2024 Nonpoint Source and Wetlands Section
Focus Watershed Application Form

Final Deadline: January 3, 2025 at 5:00 pm

Applications must be submitted through eMACS

Applicant	City of Missoula Stormwater Utility
Primary Contact	Tracy Campbell
Title	Superintendent
Address	435 Ryman St
City	Missoula
State	MT
Zip Code	59802
Phone Number	406-552-6379
Email Address	CampbellTL@ci.missoula.mt.us
Signature	

Proposed Focus Watershed

Proposed HUC 10 Watershed: Miller Creek - Bitterroot (1701020516)

List the impaired waterbodies within the proposed HUC 10 watershed, along with their identified impairments from Montana's List of Impaired Waters. https://deq.mt.gov/files/Water/WQPB/CWAIC/Reports/IRs/2020/Appendix_A_Final.pdf

Waterbody	Impairment Causes
Bitterroot River (MT76H001_030)	Causes: Alteration in stream-side or littoral vegetative covers, Lead, temperature Sources: Agriculture, Rangeland Grazing, Wet Weather Discharges (point source and non-point source)
Hayes Creek (Unlisted, but constant discharge to the impaired Bitterroot River)	Causes: temperature
Pattee Creek (Unlisted, but constant discharge to the impaired Bitterroot River)	Causes: Temperature, sedimentation/siltation, alteration in stream-side or littoral vegetative covers Sources: loss of riparian vegetation/shade, channelization, road runoff, streambank alterations
Miller Creek (MT76H004_130)	Causes: Alteration in stream-side or littoral vegetative covers, sedimentation/siltation, temperature Sources: Crop Production, Grazing in Riparian zones, loss of riparian habitat, silviculture activities
O'Brien Creek (Unlisted, but constant discharge to the impaired Bitterroot River)	Causes: Sedimentation/siltation, alteration in stream-side or littoral vegetative covers Sources: Streambank erosion, road runoff, channelization/entrenchment, instream wood removal, loss of riparian vegetation

Water Quality Impairment Causes and Solutions

Describe the root cause of water quality problem(s) and the solution(s) needed to address the issue(s) within your proposed HUC 10 watershed. **(20 pts)**

The Miller Creek-Bitterroot HUC 10 is located on the southern edge of Missoula. Land use in the watershed has been increasingly urban, causing impacts to riparian vegetation and the stream itself that cause increased suspended sediments and increased temperature. Both Miller Creek and the Bitterroot River are designated as impaired by the DEQ. Though unlisted by DEQ, Pattee Creek is considered a "stream of concern" by the Missoula Valley Water Quality District based on monitoring and assessment efforts presented in the 2020 Bitterroot Watershed Restoration Plan. Most notably, sampling has indicated that Pattee Creek contributed total suspended sediment (TSS) to the impaired Lower Bitterroot River at three times the concentration required by stormwater discharge permits. O'Brien Creek was also highlighted in the Bitterroot WRP as one of the most important tributaries for rainbow and cutthroat trout. It is estimated the non-point source delivery of sediment is at least 1-2 orders of magnitude above natural background levels.

Problem: Degraded in-stream and riparian habitats caused by silviculture, forest roads, and suburban development for all streams
Solution: Riparian vegetation and stream restoration to restore shade cover, reduce erosion, and reduce channel width/depth ratio

Problem: Severe dewatering and increased temperature caused by irrigation from Miller Creek
Solution: Improve irrigation efficiency to reduce water withdrawals in warm months and reduce return water.

Problem: Natural channel manipulation and urbanization of Pattee Creek
Solution: Restore Pattee Creek by daylighting (removing piped segment), replacing undersized culverts, managing invasive species, and mitigating impacts from road maintenance and irrigation use.
Solution: Develop outreach and education for landowners to improve riparian corridor in residential areas and to decrease impairments from grazing.

Problem: Sediment delivery from roads and erosion that impact aquatic habitat in O'Brien Creek
Solution: Restoration projects for vegetation and stream entrenchment; education and outreach; culvert removal

Problem: Urban stormwater runoff introducing sediment, metals, and nutrients to Pattee and Miller Creek
Solution: Develop outreach materials and implement green infrastructure to capture sediment and treat stormwater surface runoff

Local Momentum and Organizational Capacity

Describe the current momentum that exists within the watershed for implementing the solution(s) described above.
Describe the capacity of your organization and partners to administer focus watershed funds. **(20 pts)**

Momentum:
The City of Missoula and partners have been actively working to improve water quality in the Miller Creek-Bitterroot watershed and the Missoula Valley as a whole. Implementation plans that outline solutions to address water quality and non-point source delivery include the 2020 Bitterroot Watershed Plan, the 2018 Miller Creek Restoration Plan, and the draft Comprehensive Stormwater Quality Plan that will be completed in 2025. Non-point source pollution from lawns, streets, roods, driveways, and parking lots is concentrated in stormwater infrastructure and natural drainages. In addition to surface water quality, there has been momentum within the City to improve stormwater quality to benefit receiving surface waters and groundwaters. Momentum towards project implementation is demonstrated by numerous grant applications that have been submitted related to the proposed solutions, including: Pattee Creek stream restoration, outreach and education, and stormwater control project (ARPA Grant Application); Pattee Creek Watershed Group Establishment (Watershed Management Grant Application); and Miller Creek 7 mile Restoration (Nonpoint Source Application).

In addition to these grant applications, the City is currently implementing or has recently implemented the following water quality projects: Cattail Corner Wetland Restoration and Stormwater Infiltration Area (Pattee Creek Drainage); Takima Park Bioretention Basin (Pattee Creek Drainage), and Bitterroot Outfall Improvements (Pattee Creek Drainage).

Organizational capacity
City of Missoula Stormwater Utility has dedicated staff that are available to administer focus watershed funds. In addition, the City can provide project management and review for compliance with local regulations.

Anticipated Projects Use the table below to provide information on planned and proposed projects. The purpose of this information is to help determine local readiness to receive a significant influx of funding for projects. Projects do not need to be shovel-ready to be added to the table. Projects must restore and support native plants and animals and natural stream processes. Attach design drawings and other planning documents **where available**. **(30 pts)**

Project Name	**Waterbody and Impairment to be Addressed**	**Planned BMPs and Quantity *(e.g., feet of fencing, miles of restored stream, acres restored wetlands, # and type of education and outreach events)***	**List of Supporting Landowners and Partners**	**Estimated Total Project Cost**	**Design Drawings or Other Planning Documents Attached? (Y/N)**
Garland Park	Bitterroot River Sediment, Lead addressed by stormwater treatment	Approx. 10,000 square feet of wetland/bioretention along urban drainage	City of Missoula	$ 350,000	N
Cutthroat Corner	Bitterroot River & Pattee Creek Sediment, Lead	Approx. 0.5 acres of wetland and stormwater control directly receiving water from Pattee Creek; project location in dedicated easement to the City	University of Montana	$ 150,000	N
Cattail Corner	Bitterroot River & Pattee Creek Sediment, Lead	Approx. 2 acres of wetland restoration and native planting, sediment control measures, community education with onsite signage	City of Missoula	$ 1,200,000	Y
Pattee Creek Riparian Restoration and Demonstration Projects	Bitterroot River & Pattee Creek Sediment, vegetative cover	Demonstration projects to educate homeowners	Missoula Conservation District	$ 25,000	Y
Daylight Pattee Creek	Bitterroot River & Pattee Creek Sediment, vegetative cover	Approx. 0.5 miles of stream restoration and native planting, riparian buffer and habitat creation, community education and onsite signage	City of Missoula Private landowners	$ 2,550,000	N
Irrigation Efficiency Plan and Outreach	Miller Creek temperature	Work with adjacent landowners to identify irrigation efficiency needs and outreach for education on water quality and irrigation impacts	Private landowners USFS		N

Anticipated Projects Use the table below to provide information on planned and proposed projects. The purpose of this information is to help determine local readiness to receive a significant influx of funding for projects. Projects do not need to be shovel-ready to be added to the table. Projects must restore and support native plants and animals and natural stream processes. Attach design drawings and other planning documents **where available.**

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Miller Creek Riparian Vegetation and Stream Restoration	Miller Creek sediment, vegetative cover, temperature	Restore up to 27 miles of Miller Creek riparian banks that are classified as poor condition in the Miller Creek Watershed Restoration Plan. Include planting and restoration of morphology.	Private landowners USFS		N
Watershed Group Education and Outreach	Pattee Creek & Miller Creek sediment, temperature, vegetative cover	Establish Pattee Creek and Miller Creek Watershed Group or focus within existing group	Missoula Conservation District Clark Fork Coalition	$ 40,000	Y
O'Brien Creek Riparian Vegetation Sediment Control	O'Brien Creek sediment, vegetative cover	Address up to 25 specific locations and up to 2 miles of linear non-point source contribution sediment source as delineated in the Bitterroot Watershed Plan.	Private landowners USFS		N
Takima Park Bioretention Basin	Bitterroot River and Pattee Creek sediment, nonpoint source pollution	Approx. 1 acre of wetland and bioretention with forbs, grasses, and shrubs to reduce pollutant discharge to Pattee Creek	City of Missoula		Y
					N
					N

Anticipated Projects Use the table below to provide information on planned and proposed projects. The purpose of this information is to help determine local readiness to receive a significant influx of funding for projects. Projects do not need to be shovel-ready to be added to the table. Projects must restore and support native plants and animals and natural stream processes. Attach design drawings and other planning documents **where available**.

Project Name	**Waterbody and Impairment to be Addressed**	**Planned BMPs and Quantity** ***(e.g., feet of fencing, miles of restored stream, acres restored wetlands, # and type of education and outreach events)***	**List of Supporting Landowners and Partners**	**Estimated Total Project Cost**	**Design Drawings or Other Planning Documents Attached? (Y/N)**
					N
					N
					N
					N
					N
					N

Partners, Roles, Letters of Support Use the table below to identify specific landowners, funders, technical service providers, and other partners who will support you and your efforts to reduce nonpoint source pollution in your proposed HUC 10 watershed. **Attach letters of support from each partner**. Invite partners who provide a letter of support to provide insight into how they will contribute to the success of the focus watershed effort. **(20 pts)**

Name of Partner	Anticipated Role in Focus Watershed Effort	Letter of Support Attached?
Missoula Valley Water Quality District	Technical expertise and input on design; input on sampling protocol for monitoring effectiveness	Y
Clark Fork Coalition	Provide technical expertise and quality assurance for public outreach materials	Y
University of Montana	Provide participants and potential interface with environmental programs	N
Missoula Conservation District	Technical expertise and input on design	Y
Montana Fish, Wildlife & Parks	Technical expertise and consultation on habitat restoration, permitting and regulatory support.	Y
City of Missoula Parks and Recreation Conservation Lands	Technical expertise in habitat restoration, assistance with on-site restoration, native plant cultivation, and continued management practices	Y
		N
		N

Environmental Justice

Describe your process for identifying, engaging, and providing access for disadvantaged communities to watershed funding, including involvement in the decision-making process and protection from environmental and health hazards within the watershed. **(10 pts)**

Our process for identifying, engaging, and providing access for disadvantaged communities to watershed funding begins with intentional outreach and education efforts in highly accessible, central locations that serve diverse populations. A key example is our presence at Caras Park during the Clark Fork River Market, a hub for the community that attracts residents from all socioeconomic backgrounds. This market is free to the public, ADA-accessible, and supports disadvantaged community members by accepting food stamps. In 2024, we successfully engaged 1,093 in-person community members through free-to-the-public events, providing education on stormwater management, watershed protection, and environmental health. These efforts prioritize equity by ensuring that individuals from disadvantaged communities have the opportunity to access critical information, participate in decision-making discussions, and understand available resources to protect themselves from environmental and health hazards within the watershed. By meeting the community where they are and providing free, accessible, and inclusive opportunities, we build trust and empower disadvantaged residents to play an active role in watershed stewardship.

The proposed projects will improve public access to a healthy environment by improving riparian habitat in an urban area. Improved habitat will provide citizens many outdoor educational opportunities: e.g., bird watching, nature hikes, school visits, insect collecting, and native plant identification. The proposed projects have the potential to benefit underserved populations by improving natural riparian and wetland habitats in an area where there is a lack of access to open space.

The City of Missoula contains four census tracts that are categorized as disadvantaged by the Climate and Economic Justice Screening Tool hosted by the Council of Environmental Quality. In addition, the City Council has passed three resolutions that describe the "lenses" through which the City should look before making all decisions. These lenses include climate resilience, equity, and housing. The City has a structured foundation for considering disadvantaged parts of the community in their decisions

ATTACHMENTS

LETTERS
OF
SUPPORT

PUBLIC WORKS & MOBILITY DEPARTMENT – STORMWATER
1345 W. Broadway • Missoula, Montana 59802 • (406) 552-6379

December 18, 2024

Rebecca Gregg
Contracts Officer
Montana Department of Environmental Quality
1520 E Sixth Ave.
Helena, MT 59601

RE: Nonpoint Source and Wetlands Program Focus Watershed Request for Information

Dear Rebecca and the Review Committee:

The City of Missoula is nominating the Hayes Creek – Bitterroot HUC10 as a Focus Watershed. The City has been working hard to engage with community members and educate them about nonpoint source pollution in this watershed. This has been a focus area because Pattee Creek is the most impaired waterbody in the City limits. With extreme hydrological manipulation for flood control and juxtaposition with urban development, the stream contributes to significant perennial pollution to the Bitterroot River. We aim to mitigate for the impacts of nonpoint source pollution in this watershed and look forward to continuing the conversation with the Montana Department of Environmental Quality, to bring awareness and attention to this forgotten waterway.

Over the past several years, we have devoted time to improving riparian buffers along the urban reaches of Pattee Creek, spent $1 million to restore wetland and open water habitat, and secured another $1 million in EPA grant funding for bioengineered wetlands in this watershed. The entire aim of these projects is to improve water quality in Pattee Creek, and thus in the Bitterroot River as a whole.

Rather than soliciting additional letters of support during a busy time of year for our partners, I am including a consolidation of past letters of support. This demonstrates our long-term commitment to supporting water quality improvement projects that directly address nonpoint source pollution in this watershed.

Thank you so much for your time and consideration.

Respectfully,

Tracy Campbell
Superintendent

MISSOULA CONSERVATION DISTRICT

Missoula Conservation District
3550 Mullan Rd. Unit 106
Missoula, MT 59808

October 28, 2021

Watershed Protection Section
Montana Department of Environmental Quality
1520 E. Sixth Avenue
P.O. Box 200901
Helena, MT 59620-0901

Dear Members of the Watershed Protection Section of DEQ:

Over the past year, the Missoula Conservation District and the City of Missoula Stormwater Utility began dialog about how to preserve or enhance water quality and protect riparian habitat in our overlapping jurisdictions. We were pleasantly surprised to learn about the Utilities' forward-thinking conservation focus and are grateful for this valuable partnership as many of our goals and objectives coalesce with those of the City of Missoula Stormwater Utility.

Pattee Creek is a hard stream for the Conservation District to help and will need a diverse partnership to restore. The challenges we face are that our regulatory authority is not enough to protect the Creek, and the mosaic of landownership is such that our methods of citizen-based voluntary conservation don't apply. The most impaired portion of the Creek is in need of so much help that the District's Board of Supervisors have relinquished their authority to oversee Montana's Natural Streambed and Land Preservation Act on that reach. Without a team leader such as the City of Missoula Stormwater Utility, it is doubtful if any entity could help restore this stream to its full potential.

The Missoula Conservation District respectfully endorses the City of Missoula Stormwater Utility funding request as it will increase their capacity to implement conservation objectives throughout Pattee Creek. A publicly led restoration effort on this biologically significant stream would be a hallmark of local restoration, and would not only protect water quality and biodiversity, but add a beautiful resource for the citizens of Missoula. We ask that DEQ please be a part of this partnership and financially support the City of Missoula Stormwater Utility's grant proposal.

Sincerely,

Radley Watkins, Resource Conservationist

Missoula Conservation District
3550 Mullan Rd. Unit 106
Missoula, MT 59808

November 1, 2021

Jorri Dyer
Watershed Management Grant Program Specialist
1539 Eleventh Ave.
Helena, MT 59601

Dear Ms. Dyer and members of the Watershed Management Grant Program review committee:

Over the past year, the Missoula Conservation District and the City of Missoula Stormwater Utility began dialog about how to preserve or enhance water quality and protect riparian habitat in our overlapping jurisdictions. We were pleasantly surprised to learn about the Utilities' forward-thinking conservation focus and are grateful for this valuable partnership as many of our goals and objectives coalesce with those of the City of Missoula Stormwater Utility.

Pattee Creek is a hard stream for the Conservation District to help and will need a diverse partnership to restore. The challenges we face are that our regulatory authority is not enough to protect the Creek, and the mosaic of landownership is such that our methods of citizen-based voluntary conservation don't apply. The most impaired portion of the Creek is in need of so much help that the District's Board of Supervisors have relinquished their authority to oversee Montana's Natural Streambed and Land Preservation Act on that reach. Without a team leader such as the City of Missoula Stormwater Utility, it is doubtful if any entity could help restore this stream to its full potential.

The Missoula Conservation District respectfully endorses the City of Missoula Stormwater Utility funding request as it will increase their capacity to implement conservation objectives throughout Pattee Creek. A publicly led restoration effort on this biologically significant stream would be a hallmark of local restoration, and would not only protect water quality and biodiversity, but add a beautiful resource for the citizens of Missoula. We ask that DNRC please be a part of this partnership and financially support the City of Missoula Stormwater Utility.

Sincerely,

Radley Watkins, Resource Conservationist

MISSOULA CONSERVATION DISTRICT

Missoula Conservation District
3550 Mullan Rd. Unit 106
Missoula, MT 59808

March 7, 2022

Watershed Fund Committee
Montana Watershed Coordination Council
P.O. Box 1416
Helena, MT 59624

Dear Watershed Fund Committee:

Over the past year, the Missoula Conservation District and the City of Missoula Stormwater Utility began dialog about how to preserve or enhance water quality and protect riparian habitat in our overlapping jurisdictions. This led us to share in the hosting of a Big Sky Watershed Corp Member, Mackenzie Tenan. We are thrilled with the work Mackenzie and the City Stormwater Utility are doing and support Mackenzie's focus on Pattee Creek.

Pattee Creek is a hard stream for the Conservation District to protect and it will take diverse partnerships to achieve any restoration goals. The challenges we face are that our regulatory authority is not enough to protect the Creek, and so far, we have not had the time to promote voluntary conservation efforts. The most impaired portion of the Creek is in need of so much help and has degraded so much, that the District's Board of Supervisors have relinquished their authority to oversee Montana's Natural Streambed and Land Preservation Act on that reach. At the same time water that moves through the creek is warming and picking up nutrients it carries to the Bitterroot River. Without the public partnership approach that Mackenzie is proposing, it is doubtful if any entity could help restore this stream to its full potential and warm, nutrient rich water will continue to pour into the Bitterroot.

The Missoula Conservation District respectfully endorses Big Sky Watershed Corp Member (BSWC) and the City of Missoula Stormwater Utility funding request as it will increase their capacity to implement conservation objectives throughout Pattee Creek. A publicly led restoration effort on this biologically significant stream would be a hallmark of local restoration, and would not only protect water quality and biodiversity, but add a beautiful resource for the citizens of Missoula. We ask that Montana Watershed Coordination Council please be a part of this partnership and financially support the City of Missoula Stormwater Utility's BSWC's restoration proposal.

Sincerely,

Radley Watkins, Resource Conservationist

MISSOULA CONSERVATION DISTRICT

Missoula Conservation District
3550 Mullan Rd. Suite 106
Missoula, MT 59808

October 4, 2022

Attn: Montana Department of Environmental Quality
Re: Letter of Support – City of Missoula Department of Public Works & Mobility | Stormwater

Dear MT DEQ:

Over the past year, the Missoula Conservation District and the City of Missoula Stormwater Utility have been partnering to restore riparian vegetation along Pattee Creek with hopes that it helps keep water temperatures cool and sediment out to the stream. The Missoula Conservation District is concerned about the degradation of water quality in Pattee Creek and the ultimate impacts to the Bitterroot River.

The Missoula Conservation District is in full supportive of the city of Missoula's Storm Water Utility's proposal to improve stormwater quality at Takima Park, where Pattee Creek is heavily influenced by the populated portion of Missoula's south hills neighborhood. Pattee Creek is a hard stream for the Conservation District to protect by simply enforcing the Montana Natural Streambed and Land Preservation Act. It will take diverse partnerships to achieve any restoration goals. Next year, the Conservation District has plans to work with landowners to promote voluntary conservation efforts working with our Big Sky Watershed Corp Member. The work of Missoula's Storm Water Utility's to improve stormwater quality at Takima Park will help build community support, while directly affecting the water quality in Pattee Creek.

We ask that Montana Department of Environmental Quality please be a part of this partnership and financially support the City of Missoula Stormwater Utility's Takima Park proposal through 319 Nonpoint Source Program funding.

Sincerely,

Radley Watkins
Resource Conservationist

Missoula Public Health
City-County Health Department

Missoula City-County Health Department
WATER QUALITY DISTRICT
301 West Alder Street | Missoula MT 59802-4123
www.missoulacounty.us/HealthDept
Phone | 406.258.4890
Fax | 406.258.4781

January 30, 2020

Montana Department of Natural Resources and Conservation
CARDD Division
P.O. Box 201601
1625 Eleventh Avenue
Helena, Montana 59620-1601

Re: Takima Park RRGL Application

Dear Review Committee:

The Missoula Valley Water Quality District is a local government agency whose mission is to protect and improve surface and groundwater quality within the Missoula valley. The District is deeply interested in stormwater quality as it is known to be a leading cause of surface water degradation nationally and is certainly a concern in urban environments. As such, the District supportive of the city of Missoula's proposal to improve stormwater quality at Takima Park, a junction and discharge point of stormwater from Missoula's south hills neighborhoods into Pattee Creek.

The Water Quality District has been studying surface water quality in Pattee Creek for a number of years, including annual sampling of Total Suspended Solids (TSS), Nutrients and chlorides. We have seen marked impacts from stormwater runoff through the project section of Pattee Creek with some of the highest levels of TSS and Chloride detected within the District. The District is pleased to work with the City of Missoula in efforts to combat this trend. Please accept this letter as strong support for the City's application.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Travis Ross
Environmental Health Supervisor
Missoula Valley Water Quality District

Missoula Public Health
City-County Health Department

Missoula City-County Health Department
WATER QUALITY DISTRICT
301 W Alder|Missoula MT 59802-4123
www.missoulacounty.us/wqd
Phone|406.258.4890
Fax|406.258.4781

October 26, 2021

319 Review Committee
Montana Department of Environmental Quality
P.O. Box 200901
Helena, MT 59620

RE: Missoula Stormwater Utility 319 Grant Application: Pattee Creek Riparian Restoration Project

Dear 319 Review Committee,

The Missoula Valley Water Quality District would like to extend our support for the Pattee Creek Riparian Restoration Project. This effort goes above and beyond any requirements of the MS4 and will play an important role in decreasing loading to the Bitterroot. Additionally, it will restore aspects of ecological function important to improving local groundwater quality. Education and outreach opportunities stemming from this project will enable local landowners to understand the role and impact they can have in water quality efforts. Our strong partnership on previous collaborations make us confident this is a project that will result in meaningful, on the ground water quality improvements and encourage you to fund this project.

Thank you for the opportunity to demonstrate our support for this project.

Sincerely,

Elena Evans
Missoula Valley Water Quality District

Missoula City-County Health Department
WATER QUALITY DISTRICT
301 W Alder|Missoula MT 59802-4123
www.missoulacounty.us/wqd
Phone|406.258.4890
Fax|406.258.4781

February 23, 2022

Montana Watershed Coordination Council
PO Box 1416
Helena, MT 59624

RE: Missoula Stormwater Utility Grant Application: Pattee Creek Riparian Restoration Project

Dear MWCC Grant Review Committee,

The Missoula Valley Water Quality District would like to extend our support for the Pattee Creek Riparian Restoration Project. This effort goes above and beyond any requirements of the MS4 and will play an important role in decreasing loading to the Bitterroot. Additionally, it will restore aspects of ecological function important to improving local groundwater quality. Education and outreach opportunities stemming from this project will enable local landowners to understand the role and impact they can have in water quality efforts. Our strong partnership on previous collaborations makes us confident this is a project that will result in meaningful, on the ground water quality improvements and encourage you to fund this project.

Thank you for the opportunity to demonstrate our support for this project.

Sincerely,

Elena Evans
Missoula Valley Water Quality District

Missoula Public Health
City-County Health Department

Missoula City-County Health Department
WATER QUALITY DISTRICT
301 W Alder|Missoula MT 59802-4123
www.missoulacounty.us/wqd
Phone|406.258.4890
Fax|406.258.4781

October 7, 2022

319 Review Committee
Montana Department of Environmental Quality
P.O. Box 200901
Helena, MT 59620

RE: Takima Park

Dear 319 Review Committee,

The Missoula Valley Water Quality District is a local government agency whose mission is to protect and improve surface and groundwater quality within the Missoula valley. The District is deeply interested in stormwater quality as it is known to be a leading cause of surface water degradation nationally and is certainly a concern in urban environments. As such, the District supportive of the city of Missoula's proposal to improve stormwater quality at Takima Park, a junction and discharge point of stormwater from Missoula's south hills neighborhoods into Pattee Creek.

The Water Quality District has been studying surface water quality in Pattee Creek for a number of years, including annual sampling of Total Suspended Solids (TSS), Nutrients and chlorides. We have seen marked impacts from stormwater runoff through the project section of Pattee Creek with some of the highest levels of TSS and Chloride detected within the District. The District is pleased to work with the City of Missoula in efforts to combat this trend. Please accept this letter as strong support for the City's application.

Thank you for the opportunity to demonstrate our support for this project.

Sincerely,

Elen Evns

Environmental Health Manager/Hydrogeologist
Missoula Valley Water Quality District
eevans@missoulacounty.us

CLARK FORK COALITION P.O. Box 7593, Missoula, MT 59807 ph. 406-542-0539

November 1, 2021

Grant Review Committee
Montana Department of Natural Resources
PO Box 201601
Helena, MT 59620-1601

Dear DNRC Grant Review Committee:

On behalf of the Clark Fork Coalition (CFC), I am writing in support of the Missoula Stormwater Utility's Watershed Management Grant Application for riparian restoration on Pattee Creek, a tributary to the Bitterroot River in Missoula. The Clark Fork Coalition is a river conservation organization of some 2,700 members, dedicated to protecting clean water and restoring healthy rivers throughout the Clark Fork watershed for the past 30 years.

The project would implement recommendations for Pattee Creek developed in the Bitterroot Watershed Restoration Plan, including the restoration of riparian vegetation along at least 500 feet of the stream. Among other activities, the DNRC grant funds would also allow the Stormwater Utility to host a Big Sky Watershed Corps member to conduct public education and outreach, using the restored portion of the creek as an example how water quality and stream habitat can be protected in an urban environment. The proposed improvements to Pattee Creek would help maintain the populations of westslope cutthroat trout and Columbia spotted frogs that still inhabit the creek, and would reduce Pattee Creek's surprisingly high suspended sediment load to the Bitterroot River.

The Clark Fork Coalition worked closely with Montana DEQ and the Missoula Water Quality District to develop the recommendations for Pattee Creek in the Bitterroot Watershed Restoration Plan. We commend the Missoula Stormwater Utility for taking the lead on implementing these recommendations and urge you to provide the funding they have requested for doing so. Thank you for your consideration.

Sincerely,

John DeArment

John DeArment
Science Director
john@clarkfork.org

CLARK FORK COALITION P.O. Box 7593, Missoula, MT 59807 ph. 406-542-0539

February 24, 2022

Montana Watershed Coordination Council
Grant Review Committee
2022 BSWC Nonpoint Source Project Support
PO Box 1416
Helena, MT 59624

Dear Grant Review Committee:

On behalf of the Clark Fork Coalition (CFC), I am writing in support of the BSWC Project Support Grant Application from Mackenzie Tenan, a Big Sky Watershed Corps member currently serving with the Missoula Stormwater Utility. The grant would support urgently needed riparian restoration and on Pattee Creek, a tributary to the Bitterroot River in Missoula. The Clark Fork Coalition is a river conservation organization of some 2,700 members, dedicated to protecting clean water and restoring healthy rivers throughout the Clark Fork watershed for the past 30 years.

The project would implement recommendations for Pattee Creek developed in the Bitterroot Watershed Restoration Plan, including the restoration of riparian vegetation along 100 feet of the stream. The grant funds would also allow Ms. Tenan to conduct public education and outreach, using the restored portion of the creek as an example how water quality and stream habitat can be protected in an urban environment. The proposed improvements to Pattee Creek would help maintain the populations of westslope cutthroat trout and Columbia spotted frogs that still inhabit the creek, and would reduce Pattee Creek's surprisingly high suspended sediment load to the Bitterroot River.

The Clark Fork Coalition worked closely with Montana DEQ and the Missoula Water Quality District to develop the recommendations for Pattee Creek in the Bitterroot Watershed Restoration Plan. We commend Ms. Tenan and the Missoula Stormwater Utility for taking the lead on implementing these recommendations and urge you to provide the funding they have requested for doing so. Thank you for your consideration.

Sincerely,

John DeArment

John DeArment
Science Director
john@clarkfork.org

MISSOULA PARKS AND RECREATION DEPARTMENT
100 HICKORY ST. • MISSOULA, MT 59801 • (406) 721-7275 • FAX: (406) 552-6275
PARKS • RECREATION • URBAN FORESTRY • CONSERVATION LANDS • TRAILS

1/30/20

DNRC Renewable Resource Planning Grant

Re: Letter of Support for the City of Missoula Takima Park Stormwater proposal

The City of Missoula Manages over 4500ac. of public natural areas within the City limits. Many of these natural areas protect important natural and cultural resources. These areas also offer unique recreational opportunities for the public. While Takima park provides few public recreation opportunities it does provide important wildlife habitat and stormwater control in Missoula's South Hills.

For the past 10 years, Missoula's Conservation Lands Management Program has worked to restore riparian vegetation along Pattee Ck., in Takima Park. Even though this park is relatively small, our monitoring efforts have documented a significant level of wildlife use. Waterfowl nesting, migratory songbird nesting and a multitude of large and small mammals use the park. Two Montana State species of concern, Westslope cutthroat trout and Columbia spotted frogs, are also present in Pattee Creek.

Conservation Lands Management Staff have been working closely with Missoula Stormwater Division staff to improve stormwater retention, water quality, and wildlife habitat across the Missoula Valley. Conservation Lands Management Staff have strong backgrounds (educational & applied) in habitat restoration. Missoula's Conservation Lands Management program is committed to providing resources toward the implementation of this project once a plan is developed. A DNRC Renewable Resource Planning Grant would provide a critical first step towards implementing a holistic green infrastructure project in Takima Park, which protects and improves important local infrastructure as well as natural resources of State-wide significance.

I hope you also see the value of this project and help fund this critical first step. Please feel free to contact me if you have any questions.

Sincerely,

Morgan Valliant
Conservation Lands Manager
Missoula Parks and Rec.
100 Hickory St.
Missoula Mt. 59801
(406) 552-6263

DEPARTMENT OF PARKS & RECREATION

ECOSYSTEM SERVICES DIVISION

100 Hickory St◆ Missoula MT 59801 ◆ (406) 552-6253 ◆ (406) 327-2140 ◆ www.missoulaparks.org

CONSERVATION LANDS MANAGEMENT *URBAN FORESTRY*

To: Watershed Management Grant Administrator
Conservation and Resource Development Division
Montana Department of Natural Resources and Conservation

From: Jeff Gicklhorn, Conservation Lands Program Manager
City of Missoula Parks and Recreation
100 Hickory Street
Missoula, MT 59801

Re: Letter of support for City of Missoula DNRC Watershed Management Grant application

Dear Grant Administrator,

This letter is in support of the DNRC Watershed Management Grant application submitted by City of Missoula, Public Works - Stormwater Division for improvements to a reach of Pattee Creek within Missoula City limits. Within this reach, Missoula Parks & Recreation manages approximately 1,700 linear feet split between two small developed parks and the much larger Bancroft Ponds Natural Area. Bancroft Ponds is an engineered wetland that provides stormwater filtration as well as significant aquatic habitat for native species, including one of the few remaining Columbia spotted frog populations in the Missoula Valley. In addition, this park provides valuable learning opportunities for members of the public and local school children through an outdoor classroom and interpretive signage to be constructed and installed this winter.

Improving stormwater flow and reducing non-point source pollutants within this portion of Pattee Creek through education, outreach, and restoration activities will improve water quality both within Bancroft Ponds and downstream in the Bitterroot River. Funds from the Watershed Management Grant will be used to purchase and grow native plants for planned restoration activities as discussed in the proposal. Conveniently, the Parks & Recreation Department has our own native plant nursery, and the ability to grow and supply native plant materials at rates significantly below that of local commercial nurseries, which can stretch limited grant dollars. We look forward to assisting City of Missoula, Public Works - Stormwater Division in reducing non-point source pollutants into Pattee Creek by working to implement on-site restoration and adjusting management practices within City parks.

If you have any additional questions about anything discussed above, please do not hesitate to reach out via email at GicklhornJ@ci.missoula.mt.us or phone at (406) 552-6691.

Thank you,

Jeff Gicklhorn

MISSOULA
DEPARTMENT OF PARKS & RECREATION
ECOSYSTEM SERVICES DIVISION
100 Hickory St ◆ Missoula MT 59801 ◆ (406) 552-6253 ◆ (406) 327-2140 ◆ www.missoulaparks.org
CONSERVATION LANDS MANAGEMENT *URBAN FORESTRY*

To: 319 Program Grant Administrator
US Environmental Protection Agency

From: Jeff Gicklhorn, Conservation Lands Program Manager
City of Missoula Parks and Recreation
100 Hickory Street
Missoula, MT 59801

Re: Letter of support for City of Missoula 319 grant application

Dear Grant Administrator,

This letter is in support of the EPA 319 Program grant submitted by City of Missoula, Public Works - Stormwater Division for improvements to a reach of Pattee Creek within Missoula City limits. Within this reach, Missoula Parks & Recreation manages approximately 1,700 linear feet split between two small developed parks and the much larger Bancroft Ponds Natural Area. Bancroft Ponds is an engineered wetland that provides stormwater filtration as well as significant aquatic habitat for native species, including one of the few remaining Columbia spotted frog populations in the Missoula Valley. In addition, this park provides valuable learning opportunities for members of the public and local school children through an outdoor classroom and interpretive signage to be constructed and installed this winter.

Improving stormwater flow and reducing non-point source pollutants within this portion of Pattee Creek through education, outreach, and restoration activities will improve water quality both within Bancroft Ponds and downstream in the Bitterroot River. Funds from the 319 Program will be used to purchase and grow native plants for planned restoration activities as discussed in the proposal. Conveniently, the Parks & Recreation Department has our own native plant nursery, and the ability to grow and supply native plant materials at rates significantly below that of local commercial nurseries, which can stretch limited grant dollars. We look forward to assisting City of Missoula, Public Works - Stormwater Division in reducing non-point source pollutants into Pattee Creek by working to implement on-site restoration and adjusting management practices within City parks.

If you have any additional questions about anything discussed above, please do not hesitate to reach out via email at GicklhornJ@ci.missoula.mt.us or phone at (406) 552-6691.

Thank you,

Jeff Gicklhorn

FWP.MT.GOV

THE **OUTSIDE** IS IN US ALL.

Region 2 Headquarters
3201 Spurgin Road
Missoula, MT 59804
Phone 406-542-5500
January 30, 2020

Montana DNRC-CARDD
Attn: RRGL Program
PO Box 201601
Helena, MT 59620-1601

RE: DNRC Renewable Resource Planning Grant

Dear Application Review Committee:

This letter is written in support of the City of Missoula' application for Renewable Resource Planning Grant Funds. More specifically, the requested funds would address stormwater management issues on the edge of the Missoula within the Pattee Creek watershed. Pattee Creek has been heavily impacted by development and encroachment, but still supports a genetically pure, isolated population of Westslope Cutthroat Trout (State Species of Concern and Montana's State Fish).

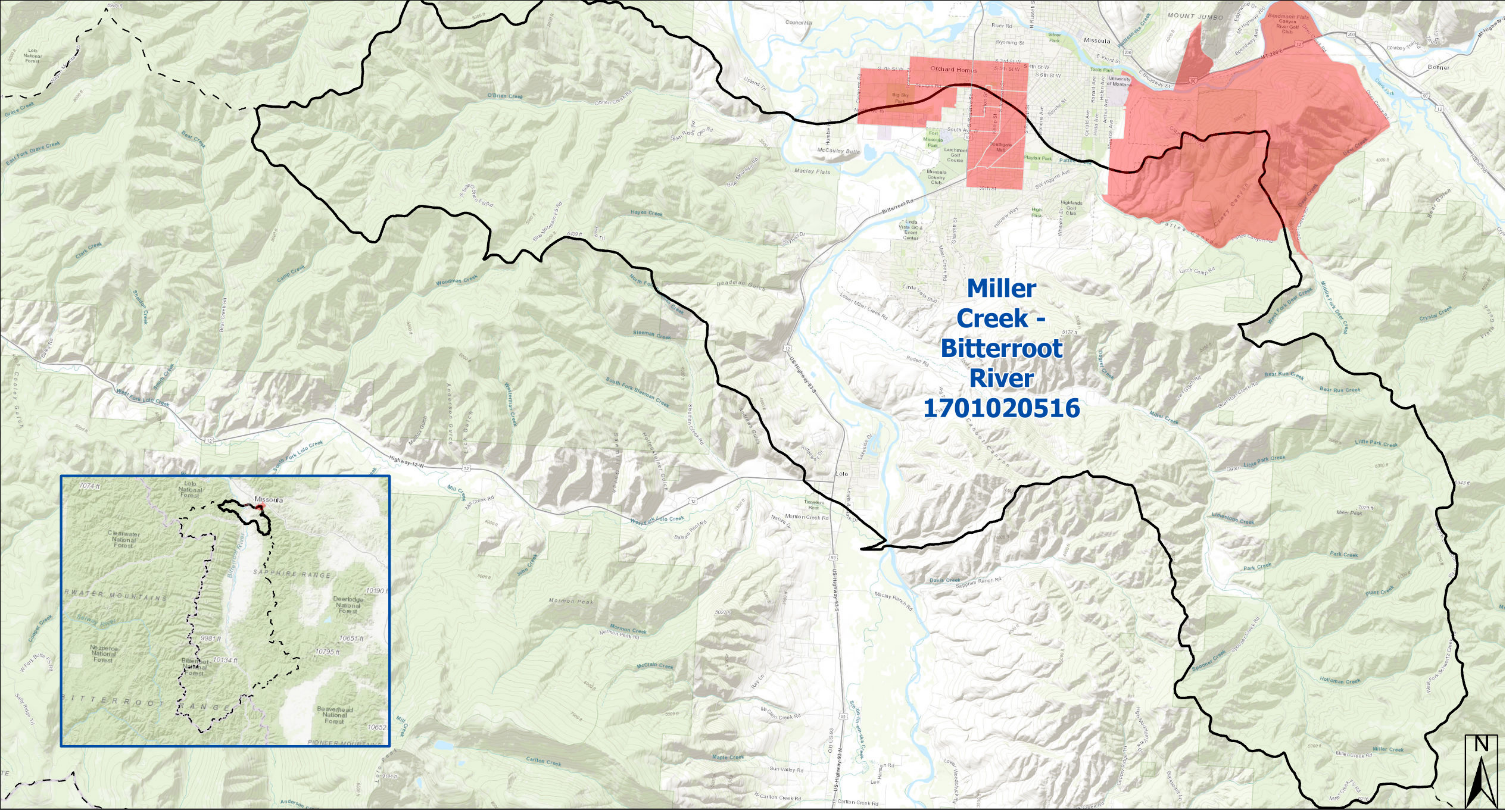
There are four outfalls that discharge untreated storm water into Pattee Creek at Takima Park. Untreated storm water is high in nutrients and total suspended sediments, thus severely diminishing habitat quality for this fishery as storm water is discharged into the creek. The effects to Pattee Creek include degraded water quality, which negatively influences aquatic and wildlife habitat. Additionally, the storm water system in this area is aging and does not function as designed. This leads to significant ponding on the roads, creating hazardous conditions. This planning effort will review options to manage and treat storm water prior to discharge into Pattee Creek, while creating amenities for aquatic and wildlife habitat, recreation, and increased public safety. The renewable resource benefits include surface water management, surface water quality preservation, development of wildlife habitat, and preservation of aquatic habitat.

Please give strong consideration to this application and feel free to contact me if you would like more information regarding Pattee Creek.

Sincerely,

Wm . Ladd Knotek
Fisheries Management Biologist

PLANNING AND DESIGN DOCUMENTS



Miller Creek - Bitterroot Focus Watershed

STORMWATER
City of Missoula

0 5,000 10,000 20,000 Feet

WBDHU8
WBDHU10
EPA Disadvantaged Communities

Created By: Lyndsey Holloway
Date: 12/19/2024

BIORETENTION BASIN - SITE PLAN

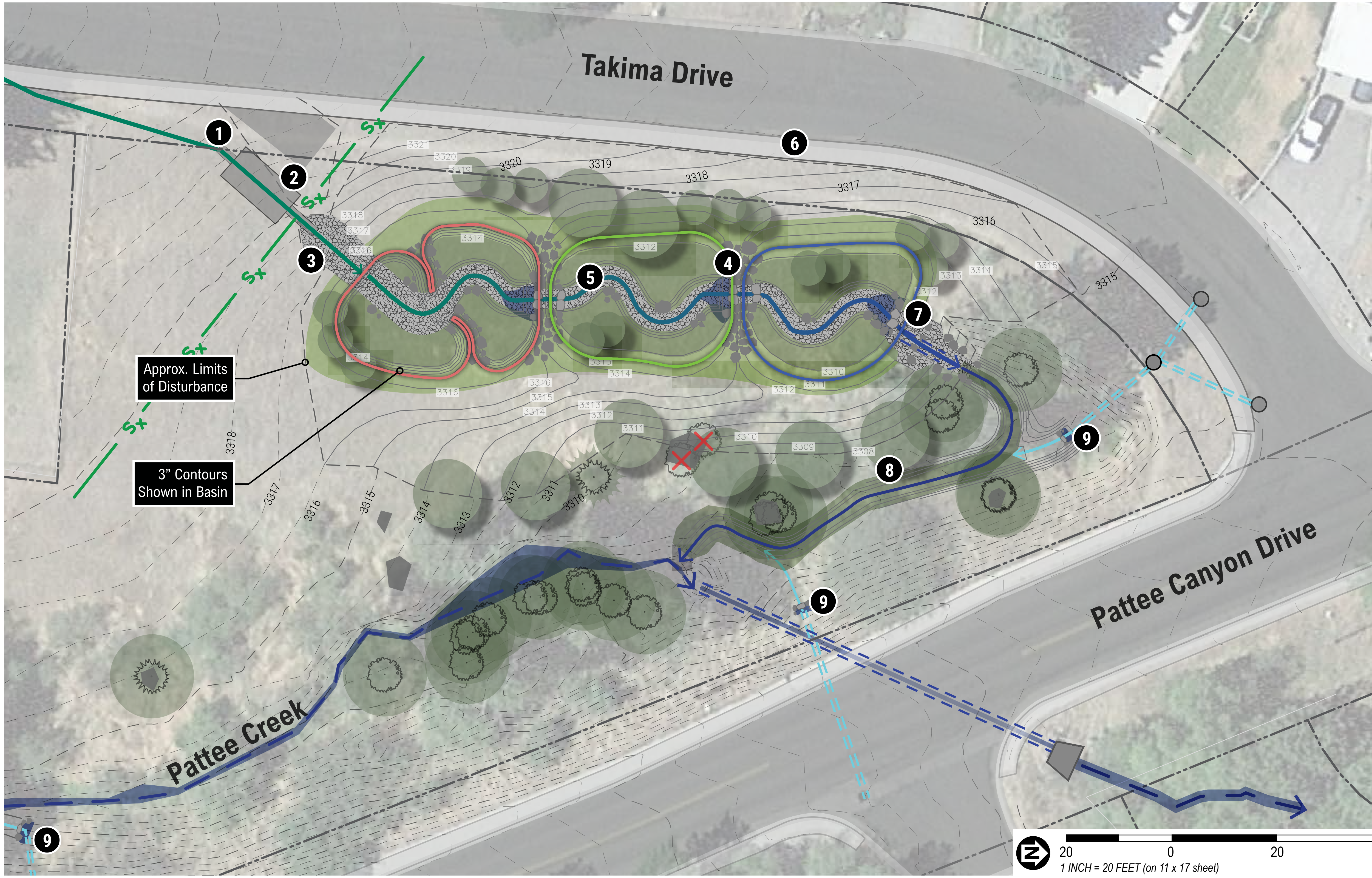
SITE PLAN LEGEND

1. Tie-into Existing Stormwater Line
2. Pretreatment Cell and Outflow
3. Rockery - Water Energy Dissipation
4. Rock Weir - 3' Drop
5. Meandering Low-flow Water Channel
6. Future Curbside Sidewalk - 6' Wide
7. Outfall - Water Overflows to Swale
8. Biofiltration Discharge Swale from "Zone 3" to Pattee Creek
9. Minor Outfall - Microdetention

- Native Plantings - Consists of Upland, Riparian, & Emergent Vegetation
- Boulders / Rip-Rap
- Existing Sanitary Sewer Line
- Existing Contours
- Proposed Contours
- Flow of Stormwater to be Treated
- Minor Storm Drain Outfalls
- Water Pooling Areas - Standing Water
- Trees to be Removed

BIORETENTION ZONES

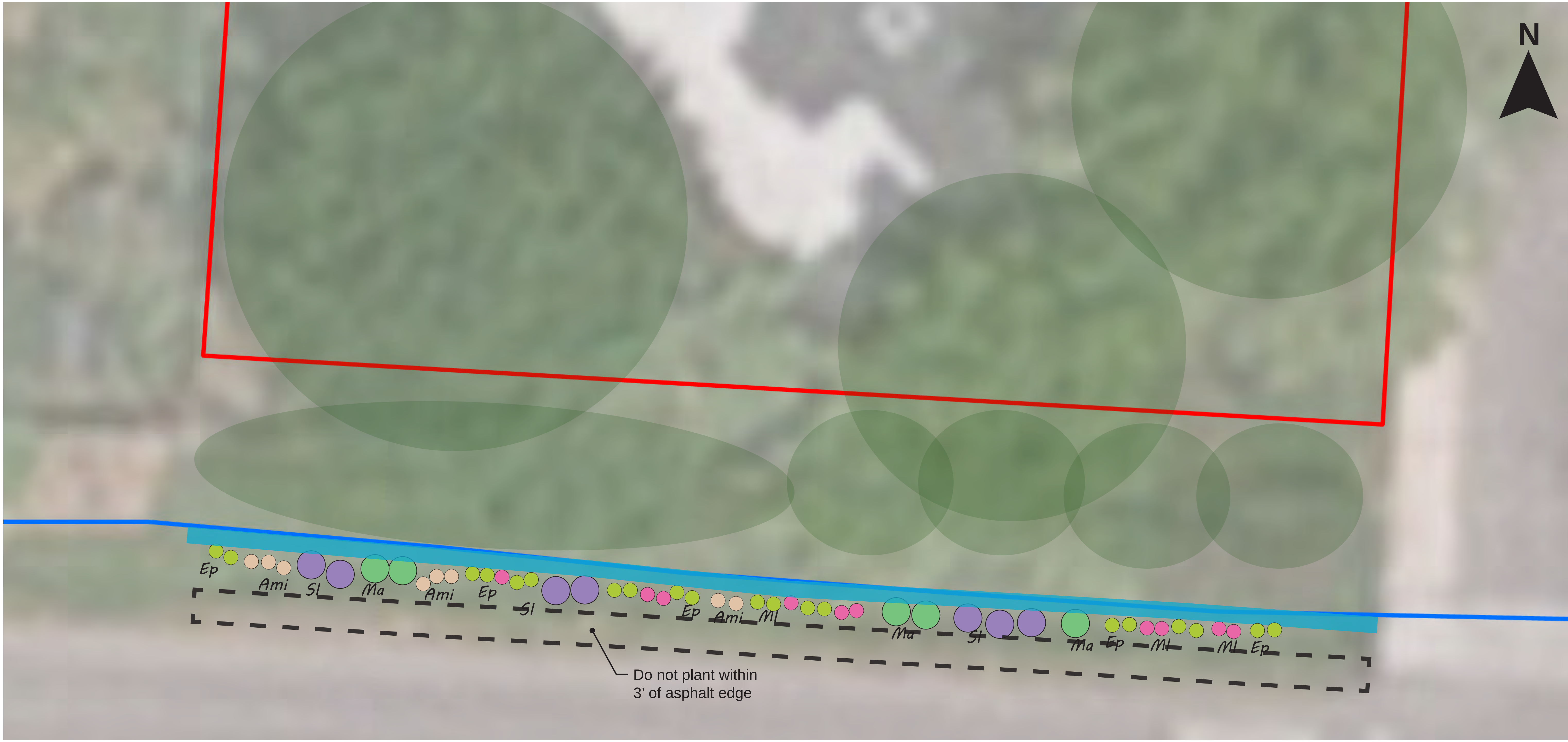
- Zone 1 - Partial Water Infiltration
- Zone 2 - Partial Water Infiltration
- Zone 3 - Occassional Standing Water



60% DESIGN PHASE

Pattee Creek Restoration Project: 3036 Queen St

STORM WATER
City of Missoula



General Notes:

- For this property, planting must only occur on the south side of the stream channel.
- The selected species should be planted on the streambank since they prefer having "wet feet."
- Do not damage existing tree and shrub roots while planting

Legend

- Property line of participating landowner
- Pattee Creek
- Approx. location of walkway/driveway
- Existing vegetation to remain undisturbed

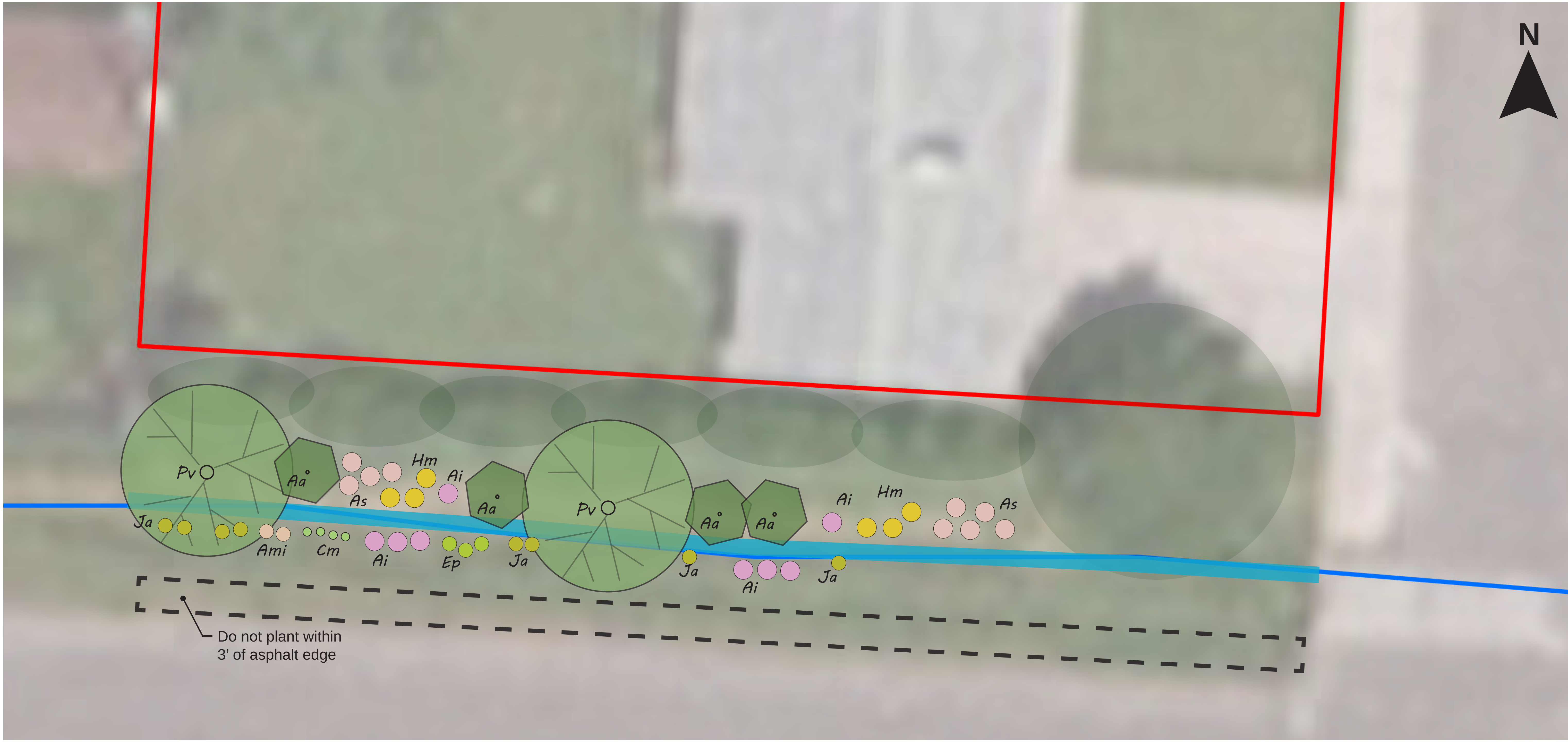
Ami	Achillea millefolium	**common yarrow**
Ep	Eleocharis palustrus	**common spikerush**
Ma	Mentha arvensis	**wild mint**
Ml	Mimulus lewisii	**purple monkey flower**
Sl	Symphyotrichum laeve	**smooth blue aster**

Plant all to full root depth, backfill with original soil

0 5 10 25 feet

Matting & Deer Protection:
- group weed matting (3-4 strips)
- Individual netting with 2 stakes at each (make sure there is room around each):
***common yarrow**
***wild mint**
***purple monkey flower**
***smooth blue aster**

Pattee Creek Restoration Project: 444 King St



General Notes:

- For this property, plantings on the south side of the stream should be planted on the streambank since they prefer having "wet feet."
- Do not damage existing tree and shrub roots while planting

Legend

- Property line of participating landowner
- Pattee Creek
- Approx. location of walkway/driveway
- Existing vegetation to remain undisturbed

Pv	Prunus virginiana	**chokecherry**
Aa	Amelanchier alnifolia	**serviceberry**
Ami	Achillea millefolium	**common yarrow**
Ai	Asclepias incarnata	**swamp milkweed**
As	Asclepias speciosa	**showy milkweed**
Cm	Carex microptera	**small wing sedge**
Ep	Eleocharis palustrus	**common spikerush**
Hm	Helianthus maximiliani	**maximilian sunflower**
Ja	Juncus arcticus	**arctic rush**

0 5 10 25 feet

Matting & Deer Protection:

- individual matting, individual fencing/netting
- Netting with 2 stakes (make sure there is room around each):
***common yarrow**
***swamp milkweed**
***showy milkweed**
***maximilian sunflower**
- Metal fencing with t posts: chokecherry, serviceberry

Serviceberry & chokecherry: dig until depth of roots, 2x wider than pot, backfill with original soil
Rest: plant to full root depth, backfill with original soil

Pattee Creek Restoration Project: 420 Pattee Creek Dr

STORM WATER
City of Missoula

General Notes:

- For this property, all plantings except Ama (Anaphalis margaritacea) and Ra (ribes aureum) must be on the stream bank
- Do not damage existing tree and shrub roots while planting

Legend

- Property line of participating landowner
- Pattee Creek
- Approx. location of walkway/driveway
- Existing vegetation to remain undisturbed

Ra — Ribes aureum **golden currant**

Ama — Anaphalis margaritacea **pearly everlasting**

Cm — Carex microptera **small wing sedge**

Dc — Deschampsia cespitosa **tufted hair grass**

Ja — Juncus arcticus **arctic rush**

Ml — Mimulus lewisii **purple monkey flower**

Sc — Solidago canadensis **Canada goldenrod**

Matting & Deer Protection:

- group weed matting (2 strips)
- Individual netting with 2 stakes (make sure there's room around each):
***pearly everlasting**
***purple monkey flower**
***Canada goldenrod**
- Individual metal fencing with t post:
***golden currant**

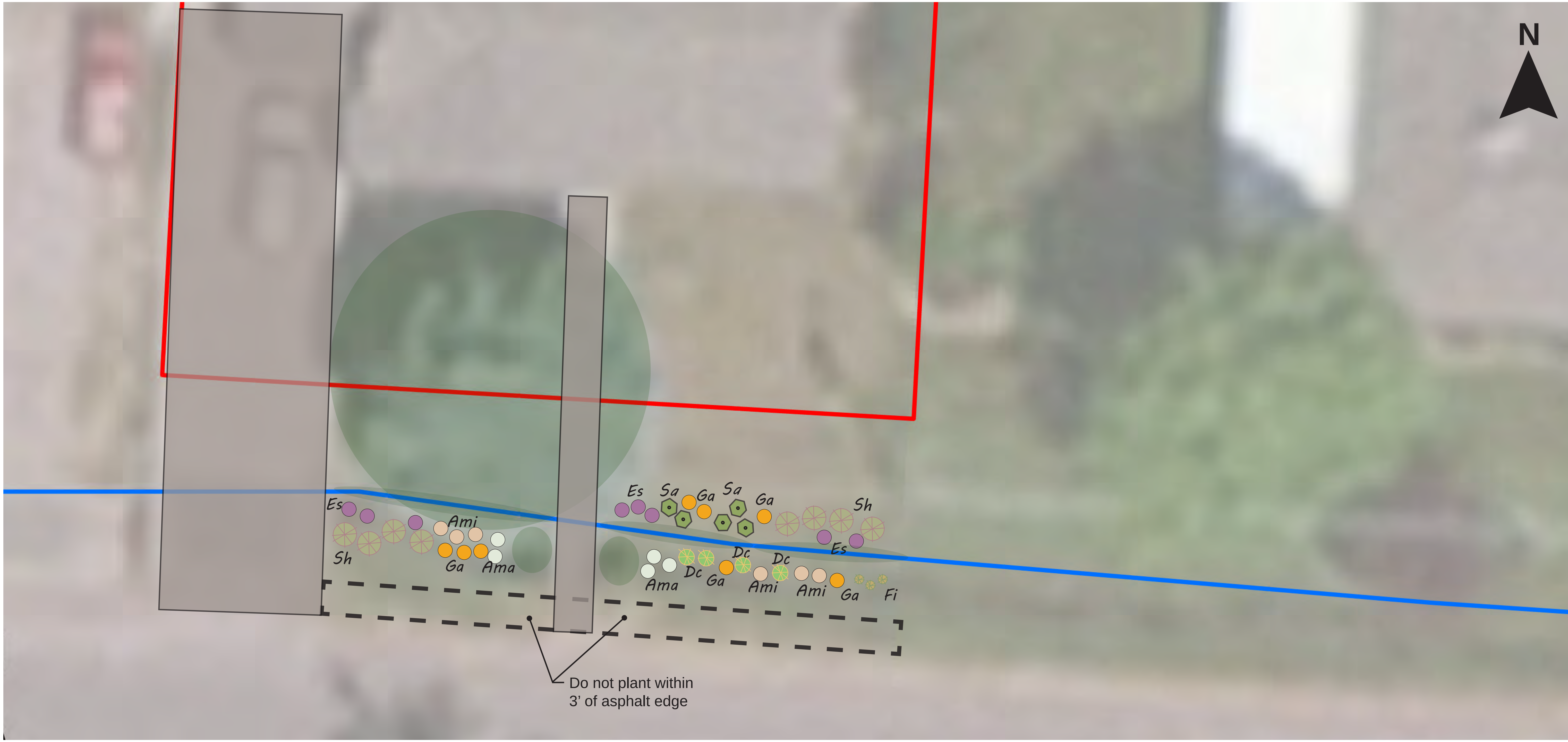
0 5 10 25 feet

Golden currant: dig until depth of roots, 2x wider than pot, backfill with original soil

Rest: plant to full root depth, backfill with original soil

Pattee Creek Restoration Project: 408 Pattee Creek Dr

STORM WATER
City of Missoula



General Notes:

- For this property, there is existing streambank vegetation that should remain. Plant 1’ from top-of-bank
- Do not damage existing tree and shrub roots while planting

Legend

- Property line of participating landowner
- Pattee Creek
- Approx. location of walkway/driveway
- Existing vegetation to remain undisturbed

Sa	Symphoricarpos albus	**snowberry**
Ama	Anaphalis margaritacea	**pearly everlasting**
Ami	Achillea millefolium	**common yarrow**
Dc	Deschampsia cespitosa	**tufted hair grass**
Es	Erigeron speciosa	**aspen fleabane**
Fi	Festuca idahoensis	**Idaho fescue**
Ga	Gaillardia aristata	**blanketflower**
Sh	Sporobolus heterolepis	**prairie dropseed**

Matting & Deer Protection:

- 3 strips of weed matting (one for each group)
- Individual netting with 2 (make sure there is room around each):
***pearly everlasting**
***common yarrow**
***aspen fleabane**
***blanketflower**
- Wire fencing with t posts: snowberrry

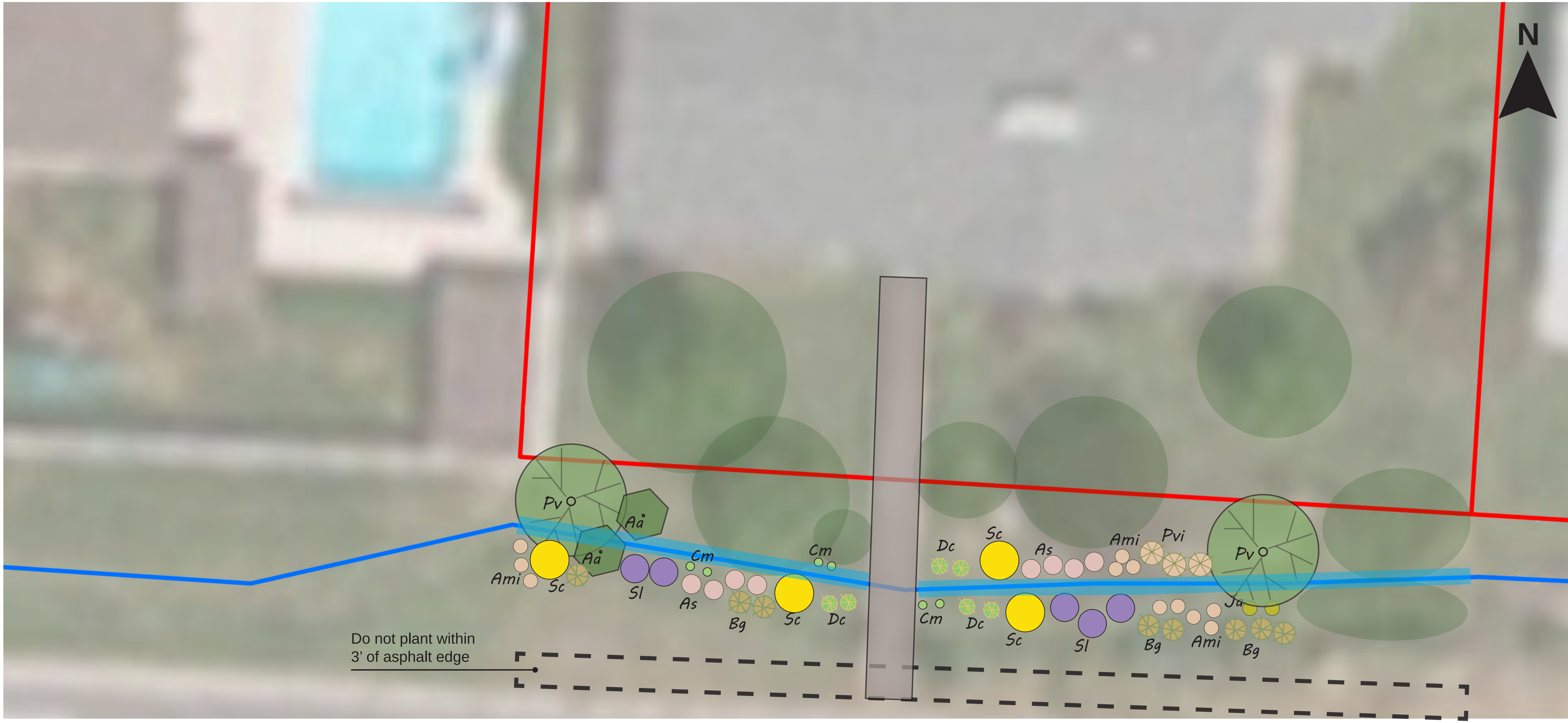
0 5 10 25 feet

Snowberry: dig until depth of roots, 2x wider than pot, backfill with original soil

Rest: plant to full root depth, backfill with original soil

Pattee Creek Restoration Project: 244 Pattee Creek Dr

STORM WATER
City of Missoula



General Notes:

- Do not damage existing tree and shrub roots while planting

Serviceberry & chokecherry: dig until depth of roots, 2x wider than pot, backfill with original soil

Rest: plant to full root depth, backfill with original soil

Legend

- Property line of participating landowner
- Pattee Creek
- Approx. location of walkway/driveway
- Existing vegetation to remain undisturbed

Pv	Prunus virginiana	**chokecherry**
Aa	Amelanchier alnifolia	**serviceberry**
Ami	Achillea millefolium	**common yarrow**
As	Asclepias speciosa	**showy milkweed**
Bg	Bouteloua gracilis	**blue grama**
Cm	Carex microptera	**small wing sedge**
Dc	Deschampsia cespitosa	**tufted hair grass**
Ja	Juncus arcticus	**arctic rush**
Pvi	Panicum virgatum	**switchgrass**
Sl	Symphyotrichum laeve	**smooth blue aster**
Sc	Solidago canadensis	**Canada goldenrod**

0 5 10 25 feet

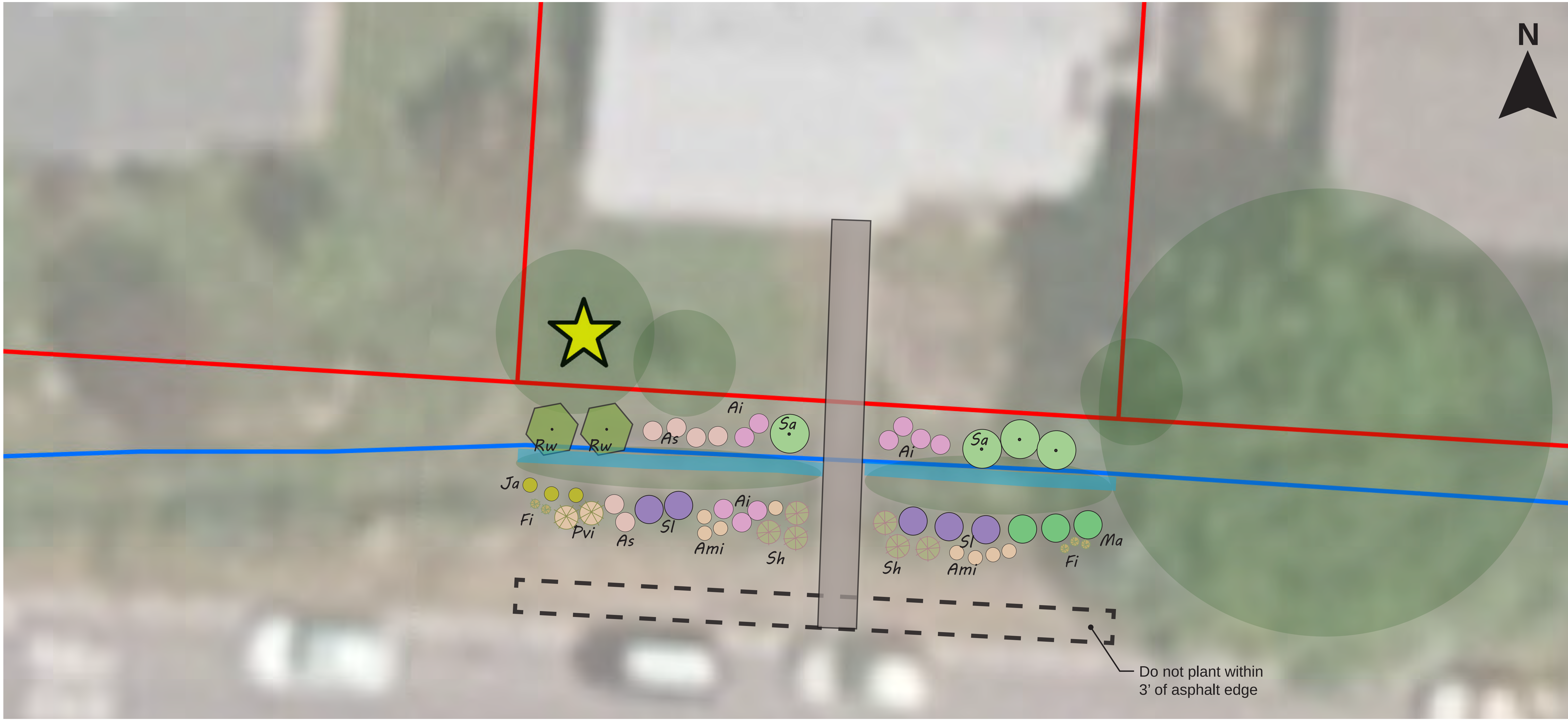
Matting & Deer Protection:

- group weed matting (3 strips)
- Individual netting with 2 stakes (make sure there is room around each):
common yarrow, showy milkweed, smooth blue aster, Canada goldenrod

- Individual metal fencing with t posts: chokecherry, serviceberry

Pattee Creek Restoration Project: 224 Pattee Creek Dr

STORMWATER City of Missoula



General Notes:

- For this property, there is existing streambank vegetation that should remain. Plant above the top-of-bank
- Do not damage existing tree and shrub roots while planting

Snowberry & woods rose: dig until depth of roots, 2x wider than pot, backfill with original soil
Rest: plant to full root depth, backfill with original soil

Legend

- Property line of participating landowner
- Pattee Creek
- Approx. location of walkway/driveway
- Existing vegetation to remain undisturbed

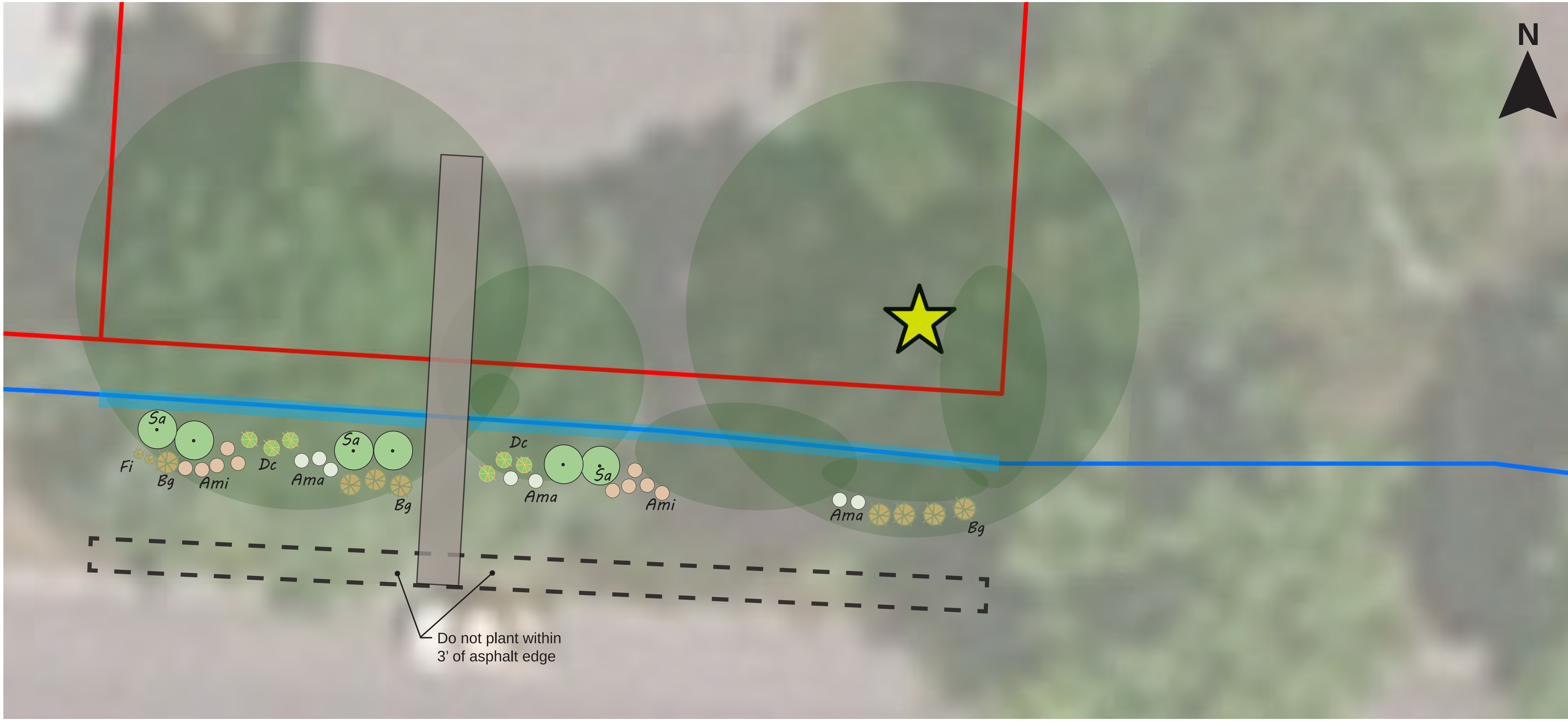
Rw	Rosa woodsii	**woods rose**
Sa	Symphoricarpos albus	**snowberry**
Ami	Achillea millefolium	**common yarrow**
Ai	Asclepias incarnata	**swamp milkweed**
As	Asclepias speciosa	**showy milkweed**
Fi	Festuca idahoensis	**Idaho fescue**
Ja	Juncus arcticus	**arctic rush**
Ma	Mentha arvensis	**wild mint**
Pvi	Panicum virgatum	**switchgrass**
Sh	Sporobolus heterolepis	**prairie dropseed**
Sl	Symphyotrichum laeve	**smooth blue aster**

0 5 10 25 feet

Matting & Deer Protection:
- group weed matting (4 strips)
- Individual netting with 2 stakes (make sure there is enough room around each): common yarrow, swamp milkweed, showy milkweed, wild mint, smooth blue aster
- Individual metal fencing with t post: snowberry
- plant in front of railroad ties on north bank if able

Pattee Creek Restoration Project: 220 Pattee Creek Dr

STORM WATER City of Missoula



General Notes:

- For this property, only plant on the south side of the stream
- Do not damage existing tree and shrub roots while planting

Legend

- Property line of participating landowner
- Pattee Creek
- Approx. location of walkway/driveway
- Existing vegetation to remain undisturbed
- Sa — Symphoricarpos albus **snowberry**
- Ama — Anaphalis margaritacea **pearly everlasting**
- Ami — Achillea millefolium **common yarrow**
- Bg — Bouteloua gracilis **blue grama**
- Dc — Deschampsia cespitosa **tufted hair grass**
- Fi — Festuca idahoensis **Idaho fescue**

0 5 10 25 feet

Matting & Deer Protection:
- group weed matting (3 strips)

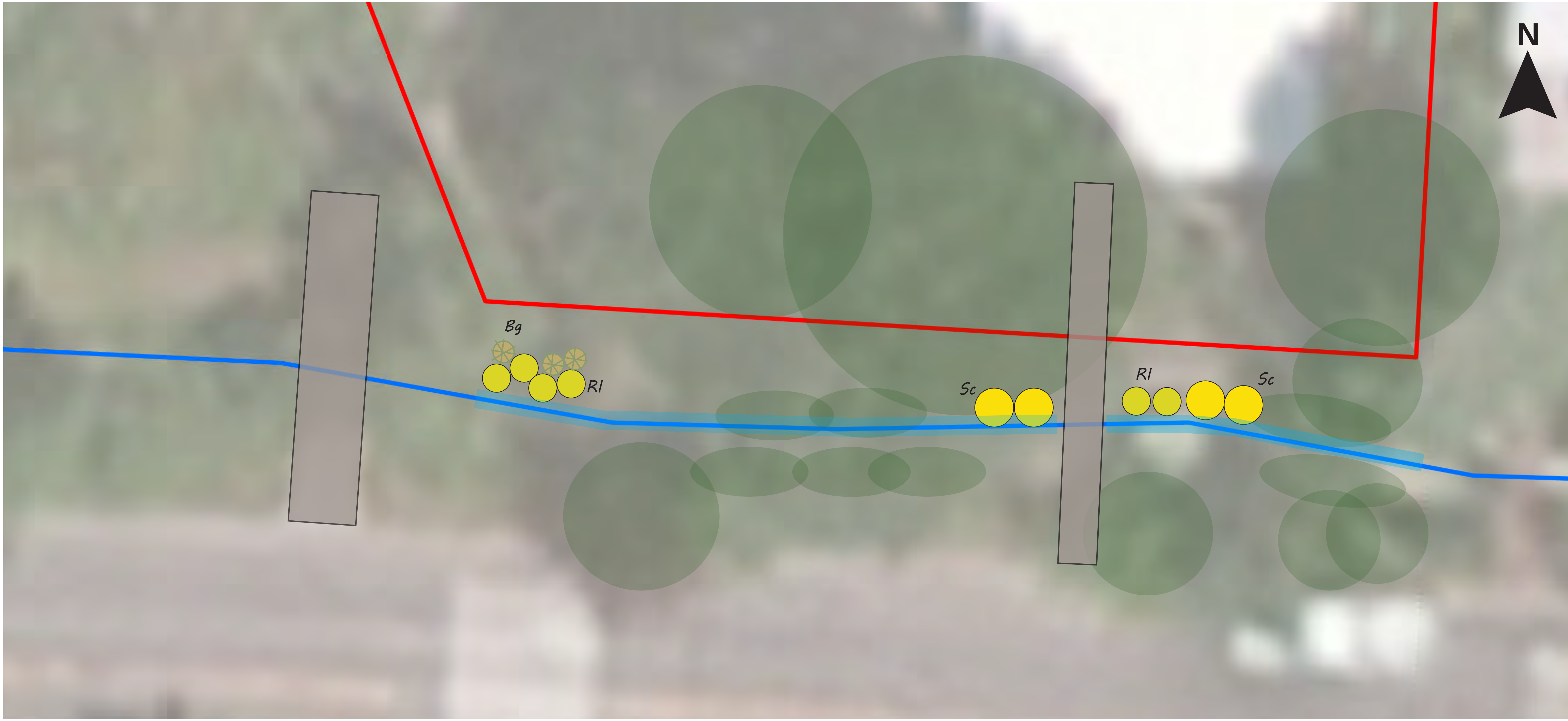
- Individual netting with 2 stakes (make sure there's enough room around each: pearly everlasting, common yarrow

- Individual metal fence with t posts: snowberry

Snowberry: dig until depth of roots, 2x wider than pot, backfill with original soil
Rest: plant to full root depth, backfill with original soil

Pattee Creek Restoration Project: 130 Pattee Creek Dr

STORM WATER City of Missoula



General Notes:

- For this property, only plant on the north side of the stream
- Do not damage existing tree and shrub roots while planting

Legend

- Property line of participating landowner
- Pattee Creek
- Approx. location of walkway/driveway
- Existing vegetation to remain undisturbed
- Bg — Bouteloua gracilis **blue grama**
- Rl — Rudbeckia lacinata **cutleaf coneflower**
- Sc — Solidago canadensis **Canada goldenrod**

0 5 10 25 feet

Matting & Deer Protection:
- group weed matting (3 strips)
- Individual netting with 2 stakes (make sure there's enough room around each):
***cutleaf coneflower**
***Canada goldenrod**

Plant all to full root depth, backfill with original soil

Pattee Creek Restoration Project: 120 Pattee Creek Dr

General Notes:

- For this property, only plant on the north side of the stream
- Do not damage existing tree and shrub roots while planting

Legend

Property line of participating landowner

Pattee Creek

Approx. location of walkway/driveway

Existing vegetation to remain undisturbed

Ep Eleocharis palustrus **common spikerush**

Sc Solidago canadensis **Canada goldenrod**

0 5 10 25 feet

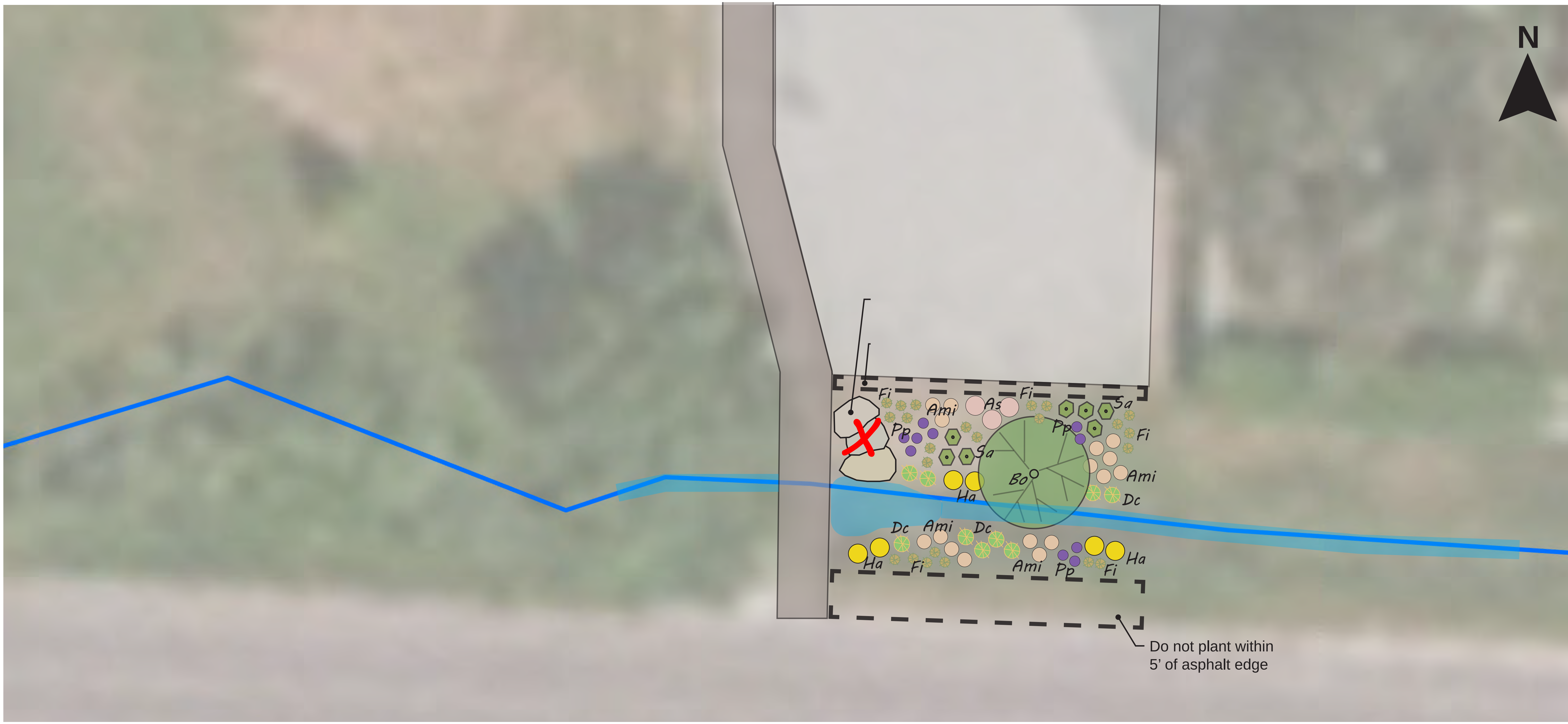
Chokecherry: dig until depth of roots, 2x wider than pot, backfill with original soil
Rest: plant to full root depth, backfill with original soil

****use extra chokecherry from Elms where homeowner removed existing bristlecone pine - northeast side of the creek**

Matting & Deer Protection:
- group weed matting (1 strip)
- Individual netting with 2 stakes at each (make sure there's enough room around each)
- Individual metal fence with t post for chokecherry

Pattee Creek Restoration Project: Elms Park

STORM WATER
City of Missoula



General Notes:

- Spread clean, dry mulch materials over the entire planting area, consisting of ¾" to 1 ¼" fir bark, or approved equal, free from foreign and harmful materials.

water birch & snowberry: dig until depth of roots, 2x wider than pot, backfill with original soil
Rest: plant to full root depth, backfill with original soil

Legend

Pattee Creek

Approx. location of walkway/driveway

Bo — Betula occidentalis **water birch**

Sa — Symphoricarpos albus **snowberry**

Ami — Achillea millefolium **common yarrow**

As — Asclepias speciosa **showy milkweed**

Dc — Deschampsia cespitosa **tufted hair grass**

Fi — Festuca idahoensis **Idaho fescue**

Ha — Helenium autumnale **sneezeweed**

Pp — Penstemon procerus **littleflower penstemon**

0 5 10 25 feet

Matting & Deer Protection:

- North bank: surround all plants with metal fence & t posts as needed
***no matting needed**
- South bank: matting for entire length
***individual netting, 2 stakes (make sure there's enough room around each): common yarrow, showy milkweed, sneezeweed, littleflower penstemon**

3.12 Miller Creek

Description

Miller Creek is located in the Missoula metropolitan area and drains into the Lower Mainstem Bitterroot River. For in depth information on Miller Creek, please see the Miller Creek Watershed Restoration Plan.

Stream Impairments[71]

Impairment Cause	TMDL Pollutant Category	Impaired Beneficial Use	TMDL Completed	Source of Impairment Cause
Alteration in stream-side or littoral vegetative cover	N/A; non-pollutant	Aquatic Life	N/A	Grazing in riparian or shoreline zones Silviculture activities Loss of riparian habitat Crop production (crop land or dry land)
Sedimentation-Siltation	Sediment	Aquatic Life	Yes	Loss of habitat Grazing in riparian or shoreline zones Silviculture activities
Temperature	Temperature	Aquatic Life	Yes	Loss of habitat Grazing in riparian or shoreline zones Silviculture activities

TMDLs and Load Reductions

Sediment[72]

Degraded in-stream and riparian habitats as well as elevated sediment loads may have been caused by silviculture, forest roads, agriculture, and suburban developments. Streambank erosion caused by human activity is a major source of elevated sediment.

71 Montana Department of Environmental Quality. Final 2018 Water Quality Integrated Report Appendix A: Impaired Waters. Helena: Montana. Department of Environmental Quality [2018]. Web.

72 Montana Department of Environmental Quality. Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan, Document No. C05-TMDL-03aF. Table 5-63: Miller Creek Sediment TMDL. 2011.

Sediment Sources		Current Estimated Load (Tons/Year)	Total Allowable Load (Tons/Year)	Sediment Load Allocation (% Reduction)
Roads		27	10	63%
Eroding Banks	**Anthropogenically Influenced**	1415	792	30%
	Natural	659	659	
Upland Erosion	**All land uses**	131	77	41%
Stormwater		0	0*	0%
Total Sediment Load		2232	1538	31%

* This allocation represents the maximum allowable load under the constraints of the current Stormwater Construction permit.

Temperature [73]

Temperatures in Miller Creek are unsuitable for native trout. The following criteria should be reached to achieve an 8F decrease in maximum daily temperature:

- Establish effective shade on 17% more of the creek (this 17% would correspond to a return to the creek's natural amount of shade). Shade loss was caused by timber, agricultural and suburban lawn care activities.
- Reduction of channel width: depth ratio from up to 48 at present to 16 or less.
- Increase irrigation efficiency by 15% to reduce water withdrawals in warm months. The lower stream, particularly below Trails End Road, experiences severe dewatering and is disconnected during periods of maximum withdrawal.
- Reduce irrigation water that is returned to the stream by 75%.

Management Measures

- Implement riparian revegetation projects. Multiple reaches have less than 25% riparian cover. Notably, there is easily-attainable revegetation potential on approximately 100,000 feet of stream.[74] Riparian vegetation will shade the stream and reduce sediment from upland and bank erosion. It will also improve water storage and groundwater infiltration to help maintain flows despite irrigation withdrawals. Riparian buffers to facilitate vegetation growth can be established on agricultural and suburban properties.

[73] Montana Department of Environmental Quality. *Bitterroot Temperature and Tributary Sediment Total Maximum Daily Loads and Framework Water Quality Improvement Plan*, Document No. C05-TMDL-03aF. Table 6-15. 2011.

[74] Montana DEQ Watershed Protection Section. "Riparian Evaluation and Wetland Priorities Results." June 2019.

- Study the irrigation system to determine where efficiencies can be improved. Encourage responsible water use practices through education and outreach activities and upgrade irrigation infrastructure.
- Implement BMPs at streamside roads and crossings
- Encourage land use BMPs on agricultural lands (e.g. offsite watering, fencing, etc.)

Projects

Restoration activities on Miller Creek will focus on revegetating riparian areas to reduce sediment loads to the stream and provide shade.

- As of 2018, BRWF is working on a $65,000 riparian fencing and revegetation project on a cattle ranch on Miller Creek with support from DEQ, MWCC, and TU. The project will protect and restore 0.6 miles of stream, and is expected to reduce sediment loads by 19 tons/year. As vegetation grows in, temperature loading will also decrease.
- Miller Creek has also been an area of focus for Clark Fork Coalition.

3.13 Pattee Creek

Description

Pattee Creek originates in the Pattee Canyon Recreation Area of the Lolo National Forest east of Missoula and southeast of the confluence of the Bitterroot and Clark Fork Rivers. Pattee Creek flows west out of the recreation area, through small agricultural fields used for often intense grazing, past an active gravel pit and through residential neighborhoods. Prior to entering the Missoula Valley, Pattee Creek goes through a stormwater detention pond and then alternates between being piped underground and flowing through ditches before entering the Bitterroot River. Although Pattee Creek is not on the 303(d) list of impaired waters, there is direct year-round discharge to the Bitterroot River. Missoula Valley Water Quality District sampling in March 2019 indicates Pattee Creek contributes to Bitterroot River impairments as Total Suspended Solids measurements at the headwaters site were measured at non-detect while discharge at the mouth measured at 282 mg/L. For reference, the benchmark value for TSS in stormwater permits 100 mg/L.

Figure 10. Pattee Creek Confluence with the Bitterroot River March 2019.

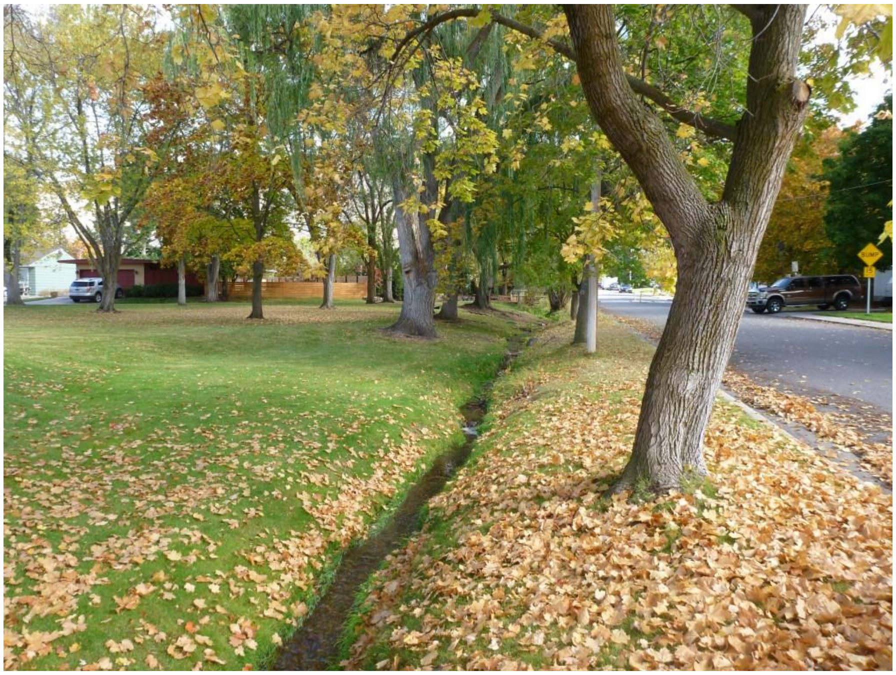


Figure 11: Pattee Creek channelized through residential development

Stream Concerns[75]

Concern Cause	TMDL Pollutant Category	Beneficial Use of Concern	TMDL Completed	Source of Concern Cause
Temperature	Temperature	Aquatic Life	No	Shade loss (removal of riparian vegetation) Channelization Streambank modifications and destabilization
Sedimentation-Siltation	Sediment	Aquatic Life	No	Road runoff (non-construction related)
Alteration in streamside or littoral vegetative covers	N/A; non-pollutant	Aquatic Life	N/A	Mowing in riparian zones Alteration of streamside vegetation

[75] Because Pattee Creek has not been assessed by DEQ, the term "impairment" does not apply. However, based on monitoring and assessment efforts completed by the Missoula Valley Water Quality District, MVWQD considers it to be a stream of concern in the Bitterroot watershed (EQUIS 2019).

TMDLs and Load Reductions

Pattee Creek does not have published TMDLs.

Management Measures

Restoration actions will include replacing undersized culverts, increasing riparian revegetation, mitigating agricultural impacts of grazing, decreasing road impacts, and decreasing residential irrigation withdrawals. Long-term, Pattee Creek should be daylighted, removed from pipes underground, and restored to natural function. Continued management of aquatic and streamside invasive species will be important to restoration of riparian vegetation.

Projects

- Partner with the City of Missoula Parks and Recreation Department to restore riparian vegetation and create educational examples of a healthy riparian corridor
- Decrease impairments caused by road maintenance activities on Pattee Creek through revegetation efforts, increasing culvert size or installing bridges or bottomless culverts and developing management plans with the City Roads Department and the USFS
- Work with landowners to decrease impacts associated with agricultural practices, such as grazing management and riparian fencing.
- Work with the City of Missoula Stormwater, Development Services, and Public Works Departments to daylight sections of Pattee creek that are currently being treated as stormwater
- Promote green instead of gray stormwater treatment
- Decrease withdrawals from Pattee Creek in residential areas for watering purposes through education regarding water rights and the lower rates for irrigation water available through Missoula Water
- Develop outreach to landowners to improve riparian corridor in residential areas

3.14 O'Brien Creek

Description

The O'Brien Creek watershed (Figure 12) encompasses 25.4 square miles and is the last major tributary to the Bitterroot River before its confluence with the Clark Fork River. Flowing east, O'Brien Creek is in the Northern Bitterroots, originating on the east face of the Grave Creek sub-range through low-gradient montane valleys and confined narrow valleys with very few depositional reaches. Primary geology is of the Belt Supergroup.

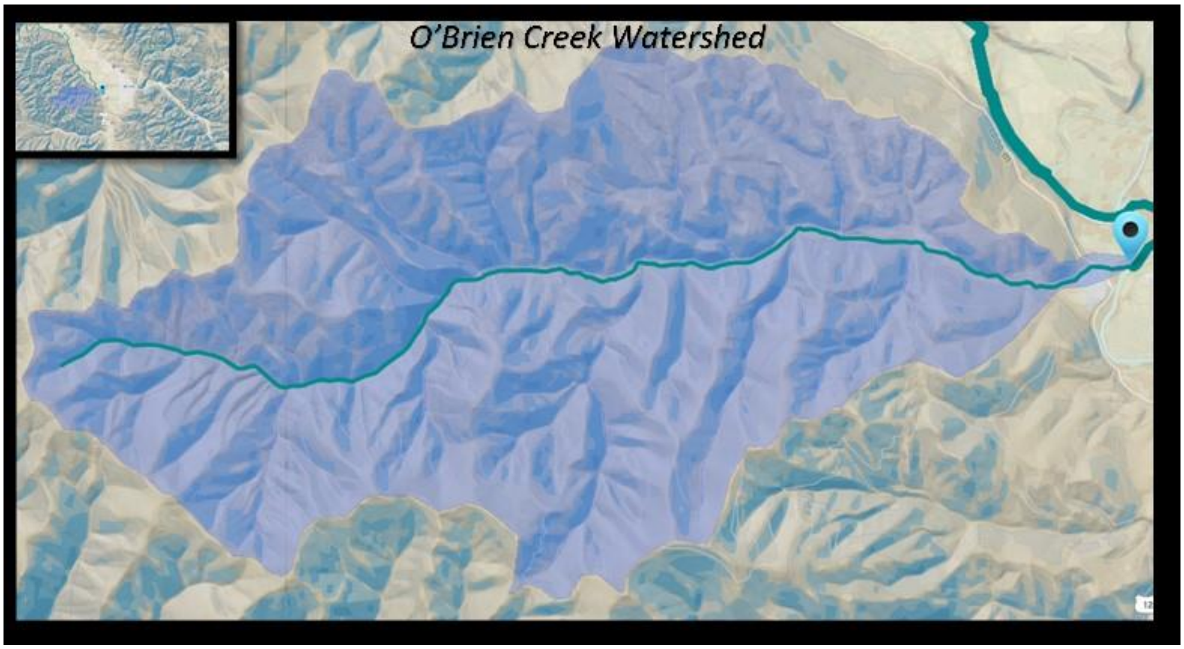


Figure 13: O'Brien Creek watershed flowing east to confluence with the Lower Bitterroot River

Land ownership in the watershed is a mix of Forest Service, Private and Weyerhaeuser ownership (78%, 20%, and 2%, respectively). The upper watershed is predominately public, USFS, land with the lower watershed occupied by private, small parcels. Several sections of the mid and upper watershed were formally private industrial forest land (i.e. Owens and Hurst, later Champion, then Plum Creek) and within the last 20-30 years have become USFS lands through exchanges aimed to swap like properties and eliminate the higher complexity, checker-board ownership pattern established in the late 1800s. Another quarter-section of private land was donated to the USFS.

O'Brien Creek and watershed have experienced heavy uses since the late 1800s. Unpublished historic records note early homesteading, tick epidemics (i.e. large "tick vat", excavated pit, carved near the creek as a treatment facility presumably for deer), at least two grain mills (one large mill at the confluence of O'Brien Creek and the Bitterroot River), miles of diversion, channelization, and manipulation (Crawford, 2019). At least historic one rail line, providing logs to Missoula, extended approximately 11-12 miles up the drainage with remnants still existing (Crawford, 2019). In the lower watershed, O'Brien Creek unnaturally went dry for years because of diversion manipulation and withdrawals; however, with recent awareness and senior water right purchase and management by the Clark Fork Coalition, Obrien Creek now flows perennially in all reaches. Current private use is multiple land parcels and varying conditions from heavily grazed and encroached to actively healing riparian vegetation and stream conditions.

General stream reconnaissance reveals obvious signs of instability (highly variable channel dimensions, lack of floodplain connection, bank erosion and at least two incision trends with new active channel forming at lower elevation, lack of wood and energy dissipation, lack of pool habitat, lack of riparian vegetation and recruitable wood, etc.)

Approximately 2668 acres (21%) of Forest Service land has been harvested. The watershed has a moderately dense road network (5.17 mi road per mi^2). O'Brien Creek has 6.2 miles of riparian road along 10.3 miles of its mainstem with significant lengths with active road fill erosion (i.e. 60% with road within 200 ft. of the stream, with many segments within 50-100 ft). There are at least two segments at the upper end of the mainstem road length where the stream has captured the old road/rail bed. There are a total of 112 road-stream crossings in the watershed; six are on the mainstem. It is presumed that several are total or partial barriers to upstream fish movement.

In the mid-1990s, the Lolo National Forest exercised a substantive road decommissioning effort on acquired private industry roads not necessary for the long-term transportation system and land management plans. This effort recontoured dozens of road miles on the former industry lands where the timber resource had extensively been utilized. This action eliminated several non-point source sediment delivery sources from undersized road-stream crossings and returned many hillslopes to natural recovery and vegetation reproduction. Some remaining roads and deferred maintenance continue to create impacts.

A very cold tributary, O'Brien Creek is one of the most important tributaries in the lower Bitterroot for rainbow and cutthroat trout (MT FWP, 2019). Table 14 highlights 2018 and 2019 data, accompanied by Figure 15, displaying 2019 thermograph readings.[76]

	Temperature (Fahrenheit)		
Date	Average	Maximum	Minimum
2018	52	60	41
2019	51	63	33

Table 14. 2019 Late Season Stream Temperature Monitoring Results

[76] Clark Fork Coalition, 2019.

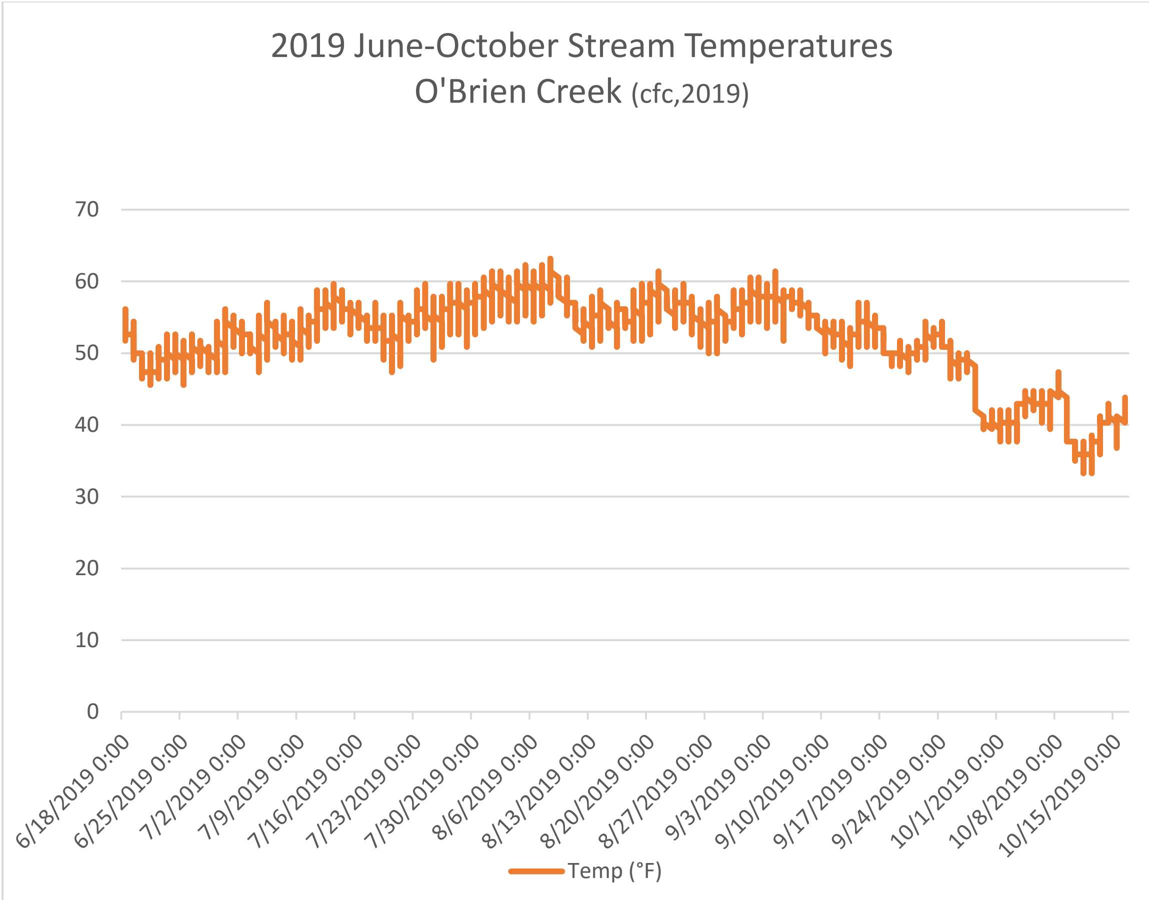


Figure 15: Late Season Stream Temperatures below Blue Mountain Road

Large portions (39%) of the watershed has experienced relatively recent wildfire. The 2003 Black Mountain fire burned 6222 acres, predominately on Forest Service, but some on private land in the lower watershed. Current wildfire risk remains very high. The Lolo National Forest, Missoula Ranger District, is heavily engaged in planning efforts to conduct prescribed fire and vegetation management aimed to create landscape conditions more similar to natural wildfire regimes where feasible (Wildfire Adapted Missoula, WAM, USFS, 2019).

Stream Concerns

The following stream concerns are based on a compendium of observations and data collected. Please see Appendix A for detailed information.

Concern Cause	TMDL Pollutant Category	Beneficial Use of Concern	TMDL Complete	Source of Concern Cause
Sedimentation-Siltation	Sediment	Aquatic Life	No	Streambank erosion, road runoff, Channelization/entrenchment; Streambank modifications and destabilization; instream wood removal;
Alteration in streamside or littoral vegetative covers	Non-pollutant	Aquatic Life	N/A	Mowing in riparian zones Alteration of streamside vegetation

TMDLs and Load Reductions

Although O'Brien Creek does not have an established TMDL, the 2011 Bitterroot TMDL includes sediment loading data from unpaved road networks, including road crossings and parallel road segments (11.98 tons/year and 10.72 tons/year, respectively). Sediment delivery from road surface sediment, road fill failure, stream bank erosion, and other sources has not been quantified; however it is very likely that non-point source delivery is at least 1-2 orders of magnitude above natural background levels. Further investigation is necessary to quantify. Immediate rehabilitation of O'Brien Creek to arrest sediment sources and establish proper fluvial geomorphic and riparian vegetation conditions is highly warranted to address sediment loading that unequivocally is producing excessive sediment contributions to the Lower Bitterroot River.

Management Measures

The following management measures are recommended to address O'Brien Creek's sediment loads as well as benefit impaired aquatic life in the stream:

- Establishing stable stream and floodplain morphology in unstable, entrenched, and/or erosive reaches
- Removing or replacing culverts
- Relocating roads away from floodplain and riparian zones
- Returning roads to a natural state
- Implementing BMPs on roads in floodplain and riparian areas
- Promoting fish and wildlife habitat protection
- Implementing measures that encourage natural flood control, erosion control, and groundwater recharge. Strategies include riparian revegetation, beaver dam analogues, and vegetation-based streambank stabilization
- Restoring aquatic habitat diversity
- Removing barriers to fish migration and habitat use
- Expanding education and outreach programs

Projects

- In approximately 1998, Missoula County replaced an undersized culvert at the Blue Mountain Road crossing. This culvert was a fish barrier.
- In approximately 1999, FWP and Water Consulting, Inc. completed a stream channel stabilization and habitat enhancement project in the confluence reach of O'Brien Creek.
- In 2017, Missoula County and Watershed Consulting planted a streamside area to mitigate for flood impacts.
- In 2019, the O'Brien Creek HOA funded remediation at a stream avulsion site and provided temporary base protection at a mass failure site. 11 large trees were donated by Hillsdale Estates.

Please see appendix A for detailed information on restoration projects on O'Brien Creek.

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

GREG GIANFORTE, GOVERNOR
1539 ELEVENTH AVENUE

STATE OF MONTANA

DIRECTOR'S OFFICE: (406) 444-2074
FAX: (406) 444-2684
PO BOX 201601
HELENA, MONTANA 59620-1601

June 7, 2024

Andrea Davis, Mayor
City of Missoula
435 Ryman St
Missoula, Montana 59802

RE: Watershed Management Grant Award Letter- Missoula Pattee Creek Watershed Group Formation

Dear Andrea,

Congratulations on receiving your Watershed Management Grant for $40,000.00 for your Missoula Pattee Creek Watershed Group Formation Project.

Before DNRC can reimburse eligible project expenses, the City of Missoula must enter into an executed grant agreement with DNRC. DNRC requires the following Startup Conditions to draft a grant agreement. Startup conditions are due within (12-MONTHS) of the date of this letter. Failure to meet the deadline to submit startup conditions may result in DNRC rescinding this grant award.

- Updated budget incorporating the decreased award amount. WMG Uniform Budget Tracker
- Current scope and schedule.
- All match must be committed and letters of commitment submitted to DNRC.
- Current Grant Management Plan

Thank you for your application and I look forward to working with your organization on your project.
Please contact me with any questions.

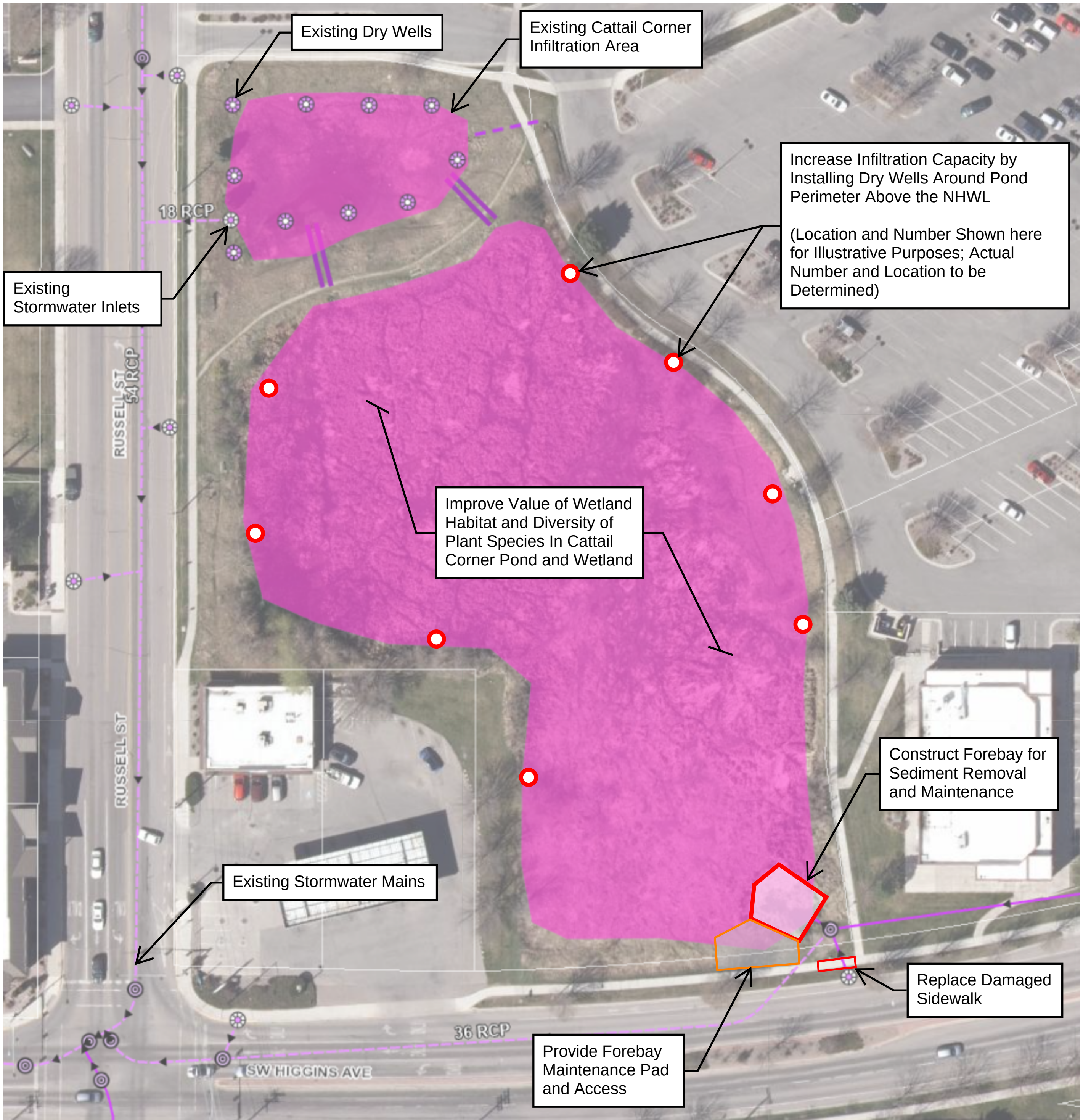
Sincerely,

M.Do

Melissa Downing
Watershed Management Grants Program Manager
Melissa.downing@mt.gov
406-444-0697

Cattail Corner - Phase 3

Cattail Corner is a key component of the South Hills Stormwater System. As the South Hills developed, stormwater discharge in the High Park drainage increased and was discharged to the valley floor where it percolated into the soils near Russel and 39th Street. Over time, silt accumulated and a wetland formed in what was previously a dry, low-lying basin. The wetland area was - and is - dominated by cattails, earning it the name Cattail Corner. In 1995 the site was dedicated to the City of Missoula as an urban wetland park and was incorporated into the City's stormwater system in the early 2000s. Improvements to Cattail Corner are proposed to increase its value as a wetland and as a stormwater control structure by increasing plant species diversity and simplifying maintenance. Additional infiltration capacity in Cattail Corner is required to offset the additional stormwater captured by project phase 2.



Note:
1. This phase also includes installing up to two (2) sediment capture BMPs elsewhere in the South Hills Stormwater System.
2. Improve hydraulic connection between the wetland area and infiltration area during large storm events.
3. Provide educational signage to communicate benefits of "green infrastructure" for stormwater control and treatment.

FROM CREEK TO DITCH AND BACK AGAIN: THE HISTORY AND FUTURE OF PATTEE CREEK, MISSOULA, MONTANA

By

Carver E. Butterfield

B.S., Montana State University, Bozeman, Montana 2020

Thesis

presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Geography

The University of Montana
Missoula, MT

Spring 2024

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Butterfield, Carver, M.S., Spring 2024 Geography

From Creek to Ditch and Back Again: The History and Future of Pattee Creek, Missoula, Montana

Chairperson: Anna E. Klene

ABSTRACT

Pattee Creek was once a free-flowing stream that meandered across the Missoula Valley, but has been channelized, piped, and degraded by logging, mining, agriculture, and urbanization. This thesis used a mixed-method approach to examine the impact of human activities on the Pattee Creek watershed. Beginning with a historical overview, the story of how the creek has been utilized and why it was buried was told. An analysis of historical photos from 1937 to 2019 revealed drastic changes in the land cover of the watershed and the channel of lower Pattee Creek. Developed land increased dramatically, while open land decreased and forested land fluctuated due to fire, logging, and regrowth. Lower Pattee Creek was heavily channelized and eventually buried underground to accommodate agriculture and urban development. Data acquired from the Missoula Valley Water Quality District (MVWQD) and the Missoula Stormwater Utility (SWU) of Total Suspended Solids (TSS), Total Nitrogen (TN), and Total Phosphorus (TP) revealed impaired water quality. Results showed that all three pollutants were elevated in Pattee Creek compared to both the Department of Environmental Quality (DEQ) nutrient standards and the other creeks of Missoula. Additionally, these pollutant parameters were strongly correlated to the amount of developed land, indicating the impact of urban areas on water quality. The human dimension of Pattee Creek was explored through participatory observation and interviews (public intercept and key informant). Some residents and government officials who interact with the creek refer to it as a "ditch" or a "stormwater conveyance" which may aid in justifying the degradation of Pattee Creek. Simultaneously, other residents and officials are spearheading an effort to recover the ecological wealth of Pattee Creek by protecting water quality and conducting ecosystem restoration. Recently, monitoring, outreach, restoration, and environmental law enforcement has increased along the creek. This study supports efforts to work towards a revitalized Pattee Creek. By learning from the past and respecting the creek, Missoulians can bring Pattee Creek back to its original place in the physical landscape of Missoula and in the collective consciousness of Missoulians.

ACKNOWLEDGMENTS

This thesis could not have been accomplished without the invaluable assistance of numerous individuals. The following chapters represent the collective effort of a diverse group of talented and passionate people, and I am sincerely grateful for each one of them.

First and foremost, I extend my heartfelt gratitude to all those who assisted me in acquiring the aerial imagery used throughout this project. The task of gathering this data was challenging, and I am deeply appreciative of those who generously provided files, scanned images, and went out of their way to assist me. Thank you to Sou Thao at the Forest Service, Gina Mazza formerly with the Montana Department of Natural Resources and Conservation, Mike Snook at the Missoula County GIS Division, and Mark Fritch at the University of Montana Library for your support in the historical imagery search.

The acquisition of water quality data was fundamental to this thesis, and I extend my thanks to Todd Sieb and Calvin Dee at the Missoula Valley Water Quality District for your assistance in obtaining this data. Additionally, I am thankful for Lynn McCamant and Nate Gordon who processed water quality samples from the Missoula Stormwater Utility (SWU), and for Lyndsey Halloway for sending me the data.

A significant component of this research involved conducting interviews with community members, and I extend my thanks to all those individuals who took the time to share their thoughts on Pattee Creek. Likewise, my gratitude extends to the following government officials who were willing to be interviewed: Radley Watkins, Elena Evens, Todd Sieb, Tracy Campbell, Marie Nelson, and Pat Brooks. Your contributions and expertise greatly enriched this project.

I am immensely grateful to Scott Powell and MontanaView for the generous funding provided to support this research. Additionally, I extend my thanks to Radley Watkins and Bryan

Vogt with the Missoula Conservation District (MCD), for a grant that contributed additional funding.

My heartfelt appreciation goes to everyone at the City of Missoula with whom I had the privilege to work with while I was employed with the SWU (between 2020 and 2023). That experience working in local government inspired this project. Specifically, thank you Tracy Campbell, Marie Nelson, and Pat Brooks. It was truly a pleasure working alongside you and learning from your hydrologic expertise.

Special thanks to Vicki Watson and Jim Habeck for sharing valuable information, including photos and historical documentation related to Pattee Creek. Also, thank you Natalie Bursztyn for your role in helping me formulate the idea for this project and for providing invaluable guidance throughout my graduate studies. In addition, I express my deepest appreciation to my committee members, Sarah Halverson, and Ben Coleman, for your expertise in research procedures and assistance in reviewing my work.

Most importantly, I extend my profound gratitude to my exceptional advisor, Anna Klene. Your guidance, motivation, technical expertise, moral support, and unwavering dedication have been instrumental in this endeavor. You have been a crucial guiding force throughout this process, and I am honored to have had the opportunity to work alongside you. I am grateful beyond words.

Finally, I want to express my heartfelt thanks to my family and friends for their steadfast support throughout this journey. Conducting research has been a lifelong dream of mine, and it is with your support that I have been able to turn that dream into a reality.

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Chapter 1: Introduction

Headwater creeks are essential components of hydrologic networks, and they have profound impacts on the hydrology, geomorphology, and biology of downstream waterbodies (Gomi et al. 2002). The Rocky Mountain region of the American West stands as the hydrologic headwaters for much of the North American Continent. Mountainous watersheds, across this region, play a critical hydrologic role as they collect snow in the winter and gradually release runoff to low lying rivers throughout the spring and summer (Hauer et al. 2007). Due to their reliance on snowmelt, these systems are particularly sensitive to climate change because of the heightened impact of temperature and precipitation on snowpack development (Kohler et al. 2010). Additionally, creeks throughout the Rocky Mountains have historically and continue to face significant challenges from deforestation, removal of beavers, farming, land drainage, mining, and urbanization (Wohl 2006).

Pattee Creek, of Missoula, MT, is a creek typical to the Rocky Mountain region, with its origins in the mountains and its confluence on the valley floor. Its headwaters are located southeast of Missoula, between Mount Sentinel and Mount Dean Stone. As Pattee Creek exits Pattee Canyon, it leaves National Forest lands and crosses the City of Missoula's urban boundary. The Pattee Creek watershed (Figure 1) is approximately 12,000 acres and over 25% of that area is developed, with more than 2,000 stormwater drains, and approximately 20 miles of pipe that discharge untreated urban runoff into the creek (City of Missoula Stormwater Utility 2023).

Amidst agricultural expansion and urbanization across southern Missoula, Pattee Creek has undergone substantial alterations. Like many urban creeks across the United States, Pattee Creek has been heavily impacted by urban and agricultural development (Carle et al. 2005). This study examines the profound impacts of human development on Pattee Creek, exploring its altered flow path, diminished water quality, and its general detachment from the community that lives on top of it.

Because the creek is mostly underground in the City of Missoula, citizens, non-profits, and government entities have few opportunities to interact with it. Therefore, little attention has been given to Pattee Creek except as a source of irrigation water and as a potential flooding hazard to be mitigated. Pattee Creek's urban invisibility erases the creek from the collective consciousness of Missoula. As people drive over it on Russell Street, unaware of its presence beneath them, they remain disconnected from the creek and unaware of their impacts on it. If Pattee Creek were more visible, citizens would be more likely to care for its well-being. The fact that Pattee Creek is buried also prevents wildlife from accessing it and disrupts the local ecosystem. While some stretches of the creek are completely buried, others still flow above ground. Throughout these stretches, many Missoulians refer to Pattee Creek as a "ditch" because in the early 1900s it was diverted away from its natural course for irrigation.

The City of Missoula Stormwater Utility (SWU) and the Missoula Valley Water Quality District (MVWQD) sample at a total of five sites along Pattee Creek several times per year. Pattee Creek has high concentrations of Total Phosphorus (TN), Total Nitrogen (TN), and Total Suspended Solids (TSS) in comparison to Missoula's other creeks. Since the early 1900s, urban and agricultural development in Missoula has transformed Pattee Creek from a free-flowing waterbody into a channelized "ditch." As the population of western Montana grows, watersheds throughout the region are facing significant pressure from urbanization. The case study of Pattee Creek, as explored in this thesis, sheds light on the hydrologically destructive capabilities of human development in the Rocky Mountains and offers suggestions to help mitigate these impacts.

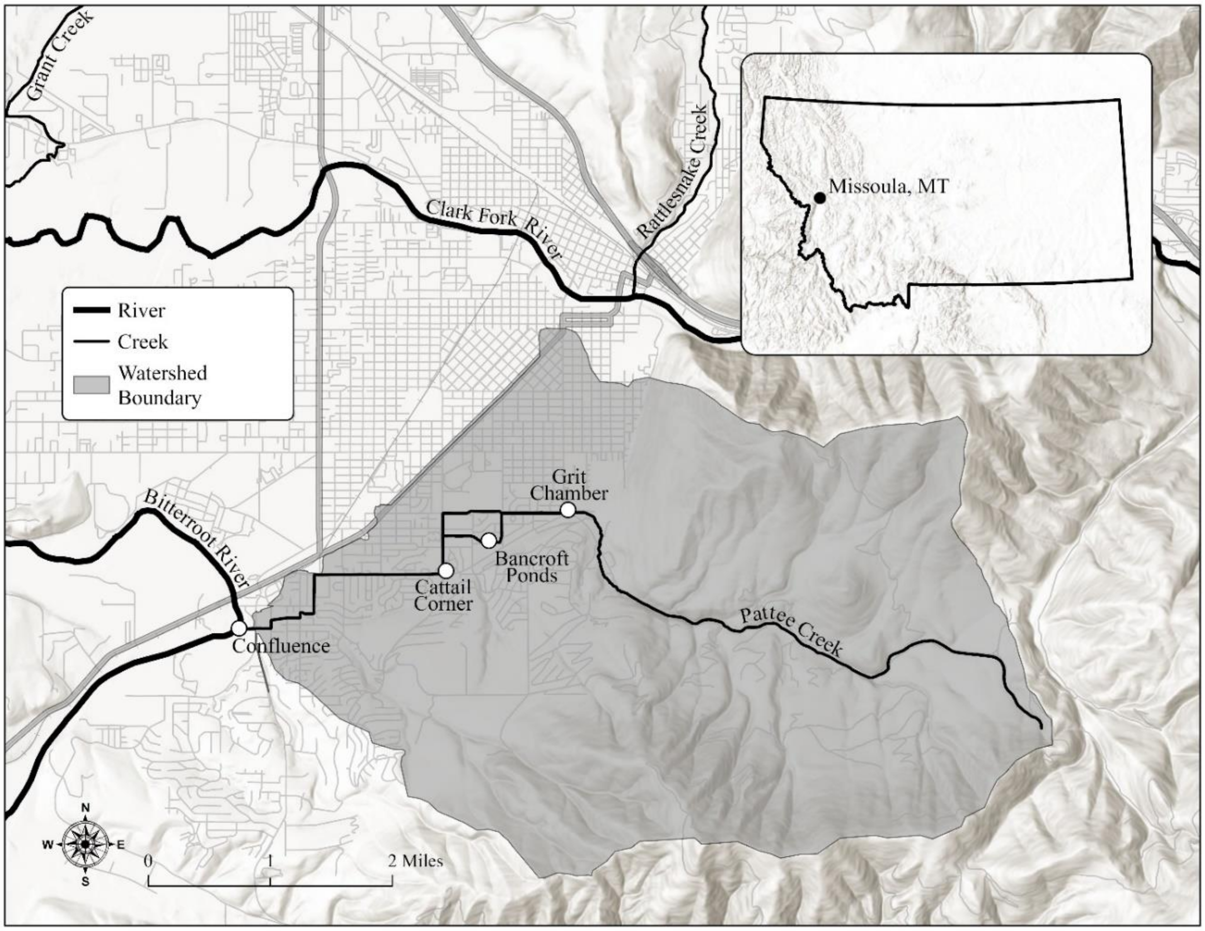

Figure 1. Map of the Pattee Creek watershed showing locations referenced in the text.

1.1) Statement of Purpose and Positionality

There are two main goals of this project: (1) to evaluate the impact of agricultural and urban development on the Pattee Creek watershed, and (2) to assess the human dimensions of water quality by investigating how Missoulians interact with and perceive Pattee Creek. Pattee Creek is currently heavily degraded, but there is a growing movement in the local government and community to restore and reclaim the creek. This research will help position local government entities and non-profit organizations to pursue additional funding for restoration efforts and for additional education campaigns focusing on the benefits of the creek.

My fascination with Pattee Creek started during my Montana Conservation Corps (MCC) term of service (2020) and grew during my employment with the City of Missoula (2020-2023). Observing how humans interacted with this waterbody sparked a deep curiosity within me about its history and current state. I became increasingly concerned about the impact of Missoula's community on the creek, particularly as I spent time working near Pattee Creek, collecting water samples, excavating sediment, and performing riparian restoration. Over the past four years, I have also spent countless hours enjoying the serenity of Pattee Creek and marveling at the wildlife that call it home.

The primary motivations behind this research were my profound curiosity and love for Missoula's waters. I sought to not only satisfy my inquisitiveness but also to contribute to the better understanding and preservation of Pattee Creek. I wanted this project to serve as a bridge between my personal connection to the water and a meaningful contribution to its well-being. The journey of this research has been enjoyable, challenging, and enlightening.

I am writing this from a position of being heavily invested in the well-being of Pattee Creek. I have worked with the creek for four years, first serving with MCC, then working with the City of Missoula, and now as a graduate student at the University of Montana. Throughout these experiences, my central aim has been to work towards the conservation, preservation, and restoration of Pattee Creek. It is important to acknowledge that perspectives on the creek differ significantly. For example, individuals directly affected by its flooding may understandably view it as more of a nuisance than an asset. For me, Pattee Creek has always been a cherished amenity, enriching my life in countless ways. I hold a deep appreciation for its natural beauty and ecological significance. Chapter 4 discusses my specific relationships with the creek in further detail.

1.2) Thesis Overview

The first chapter of this thesis will introduce Pattee Creek and give an overview of the thesis. Section 1.3 will delve into the rich historical tapestry of Pattee Creek, highlighting the cultural dynamics that have sculpted the watershed and influenced human interactions with the creek.

Chapters 2 through 4 form the core of this research. These chapters are all structured in a similar manner, each with its own background/theoretical framework to establish the conceptual stage. Following this, the methods utilized in each chapter are described in detail, presenting the methodological groundwork for the research and discussing the limitations of each approach taken. Subsequently, results are presented, followed by a discussion of the findings.

Chapter 2 describes a historical imagery analysis, where aerial imagery was gathered and processed. This imagery was used to answer the following research questions:

- How has the flow path of Pattee Creek evolved over time?
- What changes in land cover within the Pattee Creek Watershed have occurred since the emergence of urban growth in southern Missoula?

Chapter 3 provides an in-depth analysis of Pattee Creek's water quality, drawing data from two local government water-sampling programs. The research questions guiding this analysis are:

- Where in Pattee Creek is water quality most compromised?
- What factors may be contributing to Pattee Creek's notably lower water quality compared to other creeks monitored by the City and County of Missoula?

Chapter 4 shifts focus to the social context of Pattee Creek, utilizing participatory observation and interviews with residents and government officials to explore the relationships between society and the creek. The following research questions drive this chapter:

- What impact have human decisions had on Pattee Creek?
- What are the perceptions of Missoulians regarding Pattee Creek, and how do they view their impact on this waterbody?

Finally, Chapter 5 closes the thesis with a conclusive summary of the research presented. Additionally, recommendations for future research and action are presented. This chapter weaves together all the findings to provide a comprehensive understanding of Pattee Creek's story.

1.3) History of Pattee Creek

The history of the Pattee Creek watershed has been shaped by environmental and cultural processes, including the fluctuations of Glacial Lake Missoula, the engagements of Indigenous peoples with the landscape, and the far-reaching impacts of colonialism. The sacred Coyote creation stories, passed down for thousands of years by the Salish and Pend d'Oreille people, describe how the world came to be. The stories reference Glacial Lake Missoula, an enormous proglacial lake that submerged most of Pattee Creek and its watershed. This glacial lake filled and emptied repeatedly between 13,000 and 20,000 years ago (Hanson et al. 2012). The Coyote stories captured in the Tribe's oral history describe this ancient lake and the glaciers that allowed it to form, illustrating the deep relationship between Indigenous populations and this region (CSKT 2005).

Many Indigenous groups, including the Salish and Pend d'Oreille peoples, lived in and traveled through the Pattee Creek watershed. The Salish word "Sloˀté" refers to Pattee Canyon and translates as "Two Valleys Coming Together to Make One Little Valley" (CSKT 2005, 49). Indigenous peoples had a vast and complex system of trails throughout the Missoula area, used for seasonal migrations. When it was time to travel from the western mountainous region to the eastern buffalo hunting grounds, parties commonly opted for the trail that went up through Pattee Canyon instead of going through the sometimes-treacherous Hellgate Canyon (CSKT 2005).

Additionally, the Pattee Creek watershed was home to important food sources. The low-lying sections were popular bitterroot collecting sites (CSKT 2005). Further up the creek, cold and abundant water provided habitat for fish, in particular the cultural keystone species, bull trout (Salvelinus confluentus). A Pend d'Oreille elder, Mitch Smallsalmon, once described his people as "wealthy from the water" (Smith 2010). Creeks like Pattee contributed to this wealth.

Since time immemorial, Indigenous people have been interacting with and shaping the land throughout the Pattee Creek watershed. While accounts of the region by colonial settlers report untouched expanses of nature, they often fail to recognize that this land was the product of historic management practices (Land 2022). Before colonial settlement, the human inhabitants of Missoula regarded themselves as part of, and belonging to, the natural world. "It was the land, water, and sun that owned the people" (Schlatter, 2020).

The 1805 arrival of Lewis and Clark in Montana marked the beginning of an enormous change for this region and its Indigenous inhabitants. Colonial settlement brought resource extraction practices such as mining, logging, and agriculture, which significantly altered the landscape. Today, no land in the Pattee Creek watershed is managed or owned by any of its Indigenous groups (Missoula County 2023).

In 1865, when permanent colonial settlement in the Missoula region was beginning, David Pattee settled at the base of the canyon that now bears his name (Omundson 1961). Around this time, before Pattee Creek was put into an irrigation ditch, it used to flow into the Clark Fork River. Harriet Johnston, in her manuscript on the ecology of Missoula, describes the Clark Fork River by stating that "the Rattlesnake empties into it and further west, it receives the waters of Pattee Creek"

(Johnston 1929, 16). In 1877, Fort Missoula was built near the Bitterroot River, in present day southwest Missoula (Blades & Wike 1949). Throughout the remainder of the 19th century and early 20th century, the low-lying areas of the watershed were converted from native herbaceous land into farmland for crops such as wheat, barley, and vegetables. To support the newly established agriculture, Pattee Creek was rerouted into a system of ditches for irrigation, which diverted the flow towards the Bitterroot River. A heavily wooded area, which makes up the upper watershed, was designated as a Timber Reserve for Fort Missoula in 1878 and continued to experience intensive logging until the 1990s (Smith 1994).

This logging heavily impacted the upper watershed, otherwise known as Pattee Canyon. Along with logging, a gravel pit/rock quarry was established near the mouth of Pattee Canyon that is still in operation today. In 1990, according to a Biophysical Land Inventory of Pattee Canyon, the area was in a “perilous condition” and the environmental quality had been “deteriorated by grazing, logging, off-road vehicles, reactional use, country home construction, urban expansion, knapweed invasion, and man-caused fires” (Crowley 1990, 13) In addition, the water quality of Pattee Creek was described as “deteriorated as a result of: effluent from septic tanks; pesticides used on lawns, gardens, flowers, and pastures; animal wastes from pets and livestock; soot from wood stoves and fireplaces; sediment from roading, logging, trench digging, and home construction; and dust, sand, and salt from nearby roads” (Crowley 1990, 105).

Before the 1950s, southern Missoula (the lower watershed) had very little urban development and was mostly open hillsides with agriculture. At that time, Pattee Creek primarily infiltrated into the highly permeable gravel deposits of the Missoula Valley floor and would only reach the Bitterroot River during peak run-off events. During the 1960s, 1970s, and 1980s, southern Missoula experienced rapid urban growth and the installation of permeable surfaces such as concrete, asphalt, and rooftops. Instead of building a central storm-sewer system, dry wells were installed throughout the lower reaches of the watershed to dispose of stormwater by injecting it into the ground. Houses were built directly next to the creek without levees or other devices to protect them from flooding. Because the natural floodplain was paved over, Pattee Creek would regularly overtop its banks and spill into the streets of southern Missoula.

Starting in the 1960s, the regular flooding of Pattee Creek required City of Missoula employees to place sandbags along the creek in attempts to prevent it from overtopping its banks. City officials expected this hazard to worsen over the years and sought permission to “ditch” the stream in the 1960s, but property owners turned down the offer because they feared it would “decrease the aesthetic value of the stream” (Guenin 1965). In 1972, an article in the local paper (The Missoulian) described the creek as a “menace” and explained that “in its fight against the manmade structures around it, it continues to flood” (The Missoulian 1972). The flooding events throughout the 1960s and 1970s foreshadowed a larger one. The Pattee Canyon Fire of 1977, which burned 1,200 acres, further increased southern Missoula’s flood vulnerability by removing vegetation from the upper watershed, thereby increasing runoff (Forest Service Museum 2021). The Missoula community was aware of this risk, with an article in the newspaper explaining how “The Pattee Canyon fire last weekend… could pose a threat of severe soil erosion, sedimentation of waterways and flooding in the area” (Dillow 1977). This potential risk became reality in 1980.

On May 18, 1980, Mount St. Helens erupted and deposited up to one inch of ash in Missoula, which clogged most of the dry wells in the valley. Shortly after the eruption, an extreme rain event (3.64 in. of rain between May 22 and 26, 1980) occurred. The rain from this event, along with snowmelt from the winter snowpack, caused Pattee Creek to reach flows greater than 200 cubic feet per second (cfs). The dry well system was overwhelmed, and sections of southern

Missoula flooded. One article described how Pattee Creek "became a raging torrent Sunday (May 25th, 1980) afternoon, washing out Pattee Canyon Road in several places and leaving canyon residents stranded" (Miller 1980).

After this event, the City of Missoula and Missoula County needed to come up with a way to deal with the flooding more reliably. Many different ideas were put forth, including an open swale that "died because parents feared their children would fall… and drown" (Miller 1981). Finally, the two government agencies decided on a mostly piped system to convey Pattee Creek during large storm events. Between 1986 and 2002, the City of Missoula and Missoula County constructed the Missoula South Hills Storm Drainage System, a complex system of pipes and detention basins designed to handle a 100-year flood (WGM Group 2002). Most urban sections of Pattee Creek were routed underground, preserving just a small section of open channel within the city limits (WGM Group 2002). While this project reduced flooding along the Missoula Valley floor, regular flooding still occurs within the watershed due to migrating springs (McCauley 2022). The burial of the creek allowed for development to occur on top of the Pattee Creek floodplain, but it also positioned the waterbody for degradation, pollution, and neglect.

Chapter 2: Historical Imagery Analysis

2.1) Introduction

Understanding the historical evolution of waterways is crucial for assessing their present state and guiding future management strategies. In this chapter, a historical imagery analysis is conducted to map the historic flow paths of Pattee Creek and quantify the amount of land cover change that has occurred throughout its watershed. By visualizing the pre-urban development state of Pattee Creek, a deeper understanding of the waterway emerges. Mapping this change through time helps foster a fresh perspective on the current relationship between the Missoula community and Pattee Creek.

Mapping the historic channel holds significant importance because it encourages the community of Missoula to acknowledge that Pattee Creek was historically and is currently a natural creek rather than a manmade ditch. This historical mapping aims to elevate Pattee Creek's status and significance, promoting a greater sense of stewardship among residents. Additionally, quantifying the shifts in land cover throughout the watershed is crucial, as land cover plays a pivotal role in influencing the water quality of a stream. By quantifying these changes, valuable insights are gained regarding the factors influencing Pattee Creek’s water quality. The detailed mapping effort presented in this chapter not only provides a visual journey through Pattee Creek's past but also lays a foundation for informed decision-making regarding its future conservation and management.

While this project focuses on Pattee Creek, it also investigates two other creeks of Missoula, Rattlesnake Creek and Grant Creek. These other creeks are like Pattee Creek in that they both flow through urban Missoula. However, the creeks have crucial differences in size and water quality. Historical imagery analysis was not conducted on Grant Creek or Rattlesnake Creek, but recent Geographic Information Systems (GIS) data was used to delineate their watersheds.

2.2) Background

Earth's land cover has been changing rapidly due to widespread urbanization. In the past century, the global urban population has grown from 15% to 50% (Deelstra & Girardet 2000), with a variety of land being converted to impervious urban landscapes (Güneralp 2020). Additionally, it is common for the land surrounding urban areas to be altered by human practices such as logging, farming, mining, and fire. These changes in land cover heavily impact water quality and quantity (Stonestrom, 2009).

During the 19th and 20th centuries, it became common practice to bury streams and creeks, or route the water into canals, sometimes lined with concrete (Eden & Tunstall 2006). In recent years, across the globe, there has been a renewed interest in these forgotten streams. Researchers are using GIS to locate these urban streams and initiate restoration work to remediate the ecological damage that has occurred. The United Kingdom has buried more than 20 major rivers including a substantial portion of the creeks that feed into the River Thames in London. Switzerland and Denmark have buried approximately 20% and 15% of their creeks, respectively. In the US, the City of Detroit, Michigan, buried at least 500 km of stream channels since 1906 (Napieralski & Carvalhaes 2016).

In contrast to more densely populated areas worldwide, the Rocky Mountain region has relatively limited urban development. Most research examining the impact of urban landscapes on water resources tends to focus on more heavily urbanized regions globally. However, some studies conducted along the west coast of the United States have mapped urban stream burial. For instance, Post et al. (2022) documented vanished streams near Portland, Oregon, utilizing historical topographic maps. Napieralski & Carvalhaes (2016) mapped urban stream deserts across 11 "Megaregions," including one in northern California. By mapping buried streams, scientists can better comprehend the ramifications of stream burial. Additionally, these investigations can identify suitable sites for stream daylighting or restoration.

2.3) Methodology and Data Sources

2.3.1) Constructing Urban Watershed Boundaries

The first step of most watershed studies is to define the study area. The National Hydrography Dataset (NHD) does not include the Pattee Creek watershed as a Hydrologic Unit Code (HUC), and no other watershed boundaries were found. To define the study area of this project, one was created by adopting methods outlined by Parece & Campbell (2014).

The NHD does have watershed boundaries for Grant Creek and Rattlesnake Creek. However, these datasets are inaccurate near the urban area of Missoula because they fail to account for the drainage changes due to urban development. For a natural watershed (unaffected by urban or agricultural development), it is relatively straightforward to create a digital flow network, using a Digital Elevation Model (DEM), that can be used in GIS to generate an accurate watershed boundary (Pryde et al. 2007). However, this process is more challenging for urban watersheds.

Watershed GIS tools (e.g., ESRI spatial analysis hydrology tools) are primarily designed for natural landscapes, and standard geospatial methods to delineate urban watersheds are limited in the literature. To account for human changes in an urban watershed, previous studies have overlaid stormwater infrastructure shapefiles over a watershed boundary to evaluate how inlets and pipes influence how water flows in an urban area (Parece & Campbell 2014). In addition, researchers have used aerial photographs to assist with urban watershed delineation (Kaufman et al. 2001).

A combination of these two methods were used to delineate three watershed boundaries (Pattee Creek watershed, Rattlesnake Creek watershed, and Grant Creek watershed). The highest resolution Digital Elevation Models (DEMs) available from the National Elevation Dataset (NED; 10-meter pixels) were downloaded. These DEMs covered the entire study area, including the sections of each watershed that extend outside the urban boundary of Missoula. Higher resolution DEMs (3-foot pixels) were obtained from the 2019 Montana DNRC LIDAR survey but do not include much of the study area. Each set of DEMs was mosaiced in ArcMap.

For each mosaic, a separate flow accumulation and flow direction layer was generated using the ArcMap spatial analyst toolbar. The flow accumulation dataset displayed the confluence of each stream. Using this dataset, a pour point was placed at the end of each creek. A pour point is the lowest point in elevation on the boundary of a watershed and is the location from which water flows out of an area. The pour point and flow direction datasets were used as inputs for the "watershed" tool, which was used to generate a watershed boundary for each creek.

Once two watershed boundaries were created for each creek (one from each mosaic), the two were stitched together using the overlay toolset (union, erase, and intersect) in ArcMap. The boundary derived from the high-resolution DEM was utilized where available, and the lower resolution for the remaining portion. Next, stormwater infrastructure shapefiles were overlaid on the watershed boundaries. A 2020 aerial photo (3-inch pixels) provided by City of Missoula GIS Services was used as a reference to further modify the DEM-based watershed boundaries to account for human development. This was accomplished by identifying all areas that were either inside the DEM-based watershed boundary which drained through pipes to a location outside the boundary, or areas outside the DEM-based watershed which drained into the boundary. Once these areas were identified, the boundary was manually modified to remove or add areas to the watersheds. By incorporating stormwater infrastructure data and high resolution DEMs, this technique created watershed boundaries which are more accurate than the HUC boundaries offered by the NHD.

The subjectivity involved in manually manipulating watershed boundaries can be regarded as both an advantage and disadvantage. This method gave convenient freedom for implementing common sense to increase the accuracy of each watershed. However, it was monotonous and subjective. The stormwater infrastructure dataset (from 2021) used to modify the watersheds was not complete, meaning more pipes and inlets exist that were not included. Additionally, stormwater infrastructure is not the only thing that artificially removes water from a watershed in an urban landscape. Missoula has a largely unmapped network of irrigation ditches that divert water from creeks and rivers to agricultural land. Unfortunately, a comprehensive and accurate Missoula irrigation ditch GIS dataset does not exist.

While an attempt to include input and outflow from ditches were included for the Pattee Creek watershed, it was not considered for Grant Creek or Rattlesnake Creek. Ideally, the irrigation ditches that interact with Rattlesnake Creek and Grant Creek would have been included in this project, but those complex ditch networks are largely unmapped in those areas.

After the watersheds for each creek were created, watersheds for each water-quality sample site were generated to compare land-cover statistics to water quality. The methods described above were repeated for the three water-quality sample sites along Grant Creek, four sample sites along Rattlesnake Creek, and five sample sites along Pattee Creek.

2.3.2) Orthomosaic Creation and Acquisition

To quantify the historic land cover change and stream channel migration of Pattee Creek, spatially accurate orthomosaics were needed. Between the fall of 2022 and the fall of 2023, a comprehensive aerial image search was conducted (Table 1). The University of Montana Mansfield Library provided 21 aerial images of the study area, which were the earliest photos located (from 1937). These images were scanned and digitized from film rolls into TIFF files. These early images did not cover the entire study area, so the orthomosaic generated for 1937 was omitted from the land-cover analysis. Pre-existing orthomosaics were acquired from Missoula County for 1964 and 1972. Pre-existing orthomosaics were also acquired from the NAIP program for 2005 and 2019.

For the years that did not have accurate pre-existing orthomosaics, raw images needed to be converted to orthomosaics (1937, 1955, 1984, and 1995). For each of these years, the photos were imported into Agisoft Metashape software (Agisoft 2022) and then aligned to allow the program to calculate camera positions and generate a sparse point cloud. Next, default Agisoft settings were used on the sparse point cloud to create a 3D mesh of the study area. Finally, ground control points (GCPs) were located on the photos and linked with geographic points on Earth's surface, to allow the orthomosaic to be generated and exported.

The orthomosaics created here are of high quality overall, but they do have inaccuracies. While orthorectifying largely removes displacement and distortion that exists with all aerial imagery, it does not completely remove it. The upper reaches of the watershed have steep topography which increases uncertainty. There were fewer photographs of the upper reaches, and less overlap between images, increasing displacement and distortion. The orthomosaics were not color balanced.

Table 1. Aerial imagery data sources and details.

Photos Captured By[a]	Photo Type	Date of Capture	Color	Acquisition Source[b]
USFS	Raw Imagery	9/19/1937	Greyscale	UM Library
Unknown	Raw Imagery	8/17/1955	Greyscale	USGS
Unknown	Orthomosaic	1964	Greyscale	Missoula County
Unknown	Orthomosaic	1972	Greyscale	Missoula County
NHAP	Raw Imagery	8/6/1983	Color-Infrared	USGS
NHAP	Raw Imagery	8/9/1984	Color-Infrared	USGS
NAPP	Orthomosaic	7/1/1995	Greyscale	USGS
NAIP	Orthomosaic	2005	Natural Color	USDA
NAIP	Orthomosaic	2019	Natural Color	USDA

[a] The photos used for this project were captured by the United States Forest Service (USFS), National High Altitude Photography (NHAP), National Aerial Photography Program (NHAP), and National Agricultural Imagery Program (NAIP).

[b] The photos used for this project were acquired from the University of Montana (UM) Library, United States Geological Survey (USGS), and United States Department of Agriculture (USDA).

2.3.3) Land-Cover Analysis

By comparing land-cover data within a GIS, scientists can investigate the link between land cover and water quality (Huang et al. 2014). Some studies use pre-existing datasets like the National Land Cover Database (NLCD, Wilson & Weng 2010) while others generate their own (Olivera and DeFee 2007). The Multi-Resolution Land Characteristics Consortium (MRLC) creates the NLCD, which covers the entire United States and is extensively utilized in remote sensing literature. For this study, simplified categories from the NLCD were used to quantify land-cover change in the Pattee Creek watershed.

Although the NLCD's relatively coarse resolution (30-meter pixels) effectively depicts regional changes, it was coarser than desired for this study. Also, the NLCD has only been completed since 1991. For this project, NLCD land-cover criteria were used to guide the manual digitization of a more accurate, localized, and historic land-cover dataset. While this method is considerably more labor intensive than automated classification, it is recognized as a high-quality and reliable method for extracting land cover information from historical images, especially for smaller regions (Miller 2019). Accurate automated classification was not possible for this project because the black and white photos available are generally insufficient for automatic image classification.

The uncertainty of the land cover datasets is mainly caused by 1) the inherent subjectivity that comes with manual digitization, 2) the limited information present on historic black and white aerial imagery, and 3) difficulty interpreting and applying the NLCD classifications consistently from year to year. Despite these inevitable uncertainties, the land cover datasets presented here are very accurate, especially when compared to regional datasets like the NLCD.

When compared to modern natural - or false - color aerial imagery, the interpretability of historic black and white photographs is somewhat limited. It is challenging to visually interpret or distinguish between specific landcover classes (such as grassland and cultivated crops) from single band aerial photographs. To increase the accuracy and reduce the uncertainty of historic land-cover estimates, the NLCD Level 1 categories were simplified (Table 2).

Table 2. Table showing the criteria used for land-cover classification.

Simplified Land Cover Class	NLCD Land Cover Class	NLCD Definition
Developed	Developed, Open Space	Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Developed	Developed, Low Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
Developed	Developed, Medium Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
Developed	Developed, High Intensity	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.

Forest	Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
Forest	Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Open	Shrub/Scrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Open	Grassland/Herbaceous	Areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
Open	Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
Open	Cultivated Crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Because of its influence on water quality, developed land was the category of most interest for this analysis. Due to low spatial and spectral resolution, differentiating the various subcategories of development was not possible using historic imagery. Each type of development impacts water quality differently. High intensity development, with a high concentration of impervious surfaces, negatively impacts water quality by increasing flood potential and elevating stream temperatures. Developed open space may introduce pollutants through lawn maintenance activities. Distinguishing between different types of forest or open land would have been challenging and would not have yielded very different results. For example, differentiating Grassland from Cultivated Crops would have been difficult.

Once the NLCD categories were simplified, land-cover layers of the Pattee Creek watershed were created for 1955, 1964, 1972, 1984, 1995, 2005, and 2019. For each year, the watershed was divided into 32 squares (each one ~556 acres). The land cover within each square was meticulously digitized by applying the definitions outlined in Table 2 until the entire study area was complete. All features for all years were digitized at a scale of 1:5,000. For the Grant Creek and Rattlesnake Creek watershed, land cover was not digitized. Instead, the 2019 NLCD land cover dataset was used to quantify the land cover of these two watersheds.

2.3.4) Channel Mapping

As early as the 1920s, the channel of Pattee Creek was heavily altered by agricultural and urban development. To map these changes, the wetted channel centerline of Pattee Creek was digitized for 1937, 1955, 1964, 1972, 1984, 1995, 2005, and 2019. For each year, using visual interpretation of the orthomosaic, the channel was mapped from the most visible upstream point at the modern City of Missoula urban boundary line to the confluence (where it met the Bitterroot River). The creek was digitized at a scale of 1:1,000.

On the 1937 orthomosaic, irrigation ditches designed to convey Pattee Creek were already in place. Braided channels from prior flows of Pattee Creek were also visible showing that the channel used to disperse into a complex braided network of small streams once it reached the valley floor. These braided channels were clearly visible on the 1937 imagery, allowing for the creation of a "past flow" Pattee Creek channel, which existed shortly after the creek was originally diverted towards the Bitterroot River, sometime between 1916 and 1937. This layer is an estimation based solely on the 1937 orthomosaic (Figure 2).

For the years between 1937 and 1995, the creek was above ground and easily visible on the aerial imagery. All the aerial images were of high quality, except the images from 1984. It was challenging to locate the channel on the 1984 imagery, but the channels digitized from 1972 and 1995 were used as references. The urban sections of Pattee Creek were mostly buried between 1995 and 2005, and as a result, parts of the channel could not be seen on the 2005 and 2019 images. For these years, a stormwater gravity main shapefile was acquired from the SWU. This shapefile accurately depicts where the underground sections of Pattee Creek were located during 2005 and 2019. For the underground sections of Pattee Creek, the geometry of the channel was created by copying the lines from the Stormwater dataset and pasting them into the new Pattee Creek layer. The calculate geometry tool in ArcGIS Pro was used to calculate the length of the channel for each year. For this measurement, the shortest possible path from the beginning of Pattee Creek to the Bitterroot River was used.

Although the orthomosaics facilitated the mapping of Pattee Creek's lower historical course, they did have limitations, such as the low visibility of the upper segment of the creek. The upper reaches of the creek were not mapped for two reasons: 1) the upper watershed is primarily covered with trees that overhang above the channel and entirely block it from being visible via aerial imagery and 2) upper Pattee Creek has seen relatively little channel modification when compared to the lower stretches. Instead of mapping this upper extent, the NHD flowline was copied for each year. Thus, this study assumed that the upper portion of the creek did not change at all from year to year.

Additional factors that contributed uncertainty to the channel mapping of Pattee Creek include: 1) the inherent subjectivity that comes with manual digitization, 2) interpreting where a small stream was located on black and white historical photos is challenging, and 3) possible geospatial errors caused by the distortion of orthomosaics on which the stream was digitized.

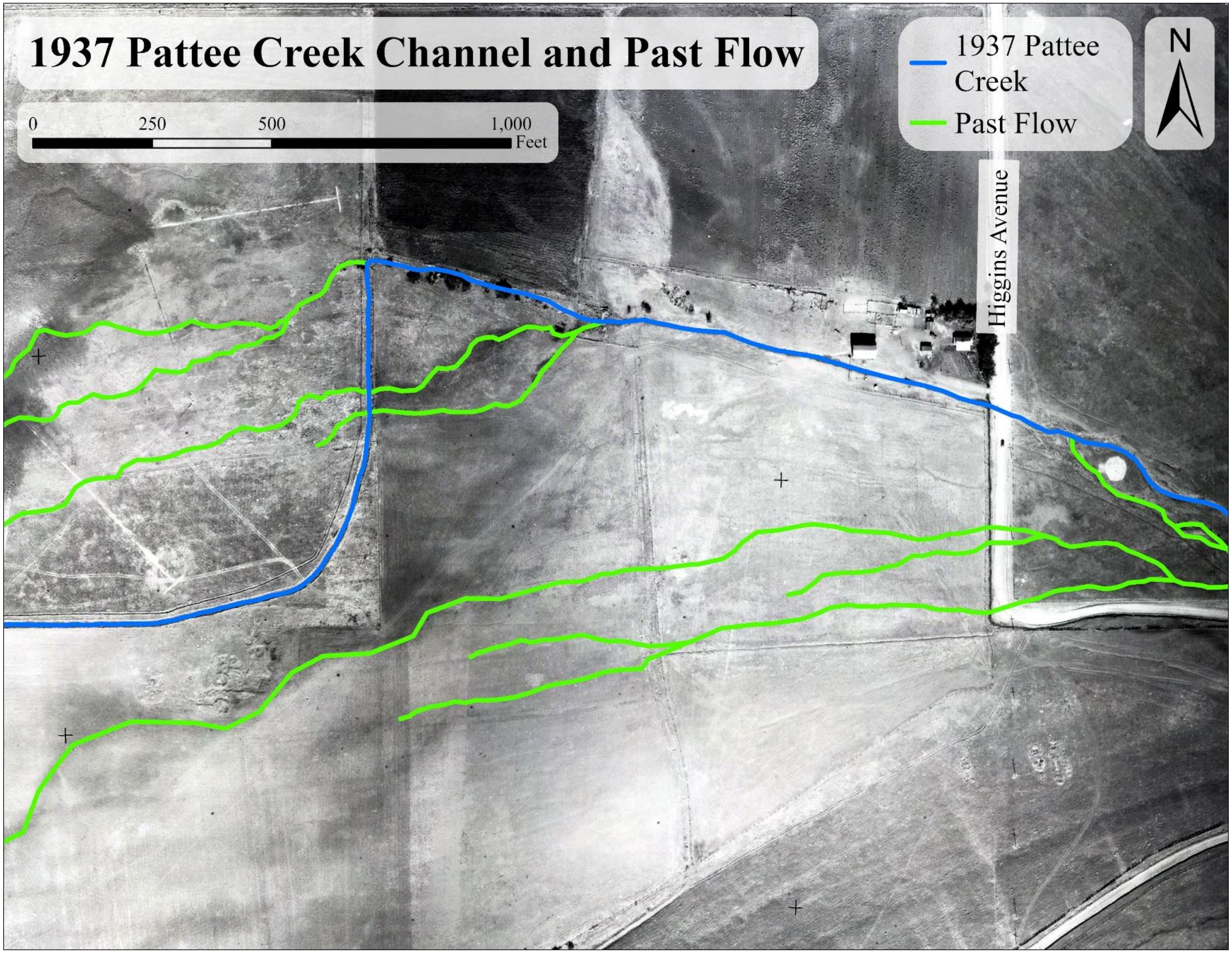

Figure 2. 1937 Pattee Creek channel and past flow near the mouth of Pattee Canyon.
The 1937 orthomosaic is the base layer of this map. The largest road running north to south on the east side of this map is Higgins Avenue.

2.4) Results

2.4.1) Watersheds

To examine the characteristics of Pattee Creek and compare it to other similar watersheds, three watersheds were created for this study: one for Pattee Creek, Grant Creek, and Rattlesnake Creek (Figure 3). The methods employed yielded highly detailed watershed boundaries, essential for the water quality analysis (Chapter 3). Grant Creek's watershed is nearly twice the size of Pattee Creek's, while Rattlesnake Creek’s is nearly five times larger (Table 3). The Rattlesnake Creek watershed drains the expansive Rattlesnake Wilderness. Its mountainous terrain facilitates orographic uplift and allows the area to receive more precipitation per acreage, resulting in a larger stream. In contrast, Pattee Creek, with the smallest watershed and lowest elevation, intercepts the least runoff, making it the smallest stream of the three. The Grant Creek watershed falls between Pattee and Rattlesnake in size, precipitation, and discharge (Geldon 1979). Despite these discrepancies, all three watersheds have developed regions throughout the lower sections of their extent. Therefore, they are all impacted by urban stormwater pollution. Differences in the water quality of these three creeks will be investigated in Chapter 3.

Table 3. Acres of each watershed.

Watershed Name	Area (Acres)
Grant Creek Watershed	19,888
Rattlesnake Creek Watershed	51,633
Pattee Creek Watershed	11,948

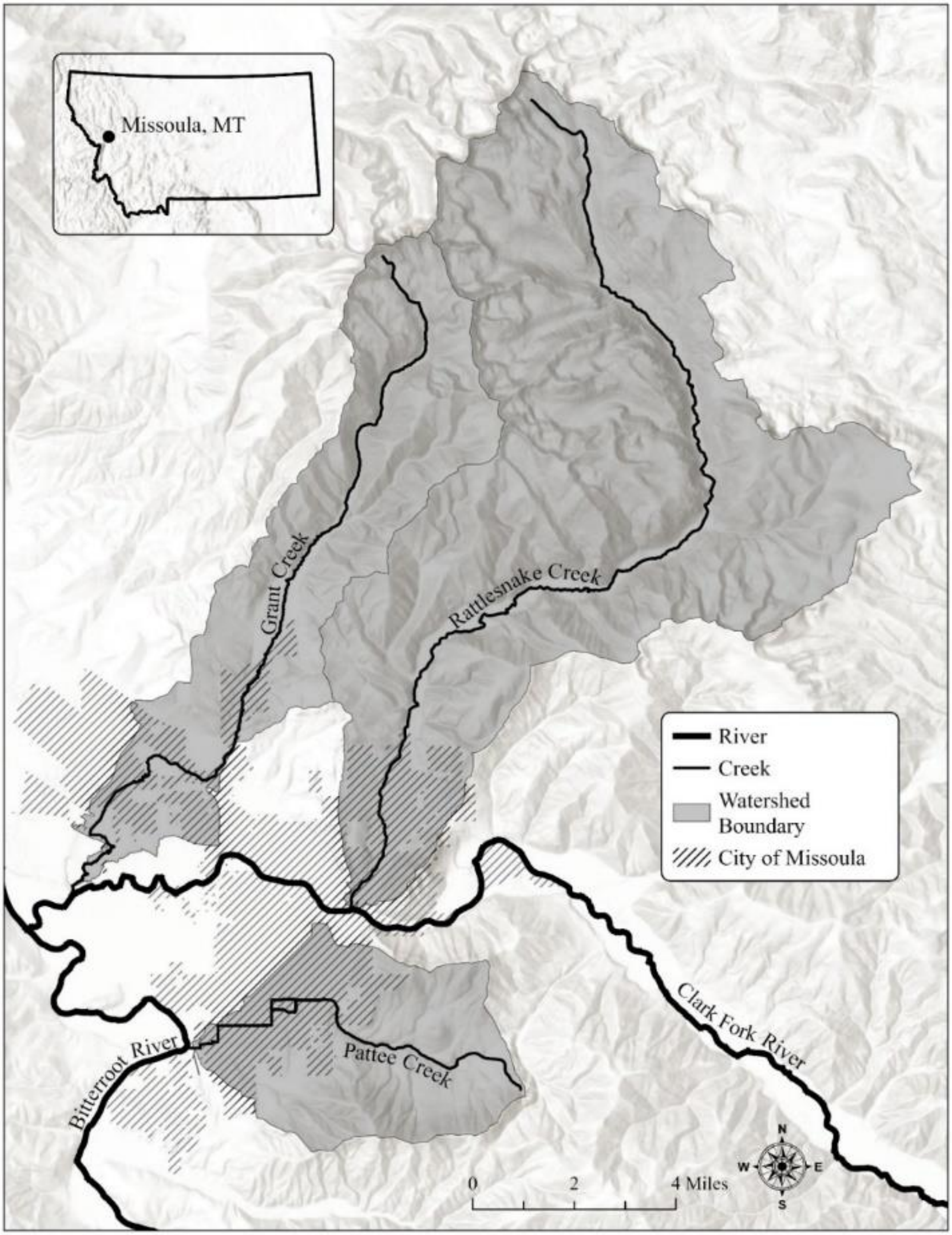

Figure 3. Map of the watersheds of Missoula's creeks.
All waterbody lines are from the NHD, except for the lower section of Pattee Creek, which was manually digitized.

2.4.2) Orthomosaics

Four orthomosaics were created for the Pattee Creek watershed and five were acquired from outside sources (Table 1). On the 1937 orthomosaic, identifying GCPs was difficult because most of the study area was undeveloped and few stationary physical features on the landscape are still visible on modern imagery. Also, the photos from that time only covered a portion of the Pattee Creek watershed, so the orthomosaic is incomplete. However, all the central low-lying sections of the watershed were included, allowing for the digitization of a 1937 and "past flow" channel layer. Twenty-nine images from 1937 were used to create this orthomosaic (Figure 4).

Five images, all from 1955, were used to create the 1955 orthomosaic (Figure 5). Five images were used to create the 1984 orthomosaic; three of the photos were from 1983 and two were from 1984. The images from 1984 covered a greater percentage of the study area, so this mosaic is referred to as "1984" (Figure 8). Six photos, all from 1995, were used to create the 1995 orthomosaic (Figure 9). The orthomosaic maps are presented below with their respective Pattee Creek layer overlaid on top.

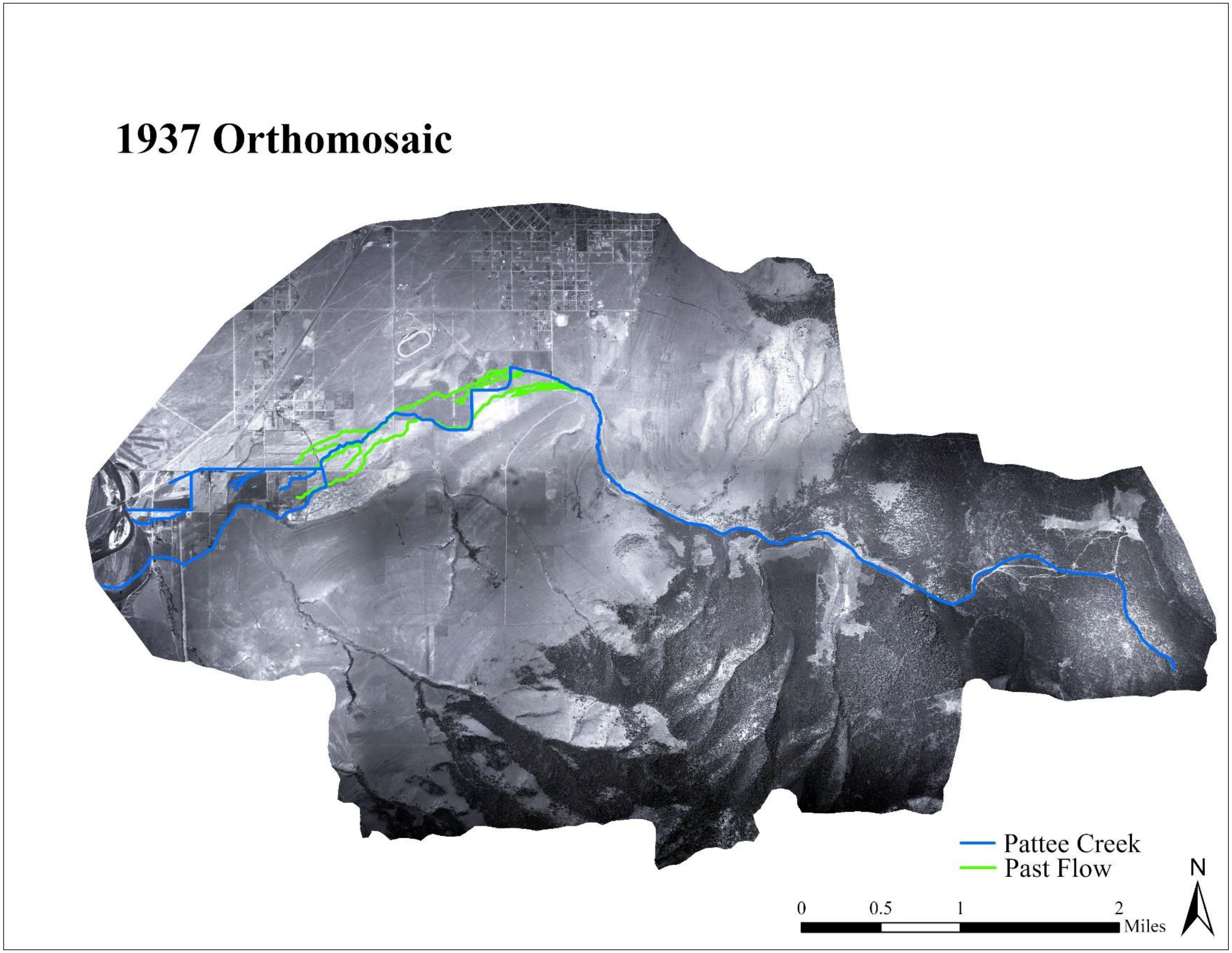

Figure 4. 1937 orthomosaic.

The 1937 orthomosaic, made with images from the UM Library, is the base layer of this map and was used to digitize the Pattee Creek layers shown.

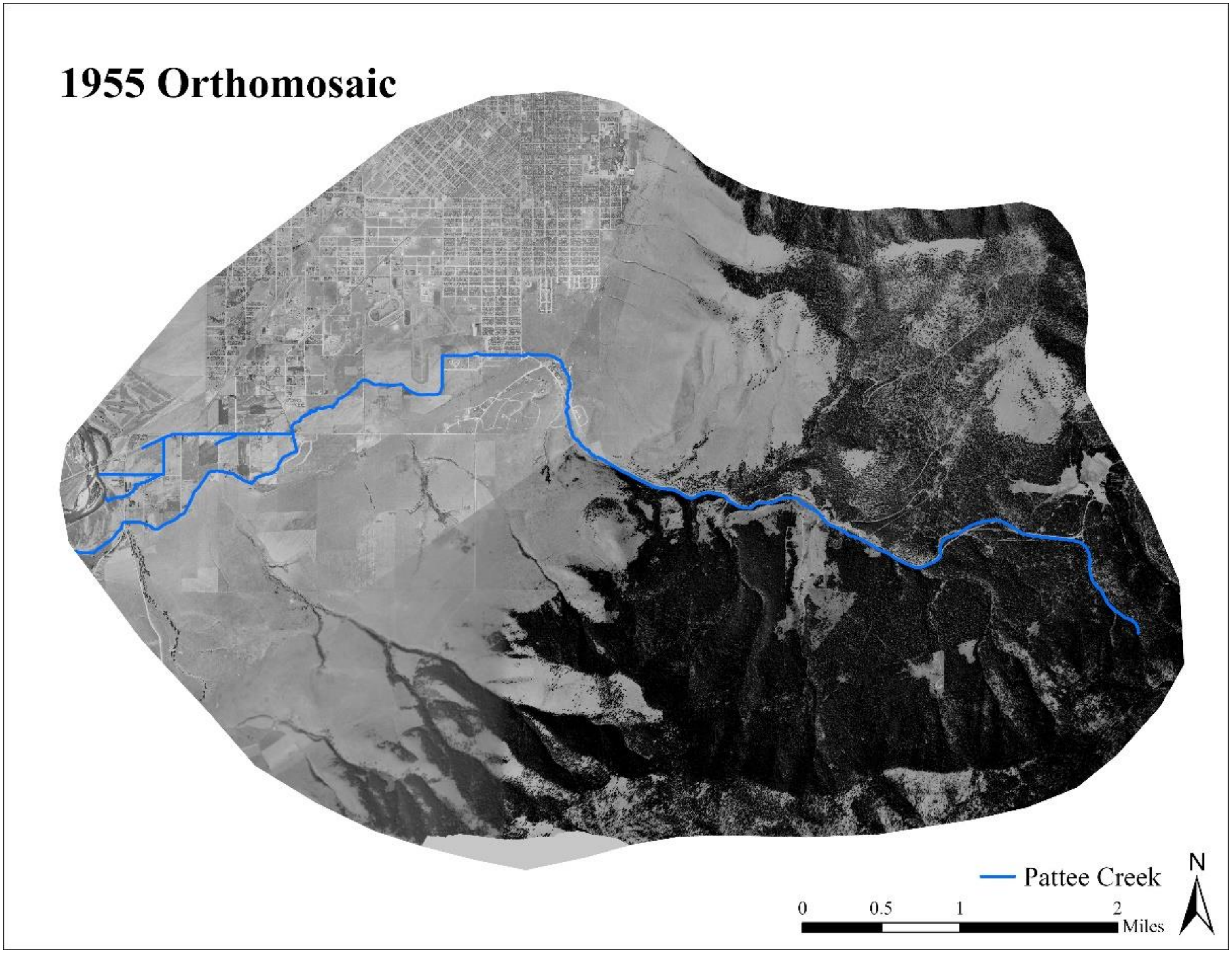

Figure 5. 1955 orthomosaic.

The 1955 orthomosaic, made with images from the USGS, is the base layer of this map and was used to digitize the Pattee Creek layer shown.

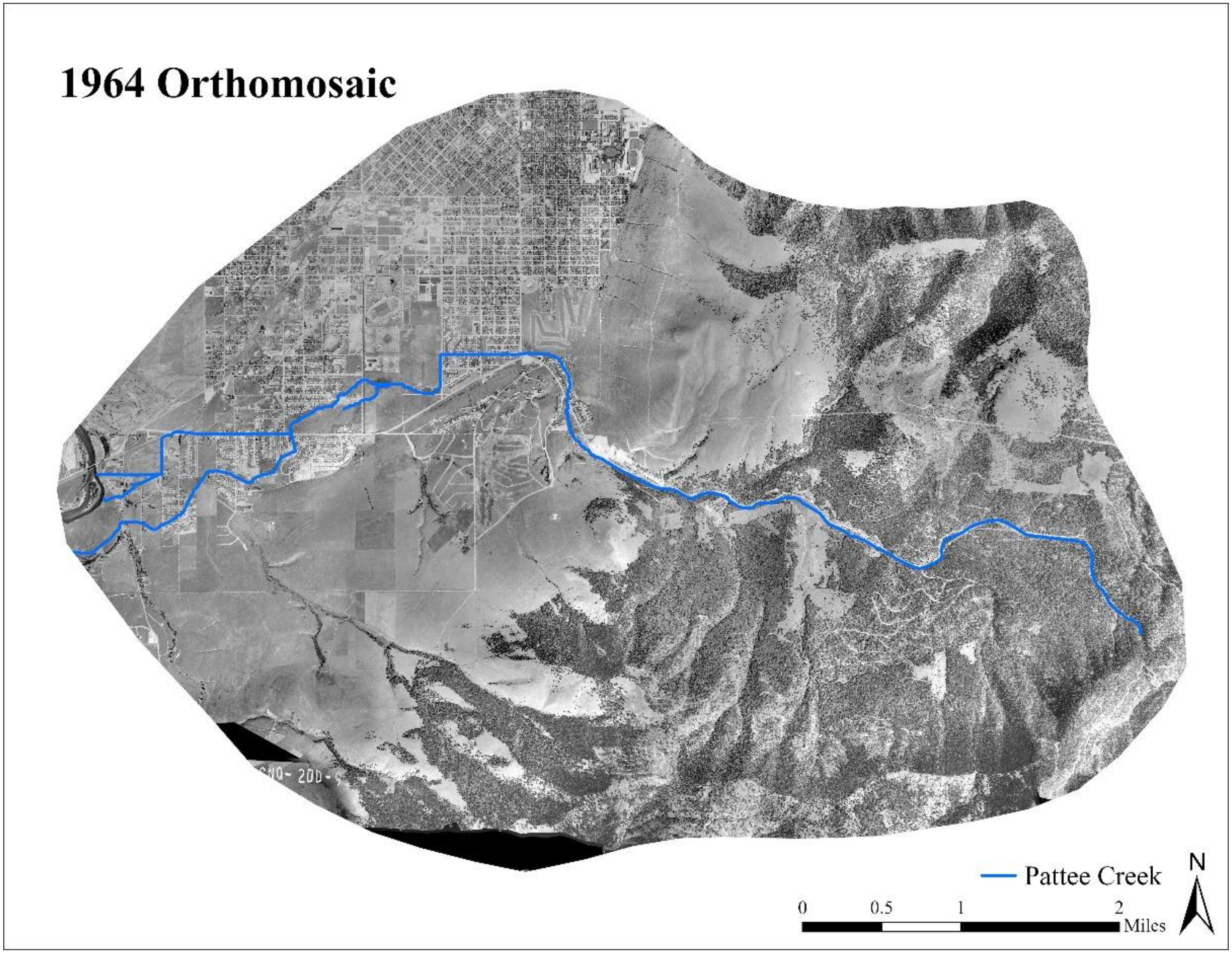

Figure 6. 1964 orthomosaic.

The 1964 orthomosaic, obtained from the Missoula County GIS, is the base layer of this map and was used to digitize the Pattee Creek layer shown.

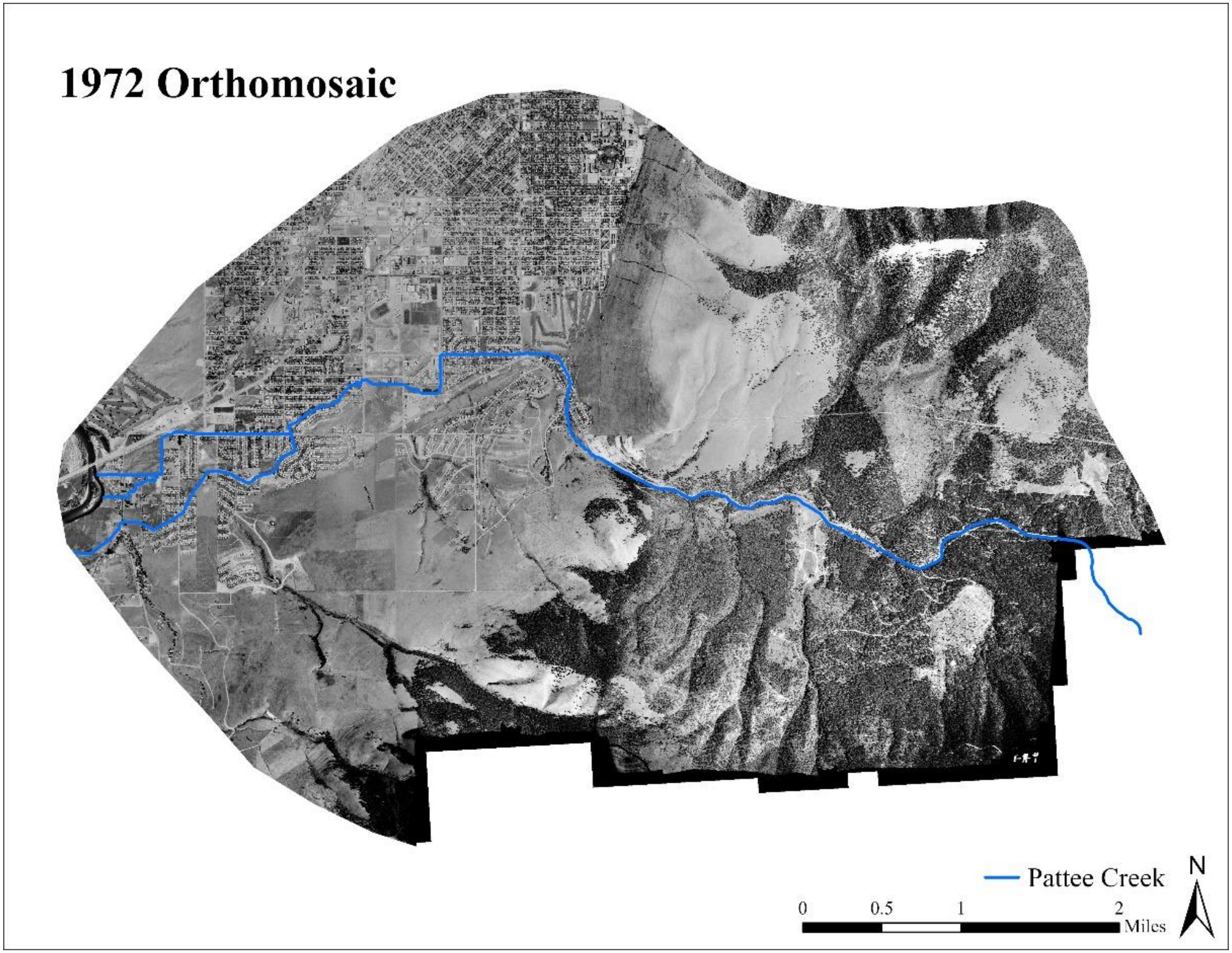

Figure 7. 1972 orthomosaic.

The 1972 orthomosaic, obtained from the Missoula County GIS, is the base layer of this map and was used to digitize the Pattee Creek layer shown.

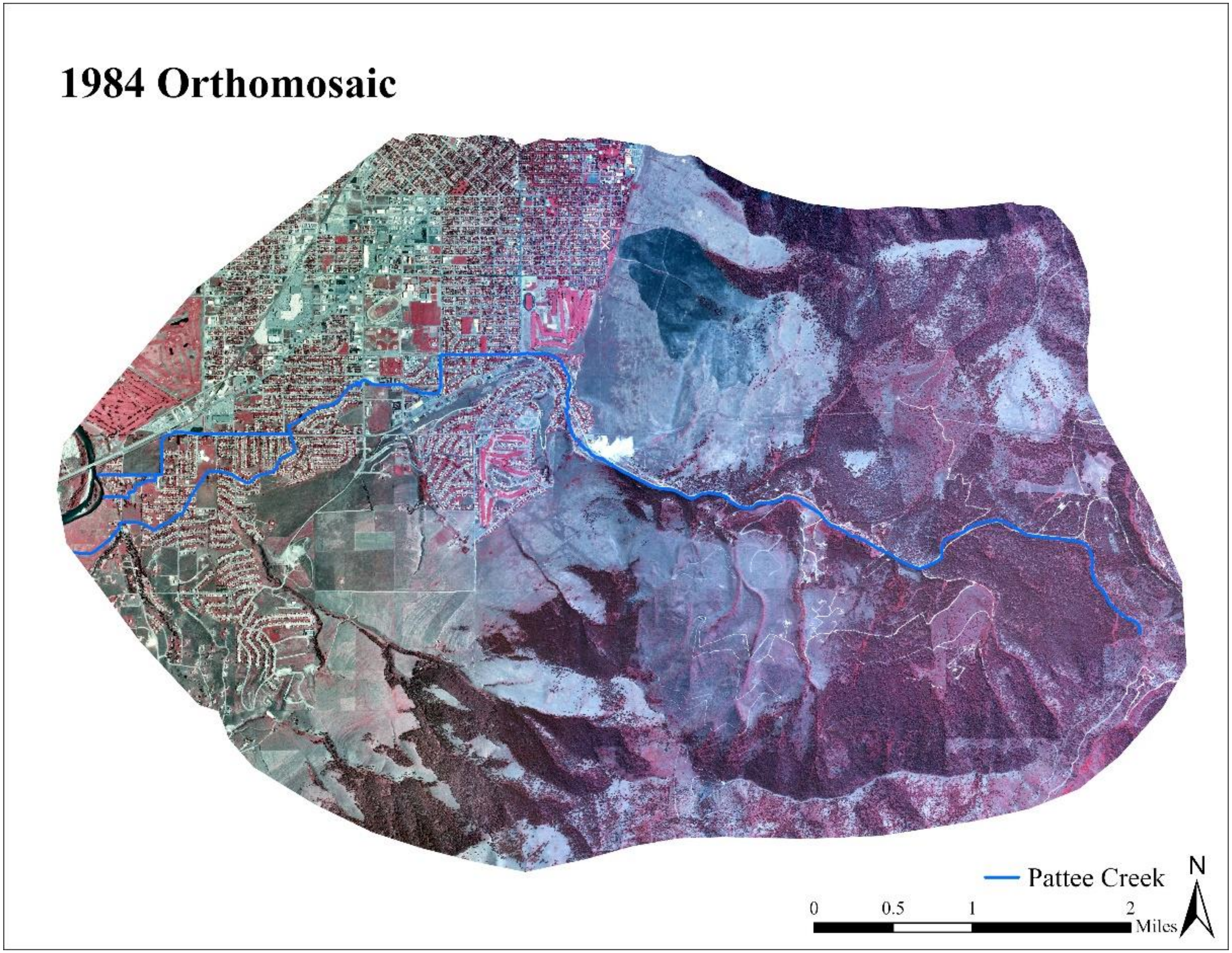

Figure 8. 1984 orthomosaic.
The 1984 orthomosaic, made with images from the USGS, is the base layer of this map and was used to digitize the Pattee Creek layer shown.

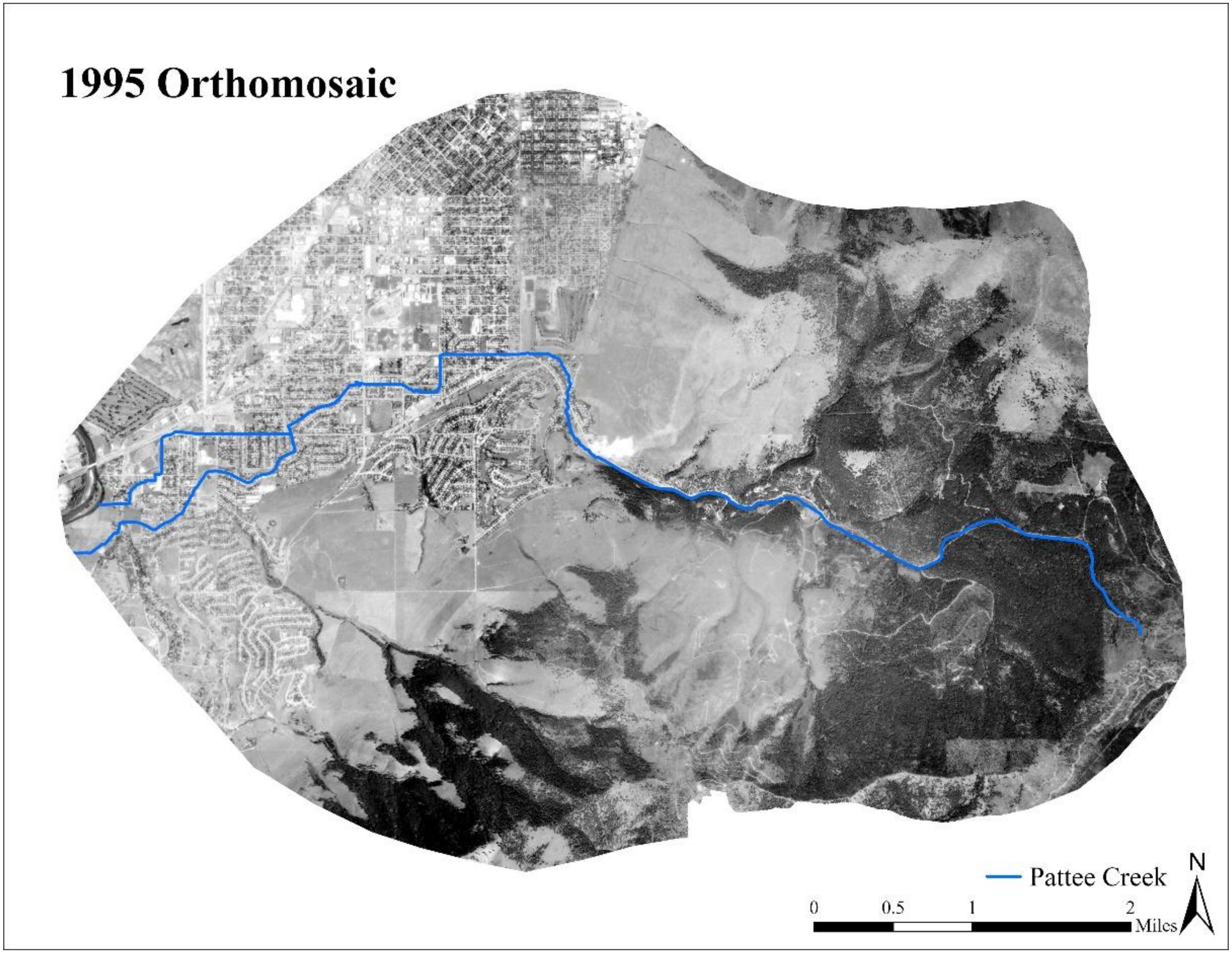

Figure 9. 1995 orthomosaic.

The 1995 orthomosaic, made with images from the USGS, is the base layer of this map and was used to digitize the Pattee Creek layer shown.

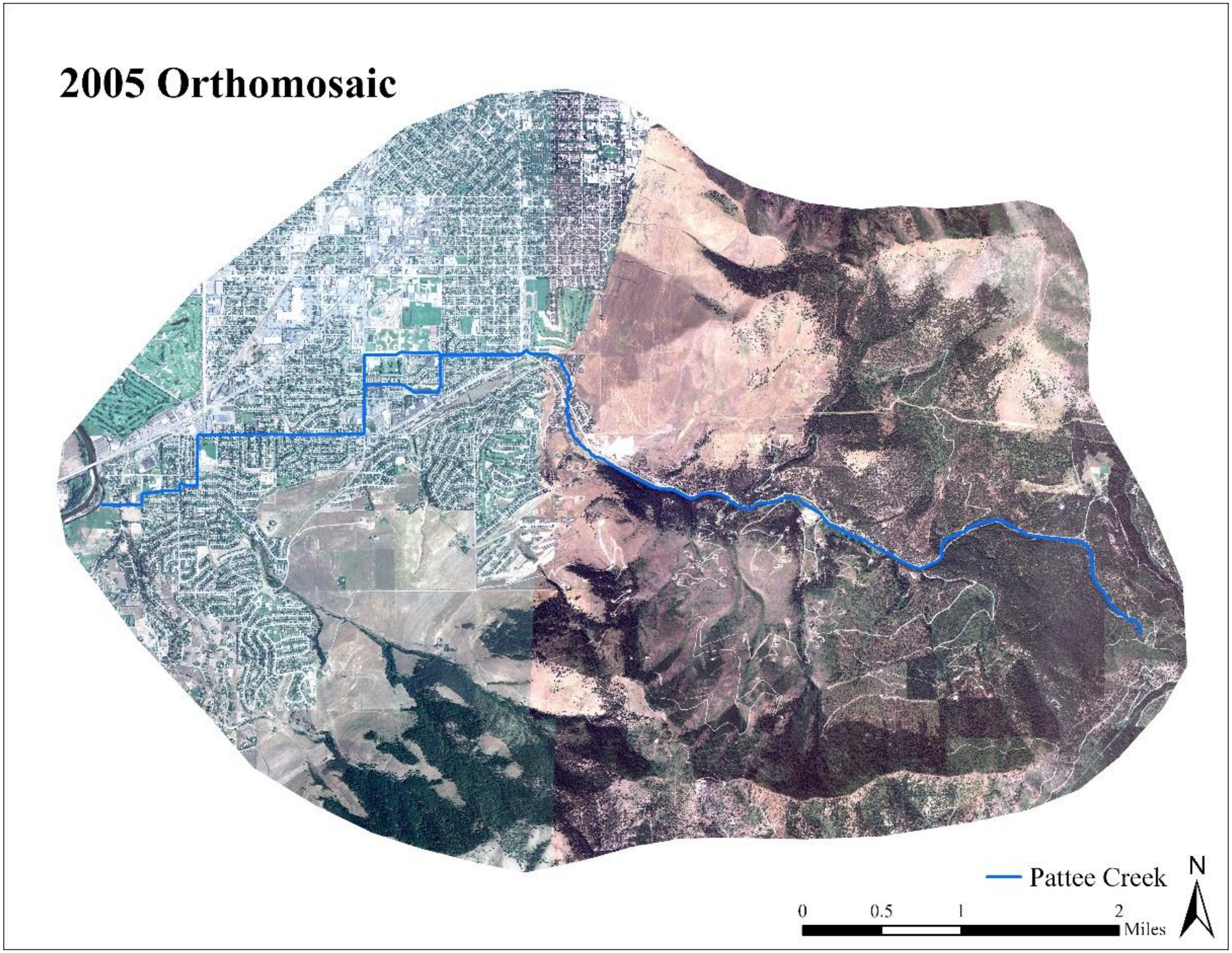

Figure 10. 2005 orthomosaic.
The 2005 orthomosaic, obtained from the USDA, is the base layer of this map and was used to digitize the Pattee Creek layer shown.

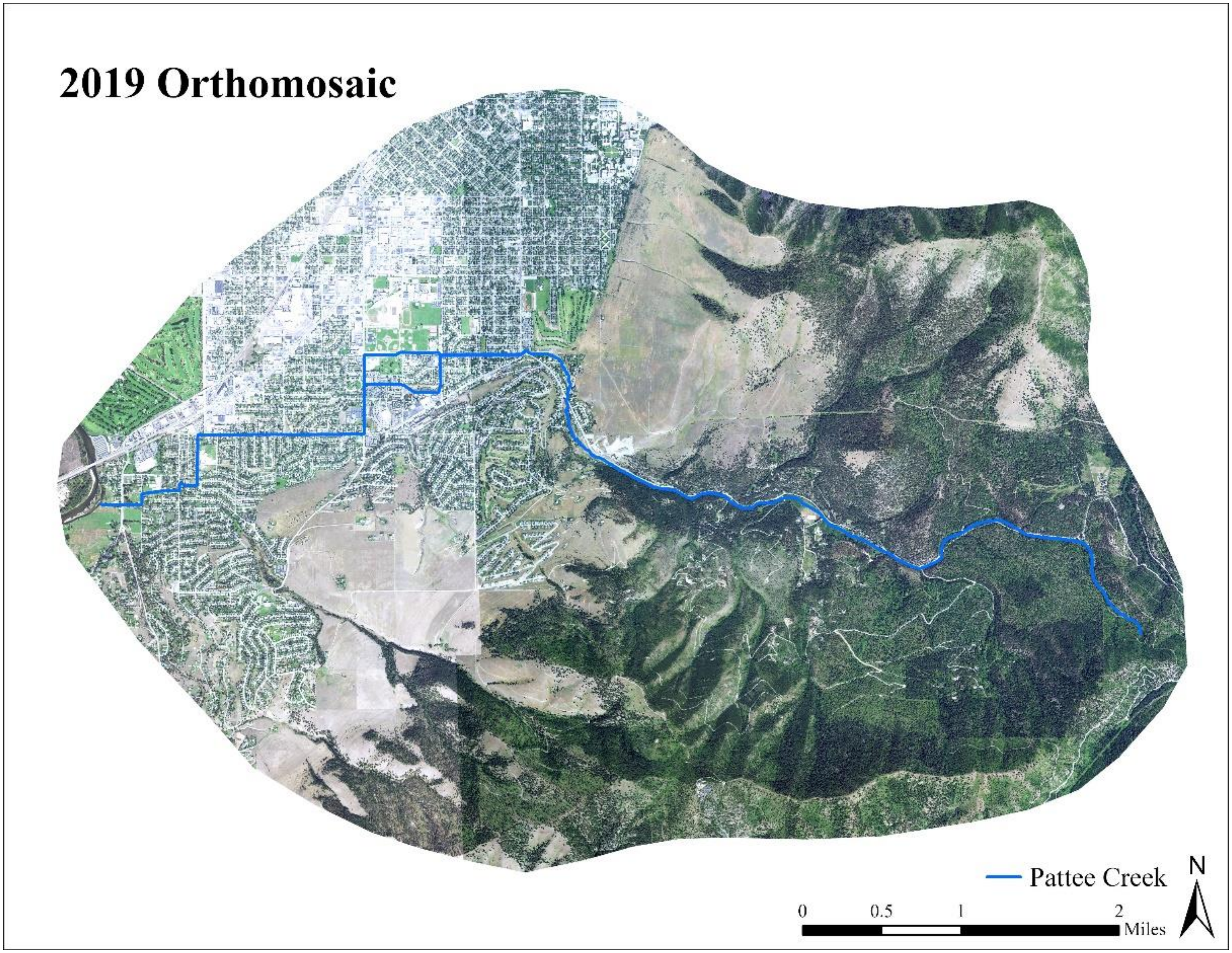

Figure 11. 2019 orthomosaic.
The 2019 orthomosaic, obtained from the USDA, is the base layer of this map and was used to digitize the Pattee Creek layer shown.

2.4.2) Extensive Land Cover Change

Since 1955, significant land cover changes have occurred throughout the Pattee Creek watershed (Figures 12-18). Widespread logging across the upper reaches of the watershed converted forested land to open land. From 1955 to 1984, the percent of forested land decreased from 44% to 34% (Figure 19). Although logging almost entirely ceased around 1984, other drivers, such as fire, continued to convert forested land into open land. For example, a severe fire on University Mountain (near the northeast section of the watershed) in 1985 cleared large swaths of forest (Smith 1994). Even so, the 1984 orthomosaic represents a significant turning point when logging stopped, and revegetation began. From 1984 to 2019, the percent of forested land increased from 34% to 45% (Figure 19).

The most dramatic change in land cover was the transformation of open land into developed land across the low-lying sections of the watershed. Throughout the study period (1955 to 2019), the amount of developed land steadily increased from 10% in 1955 to 27% in 2019 due to the urban expansion of southern Missoula (Figure 19). This urban expansion was primarily fueled by residential housing development. Agriculture was still prevalent across the valley floor in 1955, with most of the land directly adjacent to Pattee Creek being utilized for farming. During the 1960s, 1970s, and 1980s, almost all the open land in the valley floor section of the watershed transitioned from open land into developed. Development has continued across the Pattee Creek watershed from 1980 to the present, albeit at a slower rate. This urbanization has been the leading driver of open land decreasing across the study period (46% in 1955 to 29% in 2019) (Figure 19).

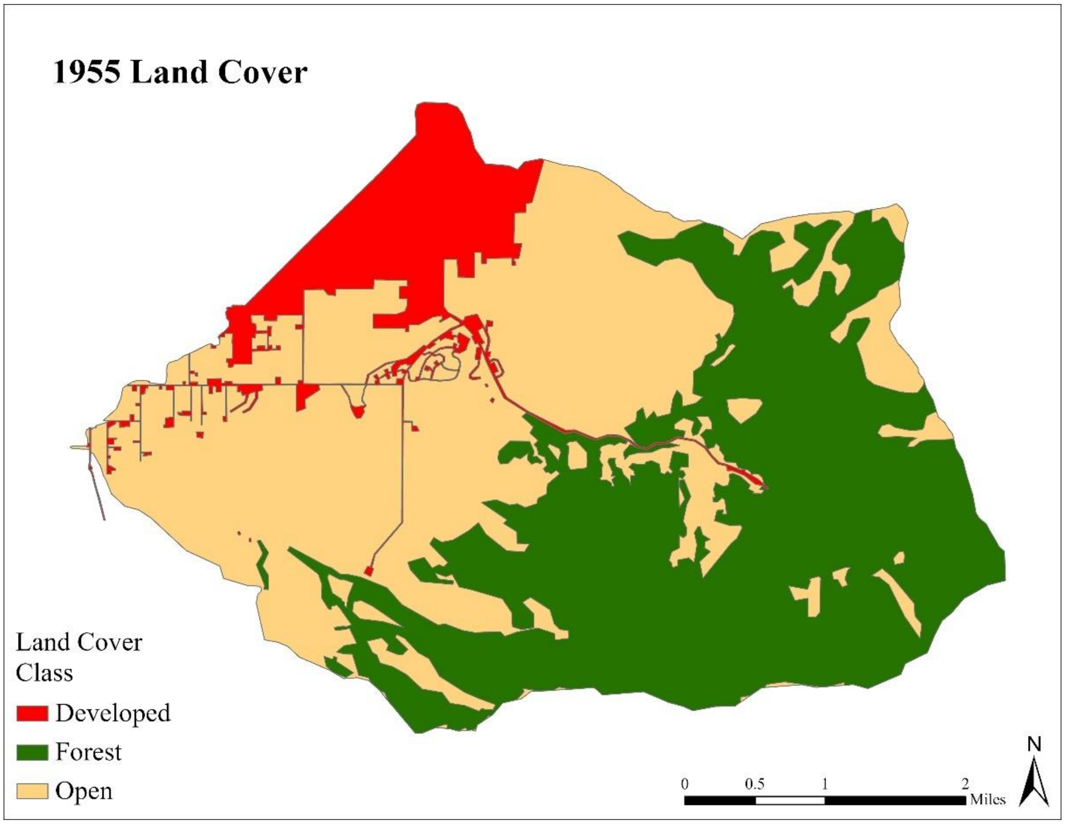

Figure 12. The digitized 1955 land cover within the Pattee Creek watershed.

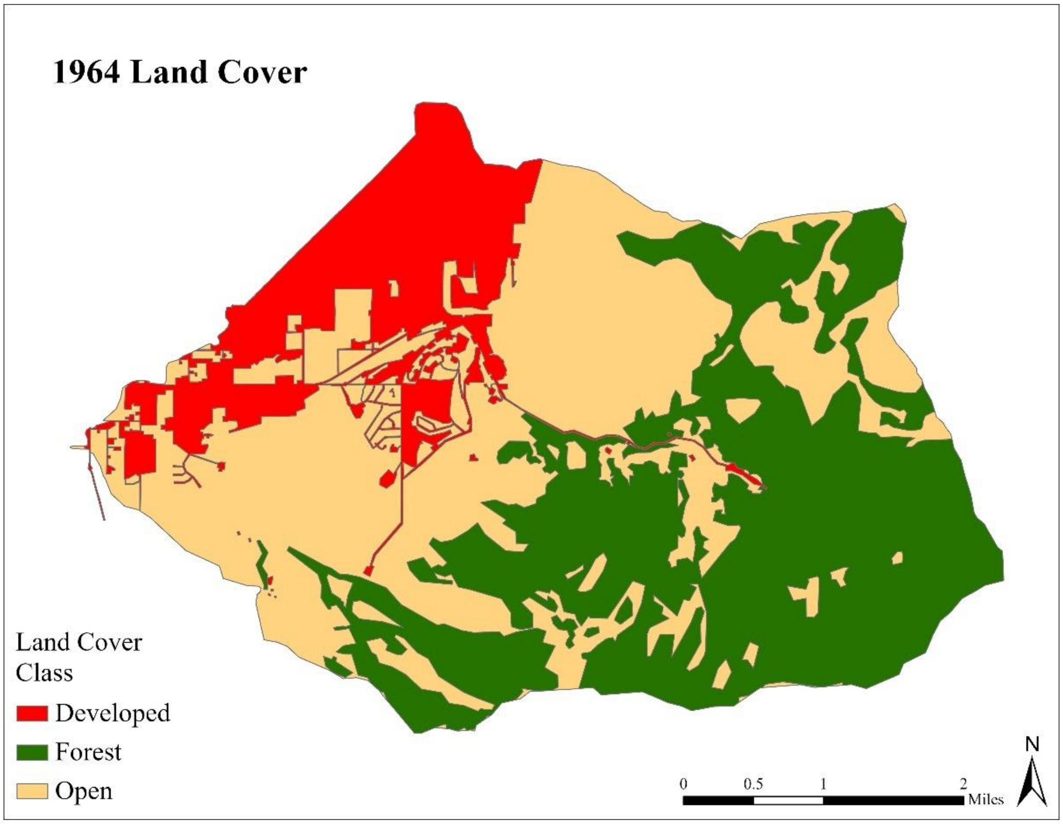

Figure 13. The digitized 1964 land cover within the Pattee Creek watershed.

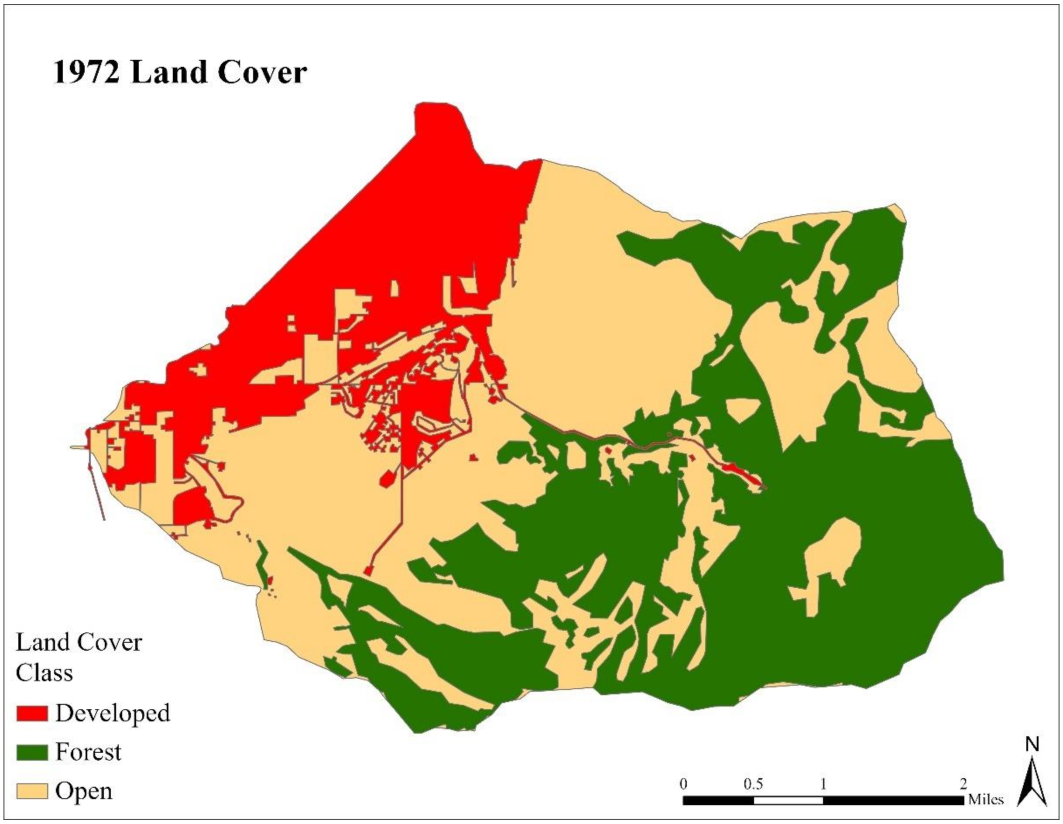

Figure 14. The digitized 1972 land cover within the Pattee Creek watershed.

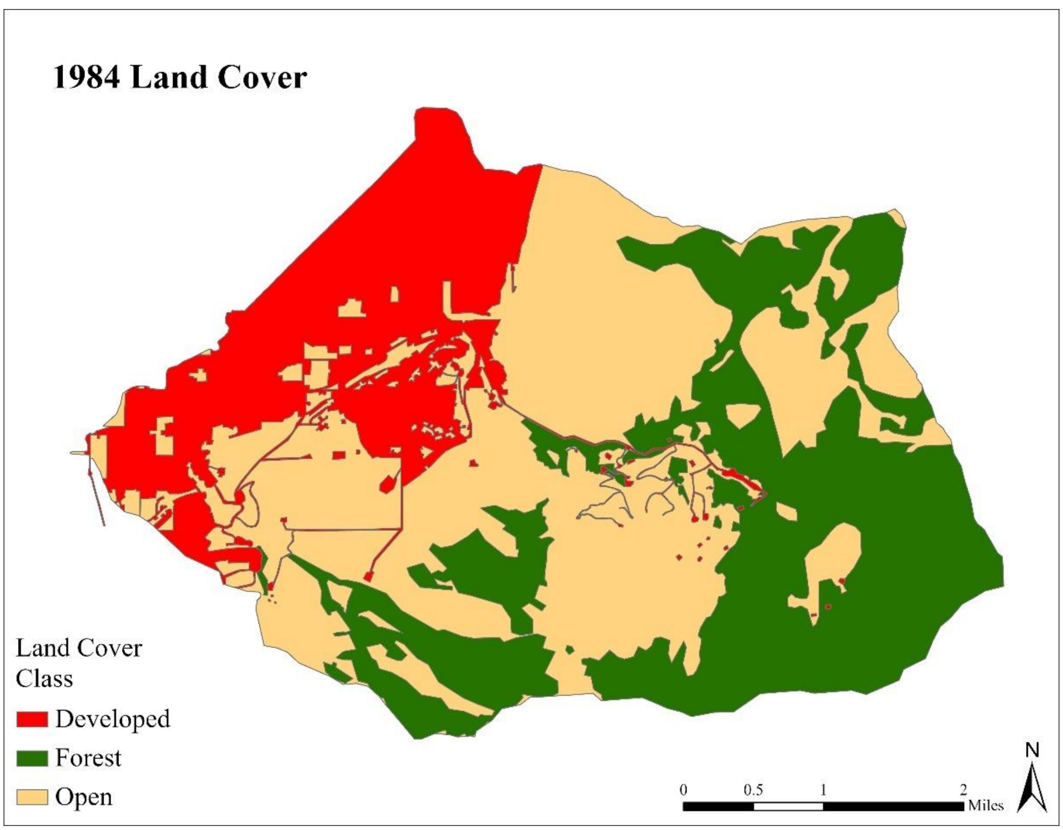

Figure 15. The digitized 1984 land cover within the Pattee Creek watershed.

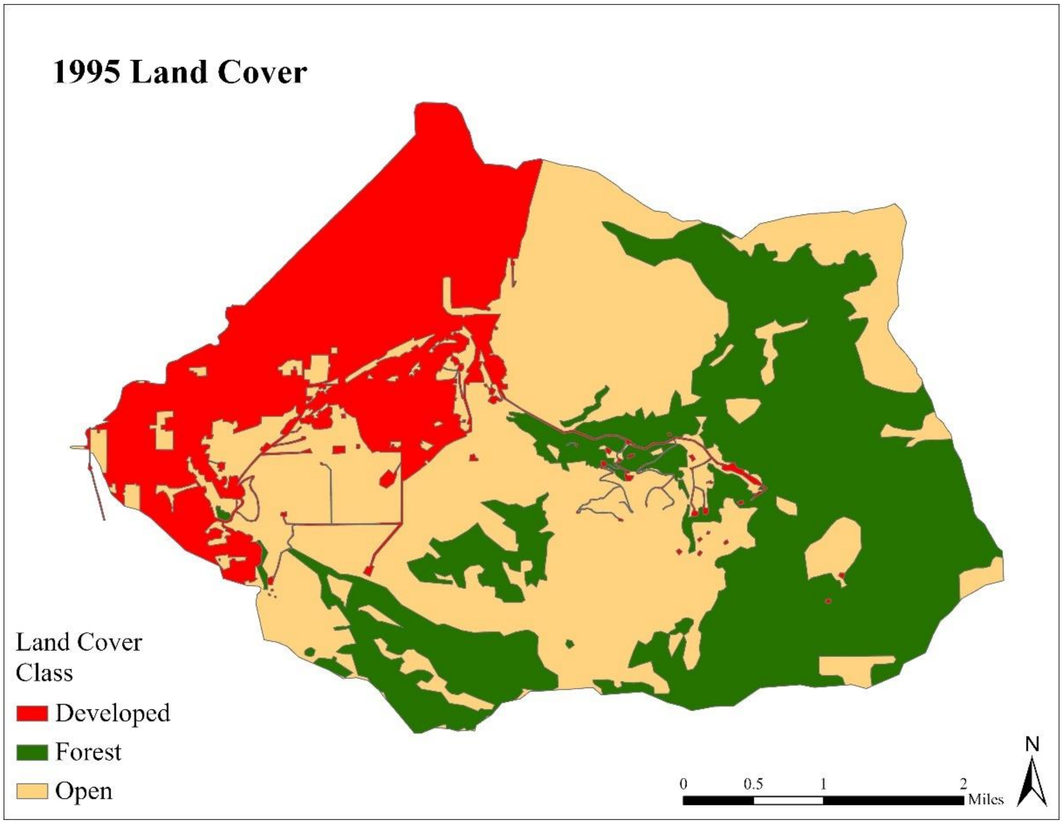

Figure 16. The digitized 1995 land cover within the Pattee Creek watershed.

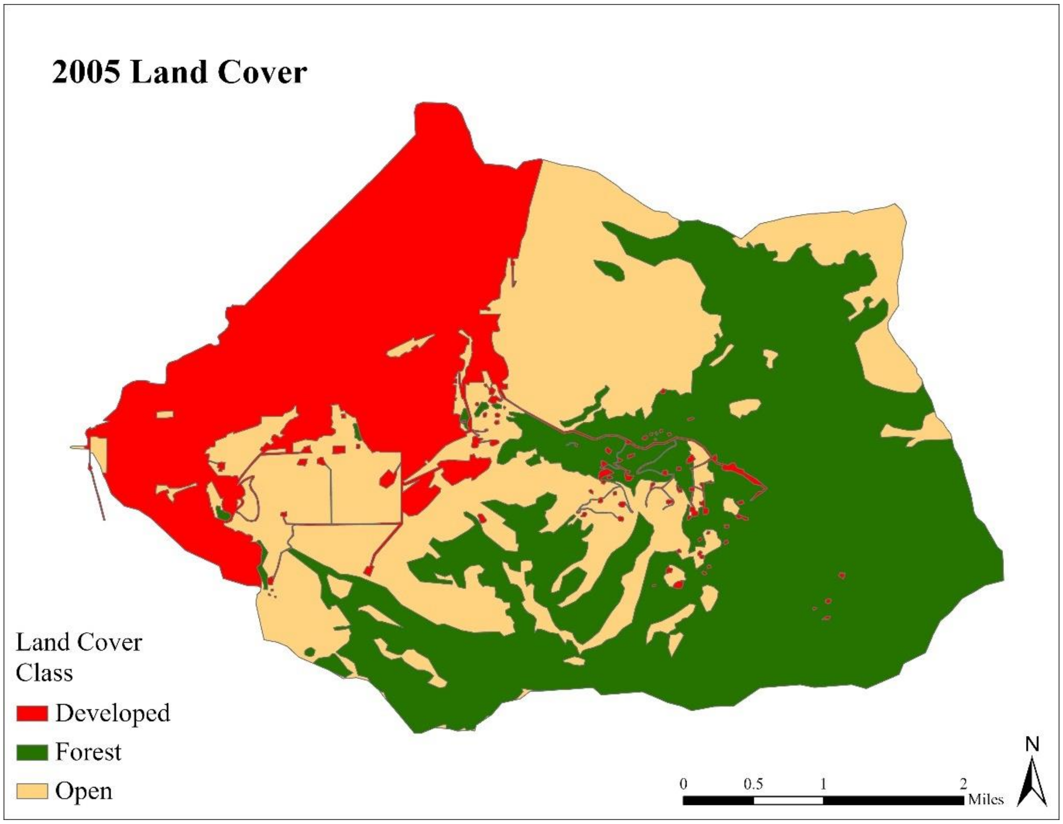

Figure 17. The digitized 2005 land cover within the Pattee Creek watershed.

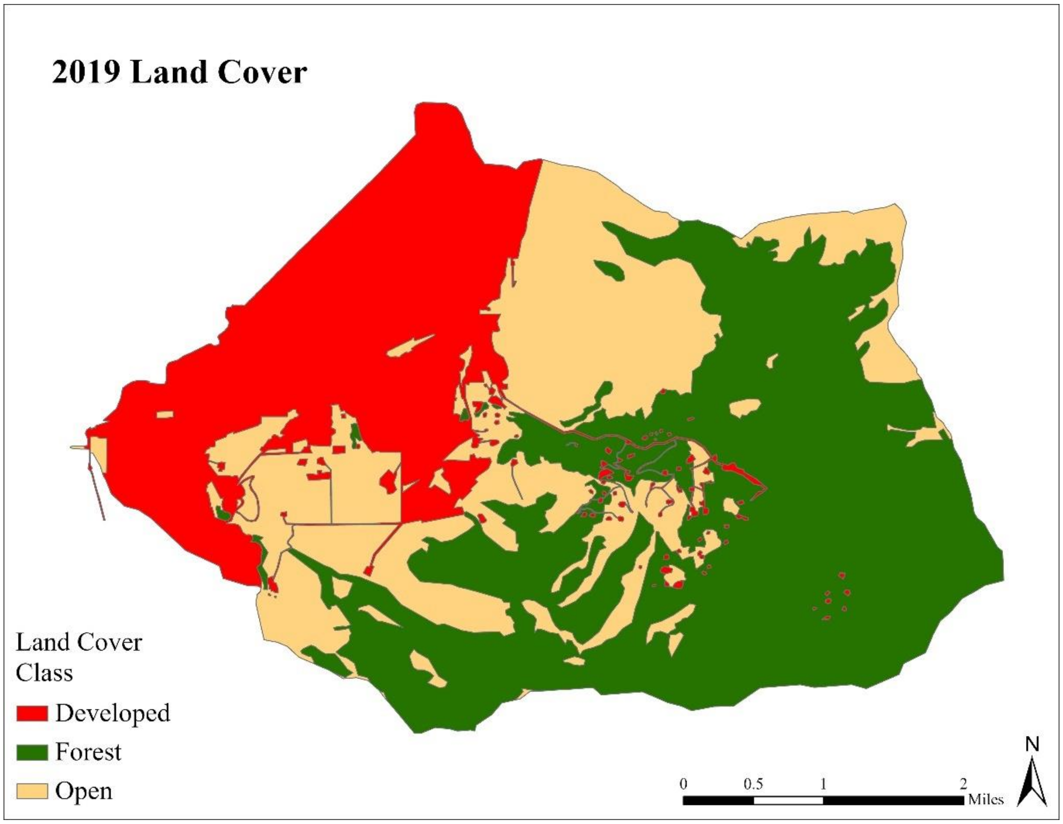

Figure 18. The digitized 2019 land cover within the Pattee Creek watershed.

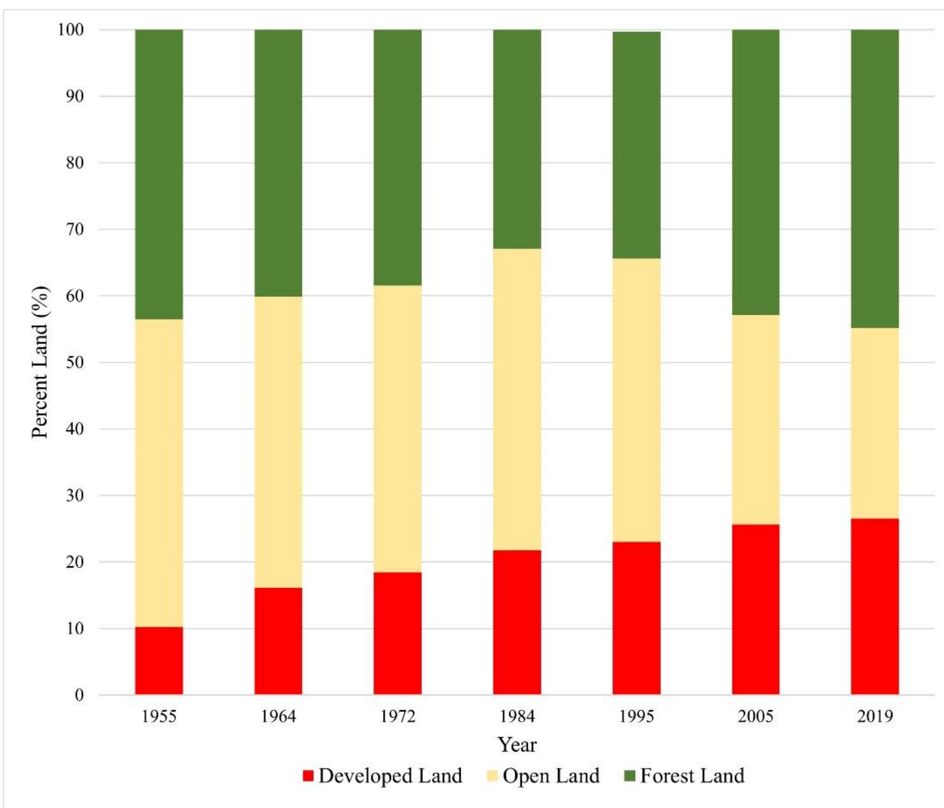

Figure 19. Pattee Creek watershed land-cover change.

2.4.3) The Channelization of Pattee Creek

Before the colonization of Missoula, Pattee Creek would disperse its flow across the Missoula Valley through a complex network of braided channels. In the early 1900s, some (if not all) of the channels turned north once they hit the valley floor and emptied into the Clark Fork River (Johnston 1929). Before impervious surfaces were built across southern Missoula, significant portions of Pattee Creek's flow would infiltrate into the ground once it hit the valley floor (WGM Group 2002). The creek likely changed paths from year to year and migrated freely across the valley, consistent with the general pattern observed in low-order streams (Bowman 2019).

Over the last century, the channel of Pattee Creek has been heavily modified by agriculture and urban development. Shortly after colonial settlement, water-dependent agricultural activities became prevalent across southern Missoula, which incentivized farmers to build irrigation ditches and utilize the water flowing through Pattee Creek. The earliest irrigation ditches were created right near the mouth of Pattee Canyon, although the year is unknown. The "past flow" layer in Figure 20 shows what Pattee Creek might have looked like between 1916 and 1937. By 1937, a complex system of irrigation ditches existed which conveyed Pattee Creek across the valley floor. However, during this year, there were still large sections of free-flowing creek that existed between the irrigation ditches.

The channel of Pattee Creek was shortened and further channelized between 1955 and 2019. By 1955, most of the valley floor sections of the stream were in a ditch. However, there were still portions of the creek that meandered back and forth across the valley and resembled a somewhat natural stream (Figure 21). From 1955 to 1984, the creek became increasingly channelized to make irrigation more efficient and to allow for more urban development (Figure 22 to Figure 24). During this period, the creek rarely made it to the Bitterroot River, except during peak runoff (WGM Group 2002). By 1995, the creek was entirely channelized across the Missoula Valley (except where it had been ponded) and there was no sign of a naturally meandering creek, other than in the upper reaches of the watershed (Figure 25). The Missoula South Hills Storm Drainage System, completed in 2002, mostly buried and straightened the creek under Missoula. Since then, Pattee Creek runs in a straight line beneath Russell Street and 39th Street (Figure 26 and Figure 27). From 1937 to 2019, Pattee Creek decreased in total length from 9.10 to 7.22 miles (Table 4).

Table 4. Pattee Creek total length.

Year	Pattee Creek Total Length (miles)
1937	9.10
1955	8.48
1964	8.51
1972	8.17
1984	8.15
1995	7.82
2005	7.21
2019	7.22

The section of Pattee Creek that used to flow above ground between Russell Street and 39th Street presents an ideal opportunity for a daylighting project (which will be discussed further in Chapter 5). This area already features an urban green corridor built around the former channel which could serve as a conduit for a restored creek (Figures 20 to 26). Additionally, the presence of residential properties along this stretch offers the potential for community engagement and interaction with the creek. Restoring this historic path of Pattee Creek could not only enhance biodiversity and water quality but provide recreational opportunities and improve quality of life for residents. Below are maps depicting this area, highlighting its potential for revitalization.

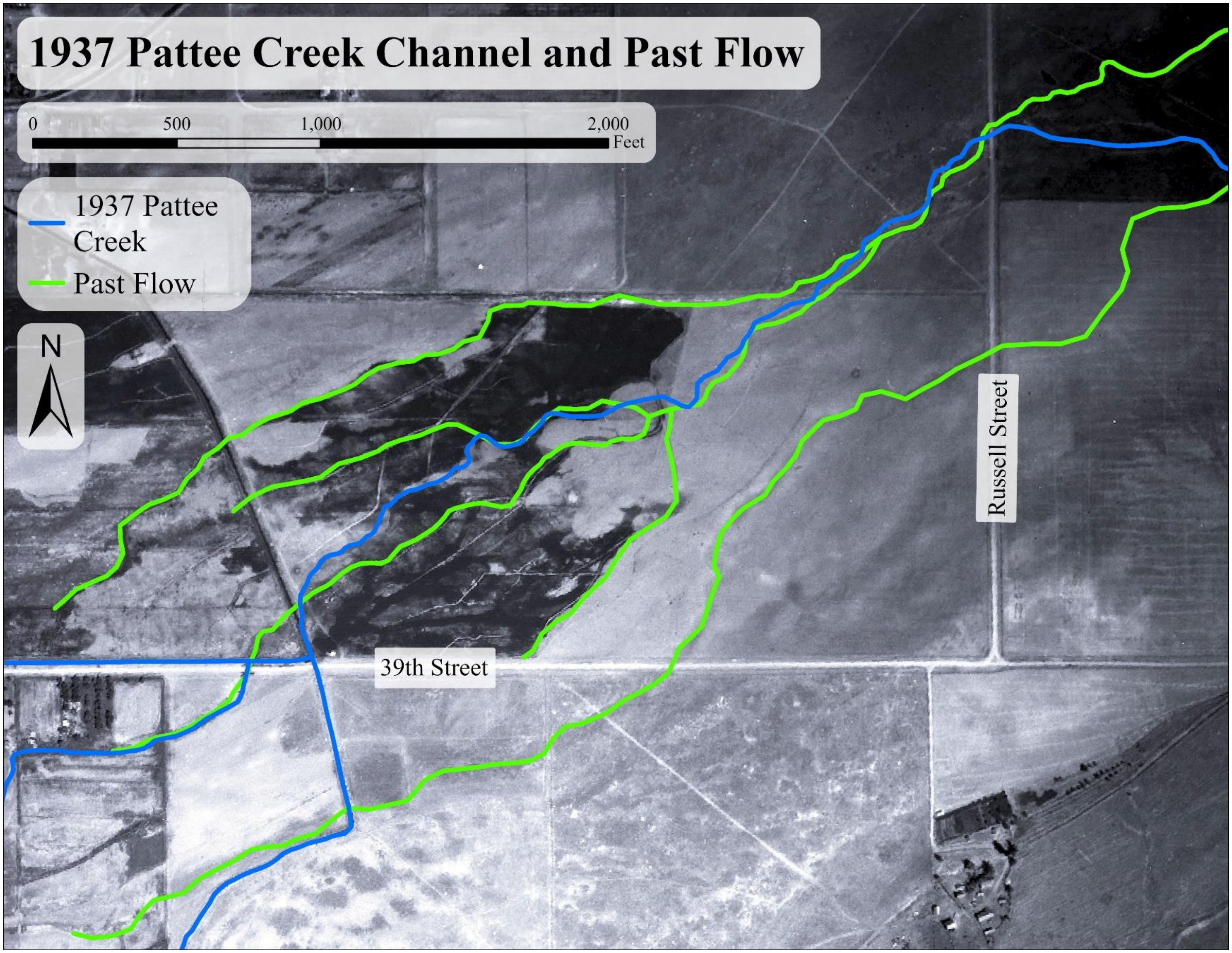

Figure 20. 1937 Pattee Creek channel and past flow.

The 1937 orthomosaic is the base layer of this map. Russell Street runs north to south on the east side of this image and 39th Street runs east to west on the south.

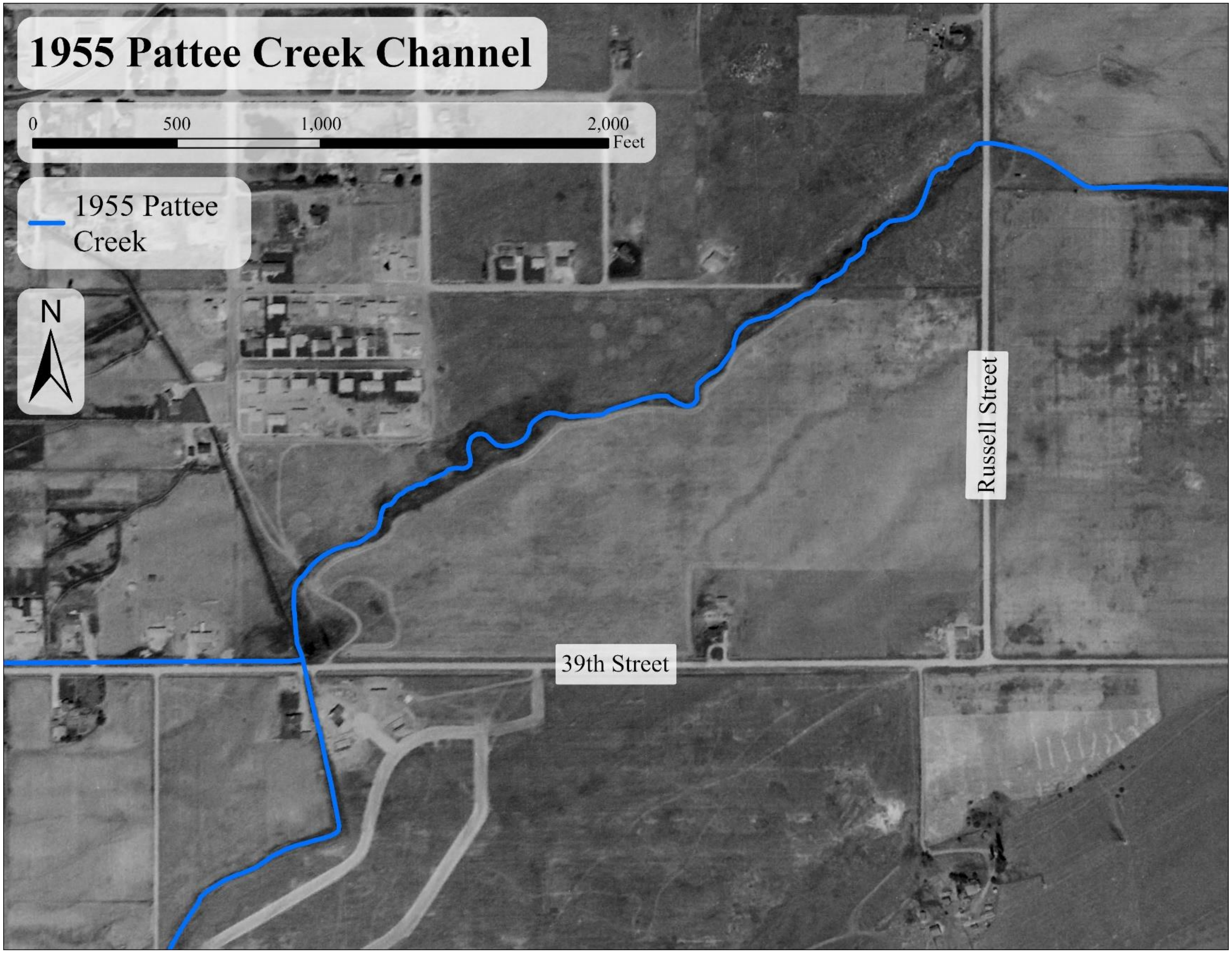

Figure 21. 1955 Pattee Creek channel.
The 1955 orthomosaic is the base layer of this map. Russell Street runs north to south on the east side of this image and 39th Street runs east to west on the south.

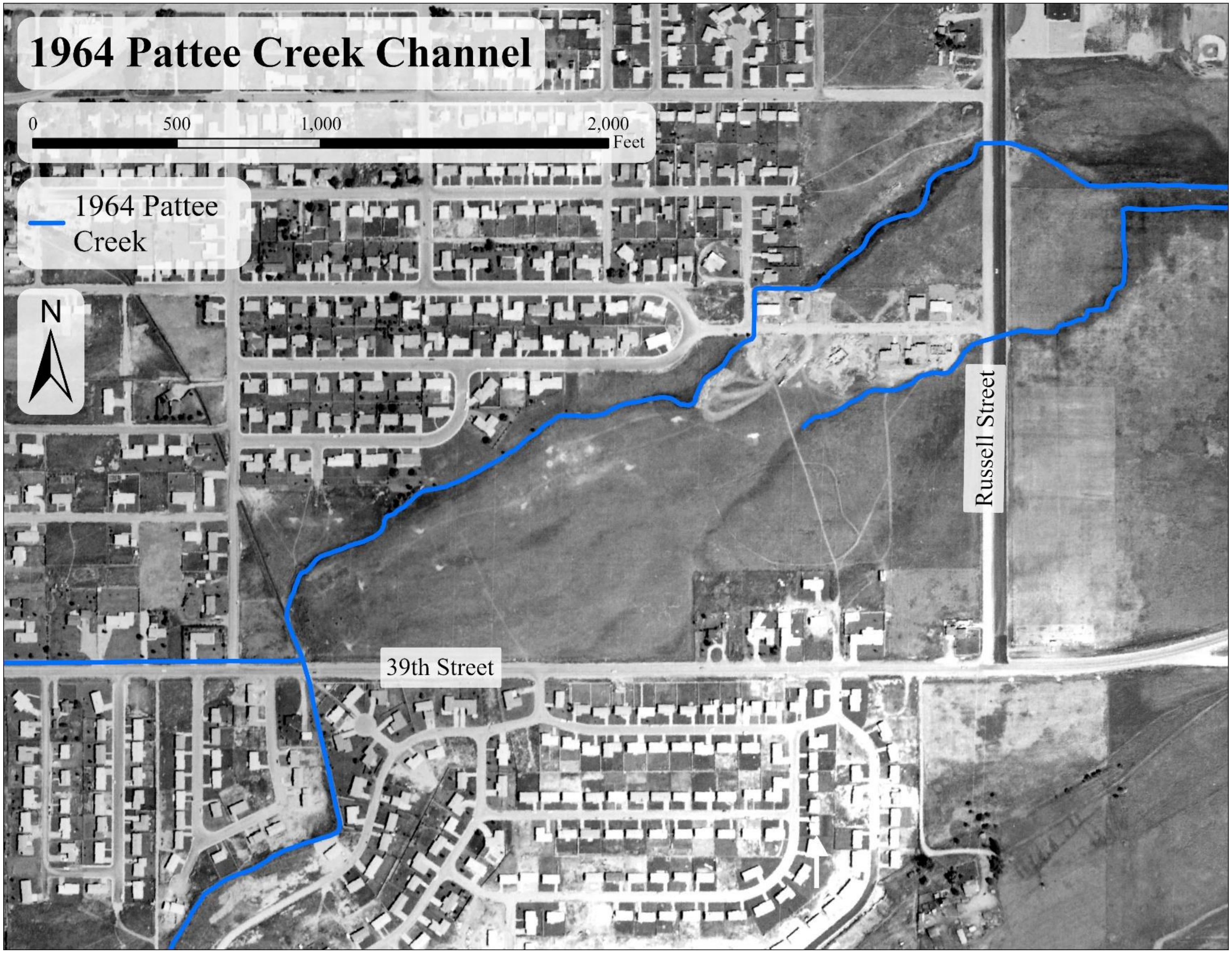

Figure 22. 1964 Pattee Creek channel.

The 1964 orthomosaic is the base layer of this map. Russell Street runs north to south on the east side of the image and 39th Street runs east to west on the south.

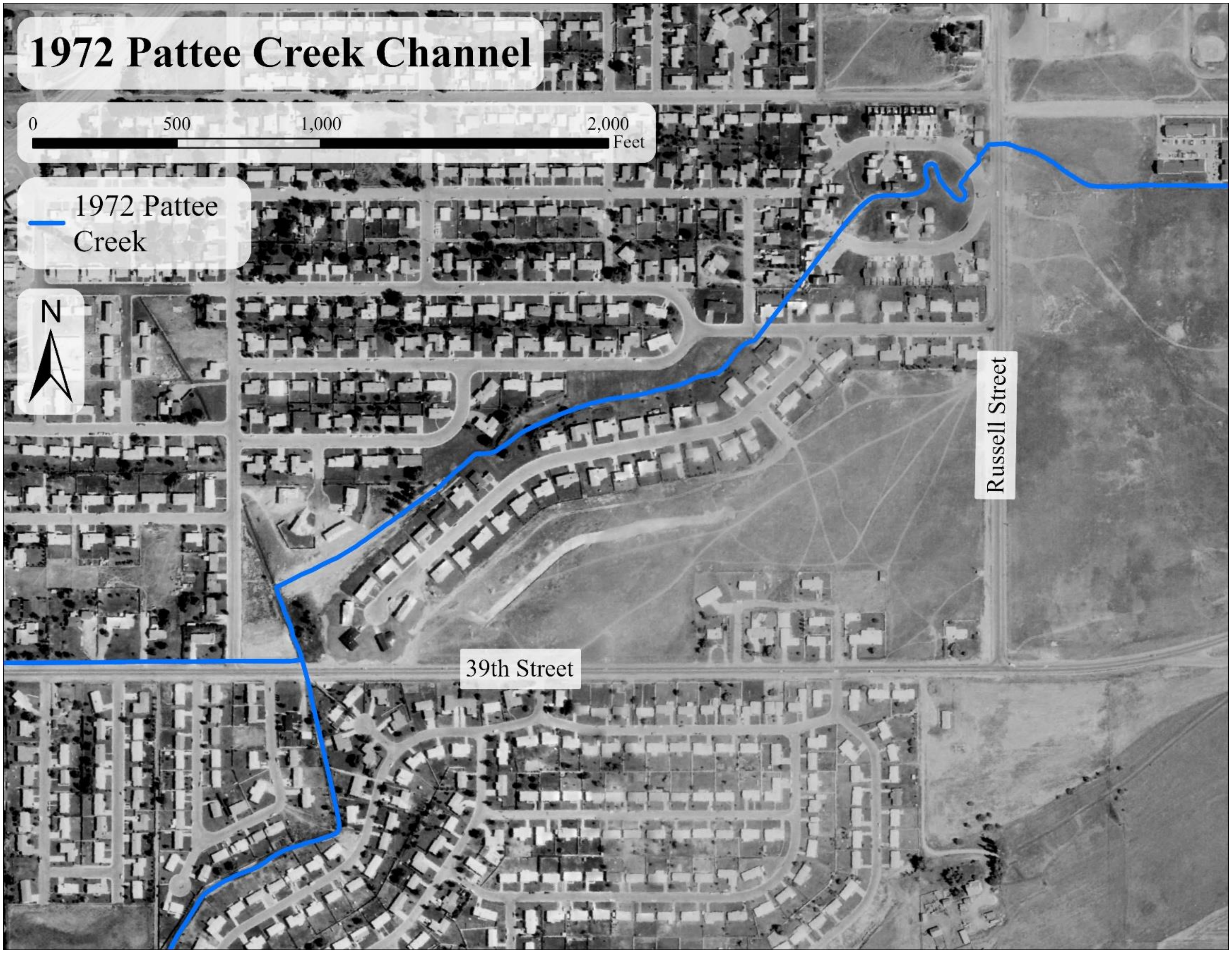

Figure 23. 1972 Pattee Creek channel.

The 1972 orthomosaic is the base layer of this map. Russell Street runs north to south on the east side of the image and 39th Street runs east to west on the south.

Figure 24. 1984 Pattee Creek channel.

The 1972 orthomosaic is the base layer of this map. Russell Street runs north to south on the east side of the image and 39th Street runs east to west on the south.

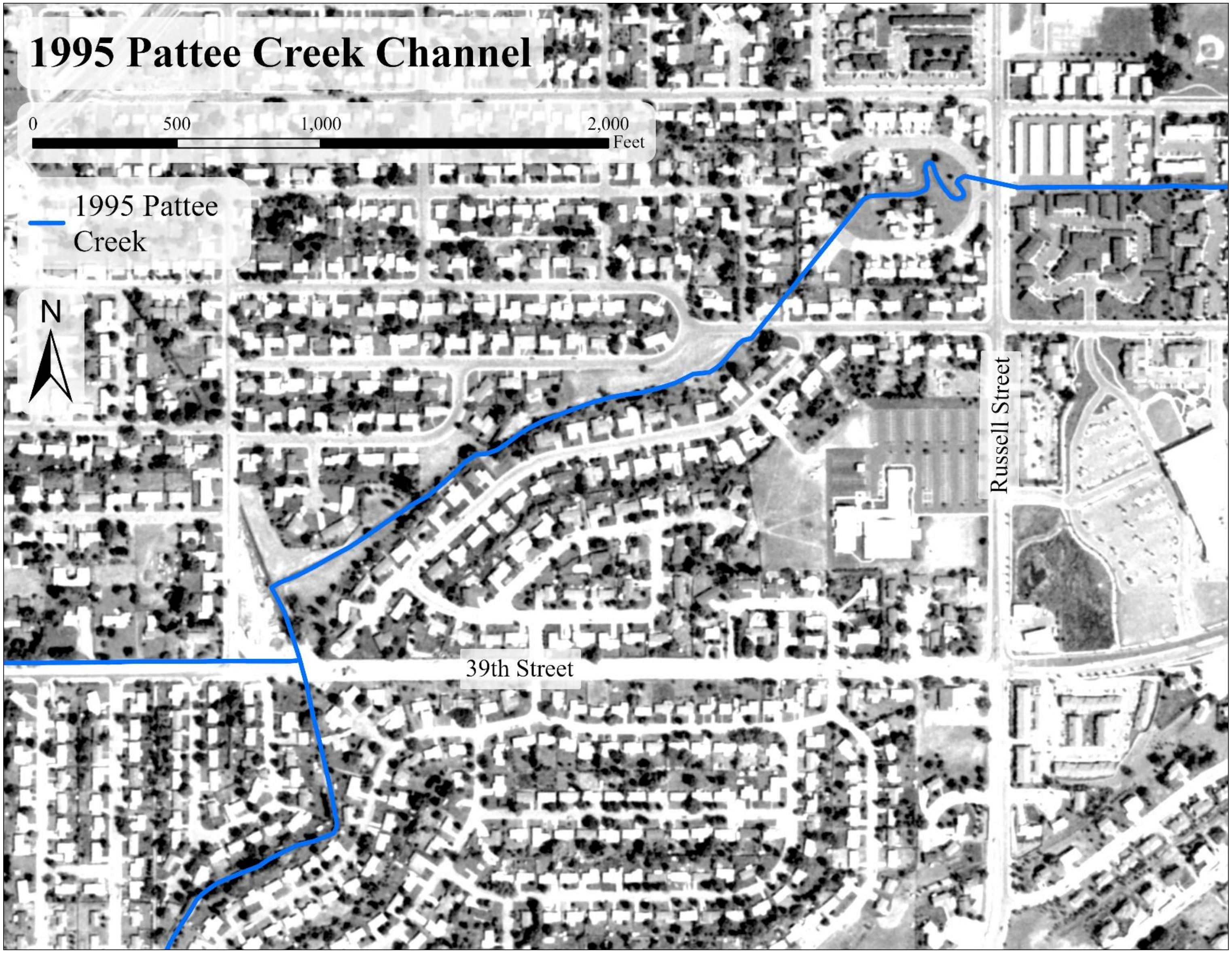

Figure 25. 1995 Pattee Creek channel.
The 1995 orthomosaic is the base layer of this map. Russell Street runs north to south on the east side of the image and 39th Street runs east to west on the south.

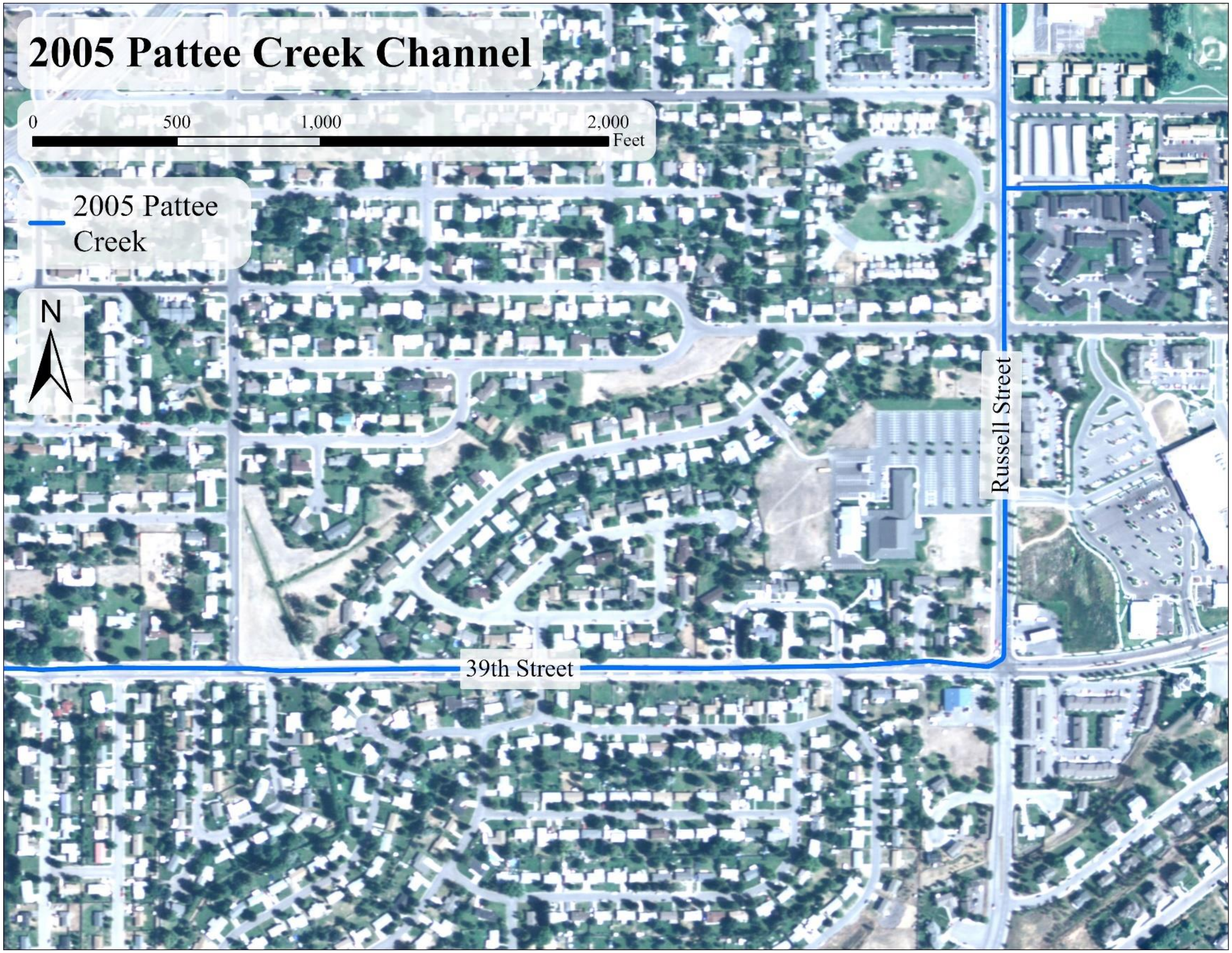

Figure 26. 2005 Pattee Creek channel.
The 2005 orthomosaic is the base layer of this map. Russell Street runs north to south on the east side of the image and 39th Street runs east to west on the south.

Figure 27. 2019 Pattee Creek channel.

The 2019 orthomosaic is the base layer of this map. Russell Street runs north to south on the east side of the image and 39th Street runs east to west on the south.

2.5) Discussion

Chapter 2 provided an analysis of the historical imagery of Pattee Creek, shedding light on how the waterbody and its watershed have evolved since the early 1900s. This research has contributed to the understanding of Pattee Creek's past and the factors that have shaped its current state. The main factors driving change include agriculture, logging, mining, and urbanization.

Across the urban world, artificial stream modification and channelization are often precursors to burial. Before creeks are buried, they are commonly rerouted to facilitate irrigation or demark property (Napieralski & Welsh 2016). Once creeks are rerouted into irrigation ditches, their floodplain disappears along with their ability to handle high water events. As urban development replaces farmland, these once helpful sources of irrigation water become problematic sources of flooding for residential neighborhoods. This well documented evolution of stream to ditch to buried channel has taken place in urban spaces all throughout globe (Eden & Tunstall 2006, Napieralski & Carvalhaes 2016).

In previous research, increases in developed land have been associated with increases in urban stream burial. Cities with a higher rate of impervious surfaces have more disappeared streams (Napieralski & Welsh 2016). Stream burial has major ramifications for human communities. Urban water features that are above ground have a unique ability to effectively mitigate the rising temperatures associated with climate change (Völker et al. 2013). Burying these water features further exacerbates the urban heat island effect, contributing to heat related illnesses. This process also exposes people to flooding (Chang et al. 2020). Furthermore, the presence of water in urban landscapes is known to increase overall optimism and happiness of humans (Nutsford et al. 2016).

Chapter 3: Water Quality Analysis

3.1) Background

Human-induced water impairments are generally considered either point-source or nonpoint-source. Point-source water pollution can be relatively easy to identify and address. For example, the effluent from a wastewater treatment plant is considered point-source pollution because the wastewater is being treated and released from a single point. Nonpoint-source pollution is more challenging to address and identify because it is a combination of pollutants from an area. Stormwater runoff is generally considered nonpoint-source pollution because it is a combination of multiple sources. Unlike point-source wastewater, nonpoint-source runoff is generally not treated and can create much larger water-quality problems that are more challenging to address (Atasoy et al., 2006). Where urban development is present, non-point water pollution is almost inevitable.

The installation of impervious surfaces results in increased runoff and elevated peak discharges, which can lead to flooding (Bhaduri et al. 1997). Flooding is caused primarily by: (1) lowered infiltration rates when soil is paved (Gilroy & McCuen 2012), (2) decreased transpiration and evaporation from vegetation loss (Bosch & Hewlett 1982), (3) shortened lag time between precipitation and peak discharge (McGrane 2016; Miller et al. 2014; Liu et al. 2003), and (4) the combination of these factors in concert (Shi et al. 2007; Guan et al. 2015; Olivera and DeFee 2007). Additionally, urban development impacts the quality of runoff.

Residential neighborhoods, roads, commercial centers, and industrial districts all introduce a unique set of pollutants to waterbodies, including heavy metals, synthetic organics, hydrocarbons, excess nutrients, suspended solids, pathogens, and bacteria, among others. As the amount of development increases in a watershed, so do the concentrations of these pollutants (Slonecker et al. 2001; Wilson et al. 2010; Huang et al. 2014).

Nonpoint-source pollution from lawns, streets, roofs, driveways, gardens, golf courses, and parking lots contribute to elevated nutrient concentrations in urban waterways (Winter et al. 2000; Waschbusch et al. 1999). Fertilizers, septic system effluent, and pet waste, are all known to exacerbate this issue. In many freshwater systems, the availability of nutrients (nitrogen and phosphorus) is a limiting factor for aquatic plant growth and increases can lead to eutrophication (Lee et al. 1978). When excess nutrients enter an urban waterbody through stormwater pollution, the growth of aquatic plants, like algae, can accelerate. These plants are deleterious to aquatic life because they eventually decompose and deplete the oxygen levels of water. In severe cases, this process can lead to the creation of "dead zones", where almost all aquatic life dies because of hypoxic conditions (Diaz & Rosenberg 2008).

Sediment, the most prevalent pollutant in urban runoff, increases with urbanization. Roberts and Pierce (1976) found sediment in the Patuxent River more than doubled after extensive urbanization occurred in the catchment area. Sediment and suspended solids can increase the turbidity of water and originate from soil, exhaust gas, traffic, sand, silt, building/asphalt erosion, and many other sources. Additionally, suspended solids have been known to clog fish gills and aid transport of chemicals (Aryal et al. 2010).

The most prevalent heavy metals found in urban stormwater are cadmium (Cd), copper (Cu), nickel (Ni), zinc (Zn), chromium (Cr), and lead (Pb). Excess levels of these metals create toxic conditions for freshwater organisms and pose a threat to human health (Aryal et al. 2010). Stormwater runoff has been linked to increased concentrations of heavy metals (Byrne and DeLeon 1987). These metals originate from a variety of different sources, but primarily from vehicles.

Davis et al. (2001) found that the brakes from vehicles contribute Cu, Pb, and Zn, tire wear contributes Zn, and the corrosion-prevention coating on the outside of vehicles contributes Cr. As development increases, heavy metal concentrations in nearby waterbodies increase (Davis et al. 2001).

Water that is contaminated with hydrocarbons can be neurotoxic, carcinogenic, and mutagenic to flora and fauna (Srivastava et al. 2019). Among other things, these toxic compounds can originate from road surfaces, fuel combustion products, lubrication products, automobile tires, paint, and corrosion products (Aryal et al. 2010). Development can contribute significant concentrations of hydrocarbons to adjacent streams via stormwater runoff (Latimer et al. 1990). The temperature of urban streams is usually warmer compared to rural and forested streams, because of elevated urban air and ground temperatures, paved surfaces, and reduced riparian canopy (Somers et al. 2013). All these factors contribute to the often heavily degraded nature of streams and rivers that are exposed to urban development and stormwater runoff.

3.2) Methodology and Data Sources

Data gathered from two sources were used for the water quality portion of this project (Table 5). First, the MVWQD sampled two sites along Pattee Creek, four sites along Rattlesnake Creek, and three sites along Grant Creek since 2019. Second, the SWU sampled the urban section of Pattee Creek at three sites annually since 2016 (Figure 28). The water quality data was compared to the percent of developed land (PDL) within their respective sample site watershed boundary (using the 2019 generated land-cover dataset) to assess how developed land might be impacting the pollutant concentrations of the creeks. Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS) were the only parameters included in the study because: 1) they were the only parameters shared by both sampling efforts and 2) these parameters are three reliable markers of urban water impairments.

TN includes organic and inorganic nitrogen. The MVWQD calculated total nitrogen by converting all the digestible forms of nitrogen into nitrate through oxidative digestion. The nitrate was then quantified using persulfate digestion (Standard Methods (SM) 4500-N C; Baird et al. 2017). The SWU calculated TN using the same methods, but they conducted a simultaneous determination of TN and TP.

For both TN and TP, the SWU used colorimetric methods with a segmented flow analyzer for the sample analysis. TP refers to organic and inorganic forms of phosphorus. The MVWQD calculated TP using semi-automated colorimetry (methods outlined by EPA 365.1, EPA 1993).

TSS measures the amount of solid particles that are suspended in water. All TSS samples (from both sources) were collected using the same method (SM 2540D; Baird et al. 2017). Water samples were passed through filter paper, which captured the suspended solids. The mass of the suspended solids was divided by the volume of water to get a milligram per liter (mg/L) measurement.

The water quality analysis in this study had multiple limitations. Primarily, these data are limited because data collection only began in 2019 (data on Pattee Creek since 2016), which prevented the assessment of long-term trends. Data was collected at different dates and times. Some water samples were taken during storm events (when stormwater input is highest), while others were taken during periods of dry weather. The influence of weather was not considered for this analysis. While there was limited data to address the seasonal component of water quality, it is known to influence the concentration of pollutants (Brett et al. 2005). Agriculture is known to influence water quality (Foy & Kirk 1995) but was not addressed here. It is likely that additional factors also influenced the water quality dynamics in these three streams.

Table 5. Pattee Creek sampling methods.

Site Code	Site Name	Source	Year Sampling Began	TN methods	TP methods	TSS methods
PC5	Pattee Creek - Bitterroot Swale	SWU	2016	SM 4500-N C	SM 4500 -P C	SM 2540D
PC4	Pattee Creek - Bancroft Ponds	SWU	2016	SM 4500-N C	SM 4500 -P C	SM 2540D
PC3	Pattee Creek - Grit Chamber	SWU	2016	SM 4500-N C	SM 4500 -P C	SM 2540D
PC2	Pattee Creek - Hillcrest Loop	MVWQD	2019	SM 4500-N C	EPA 365.1	SM 2540D
PC1	Pattee Creek - Barmeyer Trailhead	MVWQD	2019	SM 4500-N C	EPA 365.2	SM 2540D
GC3	Grant Creek - Mullan Road	MVWQD	2019	SM 4500-N C	EPA 365.3	SM 2540D
GC2	Grant Creek - Highlander	MVWQD	2019	SM 4500-N C	EPA 365.4	SM 2540D
GC1	Grant Creek - Old Grant Creek Road	MVWQD	2019	SM 4500-N C	EPA 365.5	SM 2540D
RC4	Rattlesnake Creek - Confluence	MVWQD	2019	SM 4500-N C	EPA 365.6	SM 2540D
RC3	Rattlesnake Creek - Greenough Park	MVWQD	2019	SM 4500-N C	EPA 365.7	SM 2540D
RC2	Rattlesnake Creek - Pineview Drive	MVWQD	2019	SM 4500-N C	EPA 365.8	SM 2540D
RC1	Rattlesnake Creek - Sawmill Gulch Road	MVWQD	2019	SM 4500-N C	EPA 365.9	SM 2540D

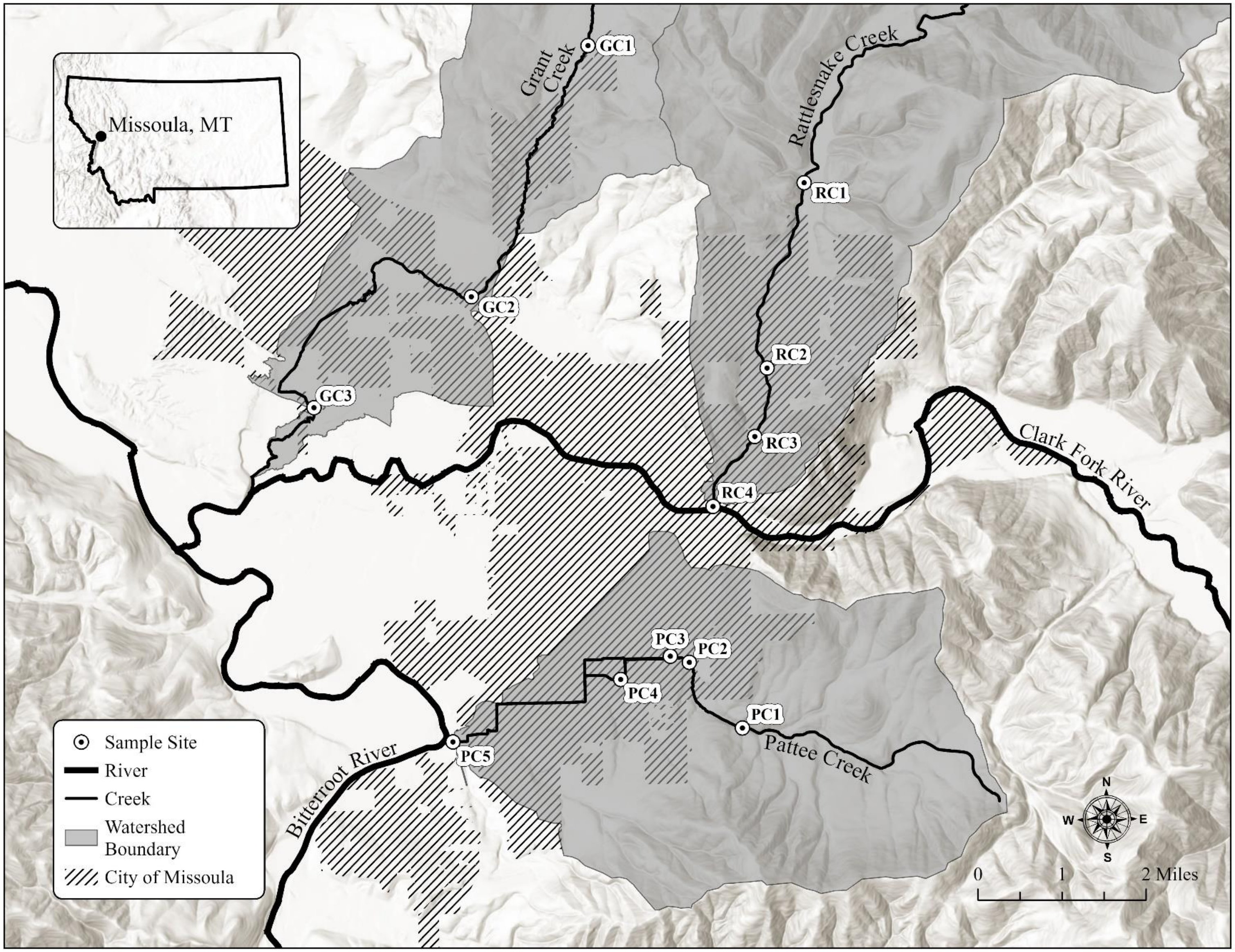

Figure 28. Map of water sampling locations.
Site labels on this map correspond with site codes from Table 5.

3.3) Results

3.3.1) Total Nitrogen (TN)

Between the MVWQD and the SWU, 60 TN measurements were taken in Pattee Creek (2016-2022), 28 in Grant Creek (2019-2022), and 27 in Rattlesnake Creek (2019-2022) (Appendix A). TN measurements of the three creeks were compared to the Montana Department of Environmental Quality (DEQ) nutrient standards. Additionally, the TN concentrations were compared to the PDL within each sample site watershed. TN was also compared to TP and TSS.

The Montana DEQ sets nutrient standards for each ecoregion of Montana. These standards are set at "levels that will protect beneficial uses and prevent exceedances of other surface water quality standards which are commonly linked to nitrogen and phosphorus concentrations" (Montana DEQ 2014, 1). In the Middle Rockies ecoregion (which all three streams belong to), the nutrient standard for TN is 300 μg/l (0.3 mg/L). These criteria are only in effect from July 1st to September 30th. Of all the collected observations, only 26 from Pattee Creek, 10 from Grant Creek, and 10 from Rattlesnake Creek were within those dates. Most of the applicable Pattee Creek TN measurements (19 of 26) exceeded the standard in Pattee Creek. Only 3 of 10 Grant Creek measurements exceeded the standard and all Rattlesnake measurements were below the standard.

Given the non-normal distribution of the data, non-parametric tests were used to analyze the differences between the three creeks. First, a Kruskal-Wallis (KW) test resulted in a low p-value (<2.2e-16), which indicated significant differences in TN between at least two of the creeks. Next, a Dunn's test, which is recommended when a KW test is rejected (Dinno 2015) and pairwise comparisons are suspected, was implemented. The p-values for the Dunn's tests were low for all comparisons (Table 6), which indicated that all pairwise comparisons between the creeks were statistically significant and that differences in TN existed among Pattee Creek, Grant Creek, and

Rattlesnake Creek. Pattee Creek consistently experienced significantly elevated levels of TN compared to the other two (Figure 29A).

Table 6. P-values for K-W and Dunn's tests.

Creek Pair	TN KW	TN Dunn
Pattee - Grant	<2.2e-16***	2.07E-09***
Pattee - Rattlesnake	<2.2e-16***	2.87E-32***
Grant - Rattlesnake	<2.2e-16***	9.85E-09***

***Significant at the 0.001 probability level.

TN was also compared to the PDL within each sample site watershed. Given the positively skewed, non-normal distribution of the TN data, a generalized linear model (GLM) with a gamma family and log link function was chosen. A Gamma distribution was most suited for the positively skewed data, and the log link function was appropriate with the multiplicative relationship between the response (TN) and predictor variable (PDL) (Lawal 2013). The same type of GLM (Gamma distribution with a log link) was used for all the GLMs in this chapter. The Pattee Creek and Grant Creek GLM resulted in low p-values, indicating a significant relationship between PDL and TN (Table 7). As the PDL increased in these watersheds, TN increased (Figure 30B). Rattlesnake Creek yielded a non-significant relationship between PDL and TN.

Table 7. P-values for the TN GLMs.

Creek	TN vs. PDL GLM	TN vs. TSS GLM	TN vs. TP GLM
Pattee	5.12E-10***	4.00E-07***	9.38E-07***
Grant	0.00316**	0.21827	0.0244*
Rattlesnake	0.198	0.1326	0.198

*Significant at the 0.05 probability level. **Significant at the 0.01 probability level. ***Significant at the 0.001 probability level.

TN values were also compared to the other pollutant parameters (TP and TSS), using GLMs. A statistically significant relationship between TN and TP was found in Pattee Creek. Grant Creek had a weaker, but still significant relationship between TN and TP, while Rattlesnake Creek had a non-significant relationship. A GLM was used to compare TN to TSS (Figure 30B).

For Pattee Creek, there was a strong and statistically significant relationship between TN and TSS. On the other hand, Grant Creek and Rattlesnake Creek had non-significant values (Table 7).

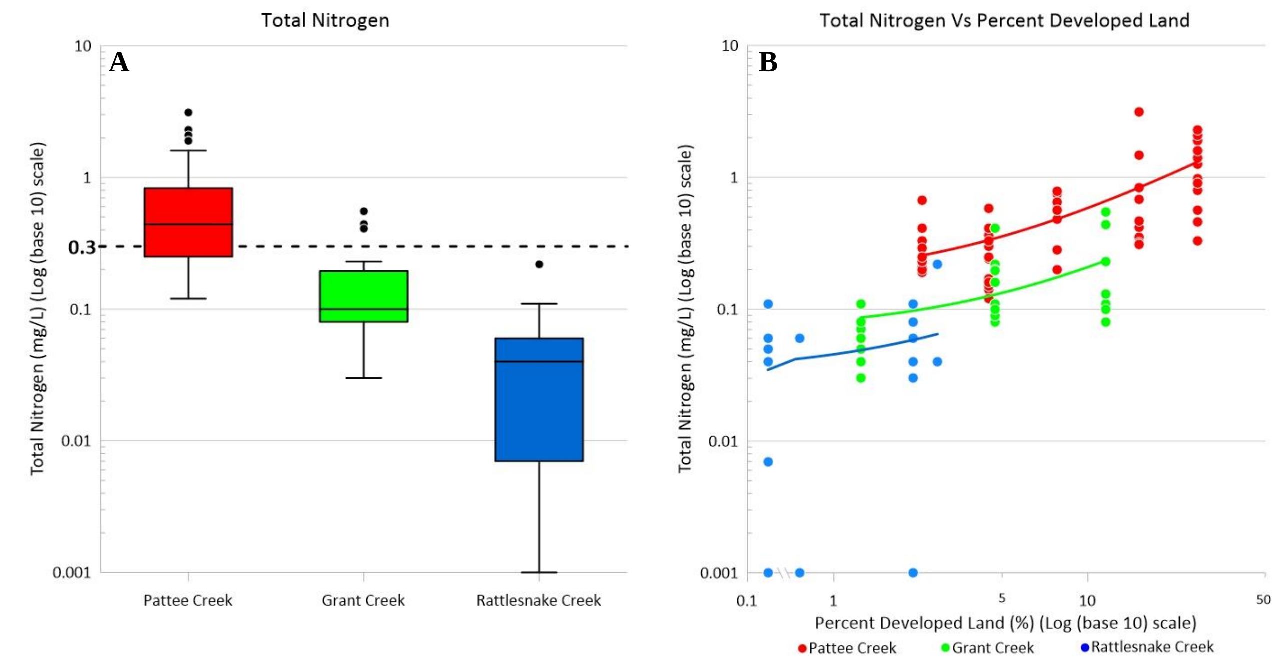

Figure 29. A) Box plot showing TN with the applicable DEQ nutrient standard (0.3 mg/L) as a dotted line and B) scatterplot showing TN Vs PDL.

Figure 30. A) scatterplot showing TN and TP and B) scatterplot showing TN and TSS.

3.3.2) Total Phosphorus

Between the MVWQD and the SWU, 60 TP measurements were taken in Pattee Creek (2016-2022), 31 in Grant Creek (2019-2022), and 29 in Rattlesnake Creek (2019-2022; Appendix A). During the dates the standard is in effect (July 1st to September 30th), all but one sample collected from Pattee Creek (21 of 22) exceeded the DEQ TP standard of 0.03 mg/L, while 3 of 11 from Grant Creek, and 4 of 14 from Rattlesnake Creek surpassed this threshold.

A KW test confirmed that significant differences in TN existed between the three creeks. The Dunn's tests' P-values were low for all comparisons (Table 8), which indicated that all pairwise comparisons were statistically significant and that differences in TP existed among the three creeks. Pattee Creek consistently experienced significantly higher levels of TP compared to the other two (Figure 31A).

Table 8. P-values for K-W and Dunn's tests.

Creek Pair	TP KW	TP Dunn
Pattee - Grant	<2.2e-16*	8.63E-13*
Pattee - Rattlesnake	<2.2e-16*	4.52E-30*
Grant - Rattlesnake	<2.2e-16*	3.63E-05*

*Significant at the 0.001 probability level.

GLMs revealed significant relationships between TP concentrations and PDL in Pattee Creek and Grant Creek. Rattlesnake Creek did not have a significant relationship between PDL and TP (Figure 31B). To compare TP and TSS, a GLM was fitted to each creek (Figure 32). For Pattee Creek, there was a statistically significant relationship between TP and TSS. On the other hand, Grant Creek and Rattlesnake Creek had non-significant p-values (Table 9).

Table 9. P-values for the TP GLMs.

Creek	TP vs. PDL	TP vs. TSS
Pattee	2.66E-03*	1.78E-07**
Grant	7.16E-06**	0.21827
Rattlesnake	0.192	0.1326

*Significant at the 0.01 probability level. **Significant at the 0.001 probability level.

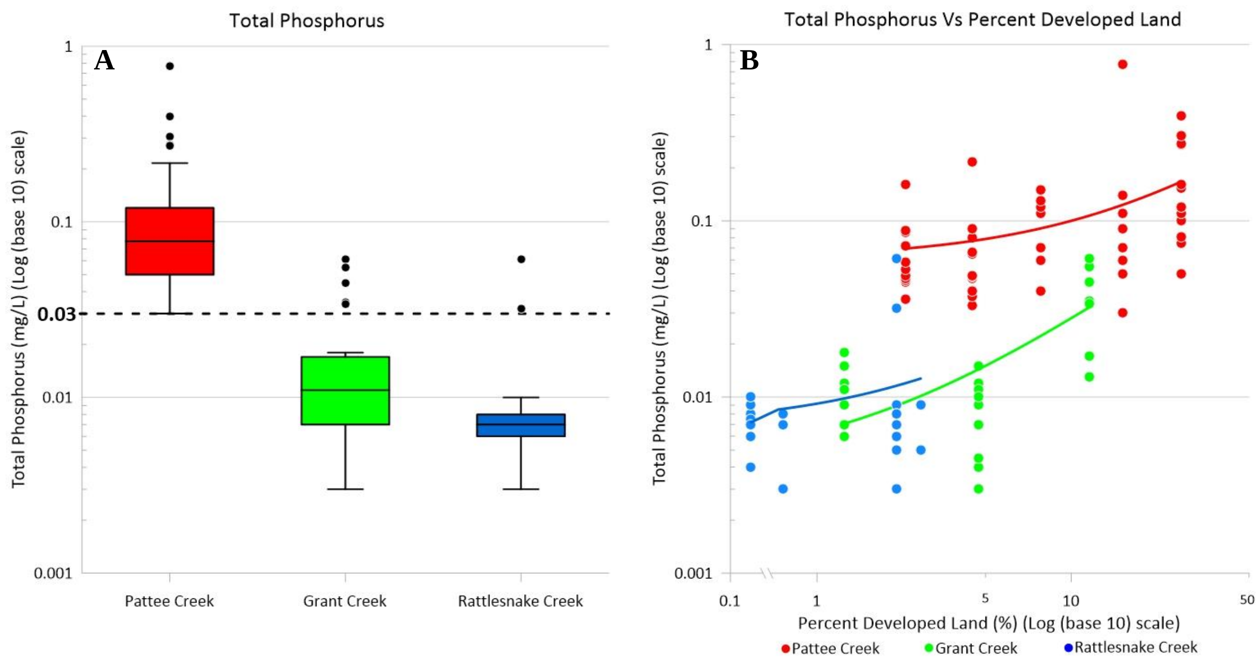

Figure 31. A) Box plot showing TP with the applicable DEQ nutrient standard (0.03 mg/L) as a dotted line and B) scatterplot showing TP vs PDL.

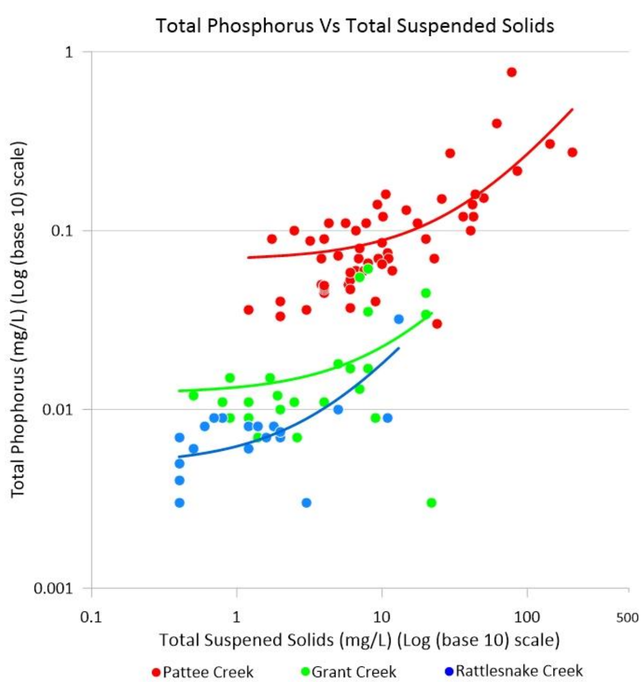

Figure 32. Scatterplot showing TP vs TSS.

3.3.3) Total Suspended Solids

Between the MVWQD and the SWU, 59 TSS measurements were taken in Pattee Creek (2016-2022), 25 in Grant Creek (2019-2022), and 22 in Rattlesnake Creek (2019-2022; Appendix A). A KW test indicated that significant differences in TSS existed between the three creeks. Next, a Dunn's test revealed significant differences in TSS concentrations among the creeks, with Pattee Creek consistently exhibiting elevated TSS levels (Table 11 and Figure 33A). Significant relationships between TSS concentrations and PDL in Pattee Creek and Grant Creek were revealed by GLMs. Rattlesnake Creek yielded a non-significant p-value, suggesting the absence of a significant relationship between PDL and TSS concentration in this creek (Table 10; Figure 33B).

Table 11. P-values for K-W and Dunn's tests.

Creek Pair	TSS K-W	TSS Dunn
Pattee - Grant	<2.2e-16**	0.00176*
Pattee - Rattlesnake	<2.2e-16**	5.83E-18**
Grant - Rattlesnake	<2.2e-16**	8.10E-08***

Table 10. P-values for the TSS GLMs.

Creek	TSS vs. PDL
Pattee	1.39E-03**
Grant	2.29E-02**
Rattlesnake	0.601

*Significant at the 0.01 probability level. **Significant at the 0.001 probability level.

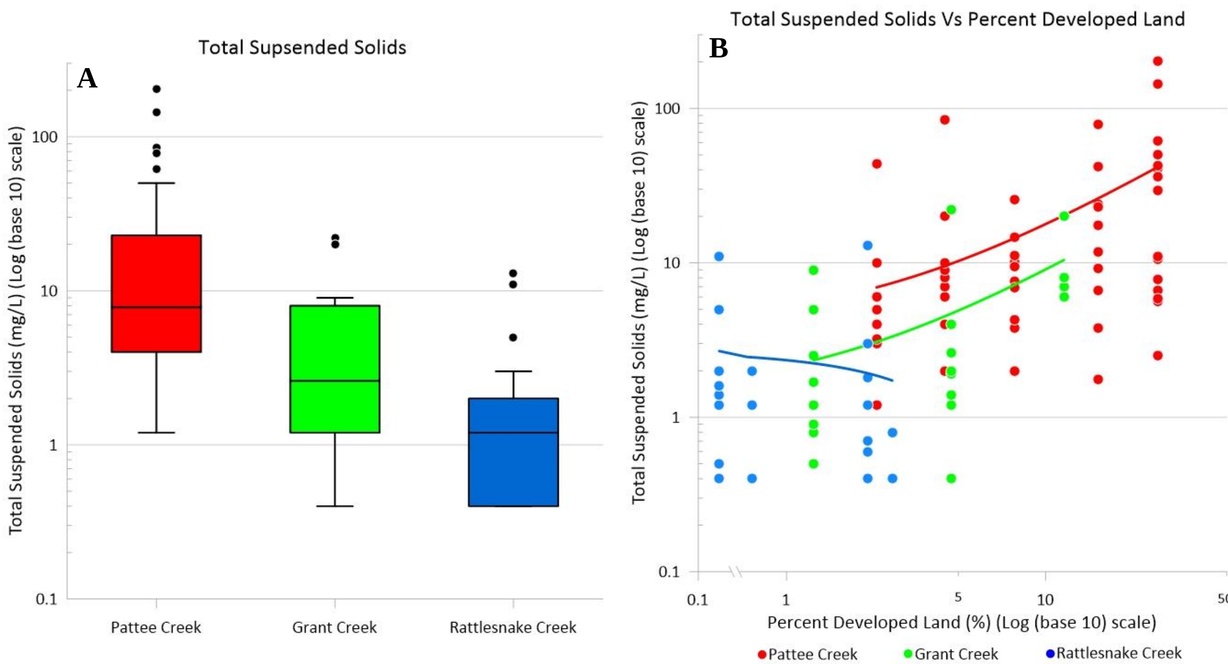

Figure 33. A) Box plot showing TSS and B) scatterplot showing TSS vs PDL.

3.4) Discussion

The water quality data reveal significant differences in pollutant levels between the creeks (Table 6, Table 8, and Table 11), with Pattee Creek consistently exhibiting higher levels of TN, TP, and TSS than Grant Creek and Rattlesnake Creek (Figure 29A, Figure 30A, and Figure 31A). There is also a strong correlation between the increase in developed land and increasing nutrient concentrations in Pattee Creek (Table 7 and Table 9). Impervious surfaces and the human activities that are associated with urban areas often lead to higher levels of nutrient runoff. The nutrient levels of Pattee Creek are high before the creek enters the City of Missoula boundary but increase as developed area increases. Throughout the upper region of Pattee Creek, there are many residential properties with highly managed lawns along the banks of the creek. Pesticides and fertilizers from these lawns, along with livestock grazing and defecation, could be contributing to elevated levels of nutrients. Ill-maintained septic systems throughout these rural neighborhoods could also be contributing (Missoula County 2023).

The association between TSS concentrations and developed land in Pattee Creek underscores the impact of anthropogenic activities on sediment loading. TSS levels of Pattee Creek climb as the waterbody passes through the City (Figure 33B). Several factors contribute to these elevated levels of TSS. Substantial amounts of road sand are spread on the steep roads of the South Hills by the City of Missoula Street Department to provide traction for winter driving. This washes into the creek, increasing turbidity. Construction activities throughout the watershed also contribute. Large portions of Pattee Creek have no riparian buffer as it runs adjacent to or under roads, with nothing preventing pollutants on the roads from entering the creek. Also, 20 miles of pipe discharge urban stormwater directly into the creek (City of Missoula Stormwater Utility 2023).

Grant Creek exhibits similarities to the highly impaired Pattee Creek but has less urban development within its watershed and lower pollutant levels (TP, TN, and TSS) than Pattee Creek. Grant Creek still shows a significant relationship between developed land and nutrient concentrations (Table 7 and Table 9). Additionally, agriculture is likely impacting this waterbody as there are many farms adjacent to the lower stretches of Grant Creek.

Rattlesnake Creek, on the other hand, is much less disturbed, with relatively minor impacts from urbanization. The headwaters include a substantial designated wilderness area and robust vegetation buffers exist along the lower reaches of Rattlesnake Creek where there is development. The absence of a statistically significant relationship between developed land and TN, TP, or TSS (Table 7, Table 9, and Table 10) in Rattlesnake Creek suggests that sediment dynamics and nutrient loading in this watershed are still dominated by natural erosion processes and nutrient cycling.

The observed relationship between TN and TP concentrations within each creek highlights the interconnected nature of nutrient cycling in aquatic ecosystems. The significant positive correlation between TN and TP concentrations in Pattee Creek and Grant Creek (Table 7) suggests that similar processes may be contributing to the enrichment of both nitrogen and phosphorus in these watersheds. On the other hand, Rattlesnake Creek appears to be dominated by more traditional nutrient cycling. In the Pattee Creek watershed, TN and TP concentrations have a significant positive correlation with TSS (Table 7 and Table 9), suggesting that sediment-associated nutrient transport processes are occurring in the waterbody. Sediment particles in streams may carry both nitrogen and phosphorus, which can assist downstream migration. This relationship between nutrients and TSS was not observed in Grant Creek and Rattlesnake Creek (Table 7 and Table 9).

Chapter 4: Pattee Creek's Hydrosocial Territory

4.1) Introduction

This chapter delves into the social context of Pattee Creek to uncover the ways in which individuals and organizations have engaged with this waterbody. Specific locations throughout the Pattee Creek watershed (Figure 1) are referenced throughout this chapter.

The chapter will integrate concepts from the field of political ecology. Originating in the 1970s, the practice of political ecology began to explore environmental problems (Neumann, 2016). Over the years, one central aim of this field has been "to understand the complex relations between nature and society" (Watts 2000, 257). The theoretical framework section delves into a diverse array of political ecology concepts that will be employed to elucidate the dynamic relations between Pattee Creek and the Missoula community.

The methods section outlines how data was collected, which includes a description of the participatory observation I partook in while working for the City of Missoula and details on the interviews conducted between 2023 and 2024. Findings, which are focused on how people relate to Pattee Creek, are found in the Results section. The Discussion section positions the findings within the context of similar studies. It also summarizes the complex interplay between human communities and Pattee Creek, emphasizing the disconnection caused by the creek's burial and the resulting challenges in water quality, maintenance, and perception.

4.2) Theoretical Framework

4.2.1) Hydrosocial Territories

The relationship between water and society has become a focal point of scientific research with the concept of the hydrosocial cycle at its core. This cycle, which incorporates water's social and political nature, is a more nuanced way to conceptualize the traditional hydrologic cycle

(Linton & Budds 2014). Leaving humans out of the hydrologic cycle is problematic, considering the domination that civilizations regularly exercise over hydrologic processes (Abbott et al. 2019). The hydrosocial cycle is typically depicted as a global or regional phenomenon.

On a smaller scale, the concept of hydrosocial territories can shed light on specific locations that make up the broader hydrosocial cycle. A hydrosocial territory refers to a spatially bound water network formed by the humanization of a watershed (Boelens et al. 2016). These territories grow and evolve from the ways in which humans interact with their local waterway. This concept has been implemented by the tradition of political ecology to uncover complex modes of water governance. Political ecologists and social geographers have also used the term “waterscape” to explore this concept (Baviskar 2007; Swyngedouw 1999). Using this concept as a lens, a specific watershed can be understood as a social and political constructed entity instead of simply a physical resource.

Because cultures vary immensely, hydrosocial territories predictably serve different functions, values, and purposes to their inhabitants, which can lead to differing perspectives between members of any given territory. Across the American West, concerns and beliefs regarding water can vary immensely based off someone’s political views, race, age, gender, etc. (Flint et al. 2017). Embracing the concept of hydrosocial territories allows for insightful exploration into the complex and diverse relationships that exist between humans and water.

As urbanization expands across the globe, trends of water depletion, stream burial, surface water diversion, and/or water contamination are plaguing hydrosocial territories. These trends develop and persist because of human managerial decisions. In many communities, for a variety of reasons, water, “a life-sustaining necessity, seems to be disappearing” (Whiteford et al. 2016, 2). Critically analyzing hydrosocial territories can illuminate how these territories came to be, and how communities can work towards more sustainable relationships with their waterways.

4.2.2) Restoration

One way that communities have been trying to rediscover sustainable hydrosocial relationships is through restoration. The concept of ecological restoration first emerged in the 1980s and has since been a subject of high praise and intense scrutiny (Jordan 2003; Katz 2012). There is a myriad of ways to conceptualize restoration, but one of the most common is this: "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (Gann et al. 2019, S7).

Stream restoration science has evolved significantly since its emergence in the 1980s. The focus has shifted from simply restoring degraded ecosystems to considering the broader services and benefits that restoration can provide (Verdonschot 2022). Small secondary creeks, like Pattee Creek, are gaining recognition for their potential to deliver ecosystem services such as flood mitigation, water purification, and biodiversity support.

As a product of urban development, the ecosystem of Pattee Creek has been heavily damaged in some locations and destroyed in others. Across the unburied urban stretches of Pattee Creek, the riparian area consists of primarily lawn grass monocultures. Since 2021, there have been multiple restoration campaigns along this stretch of the creek primarily aimed at replacing lawn grass in the riparian zone with native plants and shrubs. The goal of this vegetative restoration has been to bring back aquatic habitat for animals, provide filtration for water, and enhance the overall health of the riparian ecosystem. Restoration of Pattee Creek has also had a cultural and societal aspect, with community engagement as a focal aspect of these efforts (Missoula Current

2022). Bringing the creek back into the Missoulian consciousness has been another goal of restoration, with hopes to elevate the status of Pattee Creek and awareness of its existence.

Restoration on Pattee Creek presents a unique challenge because the current creek is a product of extensive human modification. Attempts to restore Pattee Creek are fraught with complexity, as it is impossible to turn back the clock to its pre-urban development state. Instead, the restoration efforts have been focused on understanding and harnessing the potential ecosystem services that the current-day Pattee Creek can provide. Restoration efforts along Pattee Creek, therefore, are not about returning to an idealized past but rather about enhancing its current condition.

4.2.3) Water Governance

Water governance across the American West is a highly complex and studied phenomenon. In Montana, the state constitution explains that "waters within the boundaries of the state are the property of the state for the use of its people" (Mont. Const. Article IX, section 3(3)). One of the overarching objectives of water governance in Montana is to manage water resources in the best public interest. However, defining public interest, in the context of water governance, poses a significant challenge due to the diverse and often conflicting needs and desires of various stakeholders (Squillace 2018). Different communities, industries, and individuals have varying perspectives on how water should be managed, utilized, and protected, especially across the geographically heterogenous American West (Hill & Regan 2021).

Disagreements frequently arise on how to balance competing interests, such as agriculture, urban development, environmental conservation, and Indigenous rights (Perramond 2019). The history of water governance in the West is marked by intricate legal frameworks, such as prior appropriation systems, which allocate water rights based on historical use (MacDonnell 2015).

These systems often clash with modern environmental concerns and the evolving needs of communities.

In this dynamic landscape, government agencies like the SWU and the Missoula Conservation District (MCD) play crucial roles in implementing regulations and managing water resources. These two government agencies have jurisdiction over Pattee Creek; they are responsible for managing the creek and enforcing environmental regulations throughout its run. Jurisdiction, as discussed here, pertains to the legal authority, or control a government entity holds over a body of water.

The SWU has jurisdiction over the lower stretch of Pattee Creek (from the Grit Chamber to the Confluence). This utility is required to obtain and maintain coverage under the Montana Pollutant Discharge Elimination System (MPDES) General Permit for Stormwater Discharges Associated with Small Municipal Separate Storm Sewer Systems (MS4) permit, which is administered by the Montana DEQ under permit number MTR040007. When Pattee Creek is above the Grit Chamber, it is considered “surface water” by the MS4 permit, which is defined as “any waters on the earth's surface including, but not limited to, streams, lakes, ponds, and reservoirs, and irrigation and drainage systems discharging directly into a stream, lake, pond, reservoir, or other surface water. Water bodies used solely for treating, transporting, or impounding pollutants shall not be considered surface water” (DEQ 2017, 57). The MS4 permit specifically gives the SWU jurisdiction over the City’s stormwater, which is defined as “runoff, snow melt runoff, and surface runoff and drainage” (DEQ 2017, 57). Once Pattee Creek enters the Grit Chamber, it is considered “stormwater”, and is therefore managed by the SWU.

Above the Grit Chamber, the Natural Streambed and Land Preservation Act of 1975, commonly referred to as 310 laws, comes into effect. 310 laws regulate activity on “the natural rivers and streams, and the lands and property immediately adjacent to them" in accordance with Article II Section 3, and Article IX of the Montana State Constitution (The Natural Streambed and Land Preservation Act 2020, 3). Within this act, a stream is defined as "any natural perennial flowing stream, or river, its bed and immediate banks. The term does not include a stream or river that has been designated by the Board as not having significant aquatic and riparian attributes in need of protection or preservation" (The Natural Streambed and Land Preservation Act of 1975, 5). 310 laws are enforced by the 58 Conservation Districts of Montana. In Missoula, if a property owner plans on causing a physical alteration to a natural perennial-flowing stream or river, they must first apply for a 310 permit, which is reviewed and issued by the MCD.

4.2.4) Humans and Nature

This chapter explores Pattee Creek's identity. Varied perspectives on Pattee Creek abound, adding layers of complexity to its characterization. Through interviews and participatory observation, this chapter aims to assess the multifaceted views people hold regarding Pattee Creek; some label it a "ditch" and others perceive it as a "creek." These contrasting descriptions of the creek are deeply intertwined with the intricate and often messy interplay between humans and nature.

Through the lens of political ecology, this interplay can be investigated. Within the field of political ecology, the Western perspective of nature as separate from culture is scrutinized (Willems-Braun 1997). Humans that reside in Western societies often perceive themselves as detached from the natural world (Fairhead & Leach 1995). This illusive gap between humans and nature can reinforce and justify ecological degradation (Cronon 1996). By "denaturalizing nature", the field of political ecology has challenged these preconceived notions of the natural world (Law & Lien 2018).

Nature, within this framework, is a dynamic force shaped by human actions and societal relations. The approach of political ecology underscores that the human-nature relationship is fluid, contingent upon social, economic, and political factors (Nygren & Rikoon 2008). It advocates for equitable and sustainable interactions with the environment.

This chapter is going to borrow human-nature concepts from the field of political ecology and apply them to the case study of Pattee Creek. By critically examining how Missoulians define nature and non-nature, factors that have shaped Pattee Creek into its current state are illuminated. Re-evaluating these dynamics provides insight into the diverse perceptions of Pattee Creek and offers potential pathways for its future.

4.2.5) Property

Political ecologists look at property as a complex social construct that often reflects social dynamics, power structures, and historical precedents. On a fundamental level, the existence of property necessitates some element of exclusion (Hall et al. 2013) and/or alienation (German 2022). Establishing property rights, especially in riparian areas, is problematic, because it inherently excludes others from a life nurturing resource. Additionally, it is quite difficult because the boundaries between the start and end of a water body are often blurred (Bakker 2003). This blurry interface makes the lines between "public" and "private" property especially tangled near water resources.

As Pattee Creek runs through the City of Missoula, it weaves through a complex network of private and public land, which is owned and managed by a variety of people and entities. Investigating the topic of property for the case study of Pattee Creek is critical to understanding the relationships between Missoulians and the creek.

4.3) Methodology and Data Sources

The methodology employed for this chapter aimed to provide a comprehensive understanding of Pattee Creek's hydrosocial territory, focusing on the complex interplay between societal factors and the creek. Through a combination of participant observation, public intercept interviews, and key informant interviews, this study sought to capture local views and interactions with Pattee Creek. Understanding these perspectives is crucial as residents play a significant role in shaping and influencing Pattee Creek's hydrosocial territory. Their perceptions, concerns, and interactions provide valuable insights into the challenges and opportunities for sustainable creek management. Additionally, understanding local perspectives helps identify areas where interventions and policies can be implemented effectively. This multi-faceted strategy garnered nuanced insights into the human dimensions of Pattee Creek and the factors that influence its management.

The methods employed in this research, while providing valuable insights, also come with inherent limitations and uncertainties. With only 26 recorded interviews, many details regarding how Missoulians relate to Pattee Creek were not captured. Perspectives, experiences, and concerns from various demographic groups and stakeholders may have been missed.

4.3.1) Participant Observation

Participant observation is a research method where the investigator immerses themselves in the physical and social setting they are studying. By actively participating in daily activities, observing events, and documenting experiences, researchers gain an in-depth understanding of the studied issue (Juric 2015). This method is highly applicable in environmental research, specifically in investigating the multifaceted interactions between humans and natural systems (Johnson et al.

2006). In this chapter, participant observation serves as a foundational method for exploring the human dimensions of Pattee Creek.

I served as a Conservation Fellow with the MCC, from May 2020 to October 2020. This placement program stationed me with the SWU, where I began interacting with Pattee Creek by mapping the urban infrastructure of the Pattee Creek watershed. This involved physically traversing the area to gather geospatial data on the stormwater systems that discharge into and convey Pattee Creek. Through this process, I collected valuable information on the physical structures along Pattee Creek but also observed how these systems interacted with the surrounding environment and community. During my time in the field, I had countless conversations about Pattee Creek with homeowners, residents, and visitors.

In October 2020, I was hired as a full-time employee with the SWU, which further facilitated my participant observation. Over the course of three years (from October 2020 to July 2023), I was deeply involved in the management and maintenance of Pattee Creek and its watershed. My professional duties included:

- Continuing the mapping effort that I began with MCC
- Sampling stormwater discharge coming into Pattee Creek
- Sampling and monitoring the flow of Pattee Creek and its intermittent tributary streams
- Monitoring and maintaining green infrastructure throughout the watershed (such as Bancroft Ponds, the Grit Chamber, and Cattail Corner)
- Conducting public outreach and education with the residents of the Pattee Creek watershed
- Planning and participating in restoration efforts along Pattee Creek
- Interpreting and enforcing Stormwater Pollution Prevention Plan (SWPPP) permits throughout the watershed

- Interpreting and enforcing the City of Missoula Municipal Separate Strom Sewer System (MS4) permit
- Manual excavating sediment from Pattee Creek and its tributaries
- Responding to water quality complaints throughout the watershed.

Through active involvement with the SWU, I immersed myself in the complexities of Missoula’s urban-water management. The valuable insights reaped from this experience have informed and inspired the following discussion about the interaction between humans and Pattee Creek. However, this approach to research allowed for the formation of deeply subjective opinions about Pattee Creek, which have undoubtedly influenced this chapter. The biases that I hold regarding Pattee Creek and its management have impacted the analysis of the results shared. My experiences and opinions do not represent the spectrum of experiences within the community.

4.3.2) Public Intercept Interviews

The public intercept method involves approaching and interviewing people in public spaces (Qureshi et al. 2013). Face-to-face conversations offer a direct and effective means of collecting data on public perceptions and locally relevant information. This method allows for asking open-ended questions, facilitating in-depth responses, and providing opportunities for clarification as needed. By engaging directly with individuals through public intercept interviews, researchers have been able to gain valuable insights into the views, experiences, and attitudes that humans have towards water (Flint et al. 2016).

For this study, the public intercept method was employed to gather data from individuals at two locations along Pattee Creek: Bancroft Ponds and Cattail Corner. Each interview consisted of a standardized set of ten questions (Appendix B), designed to elicit responses about individuals' perceptions, activities, and concerns regarding Pattee Creek. If the individual gave consent to be interviewed, their residence and age were confirmed before the interview was conducted. Only residents of Missoula over the age of 18 were interviewed, and the interviews lasted an average of 7 minutes.

The two locations were chosen strategically to capture diverse perspectives and experiences related to the creek. At Bancroft Ponds, a popular park where Pattee Creek visibly feeds multiple wildlife sustaining ponds, 10 interviews were conducted. The aim here was to engage with individuals interacting with the creek in its visible, open setting. Another 10 interviews were conducted at Cattail Corner, where Pattee Creek runs underground. Individuals were interviewed on the sidewalk directly next to Russell Street, where Pattee Creek flows through a 60-inch diameter pipe. This location provided insights into the perceptions and interactions that occur when the creek is not visibly present.

The public intercept method provided valuable insights into public perceptions and attitudes towards Pattee Creek. Yet, this non-probability interview method does not allow for quantitative inferences about the larger community (Baker et al. 2013). The sample size of 20 individuals interviewed at two locations does not holistically represent the diverse range of opinions within the broad Missoula community. Additionally, the interviews were relatively brief, averaging 7 minutes, which limited the depth of responses. One common critique of the public intercept method centers around selection bias. When researchers conduct public intercept interviews, they choose specific locations where they know they can find potential respondents. However, the choice of location significantly influences the type of people they encounter and, consequently, the responses they collect (Dillman 2016). With only two locations chosen for the public intercept method interviews conducted here, many different perspectives surrounding Pattee Creek were left unexplored.

4.3.3) Key Informant Interviews

The key informant method was utilized to gather insights from individuals with specific expertise and roles related to Pattee Creek regulation and management. Key informants are individuals who possess specialized knowledge or experience relevant to the research focus and can provide valuable insights into the topic (Elmendorf & Luloff 2006). Key informant interviews provide researches with in depth knowledge of environmental issues involving the dynamics between humans and nature (Okello et al. 2014)

Over the course of my employment with the City of Missoula, I made many professional connections with people involved in the management of Pattee Creek. During the initial planning phase of this research (fall of 2022), I contacted six of my colleagues to ask if they would be willing to sit down for an interview. This included:

- Three City of Missoula employees from two different departments: Two employees from the SWU, which oversees Pattee Creek below the Grit Chamber to ensure compliance with the DEQ issued MS4 permit. One employee from the Wastewater Division of the Public Works and Mobility Department, responsible for maintenance of the Missoula South Hills Storm Drainage System.
- Two County employees working for the MVWQD, tasked with enforcing the Missoula Valley Water Quality Ordinance and addressing water quality complaints in the Pattee Creek Watershed.
- One employee from the MCD, which enforces the Montana Streambed and Land Preservation Act (310 law) and takes jurisdiction over the upper part of Pattee Creek (above the Grit Chamber).

Each interviewee was asked a standardized set of fifteen questions (see Appendix C). The interviews ranged from 35 minutes to 1 hour in length and provided in-depth information regarding historic, current, and future governmental interventions along the creek. This format provided in-depth perspectives on Pattee Creek regulation, water quality management, and conservation efforts, offering a broad understanding of the various stakeholders involved in creek management.

The key informant method offered detailed insights from government employees directly involved in Pattee Creek regulation and management. However, the sample size of six key informants may not encompass the full spectrum of perspectives from all stakeholders involved in creek management. Furthermore, the focus on government employees may have overlooked perspectives from community organizations, tribes, non-profits, and advocacy groups.

4.4) Results

The results section delves into the complex web of Pattee Creek's hydrosocial territory. It unfolds in three distinct but interconnected sections: "Public Safety or Ecosystem Health?", "Regulatory Challenges", and "The Naturalism of Pattee Creek". Each section highlights a specific theme. The themes shed light on the ongoing consequences of urban development in Missoula by offering a unique lens through which to view the challenges faced by Pattee Creek.

"Public Safety or Ecosystem Health?" provides context for the struggle between infrastructure maintenance and ecological preservation. "Regulatory Challenges" delves into the legal and jurisdictional complexities impacting the creek's protection. Lastly, "The Naturalism of Pattee Creek" explores the community's perception of the creek and the conflicting values surrounding the creek's identity. These themes intertwine to paint a comprehensive picture of the multifaceted issues surrounding Pattee Creek.

4.4.1) Public Safety or Ecosystem Health?

Throughout the hydrosocial territory of Pattee Creek, there is an ongoing challenge to balance public safety with ecosystem health. When it was routed into pipes to prevent flooding and protect public safety, Pattee Creek suffered severe degradation. By the time it was clear to government officials that additional infrastructure was needed to mitigate the flooding of Pattee Creek (~1980, see section 1.3), burying the creek seemed to be the only viable option because houses were already built directly next to it. The engineers and government officials that designed/implemented this system had public safety (flood prevention) and urban expansion as their highest priorities. As a result of the Missoula South Hills Storm Drainage System, Pattee Creek is mostly buried underground as it travels through southern Missoula.

However, there was a small section of open channel preserved which flows from the Grit Chamber to Bancroft Ponds. Employees of the City of Missoula have the ability and authority to turn on and off this channel by opening or closing a gate valve at the Grit Chamber. If the gate valve is closed, Pattee Creek will run into the 60-inch diameter pipe, designed to accommodate a 100-year flood event, that flows uninterrupted to the Bitterroot River. When the gate valve is open, however, the creek flows to the channel which feeds Bancroft Ponds.

While the open-channel section of Pattee Creek is currently an amenity to some Missoulians, it is simultaneously a challenge for others who maintain it. Because it is heavily channelized and partially fed by urban stormwater drainage, it constantly fills with sediment. This requires City employees to regularly excavate the channel, which is arduous at best, and ineffective at worst. If the channel is not clear, the houses directly adjacent to it are at risk of flooding. Keeping the channel functioning is challenging and the equipment required to do the job (hydro-excavators and vacuum trucks) is costly to run. This expensive and stressful situation frustrates some government officials.

One employee interviewed thought that it is a waste of money to keep water flowing in the channel, and that it would be better to put the creek in the pipe. The City of Missoula allocates resources to maintain an urban creek that passes through private property, a practice one employee described as benefiting only "a select few." When asked about the open channel section of Pattee Creek, this city employee said:

> "All of the millions of dollars that we spent for the infrastructure and we're not using it. You know, it is kind of a waste at that point… So now we just have to work harder and spend more money… for a select few… I'm saying that because I've seen the worst of the flooding… and been out there freezing my ass off in cold water… trying to save houses… That's a pain."

Since the system was completed (2002), the annual flooding of Pattee Creek has been effectively eliminated, but there are mixed perspectives on the long-term sustainability of this infrastructure. When asked if the system could handle a significant flood event, one city employee explained that it is "meant to be activated at a 100-year event, and that has not happened yet, (so) it is a little unknown."

Going forward, climate change is expected to increase the severity of flooding in western Montana (Warner et al. 2015, Whitlock et al. 2017). It is possible that the infrastructure installed by the Missoula South Hills Storm Drainage System will be unable to accommodate future flooding events. When asked about the system, one county employee expressed concern with the "100-year flood event" way of thinking because that requires "looking at things from a perspective of stationarity, and that means (looking) back to look forward." This employee believes that "the likelihood of us getting what is considered a 100-year flood is actually higher than a 1 in 100 chance… because of the fact that we're seeing influences from atmospheric rivers and flooding and greater likelihood of rain on snow events."

The danger of increasing storm severity is compounded by problematic road maintenance practices. Throughout winter in the South Hills, large quantities of magnesium chloride, road sand, and gravel are placed on the roads to provide traction for vehicles. The road sand and gravel eventually wash into stormwater drains and ends up clogging pipes, filling ponds, and congesting channels. When asked about these road maintenance practices, one city employee stated that "We have to do it, obviously, for public safety. It is super important. Public safety tends to trump environmental impacts, but there is a balance." The balance has historically tilted towards public safety, which is illustrated by the elevated levels of TSS in Pattee Creek (Chater 3). The problem of excess sediment in Pattee Creek could be heavily mitigated if road sand was picked up after each storm event via street sweeping. However, according to one city employee, a lack of funding prevents this from happening and the "the sand is left out there all winter… so, when the snow melts or it rains (it) plugs everything up."

The regular plugging of this system causes significant maintenance headaches. When asked about the maintenance of the Missoula South Hills Storm Drainage System, one city employee explained that: "We're constantly clearing pipes… We spend a lot of our annual budget on that system, trying to keep it clear and functioning." According to one city employee, the original planners did not consider the logistical and financial challenge of maintaining this system: "well what are you going to do when there's 20 years of sediment in that pipe?" Despite significant maintenance challenges, employees still have confidence in the system. One of them stated that it is "in good shape and should function in the event of a flood."

While piping the creek has prevented floods (for now), it has simultaneously resulted in considerable harm to the ecology of Pattee Creek. The buried stretches of Pattee Creek have consistently higher pollutant concentrations than the unburied sections upstream. When compared to the other urban streams of Missoula (Grant Creek and Rattlesnake Creek) that are mostly unburied, Pattee Creek has significantly elevated levels of pollutants (section 3.4). This correlation is logical because when a creek is routed underground, the riparian vegetation that would typically aid in pollutant filtration no longer exists.

Another unintended consequence of stream burial has been the disconnection of residents from Pattee Creek. As asphalt was laid on top of the creek, a permanent physical barrier was created that separated the human inhabitants of southern Missoula from the waterway they reside on top of. Throughout the urban world, the transformation of free-flowing creeks into buried and degraded conveyances has created reinforcing cycles of degradation and neglect (McLean 2022). This unfortunate cycle is evident in southern Missoula and reinforces the disconnect between humans and the creek.

One resident, who was interviewed at Cattail Corner, said “I wouldn’t say that my everyday activities impact the creek, because I never go over there.” This interviewee was unaware of the fact that they were standing right next to the creek, and that they had just driven their vehicle over it. Out of the 20 residents interviewed, only 5 of them knew where the creek goes after it leaves Bancroft Ponds. Once the creek enters a pipe, it is mostly forgotten. Their lack of awareness is not a product of their obliviousness, but instead simply a result of the urban landscape. Maps of Missoula (such as Google Maps) show Pattee Creek mysteriously disappearing shortly after it leaves Bancroft Ponds. As the creek disappears from maps, it is simultaneously removed from the collective community consciousness.

Stream burial and the accumulation of road sand are not just logistical challenges; they are existential threats to the aquatic habitats of Missoula. As one city employee put it, the Missoula South Hills Storm Drainage System "completely eliminated riparian habitat and connectivity through (the) system." When talking about the buried stretches of Pattee Creek, one resident said, "I think it is a travesty." The plight of Pattee Creek highlights the need for a more nuanced approach to urban development that considers both public safety and ecosystem health as vital components. The lessons of Pattee Creek serve as a reminder of the importance of thoughtful, sustainable urban planning for the well-being of both humans and the environment.

4.4.2) Regulatory Challenges

Government entities, such as the DEQ, The SWU, and the MCD, do not recognize the creek as a waterbody throughout stretches that run through urban Missoula. One county employee explained how "the government entities that interact with it consider the creek (to be) stormwater once it (is) below the Grit Chamber." Below the Grit Chamber, the creek is under the jurisdiction of the SWU. While the terminology might seem insignificant, it heavily impacts the regulation and health of Pattee Creek. For example, in Montana, if a waterbody is recognized as "surface water", municipalities operating under an MS4 permit are required to regularly monitor the pipes that discharge polluted runoff to it (DEQ 2017). Because the urban section of Pattee Creek is not given the "surface water" designation, it is unable to benefit from this regulatory protection.

Similarly, throughout the urban areas of the Pattee Creek watershed, wetlands (including Bancroft Ponds and Cattail Corner) have been historically designated as non-jurisdictional, which prevents them from receiving protection from section 404 of the Clean Water Act (United States Congress 1972). This law requires construction projects that impact wetlands to obtain a 404 permit, which is designed to limit the harmful impacts of construction on aquatic habitats. Lower

Pattee Creek and its associated wetlands have been heavily urbanized and manipulated, which has prevented government officials from enforcing this law. Therefore, construction activities occurring in or near the urban sections of Pattee Creek (such as the dredging and restoration at Cattail Corner in the winter of 2023-34) can occur without 404 permits.

Above the Grit Chamber, the creek is considered to be a creek and is, therefore, under the jurisdiction of the MCD. However, even throughout its upper stretches, Pattee Creek has historically been deprived of regulatory protection. 310 permits have historically not been required along Pattee Creek, even along the sections above the Grit Chamber. An employee of the MCD described why by explaining that “there's an ability under the Montana Natural Streambed and Land Preservation Act law that says if the board (MCD) deems that there's no ecological value, (they can) relinquish jurisdiction. So that's why people can mow… into the creek.”

The ecological value of Pattee Creek has historically been underappreciated. Considering recent ecological discoveries, the decision to not enforce 310 laws along Pattee Creek is currently being revaluated by the MCD. Pattee Creek is home to an almost genetically pure population of cutthroat trout in its upper stretches. This population is 99.9% genetically pure, with some minor influence of rainbow trout genetics. The genetic purity makes the trout in Pattee Creek valuable for conservation efforts. In an interview conducted in 2024 with an MCD employee, this information was confirmed. The employee emphasized that if there were a die-off in another area or a need to reintroduce native fish, they would look for genetically pure populations, like the ones in Pattee Creek. This underscores the importance of Pattee Creek as a valuable ecosystem deserving of protection and preservation.

During the construction of houses along Pattee Creek, there was a lack of effective communication between the MCD and the City and County Planning departments. As a result, the

MCD was not involved in the residential planning process, leading to houses being constructed directly adjacent to the creek without a riparian buffer. An employee from MCD highlighted that “there's one (house) that has a footing in the creek… we never would have permitted any of that, but we were never asked, and I think that neighborhood kind of blew up without the board doing anything.” This situation has established a precedent of neglect for the creek and a lack of regulatory enforcement along its banks.

However, this precedent is being reevaluated and reconsidered. According to the same MCD employee referenced above, the MCD is planning to start enforcing 310 laws along Pattee Creek beginning in 2026. Specifically, they will be “taking complaints on potential violations up there, which could mean fines of up to $500 a day for removing vegetation.” Through internal deliberation, the MCD has decided that “it is our legal responsibility to look after the stream.”

Rather than abruptly changing its regulatory approach along Pattee Creek, the MCD has devised a strategic plan to gradually move towards stricter enforcement. They are beginning with public education and engagement as their initial steps. In August of 2023, the MCD conducted a widespread mailing campaign informing residents that 310 laws will be enforced in three years along Pattee Creek. This mailing effort was coupled with restorative planting efforts along the creek to make an example of what proper riparian habitat can look like, even as a creek runs through residential development.

Restoration efforts along the lower sections of Pattee Creek have been led primarily by the SWU. When asked what they want Pattee Creek to look like in 10 years, one SWU employee explained that they would like “the daylighted portions (to be) fully revegetated, so no one's mowing right next to the creek anymore.” While their restoration efforts have garnered some community support, there remains reluctance among other homeowners to participate in the planting initiatives. Instead, some people continue with the traditional approach of maintaining lawn grass right up to the creek's edge. Another SWU employee stated that the biggest challenge for restoration along Pattee Creek is “private property.” The City of Missoula holds an easement along the creek, which theoretically allows them to prohibit residents from mowing. However, private property rights prevent the city from taking such action. Making significant headway in restoration efforts is challenging when many property owners along the creek do not share the same vision for a healthier Pattee Creek. This issue highlights a complex tension between property rights and public interest in environmental preservation.

4.4.2) The Naturalism of Pattee Creek

In southern Missoula, residents often refer to the urban sections of Pattee Creek as a “ditch.” This misnomer has deep roots in the Missoula community. In the early 1970s, a newspaper article explained that Pattee Creek has “no stream bed of its own once it enters the city limits, it has become diverted, subverted and finally converted into no more than an irrigation ditch which empties into the Bitterroot River.” Tom Crowley, a former City Engineer, described Pattee Creek as “a natural man-made creek, if there is such a thing” (The Missoulian 1972). This description highlights the paradox of Pattee Creek, which lies in its dual nature. It is considered both “natural” and “man-made” by the Missoula community, which creates a complex and contradictory identity.

The identity of Pattee Creek changes depending on who you ask. Some residents agree with the designation of Pattee Creek as unnatural, describing it as a “channelized ditch.” Others disagree and say that is “it should be natural.” Another resident acknowledged the complexity of managing natural resources in town by saying “in urban environments and wild-urban interfaces I think it is challenging to know how to manage that stuff.” The consequences of Pattee Creek’s “man-made” designation reach further than just government regulation. Numerous restoration efforts, academic studies, and community protection campaigns have historically and are currently taking place on the more popular creeks of Missoula (Land 2022, Miller 2019, & Van der Poel 1979). These organized interventions have historically been absent along Pattee Creek. Going forward, a reconceptualization of Pattee Creek's naturalism would help inspire and justify future restoration efforts occurring along the creek.

When residents and government employees were asked if they care about the water quality of Pattee Creek, they responded with a confident and immediate response of "absolutely" or "yes." All the 26 people interviewed answered positively to this question. A city employee explained that "stream water quality is connected to our aquifer water quality", highlighting the need to protect local drinking water. One community member even referred to Pattee Creek as "sacred." Some residents stated that they wanted to see "more native riparian vegetation along the creek" and that it should be "restored back to a natural system."

Passionate cries for protection and restoration are met by contradicting practices. Before Pattee Creek goes underground, it passes through several subdivisions where homeowners maintain lawns along its banks. By mowing directly next to the creek, people prevent riparian vegetation from growing, thereby exposing the creek to elevated temperatures, fertilizer pollution, erosion, and countless other degrading factors. Near these houses, the perfectly manicured riparian zone disguises the creek as a ditch, which reinforces the non-natural look of the creek. One homeowner justified their mowing because they "want to see the water." In their eyes, the establishment of riparian vegetation would block their view and make their lawns look "messy." Other residents expressed concern with these activities by saying that there should be "incentives for people who live along the creek to take care of it" and that "no mowing" should take place along the creek.

Seemingly harmless activities such as lawn maintenance, vehicle usage, and even dog walking all negatively impact the creek through non-point source water pollution. One overarching issue is a lack of awareness that some residents have of their impact on the creek. Nine of the 20 residents interviewed said that they don't believe their everyday activities impact the creek. This answer was not unanimous across the population. The remaining 11 residents acknowledged that they do "so many things" that impact the creek like "driving cars" or "walking in the creek." Similar conflicting perspectives and values are observed in local government.

The City of Missoula advocates for the water quality of Pattee Creek by investing in restoration efforts, green infrastructure, and water quality treatment devices. On the other hand, every fall, the city incentivizes residents to rake their fallen leaves into the street. When rain washes down on this decomposing plant matter, urban runoff is heavily contaminated with nutrients, which can cause eutrophication (Hobbie et al. 2013). When asked about this practice, one disapproving city employee stated "That's not something any municipality in this country does… (the leaves) clog the system (and) cause localized flooding… Plus certainly the water quality aspect of it, with high phosphorus content in a lot of those leaves." The City of Missoula's efforts to advocate for the water quality of Pattee Creek stand in contrast to its practice of incentivizing residents to rake leaves into the street. These conflicting practices highlight the challenge of managing natural resources in the urban environment.

When asked where Pattee Creek ceases to be a creek, one county employee stated that "once it is a built and engineered environment... that's where it is delineated." After the Grit Chamber, Pattee Creek flows through and interacts with a complex system of constructed infrastructure, leading some to argue that it no longer qualifies as a natural watercourse. This same employee acknowledged potential flaws in their delineation by admitting "I would argue with myself as well because we put dams in a lot of places and below the dams, there are still often streams." The internal debate illustrated by these two quotes reflects a larger ongoing one occurring throughout the Missoula community.

One key element of this debate centers around what to call Pattee Creek. When asked what changes would benefit the creek, a SWU employee stated: "I would love for people to call it Pattee Creek and not 'the ditch'." One Wastewater Division employee weighed in on the issue by stating that "There is no ditch on any part of it. It is a natural creek all the way through… The retention pond is just to clean up the water and get rid of road sand and all that other crap that's in there." When residents call Pattee Creek a "ditch" or government entities refer to it as a "conveyance", they reinforce the misconception that this waterbody is too channelized, degraded, and artificial to be protected. Pattee Creek, even though it looks like an irrigation ditch for part of its run, is not a ditch. As discussed in section 1.3, Pattee Creek existed long before human development occurred in the Missoula Valley. The belief that extensive human modification disqualifies Pattee Creek from being natural is incorrect. Pattee Creek, throughout its entire run, is a perennial tributary of a river, and thus should be called a natural creek and treated with respect.

4.5) Discussion

The results presented in this chapter about the human dimensions of Pattee Creek shed light on the complex interactions between individuals, government entities, and the creek itself. As creeks are buried underground, a predictable pattern arises. Human communities become disconnected from the waterway they live on top of. This disconnect is known to cause issues surrounding water quality, maintenance, and public perception (McLean 2022). The case study of Pattee Creek provides an example of the intricate and interwoven issues that accompanies stream burial.

The relationships that form Pattee Creek's hydrosocial territory have created a multifaceted challenge for the Missoula community. The historical decision to bury sections of the creek for flood prevention has created unintended ecological and managerial consequences. While the Missoula South Hills Storm Drainage System has effectively curtailed annual flooding, concerns loom regarding its long-term sustainability amidst escalating climate change impacts. Regulatory challenges further complicate the management of Pattee Creek, with varying jurisdictional interpretations shaping its treatment as a waterbody or stormwater conduit. The discrepancy between public perception and governmental designation highlights the need for a more unified approach to creek stewardship. Restoration efforts, though hindered by private property rights and conflicting values, signify a hopeful trajectory toward reconnecting residents with Pattee Creek.

Chapter 5: Conclusions and Recommendations

In the first chapter of this thesis, the introduction speaks of a rich past where Indigenous peoples thrived in harmony with the land and the creek which flowed to the Clark Fork River. However, the landscape drastically changed with the onset of colonialism. Extractive practices were implemented that heavily impacted Pattee Creek. Logging, agriculture, mining, and later, urban development, led to degradation, channelization, and eventually, the burial of the creek, causing significant harm to its ecosystem.

The analysis presented in Chapter 2, focusing on historical imagery, sheds light on the dramatic alterations Pattee Creek underwent from 1937 to 2019. What was once a meandering creek across the valley floor was diverted and transformed into a heavily channelized and buried waterway. Simultaneously, rapid urban development increased developed land across the watershed, impairing the creek by exposing it to urban stormwater. In addition, water infiltration was reduced, and flooding became an almost annual occurrence. To mitigate this flooding, the City of Missoula and Missoula County decided to bury the creek in a pipe.

Moving forward, it is crucial to continue mapping efforts across the Pattee Creek watershed to monitor how ongoing changes across this area are impacting the creek. By doing so, Missoula can better protect and restore the Pattee Creek ecosystem for the benefit of both the environment and the community. It is recommended that the City of Missoula obtains or creates a comprehensive irrigation ditch dataset. Additionally, the SWU is currently working on a comprehensive stormwater asset reconciliation within the City of Missoula. This work requires field measurements with GPS units to accurately map stormwater features. Their goal, to create a comprehensive geospatial inventory of the stormwater infrastructure throughout Missoula, should be realized. These data would allow for a better understanding of how water moves through the urban landscape of Missoula.

In addition to collecting local GPS data, future geospatial research should also use remote sensing data to track how the amount of developed land continues to grow and change throughout the Pattee Creek watershed. Furthermore, other metrics besides developed land should be tracked, such as impervious surfaces. Models can be implemented to predict how planned projects and on-going management could impact these metrics. Urbanization has significant impacts on water quality, so understanding the increase in developed and impervious land is crucial for assessing water quality.

Chapter 3 delved into the available data on Pattee Creek's water quality. The elevated levels of Total Suspended Solids (TSS), Total Nitrogen (TN), and Total Phosphorus (TP) in Pattee Creek compared to Rattlesnake Creek and Grant Creek highlighted the severe degradation that Pattee Creek has suffered. Developed land emerged as a significant factor in this degradation, with urban stormwater runoff being a primary contributor to poor water quality.

Pattee Creek currently exceeds Montana water quality standards (and has significantly higher pollutant concentrations than Missoula’s other streams), which necessitates the implementation of targeted pollution reduction management strategies. Promoting centralized development while limiting the development footprint across the Pattee Creek watershed would help protect the water quality of the creek. Zoning regulations can encourage higher-density developments and mixed-use spaces can be implemented to accomplish this goal (Jacob & Lopez 2009). Previously, urban development in Missoula has involved dry wells and piped systems that discharge stormwater to streams without pretreatment. The City of Missoula should incentivize developers to use green infrastructure, like bioswales, infiltration galleries, and retention ponds.

This infrastructure can effectively reduce pollutants in stormwater runoff before it is discharged into groundwater or surface water (Anderson et al. 2016, Sadeghi et al. 2019, and Nayeb et al. 2021). Additionally, vegetative riparian buffers should be installed and maintained, especially along lower Pattee Creek where human activity is high. These riparian zones can improve water quality, reduce erosion, and provide habitat for wildlife. Along with implementing infrastructure designed to support water quality, the City of Missoula should create new and expand upon current efforts to educate the public on how individuals can protect water quality through everyday activities such as proper chemical disposal, pet waste management, and reduced fertilizer application.

In addition to the management strategies outlined above, future research should be done to document and understand the water quality of Pattee Creek. The following research recommendations would build upon the work presented in this thesis. The current water-quality sampling programs of Pattee Creek should continue to provide long term data that can be used to evaluate the effectiveness of management practices. The existing green infrastructure along Pattee Creek should be sampled to evaluate its effectiveness. For example, analyzing the influent and effluent water at Bancroft Ponds would yield important results about the water filtering capacity of this urban wetland. Additionally, including citizens in the research progress through citizen science initiatives would likely foster stewardship for Pattee Creek, increase observation frequency and spatial coverage, and raise public awareness about the health of the watershed. Simulation and modeling tools can be used to assess the future impact of continued land-cover change on water quality. Climate-change scenarios should be incorporated to anticipate future challenges and brainstorm adaptive strategies. Resources such as the Montana State Climate Assessment

(Whitlock et al. 2017) should be used to guide monitoring efforts as stream temperatures are predicted to rise.

The insights from Chapter 4's interview analysis provided a glimpse into the human dimension of Pattee Creek by exploring its hydrosocial territory. Some residents are entirely disconnected from the creek, while others refer to it as a "ditch." Additionally, by managing the creek as a "conveyance" or a waterbody that lacks the necessary ecological value to warrant protection, government entities further compound the challenges faced by Pattee Creek. Despite these challenges, there is significant hope. Residents and officials alike express enthusiasm for restoration efforts, with initiatives in place for water quality treatment devices and restoration projects. Many government officials and residents are currently reevaluating the ways in which their community has historically interacted with this creek, and they are actively changing it.

Based on the findings presented in Chapter 4, several recommendations can be made for the MCD and the City of Missoula regarding the governance of Pattee Creek. These recommendations are aimed at improving water quality, restoring habitat, enhancing public awareness, and fostering a greater sense of stewardship for the creek. To start, the MCD should begin enforcing the Montana Streambed and Land Preservation Act (310 law) along all sections of Pattee Creek, including areas below the Grit Chamber. This will help protect water quality and aquatic habitat throughout the entire creek. The MCD should also continue to engage with the community through workshops, presentations, and outreach events aimed at promoting stewardship along Pattee Creek. Restorative planting efforts along the upper reaches of Pattee Creek have already been spearheaded by the MCD to demonstrate the benefits of proper riparian habitat. These efforts should continue.

The City of Missoula should initiate a comprehensive road-sand cleanup program to prevent sediment from washing into Pattee Creek during rain events. This effort should include street sweeping after winter storms to minimize the impact of road sand on water quality. While street sweeping is already being conducted by the Missoula Streets Department, the frequency of this effort should be increased and a focus on mitigating water quality impacts should be implemented. Additionally, the practice of incentivizing residents to rake leaves into the street should cease, as this contributes to nutrient pollution and eutrophication of the creek. Alternative methods for leaf disposal that do not impact water quality should be implemented, such as composting leaves.

The City of Missoula is already investing in Green Infrastructure and Low Impact Development, but this investment should increase. Green Infrastructure, such as rain gardens, bioretention ponds, permeable pavement, and bioswales, helps improve water quality by reducing stormwater runoff and filtering pollutants (Anderson et al. 2016, Sadeghi et al. 2019, and Nayeb et al. 2021). Additionally, the natural aesthetic of green infrastructure may increase public appreciation and care for Pattee Creek. The City of Missoula should maintain and expand restoration efforts along the open channel sections of Pattee Creek, including the area from the Grit Chamber to Bancroft Ponds. These efforts should focus on restoring riparian vegetation and improving habitat.

The MS4 permit requires the City of Missoula to conduct public education and outreach aimed at protecting water quality. The MCD and the City of Missoula should continue and expand education campaigns on the importance of Pattee Creek, its role in the ecosystem, and best practices for protecting it. Specifically, focus should be emphasized on the detrimental impacts of mowing directly next to the creek.

Most importantly, the City of Missoula should bring Pattee Creek back to the surface where possible, allowing it to flow openly through pre-existing parks and open areas. Uncovering and restoring buried streams, through daylighting, can reduce water pollution, flooding, and maintenance costs, and enhance biodiversity, quality of life, and the aesthetic value of the surrounding area (Andik & Sarang 2017). Daylighting the creek can help mitigate the urban heat island effect and help the community adapt to future climate warming. Additionally, it would enhance habitat for aquatic species and significantly improve water quality by allowing natural filtration processes to occur. Furthermore, bringing the creek to the surface creates tangible connections between residents and the creek, fostering a sense of stewardship and pride in this natural asset. The historic path of Pattee Creek that used to flow above ground from Russell Street to 39th Street offers an ideal location for a daylighting project (Figure 25). The City of Missoula should invest in uncovering this portion of Pattee Creek.

While governmental intervention is important, it cannot work without community support. To achieve a healthier Pattee Creek, several recommendations have been developed for the Missoula Community. Firstly, it is crucial to change the perception of Pattee Creek by referring to it by its name rather than as a "ditch." Recognizing the creek as a natural watercourse deserving of protection and respect will help in elevating its status within the community. Property owners along Pattee Creek should establish and maintain "no mow" zones along the creek's edge, allowing riparian vegetation to grow. This will improve habitat quality and reduce non-point source pollution. Additionally, residents should become more aware of the impact their everyday activities have on waterways. Promoting responsible practices such as reduced fertilizer use, avoiding streamside mowing, maintaining vehicle leaks, and proper waste disposal will contribute significantly to the creek's health.

To advance the understanding of the human impact on water quality in Pattee Creek, several suggestions for future research are proposed. Conducting more interviews with a diverse group of residents will help gather a broader range of perceptions and opinions about Pattee Creek, providing a comprehensive understanding of public attitudes and behaviors. Comparing perspectives between Pattee Creek and other creeks in Missoula, such as Grant Creek and Rattlesnake Creek, will highlight unique challenges specific to Pattee Creek and inform targeted management strategies. Additionally, a longitudinal study tracking changes in public perception and behaviors surrounding Pattee Creek over time will offer valuable insights into the effectiveness of public outreach efforts, restoration projects, and policy changes. These research efforts would aid in identifying strategies to promote the ecosystem's well-being and ensure the creek's protection and restoration.

Addressing the challenges facing Pattee Creek requires a multi-faceted approach involving the City of Missoula, the MCD, and the community. Historically, Indigenous perspectives have not been considered in the decision-making process along Pattee Creek, which is problematic. Future restoration efforts need to reach out to tribes and seek their advice on how to care for the creek. By incorporating Indigenous knowledge and practices, the community can ensure a more holistic and effective approach to the creek's restoration and management. Cooperation and coordination among all these stakeholders are necessary for successful restoration. By implementing the above recommendations and conducting further research, it is possible to improve water quality, restore habitat, and foster a greater sense of stewardship for this important natural resource.

In conclusion, Pattee Creek's journey has been fraught with challenges. Its historical perception as an "unnatural ditch" reflects a misinterpretation rooted in the creek's tumultuous past.

We cannot alter this history; we can only shape its future. Learning from past mistakes and rectifying them is essential. Successful restoration requires a shift in perception and a recognition of the creek's inherent value. For centuries, Indigenous communities across this region have been "wealthy from the water" and deeply intertwined with the natural world around them (Smith 2010). Missoulians should learn from this legacy and consider Pattee Creek as a natural, integral part of their environment. For years, urban and agricultural development has disguised Pattee Creek as a ditch, but it is possible to remove this disguise and embrace a future where a revitalized Pattee Creek weaves through Missoula.

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Appendix A

Entity	Date	Site	Percent Developed Land	Total Phosphorus (TP) (mg/L)	Total Nitrogen (TN) (mg/L)	Total Suspended Solids (TSS) (mg/L)
MVWQD	10/1/2019	Grant Creek - Highlander	4.312903314	0.004	0.22	0.4
MVWQD	7/1/2022	Grant Creek - Highlander	4.312903314	0.009	0.1	1.2
MVWQD	5/1/2022	Grant Creek - Highlander	4.312903314	0.007	0.08	1.4
MVWQD	5/1/2021	Grant Creek - Highlander	4.312903314	0.012	0.09	1.9
MVWQD	7/1/2019	Grant Creek - Highlander	4.312903314	0.01	0.41	2
MVWQD	9/1/2021	Grant Creek - Highlander	4.312903314	0.007	0.2	2.6
MVWQD	6/1/2019	Grant Creek - Highlander	4.312903314	0.011	0.11	4
MVWQD	7/1/2020	Grant Creek - Highlander	4.312903314	0.003	0.09	22
MVWQD	6/1/2021	Grant Creek - Highlander	4.312903314	0.01	0.1	
MVWQD	5/1/2020	Grant Creek - Highlander	4.312903314	0.015	0.16	
MVWQD	10/1/2020	Grant Creek - Highlander	4.312903314	0.0045	0.195	
MVWQD	6/1/2019	Grant Creek - Mullan Road	11.76270764	0.017	0.11	6
MVWQD	5/1/2022	Grant Creek - Mullan Road	11.76270764	0.013	0.08	7
MVWQD	7/1/2020	Grant Creek - Mullan Road	11.76270764	0.055	0.55	7
MVWQD	7/1/2022	Grant Creek - Mullan Road	11.76270764	0.035	0.13	8
MVWQD	5/1/2021	Grant Creek - Mullan Road	11.76270764	0.017	0.1	8

MVWQD	6/1/2021	Grant Creek - Mullan Road	11.76270764	0.061	0.23	8
MVWQD	5/1/2020	Grant Creek - Mullan Road	11.76270764	0.034	0.13	20
MVWQD	7/1/2019	Grant Creek - Mullan Road	11.76270764	0.045	0.44	20
MVWQD	7/1/2022	Grant Creek - Old Grant Creek Road	1.275980756	0.012	0.04	0.5
MVWQD	6/1/2019	Grant Creek - Old Grant Creek Road	1.275980756	0.011	0.07	0.8
MVWQD	5/1/2022	Grant Creek - Old Grant Creek Road	1.275980756	0.009	0.06	0.9
MVWQD	6/1/2021	Grant Creek - Old Grant Creek Road	1.275980756	0.015		0.9
MVWQD	5/1/2021	Grant Creek - Old Grant Creek Road	1.275980756	0.011	0.06	1.2
MVWQD	10/1/2022	Grant Creek - Old Grant Creek Road	1.275980756	0.015	0.05	1.7
MVWQD	7/1/2019	Grant Creek - Old Grant Creek Road	1.275980756	0.011	0.04	2.5
MVWQD	10/1/2019	Grant Creek - Old Grant Creek Road	1.275980756	0.018	0.08	5
MVWQD	5/1/2020	Grant Creek - Old Grant Creek Road	1.275980756	0.009	0.11	9
MVWQD	9/1/2021	Grant Creek - Old Grant Creek Road	1.275980756	0.006		

MVWQD	7/1/2020	Grant Creek - Old Grant Creek Road	1.275980756	0.007	0.03	
MVWQD	10/1/2020	Grant Creek - Old Grant Creek Road	1.275980756	0.007		
SWU	6/29/2020	Pattee Creek - Bancroft Ponds	15.98520473	0.09	0.35	1.75
SWU	6/20/2022	Pattee Creek - Bancroft Ponds	15.98520473	0.06	0.32	6.6
SWU	8/26/2020	Pattee Creek - Bancroft Ponds	15.98520473	0.03	0.42	24
SWU	7/25/2022	Pattee Creek - Bancroft Ponds	15.98520473	0.14	1.47	42.17
SWU	8/25/2022	Pattee Creek - Bancroft Ponds	15.98520473	0.77	3.14	78.7
SWU	8/26/2020	Pattee Creek - Bancroft Ponds	15.98520473	0.05	0.31	3.8
SWU	6/29/2020	Pattee Creek - Bancroft Ponds	15.98520473	0.14	0.68	9.25
SWU	6/20/2022	Pattee Creek - Bancroft Ponds	15.98520473	0.06	0.31	11.7
SWU	8/25/2022	Pattee Creek - Bancroft Ponds	15.98520473	0.11	0.83	17.43
SWU	7/25/2022	Pattee Creek - Bancroft Ponds	15.98520473	0.07	0.47	22.9
MVWQD	10/1/2019	Pattee Creek - Barymeyer	2.224814599	0.036	0.19	1.2
MVWQD	10/1/2020	Pattee Creek - Barymeyer	2.224814599	0.036	0.19	3
MVWQD	6/1/2019	Pattee Creek - Barymeyer	2.224814599	0.088	0.33	3.2
MVWQD	10/1/2022	Pattee Creek - Barymeyer	2.224814599	0.046	0.21	4
MVWQD	9/1/2021	Pattee Creek - Barymeyer	2.224814599	0.045	0.19	4

MVWQD	7/1/2020	Pattee Creek - Barymeyer	2.224814599	0.047	0.23	4
MVWQD	7/1/2019	Pattee Creek - Barymeyer	2.224814599	0.049	0.2	4
MVWQD	6/1/2021	Pattee Creek - Barymeyer	2.224814599	0.072	0.29	5
MVWQD	5/1/2022	Pattee Creek - Barymeyer	2.224814599	0.053	0.23	6
MVWQD	7/1/2022	Pattee Creek - Barymeyer	2.224814599	0.058	0.25	6
MVWQD	5/1/2020	Pattee Creek - Barymeyer	2.224814599	0.086	0.41	10
MVWQD	5/1/2021	Pattee Creek - Barymeyer	2.224814599	0.16	0.67	44
SWU	6/20/2022	Pattee Creek - Bitterroot Swale	27.1661153	0.1	0.46	6.6
SWU	8/26/2020	Pattee Creek - Bitterroot Swale	27.1661153	0.11	1.26	7.8
SWU	8/25/2022	Pattee Creek - Bitterroot Swale	27.1661153	0.16	1.54	10.6
SWU	7/25/2022	Pattee Creek - Bitterroot Swale	27.1661153	0.1	1.91	40.7
SWU	6/29/2020	Pattee Creek - Bitterroot Swale	27.1661153	0.12	0.56	42.75
SWU	7/25/2022	Pattee Creek - Bitterroot Swale	27.1661153	0.1	1.91	2.5
SWU	8/25/2022	Pattee Creek - Bitterroot Swale	27.1661153	0.11	1.4	5.6
SWU	6/20/2022	Pattee Creek - Bitterroot Swale	27.1661153	0.05	0.33	5.9
SWU	6/6/2022	Pattee Creek - Bitterroot Swale	27.1661153	0.075	0.8	11
SWU	8/26/2020	Pattee Creek - Bitterroot Swale	27.1661153	0.27	1.57	29.4
SWU	6/29/2020	Pattee Creek - Bitterroot Swale	27.1661153	0.12	0.98	36.38

SWU	5/20/2020	Pattee Creek - Bitterroot Swale	27.1661153	0.153	0.9	50
SWU	11/19/2019	Pattee Creek - Bitterroot Swale	27.1661153	0.396	1.4	62
SWU	6/10/2021	Pattee Creek - Bitterroot Swale	27.1661153	0.306	1.6	144
SWU	12/7/2021	Pattee Creek - Bitterroot Swale	27.1661153	0.274	2.1	204
SWU	12/16/2020	Pattee Creek - Bitterroot Swale	27.1661153	0.081	2.3	
SWU	8/26/2020	Pattee Creek - Grit Chamber	7.583267561	0.04	0.48	2
SWU	7/25/2022	Pattee Creek - Grit Chamber	7.583267561	0.07	0.59	3.8
SWU	8/25/2022	Pattee Creek - Grit Chamber	7.583267561	0.11	0.75	4.3
SWU	6/20/2022	Pattee Creek - Grit Chamber	7.583267561	0.06	0.2	7.6
SWU	6/29/2020	Pattee Creek - Grit Chamber	7.583267561	0.12	0.58	10.13
SWU	8/25/2022	Pattee Creek - Grit Chamber	7.583267561	0.07	0.56	6.9
SWU	7/25/2022	Pattee Creek - Grit Chamber	7.583267561	0.07	0.65	9.4
SWU	6/20/2022	Pattee Creek - Grit Chamber	7.583267561	0.07	0.28	11.1
SWU	6/29/2020	Pattee Creek - Grit Chamber	7.583267561	0.13	0.56	14.75
SWU	8/26/2020	Pattee Creek - Grit Chamber	7.583267561	0.15	0.79	25.8
MVWQD	10/1/2019	Pattee Creek - Hillcrest	4.082743604	0.033	0.14	2
MVWQD	9/1/2021	Pattee Creek - Hillcrest	4.082743604	0.048	0.15	4
MVWQD	6/1/2019	Pattee Creek - Hillcrest	4.082743604	0.09	0.36	4

MVWQD	7/1/2019	Pattee Creek - Hillcrest	4.082743604	0.049	0.12	4
MVWQD	10/1/2022	Pattee Creek - Hillcrest	4.082743604	0.047	0.17	6
MVWQD	10/1/2020	Pattee Creek - Hillcrest	4.082743604	0.037	0.16	6
MVWQD	6/1/2021	Pattee Creek - Hillcrest	4.082743604	0.08	0.3	7
MVWQD	7/1/2022	Pattee Creek - Hillcrest	4.082743604	0.066	0.24	8
MVWQD	5/1/2022	Pattee Creek - Hillcrest	4.082743604	0.04	0.25	9
MVWQD	7/1/2020	Pattee Creek - Hillcrest	4.082743604	0.065	0.33	10
MVWQD	5/1/2020	Pattee Creek - Hillcrest	4.082743604	0.09	0.41	20
MVWQD	5/1/2021	Pattee Creek - Hillcrest	4.082743604	0.216	0.58	85
MVWQD	7/1/2019	Rattlesnake Creek - Confluence	2.559539928	0.005	0.04	0.4
MVWQD	10/1/2019	Rattlesnake Creek - Confluence	2.559539928		0.04	0.4
MVWQD	6/1/2019	Rattlesnake Creek - Confluence	2.559539928	0.009	0.22	0.8
MVWQD	6/1/2019	Rattlesnake Creek - Greenough	2.059331044	0.007	0.08	0.4
MVWQD	10/1/2019	Rattlesnake Creek - Greenough	2.059331044	0.003	0	0.4
MVWQD	7/1/2022	Rattlesnake Creek - Greenough	2.059331044	0.008	0.06	0.6

MVWQD	5/1/2022	Rattlesnake Creek - Greenough	2.059331044	0.009	0.06	0.7
MVWQD	7/1/2019	Rattlesnake Creek - Greenough	2.059331044	0.006	0	1.2
MVWQD	5/1/2021	Rattlesnake Creek - Greenough	2.059331044	0.008	0.06	1.8
MVWQD	7/1/2020	Rattlesnake Creek - Greenough	2.059331044	0.003		3
MVWQD	5/1/2020	Rattlesnake Creek - Greenough	2.059331044	0.032	0.11	13
MVWQD	10/1/2022	Rattlesnake Creek - Greenough	2.059331044	0.005	0.04	
MVWQD	6/1/2021	Rattlesnake Creek - Greenough	2.059331044	0.061	0.06	
MVWQD	9/1/2021	Rattlesnake Creek - Greenough	2.059331044	0.006	0.03	
MVWQD	10/1/2020	Rattlesnake Creek - Greenough	2.059331044	0.008	0.03	
MVWQD	10/1/2019	Rattlesnake Creek - Pineview	0.735927595	0.003	0	0.4
MVWQD	6/1/2019	Rattlesnake Creek - Pineview	0.735927595	0.008	0.06	1.2
MVWQD	7/1/2019	Rattlesnake Creek - Pineview	0.735927595	0.007	0	2
MVWQD	10/1/2019	Rattlesnake Creek - Sawmill	0.131014884	0.004	0	0.4

MVWQD	5/1/2022	Rattlesnake Creek - Sawmill	0.131014884	0.006	0.06	0.5
MVWQD	6/1/2019	Rattlesnake Creek - Sawmill	0.131014884	0.008	0.06	1.2
MVWQD	7/1/2022	Rattlesnake Creek - Sawmill	0.131014884	0.008	0.05	1.4
MVWQD	7/1/2019	Rattlesnake Creek - Sawmill	0.131014884	0.007	0	1.6
MVWQD	7/1/2020	Rattlesnake Creek - Sawmill	0.131014884	0.0075	0.007	2
MVWQD	5/1/2021	Rattlesnake Creek - Sawmill	0.131014884	0.01	0.05	5
MVWQD	5/1/2020	Rattlesnake Creek - Sawmill	0.131014884	0.009	0.11	11
MVWQD	10/1/2022	Rattlesnake Creek - Sawmill	0.131014884	0.007	0.04	
MVWQD	6/1/2021	Rattlesnake Creek - Sawmill	0.131014884	0.01	0.04	
MVWQD	9/1/2021	Rattlesnake Creek - Sawmill	0.131014884	0.006		
MVWQD	10/1/2020	Rattlesnake Creek - Sawmill	0.131014884	0.006		

Appendix B

FROM CREEK TO DITCH AND BACK AGAIN: THE HISTORY AND FUTURE OF PATTEE CREEK, MISSOULA, MT

Public Intercept Survey

The process and questions below are for the public intercept survey portion of Carver Butterfield's Master's thesis. The survey will be conducted at Bancroft Ponds and Cattail Corner in the City of Missoula.

Process:

Step #1) Introduce myself and ask if the induvial would be willing to participate:

"Hello, my name is Carver Butterfield and I am a graduate student studying geography at the University of Montana. I am conducting a study to (1) evaluate the impact of agricultural and urban development on the Pattee Creek watershed, and (2) access the human dimension of water quality in this basin by investigating how Missoulians perceive Pattee Creek. Would you be willing to take ten minutes and answer some questions for my study?"

Step #2) Ask preliminary questions (detailed below). If the respondent is 18 years of age or older and lives within the Pattee Creek Watershed, continue with the survey.

Preliminary questions (if the answer to either of these questions is no, the individual will not be interviewed):

1. Are you 18 years of age or older?
2. Do you live in the Pattee Creek Watershed? (a map of the watershed will be provided for reference)

Step #3) Obtain verbal consent:

"Your verbal consent to participate in this study includes permission to audio-record your responses to short questions as well as permission to use your survey responses to summarize results. Personal identification information, such as your name, is not requested. If at any point you wish to not answer a question or withdraw from the survey you are entitled to do so. Do you agree to continue with the survey questions?"

Step #4) If the respondent gives consent, then turn on the recorder. Record the date, time, and location of interaction.

Step #5) Ask the open-ended questions.

Step #6) Conclude the interview and ask if the respondent has any questions:

"Those are all the questions I have for you, thank you very much for your time and contribution. Are there any questions or comments you have for me? If you would like to contact me with any questions regarding this survey, or the research project in general, my email is carver.butterfield@umontana.edu. If you have any questions regarding your rights as a research subject, you can also contact the UM Institutional Review Board (IRB) at (406) 243-6672."

Introduction:

There are two main goals of this project: (1) to evaluate the impact of agricultural and urban development on the Pattee Creek watershed, and (2) to access the human dimension of water quality in this basin by investigating how Missoulians perceive Creek. The results of this study will help inform land use management decisions in the Pattee Creek Watershed by the City and County.

Open-ended questions (verbal responses recorded using an audio recording application):

1. What comes to mind when you think about Pattee Creek?
2. How would you describe the water quality of Pattee Creek?
3. What factors influence the water quality of Pattee Creek?
4. Do you know where the headwaters of Pattee Creek are? If yes, please explain
5. Do you know where Pattee Creek goes after it leaves Bancroft Ponds? If yes, please explain
6. Do you believe your everyday activities impact Pattee Creek? If so, how?
7. What changes, if any, would you like to see made to Pattee Creek? Do you think anything should be changed about the vegetation along the creek?
8. Do you care about the water quality of Pattee Creek?
9. How long have you lived in Missoula?
10. Had you heard of Pattee Creek before this survey?

Appendix C

FROM CREEK TO DITCH AND BACK AGAIN: THE HISTORY AND FUTURE OF PATTEE CREEK, MISSOULA, MT
Key Informant Interviews

Introduction:

You are invited to participate in research investigating how the City of Missoula and Missoula County responded to the flooding of Pattee Creek with the Missoula South Hills Storm Drainage System. This project will identify the benefits and drawbacks of the planning approach taken to address this environmental challenge. In addition, recommendations for the future management of Pattee Creek will be provided. This study is being conducted by Carver Butterfield, a graduate student from the Department of Geography of the University of Montana.

Procedure:

If you agree to participate, you will be asked a series of questions regarding your experience working with the Missoula South Hills Storm Drainage System and/or Pattee Creek. This semi-structured interview should last no longer than an hour. Our discussion will be recorded and transcribed later. The answers you provide will be used in Carver Butterfield's master's thesis. The questions that are going to be asked during this interview can be found at the bottom of this consent form.

Risks and Benefits:

There is no anticipated discomfort for those contributing to this study, so risk to participants is minimal. To minimize your stress during this process, you are not required to answer any questions that make you uncomfortable. There is no promise that you will receive any benefit from this study, but your answers may help inform future planning decisions.

Confidentiality:

Only the researchers and their academic advisors will have access to your recorded and transcribed interview. The transcription will not contain any information that could identify you and the digital recording will be erased. When the results of this study are presented or published, your name will not be used and will not be identified without your express permission.

If you are okay with being identified by name in any publications or presentations, please initial here _________.

If you do not want to be acknowledged by name in any publications or presentations, please initial here _________.

Voluntary Participation:

Your decision to participate in this study is entirely voluntary. Your decision will not affect your future relations with The University of Montana in any way. You may choose not to answer any individual questions, or stop the interview at any time.

Contact and Questions:

If you have any questions please contact Carver Butterfield via e-mail (butterfield.carver@umconnect.umt.edu). He will be happy to answer any questions you may have at any time. If you have any questions regarding your rights as a research subject, you may contact the UM Institutional Review Board (IRB) at (406) 243-6672.

Statement of Consent:

Your signature on this consent form indicates that you have this form and that you understand the risks and benefits of your participation in this study. You are also indicating that all your questions have been answered. Your signature indicates that you are voluntarily agreeing to participate in this study. You understand that audio recordings will be destroyed following transcription, and that no identifying information will be included in the transcription. After signing this form, you are free to ask any additional questions or to withdraw your consent for participation. You will receive a copy of this consent form.

____

Printed Names

____

Participant Signature Date

____

Researcher Signature Date

SEMI-STRUCTURED KEY INFORMANT INTERVIEW QUESTIONS:

1. What is your professional role?
2. How have you been involved with the Missoula South Hills Storm Drainage System and/or Pattee Creek in general?
3. In your opinion, how adequately does the Missoula South Hills Storm Drainage System infrastructure protect Southern Missoula from flooding?
4. What are your biggest concerns with the infrastructure currently in place along Pattee Creek?
5. What do you perceive as the most significant threat to water quality in Pattee Creek and in Missoula more generally?
6. What are the biggest challenges that prevent Pattee Creek from having clean water quality?

7. What role does public opinion play on the decisions made about Pattee Creek and its wetlands?
8. Do you view water quality as an important policy issue? Why? Why not?
9. In 10 years from now, how would you like Pattee Creek to look?
10. What are the biggest challenges you face in trying to achieve this vision?
11. What lessons can be learned from Pattee Creek?

ADDITIONAL PROBES:

12. What are the pros and cons of the current water quality regulations in Missoula?
13. What improvements or changes do you think should be made to these regulations?
14. What prevents these changes from happening?

15. Should Pattee Creek be considered a “natural” creek?

Links to news outlets uploaded by City of Missoula in support of their application.

https://newstalkkgvo.com/stormwater-project/

https://missoulian.com/rehabbing-cattai l-corner/article_587a2636-033c-5f9f-af 0e-006fb8f5b9eb.html

https://nbcmontana.com/news/local/wo rk-underway-at-cattail-corner-in-misso ula-draws-questions#

https://www.kpax.com/news/missoulacounty/current-events-addressing-runo ff-in-missoulas-south-hills