,750,000      |
| 2-yr            | \$140,000              | \$70,000              | \$0                   | \$0                 | \$200,000         |
| Expected Annual | \$1,790,000            | \$1,480,000           | \$160,000             | \$540,000           | \$3,980,000       |

Source: Highland Economics analysis of H&amp;H modeling results.

#### **7.2.4 North Creekside**

Table 44 summarizes flood damages in the North Creekside area under 2020 conditions while Table 45 summarizes flood damages in the North Creekside area under 2070 conditions. This damage would be avoided if all structures in this area were acquired and structures removed in a buy-out program.

**Table 44: North Creekside Flood Damage: 2020 Existing Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$1,440,000            | \$780,000             | \$80,000              | \$240,000           | \$2,530,000       |
| 100-yr          | \$850,000              | \$690,000             | \$80,000              | \$210,000           | \$1,830,000       |
| 50-yr           | \$780,000              | \$680,000             | \$80,000              | \$190,000           | \$1,720,000       |
| 10-yr           | \$390,000              | \$420,000             | \$40,000              | \$100,000           | \$940,000         |
| 2-yr            | \$0                    | \$0                   | \$0                   | \$0                 | \$0               |
| Expected Annual | \$140,000              | \$140,000             | \$10,000              | \$40,000            | \$330,000         |

Source: Highland Economics analysis of H&amp;H modeling results.

**Table 45: North Creekside Flood Damage: 2070 Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$1,440,000            | \$780,000             | \$80,000              | \$240,000           | \$2,540,000       |
| 100-yr          | \$860,000              | \$690,000             | \$80,000              | \$210,000           | \$1,840,000       |
| 50-yr           | \$790,000              | \$680,000             | \$80,000              | \$200,000           | \$1,750,000       |
| 10-yr           | \$520,000              | \$530,000             | \$50,000              | \$140,000           | \$1,250,000       |
| 2-yr            | \$40,000               | \$20,000              | \$0                   | \$0                 | \$60,000          |
| Expected Annual | \$180,000              | \$170,000             | \$20,000              | \$50,000            | \$420,000         |

Source: Highland Economics analysis of H&amp;H modeling results.

### **7.2.5 Mary's Creek Drive East**

Table 46 summarizes flood damages in the Mary's Creek Drive East area under 2020 conditions while Table 47 summarizes flood damages in the Mary's Creek Drive East area under 2070 conditions. This damage would be avoided if all structures in this area were acquired and structures removed in a buy-out program.

**Table 46: Mary's Creek Drive East Flood Damage: 2020 Existing Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$5,140,000            | \$4,860,000           | \$500,000             | \$1,620,000         | \$12,120,000      |
| 100-yr          | \$2,480,000            | \$2,210,000           | \$200,000             | \$800,000           | \$5,690,000       |
| 50-yr           | \$1,570,000            | \$1,320,000           | \$110,000             | \$500,000           | \$3,510,000       |
| 10-yr           | \$30,000               | \$10,000              | \$0                   | \$0                 | \$50,000          |
| 2-yr            | \$30,000               | \$10,000              | \$0                   | \$0                 | \$50,000          |
| Expected Annual | \$130,000              | \$110,000             | \$10,000              | \$40,000            | \$280,000         |

Source: Highland Economics analysis of H&amp;H modeling results.

**Table 47: Mary's Creek Drive East Flood Damage: 2070 Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$5,330,000            | \$5,050,000           | \$520,000             | \$1,680,000         | \$12,580,000      |
| 100-yr          | \$2,620,000            | \$2,370,000           | \$220,000             | \$850,000           | \$6,050,000       |
| 50-yr           | \$1,730,000            | \$1,490,000           | \$130,000             | \$570,000           | \$3,920,000       |
| 10-yr           | \$70,000               | \$30,000              | \$0                   | \$0                 | \$100,000         |
| 2-yr            | \$30,000               | \$10,000              | \$0                   | \$0                 | \$50,000          |
| Expected Annual | \$140,000              | \$120,000             | \$10,000              | \$40,000            | \$320,000         |

Source: Highland Economics analysis of H&amp;H modeling results.

### 7.2.6 All Other Structures

Table 48 summarizes flood damages to all other structures evaluated under 2020 conditions while Table 49 summarizes flood damages to all other structures under 2070 conditions. This damage would be avoided if all structures in this area were acquired and structures removed in a buy-out program.

**Table 48: All Other Structures Flood Damage: 2020 Existing Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$24,490,000           | \$30,740,000          | \$2,250,000           | \$10,270,000        | \$67,740,000      |
| 100-yr          | \$12,790,000           | \$17,630,000          | \$1,030,000           | \$6,680,000         | \$38,130,000      |
| 50-yr           | \$9,450,000            | \$13,780,000          | \$710,000             | \$4,790,000         | \$28,730,000      |
| 10-yr           | \$2,360,000            | \$6,590,000           | \$210,000             | \$2,040,000         | \$11,200,000      |
| 2-yr            | \$600,000              | \$610,000             | \$50,000              | \$260,000           | \$1,510,000       |
| Expected Annual | \$1,330,000            | \$2,600,000           | \$110,000             | \$860,000           | \$4,900,000       |

Source: Highland Economics analysis of H&H modeling results.

**Table 49: All Other Structures Flood Damage: 2070 Conditions**

| <b>Event</b>    | <b>Building Damage</b> | <b>Content Damage</b> | <b>Vehicle Damage</b> | <b>Displacement</b> | <b>Total Cost</b> |
|-----------------|------------------------|-----------------------|-----------------------|---------------------|-------------------|
| 500-yr          | \$27,220,000           | \$33,780,000          | \$2,510,000           | \$11,080,000        | \$74,590,000      |
| 100-yr          | \$14,520,000           | \$19,640,000          | \$1,170,000           | \$7,170,000         | \$42,500,000      |
| 50-yr           | \$10,840,000           | \$15,130,000          | \$810,000             | \$5,510,000         | \$32,290,000      |
| 10-yr           | \$3,430,000            | \$8,090,000           | \$280,000             | \$2,400,000         | \$14,190,000      |
| 2-yr            | \$870,000              | \$1,310,000           | \$110,000             | \$950,000           | \$3,240,000       |
| Expected Annual | \$1,720,000            | \$3,200,000           | \$150,000             | \$1,120,000         | \$6,190,000       |

Source: Highland Economics analysis of H&H modeling results.

## 8 Nature-Based Solutions and Green Stormwater Infrastructure

As discussed in detail in the economics literature review conducted for this study (see Task 1.1 Literature Review), nature-based solutions, such as preserving floodplains and riparian areas, and green stormwater infrastructure (GSI), such as local bioretention and street trees, are alternative approaches to managing stormwater runoff that can be cost-effective. These methods also provide other co-benefits such as habitat, aesthetic value, recreation opportunity, urban heat island mitigation, and air and water quality enhancement.

Economic results presented above highlight the flood damage that can result from developing in the floodplain. As demonstrated throughout the economic analysis, preserving floodplains reduces exposure to flooding by restricting development in areas that are now, or will in the future be, prone to flooding. Additionally, preserving floodplains and riparian corridors mitigates flood risk in downstream areas. Riparian zones and floodplains slow, absorb, and divert floodwaters, reducing their force, height, velocity, and volume (Siefert, 2019). These effects help protect downstream developments from flood damage, with results of this economic analysis particularly highlighting the importance of the Mary's Creek Watershed for downstream areas.

Floodplain preservation can be either proactive (i.e., protecting natural floodplains prior to development) or reactive such as in the Mary's Creek Watershed case study (i.e., managed retreat or buyout programs where governments purchase properties in the floodplain and restore the land to natural open space to reduce future flood damages, emergency response, and increase natural function and storage of floodwaters). Proactively conserving floodplains and riparian corridors before they are developed is generally much more cost-effective than restoring already developed or damaged areas. By preventing development in high-risk areas, communities can avert the costs associated with property damage, disaster recovery, and the need for expensive structural flood controls. Research on the value of upstream wetlands for downstream flood mitigation across the continental U.S indicates that the societal benefits of reduced flooding outweigh the costs of wetland conservation within just six years on average (Taylor & Druckenmiller, 2021).

GSI methods, a suite of practices that mimic natural hydrology by capturing and filtering runoff close to its source, can also be cost effective and beneficial solutions to manage stormwater. Unlike traditional gray stormwater infrastructure (e.g., pipes and concrete channels), GSI can also be designed to deliver a wide range of environmental, social, and economic co-benefits that increase return on investment (ROI) and enable local governments to achieve multiple community objectives. Since the costs and benefits of GSI vary based on GSI practice, design, scale, and local context, a successful regional strategy depends on selecting the right practices for the right locations.

Table 50 summarizes and compares the installation costs of regional detention basins, several forms of GSI, floodplain preservation, and gray stormwater infrastructure. While costs vary based on many site-specific factors, floodplain and wetland preservation is likely the least cost method to manage stormwater and mitigate flood risk. Furthermore, on average, gray stormwater infrastructure has the highest installation cost per unit of stormwater managed compared to other approaches. Furthermore, gray infrastructure does not provide environmental co-benefits as provided by the other approaches. It is important to note that life-cycle operation, maintenance, and repair (OMR) costs can be sizable for both grey and green stormwater infrastructure. OMR costs were not considered in Table 50 because of the variability by location and the fact that OMR costs for regional detention were not estimated. For evaluating cost effectiveness at any one location, life-cycle costs should be considered.

**Table 50. Costs for GSI Practices, 2026 Dollars for One Acre-Foot Stormwater Storage Capacity**

| Stormwater Management Approach                               | Installation Cost, Low   | Installation Cost, High               | Necessary Land Area (acres)                          | Magnitude of Co-Benefit Over 50 Years                                                                   |
|--------------------------------------------------------------|--------------------------|---------------------------------------|------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Regional Detention (TSI)                                     | \$6,000                  | \$283,000                             | 0.1 to 0.9                                           | May be substantial if vegetation/habitat is restored and public recreation access provided.             |
|                                                              |                          |                                       |                                                      |                                                                                                         |
| Wetlands                                                     | \$42,000                 | \$474,000 (constructed wetland costs) | 0.67                                                 | ~\$560,000                                                                                              |
| Local Bioretention                                           | \$260,000                | \$743,000                             | 0.67                                                 | ~\$155,000                                                                                              |
|                                                              |                          |                                       | 34 acres of canopy or 3 acres of tree root base area | ~\$111.6 million                                                                                        |
| Street Trees                                                 | \$374,000                | \$1,742,000                           |                                                      |                                                                                                         |
| Floodplain Preservation (Purchase of undeveloped floodplain) | \$5,000                  | \$97,000                              | ~2 <sup>b</sup>                                      | May be substantial if vegetation/habitat is preserved or restored and public recreation access provided |
|                                                              |                          |                                       |                                                      |                                                                                                         |
| Gray Stormwater Infrastructure                               | \$4,331,000 <sup>c</sup> |                                       | N/A                                                  | \$0                                                                                                     |

Sources: Highland Economics analysis of (Jack, Jaber, Heidari, & Prideaux, Green Stormwater Infrastructure for Urban Flood Resilience: Opportunity Analysis for Dallas, TX, 2021; Lofton & Porse, 2025; Lesikar, 2008).

Assumes street trees have a storage capacity of 100 cubic feet with 420 square feet of canopy, bioretention and wetland has 1.5 cubic foot of storage capacity per square foot of area, and conservatively assumes natural floodplain has 0.50 cubic foot of storage capacity per square foot of area.

b/ Very conservatively assumes floodplain storage capacity of 0.5 acre-feet per acre; this is based on H&H modeling of Mary's Creek Watershed which indicates that the storage capacity decreases by 0.5 AF per acre across the entire watershed (i.e., the change in storage capacity divided by all acres in the watershed) due to development between 2020 and 2070 conditions. As the entire watershed is not projected to be developed by 2070 and the floodplain has greater water storage capacity than elsewhere in the watershed, the actual storage capacity per floodplain acre is

likely much greater and the land cost (installation cost) much lower per AF of storage capacity.

c/ The original cost was reported as \$10.60 per gallon from Jack et al. (2025), based on the cost to upgrade the system to handle overflow from a 100-year storm, as estimated by Dallas Water Utilities in 2020. We adjusted this cost to 2026 dollars using the RSMeans Cost Index and converted it into acre-feet. We then converted the resulting value into present-value terms using a discount rate of 3.25 percent and a period of 50 years.

Costs for floodplain preservation in Table 50 are based on the costs of land for the regional detention basins as well as average land costs by county presented in Table 51.

**Table 51. Land Costs by Land Use and County, 2026\$**

| <b>County</b> | <b>Cropland</b> | <b>Grazing Land</b> | <b>Other</b> | <b>Wildlife Management</b> | <b>Average</b> |
|---------------|-----------------|---------------------|--------------|----------------------------|----------------|
| Dallas        | \$24,400        | \$18,100            | \$11,600     | \$9,100                    | \$20,400       |
| Ellis         | \$21,800        | \$26,600            | \$76,700     | \$35,300                   | \$26,100       |
| Johnson       | \$9,300         | \$8,400             | \$11,200     | \$7,400                    | \$8,600        |
| Parker        | \$8,300         | \$5,900             | \$17,600     | \$7,900                    | \$6,300        |
| Tarrant       | \$14,700        | \$14,600            | \$20,500     | \$12,100                   | \$14,700       |
| Wise          | \$22,400        | \$15,400            | \$74,500     | \$17,600                   | \$16,400       |

Source: (Texas A&M Natural Resources Institute, 2025)

Environmental co-benefits of GSI presented in Table 1 are based on findings from the economic literature review; specific values summarized in Table 50 are presented in more detail in Table 52. Benefits of each GSI practice can vary widely based on site-specific factors; the values in Table 52 are mid-range values found in the literature. See the economics literature review conducted for TSI for a full description of each GSI and NBS solution, including benefits, costs, return on investment, and siting considerations.

**Table 52: Additional (Non-Stormwater) Benefit per AF per Year of Storage Capacity**

| Mitigation Measure                                   | Bioretention   | Wetlands        | Urban Trees        |
|------------------------------------------------------|----------------|-----------------|--------------------|
| Water Quality (Sediment Capture)                     | \$40           | \$200           | N/A                |
| Water Quality (Nitrogen Capture)                     | \$5,000        | \$11,700        | \$1,400            |
| Water Quality (Phosphorus Capture)                   | \$1,300        | \$5,300         | \$400              |
| Recreation                                           | N/A            | \$900           | N/A                |
| Energy Use (effects of shade)                        | N/A            | N/A             | \$2,524,300        |
| Air Quality (Particulate Matter)                     | N/A            | N/A             | \$22,500           |
| Air Quality (Sulfur Dioxide)                         | N/A            | N/A             | \$4,700            |
| Air Quality (Nitrogen Dioxide)                       | N/A            | N/A             | \$1,200            |
| Air Quality (Carbon Dioxide)                         | N/A            | N/A             | \$2,000            |
| Habitat                                              | N/A            | \$4,700         | NA                 |
| Aesthetics                                           | N/A            | NA              | \$51,200           |
| Pavement Maintenance                                 | \$0            | \$0             | \$1,935,700        |
| <b>Total Approximate Benefit per 1 AF of Storage</b> | <b>\$6,340</b> | <b>\$22,800</b> | <b>\$4,543,400</b> |
| Present Value Over 50 Years per AF of Storage        | \$225,000      | \$560,000       | \$111,550,000      |

Sources: Highland Economics analysis of (Hathaway & Hunt, 2007; Noack, 2018; San Antonio River Authority, 2019; Hansen, 2015; Ellis, et al., 2014; Houle, et al., 2013; SEMCOG, 2023; Woodward & Wui, 2001; NOAA, 2015; Mateleska, 2016)(North Central Texas Council of Governments, 2014; Houle, Roseen, Ballester, Puls, & Sherrard Jr., 2013) (National Weather Service, 2026; City of Denton, 2008; Jaber, 2015; International Stormwater Best Management Practices Database, 2016; Middleton & Barrett, 2008; Price, et al., 2021; Marshall, et al., 2018) (US EPA, 2015; Natural Resource Conservation Service, US Department of Agriculture, 2010; Shaik, Helmers, & Langemeier, 2002) (The Trust for Public Land, 2017; City of Plano, 2023; Dallas Park & Recreation, 2017; Dallas Park & Recreation, 2025; Morrison & Mikulencak, 2012; U.S. Environmental Protection Agency, 2007; USDA NRCS, 2024) (Texas Tree Foundation, 2015; Vargas, et al., 2007) (Monear, et al., Downtown Dallas Tree Inventory & Ecosystem Services Benefits Report, 2013) (Wachter & Wong, 2008; Nordman, et al., 2018).