Eco-Friendly Parking Solutions for the M Trail: Sustainable Parking Lots, Soil Compaction, and Public Transport

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Abstract

It is no secret that the College "M" Hike in Bozeman is becoming more and more popular for students and tourists alike. What lies ahead with this fact is inevitable: the parking situation. The goal of our project is to provide options to allow more visitors to come to the M and reduce the load on the outdated parking lot. Our proposed solutions include upgrading an adjacent parking lot to be more sustainable by incorporating mitigation within the design, and establishing a bus stop at the trailhead. These are designed to allow higher foot traffic on the trail while reducing the negative impacts of cars and parking lots in wild areas.

We will cover specific characteristics that make a parking lot green and sustainable, the impacts of soil compaction and how we can avoid consequences of soil compaction, and how to introduce public transportation to the College "M" trailhead to reduce the need for additional parking.

Introduction

An increase in trail use is not only a growing trend in Bozeman, but all across the country after the 2020 COVID-19 pandemic that motivated many to get outside and explore nature (O'Connell 2024). As a result of increased popularity of trailheads, such as Bozeman's beloved College "M" Hike, cars are beginning to make a significant impact on the environment at these trails through parking on non-designated parking spots or through general accumulation of heavy metals and contaminants (O'Connell 2024).

The parking lot at the College "M" trailhead was not designed for the amount of traffic it receives today. Between 2010 and 2020, Bozeman, Montana experienced a 32.9% growth in population (Sangroniz et al. 2024). This growth is only projected to increase. If no action is taken to mitigate the impact of transportation at the College "M" or increase the parking capacity, we will continue to see harmful degradation of the current parking lot as well as the surrounding soil and aquatic systems.

We propose a solution that encompasses sustainable practices, such as contaminant-filtering bioswales, soil compaction mitigation, and public transportation to help mitigate negative environmental consequences that come with increased foot traffic at the

College “M” Trail. While we propose the comprehensive implementation of the following, each of these components may be utilized on its own for a step towards a sustainable future at the “M”.

Sustainable Parking Lots

The College “M” Hike provides a unique opportunity for Montana State University to set a standard that trailhead parking lots can be environmentally friendly. By implementing a sustainable parking lot near the College “M” Hike, other trailheads and parking areas around town can see the success and implement similar sustainable parking lot characteristics at their own sites. This collective effort will help to sustain a healthy watershed in Bozeman and the greater Gallatin Valley.

A traditional parking lot creates a large, impermeable surface that increases the chances of flooding, increases runoff, compacts soil, and can increase nutrients and heavy metals flowing into surface water and the water table (Sohn et al. 2020). What a sustainable parking lot allows for is water to percolate either directly through a porous parking lot or bioswales, a decrease in heavy metal and excess nutrients being dumped into the water table through bioswales, decreased flooding potential through the permeable surfaces, and decreased compaction via underground support structures (Rushton 2001, Ekka et al. 2021). The goal of this section is to provide options that we believe should be implemented into the parking planning going into the College “M” Trail. First we will explore the options of where to plan a sustainable parking lot then we will dive into the characteristics that make up that sustainable parking lot.

Choosing the Location

There were three primary options we looked at that would allow for the College “M” Trail to accommodate for the increasing demand for parking.

1. The first option would be to expand the already existing College “M” Trail parking lot to accommodate more cars. This seemed to be the first idea that came to mind. The trail is getting more foot traffic and therefore more cars, so let's make it bigger.
2. The second option was to bring in a new parking lot adjacent to the current College “M” Trail parking lot. This option would allow us to leave the old parking lot as is and start from scratch with an additional parking lot.
3. The final option we wanted to explore, and eventually chose, was to transform the gravel lot of the Drinking Horse Mountain Trailhead into an established sustainable parking lot.

There are two parking lots currently located at or near the College “M” Trail in Bozeman. The parking lot at the “M” trailhead, designated P 18 in Image 1 below, is located on the left of Bridger Canyon Dr. moving eastbound. This is a round-about style parking lot with a vegetative center. This vegetative area hosts a picnic table and is currently overgrown with invasive species. While there may be a high percentage of invasive species, there are also larger trees present in or near the parking lot that provide a “greening” effect that helps to keep the parking lot at a cooler temperature. There are several aspects of this parking lot, whether it be managing invasive species, tending to the wear and tear of the parking lot, or overall parking flow, that needs more management.

The second parking lot near the College “M” Trail is located 0.2 miles southwest of the College “M” Trailhead parking lot, designated as P 19 in Image 1 to the right. This is technically the parking lot for the Drinking Horse Mountain Trailhead. At this time, it consists of a mostly leveled out gravel parking lot with no designated parking spots. It sits just 0.2 miles from Bridger Creek and only 0.1 miles from the Bozeman Fish Technology Center, which is Bozeman’s fish hatchery. Bridger Canyon Drive currently separates these two parking lots, however, a short underground tunnel giving way to a 0.2 mile paved walking path leading to the College “M” Trail connects the two lots.

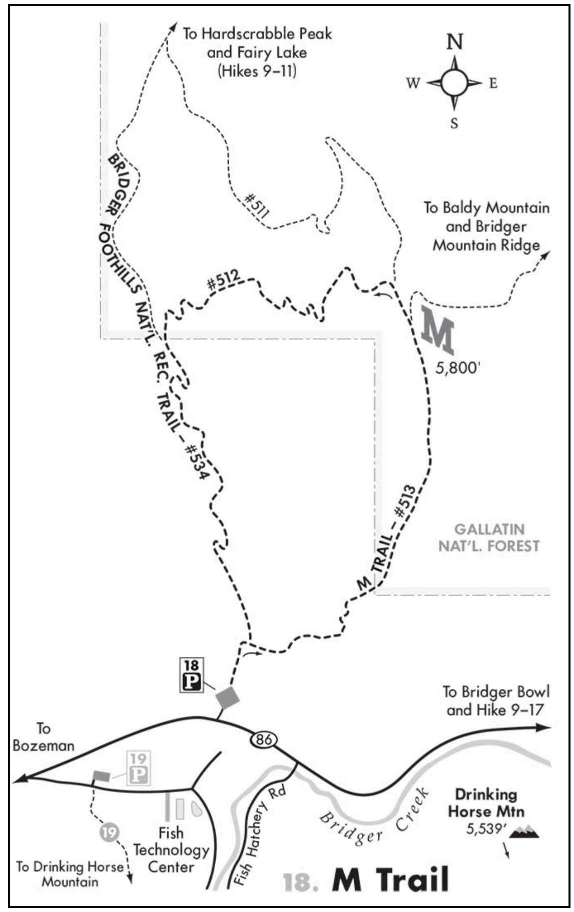

Image 1. “M” Trail Source: OutsideBozeman

We needed to decide what option would be the most effective at allowing the College “M” Trail to bring in more foot traffic while at the same time minimizing the ecological damage that would be brought with that same increasing traffic. We decided against expanding the College “M” Trail parking lot as there are already sound environmental implementations here, such as the vegetative center. Additionally, the shape of the parking lot does not allow significant expansion. We also decided that there would be too big of an environmental impact of building a new parking lot adjacent to the existing parking lot. Bringing in additional impermeable surfaces and taking habitat away from current productive land has many negative impacts on the plant and animal diversity in the area (McKinny 2008). Finally, we agreed that transforming an underdeveloped parking lot that has already been established would be the least disruptive path to increasing parking availability to the College “M” Trail. The fact that the Drinking Horse Mountain Trailhead parking lot and the College “M” Trail are already interconnected by a paved walking path made this option even more appealing, as that is something that would have had to be done. By creating an established sustainable parking lot here with designated parking spots, this will increase the number of cars that would be able to park in the existing lot without having to expand it. Regardless of which location is focused on, the following environmental applications should be considered to help reduce the negative consequences of the parking lots on the ecosystem.

Bioswales

Vehicles in parking lots leave behind oil, gas, and heavy metals wherever they go. This includes the vehicles parked at trailheads, such as the College “M”. Without any reinforcement, these pollutants get carried away with runoff and go directly into streams and rivers (Hong et al. 2006). In this case, those pollutants can end up in Bridger Creek and eventually the East Gallatin River. Bioswales are one solution to reduce the amount of pollutants reaching local water sources. Bioswales work through bioretention, where specific plants and microbial communities work together to physically take up pollutants (Hong et al. 2006). A mulch layer is typically applied to the top of the soil surface in bioretention-based bioswales for a variety of reasons (Hong et al. 2006). Mainly, mulch has a high affinity, or attraction, for oils that come from vehicles which makes removal simple (Hong et al. 2006).

The use of swales in conjunction with previous surfaces, such as porous asphalt, provides the most efficient removal of contaminants from parking lots (Rushton 2001). Table 1 shows that pervious pavement with swales had the lowest contaminant loads per year when compared with asphalt with no swales, asphalt with swales, and cement with swales.

Table 1. Yearly Constituent Loads and Percent Efficiency Calculations for Each Pavement Type (August 1998 to August 1999) (Rushton 2001).

	Asphalt, No Swale		Asphalt, with Swale				Cement, with Swale				Pervious, with Swale			
Constituents	F1 (kg/ha-year)	F2 (kg/ha-year)	F7 (kg/ha-year)	F7 (%)	F8 (kg/ha-year)	F8 (%)	F3 (kg/ha-year)	F3 (%)	F4 (kg/ha-year)	F4 (%)	F5 (kg/ha-year)	F5 (%)	F6 (kg/ha-year)	F6 (%)
Ammonia	0.57	0.43	0.11	80	0.24	45	0.08	86	0.12	73	0.11	80	0.06	85
Nitrate	0.72	0.61	0.19	74	0.34	44	0.26	64	0.36	41	0.15	79	0.21	66
Total nitrogen	1.86	1.58	0.78	58	1.44	9	0.79	58	1.33	16	0.53	71	0.92	42
Ortho phosphorus	0.15	0.19	0.15	−1	0.54	−180	0.31	−105	0.54	−180	0.06	61	0.34	−74
Total phosphorus	0.28	0.34	0.21	26	0.66	−94	0.37	−32	0.55	−62	0.07	76	0.33	3
Suspended solids	52.28	58.61	8.68	83	31.79	46	4.47	91	12.76	78	4.26	92	5.11	91
Copper	0.042	0.033	0.008	81	0.025	23	0.008	81	0.009	72	0.003	94	0.006	81
Iron	1.805	1.386	0.227	87	0.676	52	0.156	91	0.228	84	0.114	94	0.107	92
Lead	0.018	0.017	0.002	87	0.007	59	0.003	83	0.004	78	0.001	93	0.003	85
Manganese	0.042	0.041	0.007	83	0.024	40	0.004	90	0.013	68	0.003	93	0.003	92
Zinc	0.174	0.147	0.037	79	0.079	46	0.042	76	0.056	62	0.020	89	0.036	75

Note: Percent (%) represents pollution reduction achieved compared to basins without swales (F1 and F2). Negative numbers indicate more phosphorus loads were exported from some basins with swales.

<u>Pros of bioswales</u>

Removal of sediment, excess nutrients, and heavy metals - Bioswales are effective at reducing the levels of nitrogen, phosphorus, copper, iron, lead, manganese, and zinc in runoff from parking lots that end up in freshwater systems (Rushton 2001).

Increases watershed water retention - As water demands increase, water becomes a more valuable resource. Swales have the capability to reduce surface water runoff and recharge groundwater (Leroy et al. 2016, Ekka et al. 2021).

Cons of bioswales

Swale maintenance - Bioswales, like porous asphalt, can fill up with sediments. This sediment must be removed periodically to promote a functioning swale. For the first few years while plants are establishing, hand weeding or the use of herbicides may be needed to prevent the infestation of weeks (*SUSTAINABLE GREEN PARKING LOTS GUIDEBOOK* n.d.).

Permeable Surfaces

The College "M" trail sits adjacent to Bridger Creek, which flows into one of Gallatin Valley's main water sources, the East Gallatin River, as mentioned above. This means that harsh chemicals from cars could end up in Bozeman's drinking water if proper planning is not implemented. One way we can mitigate this issue is by avoiding contaminated surface water runoff directly into the streams by using permeable surfaces in our parking lot.

On a large, ecosystem level scale, a high percentage of impermeable surfaces within a watershed can severely limit the animals that exist within the watershed (Boward et al. 1999). This is due to significant impacts that impermeable surfaces, such as traditional parking lots, have on the environment. Impermeable parking lots, made out of materials like concrete or asphalt, "collect particulate matter from the atmosphere, nitrogen oxides from car exhaust, rubber particles from tires, debris from brake systems, phosphates from residential and agricultural fertilizers, and dozens of other pollutants (Frazer 2005)." These chemicals and other harmful substances flow off the parking lot and directly into natural vegetation or into surface water like streams and rivers, negatively impacting aquatic health and water quality (Frazer 2005). This is exactly what happens in agricultural settings when too much fertilizer is applied then carried by runoff into the nearest stream or river to cause harmful algal blooms (Chakraborty et al. 2017). If we let the excess nutrients and sediment from erosion and heavy metals from cars flow into our streams without first filtering it, our groundwater will become contaminated (Swisher 2002). Permeable parking lots are a solution to mitigating these negative consequences (Swisher 2002).

What constitutes a permeable surface? Permeable surfaces can come in many forms, with the most common being porous asphalt (PA), concrete pavers, and grass pavers. The most important distinguishing feature from traditional parking lot surfaces is that permeable surfaces allow water to percolate through it rather than run off of it. While each of these options may help water percolate into the ground where traditional parking lots fail, it is important to understand what option is most suitable for different projects and places. In a semi-arid continental climate like Montana, winter months of freeze-thaw cycles can have a significant impact on the durability of parking lots, such as surface cracking due to water expansion (Fakhri et al. 2022). Thus, it is important to take into account Montana's climate when deciding what permeable materials to suggest for the parking lot. Due to this harsh winter climate, porous asphalt, consisting of "stone aggregate, binder material, and other modifiers" and 18-20% of void space, was chosen as the most effective method of permeable surfaces (Briggs 2006, Houle 2008).

Pros of Porous Asphalt

Removal of pollutants - Modern porous asphalt is capable of removing most stormwater contaminants, such as hydrocarbons, microorganisms, sediment, and metals before they reach groundwater or surface water, such as Bridger Creek (Houle 2008).

Improved road conditions during winter months - A study done by Zhang and Kevern indicated that on porous asphalt, salt application could be reduced by 64%–77% when compared to a traditional asphalt parking lot while still providing equivalent, or even better, surface conditions (Zhang and Kevern 2021). The same study attributed part of this success to the nature of porous asphalt being able to melt faster than conventional asphalt pavement (2021). Swedish researchers also found that higher water levels in the soil beneath porous asphalt was able to provide enough latent heat to minimize freeze-thaw effects during winter. This difference can be visually seen when looking at a porous asphalt parking lot and a dense-mix asphalt (DMA) parking lot (Figure 1). Houle also studied skid resistance on different surfaces and came to the conclusion that “porous asphalt was found to have the highest skid resistance for wet, snow-, and compacted snow-covered pavement” (Houle 2008). This ability to outperform traditional concrete or asphalt pavements in the winter is critical for the safety of the drivers visiting the College “M” during the winter.

Figure 1. Instantaneous pavement conditions after freezing-rain: PA vs. DMA (Houle 2008).

Cons of a Porous Asphalt

Porous asphalt is vulnerable to clogging - Fine sediments that are blown onto the surface of porous asphalt, such as loose rock or winter salt, can fill the void spaces of the surface that are intended to be for water infiltration (Houle 2008). A clogged porous asphalt parking lot may be “vacuumed” to remove the fine settlement that builds up over time (Zhang and Kevern 2021). For this parking lot, this would look like a cleaning before and after the winter season to clear the surface for ice melting and to clear any remaining snowmelt debris.

Plant Shading/Greening

When creating a sustainable parking lot for the College “M” Trail and Drinking Horse, bringing in a method for additional carbon capture and storage that also acts as a heat barrier in the summer can not be overlooked (Gunwoo and Coseo 2018).

The idea of greening a parking lot is exactly how it sounds. Strategically planting trees and other shrubbery in and around parking lots can be beneficial for a handful of reasons, which we will talk about in the pros below. When planning out where to plant vegetation, a soil volume of 1,000-1,200 cu. ft. is ideal for a large canopy spread of 36 feet (Figure 2). Additionally, plants need quality soil to grow in. It is suggested that a high quality loam soil with a minimum depth of 30 inches is provided where trees will be planted.

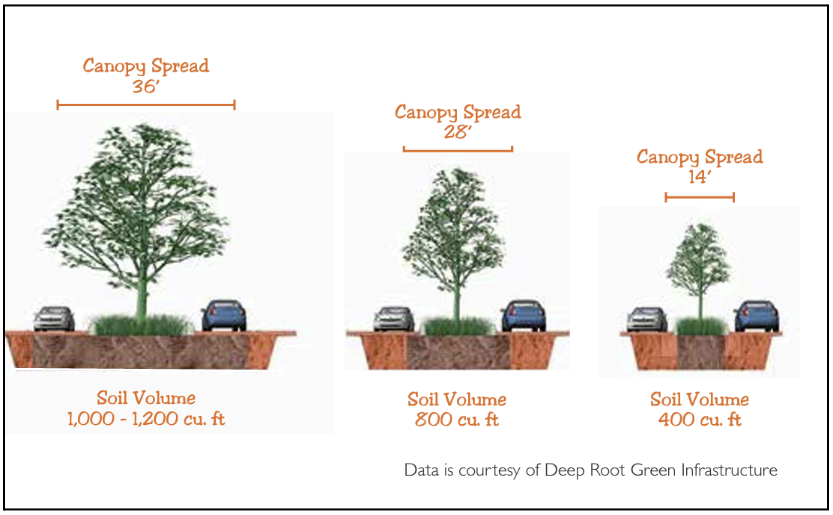

Figure 2. Recommended soil volume to canopy spread for greening parking lots (*SUSTAINABLE GREEN PARKING LOTS GUIDEBOOK* n.d.).

Pros of greening a parking lot

Decreases ambient heat in summer - Larger trees may provide shade to the parking lot. This relief from summer heat can decrease temperatures in cars that have been sitting in the parking lot while hikers are on the trail. Shaded areas in the parking lot also act as a small refuge for pets and humans while getting ready for their hike to the College “M” or Drinking Horse.

Decrease in stormwater runoff - Planting trees within the parking lot would help reduce stormwater runoff into Bridger Creek by allowing the water to directly percolate into the soil and be retained by the trees and other vegetation (*SUSTAINABLE GREEN PARKING LOTS GUIDEBOOK* n.d.).

Carbon Capture and Storage - Bringing in additional plant biomass, such as trees used for shade, can aid in the greater effort to increase carbon capture and storage through the natural process of photosynthesis (Gunwoo and Coseo 2018). As Bozeman is susceptible to the consequences of hotter and drier years, this practice of carbon capture is extremely important.

Cons of greening a parking lot

Plants will need to be protected - Trees will need to be protected from vehicle impacts, snow poling, and salt application during winter, if applicable (*SUSTAINABLE GREEN PARKING LOTS GUIDEBOOK* n.d.).

Increased in snow and ice retention - A higher level of shading on the physical surfaces of the parking lot may impact the amount of snow and ice that is able to melt during the winter months (Houle 2008). If the parking lot is shaded during all or most of the day, road conditions may not improve and continue to be slick or covered in snow. As winter months decrease in trail use, this would likely not pose a problem at the College “M”.

Soil Compaction

Soil compaction is a significant environmental issue, especially in places that contain parking lots, where the weight of heavy machinery, vehicles, construction activities, and foot traffic on trails compacts soil particles. Compression of soil particles leads to a reduced pore space, which directly impacts plant, soil microbial communities and function, and the surrounding ecosystem. If soil compaction is not managed or prevented, it can lead to a degradation in long-term soil health, making it essential to identify and implement practical solutions that allow parking lots to remain functional while protecting the enviornment.

When soil particles are compacted, air and water spaces shrink, disrupting the soil’s natural structure - thus reducing its ability to support life (Figure 1). The impact on compaction is severe on microbes, which rely on these pore spaces to access oxygen and water for vital

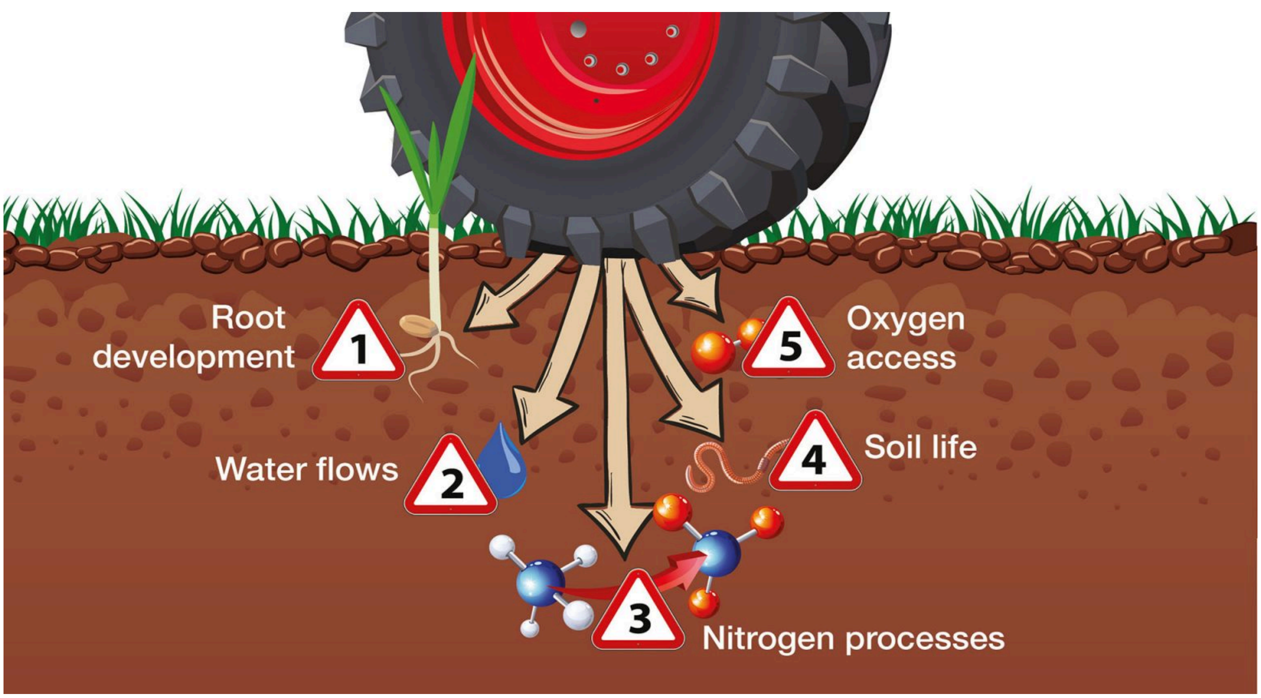

Figure 1: Diagram showing soil compaction and its cascading effects on soil processes (Compaction Prevention System).

processes and nutrient cycling (Hoorman et al., 2011). Aerobic microbes, responsible for functions like nitrification, ammonification, and decomposition, decline in population, causing nutrient cycling to slow. This results in an decrease in bioavailable nitrogen and other essential elements that plants rely on for growth. Moreover, compacted soil can favor anaerobic microbes, which produce harmful byproducts such as methane, negatively impacting soil chemistry. Compacted soil can lead to shifts in the microbial community, lowering biodiversity and making the soil more vulnerable to diseases and imbalances (Frey, Beat et al., 2009). This destabilization can make it harder for beneficial microbial relationships, like those between plants and nitrogen-fixing bacteria, to thrive.

Plants are equally affected by compacted soil. With limited pore space, roots struggle to penetrate the ground, causing stunted growth and limiting access to moisture and nutrients. For plants that manage to establish themselves, the poor infiltration of water and reduced availability of minerals like potassium and phosphorus negatively impact their ability to grow (Kozlowski, T.T., 1999). Larger trees, which rely on deep root systems, are especially vulnerable in parking lots, where their roots can become restricted, leading to ineffective water and nutrient uptake (Unger et al., 1994). The edges of parking lots, often colonized by weedy species, also suffer, further reducing the greenery and biodiversity in the area.

Without healthy soil, the broader ecosystem begins to suffer. Wildlife that relies on plants and soil microbes for food and habitat will decline, degraded soil will no longer retain water efficiently, and the risk of erosion and topsoil loss will increase. Organic matter also becomes unavailable due to lack of water movement, making it difficult for the soil to sustain microbial life. This decline in soil health ultimately reduces the ecosystem's ability to withstand environmental stressors such as droughts, heavy rains, and extreme weather events (Beylich, Anneke et al., 2010).

Though the risks of soil compaction are serious, several practical solutions exist that allow parking lots to serve their purpose while reducing environmental harm. By integrating these methods into both the design and maintenance of parking areas, soil degradation can be prevented and support ecosystem health.

Permeable Pavements - Materials like porous asphalt, permeable concrete, and interlocking pavers allow water to infiltrate the soil instead of pooling on the surface. These pavements reduce surface runoff, enabling deeper soil hydration.

Vegetated Swales and Rain Gardens - These planted areas alongside parking lots capture stormwater runoff, slow water flow, and allow moisture to soak into the ground gradually. Native plants in swales also help filter pollutants, improving the quality of water that eventually returns to groundwater sources. These green infrastructure elements enhance biodiversity and create habitat for birds, insects, and other wildlife.

Soil Amendments and Organic Matter - Adding compost, biochar, or mulch can improve soil structure by increasing porosity. Organic matter also promotes microbial activity, enhancing nutrient cycling and moisture retention. Regular application of amendments can reverse some of the negative effects of compaction by restoring soil health over time.

Subsurface Reinforcement - Technologies like geogrids and soil stabilization fabrics distribute the weight of vehicles across a larger surface area, preventing deep compaction. These reinforcements are particularly useful for heavy-use areas, such as loading zones or driveways, where stress on the soil is highest.

Tree Pits - Creating structural soil systems and large tree pits within parking lots gives trees space to grow without root restriction. These pits are designed to allow roots to spread horizontally, reducing stress and promoting healthy growth.

Ongoing Monitoring and Adaptive Maintenance – After construction, regular monitoring ensures that compaction does not return and that the mitigation methods remain effective. This can include soil moisture testing, pore space measurements, and tree health assessments (Montgomery County Planning Commision, 2016).

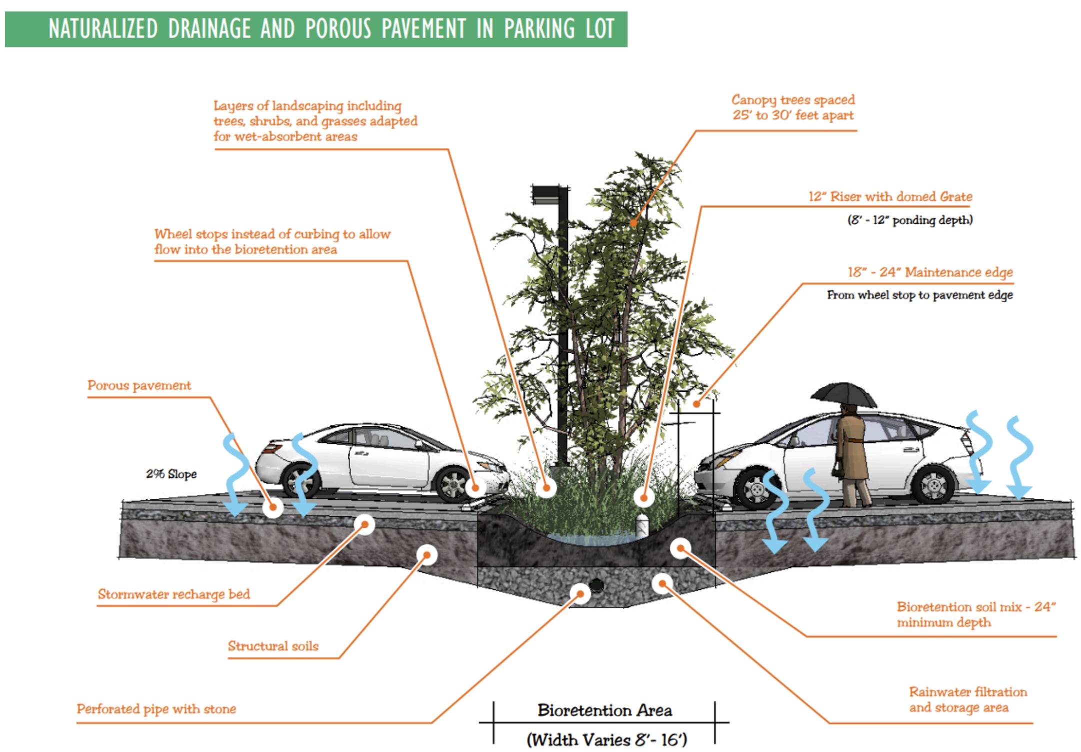

Figure 2: Implementations to parking lots to reduce the amount of soil compaction, and promote ecosystem function and diversity (Montgomery Planning Commision, 2016).

These strategies can be integrated into both existing and newly constructed parking lots to balance functionality and environmental health. In particular, the College “M” parking lot and the Drinking Horse parking lot present opportunities to implement mitigation techniques that enhance the surrounding ecosystem.

Soil compaction is a challenging issue, but it is not insurmountable. With the right strategies, parking lots can remain functional without sacrificing the environment. Mitigating compaction through permeable pavements, vegetated swales, organic amendments, reinforcement, tree pits, and continuous monitoring will foster healthier soil and more resilient ecosystems. By prioritizing these sustainable practices in both existing and new parking lot designs, we can safeguard environmental health and ensure that the College “M” Trail development and nature coexist sustainably.

Public Transportation

As the town of Bozeman grows, so too will the amount of visitors to the College M and other trailheads in the county. The growth calls for an increase in public services, including public transportation. Currently the streamline is the main bus system in town and it is currently looking to expand its capabilities. This is a greatly needed expansion to fit the expansion of the town. We are proposing that the streamline add a bus stop to the M parking lot not only to reduce the car load on the M trailhead, but also to make the outdoors more accessible in a town of outdoor enthusiasts.

Getting a bus stop at the M is the primary goal of this project not only to reduce the strain on the current parking lot but also to make the outdoors more accessible. We hope that if the M trailhead bus stop is implemented, it can be used as a stepping stone to expand the transportation system in the whole town and surrounding area. The people of the town deserve a better way to get around besides cars and the city and people developing the city have the opportunity to provide this with relatively low additional infrastructure.

Bringing a bus stop to the M will reduce the load on the parking lots with the expectation that the number of people in Bozeman will only grow in the foreseeable future. Bozeman is a growing town and the people moving here pride themselves on sustainability in theory, now it is time for them to get the chance to be sustainable in practice.

The bus project is the first step in an alternative to help escape the car-centric country we live in. Adding one new bus stop will of course have very little effect on the town as a whole but it could be used as a stepping stone to expand the bus system to include more trailheads and suburban areas. As long as we are thinking about cars and not people, we will be stuck in a loop of mowing down vegetation and paving it to make room for more carbon intensive cars. Integrating a solid transportation system will make the outdoors accessible to a much wider group of people and reduce the amount of cars on the road.

Compared to the rest of the country, the bus system in Bozeman is passable but looking at other developed countries it is laughable. There are simple ways to fix this by looking at what has worked and what hasn't in similar metropolitan areas, namely DC where part of the city was built around the transportation system (Cox, 2020). The good thing about Bozeman is that it is still growing, so there is a chance to develop the new growth around a transportation system, or at least develop them together. This improved bus system could then be expanded to other surrounding metropolitan areas and used as a framework for other rural bus systems around the country.

Why should we try to improve the public transportation system when everyone already has cars? Why shouldn't we focus on electric vehicles (EVs)? When compared to EVs, of course the carbon impact of public transit per ride is greater. This is not the only factor that should be looked at though. Cars, buses and trains are all generally powered by gas so they can be compared relatively evenly. Electric vehicles don't use gas but they take up other resources, mainly in their production. Currently car batteries in EVs use batteries that rely heavily on lithium, which is in very limited supply globally. Most of the mines are in developing countries with extremely poor working conditions and little to no environmental protections. Public transport may use gas powered engines but for now they are ethically a better alternative to exploitatively mined lithium.

When compared to gas powered cars, even when not at full occupancy, public transit systems have a much lower carbon cost per person (figure 3.1). The difference between one pound of carbon per trip in a car vs half a pound on public transit may not seem like a lot but it adds up. Bozeman won't reverse climate change by having a bus stop at the M, or even by having a robust public transit system across the whole city. Regardless of that, having a bus system would make the town part of the solution to reduce carbon emissions in the country and the world.

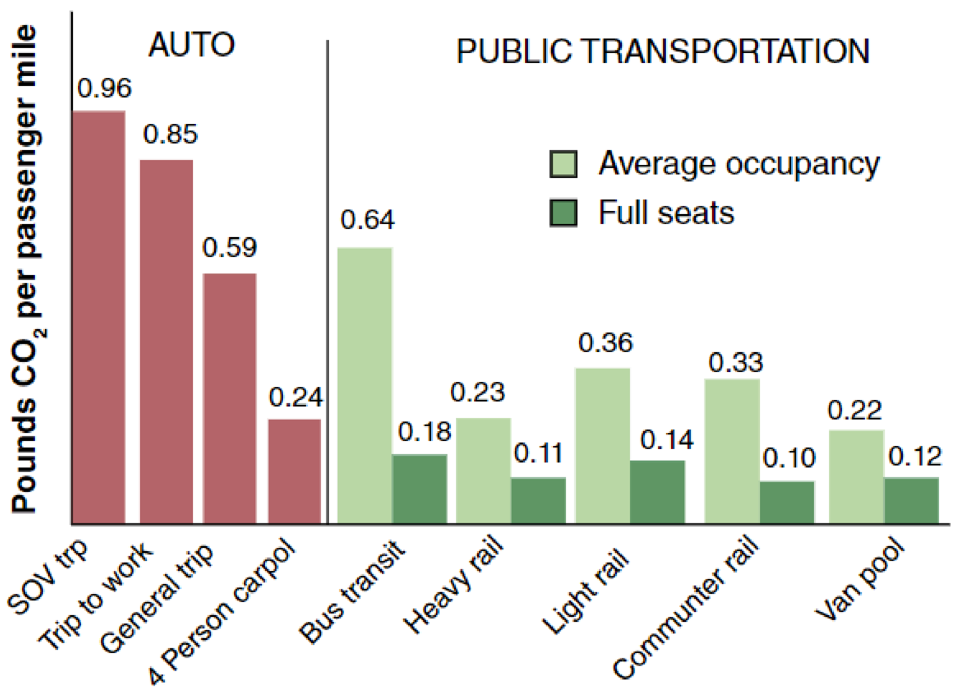

Figure 3.1: Estimated CO2 emissions per passenger mile for cars and public transportation in 2010 including average and full occupancy. Trip to work averages 1.14 passengers including driver; general trip averages 1.63 passengers
Source: Federal Transit Administration, U.S. Department of Transportation, "Public Transportation's Role in Responding to Climate Change," January 2010

Riding the bus shouldn't just reduce the amount of time in the car, it should also help the riders economically. Regardless of the amount of people, Bozeman is still physically small, so most commutes are only a few miles. Short distance commutes less than 5-10 miles likely wouldn't cost most people more than a few dollars, so the fare would have to be almost free for it to be worth buying a bus ticket. For longer trips though, like to the M (5 miles), Hyalite reservoir (20 miles), Lava Lake trailhead (30 miles), or Big Sky (45 miles), a fare of a few dollars would greatly reduce the cost on the commuter. Maybe they would only save a few dollars each time, but like carbon emissions, that small amount adds up over time, and they don't have to worry about driving.

Another benefit of public transit that is often overlooked is that drunk people on the bus can't cause accidents. Drunk drivers cause a significant amount of crashes every year, and I am sure everyone living in Bozeman has seen the crosses along Gallatin canyon, one of the deadliest roads in the country. Allowing people another option to stay off the road when they are drunk will always be a good idea.

There are some tangible, measurable constraints to having an efficient and popular transportation system. A study conducted in 2020 by Wendell Cox of John Hopkins University in Washington D.C. found that people will take a bus instead of their car only if they have to walk less than ¼ to ½ mile between destinations and if the wait time is less than 5-10 minutes at peak times. This is referred to as the "first mile, last mile" part of a trip. Cox also found that in transportation oriented development (TOD) areas, twice as many trips were on bikes and half of the amount of trips used cars. If this pattern is known and easy to follow in developing areas, then it should be easy to implement in a growing city like Bozeman.

In Seattle, a company called Via to Transit is testing a rideshare type of program that reduces the amount of walking for the first and last leg of commutes (Bleviss, 2021). It is doing this by having an on demand rideshare type of service, similar to uber or lyft, that will take people from their start or end point to a transit stop. This is an innovative way to increase the distance people will go for their first or last mile of a trip without leaning completely on ridesharing, which is effectively a normal trip. This seems more suited to large cities like Seattle that have more people to ride with and work for a company like this as well as longer commutes. If this were to be implemented in Bozeman it would mostly be useful for people going to adjacent cities like Three Forks or Livingston where it would be expensive to hire a ride sharing company. So in its current state streamline is not ready for a service like Via to Transit but if ridership increases and more routes are added, it could be a viable option for growth.

Another way to incentivise people to use the bus system in bozeman would be to develop an app specifically for planning and paying for bus rides that would include a schedule and even a tracker for buses to see if they are on time. This could help take the logistics out of planning a trip or commute. Gallatin Valley has two bus systems now, streamline in Bozeman and Skyline in Big Sky, and their routes and fares could be combined into one app for easy planning.

The Norwegian bus system is a good framework to use in this situation. They have a country-wide system of trains, buses, and ferries that are all interconnected with a user-friendly app for paying fares as well as seeing routes. Most homes are within a short walking distance of a bus stop, even in rural areas, and the buses have stops at many trailheads in the mountains.

The largest obstacle I see for getting this type of system here is public opinion. We already have a local bus system that passes by multiple trailheads and goes to Bridger in the winter, so why can't it go year round and stop at the M?

The main problem faced by other cities in getting people to use public transit is public opinion. It is possible to have a robust system that nobody uses, so the challenge is now getting people to actually ride the bus. Large cities like New York, Boston and Chicago charge heavy parking fees as a way to incentivise residents to use public transit. Traffic is also another unintended incentive for people to ride the bus. Public transport not only limits the amount of cars on the road, it also allows the passengers to relax and not have to worry about driving on congested roads. It might not be that bad in Bozeman now, but the roads are not built to handle the amount of traffic that is coming with the rapid growth in Gallatin Valley. In downtown Bzeman the parking areas are always overflowing, two lane streets near the downtown area are effectively one lane in some places from all the cars parked on them. Less people driving their cars would mean less congestion on the streets and less traffic.

In other cities the majority of commutes during peak times are from suburbs to work in the city core, then back at the end of the day. In Bozeman, people tend to value time outside and often go for a hike, fish, bike etc. The situation here is different because the after work commute is different from the before work commute. If the bus system went to trailheads then it would incentivise people to commute on the bus instead of driving.

I'm sure there are people reading this and thinking "I like driving my car and I can't take a bus on dirt roads!" I would like to put it out there that the development of a public transit system doesn't mean that you can't have a car. It means that you don't have to sit in traffic. It means that if your car breaks down you can still get to work. It means that people who can't afford a car can still get around.

Bringing a robust transit system to Gallatin Valley will make the outdoors more accessible to people and the next step is to bring a bus stop to the M, and other trailheads around the valley.

Works Cited

Bleviss DL. "Transportation is critical to reducing greenhouse gas emissions in the United States." WIREs Energy Environ. 2021; 10:e390. https://doi.org/10.1002/wene.390

Cox, Wendell, newgeography, "Population Growth Concentrated in Auto Oriented Suburbs and Metropolitan Areas," 1/14/20, http://www.newgeography.com/content/006527-population-growth-concentrated-auto-oriented-suburbs-and-metropolitan-areas

Hodges, Tina, "Public Transportation's Role in Responding to Climate Change" United States. Federal Transit Administration. Office of Policy Development. 2010-01-01. https://rosap.ntl.bts.gov/view/dot/17277

Chakraborty, S., P. K. Tiwari, S. K. Sasmal, A. K. Misra, and J. Chattopadhyay. 2017. Effects of fertilizers used in agricultural fields on algal blooms. The European Physical Journal Special Topics 226:2119–2133.

Ekka, S., H. Rujner, G. Leonhardt, G.-T. Blecken, M. Viklander, and W. Hunt. 2021. Next generation swale design for stormwater runoff treatment: A comprehensive approach. Journal of Environmental Management 279.

Fakhri, M., S. A. Siyadati, and M. R. M. Aliha. 2022. Impact of freeze–thaw cycles on low temperature mixed mode I/II cracking properties of water saturated hot mix asphalt: An experimental study 261.

Gunwoo, K., and P. Coseo. 2018. Urban Park Systems to Support Sustainability: The Role of Urban Park Systems in Hot Arid Urban Climates. Forests.

Hong, E., E. Seagren, and A. Davis. 2006. Sustainable Oil and Grease Removal from Synthetic Stormwater Runoff Using Bench-Scale Bioretention Studies. Water Environment Research 78:141–155.

Houle, K. 2008. Winter performance assessment of permeable pavements: A comparative study of porous asphalt, pervious concrete, and conventional asphalt in a northern climate.

Leroy, M., F. Portet-Koltalo, M. Legras, F. Lederf, V. Moncond'huy, I. Polaert, and S. Marcotte. 2016. Performance of vegetated swales for improving road runoff quality in a moderate traffic urban area. Science of the Total Environment 566–567:113–121.

McKinny, M. 2008. Effects of urbanization on species richness: A review of plants and animals. Springer 11:161–176.

O'Connell, N. 2024. Wildly Inaccessible: Reaching Public Lands via Public Transit.

Rushton, B. 2001. LOW -IMPACT P ARKING LOT DESIGN R EDUCES R UNOFF ANDPOLLUTANT LOADS. JOURNAL OF WATER RESOURCES PLANNING AND MANAGEMENT 127:172–179.

Sangroniz, A., R. Ebel, and M. Stein. 2024. Barriers and opportunities to agrihood development in growing cities of the Rocky Mountain Region: Acomparative case study. ournal of Agriculture, Food Systems, and Community Development.

Sohn, W., J.-H. Kim, M.-H. Li, R. Brown, and F. Jaber. 2020. How does increasing impervious surfaces affect urban flooding in response to climate variability? Elsevier 118.

SUSTAINABLE GREEN PARKING LOTS GUIDEBOOK. (n.d.). .

Swisher, D. 2002. CHEMICAL AND HYDRAULIC PERFORMANCE OF A POROUS PAVEMENT PARKING LOT WITH INFILTRATION TO GROUND WATER.