Inter-Fluve, Inc.
Draft Memorandum

TO:	Eric Nitschke, Village of Sussex, and Maureen McBroom, Wisconsin DNR
FROM:	Beth Wentzel and Andy Selle
DATE:	December 13, 2010
REGARDING:	Spring Creek Daylight Project Concept Design Memo

The Village of Sussex in partnership with the Wisconsin Department of Natural Resources enlisted the services of Inter-Fluve to provide preliminary analysis and concept designs for two alternative alignments for potential rehabilitation of a portion of Spring Creek. The stream reach targeted for rehabilitation currently enters a pipe upstream of a parking lot north of Main Street and is completely enclosed in the pipe for a distance of 470 ft until it is discharged south of Main Street. The pipe is in poor condition, and its degradation may be partially responsible for damage to the parking lot.

Spring Creek is a tributary to the Fox River. Its designated uses under the Clean Water Act, as implemented by the State of Wisconsin, are Fish and Aquatic Life, Recreation, Public Health and Welfare, and Fish Consumption. Through an assessment protocol that includes biological, chemical, and physical monitoring, Spring Creek has been identified as not supporting the Fish and Aquatic Life use, due to low dissolved oxygen, and the pollutant that has been targeted for reductions to address this impairment is total phosphorus. Potential sources of this pollutant have been identified as non-point sources and MS4s. Therefore, it is on the 303(d) list with a medium priority.

Rehabilitation of the proposed section of Spring Creek is not expected to fully restore the creek such that the identified impairments are eliminated. However, this project can be an important part of a comprehensive program to improve the ecological structure and function of the creek, and the design should address the identified impairments.

Downstream of the confluence with Spring Creek, the Fox River is also impaired due to low dissolved oxygen, and total phosphorus and sediment are listed as the pollutants of concern. Recent monitoring suggests that the fish assemblage in this portion of the Fox River is poor (personal communication with WDNR staff, 2010). Given that recolonization of Spring Creek with appropriate native fish species is dependent on connectivity to source populations, impairment of the Fox River may pose a barrier to recovery of the fish assemblage in Spring Creek. Based on conversations with WDNR staff, there are source populations of conservative species within Spring Creek, and creating additional quality stream habitat and increasing the abundance of those conservative species would improve the quality of the fish assemblage. In monitoring performance of rehabilitation activities on Spring Creek, potential barriers between the project and viable source populations should be considered.

Design Objectives

Through conversations with the Village of Sussex and the WDNR, we have identified the following objectives for the design of the project:

1. Restore several ecological functions to the stream reach, including
    a. Increase water pollutant attenuation, including nutrient uptake and increased aeration, within the reach;
    b. Establish a stable channel, within contemporary watershed constraints, that conveys water and sediment such that the processes of aggradation and degradation balance through time, and the channel form is self sustaining;
    c. Improve habitat in the reach for a variety of organisms, and
    d. Restore connectivity between the downstream and upstream reaches;
2. Create an aesthetically attractive, interesting, and accessible feature that fits within the suburban context of the area;
3. Ensure that extreme flood elevations do not increase as a result of the project;
4. Incorporate space for stormwater management elements south of Main Street to capture and treat stormwater discharges from the storm sewer that currently runs below Main Street;
5. Minimize disruption to existing businesses in the project area; and
6. Ensure compatibility with potential redevelopment of the area as a gateway to the Village.

Site Constraints

The Village has indicated that the daylighting of Spring Creek may occur in conjunction with redevelopment of the properties along Main Street, which may include removal of the buildings near the proposed stream corridor. However, it has also been suggested that this project may proceed prior to redevelopment of the properties north of Main Street. Therefore, we have developed concepts that do not require disturbance of the existing buildings in that location and include set backs from the buildings that were defined by the Village as 24 ft from the eastern building and 10 ft from the western building.

To tie into the existing creek upstream and downstream of the project, the channel will need to have invert elevations of 6 – 8 ft below the existing surface of the parking lot. Sufficient space must be allocated to achieve this difference in elevation with slopes that are safe and resistant to erosion.

A pedestrian path with a minimum 6 ft width may be desired along the rehabilitated creek. If incorporated, the path should connect to the sidewalk on Main St.

The stream will need to be conveyed under Main Street. While the best crossing for aquatic and terrestrial wildlife passage would be a bridge at this location, due to cost, infrastructure, and potential geologic concerns, the Village is interested in evaluating crossing options that consist of closed culverts. As discussed in sections below, the culvert should be designed to ensure that it does not interfere with passage of fish and wildlife.

Concept Development

Proposed conditions for two concepts were determined by establishing a channel and riparian corridor route through the existing parking lot area, determining the length and corresponding slope required to tie into the existing elevations upstream and downstream of the project, and predicting a suitable cross section geometry using the slopes and the upstream channel dimensions. The hydrologic and hydraulic analyses described in the following sections will be the primary tool for evaluating the functionality of the channel design with respect to the project objectives.

The two alternative plan forms are shown in sheets 1 and 2 of the concept (attached as Appendix A). They conform to the site constraints described above.

Proposed Channel Cross Section Geometry

The channel cross section geometry was developed iteratively using the hydraulic model described below. The model was used to ensure that the cross section will be capable of conveying all flows that will be experienced without increasing flood elevations, will promote frequent inundation of the proposed floodplain, will protect infrastructure by minimizing erosive forces on banks, will be safe, and will transport sediment that is supplied by the upstream reach without excessive deposition that would require dredging.

An important feature of the channel cross section for satisfying the design objectives is the floodplain. This floodplain will be wetted frequently to promote growth of wetland and mesic vegetation and ensure soil conditions that are optimal for achieving nitrogen removal through nitrification and denitrification. The saturated soils and wetland root interface will develop aerobic and anoxic zones which are both necessary for microbial transformation of ammonia and organic nitrogen into harmless nitrogen gas. The vegetation and microbial communities on the floodplain will also aid in sequestering phosphorus and breaking down organic pollutants from water flowing through the soils and captured in micro-pools during high water. The floodplain features vegetation that is tall enough to provide shading for the creek. This will contribute to a reduction in stream temperatures, allowing increased dissolved oxygen.

The floodplain is also critical to ensuring that neither erosion nor deposition in the channel becomes problematic. During high flow events, water is allowed to spread widely over the floodplain, slowing it down and reducing the erosive energy that it would have in a confined channel. Similarly it allows some deposition and minor natural lateral adjustments over time while maintaining capacity to carry flows.

The floodplain is a critical habitat for a wide variety of wildlife, including birds, reptiles, amphibians, birds, and small mammals. Creating this habitat along the channel will connect upstream habitat with similar communities downstream. Finally, the diversity of the plant and animal communities in the floodplain corridor will provide beauty and interesting exploration opportunities for people of the community.

Accommodating the potential that the stream will be constructed before the area is redeveloped required fitting the channel and riparian area into a narrower corridor than is preferable. Particularly in alignment 2, where the channel runs south between the road and the western building, insufficient space is available to propose gentle slopes, a pedestrian path, and an adequate floodplain. To fit all of these elements, a steeper slope is proposed on the right bank (looking downstream). If the pedestrian path is not incorporated, or if it is fit within the buffer around the building, in the constrained places, it the steep slope on the right bank may not be necessary.

Natural channels migrate laterally across their valleys over long periods of time. This process should be accommodated to the extent practical at this site. However, lateral migration limits must be in place due to the infrastructure near the channel corridor. One means of limiting lateral migration is by ensuring that bank shear is low. The hydraulic analysis described below was used to predict that shear stresses on the banks should be low, even on outer bends. A second means of limiting channel movement is use of resistant materials. In locations where a steeper valley slope is necessary, we propose burying rip rap or some other resistant material near the toe of the steep slope. This allows migration of the channel over time but ensures that the channel never undercuts the steep banks. If, during final design, it is discovered that bedrock is shallow in this area and is prevalent at the elevation of the proposed floodplain, additional stone would not be required.

Hydrology

Estimated 10 yr and 100 yr flows were obtained from the FEMA Waukesha County FIS study for Spring Creek. In this document, Spring Creek in the project reach is called the East Branch Sussex Creek, and the major stream that it joins downstream of the project is called Sussex Creek. This study included flows for Spring Creek where it flows under Waukesha Avenue and downstream of the confluence. Estimated ½-yr, 1-yr, 2-yr, 5-yr, 10-yr, and 100-yr flows were also obtained from Ruekert-Mielke for Spring Creek at the upstream end of the culvert, at the location where the storm sewers along Main Street enter the culvert, and downstream of the culvert. The Ruekert-Mielke flows do not include base flows. To determine if base flows would be significant in this stretch, we use an estimate of 7.1 in/yr, which was reported as an average baseflow for the Illinois Fox watershed by Gebert, et al. (2007). This rate would produce a baseflow of 0.39 cfs for a drainage area of approximately 0.75 sq mi. Because this value is small compared to the precision of the flow estimates considered, the flow estimates provided by Ruekert-Mielke were considered to reflect the total peak flows for each storm event.

The 100-yr flow we received from Ruekert-Mielke (178 cfs) was comparable to that referenced in the FIS (193 cfs). However, the 10-yr flows were quite different. Ruekert-Mielke reported a 10-yr flow of 77 cfs, while the FIS suggested a 10-yr flow of 159 cfs. According to Ruekert-Mielke staff, the discrepancy is due to the lack of consideration of detention ponds and other storage areas in the FIS flows. Ruekert-Mielke noted that the FIS hydrology is based on SEWRPC's 1977 report, which calculated runoff based on expected land use conditions in 2000, without consideration of stormwater management or storage upstream of undersized culverts.

Regional regression equations were also reviewed to confirm that these flows are reasonably close. The flows from the FIS, RM, and the regression equations are shown in Table 1. While the variability in the flows determined through each method is considerable, together they provide a broad range of flows that should be considered in the design. The Ruekert-Mielke 1, 2, and 10 yr events and the FIS 10 and 100 yr events were incorporated into the hydraulic analysis described in the next section.

Table 1 – Estimated Flows and Design Flows in Project Reach and Downstream (all flows in cfs)

	1 yr	2 yr	10 yr	50 yr	100 yr
FIS flows at Waukesha Ave			159	185	193
RM flows at upstream end of culvert	34	39	77		178
Regional Regression Equation flows at upstream end of culvert		29	64	97	111
RM flows at downstream end of culvert	56	63	117		243
FIS flows below confluence of Spring Creek and stream downstream of project area			351	751	990
Regional Regression Equations Flows below confluence		193	365	549	629
Flows Evaluated in Design					
Upstream of Main St	34	39	77 and 159		193
Downstream of Main St	56	63	117 and 199		258

Hydraulics

A HEC-RAS model was developed to ensure that the proposed channel slope and cross section geometry are suitable for

1. conveying flows,
2. achieving shear stresses that allow for balanced sediment transport between the upstream reach and the proposed reach,
3. ensuring that the crossing at Main Street does not pose a barrier to fish and wildlife movement, and
4. inundating the floodplain frequently to maximize pollutant attenuation.

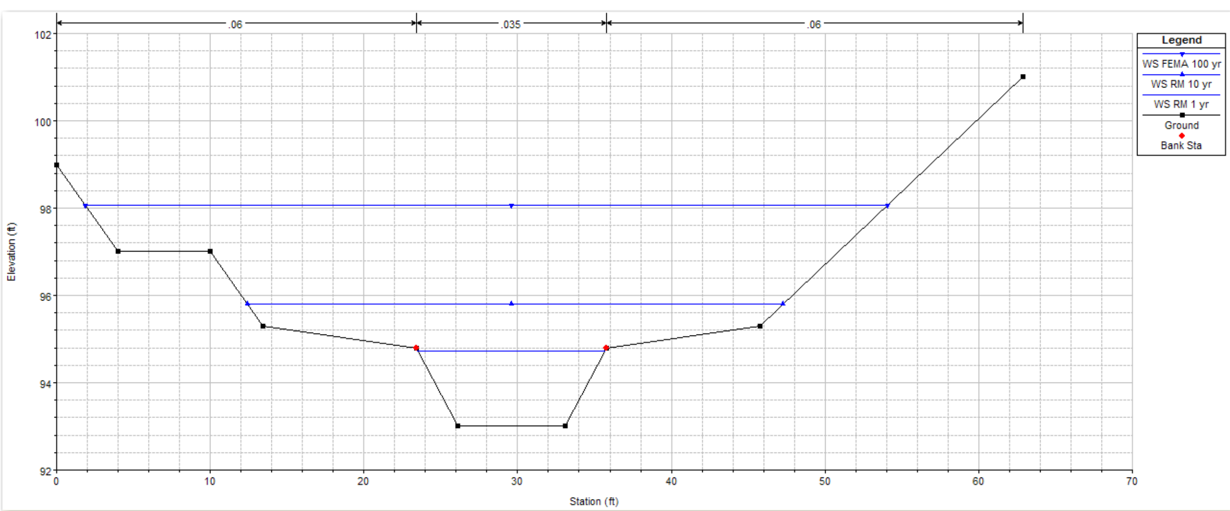
The flows described in the previous section were incorporated into a HEC-RAS model of the existing conditions that was developed using the cross section, culvert, bridge, stream, and floodplain conditions data obtained during the topographic survey. A project datum was established in the survey that has not been precisely correlated with a standard datum (such as NGVD 29). However, comparison of our survey data with the topographic data provided by the Village allows a preliminary means of comparing our elevation data with that of others.

The boundary condition for the model was entered as known water surface elevations downstream. The downstream water surface elevations were obtained from the FIS flood profiles for the 10-yr and 100-yr flows and calculated using Manning's equation (assuming normal flow conditions) for the smaller 1-yr and 2-yr flows.

Results of the existing conditions model were compared to the flood profile for the FEMA 100 year flood event and found to correlate well. This correlation is suitable for determining impacts of the proposed project on flood elevations at the concept development stage. The model may be calibrated during final design for a more refined demonstration.

A proposed condition model was developed to ensure that conceptual channel cross section and channel slope are adequate to minimize erosion and convey the flows and sediment (see Figure 1). To maximize the water quality benefits of the project, we adjusted the channel dimensions and elevation such that the model predicted floodplain inundation almost yearly. During final design, additional complexity will be incorporated into the floodplain to provide variable flooding elevations and durations at different places along the floodplain.

Figure 1 – Sample proposed cross section modeled showing
1 yr, 10 yr, and 100 yr water elevations



The predicted flood profile for the 100 yr flood event was compared to that in the FEMA Flood Insurance Study to ensure that flood elevations are not increased anywhere along the profile. As expected, the rehabilitated channel caused decreases in flood elevations by creating additional flood storage. Flood water that currently backs up upstream of the existing culvert and eventually covers the parking lot would be stored within the new stream valley below the parking lot elevation.

Although the proposed culvert system has larger flow capacity than the existing conditions, this capacity does not increase 100 yr flood elevations downstream because Spring Creek is backed up by overflow from Sussex Creek such that water does not move quickly through the proposed culvert system.

A conceptual analysis of sediment transport and the potential for the channel to aggrade or degrade over time was done by comparing channel shear stresses in the upstream reach and in the proposed channel. Upstream, channel shear stresses ranged from approximately 0.01 lb/ft^2 in the deeper pools to 0.27 lb/ft^2 in the steeper or more constrained reaches. In the proposed channel, the shear stresses ranged from 0.09 lb/ft^2 to 0.28 lb/ft^2 over the full range of flows considered. This consistency in shear stresses across the reach suggests that sediment transport capacity should be fairly consistent as well. A gravel substrate should be suitable to withstand these shear stresses without eroding.

One effect of replacing the existing culvert with an open channel will be increased capacity to convey water through this area. It is important to consider the impact this increased conveyance will have on the stability of the upstream channel. Increasing flow capacity can result in decreased water depths, increased velocities, and increased shear stresses that have the potential to cause downcutting in the upstream channel. We examined the channel shear stresses predicted in the upstream reach in the existing condition model and those in the proposed condition model. Removal of the culvert is predicted to decrease water levels by approximately 0.5 ft in the 200 ft of stream upstream of the culvert for the 1 – 2 year flow events and almost 1.5 ft for the 100 year flood event. Shear stresses are predicted to increase in the range of 0.03 to 0.1 lb/ft^2. Given the fine bed material prevalent in that reach of the stream, these small increases in shear stress could result in some material washing out. During detailed design, additional data on bed material upstream of the proposed project should be collected, and if necessary, a grade control riffle can be constructed at the beginning of the rehabilitated reach that would prevent downcutting of the stream. This may also be desired to maintain existing flood levels in the wetland.

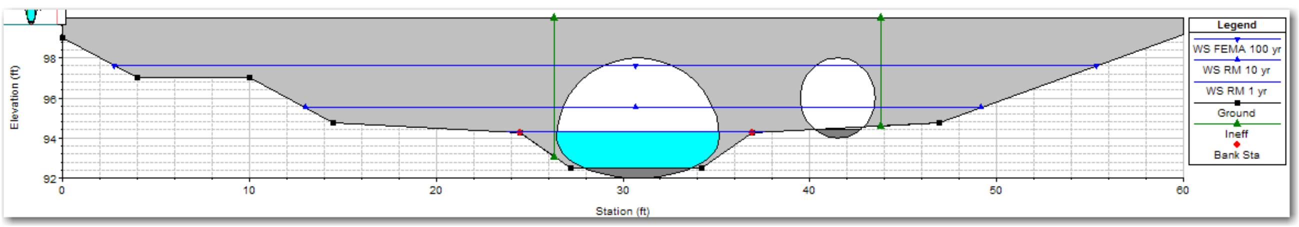
Proposed Main Street Crossing

Preliminary discussions with the Village of Sussex staff resulted in a decision to evaluate a culvert system for the Main Street crossing that would ensure that hydraulic conditions created by the culvert do not disrupt the stream substrate through scour and do not pose barriers to movement of fish and wildlife. To achieve these objectives, a two stage culvert system is proposed for the Main Street crossing. One large box or pipe arch comparable in width to the proposed channel should be placed below the invert of the channel at a slope comparable to that of the proposed channel to facilitate passage of aquatic species. It should be filled with suitable stream substrate material to simulate a natural channel bottom. A second pipe or box culvert should be located at the floodplain elevation of the proposed channel. This second culvert increases the flow capacity under Main Street to reduce flood elevations. It also mimics floodplain flow during high flow events, thereby reducing the shear stresses and scour near the primary culvert. It reduces flow velocity in the culvert allowing more regular passage by fish and wildlife. During low flow periods, the floodplain stage culvert can also provide passage under Main Street for amphibians, reptiles and mammals, creating connectivity between downstream and upstream riparian habitats. If a single culvert system is preferred to reduce expense associated with the second culvert, the single culvert should be wider than the channel top width and larger stone material would be necessary near and within the culvert to avoid scour during high flow events.

There is currently a sanitary sewer and a water main that run along Main St that will need to be accommodated. We conceptually modeled the elevation of the upstream end of the culvert at approximately 892.3 ft. According to the Village staff, the sanitary sewer at that location is at approximately 890 ft. Depending on vertical offset requirements and elevation of the water main, the elevation of the primary culvert may need to be adjusted.

Although the preliminary model included a pipe-arch and circular pipe culvert (see Figure 2), the system can consist of a larger single pipe-arch culvert, multiple pipe culverts, or box culverts.

Figure 2 – Two stage culvert system as modeled. The 1-yr, 10-yr, and 100-yr water elevations and the channel cross section upstream of the culvert are shown.



Stormwater management areas

In replacing the existing 470 ft pipe with a stream channel, it will be necessary to break the existing storm sewers that connect to that pipe and route that stormwater to the new channel. This provides an opportunity to incorporate stormwater management elements that will treat stormwater prior to discharge to the stream. Sheets 1 and 2 of the concept plan (Appendix A) show conceptual locations for such stormwater elements. Performance objectives and design of those elements will be discussed and detailed during final design.

Conceptual Costs

Planning level cost estimate for the stream construction was prepared to allow comparison of the alternative alignments and to aid in identifying funding sources for the project. There are uncertainties associated with the construction that can have a large impact on the construction costs. In particular, it is not clear the extent to which bedrock may be encountered in the excavation of the stream corridor. Village staff indicated that shallow bedrock is likely in the area. However, given that bedrock outcroppings were not observed in the stream corridor upstream or downstream of the proposed channel, we assume for estimating purposes that rock will only comprise 20% of the excavation. The cost estimate shown in Table 2 also assumes that construction will be completed and the floodplain and side slopes are well vegetated before the channel is required to convey water.

This allows time to stabilize the banks with vegetation, eliminating the need for fabric encapsulated soil lifts along the channel, and reducing construction costs by $30,000 - $40,000.

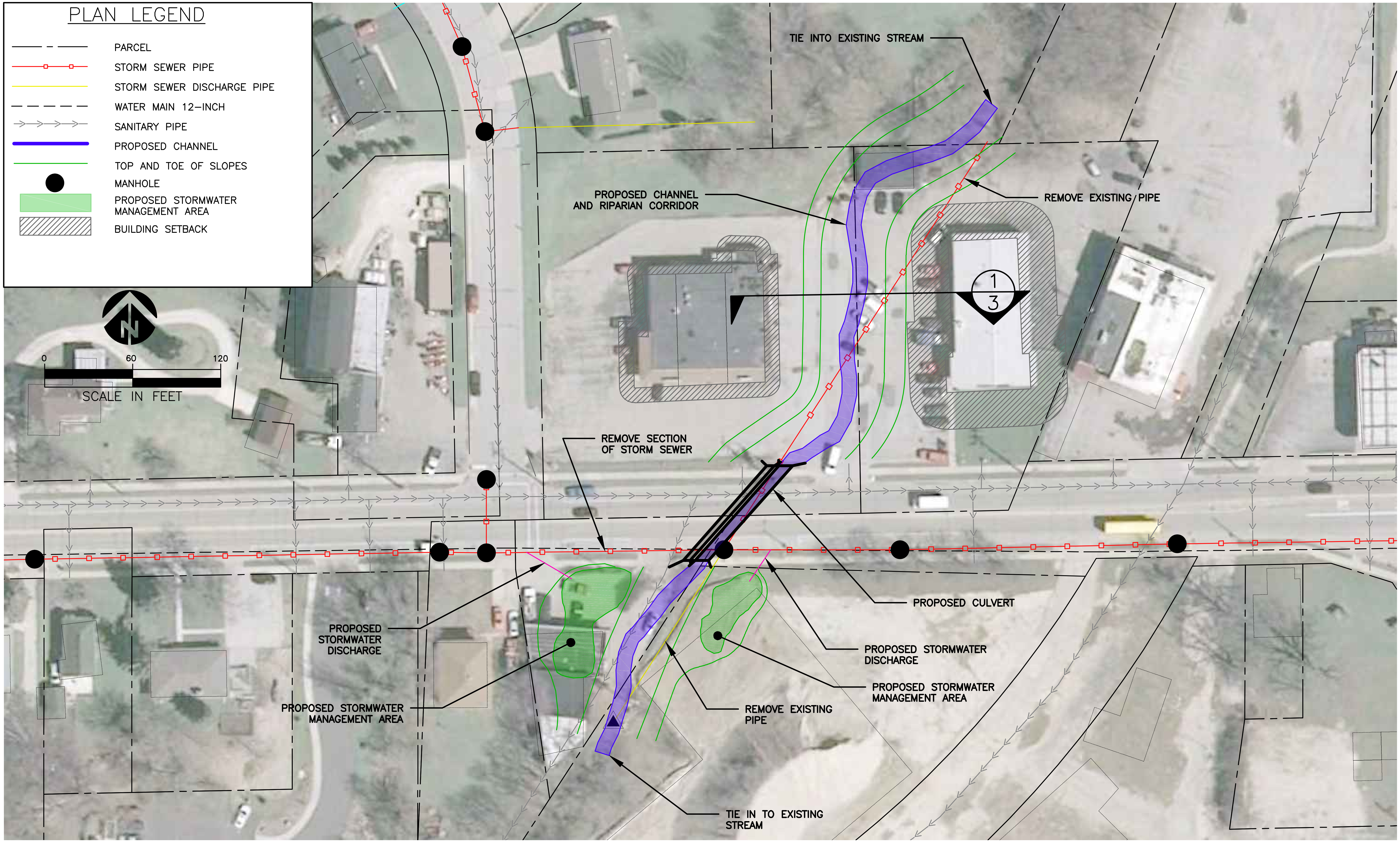
There are some significant differences between the estimated costs of the two alternatives. Alignment 2 would require considerably more excavation than Alignment 1, which is the biggest single component of the overall costs. Alignment 2 also includes building steep slopes for ~250 linear ft of bank to fit into the relatively tight space allocated. If either the western building can be moved, or the pedestrian path eliminated, the cost of the bank construction would be reduced considerably.

Table 2 – Estimated Costs Associated with Stream Construction*

Cost category	**Alignment 1**	**Alignment 2**
Mobilization and site prep (including erosion control)	$14,000	$14,500
Excavation (assumes 80% common excavation, and 20% rock excavation)	$117,700	$158,300
Installation of stream bed and bank material, including vegetated soil lifts on steep slopes	$16,300	$59,000
Seeding and planting	$12,700	$17,900
TOTAL (not including Main Street work)	$160,700	$249,700

* Does not include demolition, plugging or removing the existing culvert, Main Street road work, ground covering or amenities for the proposed pedestrian path, or structures associated with the proposed stormwater management areas.

Appendix A – Spring Creek Daylight Concept Plan



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NO.	BY	DATE	REVISION DESCRIPTION

JAT		
DRAWN	DESIGNED	CHECKED
BW	11/08/10	
APPROVED	DATE	PROJECT

SPRING CREEK DAYLIGHT PROJECT
VILLAGE OF SUSSEX

inter-fluve
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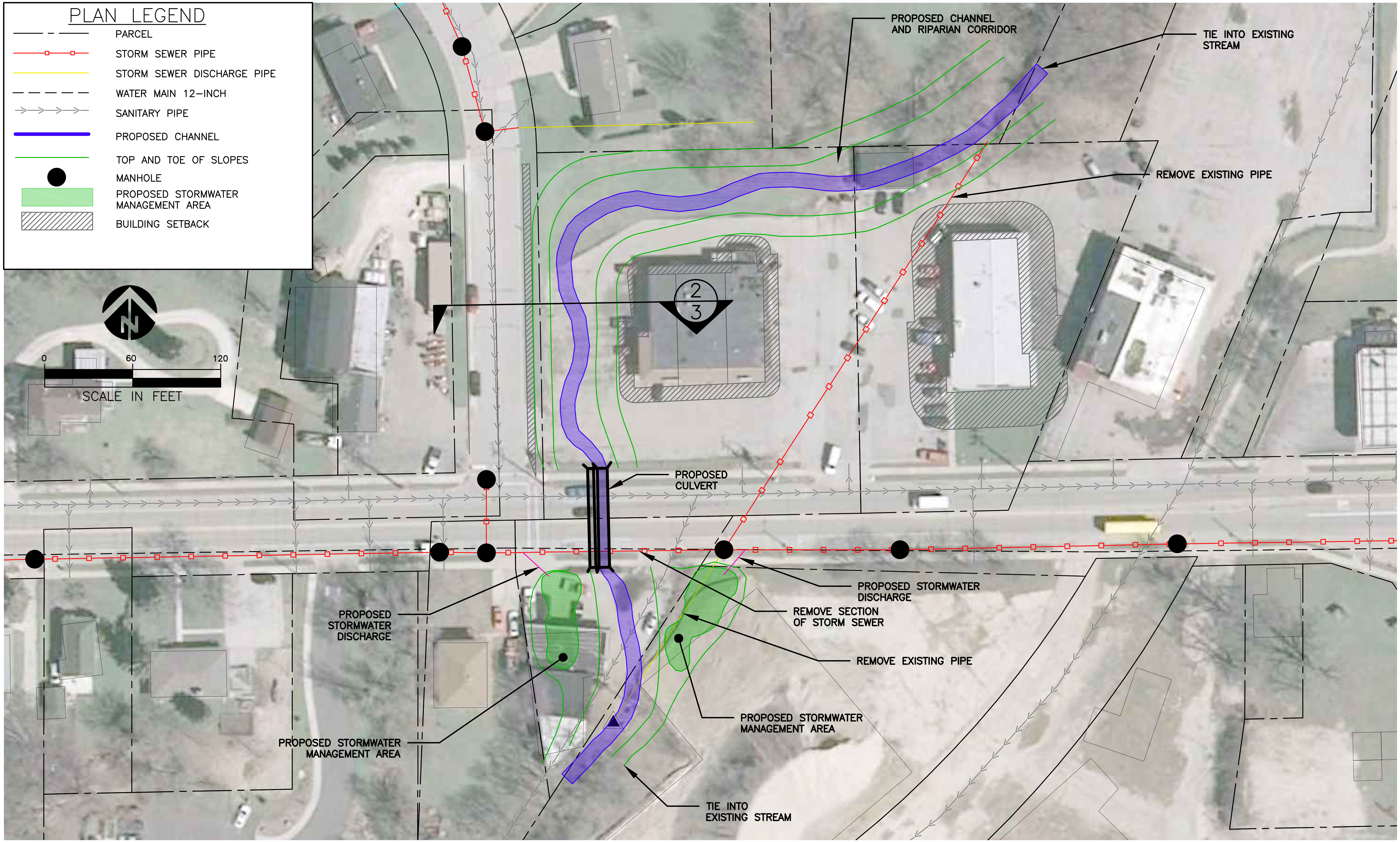
PLAN VIEW
ALIGNMENT 1

SHEET
1 OF 3



NO.	BY	DATE	REVISION DESCRIPTION

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JAT		
APPROVED	**DATE**	**PROJECT**
BW	11/08/10	

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VILLAGE OF SUSSEX

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PLAN VIEW
ALIGNMENT 2

SHEET
2 OF 3

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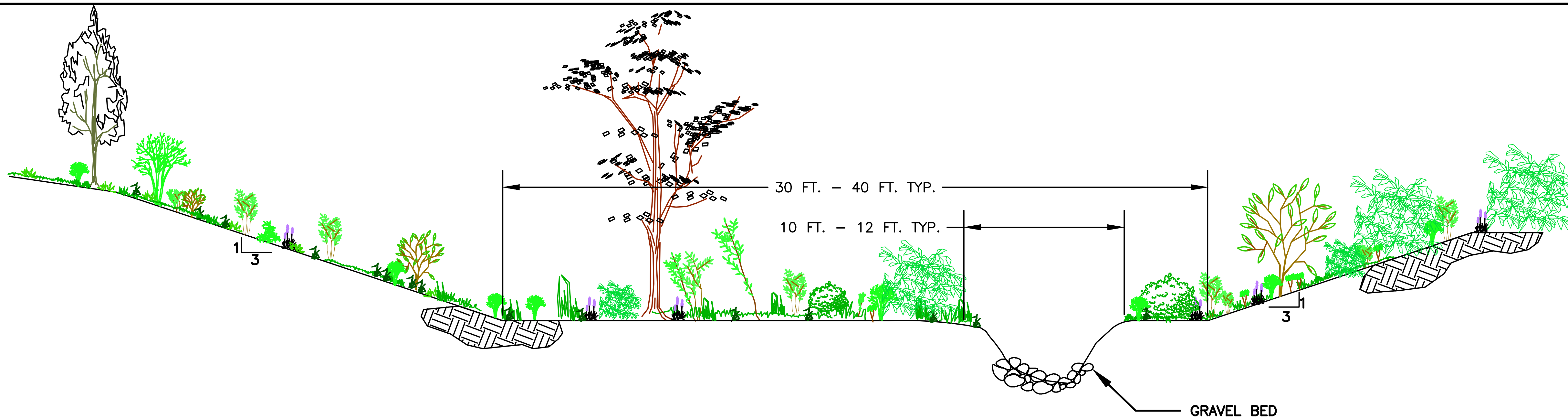
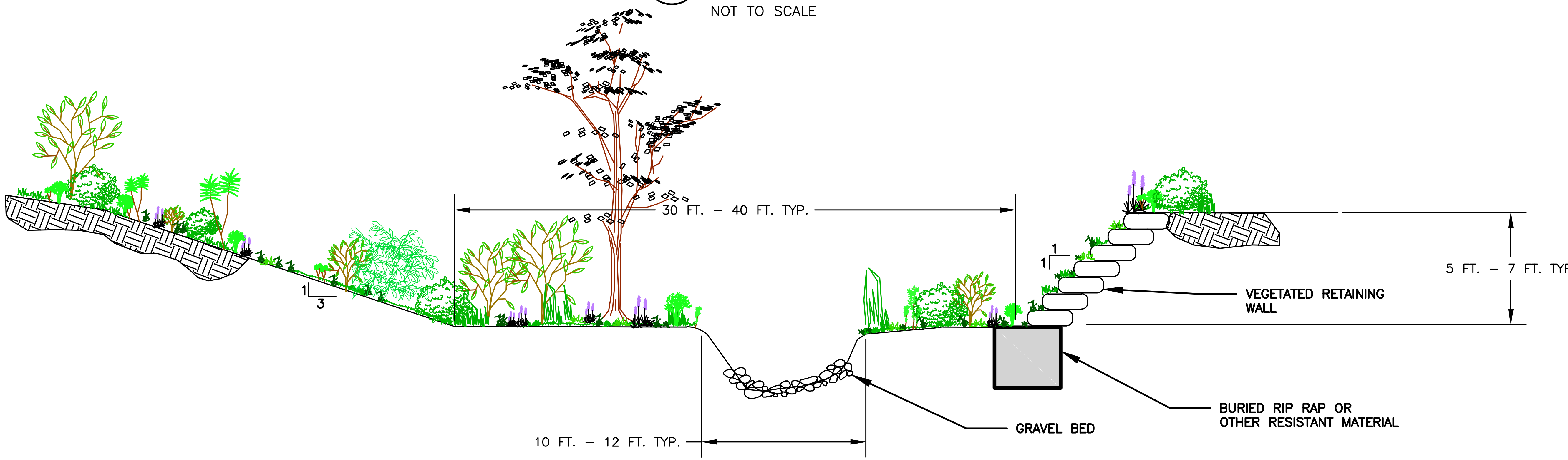


1/3 TYPICAL CROSS SECTION
ALIGNMENT 1
NOT TO SCALE



2/3 TYPICAL CROSS SECTION
ALIGNMENT 2
NOT TO SCALE

NO.	BY	DATE	REVISION DESCRIPTION

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JAT		
DRAWN	DESIGNED	CHECKED
BW	11/08/10	
APPROVED	DATE	PROJECT

SPRING CREEK DAYLIGHT PROJECT
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DETAILS – CROSS SECTION