Concept Design Report

Trout Brook Watershed Improvements
Afton Alps, Afton, Minnesota

South Washington Watershed District

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HR Green Project No. 20120012

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HRGreen

And:

inter·fluve

Executive Summary

This report provides a summary of the analysis and recommendations for the improvement of Trout Brook and the surrounding watershed at the Afton Alps Ski Resort in Washington County, Minnesota. HR Green partnered with Inter-Fluve Inc. to provide comprehensive assessment and design services for this effort. Multiple site-visits were conducted to observe specific hydrology and land-use patterns, perform a fluvial geomorphic analysis of the stream, investigate soil conditions, and determine the feasibility of proposed solutions. GIS data from multiple sources was analyzed to add 3D spatial information to field observations. A variety of solutions are proposed to improve in-stream and riparian habitat, improve stream and watershed aesthetics, and reduce the maintenance burden on the property owners. All solutions are designed to avoid interruption of normal business activities for the ski resort.

“Priority One” watershed improvements are those deemed most pressing and immediately implementable. These include maintenance modification suggestions, erosion control practices, surface treatments such as re-graveling roadways with durable, pervious, “no-fines” gravel instead of the existing soil / gravel mix, and installation of hybrid filter-swale practices. The overall objective of these solutions is to reduce sediment runoff sources, filter runoff before discharge to the stream, reduce groundwater surcharge and high-water-table issues, and cool runoff prior to stream discharge.

“Priority Two” watershed improvements focus on sediment source reduction by converting the existing parking lots to grass-paved surfaces and adding additional parking by converting problem wet, muddy areas to grass-pave as well. These improvements are more expensive to implement, but stand to improve conditions considerably. The parking lots and roads on this property are clearly the largest distinct sources of fine sediment loss to the stream, are recurring maintenance burdens, and are aesthetically unappealing. The Afton Alps property owners have stated a desire to stabilize these surfaces and add new parking spaces. Replacing these surfaces with drivable grass would alleviate the water quality issues, increase aesthetics, and meet the property owners’ need for better parking surfaces and more parking area.

In-stream improvements have been proposed by the specialists at Inter-Fluve Inc. These recommendations focus on stabilizing the stream to reduce erosion and maintenance, recreating habitat features such as pools and riffles, eliminating “perched” culverts, restoring stream buffers and vegetation, and trapping bed-load sediment coming from upstream erosion. A sedimentation pool has been collaboratively proposed by HR Green and Inter-Fluve to address this last concern. The pool would be a naturalized basin located on State Park property upstream from the Afton Alps property line. It would be passable for fish and would be designed to capture water-borne sands and coarse silts during base flow and moderate storm flow events.

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Watershed Improvements for the Afton Alps Property (HR Green)

Introduction

Trout Brook in Eastern Minnesota has experienced serious ecological and aesthetic degradation during the recent history. Independent monitoring and investigation by multiple parties has revealed elevated phosphorus and sediment loading as two major reasons for this degradation. Basic contaminant source assessments have been conducted and concept level mitigation measures have been compiled. The recommended mitigation strategy is a two-pronged approach addressing watershed runoff issues as well as in-stream habitat issues.

The Afton Alps property near the confluence of Trout Brook and the St Croix River is a prime location for progressive watershed improvement methods including source reduction strategies and runoff treatment measures. These recommendations have been designed to meet water quality goals, improve public-area aesthetics, and reduce maintenance burden on the property owners. The recommendations include maintenance modification suggestions, replacing road and parking surfaces, and installation of drainage swales with integral sand filters and rip rap under-drain trenches.

In-stream habitat issues have been identified through an independent fluvial geomorphic assessment conducted on the lower reach of Trout Brook. Improvement recommendations include re-vegetation and restoration of a two-stage streambed, installation of a sediment collection pool, increasing riparian buffers, and eliminating perched culverts.

Sources of Loading

Within the Afton Alps property, the primary source of sediment loading to Trout Brook is runoff from the parking lots and roads. During heavy rain events and the spring melt, rapid runoff from the steep upland slopes flows over the gravel and mud surfaces and into the stream adjacent to the main road. Table 1 below indicates that the suspended solids concentration in Trout Brook at a sampling point just downstream from the Afton Alps property is highly correlated to discharge and storm events. Figure 1 below shows the condition of the existing parking lot and road during an early spring runoff event – there is a culvert inlet in the center of the photo at the base of the mud drainage swale, the culvert leads directly to Trout Brook.

Table 1. Summary of 2011 Water Quality Data for Trout Brook

2011 Data (May - October)	Mean Flow [cfs]	Mean TP [mg/l]	Mean TSS [mg/l]	# Samples
Base Flow Grab Samples	2.5	0.224	4.6	5
Storm Composites	5.8	0.517	554.1	8
Correlation to Flow	1	0.32	0.85	-

Figure 1. Lower Parking Lot and Road During Runoff Event (Photo: HR Green)

In addition to direct runoff from precipitation on the road and parking areas, the unique nature of the ground surface in this area contributes to the local sediment and phosphorus export. By nature, a ski slope is tall and steep with underlying bedrock formations. Between the base of the slope and the creek is a wide flat plain used by the facility for roads, parking lots, and buildings supporting the business activities. As illustrated in Figure 2 below, groundwater from the upper slope region migrates downward toward the creek and creates problematic wet conditions in the flat plain. From a groundwater perspective the “phreatic line” (water table gradient) rises above the ground surface at the base of the hill creating wet surfaces locally and high water table characteristics in the remainder of the flat plain approaching the creek.

The Afton Alps property experiences land use problems due to this phenomenon and a lack of integrated groundwater management. The property owners have avoided paving the eastern road and parking areas due to high-water-table frost heave concerns. The dirt / gravel surface is also susceptible to frost heave and is therefore regularly re-graded to maintain a smooth surface. At other locations the flat plain at the base of the hill is very wet, muddy, and in poor condition due to maintenance vehicle traffic and overflow parking usage (see Figure 3). The end result is that the muddy plain, and continuously re-graded surfaces release large quantities of sediment during the spring thaw and subsequent rain events.

The surface runoff is also warmed by solar exposure which can lead to thermal degradation of the trout habitat. In addition subsurface anoxic conditions have been observed in some perpetually wet areas, especially the existing wet swale south of the eastern Alps Chalet parking lot. These conditions can induce otherwise-beneficial soil microbes to “dump” phosphorus, which then sorbs to sediment particles and is transported downstream during runoff events.

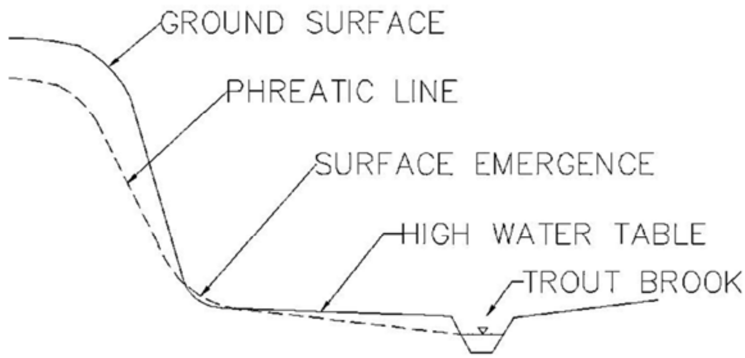


Figure 2. High Water Table Phenomenon Near Steep Slopes

Figure 3. Typically Muddy Conditions at Base of Slope Due to High Water Table (Photo: HR Green)

Recommendations

The best mitigation strategies for this site will reduce the availability of free sediment (source reduction), add measures to trap sediment and phosphorus, and reduce free water on and just below the ground surface. These measures will simultaneously prevent warming of runoff and reduce frost heave risk, which will in turn lead to further source reduction as the need for road-grading will be reduced if not eliminated.

The recommendations for improving Trout Brook are divided into improvements within the stream banks, and improvements in the contributing watershed. The in-stream assessment and improvements are provided in the Fluvial Geomorphic Assessment report and exhibits from Inter-Fluve, Inc., included below. The watershed improvements are further divided into source reduction improvements and treatment improvements. Two phases of implementation are suggested if the improvements are to be staged to reduce financial burden. The majority of these improvements are further detailed in the exhibits, attached as Appendix A.

Priority 1 Watershed Improvement Recommendations

1. A. Roadway and Parking Lot Maintenance Practice Modification

Due to the proximity of roads and parking lots to the creek, and the lack of an effective riparian barrier in many locations, special maintenance requirements exist on this property. Re-grading of roads and parking lots should be minimized as much as possible. When re-grading is absolutely necessary, care should be taken to avoid deposition of grading spoil near the creek banks or near surface drainage swales leading to the creek (see Figure 4). Spoil should be stockpiled in a location that is unlikely to create sediment laden runoff near the creek (see Figure 5). Any stockpiles remaining onsite and containing finely textured soil material should be located away from drainage paths, and encircled with silt-fencing or other appropriate measures to control sediment laden runoff.

Figure 4. Grading spoil on creek bank (Photo: HR Green)

Figure 5. Approximately 8 tons of fine textured grading spoil deposited 30 feet from the creek bank (left); Approximately 50 tons of soil stockpiled immediately adjacent to creek near employee parking lot (right) (Photos: HR Green)

1. B. Roadway and Parking Lot Maintenance Material Modification

   Most of the existing non-paved driving surfaces are composed of soil / gravel mixtures and are sparsely vegetated (especially during spring and early summer when runoff is highest). When repairing these surfaces new material should be used such as open graded (pervious) gravel aggregates with minimal fines content (such as washed ASTM D57 crushed stone). This replacement would reduce muddy conditions, reduce standing water, improve runoff water quality, reduce maintenance needs, and improve aesthetic value. Complete replacement of these surfaces is proposed and estimated in the exhibits included herein as appendices.

2. Repair Access Road and Install Drainage Swale

   The access road on the far east side of the Afton Alps property requires frequent repair due to erosion of cross-flowing surface runoff. Both the erosion and the subsequent repairs with native gravel / soil mixtures are significant sources of runoff sediment. Some seasonal snow-melt runoff does flow down the road itself, so repairs to the road surface should include installation of larger aggregate material with minimal fines.
   Runoff from the Afton Alps ski slopes crosses the access road in one concentrated location just north of the base of ski lift number 11 (see Figure 6). Additional runoff is distributed along the remaining ~500 feet of road between lift #11 and the Meadows parking lot. This section of road should be excavated and replaced with larger open-pore gravel (no fines). A culvert should be installed at the concentrated runoff location near lift #11. A small roadside swale should be installed along the west side of the road to deliver distributed runoff to the sand filter at the east end of the Meadows Chalet parking lot (see map and item #3 below). This design would improve runoff water quality and reduce the maintenance burden on the property owners.

Figure 6. Access road is routinely re-graded which stirs up sediment due to dirt / gravel surface; damage is due to seasonal cross drainage (Photo: HR Green)

3. Runoff Filtration and Improvement of Subsurface Drainage

The water in Trout Brook is primarily base-flow from groundwater seeping out of surrounding higher ground. Historically this produced clean, cold water conducive to good trout habitat, however the current developed lowland area affects the overland flow differently. In this case the water quality and land surface quality would both benefit from maintaining flow below the ground surface. Also, several problem wet areas exist at the base of the ski slopes and in the parking lots, particularly at the base of Ski Lift # 5, along the south side of the lower road and on the east and west ends of the Meadows parking lot.

Strategically placed, rip rap filled drainage trenches with overlying sand filters and grass swales could improve this situation (see Exhibit A7 in Appendix A). These would be a hybrid BMP, utilizing the surface water filtration of a bio-swale, the sediment removal character of a sand filter, groundwater collection capacity of a drainage trench, and cool conveyance properties of a rip rap thermo-cooler (based on individual designs from the Minnesota Stormwater Manual).

Groundwater in the vicinity of the drainage trenches would migrate to the trench and flow beneath the ground surface to the stream without warming, picking up surface sediment, or causing surface damage. And surface runoff would be filtered in two stages as it percolates first through the vegetated swale surface, then through the underlying sand filter. The rip rap at the trench bottom maintains a highly porous drainage path as well as providing thermal mass to cool the surface runoff. At the low end of the system a perforated culvert section collects flow from the rip rap underdrain and a standpipe weir collects swale overflow during high flow events.

Reducing the water table will improve land use for the property owners by reducing surface flow, muddy conditions and frost heave concerns. With frost heave action reduced, the road and parking surfaces can be improved without the need to continuously re-grade.

Maintenance of this design would be limited to regular removal of debris from the swale surface and replacement of the sand layer when clogged with sediment. The latter should be infrequent, especially if the road and parking surfaces are converted from the current dirt / gravel to grass-pave or porous gravel.

Priority 2 Watershed Improvement Recommendations

Grass-Paving

All gravel / dirt parking lots should be converted to durable, pervious surfaces. Grass-pave systems are a good fit for this application due to the following:

- The majority of traffic occurs during winter so heavy usage at that time would not inhibit grass growth
- Grass paving would accommodate intermittent summer use for parking, camping, weddings, etc.
- Grass will help retain sediment and maintain surface integrity
- Grass will promote biological nutrient uptake and evapotranspiration of runoff (nutrient removal is further enhanced by removal of clippings)
- Due to engineered gravel subgrade and flexible load-bearing grid materials, grass-pave systems are less affected by frost heave than conventional pavement
- The resulting surface would be aesthetically appealing for the public, and can offer an educational opportunity

Estimated Impact on Water Quality

Water quality samples were taken from Trout Brook at the downstream end of the Afton Alps property multiple times between April and October, 2011. The samples were taken by hand and by an automated ISCO sampler. The sporadic data was processed with LOADEST to interpolate total suspended solids (“TSS”) and total phosphorus (“TP”) concentration measurements based on daily discharge measurements. This technique produces estimates of contaminant flux for the duration of the sampling period and removes statistical bias that would be introduced by assuming a pure correlation between discharge and concentration. From April 16, 2011 to October 29, 2011 an estimated 270 tons TSS and 436 pounds TP were discharged past the sampling location.

Two methods of quantifying TSS and TP reductions due to watershed improvements were employed: Typical BMP assessment using P8 software, and hand calculations for source reduction improvements. Hand calculations for TSS source reduction were performed using the Universal Soil Loss Equation (“USLE”, USDA-ARS, 1961) to predict sediment losses from the soil / gravel parking lots and roads before and after improvement. Calculations were conducted to predict changes in TP loss using equations provided in Table L1 of the Minnesota Stormwater Manual. Load reductions resulting from implementation of the modified filter swales were estimated based on pertinent case studies and academic research. These percent removal estimates were applied to the input loading rates generated by the P8 model to produce annual mass reduction estimates. The modeling and calculation results are listed on each area specific Exhibit in Appendix A, and on Table 5 near the end of this report.

Additional Option - Sedimentation Basin Upstream From Afton Alps Property

As detailed in the Geomorphic Assessment Report, bed load sediment transport is of concern in Trout Brook due to widespread upstream stream bank erosion. Three options for sediment interception have been considered for the floodplain immediately east (upstream) of the Afton Alps Property Line. This location (see Exhibit A6 in Appendix A) is optimal for pool type basins because of availability, local topography, convenient access, and ample tree cover to provide shade and reduce thermal gain. A traditional sedimentation basin (see Figure 7 below) could be constructed off-line beside the existing stream, or on-line within the existing stream. Rough calculations suggest that the basin would need to be approximately 200 ft long, 5 ft deep, and 45 ft wide at the permanent pool elevation (15 ft wide bottom with 3:1 side slopes) to effectively capture sand and coarse silt.

An additional option is the use of a ramp-and-hopper type in-stream bed load collection device, see figure 8 below. This device is available with a 1 yd^3 hopper underneath which would be pumped out as needed. The pumped slurry would be routed to a remote de-watering bin which allows decanted water to drain back to the stream. The bin is compatible with conventional roll-off boxes for convenient offsite disposal. Table 3 provides a comparison matrix for the three options.

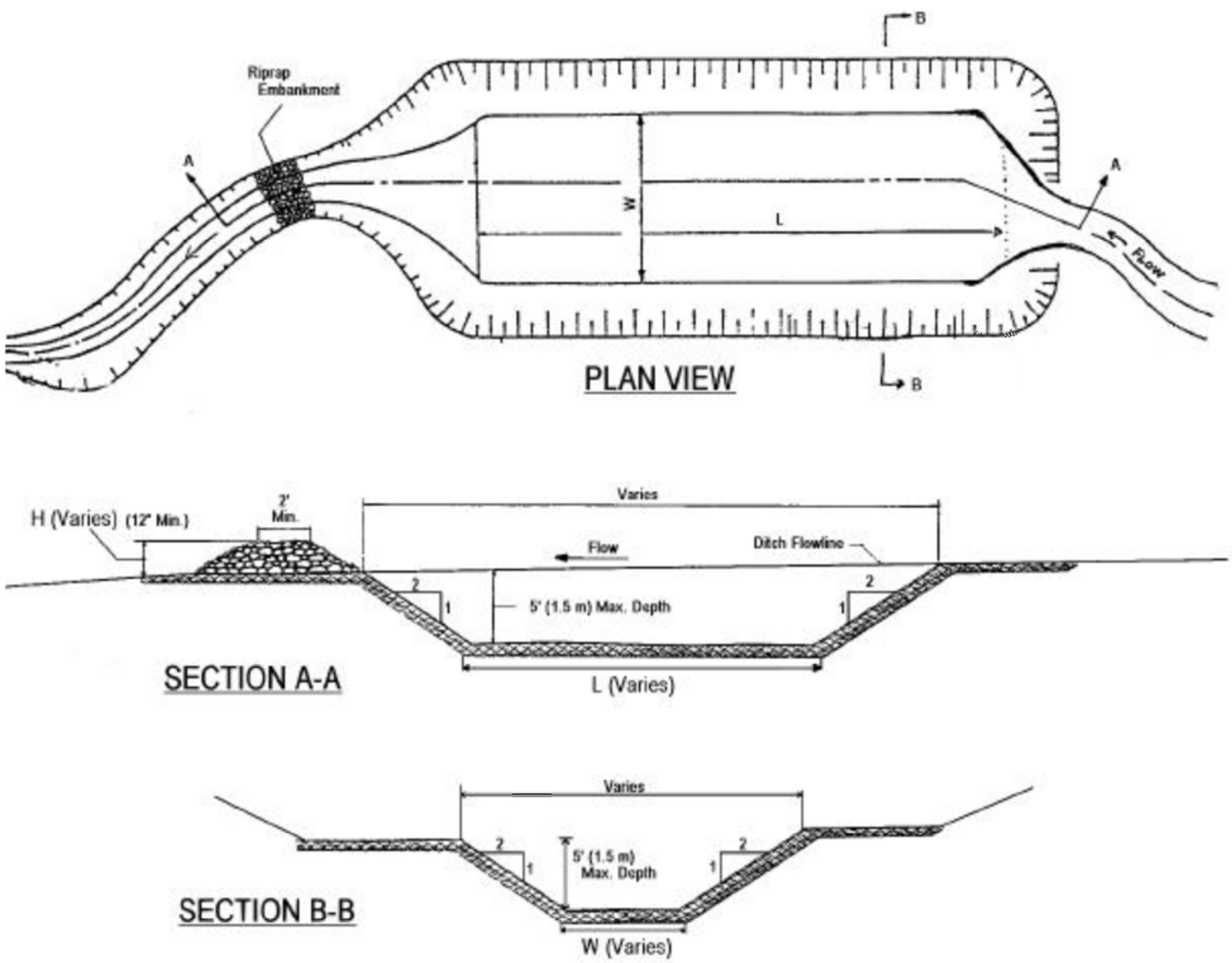


Figure 7. General Concept Sketch of a Constructed Sedimentation Basin (Image courtesy of Indiana DNR)

Figure 8. In-stream Bed Load Collection Device (photo courtesy of Streamside Systems Inc.)

Estimated Performance

Performance calculations have been made for a theoretical sedimentation basin similar to Figure 7 above with the following dimensions: 200’ long, 45’ top width, 15’ bottom width, 5’ normal depth, and 3 to 1 side slopes. Table 2 below shows the predicted removal rates for this design. This design would have capacity for at least 300 cubic yards of sediment before removal would be required.

Table 2. Estimated Percent Removal (for Traditional On-Line Basin)

	Base Flow	Highest Measured Storm Flow	One-Year Flood	Ten-Year Flood
Very Fine Silt	9.9	2.3	0.6	0.1
Coarse Silt	99.9	88.9	32.8	6.7
Very Fine Sand	100.0	99.9	88.0	25.6
Medium Sand	100.0	100.0	100.0	99.4

Recommended Design

We recommend an on-line traditional basin for this site because this design would capture the most sediment and require the least maintenance of the three options. See Exhibit A6 in Appendix A for the recommended placement.

Table 3. Sediment Removal Method Comparison

Sediment Collection Device	Removal Capability	Discharge Range	Footprint	Cost	Requies Heavy Equipment Access?	O & M Required
Proprietary Ramp and Hopper, with Pump and Dewatering Bin	Bed Load Only	All	Placed in existing stream bed, bin placed nearby	~$27,000	No	~2 hours / month operation; annual sediment hauling
Off-Line Sedimentation Basin	Bed and Suspended	Storm Flow	~6,000 sf beside existing stream	~$35,000	Yes	No operation required; Excavate sediment every few years
On-Line Sedimentation Basin	Bed and Suspended	All	~6,000 sf in-stream	~$28,000	Yes	No operation required; Excavate sediment every few years

Fluvial Geomorphic Analysis Report (Inter-Fluve)

Introduction

Trout Brook is a small stream flowing through the Afton State Park and Afton Alps Ski Area into the St. Croix River. The course of the stream has been modified over time to accommodate the ski area and parking lots and has been impacted by watershed land use changes over the last 150 years. The stream flowing through the Afton Alps Ski Area has experienced excessive sedimentation and incision in different reaches. Inter-Fluve was contracted to conduct a fluvial geomorphic assessment of the stream and produce conceptual renderings for a more stable stream.

Fluvial geomorphology is the foundational study driving the Afton Alps trout brook concept design project. Inter-Fluve geomorphologists and aquatic ecologists completed a geomorphic assessment of the study area, topographic surveys, analysis of grain-size distributions of the channel bed, and review of existing studies and relevant data. This technical memo summarizes the collected existing data in the context of this project, describes the methods and results of the geomorphic analyses completed, and describes the conceptual designs for stabilizing and restoring Trout Brook.

Geologic Setting

The Trout Brook watershed is underlain primarily by Paleozoic bedrock dominated by dolomitic sandstone and limestone. Trout Brook flows through Upper Cambrian sandstone from its headwaters to its mouth in the St. Croix River (Figure 9). A small section of the lower portion of Trout Brook and its watershed are within the Lower Ordovician dolomitic limestone. Through much of the watershed, the bedrock is currently obscured below the ground surface. Some of the sandstone bedrock is exposed on hillsides, however, as Trout Brook flows through the steeper topography in the middle of the watershed (Figure 10).

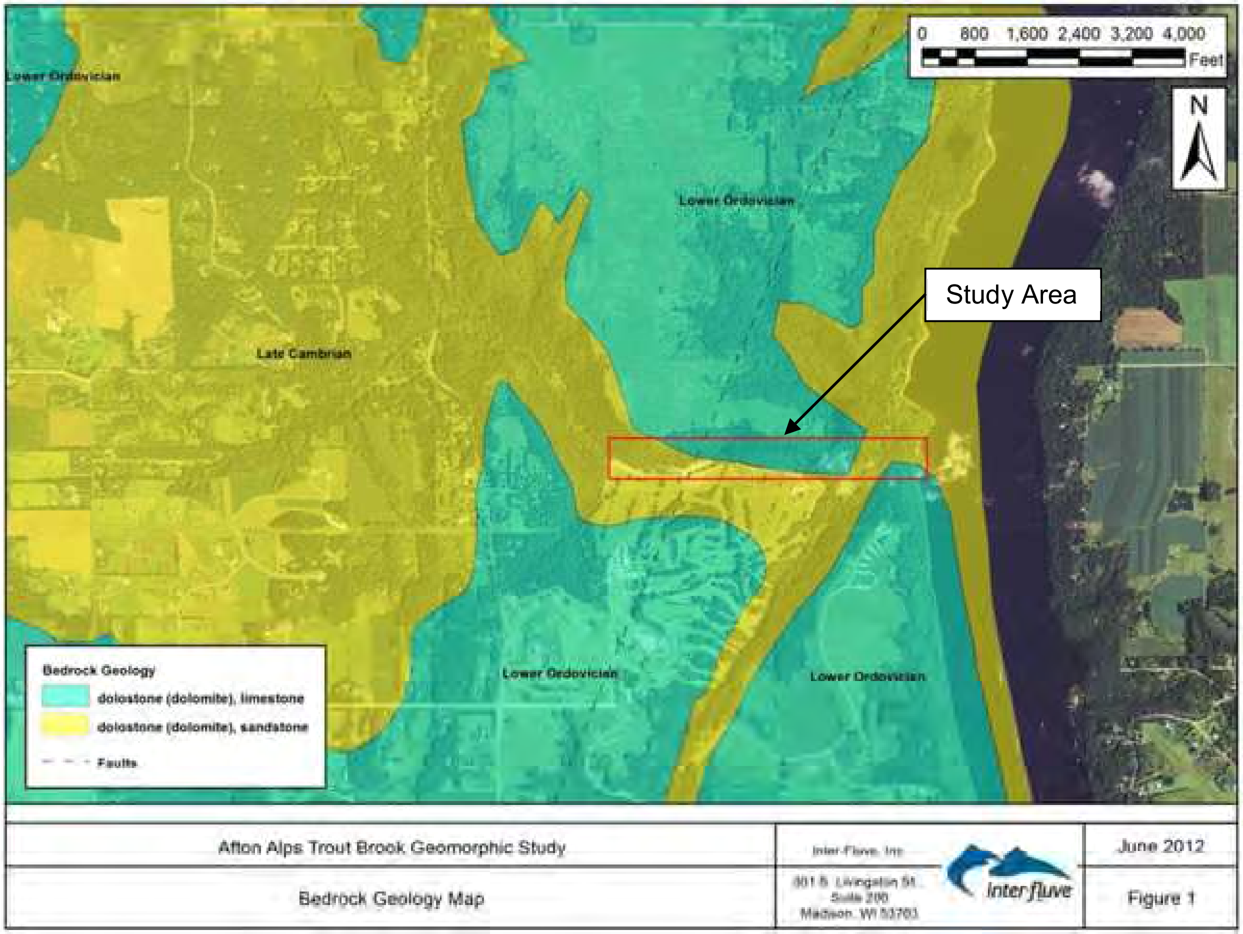


Figure 9. Bedrock geology map with study area shown with the red rectangle (adapted from USGS).

Figure 10. Exposed bedrock in higher gradient slope upstream of the Afton Alps Ski Area (Photo: Inter-Fluve).

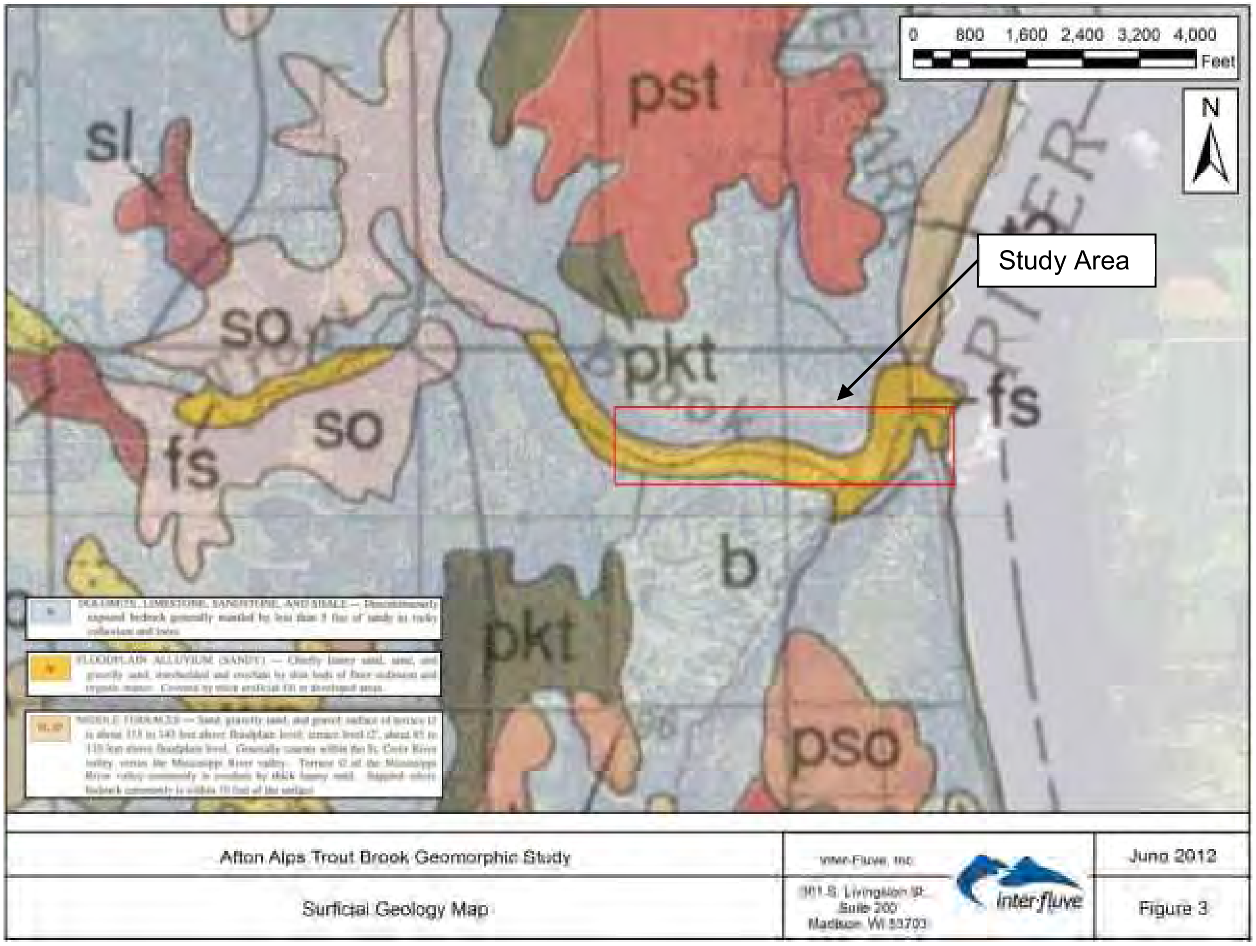


Figure 11. Surficial geology in the Trout Brook watershed with the study area identified by a red rectangle.

The majority of the ground surface in the Trout Brook watershed has less than 5 ft of colluvium and loess, which are dominated by sand and gravel, with some exposed dolomitic bedrock throughout (Figure 11). Along most of the stream bed and floodplains, including the portion within the study area, the surficial geology is primarily sandy floodplain alluvium (Figure 12). Most of the sediment within the watershed, and within Washington County, was deposited through the glacial history of the Pleistocene time period. Multiple glaciations during this period resulted in large glacial lakes, moraines, glacial topography, and the sands and gravel observed in the region today (Figure 13).

Figure 12. Sandy floodplain alluvium along Trout Brook in the study area (photos: Inter-Fluve).

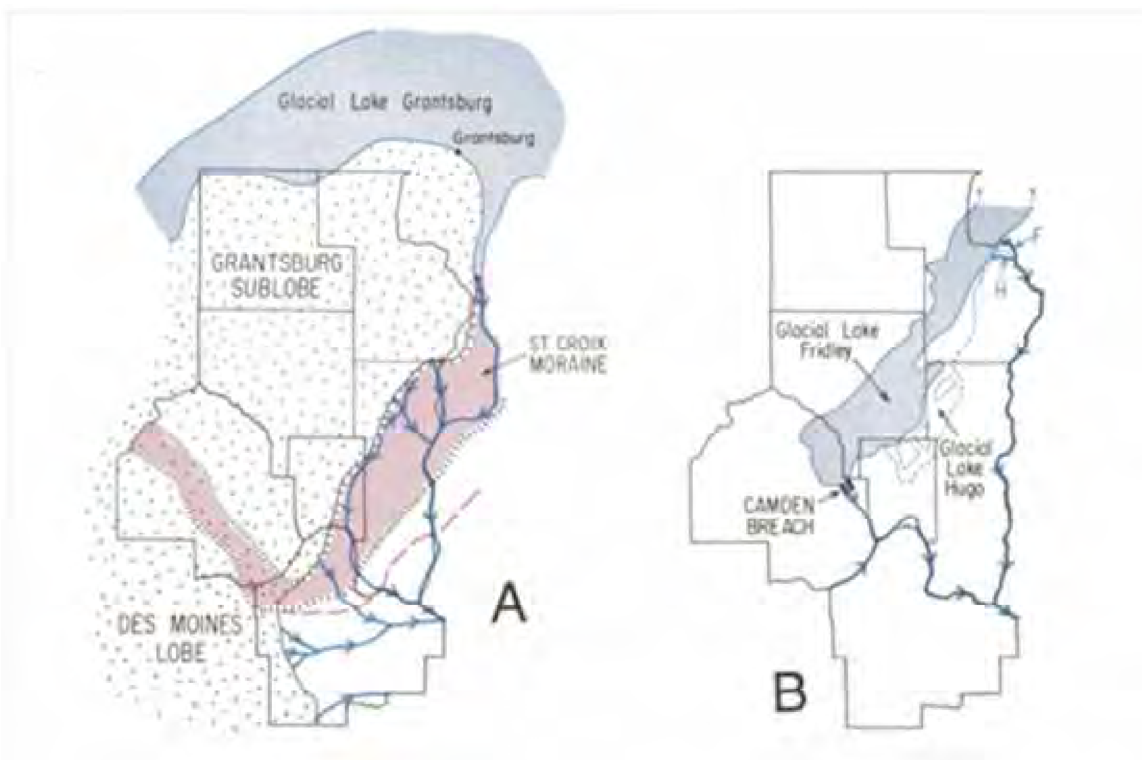


Figure 13. (Left) Superior lobe extent is indicated by red dashed line; (right) glacial lakes and their outlets near the St. Croix River (from Meyer et al., 1990).

Hydrology

The Trout Brook watershed is approximately 8.5 square miles (Figure 14). No long-term flow data is available for Trout Brook, but discharge was measured between April 15 and October 29, 2011 at the dirt road crossing on the downstream end of the Afton Alps property. Measurements every 15 minutes in this time period suggest that low flows typically range from 2-5 cfs (Figure 15). Flood estimates based on regional regression calculations obtained from the USGS Streamstats program suggest that flood flows range from 101 cfs in the 2-yr flood to 643 cfs in the 100-yr flood within the Afton Alps Ski Area property (Table 4). Two tributaries join Trout Brook between the dirt road crossing at the downstream end of the Afton Alps property and the St. Croix River, increasing flood flow estimates slightly.

Table 4. Flood flow estimates based on regression analyses and obtained from the USGS Streamstats program. 'DS Bridge' is the dirt road bridge at the downstream end of the Afton Alps property.

Location	Flows (cfs) at Given Recurrence Interval (yrs)							
	1.5	2	5	10	25	50	100	500
DS Bridge	69.9	101	200	287	415	521	643	970
Mouth of Trout Brook	81.8	118	232	331	476	596	735	1100

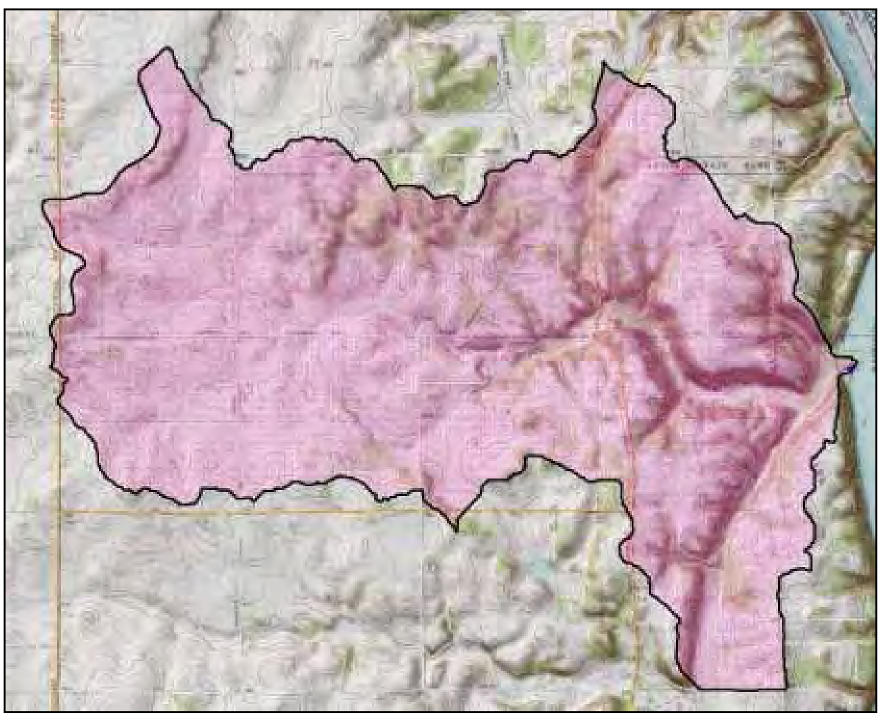


Figure 14. Trout Brook watershed (from USGS Streamstats).

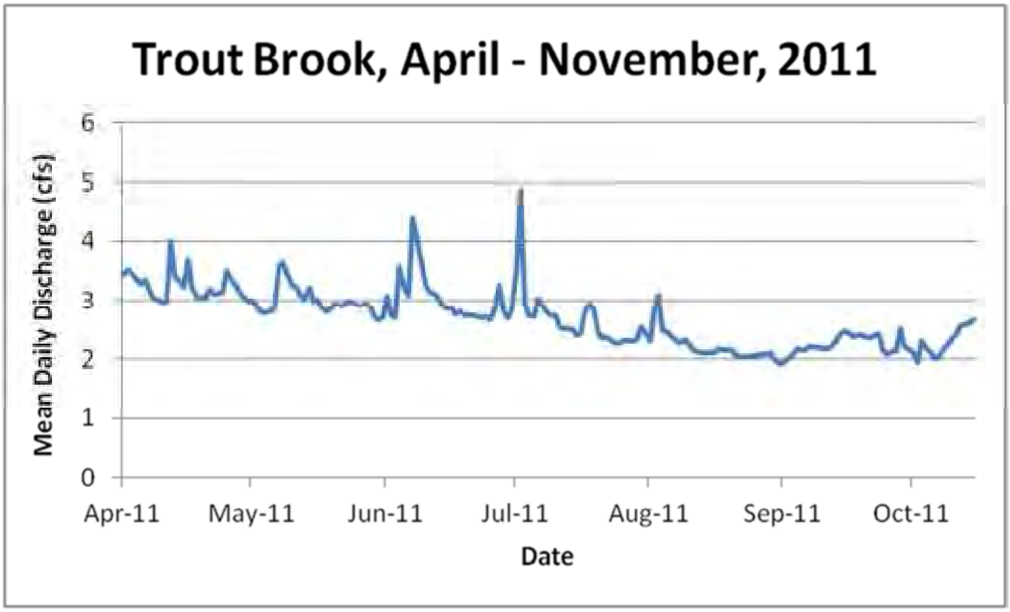


Figure 15. Mean daily discharge for Trout Brook from April to November, 2011, as measured at the dirt road bridge at the downstream end of the Afton Alps property.

Geomorphology

The slope, geometry, and form of Trout Brook has been altered, likely multiple times, by land use changes within its watershed since the mid-1800s. The 1848 plat maps show the stream to be a sinuous channel throughout its length. With prairie only identified further to the west, we can infer from the 1848 maps that the majority of the Trout Brook watershed was forested in the mid-19th century. Air photos from the 1950s and 1960s suggest that by the mid-20th century many of the trees along the river were cleared, agriculture dominated the upper portions of the watershed, and the stream was shallow, wide, and generally sinuous and sometimes multi-threaded as well (Figure 16). By 2010, increased numbers of houses and roads had been built in the watershed. With the construction of the ski area, the channel was constrained to a straightened ditch to allow for the construction of parking areas, buildings, and ski runs.

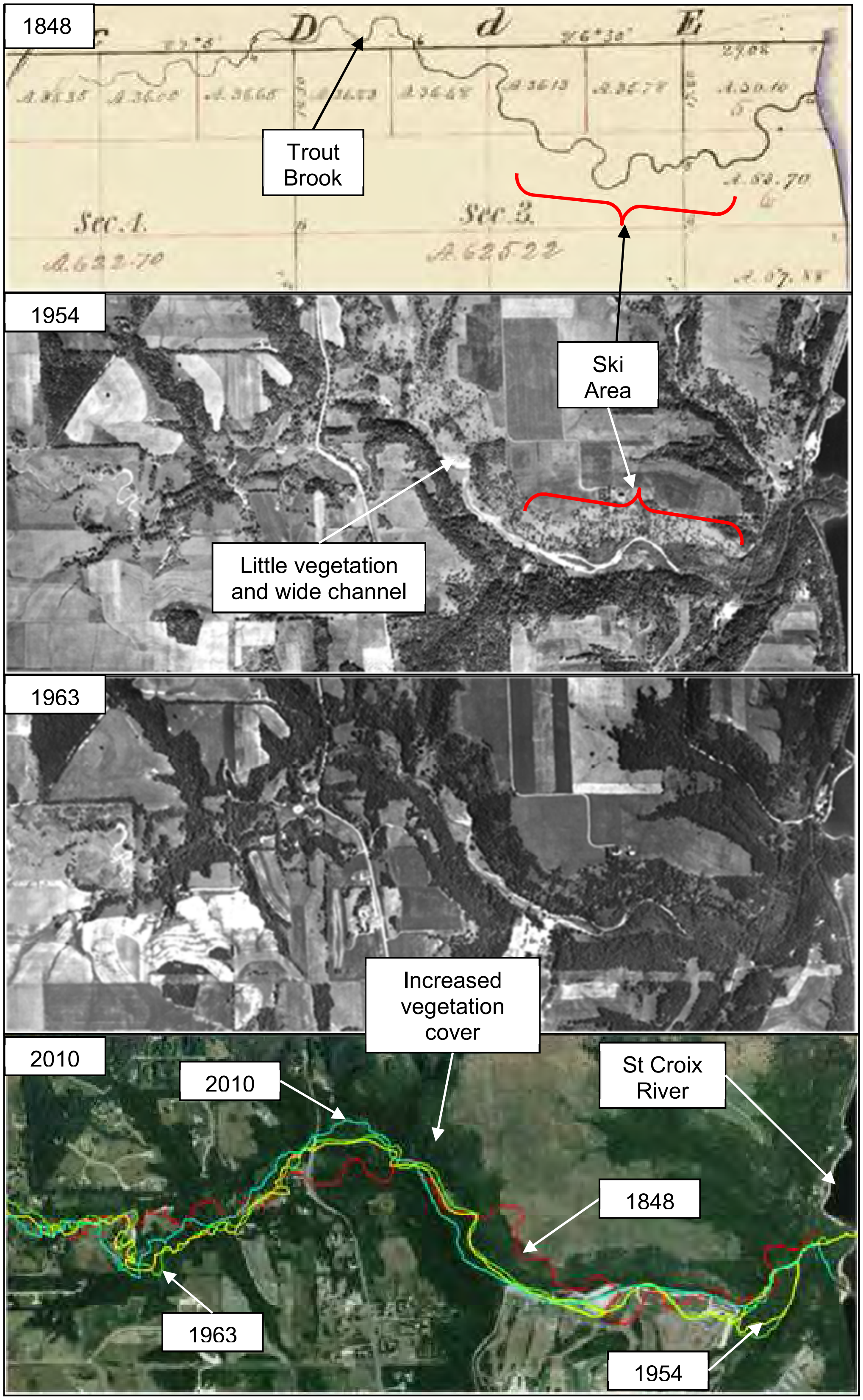


Figure 16. Maps and air photos of the study area since 1848. The lower photo shows the channel alignments for each of the above years overlain on the most recent aerial photograph.

The air photo and map analysis was corroborated by observations made in the field while conducting the geomorphic assessment. Upstream of the Afton Alps Ski Area, the channel meanders through a narrow alluvial valley with multiple floodplain and terrace surfaces. The active low-flow channel has an approximately 5-8 ft wide top width and is 1 ft deep. Grasses grow along a floodplain that is 5-10 ft wide and inset into a higher floodplain (Figure 17). This higher floodplain is approximately 3-4 ft above the channel bed and contains ~30-50 yr old trees. The floodplain surface is 30-50 ft wide on either side of the stream and channel scars suggest that this surface was the elevation of the channel bed more than 30 years ago, corresponding with the 1953 and 1964 air photos. We also identified an abandoned terrace about 8 ft above the channel bed. This terrace sustains trees more than 50 years old and exposed roots indicate that a stream channel had eroded the banks at that location decades ago. This was likely the floodplain while the channel was aggraded during the mid-1900s due to excessive sediment loads.

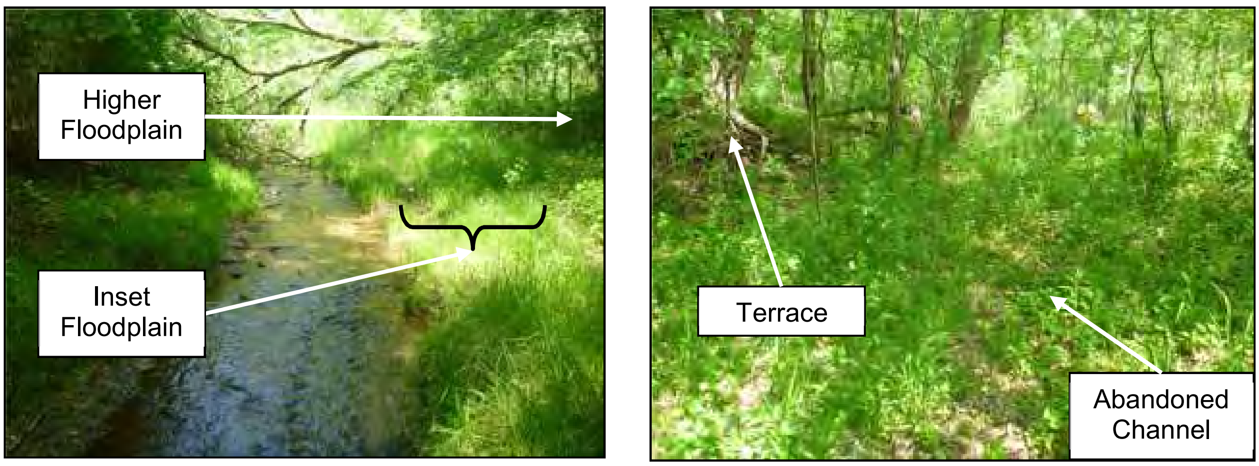


Figure 17. Channel, floodplain, and terrace features upstream of the Afton Alps property showing the evolution over the last 150 years recent incision and creation of an inset floodplain (left) within a higher floodplain that used to be the channel bed due to excessive aggradation (Photos: Inter-Fluve)

A possible timeline of land use changes and subsequent channel changes based on data collected during this study may include:

- ~1850-1950: all land not too steep to farm was cleared for agriculture; land too steep to farm was cleared for timber
- ~1900-1970: sediment loads increase due to runoff from the land clearing and agriculture; channel bed aggraded and became multi-threaded in some locations
- ~1970-present: sediment loads from land clearing and agriculture begin to lower; trees begin to grow along the alluvial valley; increased hydrology due to decreased infiltration, increased development in the watershed, and regional increase in precipitation; the stream begins to form a new channel alignment by eroding through the accumulated sediments and builds a larger channel to accommodate the increased flows
- 1960-present: Afton Alps Ski Area is constructed; channel within property is diverted into a straightened ditch to make room for parking areas, buildings, and ski lifts

Channel bed, bank, and floodplain sediments were investigated to understand the sediment transport history of the site as well as the existing grain size distribution of the stream. Upstream of the Afton Alps Ski Area, sand continues to be transported from upstream sources, accumulating in pools and behind obstructions such as log jams or beaver dams (Figure 18). Small to large gravel were identified along riffles, while sand dominated the majority of the stream, which consisted of runs and shallow pools. The stream banks were primarily composed of sand and sandy loam as were the floodplain and terrace surfaces. Pits dug into the floodplain surface, which was the channel bed in the mid-1900s, revealed multiple feet of sand with occasional organic layers. Within the Afton Alps property, the channel bed grain size ranged from fine sand to gravel and cobble (Figure 19). Upstream of the eastern-most culvert near the ski lodge, the channel slope is relatively low-gradient and sand from upstream sources accumulates within the channel. Downstream in the straightened ditch, the channel maintains a steeper riffle-pool form. Sand from upstream sources as well as from runoff from parking lots and roads has generally filled in many of the pools that may exist otherwise. Small riffles and shallow pools were observed, but the stream was dominated by long, sandy runs.

Figure 18. Sand accumulates behind obstructions (left) as well as in the pools and runs through most of the length of the stream (right). (Photos: Inter-Fluve)

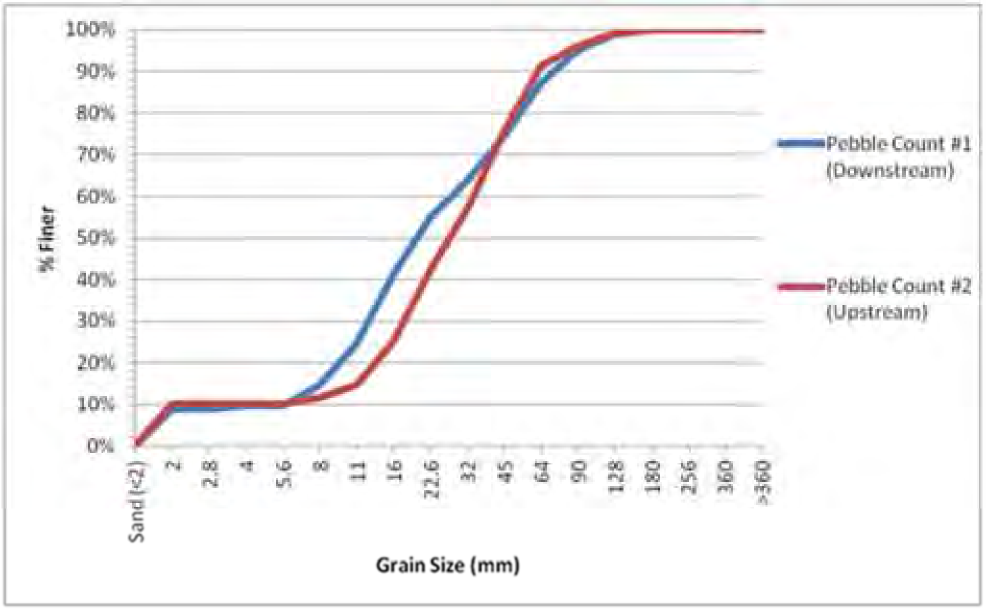


Figure 19. Grain size distribution of channel bed upstream of the western-most road crossing near the Alps Chalet (#2) and downstream of the eastern-most road crossing near the Alps Chalet (#1).

The slope of Trout Brook is relatively consistent at a 1% slope based on the topographic map and channel alignment prior to straightening and ditching within the study area (Figure 20). The first mile in the headwaters are steep and lead to a 1-mile lower-gradient reach before steepening again through the hilly portion of the watershed. This steeper reach extends to the St. Croix floodplain where Trout Brook becomes very low gradient. While the slope varies in smaller local reaches, the stream within the Afton Alps property has a similar 1% slope (see concept design plans in Appendix B).

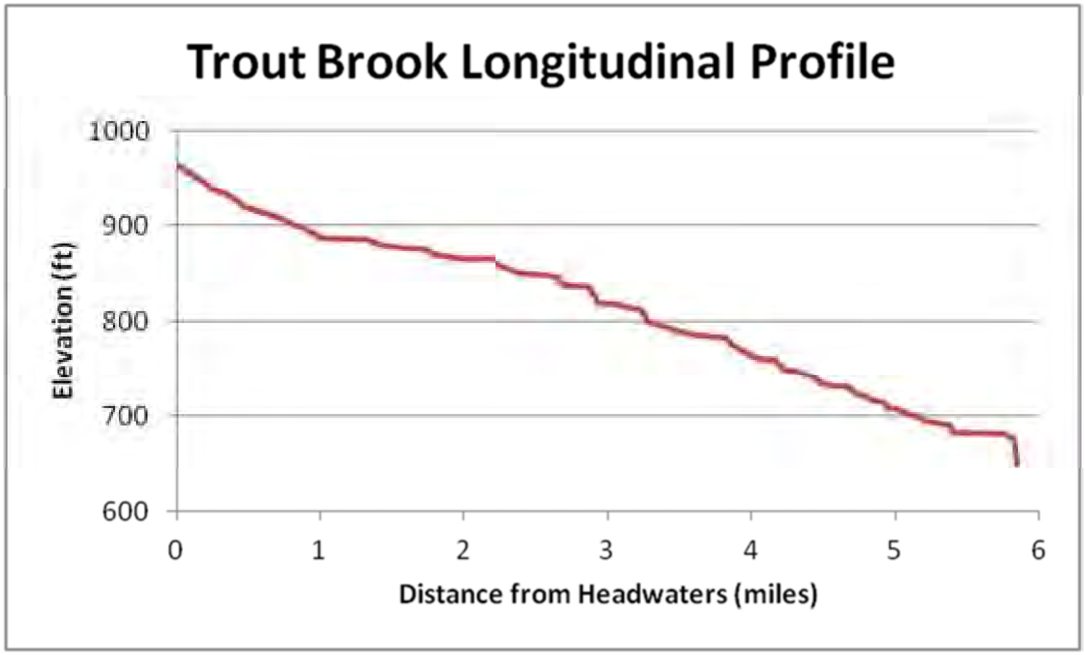


Figure 20. Longitudinal profile for Trout Brook from the headwaters to the St. Croix River (created using the USGS Streamstats program).

Implications for Stabilization and Design

Trout Brook has been impacted by land use changes since the mid-1800s. While the sediment loads have likely decreased since the period dominated by agriculture and the clearing of forests, excessive volumes of sand are still being transported through the system into the St. Croix River. This sediment is coming from sources upstream of the Afton Alps property as well as from uncontrolled stormwater runoff along the roads and parking lots within the Afton Alps property.

The stream channel continues to adjust to all of the changes in the watershed. Upstream of the Afton Alps property, the channel is incising through the aggraded sediments and may be incising through its historic channel elevation due to the increased hydrology. Within the Afton Alps property, the straightening of the channel into a ditch resulted in initial headcutting that migrated upstream to the culverts. The culverts have arrested the incision, but this has caused the culvert to be perched resulting in a fish-passage barrier, large scour pools, and erosion. Downstream of these culverts, the channel is moving towards a new equilibrium with a small inset floodplain observed in a few places and limited excessive bank erosion. Upstream of the culverts, sediment accumulation and the active removal of this sediment and management of vegetation are continually changing the form of the stream.

Stabilizing the stream through the Afton Alps property in a manner that is geomorphically and ecologically functional, as well as aesthetically pleasing to the numerous visitors to the ski area, is possible but will require regular maintenance. Because we do not know the full extent of upstream sediment sources, we recommend a more complete geomorphic assessment of the upstream watershed. This assessment would identify sediment loading sources and characterize the extent of these sediment inputs as well as their likelihood to continue into the future. Assuming that the sediment influx from upstream remains constant, a combination of approaches could be used to maintain a stable, aesthetically pleasing stream that improves geomorphic and aquatic/riparian habitat conditions.

Recommendations for Stream Stabilization

The following stream and bank restoration suggestions are also provided in the conceptual renderings in Appendix B.

Culvert replacement - The culverts beneath the two road crossings near the ski lodge are undersized, which results in stream destabilization, degradation of aquatic habitat, and creation of a fish-passage barrier. We recommend replacing these culverts with bridge spans or bottomless arch culverts (Figure 21; see also Exhibit B2 in Appendix B). This would allow the flood flows to pass through without resulting in excessive erosion and would improve habitat and fish passage.

Figure 21. The culverts under both road crossings near the Afton Alps lodge are all perched and undersized, leading to erosion and ecological concerns (top photos). These can be replaced by bottomless arch culverts (left) or bridge spans for better stream flow. (Photos: Inter-Fluve)

Sediment trap - Because the volume of sediment continuing to enter the Afton Alps property from unknown upstream sources is not likely to stop in the near future, we recommend constructing a series of steep riffles and deep scour pools upstream of the western-most road crossing. These deep scour pools would capture the sediment that is transported from upstream. Because of the proximity to the entrance to the ski area and parking lot, the sediment within the sediment trap could be easily removed when necessary. The sediment trap would provide a localized area for removal of sediment rather than removing it from large reaches of channel and floodplain.

Channel re-construction - Another method of transporting sediment is to steepen the channel and increase the flow velocities so sand is unable to be deposited as frequently. This can be accomplished by designing and constructing a narrow low-flow channel consisting of cobble/boulder riffles and steps with small pools in between. These riffles will also provide adequate grade control, which will become necessary when the culverts are replaced. This low flow channel would be built within a higher flow channel that would likely contain the approximate 5-yr flood. Channel banks would be stabilized using a variety of bioengineering techniques. The channel bed would be constructed so as to be passable by native fish and would provide a variety of habitat features throughout. Channel re-construction would likely need to occur from the upstream extent of the property to downstream of the eastern-most road crossing (approximately 1500 ft).

Buffers and re-vegetation - Through most of the stream length within the Afton Alps property, the buffer between roads, parking areas, and the stream is less than 5 ft (Figure 22). The lack of a sufficiently wide buffer results in excessive stormwater runoff, decreased bank stabilization, and decreased water quality due to lack of canopy cover, shade, and in-stream cover. We recommend increasing the buffer width to at least 15 ft and planting appropriate forbs, trees, and shrubs. Vegetation that meets the aesthetic goals of the ski area can be planted where appropriate.

Figure 22. Very little vegetative buffer exists between roads and parking lots and the stream channel. (Photos: Inter-Fluve)

Stream Re-Meandering - While we did discuss the possibility of re-routing portions of the stream back to an earlier channel alignment, we do not think it is a viable option for this site at this time (see Exhibit A8 in Appendix A). Rebuilding a sinuous channel through the Afton Alps property would require more road crossings, large construction expenses, and could be a hazard to skiers at the bottom of the ski runs. In addition, while we typically prefer to restore streams to a more natural and appropriate channel form, land development and channel evolution upstream of the property continue to impact conditions within the ski area. A more sinuous stream channel through the ski area would decrease the channel slope resulting in decreased flow velocities and increased sediment deposition. This could require increased maintenance through longer reaches of the stream.

Watershed Improvements - Stormwater management on the Afton Alps property should be addressed to improve runoff water quality, which would improve geomorphic and habitat conditions in the stream. For example stormwater basins could improve infiltration and outlet into the stream channel at an appropriate location. The above recommendations for watershed improvement (by HR Green) would adequately address these needs.

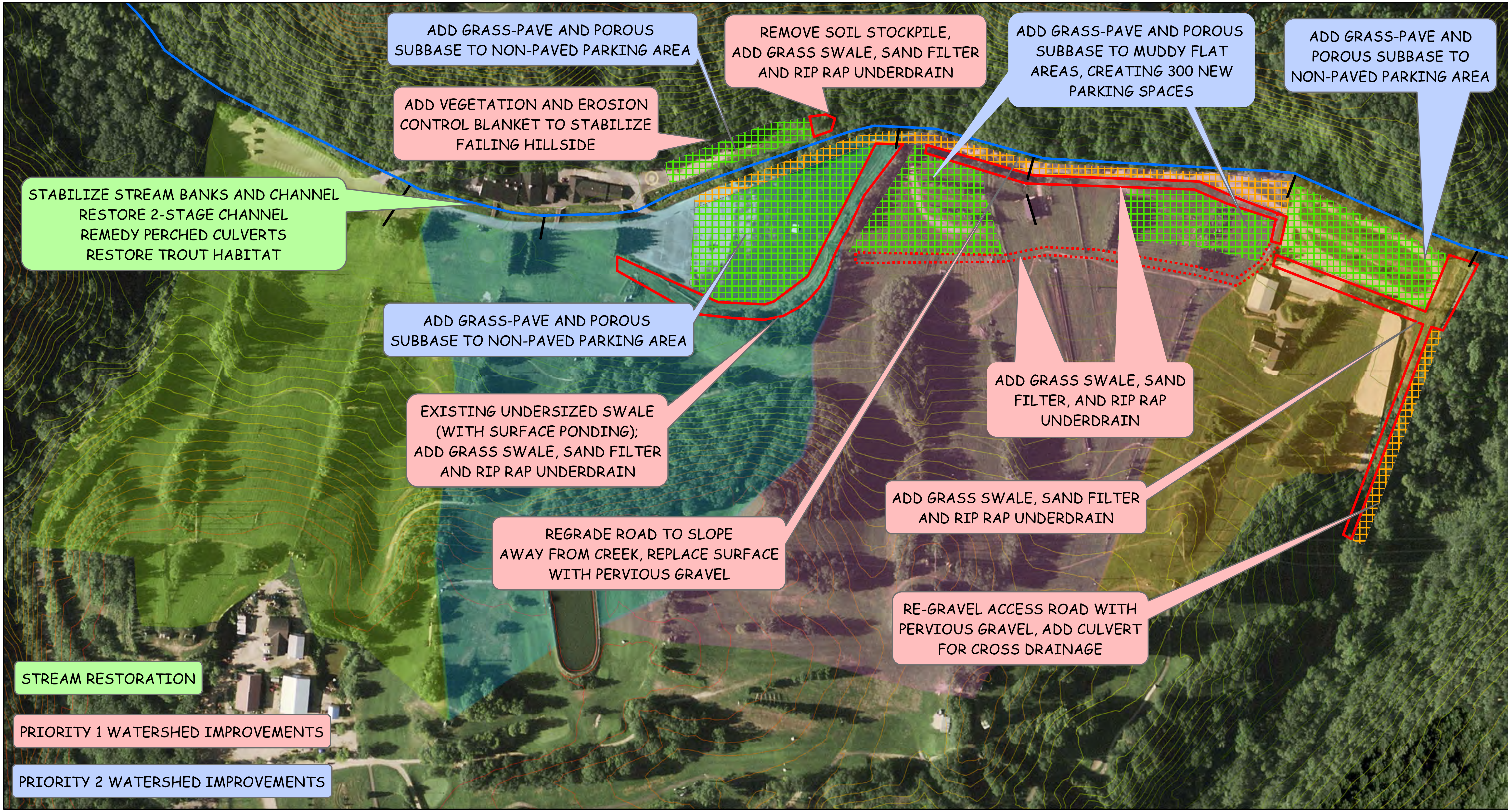
Summary Concept Options Matrix

The following table is a comparative matrix including all recommended improvements described in the report text and in the Exhibits located in the appendices. The specific design of each improvement will vary depending on the final configuration, order of implementation, and other factors. The methodology used to predict contaminant removal varies depending on each design and location, see the Exhibits in Appendix A for specific methods used for each application.

	Proposed Action	Location	Quantity	Concept OPC[1]	Design Estimate	Total Cost (w/20% contingency)	Reduction Type	TSS Reduc. %	TSS Reduc. [tons / yr]	TP Reduc. %	TP Reduc. [lbs / yr]
First Priority	Install Sedimentation Pool	West of Afton Alps	N/A	$30,000	$20,000	**$60,000**	Treatment[2]	Further Study Required to Determine Existing Bed Load			
	Grade and Re-Gravel Road	Annie's DA	20,000 ft²	$13,000	$3,000	**$19,200**	Source[3]	99	3.4	25	0.1
		Sonja's DA	50,000 ft²	$33,000	$4,000	**$44,400**	Source	99	6.5	25	0.17
		East Road	12,000 ft²	$14,000	$6,000	**$24,000**	Source	99	3	21	0.1
	Install Filter Swale	Annie's DA	1,000 ft	$48,000	$10,000	**$69,600**	Treatment	90	0.5	80	3.2
		Sonja's DA	1,200 ft	$78,000	$12,000	**$108,000**	Treatment	90	1	80	5.4
		Meadows	1,300 ft	$63,000	$12,000	**$90,000**	Treatment	90	0.4	80	2.2
		Employee Lot	2,000 ft²	$24,000	$8,000	**$38,400**	Treatment	90	0.2	80	1.5
	Remove Soil Pile	Employee Lot	N/A	$2,500	$0	**$3,000**	Source	?	?	?	?
	Stabilize Hillside	Employee Lot	N/A	$5,000	$2,000	**$8,400**	Source	78	14	57	0.03
	Restore Channel	West Boundary to Employee Lot	1,500 ft	$400,000	$120,000	**$624,000**	N/A	N/A	N/A	N/A	N/A
	Replace Road Culverts	Alps Chalet	2 roads	$375,000	$30,000	**$486,000**	N/A	N/A	N/A	N/A	N/A
	Restore Riparian Buffers	East of Alps Chalet	2000 ft	$15,000	$4,000	**$22,800**	Source and Treatment	?	?	?	?
Second Priority	Grass-Pave Parking Lot	Annie's DA	114,000 ft²	$700,000	$60,000	**$912,000**	Source	99	16	81	1.6
							Treatment	91	0.06	86	0.3
		Sonja's DA	132,000 ft²	$810,000	$70,000	**$1,056,000**	Source	99	23	76	1.4
							Treatment	72	0.75	64	4.1
		Meadows DA	85,000 ft²	$520,000	$45,000	**$678,000**	Source	99	11	81	1.1
							Treatment	99	0.03	97	0.2
		Employee Lot	25,000 ft²	$155,000	$15,000	**$204,000**	Source	99	4	81	0.4
							Treatment	58	0.32	47	1.6

Notes
1 Costs shown are rough estimates for construction only, they do not include design, permits, mobilization, etc.
2 Treatment reduction estimates are based on the ability of the design to sequester TSS and TP in runoff from sources higher in the watershed
3 Source reduction estimates are based on changes in surface quality and the resulting reduction in release from the specific surface

Appendix A – Watershed Improvement Exhibits



AFTON ALPS SKI AREA
CONCEPT BMPS
AND PRIORITIES

SOUTH WASHINGTON WATERSHED DISTRICT

WASHINGTON COUNTY MINNESOTA

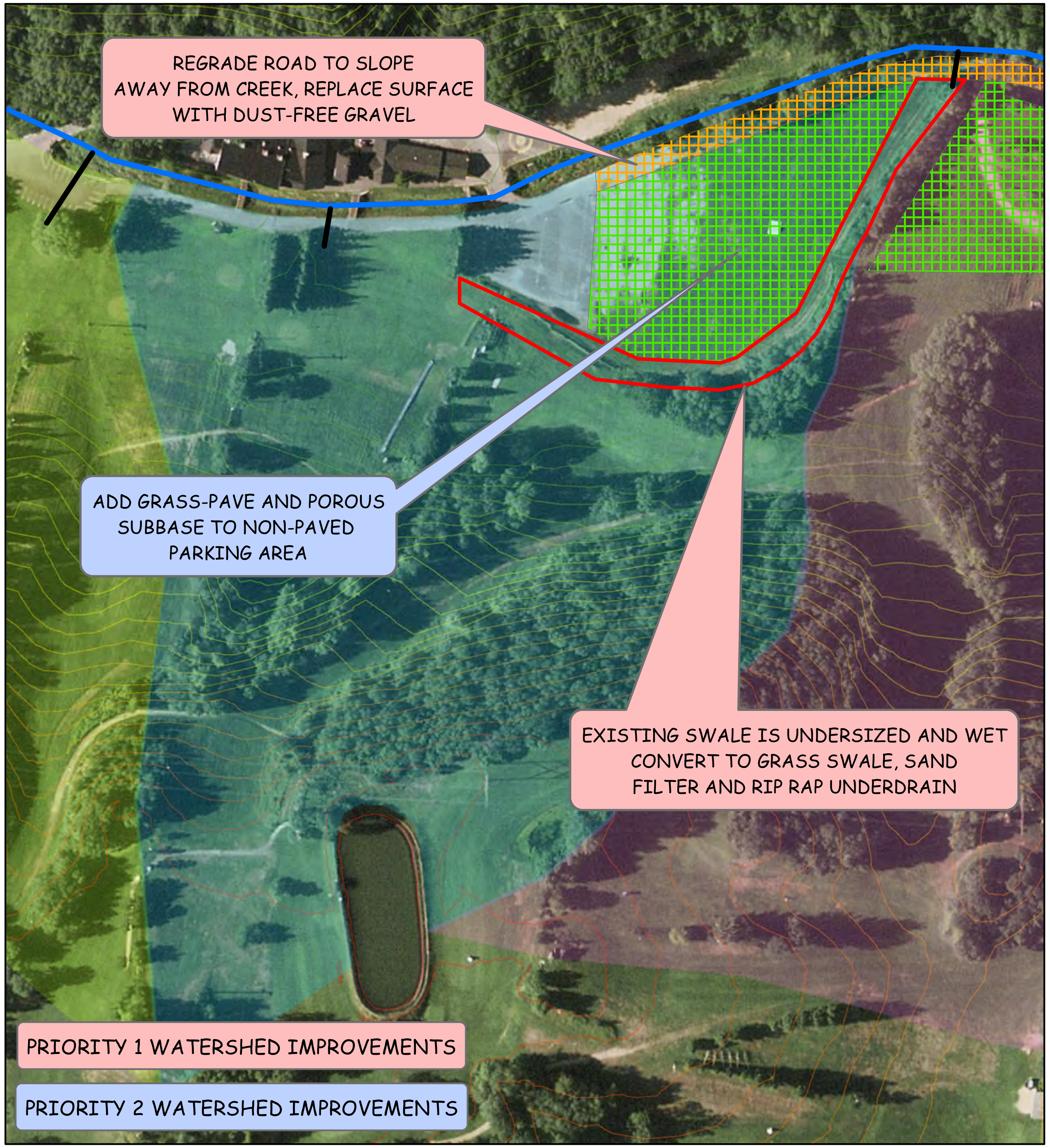
- Trout_Brook
- Outfalls
- GRASS SWALES AND SAND FILTERS
- COUNTER-SLOPED ROAD GRADING
- GRASS-PAVED PARKING LOTS
- OPTIONAL BURIED RIP RAP DRAINAGE
- TRUDY'S DA - 24 ACRES
- MEADOWS DA - 12 ACRES
- SONJA'S DA - 32 ACRES
- ANNIE'S DA - 24 ACRES

Data Source: SWWD, MNDNR
Projected Coordinate System: NAD83 HARN Adj MN Washington Feet
Projection: Transverse Mercator
Map Published: June, 2012
Author: ALG

0 125 250 500
Feet

1 inch = 250 feet

N W E S



ANNIE'S DRAINAGE AREA

ISSUES PRESENT

- Lower road and parking lot are unpaved (soil and gravel) and sloped eastward at 1.2%, no buffer exists to intercept sediment runoff
- Existing swale is undersized, eroded, and consistently wet
- Swale outfall (24" CMP) is perched 3' above ground on creek side creating a scour hole
- High water table makes hard-surface paving impractical and regular frost heave issues create need to re-grade road which exacerbates sediment runoff

RECOMMENDATIONS

- Regrade road to create 2% cross slope away from creek, install gravel with no fines to eliminate sediment source (ASTM unwashed D57 stone)
- Consider moving road 10' south to provide buffer strip between road and creek bank
- Install "modified swale filter" to intercept, filter, and cool runoff, as well as divert groundwater away from parking surfaces (native grass swale with underlying sand filter and rip rap underdrain wrapped in geotex fabric, see cross section detail)
- Install new culvert at creek flow line to eliminate drop, upstream end is flush with rip rap swale underdrain, and includes overflow weir for swale surface flow
- Install grass-pave parking lot surface to eliminate sediment source and improve filtration

ESTIMATED CONTAMINANT REDUCTION

Improvement Method	Suspended Solids Reduction	Phosphorus Reduction
Re-grade road, place new gravel (source reduc.)	99% (3.4 tons/yr)[1]	25% (0.1 lbs/yr)[2]
Swale / sand filter / underdrain (treatment)	90% (0.5 ton/yr)[3]	80% (3.2 lbs/yr)[3]
Grass-pave parking lot (source reduc.)	99% (16 tons/yr)[1]	81% (1.6 lbs/yr)[2]
Grass-pave parking lot (treatment)	91% (115 lbs/yr)[4]	86% (0.3 lbs/yr)[4]

1 = Universal Soil Loss Equation (USDA-ARS, 1961)
2 = MN Stormwater Manual Phosphorus Runoff Equation
3 = US EPA, Case Studies
4 = P8 Model Calculation

ESTIMATED COST

- Re-grade and re-gravel road (20,000 sf) = $13,000
- 1000' modified swale filter with rip rap underdrain and new culvert outfall = $48,000
- Grass-pave parking lot (114,000 sf) = $700,000

AFTON ALPS SKI AREA
CONCEPT BMPS

SOUTH WASHINGTON WATERSHED DISTRICT

WASHINGTON COUNTY MINNESOTA

OUTFALLS TO TROUT BROOK
TROUT BROOK
FILTER SWALE
COUNTER-SLOPED ROAD GRADING
GRASS-PAVED PARKING LOT
ANNIE'S DA - 24 ACRES

Data Source: SWWD, MNDNR
Projected Coordinate System: NAD83 HARN Adj MN Washington Feet
Projection: Transverse Mercator
Map Published: May 18, 2012
Author: ALG

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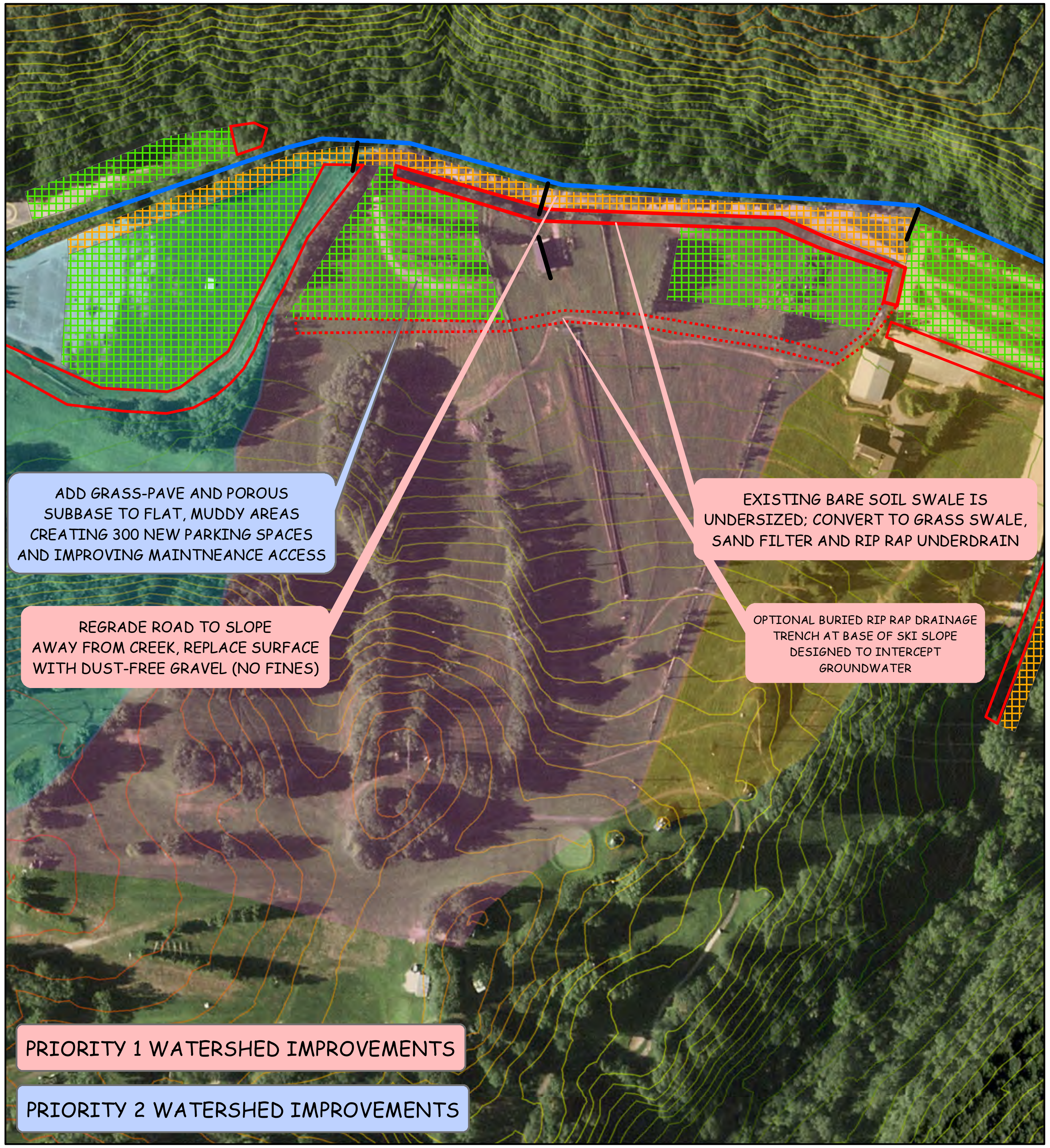
Feet

1 inch = 200 feet

N W E S



SONJA'S DRAINAGE AREA

ISSUES PRESENT

- Road is unpaved (soil and gravel), no buffer exists to intercept sediment runoff
- Area between road and ski slope is flat, muddy, and torn up from vehicular traffic.
- Surface drainage is currently routed along south road edge in a bare soil swale
- CMP outfalls are undersized and deliver high TSS runoff directly to creek
- High water table makes hard-surface paving impractical and regular frost heave issues create need to re-grade road which exacerbates sediment runoff

RECOMMENDATIONS

- Regrade road to create 2% cross slope away from creek, install gravel with no fines to eliminate sediment source (ASTM unwashed D57 stone)
- Consider moving road 10' south to provide buffer strip between road and creek bank
- Install "modified swale filter" to intercept, filter, and cool runoff, as well as divert groundwater away from parking surfaces (native grass swale with underlying sand filter and rip rap underdrain wrapped in geotex fabric, see cross section detail)
- If no buried obstructions exist, a rip rap drainage trench should be installed at the slope base. With this option the swale filter along the road would need much less rip rap for drainage
- Install new culverts at creek flow line, connect south ends to rip rap drainage trench and swale filter underdrains, also include overflow weir for swale surface flow
- Install 2 new grass-pave parking lot surfaces to eliminate sediment source, improve filtration, and add 300 parking spaces

ESTIMATED CONTAMINANT REDUCTION

Improvement Method	Suspended Solids Reduction	Phosphorus Reduction
Re-grade road, place new gravel (source reduc.)	99% (6.5 tons/yr)[1]	25% (0.17 lbs/yr)[2]
Swale / sand filter / underdrain (treatment)	90% (1 ton/yr)[3]	80% (5.4 lbs/yr)[3]
Grass-pave parking lot (source reduc.)	99% (23 tons/yr)[1]	76% (1.4 lbs/yr)[2]
Grass-pave parking lot (treatment)	72% (0.75 tons/yr)[4]	64% (4.1 lbs/yr)[4]

1 = Universal Soil Loss Equation (USDA-ARS, 1961)
2 = MN Stormwater Manual Phosphorus Runoff Equation
3 = US EPA, Case Studies
4 = P8 Model Calculation

ESTIMATED COST

- Re-grade and re-gravel road (50,000 sf) = $33,000
- 1000' roadside swale filter with rip rap underdrain and 2 culvert outfalls = $51,000
- 1200' buried rip rap at slope base and 1000' roadside swale with less rip rap = $78,000 (total)
- Grass-pave parking lots (76,000 sf (W) and 56,000 sf (E)) = $810,000

AFTON ALPS SKI AREA
CONCEPT BMPS

SOUTH WASHINGTON WATERSHED DISTRICT

WASHINGTON COUNTY MINNESOTA

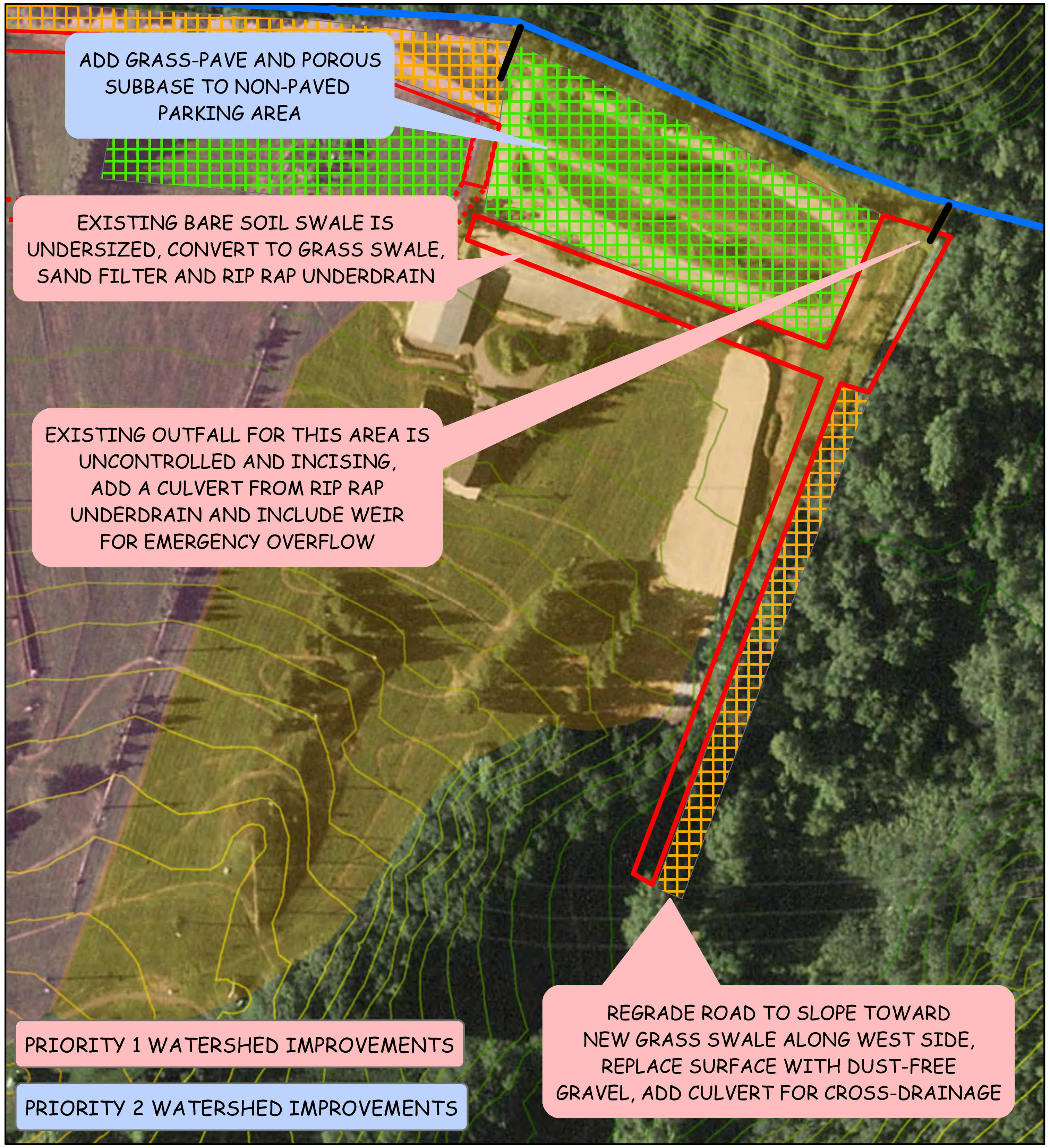
OUTFALLS TO TROUT BROOK
TROUT BROOK
BURIED RIP RAP DRAINAGE
FILTER SWALE
COUNTER-SLOPED ROAD GRADING
GRASS-PAVED PARKING LOT
SONJA'S DA - 32 ACRES

Data Source: SWWD, MNDNR
Projected Coordinate System: NAD83 HARN Adj MN Washington Feet
Projection: Transverse Mercator
Map Published: June, 2012
Author: A.L Gwinnup

0 125 250 500
Feet
1 inch = 250 feet

HRGreen

South Washington WATERSHED District



MEADOWS DRAINAGE AREA

ISSUES PRESENT

- Parking lot and east road are unpaved and in poor condition (loose soil and gravel), no buffer exists to intercept sediment runoff
- Drainage across east road surface produces sediment runoff and creates a recurring maintenance issue
- Surface drainage is currently routed to east edge of property in a bare soil swale, outfall to creek is uncontrolled and eroding
- High water table makes hard-surface paving impractical and regular frost heave issues create need to re-grade which exacerbates sediment runoff

RECOMMENDATIONS

- Regrade east road to create grass swale along west side, install gravel with no fines to eliminate sediment source (ASTM unwashed D57 stone)
- Install culvert for cross drainage near ski lift #11
- Install "modified swale filter" to intercept, filter, and cool runoff, as well as divert groundwater away from parking surfaces (native grass swale with underlying sand filter and rip rap underdrain wrapped in geotex fabric, see cross section detail)
- Install culvert outfall at creek flow line, connect south end to rip rap swale filter underdrains, also include overflow weir for swale surface flow
- Install grass-pave parking lot surface to eliminate sediment source and improve filtration

ESTIMATED CONTAMINANT REDUCTION

Improvement Method	Suspended Solids Reduction	Phosphorus Reduction
Re-grade road, place new gravel (source reduc.)	99% (3 tons/yr)[1]	21% (0.1 lbs/yr)[2]
Swale / sand filter / underdrain (treatment)	90% (0.4 ton/yr)[3]	80% (2.2 lbs/yr)[3]
Grass-pave parking lot (source reduc.)	99% (11 tons/yr)[1]	81% (1.1 lbs/yr)[2]
Grass-pave parking lot (treatment)	99% (58 lbs/yr)[4]	97% (0.2 lbs/yr)[4]

1 = Universal Soil Loss Equation (USDA-ARS, 1961)
2 = MN Stormwater Manual Phosphorus Runoff Equation
3 = US EPA, Case Studies
4 = P8 Model Calculation

ESTIMATED COST

- Re-grade and re-gravel road, add culvert (12,000 sf) = $14,000
- 1300' swale filter with rip rap underdrain and culvert outfall = $63,000
- Grass-pave parking lot (85,000 sf) = $520,000

AFTON ALPS SKI AREA
CONCEPT BMPS

SOUTH WASHINGTON WATERSHED DISTRICT

WASHINGTON COUNTY MINNESOTA

OUTFALLS TO TROUT BROOK
TROUT BROOK
FILTER SWALE
COUNTER-SLOPED ROAD GRADING
GRASS-PAVED PARKING LOT
MEADOWS DA - 12 ACRES

Data Source: SWWD, MNDNR
Projected Coordinate System: NAD83 HARN Adj MN Washington Feet
Projection: Transverse Mercator
Map Published: June, 2012
Author: A.L Gwinnup

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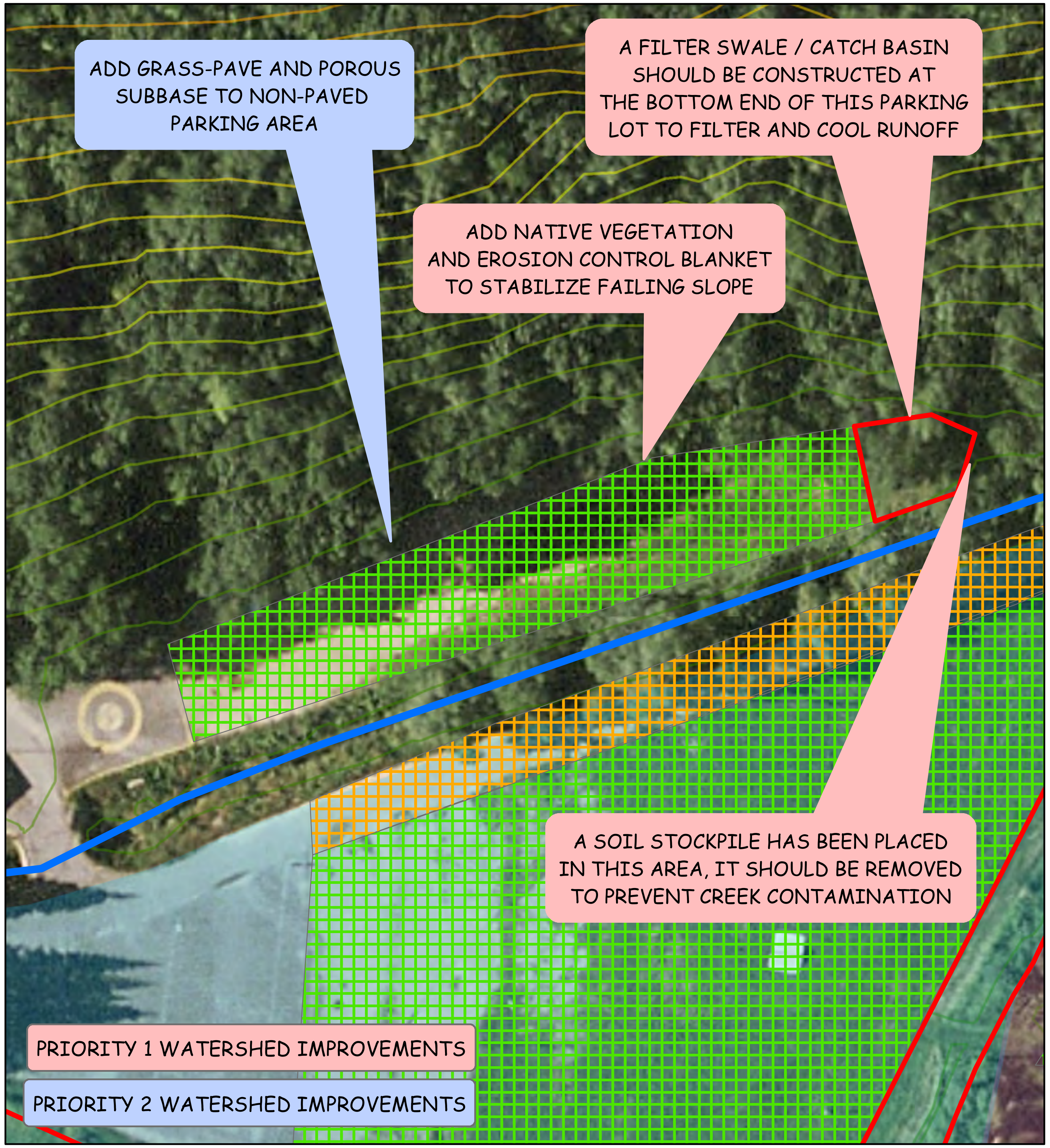
Feet
1 inch = 150 feet

HRGreen

South Washington WATERSHED District

N E S W



EMPLOYEE PARKING LOT

ISSUES PRESENT

- Parking lot is unpaved (soil and gravel), no buffer exists to intercept sediment runoff
- Cut hillside is bare soil, eroding and in danger of failing
- Loose soil is being stockpiled at bottom end of parking lot and adjacent to creek bank (directly in runoff flow path)
- High water table makes hard-surface paving impractical and regular frost heave issues create need to re-grade which exacerbates sediment runoff

RECOMMENDATIONS

- Add vegetation to failing hillside, preferably native, deep-rooted grasses; add biodegradable erosion control blanket for temporary stabilization
- Remove soil stockpile and re-vegetate area
- Install runoff catch basin at east end to intercept, filter, and cool runoff (native grass basin with underlying sand filter and rip rap underdrain wrapped in geotex fabric, similar to modified swale filters prescribed elsewhere)
- Install culvert outfall at creek flow line, connect south end to rip rap swale filter underdrains, also include overflow weir for swale surface flow
- Install grass-pave parking lot surface to eliminate sediment source and improve filtration

ESTIMATED CONTAMINANT REDUCTION

Improvement Method	Suspended Solids Reduction	Phosphorus Reduction
Vegetate hillside and install ECB (source reduc.)	78% (14 tons/yr)[1]	57% (0.03 lbs/yr)[2]
Swale / sand filter / underdrain (treatment)	90% (420 lbs/yr)[3]	80% (1.5 lbs/yr)[3]
Grass-pave parking lot (source reduc.)	99% (4 tons/yr)[1]	81% (0.4 lbs/yr)[2]
Grass-pave parking lot (treatment)	58% (630 lbs/yr)[4]	47% (1.6 lbs/yr)[4]

1 = Universal Soil Loss Equation (USDA-ARS, 1961)
2 = MN Stormwater Manual Phosphorus Runoff Equation
3 = US EPA, Case Studies
4 = P8 Model Calculation

ESTIMATED COST

- Remove soil stockpile, re-vegetate area = $2500
- Vegetate hillside with native grasses, add ECB = $5000
- 2000 sf catch basin, sand filter, rip rap underdrain and culvert outfall = $24,000
- Grass-pave parking lot (25,000 sf) = $155,000

AFTON ALPS SKI AREA CONCEPT BMPS

SOUTH WASHINGTON WATERSHED DISTRICT

WASHINGTON COUNTY MINNESOTA

OUTFALLS TO TROUT BROOK
TROUT BROOK
FILTER SWALE
GRASS-PAVED PARKING LOT

Data Source: SWWD, MNDNR
Projected Coordinate System: NAD83 HARN Adj MN Washington Feet
Projection: Transverse Mercator
Map Published: June, 2012
Author: ALG

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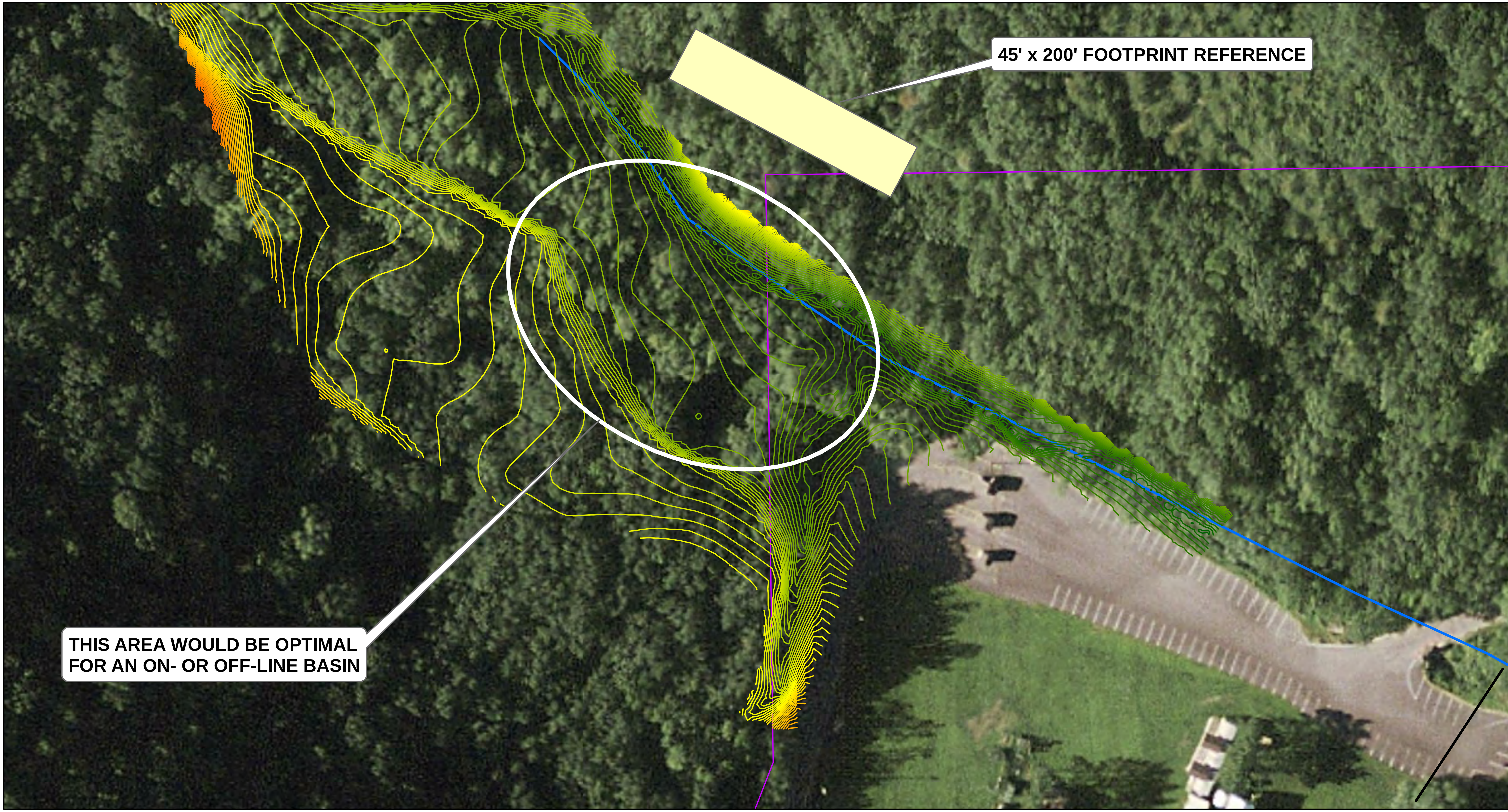
Feet

1 inch = 75 feet

HRGreen

South Washington WATERSHED District



AFTON ALPS SKI AREA PROPOSED SEDIMENT TRAP LOCATION

SOUTH WASHINGTON WATERSHED DISTRICT

WASHINGTON COUNTY MINNESOTA

- Outfalls
- Trout_Brook
- AFTON ALPS PROPERTY LINE

Data Source: SWWD, MNDNR
Projected Coordinate System: NAD83 HARN Adj MN Washington Feet
Projection: Transverse Mercator
Map Published: June, 2012
Author: ALG

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Feet

1 inch = 75 feet

HRGreen

South Washington WATERSHED District

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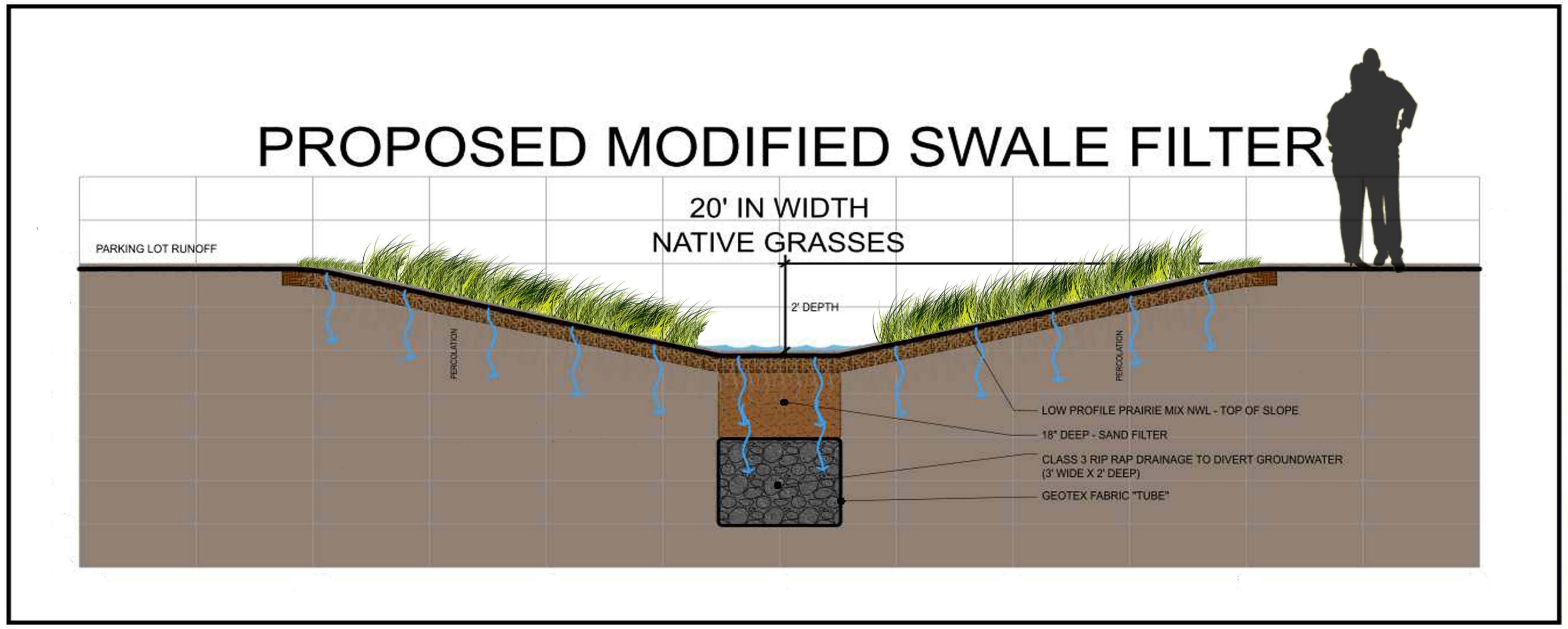
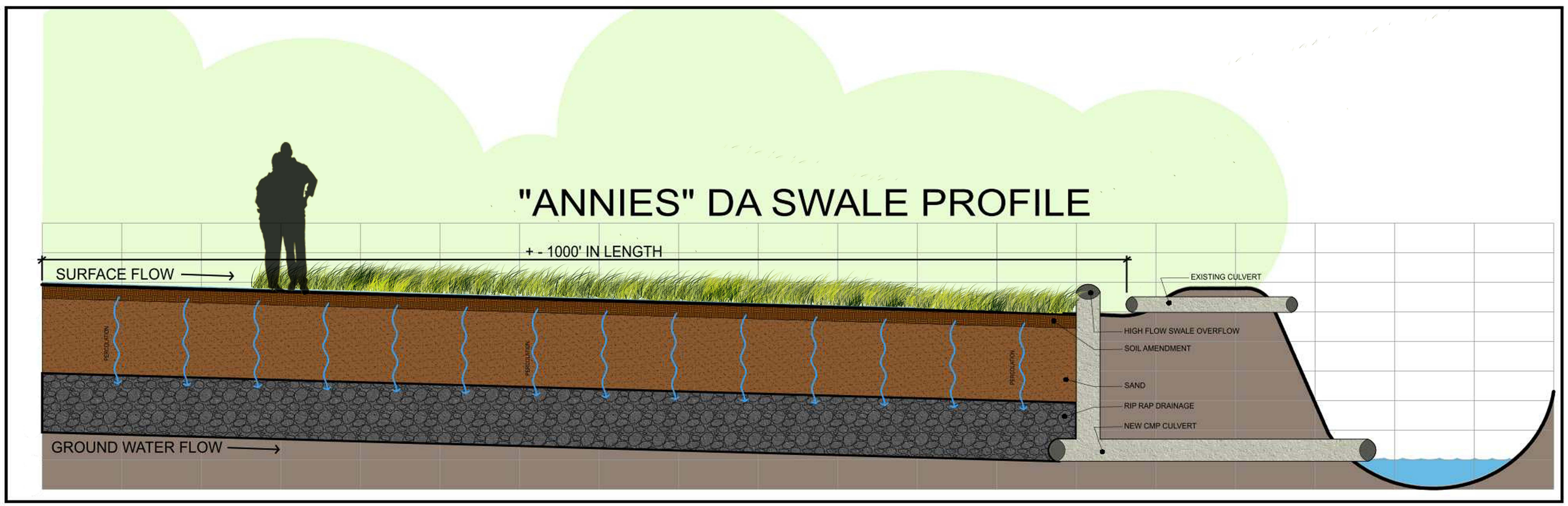




AFTON ALPS SKI AREA

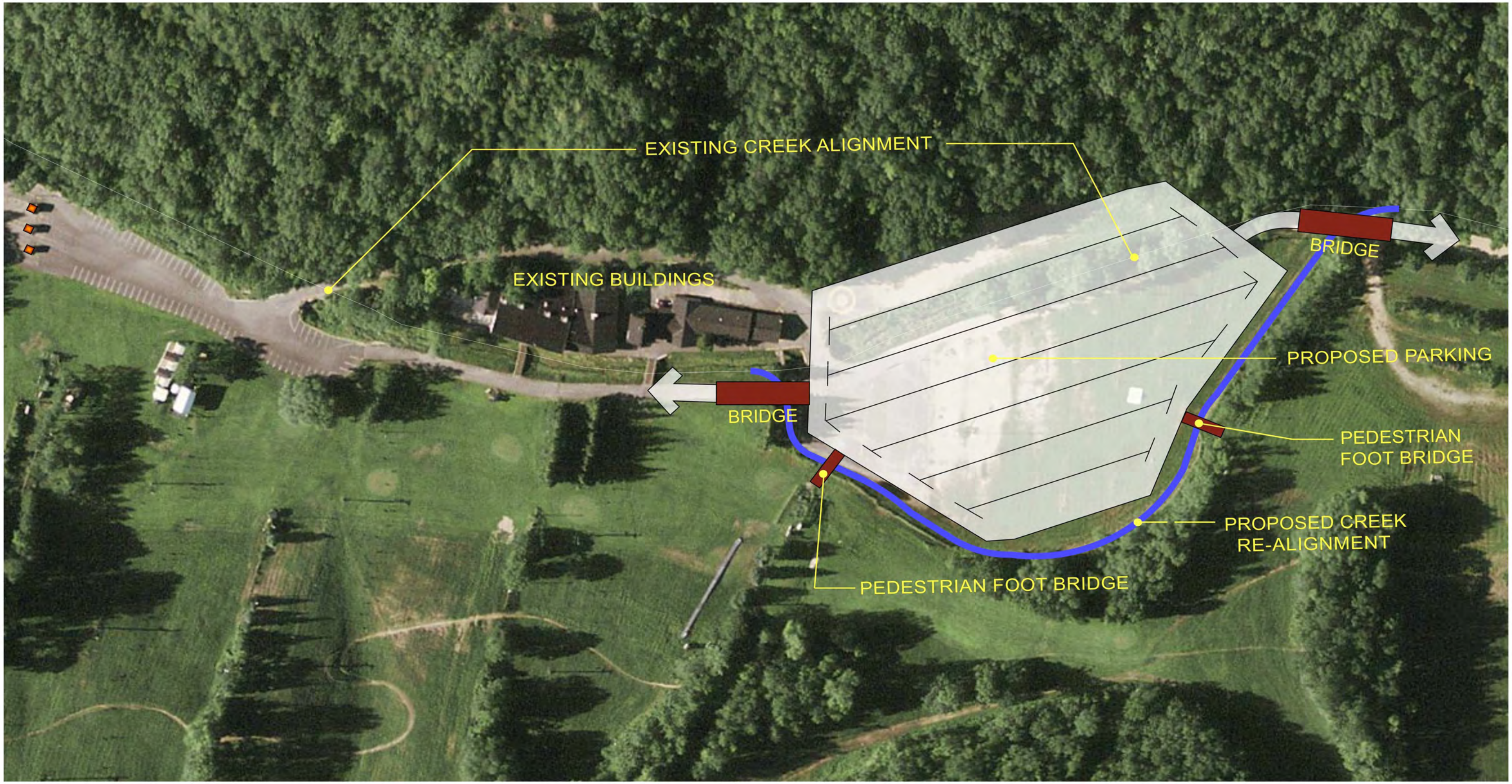
SOUTH WASHINGTON WATERSHED DISTRICT

WASHINGTON COUNTY MINNESOTA

CROSS SECTION & PROFILE

HRGreen

South Washington WATERSHED District



AFTON ALPS SKI AREA

SOUTH WASHINGTON WATERSHED DISTRICT

WASHINGTON COUNTY MINNESOTA

Stream Re-meander Option Concept Plan View

HRGreen

South Washington WATERSHED District

Appendix B – Fluvial Geomorphic Analysis Exhibits

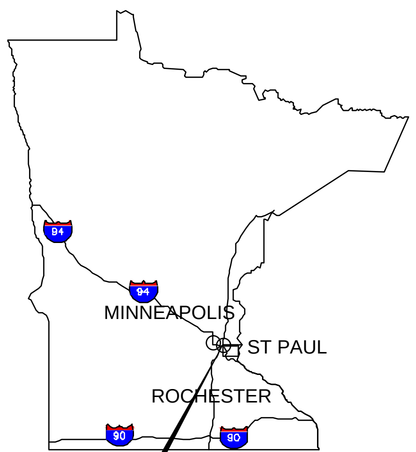
Exhibit B1 – In-Stream Improvements Recommended by Inter-Fluve Inc.

Exhibit B2 – Arch Bridge Design

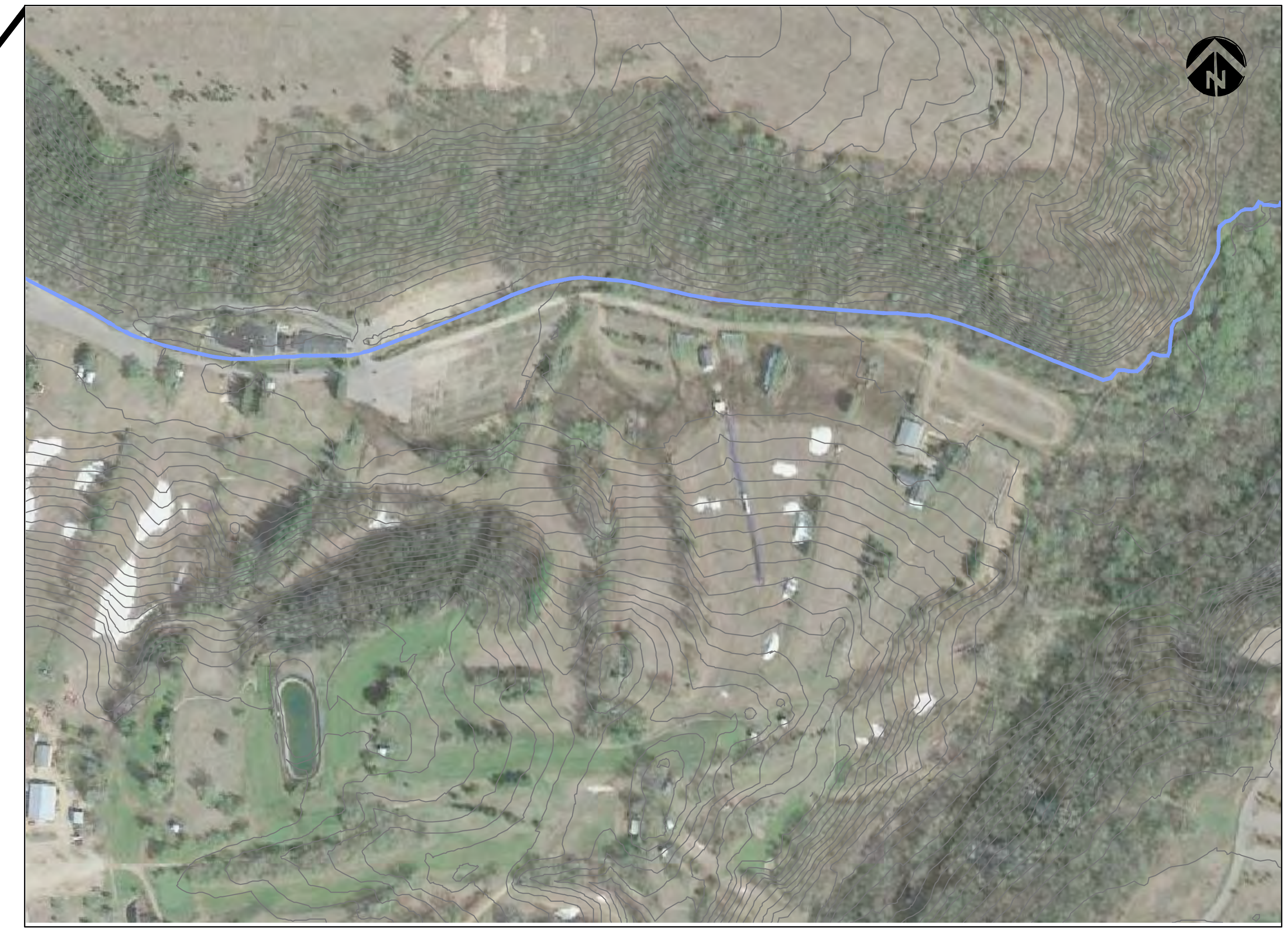
South Washington Watershed District

Washington County, Minnesota

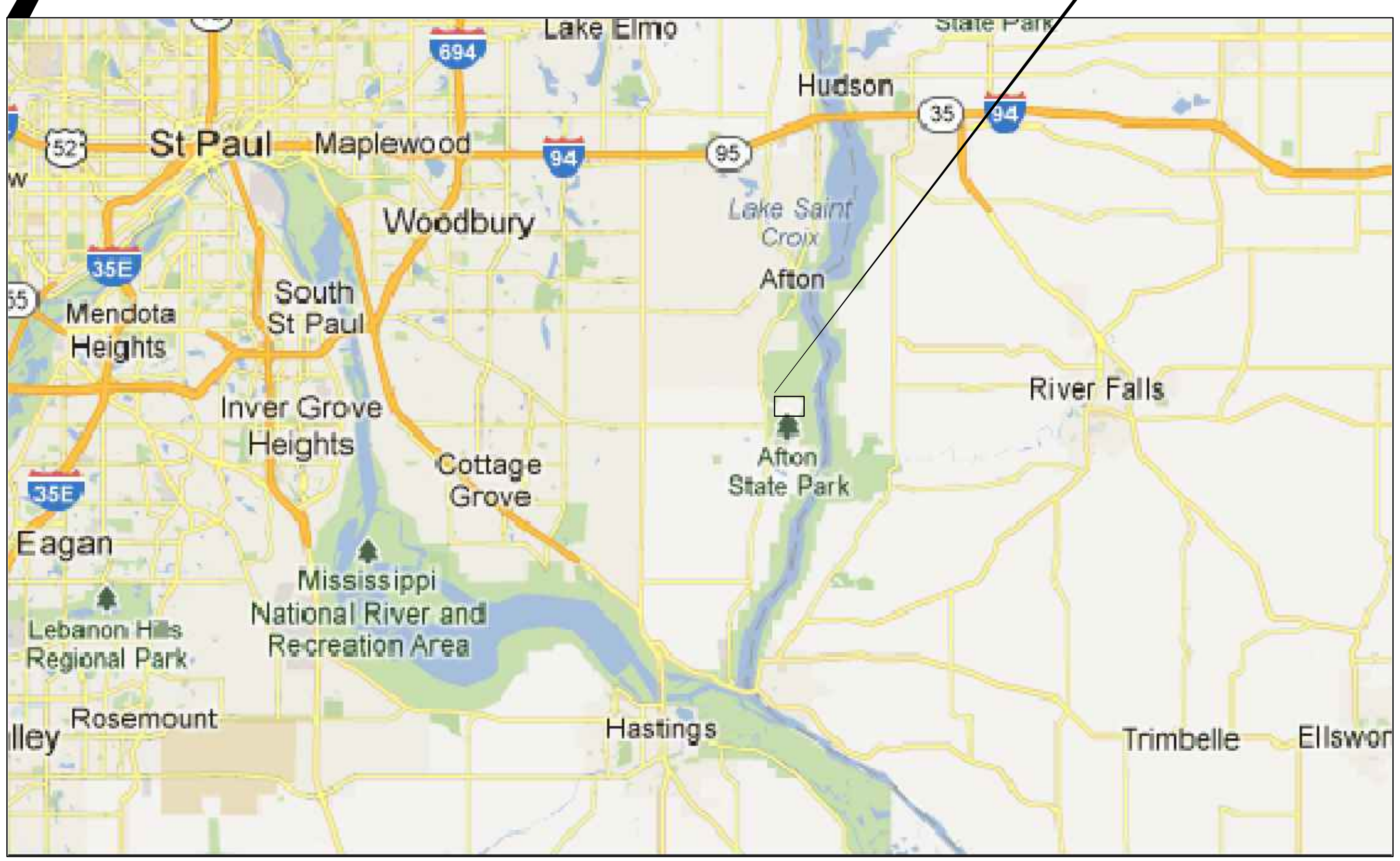
June 15, 2012



LOCATION MAP
STATE OF MINNESOTA
NOT TO SCALE



SITE MAP
SCALE 1"=500'



VICINITY MAP
NOT TO SCALE

SHEET INDEX

SITE LOCATION:

LATITUDE: 44°51'15.54" NORTH
LONGITUDE: 92°47'26.73" WEST
WASHINGTON COUNTY, MINNESOTA

Preliminary Not For Construction

inter·fluve

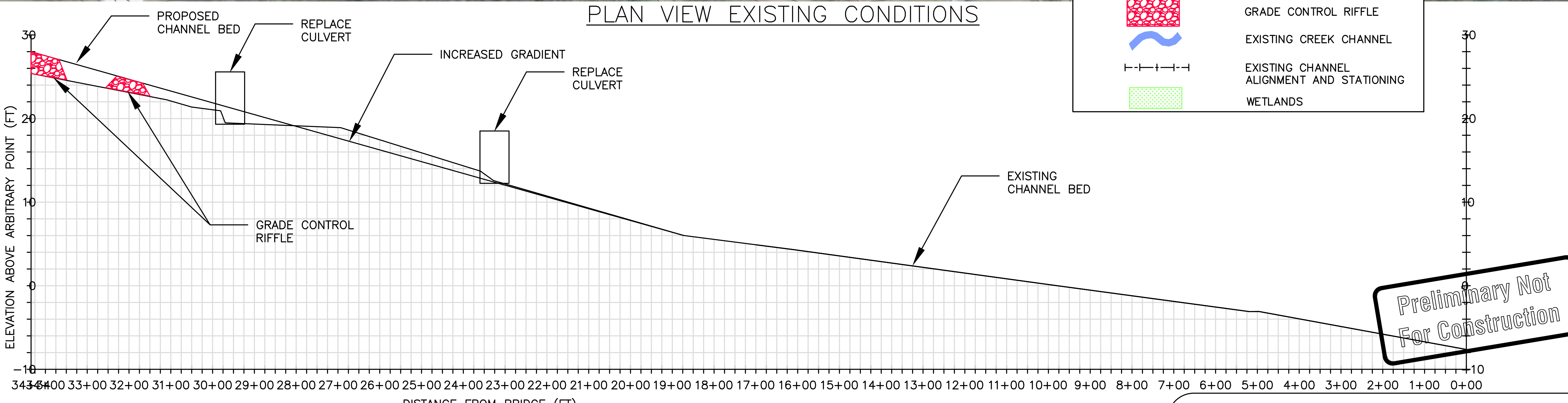
1 OF 4

Cover and Sheet Index

PLAN VIEW EXISTING CONDITIONS

LEGEND

	10' CONTOURS
	GRADE CONTROL RIFFLE
	EXISTING CREEK CHANNEL
	EXISTING CHANNEL ALIGNMENT AND STATIONING
	WETLANDS



EXISTING AND PROPOSED PROFILE VIEW

inter-fluve

SITE PLAN
EXISTING CONDITIONS & PROFILE

2

PLAN VIEW PROPOSED CONDITIONS

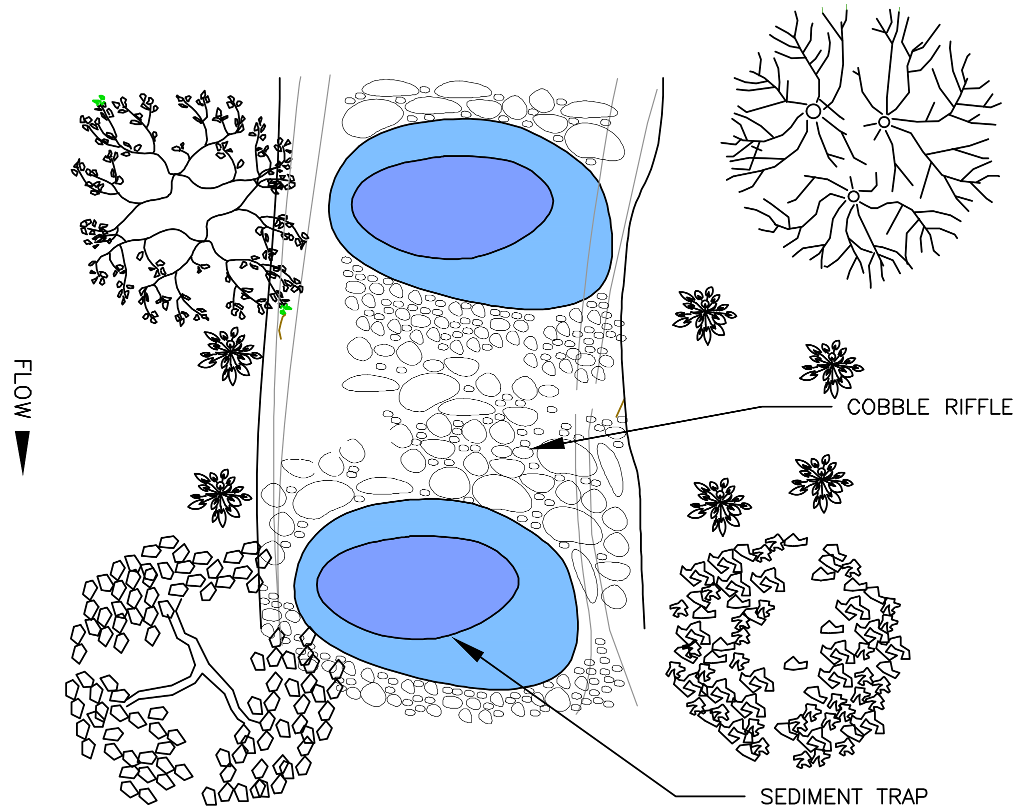
LEGEND

	10' CONTOURS
	CREEK CHANNEL
	SEDIMENT TRAP
	INCREASED CHANNEL GRADIENT
	GRADE CONTROL RIFFLE
	EXISTING CHANNEL ALIGNMENT AND STATIONING

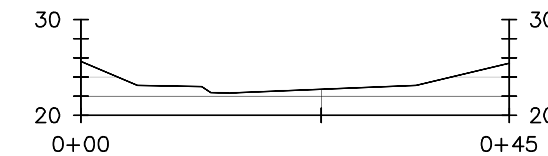
Preliminary Not For Construction

inter·fluve

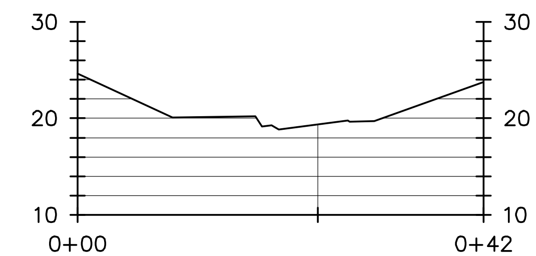
SITE PLAN
PROPOSED CONDITIONS



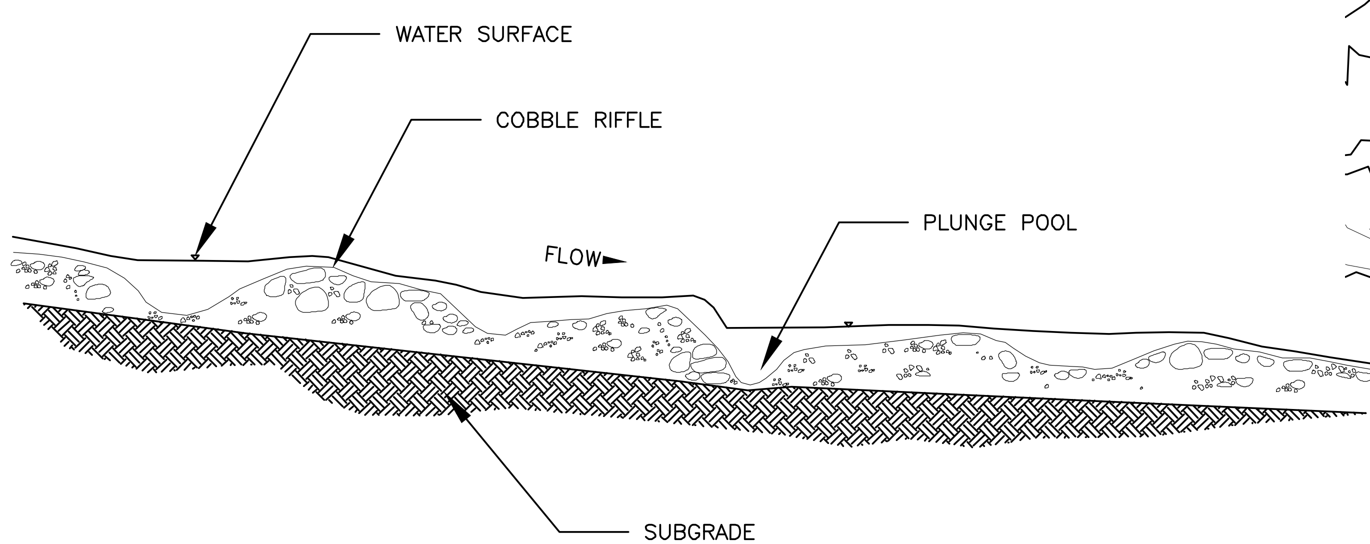
1/4 RIFFLE – POOL SEQUENCE – PLAN VIEW
NOT TO SCALE



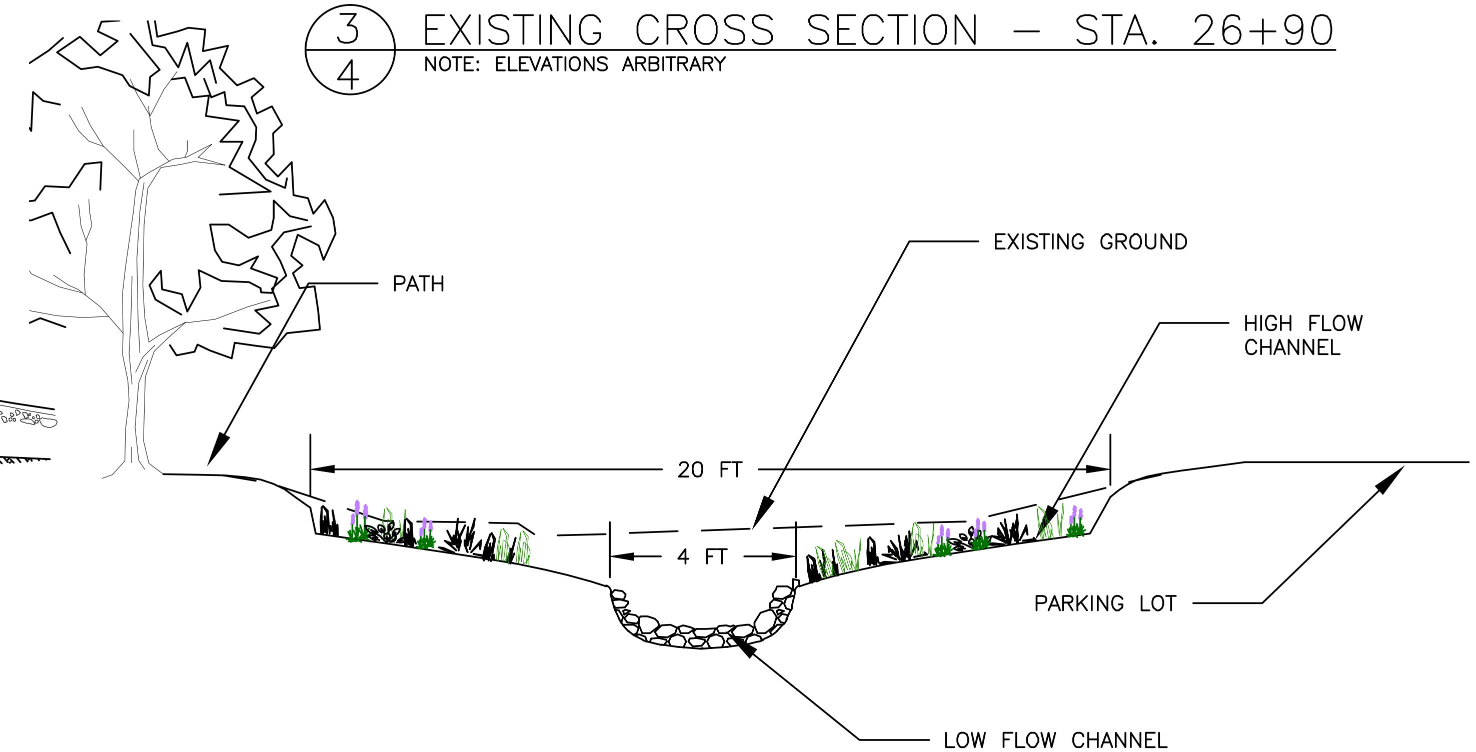
2/4 EXISTING CROSS SECTION – STA. 29+75
NOTE: ELEVATIONS ARBITRARY



3/4 EXISTING CROSS SECTION – STA. 26+90
NOTE: ELEVATIONS ARBITRARY



1/4 RIFFLE POOL SEQUENCE – PROFILE VIEW
NOT TO SCALE



4/4 TYPICAL CROSS SECTION – EXISTING AND PROPOSED
NOT TO SCALE

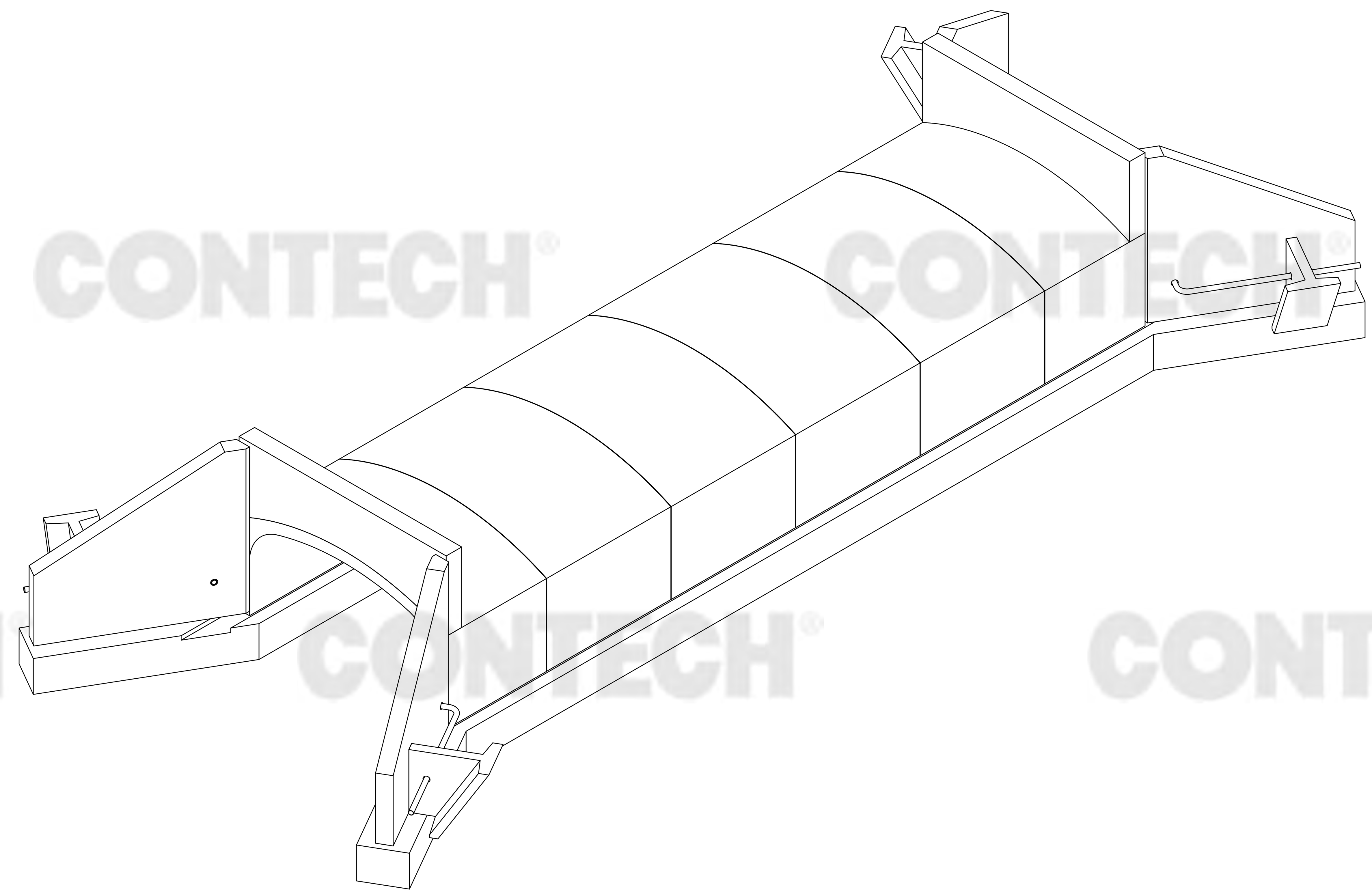
Preliminary Not
For Construction

GRADE CONTROL RIFFLE & TYPICAL CROSS SECTION

4

BRIDGE SUMMARY

1 cell of CON/SPAN® Bridge System 12' Span x 5'-10" Rise
Length: 45'
Downstream Headwall: Height= 3' from arch crown.
Upstream Headwall: Height= 3' from arch crown.
Wingwall 1: Length= 10' - Angle= 30° - End Height= 3'-11"
Wingwall 2: Length= 10' - Angle= 30° - End Height= 3'-11"
Wingwall 3: Length= 10' - Angle= 30° - End Height= 3'-11"
Wingwall 4: Length= 10' - Angle= 30° - End Height= 3'-11"



ISOMETRIC VIEW

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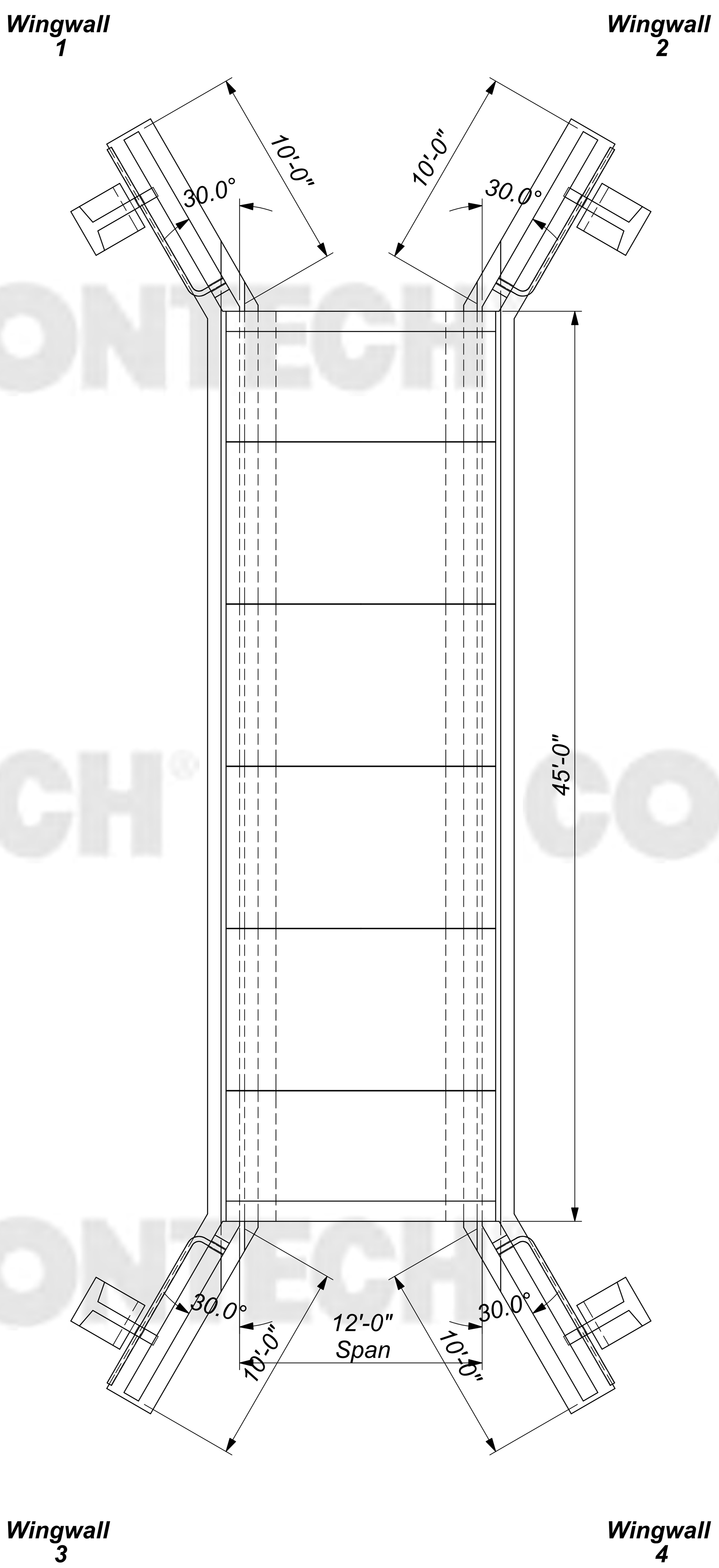
CON/SPAN® BRIDGE SYSTEMS
CONTECH **DYOB** DRAWING

Afton

Afton, MN

PROJECT NUMBER: 136356	DATE: 07/09/12
DESIGNED: DYOB	DRAWN: DYOB
CHECKED:	APPROVED:
SHEET NO.: 1 OF 3	

Upstream



Downstream

BRIDGE PLAN

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PROJECT NUMBER: 136356	DATE: 07/09/12
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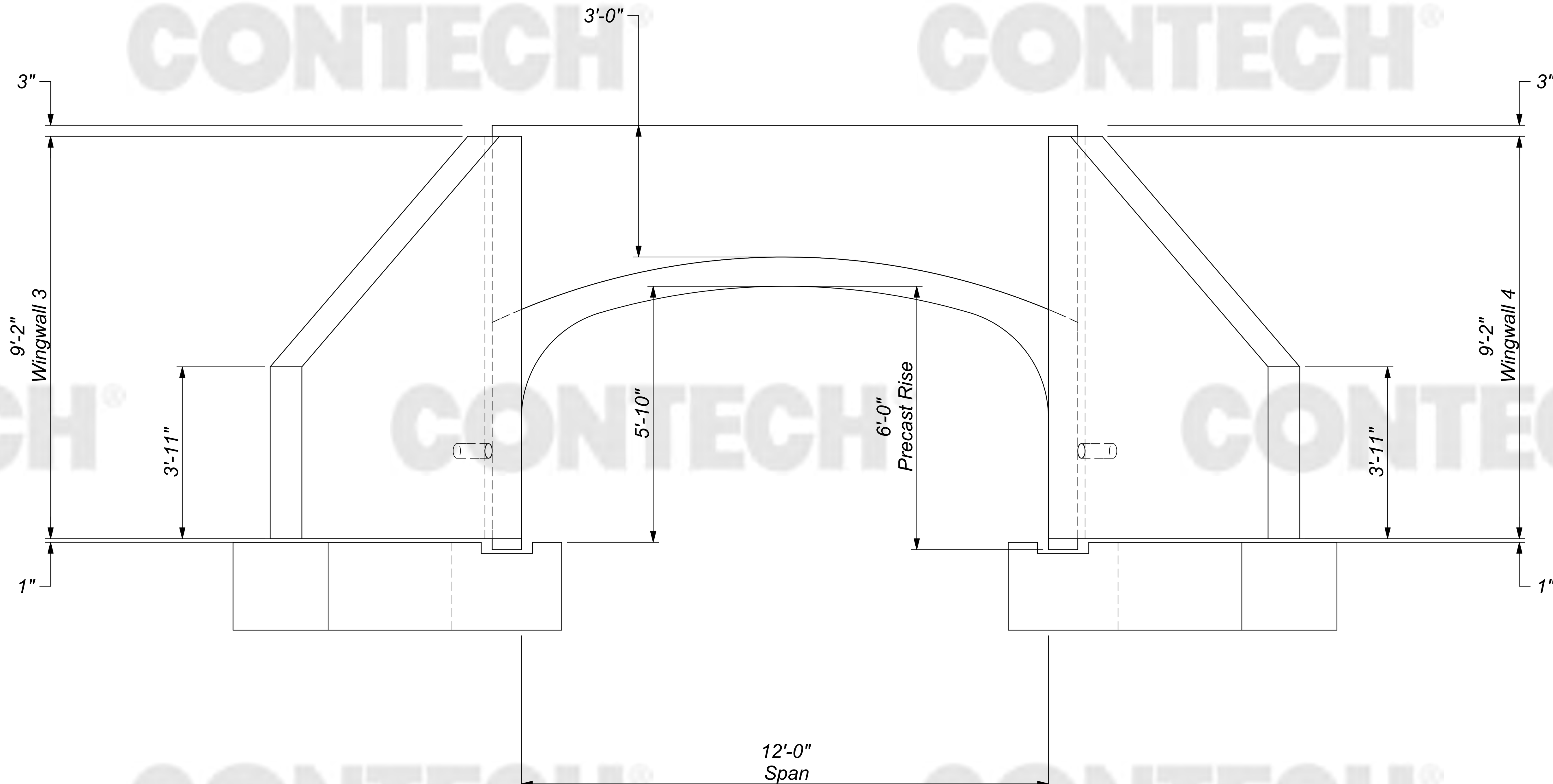
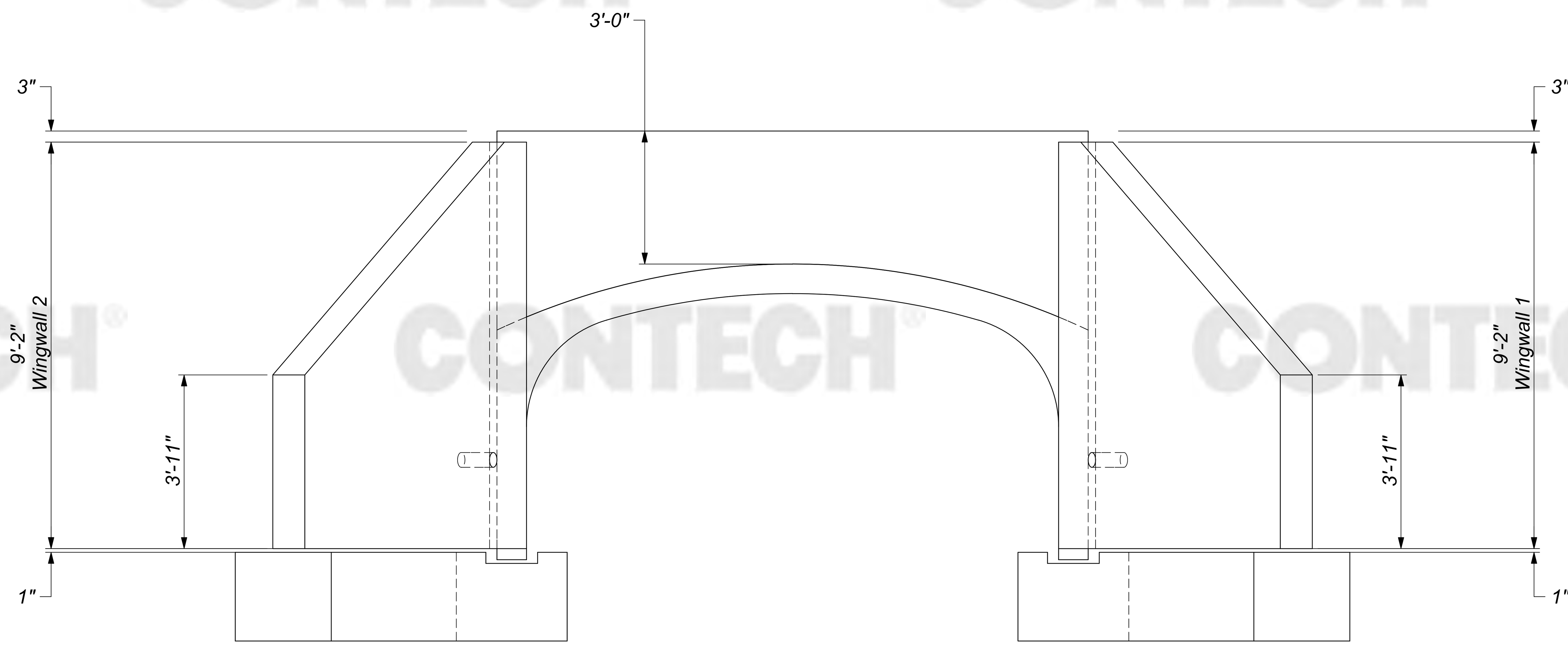
SHEET NO.: 2 OF 3	



DOWNSTREAM END ELEVATION



UPSTREAM END ELEVATION

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PROJECT NUMBER: 136356	DATE: 07/09/12
DESIGNED: DYOB	DRAWN: DYOB
CHECKED:	APPROVED:
SHEET NO.: 3 OF 3	