CITY OF MISSOULA

2025 Comprehensive Stormwater Quality Plan

Morrison-Maierle

City of Missoula
Comprehensive Stormwater Quality Plan

EXECUTIVE SUMMARY

PURPOSE OF THIS PLAN

The City of Missoula (City) Stormwater Utility manages the quantity, quality, and routing of stormwater runoff within Missoula City Limits. The effectiveness and efficiency of stormwater management have a direct impact on public health and safety, water quality, wildlife habitat, and future development. The community relies heavily on the surface water and groundwater resources that are present in the Missoula Valley. Non-point source contamination, such as stormwater runoff, is the leading cause of surface water and groundwater quality impairments throughout Missoula and all of Montana.

The City aims to be proactive in mitigating impacts to our water resources. The Comprehensive Stormwater Quality Plan will aid the Missoula Stormwater Utility in considering water quality impacts as they adapt to the changing climate, population, and permit requirements. The goal of this plan is to provide the City with necessary information to more effectively manage the stormwater system, preserve water quality, and prioritize future improvements.

OUTLINE AND SUMMARY

As demonstrated by the City of Missoula's mission statement, the Stormwater Utility is committed to protecting public health and safety, natural resources, waterways, and the aquifer. Missoula's water resources, including surface water and groundwater, are vital parts of the community. This Comprehensive Stormwater Quality Plan serves multiple purposes to aid in the City's objectives and provides focus on water quality as it relates to stormwater. There are four chapters of the report that each offer a distinct focus. This plan provides the City with the necessary information to more effectively manage the stormwater system, preserve water quality, and prioritize future improvements.

Chapter 1 – Drainage Characteristics

Chapter 1 of this plan focuses on the characteristics of 30 drainages that contribute to high priority stormwater outfalls. These drainages were selected as high priority by the City based on land use, receiving water, and size. Characteristics presented in this chapter include the contributing area, soil type, and land use. These characteristics allow for determination of the Soil Conservation Service (SCS) Curve Numbers and, where appropriate, runoff coefficients. These parameters allow for quantification of runoff, serving as a starting point for identifying undersized facilities and designing storm water best management practices (BMPs) to improve water quality.

Chapter 2 – Model Development

This chapter describes the modeling geometry, hydrologic methods, assumptions, and results for the stormwater model developed as part of this plan. The model includes the stormwater system and contributing area in the South Hills that discharges to a priority outfall on the Bitterroot River. Simulations include the 2-, 10-, and 100-year rainfall depths, as well as analysis of the water quality event. Analysis of the model results focuses on locations of planned water quality improvement projects in the model area. The model provides the City with quantified flow rates and volumes for the Bitterroot priority outfall and several other key locations in the stormwater system, including Garland Park, Takima Park, and Cutthroat Corner, among others.

Chapter 3 – Capital Improvements Plan

The Capital Improvements Plan (CIP) includes projects which were informed by the stormwater model, water quality analysis, and known future development. These projects were refined to 10 projects selected by the City as near to mid-term project needs. Each project was analyzed, and a concept level solution and cost estimate were developed. Solutions mainly focus on improving water quality in the basin or replacing aging infrastructure. Each project was scored according to several criteria and prioritized based on this scoring. This priority ranking was used to organize the projects into a 10-year CIP. The CIP provides the City with an implementation strategy and outlook for the future of improvements to the stormwater system.

Chapter 4 – Water Quality Recommendations

This chapter offers various tools and resources for stormwater management and water quality. It begins with an overview of Missoula's stormwater system, providing essential context about the area's unique characteristics. A range of stormwater management strategies and potential opportunities for planning and collaboration are outlined to assist the City in achieving its water quality goals. Additionally, a summary of existing research on stormwater infiltration and groundwater is included. These topics are intended to guide the City's stormwater utility in exploring management options and safeguarding resources. The chapter concludes with a collection of infrastructure retrofit solutions aimed at improving water quality for existing systems. Overall, the chapter provides valuable information and options to support the City's decision-making process regarding stormwater and water quality management.

CHAPTER 1 DRAINAGE CHARACTERISTICS

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CHAPTER 1 DRAINAGE CHARACTERISTICS

1.1. SUMMARY

This report identifies stormwater drainage characteristics for 30 priority stormwater outfalls owned and maintained by the City of Missoula. Results presented in this report include the contributing area of each basin and soil types and land use within the basin. Also presented are stormwater runoff response characteristics, including curve numbers and runoff coefficients, that can be used to estimate total discharge at each outfall. This data is useful to identify ways to improve water quality based on which pollutants are typical for the contributing land use, as well as to estimate the discharge rate and volume for a given storm event.

1.2. PRIORITY OUTFALLS

In Missoula, stormwater runoff discharges either to the ground through drywells or to surface water outfalls conveyed from an open and closed channel system. The stormwater outfalls that discharge to surface water are classified as point source pollution and must be authorized under a Montana Pollutant Discharge Elimination System (MPDES) permit which is regulated by the Montana Department of Environmental Quality (DEQ). The Missoula Municipal Separate Storm Sewer System (MS4) is the organizational structure that includes stormwater infrastructure under the MPDES General Permit, which requires monitoring and limitation of effluent pollutants. Montana DEQ prepares a biennial water quality integrated report analyzing conditions and trends of Montana's streams and lakes, groundwater, and drinking water, and describing the degree to which waters support their designated uses. If any of these uses are limited, the Montana DEQ categorizes the waterbody as "impaired".

Missoula's MS4 utilizes 92 outfalls to surface water, with five receiving surface water bodies: Bitterroot River, Miller Creek, Clark Fork River, Rattlesnake Creek, and Grant Creek. All these water bodies, except for Rattlesnake Creek, are classified as "impaired" based on the Montana 2020 Water Quality Report. The City of Missoula identified 30 priority outfalls as part of their MS4 management plan that will undergo basin characteristic development in this Comprehensive Stormwater Quality Plan. The vicinity of these priority outfalls is shown in Figure 1-1 below. **The basin delineated for the Bitterroot River outfall (SW-DC-10070) is included in the figure for context and will be referenced as a visual aid throughout the report.**

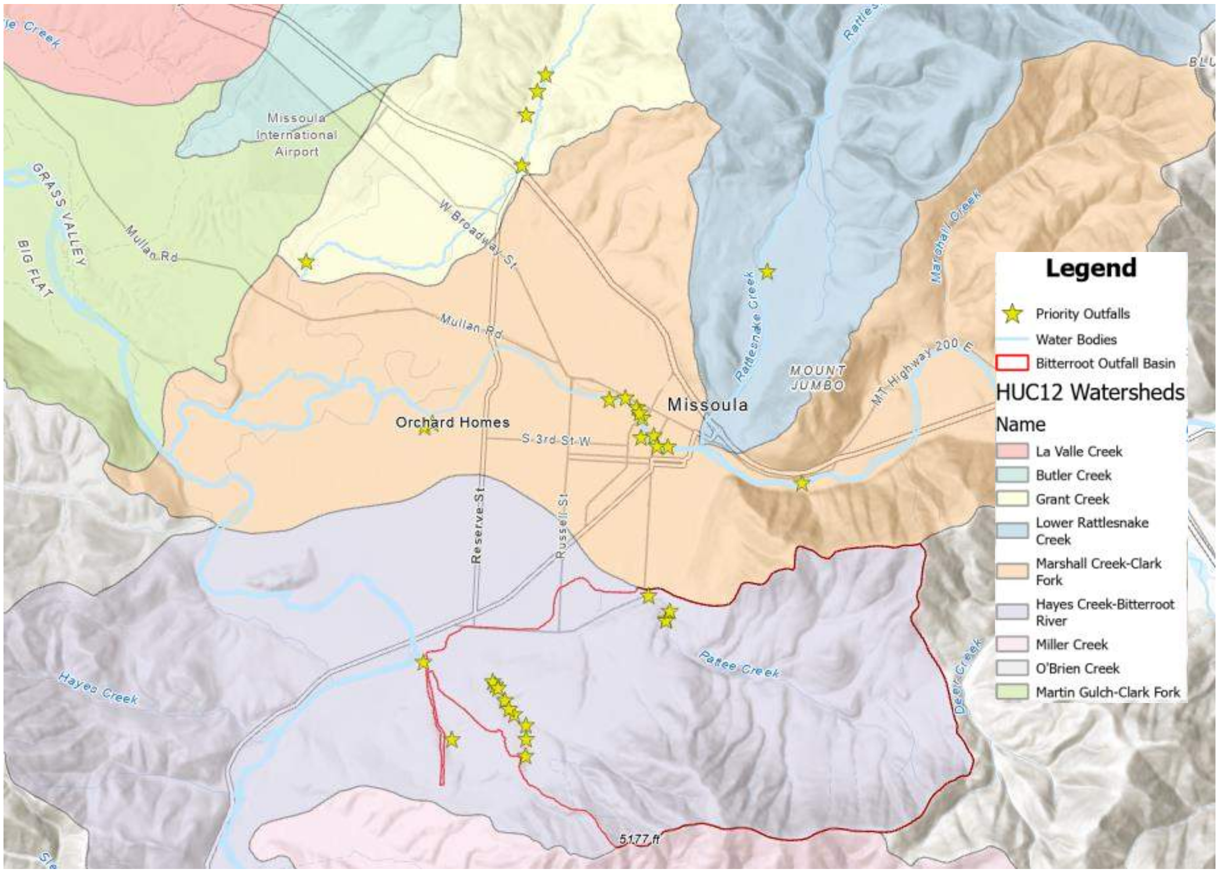

Figure 1-1: Priority Outfalls Vicinity Map

1.3. BASIN DELINEATION

A drainage basin is the area of land that hydrologically flows to a specific outfall point. For each priority outfall, a drainage basin is delineated based on surface topography and constructed conveyances, such as subsurface storm mains. The basins include only the area that drains through the physical outfall pipe, as opposed to the hydrologic watershed of the receiving waterbody.

Several sources of spatial data are used as a basis for delineations. To model the topography in GIS, a digital elevation model (DEM) is sourced from DNRC LiDAR survey data collected in 2019. The DEM is used to generate flow accumulation routes, model topographic watersheds, and generate contours for display.

The watersheds are manually delineated starting at the discharge point and consider topographical influences that direct runoff to infrastructure that contributes to the outfall. In the largest Bitterroot Outfall, the upper watershed boundaries are generated using the adjacent hydrologic unit code (HUC) watershed and modified in the down-gradient end of the basin, based on the influence of infrastructure such as roads and stormwater facilities. Aerial imagery, Google Earth Street View, and in-field verification of flow paths are utilized to identify runoff influences that are not represented in the topography model. For example, modification occurrences include culverts directing flow under a road or curb and gutter that intercept and convey runoff within the roadway, instead of continuing down the topographic drainage. A stormwater infrastructure spatial inventory, provided by the City of Missoula, displays the location of stormwater inlets, pipes, culverts, detention ponds, and drywells, all of which can impact the drainage basin delineation by providing additional conveyance, often from one basin to another.

Drywells are utilized throughout Missoula for stormwater capture and discharge. The associated catchment areas for drywells are removed from the contributing area of the priority outfall basin. Drywell delineations are based on topography and inlet placement. Drywells located on a sloped grade—which may have low stormwater collection efficiency—are not excluded from the outfall basin, as they are assumed to bypass flow and contribute to the outfall discharge. Drainage areas for drywells with negative drainage, with a visible depression and ponding area, are delineated based on topography and influence of roads and gutters. In flatter areas of Missoula, such as the University District, drywells are delineated with a broader methodology, often delineating groups of drywells and excluding larger areas from the priority outfall basin.

We made these assumptions during the initial priority outfall basin delineation process:

- Stormwater intakes and drywells capture all the stormwater that flows to them, unless otherwise noted, such as drywells on a sloped grade with no visual sag area.
- Stormwater generally flows along city streets and gutter systems in urban areas.
- Contour data generated from LiDAR and GIS-generated flow accumulation paths are used as a basis for delineation. In most instances, impacts from roadways, culverts, or stormwater infrastructure override topographical influence and are prioritized for basin delineation.
- Individual drywell catchment areas and areas containing a high concentration of drywells are omitted from the basin delineation.
- Urban basins are delineated with consideration to a water quality event, which is the first half-inch of precipitation depth. Larger precipitation events may warrant evaluation of inlet efficiencies, evaluating stormwater infrastructure performance, and expanding the basin based on these factors.

See Appendix 1A for the resulting exhibits showing the delineated basin for each priority outfall.

1.3.1. Special Case Delineations

Exceptions to the delineation process were made when additional information about an area became available. Additional information includes observations made during a site visit, City of Missoula staff observation of stormwater flow patterns, or stormwater infrastructure that controls and redirects flow.

SW-DC-10009 – Moose Can Gully

Figure 1-2: SW-DC-10009 Moose Gan Gully inlets on grade

The priority outfall SW-DC-10009, delineated on Exhibit 4 of Appendix 1A, is one outfall in a series of discharge points to Moose Can Gully. This basin captures a large portion of the uphill developments on Elk View Court and Elk Hills Court. During a field visit to verify flow patterns, it was clear the four stormwater inlets located on Clearview Way, which discharge to SW-DC-10009, may not capture all the stormwater that flows to them, due to the steep grade of the road (Figure 1-2).

This delineation assumes that during a water quality event, these inlets are 100% efficient and capture all flow that is directed to them. However, given the slope and crown of Clearview Way, it is likely that inlet efficiency is reduced, causing stormwater to bypass the inlets and flow northwest out of the priority outfall basin. This also suggests that the contributing area associated with priority outfall SW-DC-10009 may include a larger upgradient area due to a similar placement and grade upgradient inlets. If a more detailed analysis in this area is desired, inlet efficiencies should be analyzed, and the catchment area should be modified as necessary.

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SW-DC-10099 – Pattee Creek Outfall, above Cutthroat Corner

Figure 1-3: Whitaker Drive inlets intercept upgradient runoff

Similar to the Moose Can Gully basin, the basin associated with priority outfall SW-DC-10099, delineated on Exhibit 7 of Appendix 1A, may receive additional stormwater from further upgradient on Whitaker Drive and East Crestline Drive. Stormwater inlets on Whitaker Drive, as shown in Figure 1-3, intercept runoff from the upgradient area and direct it west to the Bitterroot River Outfall. The delineation assumes these inlets are 100% efficient in intercepting upgradient flow during a water quality event. However, due to the steep slopes in this area, a portion of that stormwater may bypass the inlets and enter the downgradient inlets discharging to priority outfall SW-DC-10099. If a greater detailed analysis of this area is desired, inlet efficiencies should be analyzed, and the catchment area should be modified as necessary.

SW-DC-10025 – Rattlesnake Creek near Creekwood Road

Figure 1-4: Low performing drywell at Creekwood and Creek Crossing Road

The basin for priority outfall SW-DC-10025, shown on Figure 14 of Appendix 1A, includes portions of the residential area along Fox Farm Road, Timberlane Street, and Creek Crossing Road adjacent to Rattlesnake Creek. Generally, these roads feature an inverted crown with drywell inlets located in the middle of the roadway. Drywell inlets are also located within the vegetated edge near intersections of Creek Crossing Road, such as the one shown in Figure 1-4. City of Missoula staff reported observing these drywells along Fox Farm Road and Creek Crossing Road often becoming clogged with debris. The clogged drywell inlets cause stormwater to bypass the drywells and flow to the priority outfall.

The delineation presented in this report includes the drywells along Fox Farm Road and Creek Crossing Road and assumes most runoff bypasses and contributes to the outfall. This assumption is due to historical performance and the inverted crown of the roadway preventing runoff from entering the drywells. If a more detailed analysis of this area is desired, drywell performance and the extents of the delineated basin should be investigated.

SW-DC-10059 – To Takima Park and Pattee Creek

Figure 1-5: Mansion Heights detention pond outlet structures

The priority outfall SW-DC-10059, shown on Figure 6 of Appendix 1A, is the largest of three stormwater outfalls that discharge to Takima Park. This basin is influenced by an upgradient detention pond located on the northwest edge of the Mansion Heights neighborhood, just below Spanish Peaks Drive. The detention basin has two outlet structures that split flow between two priority outfall basins. One directs discharge east to priority outfall SW-DC-10059, the other directs discharge north through Highlands Golf Club and ultimately to the Bitterroot River outfall SW-DC-10070.

The City of Missoula provided a design report and CLOMR application completed in 2002 for a project in the South Hills titled, the “Pattee Creek – South Hills Storm Drainage Project Design Report”. This report briefly mentions the typical operation of the Mansion Heights detention pond, stating that outflow is split in two directions with most flow conveyed north through Highlands Golf Club, with a smaller portion being directed east to priority outfall SW-DC-10059.

This delineation analysis assumes that during a water quality event, nominal stormwater is being conveyed to SW-DC-10059 from the detention pond and its receiving catchment area. For this reason, the basin associated with priority outfall SW-DC-10059 excludes Mansion Heights and the area directly upgradient of the neighborhood. If a more detailed analysis of this area is desired, the complete catchment to the detention pond should be considered, and the function of the detention pond should be modeled to more accurately understand discharge to each point.

SW-DC-10006 – Moose Can Gully near Hillview Way

This priority outfall, shown on Figure 5 of Appendix 1A, is located just downgradient of where Hillview Way crosses Moose Can Gully. The outfall captures runoff from Hillview Way and the hills east of the road using a series of curb inlets. Currently, open space within this basin is being developed to a 105-acre residential subdivision referred to as Wildroot. The stormwater engineering report for the Wildroot Subdivision, completed by Cushing and Terrell, indicates that runoff from the developed site will be split to two outfalls. The north half of the development will discharge to existing storm main and flow north, ultimately discharging at the Bitterroot River Outfall. The south half of the development will discharge to the existing storm main under Hillview Way and discharge to the priority outfall SW-SC-10006. The delineated basin accounts for this future division of flow patterns based on the provided stormwater report for the development.

1.4. STORMWATER DRAINAGE CHARACTERISTICS

The amount of stormwater runoff generated within a basin is impacted by the percentage of impervious area, land use type, and soil type. These characteristics dictate the rate and timing of surface water runoff through the basin and to the outfall. The identified stormwater characteristics allow City staff and outside designers to estimate the amount of runoff that is discharged to each outfall, as well as runoff that will flow to each inlet or drywell.

The SCS Curve Number (CN) Method is the recommended approach for quantifying the precipitation-runoff relationship for basins smaller than 1,920 acres. In addition to being the method adopted in the City of Missoula Public Works Standards, the SCS method offers the benefits of being widely used and understood, as well as relying on readily available data. For each of the 33 priority outfalls designated by the City of Missoula, land use and soils data are used to assign a CN.

1.4.1. Soil Characteristics

Soil information is sourced from the NRCS Soil Survey. The data include a Hydrologic Soil Group (HSG) rating for each soil type, which represents runoff potential. This information is used to create the Hydrologic Soil Group Exhibit in Appendix 1B.

A large portion of central Missoula is classified as “Urban” soils without an assigned hydrologic soil group. Soil disturbance, typical of urban development, can have large impacts on soil infiltration characteristics. Assuming primarily silts for the urban areas is considered appropriately conservative, given the well-observed high infiltration rates in the Missoula Valley. NRCS recommends HSG B for silt loam or loam disturbed soils, “provided that significant compaction has not occurred” (Natural Resources Conservation Service, 1986). If more sand is present, the HSG should be revised to A, while if more clay is encountered, the HSG should be revised to C. A majority of adjacent soils are classified as soil group B, reinforcing the decision to classify all urban soils as group B. Figure 1-6 shows hydrologic soil group data for the Bitterroot River outfall basin, which is the priority outfall with the largest contributing basin and the focus basin for Chapter 2 of this report. Soil data for all priority outfall basins are shown in Appendix 1B.

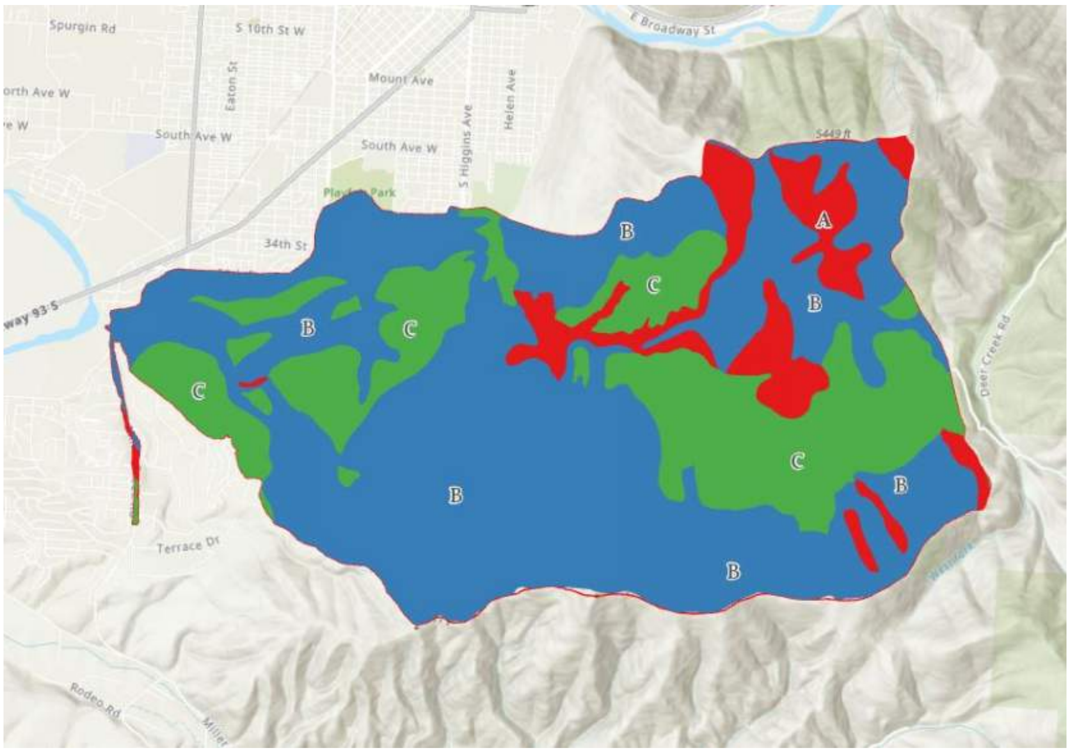

Figure 1-6: Bitterroot River Outfall Basin - Hydrologic Soil Group

1.4.2. Land Use and Impervious Cover

Spatial data for analysis of impervious areas and land use are sourced from the land use classifications outlined in the current growth policy, “Our Missoula Growth Policy 2035”. The growth policy identifies recommendations for future land use zoning to yield greater development potential than the current zoning. The future land use data are used in this analysis to account for impacts of increased stormwater runoff, due to future expansion and development in Missoula.

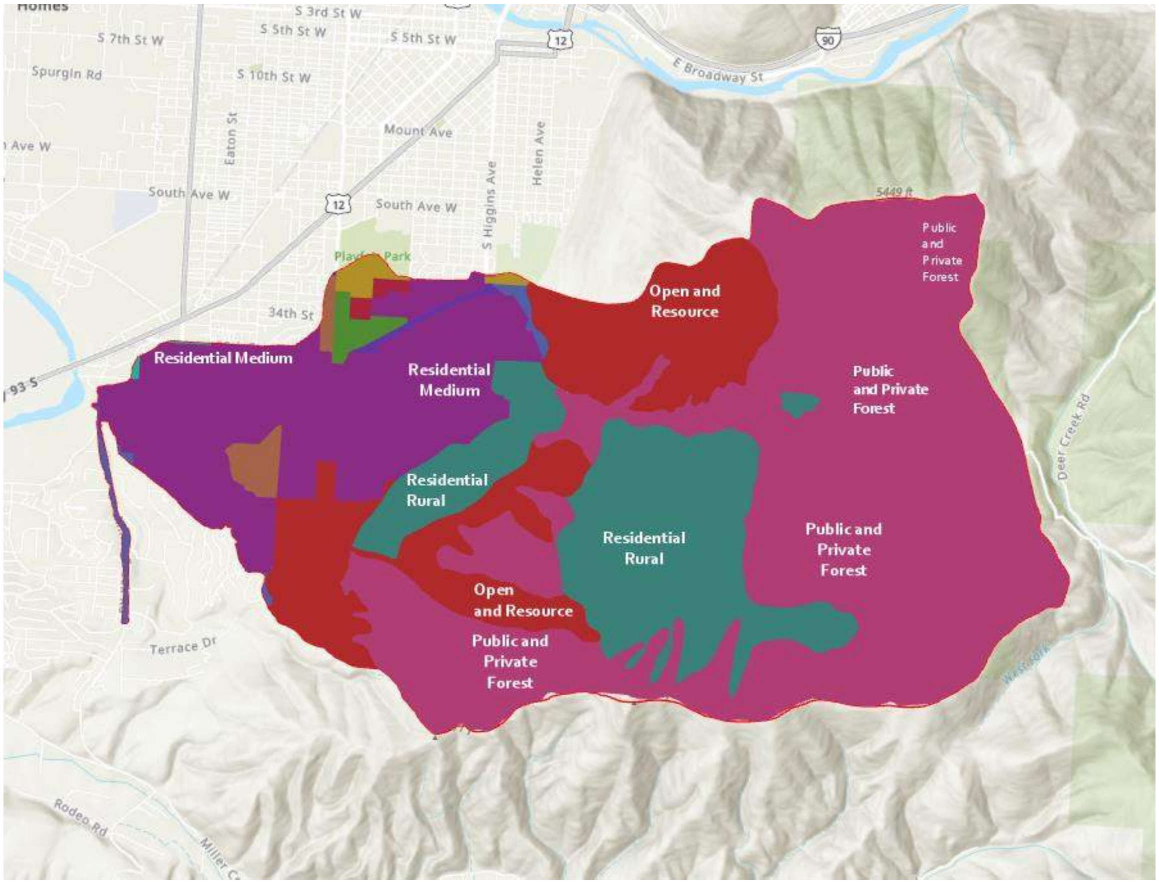

Figure 1-7: Bitterroot River Outfall Basin - Land Use

Land use zones are matched to a cover type and hydrologic condition from the SCS CN tables (FHWA, 2009). Most land use classes correspond closely to one cover type and hydrologic condition, as shown in Table 1-1. The residential area land use classes do not have perfect overlap with the cover type classes. For instance, the Residential Low land use class is described as 1-2 units per acre. The CN table land cover has separate entries for residential districts with 0.5-acre and 1.0-acre lots. Therefore, for the Residential Low land use class, the average lot size is considered to be 0.75 acres; and the CNs for this class are interpolated between values for 0.5-acre and 1.0-acre lots.

The areas assigned to the Public and Quasi-Public land use class vary widely in their use and percent impervious area. Public and Quasi-Public zones include areas like the Missoula International Airport and University of Montana Campus. The only two instances of this land use class overlapping a priority outfall basin are Playfair Park and University of Montana golf course. These are both assigned a cover type of residential with average lot size of 0.25 acres, because these areas appear to approximately match the 38% impervious specified in the TR-55 CN table.

There are additional areas outside of the City of Missoula-delineated land-use boundary. These areas are in Pattee Canyon, on Mount Sentinel, on Mount Dean Stone, and west of Grant Creek. The land use class is determined based on aerial imagery and property boundaries. The residential portions of these areas are assigned the cover type associated with residential districts with a lot size of 2 acres. Open grassland areas are assigned a cover type of open space with good hydrologic condition. Forest areas are assigned a cover type "woods" with good hydrologic condition. These areas are summarized in Table 1-1.

Table 1-1: Growth Policy Land Use and Corresponding TR-55 Cover Type

2035 Growth Policy Future Land Use Class	Assigned Cover Type for SCS Curve Number
Urban Center	Commercial and business
Community Mixed Use	Commercial and business
Neighborhood Mixed Use	Commercial and business
Regional Commercial and Services	Commercial and business
Industrial Heavy	Industrial
Industrial Light	Industrial
Residential Rural	Residential districts by average lot size - 2 acres
Residential Low: 1-2 units per acre	CNs interpolated between values for Residential districts – 0.5-acre lot and Residential districts – 1-acre lot
Residential Medium: 3-11 units per acre	CNs interpolated between values for Residential districts – 0.33-acre lot and Residential districts – 0.25-acre lot
Residential Medium-High: 12-23 units per acre	Residential districts by average lot size - 0.125 acres or less (townhouses)
Residential High: Greater than 24 units per acre	Residential with lot sizes - 0.125 acres or less (townhouses)
Open and Resource	Open Space, Good Condition
Parks and Open Lands	Open Space, Good Condition
Public and Quasi-Public	
University of Montana Golf Course	Residential with lot sizes - 0.25 acres-
Playfair Park	Residential with lot sizes - 0.25 acres
Areas Outside of Land Use Boundary	
Pattee Canyon, Mount Dean Stone, Mount Sentinel Forest Area	Woods, Good Condition
Mount Dean Stone and Mount Sentinel Grassland Area	Open Space, Good Condition
Pattee Canyon Residential Areas	Residential districts by average lot size - 2 acres
Grant Creek Grassland Areas	Open Space, Good Condition

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1.4.3. Curve Number Designation

CNs are widely used to estimate peak discharge using SCS CN method, as outlined in NRCS Technical Release 55 (Natural Resources Conservation Service, 1986). A CN is assigned to a specific area based on the unique combination of underlying soils and land use. GIS processing is used to intersect land use and soils spatial data for Missoula. The result of this intersection is a separate area for each unique combination of HSG and cover type. These areas are assigned a CN based on Table 2-2A of TR-55, which relies on these assumptions for urban areas:

- All impervious areas are directly connected to the drainage system.
- Impervious areas have a CN of 98 and pervious areas are considered equivalent to open space in good condition.

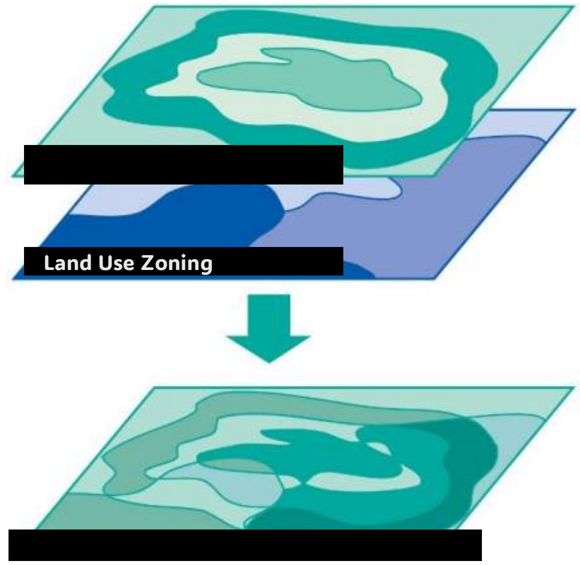

Figure 1-8: Unique Soil and Land Use Areas are assigned a Curve Number

These are standard assumptions that apply to urban Missoula. The values for commercial, industrial, and residential districts from TR-55, Table 2-2A depend on assumptions of percent impervious. The procedure for determining CNs requires assessment of whether these Table 2-2A assumptions apply. To check if the percent impervious assumptions are valid for the study area, the actual percent impervious is investigated by analyzing the 2021 National Agriculture Imagery Program (NAIP) four-band aerial imagery for Missoula. Imagery analysis was completed using ArcGIS imagery classification tools.

The percent impervious from TR-55, Table 2-2A is compared to the classified imagery for mixed use, residential, commercial, urban center, and industrial land use classes. The imagery analysis yields a percent impervious that matches well to the assumed values, although the overall process is only 60% accurate. Given that level of accuracy, using the calculated percent impervious to calculate new CNs for the land use classes is not justified. However, we felt it was valuable to compare to the assumed percent impervious from TR-55, to confirm the land cover types assigned to each land use class, particularly for the mixed-use land cover classes. The calculated values from imagery analysis compared well to the assumed values from TR-55 tables. The difference between calculated values for each land use class ranged from 13% less than, to 8% greater than, the TR-55 values, except for the neighborhood mixed use class. The TR-55 percent impervious assumed value is 21% greater than the value calculated from imagery analysis. This land use class includes the Missoula Country Club and several agricultural parcels north of Mullan Road, which reduce the calculated value. Neither are in our area of interest and therefore the higher, assumed percent impervious is considered appropriate.

Each unique soil and land use combination area, per the visual graphic in Figure 1-8, is assigned the CNs present within the outfall basin and are used to calculate a weighted-average single CN that represents the basin. Figure 1-9 shows the various distinct CN areas within the priority outfall basin SW-DC-10070 that outfalls to the Bitterroot River. The area-weighted average of these distinct areas gives the value of 63, shown in Table 1-2. See Appendix 1C for the resulting exhibits showing CNs of each soil and land cover combination within the priority outfall basins.

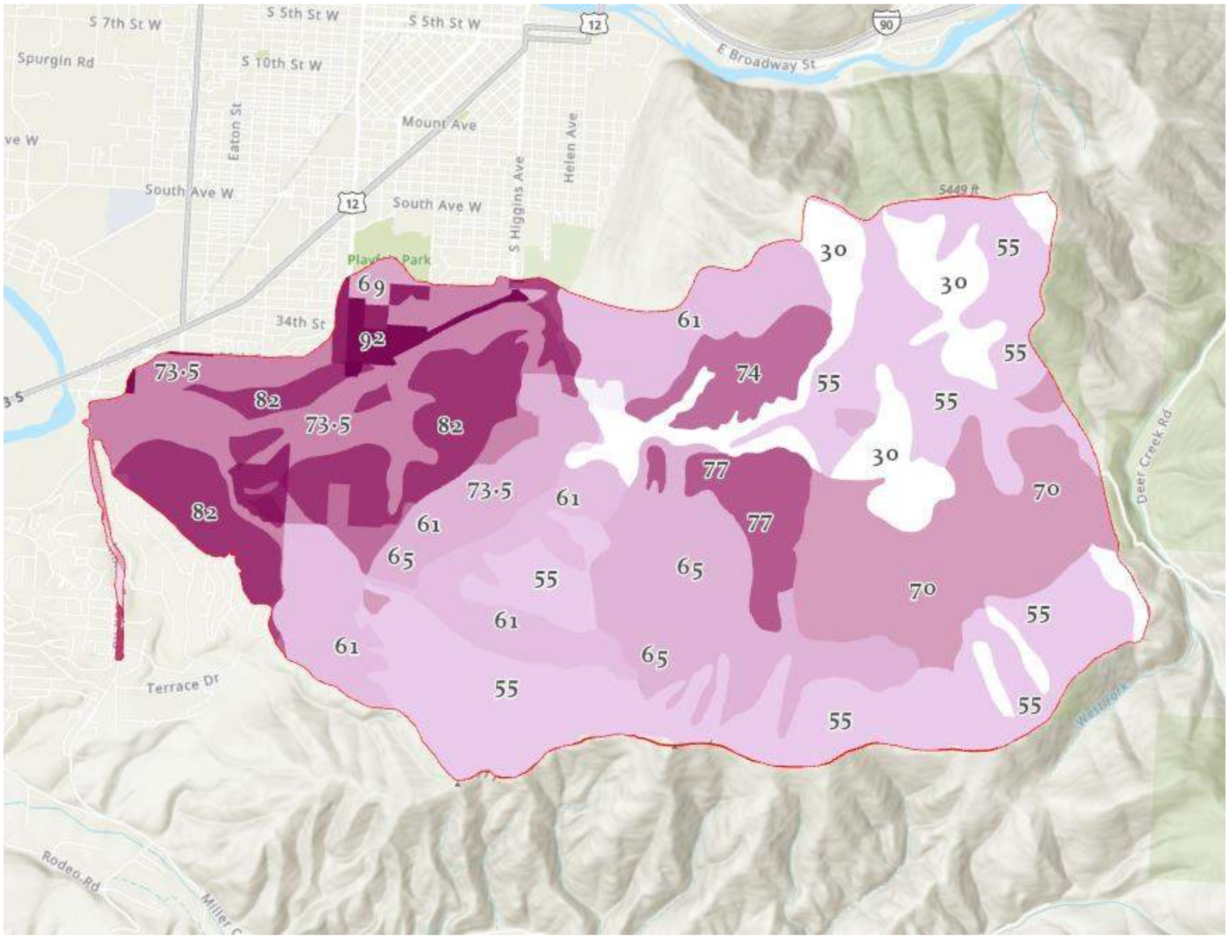

Figure 1-9. Bitterroot River Outfall Basin - Curve Numbers

Table 1-2: Outfall Basin Summary

Outfall Basin ID	Area (ac)	Dominating Land Use	Receiving Water	Weighted Curve Number
SW-DC-10006	119.4	Residential High	Bitterroot River	79
SW-DC-10008	1.2	Residential Medium	Bitterroot River	74
SW-DC-10009	8.7	Residential High	Bitterroot River	85
SW-DC-10011	0.6	Residential Medium	Bitterroot River	74
SW-DC-10014	4.1	Residential High	Bitterroot River	85
SW-DC-10016	1.4	Residential Medium	Bitterroot River	78
SW-DC-10019	4.7	Residential Medium	Clark Fork River	72
SW-DC-10025	16.4	Residential Low	Rattlesnake Creek	69
SW-DC-10027	135.8	Open and Resource	Grant Creek	61

Outfall Basin ID	Area (ac)	Dominating Land Use	Receiving Water	Weighted Curve Number
SW-DC-10029	87.9	Residential Medium	Miller Creek	76
SW-DC-10047	8.7	Parks and Open Lands	Clark Fork River	76
SW-DC-10048	240.2	Residential Medium	Grant Creek	66
SW-DC-10050	6.4	Neighborhood Mixed Use	Clark Fork River	92
SW-DC-10051	14.7	Residential Medium-High	Clark Fork River	87
SW-DC-10055	24.1	Neighborhood Mixed Use	Clark Fork River	92
SW-DC-10056	11.5	Urban Center	Clark Fork River	92
SW-DC-10059	157.8	Residential Medium	Bitterroot River	66
SW-DC-10063	131.2	Open and Resource	Grant Creek	65
SW-DC-10070	9729.4	Residential Medium	Bitterroot River	63
SW-DC-10087	0.5	Urban Center	Clark Fork River	92
SW-DC-10088	32.7	Urban Center	Clark Fork River	92
SW-DC-10090	12.4	Urban Center	Clark Fork River	92
SW-DC-10095	62.7	Urban Center	Clark Fork River	92
SW-DC-10098	3.3	Urban Center	Clark Fork River	92
SW-DC-10099	56.4	Residential Medium	Bitterroot River	77
SW-DC-10100	88.5	Parks and Open Lands	Bitterroot River	64
SW-DC-10104	24.6	Residential Medium	Bitterroot River	82
SW-DC-10105	2.2	Residential Medium	Bitterroot River	79
SW-DC-10106	33.9	Residential Medium	Bitterroot River	82
SW-DC-10107	11.1	Residential Medium	Bitterroot River	81

1.4.4. Runoff Coefficient Designation

Runoff coefficients are assigned to specific ground cover types to represent total runoff, similar to CNs. The coefficients are standardized for use with the rational method and as referenced by the City of Missoula Public Works Manual, are outlined in Hydraulic Engineering Circular No. 22 (HEC-22) (FHWA, 2009). Standard runoff coefficients are presented in HEC-22, Table 3-1 as a range of values that are assigned based on steepness of slope and rainfall event. The highest end of the range should be applied for steeply sloped areas, or for less frequent, high-intensity storms.

The rational method is appropriate for use in small catchment areas, typically limited to 5 acres or less. Because of the scale of the delineation efforts presented in this report, the rational method is not applicable and runoff coefficients are not applied to each basin individually. Runoff coefficients should be assigned uniquely for each analysis, based on the design precipitation event and site conditions. The following table outlines a suggestion for rational method runoff coefficients, for precipitation events equal to or less than the 10-year storm. For larger, less frequent storm events, HEC-22 recommends correction factors to increase the coefficient, although values should never exceed 0.95.

Table 1-3: Recommended runoff coefficients for a 10-year storm

Ground Cover/Slope	Flat (<2%)	Rolling (2-10%)	Hilly (>10%)
Pavement and Roofs	0.85	0.90	0.95
Lawns, Sandy Soil	0.10	0.15	0.20
Lawns, Heavy Soil	0.17	0.22	0.35
Unimproved Areas	0.10	0.20	0.30
Residential - <0.5-acre parcels	0.65	0.70	0.75
Residential - >0.5-acre parcels	0.50	0.55	0.60
Commercial/Industrial	0.70	0.80	0.90
Woodlands	0.15	0.20	0.25

1.5. REFERENCES

City of Missoula. (2020). *Public Works Standards and Specifications Manual.*

FHWA. (2009). *Hydraulic Engineering Circular No. 22: Urban Drainage Design Manual* (3rd ed.).

Natural Resources Conservation Service. (1986). *TR-55 Urban Hydrology for Small Watersheds .* USDA.

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WGM Group, Inc. (2002). *City of Missoula, Pattee Creek - South Hills Storm Drainage Project Design Report. Vol. 1.*

1.6. APPENDICES

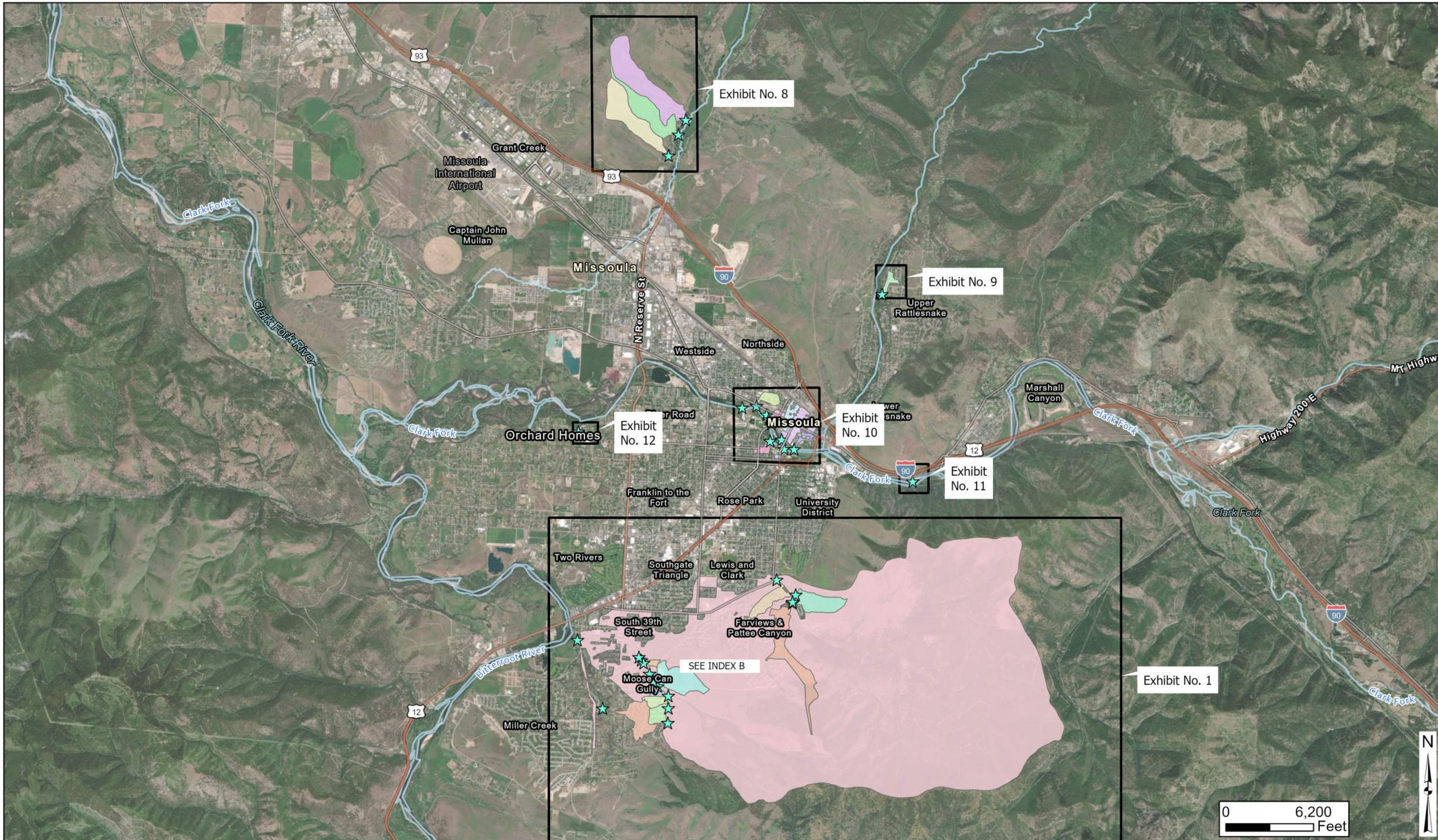
Appendix 1A Basin Delineation

Appendix 1B Overview Exhibits

Appendix 1C Curve Number Exhibits

Appendix 1D Summary Tables

APPENDIX 1A BASIN DELINEATION EXHIBITS



Source Data:
Base Map: ESRI World Imagery, 2023.
Contours: DNRC LiDAR, 2019.
Infrastructure: GIS Services, City of Missoula - Stormwater Division of Public Works, 2023.
Streams: National Hydrography Dataset.

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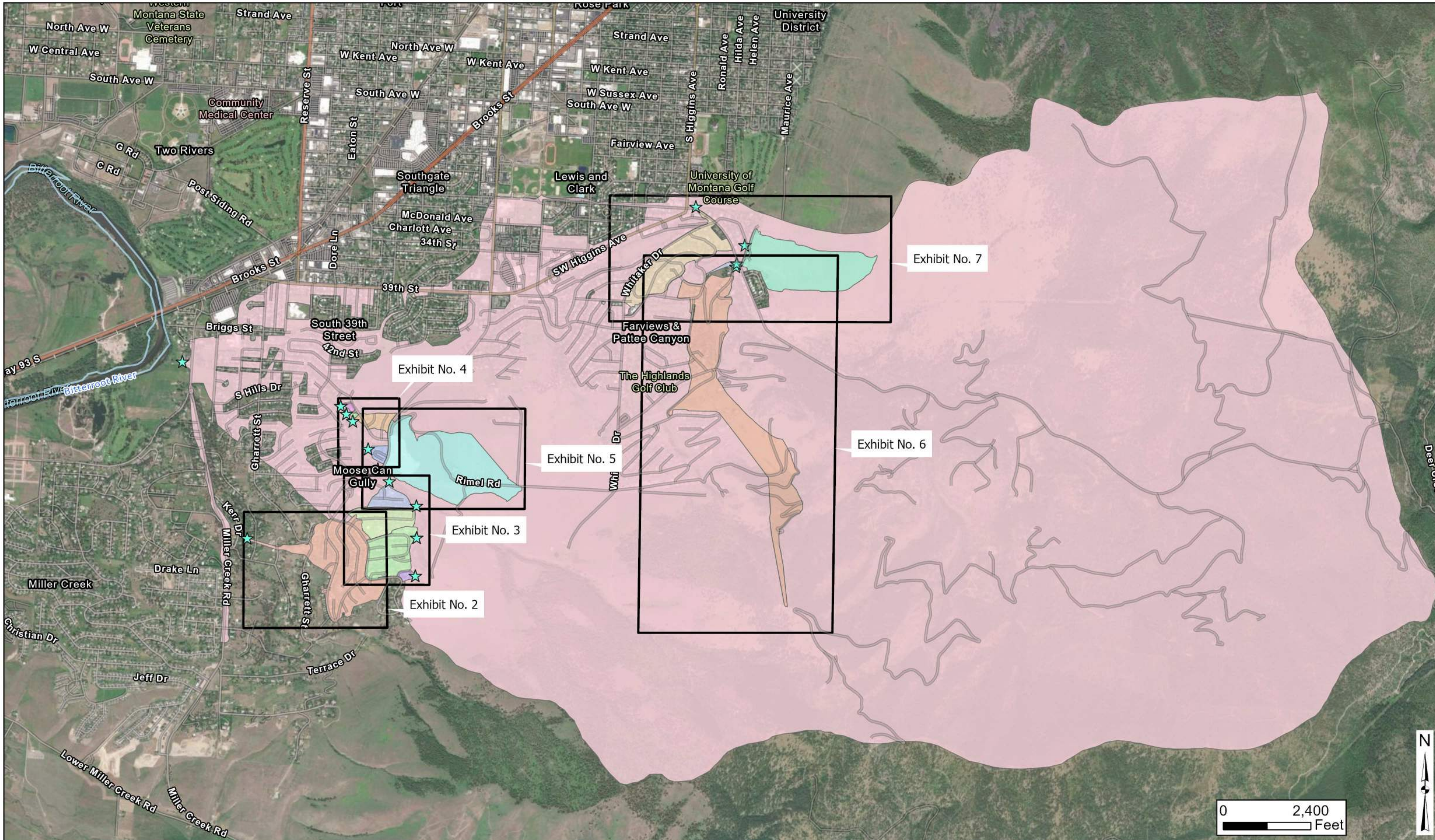

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Contours: DNRC LiDAR, 2019.
Infrastructure: GIS Services, City of Missoula - Stormwater Division of Public Works, 2023.
Streams: National Hydrography Dataset.

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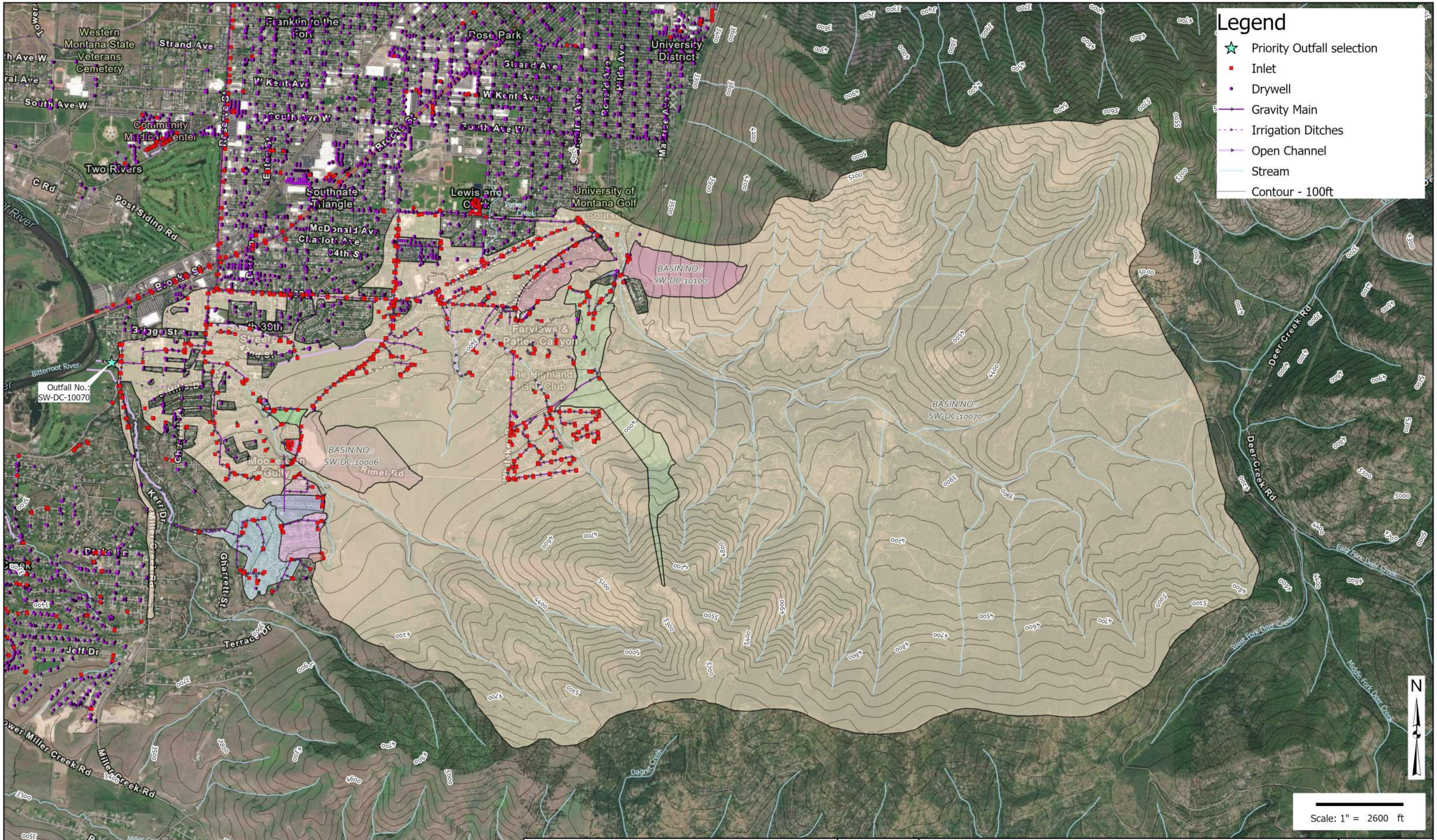

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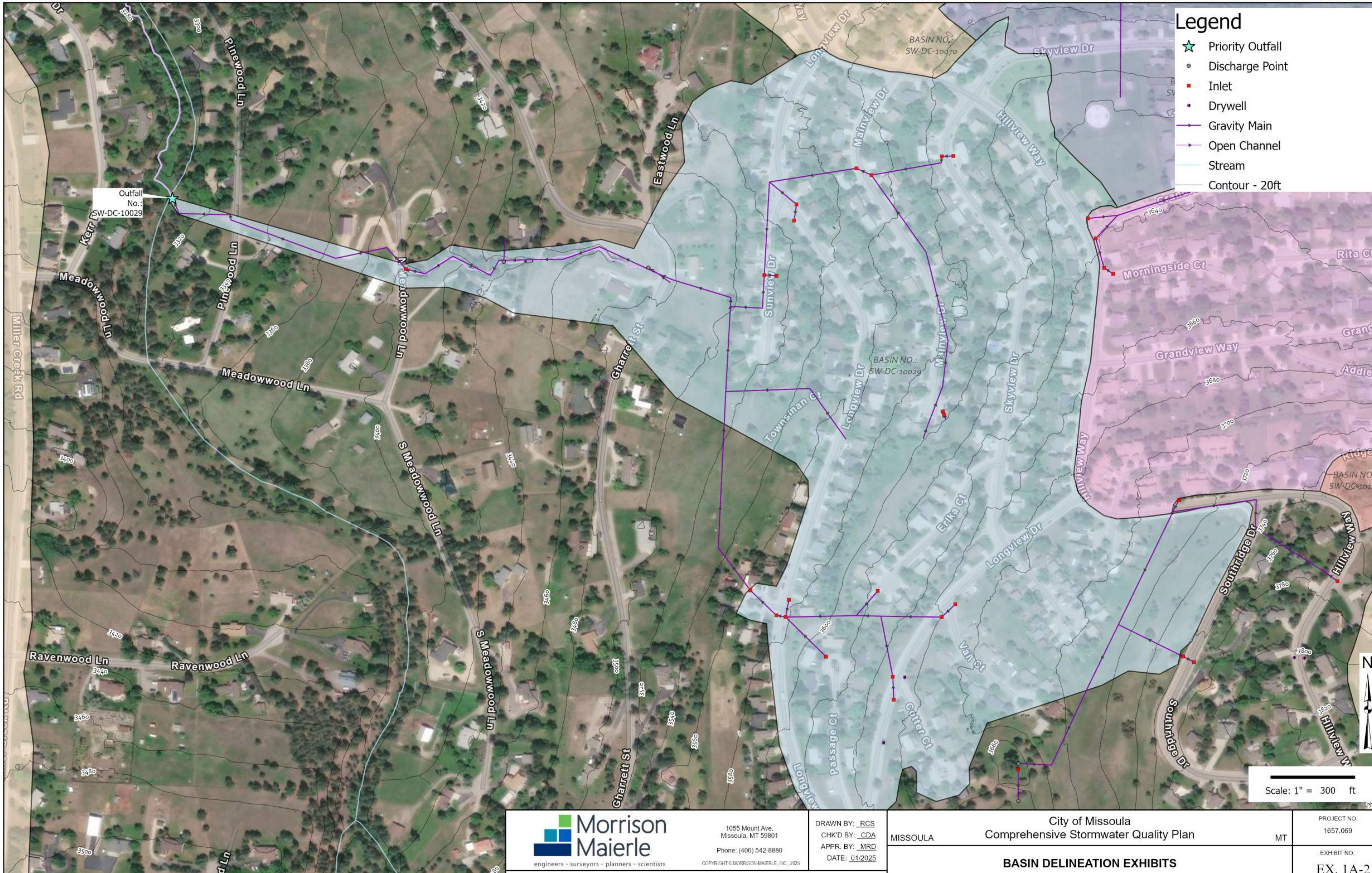

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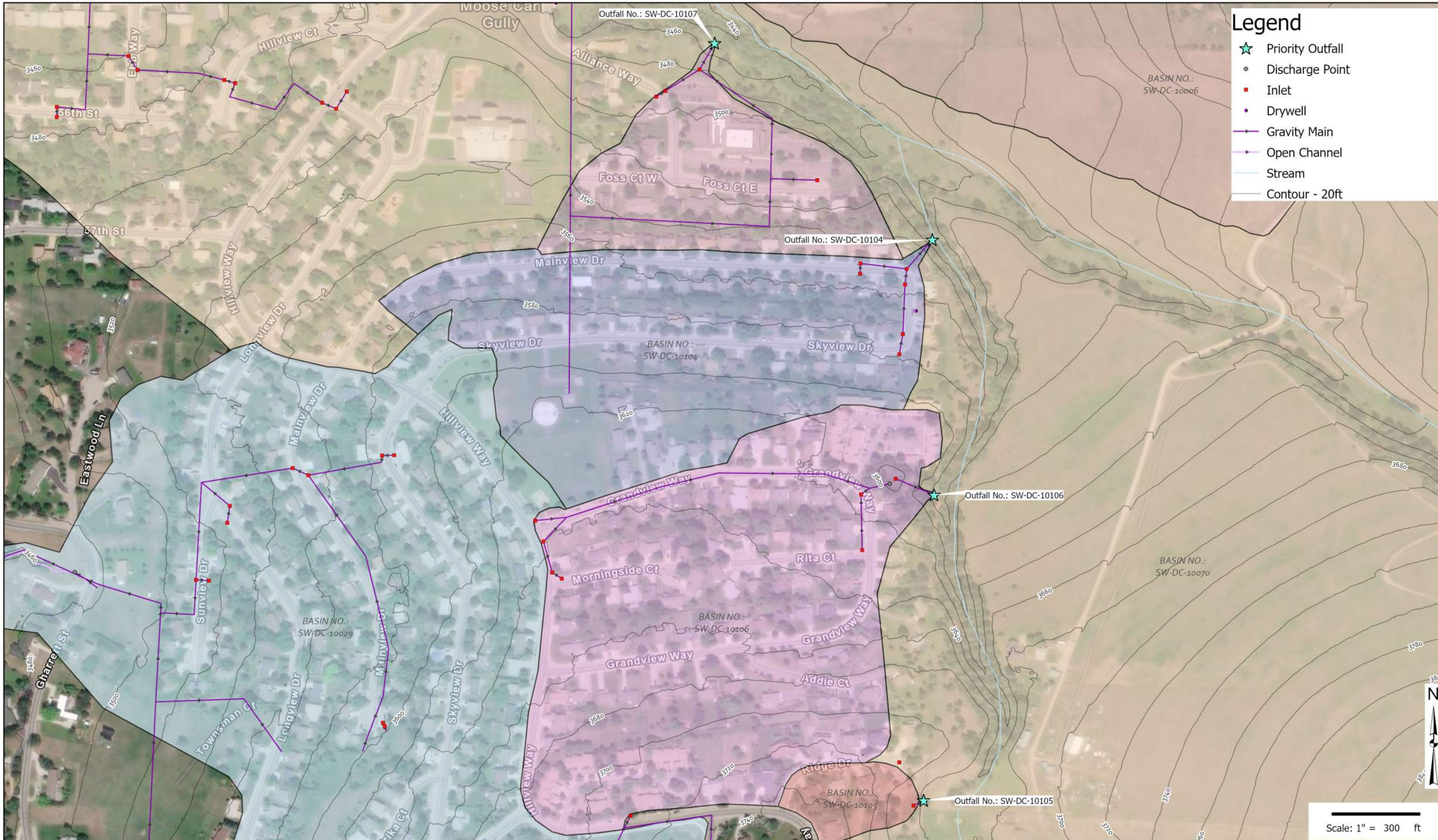

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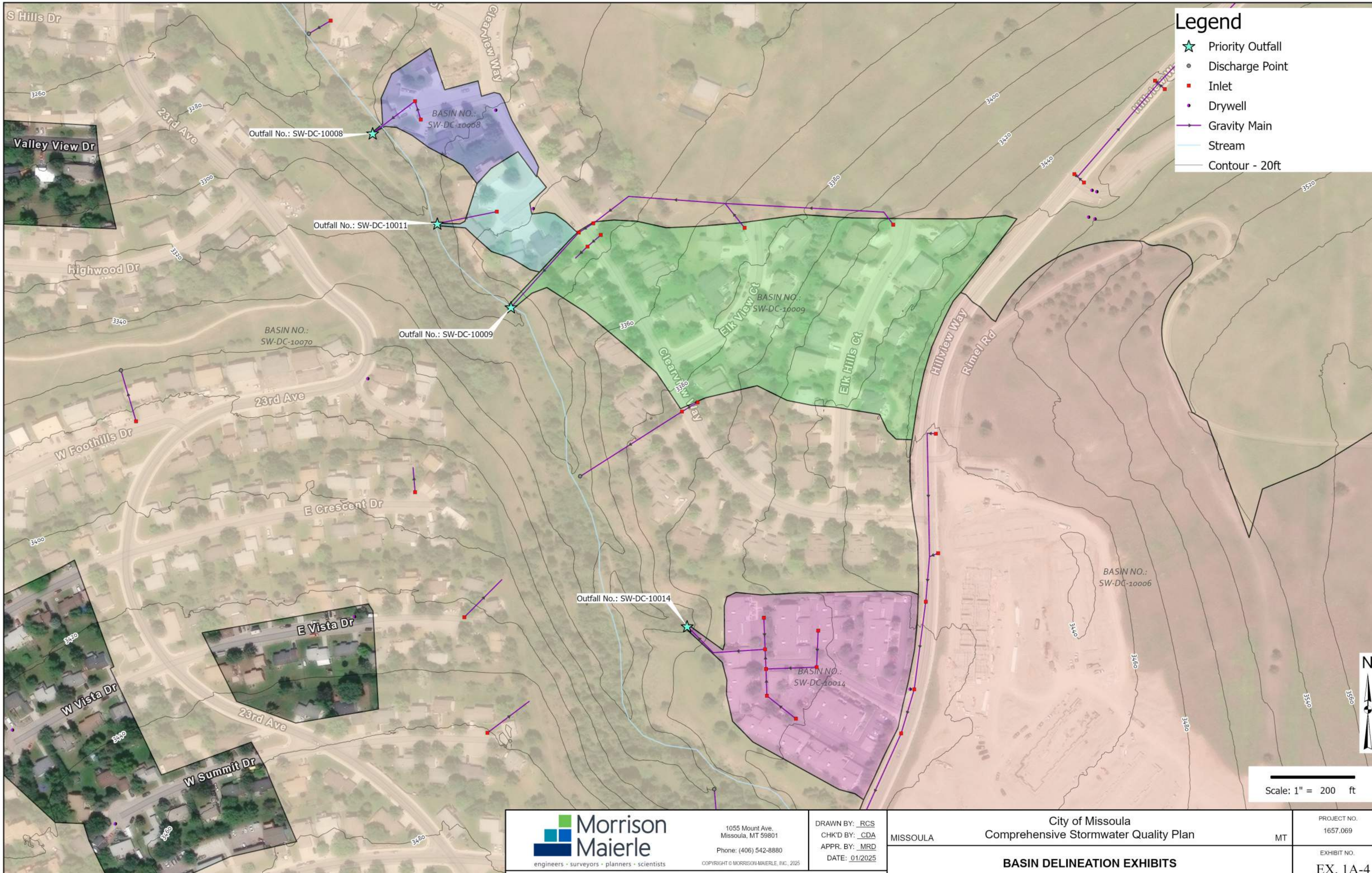

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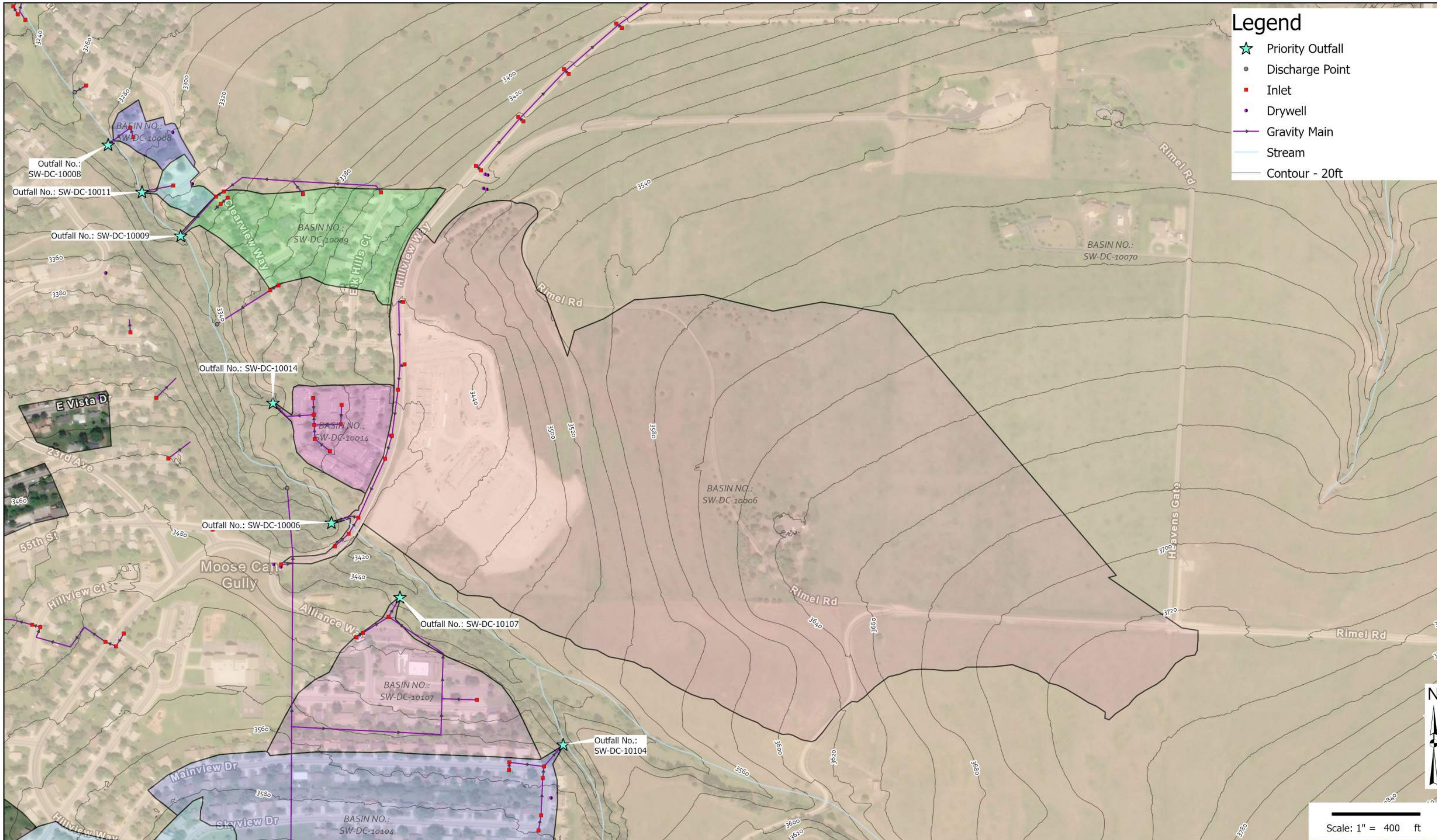

Basin SW-DC-10006 reflects future conditions and is based on the hydrology report submitted to the City for the current development of this parcel.

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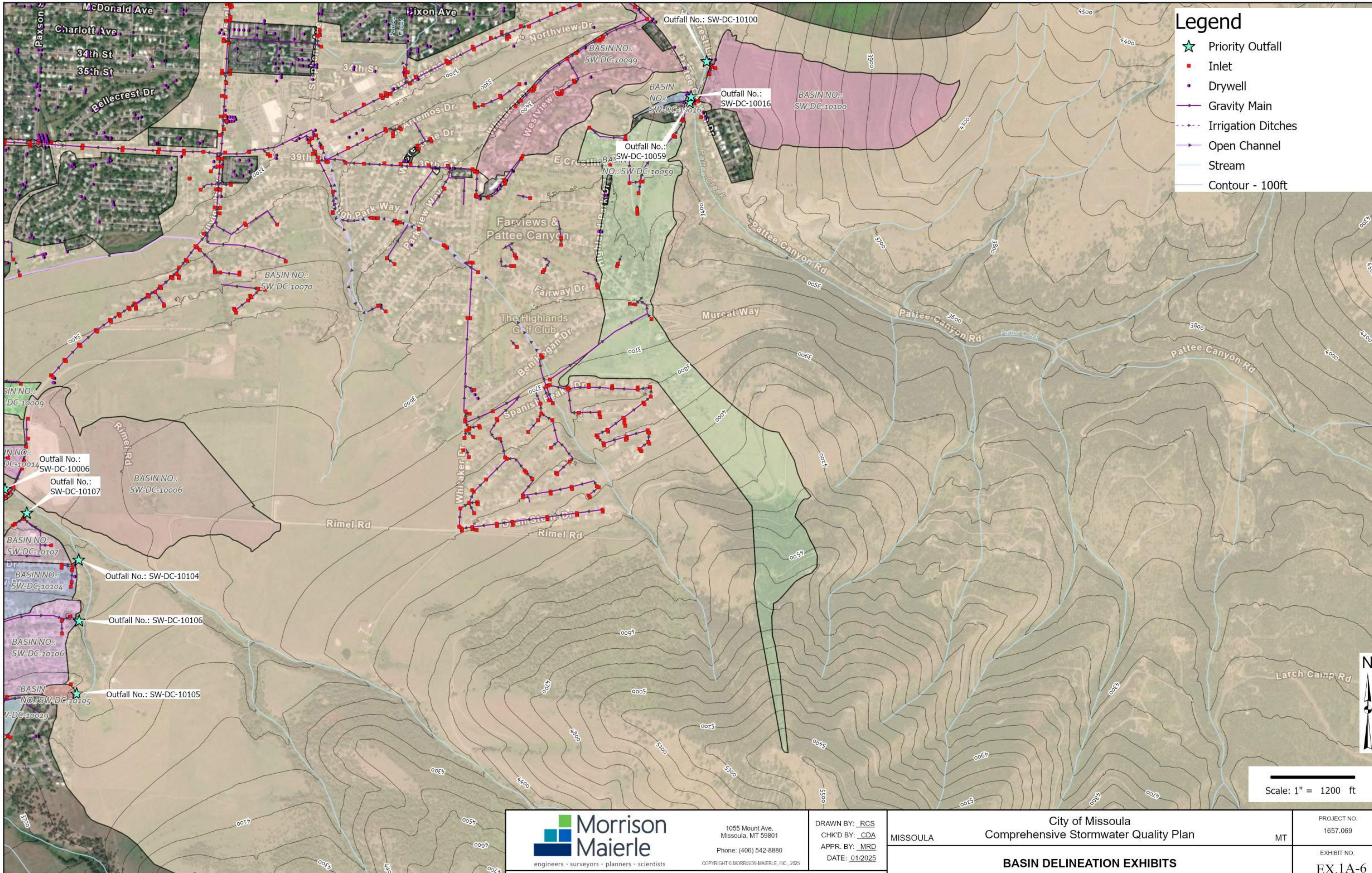

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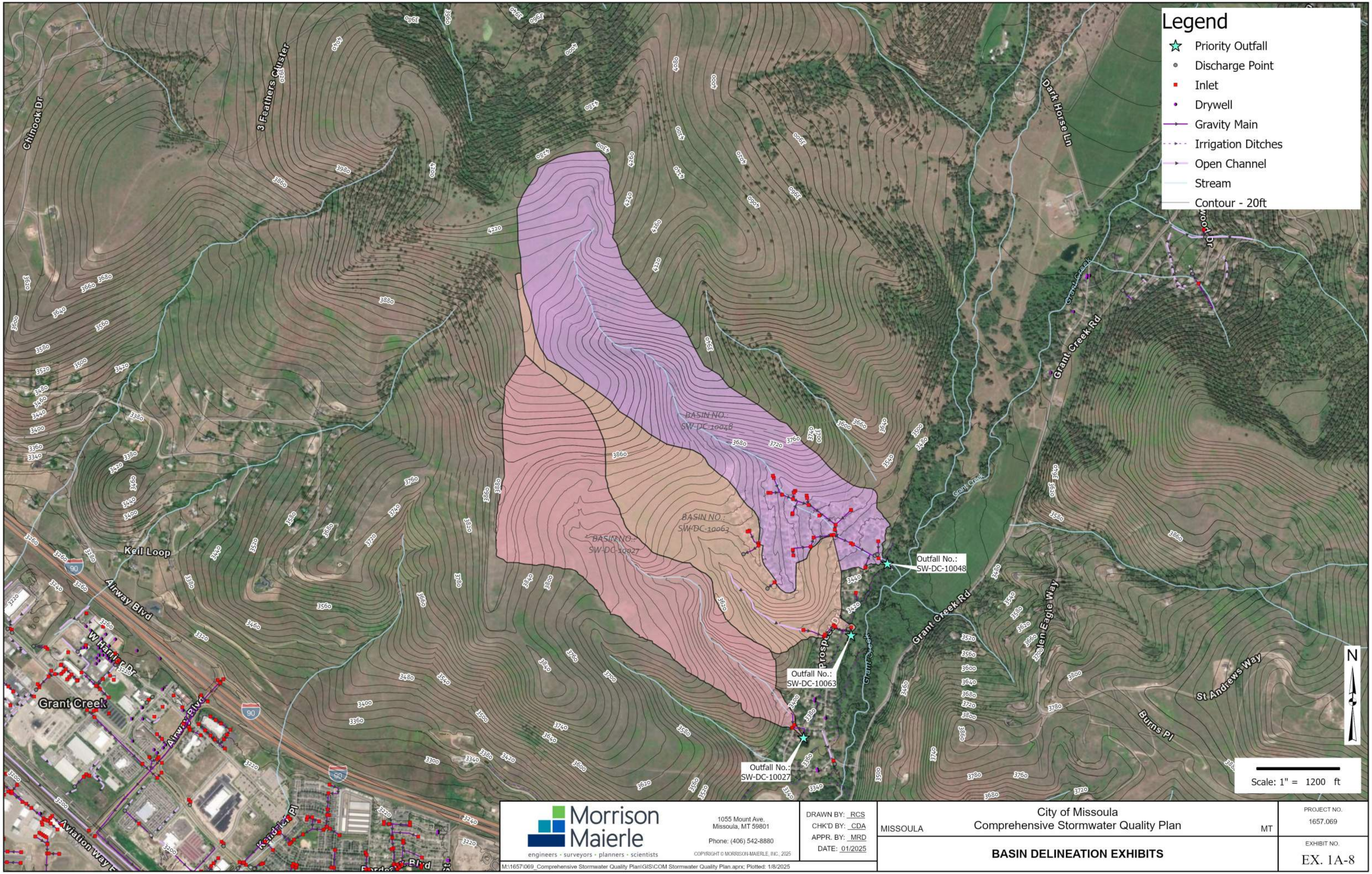

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EXHIBIT NO. EX. 1A-12

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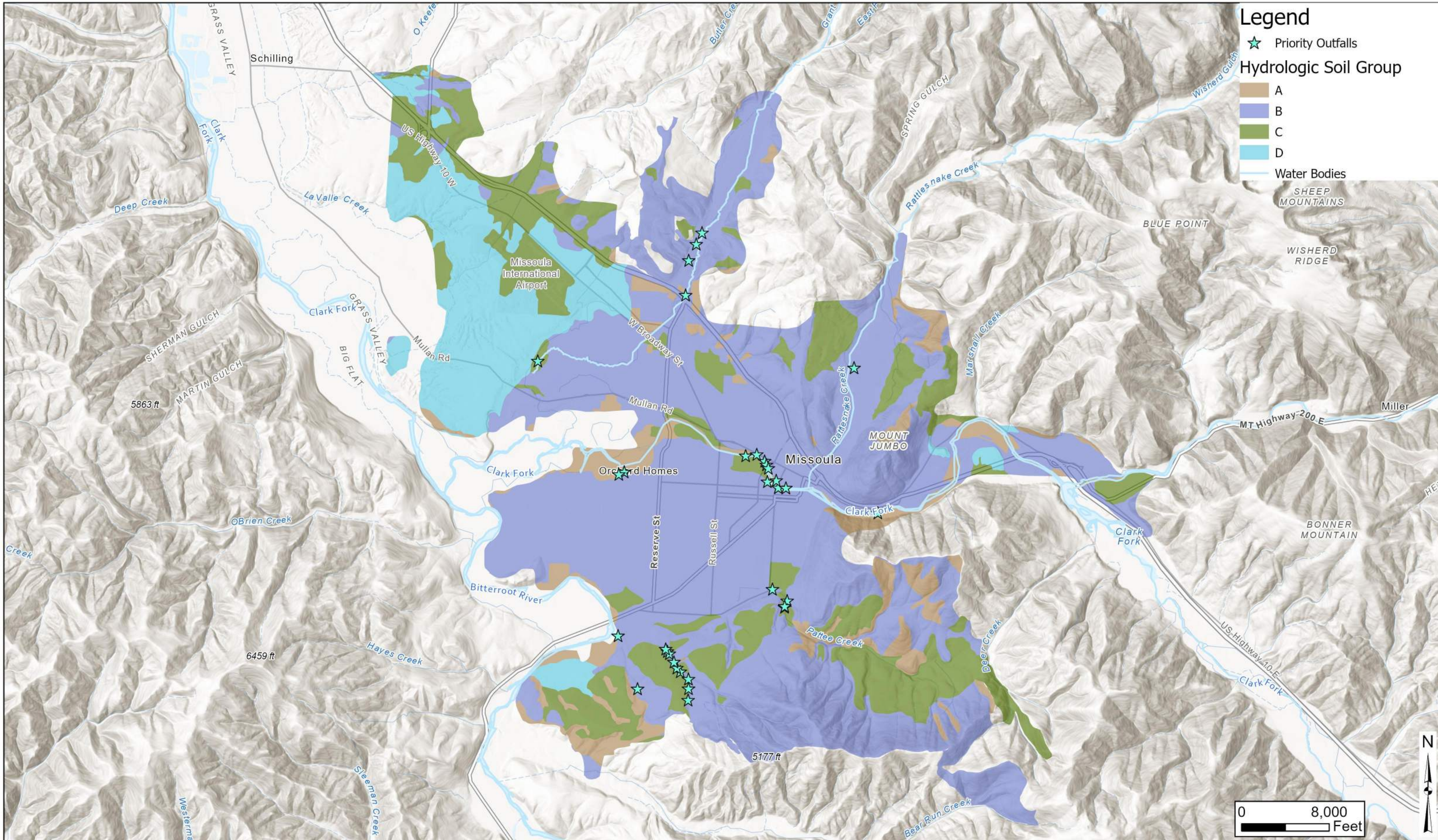
APPENDIX 1B OVERVIEW EXHIBITS



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Base Map: ESRI Topographic
Soils: NRCS Soil Survey, 2024.

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HYDROLOGIC SOIL GROUP EXHIBIT

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APPENDIX 1C CURVE NUMBER EXHIBITS

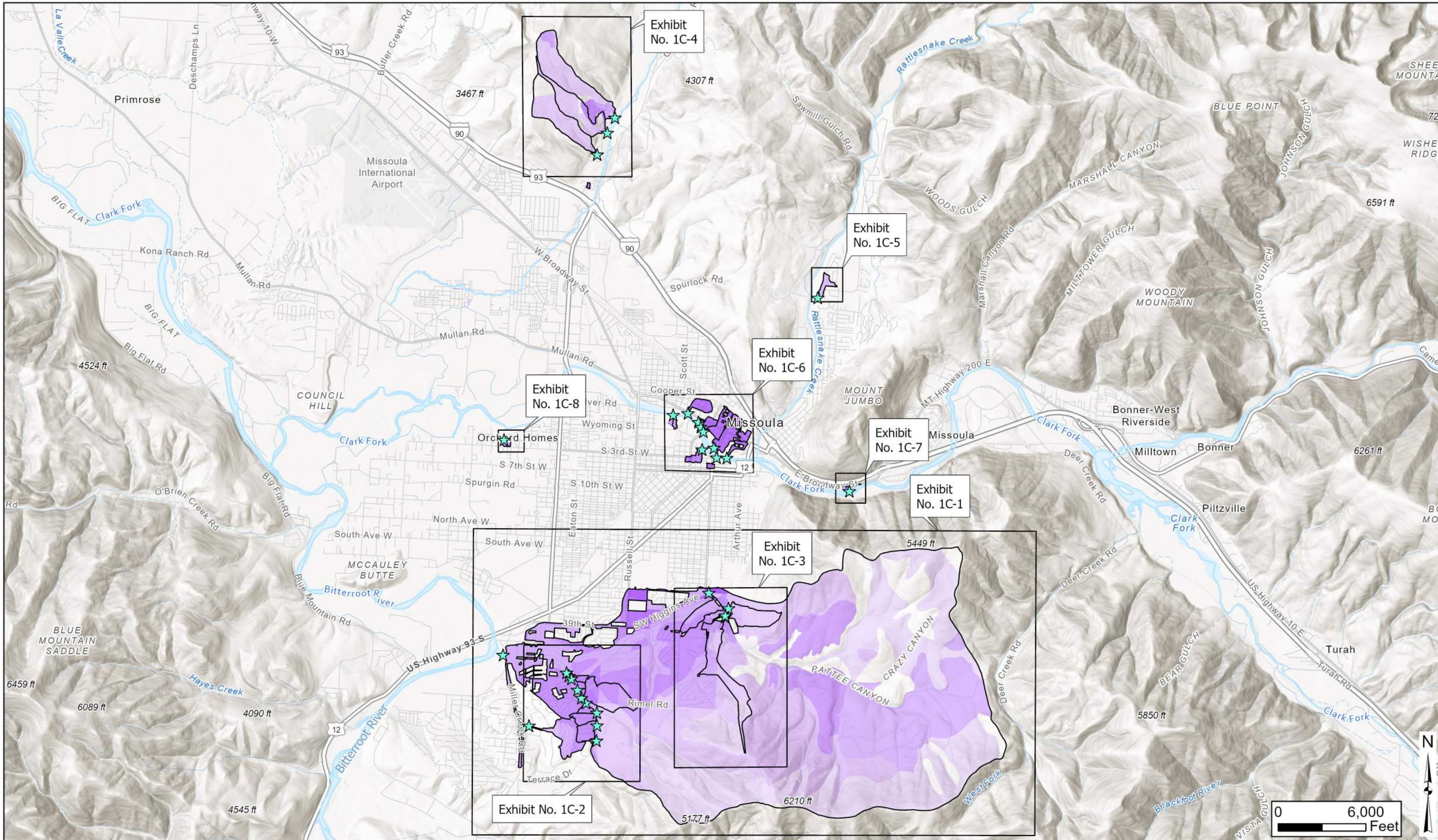

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EXHIBIT NO.
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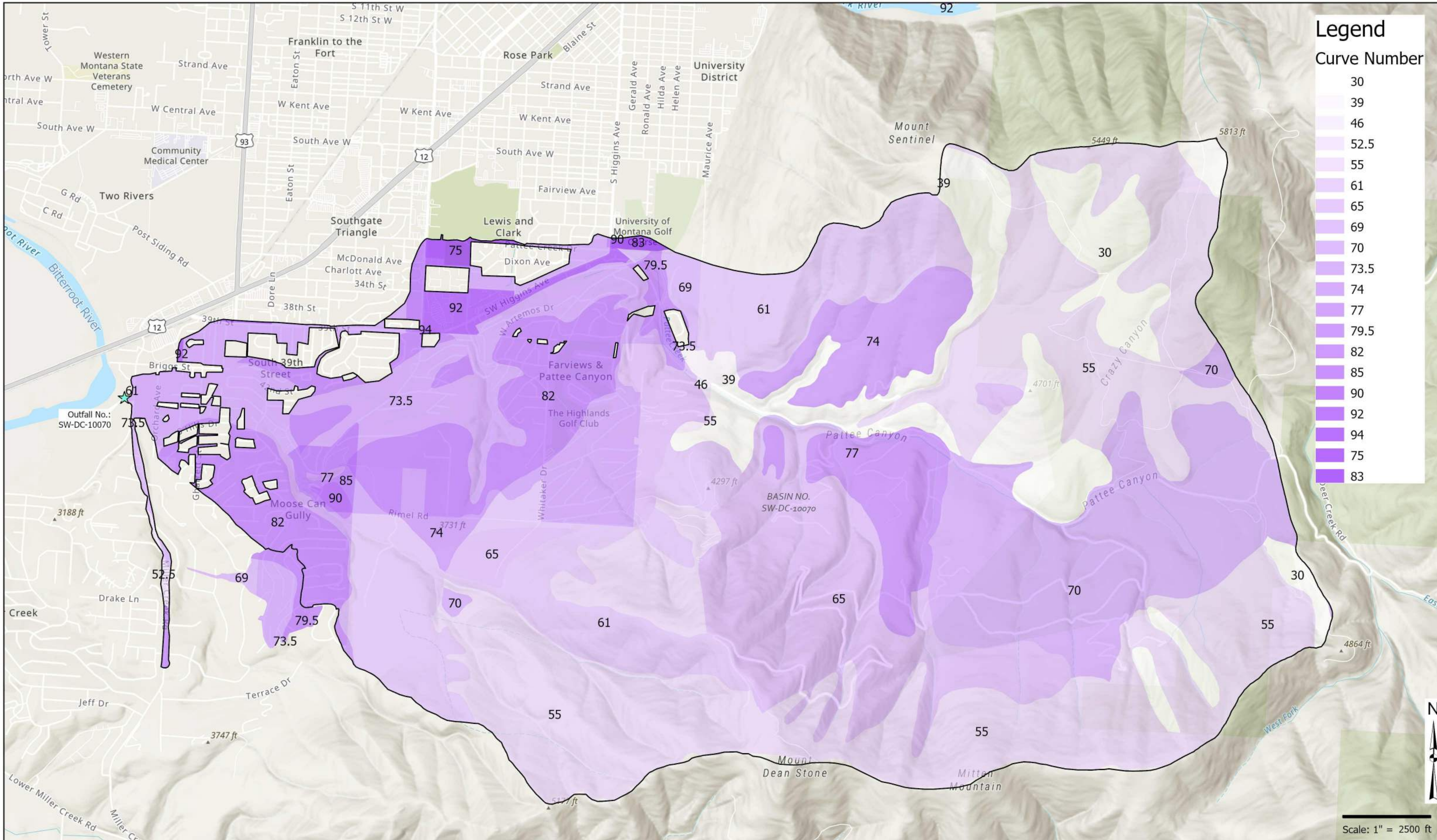

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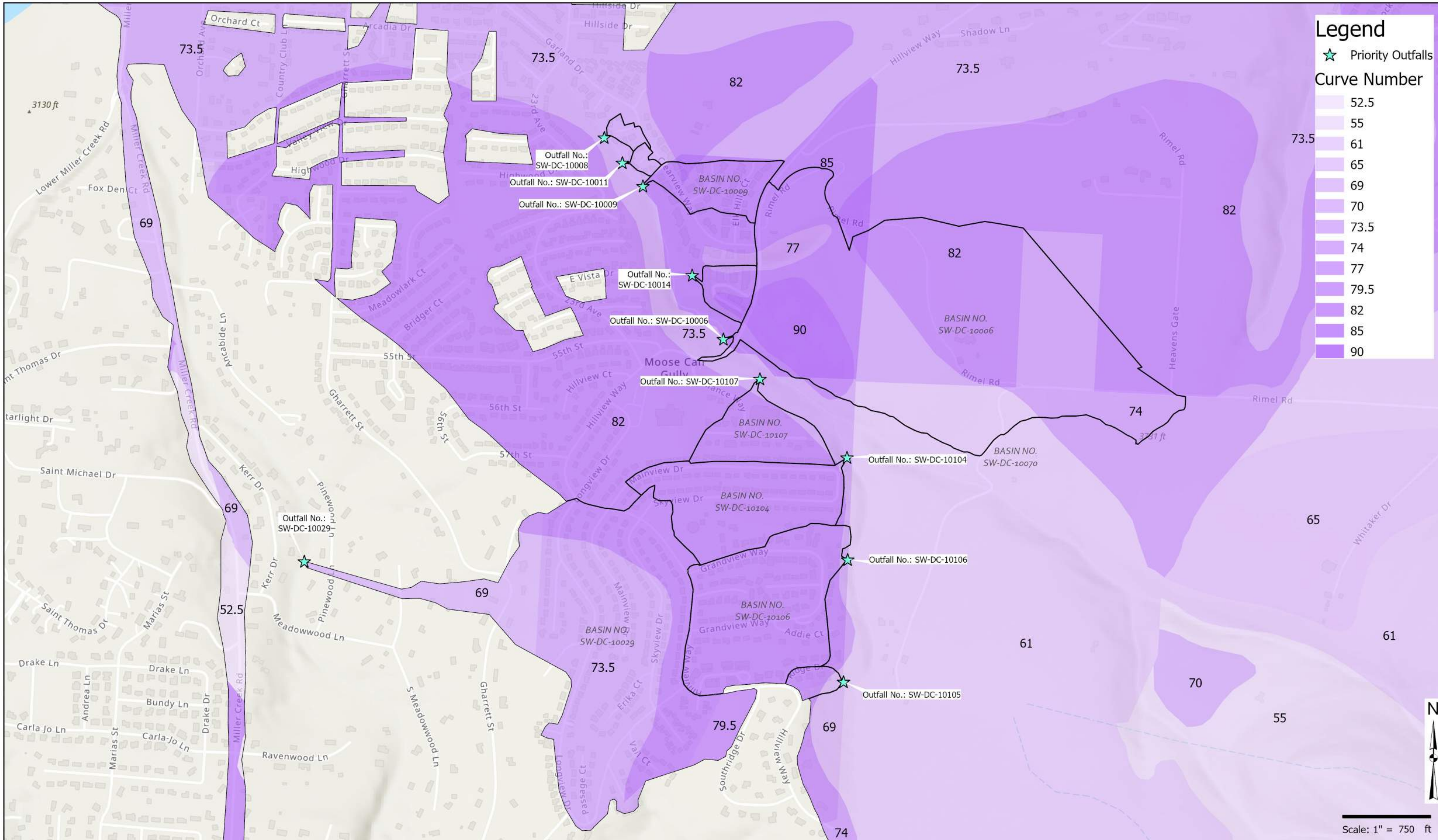

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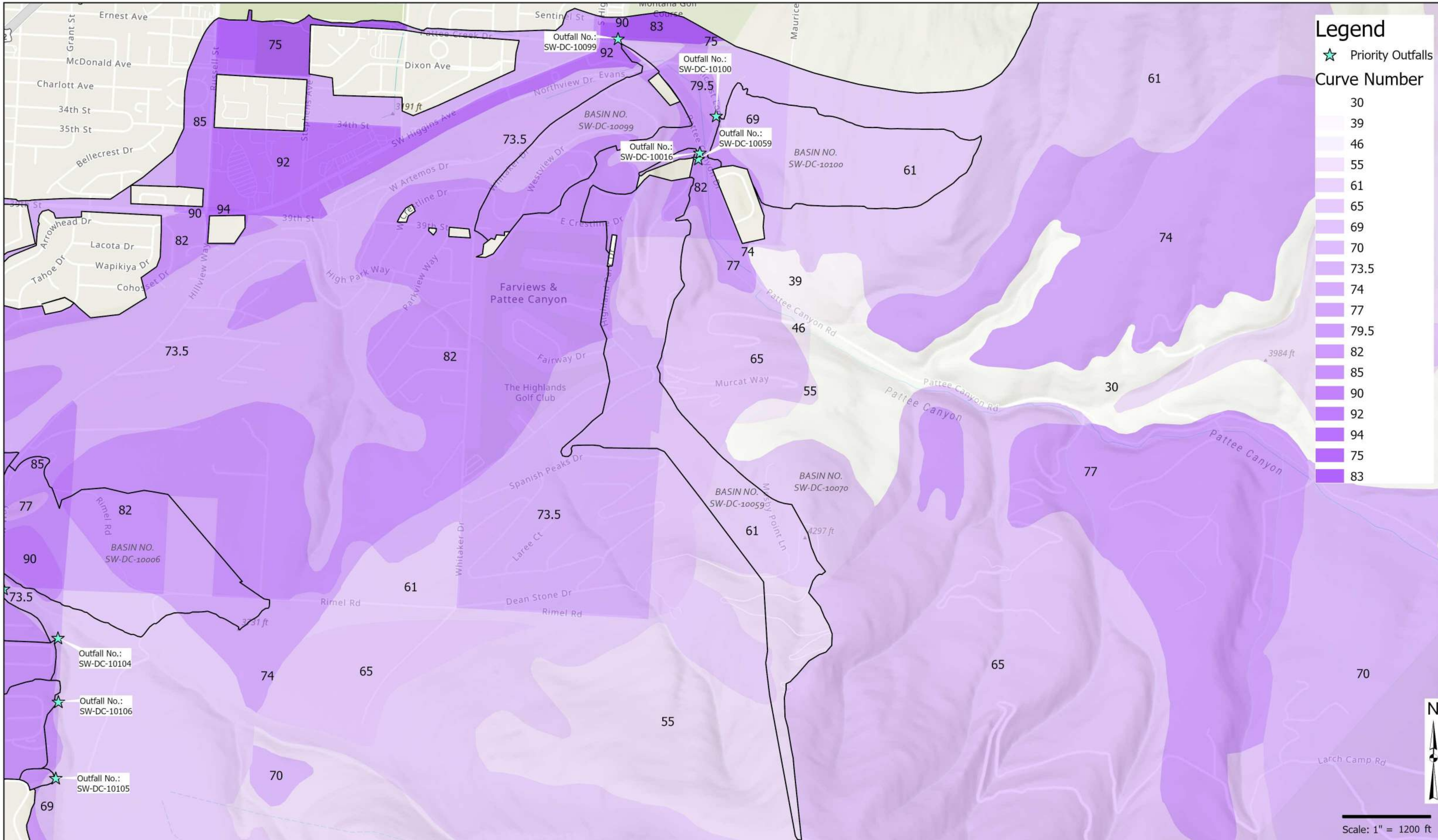

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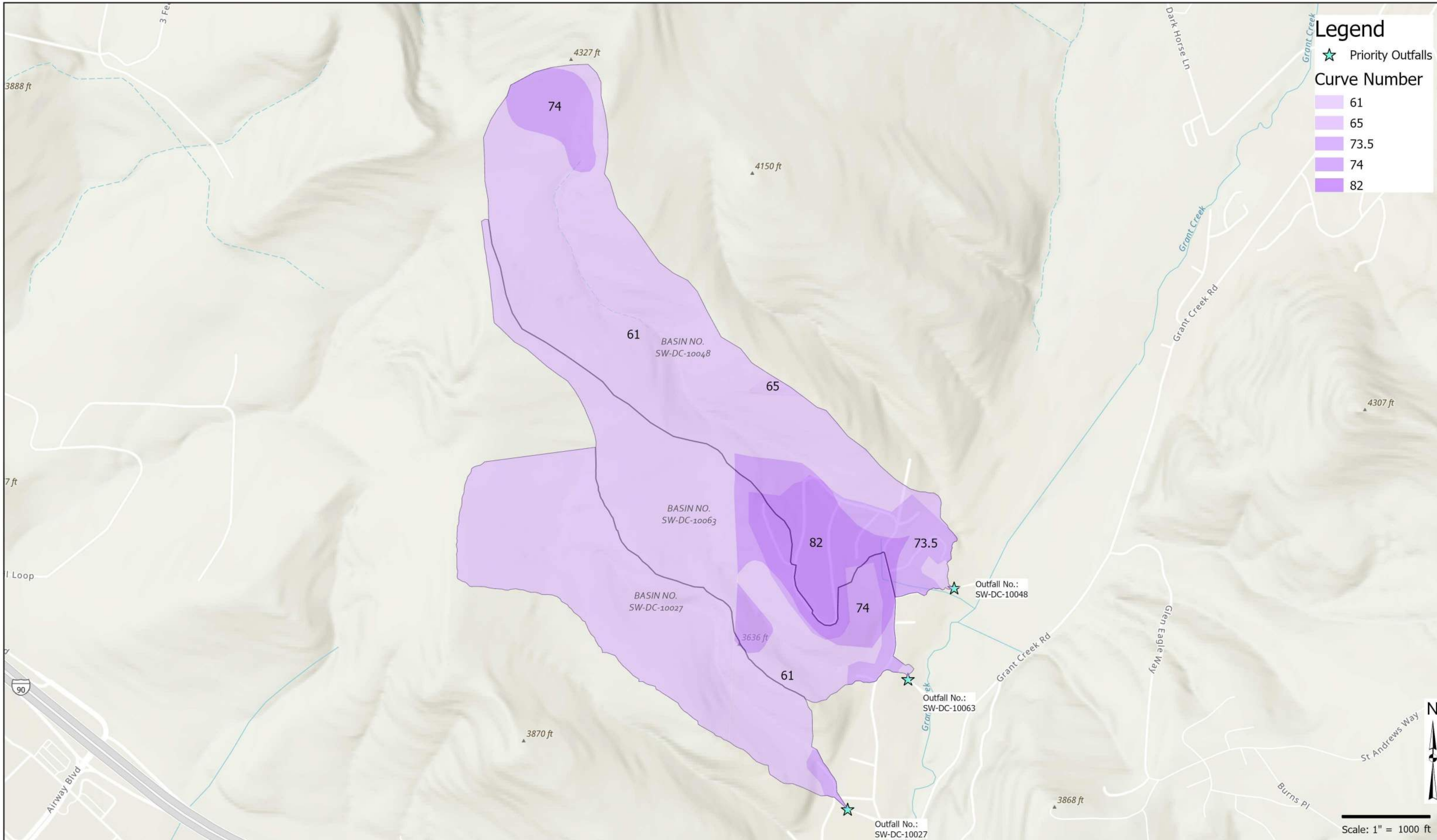

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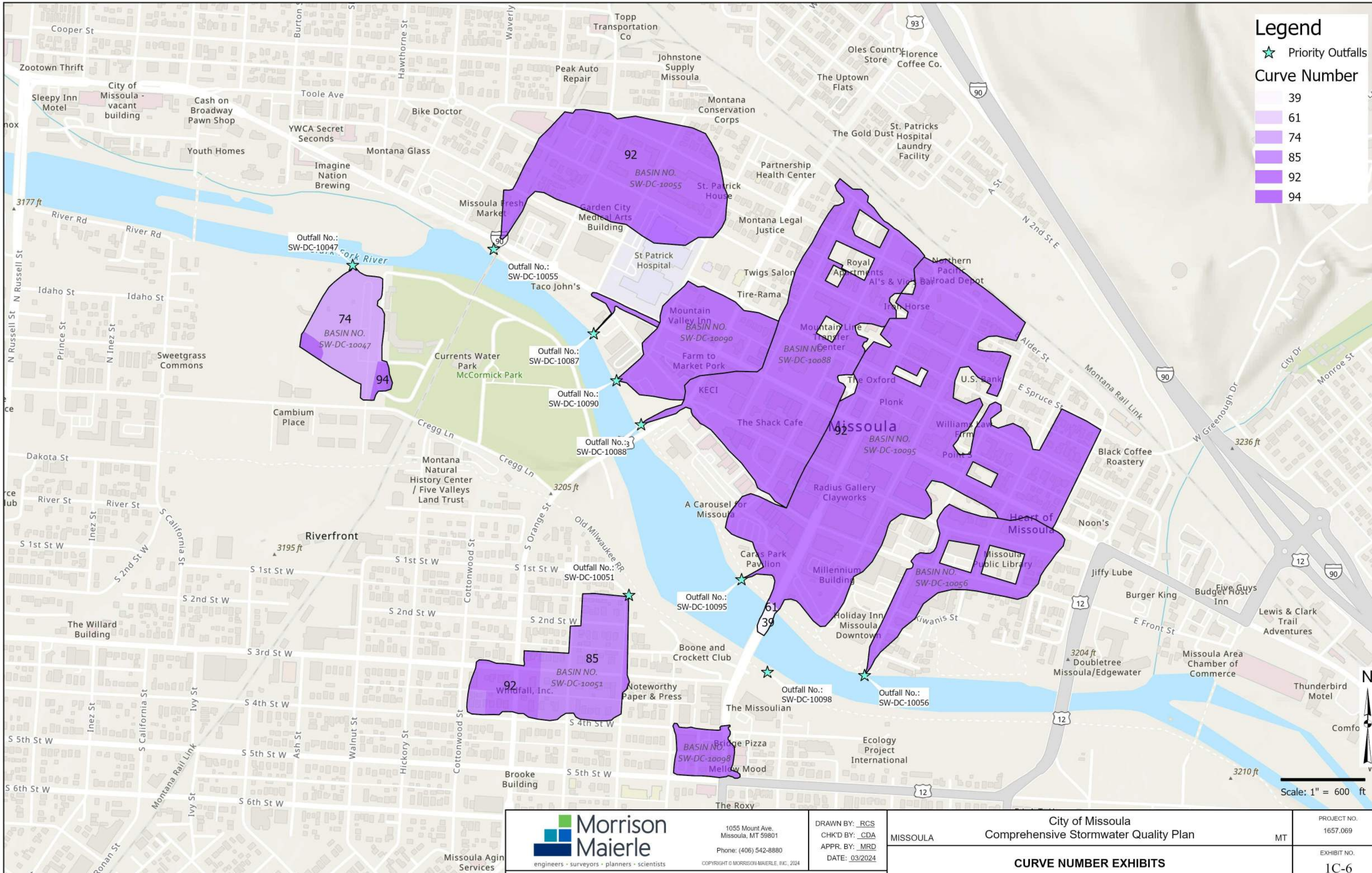
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Priority Outfalls
Curve Number
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61
74
85
92
94
92
BASIN NO.
SW-DC-10055
74
BASIN NO.
SW-DC-10047
94
BASIN NO.
SW-DC-10090
BASIN NO.
SW-DC-10088
92
BASIN NO.
SW-DC-10095
BASIN NO.
SW-DC-10056
61
39
85
92
BASIN NO.
SW-DC-10051
BASIN NO.
SW-DC-10098
Outfall No.:
SW-DC-10047
Outfall No.:
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Outfall No.:
SW-DC-10087
Outfall No.:
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Outfall No.:
SW-DC-10088
Outfall No.:
SW-DC-10051
Outfall No.:
SW-DC-10095
Outfall No.:
SW-DC-10098
Outfall No.:
SW-DC-10056
Missoula
Clark Fork River
McCormick Park
N
Scale: 1" = 600 ft
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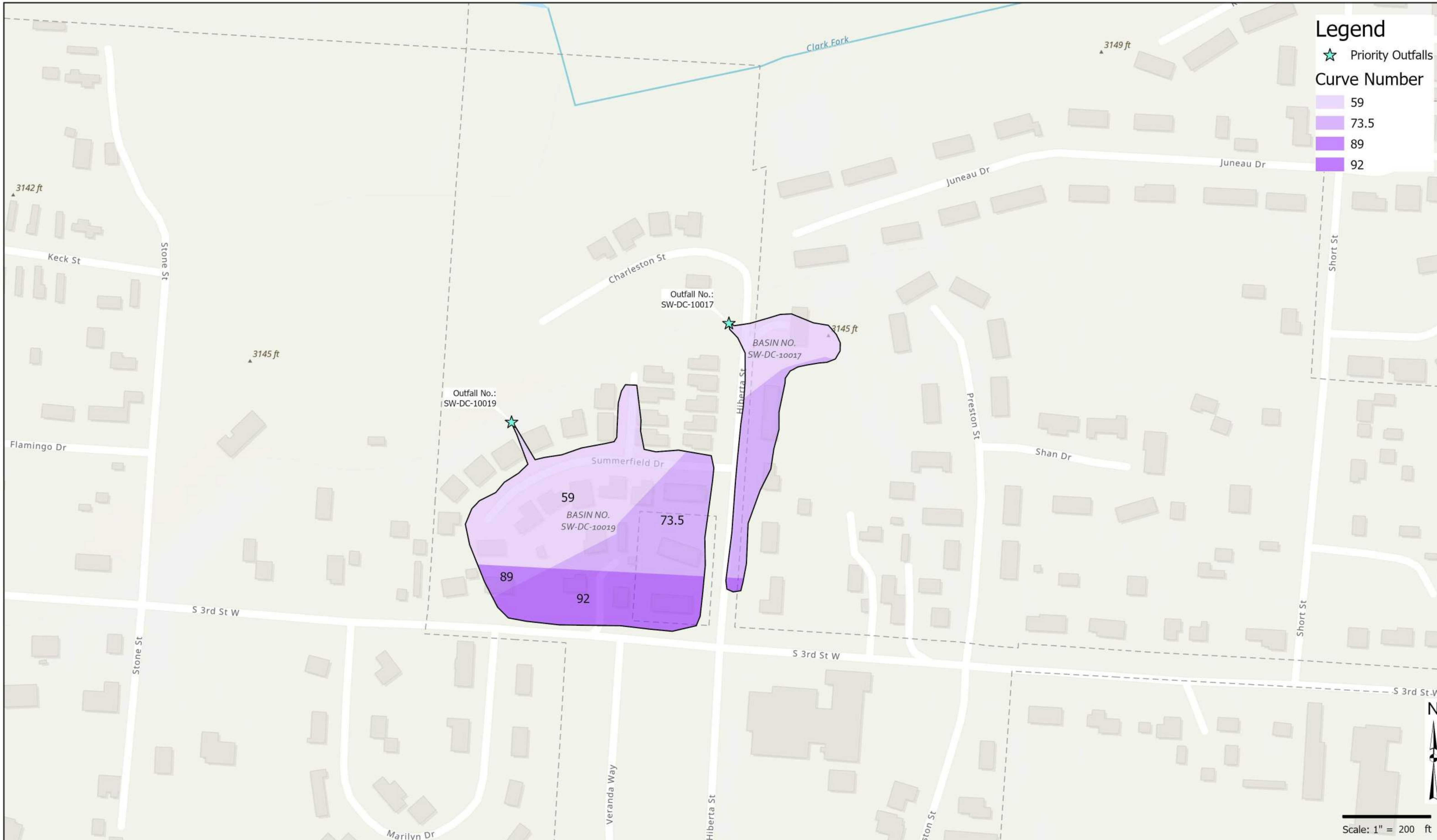

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APPENDIX 1D SUMMARY TABLES

Table A: Basin Characteristics Summary

Priority Outfall Basin	Area (ac)	Dominating Land Use	Receiving Water	Weighted Curve Number
SW-DC-10006	91.9	Residential High	Bitterroot River	79
SW-DC-10008	1.2	Residential Medium	Bitterroot River	74
SW-DC-10009	8.7	Residential High	Bitterroot River	85
SW-DC-10011	0.6	Residential Medium	Bitterroot River	74
SW-DC-10014	4.1	Residential High	Bitterroot River	85
SW-DC-10016	1.5	Residential Medium	Bitterroot River	78
SW-DC-10017	1.3	Residential Medium	Clark Fork River	67
SW-DC-10019	4.7	Residential Medium	Clark Fork River	72
SW-DC-10025	3.4	Residential Low	Rattlesnake Creek	69
SW-DC-10027	136.0	Open and Resource	Grant Creek	61
SW-DC-10029	88.0	Residential Medium	Miller Creek	76
SW-DC-10047	8.7	Parks and Open Lands	Clark Fork River	76
SW-DC-10048	240.5	Residential Medium	Grant Creek	66
SW-DC-10050	6.4	Neighborhood Mixed Use	Clark Fork River	92
SW-DC-10051	18.2	Residential Medium-High	Clark Fork River	87
SW-DC-10055	24.2	Neighborhood Mixed Use	Clark Fork River	92
SW-DC-10056	13.8	Urban Center	Clark Fork River	92
SW-DC-10059	522.3	Residential Medium	Bitterroot River	66
SW-DC-10062	102.9	Residential Medium	Grant Creek	74
SW-DC-10063	131.3	Open and Resource	Grant Creek	65
SW-DC-10070	10,062.5	Residential Medium	Bitterroot River	63
SW-DC-10084	1.8	Regional Commercial and Services	Grant Creek	89
SW-DC-10087	0.5	Urban Center	Clark Fork River	92
SW-DC-10088	35.4	Urban Center	Clark Fork River	92
SW-DC-10090	12.4	Urban Center	Clark Fork River	92
SW-DC-10095	63.6	Urban Center	Clark Fork River	92
SW-DC-10098	3.3	Urban Center	Clark Fork River	92
SW-DC-10099	58.7	Residential Medium	Bitterroot River	77
SW-DC-10100	89.3	Parks and Open Lands	Bitterroot River	64
SW-DC-10104	24.6	Residential Medium	Bitterroot River	82
SW-DC-10105	2.2	Residential Medium	Bitterroot River	79
SW-DC-10106	33.9	Residential Medium	Bitterroot River	82
SW-DC-10107	11.1	Residential Medium	Bitterroot River	81

Table B: Land Use to TR-55 Cover Type and Curve Number

2035 Growth Policy Land Use	Cover Type for Curve Number	Curve Number by Hydrologic Soil Group			
		A	B	C	D
Urban Center	Commercial and business	89	92	94	95
Community Mixed Use	Commercial and business	89	92	94	95
Neighborhood Mixed Use	Commercial and business	89	92	94	95
Regional Commercial and Services	Commercial and business	89	92	94	95
Industrial Heavy	Industrial	81	88	91	93
Industrial Light	Industrial	81	88	91	93
Residential Rural	Residential districts by average lot size - 2 acres	46	65	77	82
Residential Low	Residential districts - interpolate by lot size area between 1/2 Ac, 1 Ac	53	69	80	85
Residential Medium	Residential districts - interpolate by lot size area between 1/4 Ac, 1/3 Ac	59	74	82	87
Residential Medium-High	Residential districts by average lot size - 1/8 acre or less (town houses)	77	85	90	92
Residential High	Residential districts by average lot size - 1/8 acre or less (town houses)	77	85	90	92
Open and Resource	Open Space, Good Condition	39	61	74	80
Parks and Open Lands	Open Space, Good Condition	39	61	74	80
Public and Quasi-Public	VARIES	-	79	74	-
Public and Private Forest	Woods, Good Condition	30	55	70	77

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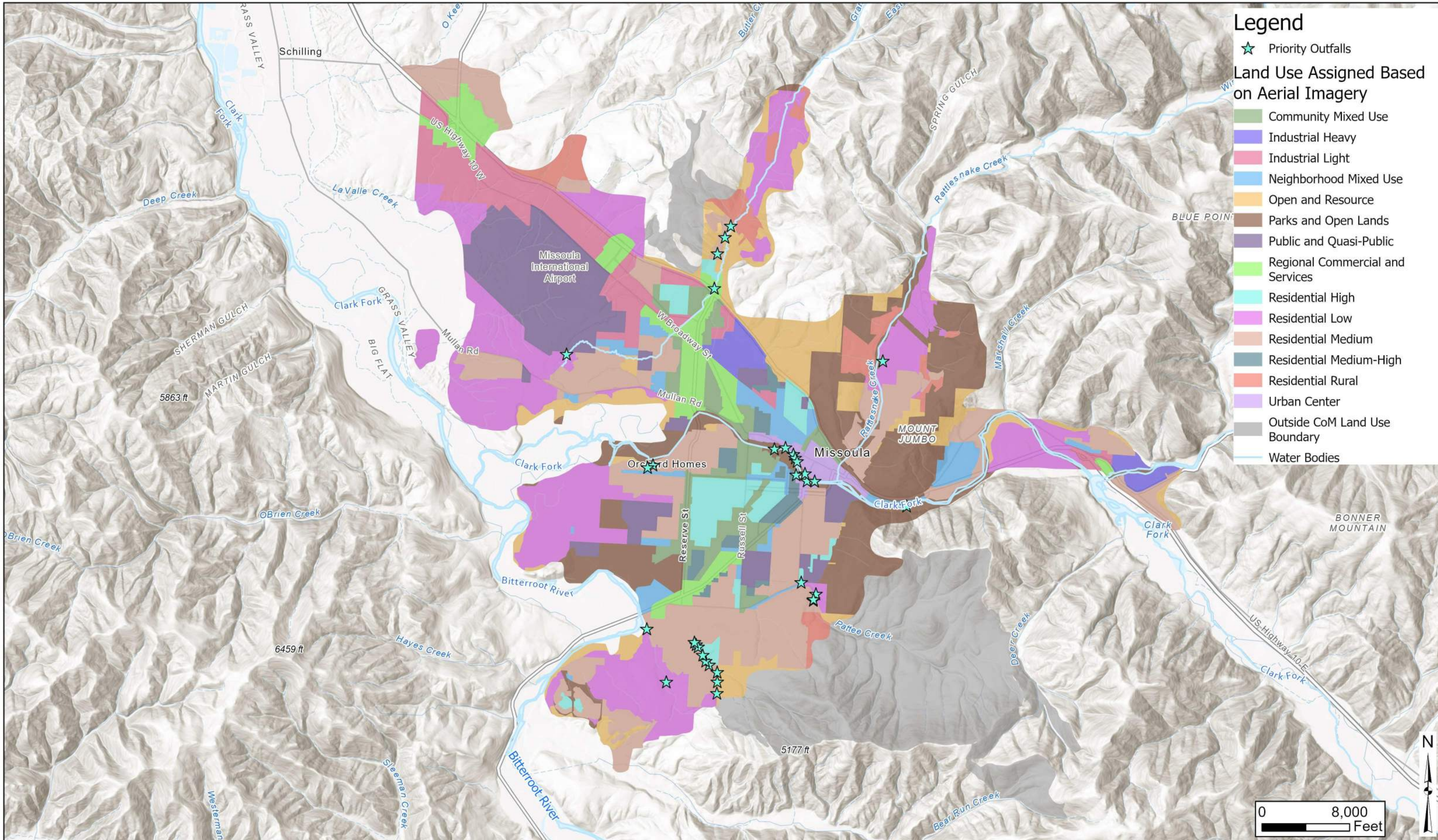

Source Data:
Base Map: ESRI Topographic
Land Use: City of Missoula Growth Policy, 2015.
Soils: NRCS Soil Survey, 2024.

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LAND USE EXHIBIT

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CHAPTER 2 MODEL DEVELOPMENT AND SYSTEM ASSESSMENT

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City of Missoula
Comprehensive Stormwater Quality Plan

CHAPTER 2 MODEL DEVELOPMENT AND SYSTEM ASSESSMENT

2.1. BACKGROUND

The City of Missoula seeks to better understand stormwater challenges and opportunities in the large drainage basin that drains Pattee Canyon and the South Hills to the Bitterroot/South Hills outfall, an outfall to the Bitterroot River just south the of the Buckhouse bridge. The Bitterroot/South Hills outfall has been identified by the City as a Municipal Separate Storm Sewer System (MS4) priority outfall and for which basin characteristics were developed. The MS4 priority outfalls, as identified by the City, are further discussed and described in Chapter 1.

The stormwater models described in this Chapter 2 simulate storms with return periods of 2, 10, and 100 years, as well as quantifying runoff amounts for the first half inch of rainfall from these storms. Analysis of the model results focuses on the locations of proposed water quality improvements in the basin. The models also consider the existing condition, with drainage basins and drainage infrastructure represented as it exists in October 2024, and a proposed condition, the includes development of specific drainage basins based on confirmed development plans. This chapter discusses the model geometry, the hydrologic methods used, and model results pertinent to the objectives.

2.2. OBJECTIVES

The models aim to meet the following objectives:

- Quantify flow rates and volumes at the Bitterroot/South Hills priority outfall.
- Quantify flow rates and volumes at the priority outfalls to Moose Can Gully and Pattee Canyon that are internal to the larger drainage area, where available data support this modeling.
- Quantify flow rates and volumes to project areas for upcoming water quality treatment projects including just upstream of the basin outfall, at Takima Park, at Garland Park, and at the detention pond at the intersection of Pattee Canyon Drive and Higgins Avenue, hereafter referred to as Cutthroat Corner.

- Provide the City with models that can be used a starting point for future efforts to improve stormwater infrastructure in the basin.

Because the objective of the model was not to evaluate the performance of street drainage or inlet capture, stormwater inlets were not modeled explicitly and instead assumed to be full capture. As such, the model is not a full dual drainage model. Future users of this model interested in inlet capture efficiency and resulting flow distributions should further refine the handling of inlets, gutters, and street drainage for their area.

2.3. MODEL GEOMETRY

Stormwater models consist of several distinct processes including rainfall-runoff, stormwater inlet capture, open channel, culvert, closed conduit hydraulics and routing through storage facilities. Each part plays an important role in simulating the generation and movement of stormwater across the Missoula urban landscape. The model geometry includes runoff-generating catchments, a downstream network of conveyances, and several linked storage ponds.

Model geometry was developed to balance accurate representation of real-world conditions and model performance. Geospatial representations of the stormwater system in the drainage basin were provided by the City of Missoula in shapefile format and imported into Bentley OpenFlows Sewer Geospatial Engineering Modeling System (SewerGEMS). Bentley OpenFlows SewerGEMS 2024 v24.00.00.25 was used through the ArcGIS Pro interface. The use of the Geographic Information System interface allowed for georeferenced locations, lengths, and sizes to be used across the model. Elevations, sizes, and material properties for this georeferenced stormwater infrastructure were added to the model based on as-built drawings, where available, Light Detection and Ranging (LiDAR) data, and limited field observations. Some infrastructure data was assumed where as-built information is not available, as detailed below. The model was then simplified to improve model stability, lump portions of the system for which data is not available to support detailed modeling, and in areas where simplifications would not compromise the results in the areas of interest. These simplifications are detailed below.

2.3.1. Catchments

Catchments, which represent runoff-generating drainage areas where rainwater collects and flows towards stormwater infrastructure, were delineated based on outside drainage studies and on manual delineations. Manual delineations were completed by examination of contours derived from the 2019 LiDAR, existing stormwater infrastructure, and direct on-site observations. Automatic delineation based on the LiDAR terrain effectively delineated some basins in the upper, open land portions of Pattee Canyon and Mount Dean Stone, but cannot resolve drainage in urban areas where stormwater infrastructure dictates drainage patterns.

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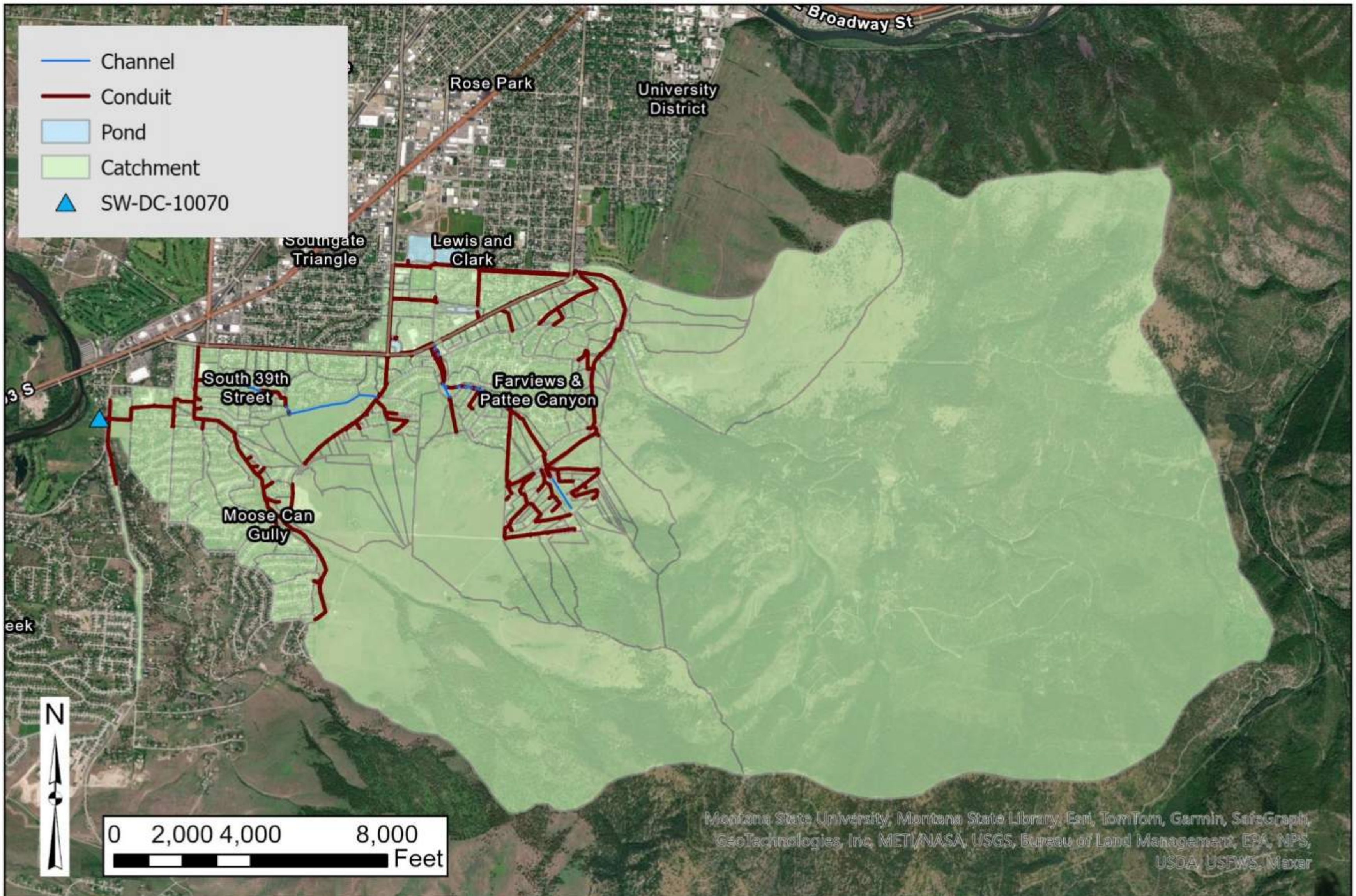

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APPR. BY: ___
DATE: 11/2024

South Hills/Bitterroot Outfall Model Area
Missoula MT

Figure 2-1. Model Area

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Catchments were defined to match delineations from previous studies for specific portions of the overall model area. The previous studies evaluated include:

- The 1997 Mansion Heights Inlet Basins Plan. A plan drawing showing the proposed Mansion Heights subdivision was provided. This plan, labeled Figure 3, was not provided with an additional report or discussion that would have accompanied it originally. The delineated catchments presented appear to match the streets and drainage system constructed and shown in the Project 98-011 drawings and Project 97-01-15 record drawings prepared by WGM Group. Because of this apparent agreement, the Inlet Basins plans were georeferenced and the delineated catchments traced into the model. These catchments cover the portion of Mount Dean Stone from the houses on the south side of Ben Hogan Drive up to Dean Stone Drive.

- 2001 SID 524 Design Report. The Special Improvement District (SID) 524 project included significant improvements to the stormwater drainage system at the base of the South Hills, along with street improvements. The design for the SID 524 project included modeling of much of the current model area. The delineations for catchments for the entire model area south of SW Higgins Avenue/39th Street, north of the Mansion Heights subdivision, and from Pattee Creek Drive in the east to Orchard Avenue in the west were adapted from SID 524. Most basins east of Hillview Way were directly traced, but catchments west of Hillview Way were further delineated by examination of the existing storm drainage system and the underlying terrain.

- 2023 Wild Root Subdivision Drainage Plans. Cushing Terrell provided the 2023 Post Subdivision Drainage Basins exhibit. The overall catchment boundary for the subdivision was used in the existing conditions model, as major grading for the subdivision has been completed. Proposed conditions modeling will include modification of the runoff coefficient to reflect a fully developed condition.

The above adopted delineations, along with other manual delineations in model area, result in 270 catchments covering the approximately 15.7 square mile area draining to the Bitterroot/South Hills outfall. Catchment hydrologic parameters were developed for use with the EPA SWMM runoff method and Green and Ampt loss method, as discussed further in Section 2.4. The catchment drainage area is calculated from its georeferenced footprint.

2.3.2. Open Channels

The storm drainage system in the model area includes both natural and constructed open channels. These can be represented in SewerGEMS either as a conduit link, the main link element type, with a single irregular cross section or as a channel link, which allows for a variation in channel cross section at each node. Where a single cross section shape represented the channel well, either due to its constructed nature or short length, these channels were represented as conduit links. Where capturing the natural variation in cross section at smaller spatial scale seemed important, the channels were modeled as channel links between cross section nodes.

For all open channels, the channel cross sections were cut from the 2019 LiDAR terrain. The conveyance channels in the model area were mostly dry during the LiDAR collection. Additionally, the low flow channels that may not be resolved in the LiDAR provide a small portion of the overall conveyance during larger storms. Cross sections were then shifted to a relative depth by subtracting the invert from each elevation. There are 43 channel links with an average length of 310 feet. There are 19 conduits representing open channels with an average length just over 600 feet. Each link representing an open channel received a material assignment from the SewerGEMS library based on field reconnaissance, which resulted in an assignment of Manning's n-value. High Park Drainage stands as an exception, as it received an n-value of 0.035 because it appeared to be somewhere between the library values for natural streams.

Table 2-1. Open Channel Materials

Material Assignment	Manning's n-value
Asphalt pavement (smooth)	0.013
Concrete	0.013
Natural stream, clean	0.030
Natural stream, clean with more stones and weeds	0.035
Natural stream, stony notes	0.050
Flood plain, brush	0.060

2.3.3. Stormwater Gravity Mains and Manholes

Stormwater gravity mains form the bulk of the storm drainage system. Conduit links representing gravity mains and inlet connections total 548 individual links modeled covering nearly 15 miles of pipe. These conduits include circular pipes ranging in diameter from 12 inches up to 60 inches, some arch pipes, and one reinforced concrete box culvert. Conduit lengths are determined geospatially. The sizes of many pipes could be pulled automatically from the GIS feature classes provided by the City.

Pipe elevations and materials were entered from record drawings where available. These elevations were largely entered as manhole inverts and the conduit ends fixed to the manholes at each end. The manhole rims were set to the ground elevation, which was pulled from the 2019 LiDAR terrain. Where record drawings for specific locations were not available, the manhole inverts were calculated from an average depth of nearby manholes that were constructed at a similar time. Where pipe diameters and materials were not available, these parameters were assumed from adjacent links that were known, while ensuring the pipe diameter increased in the downstream direction. Wherever elevations or diameters were assumed, these assumptions are included in the Notes field for that model component.

The standard head loss method in SewerGEMS allowed implementation of the approximate method for inlet and manhole losses (FHWA, 2024). HEC-22 only recommends using the approximate method for preliminary design estimates and therefore it is appropriate for this modeling effort. Manholes are universally assigned a minor loss coefficient of 0.85, which represents a 120-degree angle between inflow and outflow pipe. Smaller angles result in more losses and straighter runs result in less losses. The intermediate value provided by this value seemed to be sufficiently conservative. Conduit junctions in the model also include transitions, which are largely used to intercept inlet laterals. Transitions are assigned a minor loss value of 1.0, which represents an intermediate value between 90-degree angled and straight run inlet configurations.

2.3.4. Stormwater Inlets

Stormwater inlets mainly serve to function in the model to put water into the modeled conveyances, but their hydraulic performance is not considered in the model. SewerGEMS catch basins allow for simulation of stormwater inlets. All catch basins are set to full capture and gutter flow between inlets is not modeled. Elevation and inlet shape information were assigned to inlets where available in record drawings. Despite being set as full capture, the inlet shape information remains in the model catch basins if future model users want to develop models that include gutters and model inlet performance. Catch basins with unknown elevations were assigned from the average of known manhole depths in the nearby area and then elevated if needed to ensure positive drainage.

2.3.5. Detention Ponds and Outlet Structures

The model features fifteen detention ponds. The modeled ponds include the two detention cells at Spartan Park/Playfair Park and a pond upgradient of Simons Drive that was not included in the City of Missoula GIS data but behaves as detention storage based on site investigations. The 2019 LiDAR terrain was used to develop elevation-volume curves for most storage ponds. The LiDAR could be used for the facilities that are normally dry. The ponds at Cutthroat Corner and new ponds at Cattail Corner always hold water and therefore the elevation storage curves had to be derived from record drawings.

Each pond requires a pond outlet structure to define the routing out of the pond. The pond outlet structures mostly consist of beehive-style risers with a low-level orifice and vertical pipe with an open top. These were defined from record drawings. The Cutthroat Corner and Cattail Corner outlet structures are slightly different than the beehive risers and are also determined from record drawings.

2.3.6. Model Simplifications

Several areas of the model lacked record drawing information and could be simplified without compromising model objectives. These areas either covered relatively small drainage areas or areas that would not significantly impact inflow to existing or proposed water quality best management practices (BMP). The following items were removed to simplify the model:

- The Cutthroat Corner detention pond maintenance bypass pipe was deleted, as it will not be used during storm events.
- The inlets, pipe, and detention pond along Ironwood Place were deleted.
- Inlets and pipe along Fairway Drive, Greenwood Lane, and Rolling Green Place.
- Inlets and pipe on E Crescent Drive and W Foothills Drive.
- Inlets and pipe on Black Pine Trail, Polaris Way, and Simons Drive west of the drainage crossing.

- Inlets and pipe along Skyview Drive, Mainview Drive, Foss Court, and the detention pond below Alliance Way were lumped into one drainage catchment.
- Inlets and pipe along Pineridge Drive between Artemos Drive and E Crestline Drive.
- The SID 355 area between Whitaker Drive, Artemos Drive, Normans Lane, Overlook Way, and High Park Way was lumped into one drainage catchment.

Additionally, infiltration facilities through the model area were neglected, including distributed drywells throughout the model area, injection facilities at Spartan Park, and the injection facility at Bellevue Park. While these facilities have an important effect on the overall system behavior, it was assumed that they do not meaningfully affect peak flows.

2.4. HYDROLOGY

2.4.1. Rainfall

The hydrology follows the City of Missoula standards in its application of TR-55 and the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall estimates are used for the 2-, 10-, and 100-year events. The Missoula City Public Works Storm Water System standards dictate the use of SCS Type II rainfall distribution, as appropriate for Montana. The design storm depths from the 2020 Missoula City standards were not followed, as the NOAA Atlas 14 rainfall estimates for Montana were recently released and represent the state of the art in precipitation estimates for the country (NOAA, 2024). These estimates are shown in Table 2-2 for the centroid of the overall model area. Catchment specific local rainfall should be developed for detailed design modeling.

Table 2-2. Design Storm Depths

Storm Return Period	Storm Depth (in)
2-year	1.40
10-year	1.96
100-year	2.84

Runoff from the first half inch of rainfall is also of particular interest given the MS4 permit requirements for post-construction best management practices. While these requirements explicitly pertain to new development, the first half inch runoff was considered assuming a 10-year return period rainfall pattern.

2.4.2. Runoff Method

The EPA SWMM runoff method was used for all catchments. The SWMM method requires estimates of catchment area, percent imperviousness, catchment width, slope, Manning's roughness coefficient for overland flow, and depression storage. Several of these parameters are calculated using ArcGIS geoprocessing tools, as detailed below:

- Area: As noted previously, the area is calculated from the georeferenced footprint.

- Slope: The catchment slope is calculated from 2019 LiDAR data and averaged over each catchment.
- Catchment Width: The hydraulic flow lengths were calculated using the ArcGIS Pro Hydrology Toolset on the 2019 LiDAR surface. The catchment area was divided by maximum flow length in each catchment and this was used as the representative catchment width.

The percent imperviousness, depression storage, and Manning's roughness coefficient are calculated from recommended values published in SWMM guidance (EPA, 2016). The percent imperviousness is calculated from the estimates for each land use class, with most of the open land representing the highest portions of the model area assigned manually. The depression storage for pervious areas is calculated based on the regression with slope developed by Kidd and published in the SWMM Reference Manual, Volume 1. For impervious areas, the depression storage is set to 0.001 inches. The Manning's roughness coefficient was set based on pervious or impervious surface coverage to the values shown in Table 2-3, following standard guidance.

Table 2-3. Manning's Roughness Values for SWMM Runoff Method

Cover Type	Dominant Ground Cover	Manning's Roughness Coefficient
Pervious	Short grass prairie	0.15
Impervious	Suburban residential land use	0.055

The EPA SWMM method and SCS unit hydrograph method were both trialed, and SWMM runoff method used across the model area. The EPA SWMM method was paired with the Green and Ampt loss method and the SCS unit hydrograph method was paired with the SCS curve number method for losses. The SCS methods could not be relied upon for smaller rainfall events. TR-55 notes that the accuracy of the methods contained within are limited outside the range of initial abstraction to precipitation that are given, typically less than 0.5. For the 10-year rainfall shown in Table 2-2, this corresponds to an initial abstraction of 0.98 inches. Any catchments with a CN value of 67 or less would have a higher initial abstraction and therefore ratio of initial abstraction to precipitation below the published ranges. For the delineated catchments, 7,700 acres of the model are had a CN below 67 and therefore would have limited accuracy over most of the catchment. To further validate the choice of methods, a simple model of the Rattlesnake Creek watershed was prepared with four catchments and two segments of the creek above the Rattlesnake Creek flow gauge. Two rainfall events in 2021 and 2022 (after removal of the Rattlesnake Dam) were modeled and the modeled results compared to flows at the gauge. After minor adjustment of catchment parameters, the SWMM method yielded hydrographs with similar peak flows and overall shapes to the observed flows, albeit with sooner peaks and quicker recession. The SCS method yielded no flows for these events because the rainfall totals failed to exceed the initial abstraction threshold. While the Rattlesnake Creek watershed is bigger, higher, and less urbanized that our watershed, it was considered similar enough, with its proximity and mix of suburban residential and forest land uses, to be a valid comparison.

The model uses SWMM parameters for the Pattee Creek watershed above Takima Park that were calibrated to the peak flows predicted by the USGS regression equations (Sando, McCarthy, & Dutton, 2015). This Pattee Creek catchment has an area of 5,395 acres, constituting over half the overall modeled area. Calibrating this large contributing area to an outside predicted flow helps improve the modeled confidence. The peak flow calibration was achieved by decreasing the percent impervious area to 0.7%, from 1.9% estimated for forested areas. The results of the calibration, shown in Table 2-4, suggest that the selected methods match well for large events and overestimate smaller events. This was considered preferable to shifting the calibrated parameters to reduce peak flows and underestimating larger events.

Table 2-4. Pattee Creek Catchment Calibration

Event Return Period	USGS Regression Predicted Flow (cfs)	Model Predicted Flow (cfs)	Percent Error (%)
10 year	79	100	26.6%
100 year	165	166.3	0.7%

2.4.3. Loss Method

The Green and Ampt method provides estimates of rainfall infiltrating and is used for the loss method in this model. The Green and Ampt infiltration parameters for a loamy sand soil were used, based on examination of the physical properties of the soil types in the model area. These parameters also generated more realistic peak flows and flow volumes than the parameters for sandy loam soil type.

2.5. RESULTS

As discussed in the objectives, the analysis of model results focuses on areas of proposed stormwater treatment BMPs in the model area. For each of these areas, an individual model is created that extends both upgradient and downgradient of the area of interest.

2.5.1. Takima Park

The outfall to Takima Park drains residential neighborhoods to the south from open channel conveyances and pipes that eventually connect to a 30-inch pipe along Takima Drive. Much of the drainage area runoff is controlled by detention basins above Ben Hogan Drive that eventually discharge to an open channel in the park land at the end of Ben Hogan Drive. These detention ponds provide some attenuation of peak flows. The contributions of other local drainage result in the hydrographs and peak flows shown in Figure 2-2 and Table 2-5, respectively. The runoff volume associated with first half inch of runoff at this site is 1.5 acre-feet.

Table 2-5. Takima Park Peak Inflows and Volume

Storm Return Period	Peak Flow (cfs)	Inflow Volume (ac-ft)
2-year	16.8	3.6
10-year	19.7	4.8
100-year	24.3	6.7

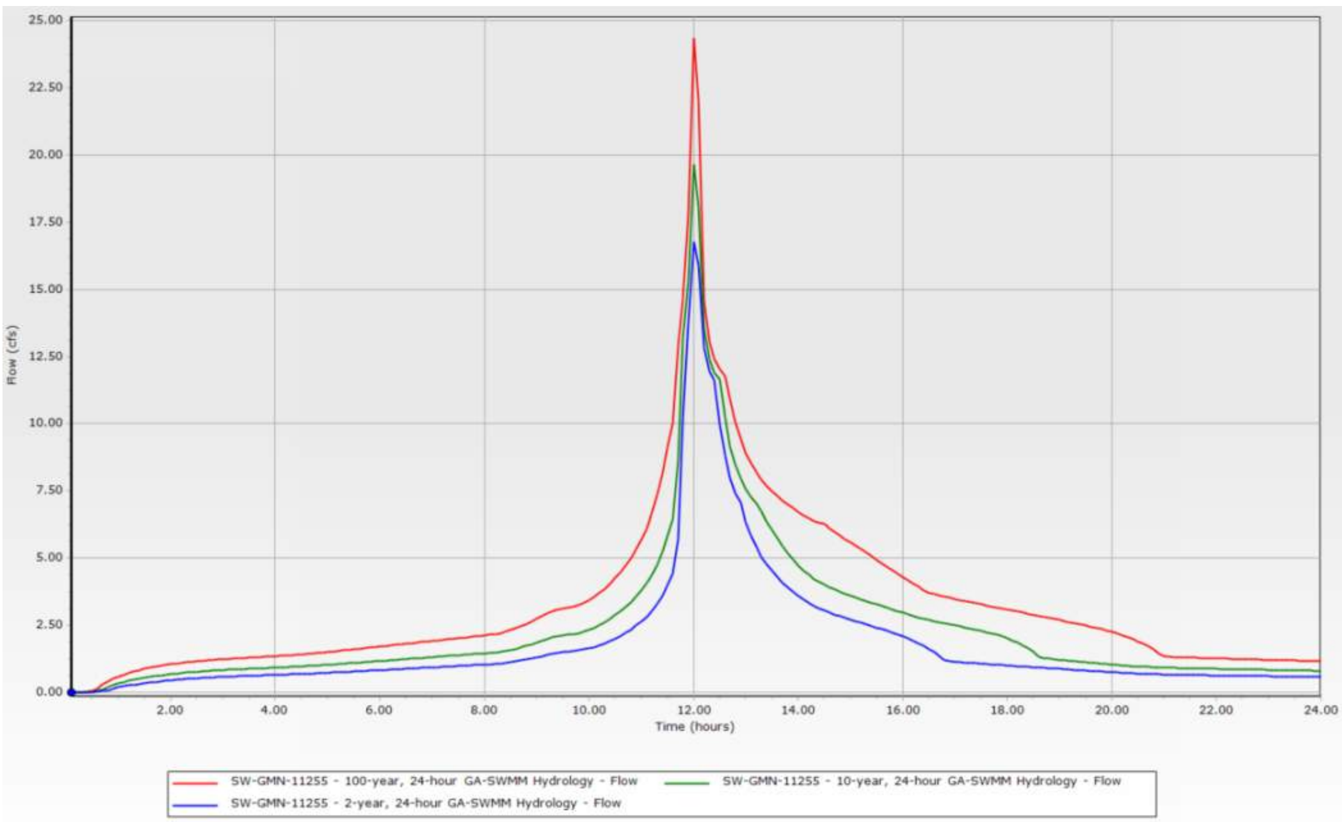

Figure 2-2. Takima Park Outfall Hydrographs

2.5.2. Garland Park

Garland Park receives flows directly from Moose Can Gully, including the 1,270 acre catchment with limited development above Hillview Way. These flows receive local drainage from developed residential neighborhoods and result in the hydrographs and peak flows shown in Figure 2-3 and Table 2-6, respectively. The total runoff volume for the first half inch of rainfall is 3.5 acre-feet.

Table 2-6. Garland Park Peak Inflows

Storm Return Period	Peak Inflow (cfs)	Inflow Volume (ac-ft)
2-year	54.3	8.5
10-year	71.4	11.6
100-year	102	16.4

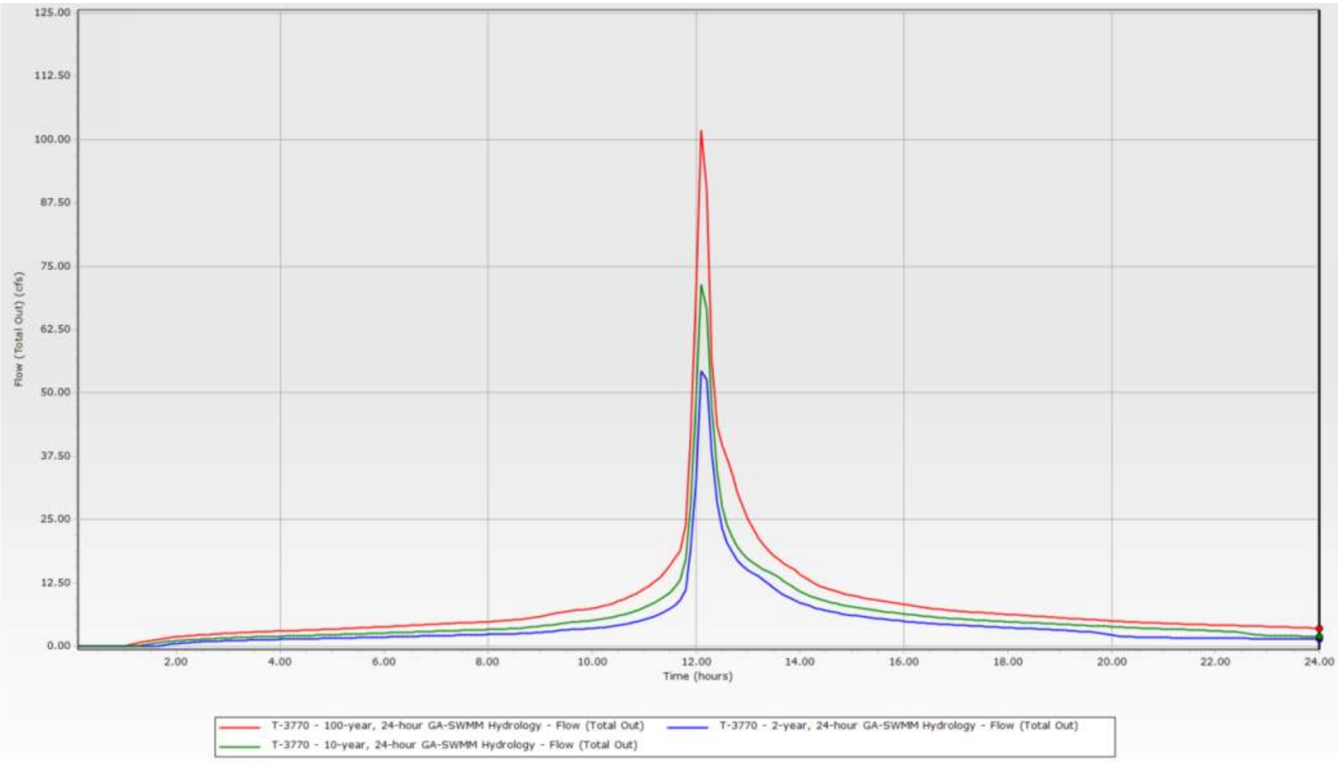

Figure 2-3. Garland Park Inflow Hydrographs

2.5.3. Cutthroat Corner

The Cutthroat Corner pond captures coarse sediment transported by Pattee Creek and will be at least partially redesigned by the City of Missoula in collaboration with the University of Montana with funding from the Environmental Protection Agency. The inflow hydrograph and peak inflows for the 2-, 10-, and 100-year storms are shown in Figure 2-4 and Table 2-7, respectively. The peak flow value of 240 cfs shown for the 100-year exceeds the peak flow calculated in the 1988 Flood Insurance Study of 195 cfs and confirmed in the 2002 Design Report in support of the SID 524 project. This could reflect the reality of a further developed condition in the catchment area, but additional calibration is recommended for final design of stormwater quality BMPs at this site. The volumes for the return period events are also shown in Table 2-7. The runoff volume for the first half inch of rainfall is 4.8 acre-feet.

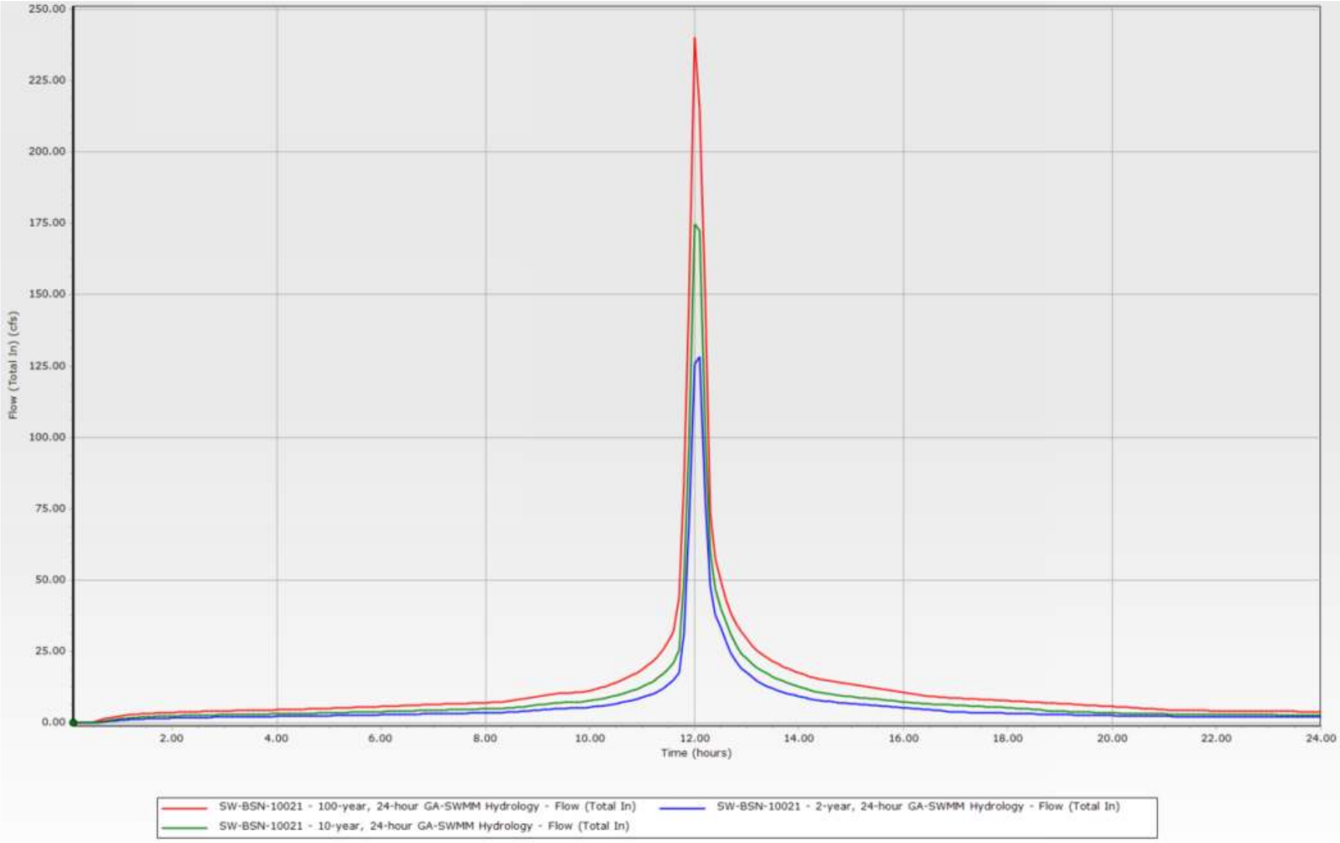

Figure 2-4. Cutthroat Corner Pond Inflow Hydrographs

Table 2-7. Cutthroat Corner Peak Inflows

Storm Return Period	Peak Flow (cfs)	Inflow Volume (ac-ft)
2-year	126	12.8
10-year	175	16.6
100-year	240	24.9

The pond currently maintains a normal pool elevation of 3,229 feet and therefore storm conditions were modeled that only consider storage above this normal pool, with a small area inserted in the table at the outlet elevations to allow them to function in the model. The pond discharges through an 18-inch normal outflow culvert to the Pattee Creek Surface drainage and through a 3-foot rise by 8-foot span box culvert that connects to a 48-inch diameter gravity main west of SW Higgins Avenue. These outflow conduits appear to be a good match for the 100-year design inflow, as this does not exceed the stated design full pool elevation of 3,231 feet, as shown in Table 2-7. This full pool elevation maintains 2 feet of freeboard below the emergency spillway. Therefore, the pond retains a significant safety margin with the current pond storage and outlet capacity.

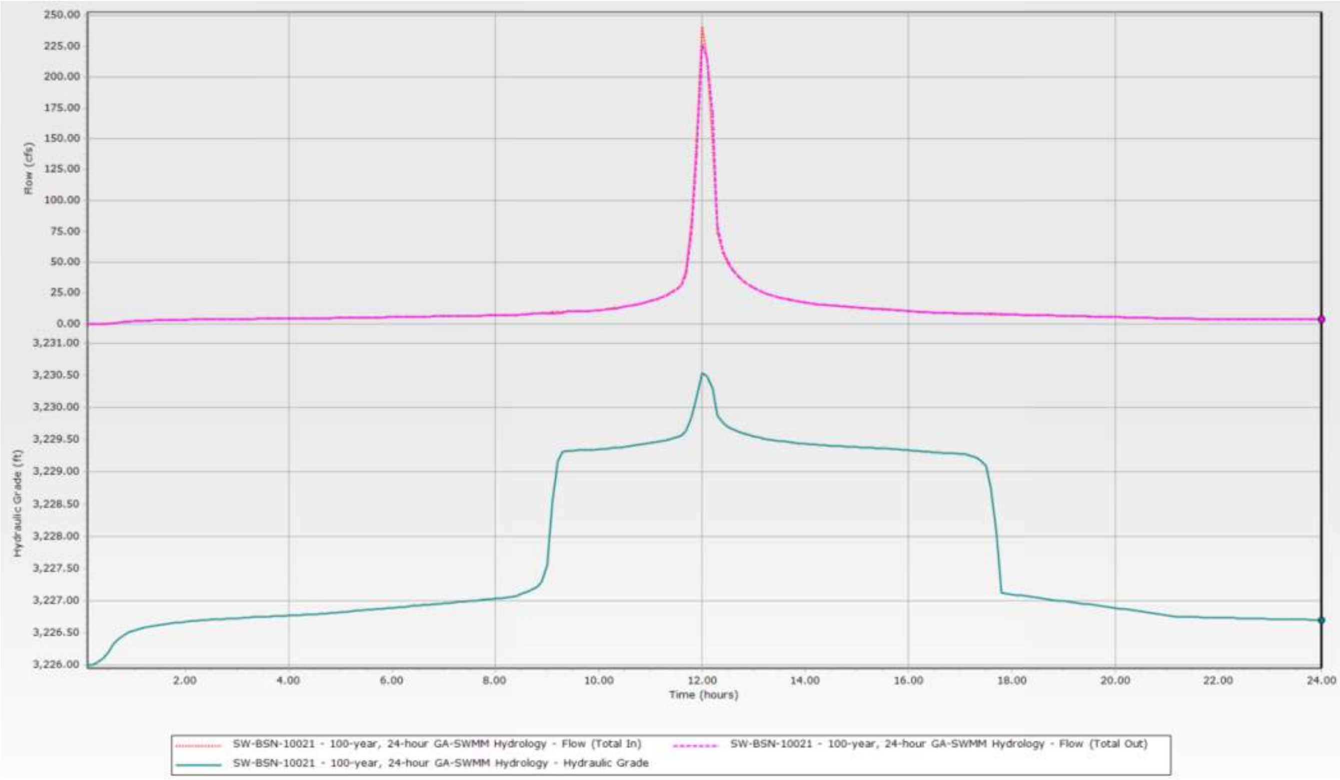

Figure 2-5. Cutthroat Corner Pond 100-year Routing Results

2.5.4. Pattee Creek and Moose Can Gully Priority Outfalls

Pattee Creek and Moose Can Gully receive flow from several priority outfalls. Select peak flows and volumes are detailed for these outfalls in Table 2-8 and Table 2-9, respectively. The Pattee Creek priority outfalls overlap with areas where results are discussed in more detail, as the Table 2-8 clarifies

Table 2-8. Pattee Creek Priority Outfalls

Outfall	100-year Peak Flow (cfs)	2-year Peak Flow (cfs)	Water Quality Volume (ac-ft)	Notes
SW-DC-10059	See Takima Park Results			
SW-DC-10016	11.4	5.12	0.13	Discharges to Takima below SW-DC-10059
SW-DC-10060/ SW-DC-10049	39.1	17.5	1.07	Discharges to Takima below SW-DC-10059; Outfalls take flow drainage areas that are merged in model
SW-DC-10100	7.16	3.22	0.070	
SW-DC-10099	35.4	25.6	1.01	* Part of Cutthroat Corner inflows

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Table 2-9. Moose Can Gully Priority Outfalls

Outfall	100-year Peak Flow (cfs)	2-year Peak Flow (cfs)	Water Quality Volume (ac-ft)
SW-DC-10105	0.92	0.64	0.080
SW-DC-10106	11.0	1.96	0.53
SW-DC-10104	35.2	16.2	0.41
SW-DC-10107	14.1	6.36	0.17
SW-DC-10006	6.90	6.90	1.46
SW-DC-10014	3.98	1.53	0.085
SW-DC-10009	13.2	5.67	0.17
SW-DC-10011	1.20	0.51	0.016
SW-DC-10008	1.44	0.64	0.021

2.5.5. High Park Drainage

The High Park Drainage, running parallel to High Park Way, faces problems with bank erosion and subsequent deposition. The drainage channel will be the subject of further study as discussed in TM-3. The channel crosses several residential streets with culverts between Whitaker Drive and Simons Drive. Downstream of Simons Drive, this channel receives tributary flows from just over 350 acres that is largely undeveloped. The runoff from this drainage area is attenuated by detention storage upgradient of Simons Drive. Peak flows are various locations along the main drainage are shown in Table 2-10. As indicated by the discrepancy in flows upgradient and downgradient of the crossings of Rimrock Way and Simons Drive, several of the culvert crossings appear to be undersized for even a 10-year flow. As indicated by the difference in the flow at the top of the drainage, below Whitaker Drive, and the flow below Simons Drive, this is a problem that persists across most of the crossings in this drainage. In smaller events, ponding above the existing beehive-type inlets provides enough storage and attenuation to manage the flows, but larger events would likely lead to road overtopping. Resolving the erosion and conveyance capacity issues will require a solution that considers and addresses both issues together.

Table 2-10. High Park Drainage Peak Flows

Location	Model Element	2-year Event (cfs)	10-year Event (cfs)	100-year Event (cfs)
Below Whitaker Drive	CS-558	22.5	27.8	39.1
Upgradient of Rimrock Way	SW-INL-10443	23.7	29.8	41.8
Downgradient of Rimrock Way	CS-561	27.0	30.3	30.3
Upgradient of Simons Drive	SW-INL-10392	10.7	10.8	11.3
Downgradient of Simons Drive	CS-566	7.1	7.3	7.4
Pipe Inlet Upgradient of High Park Way	CB-23	28.5	44.9	50.6

2.5.6. West Artemos Drive Drainage

A small open channel drains down a steep slope from West Artemos Drive and terminates to an open slope behind 509 SW Higgins Avenue, resulting in nuisance flooding. The channel appears to drain a 6.2-acre catchment bounded by Whitaker Drive, West Crestline Drive, West Artemos Drive, and a topographic divide to the west. The predicted peak flows from this drainage are shown in Table 2-11. Make a more defined connection between this drainage and the storm drainage inlets on SW Higgins Avenue could likely resolve this issue without causing capacity issues in the Higgins Avenue system.

Table 2-11. Artemos Drive Drainage Peak Flows

Storm Return Period	Peak Flow (cfs)
2-year	3.9
10-year	5.7
100-year	8.8

2.5.7. Bitterroot Outfall

The stormwater system for the entire model area drains to an outfall to the Bitterroot River west of Miller Creek Road. The outflow hydrographs for the 2-, 10-, and 100-year storms are shown in Figure 2-6 and Table 2-12, respectively. The outflow of the storm drainage system at the Bitterroot River was also analyzed as part of the SID 524 design report. The SID 524 modeling estimated 194 cfs for the 100-year event, which compares well with our results of 176 cfs.

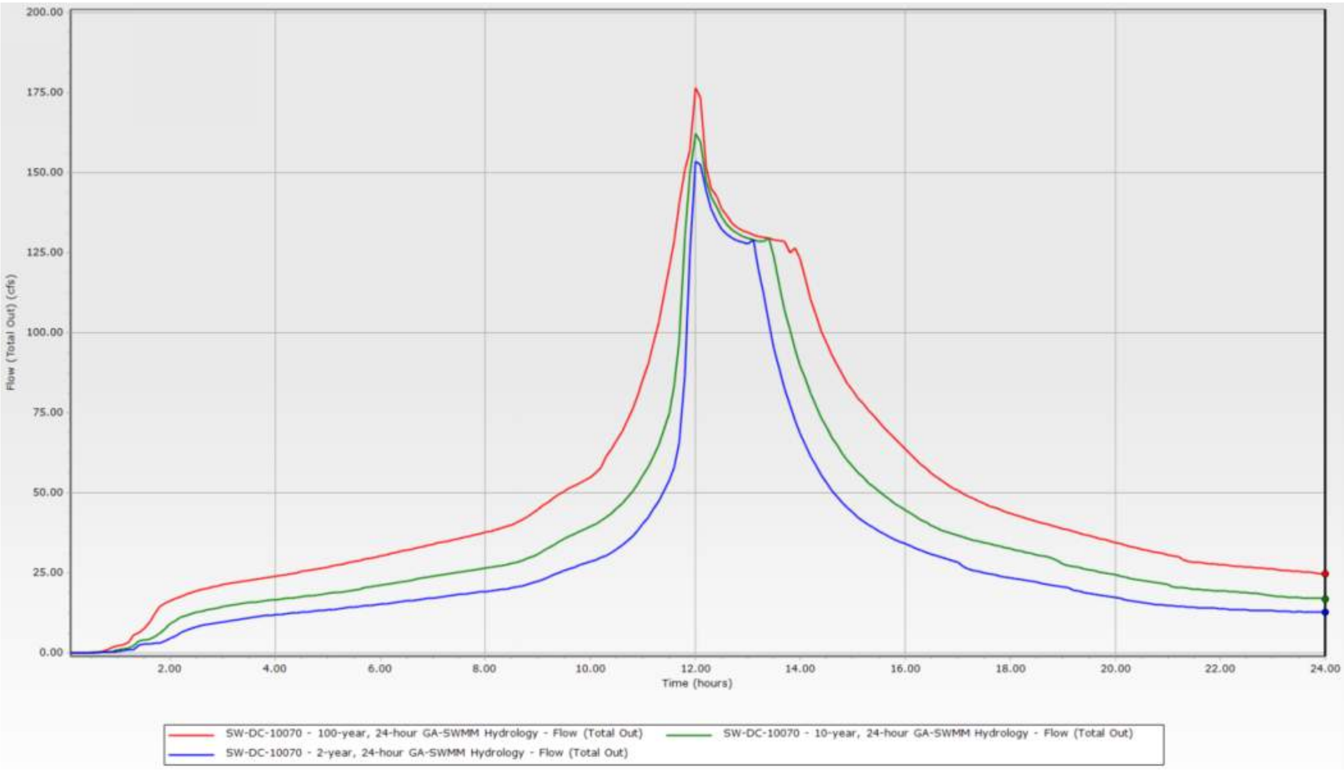

Figure 2-6. Bitterroot Outfall Outflow Hydrographs

Table 2-12. Bitterroot Outfall Peak Flows and Flow Volumes

Storm Return Period	Peak Flow (cfs)	Outflow Volume (ac-ft)
2-year	154	58.7
10-year	162	74.9
100-year	176	98.7

The peak flows at the Bitterroot outfall between the three different return period events are more closely grouped than might be expected. Given the differences in runoff generated by individual catchment, this appears to be largely driven by attenuation provided by detention basins at Cutthroat Corner, Playfair/Spartan Park, Bancroft Park, and Cattail Corner.

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CHAPTER 3 CAPITAL IMPROVEMENTS PLAN

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City of Missoula
Comprehensive Stormwater Quality Plan

CHAPTER 3 CAPITAL IMPROVEMENTS PLAN

3.1. BACKGROUND

The City of Missoula Stormwater Utility aims to be proactive with preventative maintenance and repairs to stormwater infrastructure. This approach to stormwater management will decrease the likelihood of infrastructure failure events. In addition to regular maintenance and cleanout of stormwater facilities, capital improvements projects are important to address aging infrastructure and install new infrastructure as needed to improve water quality, increase system capacity due to development and climate change, and secure public health and safety by preventing a failure scenario. This capital improvements plan provides the City of Missoula with a strategy for implementation of ten priority improvements that address a wide range of deficiencies. The main focus is on improvements to failing infrastructure and water quality at priority outfalls.

The ten projects analyzed throughout this chapter were selected by the City of Missoula Stormwater Utility and Public Works Department based on known priorities. Some projects were updated from the previous analysis completed in the City of Missoula Storm Water Facility and Operation Plan (2018) or currently pending grant funding applications. Several projects are new additions to this update of the Capital Improvements Plan (CIP) and conceptual level solutions were developed as a part of this planning effort. The capital improvements plan includes ten projects, each of which include a concept-level solution and cost estimate and are ranked for implementation priority based on several criteria. This chapter summarizes the framework of the priority ranking, outlines the criteria and basis of scoring, and describes the proposed solution for each project.

Stormwater treatment facilities and surface water outfall projects are the focus of the CIP In addition to these larger infrastructure features, the City Stormwater Utility also maintains and manages thousands of drywells that infiltrate stormwater that is eventually received by the Missoula Valley Aquifer. Because of the large inventory of drywells, the City does not currently have enough resources to maintain each structure on a regular basis. As part of this effort, a tool was developed to assist the City in ranking and prioritizing drywell maintenance, repair, and replacement. The purpose of the tool is to provide a basis for comparing drywells and justifying the prioritization of one over another.

This chapter will begin with discussion of the drywell ranking tool. Next, the framework for the CIP will be described, including an explanation of the scoring process, details on each criterion, and how the criterion are weighted and scored to provide a final prioritization score. For each of the ten projects, a description of the project need, conceptual solution, an estimated cost, and overall ranking score are presented. The results are summarized in a 10-year implementation plan.

3.2. DRYWELL RANKING TOOL

The City of Missoula manages over 5,000 drywells that infiltrate stormwater. Drywells make up the largest quantity of stormwater infrastructure due to the underlying soil characteristics and ability to infiltrate at a high rate. Because of the large number of drywells and the resources needed to perform maintenance, such as vacuuming equipment and maintenance technicians, the City aims to inspect each structure once every 5 years and perform maintenance as needed.

To assist the City in organizing, assessing, and prioritizing drywell maintenance and rehabilitation, a ranking tool was developed in conjunction with this capital improvement plan effort. The tool provides an objective approach to assessing each drywell. The framework of the ranking tool includes a set of criteria that can be weighted and scored to prioritize replacement or maintenance of the structure. The tool is in the form of and Excel spreadsheet and requires manual input and scoring by City Stormwater Utility staff.

The tool's framework was developed in collaboration with the City to accommodate the source and availability of input data needed to complete the scoring process. A main source of data anticipated for use in the scoring tool is the stormwater management crowdsourcing form that collects reports of drainage and infrastructure issues from the public. The City also uses this form to enter complaints and log requests in relation to drywell and drainage issues.

3.2.1. Sheet 1: Scoring Guide

The ranking tool spreadsheet has two sheets. The first sheet is a scoring guide that provide more detail on how each criterion should be evaluated and a numeric score from 1 to 3 assigned to each drywell. The columns on the scoring guide include the criteria name, ranking weight, and description of how to determine a score of 1, 2, or 3 based on data gathered by the user. The description column provides further insight to consider when assigning a score, and the resource column provides a link to applicable data sources.

The criteria are organized into categories: City of Missoula Lenses, Frequency, Site Suitability, and Severity. These categories are further summarized below.

The City of Missoula **Lens** categories consider Climate Resiliency, Equity, and Housing, which are the three decision "lenses" that the City looks through to direct implementation of the their goals, each with an associated resolution. Each of the lenses is an important consideration; however, only the equity criterion is numerically scored. This distinction is due to the availability of objective data for the of comparison which is the main objective of this tool.

The **Frequency** category includes criteria of storm depth during a complaint or failure event, concentration of complaints, and infrastructure condition. These criteria are assumed to give insight on how often the structure is failing. If a structure score high in all criteria under the frequency category, it is estimated that the solution that should be prioritized is maintenance to restore function of the structure.

The **Site Suitability** category includes criteria of soil classification, groundwater separation, siting, and utility conflicts. If a structure scores high in all criteria under the site suitability category, it is anticipated that it may be beneficial to consider other stormwater management options for this site. For example, if it appears the drywell is failing due to high groundwater or poorly draining soils, it may not be an effective solution to replace or maintain this structure.

The **Severity** category includes criteria of location, impacts, CIP projects, and standards. If a structure scores high in this category, is anticipated that a total rehabilitation or replacement may be most effective. For example, if a drywell is located in a location that it would not currently be approved for installation, such as in a bike lane, the City may want to consider a replacement project at this location that would move the drywell location. These anticipated solutions will show up as a warning flag in the scoring summary, reminding the user to consider these solutions. These assumed solutions are suggestions based on a possible cause of drywell failure. The actions are suggestions only and each structure should be further evaluated to consider the cause of failure and most appropriate solution.

The criteria and scoring methodologies were collaboratively developed with the City of Missoula Stormwater team. The final deliverable of the drywell ranking tool is a complete tool that can be used as is, but also should be customized by the City as needed to best fit their needs. As it is used for different scenarios, the criteria and scoring should be modified to best serve the City's goal of comparing and prioritizing infrastructure improvements.

3.2.2. Sheet 2: Data Log

The data log sheet is where the user will manually enter information about the structure and score. Each row of the data log should represent an individual drywell. The first set of columns includes data regarding a specific complaint/drainage issue. The second set of columns for scoring includes two columns for each criterion. The first column is to record a short justification for the score, and the second column is to record the score of 1-3. The weighting factor for each criterion can be changed here and is automatically factored into the final score.

The Results columns are the sum of the scores, divided into the three categories that are each associated with a potential solution. An exclamation next to the score indicated a high score in each of the criterion in that category. This warning mark is to remind the user to consider the specific suggestions of prioritizing maintenance, other stormwater management options, or rehabilitation/replacement for a potential solution.

The Total Score column is the summed and weighted score for each criterion that received a score. The Potential Max Score column is the summed and weighted score that is the maximum value for that row. This value only considered the criterion that have a score value. If a criterion score cell is left blank, it is not included in the maximum potential score. The purpose of excluding unscored categories is to prevent a drywell from being ranked uncharacteristically low due to a lack of sufficient information to justify a score. The Weighted Score column is ratio of total score to maximum score and allows for comparison of all drywells on the same numerical spectrum. The highest weighted score is a 100, which means the drywell scored a 3 in every criterion that was scored.

With this tool, the City can log known drainage issues and prioritize maintenance for drywells. The tool also highlights a potential alternative solution for the user to consider. A PDF of each tab of the drywell ranking tool is included in Appendix 3-A.

3.3. CAPITAL IMPROVEMENTS PLAN

A Capital Improvements Plan (CIP) is a resource and budgeting tool that documents needs and identifies projects with associated costs, prioritization, and funding sources. The CIP developed in this chapter of the Comprehensive Stormwater Quality Plan will aid the City Stormwater Utility in planning for future project implementation. The results of this CIP include a prioritized list and implementation plan for 10 capital projects that focus on stormwater infrastructure and water quality. The projects included in this analysis were chosen by the City of Missoula Stormwater Utility and Public Works Department. Some projects were updated from the previous CIP analysis in the City of Missoula Storm Water Facility and Operation Plan (2018) or currently pending grant funding applications. Several projects are new additions to the City's implementation plan and conceptual level solutions were developed as a part of this planning effort. The projects address a wide-range of deficiencies, but focus on improvements to failing infrastructure and water quality at priority outfalls.

Each of the ten identified projects are analyzed in this chapter, resulting in a description of the existing conditions and project need, proposed project recommendations, concept level solution exhibit, and estimated cost for implementation. The proposed project recommendations and cost estimates are for cursory budgeting purposes only. More detailed recommendations and estimates of probable cost of each project can only be developed through a more detailed design process when the project extents and specific components are better defined.

The projects were then ranked based on highest priority for implementation. This ranking is determined based on an assigned numerical score associated with several criteria, such as water quality benefits, public health and safety, and others as further described in this chapter. Information was gathered and organized for each project to provide a basis for ranking the project

The intent of this CIP is to provide a tool for the City to plan financial and maintenance budgets for the Storm Water Utility. The final draft of this CIP will be reviewed and approved by City staff. It should be noted that the CIP is always subject to change as priorities, budget, and infrastructure needs change.

3.4. RANKING CRITERIA

Six criteria and associated weighting factors were developed to rank and prioritize the ten proposed CIP projects. The criteria used to score and rank projects were determined in collaboration with the City. The rankings result in a prioritized schedule of stormwater capital improvements projects, helping the City to more effectively allocate resources to projects that most closely align with the goals and objectives of the stormwater utility.

A list of the ranking criteria and associated weighting factors are found in Table 3-1. All ten projects were analyzed in accordance with each criterion and were assigned a raw score of 1 to 3. The raw scores were multiplied by the associated criterion weighting factor to get a weighted score. The weighted scores were summed to determine the final priority ranking score. Projects with the highest priority ranking score are ranked higher and preferred to those with low priority ranking scores.

Table 3-1: Ranking Criteria and Weighting

Criterion	Weighting Factor
Public Health and Safety Benefits	6
Water Quality Benefits	5
Operations and Maintenance Needs	4
Coordination with other Infrastructure Projects	3
Climate and Resilience	2
Equity	1

Each criterion and assigned weighting factor provide insight to the goals and objectives of the Stormwater Utility and their importance. As part of this Comprehensive Stormwater Quality Plan, this CIP provides a more specific approach than typical, due to the high weight of importance assigned to water quality benefits. Criteria descriptions are detailed below.

Public Health and Safety

This criterion assesses benefits to public health and safety provided by the project. The following scoring strategy was used to prioritize projects:

Score	Description
1	There are no existing threats to public health and safety. Infrastructure is in fair condition.
2	The project will mitigate risk to public health and safety by replacing aging infrastructure. No additional capacity will result from the project.
3	The project will mitigate risk to public health and safety by replacing aging and increasing system capacity.

Water Quality Benefits

This criterion assesses the surface and/or groundwater quality benefits provided by project features, in terms of pollutant loadings prevented or reduced. The following scoring strategy was used to prioritize projects:

Score	Description
1	The project does not include water quality features.
2	The project will provide localized water quality treatment.
3	The project will provide water quality treatment for a large area that discharges to surface or groundwater.

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Operations and Maintenance

This criterion assesses the existing operations and maintenance requirements at the project site and if the project will reduce maintenance cost and/or frequency. The following scoring strategy was used to prioritize projects:

Score	Description
1	The existing conditions do not require extensive operations and maintenance activities.
2	The project will moderately reduce operations and maintenance needs for the site.
3	The project will greatly reduce operations and maintenance needs for the site.

Coordination with other Infrastructure Projects

This criterion assesses the potential to combine the scope of work with other simultaneous projects in the area. The following scoring strategy was used to prioritize projects:

Score	Description
1	The project site is not anticipated to undergo future improvements projects that can be combined with a stormwater project.
2	The project site is anticipated to undergo minor improvements such as utility replacements or resurfacing. The project can be coordinated for cost savings.
3	The project site is anticipated to undergo complete redevelopment. The project can be coordinated for cost savings.

Climate and Resilience

This criterion is directly related to the Climate Action and Resiliency Implementation Resolution which is one of the three decision lenses the City of Missoula uses to guide implementation of strategic goals. The following scoring strategy was used to prioritize projects:

Score	Description
1	The project does not address climate resiliency by increasing capacity or incorporating green infrastructure.
2	The project increases system capacity but does not include green infrastructure or low impact development features.
3	The project increases system capacity and utilizes green infrastructure to improve climate change resiliency.

Equity

This criterion is directly related to Council Resolution 8659, which is dedicated to inclusivity and equity, and is one of the three decision lenses the City of Missoula uses to guide implementation of strategic goals. Disadvantaged community census tracts four disadvantaged census tracts are identified by the

Climate and Economic Justice Screening Tool. The following scoring strategy was used to prioritize projects:

Score	Description
1	Project is not located within a disadvantaged community.
2	Project is located within a disadvantaged community.
3	Project is located within a disadvantaged community and benefits a large portion of a watershed located within or discharging to a disadvantaged community.

3.5. PROJECTS

Ten projects were identified for consideration in collaboration with the City of Missoula staff. These projects include a mix of water quality improvements and infrastructure improvements. Two of the projects were previously identified in the City of Missoula Storm Water Facility and Operations Plan (2018) but had not been addressed yet. Several of the projects also concern City identified priority outfalls. These projects are summarized in Table 3-2, with the general parameters of each project.

Table 3-2: Capital Improvement Project Summary

CIP Rank	Project	2018 CIP	Priority Outfall	Water Quality Improvements	Infrastructure Improvements
1	High Park Drainage System Improvements	X			X
2a	Whippoorwill Drive Outfall Improvements		*	X	X
2b	Clark Fork Outfall Water Quality Improvements		X	X	X
4	Grant Creek Levee Maintenance	X			X
5a	Fox Site/Orange Street Outfall Repair		X		X
5b	Reserve Street Outfall Stormwater Treatment		*	X	X
7	Bess Reed Park Stormwater Treatment		X	X	X
8	Lincoln Hills and Lincolnwood Drainage Study		X		
9a	Missoula Public Library Living Roof			X	X
9b	Majestic Drive Drainage Plan				
* = these outfalls are to impaired water bodies but are owned by MDT and therefore not priority outfalls under the City's MS4.					

These projects were ranked according to the criteria and weighting factors described above to yield the overall scores and rankings shown in Table 3-B-1 of Appendix 3-B. The projects are described in detail below.

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3.5.1. High Park Drainage System Improvements

Description

The High Park Drainage System Improvements project includes improvements to four distinct areas in the South Hills area. This capital improvement project is updated from the City of Missoula Stormwater Facility and Operations Plan (2018). The 2018 planning document includes infrastructure improvements in three separate areas lacking adequate stormwater infrastructure and improvements to the natural drainage parallelling High Park Way, which will be the subject of separate planning efforts funded by the Montana Coal Endowment Program (MCEP). The proposed project will address known issues related to storm water infrastructure and assess whether other improvements are necessary.

Project Need

The project includes four areas in need of improvement related to stormwater conveyance and erosion. The first area experiences erosion at an intersection of an unpaved and paved road. The second area experiences on-going issues with probable spring water resulting in asphalt failure. The third area lacks adequate conveyance of stormwater near the end of a pavement section. A fourth area has several areas that experience issues with road overtopping and channel erosion. Further study at this location is required to effectively determine a solution.

Site Specific Information

Area 1: The first infrastructure project is located at the intersection of Rimel Road/Dean Stone Drive and Whitaker Drive, which is experiencing erosion of the asphalt pavement and other areas. Stormwater runoff is directed down the hill onto Dean Stone Drive and flows to this intersection where it is then dispersed onto Whitaker Drive and Rimel Road. The City is currently using rubber stops to direct water down Rimel Road into a drainage ditch that continues along the road and down the hill. The latitude and longitude are 46°49’12”N and 114°0’12”W.

Area 2: The second infrastructure project is located at the intersection of Mansion Heights Drive and Spanish Peaks Drive, which is experiencing pavement failure and typically displays moisture. The pavement failure is likely attributed to the constant exposure to moisture. It has been noted by City staff that the appearance of water at this location is not seasonal but is found year-round. Water in this area is likely a result of a spring. The latitude and longitude are 46°49’31”N and 113°59’58”W.

Area 3: This infrastructure improvement is located at the intersection of Ben Hogan Drive and Highland Park Drive, which lacks adequate conveyance of runoff. The pavement ends approximately 120 feet past the intersection considered the end of Ben Hogan Drive. Direction of water past the intersection increases the probability of runoff ending up on adjacent residents’ property. Topography at the intersection is unfavorable for shifting the flow of water down Highland Park Drive and damage to the residence to the northeast of the intersection is possible. The latitude and longitude are 46°49’46”N and 113°59’39”W.

Area 4: This area is located along a natural drainage channel that runs parallel to the High Park Way. Where the drainage crosses Simons Drive, it has historically displayed issues with the flow of stormwater runoff crossing Simons Drive. Runoff is directed into this drainage system from the east of Whitaker Drive. This system consists of a series of open channels, inlets, and pipes to convey water through the residential area. The City has installed beehive grates at several locations in the drainage including: south of Simons, north of Continental Way, and north of Rimrock Way. Additionally, makeshift check structures have been installed by area residents indicating ongoing issues with the conveyance of runoff. Morrison-Maierle conducted site visits in 2023 and 2024 to assess the drainage. During these visits, significant erosion and sedimentation were documented. A Preliminary Engineering Report (PER) of this drainage is required to assess the adequacy of the system and the potential need for additional improvements. The PER would also consider water usage on the drainage as it appears many homes are pumping surface water from the drainage.

Figure 3-1. Beehive inlet structure being installed along Rimrock Way, 2023.

Figure 3-2. Previously installed beehive inlet structure along Continental Way, 2023.

Proposed Project Recommendations

The proposed project recommendations differ by areas, as detailed below.

Area 1: At the current location of the rubber stops, the intersection will be re-graded to preclude drainage onto Whitaker and a buried perforated drain pipe will be constructed to better direct flow into the drainage ditch along Rimel Road. A retaining wall on the downhill side will be needed to facilitate grading and provide adequate cover over the perforated drain pipe. This infrastructure will prevent storm drainage from inundating the intersection of Rimel Road and Whitaker Drive.

Area 2: To mitigate the apparent effects of the spring, the pavement will be excavated and a perforated drain pipe will be buried and routed to a catch basin. The catch basin outflow will then be routed to the detention basin downhill of Spanish Peaks Drive. The affected asphalt will be restored to a new condition.

Area 3: The continuation of Ben Hogan Drive past the intersection with Highland Park Drive will be paved, curb and gutter extended, four inlets added to capture runoff, and drainage pipe installed to convey runoff from the inlets to the natural drainage northeast of the intersection.

Area 4: A PER will be completed to address the entire drainage paralleling High Park Drive that runs from Whitaker Drive to Simons Drive, as well as the tributary to the south that meets it downgradient of Simons Drive, to determine any deficiencies with the drainage and any potential improvements that need to be implemented. The City recently received a Montana Coal Endowment Program grant to complete the PER, but the PER is not complete and therefore further recommendations for improvements are not yet available. Recommendations are likely to include replacing, upsizing, or rehabilitating existing culverts; installing measures to stabilize banks and channel bottoms, including revetments, grade control structures, root wads, and/or new plantings; and managing sediment inputs from street inlets and outputs required as regular maintenance.

Estimated Capacity and Cost

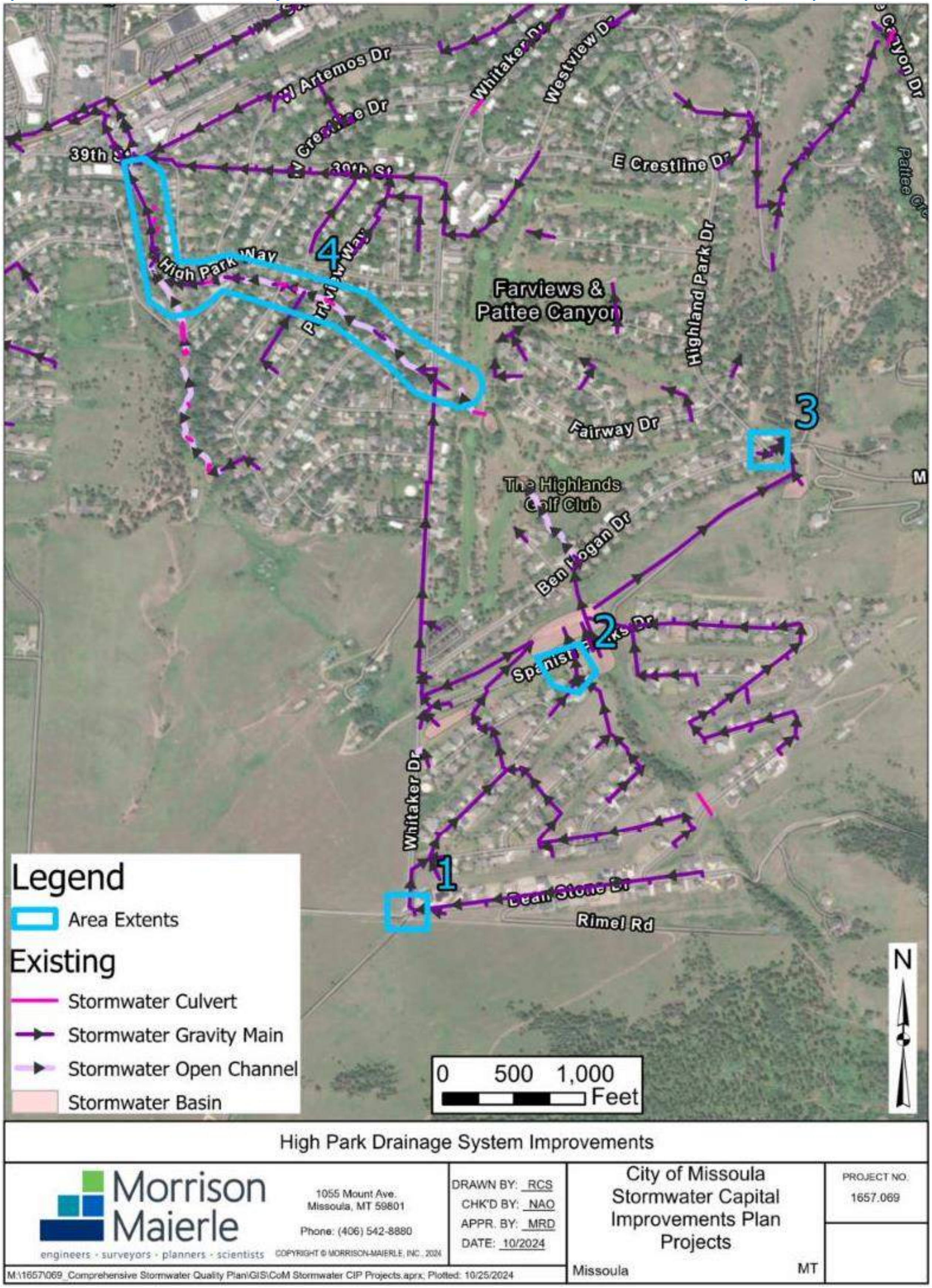
The project scopes for Areas 1, 2, and 3 were sourced from the City of Missoula Stormwater Facility and Operations Plan (2018) and unit prices were updated to reflect best estimates of current prices. Professional services for Area 4 are current and under contract. The cost is estimated to be $755,000 for the three areas of improvement and the Area 4 Preliminary Engineering Report. A detailed cost estimate is provided in Appendix 3-C.

Project Score

The proposed concept received a score of 53 and an overall rank of first. Table 3-3 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B.

Table 3-3. High Park Drainage System Improvement Ranking

Criterion	Weighting Factor	Score	Weighted Score
Public Health and Safety	6	3	18
Water Quality Benefits	5	3	15
Operations and Maintenance	4	3	12
Coordination with other Infrastructure Projects	3	1	3
Climate and Resilience	2	2	4
Equity	1	1	1
		Total Ranking Score	**53**


W Artemos Dr
W Crestline Dr
39th St
Whitaker Dr
Westview Dr
E Crestline Dr
High Park Way
Parkview Way
4
Farviews &
Pattee Canyon
Highland Park Dr
Fairway Dr
3
The Highlands
Golf Club
Ben Hogan Dr
2
Whitaker Dr
1
Dean Stone Dr
Rimel Rd
Legend
Area Extents
Existing
Stormwater Culvert
Stormwater Gravity Main
Stormwater Open Channel
Stormwater Basin
0 500 1,000
Feet
N
High Park Drainage System Improvements
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APPR. BY: MRD
DATE: 10/2024
City of Missoula
Stormwater Capital
Improvements Plan
Projects
Missoula MT
PROJECT NO.
1657.069
M:\1657\069_Comprehensive Stormwater Quality Plan\GIS\CoM Stormwater CIP Projects.aprx; Plotted: 10/25/2024

Figure 3-3

3.5.2. Whippoorwill Drive Outfall Improvements

Description

This stormwater outfall (SW-DC-10061) discharges to Grant Creek south of the intersection of Whippoorwill Drive and West Broadway Street. It is owned and maintained by Montana Department of Transportation (MDT). According to the City stormwater GIS database, this outfall receives runoff from over 100 inlets throughout the Grant Creek industrial area, collecting runoff from approximately 520 acres of watershed. The dominant land use is light industrial.

Project Need

The area around the outfall experiences significant erosion and head-cutting of the outfall channel due to stormwater discharge velocities and lack of stabilization in the receiving channel. Sections of the outfall pipe have been removed as the ground around it has eroded away. MDT has placed riprap around and downgradient of the outfall pipe to temporarily stabilize the area.

A re-alignment of Grant Creek is slated to occur in 2025. During preliminary design, engineers of record HDR and DJ&A analyzed two alternatives to convey runoff from this outfall to the new Grant Creek alignment. These alternatives explored ways to convey runoff from the existing outfall location to the new Grant Creek alignment by routing through the MDT right-of way by either a 48-inch reinforced concrete pipe (RCP) storm drain or an open channel. Neither of these alternatives were considered for implementation due to the costs and constraints for future development in the area. The project will temporarily address stormwater at this outfall by utilizing the abandoned creek channel for storage and

Figure 3-5: Erosion near the Whippoorwill outfall, 2024

Figure 3-4: Erosion and installed riprap near the Whippoorwill outfall, 2024.

conveyance. The preference of the City is to install a new storm main in conjunction with a future subdivision so that it can follow the roads within the future subdivision.

The long-term solution as preferred by the City includes a piped conveyance through the roads of the future development, which will serve as a stormwater main that the developer can connect to. This main will discharge to a storage and/or water quality facility located in the 100-foot-wide riparian corridor upgradient of a new outfall to the relocated Grant Creek. This will require negotiation with MDT for the city to take over ownership or maintenance of the existing stormwater mains that discharge to the Whippoorwill outfall.

Proposed Project Recommendations

The proposed concept includes a new stormwater main that will be installed in coordination with future development. The stormwater main will capture runoff from the existing Whippoorwill outfall and runoff from the new development. The new pipe will be installed during construction of the new roads and allow connection from the future development.

The existing 42-inch RCP culvert under West Broadway that serves as the Whippoorwill outfall has a design capacity of about 100 cubic feet per second (cfs) based on survey data noted in the Grant Creek Realignment construction drawings. This design capacity flow rate is calculated with elevation data and diameter using the Manning's Equation only and does not account for hydrology or detention present in the contributing watershed. A high-level Storm and Sanitary Analysis (SSA) model was created to calculate assumed runoff from the new development utilizing the Natural Resource Conservation Service Technical Release 55 (TR-55) methodology (NRCS, 1986). In addition to the peak flow of 100 cfs from the catchment area north of West Broadway, the future development area, approximately 40 acres, is estimated to contribute another 50 cfs during a 10-year event. The proposed stormwater main, sized for 150 cfs capacity, is estimated to be a minimum of 48-ich RCP storm drain at a standardized assigned slope of 1%. The proposed stormwater main will be located and constructed with the new roads for the development and discharge to a new outfall on the new alignment of Grant Creek. This preliminary pipe size should be refined based on further evaluation of the hydrology, stormwater conveyance, and detention present in the upstream catchment area.

This concept assumes that the upper catchment north of West Broadway provides adequate stormwater BMPs for most of that drainage. It appears that 457 acres, or 83% of the upgradient drainage area, is routed through some sort of stormwater detention or water quality treatment basin. The middle 97 acres appears to be conveyed directly to the outfall, with some localized BMPs. Further study should confirm the intended function of the upgradient stormwater basins and the biofiltration swale should be designed to handle pollutant loading from the additional 97 acres. An additional detention basin may be needed downstream of Whippoorwill Drive if the swale cannot handle the additional loading. If water quality treatment and/or detention is necessary for the offsite catchment area that contributes to this site, the designer and developer may want to consider options to treat the water quality event for the entire contributing area.

A new flow splitting structure installed just upstream of the new Grant Creek outfall will divert the water quality event to a biofiltration swale and allow larger events to discharge directly to Grant Creek. The new stormwater treatment biofiltration swale will be implemented within the riparian buffer of Grant Creek and will be sized to handle the water quality flow from only the area of new development between the new Grant Creek and Whippoorwill Drive.. The new swale is estimated to be 1,200 linear feet with a 5-foot bottom width and 4:1 side slopes. At 0.5% slope and 2 feet of flow depth, the swale has a capacity of 100 cfs, which is anticipated to be well above the water quality flow rate coming from the new development. The biofiltration swale will include dense grass plantings and a pretreatment forebay to settle sediment. The swale will discharge back to Grant Creek.

The project concept developed in this chapter used preliminary development layouts provided by the City and developed by HDR and DJ&A during the Grant Creek Re-alignment project. Prior to implementation, the pipe size and location should be further developed in partnership with the City and the developer.

Estimated Capacity and Cost

The concept hydraulic analysis estimated the pipe size based on limitation of the upstream culvert under West Broadway. Based on this analysis and consideration of future development, the proposed new storm main described above has a capacity of about 150 cfs.

The biofiltration swale should be sized for the water quality flow event from the area of new development only at a minimum. It is anticipated that this rate will be less than the 10-year discharge of 50 cfs. The proposed dimensions of the swale currently allow for a capacity of 100 cfs. The bioswale design should be modified to accommodate treatment objectives and include a more detailed hydrologic assessment.

The total cost for install and materials estimated for this project is $2,009,800. This cost is for the stormwater features only and does not account for other elements of the development such as paving or infill of the existing storm drain along West Broadway. A conceptual cost estimate for the proposed project can be found in Appendix 3-C. This project will require funding agreements between the City, developer, and MDT.

Project Score

The proposed concept received a score of 45 and tied for an overall rank of 2 of 10 projects. Table 3-4 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B. Although the high ranking of this project will place it as a near-term priority for implementation, the timing of this project will be dictated based on the future development.

Table 3-4: Whippoorwill Drive Outfall Improvements Ranking

Criterion	Weighting Factor	Score	Weighted Score
Public Health and Safety	6	2	12
Water Quality Benefits	5	3	15
Operations and Maintenance	4	1	4
Coordination with other Infrastructure Projects	3	3	9
Climate and Resilience	2	2	4
Equity	1	1	1
		Total Ranking Score	**45**

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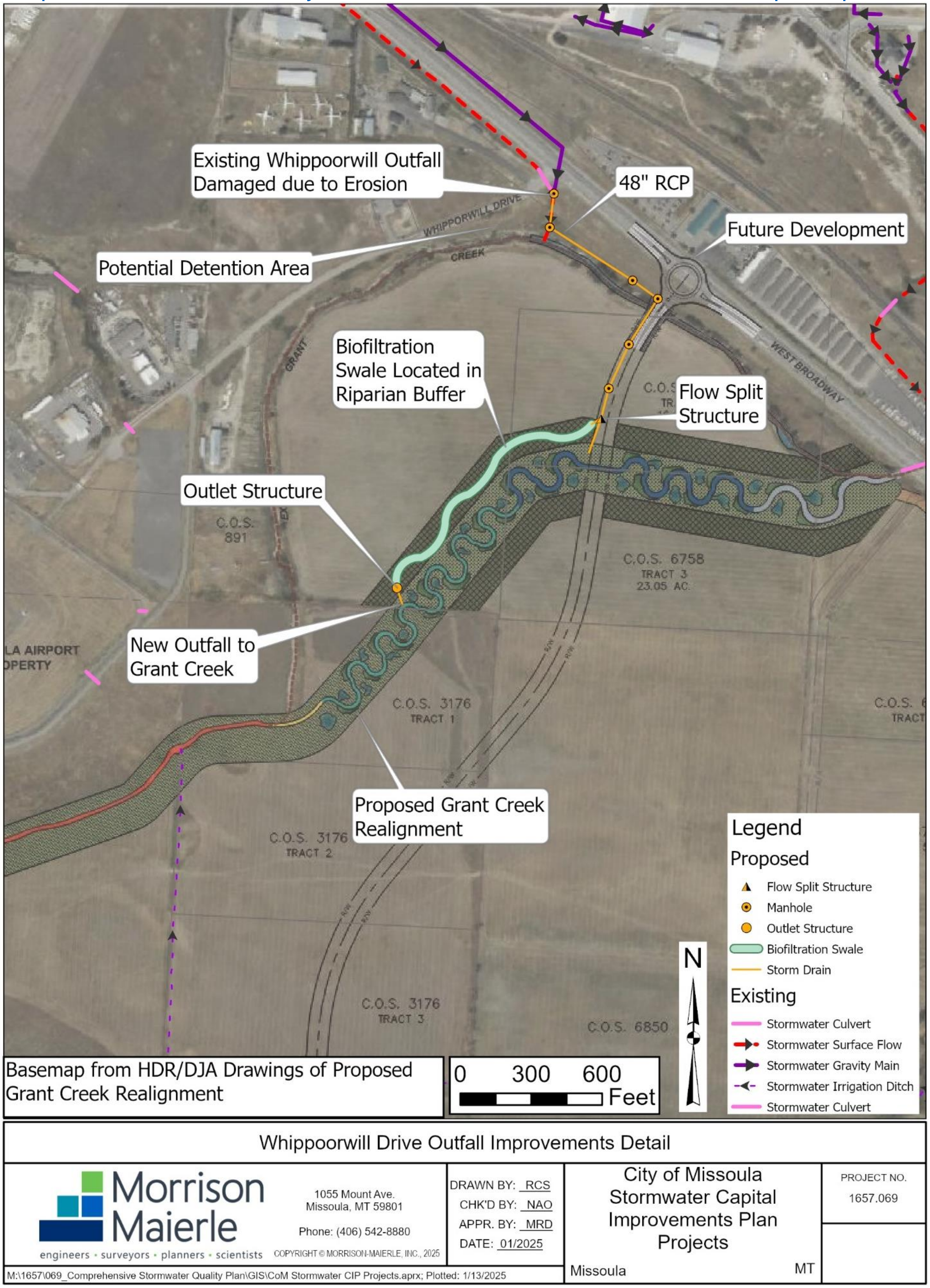
Existing Whippoorwill Outfall
Damaged due to Erosion
48" RCP
Future Development
Potential Detention Area
WHIPPOORWILL DRIVE
CREEK
GRANT
Biofiltration
Swale Located in
Riparian Buffer
Flow Split
Structure
WEST BROADWAY
Outlet Structure
C.O.S.
891
C.O.S. 6758
TRACT 3
23.05 AC.
New Outfall to
Grant Creek
LA AIRPORT
OPERTY
C.O.S. 3176
TRACT 1
Proposed Grant Creek
Realignment
C.O.S. 3176
TRACT 2
C.O.S. 3176
TRACT 3
C.O.S. 6850
Legend
Proposed
Flow Split Structure
Manhole
Outlet Structure
Biofiltration Swale
Storm Drain
Existing
Stormwater Culvert
Stormwater Surface Flow
Stormwater Gravity Main
Stormwater Irrigation Ditch
Stormwater Culvert
N
Basemap from HDR/DJA Drawings of Proposed
Grant Creek Realignment
0 300 600
Feet
Whippoorwill Drive Outfall Improvements Detail
Morrison
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Stormwater Capital
Improvements Plan
Projects
Missoula MT
PROJECT NO.
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Figure 3-6

3.5.3. South 4th Street Clark Fork Outfall Water Quality Improvements

Description

This stormwater outfall (SW-DC-10098) discharges to the Clark Fork River behind the former Missoulian building located at 500 S Higgins Ave and is the City's 9th highest priority outfall according to the City of Missoula 2023 Stormwater Management Plan. The outfall is 24-inch diameter reinforced concrete pipe. According to the City of Missoula stormwater GIS database, the outfall receives runoff through five inlets near the intersection of South Higgins Ave and 4th Street, collecting approximately 3.3 acres of watershed. The dominating land use in the collection area is urban city center.

Project Need

This stormwater outfall is high priority for the City to implement water quality treatment due to the urban land use and discharge to an impaired water body. Waste load allocations were monitored through the MS4 on this reach of the Clark Fork include copper and lead; however, TMDLs are also set for chlorophyll, iron, Total Nitrogen, and Total Phosphorus

The primary need for this site as identified by the City is a method of water quality treatment. Additionally, repairs to the outfall structure and conveyance system will need to be completed. The July 19th site visit revealed the outfall pipe and headwall are completely detached from the rest of the gravity main. It appears the headwall structure along the river was undermined, caused the connected headwall-pipe concrete structure to drop towards the riverbed, and separating it from the upgradient pipe.

Figure 3-8: Looking inside the damaged outfall structure. 2024.

Figure 3-7. Damaged outfall structure. 2024.

Proposed Project Recommendations

Due to the means of collection through five inlets and the redevelopment potential of the area, the recommended stormwater treatment includes retrofits at each inlet. The concept drawing is based on the proposed Higgins Corridor Master Plan. Stormwater bioretention basins are proposed with curb inlets to collect surface runoff. The bioretention basins will be allow for filtration through a mulch layer and amended soil material. A perforated drain will collect stormwater and discharge it to the existing storm main that outfalls to the Clark Fork. An overflow beehive grate will allow for infiltration or discharge to the outfall during large events. The bioretention planters are conceptually placed to allow 1-3 feet between the street and the edge of the basin to provide a clearance for safe maintenance.

The configuration and size of the bioretention basins should be modified to fit with the future development of the Higgins Corridor and Missoulian property. For conceptual planning, the basin size is estimated at 4 feet wide by 20 feet long. Basins will hold about 8 inches of mulch atop an amended soil comprised of loamy soil, sand, and compost. An aggregate filter layer comprised of sand and small gravel will prevent fines migration into the drainage aggregate below, which surrounds the perforated collection pipe. The basin bottom could be left open to allow infiltration to native subgrade or discharge to the Clark Fork through the existing storm system. Existing stormwater inlets will be converted to manholes that will tie into the bioretention basin drains. Curb openings will collect runoff from the intersection and allow flows into the basin. Curb cuts may include a grate to maintain pedestrian walkways. During final design, sediment collection via a small forebay should be considered. The forebay may include a check dam or retention area to encourage sedimentation and may include reinforcement at the entrance of the basin to prevent erosion due to flow velocities.

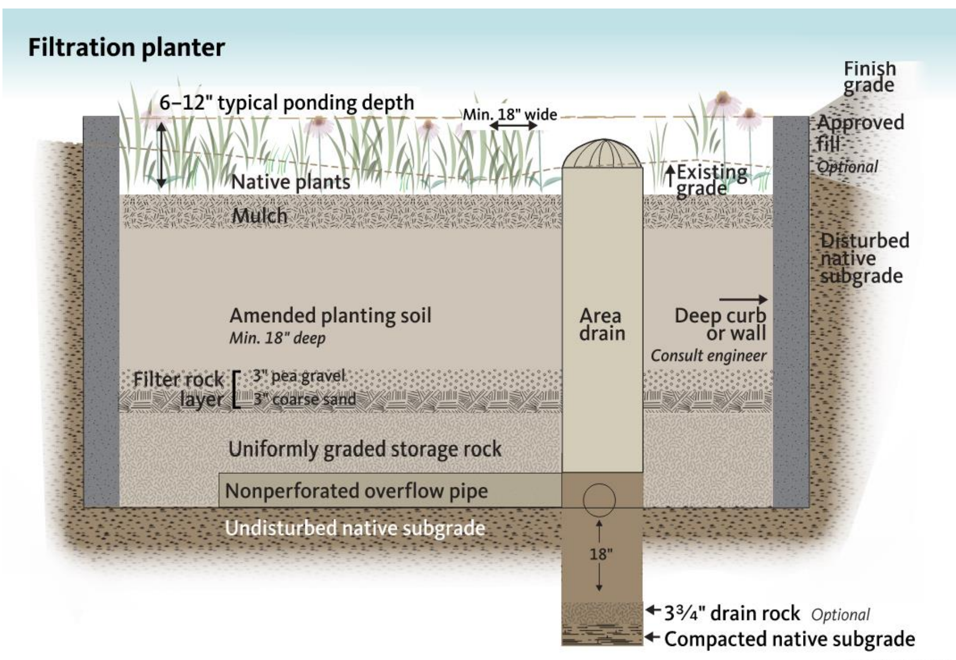

Figure 3-9. Filtration Planter Detail

In addition to bioretention planters, a bioretention area is proposed upgradient of the outfall. This bioretention area should be installed in collaboration and partnership with the future development of the Missoulian property. A new flow splitter will divert the water quality event to a depressed area to allow for infiltration. The area will be sized for the water quality volume not stored in the bioretention planters in addition to the volume generated from the Missoulian property.

Estimated Capacity and Cost

Bioretention facilities should be sized to retain the water quality volume in accordance with design guidance from the Montana Post Construction BMP Manual. The catchment area for this outfall is 3.3 acres and produces a runoff reduction volume of 5,200 cf.

The approximate retention volume for the proposed bioretention planters is 1,800 cubic feet, which is based on 8 planters of 4 feet by 20 feet dimensions with a 1-foot ponding depth, 25% void space in the soil media, and 40% void space in the drainage aggregate. Flows for larger events will enter the overflow drain and discharge directly to the outfall without filtration.

To treat the remaining 3,400 cubic feet of the water quality volume, the new offline 3,000 square foot bioretention area will be excavated approximately 3 feet to provide 6,000 cubic feet of storage at 2 feet ponding depth. This area will manage the remining water quality volume and additional volume from the Missoulian redevelopment. The bioretention area will include two feet of amended soil and vegetation plantings to promote filtration and treatment of stormwater. Due to the location of the proposed bioretention area on private land, a new easement and/or agreement with the developer may be necessary. The former Missoula building is slated for redevelopment.

The total cost for install and materials estimated for this project is $731,200. This cost is for the stormwater features only and does not account for other elements of the development such as paving or infill of the existing storm drain along South Higgins Ave and South 4th Street. There is potential for this project to be partially funded by private development. A detailed cost estimate is provided in Appendix 3-C.

Project Score

The proposed concept received a score of 45 and tied for an overall rank of second. Table 3-5 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B.

Table 3-5. South 4th Street Clark Fork Outfall Water Quality Improvements Ranking

Criterion	Weighting Factor	Score	Weighted Score
Magnitude of Impact	6	2	12
Operations and Maintenance Needs	5	3	15
Coordination with other Infrastructure Projects	4	1	4
Climate and Resilience	3	3	9
Equity	2	2	4
Age/Condition	1	1	1
		Total Ranking Score	**45**

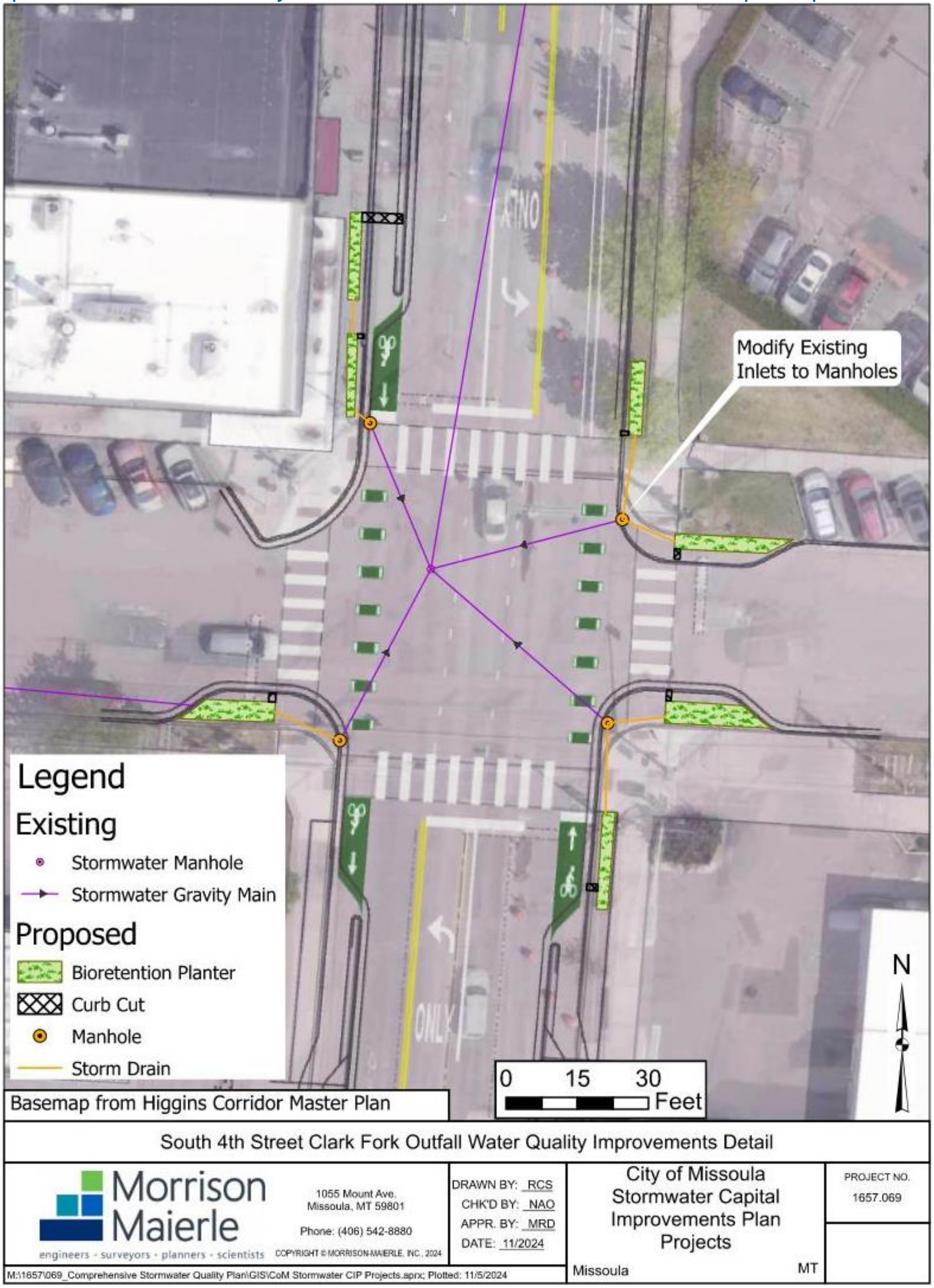
Modify Existing
Inlets to Manholes
Legend
Existing
Stormwater Manhole
Stormwater Gravity Main
Proposed
Bioretention Planter
Curb Cut
Manhole
Storm Drain
Basemap from Higgins Corridor Master Plan
0 15 30
Feet
N
South 4th Street Clark Fork Outfall Water Quality Improvements Detail
Morrison
Maierle
engineers - surveyors - planners - scientists
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Figure 3-10


Proposed Manhole
Outlet Structure
Flow Split Structure
3,000 SF Bioretention Wetland
S Higgins Ave
S Higgins Ave
S Higgins Ave
The Missoulian
The Babs
Bridge Pizza
Mellow Mood
Legend
Proposed
Storm Drain
Flow Split Structure
Manhole
Outlet Structure
Bioretention Planter
Bioretention Wetland
Curb Cut
Existing
Stormwater Gravity Main
Stormwater Manhole
Stormwater Discharge Point
0
50
100
Feet
N
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Figure 3-11

3.5.4. Grant Creek Levee Maintenance

Description

The Grant Creek Levee is located approximately 0.3 miles north of the North Reserve Street/Grant Creek Road exit. The levee is operated and maintained by the City of Missoula. It is also subject to regulation by the US Army Corps of Engineers (USACE). It protects the Rocky Mountain Elk Foundation, as well as business and residences along Stonebridge Road and Expo Parkway. According to USACE Inspection Reports, the levee is approximately 3,100 feet in length, has an average height of 4 feet, and is located approximately 200 feet to the west of Grant Creek Road. The levee is 12 feet in top width with 2-3H:1V side slopes. USACE Seattle District performs a levee inspection every two years. In 2016, it was determined that this levee was "minimally acceptable" and required attention. Recommendations provided to the City of Missoula by USACE included the removal of cottonwood trees and reduction of vegetation within the levee prism. This capital improvement project was sourced and updated from the City of Missoula Stormwater Facility and Operations Plan (2018).

Project Need

A dense population of cottonwood trees and vegetation lines the main channel of Grant Creek. According to inspection reports by USACE (December 14, 2016), the density of vegetation increases the risk of levee failure and flooding that could occur, especially during higher flow events. Increased potential for failure of this levee could be detrimental to areas located adjacent to the Grant Creek floodplain. As the levee exists today, it has been designated "minimally acceptable" by USACE. This levee must meet regulatory standards as set forth by USACE and is on the verge of unsatisfactorily meeting these

Figure 3-13: Grant Creek between Stonebridge Rd. and Expo Pkwy, 2024.

Figure 3-12: Looking upstream at Stonebridge Rd. Trees growing on the Grant Creek Levee, 2024.

standards. Consequences of no action would include continued risk of increased flooding, continued unsatisfactory ratings from USACE, disqualification from the Public Law 84-99 (PL 84-99) program, and increased costs due to deferred maintenance associated with vegetative growth.

Proposed Project Recommendations

During the initial site visit for this Project, it was observed that several large trees had fallen along Grant Creek, and several appeared to be on the verge of falling. Large, fallen trees can obstruct the flow in the creek and cause a rise in flood elevation. These trees also introduce the risk of scour in the channel and adjacent levee. Left unattended, fallen trees can cause the levee to overtop or can cause a breach through loss of material.

It is recommended that all cottonwood trees and existing vegetation located within the prism of the levee be removed; however, due to the significant number of trees present, this project assumes that the work will be limited to trees that are ready to fall and are already dead. Removal of healthy trees could occur over a longer duration of time and are not included in this project nor is the removal of downed trees located in the creek bottom. It is recommended that the proposed work be performed by a Contractor. This project also includes clearing of trees immediately up and downgradient of the bridge on Prospect Drive. Numerous permits may be required including, but not limited to, USACE 404 and 408 permits, 310 permit, SPA 124 permit, Floodplain permit, and 318 permit. All work performed for this project must be in accordance with any required permits. The removal of vegetation should adhere to the USACE standards listed in ETL 1110-2-583.Estimated Capacity and Cost

The total project cost includes removal and disposal of dead or fallen trees, contractor overhead, and traffic control. Professional services for bidding assistance and construction oversight are also included. The estimated cost to complete the project is $578,400. A detailed cost estimate is provided in Appendix 3-C. It is possible that this project and future maintenance needs of the levee could be funded by a Special Improvement District (SID) or Levee District.

Project Score

The proposed concept received a score of 42 and an overall rank of fourth. Table 3-6 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B.

Table 3-6. Grant Creek Levee Maintenance Ranking

Criterion	Weighting Factor	Score	Weighted Score
Public Health and Safety	6	3	18
Water Quality Benefits	5	2	10
Operations and Maintenance	4	2	8
Coordination with other Infrastructure Projects	3	1	3
Climate and Resilience	2	1	2
Equity	1	1	1
		Total Ranking Score	**42**

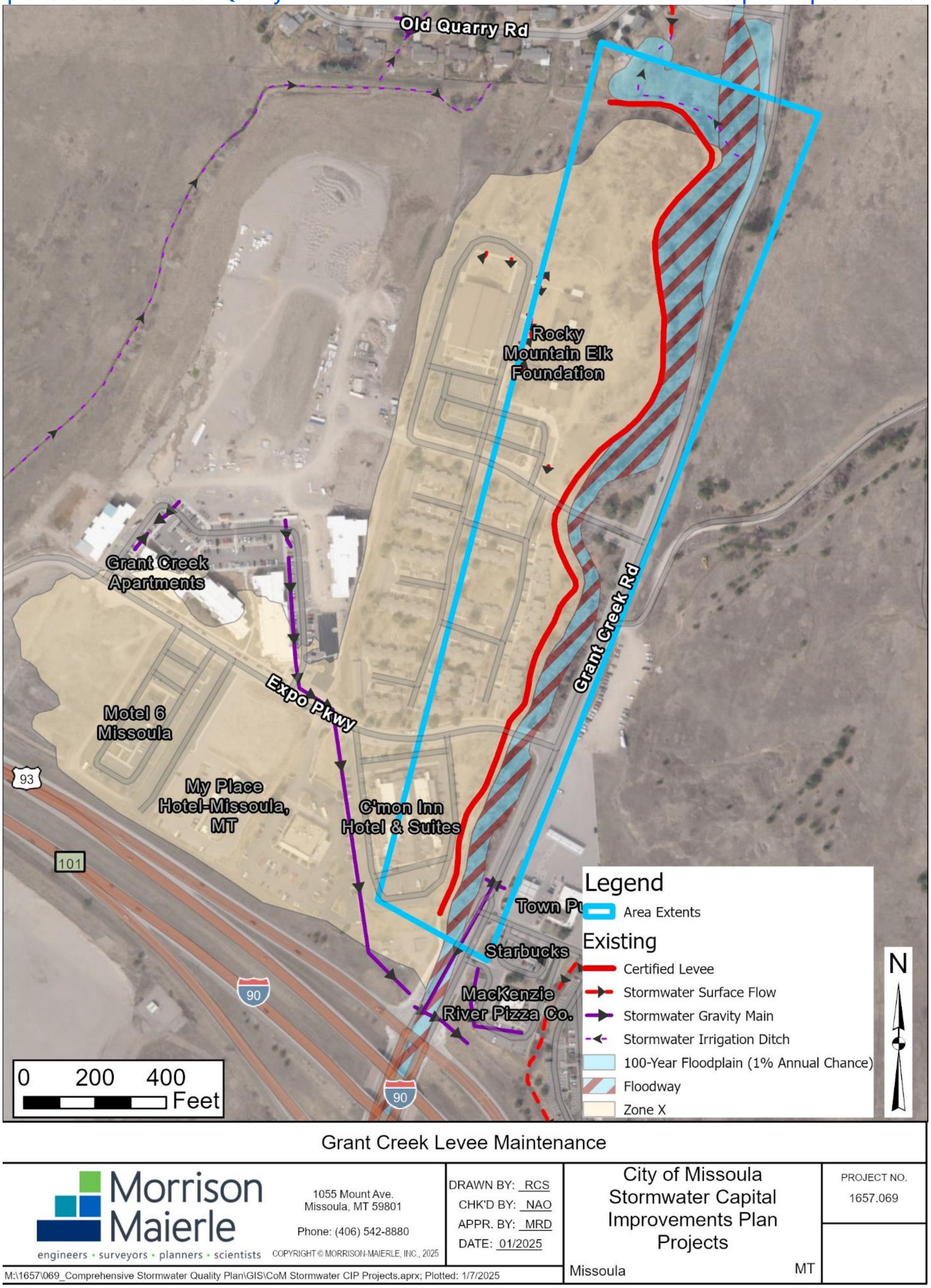
Old Quarry Rd
Rocky Mountain Elk Foundation
Grant Creek Apartments
Expo Pkwy
Motel 6 Missoula
My Place Hotel-Missoula, MT
C'mon Inn Hotel & Suites
Grant Creek Rd
Town Pu
Starbucks
MacKenzie River Pizza Co.
93
101
90
90
0 200 400
Feet
Legend
Area Extents
Existing
Certified Levee
Stormwater Surface Flow
Stormwater Gravity Main
Stormwater Irrigation Ditch
100-Year Floodplain (1% Annual Chance)
Floodway
Zone X
N
Grant Creek Levee Maintenance
Morrison Maierle
engineers • surveyors • planners • scientists
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Figure 3-14

3.5.5. Fox Site Orange Street Outfall Repair

Description

The Fox Site Orange Street Outfall is located on the north bank of the Clark Fork River, downstream of the Orange Street bridge. The outfall has a contributing area of approximately 136 acres and 88 contributing stormwater inlets. The contributing area land uses are urban center, community mixed, and parks and open land. A large portion of the stormwater from downtown Missoula discharges at the Fox Site outfall.

Project Need

During the July 19, 2024, site visit, erosion of the bank around the 42-inch outfall pipe was documented. Erosion has undercut the outfall approximately 3 feet back from the end of the pipe. Additionally, dry weather flow approximately 2-inches deep was exiting the outfall pipe. The City reported this dry weather flow has been traced to the Heating, Ventilation, and Air Conditioning (HVAC) systems of nearby buildings. A hydrodynamic separator (HDS) unit is located upgradient of the Fox Site outfall to provide quality treatment.

The Fox Site Orange Street Outfall Repair Project involves repairing the erosion around the 42-inch outfall pipe. During the July 19, 2024, site visit, measurement of the erosion was taken. The concrete outfall transition is currently perched approximately 3 feet above the current ground surface below.

Figure 3-15. Erosion and dry weather flow Fox Site outfall, 2024.

Figure 3-16. Erosion around Fox Site outfall pipe, 2024.

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Proposed Project Recommendations

The proposed concept includes stabilization and infill of the eroded areas around the outfall. Fill will be used to rebuild the bank up to the base of concrete outfall apron, geotextile will be placed and keyed into the top and bottom of the bank, a concrete cutoff wall will be poured to tie into the outfall, and riprap will be placed around the outfall to the ordinary high-water mark. Riprap will be used to stabilize the channel above the ordinary high-water mark. Below the outfall, natural boulders will be used to create a stable plunge pool to absorb energy from the drop and convey it to the Clark Fork River. Because there will be work below the ordinary high water mark, as well as within a Zone AE floodplain, there will be a significant permitting effort before work can begin.

Estimated Capacity and Cost

The existing capacity of the outfall will be maintained with this project. The estimated cost to stabilize and repair the outfall is $70,500. A detailed cost estimate is provided in Appendix 3-C.

Project Score

The proposed concept received a score of 91 and an overall rank of seventh. Table 3-7 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B.

Table 3-7: Fox Site Orange Street Outfall Repair Ranking

Criterion	Weighting Factor	Score	Weighted Score
Water Quality Benefits	8	1	8
Public Health and Safety Benefits	7	3	21
Magnitude of Impact	6	2	12
Operations and Maintenance Needs	5	5	25
Coordination with other Infrastructure Projects	4	1	4
Climate and Resilience	3	2	6
Equity	2	5	10
Age/Condition	1	5	5
		Total Ranking Score	**91**

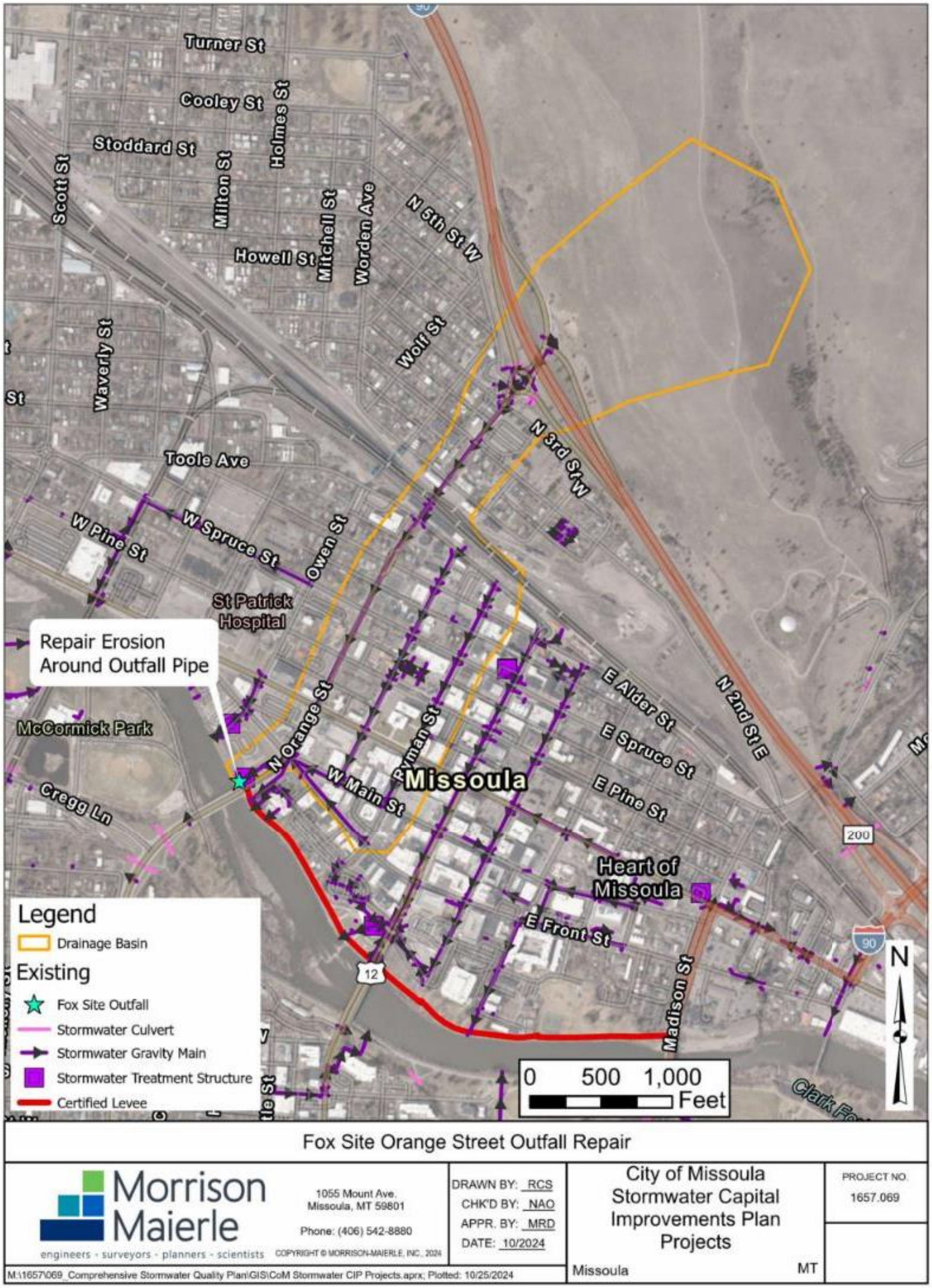
Turner St
Cooley St
Holmes St
Stoddard St
Scott St
Milton St
Mitchell St
Worden Ave
N 5th St W
Howell St
Waverly St
Wolf St
Toole Ave
N 3rd St W
W Pine St
W Spruce St
Owen St
St Patrick Hospital
Repair Erosion Around Outfall Pipe
McCormick Park
N Orange St
Ryman St
E Alder St
N 2nd St E
E Spruce St
Missoula
W Main St
Cregg Ln
E Pine St
200
Heart of Missoula
E Front St
Madison St
90
12
N
Legend
Drainage Basin
Existing
Fox Site Outfall
Stormwater Culvert
Stormwater Gravity Main
Stormwater Treatment Structure
Certified Levee
0 500 1,000 Feet
Fox Site Orange Street Outfall Repair
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Figure 3-17

3.5.6. Reserve Street Stormwater Treatment

Description

The Reserve Street stormwater outfall is within the City's MS4 but is owned and maintained by MDT. According to the City stormwater GIS database, the outfall receives runoff from many inlets on Brooks Street and on Reserve Street from the intersection at Brooks Street to Spurgin Road, collecting runoff from approximately 73 acres of watershed. The pipe daylights into the roadside ditch and a sedimentation pond before discharging to the Bitterroot River, just upstream of the U.S. Highway 93 bridge. The dominating land use of the watershed is high use roads and urban.

Project Need

The developed regions along Reserve and Brooks Streets generate pollutants from streets, alleys, dumpsters, and commercial areas such as hazardous material, gasoline, oil, hydraulic fluid, and trash. Additionally, stormwater carries a significant amount of sediment as a result of sanding operations during the winter season. The Missoula Valley Water Quality District (MVWQD) sampled the stormwater discharging from the Reserve Street outfall at various intervals from 2007 to 2013. The MVWQD sampled for a range of pollutants including total suspended solids (TSS), nutrients, and heavy metals among other things. The results of the stormwater quality sampling can be found in Appendix 3-D. The TSS and nutrient levels recorded in the stormwater discharging from the Reserve Street outfall exceeded target event mean concentrations for those contaminants as established by the Montana Department of Environmental Quality.

Figure 3-18. Roadside sedimentation pond, partially full, 2015.

Proposed Project Recommendations

The proposed project will include several distinct measures to address this large drainage area that is dominated by pollutant generating surfaces. The BMPs available at this site are complicated by Missoula Valley Water Quality Code, which sets U.S. Highway 93 as the primary north-south hazardous waste transportation route. Reserve Street and Brooks Street constitute Highway 93 through the drainage area. BMPs that rely on infiltration will not be used for this basin, given the risk of contamination with hazardous waste. Runoff from the north 55 acres of the drainage area will be treated in a new offline detention basin located between the railroad tracks and Brooks Street. Runoff from the furthest downgradient 21 acres will be managed with an improved extended detention basin at the current MDT-owned sedimentation pond. Both of these locations are not owned by the City and therefore will require partnerships with other organizations, namely MDT and Montana Rail Link, to negotiate easements for drainage infrastructure on these parcels.

The new extended detention basin is proposed between Brooks Street and the railroad tracks, just downgradient from 39th Street. A new flow split structure will be placed in the stormwater main on Brooks Street near the intersection with 39th Street. The flow split structure will divert the runoff treatment volume of 2.08 acre-feet from the north 55 acres of the drainage basin to the new detention basin for treatment. The basin concept shown has an area of 0.54 acres, meaning it will have an average depth of 3.8 feet to contain the runoff treatment volume. Runoff from rainfall after the first half inch will continue in the existing stormwater main down Brooks Street. The area has an existing storage capacity of approximately 1.1 acre-feet below the estimated top of pond of 3,159 feet with 1 foot of freeboard. The outflow from the detention basin will have to be routed to intercept the stormwater main after the flow splitter for the downgradient detention basin to avoid duplicate treatment. The placement of new flow splitters and the alignments of pipes routing to detention basin forebays will have to be carefully controlled in final design and construction. Grades must be set to ensure adequate flow velocity to prevent sedimentation, provide sufficient depth for treatment and storage requirements, avoid conflicts with existing utilities, and prevent potentially hazardous depths.

The improved extended detention basin, proposed in the roadside ditch area currently used for the sedimentation pond, will have a capacity of 0.68 acre-feet to match the runoff treatment volume for the most downgradient 18 acres. The existing sedimentation pond will be improved by reconstructing the pond to include a layer of mulch and amended soil built into the base of the pond to act as a biofiltration layer. Detained water will drain through this filtration layer to an underdrain system that will connect to the existing outlet pipes. The outlet structure, currently configured as a drop inlet that connects with the storm main, will be revised to encourage this filtration and more settling of sediment. The existing 42-inch RCP under the ponds will be maintained for discharge to the outfall. A new flow split structure will be installed near the intersection of Brooks Street with Miller Creek Road and direct flow to a new pretreatment forebay at the upgradient end of the new detention basin. Flow during large events will be split and directed to the existing 42-inch RCP pipe that outfalls to the Bitterroot River. The improved detention basin will have to be constructed as two separate cells joined by the existing culverts under the highway approach road. These cells combine for a total area of 0.28 acres, meaning the basin will have an average depth of 2.4 feet. The depth will have to be deeper near the river and shallower near the top end.

The extended detention basins should improve water quality in terms of TSS. Nutrients were also a problem in the 2014 sampling with nitrogen, phosphorus, and chemical oxygen demand (COD) values above target values. The addition of a biofiltration component at the online basin will provide some nutrient removal (Mile High Flood District, 2010). If further nutrient removal is desired, use of wet detention basins or constructed wetlands could be explored, although this would introduce additional grade constraints. The County-owned Larchmont Golf Course could provide a location for such a facility, but this would require extensive coordination with the County, as well as considerable additional pipe to route outflows back to the storm drainage system.

Estimated Capacity and Cost

The two detention basins will treat the entire runoff treatment volume from the 76 acre drainage area, which is estimated to be 2.77 acre-feet. The total cost for these facilities is estimated to be $1,293,400. A detailed cost estimate is provided in Appendix 3-C.

Project Score

The proposed concept received a score of 39 and tied for an overall rank of fifth. Table 3-8 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B.

Table 3-8. Reserve Street Stormwater Treatment Ranking

Criterion	Weighting Factor	Score	Weighted Score
Magnitude of Impact	6	2	12
Operations and Maintenance Needs	5	3	15
Coordination with other Infrastructure Projects	4	1	4
Climate and Resilience	3	1	3
Equity	2	1	2
Age/Condition	1	3	3
		Total Ranking Score	**39**

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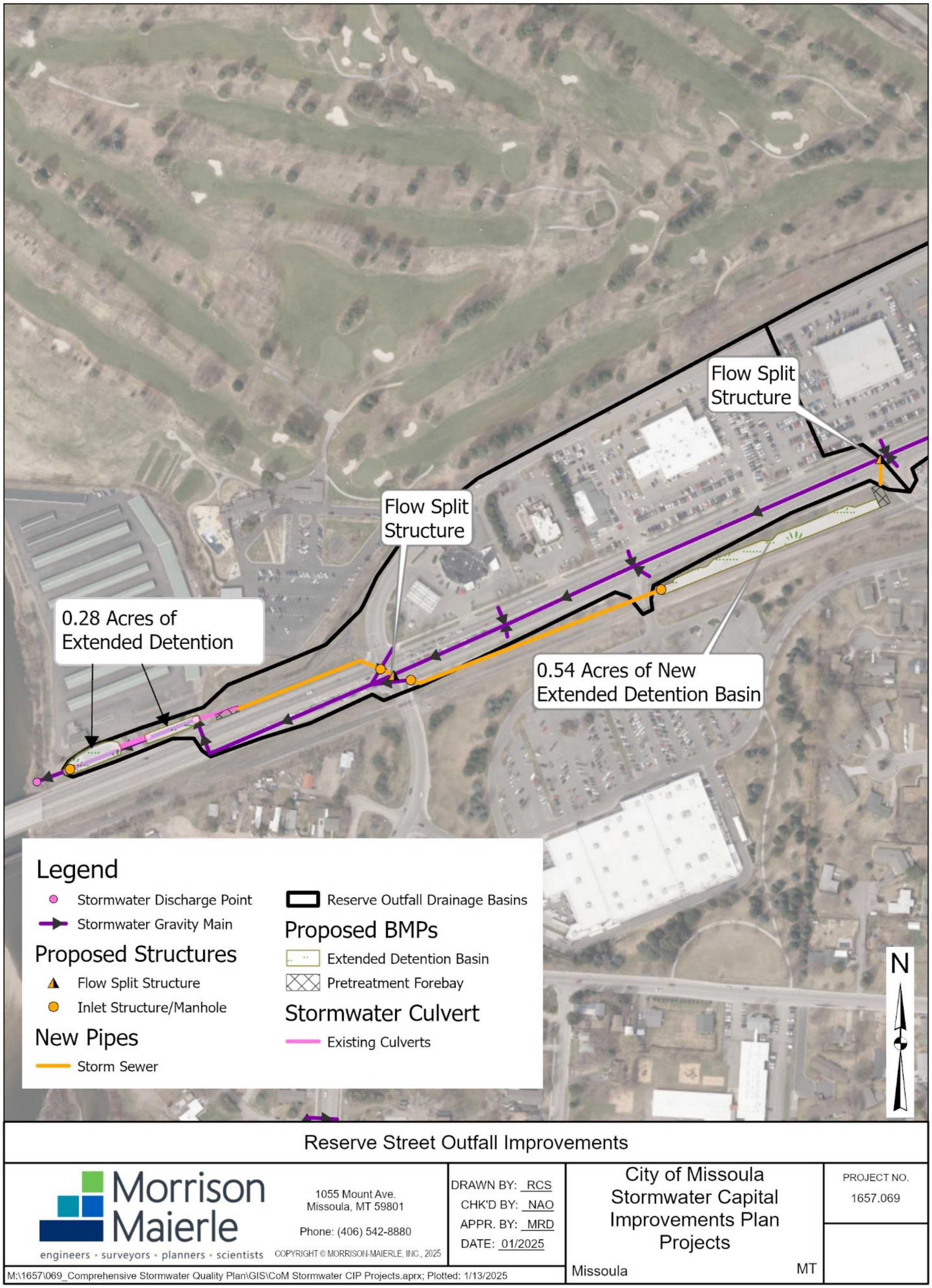
Flow Split Structure
Flow Split Structure
0.28 Acres of Extended Detention
0.54 Acres of New Extended Detention Basin
Legend
Stormwater Discharge Point
Stormwater Gravity Main
Proposed Structures
Flow Split Structure
Inlet Structure/Manhole
New Pipes
Storm Sewer
Reserve Outfall Drainage Basins
Proposed BMPs
Extended Detention Basin
Pretreatment Forebay
Stormwater Culvert
Existing Culverts
N
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Figure 3-19

3.5.7. Bess Reed Park Stormwater Treatment

Description

This stormwater outfall (SW-DC-10056) discharges to the Clark Fork River near Clay Street in Bess Reed Park and is the City's 7th highest priority outfall. According to the City Stormwater Management Plan, the outfall is an 18-inch diameter reinforced concrete pipe that receives runoff through several inlets on Clay Street, collecting runoff from approximately 11.5 acres of drainage area. The dominant land use in the collection area is urban.

Project Need

This stormwater outfall is high priority for the City due to urban land use, number of contributing inlets, overflow potential, and discharge to an impaired waterbody. Wasteload allocations were monitored through the MS4 on this reach of the Clark Fork include copper and lead; however, TMDLs are also set for chlorophyll, iron, Total Nitrogen, and Total Phosphorus.

During the July 19th site visit, sediment deposition was noticed at the end of Clay Street suggesting ponding of stormwater during rain events. Standing water was noticed in two of the downgradient stormwater intakes. City maintenance staff reports dry weather flow that has been traced to the HVAC systems of nearby apartment buildings. the dry weather flow at this location either needs to be addressed by the City as a matter of policy, included in the design of the stormwater quality treatment system, or both.

Figure 3-20. Gravity main inlet and evidence of ponding upgradient of Clay Street outfall, 2024.

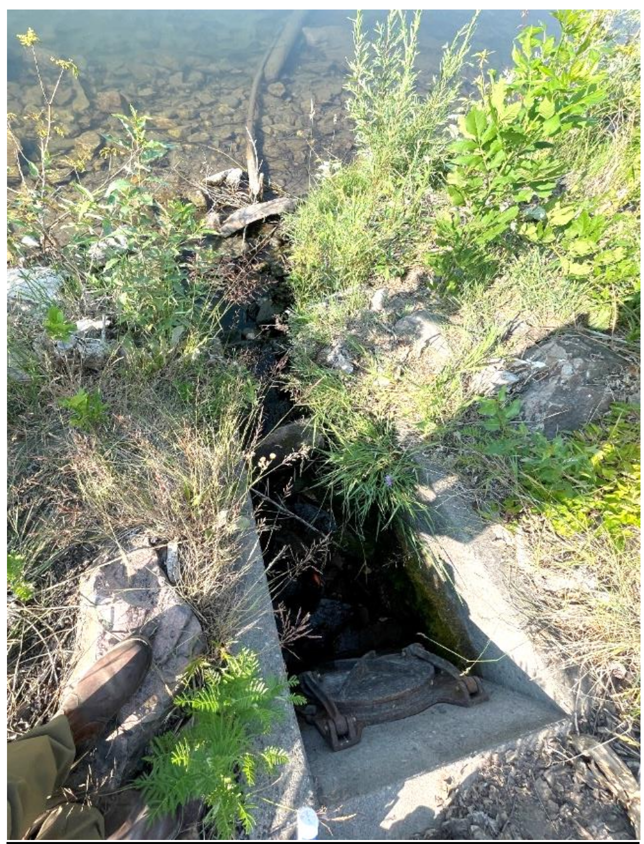

Figure 3-21. Clay Street outfall, 2024.

The Clay Street Outfall Improvements project involves incorporating a stormwater quality treatment system upgradient of the outfall to remove pollutants from the stormwater before it discharges to the Clark Fork River.

The City is currently preparing a grant application to fund community-wide stormwater treatment improvements. Bess Reed Park is within the scope of the application for installing an extensive stormwater in the park with board walks and community amenities. The alternative provided in this CIP is less complex and can be considered for implementation in the event that funding for the more extensive scope is not awarded.

Proposed Project Recommendations

To provide water quality treatment prior to discharge to the Clark Fork River, a landscape bioretention area with a low flow channel is proposed in Bess Reed Park. A new flow splitter will intercept the existing storm drain and divert the first flush volume during storm events to be routed through the retention area for treatment. Larger events will discharge directly to the outfall. The low flow channel will be stabilized to receive regular baseflows due to current urban flows discharged to the storm drain.

Figure 3-22: Example of a landscaped bioretention area with low flow channel.

The concept design shown in Figure 3-23 includes approximately 15,000 square feet of bioretention area, sloped and excavated 4-5 feet. The estimated storage capacity for this facility is 19,000 cubic feet with a to allow for storage of the runoff reduction volume. Present baseflows from urban discharge and the first half inch of rain in the contributing basin will be intercepted near the entrance to Bess Reed Park. A new flow splitter structure will be installed on the storm drain that will divert small events to the surface. The site will be graded to direct flow first through a forebay area that is divided and has easy access for sediment removal by equipment. Pedestrian bridges will maintain trail connection through the area.

A structure to allow overflow discharge back to the outfall pipe may be designed depending on surcharge conditions during large storm events. In addition, overflow can be handled by drywells as needed. The concept must be further developed to consider site conditions and restraints such as urban baseflows and groundwater depth.

Estimated Capacity and Cost

This stormwater bioretention area will be designed with capacity to store the water quality volume for the 11.5-acre watershed, which is estimated at 19,000 cubic feet. The concept design includes a swale type depression with a low flow stabilized channel and landscape side slopes to contain the water quality volume. The conceptual grading includes excavation depth of 5 feet with 3 to 1 side slopes. With an 8-foot channel bottom and a length of 350 feet, the facility has capacity to retain the water quality event. The low flow channel will be stabilized to receive regular baseflows and small events, and the side slopes of the area will be landscaped with amended soil and plantings to promote stormwater infiltration and treatment. Design methodologies may follow guidance for bioretention and/or extended dry detention in accordance with the Montana Post Construction BMP Manual. Approximately one-third of the facility volume will be separated for pretreatment and sedimentation. During final design, projects extents should be refined to ensure there is no impact to the adjacent levee prism. The total cost for this facility is estimated to be $493,400. A detailed cost estimate is provided in Appendix 3-C.

Project Score

The proposed concept received a score of 37 and an overall rank of seventh. Table 3-9 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B.

Table 3-9. Bess Reed Park Stormwater Treatment Ranking

Criterion	Weighting Factor	Score	Weighted Score
Public Health and Safety	6	1	6
Water Quality Benefits	5	3	15
Operations and Maintenance	4	1	4
Coordination with other Infrastructure Projects	3	1	3
Climate and Resilience	2	3	6
Equity	1	3	3
		Total Ranking Score	**37**


Clay St
Flow Splitting Structure
Le Vasseur St
Overflow Drywell
15,000 SF Stormwater Bioretention
Bess Reed Park
Overflow Drywell
Outlet Structure
Legend
Existing
Stormwater Manhole
Clay St. Outfall
Stormwater Inlet
Stormwater Drywell
Stormwater Gravity Main
Certified Levee
Proposed
Flow Split Structure
Outlet Structure
Overflow Drywell
Bioretention Area
Channel Bottom
Low Flow Channel
Pedestrian Bridge
Clark Fork River
0 30 60
Feet
N
Bess Reed Park Stormwater Treatment Proposed Design
Morrison Maierle
engineers · surveyors · planners · scientists
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Missoula, MT 59801
Phone: (406) 542-8880
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Figure 3-23

3.5.8. Lincoln Hills and Lincolnwood Drainage Study

Description

The Lincoln Hills and Lincolnwood neighborhoods are located in the Rattlesnake Valley north of downtown Missoula. These neighborhoods are near the bottom of the Rattlesnake Creek watershed with contributing area land uses characterized as rural and residential. The Lincolnwood area includes Lincoln Road, Timberlane Street, and Fox Farm Road, which is approximately 70 acres adjacent to Rattlesnake Creek. The Lincoln Hills area includes mainly the residential area east of Rattlesnake Drive and south of Lincoln Hills Drive, which is approximately 212 acres.

Project Need

The Lincoln Hills and Lincolnwood neighborhoods have minimal stormwater infrastructure in place. Most of the stormwater in these neighborhoods is directed down streets and into backyards. This often causes ponding in streets and occasionally causes flooding of structures. There are some infiltration facilities in the neighborhoods. Generally, these are in common areas and rights-of-way. They appeared undersized for the quantity of stormwater directed to them during the July 19, 2024 site visit. In addition, the areas around many pipe outfalls in the Lincoln Hills/Lincolnwood neighborhoods are significantly eroded. These

Figure 3-24: Drywell inlet and evidence of ponding at Fox Farm Rd. and Creek Crossing Rd, 2024

Figure 3-25: Infiltration facility Greenbrier Drive and Greenbrier Ct., 2024.

areas need to be stabilized to prevent continued damage to infrastructure and sediment transport to Rattlesnake Creek.

The City is prioritizing stormwater infrastructure located upgradient in these drainage basins in order to reduce flows and increase current infrastructure efficiency at lower elevations. A study of these areas is needed to assess current infrastructure conditions, soil characteristics, and the need for additional stormwater infrastructure improvements.

Proposed Project Recommendations

A detailed assessment of the area is recommended to better understand stormwater impacts. Based on the results of the hydraulic analysis and a combination of the following improvements are likely to be recommended for design and construction:

- New curb and gutter to manage stormwater flow from/along streets,
- Improved conveyance pathways where street runoff is directed,
- More/deeper infiltration facilities with pretreatment for sediment,
- New outfall(s) to Rattlesnake Creek, if necessary:
  - Lincoln Hills: A potential conveyance route down Dickinson Street could be followed to place outfall near north end of Wylie St.
  - Lincoln Wood: The swale at the end of Creek Crossing Rd could be improved.
- Locations such as parks or common areas for potential new detention facilities
- Focused efforts in upgradient to minimize peak flows, and
- Stabilization of outfalls to prevent sediment loading in Rattlesnake Creek.

Estimated Capacity and Cost

The estimated cost for a hydraulic assessment and engineering design is $92,900. A detailed cost estimate is provided in Appendix 3-C.

Project Score

The proposed concept received a score of 35 and an overall rank of eighth. Table 3-10 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B.

Table 3-10. Lincoln Hills and Lincolnwood Drainage Study Ranking

Criterion	Weighting Factor	Score	Weighted Score
Magnitude of Impact	6	2	12
Operations and Maintenance Needs	5	1	5
Coordination with other Infrastructure Projects	4	2	8
Climate and Resilience	3	1	3
Equity	2	3	6
Age/Condition	1	1	1
		Total Ranking Score	**35**

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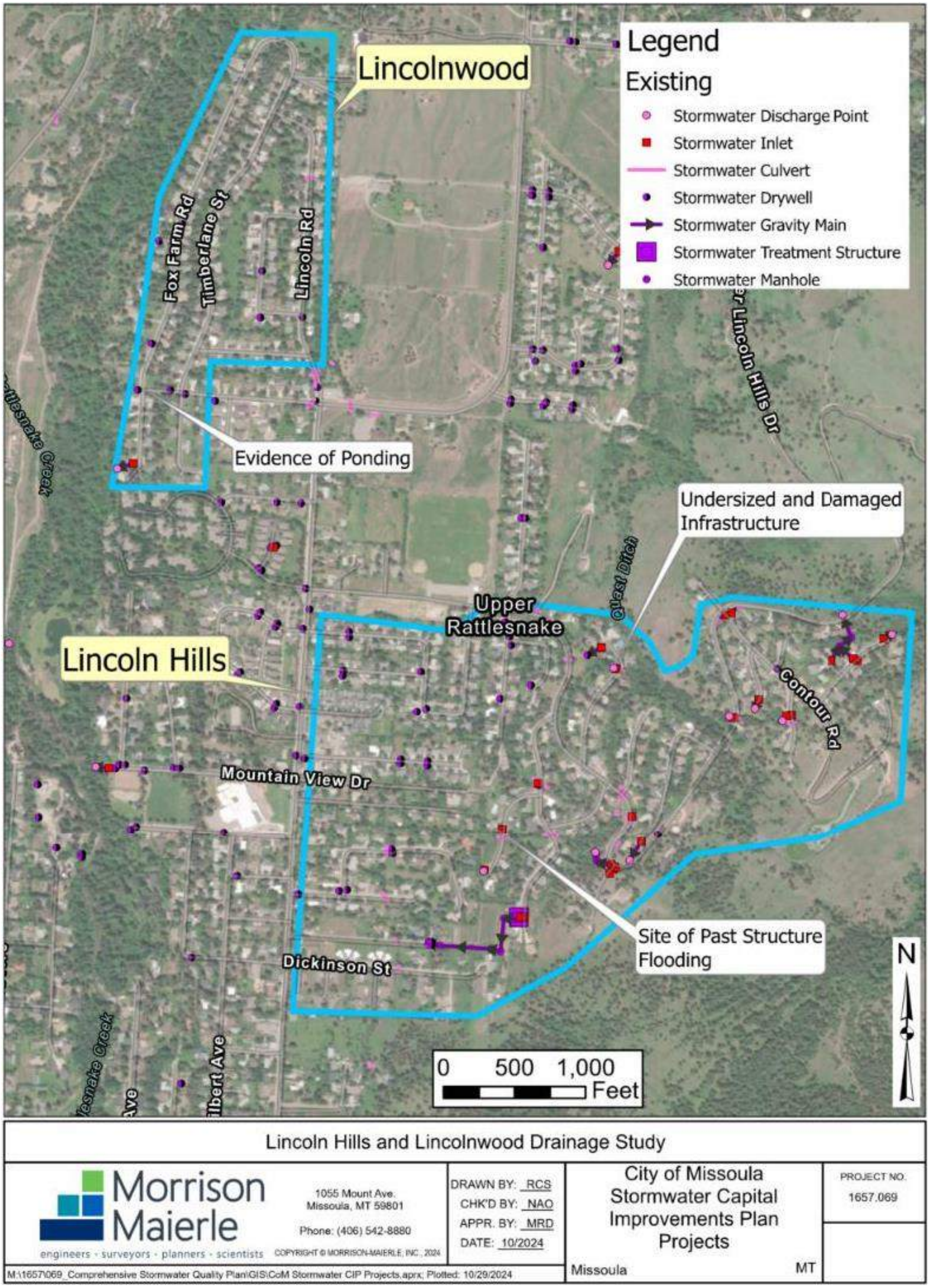
Lincolnwood
Legend
Existing
Stormwater Discharge Point
Stormwater Inlet
Stormwater Culvert
Stormwater Drywell
Stormwater Gravity Main
Stormwater Treatment Structure
Stormwater Manhole
Fox Farm Rd
Timberlane St
Lincoln Rd
Lincoln Hills Dr
Evidence of Ponding
Rattlesnake Creek
Undersized and Damaged Infrastructure
Quast Ditch
Upper Rattlesnake
Lincoln Hills
Contour Rd
Mountain View Dr
Site of Past Structure Flooding
Dickinson St
N
0 500 1,000
Feet
Lincoln Hills and Lincolnwood Drainage Study
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engineers · surveyors · planners · scientists
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Figure 3-26

3.5.9. Missoula County Public Library Living Roof

Description

The Missoula Public Library is located on the east side of downtown, between East Main and East Front Streets. The Library is approximately 0.15 miles north of the Clark Fork River and 0.75 miles south of the wooded and floodplain habitats of the Lower Rattlesnake Canyon. Stormwater runoff from the Library property is infiltrated through drywells located in the parking area. This includes stormwater captures on the roof and on the adjacent ground surface and parking lot. There is no pretreatment feature prior to infiltrating through the drywells.

The Missoula Public Library and City of Missoula have collaborated on multiple funding applications to fund a new living roof on the second and third level roofs of the library. At the time of this report, these funding applications are pending review. The living roof would be a demonstration project and an educational opportunity on stormwater quality for the thousands of visitors each year.

Project Need

The Missoula Public Library has 13,000 square feet of roof space covered with conventional rock ballast. The roof is highly visible through floor-to-ceiling windows on the upper floors. Stormwater runoff management from the roof does not include any quality pre-treatment or retention. The stormwater system is not resilient to intense precipitation events anticipated as the climate changes. Additionally, the Library contributes to heat island impacts experienced in urban Missoula. The rock ballast roof absorbs energy and heat from sunlight. This heat flux increases the temperature of the building, creating additional

Figure 3-27: Proposed Living Roof & Outdoor Patio Rendering

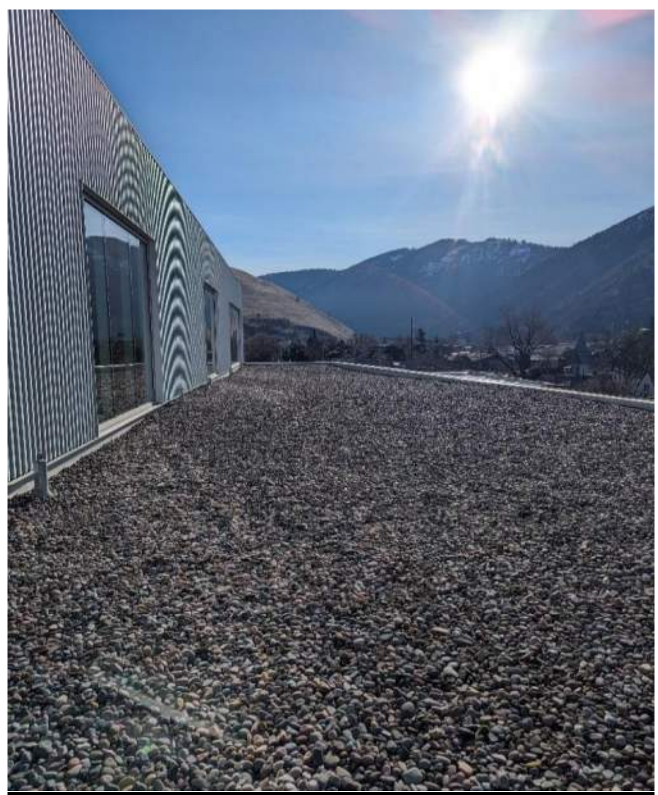

Figure 3-28: Existing Library Rock Ballast Roof

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stress on the air-cooling system, in turn increasing energy usage and greenhouse gas emissions from conventional power sources. The project would provide benefits for stormwater management, water quality, energy efficiency, and pollinator habitat.

Proposed Project Recommendations

Two alternatives were developed for the living roof. The first alternative is a smaller scope of work and cost. The alternative includes a living roof above level 2 of the Library with an educational exhibit. The level two roof is highly visible through floor-to-ceiling windows that enclose the third floor of the library. The retrofit includes removing 6,200 square feet of existing rock ballast and replacing with living roof modules. Living roof modules include 6 inches of soil media and a 3-inch water retention layer that provides storage and reduces stormwater runoff. The roof will be planted with hardy sedum species and include an irrigation system.

The second alternative is an extensive retrofit and has a higher estimated cost. This alternative includes transforming over 9,000 square feet of rock ballast on the library's level 2 and 3 roofs to a vegetative living roof and outdoor patio space accessible to the public from the third floor. Plantings will be native species and include a variety of heights and flowering plants. An additional entrance/exit, new walkway, irrigation system, and safety features are required. This is the preferred alternative, pending available funding.

Estimated Capacity and Cost

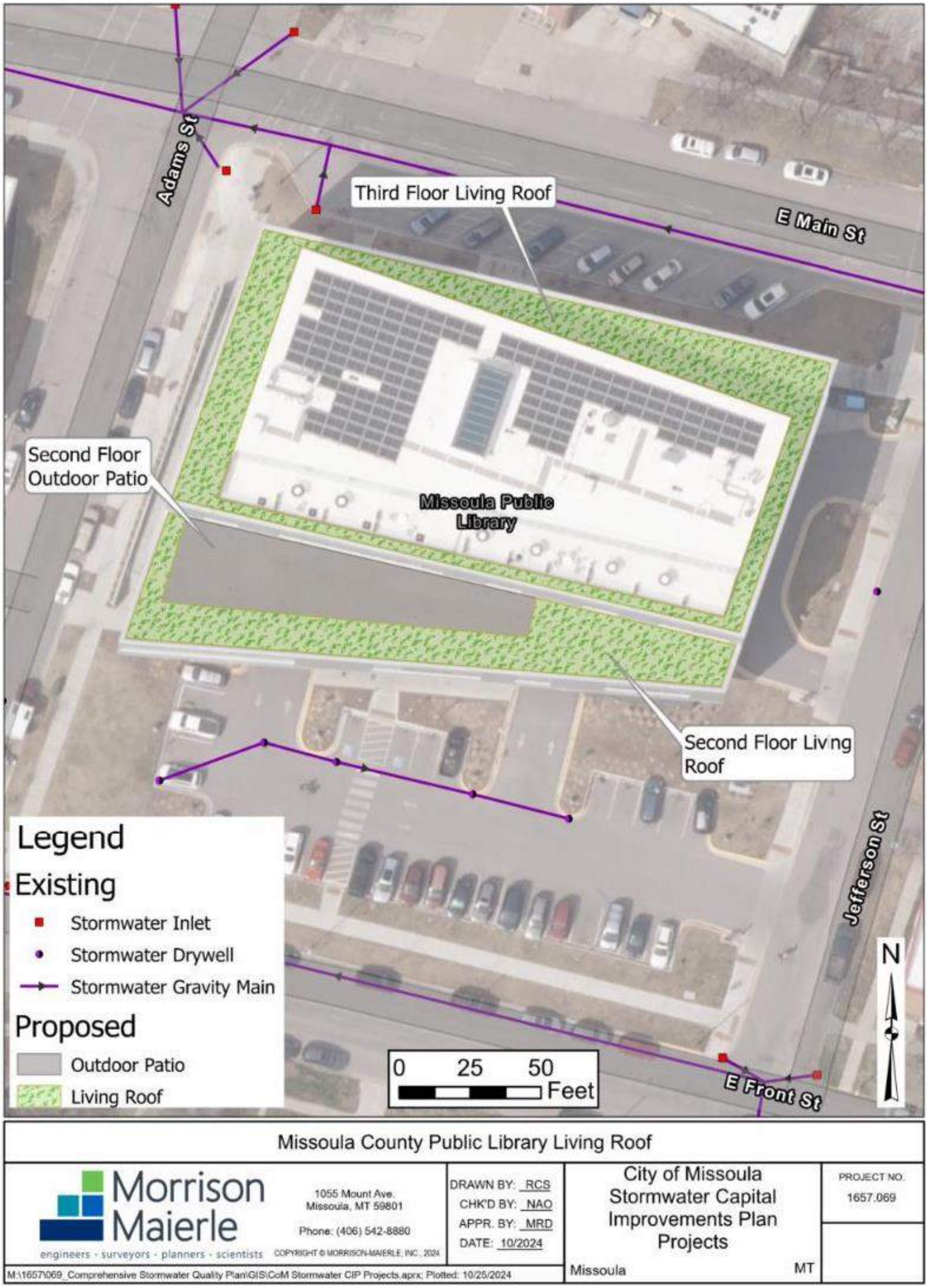
The estimated cost for design and construction of the preferred alternative is $780,000. This project is currently pending multiple applications for grant funding. If grant funding is not awarded, it is likely that the project will not proceed. A detailed cost estimate is provided in Appendix 3-C.

Project Score

The proposed concept received a score of 31 and tied for an overall rank of ninth. Table 3-11 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B.

Table 3-11. Missoula Public Library Living Roof Ranking

Criterion	Weighting Factor	Score	Weighted Score
Public Health and Safety	6	1	6
Water Quality Benefits	5	2	10
Operations and Maintenance	4	1	4
Coordination with other Infrastructure Projects	3	1	3
Climate and Resilience	2	3	6
Equity	1	2	2
		Total Ranking Score	**31**


Adams St
E Main St
Third Floor Living Roof
Second Floor Outdoor Patio
Missoula Public Library
Second Floor Living Roof
Jefferson St
E Front St
Legend
Existing
Stormwater Inlet
Stormwater Drywell
Stormwater Gravity Main
Proposed
Outdoor Patio
Living Roof
0 25 50 Feet
N
Missoula County Public Library Living Roof
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engineers · surveyors · planners · scientists
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Figure 3-29

3.5.10. Majestic Drive Drainage Plan

Description

The Majestic Drive storm drain outfall has a contributing area of approximately 42 acres and 7 contributing stormwater inlets. The contributing area land use is characterized as community mixed use, light industrial, and regional commercial and services. The primary conveyance to the Majestic outfall is man-made vegetated channels. These channels flow to culverts that convey stormwater under Express Way, under the BNSF railroad tracks, and then discharge stormwater to Grant Creek north of West Broadway Street.

Project Need

Drainage from Majestic Drive presents a potential issue for stormwater management due to the undetermined contributions to the public drainage infrastructure by private systems. The private stormwater system on Majestic Drive drains to a publicly owned culvert under the railroad that then discharges to Grant Creek. The City identified this culvert as being either damaged or blocked. This was confirmed during the July 19, 2024, site visit, however, no ponding was evident upgradient of this culvert. As development of this area continues, a stormwater management strategy should be developed to estimate future needs of the area and provide a plan for the City and developers.

A detailed investigation of the storm drainage infrastructure, including survey for sizes, capacity, and condition, is recommended from Majestic Drive to the outfall at Grant Creek.

Figure 3-30. Clogged culvert under railroad upgradient of the outfall, 2024.

Figure 3-31. Area inlet near Expressway and Majestic Drive, 2024.

Proposed Project Recommendations

A detailed study is recommended to determine if there are any blocked or damaged pipes in this area and to better understand water quantity and quality impacts from the increasing development along Majestic Drive. The study should include survey and inventory of stormwater infrastructure, condition assessment, a detailed hydraulic analysis of the catchment area and infrastructure, and a stormwater management strategy for future development in the area.

Estimated Capacity and Cost

The estimated cost for this study project is $45,000. A detailed cost estimate is provided in Appendix 3-C.

Project Score

The proposed concept received a score of 31 and tied for an overall rank of ninth. Table 3-12 indicates how the proposed concept scored by criteria. Additional detail and rational for the given scores for each criterion can be found in Appendix 3-B.

Table 3-12. Majestic Drive Drainage Plan Ranking

Criterion	Weighting Factor	Score	Weighted Score
Public Health and Safety	6	1	6
Water Quality Benefits	5	1	5
Operations and Maintenance	4	2	8
Coordination with other Infrastructure Projects	3	3	9
Climate and Resilience	2	1	2
Equity	1	1	1
		Total Ranking Score	**31**

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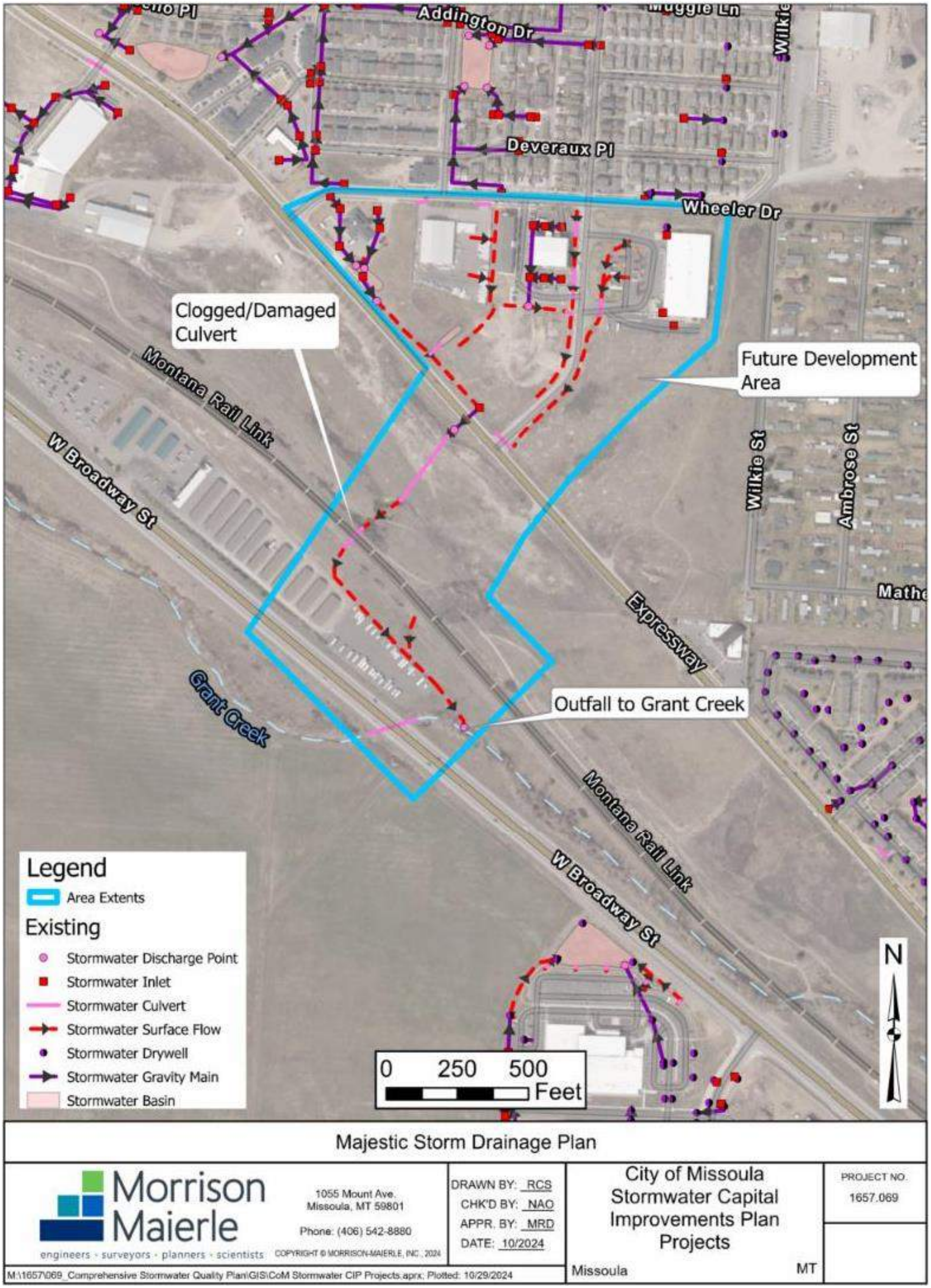
Addington Dr
Deveraux Pl
Wheeler Dr
Wilkie St
Ambrose St
Expressway
Montana Rail Link
W Broadway St
Grant Creek
Clogged/Damaged Culvert
Future Development Area
Outfall to Grant Creek
Legend
Area Extents
Existing
Stormwater Discharge Point
Stormwater Inlet
Stormwater Culvert
Stormwater Surface Flow
Stormwater Drywell
Stormwater Gravity Main
Stormwater Basin
0 250 500 Feet
N
Majestic Storm Drainage Plan
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Figure 3-32

3.6. PRIORITIZATION AND CAPITAL IMPROVEMENTS PLAN

The City of Missoula provided a list of capital improvements projects that was refined and further defined, resulting in the recommended projects described above. These projects were scored based on the ranking criteria, ranked for priority, and organized into a 6-year capital improvements plan shown in Table 3-13. The highest potential score for a project is 180 and the lowest is 36. The highest scoring projects are scheduled for implementation in 2025 and organized into the next several years based on priority.

It should be noted that some projects received a high score due to their compatibility with a future redevelopment project or master plan, such as the Whippoorwill outfall project (ranked fourth) and the South 4th Street Clark Fork Outfall (ranked second). The actual implementation of these projects should be modified based on the anticipated date for the associated overarching project. In addition, some projects with pending grant applications may move up in the schedule due to funding availability. The schedule presented in this capital improvements plan is a starting point based that should be modified by the City as needed.

Cost estimates were developed for the projects based on standards developed by the American Association of Cost Engineers (AACE). The AACE established definitions commonly used in cost estimating and collected and published the limits of confidence associated with different AACE-defined levels of cost estimates. (*Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Building and General Construction Industries*, AACE, 2020) The cost estimates presented in this Plan are categorized by AACE as a Class 4 Estimate based on the following description:

> *Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval.*

Class 4 estimates are typically prepared for preliminary budget approval, such as a Capital Improvements Plan and by definition have an expected accuracy range of -15% to +30% depending on the complexity of the project and level of definition of the project.

Estimates for general conditions, engineering costs, and specific project components were developed using average costs from actual projects in Missoula and other municipal projects in Montana over the last five years. The total project cost is estimated for FY2025 and inflated at a rate of 3.8% per year to determine approximate cost at the scheduled implementation year. A contingency of 25% was used for conservative as these estimates are based on a concept-level analysis.

Table 3-13a: Recommended Capital Improvements Plan FY 2025-2030

Project Rank	Project	Priority Ranking Score	Base Cost FY2025	Adjusted Cost with Escalation					
				FY2026	FY2027	FY2028	FY2029	FY2030	FY2031
1	High Park Drainage System Improvement	53	$755,000	$60,000	$721,549				
2a	Whippoorwill Drive Outfall Improvements	45	$2,009,800		$319,766	$917,150	$952,186		
2b	South 4th Street Clark Fork Outfall Water Quality Improvements	45	$733,800					$129,771	$750,352
4	Grant Creek Levee Maintenance	42	$578,400					$671,974	
5a	Fox Site Orange Street Outfall Repair	39	$70,500					$81,906	
5b	Reserve Street Stormwater Treatment	39	$1,293,400						$247,692
7	Bess Reed Park Stormwater Treatment	37	$493,400						
8	Lincoln Hills and Lincolnwood Drainage Study	35	$92,900						
9a	Majestic Drive Drainage Plan	31	$45,000						
9b	Missoula Public Library Living Roof	31	$780,000						
TOTAL ANNUAL COST				**$60,000**	**$1,041,315**	**$917,150**	**$952,186**	**$883,650**	**$998,045**

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Table 3-13b: Recommended Capital Improvements Plan FY 2025-2029

Project Rank	Project	Priority Ranking Score	Base Cost FY2025	Adjusted Cost with Escalation				
				FY2032	FY2033	FY2034	FY2035	FY2036
1	High Park Drainage System Improvement	53	$755,000					
2a	Whipporwill Drive Outfall Improvements	45	$2,009,800					
2b	South 4th Street Clark Fork Outfall Water Quality Improvements	45	$733,800					
4	Grant Creek Levee Maintenance	42	$578,400					
5a	Fox Site Orange Street Outfall Repair	39	$70,500					
5b	Reserve Street Stormwater Treatment	39	$1,293,400	$685,975	$712,179			
7	Bess Reed Park Stormwater Treatment	37	$493,400			$93,542	$586,722	
8	Lincoln Hills and Lincolnwood Drainage Study	35	$92,900			$116,333		
9a	Majestic Drive Drainage Plan	31	$45,000			$56,351		
9b	Missoula Public Library Living Roof	31	$780,000					$1,134,762
TOTAL ANNUAL COST				**$685,975**	**$712,179**	**$266,225**	**$586,722**	**$1,134,762**

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3.7. REFERENCES

HDR. (2017). *Montana Post-Construction Storm Water BMP Design Guidance Manual.* Montana Dept of Environmental Quality.

HDR, DJ&A. (2024). *Grant Creek Restoration and Flood Control Preliminary Design Drawings.* City of Missoula.

Morrison-Maierle, Burns & McDonnell. (2018). *Storm Water Facility and Operations Plan Project.* City of Missoula.

NRCS. (1986). *TR-55: Urban Hydrology for Small Watersheds.* US Department of Agriculture.

(2024). *Stormwater Management Manual for Eastern Washington.* Washington Dept of Ecology.

3.8. APPENDICES

Appendix 3-A: Drywell Ranking Tool PDF

Appendix 3-B: Project Ranking and Description

Appendix 3-C: Project Conceptual Cost Estimates

Appendix 3-D: 2014 Stormwater Sampling Data

Appendix 3-A: Drywell Ranking Tool PDF

Appendix 3-B: Project Ranking and Description

Table 3-B-1: Ranking Summary

Project	Priority Ranking Score	Ranking	Description
High Park Drainage System Improvement (Facility Plan)	53	1	The proposed project ranks highly because it significantly mitigates risk to public health and safety, provides resistance to flooding, and the existing infrastructure was installed in the 1960s-1970s. The proposed project scores low because it is not within a disadvantaged community and is not being coordinated with other infrastructure projects.
Whippoorwill Drive Outfall Improvements	45	2	The proposed project scored high on the increased water quality benefit, public health and safety benefits, and the coordination with other infrastructure. It scored low on equity because it's not within a disadvantaged community.
South 4th Street Clark Fork Outfall Water Quality Improvements	45	2	The proposed project scores highly because it will provide water quality benefits for a large area discharging to surface water, mitigates risk to public health and safety, and will be coordinated with other infrastructure projects. It scores low because it is not within a disadvantaged community.
Grant Creek Levee Maintenance (Facility Plan)	42	4	The proposed project scored highly because it greatly reduces the risk and/or consequences of flooding and provides some localized water quality benefit. It scores low because it is not coordinated with other infrastructure projects, does not address future climate conditions, and is not within a disadvantaged community.
Fox Site Orange Street Outfall Repair	39	5	The proposed project scores highly because it will require less maintenance than is currently required, is within a disadvantaged community, and the existing infrastructure was installed in the 2000s. It scores low because it doesn't include water quality retrofits and is not coordinated with other infrastructure projects.
Reserve Street Stormwater Treatment	39	5	The proposed project scores highly because it provides treatment for a large service area that discharges to surface water. It scores low because it is not coordinated with other infrastructure projects.
Bess Reed Park Stormwater Treatment	37	7	The proposed project scores highly because it will significantly reduce pollution and/or sediment loading in stormwater and is within a disadvantaged community. It scores low because it is not coordinated with other infrastructure projects and doesn't address aging or damaged infrastructure.
Lincoln Hills and Lincolnwood Drainage Study	35	8	The proposed project scores highly because it will affect a large service area and will identify improvements to reduce maintenance issues. It scores low because it is not within a disadvantaged community and is not being coordinated with other infrastructure projects.
Majestic Drive Drainage Plan	31	9	The proposed project scores highly because it can be coordinated with redevelopment in the area. It scores low because it does not provide water quality features, doesn't significantly mitigate the risk to public health and safety, and is not within a disadvantaged community.
Missoula Public Library Living Roof	31	9	The proposed project scores highly because it provides localized water quality treatment and uses green infrastructure to improve resilience to climate change. It scores low because it does little to mitigate the risk to public health the safety, will require significant maintenance compared to current conditions, and is not coordinated with other infrastructure projects.

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Table 3-B-2: Project Scoring Summary

Criterion	Weighting Factor	High Park Drainage Improvements		Whippoorwill Drive Outfall Improvements		South 4th Street Clark Fork Outfall Water Quality Improvements		Grant Creek Levee Maintenance	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Public Health and Safety	6	3	18	2	12	2	12	3	18
Water Quality Benefits	5	3	15	3	15	3	15	2	10
Operations and Maintenance	4	3	12	1	4	1	4	2	8
Coordination with other Infrastructure Projects	3	1	3	3	9	3	9	1	3
Climate and Resilience	2	2	4	2	4	2	4	1	2
Equity	1	1	1	1	1	1	1	1	1
TOTAL			**53**		**45**		**45**		**42**

Criterion	Weighting Factor	Fox Site Orange Street Outfall Repair		Reserve Street Stormwater Treatment		Bess Reed Park Stormwater Treatment		Lincoln Hills and Lincolnwood Drainage Study	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Public Health and Safety	6	2	12	2	12	1	6	2	12
Water Quality Benefits	5	1	5	3	15	3	15	1	5
Operations and Maintenance	4	3	12	1	4	1	4	2	8
Coordination with other Infrastructure Projects	3	1	3	1	3	1	3	1	3
Climate and Resilience	2	2	4	1	2	3	6	3	6
Equity	1	3	3	3	3	3	3	1	1
TOTAL			**39**		**39**		**37**		**35**

Criterion	Weighting Factor	Majestic Drive Drainage Plan		Missoula Library Living Roof	
		Raw Score	Weighted Score	Raw Score	Weighted Score
Public Health and Safety	6	1	6	1	6
Water Quality Benefits	5	1	5	2	10
Operations and Maintenance	4	2	8	1	4
Coordination with other Infrastructure Projects	3	3	9	1	3
Climate and Resilience	2	1	2	3	6
Equity	1	1	1	2	2
TOTAL			**31**		**31**

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Appendix 3-C: Project Conceptual Cost Estimates

Appendix 3-D: 2014 Stormwater Sampling Data

Storm Water Sampling

Buckhouse Bridge Outfall (001A)

	Median Concentrations / Desired Range / Standard Value	January 1 - June 30, 2007	October 19, 2007	June 11, 2008	November 7, 2008	June 15, 2009	December 16, 2009	May 27, 2010	October 4, 2010	June 29, 2011	November 14, 2011	June 26, 2012	October 28, 2012	June 13, 2013	November 6, 2013 (~100 gpm)	Average	Median	Max	Removal	% Removal
Total Suspended Solids (mg/L)	125	No Sample	216	28.450	120.500	20.600	448.300	265.600	258.100	176.80	190.50	26.30	115.20	138.00	87.8	160.93	138.00	448.30	323.30	72%
Chemical Oxygen Demand (mg/L)	80		201	6.300	149.000	81.600	387.600	190.600	226.100	214.80	81.20	19.05	123.08	259.30	154.9	161.12	154.90	387.60	307.60	79%
Total Phosphorus (mg/L)	0.41		0.49	0.085	0.277	0.229	0.600	0.334	0.554	0.74	0.27	0.07	0.26	0.57	0.38	0.37	0.33	0.74	0.33	45%
Total Nitrogen (mg/L)	2		2.44	0.352	2.552	2.918	7.580	2.262	3.945	5.58	2.30	2.17	2.13	5.81	3.5	3.35	2.55	7.58	5.58	74%
Copper (mg/L)	0.04		0.04	ND	0.02	ND	0.06	0.03	0.043	0.018	0.018	0.0033	0.022	0.0264	0.0227	0.03	0.02	0.06	NA	
Lead (mg/L)	0.165		0.02	ND	0.01	ND	0.03	0.02	0.023	0.004	0.008	0.00147	0.0175	0.0150	0.00714	0.01	0.02	0.03	NA	
Zinc (mg/L)	0.21		0.29	0.04	0.18	0.17	0.44	0.23	0.283	0.090	0.123	0.013	0.162	0.191	0.219	0.19	0.18	0.44	NA	
pH (standard units)	6 - 9		7.473	7.534	7.709	7.600	8.090	7.777	7.750	8.00	6.440	7.280	7.980	8.10	7.08	7.60	7.71	8.10	NA	
Oil and Grease (mg/L)	10		26.4	3.350	15.770	2.360	8.400	9.770	3.710	3.150	4.980	1.54	5.060	10.66	5.54	7.75	5.06	26.40	NA	

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CHAPTER 4 STORMWATER QUALITY RECOMMENDATIONS

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CHAPTER 4 STORMWATER QUALITY RECOMMENDATIONS

The City of Missoula is committed to protecting natural resources. The Mission Statement of the City of Missoula Stormwater Utility states that *the Stormwater Utility is committed to protecting public health and safety, natural resources, waterways, and our aquifer, while meeting or exceeding state and federal environmental quality regulations.* In addition, the City of Missoula has adopted the Climate Action & Resiliency Implementation Resolution, which promotes contributing to a healthy, clean environment. Chapter 4 - Stormwater Quality Recommendations informs the City of Missoula of stormwater quality opportunities to allow the City to align with their Missions and Resolutions of a clean, healthy environment. Many of the concepts presented here reflect strategies other communities have already implemented. Should the City elect to carry forward with any of these recommendations, then additional assessment may be warranted to refine these recommendations to best fit the needs of the City of Missoula.

The content of this chapter provides the City with many tools to consider. Included throughout this chapter is background information on Missoula's stormwater system, recommendations for planning & collaboration efforts, stormwater management recommendations, and research and recommendations related to stormwater infiltration. Additionally, the final section of this chapter suggests options for retrofitting existing infrastructure types to add water quality features. On September 4, 2024, the content of this chapter was presented to a group of stakeholders. The purpose of this stakeholder meeting was to get considerations from other groups with interest in stormwater quality. Representatives from several City of Missoula sectors were present, including the stormwater utility, public works, streets, and parks and recreation. External representatives from the University of Montana and Missoula Valley Water Quality District were also present. Discussions focused on the importance of maintenance in stormwater infrastructure, a lack of resources to implement a robust maintenance program, and importance of emergency response and data collection to understand potential impacts to aquifer quality. Other topics related to the water quality recommendations presented were also discussed. Some recommendations in this chapter were added as a result of the feedback received at the stakeholder meeting.

4.1. BACKGROUND

Regulations to protect surface and groundwater quality are ever evolving. In anticipation of more stringent requirements on stormwater quality, this report outlines potential actions and retrofits that can be completed to progress towards local standards to guide water quality features in stormwater discharge.

The purpose of this chapter is to outline a catalog of possible water quality protection measures that may be reviewed and implemented by the City of Missoula. The measures recommended here can be tailored to fit the City's needs and vision for protection of surface and groundwater quality.

The City of Missoula operates a Municipal Separate Storm Sewer System (MS4), permitted under the Montana Pollutant Discharge Elimination System (MPDES) and administered by the Montana Department of Environmental Quality (DEQ). The Missoula MS4 permit is reissued on a five-year cycle. The current permit no. MTR040007 expires March 31, 2027. The City is responsible for managing the quantity, quality, and routing of stormwater and must report to the DEQ annually on permit requirements. These permit requirements include public outreach and education, illicit discharge elimination, construction site management, post construction management, and pollution prevention.

There are nine sub-watersheds that intersect the City of Missoula: Pattee Creek, La Valle Creek, Grant Creek, Butler Creek, O'Keefe Creek, Rattlesnake Creek, Miller Creek, Bitterroot River and Clark Fork River. Within these sub-watersheds, 92 outfalls discharge stormwater to one of nine waterbodies: five streams, three irrigation ditches, and one unnamed drainage. Under the General Permit for Small MS4's, the Storm Utility is required to manage discharge of pollutants of concern and ensure stormwater will not cause or contribute to instream exceedances of water quality standards. The MDEQ has assigned some wasteload allocations (WLAs) to the City's MS4, which ensure that water quality based effluent limits for point source discharges will be protective of the designated use of waterbodies. The WLAs include:

- Lead and temperature in the Bitterroot River
- Sediment and temperature in Miller Creek
- Nutrient and metals in Clark Fork
- Nutrient, sediment, and temperature in Grant Creek

The City Storm Utility has developed a Stormwater Sampling Plan to comply with permitting requirements. This sampling plan includes six monitoring locations, five at storm outfalls and one upstream of the MS4 on the Clark Fork. Sampling results monitor for permit compliance and performance of existing green infrastructure including sediment settling ponds, detention basins, hydrodynamic separators, and swales. Sampling occurs for measurable rain events with a minimum frequency of twice per site per year. As reported to MDEQ in the Stormwater Annual Report for 2021, water quality sampling data generally showed a decrease in nutrients and sediment downstream of green infrastructure.

In addition to stormwater outfalls to surface water, City of Missoula stormwater infrastructure is mostly comprised of Class V injection wells (commonly referred to as drywells or sumps), which allow for subsurface infiltration and aquifer recharge. According to the City of Missoula Stormwater Management Plan, there are approximately 5,100 city-owned drywells of the 8,000 total drywells inventoried within City limits. Stormwater and nearby surface waters provide recharge to the unconfined Missoula Valley Aquifer, which is designated as a "Sole Source Aquifer" by the EPA due to the population's reliance on the aquifer for drinking water.

Recharge occurs as surface waters and injected stormwater percolate through the vadose zone, which is the subsurface layer between the land surface and the saturated zone of the water table. The Missoula

Valley floor is mainly comprised of alluvial sands and gravels deposited from Glacial Lake Missoula. The geology of the Missoula Valley allows for unusually high percolation rates between 10 inches per hour and 430 inches per hour as tested by the City. For perspective, Montana DEQ standard percolation rate for design of infiltration structures in gravelly soils is 2-3 inches/hour, as outlined in Circular 8, Montana Standards for Subdivision Stormwater Drainage. Although there is currently no regulation or concern for the quality of the aquifer, the Utility aims to be preventative and vigilant in discharge to groundwater.

The US EPA maintains oversight of Underground Injection Control (UIC) usage by requiring inventory record of each Class V injection well. Class V wells, which inject non-hazardous fluids, are exempt from being permitted under Federal UIC regulations but are regulated under the Safe Drinking Water Act. Implementation of further regulations for drywell use falls upon local jurisdictions or regional water quality districts. Many states such as Oregon and Washington have implemented regulations governing the use of infiltration facilities under the Safe Drinking Water Act. Such local regulations often include siting and construction criteria, pretreatment for areas with a sensitive aquifer or areas likely to generate pollutants and permitted approval with the State program inventory. The State of Montana does not have general standards governing the use of drywells.

4.2. PLANNING AND COLLABORATION RECOMMENDATIONS

The following recommendations are provided as a catalog of potential opportunities the City could implement in the pursuit of stormwater planning and information gathering. These planning recommendations focus on information that would help the stormwater utility be prepared as regulations change and provide data that can inform and serve as a basis for future stormwater implementation projects. The provided recommendations are meant to inspire consideration of how they might be implemented and customized to suit the City of Missoula. Due to the broad nature of these recommendations, responsibility may not fall on the City as an entity alone, but this catalog may serve as a starting point for discussion and identification of goals related to water quality.

4.2.1 Source Water Protection Planning and Spill Response	4.2.2 Refine Hazardous Waste Routing	4.2.3 Groundwater Monitoring Frequency
Update Missoula's Source Water Delineation and Assessment Report (2015) and add emergency response planning	Assess routing, signage, and emergency response for hazardous transport through Missoula.	Consider increasing frequency of groundwater quality monitoring to have data for each season.

4.2.4 Urban Watershed Stormwater and Restoration Plan	4.2.3 Chemical De-Icer Usage Monitoring	4.2.4 Aquifer Quality and Recharge Analysis
Assess condition of existing resources and plan water quality improvements on a watershed scale.	Practice source reduction for chloride and salt applications due to difficulty in removal and treatment.	Assessment on current condition of aquifer and recharge sources.

Montana Bureau of Mines and Geology administers the Ground Water Investigation Program (GWIP) established in 2009 by Legislature via House Bill 52. This program applies scientific research to answer the most urgent water issues in Montana. The program requires a project sponsor to prepare and submit a competitive application that is ranked and selected. The project is completed at no cost to the project sponsor over a period of 2-4 years. This program may be useful in providing resources to complete some of the following recommendations.

4.2.1. Source Water Protection Planning & Spill Response

Studies have shown that infiltration rates in Missoula are rapid with one study measuring stormwater that enters a 50-foot vadose zone reaching the aquifer in as little as one hour (Woessner, 2010). The vadose zone mapped in the Woessner study has the most depth in the eastern portion of the Missoula Valley below Mount Sentinel and has the least depth to the west, reducing to below 10 feet near the Bitterroot and Clark Fork confluence. This information suggests that even a rapid emergency response to an illicit discharge of impacted stormwater or chemical spill to the vadose zone will be mostly ineffective. It is probable that groundwater quality impacts from pollutants would immediately occur; however, the extent of the negative impacts is hard to define without further definition of the aquifer size, movement, and recharge characteristics as it relates to pollutant spills. According to the 2023/2024 Annual Water Quality Report, the City of Missoula has not detected pollutant concentrations that exceed drinking water standards.

A Source Water Delineation and Assessment report was completed for Missoula Water (formerly Mountain Water Company) in 2015. This report includes identification of potential threats to groundwater, delineating protection areas, outlines the existing water resources and drinking water distribution system, and historical groundwater quality and characteristics.

Regarding stormwater, the Missoula source water delineation and assessment report references the 1988 groundwater study by Wogsland and states:

> "Even with source control, storm water will likely cause general degradation of water quality over time, reduced attenuation in the vadose zone, and increased levels of metals and major cations and anions. There may also be acute risks from spills and releases into storm drains and injection wells in close proximity to drinking water wells. Injection wells within 500 feet of MWC wells will be considered a high risk."

The report completed a susceptibility assessment of the drinking water system using sensitivity and potential hazard parameters recommended by Montana DEQ. Due to the unconfined alluvial aquifer characteristics, all public water supply wells are considered to have high source water sensitivity. Due to proximity to sewered and non-sewered residences, nearly all wells have a high hazard rating. Nearly all drinking water wells are of the maximum susceptibility ratings outlined by Montana DEQ.

Stormwater is not included in the MDEQ hazard rating; however, the Missoula source water delineation and assessment report considers wells within 500 feet of stormwater injection wells to be considered high hazard due to potential impacts. The report states, "Storm water can be a significant source of chemical and biological contaminants if discharged directly underground. There are two concerns with storm water injection wells: the first is the potential for accidental releases to be directly injected into the subsurface; and the second is the more chronic concern of the runoff from impervious surfaces that contains low levels of organics, metals, and inorganic nutrients." The report acknowledges the lack of information regarding impacts from stormwater injection and concludes that the drinking water system is highly susceptible to contamination.

To ensure all measures have been taken to reduce system susceptibility, next steps may include updating the 2015 Missoula source water delineation and assessment report. Additionally, the source water protection plan update may include developing new standards, emergency action planning, and planning the implementation of emergency protective actions. Emergency actions may include identifying personnel, steps for shutting down well pumps and isolating contaminated water that may have entered the system during a pollutant spill.

4.2.2. Refine Hazardous Waste Routing

Due to the vadose zone characteristics and high susceptibility of drinking water wells as identified in the 2015 Source Water Assessment, a hazardous waste spill that enters a stormwater drywell would have enter the vadose zone very quickly. Currently, the Missoula Municipal Code includes the following ordinance on hazardous substance transport per Chapter 13.26.091: "U.S. Highway 93 and Interstate Highway 90 shall serve as the principal North-South and East-West Hazardous Waste transportation routes in the Missoula Valley. The City of Missoula must provide adequate signing to indicate location of the routes to persons who transport Hazardous Waste through the valley."

A refinement of hazardous waste routing strategies may include assessing the route in more detail, adding signage, and evaluating stormwater infrastructure along each route. It may be beneficial to identify the most susceptible areas along the route, where is the discharge point, and what actions should be taken upon detection of a spill. This recommendation was added based on feedback provided during the stakeholder meeting.

4.2.3. Groundwater Monitoring Frequency

Currently, the Missoula Valley Water Quality District performs groundwater sampling and monitoring of aquifer water quality. Monitoring occurs once per year. Due to the fluctuation in groundwater movement and water quality throughout the year, it should be considered to increase sampling to a monthly basis, for at least one concurrent year. Having monitoring results for each month can further provide a basis for demonstrating whether there are concerning impacts occurring from stormwater runoff or other sources. To further develop information on the impacts of stormwater specifically, monitoring through the winter months is imperative. A likely conclusion may be that there are measurable impacts occurring, but at negligible levels below any drinking water contamination limits. Having a complete picture of groundwater quality trends can help demonstrate the extents or deficiency of aquifer impacts occurring from stormwater. This recommendation was added based on feedback provided during the stakeholder meeting.

4.2.4. Urban Watershed Stormwater and Restoration Plan

A small-scale watershed analysis allows assessment of water quality improvement and restoration potential in Missoula's stormwater system and urban streams. A watershed plan may involve prioritizing watersheds based on highest need for quality improvements and developing a restoration plan that includes several elements and analyses the system throughout that overall watershed. The plan may include stormwater infrastructure retrofits to provide improved quality, such as those identified in this report. Additionally, specific actions may be identified such as riparian area restoration, parking lot retrofits to include green infrastructure, and public lands that may be ideal for stormwater quality features.

A great resource for developing an urban watershed plan is provided by the Center for Watershed Protection Online Watershed Library. The Urban Subwatershed Restoration Manual provides thorough guidance on creating and implementing a restoration plan to improve water quality on a larger scale.

4.2.5. Chemical De-Icer Usage Monitoring

Case studies specific to Missoula suggest that stormwater generated during the summer period is commonly characterized by low concentrations of major ions and minor constituents. In contrast, winter runoff has significantly higher value of major and minor constituents with their composition reflecting street de-icers. The percolation of stormwater through the thick vadose zone dominated by sand, gravel, pebbles and boulders is rapid and has little measurable capacity to reduce major chemical components (Woessner, 2010).

Currently, no stormwater treatment systems exist that capture and retain salts or chlorides. Chlorides in stormwater runoff are primarily associated with street de-icers. Chlorides and salts from snowmelt and roadway runoff are discharged in stormwater to a surface water outfall or wash through the vadose zone, eventually reaching groundwater. Chlorides have the potential to increase the mobility and toxicity of metals that are also present in runoff. In high concentration, chlorides can be harmful to vegetation, wildlife, and aquatic life, and corrode metal and concrete.

During discussions at the stakeholder meeting, the Missoula Valley Water Quality District reported increasing trends of chloride concentrations present in the aquifer as determined by their groundwater monitoring. Although it is reported that chloride concentrations are frequently well below the secondary maximum contaminant limit (MCL) set by the DEQ for drinking water, trending concentrations of chlorides may justify the need to better understand what impacts of chloride may be in the future, or for downstream water users. This topic generated much discussion at the stakeholder meeting, emphasizing the importance of understanding the potential impact of chlorides.

Because of the difficulty to remove chlorides from runoff via treatment, source reduction and limiting chloride use is critical to controlling the concentrations of chloride that reach surface and groundwaters. The City should continue monitoring street de-icer use, including the variations in liquid deicer and salt compositions, locations and volumes of applications, potential alternatives to chemical de-icer, and identification of which municipal wells are most likely to be impacted. The City of Missoula Municipal Code outlines an approval process and chemical breakdown for de-icer prior to use. This code also outlines recommended usage and procedures.

4.2.6. Aquifer Quality and Recharge Analysis

Knowing that location and sources contributing to aquifer recharge is important with monitoring groundwater and drinking water quality. Local Groundwater Protection Approaches, completed by Fox in 1992, summarizes data collected in regard to the Missoula Valley Aquifer function. The paper reports that the Clark Fork accounts for an estimated 77% of total aquifer recharge, with other recharge sources including irrigation seepage (3%), stormwater (<1%), and other streams. Aquifer discharge contributes to river baseflow, pumping wells, and evapotranspiration.

The study also reports that recharge to the aquifer is estimated to be 15 times greater than the amount of water withdrawn. This, combined with the high hydraulic conductivity of overlying soils, results in a diluting effect for pollutants that reach the aquifer. This effect is beneficial to maintain low concentrations of pollutants, but the aquifer quality should be closely monitored. Changes in recharge source and pollutant concentration can compromise the quality and health of the aquifer.

A new study of recharge, withdrawal, current state of pollutant concentration, and groundwater depth and flow paths may be a beneficial tool to educate on water quality and monitor progress and prioritization of new water quality standards. An updated study of aquifer quality and recharge would provide a resource on the current condition of the drinking water source and identify any changes to contributing recharge and quality.

During the stakeholder meeting, a suggestion was made to include emphasis on development of a current groundwater model. A model of the Missoula Aquifer can be useful to better characterize, monitor, and predict conditions of the aquifer. The development of a groundwater model for Missoula would be beneficial in ensuring overall aquifer health, covering more than just impacts from stormwater.

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4.3. STORMWATER MANAGEMENT RECOMMENDATIONS

The following recommendations are provided as a catalog of potential opportunities the City could implement as part of their stormwater management practices. Some of these strategies may not be applicable for the City to implement at this moment, but are included to inspire forethought and provide options. The provided recommendations are broad and should be detailed and customized to suit the City of Missoula prior to implementation. This catalog of recommendations may serve as a starting point for discussion and identification of goals related to water quality.

4.3.1 Publication of Emerging Guidance	4.3.2 Redevelopment Fee-in-Lieu	4.3.3 Use of Geotextile Fabric	4.3.4 Pollutant Loading Analysis Standard Procedure
Develop design standards, resources, and BPMs to be offered as guidance to planner and designers.	Waive stormwater quality requirements for redevelopment projects in exchange for fee to be used for other stormwater quality projects.	Increase the use of geotextile fabric to extend the life of stormwater infrastructure.	Develop a standard procedure to assess pollutant loading.

4.3.5 Integrated Projects	4.3.6 Prohibited Discharge to Infiltration	4.3.6 Benefit-Cost Analysis
Retrofit existing open space to incorporate stormwater quality improvements	Require stormwater from certain facilities to be treated with a closed loop system.	Assess BMPs and maintenance needs to determine cost of implementation and manitnenace, versus water qaulity benefit.

4.3.1. Publication of Emerging Guidance

The process of implementing new regulations and design guidance can be lengthy. The Stormwater Utility may develop or identify new design standards, resources, or best practices. Often, new regulations cannot be incorporated into the design standards or City Code until thorough review and approval. In the meantime, resources and design guidelines may be published as "emerging guidance." This will give planners and designers a chance to become familiar with practices that may be incorporated into the design manual in the future. Emerging guidance can be offered as an additional resource that may be used by those implementing stormwater infrastructure in Missoula. Guidance could be offered as an appendix or add-on to the 2024 Missoula City Public Works Manual, with a disclaimer that the guidance is recommended, but not required.

4.3.2. Redevelopment Fee-in-Lieu

Infill and redevelopment projects provide an opportunity to achieve stormwater treatment where it previously did not exist. Due to the common characteristics of redevelopment projects, such as small size, higher compliance cost, and physical site restraints, it may be difficult to comply with more strict stormwater standards for new development. Special criteria can be created for redevelopment projects and a fee-in-lieu approach may be considered.

The concept of the fee-in-lieu approach is to waive stormwater quality requirements for the redevelopment project in exchange for a fee that is used to build or retrofit stormwater quality infrastructure elsewhere. This method may be beneficial for lower use developments that do not pose high threat to water quality or are in a watershed that already has downstream treatment. Fees could be used to implement treatment retrofits at high priority sites with greater threat to ground or surface water quality. The fee may be derived based on the cost to retrofit an equivalent area of impervious cover or average cost to remove a similar pollutant load. The City of Tacoma practices a similar approach which is further described in the City of Tacoma Regional Stormwater Facility Plan, chapter 4.

The appropriateness of this strategy for application with the current standards must be evaluated. Although this approach may not be suitable with current stormwater requirements, it is included to document potential options for the future.

4.3.3. Use of Geotextile Fabric

Geotextile is often specified for underground detention or infiltration systems. According to an article titled "Filter Fabric in Detention and Infiltration Systems" by Caitlyn Saranchak, PE, the geotextile fabric acts as a barrier between surrounding soils, preventing fine sediment particles from entering void spaces in the aggregate backfill while allowing water to flow through. This separation is especially important where the infiltration system relies on the void space of the aggregate backfill for storage capacity. Lightweight geotextile should be used for separation of infiltration facilities, with medium and heavy weight fabric used for erosion and stabilization applications. Woven geotextile is more commonly used for roadway designs and erosion control. Non-woven geotextile is more commonly used for underground detention and infiltration facilities.

Adding a geotextile barrier around an infiltration system to separate the clean aggregate and the native backfill will prolong the life of the system by preserving the void spaces for water storage and preventing settlement due to migration of fines from the natural backfill surrounding the structure. The use of geotextile is standard practice, and is recommended in numerous design guidelines for drywells and infiltration facilities such as the Minnesota Stormwater Manual. The City of Missoula currently requires fabric surrounding drywells and aggregate on the sides only, which is the same practice implemented by the Minnesota Stormwater Manual.

4.3.4. Pollutant Loading Analysis Standard Procedure

The City may choose to develop a procedure for pollutant loading analysis which designers and developers would use for approval of low-impact development. A pollutant loading analysis is a calculation of stormwater quality based on land use and removal efficiencies of Low Impact Development (LID) methods. This analysis can compare pre-development and post-development pollutant loading to provide a standardized analysis of water quality that can demonstrate reduction of non-point source pollutant loads with actual calculations.

Developing a standard procedure may involve:

- Sourced pollutant removal efficiencies for LID infrastructure based on case studies
- Developing typical pollutant concentration based on land use
- Identifying required minimum pollutant removal efficiencies per pollutant type
- Summarized equations and processes for calculation methodology

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A “Simple Method” formula for completing a pollutant analysis was developed by Tom Schueler (1987). Further methodology, specifically for LID treatment methods placed in series, has been developed by Steven Trinkaus and published in several papers hosted by American Society of Civil Engineers (ASCE).

4.3.5. Integrated Projects

A wholistic view of surface and groundwater quality requires taking a step back to view the entirety of the watershed as opposed to at outfalls or failing infrastructure only. Knowing the delineated catchment area of each urban watershed can help identify areas that would maximize water quality improvements and minimize cost and site requirements. Watersheds with high retrofit potential may have low impervious cover rates, high density of stormwater ponds, open stream corridors, and publicly owned land.

Big picture projects can include a series of water quality treatments, big or small, that can impact the watershed as a whole and benefit the community. Parks and playgrounds are commonly retrofitted to include stormwater quality treatment as they have high visibility, dedicated open space, and provide both recreational opportunities and water quality improvements. In large drainages, parks can be designed to flood during high runoff events and have dry or little baseflows during most of the time.

Stormwater parks and integrated stormwater facilities provide water quality improvements, resiliency to climate change, recreational opportunities, and benefit habitat. The City of Seattle retrofitted a local detention basin after a large stormwater flood damaged many nearby homes. The Madison Valley Stormwater Park, taking up half of a city block, provides detention space for when downstream stormwater infrastructure is inundated. Most of the time, the park is an open space for community members to recreate and enjoy. The park and downgradient infrastructure has capacity for up to a 150-year flood event.

Figure 4-1: Madison Valley Stormwater Park, Seattle, WA

An interdisciplinary approach to planning big picture projects is necessary to ensure success. Alongside the Public Works and Stormwater team, other representatives from Parks and Recreation, natural resources, community planning, transportation, and community engagement should have the opportunity to weigh in on the prospect.

Integrated big picture projects are strong candidates for grant funding. Prior to applying for funding, effort should be put in to analyze the watershed, contributing area, water quality event, site constraints, and other key elements that could impact feasibility and cost.

4.3.6. Prohibited Discharge to Infiltration

Some contaminants are not easily removed from stormwater with standard treatment BMPs. To protect groundwater quality in the most vulnerable locations, the City may choose to prohibit use of infiltration facilities that are proposed for specific land uses. Stormwater from a facility subject to a prohibited activity must be handled on a closed loop treatment system.

The following list contains example activities compiled from similar cities that may be prohibited from discharging runoff to infiltration facilities:

- Vehicle maintenance, repair, servicing
- Commercial or fleet vehicle washing
- Airport de-icing
- Storage of treated lumber
- Storage or handing of hazardous materials
- Generation, storage, transfer, treatment, or disposal of hazardous wastes
- Handling of radioactive materials
- Solid waste handling, recycling, or composting
- Concrete or asphalt recycling
- Industrial or commercial areas without management plans for proper storage and spill prevention.
- High ADT intersections

4.3.7. Benefit-Cost Analysis of Recommended BMPs

Stormwater treatment BMPs vary in maintenance requirements, water quality benefit, and installation cost. Prior to making a recommendation on BMPs for specific sites, the City may consider assessing the benefits and cost of specific BMPs to determine if the cost of installation and maintenance is providing enough long-term value to justify implementation. A similar analysis may be completed for potential incentive programs to determine if residential runoff reduction will amount to a sufficient cost reduction that would allow an incentive to be distributed.

For example, streetside bio-swales may be analyzed in their cost of installation and maintenance, as well as frequency of maintenance. This value can be compared over the anticipated life of the structure to estimated water quality benefits. Prior to initiating the analysis, an outline should be developed to determine what BMPs should be assessed, what criteria should be considered, and how water quality benefits will be quantified. Upon completion of this analysis, the City will have guidance on what BMPs provide the best water quality improvement for the lowest cost. This recommendation was added based on feedback provided during the stakeholder meeting.

4.4. STORMWATER INFILTRATION: RESEARCH AND RECOMMENDATIONS

With injection wells being used to control a large portion of stormwater runoff in Missoula, a better understanding of potential impacts from infiltrating stormwater will aid in making decisions regarding stormwater standards enforced by the City and prepare the City and stormwater utility for any potential federal regulations that may impact stormwater discharge to groundwater. This section includes a literature review to outline studies performed about stormwater infiltration in Missoula, a summary of cities with similar geology and means of discharging stormwater through infiltration, and a catalog of potential options should the City implement a pretreatment requirement for stormwater infiltration dry wells.

4.4.1 Literature Review	4.4.2 Infiltration in Other Municipalities	4.4.3 Pretreatment for Infiltration	4.4.4 Future Considerations for Stormwater Management in Missoula
Summary of case studies in Missoula regarding stormwater infiltration	Discussion of cities with similar geology and means of stormwater infiltration	Discussion of pretreatment benefits and potential framework criteria	Strategy for future development and protecting groundwater quality.

4.4.1. Literature Review

A literature review was conducted to provide greater understanding of infiltration and groundwater characteristics in the Missoula area. Two studies were assessed and summarized below. Both studies were completed in the Missoula Valley regarding stormwater infiltration and potential impacts to groundwater quality.

A main conclusion from the assessed studies is that stormwater infiltration has potential to degrade the aquifer quality, but observed concentration of pollutants in runoff are typically lower than maximum contaminant levels (MCLs) for drinking water. Additionally, the contribution to aquifer recharge from stormwater is relatively low and is further diluted due to consistent recharge of the aquifer from other sources. According to these studies, residential areas show no measurable change in groundwater quality. In commercial areas, observed changes in major ion chemistry were likely the result of winter deicer use.

A 1988 study titled "Effect of urban storm water injection by Class V wells on the Missoula Aquifer" by Wogsland concluded that over the one-year monitoring period, the vadose zone in Missoula was successful at attenuating metal concentrations, which were frequently detected pollutant in stormwater runoff samples. The greatest pollutant concentrations detected in runoff included total dissolved solids (TDS) and chloride. Additionally, sodium concentrations exceeded the maximum contaminant levels in snowmelt only. The study measured at two depths within the vadose zone and found that the vadose zone was not successful in attenuating ion and TDS concentrations after a storm. These results suggest that infiltration through drywells may increase concentrations of particulates and salts in groundwater.

The author suggests pretreatment be implemented to capture pollutants from runoff prior to entering drywells.

A 2010 study titled "Coarse-Grained Vadose Zone Impacts on Mountain Basin Groundwater Recharge" by Woessner found that percolation rates throughout the five monitoring sites included in the study varied from a 36 inches per hour to over 108 inches per hour. In settings with a 50 ft vadose zone, the first arrival of stormwater observed after controlled tracer tests was as soon as 1 hour. The results concluded that low concentrations of major ions are present in summer runoff. In contrast, winter runoff contained much higher concentrations of pollutants that reflect the composition of street deicers. Due to rapid percolation, large particle size, the vadose zone was determined to have little measurable capacity to reduce pollutant concentrations. It was concluded that the vadose zone has limited capacity to partially remove trace quantities of metals and organic compounds, yet the vadose zone may also store and release dissolved ions. Although no direct water quality impacts to the aquifer were observed related to stormwater, the author recommends monitoring usage of street deicers and identifying municipal wells that may be impacted, considering implementation of multi-chambered storm systems (ie. settling chamber/catch basin), further investigating vadose zone properties, and continued monitoring of runoff quality.

Woessner iterates the importance of having the capability and readiness to rapidly respond to chemical spills or impacted stormwater runoff. With such high infiltration rates in Missoula, water quality impacts after a spill will be almost immediate. Aquifer protection and response planning should include emergency measures to isolate and shut down public water supply if necessary.

4.4.2. Infiltration in Other Municipalities

An understanding of stormwater regulations in other municipalities provides insight to how their communities are addressing stormwater quality. This section identifies cities of similar size and geology for analysis of stormwater principles and practices. Specifically, infiltration and groundwater protection practices were researched and summarized below.

Many of the assessed communities are from the State of Washington, because this state has implemented further regulations under the Safe Drinking Water Act governing stormwater infiltration through Class V injection wells. The State of Washington Department of Ecology administers an underground injection control (UIC) facility program to permit and regulate discharges to groundwater in Washington State. The program implements strategic siting, design, and treatment requirements to reduce pollution of groundwater from stormwater discharge. Based on treatment capacity of the underlying soils and land use, pretreatment prior to infiltration is enforced for different pollutants. The UIC program and regulations are summarized in "Guidance for UIC Wells that Manage Stormwater" published by the Washington Department of Ecology. Under this general state guidance, UIC wells are required to be registered with the Department of Ecology and discharge must meet the "non-endangerment performance standard," which is based on the presence of source control methods to control pollutant loading, pretreatment features, and availability of vadose zone treatment capacity.

Tacoma, Washington

The City of Tacoma has a robust Stormwater Management Manual outlining urban watersheds, minimum requirements for design and construction, and a BMP Library. Their local standards are based on the Stormwater Management Manual for Western Washington. Pretreatment is required from a list of approved BMPS, included pre-settling basins, prior to any infiltration. Additionally, this manual defines basic treatment with a performance goal of 80% removal of total suspended solids. For solids concentrations less than 100 mg/l, the basic treatment BMP should achieve an effluent goal of 20 mg/l total suspended solids. Enhanced treatment is defined by an approved list of BMPs or two-series BMP train.

Tacoma is located above a sole source aquifer. Tacoma County Health Department has established a South Tacoma Groundwater Protection District (STGPD) that requires a permit and fee for infiltration within the district. Infiltration facilities within the district are required to meet regulations in the stormwater manual as well as additional regulations set by the groundwater protection district. All infiltration within the STGPD is required to provide basic treatment, or more enhanced treatment depending on land use. The design, permitting, and maintenance requirements for infiltration facilities are laid out clearly in a table included in the South Tacoma Groundwater Protection District Infiltration Policy (ESD17-1).

Vancouver, Washington

The City of Vancouver is located above the Troutdale Sole Source Aquifer. Vancouver has established the entire city as a Critical Aquifer Recharge Area (CARA) and established a Water Resources Protection Ordinance in the city code to protect the resource. The ordinance outlines designated protection areas, prohibitions, and allows discharge via infiltration if the stormwater pollutant concentrations that reach groundwater are not expected to exceed water quality standards for groundwater in the State of Washington. This practice is outlined in the statewide Guidance for UIC Wells that Manage Stormwater. Infiltration is approved using either a presumptive or demonstrative approach. For infiltration to be approved using a presumptive approach, the following criteria are outlined and must be addressed per the framework developed in the guidance document:

- The potential pollutant loading expected in the stormwater runoff
- Source control of pollutants
- Known treatment methods
- Siting
- Potential vadose zone treatment capacity
- Operations and maintenance

If no vadose zone treatment capacity exists, the presumptive approach cannot be used. Infiltration facilities must then be approved using the demonstrative approach, which includes site-specific analysis of pollutants, soils, and a technical basis of pollutant removal.

Spokane, Washington

The Spokane Valley-Rathdrum Prairie Aquifer is a sole-source aquifer providing drinking water for over 500,000 people. Critical aquifer recharge areas (CARA), and Aquifer Sensitive Areas (ASA), have been designated surrounding the Spokane Region. Within these delineated areas, and based on other applicability criteria such as distance to wells and ADT, all stormwater runoff from impervious surfaces must be treated with a basic treatment BMP that provides removal of total suspended solids. In urban areas, bio-infiltration swales are the expected BMP for providing basic stormwater quality treatment. Treatment of runoff must be effective by the time the runoff reaches the water table.

The basic level of water quality treatment is not required for projects located outside of the CARA nor those that are not proposing moderate/high-use or high ADT sites; however, pretreatment for sediment removal is required for all discharges to UIC for the purpose of operational benefits and maintaining infiltration rates. Further treatment of metals, oils, or phosphorus may be required based on land use. The applicability and design of infiltration facilities is outlined in the Spokane Regional Stormwater Manual.

Modesto, California

In Modesto, California, rockwells comprise over two-thirds of the stormwater system. A rockwell is a hole filled with aggregate connected to a catch basin and ranging from 20 to 75 feet in depth. The City requires pretreatment using grassy channels, vegetated buffer strips, vegetated swales, or other features to protect the rockwells and drywells from high sediment loads. According to the Modesto Storm Drainage Master Plan, the use of rockwell systems is highly dependent on preventative maintenance in order to maintain function. Due to their dependence on continual maintenance, rockwells are expensive to operate. A key goal of the Master Plan for Modesto is to create piped stormwater systems in areas that are currently served exclusively by rockwells.

Elk Grove, California

The City of Elk Grove completed the Dry Well Project, a study about the risks to groundwater quality associated with use of drywells in their community. The project was partially funded by a State grant and had a total cost of $850,000. The study was completed over a four-year period and included groundwater monitoring, vadose zone modeling, and assessment of regulations and literature to make an assessment of stormwater impacts to groundwater quality. The study resulted in documented findings and fact sheets on the City's experience with dry wells, lessons learned, and recommendations specific to the City of Elk Grove. The results of the project concluded that there was no evidence of drywells with pretreatment features (typically grassy swales) posing a threat to groundwater quality. The study found that 50-65% of sediments were removed by vegetated pretreatment features. The study resulted in recommendations related to drywell siting, design, monitoring, and maintenance.

4.4.3. Pretreatment for Stormwater Infiltration

This section provides information on common pretreatment standards and provides information to the City of consider when deciding if pretreatment should be a requirement prior to infiltration. Due to susceptibility of the sole source aquifer, additional treatment of stormwater prior to infiltration by drywells may be warranted.

The City of Missoula currently requires infiltration, evaporation, or reuse of the first half-inch of runoff for medium and high priority developments, as well as any low priority developments with more than one

Morrison Maierle

acre of land disturbance. Developments that cannot meet this requirement must provide treatment to remove 80% TSS before discharging to surface water.

The following recommendations are provided as a catalog of potential management strategies the City may consider for protecting groundwater quality. The provided recommendations were sourced from Washington State and other local jurisdictions stormwater guidance for siting criteria, suitability, and pretreatment for infiltration. These items are meant to inspire contemplation of how they might be implemented and customized to suit to the City of Missoula.

Pretreatment Applicability – Preservation of Flow Control vs Water Quality

In many cases, such as throughout the State of Washington, drywells may be classified with an objective of flow control and/or water quality, with respective pretreatment requirements for each. In Missoula, drywells are used primarily for flow control. For drywells that are installed with the purpose of flow control, pretreatment for sediment may be beneficial for operations and long-term maintenance of the structure. This may be completed by grassy swales, sediment settling chambers (two-stage drywells), or more complex BMPs such as bio infiltration basins that have proven removal rates.

One strategy that may be beneficial to implement is requiring sediment removal prior to infiltration via drywell. This would preserve infiltration rates and prolong the life of the drywell. Depending on the means for sediment removal, regular maintenance is likely needed to preserve the capacity for sediment removal. This strategy can be as simple as requiring the flow path to run through a grassy swale prior to entering the drywell, or a two stage drywell with a catch basin that doubles as a sedimentation well.

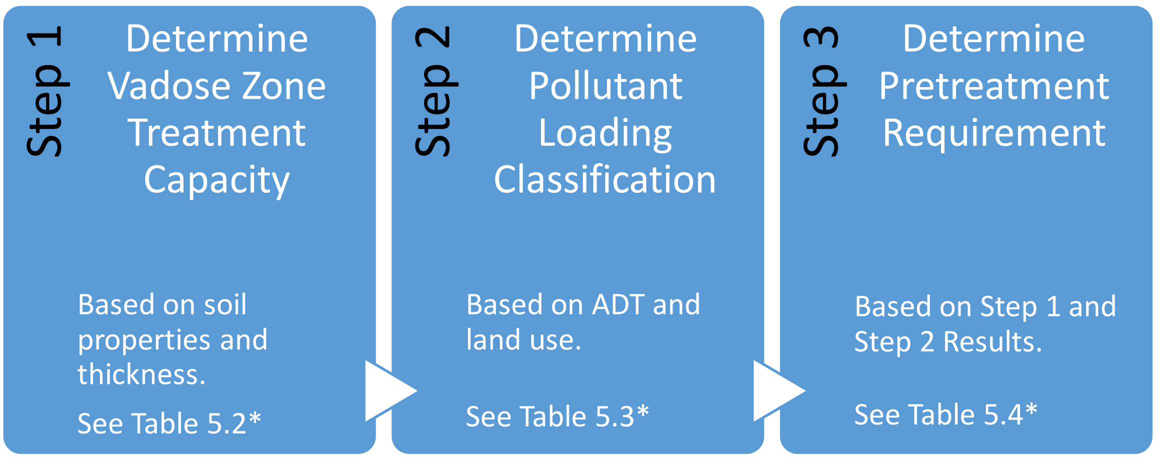
For drywells with an objective of water quality treatment, pretreatment to protect groundwater quality may include suitable BMPs that have demonstrated effectiveness against the target pollutants. For instance, some municipalities require pretreatment for all drywells with requirements based on overarching state groundwater quality standards that are based on drinking water standards. Other municipalities require pretreatment from an approved list of BMPs, or only for runoff that originates from high use sites that generate high concentrations of pollutants.

Pretreatment requirements should account for the most concerning and present pollutants that threaten the aquifer’s quality. Due to a lack of data and the difficulty to measure the effects of stormwater discharge on aquifer quality, implementing extensive regulations such as those in Washington may be unnecessary; however, further investigation of what pollutants may be threatening the aquifer would lead to an informed decision on when to require water quality treatment prior to infiltration.

Developing a Framework for Water Quality Pretreatment

Due to the geology of Missoula and the currently unknown capacity for stormwater to impact aquifer quality, the City may choose to explore a more robust framework for preserving water quality prior to infiltration. A pretreatment framework is most typically based on typical pollutant loaded based on land use, and underlying vadose zone qualities. Identifying locations that pose the highest threat to groundwater quality can form a framework for stormwater regulations that require pretreatment. If criteria were to be developed for Missoula, they should take into account specific characteristics of the Missoula valley such as aquifer recharge, sensitivity, and vadose characteristics.

The State of Washington uses a robust siting criteria approach to regulating UIC wells and water quality. The statewide guidance requires that all UIC wells used for flow control are required to have solids removed prior to discharge in order to preserve infiltration rates. Pretreatment for UIC wells to remove pollutants in order to preserve water quality is determined based on two parameters: vadose zone treatment capacity and pollutant loading. The process for determining pretreatment requirements as outlined in Guidance for UIC Wells that Manage Stormwater is pictured in Figure 2 and further described in this section.



*Refer to "Guidance for UIC Wells that Manage Stormwater" published by Washington State Department of Ecology, December 2006. Publication No. 05-10-067

Figure 4-2: Determining Pretreatment Requirements for UIC Wells in Washington

Existing UIC wells constructed prior to when this guidance was issued are exempt from the forementioned rules; however, all UIC wells constructed prior to February 2006 must undergo a well assessment and registration to determine if the well is a high threat to groundwater. If the existing well is considered high threat to groundwater, it must be retrofitted to protect groundwater quality. For preservation and maintenance projects, a UIC may be retrofitted or reconstructed in place without being considered a new well.

Several potential criteria related to delineating high-threat areas to groundwater quality are summarized in the following section. To be useful in Missoula, more information may be required to develop a reliable framework; however, the following criteria are described to showcase what a robust approach to stormwater quality regulation and groundwater protection may look like:

- Vadose Zone Treatment Capacity: Delineation of areas that provide treatment capacity within the vadose zone.
- Aquifer Sensitive Areas: Locations where the aquifer is sensitive to discharge based on geology, hydraulic conductivity, and depth to groundwater.
- Pollutant Generating Impervious Surfaces: Classification of land use with high traffic volume or likelihood of pollutants deposited and captured in stormwater runoff.

Vadose Zone Treatment Capacity

The Vadose zone is defined as the subsurface layer between the land surface and the saturated zone of the water table. The vadose zone may provide adequate filtration, adsorption, or other pollutant reduction capacity that eliminates the need for pretreatment of metals, solids, and oils. The City may develop a classification system for designers and developers to consider the treatment effectiveness of the vadose zone. For example, the state of Washington has developed a vadose zone classification system to classify the treatment capacity of the vadose zone based on several factors. Characteristics of a high treatment capacity vadose zone includes silty, poorly graded soils, a low hydraulic conductivity, and soil material with a relatively small grain size.

Areas that have a vadose zone with high treatment capacity can minimize groundwater separation and/or bypass pretreatment requirements.

Research by Woessner in the Missoula Valley shows that the siliceous nature of the sediment, the low organic carbon content, and the ion exchange capacity limits the ability of the vadose zone to remove pollutants found in stormwater runoff. Applicability of the vadose zone characteristics for Missoula should be investigated and considered for importance. Woessner states with his research “the relationship between infiltration rates and groundwater recharge rates is not straight forward, thus, under most circumstances, infiltration rates alone cannot be used to predict either percolation rates or the timing and volume of local groundwater recharge.” A more detailed analysis of vadose zone geochemistry is recommended to predict the composition of recharge entering groundwater beneath stormwater drywells.

Using the State of Washington’s vadose zone treatment capacity classification system, it is probable that the majority of Missoula overlays a vadose zone with low or zero treatment capacity. Characteristics of a vadose zone with low to zero treatment capacity may include a relatively large grain size, high hydraulic conductivity, and well-sorted gravel soils with minimal organic content. In areas that the Vadose of zero to low treatment capacity, pre-treatment facilities for stormwater infiltration structures may be necessary, and are required per State of Washington's Underground Injection Control program. Based on the estimated pollutant loading/land use, treatment requirements are a two-stage drywell with sedimentation well, solids removal, or oil removal.

Designation of Aquifer Sensitive Areas

Aquifer Sensitive Areas (ASAs), or Critical Aquifer Recharge Areas (CARAs) could be designated in Missoula to further inform the pretreatment framework and possibly restrict use of infiltration facilities without water quality pretreatment. The ASAs may be designated based on geologic conditions, adjacent land use and potential for contamination, depth to the aquifer, and wellhead protection areas.

Delineated ASAs for Missoula may include drinking water supply wells that are identified and mapped. The delineation may be made based on a buffer distance from each well, with higher priority given to high concentration of single household wells, multi-household supply wells, public water supply wells, or other prioritization criteria identified by the City.

The delineations should also account for soils, geology, and existing pollutant generating facilities. To determine the susceptibility of the aquifer and delineate ASAs, the City may choose to consult a hydrogeologist to assist in designating the most at-risk areas. Guidelines for designating and implementing Critical Aquifer Recharge Areas was published by the State of Washington Department of Ecology in March 2021.

Identification of Pollutant Generating Impervious Surfaces

Pollutant generating impervious surfaces (PGIS) are significant sources of pollutants in stormwater runoff. These areas include surfaces subject to traffic, industrial use, or storage and handing of potentially hazardous or erodible materials.

High-use sites generate high concentrations of oil due to high traffic or frequent transfer of petroleum products. Any site subject to above average vehicle traffic should be classified as a high-use site and PGIS. Other land uses may include:

- Gas stations
- Commercial or industrial sites subject to use, storage, or maintenance of a fleet of 25 or more vehicles
- Maintenance facilities for vehicles, aircrafts, construction equipment, rail equipment or industrial machinery or equipment
- Railroad yards
- Commercial parking lots
- Outdoor storage yards with frequent forklift or other hydraulic equipment use
- High-ADT roads or on-street parking areas.

For high vehicular use sites such as roads, parking lots, vehicle storage, commercial facilities, gas stations, and airport runways, it may be beneficial to require pretreatment specifically for oil separation.

The case studies presented in Section 4.4.1 suggest that although runoff is mostly dominated by roadway pollutants, little to no measurable change in groundwater quality was found in residential areas. In commercial areas, observed changed to groundwater chemistry were likely the result of winter deicer use. Retrofits and standards that apply to high-use vehicular areas may be the most appropriate and beneficial when considering the implementation of treatment practices.

Pretreatment BMP Options

Pretreatment prior to drywell infiltration can remove much of the sediments and other pollutants such as nutrients and metals that are suspended in stormwater runoff. The most effective pretreatment of stormwater runoff before entering a drywell to be infiltrated includes a series of features that act as a treatment train, such as a vegetated pretreatment feature and a structural pretreatment feature, before discharging to the drywell.

The vegetated pretreatment feature can be a bioretention basin, a rain garden, or simply a grassy swale. The vegetation filter collects stormwater runoff on the surface and filter out sand, gravel, debris, and suspended sediment before it reaches the structural element of the treatment train.

During the stakeholder meeting, design and construction considerations for vegetative features were discussed. The following items should be considered during design or development of a standard detail for a vegetative pretreatment feature:

- **Rim height:** The grated inlet that collects discharge should be elevated above finished grade to prevent impacts from sedimentation or vegetation over-growth.
- **Trees and vegetation:** Consider specifying adequate space for tree plantings within vegetated features. Consider specifying specific, hardy vegetation types that can survive without irrigation.
- **Concrete Apron:** For aprons where flow is directed through a curb cut, consider specifying the slope, foundation material, and connection joint to prevent impacts from sediment build up or settling.
- **Maintenance:** The design should consider maintenance access, safety, and frequency. Consider incorporating a forebay or sediment trap to capture particles and floatables for easy removal.

The structural pretreatment feature is most typically a sedimentation well that allows suspended solids to settle prior to discharging to the drywell for infiltration. This type of structure is also referred to as a two-stage drywell, with the first stage being the sedimentation well and the second stage being the drywell itself. The sedimentation wells should be deep to allow suspended sediment to settle. Stormwater regulations for Portland, Oregon and the State of Minnesota recommend 3-4 feet between sump invert and the pipe connection to the drywell. In some cases, Portland implements a catch basin followed by a sedimentation manhole, providing nearly a full standard manhole depth for sedimentation. The sedimentation well can have a grated inlet or beehive grate and provides an easy maintenance point for sediment cleanout. Capturing sediment in the sedimentation well will increase longevity and performance of the drywell infiltration.

The City of Missoula has a remote drywell standard construction detail (STD-617) that is a basic layout of a drywell with a structural pretreatment feature. Ideally, the catch basin that acts as the sedimentation well would provide at the maximum depth possible below the outlet pipe to provide maximum treatment potential and particle settling. A remote drywell, or a drywell with at least one form of pretreatment feature, structural or vegetation, could be implemented as the standard for new infiltration facilities if sediment pretreatment requirements were in effect. During the stakeholder meeting, the option of repurposing failed drywells as settling manholes for pretreatment was discussed. This may be a consideration where new drywells are added adjacent to failed drywells. The new drywell would be the flow control structure, and the existing, poorly performing drywell can be modified as needed to act as a settling manhole and provide structural pretreatment.

Another advantage of sedimentation manholes is their application in pollutant generating areas or areas at risk of hazardous spills that may enter the drywell. Valves or emergency shutoff measures may be enforced at high-risk locations to provide an emergency measure to prevent spills from reaching the drywell. Additionally, shut off valves can be employed during storm events that are anticipated to produce a high amount of sediment and debris that may clog the drywell.

4.4.4. Future Considerations for Stormwater Management in Missoula

As Missoula continues to grow and areas of the City are redeveloped, there is an opportunity to rethink and experiment on how stormwater is typically managed. Tom McCarthy, a founding partner of WGM group and former professional engineering consultant for the City of Missoula, has a unique suggestion for infiltration that is meant to align with the Missoula Valley's unique soil characteristics and high infiltration rates. His ideas, provided during a meeting with the City and Morrison-Maierle, are summarized here-in.

Currently, a typical stormwater system in Missoula includes drywells that infiltrate small to medium-sized runoff events and are disconnected from any conveyance system. Piped stormwater conveyances are sized to collect and carry large runoff events offsite and prevent flooding of nearby infrastructure. Due to more frequent small runoff events carrying the most concentrated runoff with pollutants and sediment, it is common to see the infiltration capacity of drywells decrease over time. Also, there is potential that the highly concentrated runoff is impacting the aquifer. Tom McCarthy suggests that to maintain the integrity of the soils and infiltration capacity, small runoff events should not be infiltrated. His concept involves conveying the first flush of runoff to a treatment facility through a piped system, while allowing larger storm events to infiltrate through a grid of perforated pipe. This system would ideally include a solid-bottom manhole, with a minimally sized conveyance pipe to collect the first flush. Larger events would fill the manhole, eventually entering the perforated pipe placed near the top of the structure. The perforated pipe grid would allow more surface area for infiltration capacity. A plan view and detail of this system are shown in Figure 4-3. Because the first flush of highly sedimented and polluted water is collected through the piped system, it is anticipated that the infiltration capacity of native soils will be better maintained. This system also provides greater mitigation against impacts to groundwater by collecting the first flush and any contaminant spills that may occur during dry weather.

The discussion around this concept focused on potential challenges such as maintenance, floating debris, cost, and implementation conflicts for such a large-scale system. These obstacles must be considered and tested. If the City would like to test this stormwater management system, a suggested path forward would include a pilot project in an area of new development.

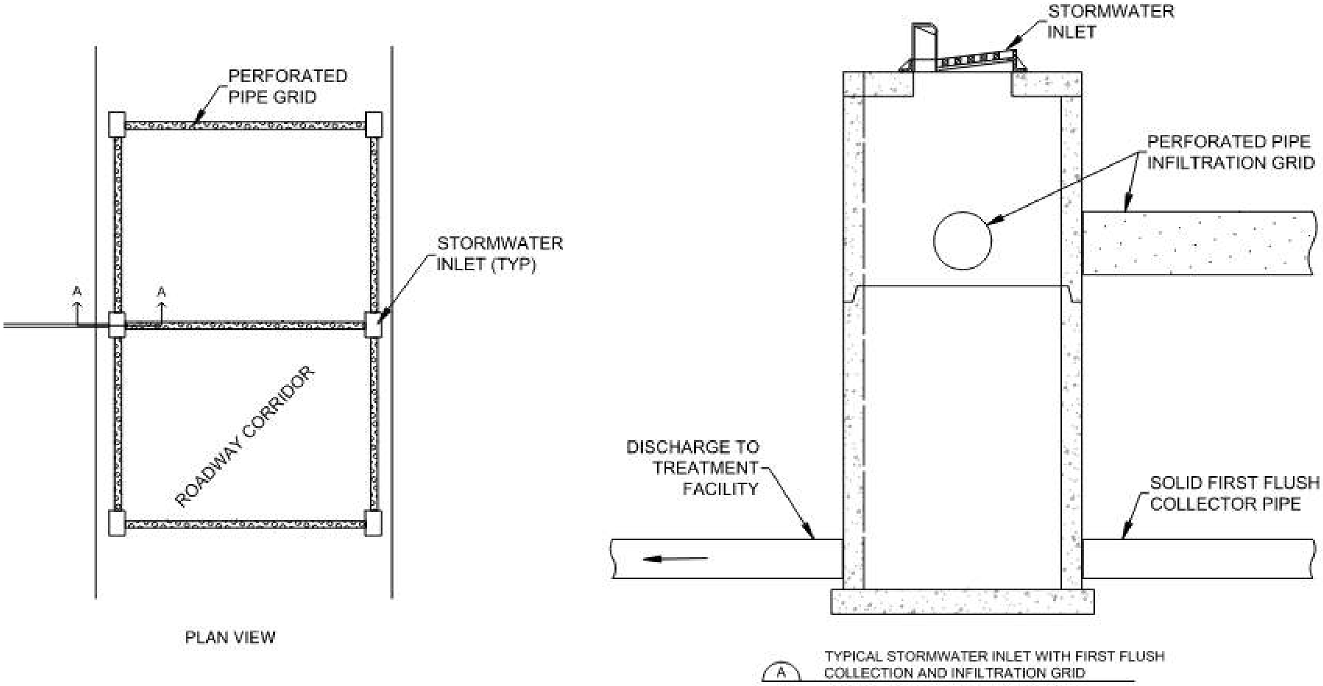


Figure 4-3: First Flush Collection System

4.5. LOOKING FORWARD – FEDERAL INPUT ON INJECTION WELLS

Regulations set forth by State and local governments are continually evolving to address impacts to natural resources from stormwater runoff. Impacts to surface water are scrutinized thoroughly due to regulations governing discharge to surface water such as the Clean Water Act, National Pollutant Discharge Elimination System (NPDES), Total Maximum Daily Loads (TMDL), and other programs. Regulations governing stormwater discharge to groundwater are not as extensive. It is likely that regulations will evolve regarding Class V injection wells, especially in regions where subsurface water quality is imperative to protect drinking water supply. This directly relates to the City of Missoula Stormwater Utility and the likelihood of more stringent stormwater quality requirements looking forward.

An example of more stringent regulation is an on-going legal suit that will likely affect regulation around drywells moving ahead. In 2020, the case of *County of Maui v. Hawaii Wildlife Fund* rose to the U.S. Supreme Court regarding the County of Maui discharging wastewater treatment facility effluent to groundwater via injection well, which was showing up in the Pacific Ocean by indirect flow through groundwater. The Court considered whether a point source discharge that travels through groundwater to a water of the United States (WOTUS) requires a NPDES permit. The Court concluded that discharges to groundwater are subject to NPDES permitting if the discharge is the “functional equivalent” of a direct discharge from a point source to a WOTUS.

According to the EPA, the Clean Water Act prohibits anybody from discharging "pollutants" through a "point source" into a "water of the United States" unless they have an NPDES permit. Up to this point in time, groundwater is not considered a “water of the Unites States,” so the injection well was not regulated under NPDES. Under this court case, the Maui injection well was ruled as “functionally equivalent” to a direct discharge to surface water due to the hydrologic connection between surface and ground water. If all discharges to groundwater are held to NPDES standards, they must be monitored for quality and meet all TMDLs as applicable to outfalls to surface water.

At the time of this report in July 2024, the EPA has issued draft guidance titled, *Applying the Supreme Court's County of Maui v. Hawaii Wildlife Fund Decision in the Clean Water Act Section 402 National Pollutant Discharge Elimination System Permit Program to Discharges through Groundwater*. This draft guidance has received public comments and is still under review. The guidance describes the proposed "functional equivalent" analysis and explains the information required to determine which discharges to groundwater may require a NPDES permit. The guidance states that a determination of "functional equivalency" should be based on fact-specific analysis with time and distance being the most important characteristics in most cases. The draft guidance identifies two factors that EPA believes are not relevant to a functional equivalent determination: whether a discharge is intentional, and the existence of a state groundwater protection program.

For Missoula, the finalization of this rule may result in groundwater discharge being held to the same quality standards and permit procedures as discharge to surface water. The hydrologic connection between surface water and groundwater has been recognized by the State of Montana in water plans such as the Clark Fork & Kootenai River Basins Water Plan. Although the timeline for the regulatory action of this rule could be postponed by years of litigation, there is opportunity for proactive involvement in the decision-making process. The City of Missoula should look for opportunities to engage with the state and federal regulators that may play key roles in implementing this rule.

4.6. RETROFIT BMP LIBRARY

This section focuses on actions the City may take to retrofit existing systems to improve water quality. These retrofit BMPs could be applied at numerous locations throughout the system and are meant to provide a generalized approach to identifying a potential project site and possible retrofit solutions. The retrofit options provided in this section can be targeted to specific subwatersheds with TMDLs or known water quality concerns.

4.6.1 Onsite Retrofits	4.6.2 Drywell	4.6.3 Outfall	4.6.4 Open Channel Conveyance	4.6.5 Detention Basin
Site specific water quality retrofits	Existing drywell water quality retrofits	Existing surface water outfall water quality retrofits	Existing open channel water quality retrofits	Existing detention basin water quality retrofits

Much of the provided strategy and retrofit options discussed in this BMP Library was sourced from Manual 3 of the Urban Sub-watershed Restoration Manual Series published by the Center for Watershed Protection. In addition to stormwater quality retrofits, this manual is an excellent resource for urban watershed restoration planning, urban stream repair, riparian management, and a holistic approach to water quality improvements.

4.6.1. Onsite Retrofits

This collection of retrofits is based on typical land uses and the water quality retrofit projects that may be suitable for each. The City may identify several project locations based on property ownership, prioritize them based on need for water quality improvement, and identify a retrofit that is suitable for the site.

Common Areas and Public Spaces

To identify an ideal site for a stormwater quality retrofit, key site suitability criteria such as property ownership, adjacent existing infrastructure, and non-point source generating areas should be analyzed.

Public lands such as community parks, right-of-ways, stream corridors, floodplains, or along trails can be great sites for stormwater retrofits. Additionally, sites such as City Hall, schools, libraries, public parking facilities, or staging areas may also be good sites to consider. These sites can serve as a potential location for a retrofit project. High visibility projects can serve as a demonstration project to educate community members on green infrastructure, urban watersheds, and water quality. Additionally, high visibility projects can increase community acceptance by providing a local example of a completed project.

For sites that receive stormwater from a large drainage area upstream, a series of retrofit projects may be suitable to divert and treat stormwater that passes through the site. Water quality BMPs such as bioretention galleries, stormwater wetlands, permeable pavers, green roofs, and other methods installed in series may provide stormwater quality improvements and serve as a high visibility demonstration project.

Pollutant Generating Locations

High pollutant generating locations such as parking lots, streets, rooftops, industrial areas, and other high use hardscapes may be an ideal location for a stormwater quality retrofit that will provide the most impact. Parking lots may be modified to include permeable pavers, curb cut outs to swales or bioretention cells, rain gardens, or vegetation filter strips.

River Corridors

Non-point source pollutant generated from lands adjacent to the rivers that run through Missoula are ideal locations to install quality retrofits such as vegetated buffer strips, bioswales, or bioretention cells. Parking lots or other developments that are directly adjacent to the river corridor could benefit from pollutant reduction, beautification, and be great demonstration projects that the general public may be more likely to rally behind.

Streets and Rights-of-Way

Retrofit projects along highways and streets are ideal because runoff pollution concentrations are high, and land is already dedicated in the right-of-way. Streets with open stormwater drainage can employ retrofit strategies such as diverting stormwater to a surface treatment prior to entering storm drain or drywells. Swales, rain gardens, and bioretention cells can be installed in existing tree pits, medians, cul-de-sacs, right-of-way boulevards, traffic calming features, and other existing streetside features. Curb cut outs located just upstream of catch basins, or flow splitters retrofitted into existing catch basins can be utilized for diversion of stormwater flow. Ideal streetside areas for retrofit projects may include large cul-de-sacs, wide rights-of-way, existing or new traffic calming features, or streets with utilities installed beneath the pavement. Areas with on-street parking demand, underground and overhead utilities, or mature trees may be difficult areas to implement streetside retrofits.

Input from several stakeholders is beneficial to streetside retrofits in consideration of maintenance, vegetation, community involvement. Street improvements that also reinforce other neighborhood concerns, such as common basement flooding, traffic calming, pedestrian safety, and enhanced landscaping, are most likely to be successful.

The City of Missoula may adopt green infrastructure design elements into standardized street cross-section designs. This could include features noted above that would be identified as a requirement for standard road design,

4.6.2. Drywells

Existing drywells offer several retrofit options to add pretreatment for water quality.

Option 1: Settling Basin Insert

An inexpensive way to provide water quality improvements and pretreatment at existing drywells is to install an insert that creates a sedimentation basin within the drywell itself. Inserts such as the Drywell Retrofit Sump Insert by Drywell Retrofit Solutions (DRS) creates a settling basin in the drywell that captures oil, grease, sediment, and debris, then utilizes the existing barrel perforations for infiltration. This retrofit would be useful for drywells that require extensive cleanout to maintain performance or are located in high use areas that see a lot of large particles such as roadways. Also, inserts can be fabricated with baffles for areas that see high oil and grease contamination.

The sedimentation insert adds further capability by creating a deeper sump to keep fine particles from clogging the infiltration chamber, reducing maintenance, improving performance, and providing water quality improvements prior to infiltration.

Option 2: Flow Split Adapter to Treatment Feature

For drywells with adjacent space for an offline treatment feature to be added, a flow split adapter such as the DRS retrofit diverter top can be placed on the drywell barrel. The converter has a flow splitting weir to divert flow that is captured in the grated inlet to an adjacent treatment feature. The diverter top also has an inlet that allows pretreated flow to be directed back to the drywell for infiltration. This retrofit may be ideal to drywells that are in high use areas or pollutant generating areas with adjacent space for above or below ground treatment features. For example, a drywell located within a curb adjacent to a roadside ditch could be retrofitted to collect runoff from the inlet and divert in into the vegetated swale. After treatment or during large runoff events, flow can be directed back to the sump for infiltration.

This retrofit also provides an opportunity to repair paving adjacent to the inlet and change inlet types, if necessary, without excavating and replacing the entire drywell.

Option 3: Engineered Soil Filter

For drywells located in the gutter along roadways, a bioretention cell can be installed just upstream to intercept the first flush of runoff and treat for sediments, metals, nutrients, oil, and grease. The drywell will remain to capture overflow or bypass downgrade of the bioretention unit.

Engineered soil media filters can also be incorporated into vegetated swale design, rain gardens, and structural pretreatment features such as bioretention. The media promotes infiltration in the top layer of soil and captures pollutants by filtering.

Option 4: Connect to Piped System

During retrofit prioritization and development, adjacent existing infrastructure should be investigated. In high pollutant generating areas, it may be most beneficial to remove the drywell completely and replace with a catch basin and connection to a storm main to preserve quality of water that is discharged to the aquifer. If connecting to a piped system, the runoff should be directed to a facility like a bioengineered wetland or detention basin, and not a direct outfall to a surface water

Some critical components to review when considering a drywell retrofit include:

- Future capital projects planned for the area that could include stormwater improvements
- Utility locations and suitability for infiltration facilities
- Adjacent existing stormwater infrastructure, piped connection, downstream treatment facilities
- Groundwater separation
- Maintenance, sediment loading, cold-weather performance

4.6.3. Outfall

Outfall retrofits are ideal because they maximize the upland drainage area treated. In addition, the treatment facility only needs to be designed for the water quality event and larger runoff flows will bypass the retrofit.

Option 1: Splitter to Treatment Cell between Outfall and Waterbody

This retrofit includes diversion of flow upstream of the outfall. The flow diversion intercepts all or a portion of the discharge and directs it to an adjacent treatment cell. This retrofit is ideal for outfalls to surface water that are more remote with room to implement above grade treatment facilities. The flow could be diverted to a detention pond with pretreatment forebay, a constructed wetland, or a series of bio-infiltration cells to treat for sediment, oils, nutrients and metals prior to discharge. Constructed wetlands are preferred in floodplain areas where groundwater is high.

Considerations when determining offline treatment cell suitability:

- Sufficient gradient for flow diversion to the treatment retrofit and return to the outfall or stream.
- Open space upstream of the outfall to place the treatment retrofit and overflow route,
- Is outfall subject to backwater conditions
- Publicly owned parcels associated with stormwater outfalls

Option 2: Hydrodynamic Separator (HDS)

A hydrodynamic separator is suitable upstream of outfalls that do not have space for an above ground treatment retrofit. An HDS unit will intercept flow to the outfall and separate sediment, debris, oil and grease. To maintain effectiveness of an HDS, install the unit offline from the main conveyance and divert flows above the water quality event to bypass the HDS.

4.6.4. Open Channel Conveyance

Water quality retrofits in open channels are appropriate in channels that lack perennial flow. Channels that have been hardened or channelized are ideal candidates for retrofit.

Option 1: Linear Series of Wetland/Bioretention Treatment Cells

Grass channels can be modified to include areas of bio-infiltration and settling basins to get additional treatment capacity during small runoff events. Check dams can be incorporated to dissipate energy and create opportunities for bio-infiltration. Portions of the open channel can be excavated and replaced with engineered soils to promote treatment and infiltration. An engineered soil media is a specific soil blend of sand, silt, clay and organic material designed with a rapid infiltration rate and ability to attenuate pollutants. Landscaping and native vegetation in these areas can reduce maintenance by reducing area for mowing, provide an aesthetic landscaped pod and can create more variety in a grass swale. Bio-infiltration cells can also be constructed adjacent to the channel and receive only the first water quality volume that is diverted offline for treatment.

These features often go well in public spaces that are designed to withstand stormwater runoff impacts during large events. Pods of bio-infiltration cells can be paired with educational material in residential areas.

Option 2: Natural Channel Design and Stabilization

Steep hillside drainages have potential to erode and headcut as development causes an increase in runoff volumes. Urban streams can be designed in a stable form while maintaining a natural aesthetic and operating under the natural requirements of the stream to transport flow and sediment. Stream bed and banks can be protected to stabilize the natural channel using native plantings, boulders, and logs. The option of a natural channel design would be best suited to a conveyance with perennial flow. This restoration method would be best in a rural or residential area where the stream vegetation will not be impacted by homeowners and can provide habitat for wildlife.

4.6.5. Detention Basin

Existing detention basin retrofits are ideal because the land is already devoted to stormwater management. Modifications are typically inexpensive and can provide numerous benefits to stormwater quality, as well as for the adjacent community members. The best candidates for retrofit are dry detention ponds that were constructed as part of subdivision development or as regional flood control. Older ponds also may have lost their storage capacity due to upstream development or sedimentation, which can be addressed simultaneously with a water quality retrofit project. It is likely that modern detention ponds may already include elements for water quality.

Option 1: Pretreatment Forebay and Trickle Channel

For detention ponds with a single inlet location, a pretreatment forebay can be constructed to contain the first water quality volume of runoff. The forebay provides sediment settling and extended detention. A forebay can be easily added to an existing detention basin by slightly excavating the forebay and creating a berm and overflow spillway. A trickle channel is a constructed low flow path that extends the flow distance and can mimic a more natural channel.

Option 2: Extended Detention and Infiltration

Existing detention ponds can be modified to restrict outflow and store runoff for over 12 hours. This temporary storage allows particulates to settle and be filtered through infiltration. The pond base may be comprised of engineered soil and base course designed to effectively filter pollutants during infiltration. The basin can be planted with grass and native plants to increase plant uptake and allow infiltration through the soil media.

Option 3: Constructed Stormwater Wetland

A constructed stormwater wetland is a water quality retrofit that is most suitable where the groundwater table is high. A construction wetland replicates natural wetland ecosystems and are shallow depressions that receive stormwater runoff. A trickle channel can allow an extended flow path for low flows. Benches placed at higher elevations can be planted with more upland plant species where appropriate.

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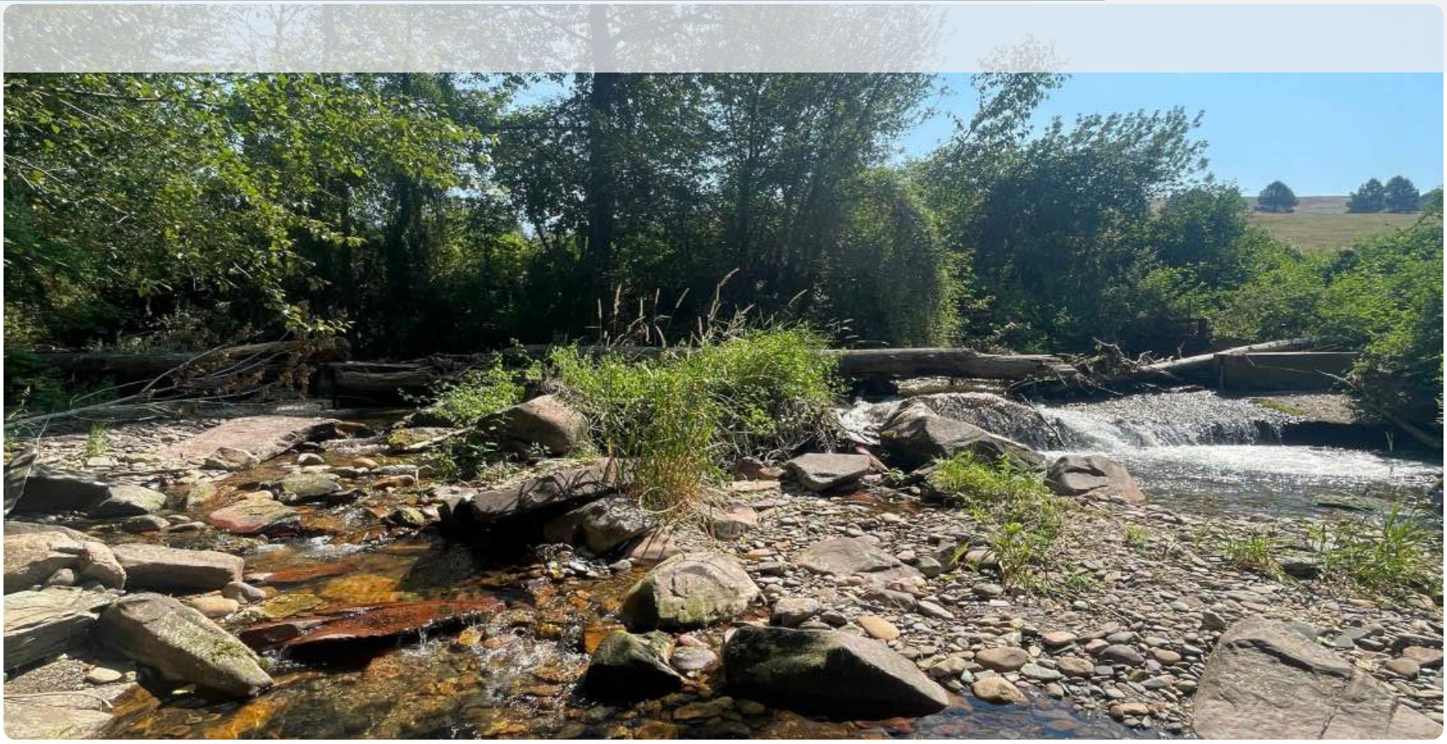

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