YELLOW RIVER PARK

TRAIL SYSTEM ASSESSMENT
AND
REDEVELOPMENT PLAN

JULY, 2012

COMPLETED FOR:

Gwinnett County Division of Parks and Recreation

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EXECUTIVE SUMMARY

Gwinnett County Parks and Recreation Division (GCPR) requested the Foresite Group and Trail Dynamics to complete a trail sustainability assessment and redevelopment recommendations for Yellow River Park. The team met with GCPR staff, interested stakeholders, and conducted a complete field reconnaissance of the park's trails in May 2012. In June and July, the team employed the results of the field assessment, along with spatial data provided by the County, to develop metrics of physical, social, and managerial sustainability of the trail system and provide recommendations for the improvement of the trails.

The Yellow River Park Master Plan, completed in 2002, presented a 12-mile trail system for the park. The Plan stated that these trails were already in existence and used by mountain bikers and equestrians and that there were more trails on the property than were considered for the trail system. While historically these two use types employed all the trails on the parcel, the Plan called for separate trails for each use type. While this decision was made ostensibly to mitigate potential conflict between these users, it consequently reduced the amount of trails available to each use. Subsequent to the use separation, the County began the process of trail reconstruction, where it was determined that improvements were necessary. This reconstruction process dramatically altered the experience being provided from very narrow, twisting, somewhat rough informal paths to relatively highly engineered, wide, smooth pathways that could fully accommodate County-owned all-wheel drive maintenance vehicles. Combined, the trail separation and reconstruction left trail users particularly unsatisfied and the began the process of 1) reopening old trails that were not included in the Master Plan, 2) creating new trails that more closely approximated their desired recreational experience, and 3) using all trails in the park, regardless of the signed allowed use. These socially developed trails now more than double the trail mileage in the park from the Master Plan and, in the process, have resulted in more than 220 trail intersections, an average of one intersection every 0.1 mile.

The design, construction, and maintenance of the Master Plan trail system is inadequate and does not create a positive recreational experience for most trail users. The socially developed trails have similar design flaws and the "spaghetti bowl" of trails that has resulted is not navigable. Together, the impact footprint of the current trail system is unacceptable and the maintenance need that the system requires cannot be met by the County.

The team has recommended a complete retrofit of the Yellow River Park trail system to improve its sustainability characteristics and provide a much-improved recreational experience. A conceptual plan demonstrates approximately 16 miles of rolling contour trail. At widths of two to four feet, these trails would improve physical sustainability while vastly decreasing the ecological footprint and maintenance needs of the current trails. Loops with a few discreet intersections have been recommended to improve navigability and allow park visitors to choose an experience that aligns with the time and ability each visitor brings into the park. The team has recommended retaining a roughly 5.5-mile perimeter loop for the very limited equestrian use that the park receives and regulating the interior 15.5 miles for mountain bike/pedestrian use. Finally, an implementation model and cost opinion has been suggested for undertaking the recommended redevelopment in the most cost-effective manner possible, as well as developing a volunteer stewardship force to assist the County in both the trail system redevelopment and ongoing maintenance of the Yellow River Park trails.

BACKGROUND

The 565-acre Yellow River Park site was originally assembled by the Gwinnett County Department of Public Utilities (DPU) for use as a waste water reclamation facility. In 1998 the Board of Commissioners purchased the site from DPU for use as an open space park. A majority of the park has fairly steep topography with some terracing present from historical soil conservation practices. Naturally flat areas parallel some parts of the river in the floodplain. The park is divided by Yellow River and currently onto the portion of County property west of the river has been developed. The site has a net 200-foot elevation change, from 930 feet to the lowest of 702 feet (at the river's edge).

A Master Plan was adopted for the park in 2002. The principal goals of the Master Plan were stated as follows:

- Preserve the natural resources associated with the park.
- Provide well-built trails for mountain bikers, equestrian riders, and pedestrians.
- Provide amenity areas to service surrounding neighborhoods and a variety of user groups.
- Provide a safe, environmentally sustainable and usable environment for passive park activities.

Prior to the county's acquisition, DPU had allowed equestrian and mountain biking groups to create trails for their use on the portion of the site west of the Yellow River, which is accessible from Juhan Road. The Master Plan document stated that natural surface:

> *Mountain Bike and Equestrian trails are well established on the site and are fairly well organized west of the river. Users on the west side of the river find a complex network of equestrian and bike trails which pedestrians share. Bike trails range in width from less than a foot to nearly eight feet. Horse trails are significantly wider in most parts, but may be as narrow as three feet wide in some areas.*
>
> *Trail conditions vary. Some well-established trails meander over slopes and drain well without soil disruption. However, during rain events, some trails have low spots that collect water or soils that erode and make their way into the river. Trails that meander along the riverbank often come dangerously close to the river and erosion is a problem in many of these areas.*

The Master Plan recommended separation of natural surface mountain bike and equestrian trails and parking facilities, with approximately five miles reserved for each use group. Pedestrian use would be allowed on all trails, with a few trails for sole use by pedestrians. Costs for trail-related improvements were estimated to be approximately $470,000 for the currently developed portion of the park west of the Yellow River.

While the Master Plan stated that all the existing trails in the park may not have been inventoried, it does recommend retaining approximately 60% of the existing routes into the official trail system, with realignment to provide use separation and reconstruction to improve sustainability on the remaining 40% of the trail system length. The Master Plan does not provide design or construction specifications for the trails, and a look at the

BACKGROUND

current incarnation of the trails indicates that those specifications are dissimilar from the socially developed trails, either those existing at the time of the plan development or developed since.

The Master Plan similarly recommends a trail signage system to aid in the regulated separation of use. Currently, the signage program primarily consists of map/regulatory kiosks, intersection navigation, and blazed trees. The numerous socially developed trails are blazed with white open circles with a "do not use" cross. Hazard trees are also blazed.

While the Master Plan recommends approximately 12 miles of natural surface trails in Yellow River Park, a recent inventory demonstrates more than 22 miles. Some of these trails likely existed prior to the Master Plan-recommended trail system, and others have been socially developed since the County began implementing the Plan.

The trail system growth has led the County to question whether the Master Plan goals are being met and secured professional consulting services to assess that condition and provide recommendations on redevelopment or management alterations necessary to better meet the original goals of the Yellow River Park trail system.

PURPOSE AND NEED

Gwinnett County hosts a large and diverse park system, with a number of large acreage, open space parks that provide considerable natural surface trail recreation. Guiding principles for the Parks and Recreation Division (GCPR) focus on excellence, specifically stated as:

> ***Mission Statement***
> *In partnership with our citizens, Gwinnett County Parks and Recreation provides high quality, broad-based parks, facilities, programs, and services creating a sense of community, enabling a safe and secure environment, and enhancing Gwinnett's quality of life.*
>
> ***Vision Statement***
> *Gwinnett County Parks and Recreation pledges to sustain the delivery of the highest standard of excellence of parks, facilities, programs and services by:*
>
> - *Being responsive to the changing recreational needs of a diverse and growing community*
> - *Continue a citizen-driven and professional approach to provide safe, well designed and maintained facilities and programs*
> - *Providing responsible stewardship of human, fiscal, natural and historic resources*
> - *Maximizing community resources*

The purpose of this trail assessment and redevelopment planning process is to assist the County in making management decisions that fulfill the goals of the Mission and Vision Statements and Yellow River Park Master Plan as they relate to trails in the park. An extensive field assessment of the entire trail system, followed by discussions with GCPR officials and interested stakeholders, helped to distill the major issues that are hindering the efficient management of the park's trail resources. The needs that must be addressed in the trail system are outlined below and covered in more detail in Alternatives section.

Trail Proliferation
The public's lack of compliance with the Master Plan-recommended trail system is a signal that either 1) the GCPR is not managing the Yellow River Park trail system in a manner that satisfies the changing recreational needs of this community, or 2) there were flaws in the recommendations put forth in the Master Plan.

The current trail system, with almost twice the mileage originally envisioned, has led to the creation of dozens and dozens of intersections that make navigation difficult at best. In the context of incident response for Park or emergency management personnel, the socially developed trail system is a major and potentially dangerous hindrance.

PURPOSE AND NEED

Use Separation

The Master Plan called for separated trails for horses and mountain bikers with approximately five miles open to each use. Yellow River Park's trail system was formalized in 2002 prior to the trail systems in other open space parks in the County, including Harbins and Little Mulberry, that provided additional trail opportunities for these use groups. It can be inferred that recreational pressure from both mountain bike and equestrian users was expected to rise when the Master Plan was created and that this idea helped guide the decision to separate uses and create separate trailhead facilities.

With significant infill development in the Yellow River Park vicinity and the development of larger equestrian trail systems at other open space parks, equestrian visitation has decreased and the horse trailer-friendly parking lot has become known as a regular site for illicit activity. On the park's trails, it is clear that use separation is not occurring, with regular signs of horse use on mountain bike trails and vice versa, both with little reported conflict. The sum of these conditions has led the GCPR to question whether the trail system is meeting the needs of park visitors, creating undo confusion, and/or how to better manage and regulate use.

Environmental Stewardship

The Yellow River Park trails have a number of physical sustainability-related issues and the proliferation of non-system trails raise the question of the overall trail "footprint" in the park and whether this open space landscape is being stewarded in the most responsible manner. These issues originated in the design standards and construction specifications from both members of the public that have created trails on this property and the GCPR in implementing the Master Plan recommendations.

The slopes in the park are quite suitable (with the notable exceptions of the Yellow River floodplain and banks) for trails, and the soils are very durable when combined with proper design and construction. In fact, the durability of the soils has slowed the rate of trail incision on many alignments that exceed a sustainable grade. The resulting erosion and deposition has been difficult to detect as major "blow outs" have not been frequent. However, this degradation is taking place on both official and non-official trails. The results are trails that carry stormwater, entrain sediment to the Yellow River or create deposition areas that become muddy and often exceedingly wide, and degrade the intended trail experience.

Recreational Desires

It is clear, from the lack of compliance with regulated use and the proliferation of non-system trails, that recreational desires are not being met. The GCPR has stated a need for trails to be at least six feet wide to accommodate maintenance and emergency response vehicles. Avid trail users have clearly stated their opinion that the trail realignment and reconstruction implemented by GCPR is the major cause of trail-related erosion while also degrading the quality of the trail experience by creating unnecessarily wide trails. They feel that their response of using/creating narrow, non-system trails is both meeting their recreational desires and decreasing user-caused impacts on the system trails.

DECISION FRAMEWORK

This document provides an assessment of the current conditions of the Yellow River Park trail system and a conceptual redevelopment plan to rectify the current trail system's problems. The assessment is, in effect, an objective snapshot of the current trail system. The findings do not take into account the system that was present prior to the park's ownership by GCPR, nor does it attempt to ascertain any cause-effect relationships regarding trail construction and maintenance by the GCPR or social trail development since the implementation of the park's Master Plan. The assessment does not attempt to qualify whether any of the trail maintenance activities meet a specification provided by the County.

The conceptual redevelopment alternative presents a trail system with qualities that the consulting team believes 1) best meets GCPR's needs in the sound management of the park's natural resources and 2) improves the trail experience for a broader and more diverse demographic of park visitors. The conceptual plan is not a field verified design and could not be used for the development of construction estimates.

The conceptual plan does not represent a decision for the future of the trails at Yellow River Park, nor does it serve to allocate funds to the park's trails. The implementation of recommendations included in this plan depend on the GCPR's consideration of them as viable alternatives from capital improvement, manpower, and overall prioritization standpoints. It is also dependent upon the opinions of public stakeholders regarding the proposed changes. Perhaps most salient, it will depend upon decision makers' willingness to invest public dollars for a project that has already seen considerable investment.

Realizing a positive change to the Yellow River Park trail system will depend on an improved collaborative relationship between the County and the park's trail users. There appears to be significant and justified levels of mistrust from both parties. These issues will have to be dealt with in an open, conscientious manner and a decision to move forward will require a high level of commitment from both the GCPR staff and stakeholders. If achieved, the best practices demonstrated in a retrofitted Yellow River Park trail system could extend to other Gwinnett County trail systems and result in County-wide improvements in trail sustainability and environmental quality. Finally, creating a modern, professionally developed trail system at Yellow River Park could better serve more visitors and help highlight the conservation success the County achieved in permanently protecting this high quality landscape.

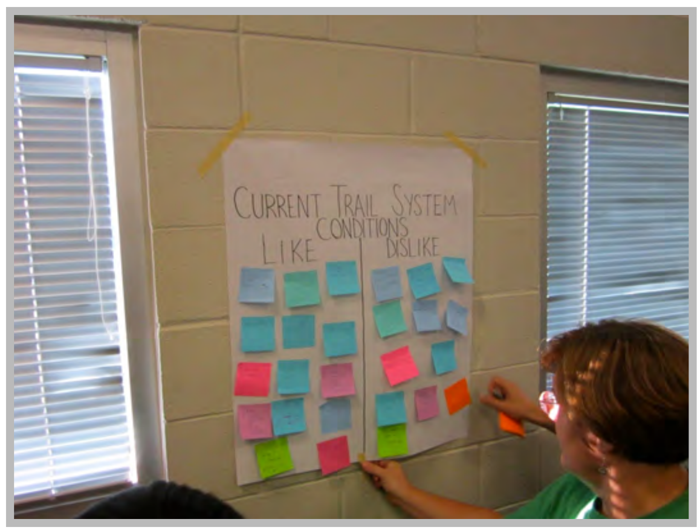
PUBLIC INVOLVEMENT

The consulting team met with GCPR officials in February, 2012 to gather initial opinions regarding issues they deemed to be a challenge with the Yellow River Park trail system. During the field assessment process in May, 2012, a meeting was held with GCPR decision makers to expand upon these initial concerns and confirm that the assessment process was moving forward in a manner that would address those concerns.

Following the field assessment and visits to other Gwinnett County open space parks with similar trail systems, a public meeting was held on the evening of Thursday, May 17 at the Mountain Park Aquatic Center. The meeting was broadly advertised on signs at each open space park trailhead, in the reception message on the GCPR phone system, and via a number of internet message boards. Along with the consulting team, approximately five GCPR officials and 30 interested stakeholders attended.

The stakeholders were provided the opportunity to provide their opinions of the Yellow River Park trail system from a number of different standpoints, including:

- Mode of travel, general skill level, estimated visit frequency, and duration
- Likes and Dislikes of the current trail system
- Opportunities and Challenges related to the trail system
- Ideas regarding the “optimal” trail system



Participants in the exercise were not limited in their number of responses, nor were they required to provide responses for all of the questions. The responses were tallied, with some level of generalization necessary to provide for logical grouping of ideas, and are presented below.

PUBLIC INVOLVEMENT

Table 1. Use Type and Skill Level

Use Type	*Skill Level*	*Number of Respondents*
Hiker/Walker	Beginner	6
	Intermediate	7
	Advanced	7
Mountain Biker	Beginner	2
	Intermediate	8
	Advanced	6
Trail Runner	Beginner	2
	Intermediate	2
	Advanced	1
Equestrian		2
Dog Walker		3
Paddler		3
Playground User		1
Mountain Scooter		1
Listed Multiple Use Types		5

PUBLIC INVOLVEMENT

Table 2. Visit Frequency

Visit Frequency	*Number of Respondents*
Five to seven visits/week	6
Two to four visits/week	17
One visit/week	6
One to two visits/month	4
A few visits/year	4

Table 3. Visit Duration

Visit Duration	*Number of Respondents*
Less than one hour	1
One hour	10
One to three hours	19
More than three hours	4

PUBLIC INVOLVEMENT

Table 4. Likes of Yellow River Park

"Likes" of Yellow River Park	Number of Respondents
Extensive network and variety of trails	10
Natural setting and river views	6
Challenging trails	4
Historic, "old" system of trails	3
Everything, "perfect as it is"	3
Smooth trails (w/o rocks for horses/equestrians)	1

Table 5. "Dislikes" of Yellow River Park Trails

"Dislikes" of Yellow River Park	Number of Respondents
Confusing navigation, signage, intersections	11
County alterations to the trails	7
Erosion on wider trails	5
Lack of advanced mountain bike trails	2
Overbuilt, slippery bridges	2
Lack of access across Yellow River	1
New trails being cut by mountain bikers	1
Horse use designation	1
Lack of wildlife	1
Lack of solar lights	1
Nothing	1
Can't recommend trail system to new visitors	1

PUBLIC INVOLVEMENT

Table 6. Opportunities at Yellow River Park

Opportunities at Yellow River Park	*Number of Respondents*
Developing trails on the other side of Yellow River	4
Well-marked trails for a variety of skill levels	2
Many miles of trails	2
Improved signage/navigation	2
“Don’t change it/anything”	2
Enhanced mountain bike trails and trail features	1
Mountain bike races	1
Plant community preservation	1
Better separation from surrounding neighborhoods	1

Table 7. Challenges at Yellow River Park

Challenges at Yellow River Park	*Number of Respondents*
Navigation, signage, intersection abundance	4
Maintenance, erosion issues	2
Relatively small park for many activities, types of trails	2
Providing, identifying skill levels of trails	1
Lack of bridge over Yellow River	1
Insufficient paddling access to Yellow River	1
County’s lack of understanding of trail users and their desires	1
No drinking water for horses	1
Degrading condition of overflow parking lot (i.e. paver condition)	1

PUBLIC INVOLVEMENT

Table 8. Optimal Recreation Experience

Optimal Recreation Experience	*Number of Respondents*
Diverse and challenging mountain bike trail system	11
Natural experience (views, wildlife, tranquility)	9
Ease of navigation/choice of experience	5
Variety of trails in one place	6
Aerobically challenging workout	5
Narrow trails/singletrack	5
Smooth trails	2
Good stream crossings	2
Etiquette education/regulation	1
Convenient paddling access	1

PUBLIC INVOLVEMENT

ASSESSMENT & ALTERNATIVES

Discussions with GCPR staff and public meeting participants confirmed many of the issues identified by the consulting team during the field assessment. Government officials and public stakeholders had somewhat different ideas regarding the seriousness of different issues and prioritization of rectifying those issues. In moving forward to create a sustainable trail system, all pertinent issues should be addressed to optimize the trail system for management by Gwinnett County and use by the public.

Four alternatives for the future Yellow River Park trail system were considered in this process, including:

- **Master Plan Trail System**
- **Current Trail System**
- **Retrofitted Shared-Use Trail System**
- **Retrofitted Segregated-Use Trail System**

Trail system sustainability has three different aspects- the physical, social, and managerial. A sustainability assessment of the first two alternatives was undertaken by extensive field reconnaissance and spatial analyses of trail grade, slope ratio, trail system footprint, and navigability. The Retrofitted Trail System options include conceptual projections of these sustainability aspects, based on specifications provided for trail design and construction of the retrofitted trails. The sustainability metrics for each alternative are objectively compared, and a recommended alternative is provided for consideration along additional opinions a relative to improvements in the recreational quality and visitor experience of a potentially retrofitted trail system. Finally, an implementation recommendation and cost opinion are presented to facilitate and capital/human resource comparison of alternatives.

Physical Sustainability
Physical sustainability of a trail relates most closely to its position on the landscape and the subsequent ability to manage water and limit sediment movement- erosion and deposition. Trails located on the fall line or on exceedingly flat areas incur numerous problems in this regard and result in both natural resource impacts and a degraded recreational experience. A physically sustainable trail system is a goal of the Yellow River Park Master Plan, primarily reflected as minimizing natural resource impacts and providing high quality construction of park facilities and secondarily in providing safe facilities and high quality recreation.

The relationship between trail gradient and landscape gradient can be quantified through a Trail-Slope Analysis. The slope of the trail is divided by the topographic slope. Slope ratios between 0.50 and 1.00 indicate a trail with grades more than half the adjacent slope, a relationship that makes functional water management very difficult. The analysis has been completed for the Master Plan Trail System and the Current Trail System to provide a comparative measure of each system's physical sustainability.

Social Sustainability
The social sustainability of a trail system relates to how the public interacts with the trail opportunities that are provided. Sustainability levels decrease when trail users leave the trail, have conflicts with other visitors or

facilities, or don't visit the park at all. Issues with social sustainability include trail system design and construction mistakes that degrade the natural experience or create potential use conflict hotspots, overcrowding, navigation-related problems, and introduce external factors that degrade the trail experience (i.e. trail location adjacent to busy roads, under power lines, etc.).

Each of the trail system alternatives presented are quantified in two manners that allow a comparison relative to social sustainability factors. First, each alternative is compared by the number of trail intersections, as this factor relates closely to the most important concerns raised by Gwinnett County (social trail development) and recreationists (navigation). Second, each alternative has been quantified by an approximate "trail footprint". The footprint of a trail system directly relates the length and width a trail system by acreage of the park area where trails are located. Together, these metrics directly relate to Master Plan goals of providing safe and high quality park facilities and indirectly to the goal of minimizing natural resource impacts.

Managerial Sustainability

Managerial sustainability is defined by the ability of an agency and/or volunteers to efficiently and economically adhere to the standards and specifications developed for the trail system. This includes trail tread and corridor maintenance, risk management, signage and trailhead facility upkeep. When trail maintenance is conducted in a manner that does not rectify the problem addressed, active logs of risk and/or maintenance assessment are not maintained, signage is confusing or missing, or trailheads are degraded or pose a security issues, significant negative impacts are realized that are in direct opposition to the Master Plan goals of construction quality, safety, recreational quality, and natural resource conservation.

The most objective and direct measure of managerial sustainability is the amount of capital required to maintain trails. Quite often, maintenance budgets are based solely on cumulative mileage of trails. However, it is more accurate to judge the maintenance need by length, width, and the relationship between the trail tread gradient and landscape gradient. The wider the trail, the harder it becomes to move water off it, the longer it takes to complete the work, and the more specialized and expensive the trail maintenance equipment. The closer the trail gradient is to the landscape gradient, the more difficult it is to move water off the trail and the greater the recurrence interval of maintenance that is required.

To provide an objective comparison between trail system alternatives, the slope analysis from the physical sustainability comparison is multiplied by the mileage of trail within each slope class. The resulting data is then separated and assigned a Trail Class (CL 1-5), relative to the difficulty of trail tread maintenance. A linear relationship is assumed. For instance, a CL 5 slope ratio (essentially fall line) is five times as difficult to maintain as a CL 1 slope-ratio portion of trail. This is not a scientifically verified relationship, but is generally accurate and provides for comparison between different alternatives.

Similarly, trail width and mileage in each width class are multiplied to provide a comparative measure of the effort/efficiency of conducting trail maintenance. Again, this is not a scientifically verified relationship, but is generally accurate. The resulting matrix of objectively measured elements provides a direct comparison of the managerial sustainability of the potential trail system alternatives.

MASTER PLAN TRAIL SYSTEM

MASTER PLAN TRAIL SYSTEM

The Master Plan Trail System was created from trails that were present when the County took over management of what is now the Yellow River Park. Subsequently the County has undertaken maintenance and reconstruction activities on the trails, generally attempting to close eroding, fall-line sections and widening the trails to provide maintenance vehicle access throughout the trail system. The result of these maintenance and reconstruction activities is much more formal trail system than was present before GCPR management- trails are quite wide for natural surface trail treads, very large bridges span much smaller intermittent stream channels, long turnpikes with sidewalls 18+" above grade, and four-sided signs have been set in concrete footers in great numbers.

Highly developed trailhead facilities and mapping/directional components. Note there is "no trail" to the right (above, right)

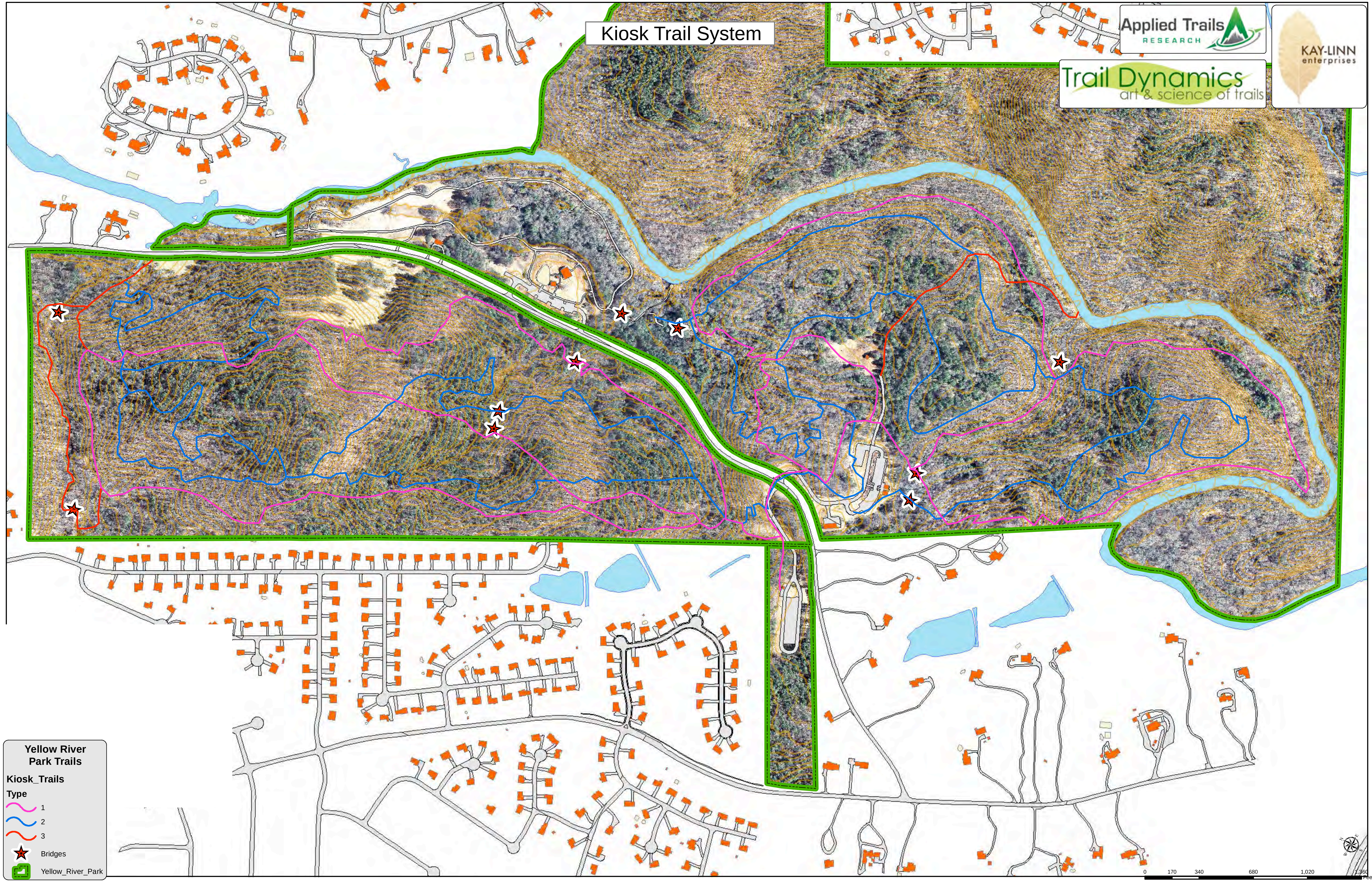
MASTER PLAN TRAIL SYSTEM

Trail Uses and Recreation Provided

Allowed Trail Uses	Hiking, Mountain Biking, Horseback Riding
Mileage Provided/Use	Hiking- 12.5 miles Mountain Biking- 5.8 miles Horseback Riding- 5.1 miles
Recreation Time Provided/ Use	Hiking- ~3.5 hours (@ 3 mph) Mountain Biking- ~1 hour (@ 6 mph) Horseback Riding- ~ 1 hour (@ 4-5 mph)

Trail Specifications

Difficulty Rating	None
Typical Tread Width (estimated from field assessment)	10’ (Equestrian), 8’ (Hiking), 6’ (Mountain Bike)
Typical Corridor Width	10 - 12’
Tread Rugosity	Not Specified
Average Gradient	Not Specified
Maximum Sustained Grade	Not Specified
Maximum Grade	Not Specified
Typical Tread Materials	Natural Surface
Typical Landscape Gradient	Not Specified
Turn Radius	Not Specified
Structure Formality	Not Specified
Duty of Care	Not Specified



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Type
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Bridges
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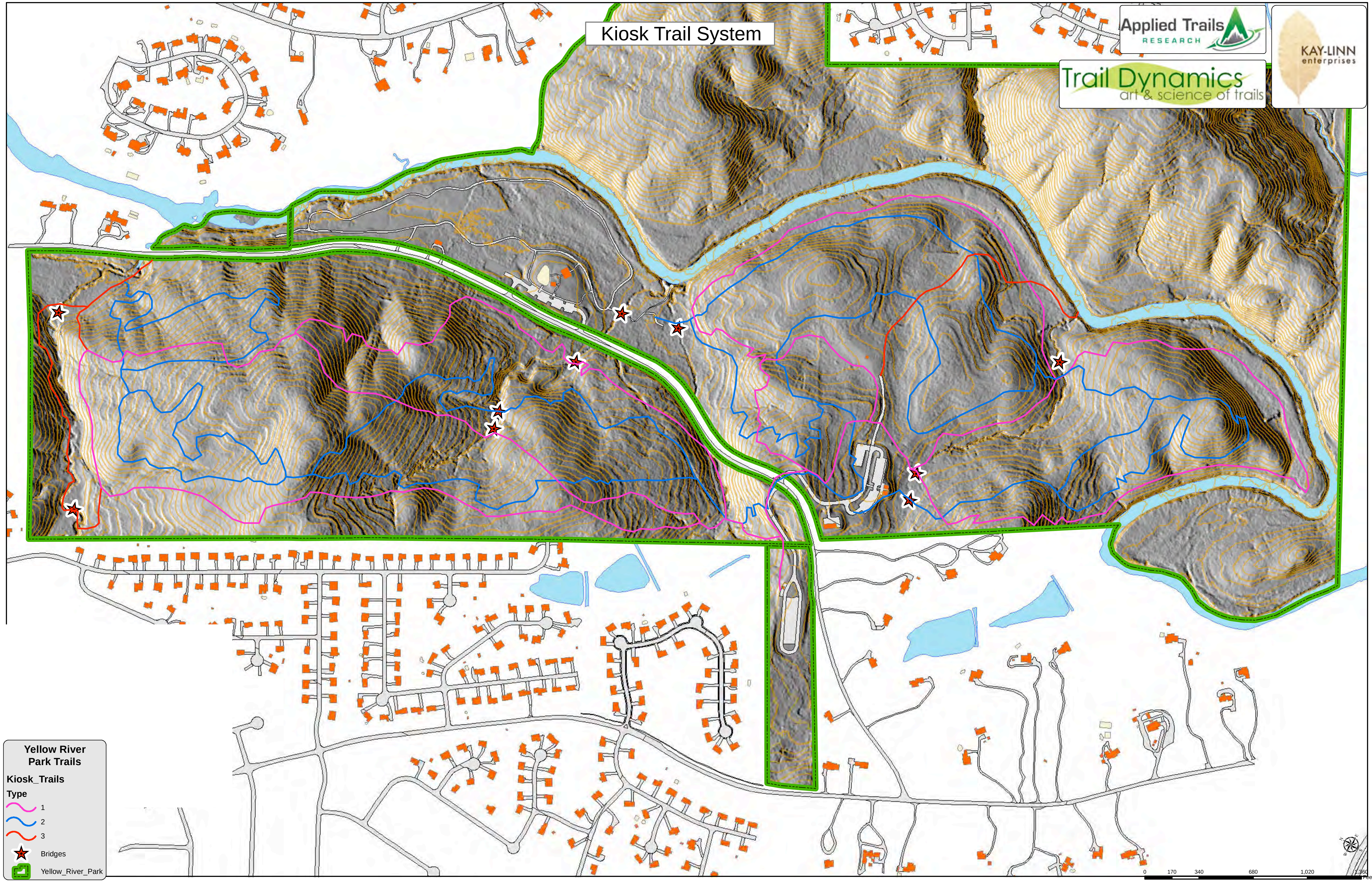
Feet



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MASTER PLAN TRAIL SYSTEM

Physical Sustainability Assessment

Existing Trail Gradients (Miles of trail in each class)

CL 1: 0-3%	3.47
CL 2: 3-5%	1.66
CL 3: 5-10%	3.16
CL 4: 10-15%	2.03
CL 5: 15+%	2.18

Slope Ratio- Trail Gradient/Landscape Gradient (Miles of trail in each class)

SR CL 1: 0.00 - 0.25	2.88
SR CL 2: 0.25 - 0.50	2.23
SR CL 3: 0.50 - 0.75	2.24
SR CL 4: 0.75 - 0.90	1.41
SR CL 5: 0.90+	3.75

Unsustainable Trail Mileage (SR CL 3-5): 7.4

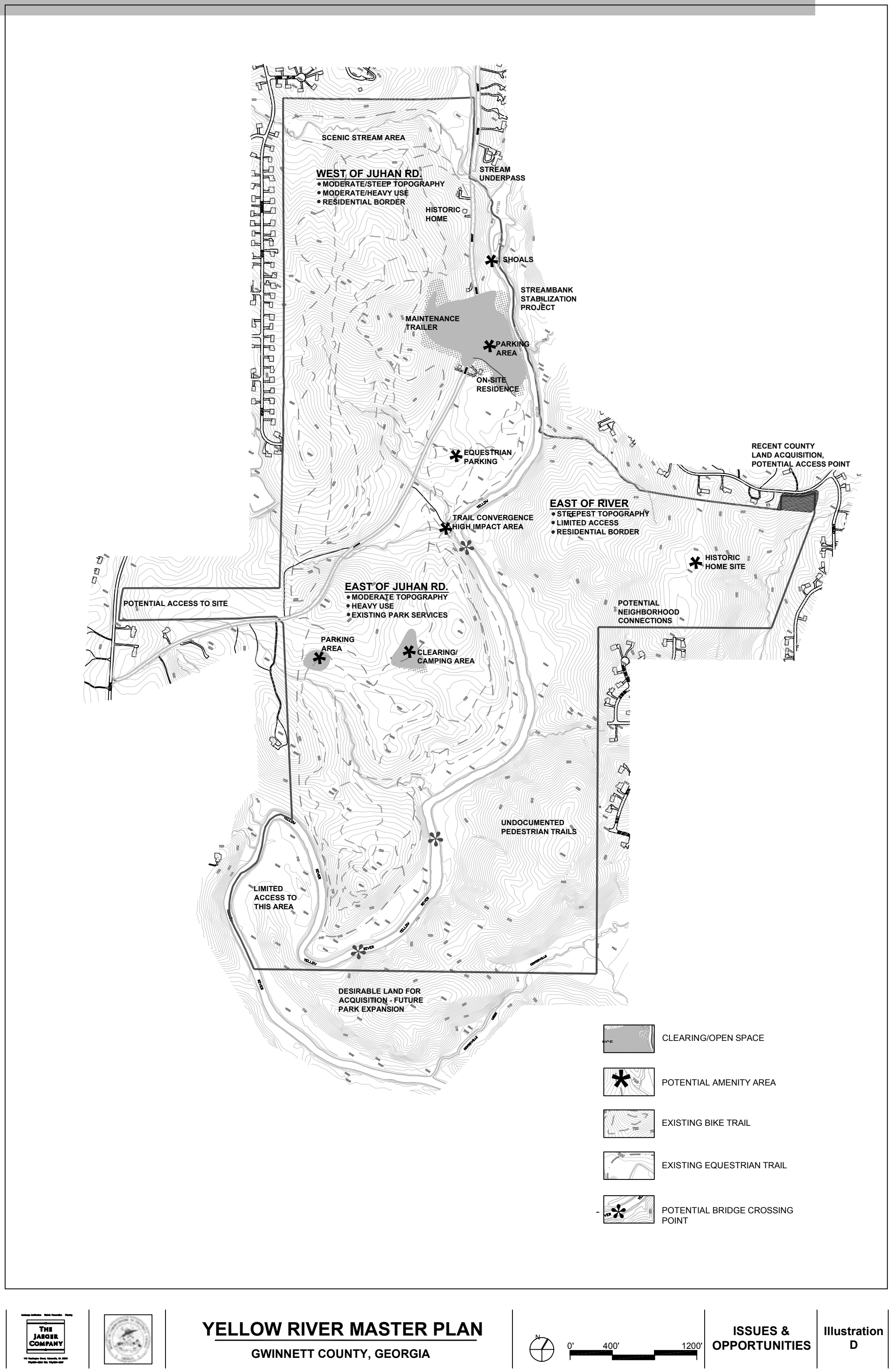
Unsustainable Trail Percentage (SR CL 3-5): 59%

Master Plan trails running down shallow gradients, but on the fall line, are entraining significant amounts of soil, with deposition occurring at the lowest point of the trail, such as this bridge

Significant Issues:

- Unplanned trail system
- No direction on needed reconstruction
- No specifications
- Plan did not indicate existing trails to be removed from the system
- First-developed open space park for Gwinnett County no longer reflects recreation demographics

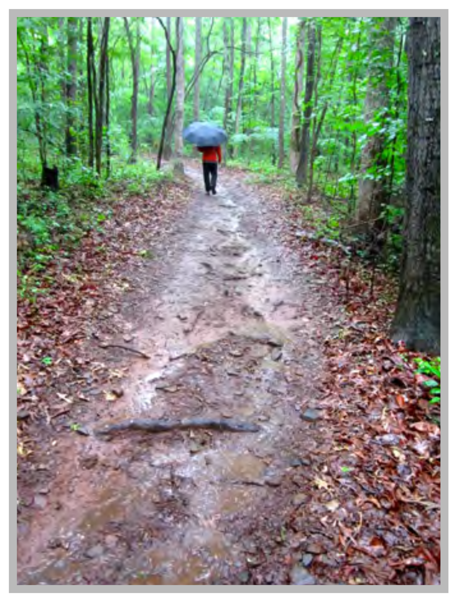
MASTER PLAN TRAIL SYSTEM



MASTER PLAN TRAIL SYSTEM

Left: Fall line trail with indications of incision- organic debris removed from path of flow

Right: Wide trail running down a relatively gentle gradient (~10%), but located directly on the fall line



Left: Flat trail near Group Camp area with no functional drainage

Right: Wide trail with dual erosion channels forming

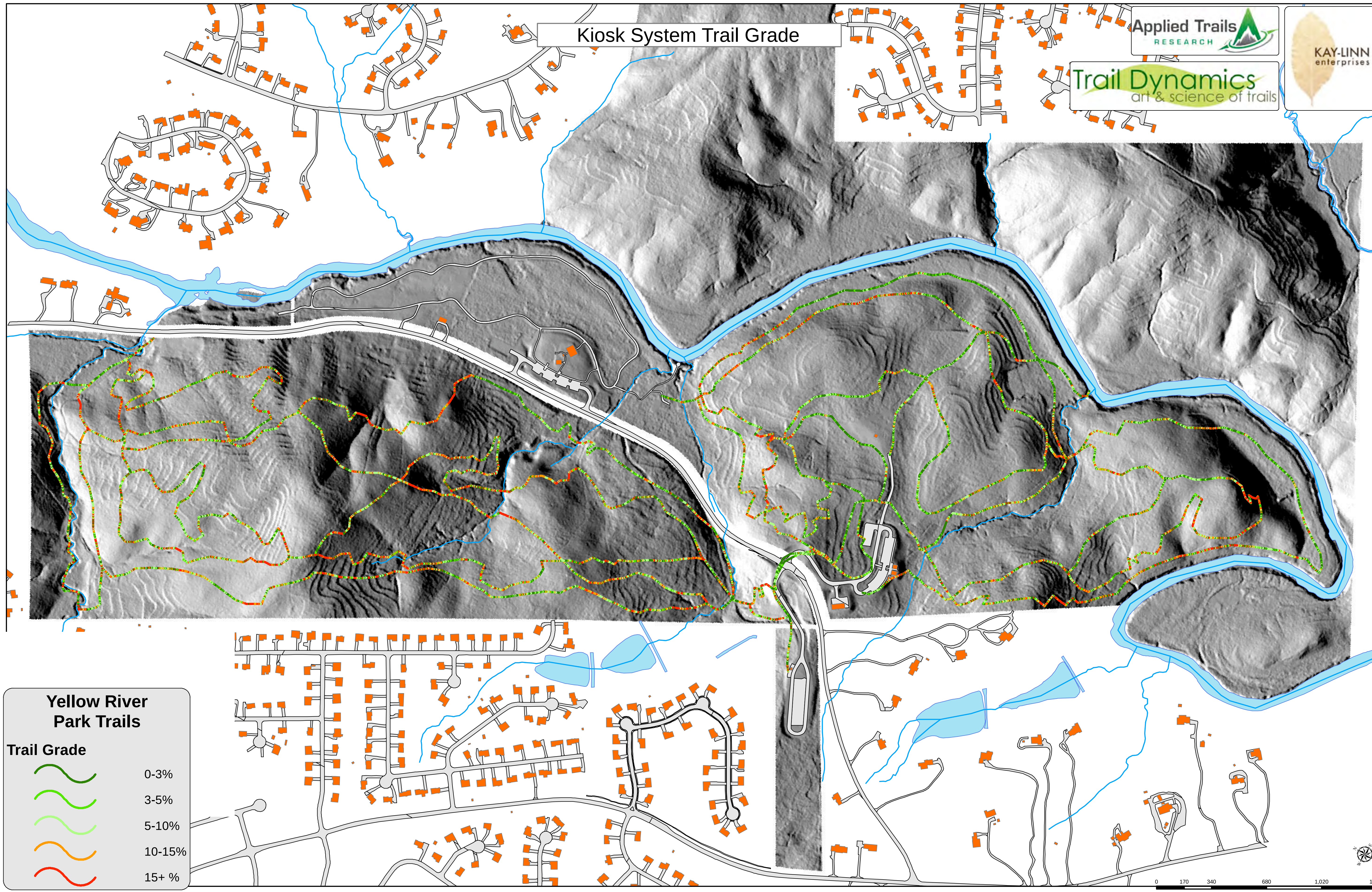
MASTER PLAN TRAIL SYSTEM

Left: Fall line trail, eroding over a width of 6' and depth of 9"

Right: Sediment deposition from trail, piling upslope of tree

Left: Lack of functional drainage and evidence that clay particles have been entrained

Right: Clay-laden runoff draining from the trail into the Yellow River (background)



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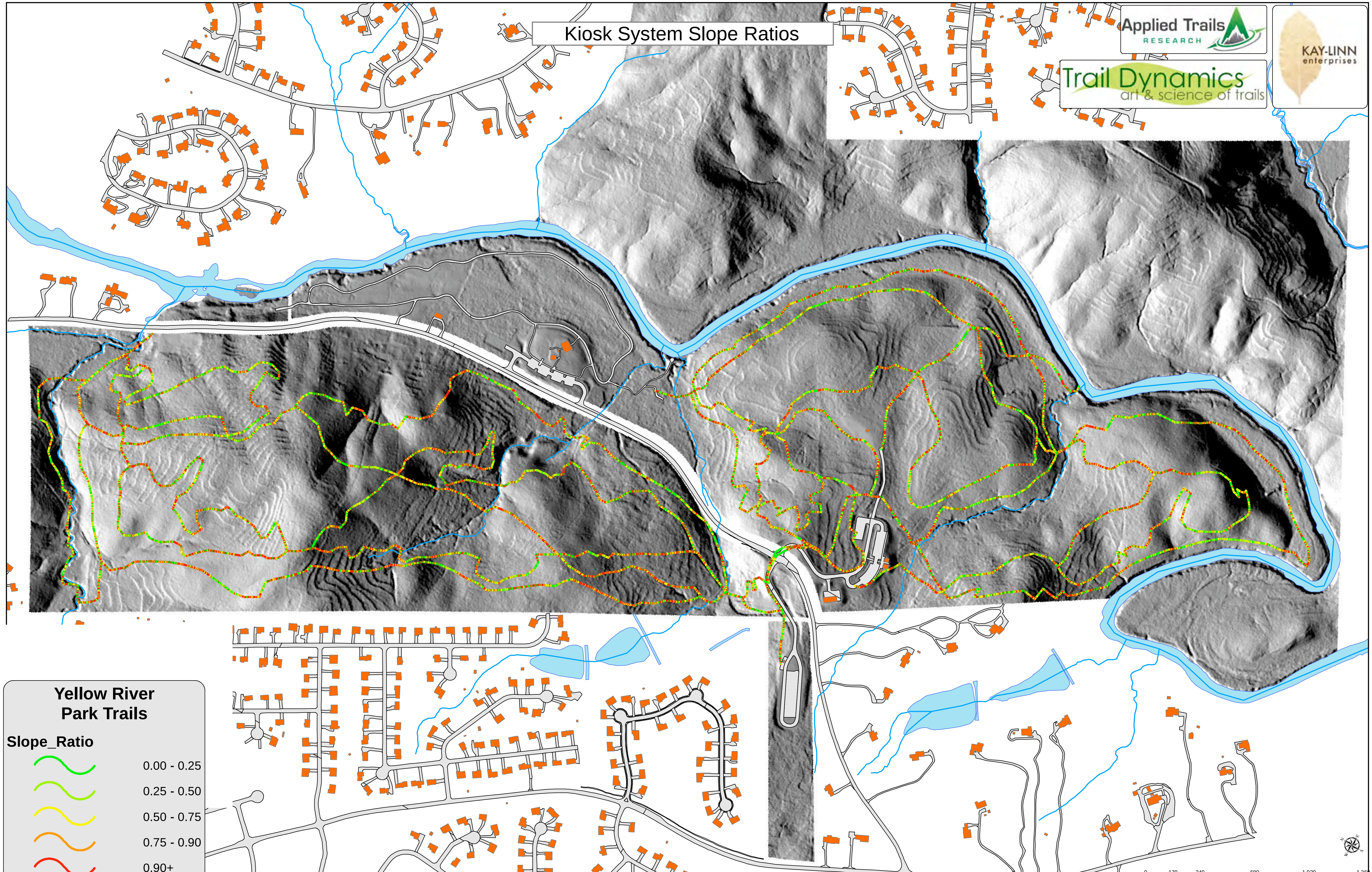
Trail Grade
0-3%
3-5%
5-10%
10-15%
15+ %
0
170
340
680
1,020
1,360
Feet



Kiosk System Slope Ratios
Applied Trails
RESEARCH
Trail Dynamics
art & science of trails
KAY-LINN
enterprises
Yellow River
Park Trails
Slope_Ratio
0.00 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 0.90
0.90+
0
170
340
680
1,020
1,360
Feet

MASTER PLAN TRAIL SYSTEM

Social Sustainability Assessment

Trail Footprint

Trail Length (miles)	12.63
Trail Footprint (acres)	12.08

Shared-use portion of trail on the Master Plan, segregated-use trail system

Navigability/Conflict Potential

Total Intersections	37
Intersections/Mile of Trail	2.93
Intersections Between Use	18

Significant Issues:

- Intersection sign pollution- most intersections have 6 or more signs, and at one location 14 signs were visible
- Many intersections are located where conflict potential is magnified- bottom of descending trails, in close proximity to other intersections
- Trailhead distance/direction signs enhance confusion- trailhead names are not indicated and often two trailhead distance/direction signs occur at a single intersection
- Confusing blazing that redundantly indicate horse-open trail, bike-open trail, shared-use trail, not-a-trail, made further confusing as identified hazard trees are marked with orange-red “X’s”
- “Not A Trail” signs- white circles with a diagonal bar- are far more visible than the blue or orange blazes denoting the official trails. This encourages continued use of the social trails
- Sign iconography is inaccurate and confusing- road cyclist instead of mountain biker, horses jumping in tandem, “family at table”-standard icons are readily available and more widely understood
- Segregated use is inconsistent. Trail sharing still occurs between equestrians and mountain bikers in a few locations
- Hiking-only trail system is difficult to interpret and generally does not provide a hiking-only experience

MASTER PLAN TRAIL SYSTEM

Left: Master Plan map employed at the mountain bike trailhead

Right: Trail intersection placed on fall line

Left: Typical intersection of Master Plan trails, at least 6' wide

Right: Typical trail marker showing road cyclist and horse jumping icons

MASTER PLAN TRAIL SYSTEM

Managerial Sustainability Assessment

Maintenance Difficulty Slope Ratio Class # x Miles of Trail in Trail Slope Class)

	SR CL 1: < 0.25	SR CL 2: 0.25 - 0.50	SR CL 3: 0.50 - 0.75	SR CL 4: 0.75 - 0.90	SR CL 5: > 0.90
Miles of Trail in Slope-Ratio Class	2.88	2.23	2.24	1.41	3.75
Maintenance Difficulty Quotient	2.88	4.46	6.72	5.64	18.75

Cumulative Maintenance Difficulty: 38.45

Maintenance Effort/Efficiency (Maint. Class # x Miles of trail in Maint. Class)

	Maint. CL 1: < 2' wide	Maint. CL 2: 2 - 4' wide	Maint. CL 3: 4 - 6' wide	Maint. CL 4: 6 - 8' wide	Maint. CL 5: > 8' wide
Miles of Trail in Maintenance Class	0	0	5.1	1.6	5.8
Maintenance Effort/ Efficiency Quotient	0	0	15.3	6.4	29.0

Cumulative Maintenance Effort/Efficiency: 50.7

Significant Issues:

- Trail construction/reconstruction has not adequately addressed best practices in water management
- Trail construction/reconstruction have not adequately addressed trail gradient problems
- Trail construction/reconstruction have widened trails to an extent that recreational quality is seriously hindered, potential use conflict is increased, and maintenance intervals must be greater and the efficiency of the work is compromised
- Maintenance practices intending to remove water from the trail tread are largely non-functional
- "Turnpikes" are unnecessarily large, incomplete, and created with questionable materials
- Trail closure attempts are over-engineered- rip rap, silt fence, split rail fence- and less effective than vegetation reestablishment

MASTER PLAN TRAIL SYSTEM

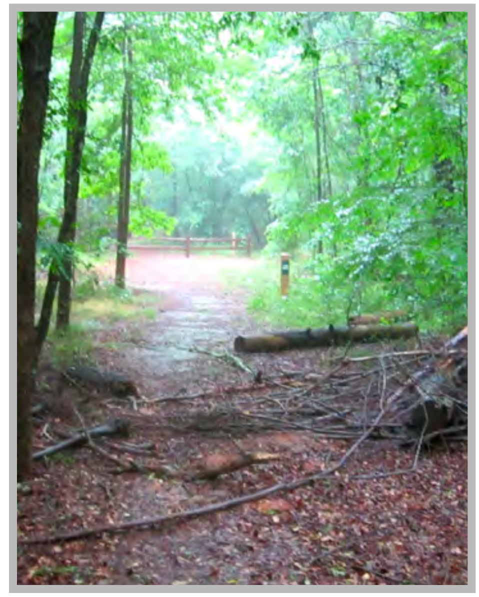
Left: Large water bar, completely filled by sediment

Right: Fall line trail with multiple flow rills, no attempt at water management

Left: "Turnpike" structure, ~9" unfilled and without drainage

Right: Rolling grade dip attempt on fall line- crest not present, drain not gathering runoff

MASTER PLAN TRAIL SYSTEM



Left: Closed trail, no restoration, trail signs not removed

Right: Trail closure, no attempt to close visual corridor, debris not sufficient to remove use

Left: "Turnpike" structure, no functional drainage

Right: Trail closure attempt, rip rap and silt fence but no alteration of drainage pattern, sign still present

MASTER PLAN TRAIL SYSTEM

CURRENT TRAIL SYSTEM

CURRENT TRAIL SYSTEM

The Current Trail System includes the Master Plan Trail System and many miles of socially developed, narrow singletrack trails. Long-time users of the trails state that many of the trails were present when GCPR took over management of the property. It is quite apparent that newer socially-developed singletrack, technical trail features, and neighborhood access routes have developed since GCPR management began.

The socially developed trails are quite informal- unconstructed other than brushing out a trail corridor, multiple parallel routes near the river, very short trail segments leading to an incredible number of intersections, unsigned except for County-installed “Not-A-Trail” white blazes, and technical features haphazardly constructed from nearby materials.

A multitude of signs creates navigation confusion while socially developed trails have many of the same alignment issues as the master plan trails.

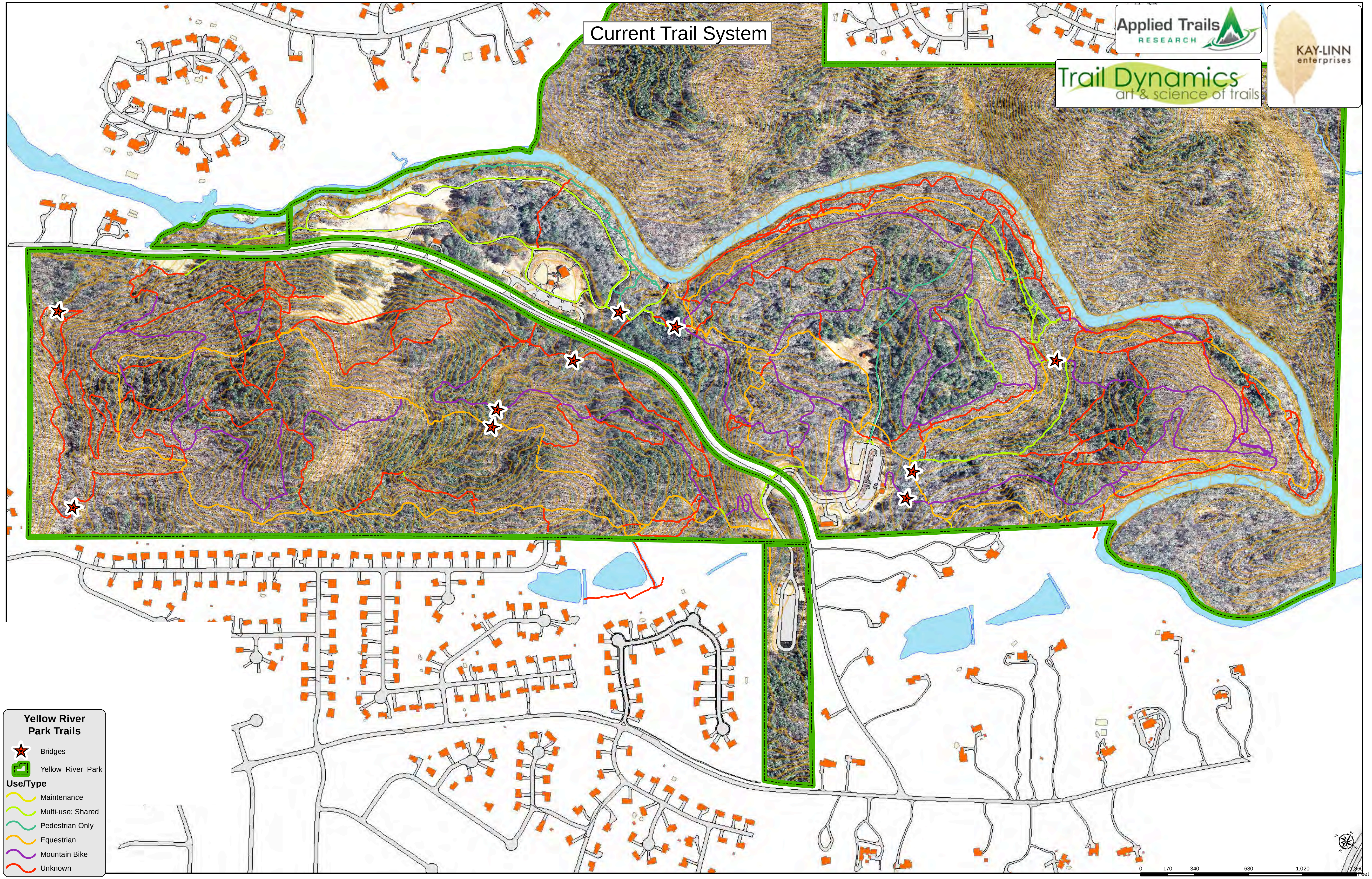
CURRENT TRAIL SYSTEM

Trail Uses and Recreation Provided

Allowed Trail Uses	Hiking, Mountain Biking, Horseback Riding
Mileage Provided/Use	Hiking- 22.33 miles Mountain Biking- 17.23 miles Horseback Riding- 16.93 miles
Recreation Time Provided/Use	Hiking- ~7.5 hours (@ 3 mph) Mountain Biking- ~3 hours (@ 6 mph) Horseback Riding- ~3.5 hours (@ 4-5 mph)

Trail Specifications

Difficulty Rating	None
Typical Tread Width (estimated from field assessment)	10' (Equestrian), 8' (Hiking), 6' (Mountain Bike): Master Plan 2 - 3': Social Trails
Typical Corridor Width	10 - 12': Master Plan Trails 3 - 5': Social Trails
Tread Rugosity	Not Specified
Average Gradient	Not Specified
Maximum Sustained Grade	Not Specified
Maximum Grade	Not Specified
Typical Tread Materials	Natural Surface
Typical Landscape Gradient	Not Specified
Turn Radius	Not Specified
Structure Formality	Not Specified
Duty of Care	Not Specified


Current Trail System
Applied Trails
RESEARCH
Trail Dynamics
art & science of trails
KAY-LINN
enterprises
Yellow River
Park Trails
Bridges
Yellow_River_Park
Use/Type
Maintenance
Multi-use; Shared
Pedestrian Only
Equestrian
Mountain Bike
Unknown
N
E
S
W
0
170
340
680
1,020
1,360
Feet


Current Trail System
Applied Trails
RESEARCH
Trail Dynamics
art & science of trails
KAY-LINN
enterprises
Yellow River
Park Trails
Bridges
Yellow_River_Park
Use/Type
Maintenance
Multi-use; Shared
Pedestrian Only
Equestrian
Mountain Bike
Unknown
0
170
340
680
1,020
1,360
Feet

CURRENT TRAIL SYSTEM

Physical Sustainability Assessment

Existing Trail Gradients (Miles of trail in each class)

CL 1: 0-3%	**7.01**
CL 2: 3-5%	**3.07**
CL 3: 5-10%	**5.34**
CL 4: 10-15%	**2.96**
CL 5: 15+%	**2.94**

Slope Ratio- Trail Gradient/Landscape Gradient (Miles of trail in each class)

CL 1: 0.00 - 0.25	**4.90**
CL 2: 0.25 - 0.50	**4.11**
CL 3: 0.50 - 0.75	**3.99**
CL 4: 0.75 - 0.90	**2.17**
CL 5: 0.90+	**6.16**

Unsustainable Trail Mileage (SR CL 3-5): 12.32

Unsustainable Trail Percentage (SR CL 3-5): 58%

Social trails abound at Yellow River Park, created and used by all manner of park visitors

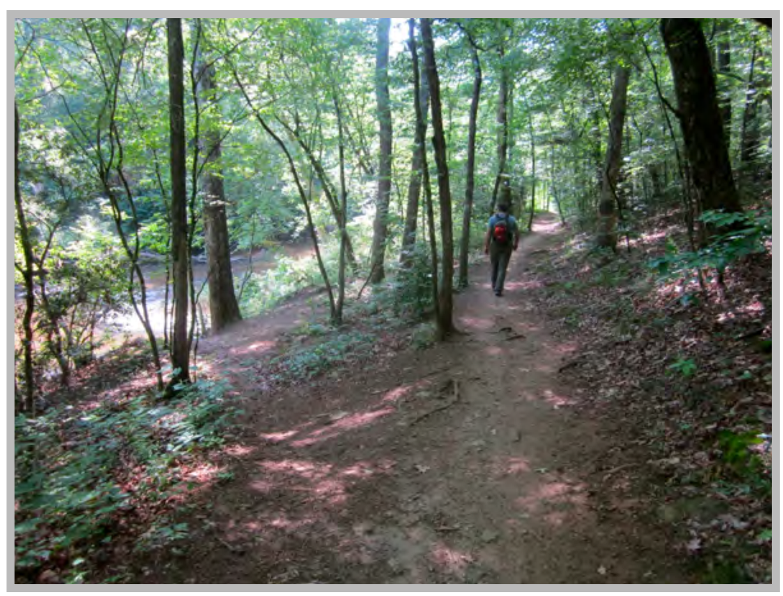
Significant Issues:

- Unplanned trail system
- Significant fall line trail alignment
- Unconstructed (hiked or ridden-in) trails retain organic material and thus moisture
- Unconstructed (hiked or ridden-in) trails compact, become incised, and carry water

CURRENT TRAIL SYSTEM

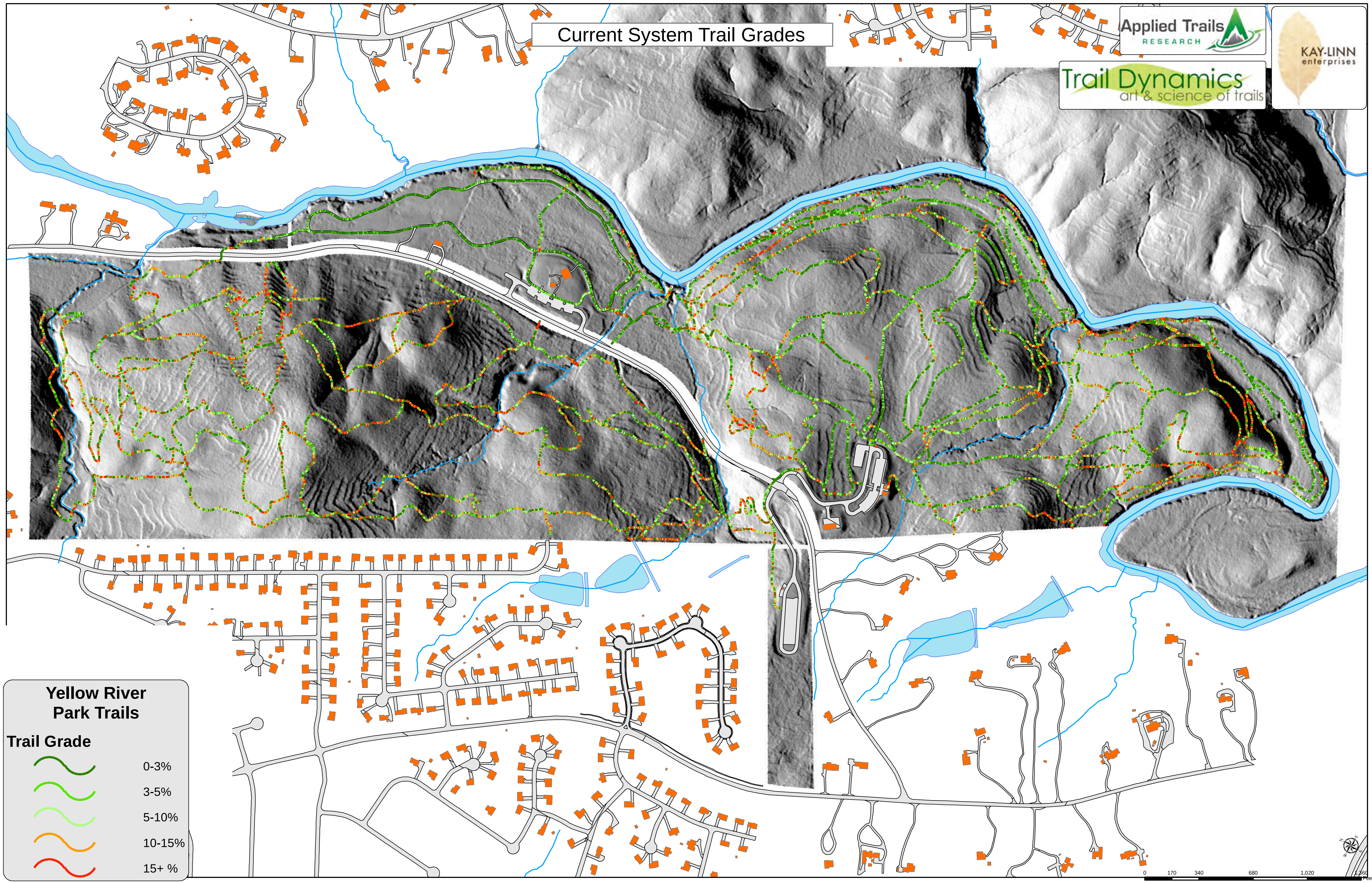
Left: Fall line trail, widening as obstacles become larger as soils are further eroded

Right: One of dozens of fall line social trails intersecting a wide Master Plan trail



Left: Dry drainage crossing widening as roots become more exposed

Right: One of dozens of trail braids present on the floodplain of Yellow River


Current System Trail Grades
Applied Trails
RESEARCH
Trail Dynamics
art & science of trails
KAY-LINN
enterprises
Yellow River
Park Trails
Trail Grade
0-3%
3-5%
5-10%
10-15%
15+ %
N
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S
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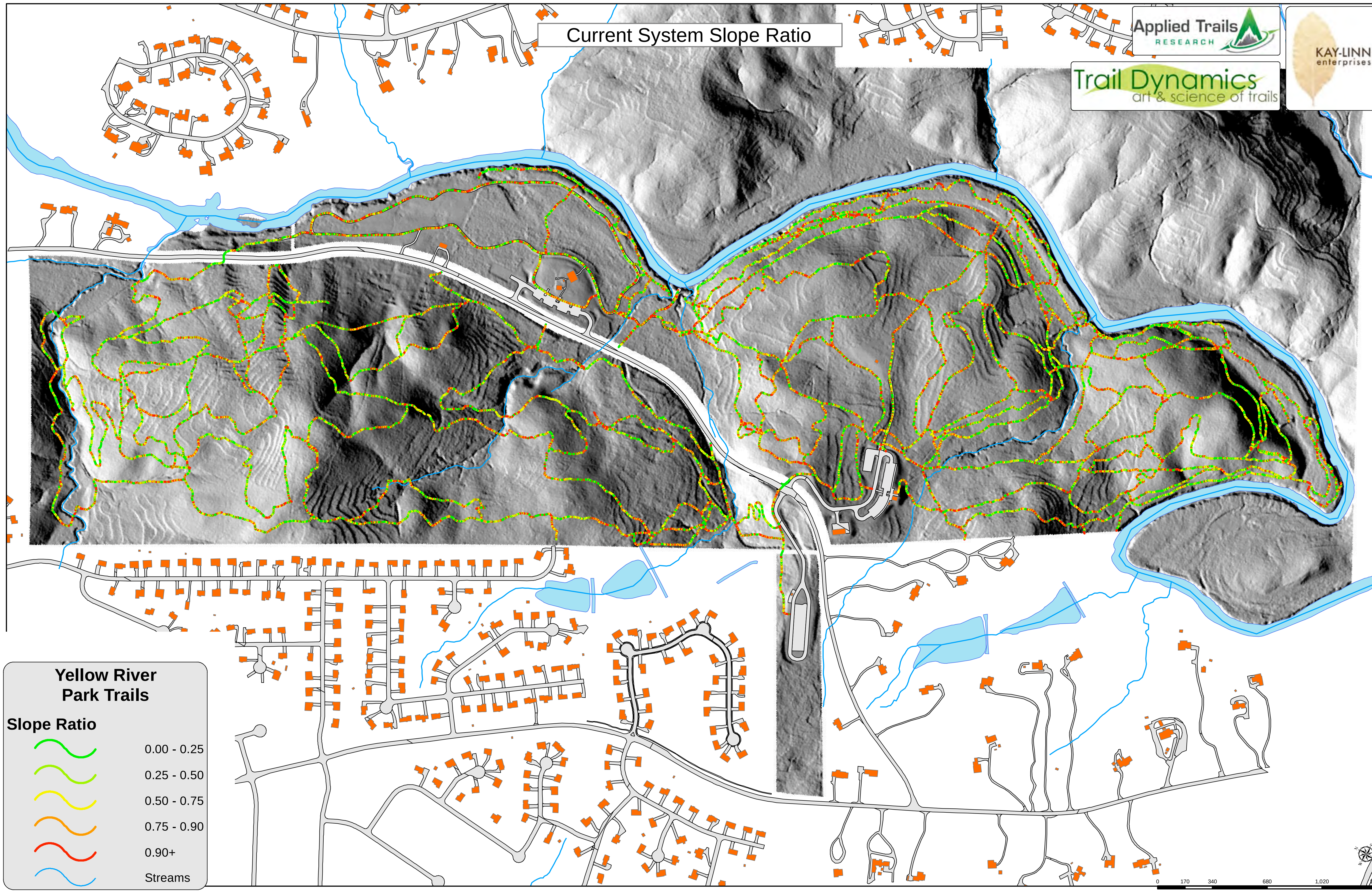
0
170
340
680
1,020
1,360
Feet


Current System Slope Ratio
Applied Trails
RESEARCH
Trail Dynamics
art & science of trails
KAY-LINN
enterprises
Yellow River
Park Trails
Slope Ratio
0.00 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 0.90
0.90+
Streams
0 170 340 680 1,020 1,360
Feet

CURRENT TRAIL SYSTEM

Social Sustainability Assessment

Trail Footprint

Trail Length (miles)	22.33
Trail Footprint (acres)	12.62

Navigability/Conflict Potential

Total Intersections	225
Intersections/Mile of Trail	10.1
Intersections Between Use	225

Socially created stream crossing in a very sustainable, naturally armored location

Significant Issues:

- Impossible system to navigate without many visits and advanced sense of direction
- Lack of compliance with Master Plan use mode regulations introduces additional potential use conflict
- Use of social trails by all use types increases potential for conflicts
- Intersections with official trails are often at the bottom of a descent, increasing potential for startling
- Intersections so numerous that an uninterrupted trail experience (i.e. requiring no navigation choices) is impossible
- Density of trails is very high for a suburban park of this acreage
- New social trail and technical trail feature development gives the impression that additional trails are justified for anybody willing to put forth some time and effort
- Technical trail features are not durably constructed

CURRENT TRAIL SYSTEM

Left: Abundant regulatory signage is present throughout Yellow River Park

Right: A technical trail feature permanently installed near the Group Camp area

Left: Technical trail feature on social trail, minimally constructed

Right: Social trail near Yellow River, with Gator tire tracks in foreground

CURRENT TRAIL SYSTEM

Managerial Sustainability Assessment

Maintenance Difficulty (Slope Ratio Class # x Miles of Trail in Trail Slope Class)

	TSA CL 1: < 0.25	TSA CL 2: 0.25 - 0.50	TSA CL 3: 0.50 - 0.75	TSA CL 4: 0.75 - 0.90	TSA CL 5: > 0.90
Miles of Trail in TSA Class	4.90	4.11	3.99	2.17	6.16
Maintenance Difficulty Quotient	4.90	8.22	11.97	8.68	30.8

Cumulative Maintenance Difficulty: 64.57

Maintenance Effort/Efficiency (Maint. Class # x Miles of trail in Maint. Class)

	Maint. CL 1: < 2' wide	Maint. CL 2: 2 - 4' wide	Maint. CL 3: 4 - 6' wide	Maint. CL 4: 6 - 8' wide	Maint. CL 5: > 8' wide
Miles of Trail in Maintenance Class	0	8.82	5.1	1.6	5.8
Maintenance Effort/ Efficiency Quotient	0	17.64	15.3	6.4	29

Cumulative Maintenance Effort/Efficiency: 68.34

Significant Issues:

- All issues presented in Master Plan Trail System Managerial Sustainability Assessment
- No maintenance visible on social trails

CURRENT TRAIL SYSTEM


Left: Fall line alignment makes maintenance very difficult

Right: Numerous bike tracks on horse trail


Left: Fall line drop over historic terrace

Right: Alternate route developed by horses due to steepness and depth of drop

RETROFITTED, SHARED-USE TRAIL SYSTEM

RETROFITTED, SHARED-USE TRAIL SYSTEM (as proposed by Trail Dynamics)

A potential Retrofitted, Shared-Use Trail System envisions a loop-based system consisting of an outer shared-use (hike, bike, horse) loop on both the creekside and riverside portions of the park and internal shared-use (hike, bike) loops with limited connections to the outer loops. The outer loop would be optimized for less difficult travel, developed wide enough for safe passage, room to hike side-by-side, and longer sightlines to minimize startling potential between trail users.

The riverside inner loops, accessed directly from the mountain bike trailhead, would consist of beginner to intermediate difficulty level trails in three distinct loops emanating from a mountain bike skills development area (pump track and constructed feature trail) located adjacent to the parking lot.

The Creekside internal loops, accessed from the perimeter trail, would consist of intermediate to advanced difficulty level trails in three distinct loops. The westernmost loop would be optimized for hiking use along the scenic stream valley and include a connecting trail to the playground/paved loop trail head. The central loops would be optimized for mountain bike use and include a number of downhill directional mountain bike-only (to minimize conflict potential while maintaining a minimal trail footprint) routes that employ the historic terracing and sustainably constructed features to add excitement and challenge.

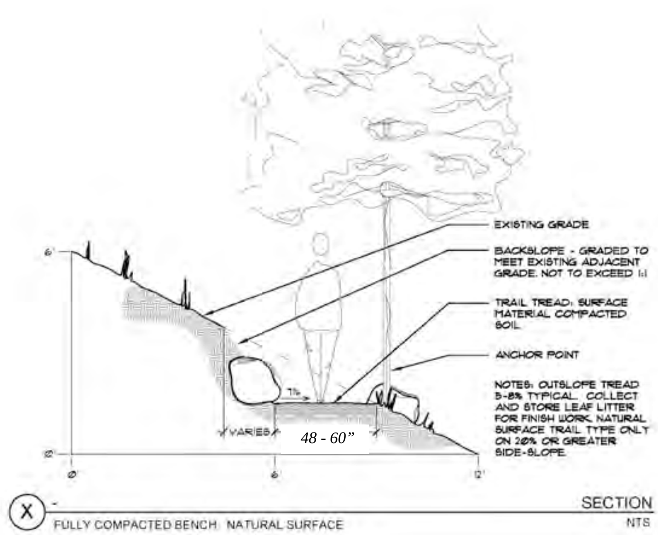
Trail Uses and Recreation Provided

Allowed Trail Uses	Hiking, Mountain Biking, Horseback Riding
Mileage Provided/Use	Hiking- 15.8 miles Mountain Biking- 15.8 miles Horseback Riding- 5.4 miles
Recreation Time Provided/ Use	Hiking- ~5 hours (@ 3 mph) Mountain Biking- ~2.5 hours (@ 6 mph) Horseback Riding- ~1 hour (@ 4-5 mph)

RETROFITTED, SHARED-USE TRAIL SYSTEM

Trail Specifications- Type 1 (Yellow on maps) Perimeter Shared-Use and Less Difficult Loops

Difficulty Rating	Less Challenging
Typical Tread Width	48 - 60” (providing maintenance access)
Typical Corridor Width	60 - 84”, with vertical choke points (trees) never closer than 60”, rock anchor choke points never closer than 48”
Tread Rugosity	Mostly smooth
Average Gradient	< 6%
Maximum Sustained Grade	10%
Maximum Grade	15%
Typical Tread Materials	Natural Surface, hardened with 3/8” surfacing where necessary to maintain a firm trail tread surface
Typical Landscape Gradient	0 - 40% slopes
Turn Radius	Wide, to maintain sight lines
Structure Formality	Formal
Duty of Care	Moderate to High

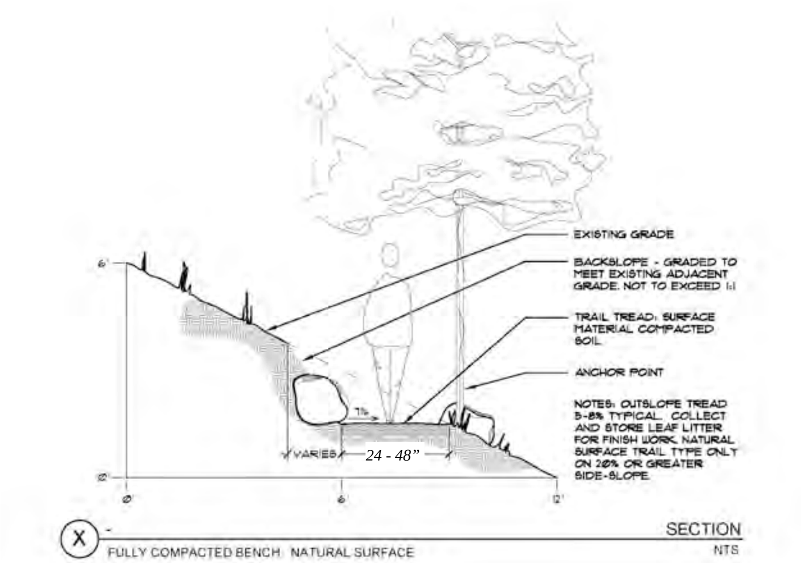


48 - 60”

RETROFITTED, SHARED-USE TRAIL SYSTEM

Trail Specifications- Type 2 (Pink on maps) Internal Shared-Use Loops,More Difficult

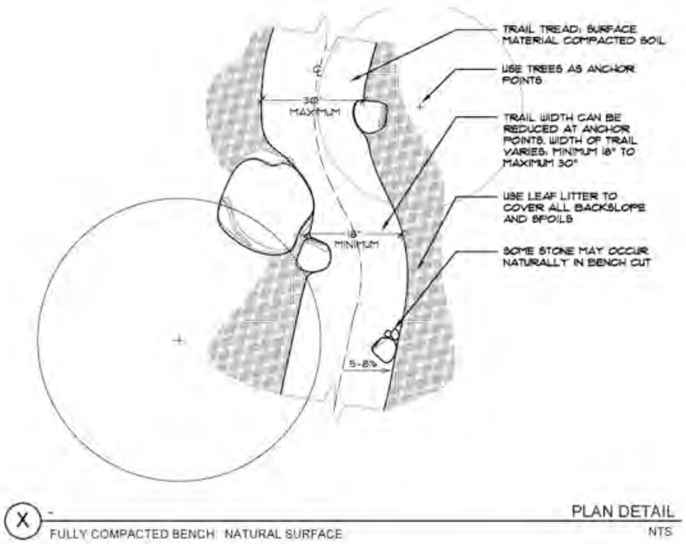
Difficulty Rating	Moderate
Typical Tread Width	24 - 48”
Typical Corridor Width	36 - 60”, with vertical choke points (trees) never closer than 36”, rock anchor choke points never closer than 24”
Tread Rugosity	Uneven, with regular rock and root protrusions above trail tread
Average Gradient	< 10%
Maximum Sustained Grade	15%
Maximum Grade	20%
Typical Tread Materials	Mostly natural surface with some rock armoring of wet and/or steep sections
Typical Landscape Gradient	0 - 50+% slopes
Turn Radius	Tight turns, with possible switchbacks
Structure Formality	Low
Duty of Care	Low



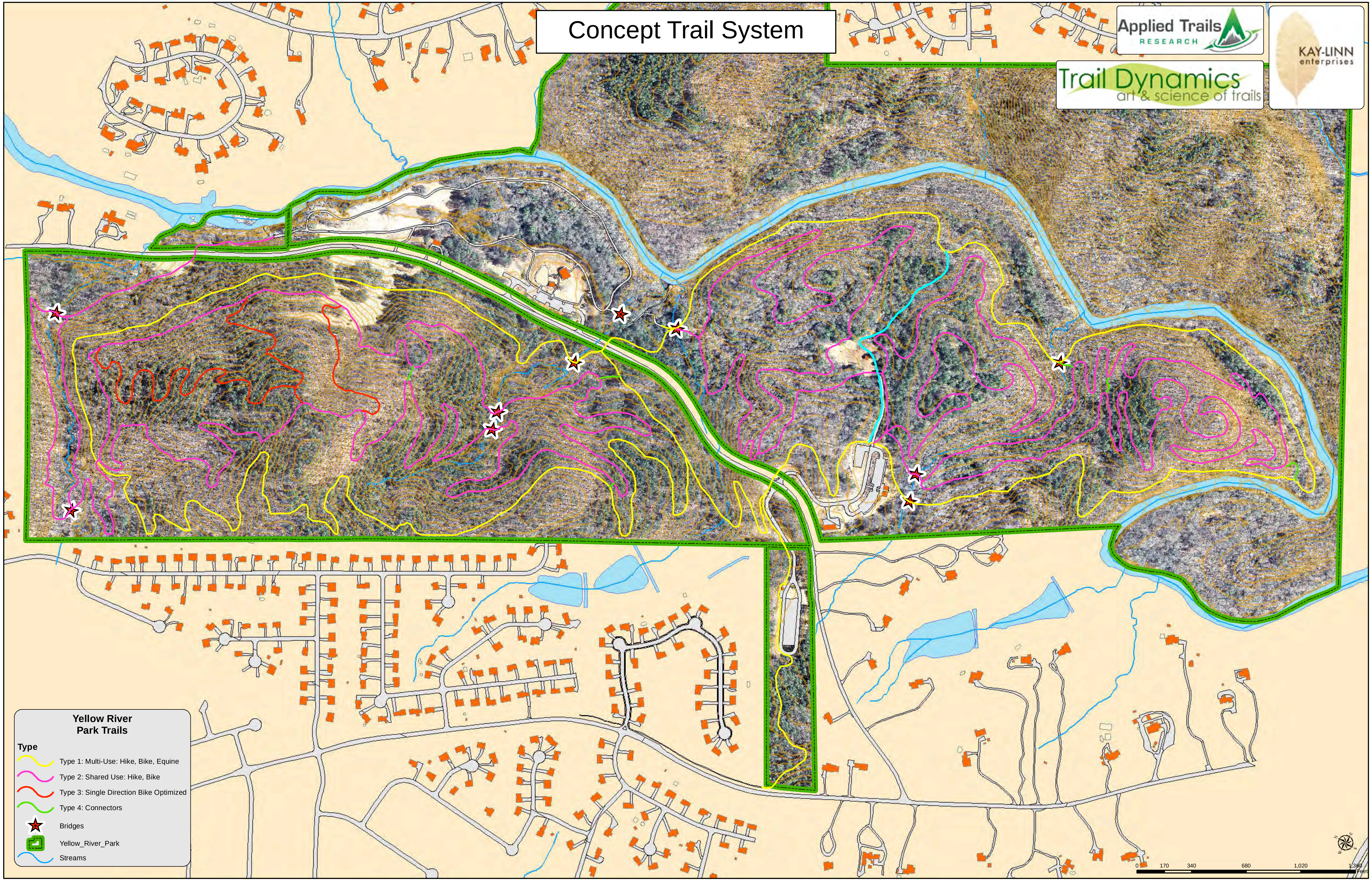
RETROFITTED, SHARED-USE TRAIL SYSTEM

Trail Specifications- Type 3 (Red on maps) Internal Shared-Use Loops, Most Difficult

Difficulty Rating	Moderate
Typical Tread Width	18 - 30”
Typical Corridor Width	24 - 48”, vertical choke points (trees) never closer than 32”, rock anchor choke points never closer than 12” unless providing a mandatory feature in the trail
Tread Rugosity	Rough and uneven, potentially with natural-enhanced or imported materials
Average Gradient	< 12%
Maximum Sustained Grade	20%
Maximum Grade	30%, potentially greater on constructed/terrace descents
Typical Tread Materials	Natural surface, with imported rock armoring of wet and/or steep sections
Typical Landscape Gradient	No limitations
Turn Radius	Tight turns, with likely switchbacks
Structure Formality	Aesthetically Low, Construction Durable
Duty of Care	Very Low, except for regular structure inspection



Trail Dynamics
art & science of trails
KAY-LINN enterprises
Applied Trails RESEARCH


Concept Trail System
Applied Trails
RESEARCH
Trail Dynamics
art & science of trails
KAY-LINN
enterprises
Yellow River
Park Trails
Type
Type 1: Multi-Use: Hike, Bike, Equine
Type 2: Shared Use: Hike, Bike
Type 3: Single Direction Bike Optimized
Type 4: Connectors
Bridges
Yellow_River_Park
Streams
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170
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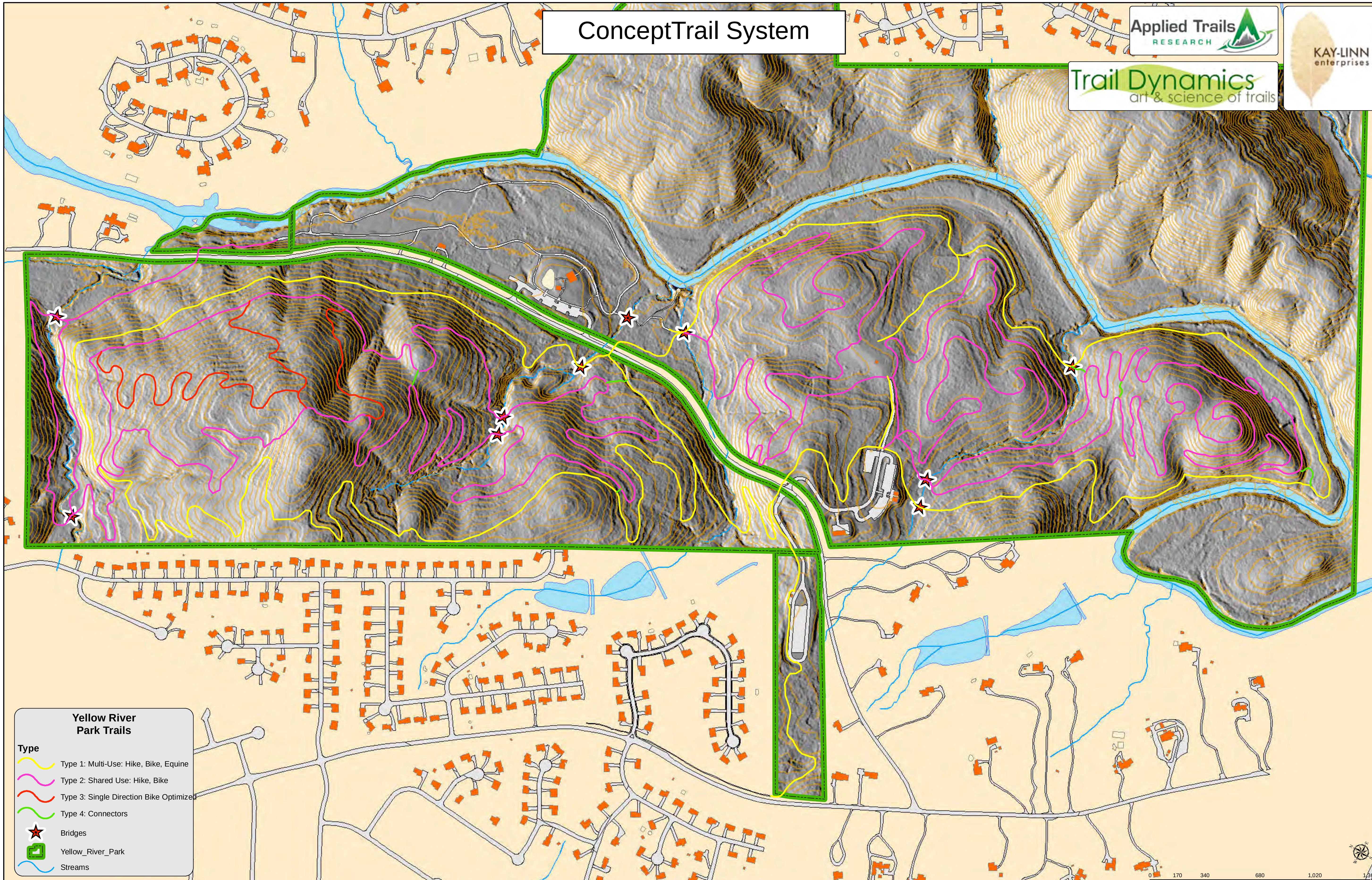
1,360
Feet

ConceptTrail System



RETROFITTED, SHARED-USE TRAIL SYSTEM

Social Sustainability Aspects

Trail Footprint

Trail Length (miles)	15.78
Trail Footprint (acres)	6.73

Navigability/Conflict Potential

Total Intersections	32
Intersections/Mile of Trail	2.03
Intersections Between Use	7

Managerial Sustainability Aspects

Maintenance Difficulty (Slope Ratio Class # x Miles of Trail in Trail Grade Class)

	TSA CL 1: < 0.25	TSA CL 2: 0.25 - 0.50	TSA CL 3: 0.50 - 0.75	TSA CL 4: 0.75 - 0.90	TSA CL 5: > 0.90
Approximate Miles of Trail in TSA Class	5.54	9.29	0.95	0	0
Maintenance Difficulty Quotient	5.54	18.58	2.85	0	0

Cumulative Maintenance Difficulty: 26.97

Maintenance Effort/Efficiency (Maint. Class # x Miles of trail in Maint. Class)

	Maint. CL 1: < 2' wide	Maint. CL 2: 2 - 4' wide	Maint. CL 3: 4 - 6' wide	Maint. CL 4: 6 - 8' wide	Maint. CL 5: > 8' wide
Miles of Trail in Maintenance Class	0	10.36	5.42	0	0
Maintenance Effort/ Efficiency Quotient	0	20.72	16.26	0	0

Cumulative Maintenance Effort/Efficiency: 36.98

RETROFITTED, SHARED-USE TRAIL SYSTEM

RETROFITTED, SEGREGATED TRAIL SYSTEM

RETROFITTED, SEGREGATED-USE TRAIL SYSTEM

The potential Retrofitted, Segragated-Use Trail System envisions loop-based systems for equestrians on the creekside portion of the park and for mountain bikes on the riverside portion of the park. Separating horseback riding and mountain biking with the natural demarcation line of Juhan Road, as the trailhead parking for each use currently exists, would allow for easier regulation of allowed use. This alternative would still minimize intersections and optimize trail mileage/footprint for the property.

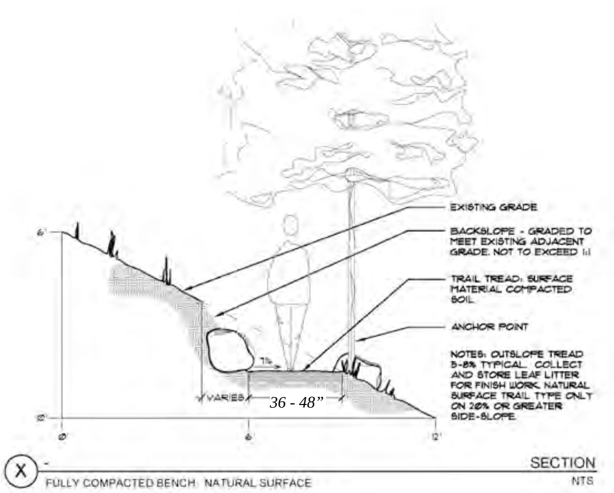
Trail Uses and Recreation Provided

Allowed Trail Uses	Hiking, Mountain Biking, Horseback Riding
Mileage Provided/Use	Hiking- 15.01 miles Mountain Biking- 7.66 miles Horseback Riding- 7.35 miles
Recreation Time Provided/ Use	Hiking- ~5 hours (@ 3 mph) Mountain Biking- ~1.25 hours (@ 6 mph) Horseback Riding- ~ 1.5 hours (@ 4-5 mph)

RETROFITTED, SEGREGATED TRAIL SYSTEM

Trail Specifications- Equestrian Loops (Red on maps), More Difficult

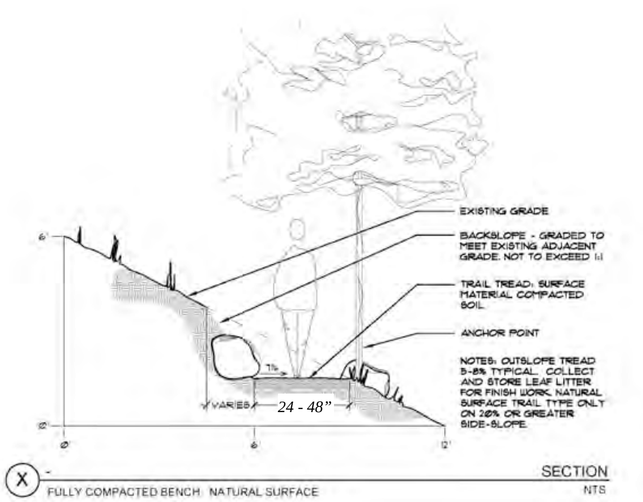
Difficulty Rating	Moderate
Typical Tread Width	36 - 48”
Typical Corridor Width	36 - 60”, with vertical choke points (trees) never closer than 36”, rock anchor choke points never closer than 24”
Tread Rugosity	Uneven, with regular rock and root protrusions above trail tread
Average Gradient	< 7%
Maximum Sustained Grade	10%
Maximum Grade	15%
Typical Tread Materials	Mostly natural surface with some rock armoring of wet and/or steep sections
Typical Landscape Gradient	0 - 50+% slopes
Turn Radius	Tight turns, with possible switchbacks
Structure Formality	Low
Duty of Care	Low



RETROFITTED, SEGREGATED TRAIL SYSTEM

Trail Specifications- Mountain Bike Loops (Blue on maps), More Difficult

Difficulty Rating	Moderate
Typical Tread Width	24 - 48”
Typical Corridor Width	36 - 60”, with vertical choke points (trees) never closer than 36”, rock anchor choke points never closer than 24”
Tread Rugosity	Uneven, with regular rock and root protrusions above trail tread
Average Gradient	< 10%
Maximum Sustained Grade	15%
Maximum Grade	20%
Typical Tread Materials	Mostly natural surface with some rock armoring of wet and/or steep sections
Typical Landscape Gradient	0 - 50+% slopes
Turn Radius	Tight turns, with possible switchbacks
Structure Formality	Low
Duty of Care	Low



RETROFITTED, SEGREGATED TRAIL SYSTEM

Social Sustainability Aspects

Trail Footprint

Trail Length (miles)	15.02
Trail Footprint (acres)	6.45

Navigability/Conflict Potential

Total Intersections	25
Intersections/Mile of Trail	1.67
Intersections Between Use	3

Managerial Sustainability Aspects

Maintenance Difficulty (TSA Class # x Miles of Trail in TSA Class)

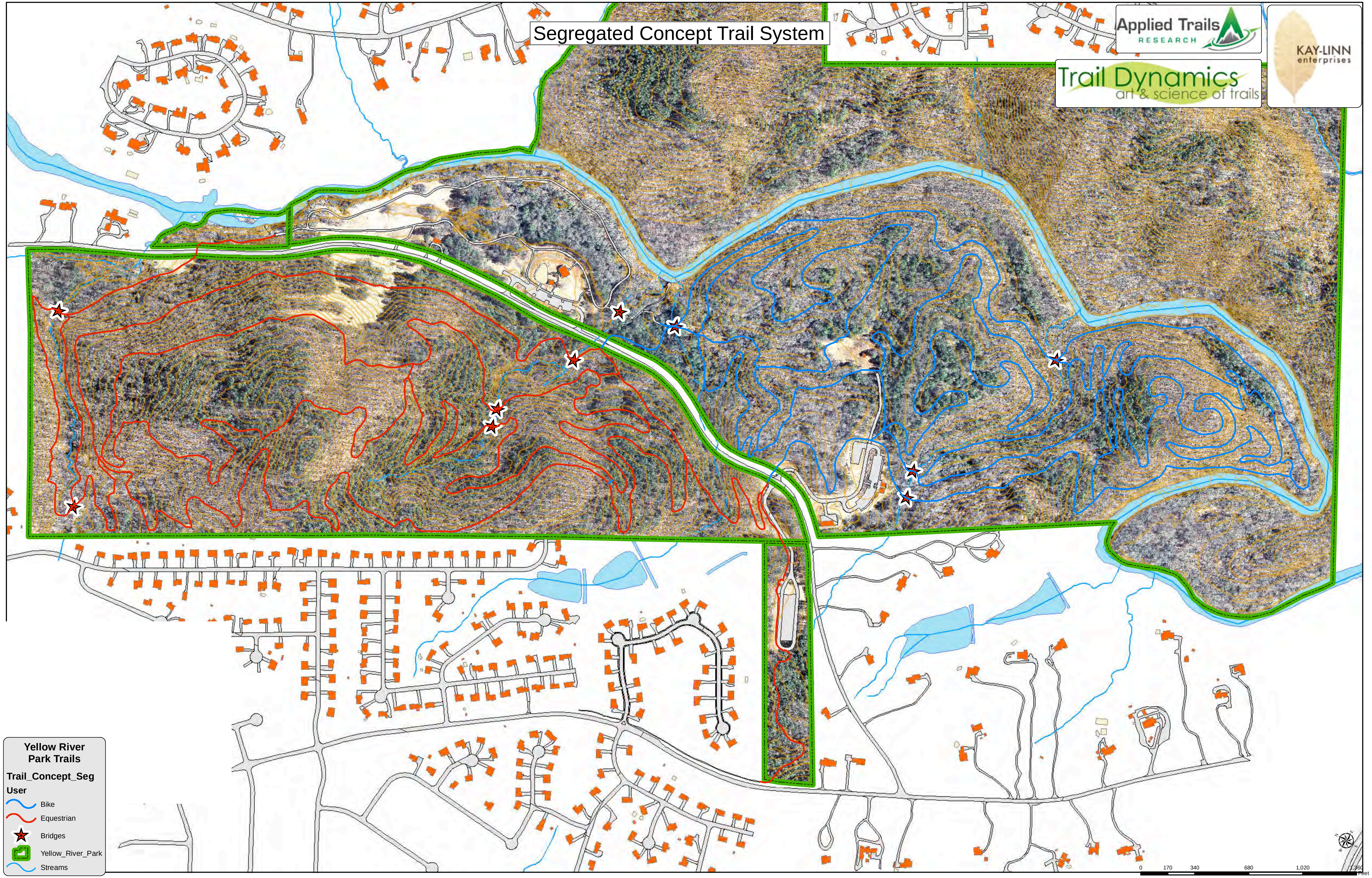
	TSA CL 1: < 0.25	**TSA CL 2: 0.25 - 0.50**	**TSA CL 3: 0.50 - 0.75**	**TSA CL 4: 0.75 - 0.90**	**TSA CL 5: > 0.90**
Approximate Miles of Trail in TSA Class	5.54	9.6	0	0	0
Maintenance Difficulty Quotient	5.54	19.2	0	0	0

Cumulative Maintenance Difficulty: 24.64

Maintenance Effort/Efficiency (Maint. Class # x Miles of trail in Maint. Class)

	Maint. CL 1: < 2’ wide	**Maint. CL 2: 2 - 4’ wide**	**Maint. CL 3: 4 - 6’ wide**	**Maint. CL 4: 6 - 8’ wide**	**Maint. CL 5: > 8’ wide**
Miles of Trail in Maintenance Class	0	9.6	5.42	0	0
Maintenance Effort/ Efficiency Quotient	0	19.2	16.26	0	0

Cumulative Maintenance Effort/Efficiency: 35.46



Segregated Concept Trail System
Applied Trails
RESEARCH
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enterprises
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art & science of trails
Yellow River
Park Trails
Trail_Concept_Seg
User
Bike
Equestrian
Bridges
Yellow_River_Park
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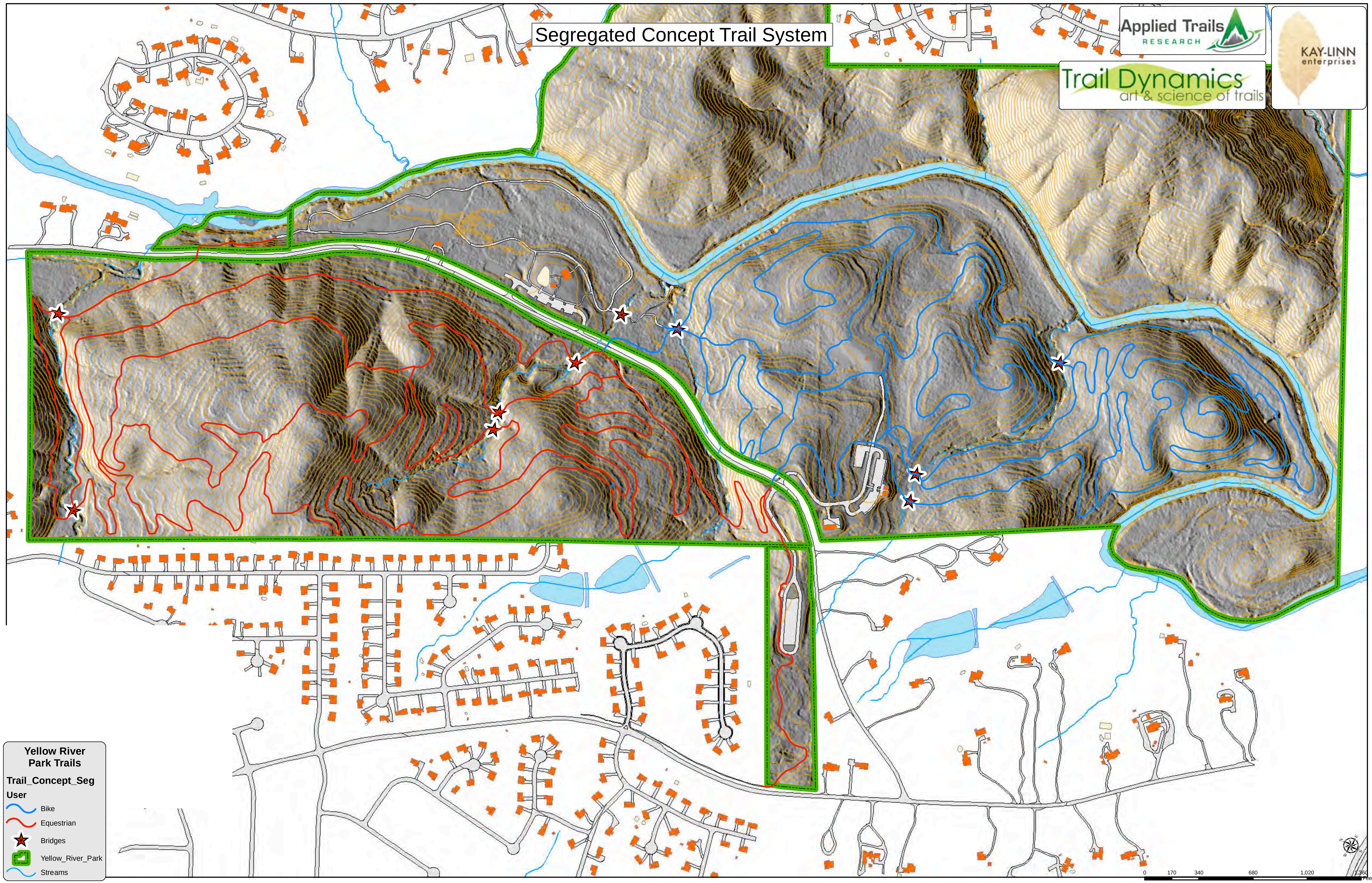
Feet


Segregated Concept Trail System
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Trail_Concept_Seg
User
Bike
Equestrian
Bridges
Yellow_River_Park
Streams
0
170
340
680
1,020
1,360
Feet

COMPARISON OF ALTERNATIVES

Physical Sustainability

Trail System Alternative	Unsustainable Mileage	Unsustainable Percentage
Master Plan Trail System	7.4	59
Current Trail System	12.32	58
Retrofitted, Shared-Use Trail System (Conceptual)	0	0
Retrofitted, Segregated Trail System (Conceptual)	0	0

The Trail-Slope Analysis reveals that, in both the Master Plan and Current trail systems, over half the total trail mileage is in an unsustainable alignment where the trail grade is more than half the hillslope grade. Trails with this relationship to the landscape create water management issues. This is the typical condition for trails that have not been designed with the intent of sustainability. Ease of travel often defined the trail location and trails were established in flat locations and down the fall line of low-gradient slopes. This is the defining characteristic of the Yellow River Park trail system. While erosion and deposition rates seem relatively low due to the clay-based soil that is prevalent in the park, the trail system essentially acts as a series of rain gutters throughout the property. This problem is exacerbated by the general lack of rolling grade in the park's trail system. Undesigned trails are often quite linear, again following a path of least resistance.

Trails designed and constructed with a lower slope ratio (less than half the hillslope grade) become "hydrologically invisible" and do not alter stormwater runoff patterns. Paired with a designed rolling contour, water management is a natural condition of the trail.

The topography in Yellow River Park is ideal for a sustainably designed trail system. The conceptual, retrofitted trail system design locates the majority of the trails on 25% to 60% slopes, which are prevalent and very easy to develop trails with a low slope ratio. The notable exception is the Yellow River floodplain, where natural trail drainage can only occur near the steep drop to the river, on the primary levee, and on isolated spots of slightly higher elevation. The conceptual design indicates generally where a sustainable riverside trail could be located, a condition that would be optimized in a field design process.

COMPARISON OF ALTERNATIVES

Social Sustainability

Trail System Alternative	Trail System Length	Trail System Fooprint	Total Intersections	Intersections/ Mile	Intersections Between Uses
Master Plan Trail System	12.63 Miles	12.08 Acres	37	2.93	18
Current Trail System	22.33 Miles	12.62 Acres	225	10.1	225
Retrofitted, Shared-Use Trail System (Conceptual)	15.78 Miles	6.73 Acres	32	2.03	7
Retrofitted, Segregated-Use Trail System (Conceptual)	15.02 Miles	6.45 Acres	25	1.67	3

The Master Plan trail system, adopted from existing socially developed trails and reconstructed since 2002, has a substantial footprint. The width of the trails (greater than 6-feet) allow for maintenance vehicle access, but have potential use conflict repercussions. Wide trails allow high speeds and large speed differentials between trail users. These wide trails also facilitate easy side-by-side travel, which complicates passing situations, especially when at least one trail user is moving at a higher speed. The reconstructed trail width and the general fall line nature of the trail alignment, combined with 18 intersections where a mountain bike trail crosses an equestrian is a recipe for a startling encounter.

The Current Trail System, however, indicates compliance is very low. Indications of mountain bike use on equestrian trails and vice versa is the norm. Socially developed routes roughly double the mileage of the park's trails and add nearly 200 intersections. As these trails are not signed, navigation becomes very difficult for all but the most familiar park visitors. With a decision to make at an average of 0.10-mile intervals, the trail experience is harmed from a number of different aspects.

COMPARISON OF ALTERNATIVES

The Retrofitted, Shared-Use Trail System concept could reduce the potential footprint of the trail system to roughly half, relying on narrower, more appropriate trail widths. Four to five-foot wide trail tread on the perimeter loops shared by all users provides safe passing space while retaining an intimate feeling with the surrounding forest. Trails of this width, especially when constructed on the side of the hill, still provide a narrow feeling corridor and thus do not encourage higher speeds. Three-foot wide (on average) trails in the internal loops shared by hikers and mountain bikers is similarly appropriate.

This alternative would resolve the issue of potential conflicts at intersections between use types. The seven or fewer intersections would only occur at short connector trails between the internal and perimeter loops. Gateway trail features can be incorporated to slow and passively manage users at these junctions. As navigation signage at these locations will be necessary, intersection warning and/or regulatory signage can be incorporated into these junctions, as well.

The Retrofitted, Segregated-Use Trail System would have similar effects on the trail system footprint, reducing it by more than half from the Master Plan system. Limiting mountain bike trail use to the riverside of the park and equestrian use to the creekside portion would more logically separate use and further reduce problematic intersections to hiking-only crossings of Juhan Road.

While this alternative provides a more manageable separation of mountain bike and horse use, the level of horse use in the park appears to be quite low. With this low level of use, it is not necessary to reserve approximately half the park for those relatively few total visits.

COMPARISON OF ALTERNATIVES

Managerial Sustainability

Trail System Alternative	Trail System Maintenance Difficulty	Trail System Maintenance Effort/Efficiency
Master Plan Trail System	38.45	50.70
Current Trail System	64.57	68.34
Retrofitted, Shared-Use Trail System (Conceptual)	26.97	36.98
Retrofitted, Segregated-Use Trail System (Conceptual)	24.64	35.46

The Master Plan Trail System has very significant maintenance issues. With nearly 60% of the trail mileage having slope ratios greater than 0.50, water management is very difficult. In order to be successful in the future, large amounts of tread and drainage enhancements would be necessary. These activities would then need repeated similar treatments on regular intervals. Further complicating the water management issue is the width of the reconstructed trail tread. Maintaining sheet flow across the trails during runoff events is very difficult as tread widths exceed five feet. As all the reconstructed trail tread is at least six feet wide, large machines must be employed, and the trail becomes much more like a road, harming the recreational experience that most visitors are seeking on natural surface trails.

The Current Trail System, because of similar slope ratio issues on the non-system trails, is also difficult to maintain. If legitimized, almost five miles of fall line trail would be added to the maintenance docket along with hundreds of signs. That stated, the narrower width of the the non-system trails would allow for volunteer-led maintenance.

The Retrofitted, Shared-Use and Segregated-Use Trail Systems are optimized for minimal maintenance difficulty with a contour-focused design that maintains slope ratios less than 0.50. The perimeter trails are proposed with a width that allows for efficient maintenance by relatively inexpensive skid steers and excavators typically employed for trailbuilding. The interior trails would be developed at an average three-foot width that allows for small machine access and feasible volunteer-led maintenance activities.

RECOMMENDED ALTERNATIVE

To best meet the original goals of the Master Plan and rectify the issues that currently hinder the Yellow River Park trail system, the trail system should be retrofitted to modern best practices in trail development- purpose-designed and constructed to provides high quality experiences for all trail users, improve navigability, and reduces impacts to the landscape. The Retrofitted, Shared-Use Trail System can be designed within the original intent of the Master Plan, but with significant sustainability improvements over both the planned and socially debeloped trails that currently exist in the park. A more appropriate trail system for meeting the changing recreational needs of park users will be composed of 4-5' wide perimeter trails on both the riverside and creekside portions of the park with narrow singletrack loops within. The perimeter trails will be shared-use, low-gradient, long sightline trails designed for more casual use. The width and surface of these trails will make them suitable for utilization by park staff and their maintenance vehicles. The singletrack loops would incorporate minimal intersections, appeal to more active and adventurous trail users, and provide the intimate trail experience that is currently desired and being socially developed, but can be designed in a manner that minimizes erosion and subsequent maintenance. The singletrack trails would not be wide enough, or appropriate, for use by County maintenance vehicles.

The Retrofitted, Shared-Use Trail System would effectively deal with design and construction-related issues present in the Master Plan trails. Many of the constructed trails were not built with sustainable grades or effective water management, leading to a condition that requires annual maintenance that is not currently being implemented. The result, verified during the field assessment, is that these trails carry water and sediment long distances, in some cases depositing clay-laden sediment directly into the Yellow River. These trails also remain wet for relatively long periods following a precipitation event. The six to twelve-foot width of most of the constructed trail creates both maintenance and water management difficulties. Many of the constructed trails are overly straight. Combined with the excess width, the recreational experience that is being provided becomes very similar to a paved greenway trail, which has already been provided in the park.

While the socially developed trails also have many of the same issues (i.e. exceeding sustainable grades, not managing water on the trail) as those trails indicated in the Master Plan, their narrower width creates less soil movement and vegetation damage on a per foot of trail basis. However, the sheer quantity of these trails and the constant development of new trails and technical trail features increases the impact footprint of the system and the social development shows no signs of abatement. A professionally designed and developed trail system can meet the desires of avid trail users that frequent the park in a more sustainable manner. The addition of technical trail features in suitable locations, implemented with durable materials and construction techniques will help to provide the excitement and challenge being sought by many visitors to Yellow River Park.

A retrofit of the trails can be accomplished in a manner that vastly improves navigability by reducing intersections, developing trails as loops, and designing these trails within the "pods" created by the perimeter trails. This will allow visitors to enjoy the natural surroundings and choose an appropriate trail experience without worry of becoming lost or finding themselves on a trail that is technically closed to their mode of use. It will also decrease costs for signage development and maintenance as well as the perceived need to blaze trees to indicate regulated use in the park.

IMPLEMENTATION PROCESS AND COST OPINION

This Trail System Assessment and Redevelopment Plan represents the first step in a proposed redevelopment of Yellow River Park. The Plan objectively identifies inherent problems with the existing trail layout and construction/maintenance techniques and provides recommendations for improvements to the physical sustainability of the trail system. In addition to physical sustainability issues, the current trail system is exceedingly difficult to navigate. The official trail signs and substantial social trail development both compromise the utility and enjoyment of the trails by the public and create unnecessary maintenance and risk management issues.

A better designed trail system would mitigate these physical, social, and managerial issues. The maps developed for this document provide a conceptual trail system that would mitigate the sustainability issues. This concept attempts to illustrate, from a mapping perspective, how the system could be better developed.

That stated, the concepts presented do not reflect detailed trail alignments that have been ground-truthed throughout their length. Appropriate and informed natural surface trail design happens in the field and on the ground, where site-specific alignment is designed in a manner that minimizes long-term resource impacts, navigation challenges, and risk management issues while it maximizes the recreational qualities of the trail. Should Gwinnett County decide to move forward with improving the physical, social, and managerial sustainability of the trails in Yellow River Park, the second step of the process would be a professional, field design.

The third step of the process is the construction implementation. The most cost-efficient manner to undertake the second and third steps is through a Design-Build Hybrid Construction model. Alternatively, but considerably more expensive, separate Design and Construction processes are possible. Finally, turnkey construction by a vetted trail contractor would be possible, but more expensive than a hybrid model where a contractor works closely with volunteer groups to implement the construction plan.

Our team would highly recommend a Design-Build Hybrid Construction process for the redevelopment of the proposed hike-bike trails. Cost savings and volunteer involvement/ownership of the process are incredibly positive attributes to this model and Yellow River Park is ideal for this model. The narrower nature of the specification for these trails would require smaller mechanized equipment (< 4' wide), hand tool-based construction and considerable volunteer assistance in the finish work. Hybrid construction projects identify tasks that volunteers can accomplish based on their skills and assigning those tasks to local trail users instead of the trail contractor. Examples of trail construction tasks performed by

IMPLEMENTATION PROCESS AND COST OPINION

volunteers can include corridor clearing (if certified chainsaw operators are available), root cutting, final tread shaping, leaf blowing and raking, and general finish work. Depending on the commitment levels of volunteers and number of tasks that local trail users can accomplish, the total construction cost can be cut by 20-50%.

Construction of the outer loop trails (hike-bike-horse) would be most cost effectively and quickly completed without the assistance of volunteers. The width and surface specifications of these trails are more conducive to multiple, larger trailbuilding equipment (> 4' wide) working efficiently in small spaces where volunteer management and safety would be compromised and utility would be diminished.
The field-based design, followed immediately by construction implementation could be staged in two separate but subsequent phases, split by Juhan Road. This would allow for trailheads and trails to remain open in the park at all times throughout the implementation process.

IMPLEMENTATION PROCESS AND COST OPINION

Construction costs portrayed in the original Master Plan and in a cost estimate prepared by WK Dickson were extremely high relative to the broader trailbuilding market at the time each estimate was produced. Our team's baseline trail design and construction cost estimates are significantly lower than those previously portrayed and are based on similar trail design and construction projects undertaken in the last five years in the states of Georgia, North Carolina, South Carolina, Alabama, Virginia, and Florida.

In addition to new trail design and construction, old alignment obliteration and improved restoration tasks will be vital to a successful trail system, natural hydrologic patterns, and habitat succession. Trail contractors will need to scarify old tread-ways and move larger masking materials to begin the restoration process. Volunteers could be involved in this important step, masking old alignments by planting live vegetation, installing erosion control measures, and actively restoring a native floral assemblage. Effective natural habitat restoration and public education is a very important part of larger redesign and development projects such as proposed for Yellow River Park.

The ideas and concepts presented in this trail plan are not basic maintenance items but much more complicated. Choosing a contractor to work with in this re-development plan will be paramount to the success of the project. The contractor must have experience in many areas including: trail design, bike specific new trail construction, hybrid trail construction projects, managing volunteers, good restoration work, and design/build of optional trail features that will keep mountain bikers happy and engaged.

Currently, the reconstructed trails within Yellow River Park are not receiving adequate maintenance. Rolling grade dips are not properly located, constructed, or maintained on a regular basis. Additionally, there are far fewer structures than is needed, given the slope ratio of the trails. With 60% of the trail system in this condition, approximately 7.5 miles of trail require improved maintenance. With a the placement of a rolling grade dip every 200 feet on these sections of trail (estimate based on prevailing trail slopes and soil structure), an additional 200 rolling grade dips are necessary to minimize resource and water quality-related impacts. With typical costs of $6.50/linear foot for these structures that, when properly developed, require 50 linear feet of construction, each additional rolling grade dip represents a $325 deferred maintenance need, or $65,000. With clean-out/reconstruction intervals of two years at approximately $125/structure, the water diversion structures alone would require a $12,500 annual investment or $125,000 in a ten-year period.

Sustainable trail maintenance requirements- corridor clearing, hazard tree removal, and basic drainage work- typically requires operating budgets of approximately $500/mile of trail. The Retrofitted, Shared-Use Trail System would then require approximately $10,000 year in basic upkeep. With trained volunteer sawyers and the increased stewardship presence, that annual investment could be reduced to $2,500 and 500 hours of volunteer assistance. The Master Plan trail system, following the implementation of the deferred maintenance, would require approximately $20,000/year in maintenance input.

IMPLEMENTATION PROCESS AND COST OPINION

Turnkey Plan Implementation Cost Opinion

Retrofitted, Shared-Use Trail System Implementation Components	*Quantity*	*Units*	*Unit Cost*	*Total*
Professional Design	15.8	mile	$1,250	$19,750
Type 1: Shared-Use Perimeter Trail	5.4	mile	$18,500	$99,900
Type 2: Hike-Bike, More Difficult	9.0	mile	$20,000	$180,000
Type 3: Hike-Bike, Most Difficult	1.4	mile	$23,500	$32,900
Technical Trail Features/Skills Areas	1,500	linear feet	$10	$15,000
Trail Closure/Restoration	12	mile	$5,000	$60,000

Total: $407,550

Hybrid Plan Implementation Cost Opinion

Retrofitted, Shared-Use Trail System Implementation Components	*Quantity*	*Units*	*Unit Cost*	*Total*
Professional Design	15.8	mile	$1,250	$19,750
Type 1: Shared-Use Perimeter Trail	5.4	mile	$18,500	$99,900
Type 2: Hike-Bike, More Difficult	9.0	mile	$12,500	$112,500
Type 3: Hike-Bike, Most Difficult	1.4	mile	$15,000	21,000
Technical Trail Features/Skills Areas	1,500	linear feet	$10	$15,000
Trail Closure/Restoration	12	mile	$1,000	$12,000

Total: $280,150

IMPLEMENTATION PROCESS AND COST OPINION

Previous Cost Estimate

Master Plan Trail System Implementation Components	Quantity	Units	Unit Cost	Total
Professional Design	0	NA	$0	$0
New Equestrian Trail	2.2	mile	$36,960	81,320
Restored Equestrian Trail	4	mile	$18,500	$74,000
New Mountain Bike Trail	3.2	mile	$36,960	$118,272
Restored Mountain Bike Trail	3.7	mile	$18,500	$68,450
Trail Closure/Restoration	11.4	mile	$5,290	$60,333

Total: $402,375

Implementation Cost Comparison

Trail System	Equestrian Mileage	Mountain Bike Mileage	Total Mileage	Total Cost	Average Cost/ Mile
Master Plan*	6.2	6.7	12.9	$402,375	$31,192
Recommended Alternative- Turnkey Implementation	5.4	15.8	15.8	$407,550	$25,794
Recommended Alternative- Hybrid Implementation	5.4	15.8	15.8	$280,150	$17,731

* Deferred water management-related maintenance of $65,000 and additional $100,000 maintenance requirement over a ten year period (above the hybrid implementation and subsequent volunteer stewardship) would raise the total trail system investment to $592,375 or $45,920/mile by 2022.

APPENDICES

APPENDIX A: MOUNTAIN BIKE SKILLS AREAS AND TECHNICAL TRAIL FEATURES

APPENDIX A

Mountain bikers, like most trail users, enjoy the challenge of testing their abilities. Whether this relates to the distance traveled on a ride, pace and stamina in a race setting, or the technical capacity to take on difficult trail situations, riders of all types appreciate the opportunity to better themselves. The opportunity for skills progression not only creates more satisfied trail users, but can also reduce potential conflicts between different types of trail users. Mountain bikers that have advanced strength, stamina, balance, and bike handling skills are much less likely to injure themselves or startle others on the trail.

Balance features, constructed of wood or rock, with managed fall zones adjacent to a trail

For those riders specifically interested in bike handling and balance improvement, whether they be new riders (kids and adults alike) or just looking to bring their skills to a new level, the construction of technical trail features that mimic skills and challenges found in a natural situations has become quite prevalent all over the world. Properly constructed in a durable manner with a defined progression in skill/challenge level, managed

Challenge features,that allow riders with the skills to jump/drop, constructed within the trail tread and at the same difficulty level as the remainder of the trail

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“fall zone” areas, and even interpretive signage, these are attendant features that improve a visitor’s experience in a similar manner to typical nature interpretation signage, managed vistas, developed river/water access areas, or playgrounds.

Technical trail features can be placed parallel to existing trails to provide an optional challenge or within the defined trail tread, so long as the challenge level of the feature is similar to other natural or built features on that trail. Features are often grouped in relatively compact areas near trailheads or access areas, developed in a small loop of interconnected challenges. These bike skills areas can serve as warm up areas for experienced riders, easily observed kids play areas, and congregating points where best practices in trail use can be related. Going a step further, many communities are now developing full-size bike parks between one and fifty acres with multiple different skills areas and trail types.

While the nomenclature around different types of skills, trails, and features is sometimes difficult to discern, many professional trail contractors have considerable experience in developing these skill features, with a small and growing number of companies specializing in solely the development of bike parks.

Pump Track photos (from public parks)

Clockwise from upper left: Vortex Freeride Park, FL Office of Greenways and Trails, Ocala; Big Creek Park, Roswell, GA; Highbridge Park, New York City, NY

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Bike Skills Area, Fort Collins CO

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Trailside Bike Park, Park City, UT

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Valmont Bike Park Boulder, CO

APPENDIX B: TRAIL IMPACT LITERATURE REVIEW

APPENDIX B

Introduction
Much research has been conducted to analyze recreational impacts to public lands; some of this research has focused on understanding impacts of different types of recreational use on trails, trail systems and the natural settings in which trails exist.

Trails are generally regarded as essential facilities in parks and forests. They provide access to remote areas, accommodate a diverse array of recreational activities, and protect resources by concentrating visitor trampling on narrow and resistant tread surfaces. Formal or designated trails are generally designed and constructed, which involves vegetation removal and soil excavation. These changes may be considered "unavoidable," in contrast to "avoidable" post-construction degradation from their subsequent use (e.g., trail widening, erosion, muddiness), or from the development and degradation of informal visitor-created trails.

Common environmental impacts associated with recreational use of trails include:

- Vegetation loss and compositional changes
- Soil compaction
- Erosion
- Muddiness
- Degraded water quality
- Disruption of wildlife

This review is organized into four broad categories: impacts to vegetation, soil, water, and wildlife.

Impacts to Vegetation: General Research
On formal trails, most vegetation is typically removed by construction, maintenance, and visitor use. This impact is necessary and "unavoidable" in order to provide a clear route for trail users. One goal of trail construction and maintenance is to provide a trail only wide enough to accommodate the intended use. Trails made wider than this through visitor use or erosion represent a form of "avoidable" impact. For example, a doubling of trail width represents a doubling of the area of intensive trampling disturbance. Wider trails also expose substantially greater amounts of soil to erosion by wind or water.

The creation and maintenance of trail corridors also removes shrubs and trees, allowing greater sunlight exposure that favors a different set of groundcover plants within trail corridors. Occasional trailside trampling within trail corridors also favors the replacement of fragile plants with those more resistant to trampling traffic. For example, shade-tolerant but fragile broadleaved herbs are frequently replaced by grasses and sedges that are trampling-resistant and require more sunlight to survive. Trail construction, use, and maintenance can also be harmful when trails divide sensitive or rare plant communities.

Trampling - the action of crushing or treading upon vegetation, either by foot, hoof, or tire - contributes to a wide range of vegetation impacts, including damage to plant leaves, stems, and roots, reduction in vegetation height, change in the composition of species, and loss of plants and vegetative cover (Leung & Marion, 1996;

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Thurston & Reader, 2001). Trampling associated with "avoidable" off-trail traffic can quickly break down vegetation cover and create a visible route that attracts additional use. Complete loss of vegetation cover occurs quickly in shady forested areas, less quickly in open areas with resistant grassy vegetation. Regardless, studies have consistently revealed that most impact occurs with initial or low use, with a diminishing increase in impact associated with increasing levels of traffic (Hammit & Cole, 1998; Leung & Marion, 1996). Furthermore, once trampling occurs, vegetative recovery is a very slow process.

Compositional changes in the vegetation along trail corridors* can have both beneficial and adverse effects. Trampling-resistant plants provide a durable groundcover that reduces soil loss by wind and water runoff, and root systems that stabilize soils against displacement by heavy traffic. The ecological impacts of such compositional changes are not fully known, except when non-native vegetation is introduced to and spreads along trail corridors. Many of these species are disturbance-associated and are naturally limited to areas where the vegetation is routinely trampled or cut back. However, a few non-native species, once introduced to trail corridors, are able to out-compete native plants and spread away from the trail corridor in undisturbed habitats. Some of these species form dense cover that crowd out or displace native plants. These "invasive" species are particularly undesirable and land managers actively seek to prevent their introduction and spread. Unfortunately their removal is difficult and expensive.

See Wells and Lauenroth 2007 for a case study examining horse and pack stock as dispersal mechanism for plants along recreational trails.

Impacts to Vegetation: Management Implications

Trail managers can either avoid or minimize impacts to vegetation through careful trail design, construction, maintenance, and management of visitor use. Here are some recommendations to reduce vegetation impacts:

- Design trails that provide the experience that trail users seek to reduce their desire to venture off-trail.
- Locate trails away from rare plants and animals and from sensitive or critical habitats of other species. Involve resource professionals in designing and approving new trail alignments.
- Keep trails narrow to reduce the total area of intensive tread disturbance, slow trail users, and minimize vegetation and soil impacts.
- Limit vegetation disturbance outside the corridor when constructing trails. Hand construction is least disruptive; mechanized construction with small equipment is less disruptive than full-sized equipment; skilled operators do less damage than those with limited experience.
- Locate trails on side-hills where possible. Constructing a side-hill trail requires greater initial vegetation and soil disturbance but sloping topography above and below the trail bench will clearly define the tread and concentrate traffic on it. Trails in flatter terrain or along the fall line may involve less initial disturbance but allow excessive future tread widening and off-tread trampling, which favor non-native plants.

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- Construct and formalize meet-up and "tie-up" areas in a fashion that contains and concentrates visitor use to durable surfaces
- Use construction techniques that save and redistribute topsoil and excavated plants.

There are also important considerations for maintaining and managing trails to avoid unnecessary ongoing impacts to vegetation:

- While it is necessary to keep the trail corridor free of obstructing vegetation, such work should seek to avoid "day-lighting" the trail corridor when possible. Excessive opening of the overstory allows greater sunlight penetration that permits greater vegetation compositional change and colonization by non-native plants.
- An active maintenance program that removes tree falls and maintains a stable and predictable tread also encourages visitors to remain on the intended narrow tread. A variety of maintenance actions can discourage trail widening, such as only cutting a narrow section out of trees that fall across the trail, limiting the width of vegetation trimming, and defining trail borders with logs, rocks, or other objects that won't impede drainage.
- Use education to discourage off-trail travel, which can quickly lead to the establishment of informal visitor-created trails that unnecessarily remove vegetation cover and spread non-native plants. Such routes often degrade rapidly and are abandoned in favor of adjacent new routes, which unnecessarily magnify the extent and severity of trampling damage.
- Educate visitors to be aware of their ability to carry non-native plant seeds on their bikes or clothing, and encourage them to remove seeds by washing mud from bikes, tires, shoes, and clothing. Preventing the introduction of non-natives is key, as their subsequent removal is difficult and costly.
- Educate visitors about low impact riding practices, such as those contained in the IMBA-approved Leave No Trace Skills & Ethics: Mountain Biking booklet (www.LNT.org).

For further reading see: Pickering et al 2010, Cessford 1995; Gruttz and Hollingshead 1995; Thurston and Reader 200l.

Impacts to Soils: General Research

The creation and use of trails also results in soil disturbance. Some loss of soil may be considered an acceptable and unavoidable form of impact on trails. As with vegetation loss, much soil disturbance occurs in the initial construction and use of the trail. During trail construction, surface organic materials (e.g., twigs, leaves, and needles) and organic soils are removed from treads; trails built on sidehill locations require even more extensive excavation. In addition, the underlying mineral soils are compacted during construction and initial use to form a durable tread substrate that supports trail traffic.

In contrast, post-construction soil displacement, erosion, and muddiness represent core forms of avoidable trail impact that require sustained management attention to avoid long-lasting resource degradation. This degradation can reduce the utility of trails as recreation facilities and diminish the quality of visitor experiences.

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For example, soil erosion exposes rocks and plant roots, creating a rutted and uneven tread surface. Erosion can also be self-perpetuating when treads erode below the surrounding soil level, hindering efforts to divert water from the trail and causing accelerated erosion and muddiness. Similarly, excessive muddiness renders trails less usable and aggravates tread widening and associated vegetation loss as visitors seek to circumvent mud holes and wet soils (Marion, 2006).

Research has shown that visitors notice obvious forms of trail impact, such as excessive muddiness and eroded ruts and tree roots, and that such impacts can degrade the quality of visitor experiences (Roggenbuck and others., 1993; Vaske and others., 1993). Such conditions also increase the difficulty of travel and may threaten visitor safety. Remedying these soil impacts can also require substantial rehabilitation costs. Clearly, one primary trail management objective should be the prevention of excessive soil impacts.

The Four Common Forms of Soil Degradation on Trails:

- Compaction
- Muddiness
- Displacement
- Erosion

Compaction

Soil compaction is caused by the weight of trail users and their equipment, which passes through feet, hooves, or tires to the tread surface. Compacted soils are denser and less permeable to water, which increases water runoff. However, compacted soils also resist erosion and soil displacement and provide durable treads that support traffic. From this perspective, soil compaction is considered beneficial, and it is an unavoidable form of trail impact. Furthermore, a primary resource protection goal is to limit trailside impacts by concentrating traffic on a narrow tread. Success in achieving this objective will necessarily result in higher levels of soil compaction.

The process of compacting the soil can present a difficult challenge, especially on new trails. Unless soils are mechanically compacted during tread construction, initial use compacts the portions of the tread that receive the greatest traffic, generally the center. The associated lowering of the tread surface creates a cupped cross-section that intercepts and collects surface water. In flat terrain this water can pool or form muddy sections; in sloping terrain the water is channeled down the trail, gaining in volume, speed, and erosive potential.

Displacement

Trail users can also push soil laterally, causing displacement and development of ruts, berms, or cupped treads. Soil displacement is particularly evident when soils are damp or loose and when users are moving at higher rates of speed, turning, braking, or other movements that create more lateral force. Soil can also be caught in hooves, footwear, or tire treads, flicked to the side or carried some distance and dropped. Regardless of the mechanism, soil is generally displaced from the tread center to the sides, elevating inslopes or berms, and compounding drainage problems.

Muddiness

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When trails are located in areas of poor drainage or across highly organic soils that hold moisture, tread muddiness can become a persistent problem. Muddiness is most commonly associated with locations where water flows across or becomes trapped within flat or low-lying areas. Soil compaction, displacement, and erosion can exacerbate or create problems with muddiness by causing cupped treads that collect water during rainfall or snowmelt. Thus, muddiness can occur even along trails where there is sufficient natural drainage. Subsequent traffic skirts these problem spots, compacting soils along the edges, widening mud holes and tread width, and sometimes creating braided trails that circumvent muddy sections.

Erosion

Soil erosion is an indirect and largely avoidable impact of trails and trail use. Soil can be eroded by wind, but generally, erosion is caused by flowing water. To avoid erosion, sustainable trails are generally constructed with a slightly crowned (flat terrain) or outsloped (sloping terrain) tread. However, subsequent use compacts and/or displaces soils over time to create a cupped or insloped tread surface that intercepts and carries water. The concentrated run-off picks up and carries soil particles downhill, eroding the tread surface.

Loose, uncompacted soil particles are most prone to soil erosion, so trail uses that loosen or detach soils contribute to higher erosion rates. Erosion potential is closely related to trail grade because water becomes substantially more erosive with increasing slope. The size of the watershed draining to a section of trail is also influential - larger volumes of water are substantially more erosive.

Water and the sediment it carries will continue down the trail until a natural or constructed feature diverts it off the tread. Such features include a natural or constructed reversal in grade, an outsloped tread, rocks or tree roots, or a constructed drainage dip or water bar. Once the water slows, it drops its sediment load, filling in tread drainage features and causing them to fail if not periodically maintained. Sediment can also be carried directly into watercourses, creating secondary impacts to aquatic systems. Properly designed drainage features are designed to divert water from the trail at a speed sufficient to carry the sediment load well below the tread, where vegetation and organic litter can filter out sediments. A well-designed trail should have little to no cumulative soil loss, for example, less than an average of one-quarter inch (6.3 mm) per year.

Impacts to Soils

Many studies have evaluated the soil impacts of different types of recreational uses. The general consensus of this research has shown that motorized and equestrian use are significantly more impacting to soils than human powered recreation (hiking, trail running, cycling). The trail system at Cave Run Lake is showing significant signs of degraded soils as a result of heavy use, poor design and a general lack of appropriate maintenance.

Several key studies comparing the impacts to soils by user-type are reviewed below:
Wilson and Seney (1994) evaluated tread erosion from horses, hikers, mountain bikes, and motorcycles on two trails in the Gallatin National Forest, Montana. They applied one hundred passes of each use-type on four sets of 12 trail segments, followed by simulated rainfalls and collection of water runoff to assess sediment yield at the base of each segment. Control sites that received no passes were also assessed for comparison. Results indicated that horses made significantly more sediment available for erosion than the other uses, which did not

significantly vary from the control sites. Traffic on pre-wetted soils generated significantly greater amounts of soil runoff than on dry soils for all uses.

Marion (2006) studied 78 miles (125 km) of trail (47 segments) in the Big South Fork National River and Recreation Area, Tennessee and Kentucky, measuring soil loss along transects across the trail to evaluate the influence of use-related, environmental, and management factors.

Sidehill-aligned trails were significantly less eroded than trails in valley bottom positions, in part due to the influence of periodic floods. Trail grade and trail alignment angle were also significant predictors of tread erosion. Erosion rates on trails with 0-6 percent and 7-15 percent grades were similar, while erosion on trails with grades greater than 16 percent were significantly higher. And there was significantly greater erosion on fall line trails (alignment angles of 0-22 degrees) than those with alignments closer to the contour.

This study also provided an opportunity to examine the relative contribution of different use types, including horse, hiking, mountain biking, and ATV. Trails predominantly used for mountain biking had the least erosion of the use types investigated. Trails receiving equestrian use had significantly less erosion when rock content was high and grades were minimized.

Cessford (1995) provides a comprehensive, though dated, summary of trail impacts with a focus on mountain biking. Of particular interest is his summary of the two types of forces exerted by bike tires on soil surfaces: The downward compaction force from the weight of the rider and bike, and the rotational shearing force from the turning rear wheel. Mountain bikers generate the greatest torque, with potential tread abrasion due to slippage, during uphill travel. However, the torque possible from muscle power is far less than that from a motorcycle, so wheel slippage and abrasion occur only on wet or loose surfaces. Tread impact associated with downhill travel is generally minimal due to the lack of torque and lower ground pressures. Exceptions include when riders brake hard enough to cause skidding, which displaces soil downslope, or bank at higher speeds around turns, which displaces soil to the outside of the turn. Impacts in flatter terrain are also generally minimal, except when soils are wet or uncompacted and rutting occurs.

Impacts to Soils: Management Implications
Soil loss is among the most enduring forms of trail impact, and minimizing erosion and muddiness are the most important objectives for achieving a sustainable trail. Soil cannot easily be replaced on trails, and where soil disappears, it leaves ruts that make travel and water drainage more difficult, prompting further impacts, such as trail widening.

Existing studies indicate that motorized and equestrian use have far greater impacts to soils than human powered recreation. Other factors, particularly trail grade, trail/slope alignment angle, soil type/wetness, and trail maintenance, are more influential determinants of tread erosion or wetness.

There are a number of tactics for avoiding the worst soil-related impacts to trails:

- Discourage or prohibit off-trail travel. Informal trails created by off-trail travel frequently have steep grades and fall-line alignments that quickly erode, particularly in the absence of tread maintenance. Exceptions include areas of solid rock or non-vegetated cobble.
- Design trails with sustainable grades and avoid fall-line alignments. Where equestrian or motorized use is allowed, minimize trail grades and import rock material to form a durable substrate should the native soils not have substaintial rock content.
- When possible, build trails in dry, cohesive soils that easily compact and contain a larger percentage of coarse material or rocks. These soils better resist erosion by wind and water or displacement by feet, hooves and tires.
- Minimize tread muddiness by avoiding flat terrain, wet soils, and drainage-bottom locations.
- Use grade reversals to remove water from trail treads. Grade reversals are permanent and sustainable - when designed into a trail's alignment they remain 100 percent effective and rarely require maintenance.

Other strategies are more temporary in nature and will require periodic maintenance to keep them effective:

- While the use of a substantial outslope (e.g., 5 percent) helps remove water from treads, it is rarely a long-term solution. Tread cupping and berm development will generally occur within a few years after tread construction. If it is not possible to install additional grade reversals, reshape the tread to reestablish an outsloped tread surface periodically, and install wheel-friendly drainage dips or other drainage structures to help water flow off the trail.
- If it is not possible to install proper drainage on a trail, consider rerouting trail sections that are most problematic, or possibly hardening the tread with the addition of local or imported material (rocks).
- In flatter areas, elevate and crown treads to prevent muddiness, or add a gravel/soil mixture in low spots.
- Finally, it is important to realize that visitor use of any type on trails when soils are wet contributes substantially greater soil impact than the same activities when soils are dry. Thus, discouraging or prohibiting the use of trails that are prone to muddiness during rainy seasons or snowmelt is another effective measure. Generally such use can be redirected to trails that have design or environmental attributes that allow them to better sustain wet season uses.

For further reading see: Pickering et al 2010, Cessford 1995, Thurston and Reader 2001, Newsome et al 2004.

Impacts to Water Resources: General Research
Trails and their use can also affect water quality. Trail-related impacts to water resources can include the introduction of soils, nutrients, and pathogenic organisms (e.g., Giardia), and alter the patterns of surface water drainage. However, in practice, these impacts are avoidable, and properly designed and maintained trails should not degrade water quality. Unfortunately there is very little research to draw from on these topics, and none that is specific to different modes of trail use.

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Poorly sited and/or maintained trails can be eroded by water, with tread sediments carried off by runoff. Generally, if water control features such as grade reversals and outsloped treads are used to divert runoff from trails, the water drops its sediment close to trails, where it is trapped and held by organic litter and vegetation. Soils eroded from trails rarely enter water bodies, unless trails cross streams or run close to stream or lake shorelines and lack adequate tread drainage features. Since many recreational activities, such as fishing, swimming, boating, and viewing scenery (e.g., waterfalls) draw visitors and trails to the vicinity of water resources, it is often necessary to route trails to water resources or visitors will simply create their own informal trails.

Trails that are close to water resources require special consideration in their design and management to prevent the introduction of suspended sediments into bodies of water. Eroded soil that enters water bodies increase water turbidity and cause sedimentation that can affect aquatic organisms (Fritz and others 1993). Trout and other fish lay their eggs in gravels on the bottom of streams and lakes, and sediments can smother those eggs, reducing reproductive success. Sedimentation can also hurt invertebrate organisms, which serve as food for fish and other creatures. In addition, some sediment may contain nutrients that can contribute to algal blooms that deplete the dissolved oxygen in water bodies when they die off.

Poorly designed trails can also alter hydrologic functions - for instance, trails can intercept and divert water from seeps or springs, which serve important ecological functions. In those situations, water can flow along the tread, leading to muddiness or erosion and, in the case of cupped and eroded treads, the water may flow some distance before it is diverted off the trail, changing the ecology of small wetland or riparian areas.

Trail users may also pollute water with pathogenic organisms, particularly those related to improperly disposed human waste. Potential pathogenic organisms found through surveys of backcountry water sources include Cryptosporidium spp., Giardia spp., and Campylobacter jejuni (LeChevallier and others, 1999; Suk and others, 1987; Taylor and others, 1983). This is rarely a significant concern where trail use is predominantly day-oriented, and waste issues can be avoided by installing toilet facilities or following Leave No Trace practices (i.e., digging cat-holes for waste away from water resources).

Impacts to Water Resources: Management Implications

The same trail design, construction, and maintenance measures that help minimize vegetation and soil impacts also apply to water. But there are also some additional efforts needed to protect water resources:

- Trails should avoid close proximity to water resources. For example, it is better to build a trail on a sidehill along a lower valley wall than to align it through flat terrain along a stream edge, where trail runoff will drain directly into the stream.
- It is best to minimize the number of stream crossings. Where crossings are necessary, scout the stream carefully to select the most resistant location for the crossing. Look for rocky banks and soils that provide durable surfaces.

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- Design water crossings so the trail descends into and climbs out of the steam crossing, preventing stream water from flowing down the trail.
- Armor trails at stream crossings with rock, gravel or concrete to prevent erosion.
- Include grade reversals, regularly maintained outsloped treads, and/or drainage features to divert water off the trail near stream crossings. This prevents water and sediment from flowing down the trail into the stream, and allows trailside organic litter, vegetation, and soils to slow and filter water.
- On some heavily used trails, a bridge may be needed to provide a sustainable crossing.
- Where permanent or intermittent stream channels cross trails, use armoring, open rock culverts or properly sized buried drainage culverts to allow water to cross properly, without flowing down the trail.

Impacts to Wildlife: General Research
Trails and trail users can also affect wildlife. Trails may degrade or fragment wildlife habitat, and can also alter the activities of nearby animals, causing avoidance behavior in some and food-related attraction behavior in others (Hellmund, 1998; Knight & Cole, 1991). While most forms of trail impact are limited to a narrow trail corridor, disturbance of wildlife can extend considerably further into natural landscapes (Kasworm & Monley, 1990; Tyser & Worley, 1992). Even very localized disturbance can harm rare or endangered species.

Different animals respond differently to the presence of trail users. Most wildlife species readily adapt or become "habituated" to consistent and non-threatening recreational activities. For example, animals may notice but not move away from humans on a frequently used trail. This is fortunate, as it can allow high quality wildlife viewing experiences for visitors and cause little or no impact to wildlife.

Other forms of habituation, however, are less desirable. Visitors who feed wildlife, intentionally or from dropped food, can contribute to the development of food-related attraction behavior that can turn wild animals and birds into beggars. In places where visitors stop to eat snacks or lunches, wildlife quickly learn to associate people with food, losing their innate fear of humans and returning frequently to beg, search for food scraps, or even raid unprotected packs containing food. Feeding wild creatures also endangers their health and well-being. For instance, after food-attracted deer in Grand Canyon National Park became sickly and dangerously aggressive, researchers found up to six pounds of plastic and foil wrappers obstructing intestinal passages of some individuals.

The opposite conduct in wildlife - avoidance behavior - can be equally problematic. Avoidance behavior is generally an innate response that is magnified by visitor behaviors perceived as threatening, such as loud sounds, off-trail travel, travel in the direction of wildlife, and sudden movements. When animals flee from disturbance by trail users, they often expend precious energy, which is particularly dangerous for them in winter months when food is scarce. When animals move away from a disturbance, they leave preferred or prime habitat and move, either permanently or temporarily, to secondary habitat that may not meet their needs for food, water, or cover. Visitors and land managers, however, are often unaware of such impacts, because animals often flee before humans are aware of the presence of wildlife.

Two studies of possible interest are summarized below:
A study of the Boise River in Idaho examined flushing distances of bald eagles when exposed to actual and simulated walkers, joggers, fishermen, bicyclists, and vehicles (Spahr 1990). The highest frequency of eagle flushing was associated with walkers (46 percent), followed by fishermen (34 percent), bicyclists (15 percent), joggers (13 percent), and vehicles (6 percent). However, bicyclists caused eagles to flush at the greatest distances (mean = 148 meters), followed by vehicles (107m), walkers (87m), fishermen (64m), and joggers (50m). Eagles were most likely to flush when recreationists approached slowly or stopped to observe them, and were less alarmed when bicyclists or vehicles passed quickly at constant speeds. Similar findings have been reported by other authors, who attribute the difference in flushing frequency between walkers and bikers/ vehicles either to the shorter time of disturbance and/or the additional time an eagle has to "decide" to fly (Van der Zande and others. 1984).

Impacts to Wildlife: Management Implications

- Many potential impacts to wildlife can be avoided by ensuring that trails avoid the most sensitive or critical wildlife habitats, including those of rare and non-rare species. There are a number of tactics for doing this:
- Route trails to avoid riparian or wetland areas, particularly in environments where they are uncommon. Consult with fish and wildlife specialists early in the trail planning phase.
- For existing trails, consider discouraging or restricting access during sensitive times/seasons (e.g., mating or birthing seasons) to protect wildlife from undue stress.
- The education of trail users is also an important and potentially highly effective management option for protecting wildlife. Organizations should encourage Leave No Trace practices and teach appropriate behaviors in areas where wildlife are found:
- Store food safely and leave no crumbs behind - fed animals too often become dead animals.
- It's OK for wildlife to notice you but you are "too close" or "too loud" if an animal stops what it’s doing and/or moves away from you.
- It's best to view wildlife through binoculars, spotting scopes, and telephoto lenses.
- All wildlife can be dangerous - be aware of the possible presence of animals and keep your distance to ensure your safety and theirs.

Conclusion

Scientific studies have examined the impacts of recreational use on trails and public lands. These studies provide an objective lens to view and understand how to better manage recreational use while minimizing impacts to natural resources and other users. The body of research has shown that motorized and equestrian use have significantly greater impacts to the natural resources than human powered trail uses. Studies present data that suggest ways to minimize impacts associated with trails, through proper design and construction (shallower grades, frequent grade reversals or water control features, more durable substrates with higher rock content).

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APPENDIX C: RECOMMENDED TRAIL DEVELOPMENT RESOURCES

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Conflicts on Multiple-Use Trails. Roger Moore. U.S. Federal Highway Administration, 1994.
www.fs.fed.us/cdt/carrying_capacity/conflicts_trails_synthesis_1994.pdf
This resource offers a comprehensive review of the research literature related to recreation conflict, and has served as an invaluable resource for trail managers, volunteers, and advocates for more than a decade. The information summarized in Section 2.5 is built upon the foundation of knowledge presented in this free publication.

Fromme Mountain Sustainable Trail Use and Classification Plan. District of North Vancouver, 2008 (http://www.dnv.org/article.asp?c=988)
This document is a good example of system-wide trail master plan. It was created through a 5-year process, and formalizes a shared-vision for the trails on Fromme Mountain. The document includes assessment of each system trail to provide an overall vision, best practices for environmental sustainability, and provides trail guidelines for future trail projects.

Lightly on the Land: The Student Conservation Association Trail-Building and Maintenance Manual. Robert Birkby, SCA, 2005 (*www.imba.com*)
Lightly on the Land focuses on crew leadership and the nuts and bolts of trail construction and maintenance. It contains detailed instructions on many technical skills such as building with rock, felling and buckling, building with timber, bridge construction, transplanting, and environmental restoration. It gets down and dirty with tools, tool repair, knots, and rigging. Instead of photos, it uses hundreds of fine illustrations to depict specialized techniques such as surveying, rigging, stonework, chainsaw skills, timber joinery, and bridge building.

Managing Mountain Biking: IMBA's Guide to Providing Great Riding. IMBA, 2007 (*www.imba.com*)
Managing Mountain Biking offers a collection of best practices for planning, designing, and managing successful trail networks and bike parks. More than 50 experts—including land managers, recreation ecologists, professional trailbuilders, and experienced advocates—contributed to Managing Mountain Biking, creating a complete reference. Managing Mountain Biking details overcoming user conflict, minimizing environmental impact, managing risk, and providing technically challenging riding. While Trail Solutions covers trail construction, Managing Mountain Biking focuses on solving mountain biking issues through innovative trail design, effective partnerships, and visitor management strategies.

Natural Surface Trails by Design: Physical and Human Design Essentials of Sustainable, Enjoyable Trails. Troy Scott Parker, 2007 (*www.imba.com*)
This groundbreaking book explores trail design from a theoretical perspective, covering the physical and human forces and relationships that govern trails—how we perceive nature, how trails make us feel, how trail use changes trails, and how soils, trail materials, water, drainage, and erosion behave.

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Recreational Trail Study for British Columbia: Phase 1 – Background Report. Ministry of Tourism, Sports and the Arts, Ministry of Environment, and Province of British Columbia, 2007 www.tsa.gov.bc.ca/sites_trails/docs/Provincial_Trails_Strategy/Trail_Strategy_Appendix1_May23.pdf
The first phase of this multi-phased project is the creation of this background report. This document is a great reference for information on Canadian laws and rules related to trails, best trail management practices from across North America, and discussion on the overall benefits of trails. It also includes a comprehensive survey, and the results, to help create a vision for the provincial trail planning, potential funding sources, and a province-wide trail inventory.

Region 5 Mountain Bike Management Strategy: Situational Assessment and Implementation Toolbox. Garrett Villanueva. U.S. Forest Service, 2007.
http://www.fs.fed.us/r5/mountainbikes/
This management strategy and situational assessment characterizes existing mountain bike trail conditions and provides methods for management. This document is written specifically for Region 5 in California, but its format, as a toolbox provides trail management advice that can be applied in any trail system. It is also a good example of a system-wide master plan.

Sea to Sky Corridor Recreation Trail Strategy. British Columbia, Ministry of Tourism, Sport and the Arts, 2007 (http://www.tsa.gov.bc.ca/sites_trails/Initiatives/SeatoSky-Strategy/sea_to_sky_strategy.htm)
The Ministry of Tourism, Culture and the Arts (MTCA) developed this comprehensive strategy to provide guidance on the management of this regional trail system. The strategy provides a framework for legal authorization and establishment of the vast majority of previously unauthorized trails on Crown land, recommends a process and organizational structure for ensuring a Corridor-wide coordinated approach to management of the extensive trail network, identifies opportunities and actions required to ensure a sustainable and economically beneficial network, and outlines and recommends trail construction, maintenance and sign standards and guidelines. This document is a useful example of a regional trail masterplan.

Trail Construction and Maintenance Notebook. Woody Hesselbarth, Brian Vachowski, and Mary Ann Davies. U.S. Forest Service, 2007 (www.fhwa.dot.gov/environment/rectrails/trailpub.htm)
This pocket-sized notebook is oriented to the needs of a trailworker. It pulls together basic trail construction and maintenance information in an easy-to-understand format. It includes a lot of the information detailed in Trail Solutions, plus a few additional strategies for trails in wet areas. It is concise with lots of illustrations – a perfect book to keep in a backpack out on the trail.

Trail Planning, Design, and Development Guidelines. Minnesota Department of Natural Resources, Trails and Waterways Division, 2007 (www.comm.media.state.mn.us/bookstore)
This comprehensive guide to shared-use paved trails, natural surface trails, winter use trails and bikeways is an excellent reference, well organized with tabs and an easy to follow lay-out. The book features dozens of useful reference illustrations and pictures for each specific topic (i.e. 6 pictures of different types of water caused erosion). Some information is Minnesota specific, but most is relevant to all climates and situations.

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Trail Solutions: IMBA's Guide to Building Sweet Singletrack. IMBA, 2004 (*www.imba.com*)
This comprehensive trailbuilding resource combines cutting-edge trailbuilding techniques with proven fundamentals in an easy-to-read format. The book is divided into eight sections that follow the trailbuilding process from beginning to end. Readers will be guided through the essential steps of trail planning, design, tool selection, construction, and maintenance. Additionally, Trail Solutions provides detailed advice on banked turns, rock armouring, mechanized tools, freeriding, downhilling, risk management, and other pioneering techniques. Trail Solutions is an essential tool for land managers and volunteer trailbuilders aspiring to raise their shared-use trail systems to the next level.

Wetland Trail Design and Construction. U.S. Forest Service, 2007. www.fhwa.dot.gov/environment/fspubs.
This manual describes common techniques for building a wetland trail. Starting with identifying the type of wetlands, this manual outlines how to build a dozen different types of wetland crossing structures (with and without foundations), what tools and materials to use, and instruction on maintaining drainage to minimize environmental impacts. This book is written for wetland trails, the techniques described can also be used for correcting other poorly drained low areas in existing trails.