Prepared by: EOR

For the Comfort Lake-Forest Lake Watershed District

(5228-L) WASHINGTON JUDICIAL DITCH 6 ASSESSMENT AND FEASIBILITY STUDY

12.6.2018

EOR water ecology community

Cover Image

Washington Judicial Ditch 6 south of Highway 97 [Greg Graske, September 2018]

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1. INTRODUCTION

As outlined in the 2017 Forest Lake Diagnostic study, the Washington Judicial Ditch 6 (WJD 6) subwatershed accounts for 26% of the total drainage area and 30% of the total flow and phosphorus load to Forest Lake. The study also identified a phosphorus reduction goal of 169 lb/yr from the WJD 6 subwatershed for Forest Lake to meet the District long-term goal of in-lake growing season average phosphorus concentrations at or below 30 µg TP/L.

The WJD 6 subwatershed largely consists of wetland areas and large lot residential development (Figure 1). According to the Minnesota Land Cover Classification System (MLCCS), the WJD 6 watershed is 32% deciduous tree canopy, 27% grass/shrub, 17% emergent wetlands, 12% forest/shrub, 6% agriculture, and 6% other. Note that the grass/shrub category includes hay fields and former pastures that may be cropped in the future. Very little active farming still occurs along the ditch system and the ditch system is largely in disrepair. A portion of the ditch system also runs through the DNR owned Hardwood Creek Wetland Management Area (WMA). However, implementation planning based only on current land use could miss phosphorus hotspots and therefore result in identification of practices with poor cost-effectiveness. Therefore, targeted monitoring and field reconnaissance is needed in this subwatershed to identify legacy phosphorus hotspots and develop non-structural management practices to address phosphorus hotspots.

This report summarizes additional targeted tributary monitoring, diagnostic modeling, and preliminary project feasibility and planning that was completed in 2018. Due to the large size of this subwatershed, it is expected that project feasibility and planning will continue into 2019. The 2019 work will likely include additional wetland assessments, further refinement of project designs, H&H modeling of project conditions on upstream water levels, discussions with landowners, and one or more recommended projects ready for grant applications with preliminary cost-estimates.

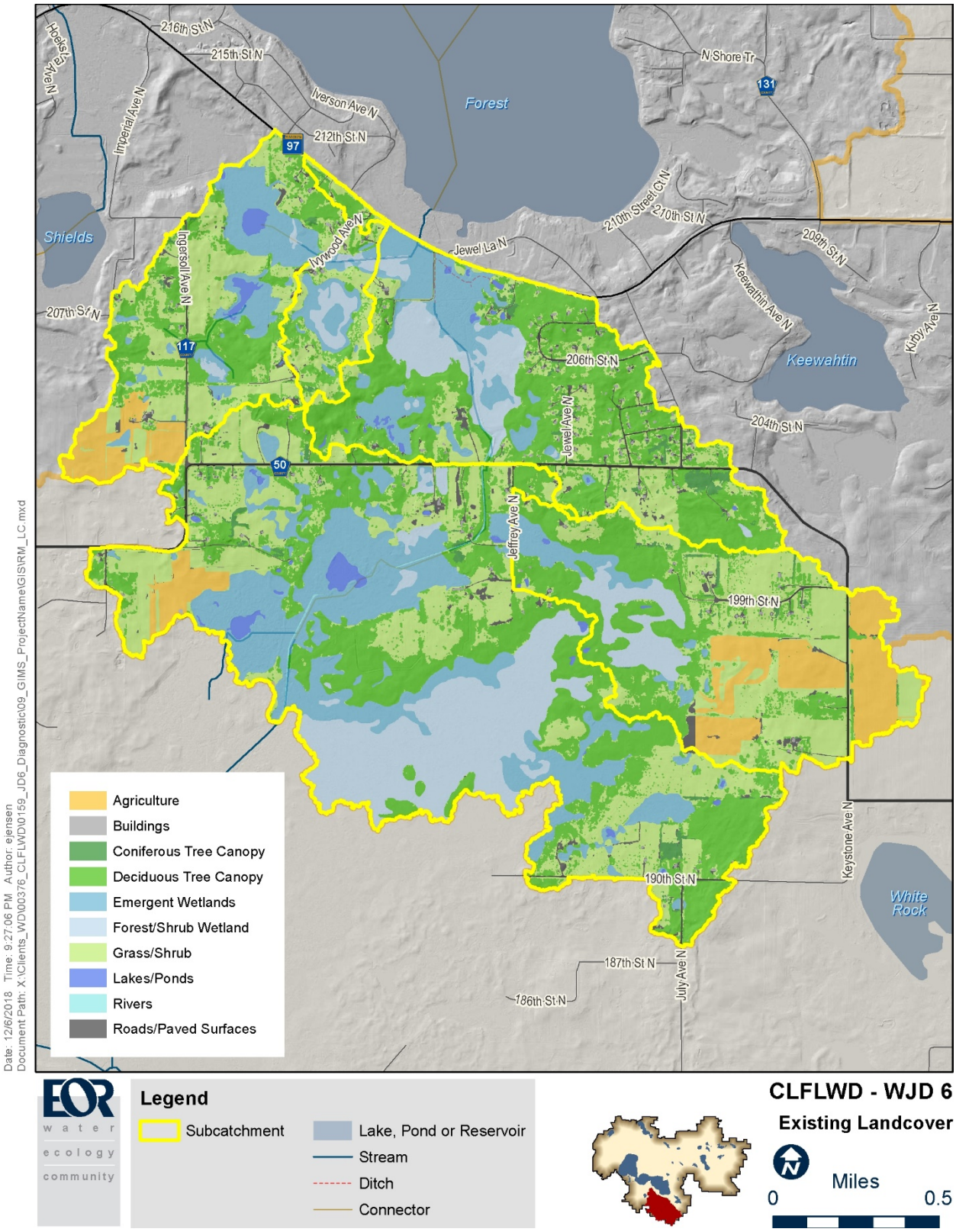


Figure 1. WJD 6 Subwatershed Existing Land Cover

(Note that the grass/shrub category includes hay fields and former pastures that may be cropped in the future)

2. TRIBUTARY MONITORING

Continuous flow and water quality grab samples were collected at six locations (Figure 2) following eight runoff events in 2018 to further refine the distribution of phosphorus loading throughout the WJD 6 subwatershed. Only water quality grab samples were collected from WJD 6 at Highway 97 (R7) because water levels at R7 are influenced by the water level of Forest Lake and therefore continuous flow and loads could not be calculated.

Continuous flow was monitored using a level logger from April 23 through October 24, 2018 for a total of 185 days. Instantaneous flow measurements were collected using a Marsh McBirney flow meter several times in spring and early summer and once in September, when there was stream flow (April 23, April 26, May 3, May 25, May 30, June 6, June 26, and September 21). A rating curve was developed for each location using instantaneous flow measurements collected during grab sampling. These rating curves had very strong goodness of fit with high R^2 (>0.97).

Water quality samples were collected during the grab sampling for total phosphorus (TP), ortho-phosphorus (Ortho-P), total iron (Total Fe), and total suspended solids (TSS). All water quality sample data collected at each location and date are listed in Appendix B.2. Continuous flow records and grab sample total phosphorus concentrations are illustrated in Appendix B.1. These data were used as inputs to the FLUX32 model to calculate phosphorus and TSS loads (Table 1), and to characterize the reactivity and availability of phosphorus loads for algal growth (Table 2).

Total flow and load measured for 2018 in the WJD 6 subwatershed were estimated as the sum of the R7W and R7E sites (2,115 acres) since continuous flows could not accurately be collected at the outlet (R7). For the WJD 6 subwatershed, the total flow was 980 acre-feet (or one football field filled with 742 feet of water), the total phosphorus load was 869 lb/yr, and the total sediment load was 31,100 lb/yr (or approximately one large dump truck load).

In general, phosphorus and TSS loads are fairly evenly distributed throughout the WJD 6 subwatershed. That is to say, the subcatchments do not discharge a greatly disproportionate amount of phosphorus and sediment compared to flow. However, between 202nd Street North (R7U) and Highway 97 (R7E), the flow weighted mean phosphorus concentration increases from 241 µg/L to 339 µg/L and the total phosphorus load doubles. Moreover, the phosphorus load at R7E was 91% of the total monitored load in 2018. The flow weighted mean phosphorus concentration at R7D is also slightly high (304 µg/L) but decreases downstream at R7W (232 µg/L), and represents just 9% of the total monitored load.

Sediment flow weighted mean concentrations are low throughout the WJD 6 subwatershed (6-15 mg/L), which is expected for a wetland dominated watershed. While average ortho-phosphorus concentrations are high (~70% or greater) like many wetland systems, the corresponding moderate to high average iron to phosphorus ratios (9.5-17) indicate that the wetland soils in the WJD 6 subwatershed are not degraded and have phosphorus adsorption capacity.

Table 1. 2018 Monitoring Location Flow, Load and FWMC for Phosphorus and Sediment (FLUX)

Location	Drainage Area (ac)	Flow		Phosphorus			Sediment (TSS)		
		(ac-ft)	(% Total)	Load (lb/yr)	Load (% Total)	FWMC (µg/L)	Load (lb/yr)	Load (% Total)	FWMC (mg/L)
Jeffrey Ave	390	106	11%	71	8%	245	1,698	5%	6
R7U	1,326	609	62%	399	46%	241	18,505	60%	11
R7E	1,672	862	88%	795	91%	339*	26,279	84%	11
R7D	378	121	12%	100	12%	304	2,957	10%	9
R7W	443	117	12%	74	9%	232	4,821	16%	15
Total (R7W + R7E)	**2,115**	**980**		**869**			**31,100**		

FWMC = flow weighted mean concentration, equivalent to the total load divided by the total flow

* Denotes high uncertainty in load and flow weighted mean concentration estimate in FLUX

Table 2. 2018 Monitoring Location Orthophosphorus and Iron Data

Location	Ortho P (as % Total Phosphorus, TP)			Iron (Fe) : TP ratio		
	Average	Min	Max	Average	Min	Max
Jeffery Ave	**85%**	70%	95%	**9.5**	1.7	21.2
R7U	**70%**	22%	83%	**9.9**	5.9	13.2
R7E	**70%**	16%	88%	**13.3**	2.3	18.5
R7D	**68%**	35%	85%	**9.5**	5.8	14.1
R7W	**80%**	58%	89%	**12.1**	10.2	15.4
R7	**70%**	55%	83%	**17.0**	8.4	46.4

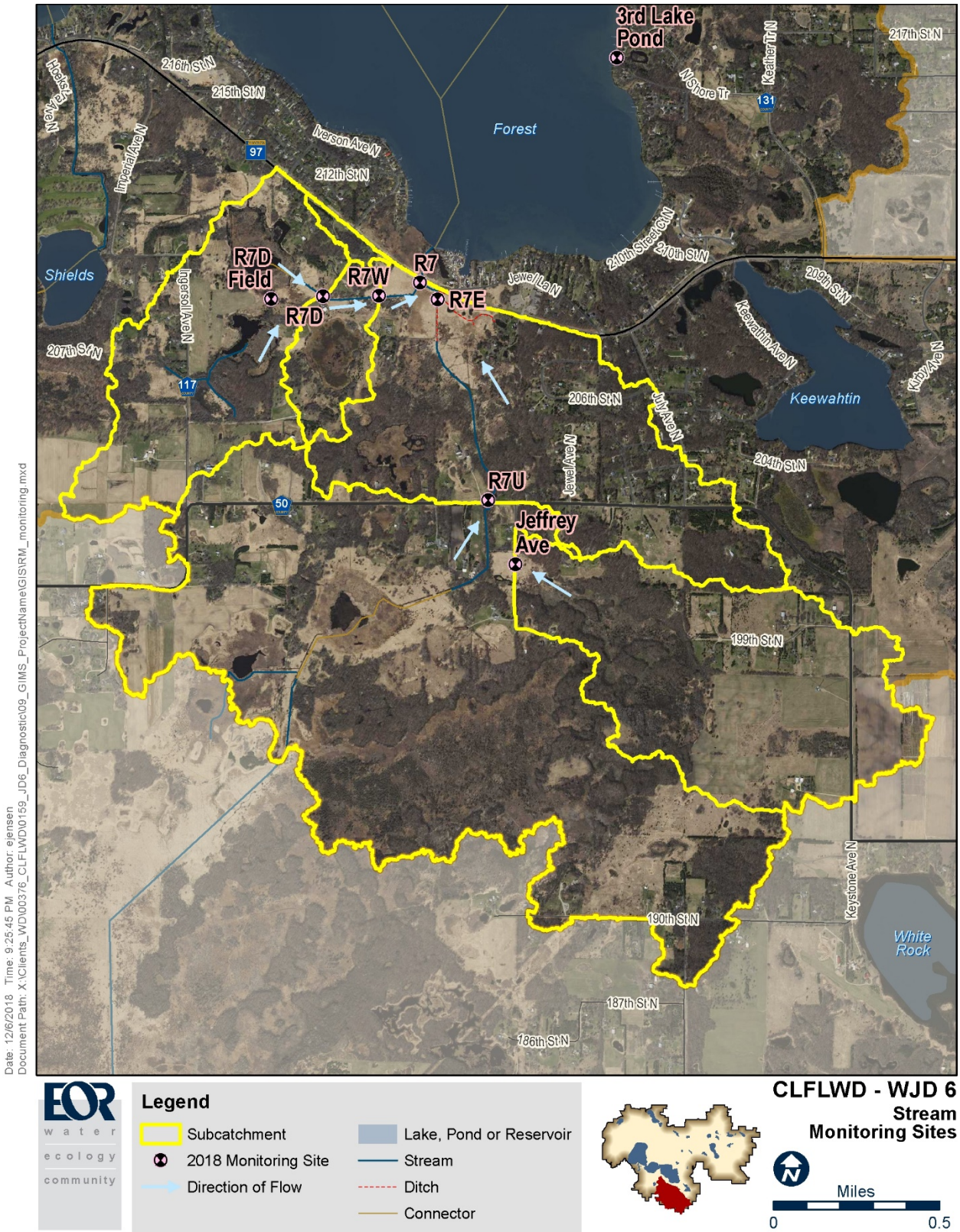


Figure 2. 2018 Tributary Monitoring Locations

3. WETLAND AND LAND COVER CHARACTERISTICS

Wetland water level monitoring was conducted in 2018 using level loggers in soil piezometers at five locations (Figure 3) in the WJD 6 subwatershed to characterize subsurface flow and phosphorus quality within several wetland areas and determine the feasibility of wetland restoration projects. In addition, desktop analysis of LiDAR topography, soil type, land use, and historical imagery was used to identify historic changes in wetland cover and land use at these locations to identify any probable locations of legacy phosphorus hotspots (see Appendix A).

3.1. Jeffrey Avenue Wetland

The Jeffrey Avenue wetland basin is located east of Jeffery Avenue. It outlets through a culvert under Jeffery Avenue, flows west, and then converges with WJD 6 south of 202nd Street. There are a number of hobby farms in the contributory watershed that appear to have been there for many decades. Currently there are a few small hobby farms and small-scale agricultural activities in the drainage area and many acres of wetland. Large wetlands areas are evident since the first available aerial imagery in 1936.

The water level stage data collected at Jeffery Avenue closely correlates with the well data (Jeffrey Ave Well; see Figure 7 in Appendix A.1) collected in the wetland east of Jeffery Avenue (PIN 163-2403221330002). Bounce in the wetland and stage in the ditch respond to precipitation events indicating the wetland hydrology is surface water driven. It is not clear if the ditch is causing the wetland drawdown or if indeed, the entire basin and the ditch have a similar hydrologic response to precipitation events. Additional monitoring data would be necessary to determine what affect, if any the artificial drainage is having on the wetland. This would involve installing a well transect that extends perpendicular to the ditch with three or more wells spaced several hundred feet apart to allow any lateral effects of the ditch to be understood.

Wetlands affected by artificial drainage can degrade overtime and become a source of phosphorus. Restoration concepts for artificially drained wetlands involve restoring a natural hydrologic regime to prevent drainage, increase evapotranspiration, and reduce nutrient export. This wetland is not on the Public Waters Inventory so the local Wetland Conservation Act and the US Army Corps of Engineers are the two wetland regulatory entities involved. Wetland restoration activities conducted by public agencies are given wetland permitting flexibility, often alleviating the need for compensatory mitigation.

A project in the Jeffrey Avenue Wetland was identified as low priority and is described in more detail in Section 6.3.

3.2. R7E Wetland

The R7E wetland basin is located south of Highway 97 and east of the private driveway. WJD 6 flows north through the west side of this wetland basin and continues north, under Highway 97 to Forest Lake. The immediate watershed of this wetland is comprised of a high number of large lot residential homes. Many of these homes have been in existence for several decades and are served by individual

septic treatment systems (ISTS). Since the first available aerial imagery in 1936, this wetland has been in existence although it does appear to be more wet now than in some periods previous.

The water level stage data collected near Highway 97 in WJD 6 does not correlate with the well data (R7E Well; see Figure 8 in Appendix A.1) collected in the wetland area (PIN 163-2303221110013). The bounce in the ditch responds more closely to precipitation events but the wetland stays relatively stable throughout precipitation events and the growing season. The well water level is consistently about one foot higher than recorded in the ditch. This is consistent with field observations; standing water was observed at the well location during data collection visits. Since the well is quite far from the ditch, an additional season of well monitoring in a transect close to the ditch would be useful for understanding the ditch lateral effect.

At this point, it is not clear what benefits hydrologic restoration of this wetland basin would provide. For the most part the basin retains its seasonal hydrology; the one unknown is of course the lateral effect closer to the ditch.

From field observations and a review of aerial imagery, WJD 6 that runs along the west side of this wetland is showing a meandering pattern. This is very typical of artificial drainage ditches. The ditch starts to meander because a linear ditch pattern is not stable. Streams with low gradients such as this one, typically have high sinuosity in their stable state. The ditch does have more gradient to the south and therefore more velocity. Some signs of erosion are noted in this ditch segment as well. A geomorphic assessment of the steeper gradient section to the south and the wetland section of the ditch is recommended (PIN 163-2303221410006).

This is a public ditch and for the most part in wetland. Projects that involve alterations to the ditch may require Drainage Law proceedings since this is a public ditch. Wetland regulatory agencies will also need to be consulted before any ditch construction work is conducted. Wetland regulations provide flexibility for repair projects on public drainage systems. This wetland is not on the Public Waters Inventory.

A project in the R7E Wetland may be included as part of the high priority Sunrise Headwater Restoration project described in Section 6.1.

3.3. R7W Wetland

The R7W wetland basin is located south of Highway 97 and west of the private driveway. The main branch of WJD 6 flows along a short section of the northeast corner of the wetland basin along Highway 97 before flowing north under the highway towards Forest Lake. A branch of WJD 6 extends westerly through the basin to subcatchment R7D. The immediate watershed of this wetland is comprised of a scattering of large lot residential homes and some hobby farms. Since the first available aerial imagery in 1936, this wetland has been in existence, although it does appear to be more wet now than in some periods previous.

The well data (R7W Well; see Figure 9 in Appendix A.1) collected near Highway 97 in WJD 6 (PIN 163-2303221120005) does correlate more closely to the monitored ditch stage than data in Well 3, east of the driveway. The stage in the ditch responds closely to precipitation events as does the wetland water level. Similar to R7E Well, water level recorded by R7W Well is consistently about

one foot higher than that recorded in the ditch. This is consistent with field observations; standing water was observed at the well location during data collection visits. Since the well is quite far from the ditch, an additional season of well monitoring in a transect close to the ditch would be useful for understanding the ditch lateral effect.

At this point, it is not clear what benefits hydrologic restoration of this wetland basin would provide. For the most part the basin retains its seasonal hydrology, the one unknown is of course the lateral effect closer to the ditch.

In reviewing the aerial imagery the west branch of WJD 6 coursing through this wetland is not showing a meandering pattern. A close examination of this channel is recommended to determine if meandering is occurring to determine if channel stability is of concern.

Since this is a public ditch and for the most part in wetland, wetland regulatory agencies will need to be consulted before any ditch construction work is conducted. Projects that involve alterations to the ditch may require Drainage Law proceedings. This wetland is not on the Public Waters Inventory.

A project in the R7W Wetland may be included as part of the high priority Sunrise Headwater Restoration project described in Section 6.1.

3.4. R7D Wetland

The R7D wetland basin is located west of Ivywood Ave N. The west branch of WJD 6 is well defined flowing into and out of the wetland. The immediate watershed of this wetland is comprised of large lot residential homes, hobby farms and agricultural lands. Since the first available aerial imagery in 1936, this wetland has been in existence although it does appear to be more wet now than in some periods previous. The wetland currently has two open water areas, one is at the center of the basin and the other is, what appears to be an excavated area along the north boundary of the basin.

The well data (R7D Well; see Figure 10 in Appendix A.1) collected in the easterly portion of the wetland (PIN 163-230322120005) correlates with precipitation patterns. The wetland shows increased water surface elevations following precipitation events and gradual drawdown in periods of less frequent precipitation. The well data also shows expected seasonal variability; water table increases as evapotranspiration decreases later in the growing season. Additional water level gauging at the outlet of this basin, near Ivywood, would be beneficial to better understand the hydrology of this basin and contributing watershed. Since this basin is ditched, some water quality benefits could be realized with a stabilized outlet that maximizes storage and evapotranspiration.

This wetland is on the Public Waters Inventory so coordination with MN DNR Waters is required for any proposed modifications. The site is not on the official WJD 6 alignment, however projects that involve alterations to the ditch may still require Drainage Law proceedings if it is determined that this is a lawfully connected private ditch.

A project in the R7D Wetland was identified as medium priority and is described in more detail in Section 6.2.

3.5. R7 Wetland

The R7 wetland basin is located north of Highway 97 (PIN 163-2303221120002). WJD 6 bisects this wetland and outlets into Forest Lake. This area adjacent to the outlet of WJD 6 is entirely wetland between Highway 97 and the lake shoreline, therefore the shoreline of Forest Lake is undeveloped in this area.

The water level data (R7 Well; see Figure 11 in Appendix A.1) collected north of Highway 97 near WJD 6 correlates with Forest Lake water elevations. Due to the close connection with the lake, this location is not highly valuable for assessing the hydrology and water quality trends of the WJD 6 drainage area.

No hydrologic restoration projects for this wetland are recommended at this time since it is hydrologically connected to Forest Lake.

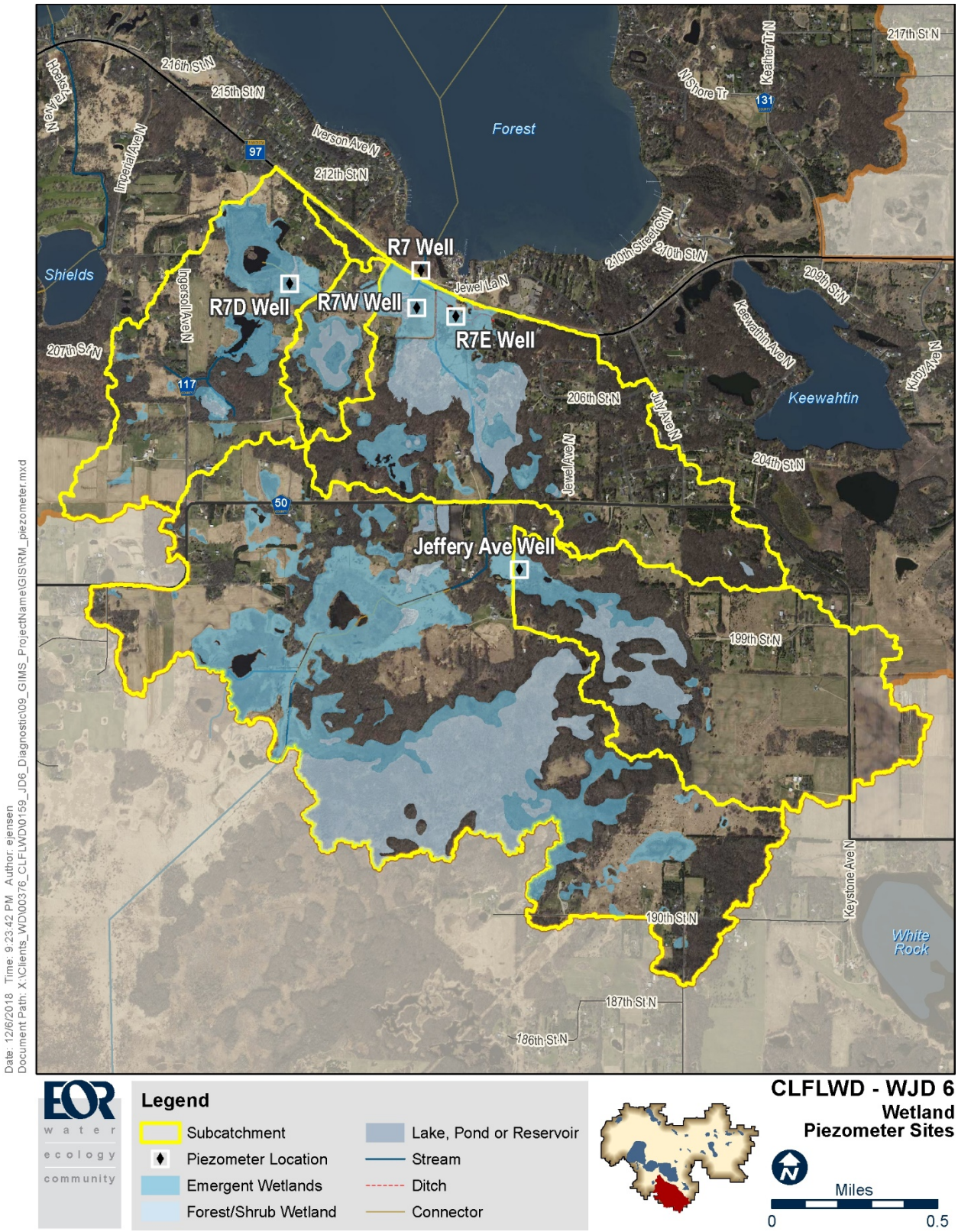


Figure 3. 2018 Wetland Piezometer Monitoring Locations

4. JUDICIAL DITCH SURVEY

In 2018, the main channel and key crossings of the entire WJD 6 ditch system were surveyed. Ditch centerlines, cross sections and culverts were field surveyed with DGPS. The portion of the system that is tile line is currently assumed to be in disrepair. This project did not include potholing for the tile line, however the old alignment was walked but no sections of tile were exposed or near the surface. In addition, a few hand borings were completed in the ditches to estimate sediment accumulation and the original channel bottom. Surveys of the ditch systems were completed in July and August 2018.

4.1. Historic Conditions

From the 1921 Engineer's Report, the approximate area of wetlands benefitted by draintile [via construction of WJD 6] is 460 acres (Figure 4). According to the January 8, 2015 memorandum by the RCWD Engineer to the RCWD District Administrator:

"The WJD 6 pubic drainage system is in general disrepair, with many tiles clogged with sediment and tree roots. Much of the system is located in deep marshes and in forested areas which have accelerated the deterioration of the system. Several open channels have been excavated parallel to or crossing the historic alignment, presumably damaging portions of the tile systems (if the tiles were intact at the time of the excavation). Very few remnants of the historic tile system are visible at the surface, even at locations where the excavated channels cross the tile system."

WJD 6 was transferred from Rice Creek Watershed District to Comfort Lake – Forest Lake Watershed District in 2017.

4.2. Current Conditions

The current ditch system, while still functioning as a drainage way for surface water, is no longer actively being maintained as an agricultural drainage system. The historic documents indicate that the ditch system south of County Road 50 was originally a tile system. The tile system appears to be abandoned with those areas now replaced with open ditch. The lower portion of the ditch system from County Road 50 to Highway 97 was originally open ditch and has greater slope then the upper portion of the system. The historic records indicate that, prior to ditching, the channel was approximately a couple feet higher than the planned profile and it was a meandering channel. The current channel appears to still be lower than pre-ditch conditions, however there is some sediment accumulation along the profile and the channel is trying to re-meander itself. This is indicative of a channel that is currently not stable, prone to erosion, and likely transporting sediment and nutrients downstream.

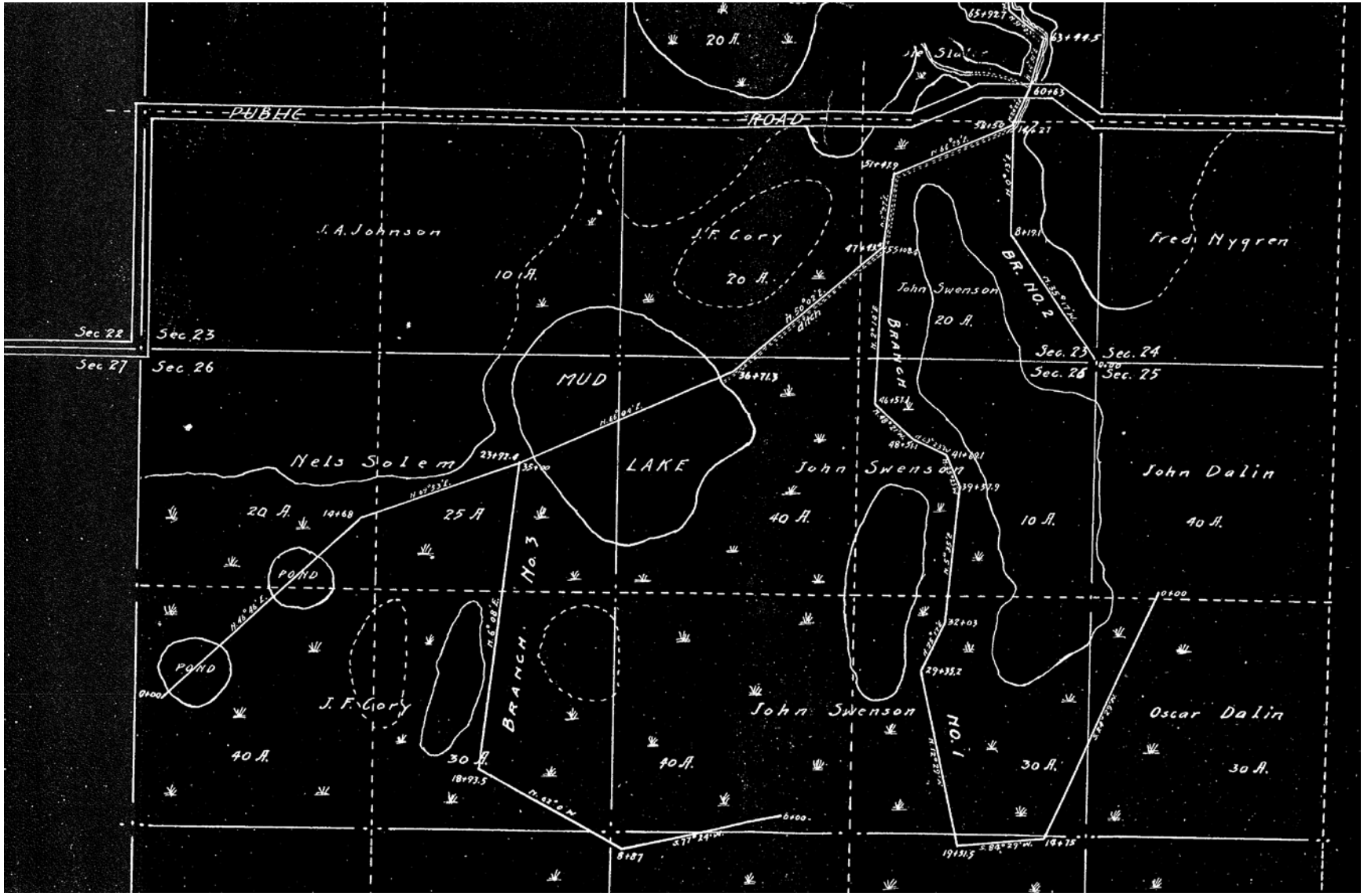


Figure 4. Proposed JD 6 alignment (RCWD 1921 Engineer's Report)

4.3. Regulatory Constraints

The WJD 6 system is a Judicial Ditch which has certain regulatory constraints and drainage rights that belong to the benefited properties that were originally assessed for the drainage system. If the District were to undertake a project that would potentially impact the drainage capacity compared to the original design, further assessment of the original profile and original capacity of the ditch system would be required. If there is no longer any interest in maintaining the ditch system the District could pursue abandonment of the entire ditch system. If this is not desired, the District could consider partial abandonment of a particular section of the ditch system. These types of ditch proceedings required public notices and hearings. Prior to pursuit of any type of abandonment preceding the District should contact key landowners were a project might be considered and gauge interest in having a project completed on their property.

5. SWMM MODEL UPDATE

The former District SWMM model was updated in 2018 based on the plan and profile of the WJD 6 system, and converted from XPSWMM to PCSWMM. Hydrologic boundaries were updated based on LIDAR and the recent boundary revision work, and the model was calibrated to available flow and water quality data from 2016. This model will be needed in 2019 to understand how proposed alterations to the system will affect wetland water levels and flood elevations in the system. In addition, the model will be used to estimate the water quality reduction benefits to Forest Lake from potential projects for District prioritization and the competitive grant process.

The former District SWMM model was based on an incomplete and outdated understanding of the CLFLWD watershed boundary with Rice Creek Watershed District, which was revised in 2016 using current LiDAR data and a desktop survey of major hydraulic structures in the areas south of Forest Lake. Previously, the watershed divide was thought to occur at a field road that crossed WJD 6 just south and west of the intersection of 202nd St N and Jeffrey Ave N. With the new data in hand, it was discovered that the divide was actually located about one mile southwest of that location. This led to the incorporation of about 900 additional acres of drainage area to WJD 6 – the vast majority of which is classified in the Minnesota Land Cover Classification System (MLCCS) as natural (emergent wetlands, forest/shrub wetlands, deciduous tree canopy, and grass/shrub).

The former model consisted of 14 subcatchments covering approximately 1,200 acres, including 7 junctions, 7 storages, and 13 links. However, some areas had multiple overland flow routes and, as such, not all of this area was tributary to WJD 6 for all events. The new model consists of 30 subcatchments covering 2,109 acres, including 262 junctions, 72 storages, and 230 links. Over half of the watershed (1,332 acres) drains through the culvert under 202nd Ave N. Portions of the watershed appear to be landlocked under some conditions due to the large number of depressions and wetlands present. Seventy-two storage areas (all larger than 1 acre in size at overflow) have been incorporated into the new model, which will significantly improve the usefulness of the model in identifying the relative contribution of WJD 6 flows coming from different portions of the watershed.

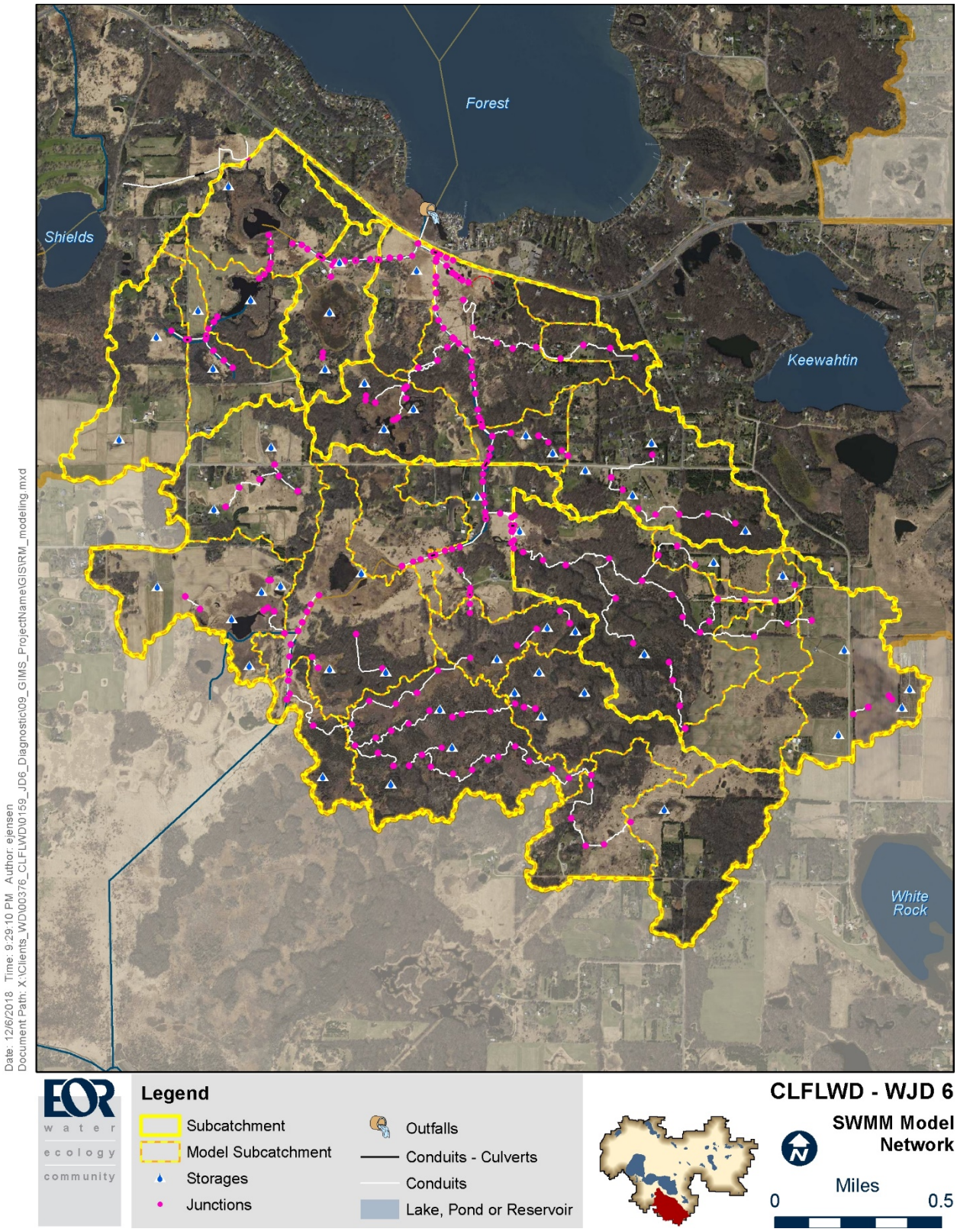


Figure 5. Updated SWMM Model Subcatchments, Storage Nodes, and Junctions

6. POTENTIAL PROJECTS

Through the data collection and review process completed in 2018, several potential project locations were identified in the WJD 6 subwatershed. The location of these project areas are shown in Figure 6 and described below. These projects are ordered from most favorable cost/benefit to least favorable cost/benefit. It is recommended that the District first focus on projects labeled as medium to high priority.

6.1. High Priority Projects

Sunrise Headwater Restoration

Based on the 2018 monitoring results, a large percentage of the total phosphorus loading is being delivered from the main branch of WJD 6 upstream of the field road crossing just south of Highway 97. Approximately 800 pounds of phosphorus is flowing through this location per year. This is believed to be a function of an unstable channel and a degraded wetland ditch system. It appears that the corridor from this field crossing up to Highway 50 would be a prime candidate for a large-scale stream and wetland restoration. There are three primary landowners along this stretch and it is recommended that they be contacted to gauge interest in a project for this particular area.

Due to the high dissolved phosphorus content throughout this system, additional project enhancements that can remove dissolved phosphorous should be considered (such as cattail harvesting, iron-sand filters, spent lime, etc.) to achieve the phosphorus reduction goals for the WJD 6 subwatershed. The portion of WJD 6 that runs between Highway 97 and County Road 50 is showing a meandering pattern. A geomorphic assessment of the ditch is recommended to determine the current state of stability and to evaluation options for constructing a stable channel. An additional season of well monitoring in a transects close to the ditch would be useful for understanding what if any effect the ditch has on wetland hydrology. Additional wetland soil testing should also be considered to determine the potential for phosphorus capture or release.

Extending this project a bit further upstream and downstream could result in a corridor connecting Hardwood Creek WMA and Forest Lake. While increasing the size of the project would require coordination with additional landowners, a future 'green corridor' project would be sensible for future long-term, regional planning. It is recommended that these additional land owners also be contacted as part of the stream and wetland restoration project to gauge if there is enough interest from the property owners in the key area identified above. These areas would not necessarily be needed to achieve the hydrologic and water quality benefits of the project proposed, but it would enhance the project. These properties could also be pulled in at a later date if desired.

Depending on the desired future land use along the WJD 6 system, the entire ditch system could also potentially be abandoned and converted back to a more natural wetland/channel system. If this is a desired outcome for this subwatershed, comprehensive planning is recommended, such that property/easement acquisition could occur when future opportunities arise along this corridor. This is a public ditch and for the most part in wetland. Projects that involve alterations to the ditch may require Drainage Law proceedings. Wetland regulatory agencies will also need to be consulted before

any ditch construction work is conducted. Wetland regulations provide flexibility for repair projects on public drainage systems. This wetland is not on the Public Waters Inventory.

6.2. Medium Priority Projects

R7D Wetland Enhancement

The western tributary ditch flowing to WJD 6 is well defined flowing into and out of the wetland located between the R7D and R7W monitoring locations. Since this basin is ditched, some water quality benefits could be realized with a stabilized outlet that maximizes storage and evapotranspiration. Water quality monitoring indicates approximately 100 pounds of phosphorus discharging from this wetland annually. Additional water level and water quality monitoring on both the north and south basin of this Public Water wetland and surveyed cross-sections of the basins would be beneficial to better understand the hydrology and water quality fluctuations in this basin. This information could be used in conjunction with the SWMM model to assess potential benefits and water level impacts. Water levels would potentially be impacted on several upstream properties so landowner coordination and support for the project would be an important component of this project.

This wetland is on the Public Waters Inventory so coordination with MN DNR Waters is required for any proposed modifications. The site is not on the official WJD 6 alignment, however projects that involve alterations to the ditch may still require Drainage Law proceedings if it is determined that this is a lawfully connected private ditch.

Agricultural BMPs

Minimal active farming is still occurring in the WJD 6 subwatershed. However, there are pockets of larger scale active farming in the southwest and the southeast portions of the watershed. This active farming includes some row crops and potentially some livestock, and appears to consist of about six primary landowners. It is recommended that District staff engage with these landowners to discuss the landowners' plans for ongoing farming operations, current best management practices, and to gauge any interest in working with the District or Conservation District on implementation of additional BMPs.

6.3. Low Priority Projects

Wetlands North of Highway 97

Hydrology in the wetland north of Highway 97 closely correlates with Forest Lake water elevations. Due to the close hydrologic connection with the lake, this location is not highly valuable for project implementation. No hydrologic restoration projects or continued monitoring for this site is recommended at this time.

Northeastern Neighborhood Stormwater Management

The neighborhood located in the northeastern portion of the WJD 6 subwatershed consists of residential areas located along Jewel Avenue, Jody Avenue, 203rd Street, 204th Street, 206th Street and 207th Street. These houses were primarily built in the 1970's and 1980's prior to any stormwater management. The lots are relatively large and wooded. The roads are rural section and have grassed

swales providing drainage. These swales could be enhanced with many opportunities for incorporation of raingardens if the landowners were interested and the soils were favorable. Aging septic systems could also be a source of phosphorus to the WJD 6 system. An assessment of the age and condition of the septic systems in this area could be considered.

Jeffrey Avenue Wetland Enhancement

A large wetland complex extends to the east of Jeffery Avenue. A project here would consist of disabling the ditch or installing an outlet structure near Jeffery Avenue to better manage wetland drainage. Due to the size of this wetland area, volume reductions and likely nutrient reductions could be achieved by retaining the water in the wetland. It is currently unclear if artificial drainage is having an effect on this wetland and additional monitoring data is recommended if this project were to be pursued in the future. If the wetland indicates partial drainage by the ditched outlet, options for stabilizing the hydrology should be evaluated. A project here would require coordination with several landowners. This wetland is not on the Public Waters Inventory so the local Wetland Conservation Act and the US Army Corps of Engineers would be the only two wetland regulatory entities involved. Wetland restoration activities conducted by public agencies are given wetland permitting flexibility, often alleviating the need for compensatory mitigation.

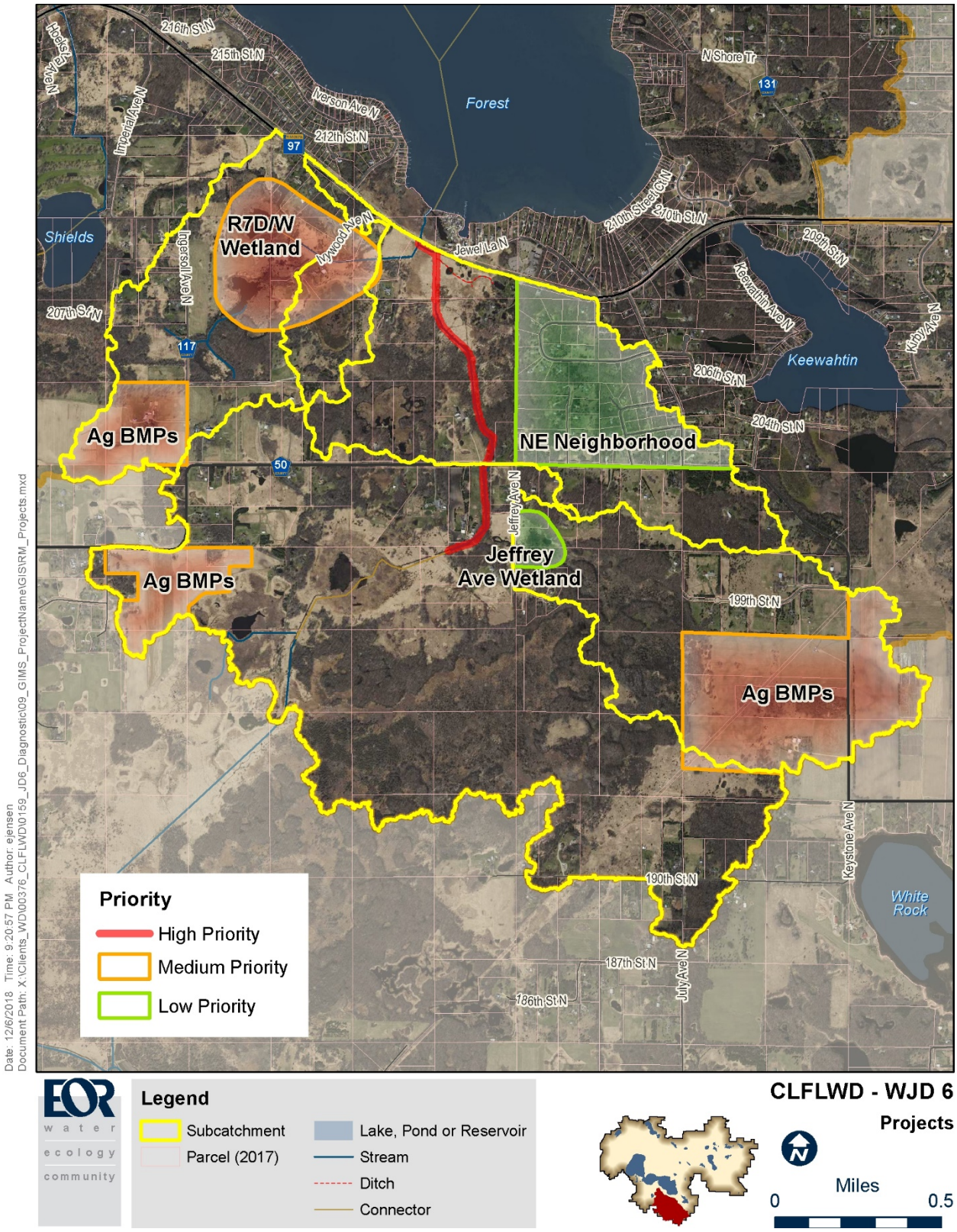


Figure 6. WJD 6 Subwatershed Potential Project Location and Prioritization

APPENDIX A. WETLAND AND LAND COVER CHARACTERISTICS

Appendix A.1. Wetland Water Level Figures

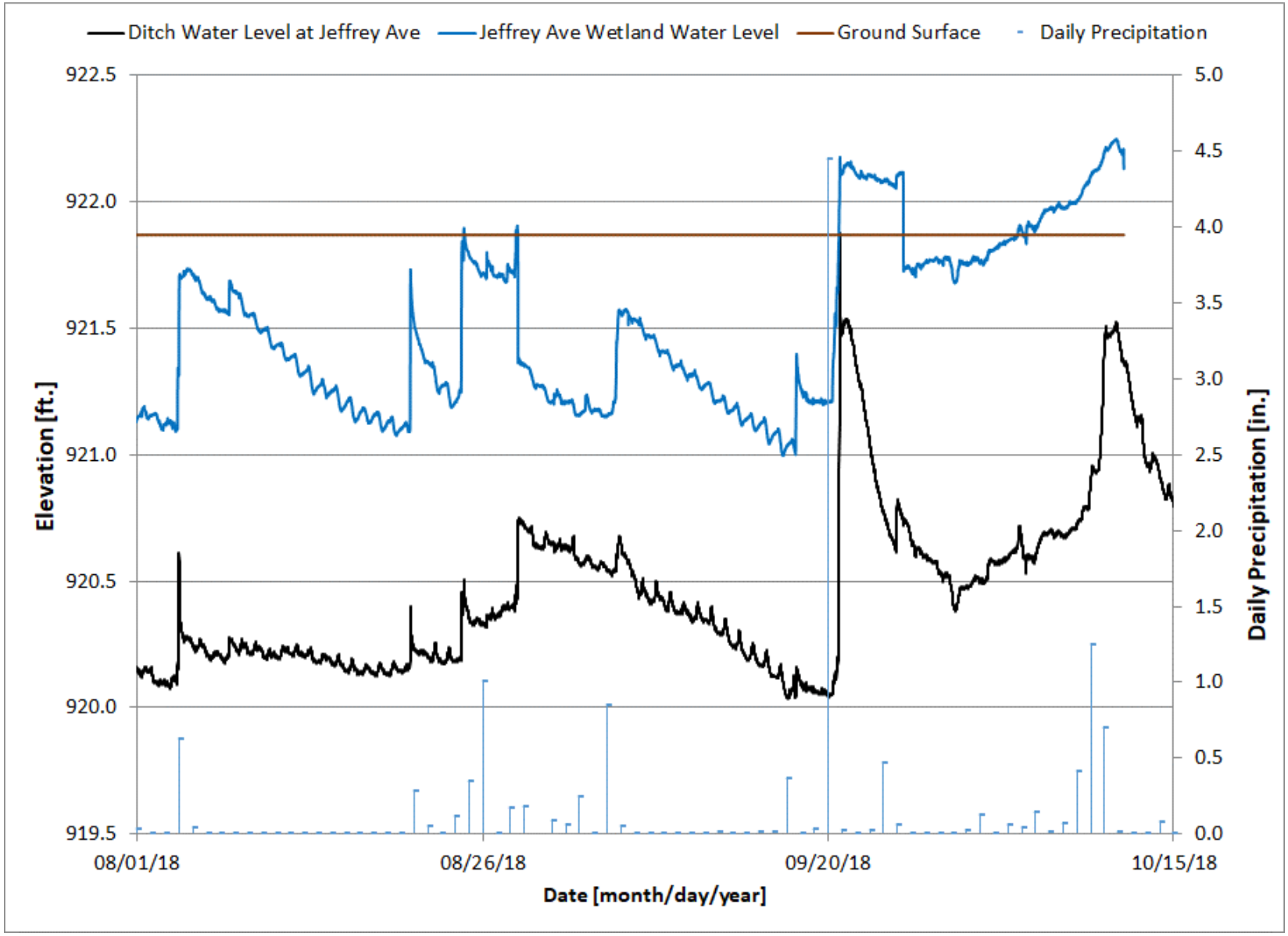


Figure 7. Jeffrey Avenue Wetland Water Level Characteristics (2018)

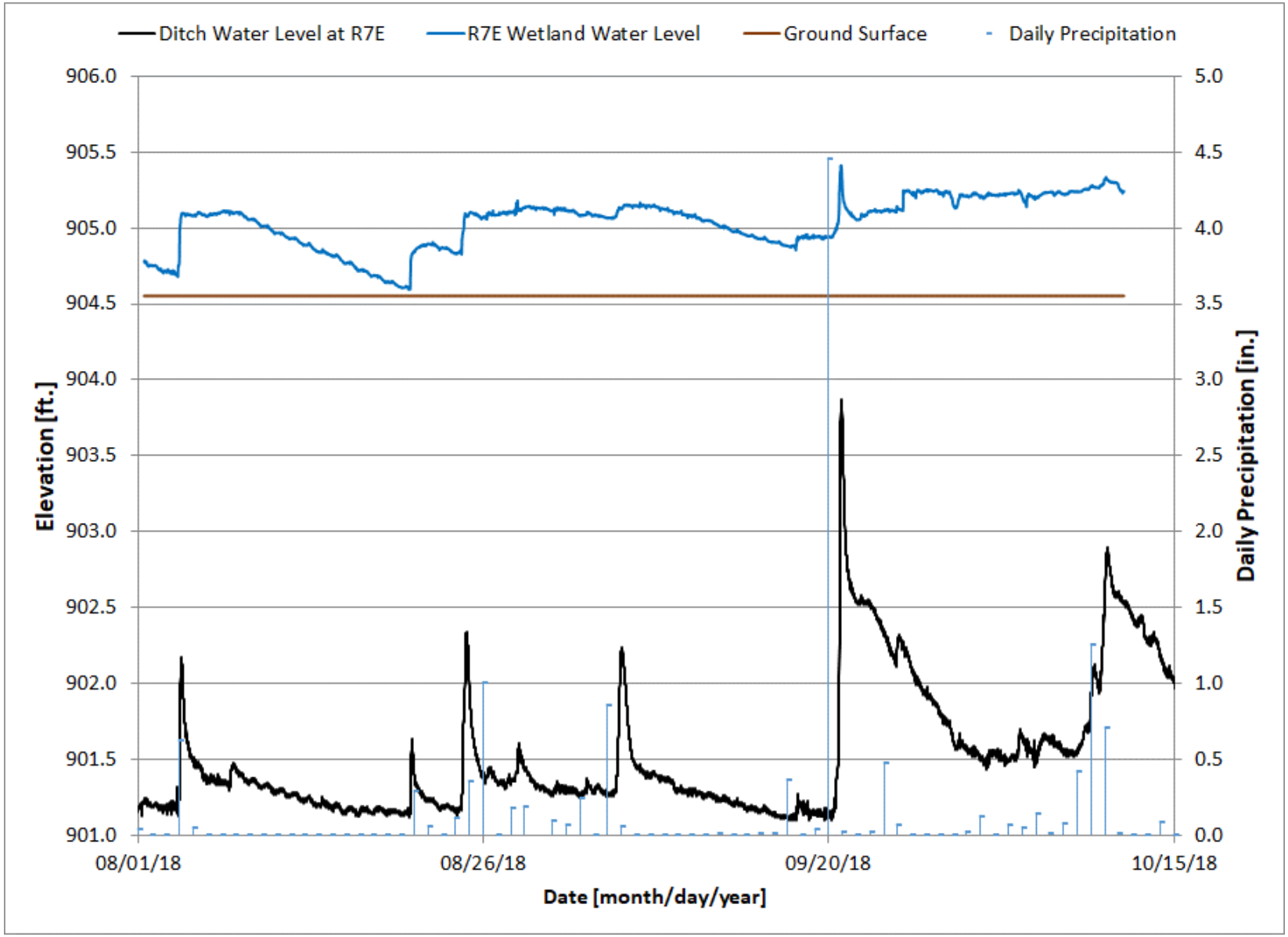


Figure 8. R7E Wetland Water Level Characteristics (2018)

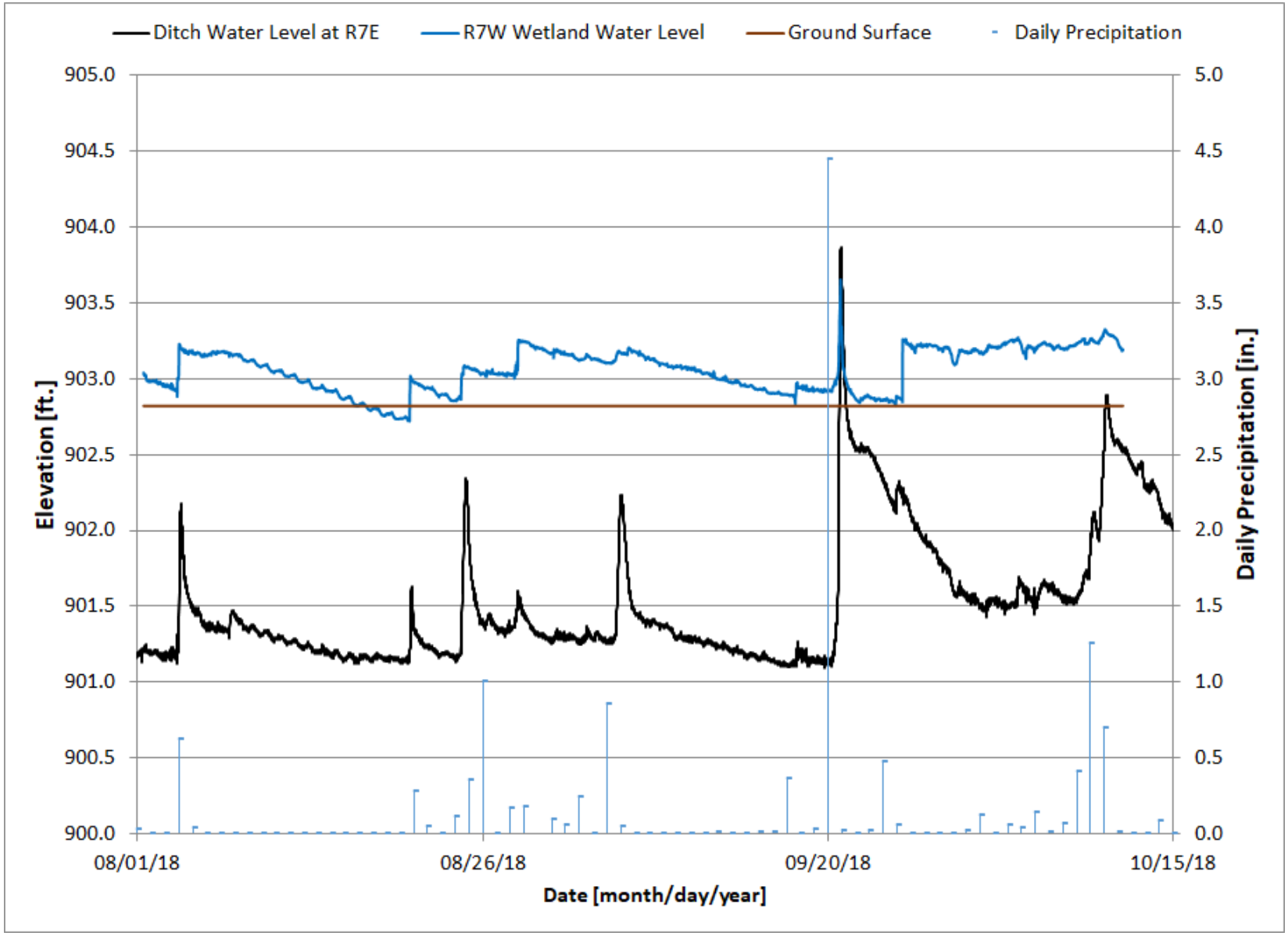


Figure 9. R7W Wetland Water Level Characteristics (2018)

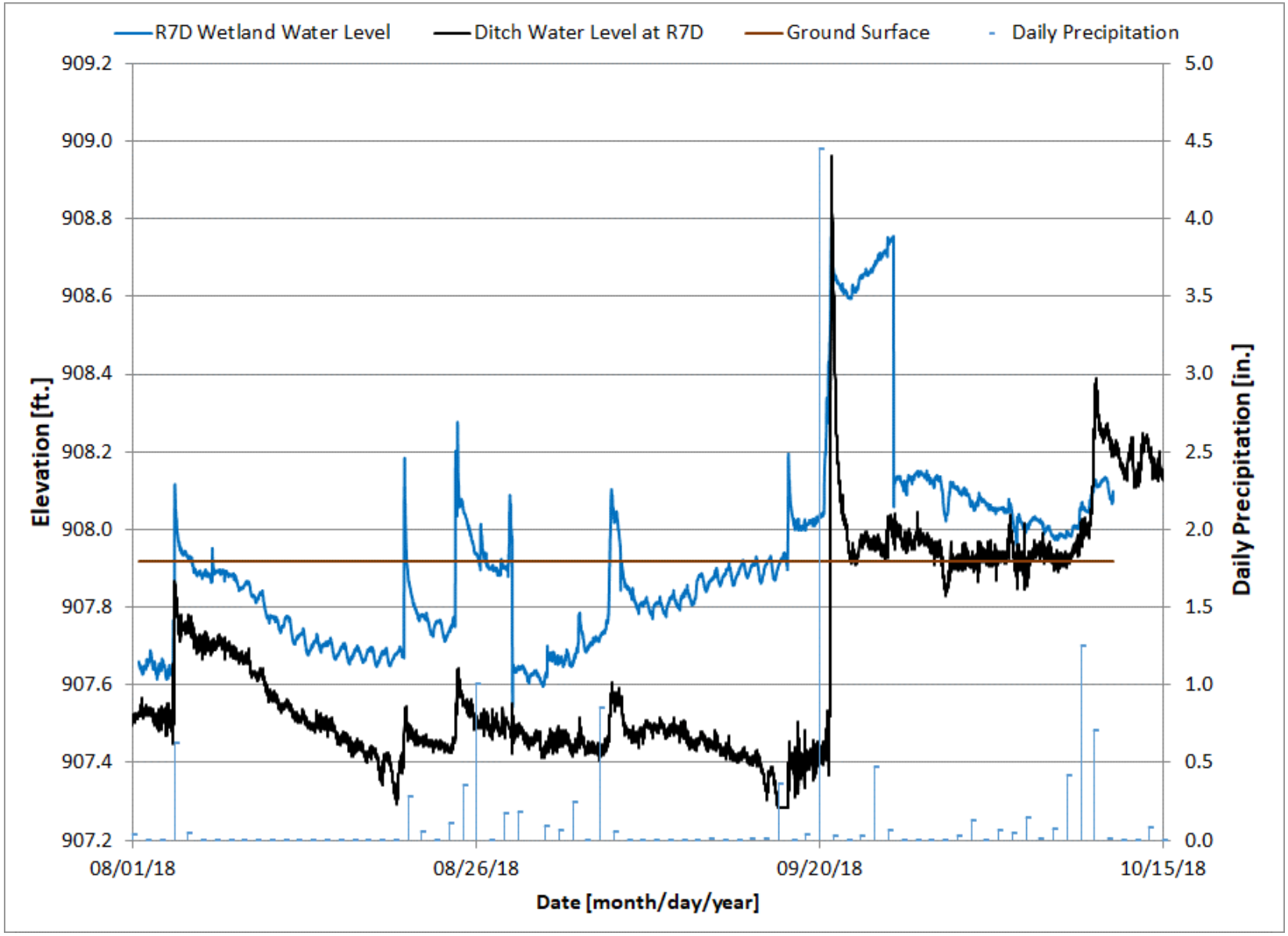


Figure 10. R7D Wetland Water Level Characteristics

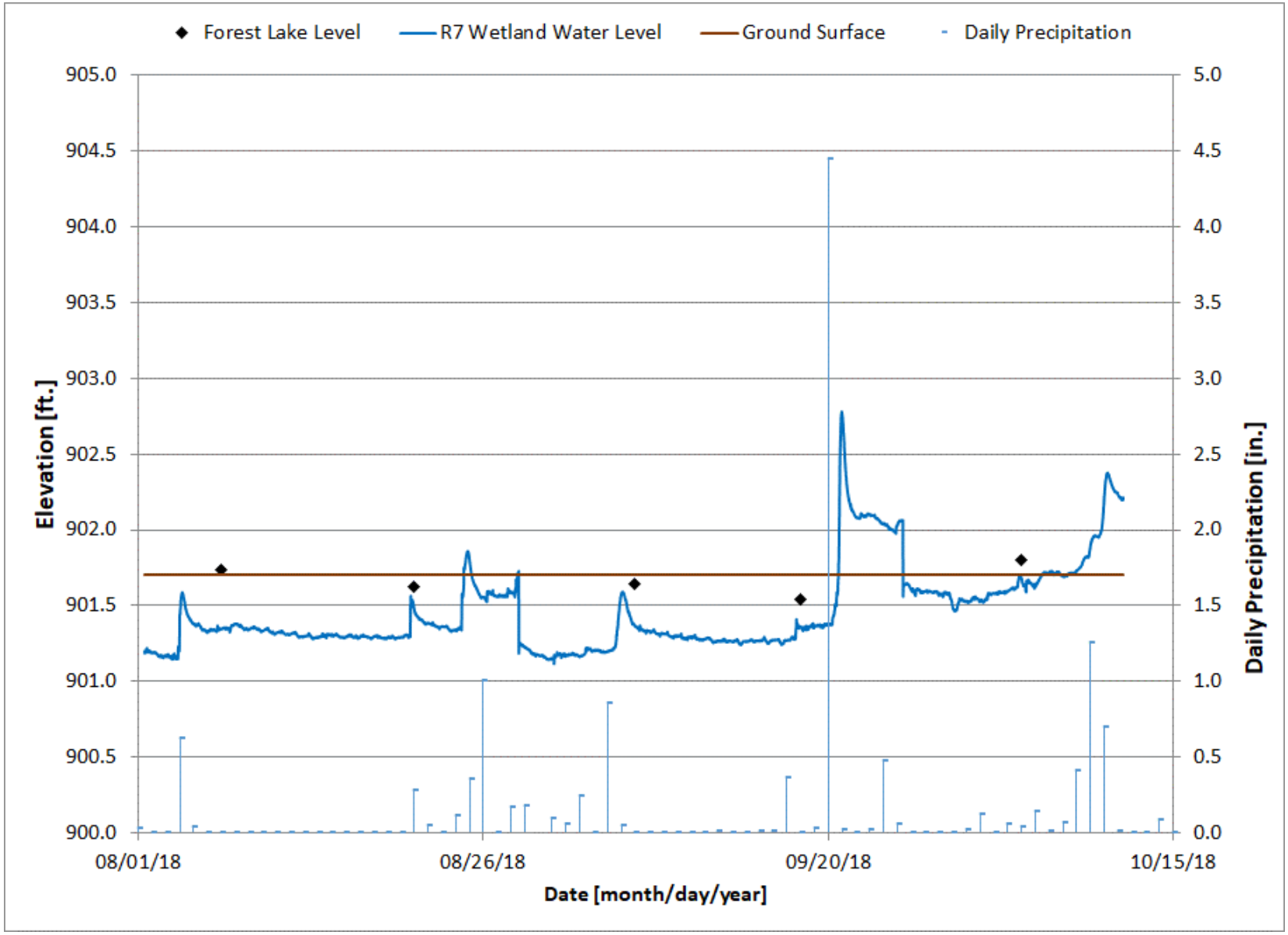


Figure 11. R7 Wetland Water Level Characteristics

Appendix A.2. Historical Aerial Photographs

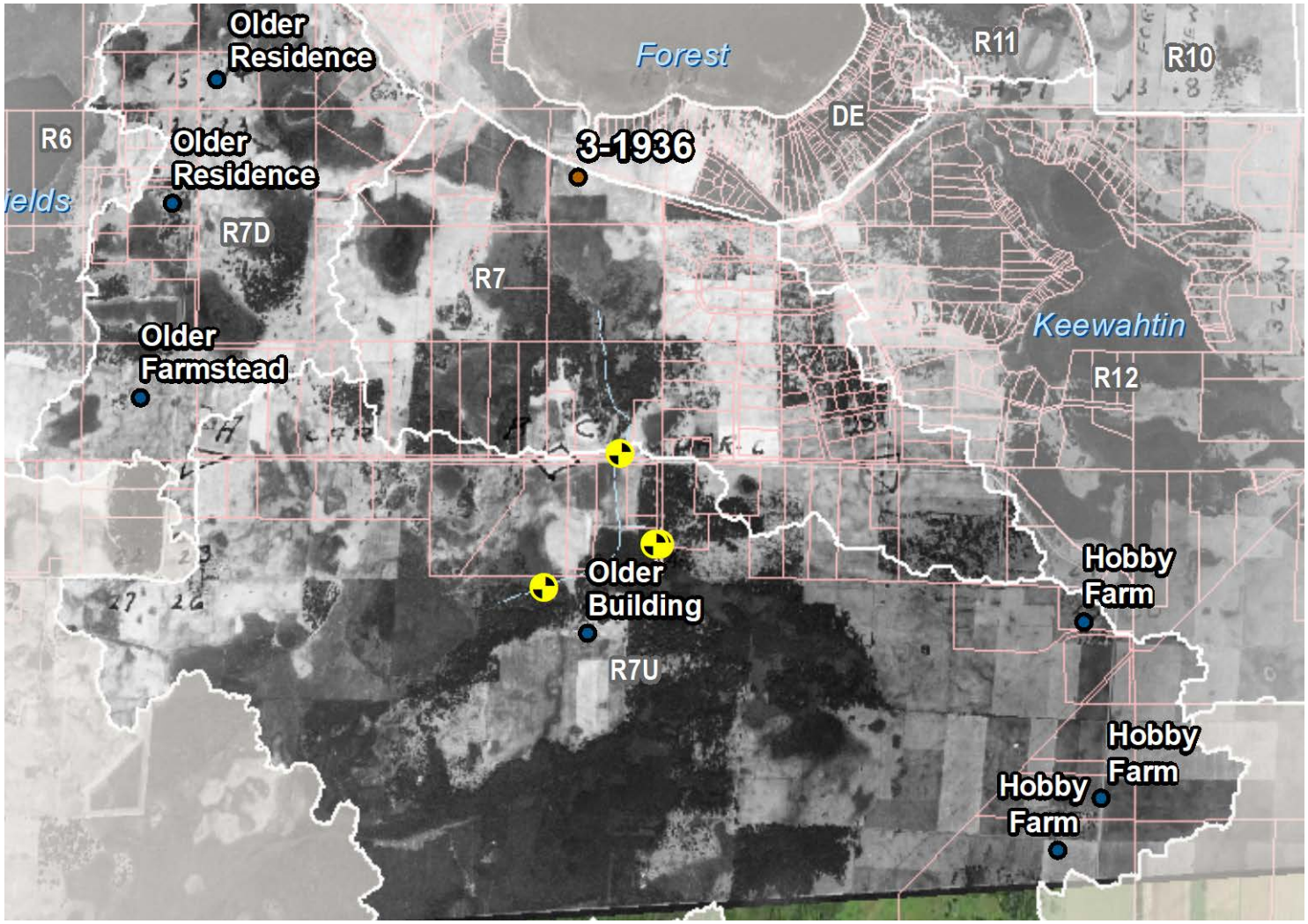


Figure 12. March 1936

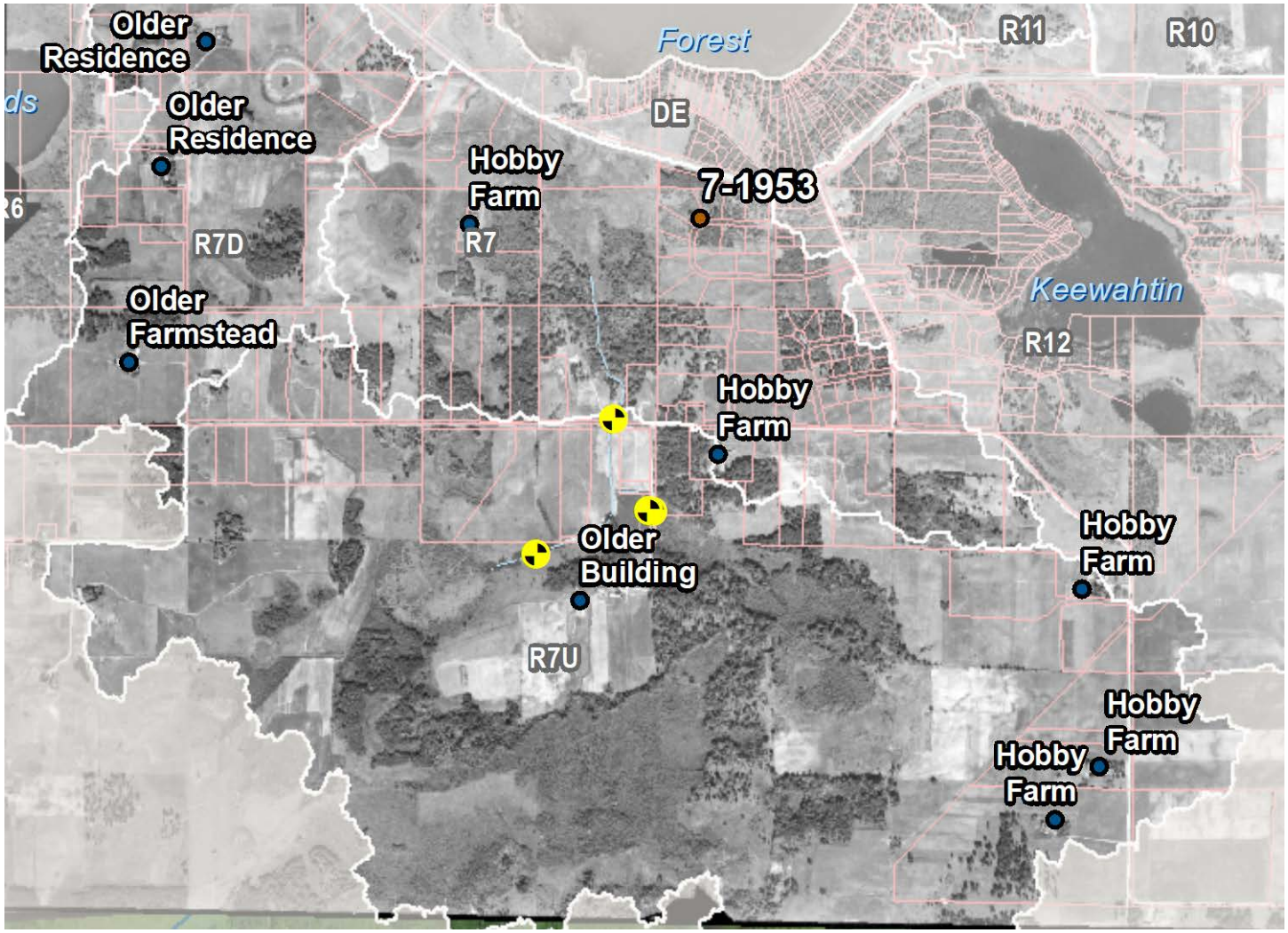


Figure 13. July 1953

Figure 14. October 1957

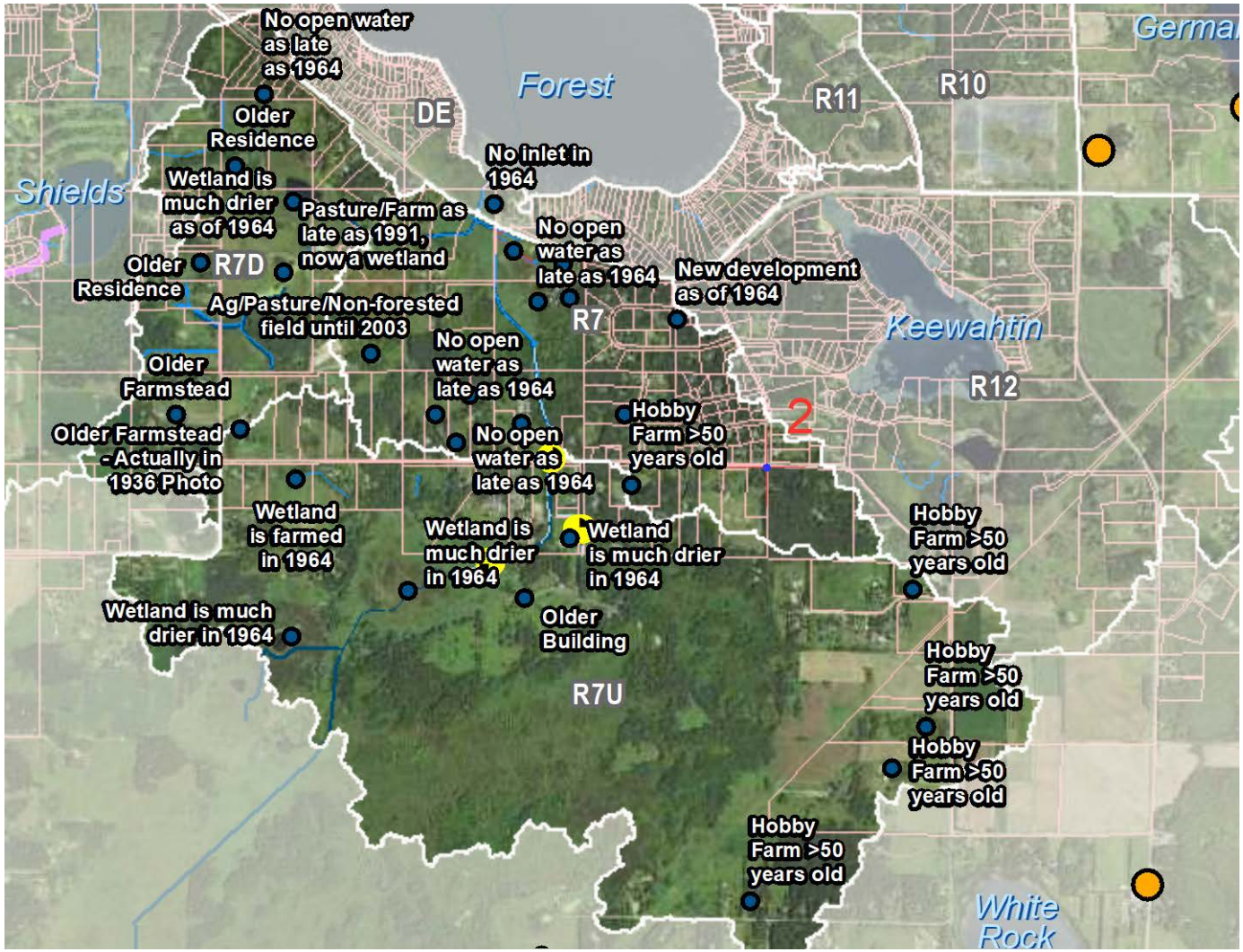


Figure 15. June 1964

Appendix A.3. Historical Land Use

In the following tables, colors are used to denote changes in land cover from year to year based on the following:

- Green shading indicates a significant positive increase in the amount of area (acreage) associated with a given land use
- Orange shading indicates a possible discrepancy in the GIS data
- Red shading indicates a significant negative increase in the amount of area (acreage) associated with a given land use

Note that more accurate mapping began in 2000 with a slightly different and more refined color scheme for the legend.

Table 3. 1984-2016 Land Use Changes by WJD 6 subcatchment

Year	Basin	Land use					
		Farmsteads	Park, Recreation, Preserve	Single Family Residential	Water	Undeveloped	Agricultural
1984	R7	2.1		101.9		372.2	8.7
	R7D	4.1		28.9		228.7	115.5
	R7U	8.7	223.4	29.8		729.8	337.1
1990	R7	2.1		110.6		363.6	8.5
	R7D	4.1		41.0		220.7	111.5
	R7U	8.7	223.4	46.6		718.3	331.8
1997	R7	2.1		122.8		351.6	8.2
	R7D	1.3		45.0		219.9	111.1
	R7U	10.2	362.7	54.5		616.6	284.8
2000	R7	2.2		122.8		353.8	8.1
	R7D	4.3		45.0	12.6	239.5	80.4
	R7U	8.2	200.6	54.5	6.9	798.9	252.4
2005	R7	2.2		125.7		346.0	10.9
	R7D	2.7		54.2	12.6	223.2	84.6
	R7U	6.3	200.6	73.5	6.9	822.4	219.1
2010	R7	2.2		134.1		337.6	10.9
	R7D	2.7		57.5	12.6	219.3	85.2
	R7U	6.3	213.0	78.5	6.9	780.6	242.6
2016	R7			140.2		337.6	7.0
	R7D	3.0		58.2	12.6	216.6	86.9
	R7U	4.6	213.0	92.5	6.9	766.1	244.8

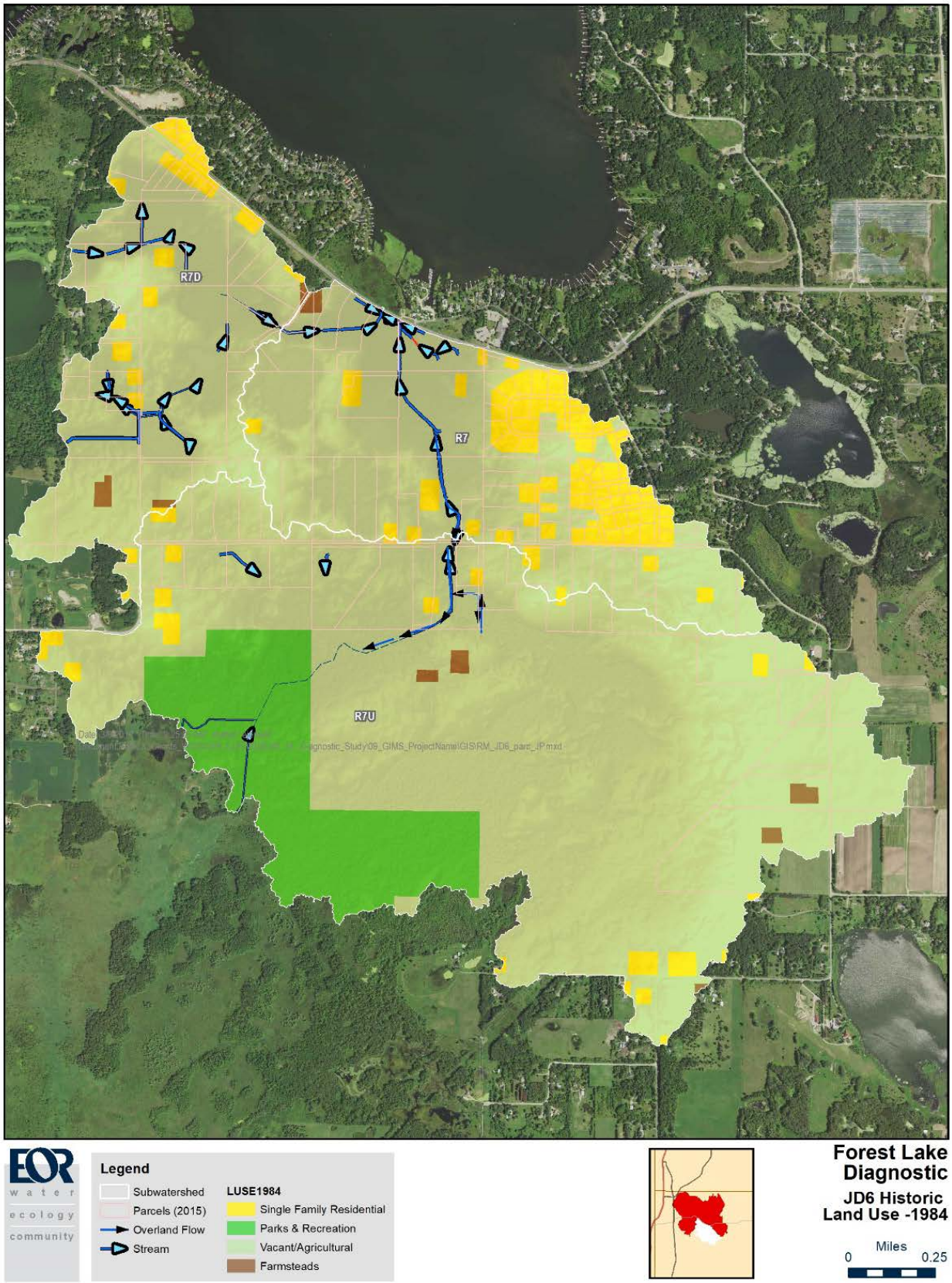


Figure 16. WJD 6 Subwatershed Historic Land Use (1984)

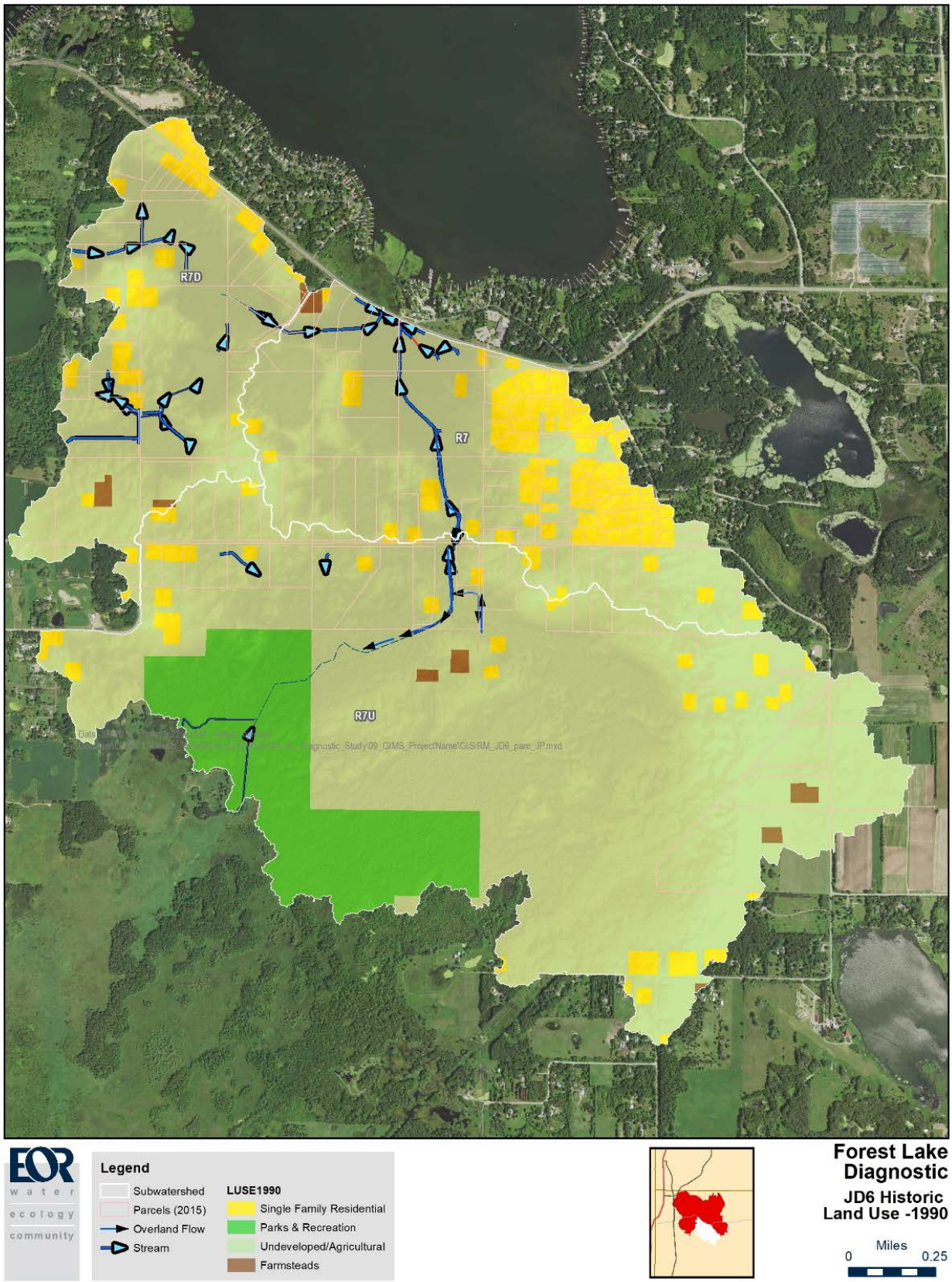


Figure 17. WJD 6 Subwatershed Historic Land Use (1990)

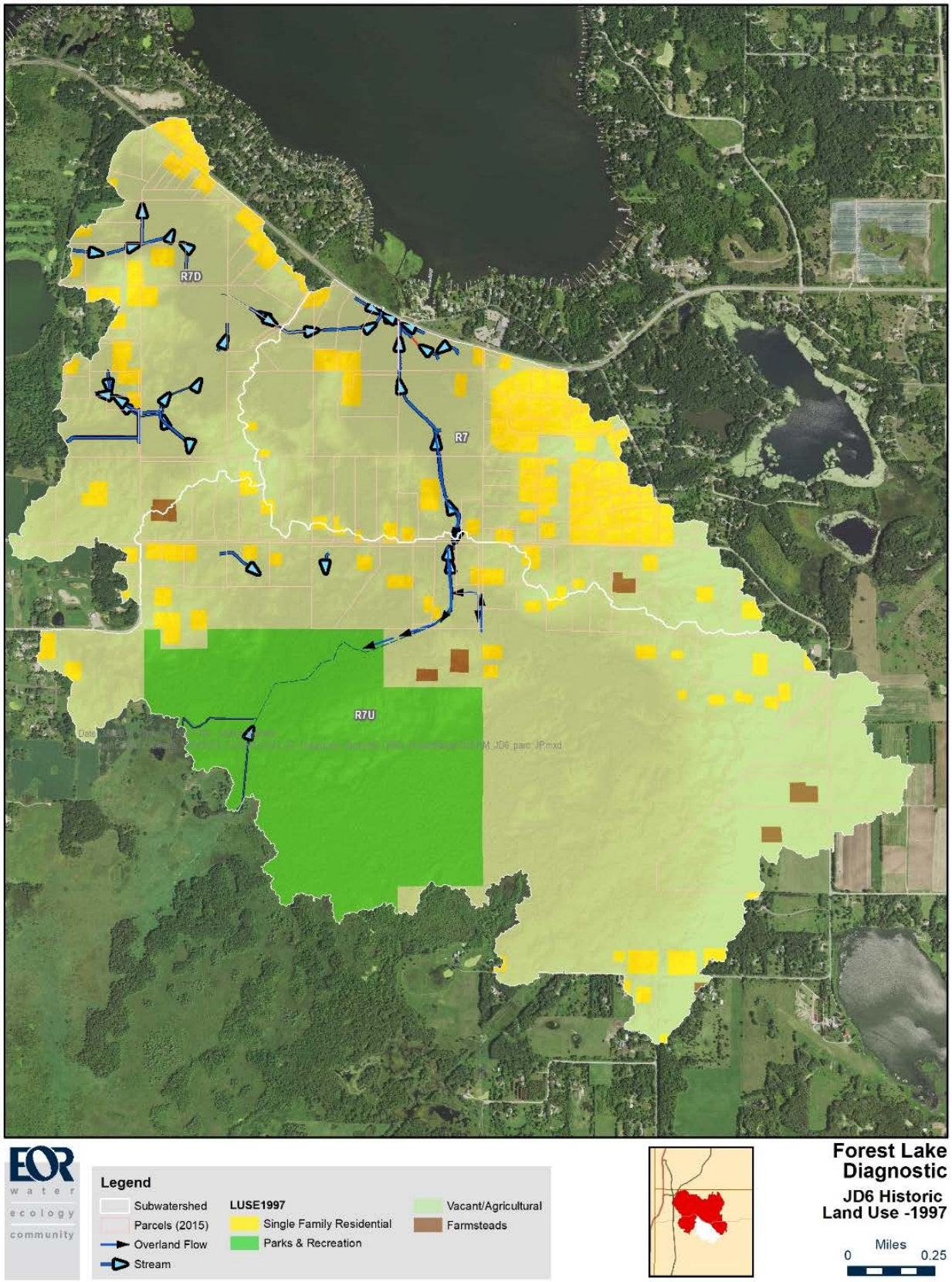


Figure 18. WJD 6 Subwatershed Historic Land Use (1997)

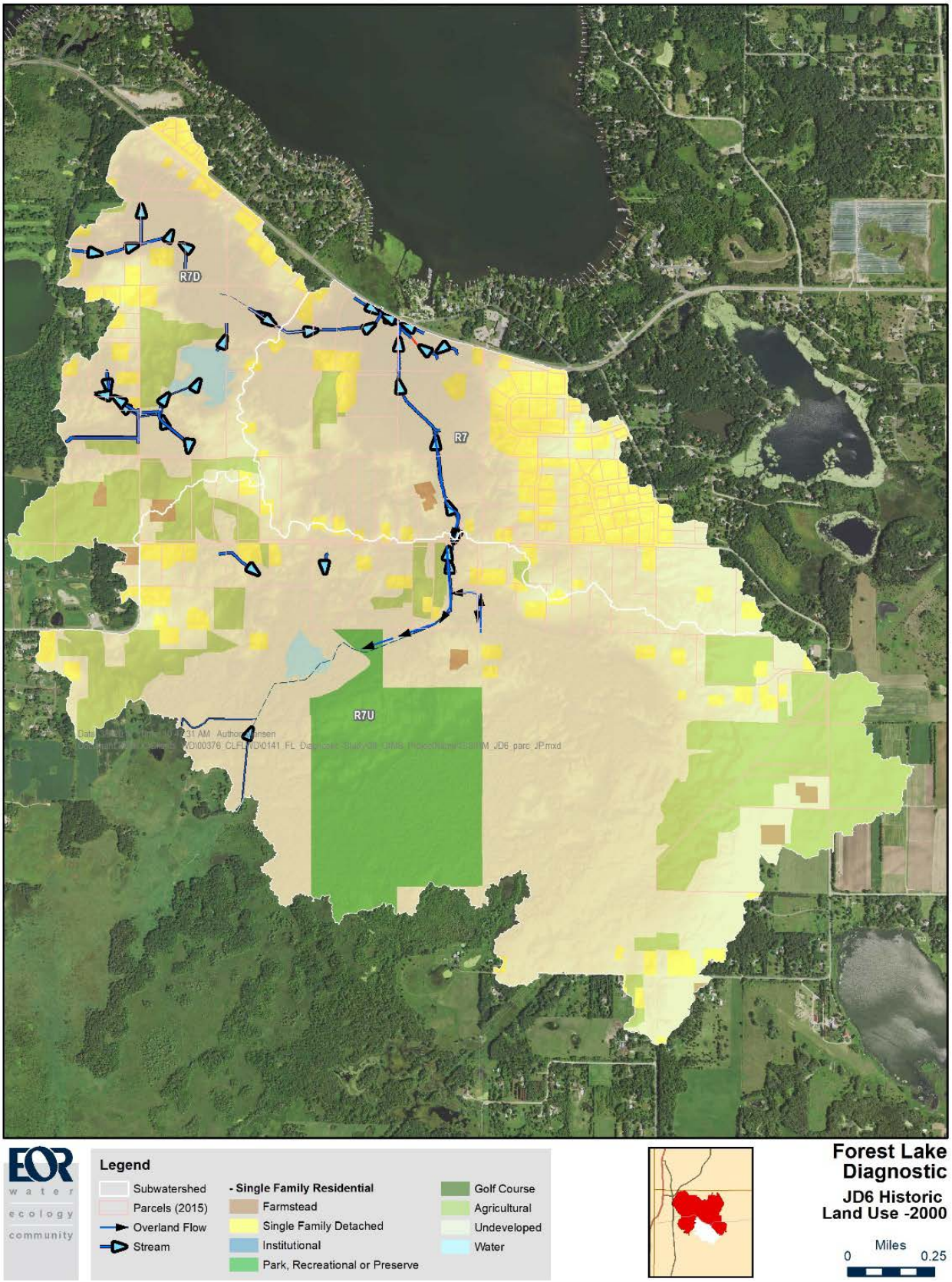


Figure 19. WJD 6 Subwatershed Historic Land Use (2000)

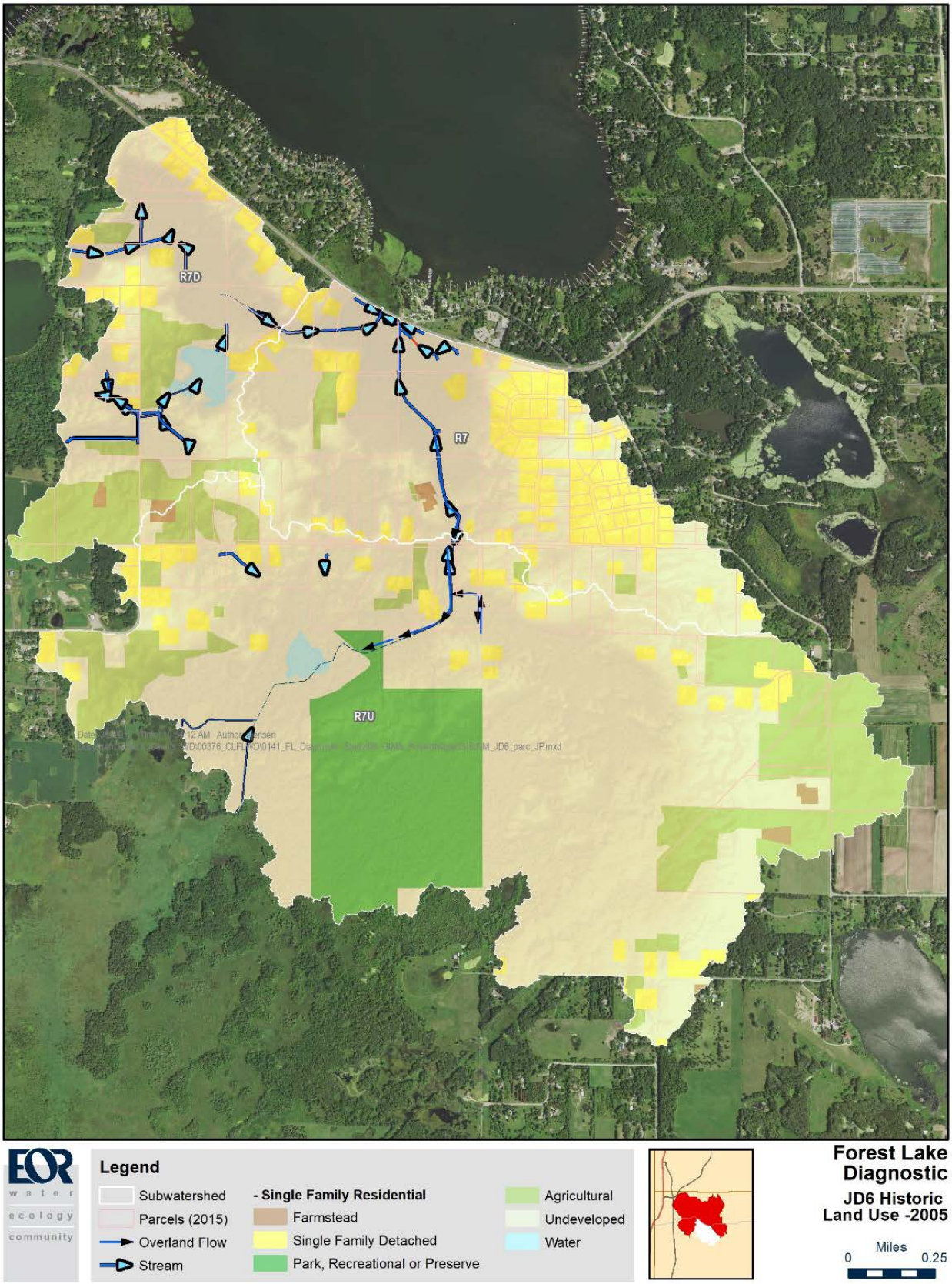


Figure 20. WJD 6 Subwatershed Historic Land Use (2005)

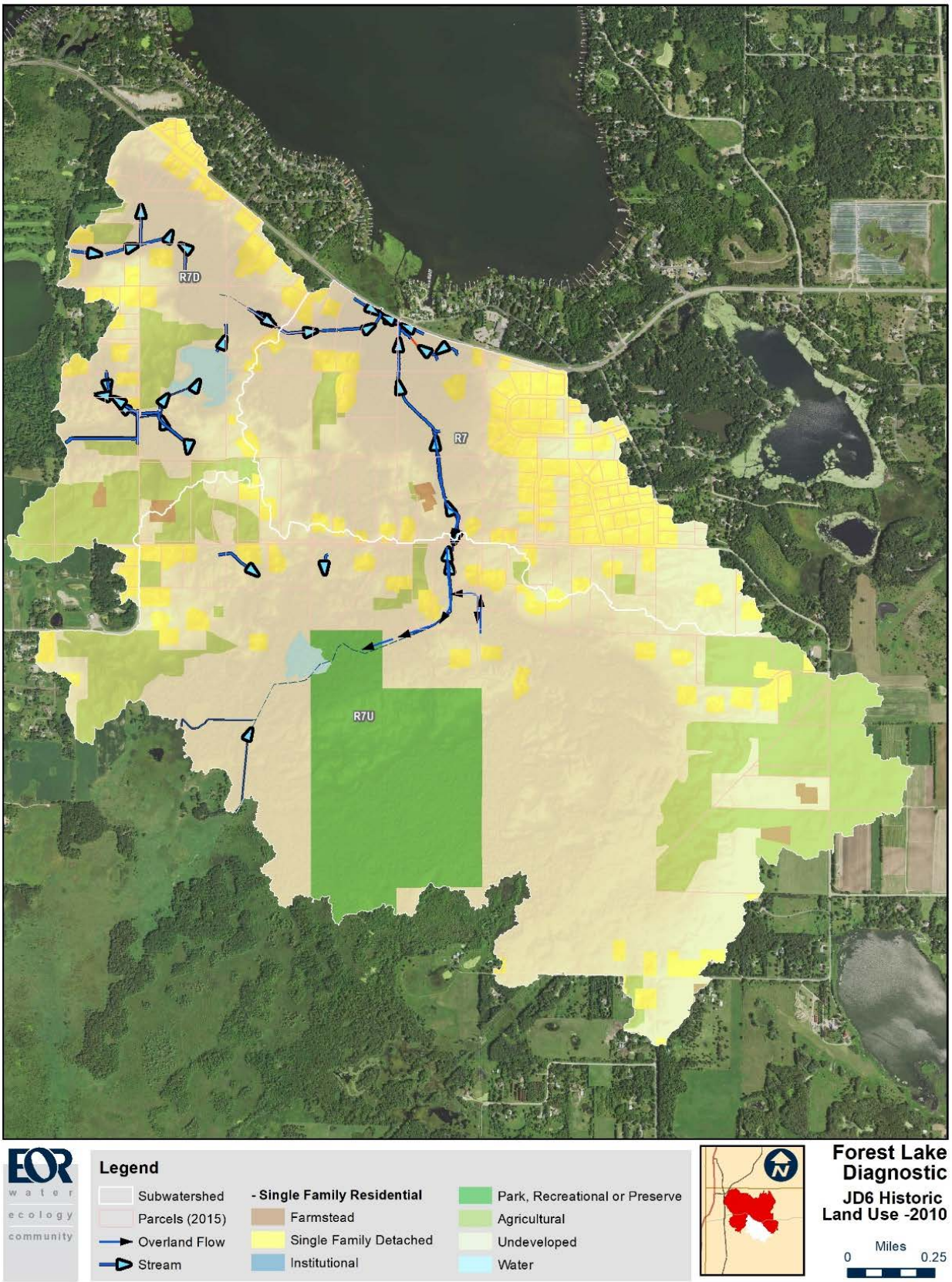


Figure 21. WJD 6 Subwatershed Historic Land Use (2010)

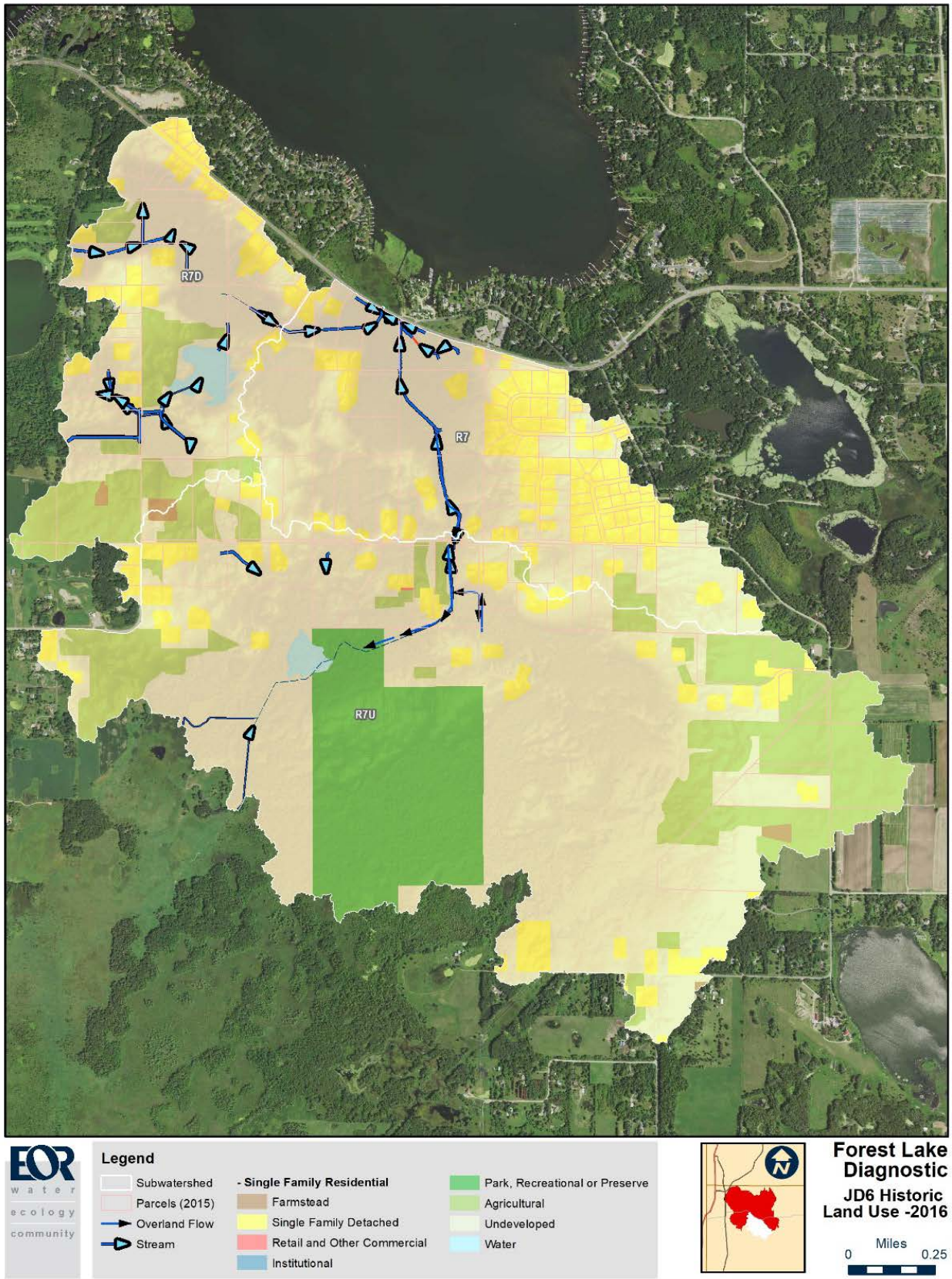


Figure 22. WJD 6 Subwatershed Historic Land Use (2016)

Appendix A.4. Topography

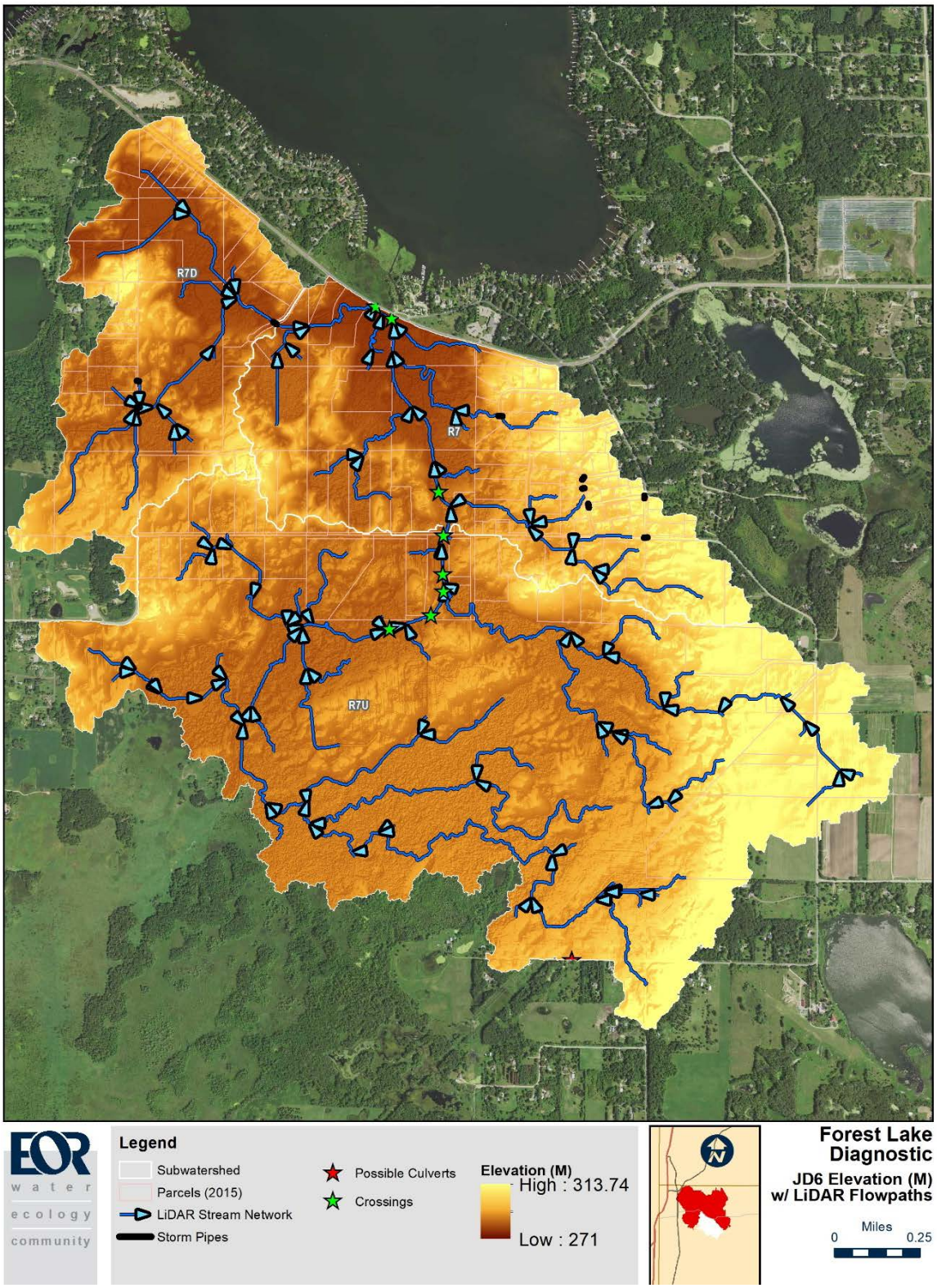


Figure 23. WJD 6 Subwatershed Elevation and LiDAR Flowpaths

Appendix A.5. Soils

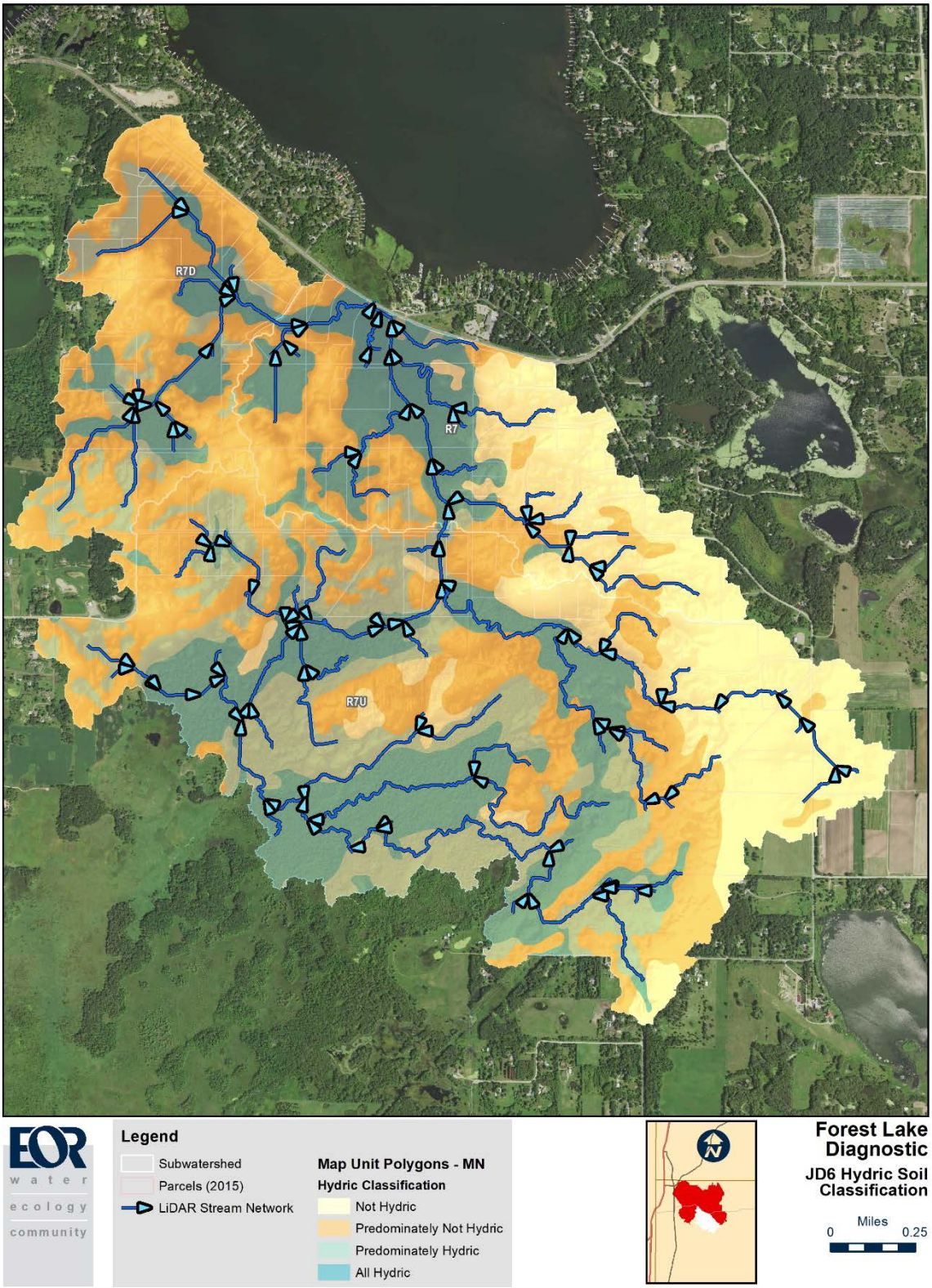


Figure 24. WJD 6 Subwatershed Hydric Soil Classification

Appendix B.1. Continuous Flow and Phosphorus Sample Figures

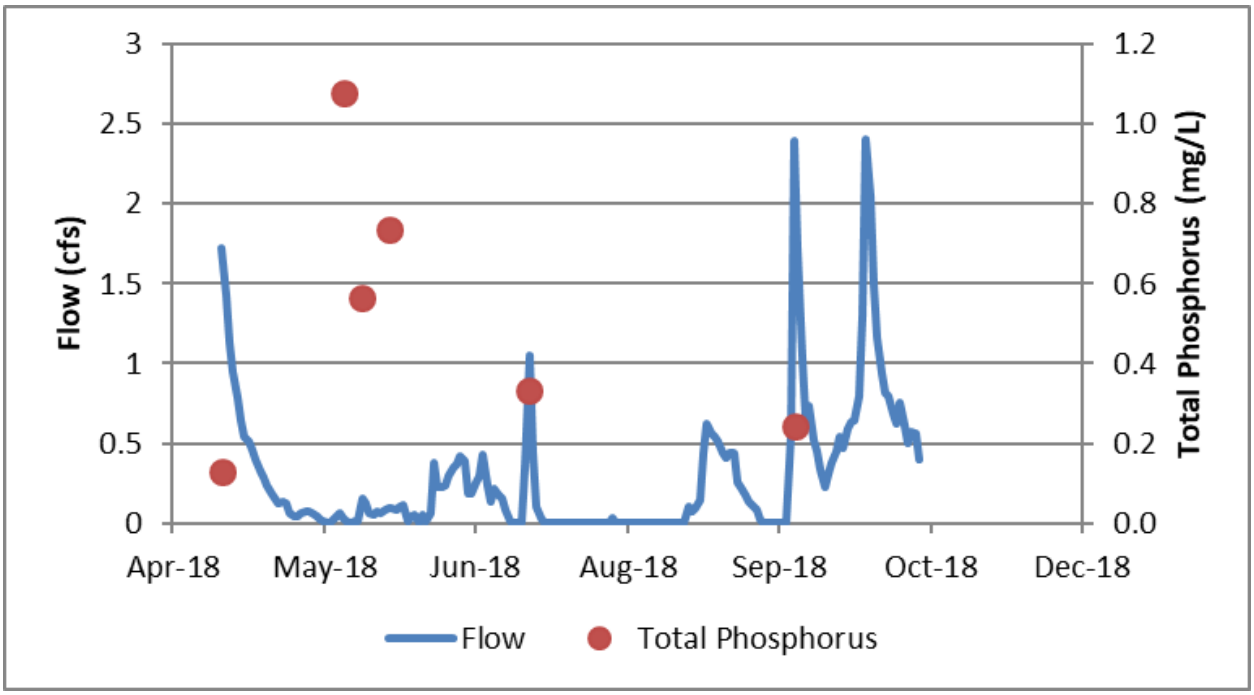


Figure 25. Jeffrey Avenue Flow and Phosphorus (2018)

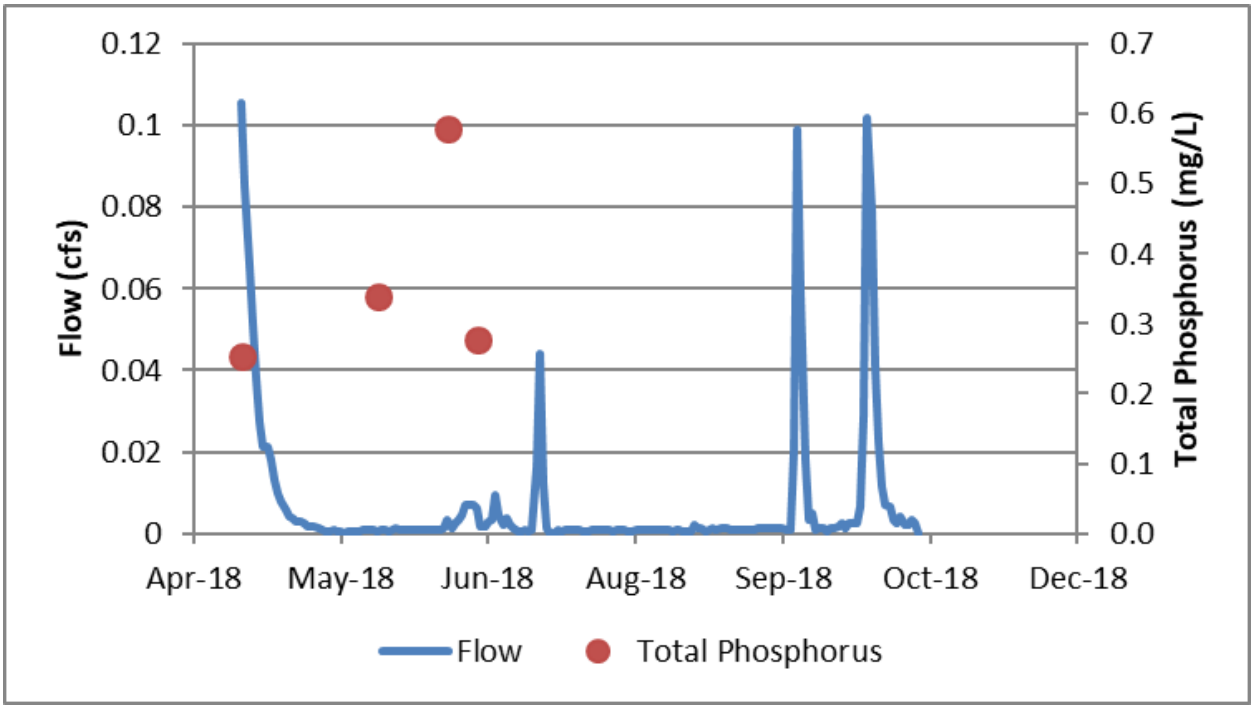


Figure 26. WJD 6 Ditch Flow and Phosphorus (2018)

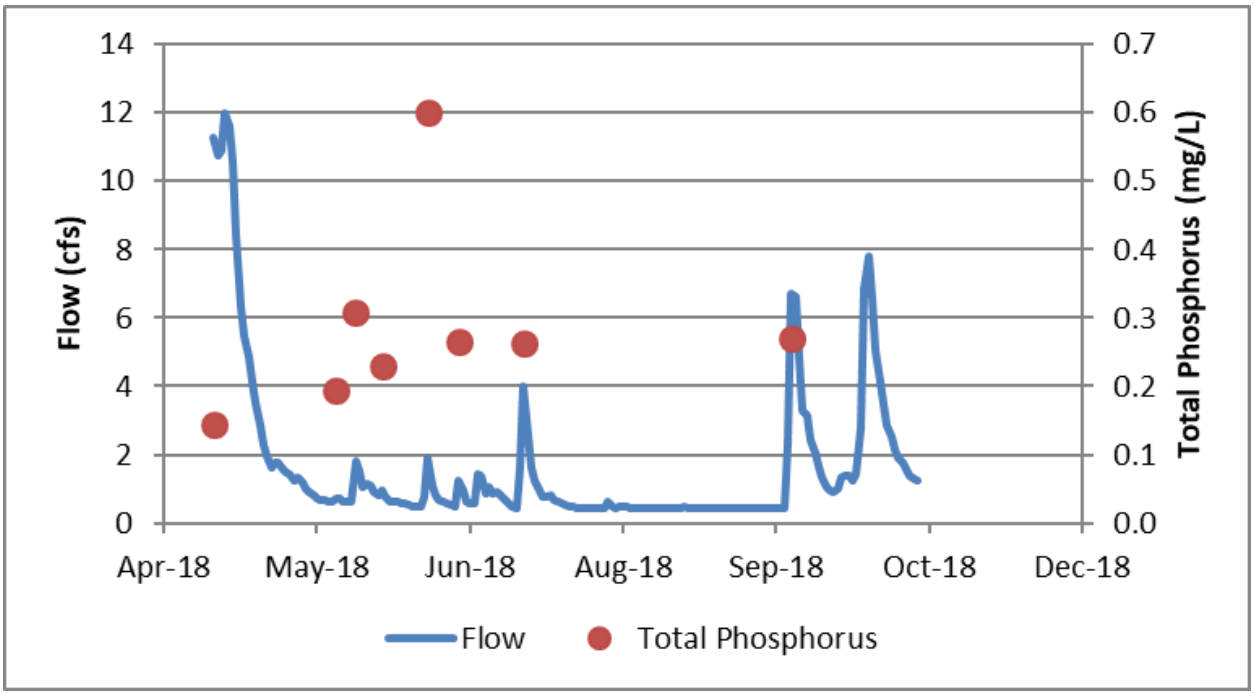


Figure 27. R7U Flow and Phosphorus (2018)

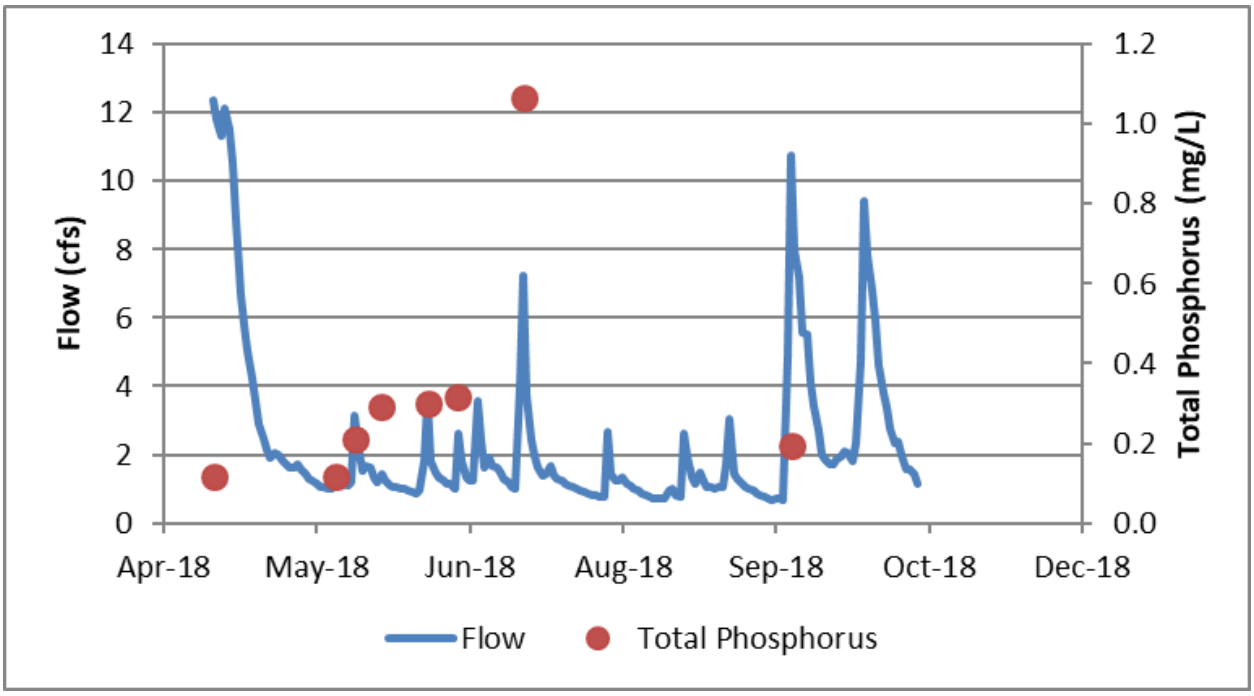


Figure 28. R7E Flow and Phosphorus (2018)

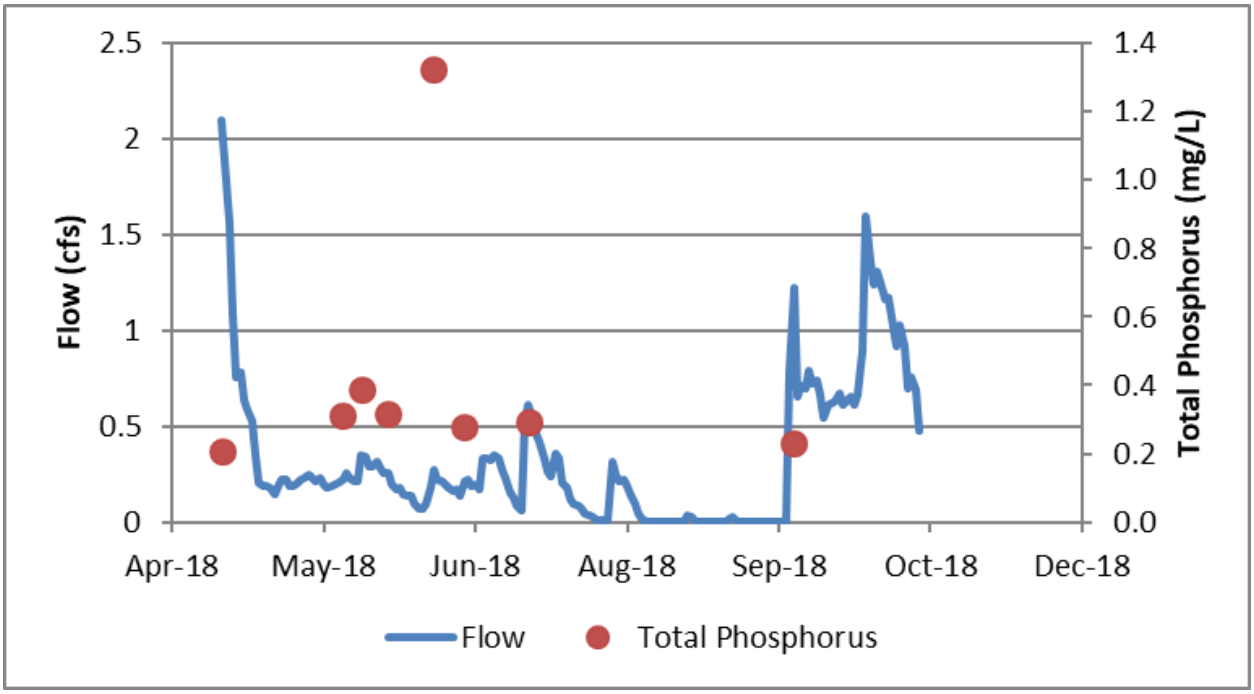


Figure 29. R7D Flow and Phosphorus (2018)

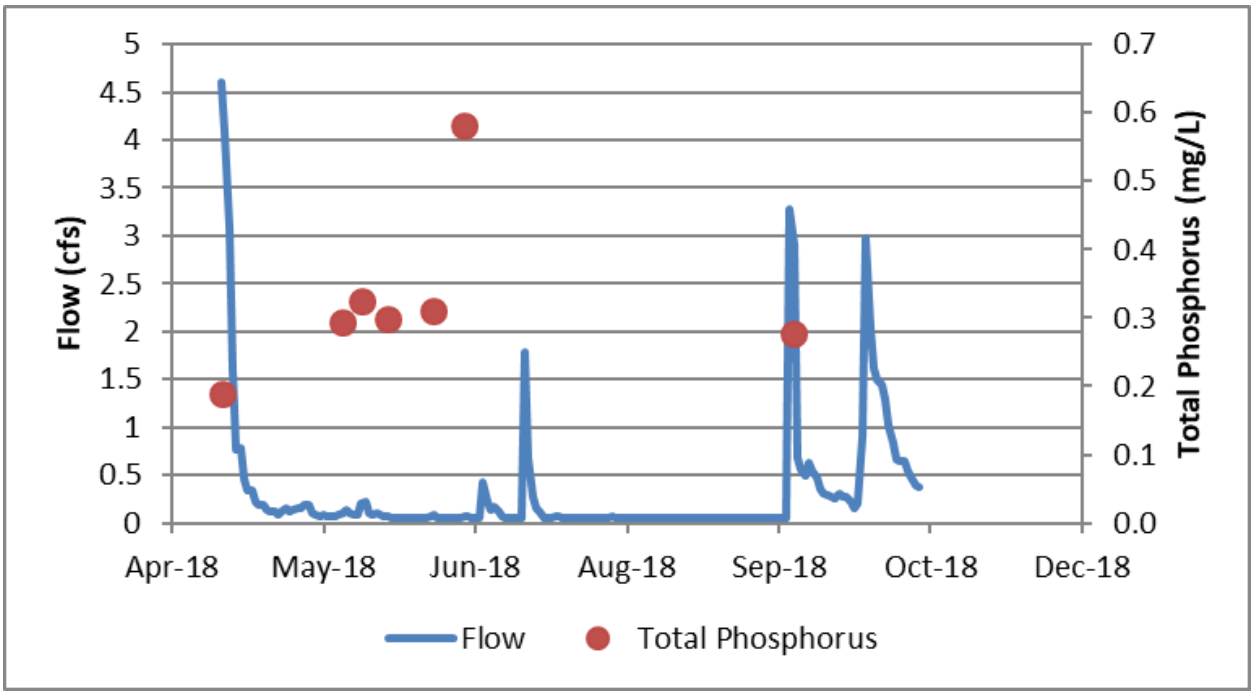


Figure 30. R7W Flow and Phosphorus (2018)

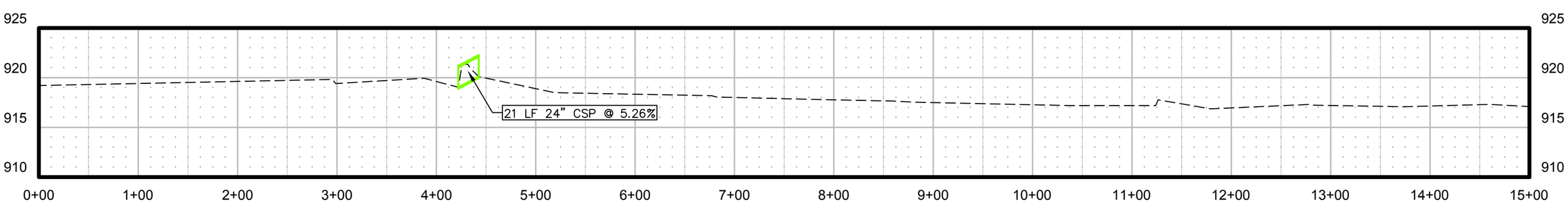
Appendix B.2. Water Quality Sample Data

Site	Date	Time	TP [mg/L]	Ortho P [mg/L]	TSS [mg/L]	Fe [mg/L]	Ortho P (%TP)	Fe: TP	Notes
WJD 6 Ditch	4/23/2018	14:15	0.253	0.183	9.4	1540	72%	6.1	snowmelt grab
WJD 6 Ditch	5/25/2018								no flow in ditch, no sample
WJD 6 Ditch	5/30/2018	13:50	0.338	0.320	16.4	5840	94%	17.3	rain event sample
WJD 6 Ditch	6/18/2018	11:50	0.578	0.561	21.4	4430	97%	7.7	rain event sample
WJD 6 Ditch	6/26/2018	14:10	0.276	0.259	34.4	4300	94%	15.6	rain event sample
Jeffery Ave	4/23/2018	13:55	0.128	0.089	7.2	2710	70%	21.2	snowmelt grab
Jeffery Ave	5/25/2018	13:00	1.080	0.878	41.2	10400	81%	9.6	baseflow (post rain event sample)
Jeffery Ave	5/30/2018	13:30	0.565	0.490	21.6	5580	87%	9.9	rain event sample
Jeffery Ave	6/6/2018	12:50	0.737	0.651	7.8	7180	88%	9.7	rain event sample
Jeffery Ave	7/13/2018	13:00	0.334	0.295	4.1	1650	88%	4.9	rain event sample
Jeffery Ave	9/21/2018	10:15	0.241	0.228	4.0	405	95%	1.7	rain event sample
R7	4/23/2018	12:30	0.136	0.081	6.4	1610	60%	11.8	snowmelt grab
R7	5/25/2018	11:40	0.105	0.087	5.6	1920	83%	18.3	baseflow (post rain event sample)
R7	5/30/2018	12:20	0.194	0.126	12.0	3070	65%	15.8	rain event sample
R7	6/6/2018	12:30	0.304	0.209	83.4	14100	69%	46.4	rain event sample
R7	6/18/2018	13:10	0.265	0.155	20.0	4080	58%	15.4	rain event sample
R7	6/26/2018	13:30	0.576	0.316	86.0	9790	55%	17.0	rain event sample
R7	7/13/2018	12:10	0.223	0.179	5.6	2380	80%	10.7	rain event sample
R7	7/13/2018	12:40	0.181	0.150	8.2	1700	83%	9.4	rain event sample (replicate)
R7	9/21/2018	11:53	0.210	0.169	6.6	1770	81%	8.4	rain event sample
R7D	4/23/2018	12:00	0.206	0.073	9.2	1350	35%	6.6	snowmelt grab
R7D	5/25/2018	10:30	0.312	0.263	4.0	3090	84%	9.9	baseflow (post rain event sample)

Site	Date	Time	TP [mg/L]	Ortho P [mg/L]	TSS [mg/L]	Fe [mg/L]	Ortho P (%TP)	Fe: TP	Notes
R7D	5/30/2018	11:20	0.389	0.322	15.6	4350	83%	11.2	rain event sample
R7D	6/6/2018	12:00	0.319	0.250	6.8	3060	78%	9.6	rain event sample
R7D	6/18/2018	12:40	1.325	0.327	13.6	7680	25%	5.8	rain event sample
R7D	6/26/2018	13:10	0.281	0.212	10.8	3970	75%	14.1	rain event sample
R7D	7/13/2018	12:00	0.291	0.218	9.2	3010	75%	10.3	rain event sample
R7D	9/21/2018	11:05	0.229	0.196	6.6	1920	85%	8.4	rain event sample
R7D Field	9/21/2018	11:17	0.169	0.117	9.3	2480	69%	14.7	rain event sample
R7E	4/23/2018	12:50	0.118	0.079	5.6	1640	67%	13.9	snowmelt grab
R7E	5/25/2018	12:00	0.118	0.088	7.6	2120	75%	18.0	baseflow (post rain event sample)
R7E	5/30/2018	12:30	0.209	0.151	14.8	3330	72%	16.0	rain event sample
R7E	6/6/2018	12:20	0.291	0.256	23.4	5390	88%	18.5	rain event sample
R7E	6/18/2018	13:00	0.300	0.240	18.6	4730	80%	15.8	rain event sample
R7E	6/26/2018	13:50	0.317	0.245	30.0	5140	77%	16.2	rain event sample
R7E	7/13/2018	12:30	1.065	0.172	12.0	2420	16%	2.3	rain event sample
R7E	9/21/2018	11:56	0.194	0.160	7.8	1130	82%	5.8	rain event sample
R7U	4/23/2018	13:35	0.144	0.105	9.2	1340	73%	9.3	snowmelt grab
R7U	5/25/2018	12:40	0.194	0.142	6.8	2090	73%	10.8	baseflow (post rain event sample)
R7U	5/30/2018	13:00	0.309	0.198	20.0	3610	64%	11.7	rain event sample
R7U	6/6/2018	12:40	0.230	0.190	7.4	2800	83%	12.2	rain event sample
R7U	6/18/2018	11:45	0.600	0.134	16.3	3740	22%	6.2	rain event sample
R7U	6/26/2018	14:30	0.265	0.221	11.6	3500	83%	13.2	rain event sample
R7U	7/13/2018	12:50	0.264	0.219	11.6	2570	83%	9.7	rain event sample
R7U	9/21/2018	10:30	0.271	0.216	11.4	1590	80%	5.9	rain event sample

Site	Date	Time	TP [mg/L]	Ortho P [mg/L]	TSS [mg/L]	Fe [mg/L]	Ortho P (%TP)	Fe: TP	Notes
R7W	4/23/2018	13:15	0.190	0.111	18.0	2000	58%	10.5	snowmelt grab
R7W	5/25/2018	11:10	0.295	0.245	47.6	3220	83%	10.9	baseflow (post rain event sample)
R7W	5/30/2018	11:50	0.325	0.281	23.2	4800	86%	14.8	rain event sample
R7W	6/6/2018	12:10	0.298	0.248	9.4	3550	83%	11.9	rain event sample
R7W	6/18/2018	12:50	0.309	0.240	8.4	4750	78%	15.4	rain event sample
R7W	6/26/2018	14:50	0.580	0.515	11.2	6530	89%	11.2	rain event sample
R7W	9/21/2018	11:27	0.277	0.236	9.0	2820	85%	10.2	rain event sample

APPENDIX C. WJD 6 PLAN AND PROFILE DRAWINGS



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2			
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SCALE IN FEET

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SUBMISSION DATE: 04/19/2018

DESIGN BY KDC | DRAWN BY BR

EOR PROJECT NO. 1292-0007

Emmons & Olivier Resources, Inc.
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Oakdale, MN 55128
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WAYZATA, MN, 55391

CORCORAN SOLAR GARDEN
CORCORAN, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. --- | CITY PROJECT NO. ---

JD-6 PLAN & PROFILE
STA 0+00 - 15+00

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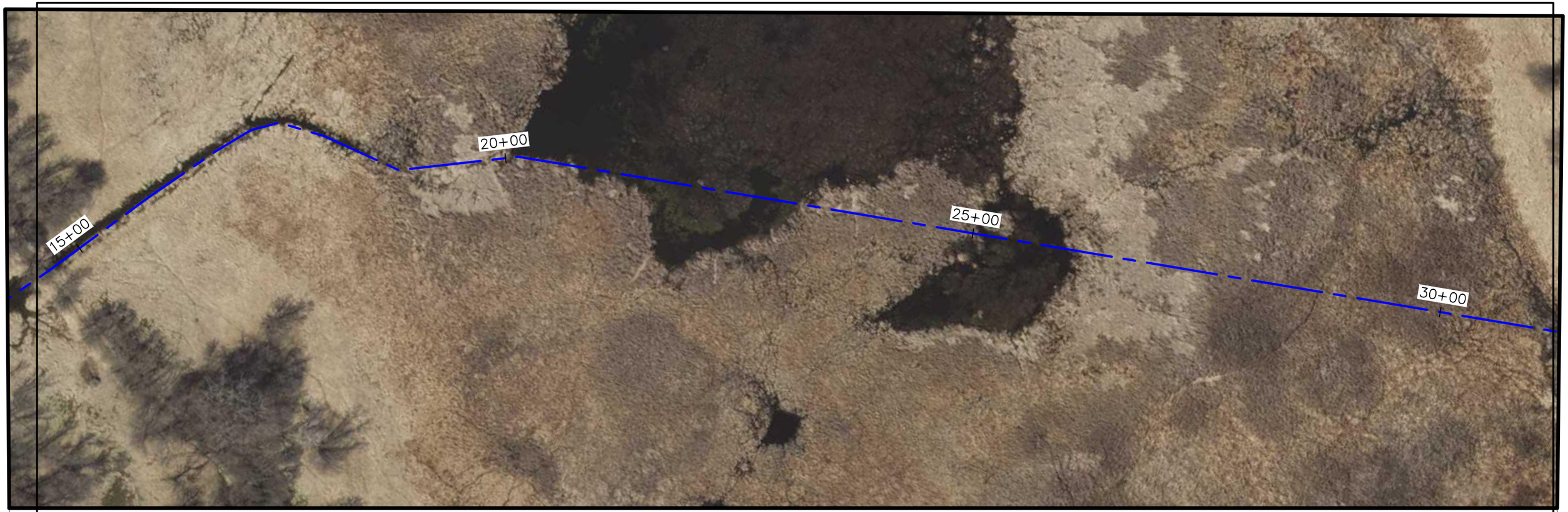

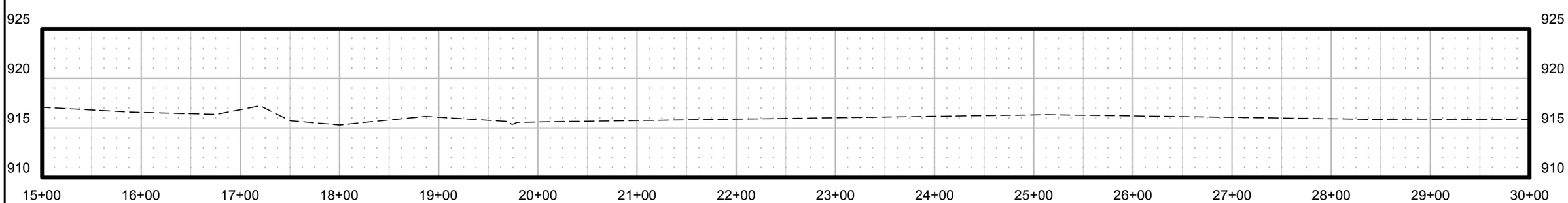

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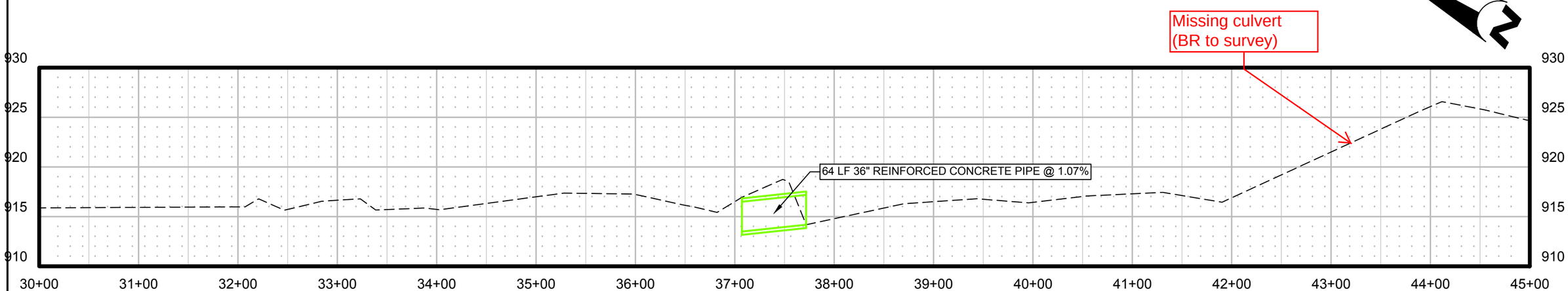

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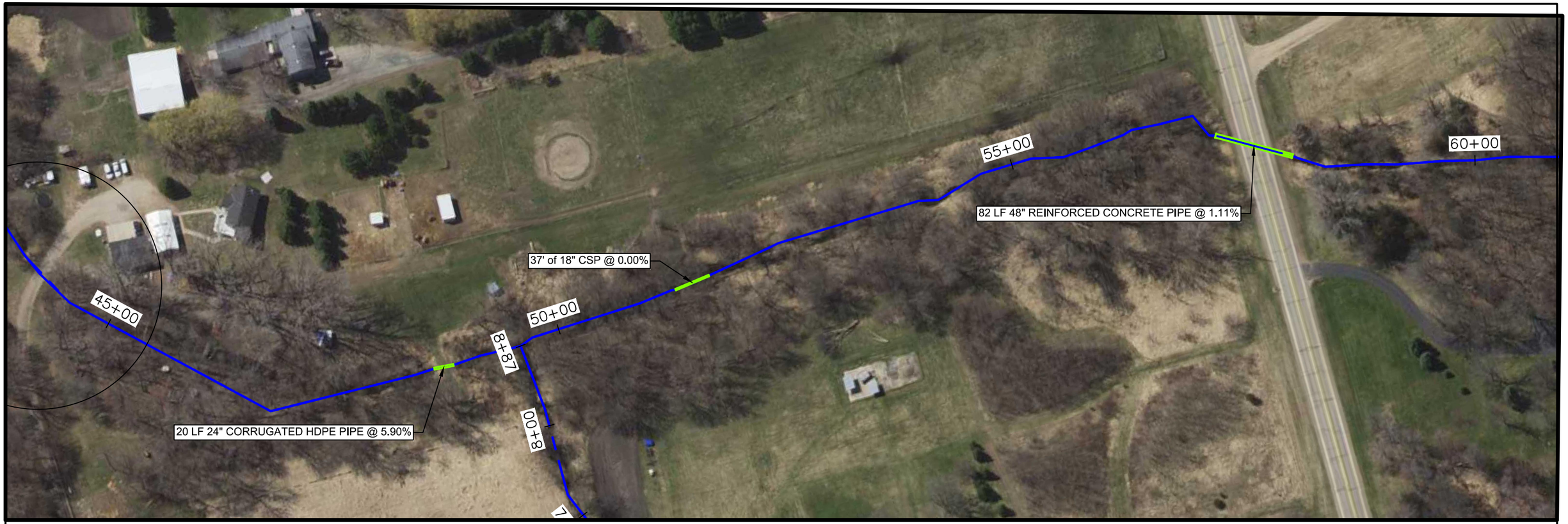

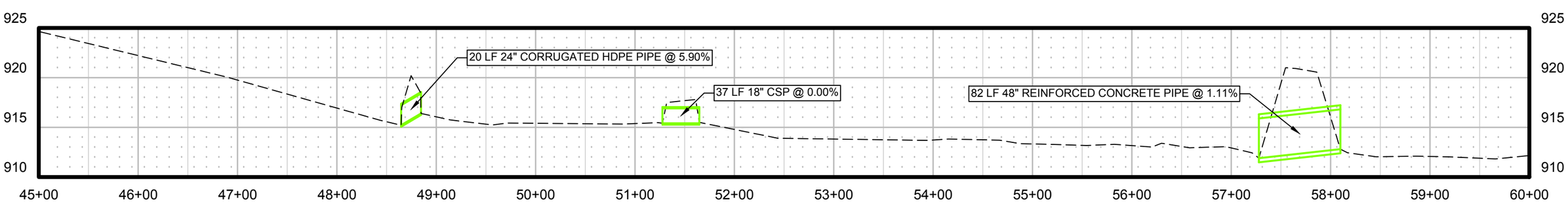

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SCALE IN FEET

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JD-6 PLAN & PROFILE
STA 45+00 - 60+00

SHEET 05 OF 19 SHEETS

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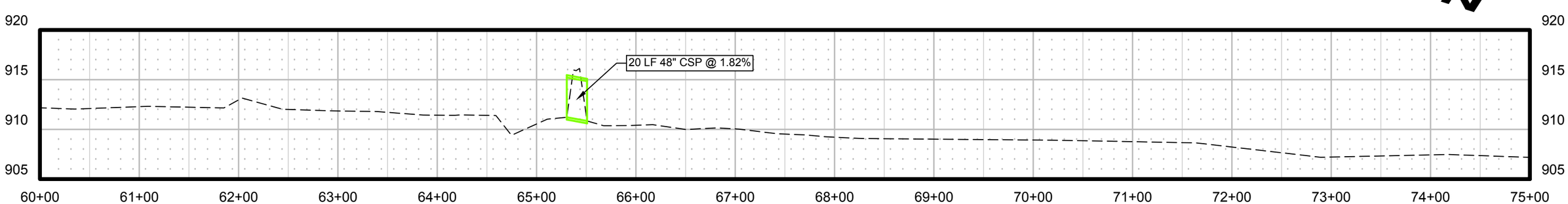

NO	DATE	BY	REVISION
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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

0 50 100 200

SUBMISSION DATE: 04/19/2018

DESIGN BY KDC | DRAWN BY BR

EOR PROJECT NO. 1292-0007

Emmons & Olivier Resources, Inc.
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water ecology community

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WAYZATA, MN, 55391

CORCORAN SOLAR GARDEN
CORCORAN, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. --- | CITY PROJECT NO. ---

JD-6 PLAN & PROFILE
STA 60+00 - 75+00

SHEET 06 OF 19 SHEETS

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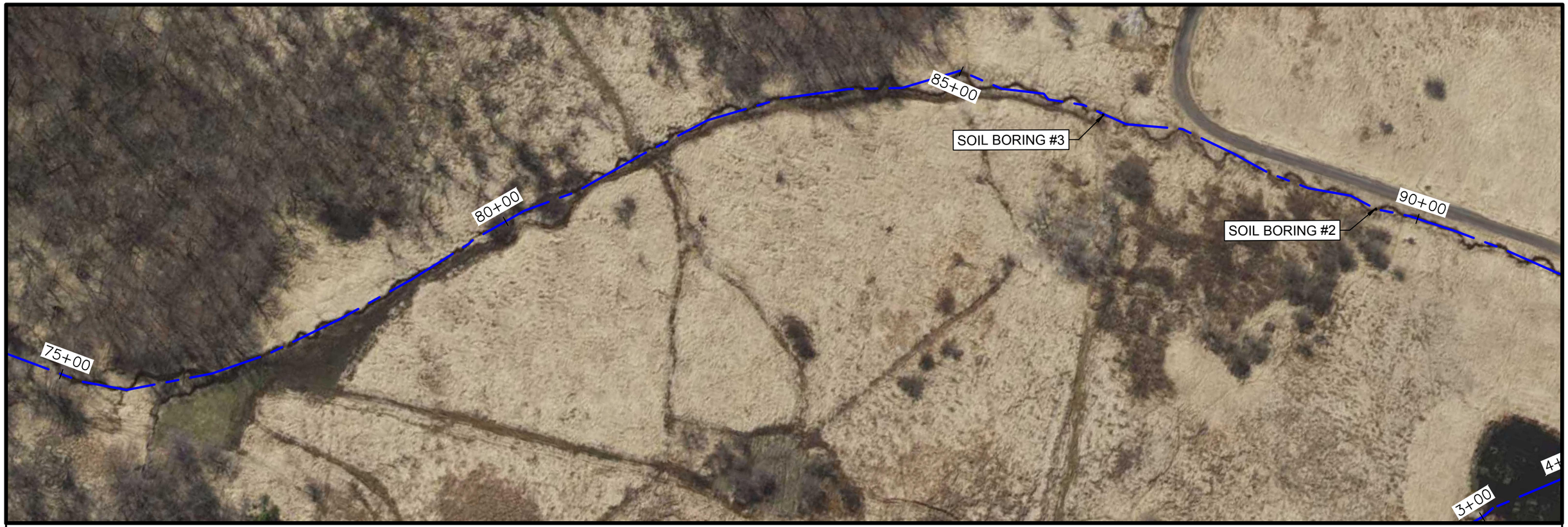

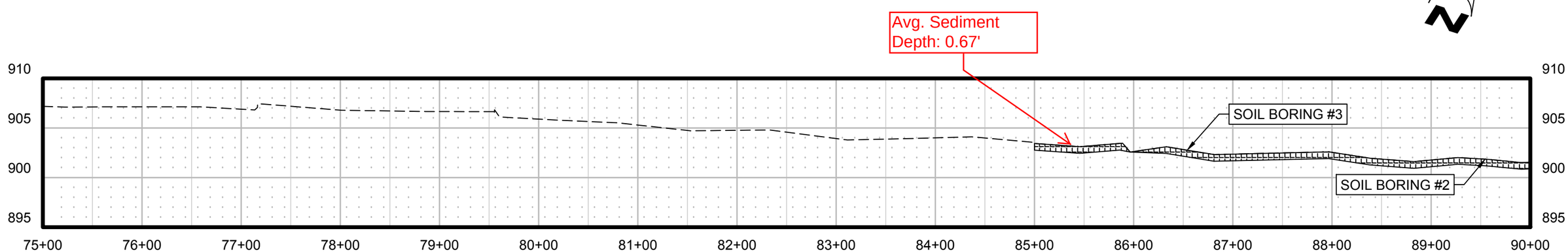

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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

0 50 100 200

SUBMISSION DATE: 04/19/2018

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CORCORAN, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. --- | CITY PROJECT NO. ---

JD-6 PLAN & PROFILE
STA 75+00 - 90+00

SHEET 07 OF 19 SHEETS

Plot Date: 11/28/2018
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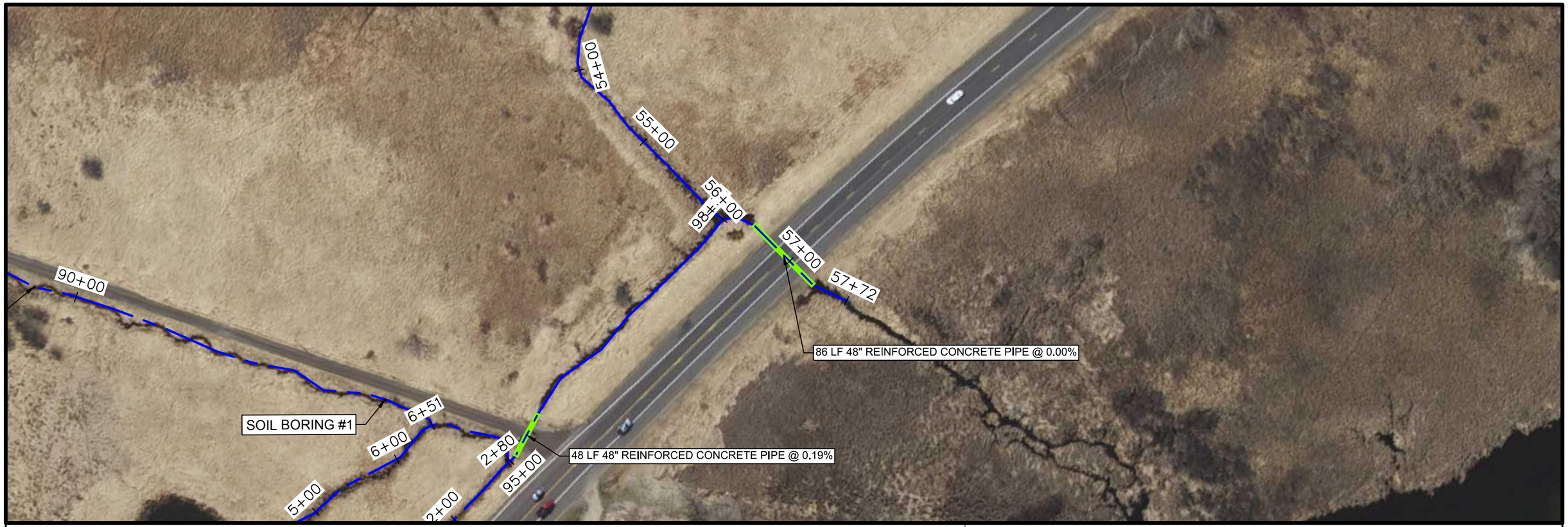

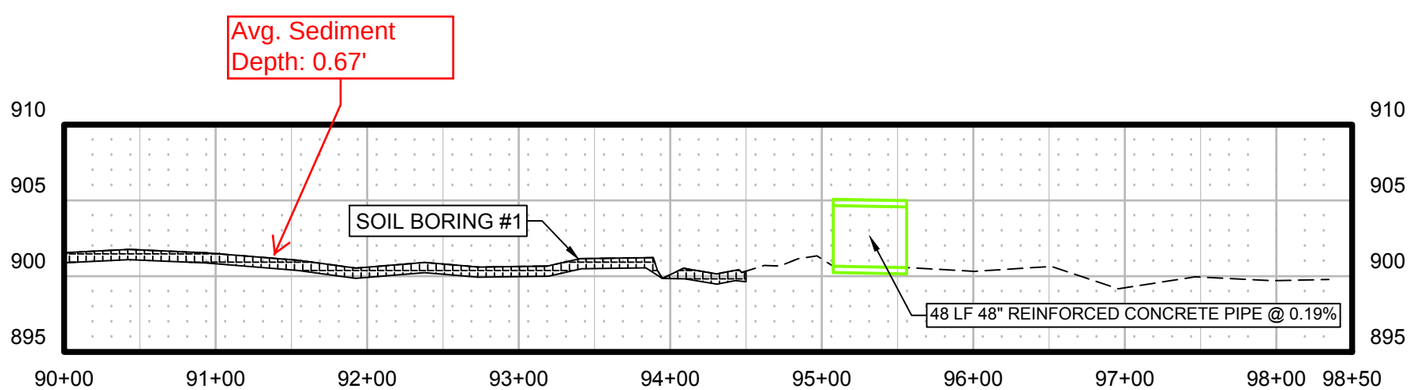

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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

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SUBMISSION DATE: 04/19/2018

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STATE PROJECT NO. --- CITY PROJECT NO. ---

JD-6 PLAN & PROFILE
STA 90+00 - 105+00

SHEET 08 OF 19 SHEETS

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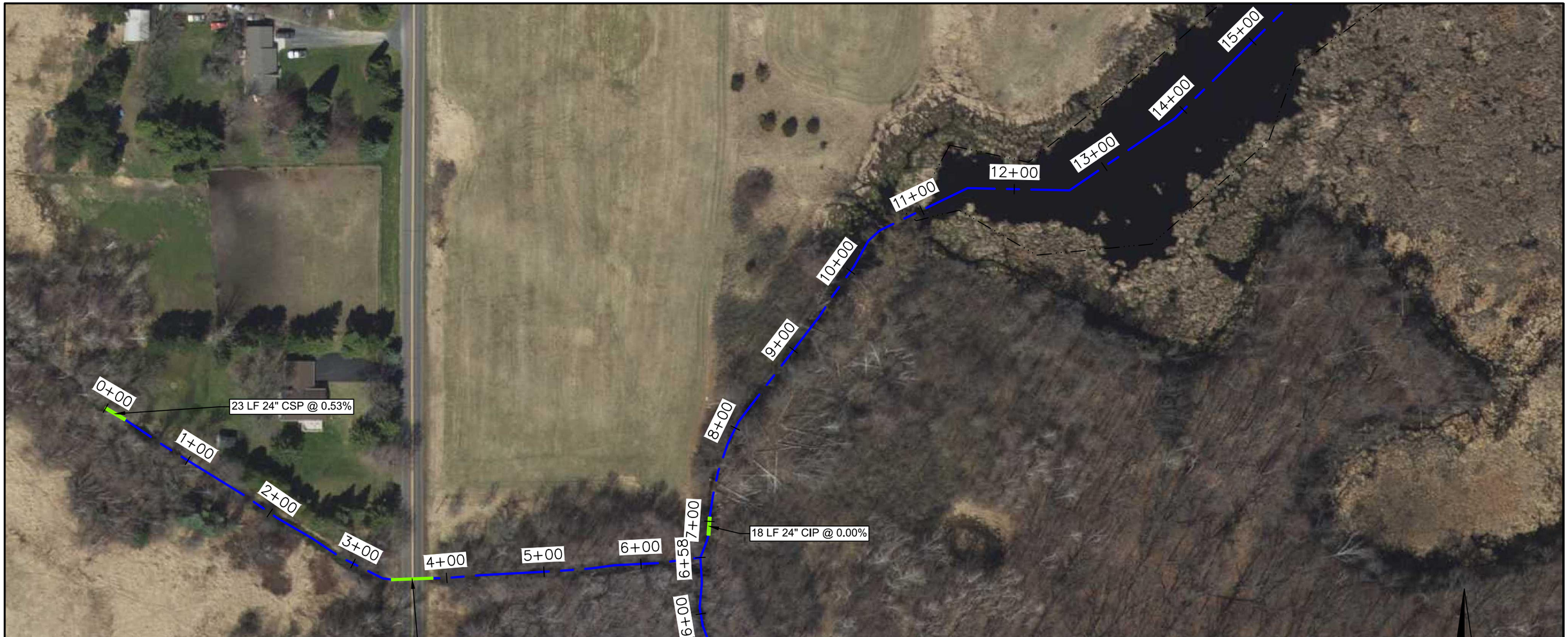

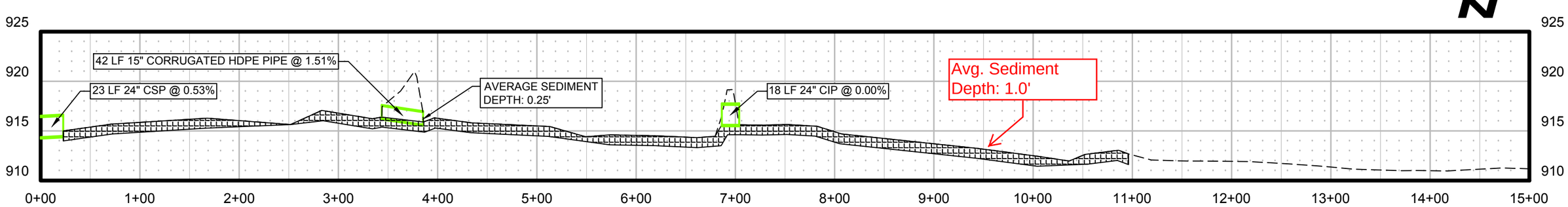

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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

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SUBMISSION DATE: 04/19/2018

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STATE PROJECT NO. --- | CITY PROJECT NO. ---

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STA 0+00 - 15+00

SHEET 09 OF 19 SHEETS

Plot Date: 11/28/2018
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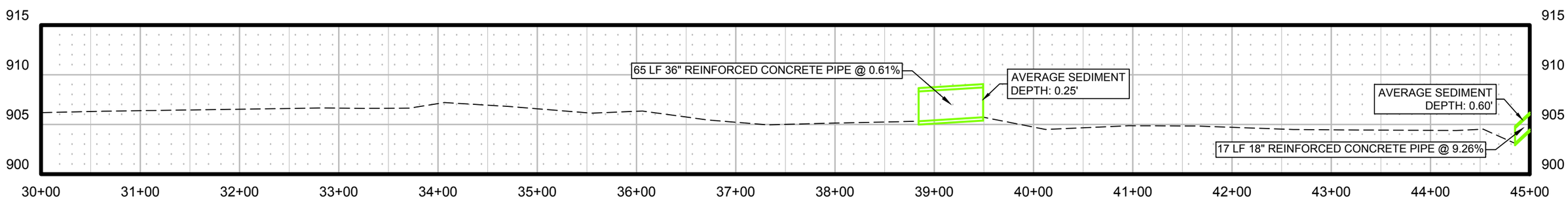

NO	DATE	BY	REVISION
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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

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SUBMISSION DATE: 04/19/2018

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STATE PROJECT NO. --- | CITY PROJECT NO. ---

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STA 15+00 - 30+00

SHEET 10 OF 19 SHEETS

Plot Date: 11/28/2018
Drawing name: X:\Clients_WD\00376_CLF\LWD\0159_JD6_Diagnostic\09_GIMS_ProjectName\dwg\376-0159_P&Ps.dwg
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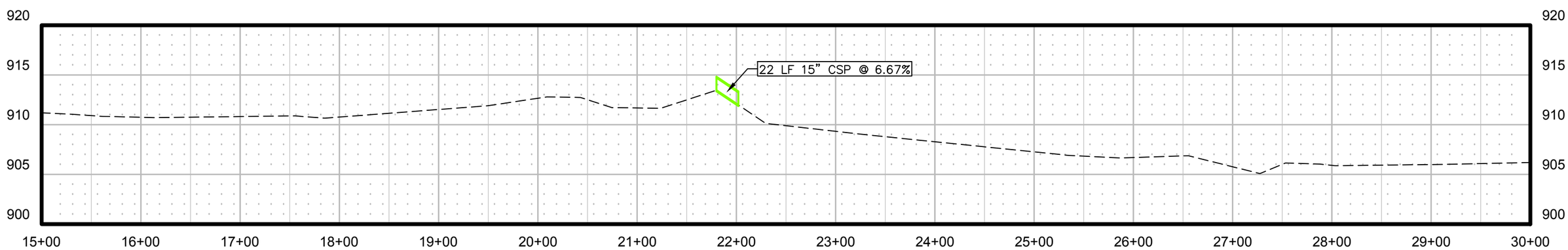

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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

0 50 100 200

SUBMISSION DATE: 04/19/2018

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EOR PROJECT NO. 1292-0007

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STATE PROJECT NO. --- | CITY PROJECT NO. ---

CENTER PLAN & PROFILE
STA 30+00 - 45+00

SHEET 11 OF 19 SHEETS

Plot Date: 11/28/2018
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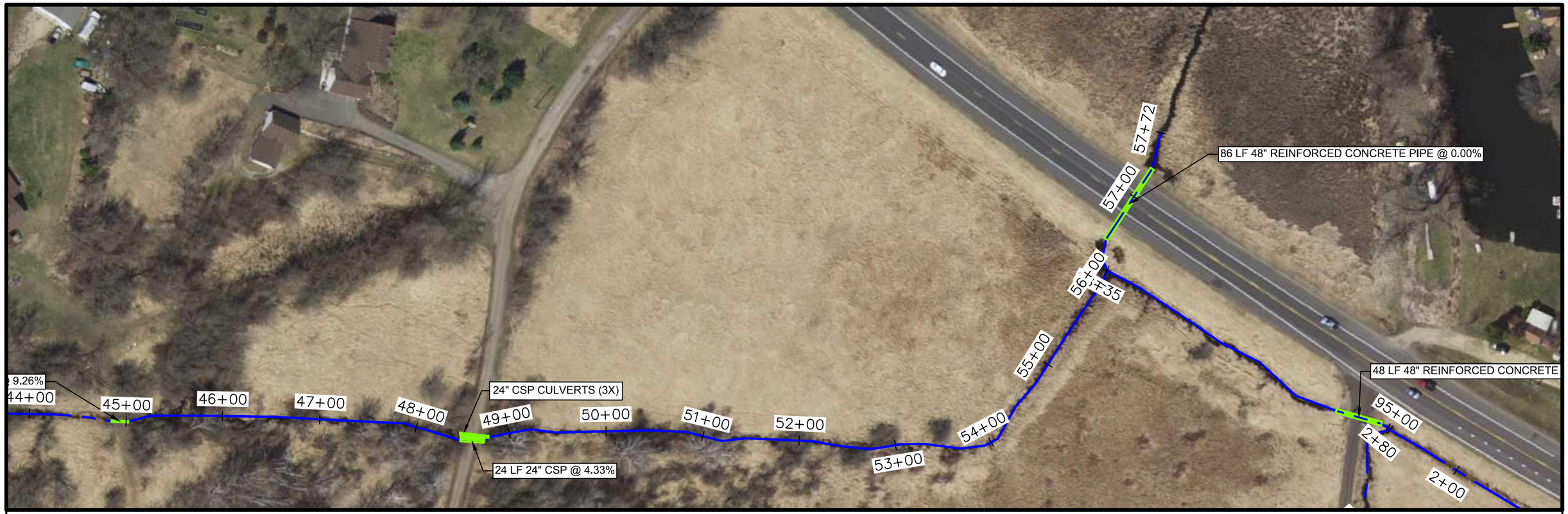

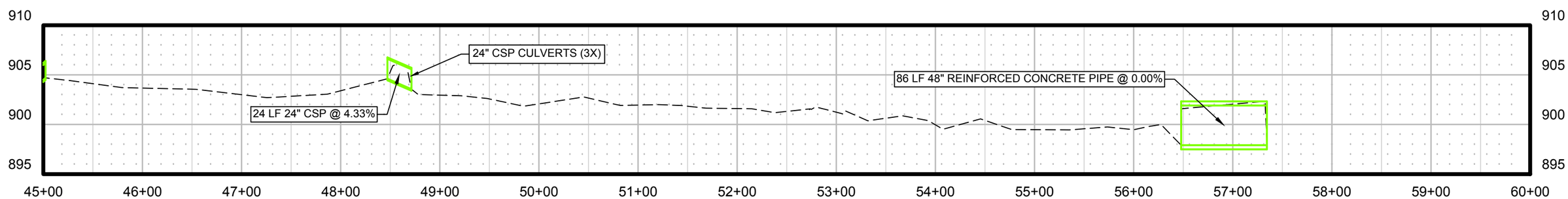

NO	DATE	BY	REVISION
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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

0 50 100 200

SUBMISSION DATE: 04/19/2018

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EOR PROJECT NO. 1292-0007

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STATE PROJECT NO. --- | CITY PROJECT NO. ---

CENTER PLAN & PROFILE
STA 45+00 - 60+00

Plot Date: 11/28/2018
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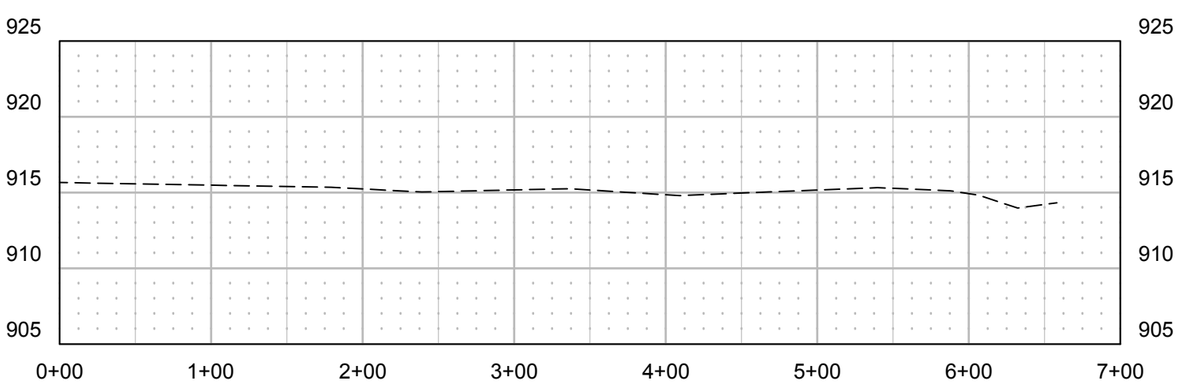

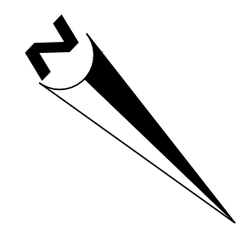

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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

0 50 100 200

SUBMISSION DATE: 04/19/2018

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CORCORAN, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. --- | CITY PROJECT NO. ---

EAST BRANCH PLAN & PROFILE
STA 0+00 - 15+00

SHEET 13 OF 19 SHEETS

Plot Date: 11/28/2018
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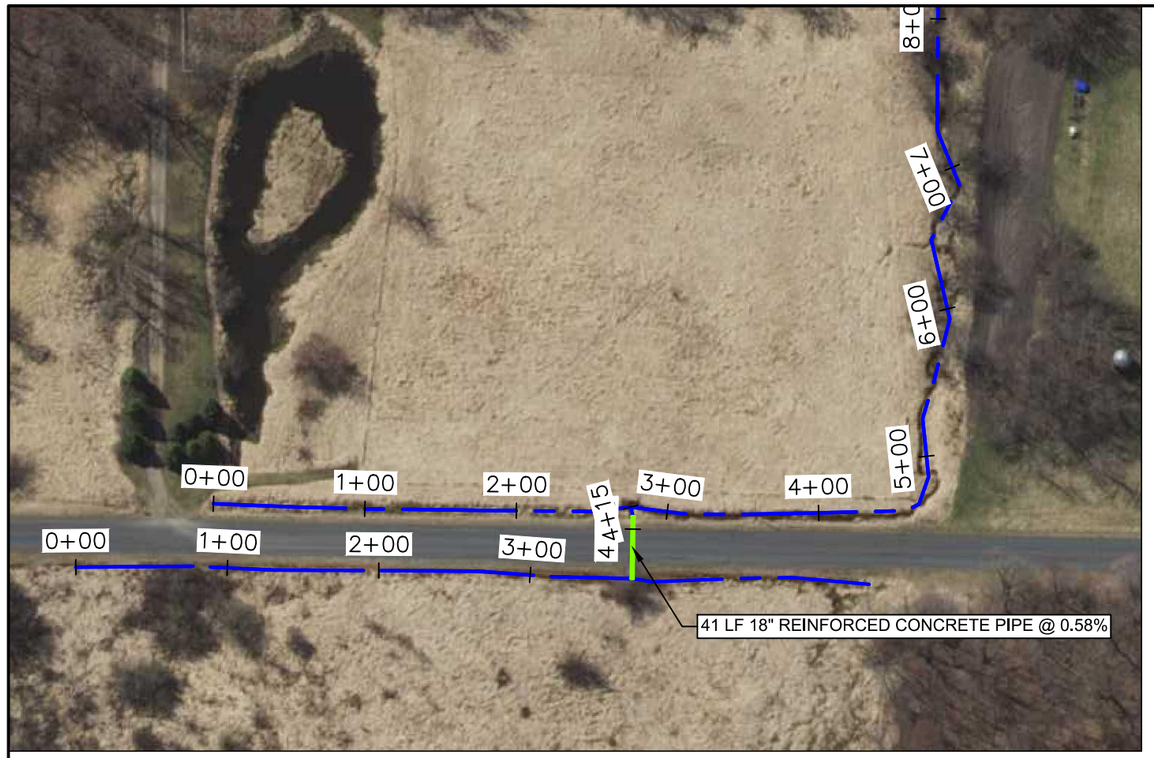

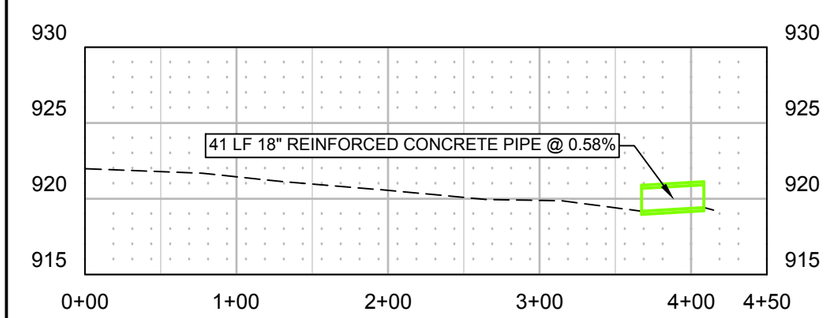

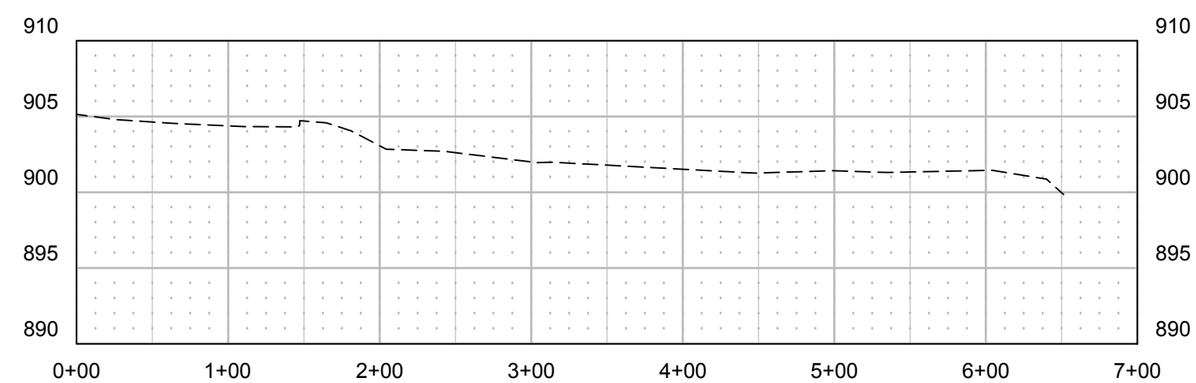

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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

0 50 100 200

SUBMISSION DATE: 04/19/2018

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CORCORAN, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. --- | CITY PROJECT NO. ---

EAST JEFFREY PLAN & PROFILE
STA 0+00 - 10+00

SHEET 14 OF 19 SHEETS

Plot Date: 11/28/2018
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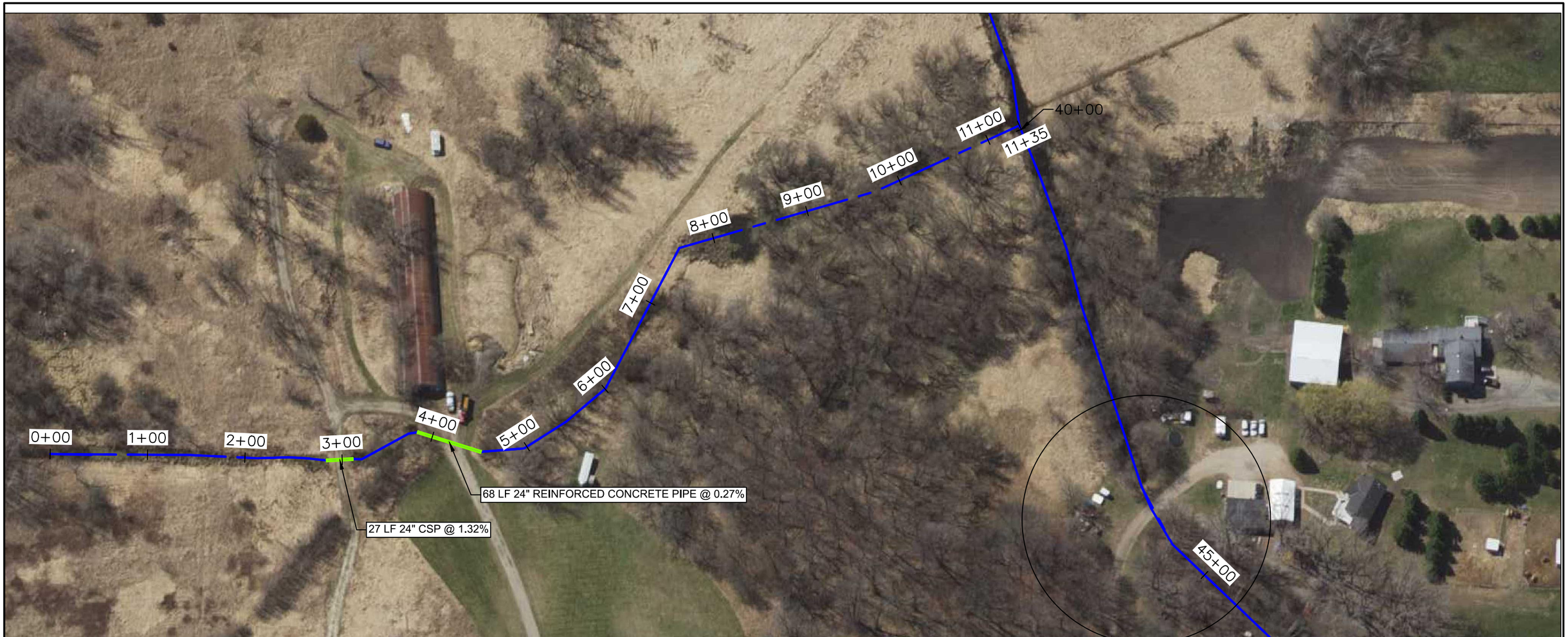

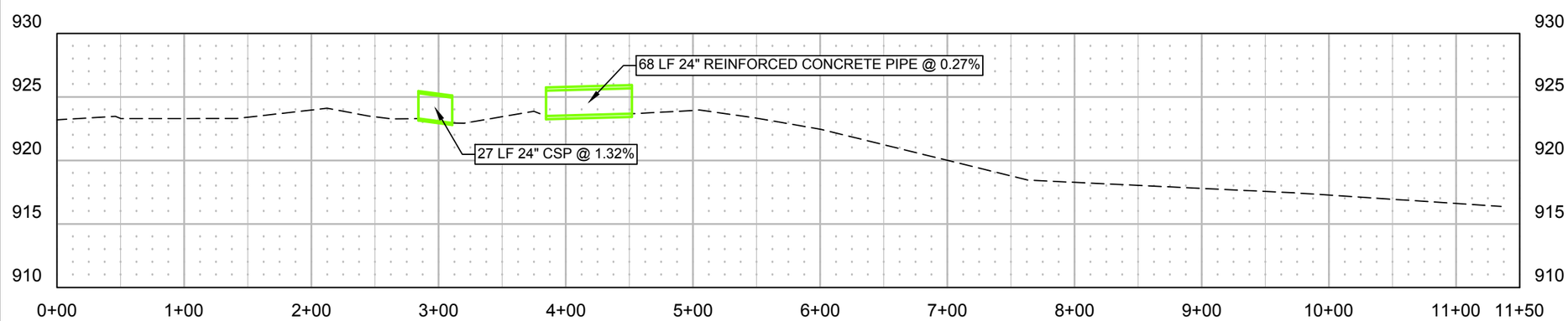

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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

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SUBMISSION DATE: 04/19/2018

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CORCORAN SOLAR GARDEN
CORCORAN, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. --- | CITY PROJECT NO. ---

EAST WETLAND PLAN & PROFILE STA 0+00 - 10+00

SHEET 15 OF 19 SHEETS

Plot Date: 11/28/2018
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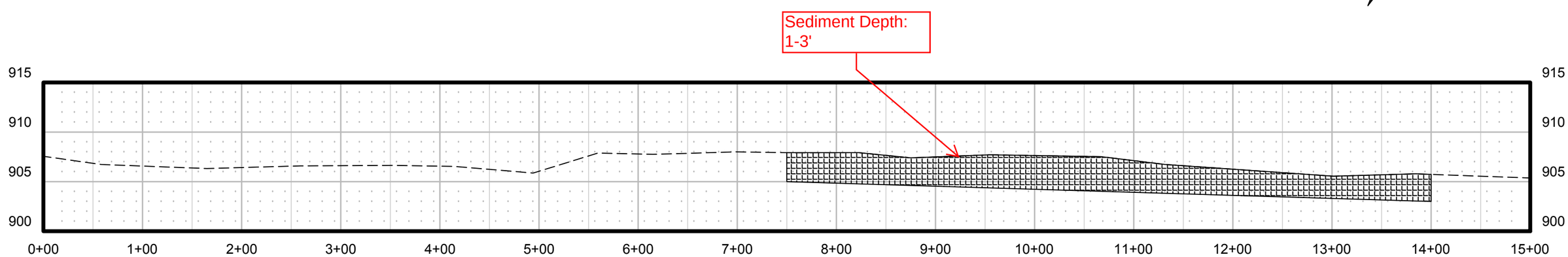

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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

0 50 100 200

SUBMISSION DATE: 04/19/2018

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CORCORAN SOLAR GARDEN
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STATE PROJECT NO. --- CITY PROJECT NO. ---

MOODY OUTLET PLAN & PROFILE
STA 0+00 - 15+00

SHEET 16 OF 19 SHEETS

Plot Date: 11/28/2018
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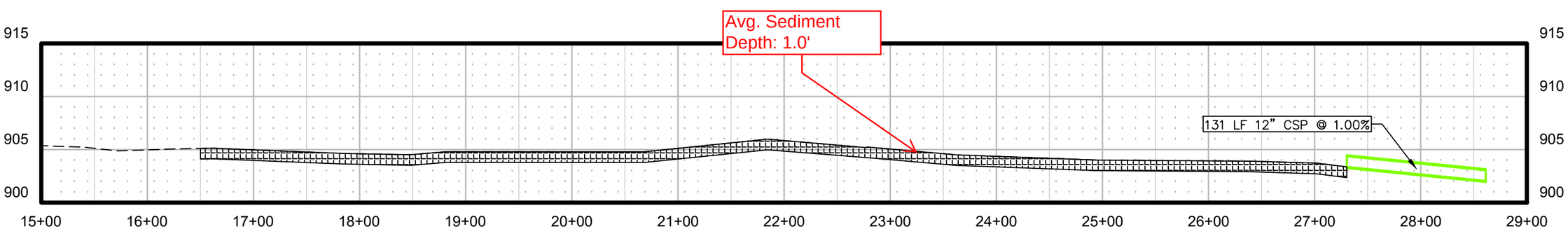

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1	04/19/2018	KDC	FINAL CONSTRUCTION PLANS (IFC)

SCALE IN FEET

0 50 100 200

SUBMISSION DATE: 04/19/2018

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CORCORAN SOLAR GARDEN
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STATE PROJECT NO. --- | CITY PROJECT NO. ---

MOODY OUTLET PLAN & PROFILE STA 15+00 - 30+00

SCALE IN FEET

0 50 100 200

Plot Date: 11/28/2018
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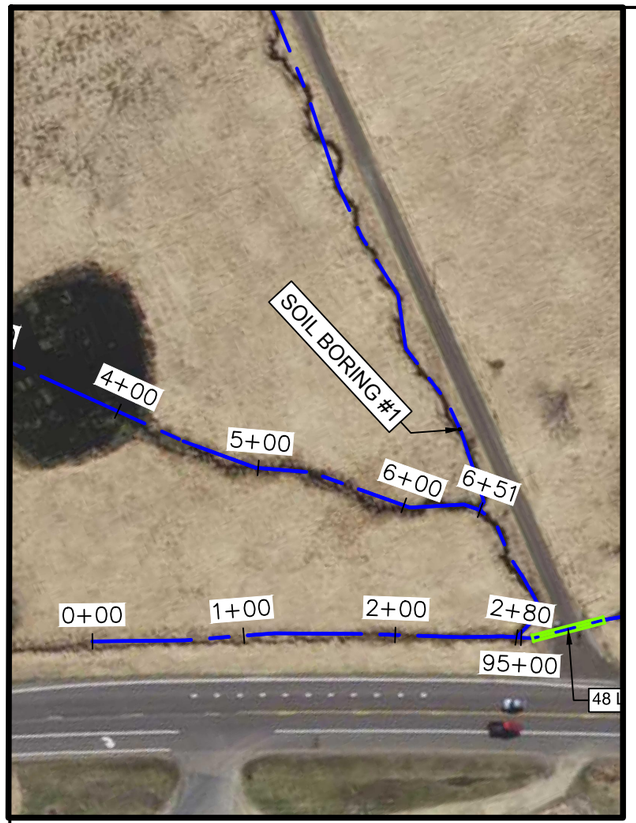

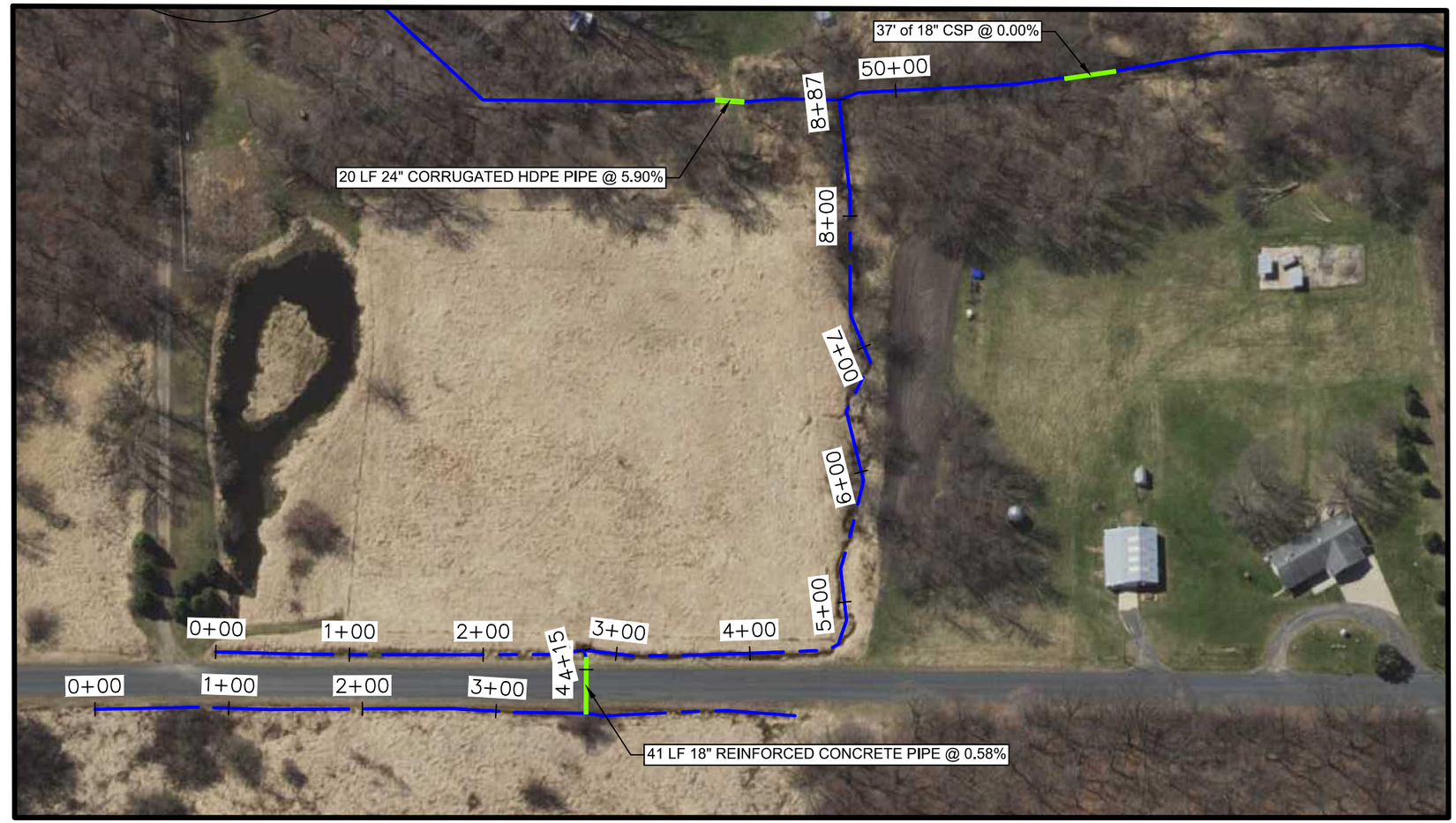

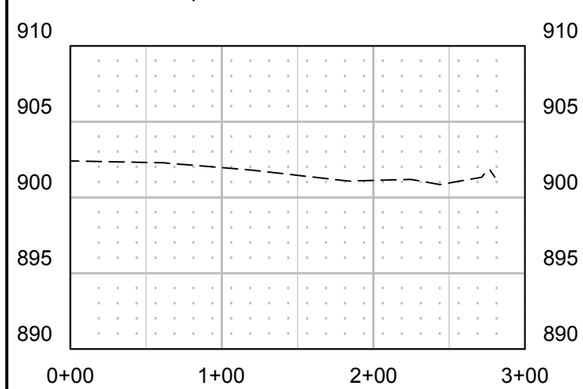

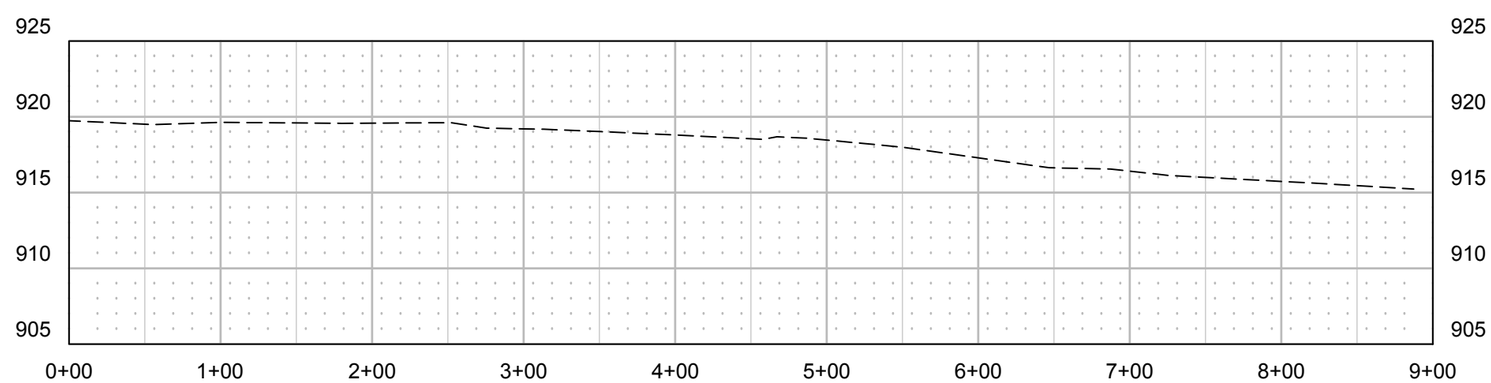

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NO	DATE	BY	REVISION
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EOR PROJECT NO. 1292-0007

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CORCORAN, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. --- | CITY PROJECT NO. ---

WEST JEFFREY PLAN & PROFILE STA 0+00 - 15+00