JUDICIAL DITCH #19 WATERSHED PLAN

Middle-Snake-Tamarac Rivers Watershed District

Screening of Alternatives for Detailed Review

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1 APPROACH

The Middle Snake Tamarac Rivers Watershed District (MSTRWD) entered into a cooperative agreement with the National Resource Conservation Service (NRCS) in 2016 to complete a Watershed Plan through the Regional Cooperation Partnership Program (RCPP) for the Judicial Ditch #19 Watershed (JD 19). The JD 19 Watershed is a 104 square mile sub-watershed of the Tamarac River Watershed and is shown on **Figure 1**. Review Point #4 of the NRCS Watershed Planning process consists of reviewing potential alternatives within the watershed. This document summaries the screening of alternatives for the Judicial Ditch #19 Watershed Plan.

1.1 PURPOSE AND NEED

Preliminary development of alternatives focused on narrowing the range of alternatives by reviewing and analyzing technical and practical considerations to evaluate potential to meet project objectives from the Purpose and Need. Strategies were first evaluated based on known causes of flooding. In some cases, a preliminary hydrologic analysis was completed to reasonably evaluate a strategies' potential to meet flood damage reduction objectives. Alternative concepts that were based on strategies that would meet the project objectives were then developed and preliminarily analyzed to further narrow the range of alternatives based on the ability to address the Purpose and Need. The Purpose and Need specifies objectives listed below for the Project.

1. Provide flood damage reduction to agricultural lands due to a 10-year 24-hour rainfall event.
2. Reduce flood damage to public transportation infrastructure within the Judicial Ditch #19 sub-watershed.
3. A secondary purpose to contribute to the overall basin-wide goal of reducing peak flows to the Red River of the North by 20%.

To assist with a comparative analysis of the alternatives, the following indicators were established as pass-fail criteria for the preliminary development of alternatives. The objectives and associated indicators are summarized below:

- **INDICATOR NO. 1:** Reduce total inundated acres for flood durations between 24 and 120 hours (1-5 days) for the 10-year, 24-hour rainfall event by 5%. While crop damage depends on both duration and depth of inundation, for this analysis it was assumed crop damages would not occur for durations less than 24 hours. Inundation greater than 5 days would result in total crop loss. Due to the existing flood damages that occur within the watershed, many landowners have taken cropland out of production. If the total inundation is reduced for durations between 24 and 120 hours during a 10-year event, then land currently out of agricultural production may be reintroduced as cropland.
- **INDICATOR NO. 2**: Reduce the peak flow rate at the US Highway 59 and Judicial Ditch #19 crossing by 20% for the 10-year and 100-year, 24-hour rainfall event.
- **INDICATOR NO. 3**: Reduce the volume of flow at the US Highway 59 and Judicial Ditch #19 crossing by 20% for the 10-year and 100-year, 24-hour rainfall event.
- **INDICATOR NO. 4**: No increase in peak flow rate at the outlet of the Judicial Ditch #19 Watershed for the 10-year and 100-year, 24-hour rainfall event. This indicator will be measured based on the flow rate of the Tamarac River downstream of the JD 19 confluence.

The alternatives that successfully achieve the objectives defined in the Purpose and Need statement based on the presented indicators are proposed to be carried forward for a detailed review. All reasonable alternatives that were identified were considered, regardless of eligibility under Public Law 83-566, or other NRCS administered funding sources.

1.2 EXISTING CONDITIONS

The upstream 69 square miles of the JD 19 watershed flows through the existing East Park Flood Control Wildlife Management Area (Nelson Slough) impoundment. Nelson Slough's footprint covers1,700 acres and qualifies as a low hazard dam within the 10,427 acre East Park Wildlife Management Area. Construction of Nelson Slough was completed in 1971, and the outlet structure was repaired in 2003. The outlet structure consists of a sliding gate and a two stage concrete spillway. The sliding gate consists of a 6-foot wide mechanical gate that opens from the sill of the outlet structure with a maximum opening height of 4.5'. This gate is not used for day to day operation and remains closed unless drawdown is necessary for internal maintenance. The primary outlet and weir crest is a 6-foot wide fixed concrete weir, and the secondary spillway is a 70-foot wide fixed concrete weir acting as the auxiliary spillway. The critical elevations for Nelson Slough are shown in **Table 1**. The map overview is shown on **Figure 1.2**.

The plans and operations and maintenance manual for Nelson Slough reference elevations in the National Geodetic Vertical Datum of 1929 (NGVD29). Elevations within this report are in reference to the North American Vertical Datum of 1988 (NAVD88). The conversion between the two datums varies throughout North America. A conversion factor for Nelson Slough was produced using the National Geodetic Survey, VERTCON conversion tool. The conversion factor for Nelson Slough is 1.30 feet.

$$NGVD29 + 1.3' = NAVD88$$

$$1101.0'(NGVD29) + 1.3' = 1102.3'(NAVD88)$$

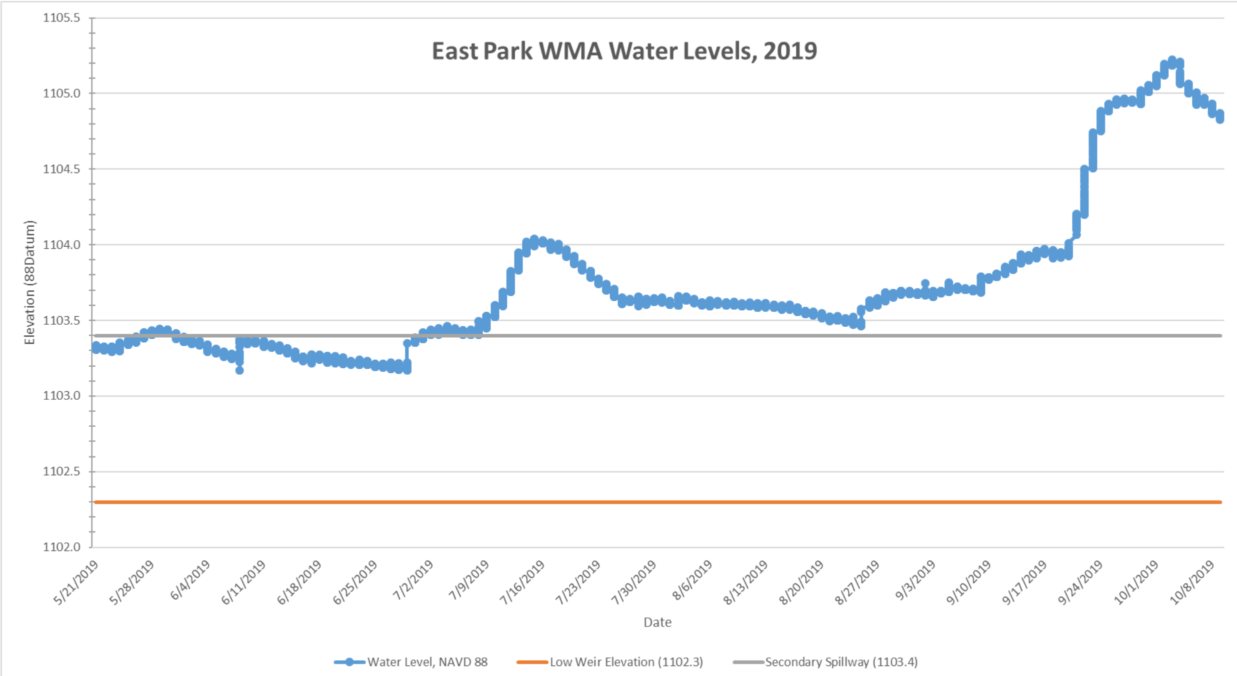
Table 1: East Park WMA - Nelson Slough Impoundment

Critical Elevation[1]	Length	NGVD29	NAVD88
Sill of Primary Sliding Gate[2]	6 feet	1097.2	1098.5
Primary Weir Crest	6 feet	1101.0	1102.3
Secondary Weir Crest	70 feet	1102.2	1103.5
Top of Dam	5.1 miles	1105.0	1106.3

[1] Lengths and Elevations are published values in the Operations and Maintenance Manual
[2] Sliding gate installed in 2003. Gate is only used for drawdown.

With the current operation plan and outlet structure geometrics, Nelson Slough often maintains an elevation higher than the normal pool elevation identified in the operating plan of 1102.3'. The primary weir crest consists of a 6-foot wide weir at 1102.3'. The secondary weir crest consists of a 70-foot wide weir at 1103.5'. The DNR installed a temporary gage in 2019 to record the water level within the Nelson Slough. During this time period, the lowest water level recorded was approximately 1103.2' and the highest water level recorded was approximately 1104.1'. There was flow over the secondary spillway for approximately 75% of this time period, and the water level was 0.9' to 1.8' above the normal pool elevation for the duration of monitoring. The temporary gage readings are shown in **Table 2**.

Table 2: Nelson Slough 2019 Water Level Gage Data



Hydraulic and hydrologic modeling indicates that it would take multiple months, without any additional rainfall, for the site to draw down from 1103.5 to 1102.3. These results are validated by the water level recordings from the summer of 2019. Based on this information, it is evident that with the existing outlet operations the site will rarely operate at the normal pool elevation of 1102.3.

The starting water surface elevation for Nelson Slough for all simulations in this analysis, unless otherwise noted, was set to 1103.5'. This elevation was selected based on the 2019 DNR gage readings and the hydrologic and hydraulic modeling analysis and the drawdown duration.

2 INITIAL STRATEGY SCREENING

The initial phase of the development of alternatives was a review of a comprehensive list of strategies that represent categorized types of alternatives. The goal of the strategy evaluation was to narrow the scope of preliminary alternative review through the acceptance or elimination of strategies based on limited technical evaluation and practical considerations. To aid in this review, strategies from the Technical and Scientific Advisory Committee of the Red River Basin Flood Damage Reduction Work Group Technical Paper No. 11 (TSAC, 2004) were categorized into five generalized groups.

1. No-Action involves forecasting the watershed condition if no alternative plan is selected.
2. Reduce runoff volume involves structural and non-structural practices that result in reductions to the excess runoff volume from the water budget during a rain event.
3. Increase conveyance capacity provides additional hydraulic capacity within the watershed at known damage locations.
4. Increase temporary flood storage provides additional flood storage within the watershed, typically through structural measures that would maximize available flood storage.

5. Protection/Avoidance are structural and non-structural practices that would reduce damage frequency for land, structures, and infrastructure.

A description of strategies that have been identified and considered within each category is provided in **Table 3.**

Table 3: Flood Damage Reduction Strategy Description

Category	Strategy	Description
No-Action	No-Action	The future-without-project, or No-Action, alternative is required under Public Law 83-566 Watershed Planning. Involves forecasting the watershed conditions that are expected to exist if an alternative plan is not selected.
Reduce Runoff Volume	Cropland Better Management Practices	Cropland management practices have been developed to conserve soil and water resources. These are collectively referred to as best management practices (BMPs). The most commonly used agricultural BMPs are forms of conservation tillage that leave the soil better protected by crop residues than other tillage methods. This may also increase infiltration, thereby reducing runoff. The reduction in runoff varies with the topography, amount of rain, and type of soil.
	Conversion to Grassland	Perennial grassland including CRP, hay meadow, and well-managed pasture can produce less rainstorm runoff than cultivated cropland.
	Conversion to Forest	Forestland can produce less rainstorm runoff than cultivated cropland. The effects on snow accumulation and spring snowmelt runoff from forestland have not been well documented.
	Restore or Create Wetlands	Depressional areas within the landscape capture runoff and allow time for evaporation and infiltration to occur, which normally results in natural seasonal drawdown. This drawdown storage is replaced during subsequent runoff events which reduces the downstream flood volume.
	Other beneficial uses of stored water	Stored water can be used for domestic or industrial purposes, or for stream flow augmentation during drier periods of the year to improve fish habitat and provide other instream flow benefits. Use of this water results in drawdown of a storage reservoir, providing annual removal of water from the spring flood volume.
Increase Conveyance Capacity	Channelization	Channelization projects may include enlarging or realigning natural channels or creating channels in areas of natural overland flow. Channelization projects are usually constructed to decrease localized flooding; however, the potential increase to flooding downstream of the channelization extents must be considered and mitigated for.
	Drainage	The primary purpose of agricultural drainage in the Red River Basin is to remove excess surface water and soil moisture. Depending on the type of drainage, this can allow the ground to warm up faster in the spring, provide an aerated rooting zone for crop development, and minimize drowning of crops by excess precipitation. The need for outlets for field drainage led to the development of larger collector ditch systems in many areas of the Red River Basin.

Category	Strategy	Description
	Flood Water Diversion	Diversion projects typically remove water from a flood-prone stream, convey it safely around a known damage site, and return it to a downstream watercourse. A diversion is an alternative to channelization or protection measures, such as levees and floodwalls, when environmental impacts, cost, or other land use issues are better addressed by this measure.
	Setback Levees	Levees constructed along flood-prone waterways often restrict conveyance enough to cause a backwater effect by encroaching on the floodway. Moving the levees back farther away from the channel will restore a portion of the lost floodway capacity. Doing so with a primary purpose of increasing conveyance will primarily benefit lands upstream from the levee encroachment.
	Increase Roadway Capacity	During high flows in flat topography, road crossings typically restrict conveyance more than the available channel capacity. Roadway capacities can be increased in these instances to reduce flooding caused by high headwater elevations on roadway bridges and/or culverts. While this strategy can reduce localized flooding upstream of roadways, downstream flooding must be considered and mitigated for.
Increase Temporary Flood Storage	On-Channel Impoundment	On-channel impoundments are constructed to temporarily store and attenuate peak flows downstream. The most important consideration from an overall flood control standpoint is the timing of the storage and release of attenuated peak flows. An embankment is typically constructed across a natural water course with a regulated outflow structure.
	Culvert Sizing	Culvert sizing is a technique that can be used to control runoff rates. By appropriately sizing road and drainage system culverts throughout a subwatershed or watershed, the flow rates can be regulated to better suit downstream channel capacities. Excess water is temporarily detained upstream of culverts.
	Wetland Restoration/Creation	Created or restored wetlands are basins that are implemented primarily to attain a natural resource and/or habitat objective. Wetlands developed for natural resource and/or habitat objectives can provide temporary flood storage. Temporary flood storage is considered beneficial if the topography allows for levels to be managed to provide a reasonable assurance that flood storage is available when needed without adversely impacting other objectives.
	Setback Levees	Levee systems set back from a river channel or ditch system can be used to increase channel retardance, increase the channel conveyance, and increase floodplain connectivity allowing for increased storage within the river corridor. Setback levees require balancing the increased channel retardance with the increased conveyance volume from containing breakout flows. Setback levees are generally located where geotechnical stability is ensured. Setback levees require careful consideration to drainage of lands directly adjacent to the levees to ensure additional damages are not caused by a lack of an adequate outlet when high water conditions are present within the levee corridor.

Category	Strategy	Description
	Drainage	Drain tile and culvert sizing can be used to store runoff within the existing landscape. Utilizes existing depressions within the watershed that consist of agricultural fields bounded by existing roads. Culverts at the outlet of the depressions are sized so that runoff is stored for a short time so that agricultural lands are not adversely impacted.
	Off-Channel Impoundment	Off-channel impoundments are constructed to temporarily store and release flood waters when downstream flooding recedes. The most important consideration from an overall flood control standpoint is the timing of the storage and release of floodwaters. Off-channel impoundments typically consist of an embankment constructed around an area adjacent to a channel with topography conducive to storing runoff. From a locally acceptable perspective, the best suited locations are typically in already flood prone areas, where higher value crop land or pastureland is not required to be removed from production. A control structure is typically required to divert flows from the channel into the impoundment location.
	River Corridor Protection/ Restoration	Existing riparian corridors would be restored and protected to ensure proper geomorphic conditions are present. From a flood damage reduction standpoint, restoration of a degrading channel would allow for more frequent access to a vegetated floodplain to reduce downstream flow rates. Incised channels can be modified to reduce channel conveyance for increased floodplain connectivity. Setback levees are often required to contain the floodplain and to keep break out flows contained within the riparian corridor.
Protection/ Avoidance	Levees	Levee systems are meant to contain the natural floodwaters and the natural floodplain and can be used to protect communities, rural farmsteads, and cropland. If a levee system encroaches on the natural floodplain, the system can result in increased flows and downstream flooding must be considered and mitigated for. As with setback levees, consideration for drainage of land directly adjacent to the levee is critical. In many urban settings, this results in large lift stations being installed with high capacity electrical pumps to lift water over the levee during floods.
	Flood Warning and Emergency Response Planning	Flood warnings and emergency response begins with long- and short-term forecasts of flood potential and can lead to sandbagging, earthen levee construction, or other emergency protection methods, and ultimately evacuation, if necessary. Available timing between flood warning issuance and actual flood conditions is critical to ensure emergency response can be coordinated.
	Floodproofing	Floodproofing means making flood-prone property resistant to damage through raising buildings and essential access routes above the flood level and using flood resistant materials or construction techniques.
	Evacuation of the Floodplain	Landowners would be compensated through establishment of a set-aside easement to no longer operate on flood prone areas. (Emergency Watershed Protection Program, etc.)

2.1 TECHNICAL CONSIDERATIONS

A technical evaluation was completed to provide sufficient information of various strategy types for initial review to meet objectives from the Purpose and Need. The technical evaluation utilized the hydrologic and hydraulic models developed for the Judicial Ditch #19 Watershed. The 10-year and 100-year, 24-hour rainfall events were used to compare hydrologic and hydraulic model results. Multiple reporting locations were selected to evaluate hydrologic and hydraulic model results. The reporting locations are shown on **Figure A.1** in **Appendix A** and are further summarized below.

- JD 19 at Minnesota State Highway 32 – The upstream watershed at this location is approximately 37 square miles (36% of the JD 19 watershed).
- JD 19 at the Outlet of Nelson Slough – Flows are measured leaving the Nelson Slough Impoundment. The upstream watershed at this location is approximately 69 square miles (66% of the JD 19 watershed).
- JD 19 at US Highway 59 – The upstream watershed at this location is approximately 94 square miles (91% of the JD 19 watershed).
- JD 19 Outlet – Flows are measured downstream of the JD 19 watershed along the Tamarac River. Breakout flows occur along JD 19 near US Highway 59. This reporting location is downstream of where the breakout flows re-enter the system.

To accurately evaluate the technical consideration alternatives, both the changes in peak flow and inundated acres need to be compared to existing conditions. Inundated acres are calculated based on the Cropland Data Layer produced by the National Agricultural Statistics Service in 2017 (NASS, 2017). **Table 4** provides information on peak flow and inundated acres for the different technical considerations alternatives as discussed in the following sections.

2.1.1 REDUCE RUNOFF VOLUME

A sensitivity analysis was completed using the watershed hydrologic and hydraulic models to assess the maximum flood volume reduction benefits that could be attained by converting cropland to perennial vegetation. While not all strategies that categorically fit under the *Reduce Runoff Volume* category are focused on cropland conversion to perennial vegetation, this review assumed that other strategies within the category would hydrologically perform equivalent to perennial vegetation at their optimum design. For this analysis, cropland refers to lands with NLCD Land Use Codes of pasture/hay (81) and cultivated crops (82) (Homer, et al., 2015). While conversion of all the cropland within the watershed may not be practical to implement, it provides a baseline of the highest potential flood volume reduction in the watershed through the use of these practices. In total, based on the 2011 NLCD Land Use Codes, there are 47.6 square miles (46% of the total area) of cropland within the JD 19 Watershed. Two scenarios were evaluated for the purposes of this analysis. The scenarios consisted of converting cropland (pasture/hay and cultivated crops) to perennial vegetation in two regions of the JD 19 Watershed. The two regions are shown on **Figure 2.1.1** and the regions that were selected include;

- All cropland within the JD 19 Watershed would be converted to perennial vegetation. (30,452 acres, 46% of the total area)
- Cropland upstream (east) of Nelson Slough in the JD 19 Watershed would be converted to perennial vegetation. (16,468 acres, 25% of the total area)

While conversion from cropland to perennial vegetation would represent the maximum achievable hydrologic reduction to runoff volume, a more practical ability to implement would be somewhere between the results of the sensitivity analysis and the existing conditions.

NRCS Curve Number values were adjusted in the hydrologic model to assume that all cropland within the two regions discussed would be converted to perennial vegetation based on guidance from *TR-55 Urban Hydrology for Small Watersheds* (NRCS, 1986). **Table 4** below summarizes the existing and modified NRCS Curve Numbers that were used for this analysis.

Table 4: NRCS 24 Hour Curve Number Modifications for Perennial Vegetation Analysis

NLCD Land Use Code	Condition	Hydrologic Soil Type						
		A	B	C	D	A/D	B/D	C/D
Pasture/Hay (81)	*Existing*	49	69	79	84	84	84	84
	Perennial Vegetation	30	58	71	78	78	78	78
Cultivated Crops (82)	*Existing*	61	71	78	81	61	71	78
	Perennial Vegetation	30	58	71	78	30	58	78

The hydrologic and hydraulic models for the JD 19 Watershed were used to compute reduced volume flood hydrographs that would result from cropland conversion. **Table 5** shows peak flow reductions and changes to inundated acres for the two scenarios. Hydrographs showing preliminary modeling results are available in **Appendix A.2**.

2.1.2 INCREASE CONVEYANCE CAPACITY

Increased hydraulic capacity within the watershed would result in a reduced travel time and reduced access to natural floodplain areas. To estimate the effects of increased conveyance capacity within the JD 19 Watershed, existing crossings along the main of JD 19 were doubled in available flow area and analyzed using the hydraulic model. The crossings that were modified for this analysis are shown on **Figure 2.1.2**. A total of 10 crossings were modified. The analysis indicated that peak flow rates at US Highway 59 increased by 12% during the 100-year, 24-hour rainfall event. Peak flood flow rates at the JD 19 outlet had a negligible change during the 10-year, 24-hour rainfall event, and a 4% increase during the 100-year, 24-hour rainfall event. Refer to **Table 5** for changes in peak flow at the reporting locations and changes to inundated acres for this scenario. Hydrographs showing preliminary modeling results are available in **Appendix A.3**.

2.1.3 INCREASE TEMPORARY FLOOD STORAGE

The hydrologic model was used to estimate the effects of removing flood volume east of Nelson Slough for two scenarios. The scenarios include; 1) removing all runoff volume from east of Nelson Slough and 2) removing all runoff volume upstream of Minnesota Highway 32 as shown on **Figure 2.1.3**. **Table 5** shows peak flow reductions and changes to inundated acres for the two scenarios described for the 10-year and 100-year, 24-hour rainfall events. Hydrographs showing modeling results are available in **Appendix A.4**. Hydrographs from technical consideration alternatives may be identical depending on the alternative being analyzed relative to the reporting location and whether the upstream subwatershed was included in the alternative.

Table 5: Peak Flow Changes for Technical Consideration Alternatives

Scenario	Existing Conditions		Reduce Runoff Volume				Increased Roadway Conveyance Capacity		Increase Temporary Flood Storage			
			Cropland Conversion - Upstream of Nelson Slough		Cropland Conversion - Full Watershed				Upstream of MN32		Upstream of Nelson Slough	
Recurrence Interval and Location	*Peak Flow – 10-year,24 hour rainfall event, cfs (% Change)*											
Highway 32	467		351 *(-24.8%)*		351 *(-24.8%)*		483 *(3.4%)*		0 *(-100.0%)*		0 *(-100.0%)*	
Nelson Slough Outlet	234		192 *(-17.9%)*		192 *(-17.9%)*		234 *(0.0%)*		130 *(-44.4%)*		22 *(-90.6%)*	
US Highway 59	495		495 *(0.0%)*		321 *(-35.2%)*		490 *(-1.0%)*		495 *(0.0%)*		489 *(-1.2%)*	
JD 19 Outlet	949		951 *(0.2%)*		550 *(-42.0%)*		948 *(-0.1%)*		949 *(0.0%)*		928 *(-2.2%)*	
Recurrence Interval and Location	*Peak Flow – 100-year, cfs (% Change)*											
Highway 32	905		829 *(-8.4%)*		829 *(-8.4%)*		1,125 *(24.3%)*		0 *(-100.0%)*		0 *(-100.0%)*	
Nelson Slough Outlet	564		509 *(-9.8%)*		509 *(-9.8%)*		575 *(2.0%)*		393 *(-30.3%)*		29 *(-94.9%)*	
US Highway 59	1,317		1,320 *(0.2%)*		1,091 *(-17.2%)*		1,480 *(12.4%)*		1,317 *(0.0%)*		1,286 *(-2.4%)*	
JD 19 Outlet	3,042		3,042 *(0.0%)*		2,248 *(-26.1%)*		3,157 *(3.8%)*		3,042 *(0.0%)*		3,038 *(-0.1%)*	
Duration (hours)	*Inundated Acres – 10-year, 24 hour rainfall event (% Change)*											
	Cropland	Total	Cropland	Total	Cropland	Total	Cropland	Total	Cropland	Total	Cropland	Total
0-24	4,394	16,494	4,231 *(-3.7%)*	15,627 *(-5.3%)*	3,555 *(-19.1%)*	13,941 *(-15.5%)*	4,401 *(0.2%)*	16,525 *(0.2%)*	4,067 *(-7.4%)*	13,066 *(-20.8%)*	3,487 *(-20.6%)*	9,532 *(-42.2%)*
24-48	1,067	5,968	996 *(-6.7%)*	5,431 *(-9.0%)*	816 *(-23.5%)*	4,938 *(-17.3%)*	1,059 *(-0.7%)*	5,940 *(-0.5%)*	870 *(-18.5%)*	4,205 *(-29.5%)*	798 *(-25.2%)*	3,122 *(-47.7%)*
48-72	384	2,880	346 *(-9.9%)*	2,562 *(-11.0%)*	283 *(-26.3%)*	2,253 *(-21.8%)*	385 *(0.3%)*	2,883 *(0.1%)*	320 *(-16.7%)*	2,045 *(-29.0%)*	294 *(-23.4%)*	1,486 *(-48.4%)*
72-96	213	1,701	195 *(-8.5%)*	1,515 *(-10.9%)*	176 *(-17.4%)*	1,372 *(-19.3%)*	215 *(0.9%)*	1,710 *(0.5%)*	177 *(-16.9%)*	1,259 *(-26.0%)*	161 *(-24.4%)*	917 *(-46.1%)*
96-120	143	1,087	132 *(-7.7%)*	989 *(-9.0%)*	105 *(-26.6%)*	910 *(-16.3%)*	144 *(0.7%)*	1,089 *(0.2%)*	122 *(-14.7%)*	849 *(-21.9%)*	111 *(-22.4%)*	552 *(-49.2%)*
>120	1,069	8,069	1,035 *(-3.2%)*	7,640 *(-5.3%)*	951 *(-11.0%)*	7,232 *(-10.4%)*	1,065 *(-0.4%)*	8,059 *(-0.1%)*	935 *(-12.5%)*	6,399 *(-20.7%)*	847 *(-20.8%)*	4,818 *(-40.3%)*
TOTAL	7,269	36,199	6,935 *(-4.6%)*	33,763 *(-6.7%)*	5,886 *(-19.0%)*	30,646 *(-15.3%)*	7,270 *(0.0%)*	36,205 *(0.0%)*	6,491 *(-10.7%)*	27,824 *(-23.1%)*	5,698 *(-21.6%)*	20,427 *(-43.6%)*

2.2 PRACTICAL CONSIDERATIONS

The practicality of each strategy was also assessed to determine if there is a reasonable ability for the local sponsor to successfully finance, implement, and maintain the alternative.

2.2.1 LOCAL FINANCING AND ACCEPTANCE

The sponsoring local organization (SLO) operates under provisions of Minnesota Statute 103D, which allows for project specific taxing authority through the formulation of an assessment over the entire watershed district to finance project planning, installation, operation and maintenance, and rehabilitation.

2.2.2 ENVIRONMENTAL CONCERNS

The ability to successfully address regulatory concerns was considered during the strategy evaluation. While the planning effort will be used to identify potential impacts and work to minimize any such impacts, if certain strategies were likely to lead to significant environmental known issues they were eliminated from further consideration.

2.2.3 ABILITY TO IMPLEMENT

The ability of strategies to be permitted and implemented in a reasonable timeframe was considered to ensure that outcomes from the planning effort can efficiently be implemented after permitting is completed and financing is in place. The primary considerations were the SLO's ability to secure land rights, assurances of participation for any required voluntary programs, and potential for violation of current local/state laws and zoning ordinances.

2.3 OUTCOMES

From the initial strategy evaluation, the following strategies were selected to move forward with preliminary alternative identification:

- No-Action
- Other Beneficial Uses of Stored Water (Reduce Runoff Volume)
- Drainage (Increase Conveyance Capacity)
- On-Channel Impoundment (Increase Temporary Flood Storage)
- Off-Channel Impoundment (Increase Temporary Flood Storage)

Table 6 provides a list of strategies within each category, and rationale for strategies' determination to either carry forward or eliminate from further review.

Table 6: Strategy Review

Category	Strategy	Determination	Rationale
No-Action	No-Action	Carry Forward	• Required; based on public comment and the SLO's desire to pursue solutions for flood damages, this alternative is not locally preferred. • For the JD #19 Watershed Plan, existing conditions is the No-Action alternative.
Reduce Runoff Volume	Cropland Better Management Practices	Eliminate	• Alternative considered undesirable for local landowners. • While not practical as an individual alternative, this concept can be a component of other alternative enhancements.
	Conversion to Grassland	Eliminate	• Converting prime farmland and farmland of statewide importance to grassland is considered undesirable for local landowners.
	Conversion to Forest	Eliminate	• Converting prime farmland and farmland of statewide importance to forest is considered undesirable for local landowners. • Implementation of conversion to forest would take considerable amount of time, and the alternative would not be effective for several years.
	Restore or Create Wetlands	Eliminate	• Wetland restoration within the sub-watershed may have potential to lower downstream peak water surface elevations. • The ability of the SLO to successfully implement in a reasonable timeframe and maintain sufficient locations is limited, given land rights are typically secured through a voluntary easement program. • It is not practical for the SLO to successfully implement sufficient acres to attain the objectives in the Purpose and Need. • While not practical as an individual alternative, wetland restoration/creation can be a component of other alternative enhancements.

Category	Strategy	Determination	Rationale
	Other Beneficial Uses of Stored Water	Carry Forward	• Currently the East Park WMA storage reservoir, Nelson Slough, exists within the JD #19 sub-watershed. There is local interest to modify/update the current operation plan to increase Flood Damage Reduction Benefits at the site.
Increase Conveyance Capacity	Channelization	Eliminate	• Channelization throughout the watershed would not be practical because shorter flow paths produce larger flow rates downstream of the planning watershed and the entire sub-watershed is made up of artificial ditches part of the JD #19 ditch system.
	Drainage	Carry Forward	• Increased drainage within the JD #19 ditch system or from farm fields would cause increased peak flow and inundation in downstream areas. • Additional measures may be needed to mitigate any increased downstream flow rates.
	Flood Water Diversion	Eliminate	• Diversion within the JD #19 sub-watershed would not be practical because shorter flow paths produce larger flow rates downstream of the planning watershed. • With the complex layout of the JD #19 ditch system a diversion is not practical as an alternative.
	Setback Levees	Eliminate	• Setback levees in areas along JD #19 would minimize breakout flows and provide floodplain storage. Narrowed floodplains would cause increased peak flow and inundation in downstream areas. • Extensive measures would need to be taken in order to route runoff from adjacent lands into JD #19.
	Increase Roadway Capacity	Eliminate	• Increasing conveyance capacity could be used in localized areas to reduce ag damages by removal of cropland floodplain. However, model results (Section 2.1.2) showed that increasing conveyance capacity would increase flow rates downstream of the planning watershed.

Category	Strategy	Determination	Rationale
Increase Temporary Storage	On-Channel Impoundment	Carry Forward	• Storage would be used to attenuate peak flow rates associated with flood damages. • Model results indicate that attenuated flood volume would reduce peak outflows downstream of the planning watershed.
	Culvert Sizing	Eliminate	• Due to land slope and breakout elevations, systematically down-sizing culverts throughout the project area to retain water behind roadways will not meet the overall project goal of 10-year protection of agricultural lands.
	Wetland Restoration/ Creation	Eliminate	• Wetland restoration within the sub-watershed may have potential to lower downstream peak water surface elevations. • The ability of the SLO to successfully implement in a reasonable timeframe and maintain sufficient locations is limited, given land rights are typically secured through a voluntary easement program. • It is not practical for the SLO to successfully implement sufficient acres to attain the objectives in the Purpose and Need. • While not practical as an individual alternative, wetland restoration/creation can be a component of other alternative enhancements.
	Setback Levees	Eliminate	• Levees would be used to contain breakout flows and provide floodplain storage along portions of the JD #19 system. • Measures may be needed to mitigate flow rate increases because of elimination of breakout flows.
	Drainage	Eliminate	• The ability of the SLO to successfully implement drain tile or culvert sizing scheme on private lands in a reasonable timeframe is limited and not practical.
	Off-Channel/On-Channel Impoundment	Carry Forward	• Storage would be used to attenuate peak flow rates associated with flood damages. • Model results show that attenuated flood volume would reduce peak outflows downstream of the planning watershed.

Category	Strategy	Determination	Rationale
	River Corridor Restoration/ Protection	Eliminate	• Since no existing river corridors exist within this sub-watershed this strategy is not practical.
Protection/ Avoidance	Levees	Eliminate	• Ring levees around farmsteads were not considered for an individual alternative because they would not adequately address the objectives in the Purpose and Need.
	Flood Warning and Emergency Response Planning	Eliminate	• Not practical for the JD #19 sub-watershed. • This would have no effect on agricultural land damage and would not adequately address the objectives in the Purpose and Need.
	Floodproofing	Eliminate	• Floodproofing might reduce flood risk for some properties, but it is impractical to floodproof every property at risk within the watershed. • Floodproofing would have no effect on agricultural land damages and would not adequately address the objectives in the Purpose and Need.
	Evacuation of the Floodplain	Eliminate	• The evacuation of the floodplain would have positive effects utilizing existing flood storage and partially remove the need for a flood damage reduction type project within the sub-watershed. However, a large amount of land within the watershed would need to adopt evacuation to meet the projects established goals for flood damage reduction. It is not practicable to assume so many different landowners within the watershed would be willing to embrace these conservation measures.

3 PRELIMINARY ALTERNATIVES

The strategies identified in the Initial Strategy Evaluation were used to preliminarily identify a range of alternatives. These alternatives were then analyzed to determine their potential to attain the objectives from the Purpose and Need statement. The following sections provide a brief description of each alternative considered.

For the JD 19 Watershed, the no-action alternative, is identical to existing conditions within the watershed. No land use changes, potential hydrologic changes, or potential hydraulic changes are anticipated if an alternative is not selected as part of the Watershed Plan.

3.1 ALTERNATIVE IDENTIFICATION AND ANALYSIS

Alternatives identified for this phase of alternative investigation consisted of review of the existing conditions hydrologic and hydraulic model, available topographic field survey data, LiDAR topographic data, and other readily available geospatial information. A watershed map illustrating the location(s) of the identified alternative components is shown on **Figure 3.1a**. Throughout the alternative development process, an effort was made to minimize impacts to wetlands, biodiverse areas, and building sites. Therefore, alternative components were located to minimize the impact to native plant species identified by the Minnesota County Biological Survey (MCBS). Native plant species within the JD 19 Watershed are shown on **Figure 3.1b**. The 10-year and 100-year, 24-hour rainfall events were used to compare hydrologic and hydraulic model results. In order to evaluate the hydrologic and hydraulic model results, the same reporting locations presented in Section 2.1 were used as shown on **Figure B.1** in **Appendix B**.

3.1.1 ALTERNATIVE 1 – DRAINAGE IMPROVEMENT

The hydraulic model for the JD 19 Watershed was used to estimate the current capacity of the ditch system. Currently the JD 19 system is between a 5-year and 10-year capacity. Meaning that between a 5-year and 10-year event, the water surface elevation in the ditch matches the approximate adjacent natural ground elevation. When JD 19 water surface elevations are at or above this level, adjacent land cannot drain into the ditch, causing flows to break out of the ditch and inundate adjacent land. A drainage improvement alternative was analyzed with the hydraulic model to evaluate the ability to meet the objectives from the Purpose and Need. The drainage improvement alternative would consist of improving portions of the JD 19 Main system to a 10-year capacity. During a 10-year, 24-hour event, water levels within the improved ditch would be below adjacent natural ground elevation providing flood protection to adjacent lands and allow side inlet pipes to drain more efficiently as water levels within the ditch subside. This alternative includes improving approximately 22.9 miles of the JD 19 Main system from 460th Street NE to the outlet as shown on **Figure 3.1.1**. Structures along the improvement were not increased. Results from the Increased Conveyance Capacity strategy analysis indicate that the existing structures are adequate for passing the 10-year event. Structure sizes remained the same, however the structures were lowered to the new proposed channel grade.

The drainage improvement alternative was analyzed with the hydraulic model to evaluate the ability to meet objectives from the Purpose and Need. Total inundated acres for the 10-year, 24-hour event would be reduced by 2%. Peak flows at US Highway 59 were increased by 12% and 30% for the 10-year and 100-year, 24-hour events, respectively. At the JD 19 outlet, peak flows were increased by 1% for the 10-year and 8% for the 100-year, 24-hour events. The increase in peak flows at the outlet of the JD 19 Watershed would result in increased damages downstream on the Tamarac River. **Table 8** and **Table 9** show the resulting peak flow and volume changes at the identified reporting locations, and inundated acreage changes in the JD 19 Watershed. Hydrographs showing preliminary modeling results are available in **Appendix B.2**.

3.1.2 ALTERNATIVE 2 – BRANCH M IMPOUNDMENT SITE

Alternative 2 consists of a proposed impoundment site in East Park Township along Branch M of JD 19. The site would consist of an impoundment constructed of earthen embankments primarily located in Sections 33 and 34 in East Park Township and Sections 3 and 4 of New Maine Township. The impoundment would be constructed across JD 19 Branch M. In the upstream watershed, a 1.8 mile diversion ditch would divert flows from the upstream watersheds of Branch J and Branch K into the headwaters of Branch M. Branch M carries flows from the upstream watershed into the site. The impoundment site would include an outlet riser structure and earthen auxiliary spillway.

Branch M Impoundment Site would have a drainage area of 10.7 square miles and would provide 1,723 acre-feet (3.0 inches) of flood storage at the gated pool with a total of 2,890 acre-feet (5.1 inches) of flood storage below the auxiliary spillway. A portion of the drainage area that currently contributes to Nelson Slough will be diverted to the impoundment site via the diversion ditch. The flood pool would require a total estimated area of 1,060 acres at the top of dam elevation. Impoundment site statistics are shown in **Table 7**. The inundated area within the impoundment site would vary depending on the flood event. A site map for the Branch M Impoundment Site is shown on **Figure 3.1.2**.

The hydraulic model was modified to include the Branch M Impoundment Site and was used to analyze the 10-year and 100-year, 24-hour events. At US Highway 59, peak flow rates are reduced by 0% for the 10-year event and 2% for the 100-year event. The volume of flow at US Highway 59 is reduced by 12% and 7% for the 10-year and 100-year event, respectively. The total inundated acres during the 10-year event would be reduced by 2%. **Table 8** and **Table 9** show the resulting peak flow and volume changes at the identified reporting locations, and inundated acreage changes in the JD 19 Watershed. Inundated acres within the impoundment flood pool are not included in the reported values. Hydrographs at the identified reporting locations are available in **Appendix B.3**.

3.1.3 ALTERNATIVE 3 – BRANCH J IMPOUNDMENT SITE OPTION 1

Alternative 3 consists of a proposed impoundment site in Huntly Township along Branch J of JD 19. The site would consist of an impoundment constructed of earthen embankments primarily located in Sections 16, 17, 18, 19, and 20 in Huntly Township. The impoundment would be constructed across JD 19 Branch J near the confluence of Branch J and JD 19 Main. Branch K and Branch J carry flows from the upstream watershed into the site. The impoundment site would include an outlet riser structure and earthen auxiliary spillway.

Branch J Impoundment Site Option 1 would have a drainage area of 9.5 square miles and would provide 887 acre-feet (3.1 inches) of flood storage at the gated pool with a total of 1,154 acre-feet (6.9 inches) of flood storage below the auxiliary spillway. The site and drainage area are located entirely upstream of Nelson Slough. The flood pool would require a total estimated area of 1,714 acres at the top of dam elevation. Impoundment site statistics are shown in **Table 7**. The inundated area within the impoundment site would vary depending on the flood event. A site map for the Branch J Impoundment Site Option 1 is shown on **Figure 3.1.3**.

The hydraulic model was modified to include the Branch J Impoundment Site Option 1 and was used to analyze the 10-year and 100-year, 24-hour events. At US Highway 59, peak flow rates are reduced by 0% for the 10-year and 100-year event. The volume of flow at US Highway 59 is reduced by 14% and 17% for the 10-year and 100-year event, respectively. The total inundated acres during the 10-year event would be reduced by 8%. **Table 8** and **Table 9** show the resulting peak flow and volume changes at the identified reporting locations, and inundated acreage changes in the JD 19 Watershed. Inundated acres within the impoundment flood pool are not included in the reported values. Hydrographs at the identified reporting locations are available in **Appendix B.3**.

3.1.4 ALTERNATIVE 4 – BRANCH J IMPOUNDMENT SITE OPTION 2

Alternative 4 consists of a proposed impoundment site in Huntly Township along Branch J of JD 19. The site would consist of an impoundment constructed of earthen embankments primarily located in Sections 16, 17, 18, 19, 20, and 21 in Huntly Township. The impoundment would be constructed across JD 19 Branch J near the confluence of Branch J and JD 19 Main. Two diversion ditches would be constructed in the upper watershed to divert water from Branch H and Branch I. In total, the two diversions would be less than 0.4 miles. Branches J, K, H, I, and the diversion channels carry flows from the upstream watershed into the site. The impoundment site would include an outlet riser structure and earthen auxiliary spillway.

Branch J Impoundment Site Option 2 would have a drainage area of 14.6 square miles and would provide 1,009 acre-feet (3.1 inches) of flood storage at the gated pool with a total of 1,427 acre-feet (6.0 inches) of flood storage below the auxiliary spillway. The site and drainage area are located entirely upstream of Nelson Slough. The flood pool would require a total estimated area of 1,854 acres at the top of dam elevation. Impoundment site statistics are shown in **Table 7**. The inundated area within the impoundment site would vary depending on the flood event. A site map for the Branch J Impoundment Site Option 2 is shown on **Figure 3.1.4**.

The hydraulic model was modified to include the Branch J Impoundment Site Option 1 and was used to analyze the 10-year and 100-year, 24-hour events. At US Highway 59, peak flow rates are reduced by 0% for the 10-year and 100-year event. The volume of flow at US Highway 59 is reduced by 15% and 19% for the 10-year and 100-year event, respectively. The total inundated acres during the 10-year event would be reduced by 3%. **Table 8** and **Table 9** show the resulting peak flow and volume changes at the identified reporting locations, and inundated acreage changes in the JD 19 Watershed. Inundated acres within the impoundment flood pool are not included in the reported values. Hydrographs at the identified reporting locations are available in **Appendix B.3**.

3.1.5 ALTERNATIVE 5 – EAST PARK TOWNSHIP IMPOUNDMENT SITE

Alternative 5 consists of a proposed impoundment site in East Park Township. The site would consist of an impoundment constructed of earthen embankments primarily located in Sections 25 and 26 in East Park Township. Runoff from portions of Branches L, M, J, and K would be diverted to the impoundment set. A total of 1 mile of diversion ditches would be constructed in the upper watershed to divert floodwaters into the site. The impoundment site would include an outlet riser structure and earthen auxiliary spillway.

East Park Township Impoundment Site would have a drainage area of 7.9 square miles and would provide 353 acre-feet (3.0 inches) of flood storage at the gated pool with a total of 479 acre-feet (4.8 inches) of flood storage below the auxiliary spillway. The site and drainage area are located entirely upstream of Nelson Slough. The flood pool would require a total estimated area of 685 acres at the top of dam elevation.

Impoundment site statistics are shown in **Table 7**. The inundated area within the impoundment site would vary depending on the flood event. A site map for the East Park Township Impoundment Site is shown on **Figure 3.1.5**.

The hydraulic model was modified to include the East Park Township Impoundment Site and was used to analyze the 10-year and 100-year, 24-hour events. At US Highway 59, peak flow rates are reduced by 0% for the 10-year and 100-year event. The volume of flow at US Highway 59 is reduced by 6% and 4% for the 10-year and 100-year event, respectively. The total inundated acres during the 10-year event would be reduced by 1%. **Table 8** and **Table 9** show the resulting peak flow and volume changes at the identified reporting locations, and inundated acreage changes in the JD 19 Watershed. Inundated acres within the impoundment flood pool are not included in the reported values. Hydrographs at the identified reporting locations are available in **Appendix B.3**.

3.1.6 ALTERNATIVE 6 – LINCOLN TOWNSHIP IMPOUNDMENT SITE

Alternative 6 consists of a proposed impoundment site in Lincoln and Nelson Park Townships along the mainstem of JD 19. The site would consist of an impoundment constructed of earthen embankments primarily located in Sections 18, 19, and 20 in Lincoln Township and Sections 13 and 24 in Nelson Park Township. The impoundment would be constructed across JD 19 near the confluence of JD 19 and the Tamarac River. The impoundment site would include an ungated low flow culvert along JD 19. When flows exceed the capacity of the low flow culvert, floodwaters upstream would be stored within the site. The site would also include a riser tower and earthen embankment.

Lincoln Township Impoundment Site would have a drainage area of 104.8 square miles and would provide 1,071 acre-feet (1.2 inches) of flood storage at the gated pool with a total of 1,185 acre-feet (1.6 inches) of flood storage below the auxiliary spillway. The site is located at the outlet of the JD 19 watershed. The flood pool would require a total estimated area of 1,610 acres at the top of dam elevation. Impoundment site statistics are shown in **Table 7**. The inundated area within the impoundment site would vary depending on the flood event. A site map for the Lincoln Township Impoundment Site is shown on **Figure 3.1.6**.

The hydraulic model was modified to include the Lincoln Township Impoundment Site and was used to analyze the 10-year and 100-year, 24-hour events. At US Highway 59, peak flow rates and volumes are unchanged for the 10-year and 100-year event. The peak flow rate at the outlet of the JD 19 Watershed is reduced by 61% and 53% for the 10-year and 100-year event, respectively. The total inundated acres during the 10-year event would be reduced by 6%. **Table 8** and **Table 9** show the resulting peak flow and volume changes at the identified reporting locations, and inundated acreage changes in the JD 19 Watershed. Inundated acres within the impoundment flood pool are not included in the reported values. Hydrographs at the identified reporting locations are available in **Appendix B.3**.

3.1.7 ALTERNATIVE 7 – NELSON SLOUGH IMPROVEMENTS

Alternative 7 consists of improvements to the Nelson Slough impoundment site. The improvements include raising the top of dam from 1106.3 to 1109.0. Raising the top of dam will bring the impoundment site into compliance with current dam safety design standards. The outlet structure would also be reconfigured. The new outlet structure would be a concrete weir structure with 3 stages. The first stage has two 20-foot openings at 1102.0. The wider and lower first stage outlet will allow for the normal water level to be near 1102.3 which is the current normal pool operating level. During normal operations one 20-foot opening would be closed and only operated during drawdown conditions. Results presented in this report only have a 20-foot wide first stage opening. The second stage is a 70-foot opening at 1104. The third stage is a 300-foot opening at 1105.5. This outlet configuration would act as both the primary and secondary spillway. The extents of the drainage area and flood pools at the different stages are shown on **Figure 3.1.7a** and **Figure 3.1.7b**.

The site would be designed to incorporate removable stop logs for the first and second stage outlets. The stop logs would be used to control spring runoff volume from the upstream watershed. Results presented in this report show both open condition (no stop logs in place) and closed conditions (both the first and second stage outlets with stop logs in place).

The hydraulic model was modified to include the Nelson Slough Improvements and was used to analyze the 10-year and 100-year, 24-hour events. At US Highway 59, peak flow rates for the open (no stop logs) scenario are reduced by 3% for the 10-year and 2% for the 100-year event. At US Highway 59, peak flow rates for the closed (stop logs in place) scenario are reduced by 5% for the 10-year and 3% for the 100-year event. The volume of flow at US Highway 59 for the open scenario is reduced by 19% and 7% for the 10-year and 100-year event, respectively. The volume of flow at US Highway 59 for the closed scenario is reduced by 63% and 48% for the 10-year and 100-year event, respectively. The total inundated acres during the 10-year event would be reduced by 13% for both open and closed scenarios. **Table 8** and **Table 9** show the resulting peak flow and volume changes at the identified reporting locations, and inundated acreage changes in the JD 19 Watershed. Inundated acres within the impoundment flood pool are not included in the reported values. Hydrographs at the identified reporting locations are available in **Appendix B.3**.

Table 7:: Impoundment Site Statistics

Site	Drainage Area	Gated Elevation	Top of Dam Elevation	Max Dam Height	Gated Storage			Auxiliary Spillway			Top of Dam		
	sq. mi.	*NAVD88*	*NAVD88*	*feet*	*acres*	*ac-ft*	*inches*	*acres*	*ac-ft*	*inches*	*acres*	*ac-ft*	*inches*
Branch M	10.7	1,105.0	1,110.0	13.0	536	1,723	3.0	839	2,890	5.1	1,060	5,955	10.5
Branch J - Option 1	9.5	1,127.6	1,132.6	10.6	887	1,562	3.1	1,154	3,515	6.9	1,714	8,080	15.9
Branch J - Option 2	14.6	1,128.5	1,133.5	11.5	1,009	2,433	3.1	1,427	4,682	6.0	1,854	9,749	12.6
East Park Township	7.9	1,113.6	1,118.6	12.6	353	1,253	3.0	479	2,020	4.8	685	3,884	9.2
Lincoln Township	104.8	1,045.0	1,050.0	16.0	1,071	6,630	1.2	1,185	8,722	1.6	1,610	12,986	2.3

Table 8: Peak Flow Changes for Identified Alternatives

Scenario	Existing Conditions		Alternative 1 Drainage Improvement		Alternative 2 Branch M Impoundment Site		Alternative 3 Branch J Impoundment Site Option 1		Alternative 4 Branch J Impoundment Site Option 2		Alternative 5 East Park Township Impoundment Site		Alternative 6 Lincoln Township Impoundment Site		Alternative 7 Nelson Slough Improvements Open		Alternative 7 Nelson Slough Improvements Closed	
Recurrence Interval and Location	*Peak Flow – 10-year, cfs (% Change)*																	
Highway 32	467		739 *(58.2%)*		467 *(0.0%)*		467 *(0.0%)*		467 *(0.0%)*		467 *(0.0%)*		467 *(0.0%)*		467 *(0.0%)*		467 *(0.0%)*	
Nelson Slough Outlet	234		284 *(21.4%)*		216 *(-7.7%)*		174 *(-25.6%)*		166 *(-29.1%)*		211 *(-9.8%)*		234 *(0.0%)*		133 *(-43.2%)*		0 (-100.0%)	
US Highway 59	495		554 *(11.9%)*		493 *(-0.4%)*		494 *(-0.2%)*		494 *(-0.2%)*		494 *(-0.2%)*		495 *(0.0%)*		479 *(-3.2%)*		470 (-5.1%)	
JD 19 Outlet	949		960 *(1.2%)*		946 *(-0.3%)*		948 *(-0.1%)*		948 *(-0.1%)*		947 *(-0.2%)*		373 *(-60.7%)*		919 *(-3.2%)*		906 (-4.5%)	
Recurrence Interval and Location	*Peak Flow – 100-year, cfs (% Change)*																	
Highway 32	905		1,166 *(28.8%)*		905 *(0.0%)*		905 *(0.0%)*		905 *(0.0%)*		905 *(0.0%)*		905 *(0.0%)*		905 *(0.0%)*		905 *(0.0%)*	
Nelson Slough Outlet	564		839 *(48.8%)*		545 *(-3.4%)*		353 *(-37.4%)*		344 *(-39.0%)*		521 *(-7.6%)*		564 *(0.0%)*		485 *(-14.0%)*		123 *(-78.2%)*	
US Highway 59	1,317		1,700 *(29.1%)*		1,295 *(-1.7%)*		1,314 *(-0.2%)*		1,314 *(-0.2%)*		1,314 *(-0.2%)*		1,317 *(0.0%)*		1,293 *(-1.8%)*		1,279 *(-2.9%)*	
JD 19 Outlet	3,042		3,290 *(8.2%)*		3,039 *(-0.1%)*		3,042 *(0.0%)*		3,042 *(0.0%)*		3,041 *(0.0%)*		1,446 *(-52.5%)*		3,036 *(-0.2%)*		3,031 *(-0.4%)*	
Duration (hours)	*Inundated Acres – 10-year (% Change)*																	
	Crop.	*Total*	*Crop.*	*Total*	*Crop.*	*Total*	*Crop.*	*Total*	*Crop.*	*Total*	*Crop.*	*Total*	*Crop.*	*Total*	*Crop.*	*Total*	*Crop.*	*Total*
0-24	4,394	16,494	4,468 (2%)	17,006 (3%)	4,408 (0%)	16,177 (-2%)	3,805 (-13%)	14,479 (-12%)	4,416 (1%)	16,272 (-1%)	4,368 (-1%)	16,225 (-2%)	3,563 (-19%)	14,521 (-12%)	3,856 (-12%)	14,835 (-10%)	3,856 (-12%)	14,839 (-10%)
24-48	1,067	5,968	1,009 (-5%)	5,816 (-3%)	1,012 (-5%)	5,800 (-3%)	1,005 (-6%)	5,534 (-7%)	1,031 (-3%)	5,579 (-7%)	1,067 (0%)	5,943 (0%)	1,055 (-1%)	5,985 (0%)	1,088 (2%)	6,036 (1%)	1,088 (2%)	6,044 (1%)
48-72	384	2,880	355 (-8%)	2,699 (-6%)	370 (-4%)	2,824 (-2%)	368 (-4%)	2,708 (-6%)	382 (-1%)	2,666 (-7%)	369 (-4%)	2,873 (0%)	380 (-1%)	2,857 (-1%)	370 (-4%)	2,722 (-6%)	371 (-3%)	2,733 (-5%)
72-96	213	1,701	201 (-6%)	1,557 (-9%)	203 (-5%)	1,635 (-4%)	213 (0%)	1,609 (-5%)	220 (3%)	1,594 (-6%)	212 (-1%)	1,684 (-1%)	219 (3%)	1,688 (-1%)	201 (-6%)	1,479 (-13%)	204 (-4%)	1,492 (-12%)
96-120	143	1,087	139 (-3%)	1,027 (-6%)	152 (6%)	1,080 (-1%)	145 (1%)	1,062 (-2%)	134 (-6%)	1,035 (-5%)	146 (2%)	1,107 (2%)	154 (8%)	1,096 (1%)	137 (-4%)	883 (-19%)	138 (-4%)	894 (-18%)
>120	1,069	8,069	1,017 (-5%)	7,531 (-7%)	1,049 (-2%)	7,910 (-2%)	1,061 (-1%)	7,916 (-2%)	1,103 (3%)	7,871 (-3%)	1,057 (-1%)	8,014 (-1%)	1,024 (-4%)	7,943 (-2%)	1,012 (-5%)	5,594 (-31%)	1,006 (-6%)	5,542 (-31%)
TOTAL	7,269	36,199	7,188 (-1%)	35,635 (-2%)	7,196 (-1%)	35,426 (-2%)	6,597 (-9%)	33,309 (-8%)	7,285 (0%)	35,018 (-3%)	7,220 (-1%)	35,846 (-1%)	6,395 (-12%)	34,091 (-6%)	6,665 (-8%)	31,549 (-13%)	6,664 (-8%)	31,545 (-13%)

Table 9: Volume Change at Reporting Locations for Identified Alternatives

Scenario	Existing Conditions	Alternative 1 Drainage Improvement	Alternative 2 Branch M Impoundment Site	Alternative 3 Branch J Impoundment Site Option 1	Alternative 4 Branch J Impoundment Site Option 2	Alternative 5 East Park Township Impoundment Site	Alternative 6 Lincoln Township Impoundment Site	Alternative 7 Nelson Slough Improvements Open	Alternative 7 Nelson Slough Improvements Closed
Recurrence Interval and Location	*Volume – 10-year, ac-ft (% Change)*								
Highway 32	1,538	1,964 *(28%)*	1,538 *(0%)*	1,537 *(0%)*	1,538 *(0%)*	1,539 *(0%)*	1,537 *(0%)*	1,538 *(0%)*	1,538 *(0%)*
Nelson Slough Outlet	2,774	3,305 *(19%)*	2,564 *(-8%)*	2,171 *(-22%)*	2,114 *(-24%)*	2,541 *(-8%)*	2,774 *(0%)*	1,962 *(-29%)*	0 *(-100%)*
US Highway 59	4,363	4,856 *(11%)*	3,853 *(-12%)*	3,762 *(-14%)*	3,701 *(-15%)*	4,110 *(-6%)*	4,363 *(0%)*	3,527 *(-19%)*	1,602 *(-63%)*
JD 19 Outlet	6,262	6,733 *(8%)*	5,760 *(-8%)*	5,668 *(-10%)*	5,605 *(-11%)*	6,017 *(-4%)*	2,382 *(-62%)*	5,412 *(-14%)*	3,547 *(-43%)*
Recurrence Interval and Location	*Volume – 100-year, ac-ft (% Change)*								
Highway 32	3,010	3,813 *(27%)*	3,010 *(0%)*	3,010 *(0%)*	3,010 *(0%)*	3,008 *(0%)*	3,010 *(0%)*	3,010 *(0%)*	3,010 *(0%)*
Nelson Slough Outlet	6,181	8,598 *(39%)*	5,954 *(-4%)*	4,445 *(-28%)*	4,213 *(-32%)*	5,757 *(-7%)*	6,181 *(0%)*	5,429 *(-12%)*	1,309 *(-79%)*
US Highway 59	10,145	12,717 *(25%)*	9,401 *(-7%)*	8,468 *(-17%)*	8,233 *(-19%)*	9,754 *(-4%)*	10,145 *(0%)*	9,423 *(-7%)*	5,323 *(-48%)*
JD 19 Outlet	15,697	17,936 *(14%)*	14,839 *(-6%)*	14,012 *(-11%)*	13,783 *(-12%)*	15,281 *(-3%)*	5,664 *(-64%)*	14,803 *(-6%)*	10,752 *(-32%)*

3.2 PRELIMINARY EVALUATION

The identified preliminary alternatives were evaluated using the hydrologic and hydraulic model in order to assess their potential to meet objectives from the Purpose and Need. The indicators described in Section 1 were used to determine if the alternatives meet the objectives from the Purpose and Need. Available GIS data was also reviewed to estimate potential resource impacts. Based on this review, the alternatives that will be carried forward are listed as follows:

- Alternative 7 – Nelson Slough Improvements

All of the alternatives failed to meet Indicator 2, 20% peak flow reduction at US Highway 59. Results indicate that the peak flow at US Highway 59 is driven by localized runoff. The alternatives do show significant changes to the volume of flow passing US Highway 59. In general, the volume of flow is reduced on the trailing limb when the upstream watershed contributes to US Highway 59.

Table 10 provides information on the ability of each Alternative to meet objectives defined in the Purpose and Need statement based on performance for the indicators discussed in Section 1 and provides the rationale to either carry forward or eliminate alternatives from further consideration. Due to the preliminary nature of this review, if the alternative peak flow was within 1% of the required peak flow reduction for an indicator, it was considered passing for that indicator. Alternatives were categorized as either meeting the indicator, partially meeting the indicator or failing to meet the indicator. Alternatives evaluated in this report should be considered conceptual and are subject to revision as each of the selected alternatives are evaluated in detail.

Table 10: Preliminary Alternative Evaluation Summary

Alternative	INDICATOR 1 Reduce total inundation for flood durations between 24 and 120 hours (1-5 days) for the 10-year event by 5% *(Percent Change)*	INDICATOR 2 Reduce the peak flow rate at US Highway 59 by 20% *(Percent Change)*		INDICATOR 3 Reduce the volume of flow at US Highway 59 by 20% *(Percent Change)*		INDICATOR 4 No increase in peak flow rate at the JD 19 outlet *(Percent Change)*		Determination	Additional Comments
		10-year	100-year	10-year	100-year	10-year	100-year		
1. Drainage Improvement	YES -5%	NO 12%	NO 29%	NO 11%	NO 25%	NO 1%	NO 8%	Eliminate	• Alternative does not meet Indicator 2, 3 or 4. • Drainage Improvement causes an increase in peak flows in the lower portion of JD 19 Watershed and at the outlet of the watershed.
2. Branch M Impoundment Site	Partially Met -3%	NO 0%	Partially Met -2%	Partially Met -12%	Partially Met -7%	YES 0%	YES 0%	Eliminate	• Alternative does not meet Indicator 2. • The location of the impoundment site would have permitting difficulties with multiple native plant species existing within the impoundment.
3. Branch J Impoundment Site Option 1	YES -6%	NO 0%	NO 0%	Partially Met -14%	Partially Met -17%	YES 0%	YES 0%	Eliminate	• Alternative does not meet Indicator 2. • The impoundment site is located upstream of Nelson Slough. Nelson Slough minimizes the downstream benefit of the site
4. Branch J Impoundment Site Option 2	YES -7%	NO 0%	NO 0%	Partially Met -15%	YES -19%	YES 0%	YES 0%	Eliminate	• Alternative does not meet Indicator 2. • The impoundment site is located upstream of Nelson Slough. Nelson Slough minimizes the downstream benefit of the site
5. East Park Township Impoundment Site	NO 0%	NO 0%	NO 0%	Partially Met -6%	Partially Met -4%	YES 0%	YES 0%	Eliminate	• Alternative does not meet Indicator 1 or 2. • The impoundment site is located upstream of Nelson Slough. Nelson Slough minimizes the downstream benefit of the site
6. Lincoln Township Impoundment Site	NO 0%	NO 0%	NO 0%	NO 0%	NO 0%	YES -61%	YES -53%	Eliminate	• Alternative does not meet Indicator 1, 2 or 3. • The location of the impoundment site would not provide a benefit to the JD 19 Watershed.
7. Nelson Slough Improvements Open	YES -4%	Partially Met -3%	Partially Met -2%	YES -19%	Partially Met -7%	YES -3%	YES 0%	**Carry Forward**	• Alternative meets or partially meets all indicators.
7. Nelson Slough Improvements Closed	YES -4%	Partially Met -5%	Partially Met -3%	YES -63%	YES -48%	YES -5%	YES 0%	**Carry Forward**	• Alternative meets or partially meets all indicators. • Operating the structure with the stop logs in place provides greater reductions to positionally meet the Indicators.

4 REFERENCES

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FIGURES

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Figure 1.2: East Park Flood Control WMA (Nelson Slough)
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Figure 2.1.2: Increased Conveyance Capacity
Figure 2.1.3: Increased Temporary Flood Storage
Figure 3.1a: Identified Alternatives
Figure 3.1b: Environmental and Public Concerns
Figure 3.1.1: Alternative 1 – Drainage Improvement
Figure 3.1.2: Alternative 2 – Branch M Impoundment Site
Figure 3.1.3: Alternative 3 – Branch J Impoundment Site Option 1
Figure 3.1.4: Alternative 4 – Branch J Impoundment Site Option 2
Figure 3.1.5: Alternative 5 – East Park Township Impoundment Site
Figure 3.1.6: Alternative 6 – Lincoln Township Impoundment Site
Figure 3.1.7a: Alternative 7 – Nelson Slough Improvements
Figure 3.1.7b: Alternative 7 – Nelson Slough Elevations

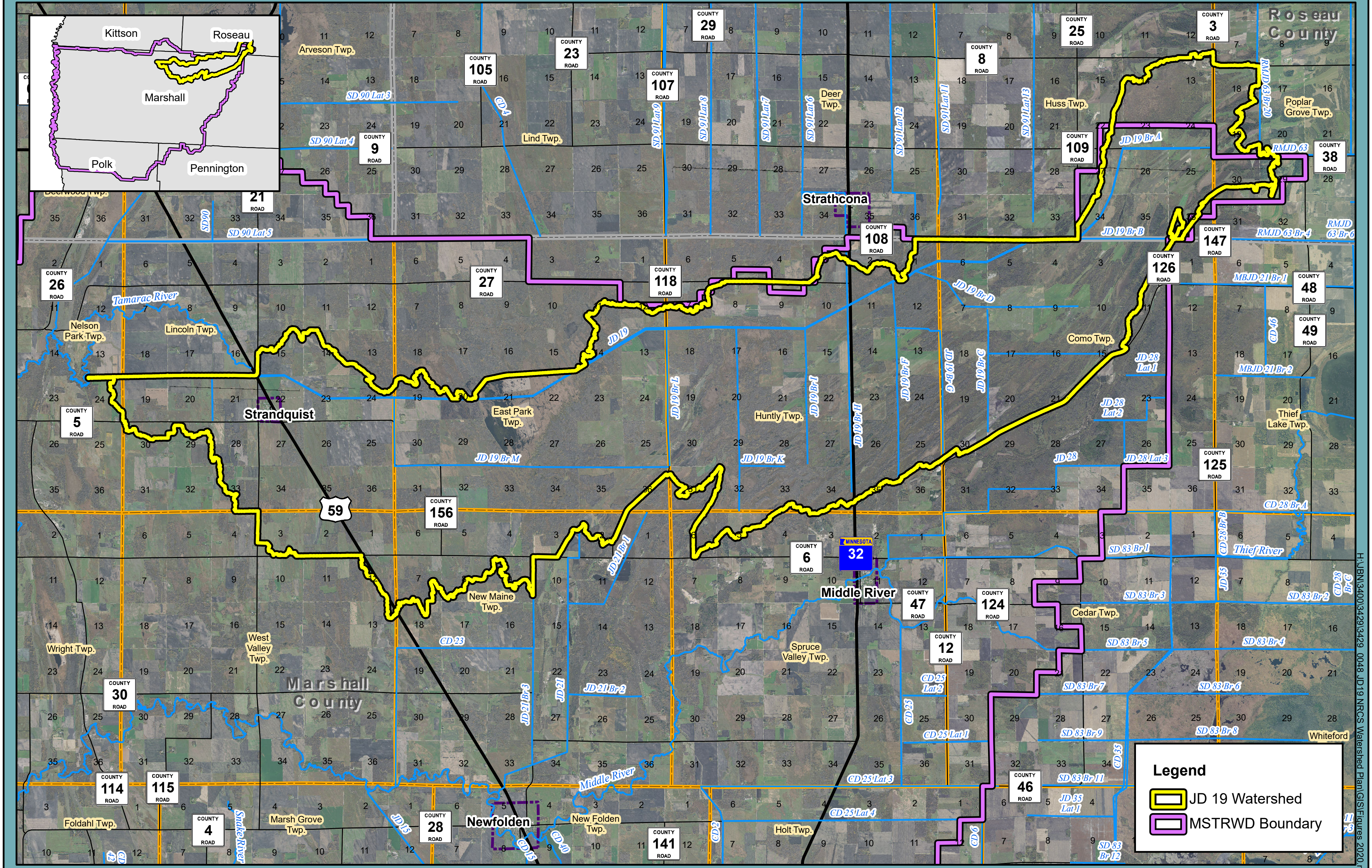

Fig. 1

Figure 1: JD 19 Watershed

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

N W E S

0 1 2 4 Miles

Houston Engineering Inc.

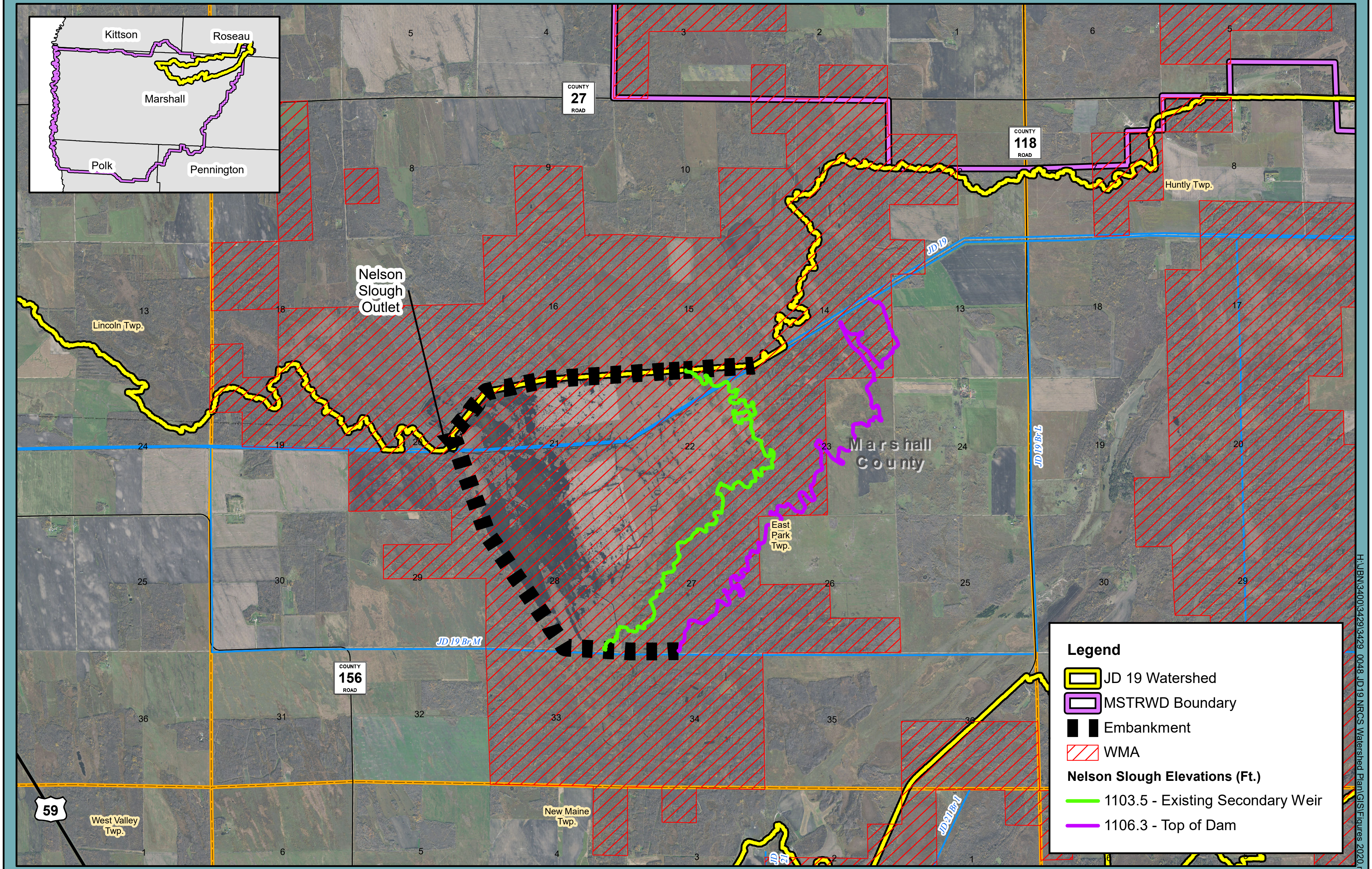

Fig. 1.2

Figure 1.2: East Park WMA (Nelson Slough)

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

N W E S

0 0.375 0.75 1.5 Miles

Houston Engineering Inc.

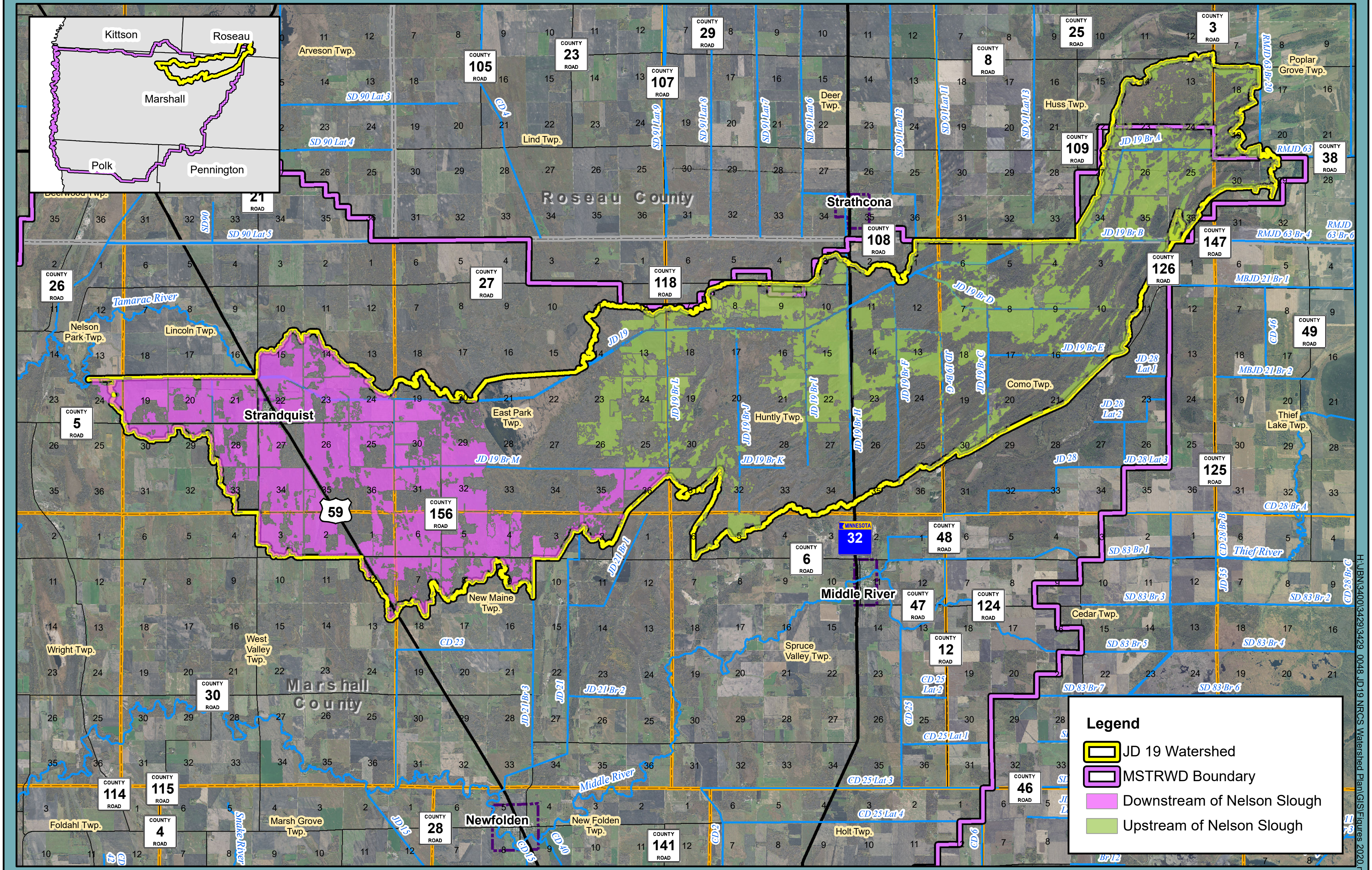

Fig. 2.1.1

Figure 2.1.1: Reduce Runoff Volume

Judicial Ditch #19 Watershed Plan

Screening of Alternatives for Detailed Review

Middle-Snake-Tamarac Rivers Watershed District

0 1 2 4 Miles

Houston Engineering Inc.

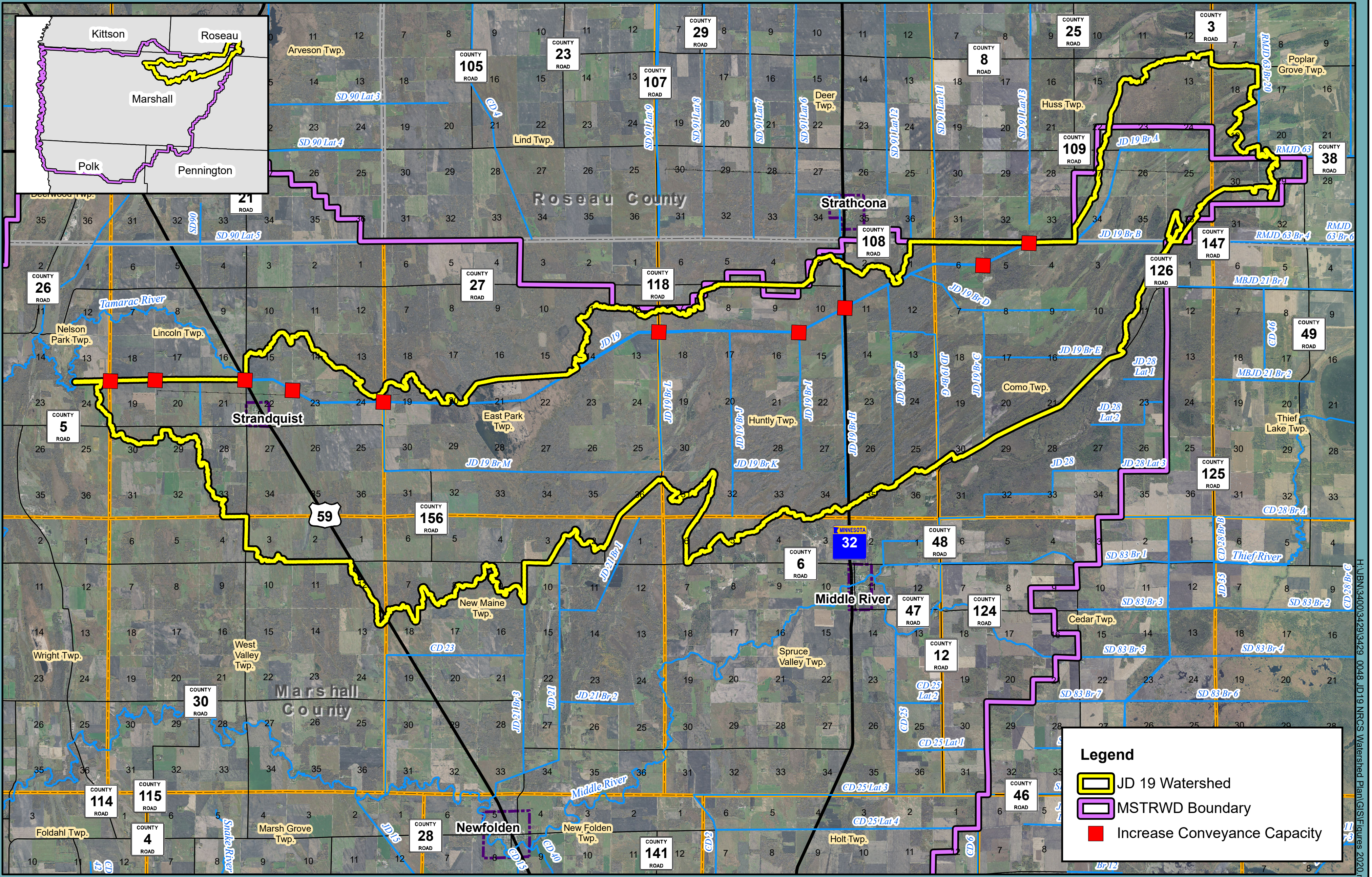

Fig. 2.1.2

<u>Figure 2.1.2: Increase Conveyance Capacity</u>

Judicial Ditch #19 Watershed Plan

Screening of Alternatives for Detailed Review

Middle-Snake-Tamarac Rivers Watershed District

0 1 2 4 Miles

Houston Engineering Inc.

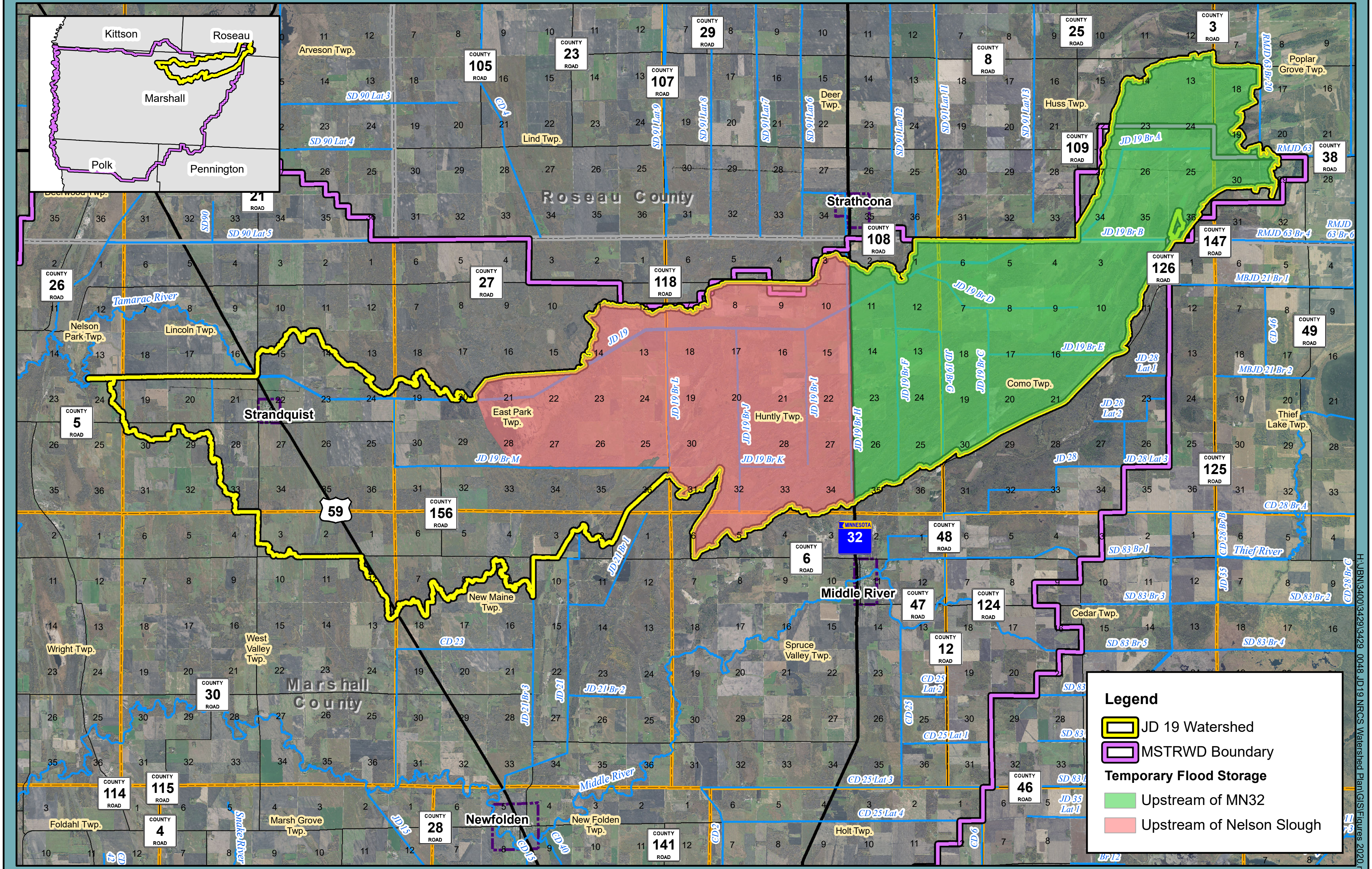

Fig. 2.1.3

Figure 2.1.3: Increase Temporary Flood Storage

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

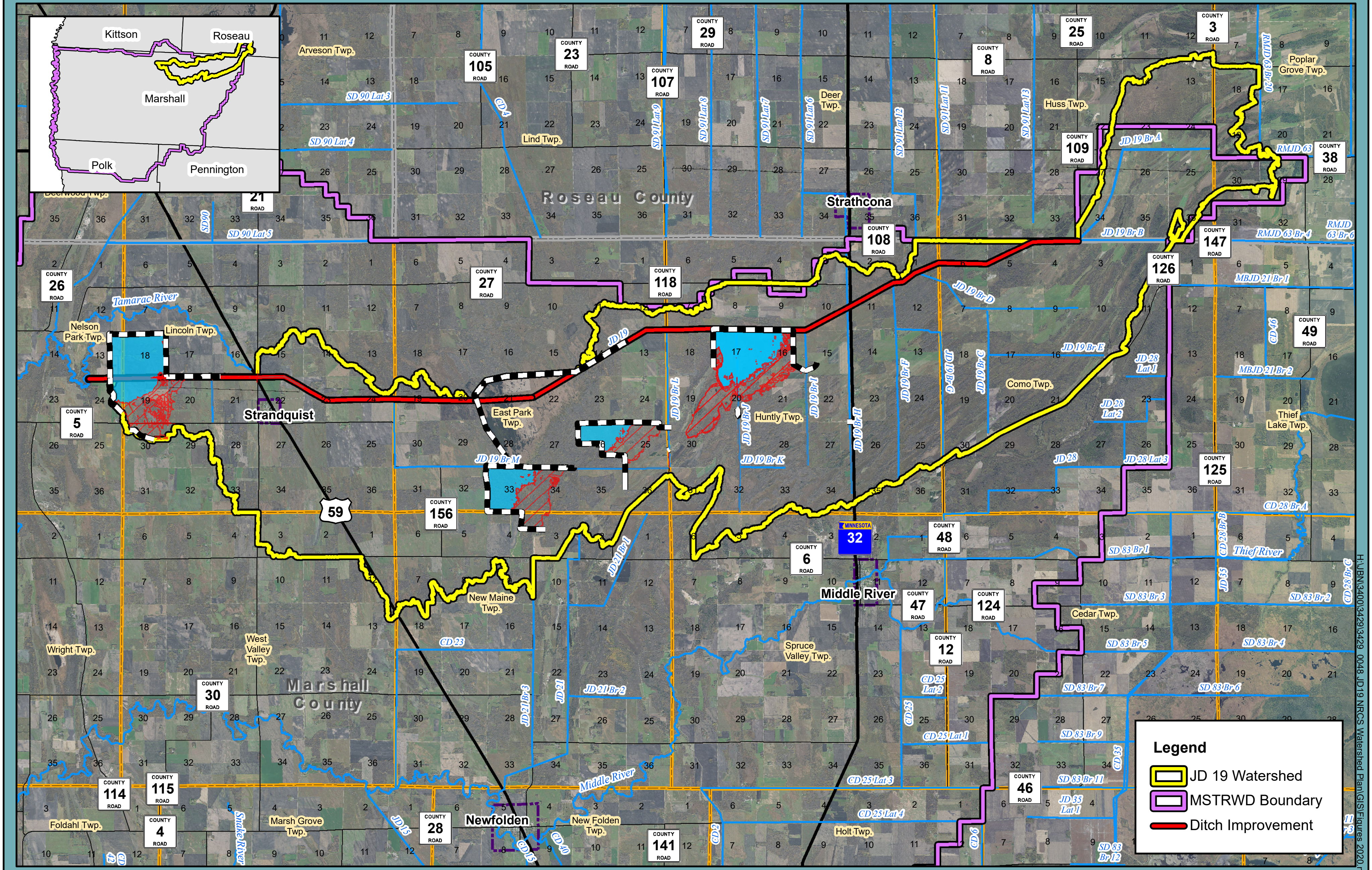

Fig. 3.1a

Figure 3.1a: Identified Alternatives

Judicial Ditch #19 Watershed Plan

Screening of Alternatives for Detailed Review

Middle-Snake-Tamarac Rivers Watershed District

Houston Engineering Inc.

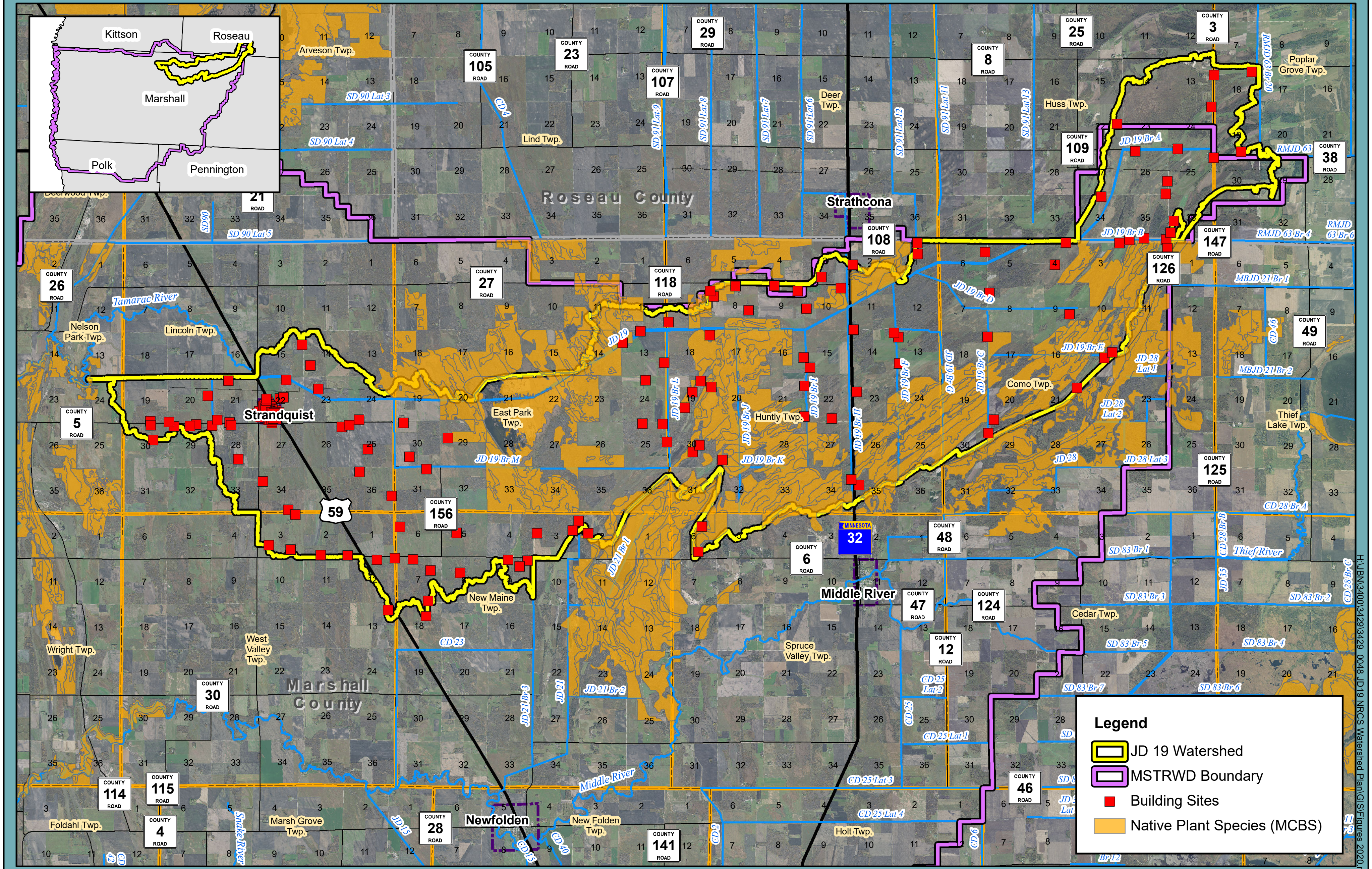

Fig. 3.1b

Figure 3.1b: Enviromental and Public Concerns

Judicial Ditch #19 Watershed Plan

Screening of Alternatives for Detailed Review

Middle-Snake-Tamarac Rivers Watershed District

N W E S

0 1 2 4 Miles

Houston Engineering Inc.

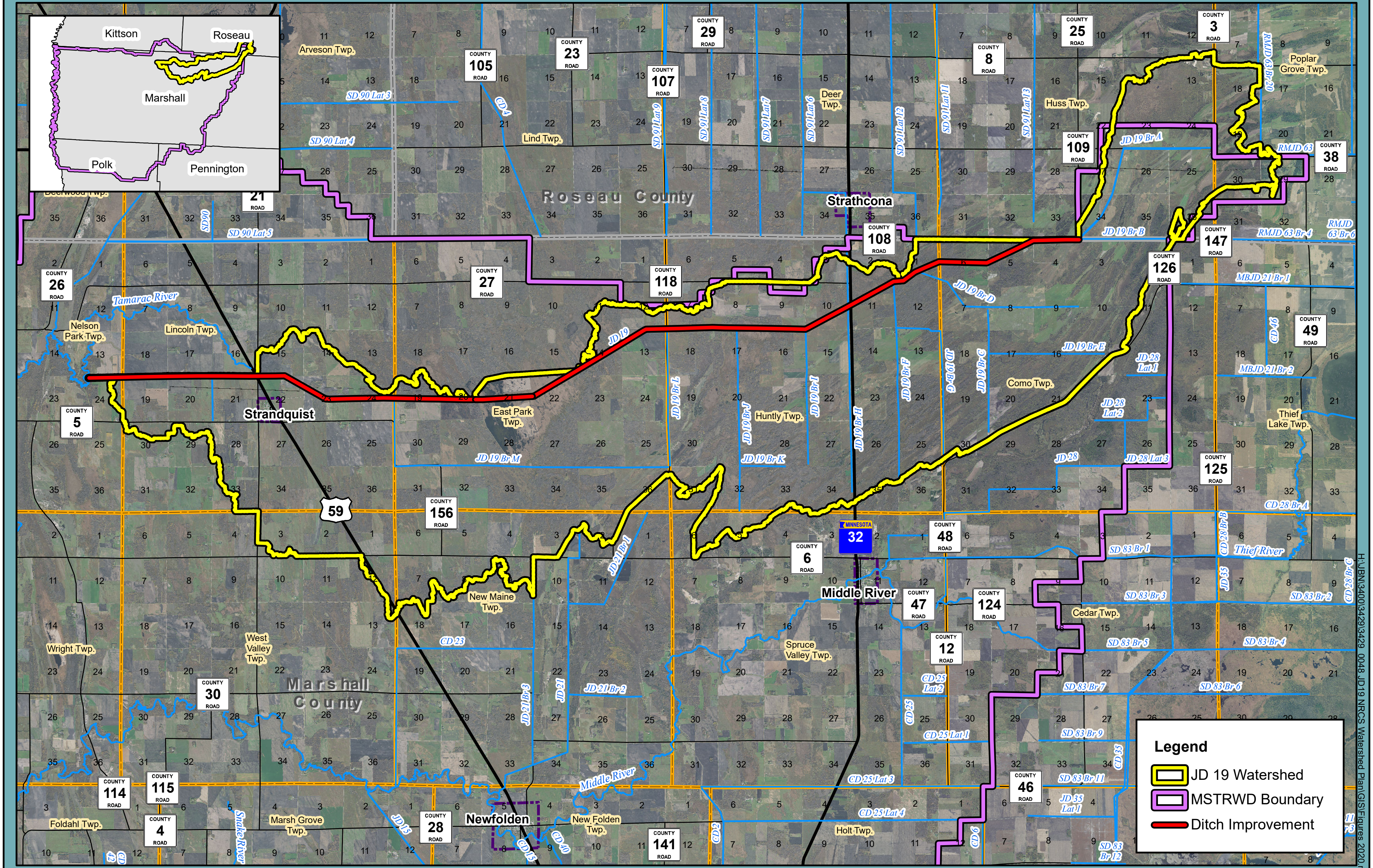

Fig. 3.1.1

Figure 3.1.1: Alternative 1 - Drainage Improvement

Judicial Ditch #19 Watershed Plan

Screening of Alternatives for Detailed Review

Middle-Snake-Tamarac Rivers Watershed District

N W E S

0 1 2 4 Miles

Houston Engineering Inc.

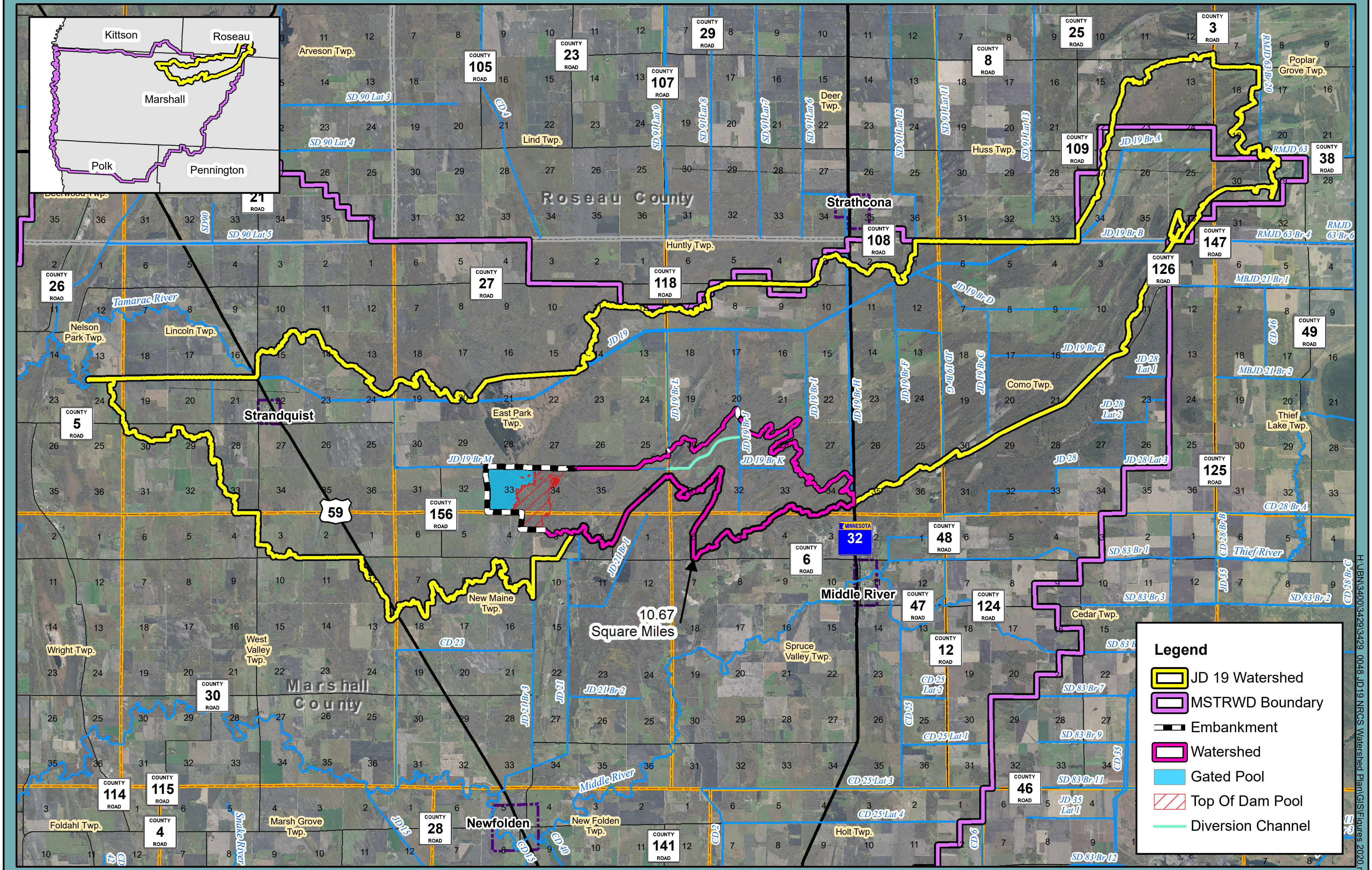

Fig. 3.1.2

Figure 3.1.2: Alternative 2 - Branch M Impoundment Site

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

Houston Engineering Inc.

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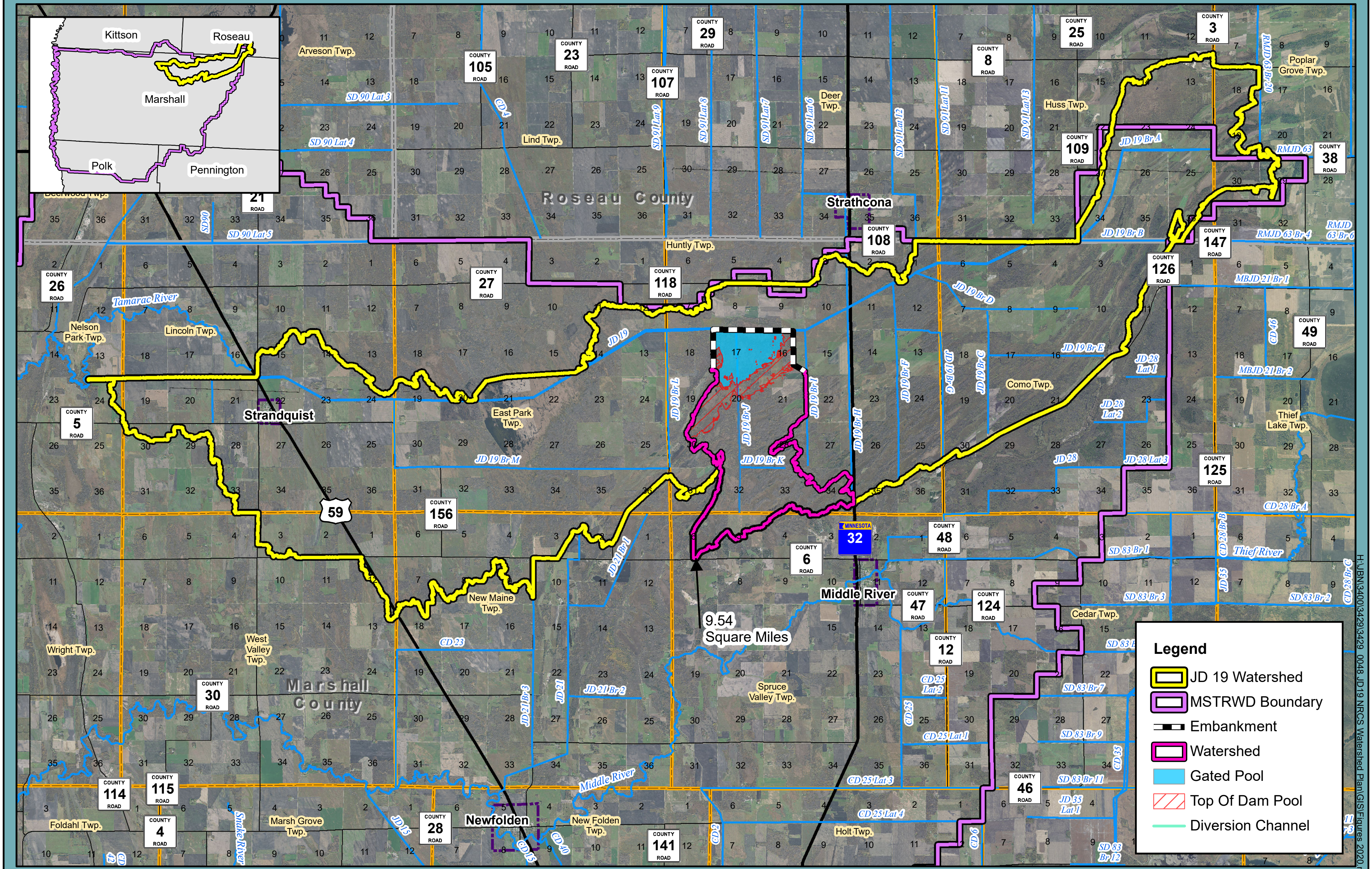

Fig. 3.1.3

Figure 3.1.3: Alternative 3 - Branch J Impoundment Site Option 1

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

Houston Engineering Inc.

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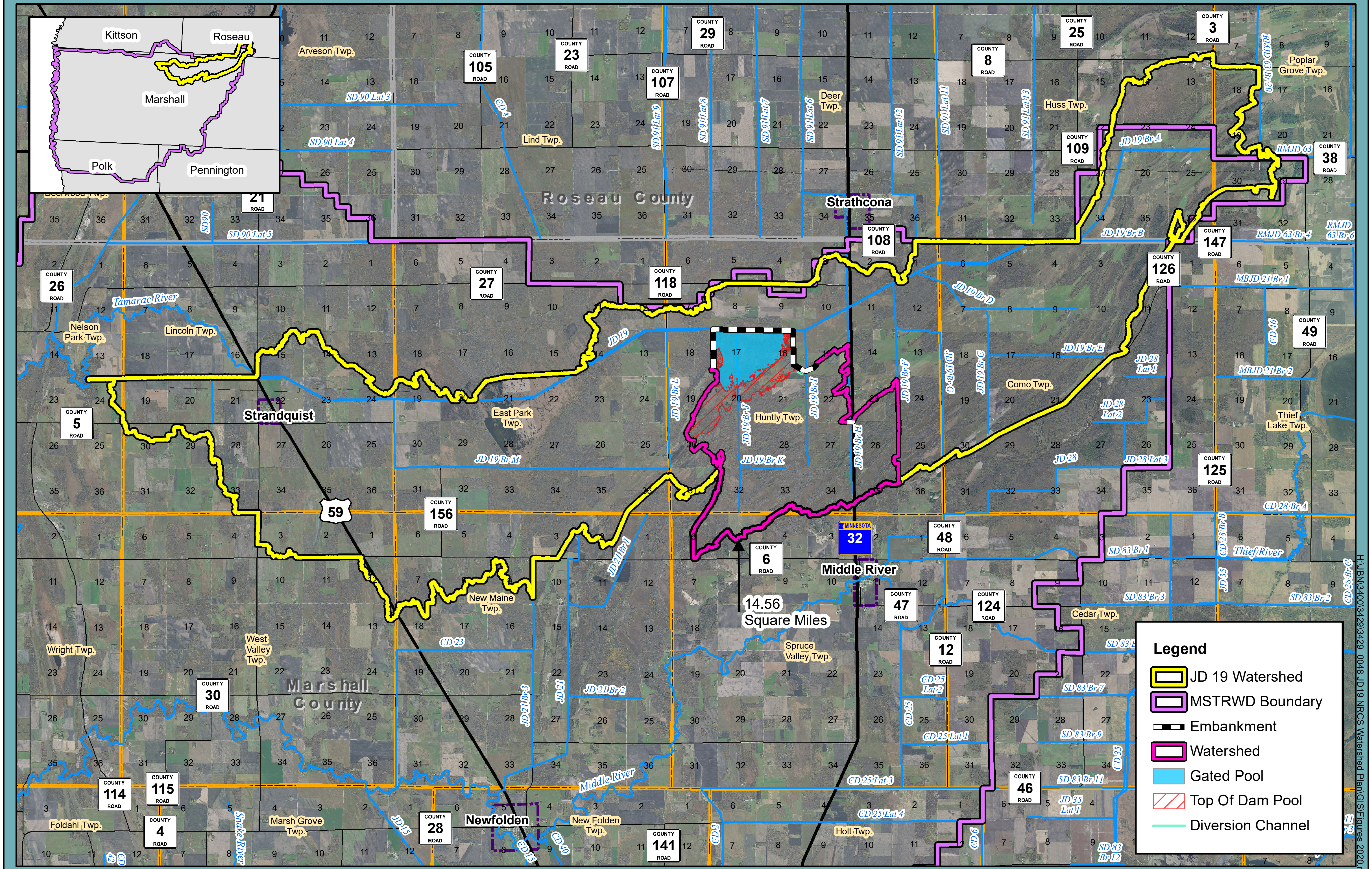

Fig. 3.1.4

Figure 3.1.4: Alternative 4 - Branch J Impoundment Site Option 2

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

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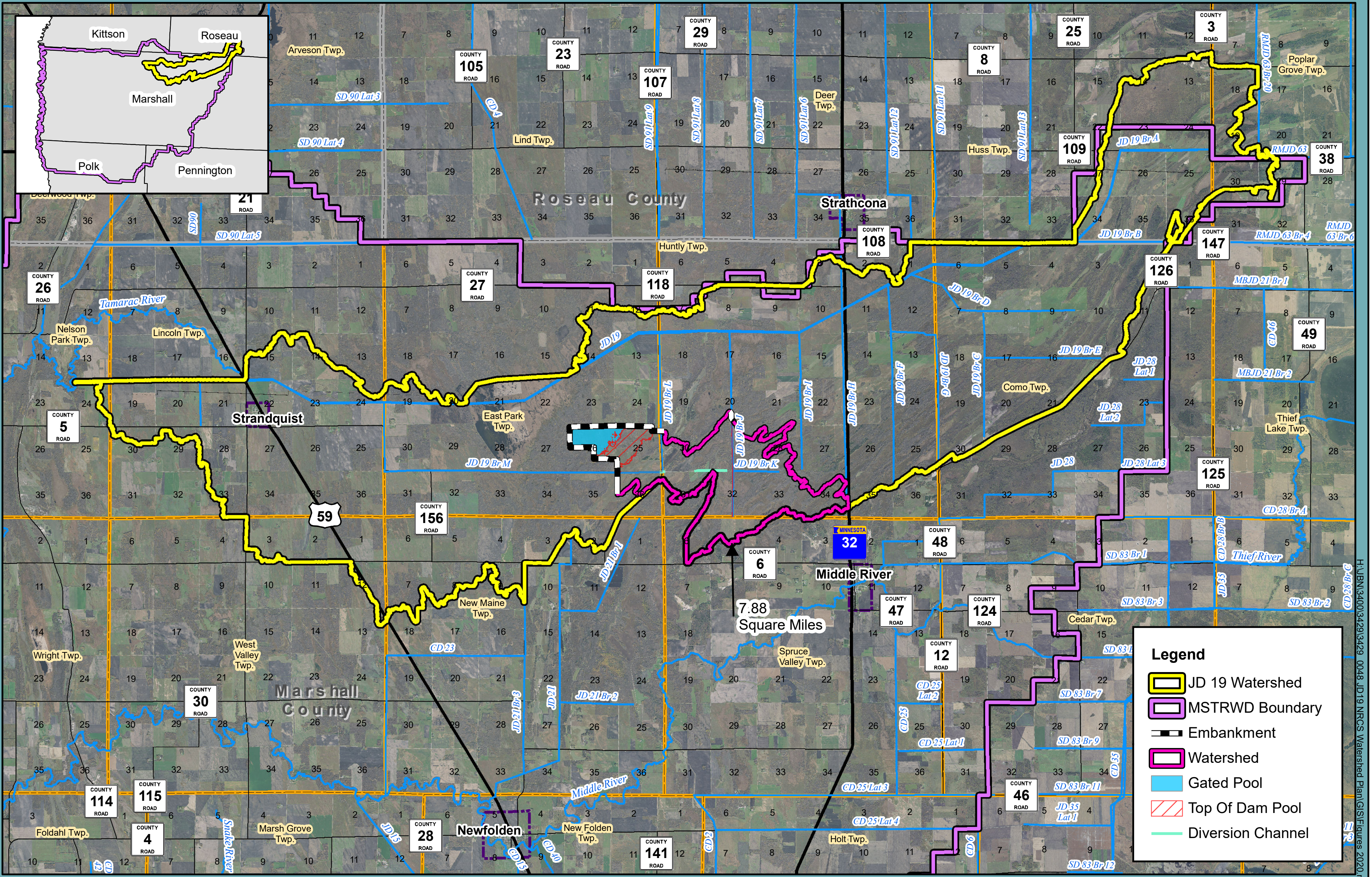

Fig. 3.1.5

Figure 3.1.5: Alternative 5 - East Park Township Impoundment Site

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

N W E S

0 1 2 4 Miles

Houston Engineering Inc.

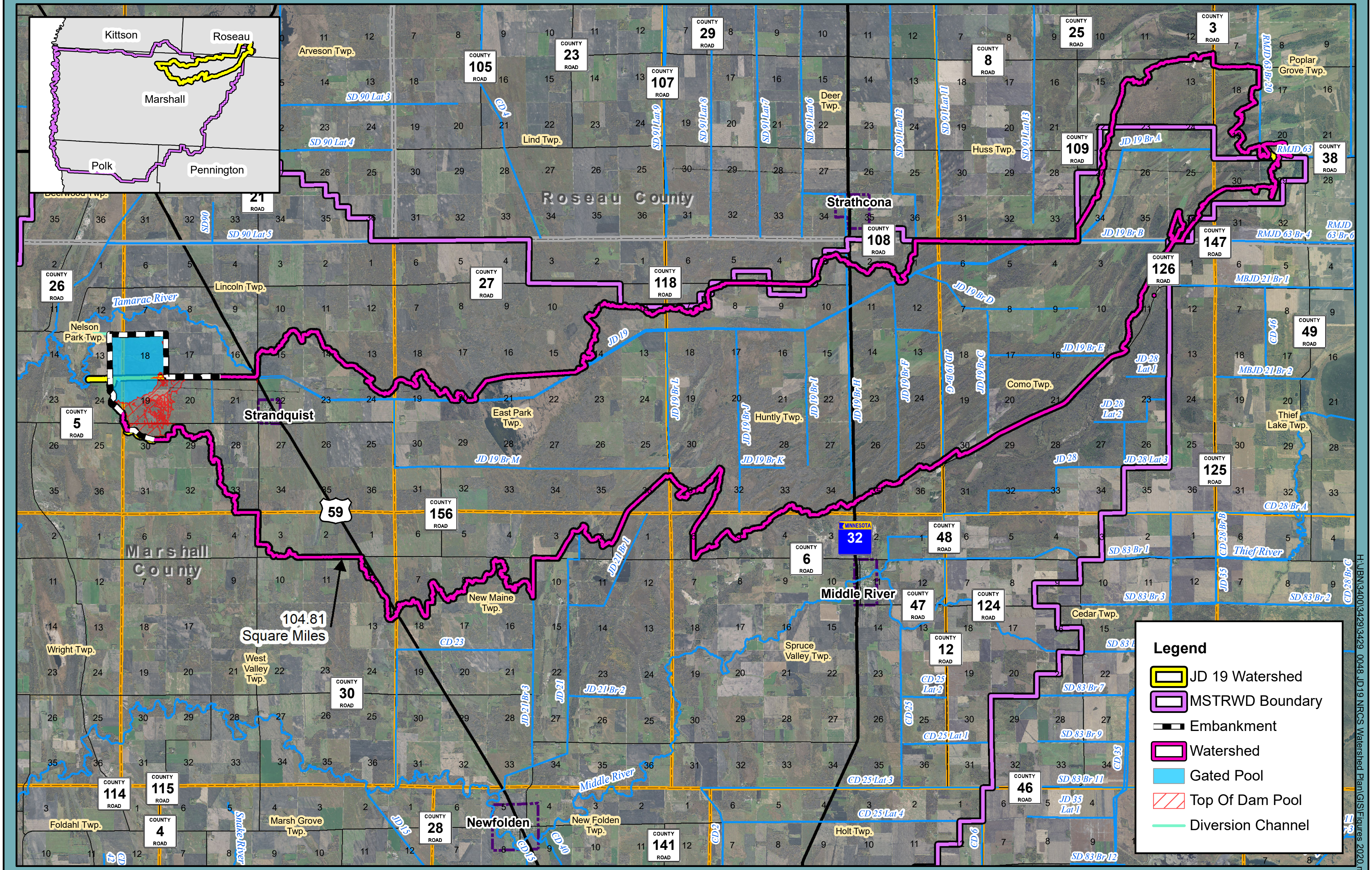

Fig. 3.1.6

Figure 3.1.6: Alternative 6 - Lincoln Township Impoundment Site

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

N W E S

0 1 2 4 Miles

Houston Engineering Inc.

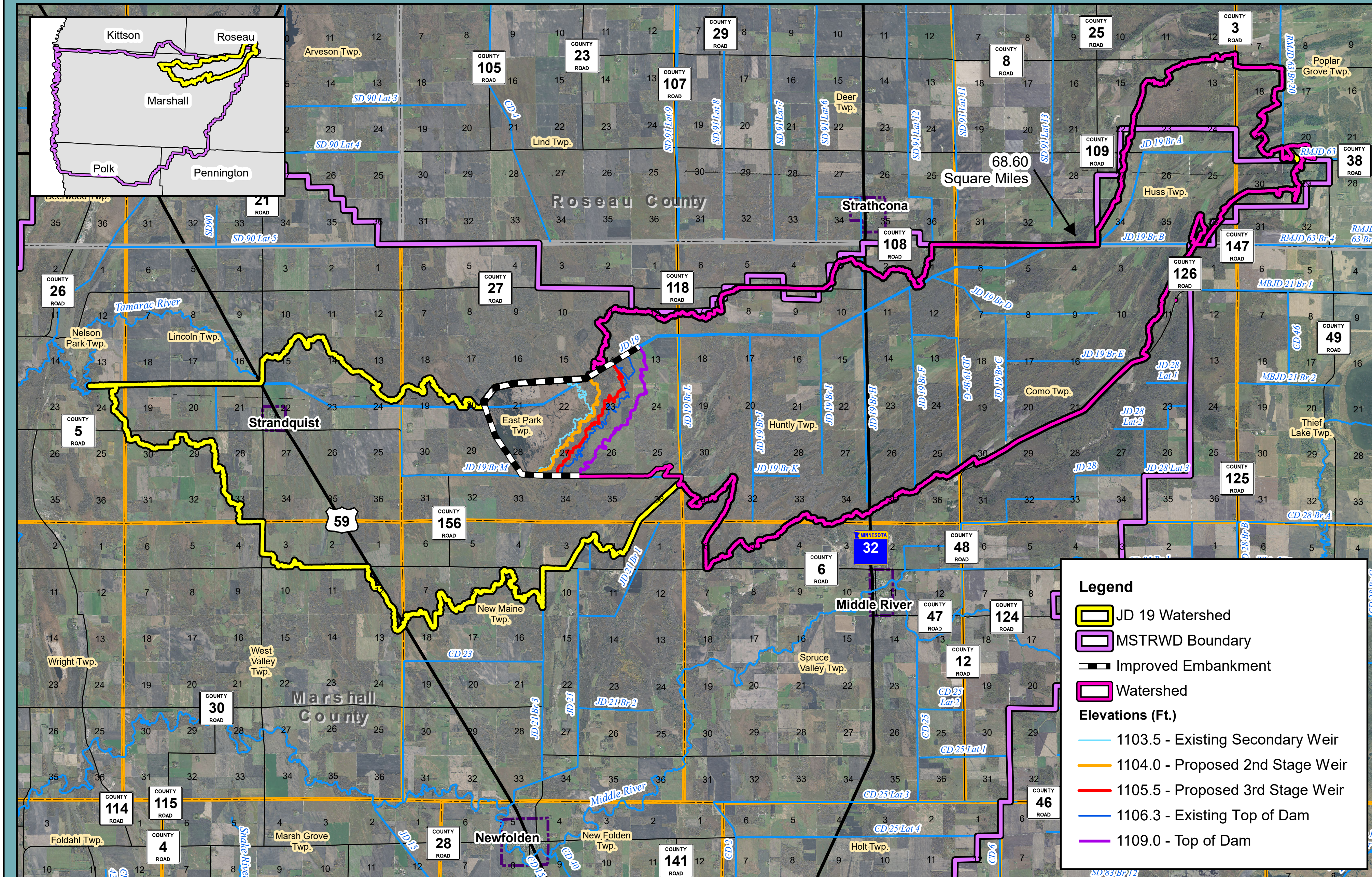

Fig. 3.1.7a

Figure 3.1.7a: Alternative 7 - Nelson Slough Improvements

Judicial Ditch #19 Watershed Plan

Screening of Alternatives for Detailed Review

Middle-Snake-Tamarac Rivers Watershed District

N W E S

0 1 2 4 Miles

Houston Engineering Inc.

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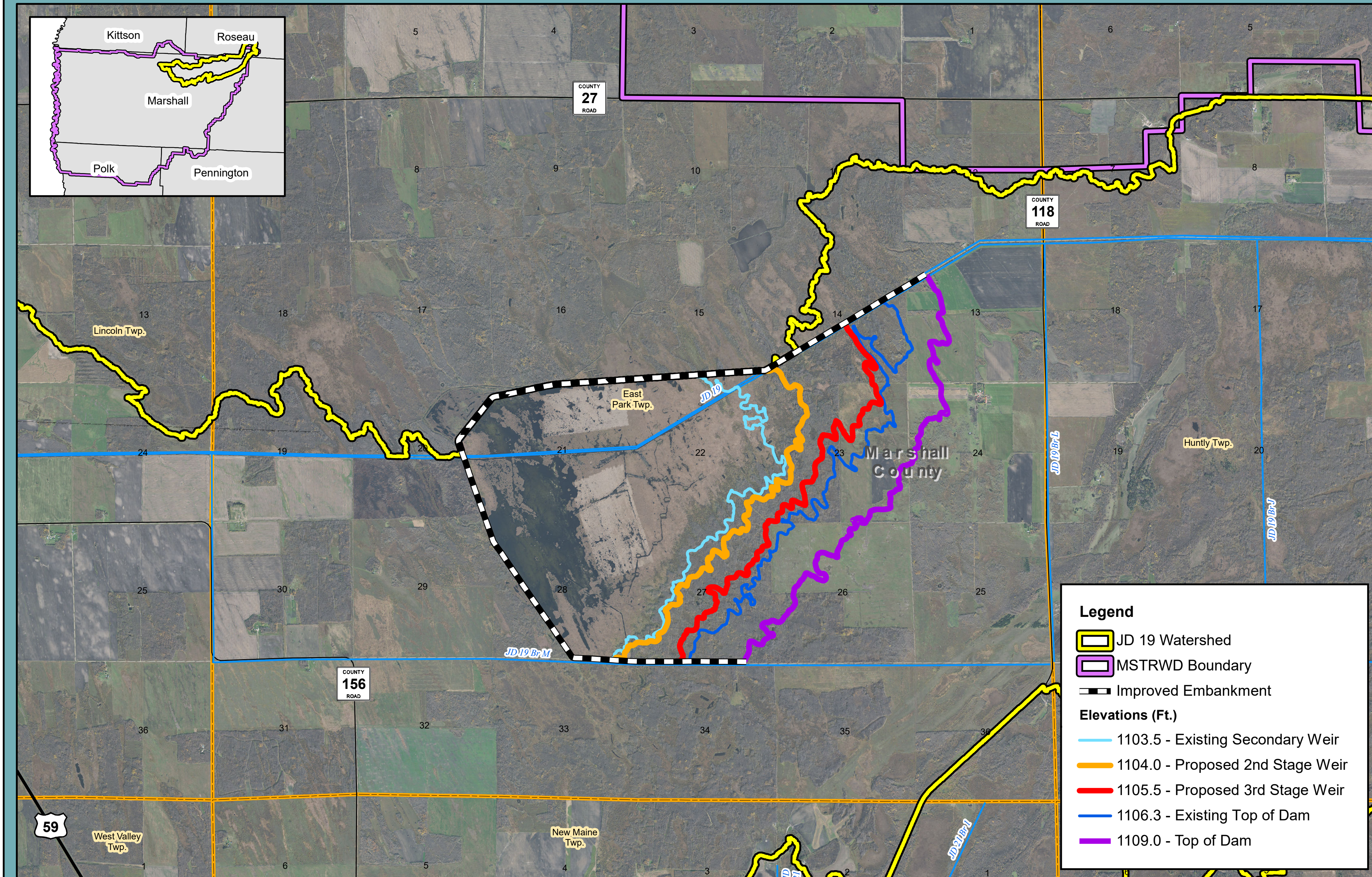

Fig. 3.1.7b

Figure 3.1.7b: Alternative 7 - Nelson Slough Elevations

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

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APPENDIX A

Figure A.1: Technical Considerations – Reporting Locations
A.2 Reduce Runoff Volume – Hydrographs
A.3 Increase Conveyance Capacity – Hydrographs
A.4 Increase Temporary Flood Storage – Hydrographs

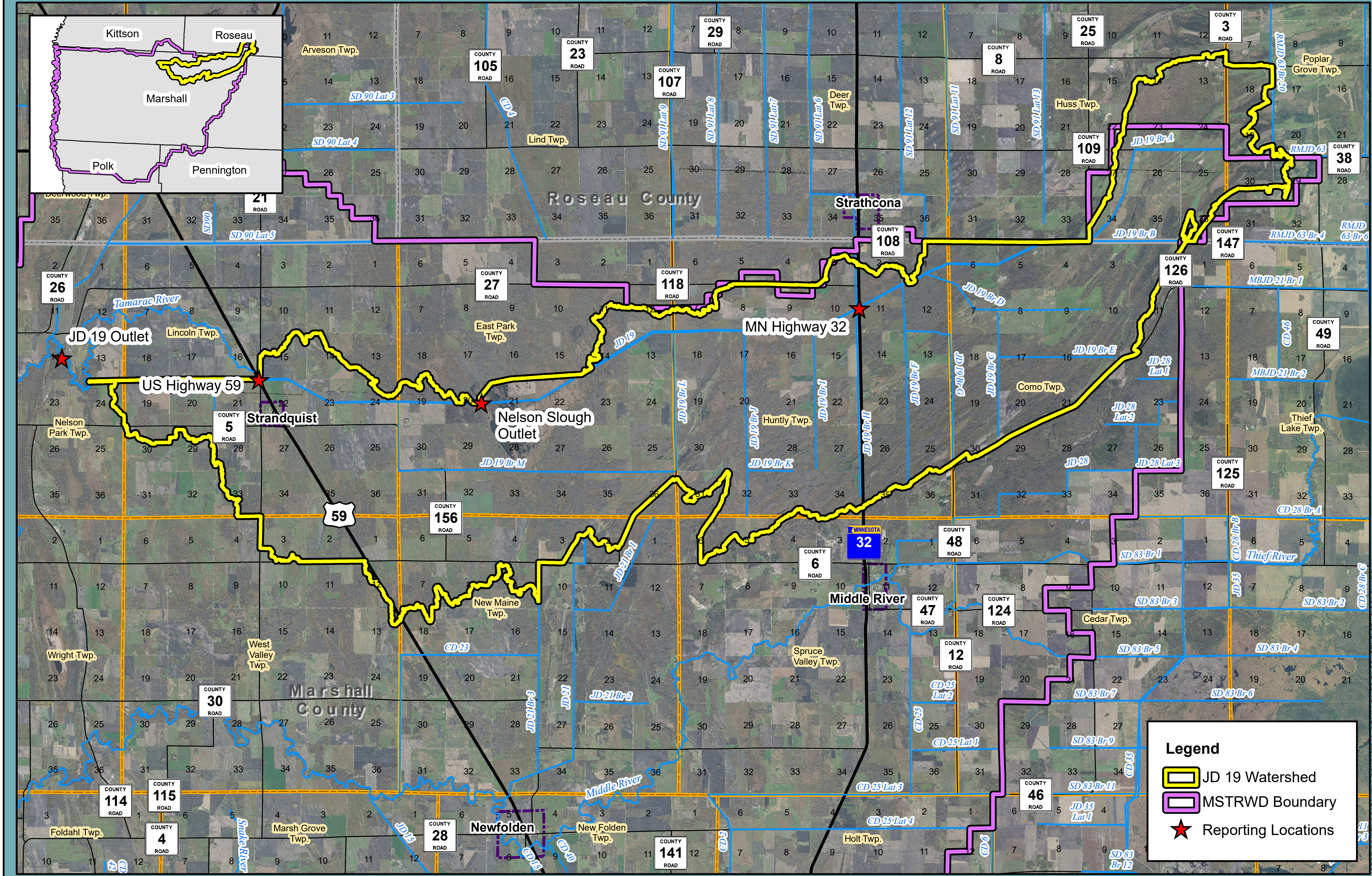

Fig. A.1

Figure A.1: Technical Considerations - Reporting Locations

Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

0 1 2 4 Miles

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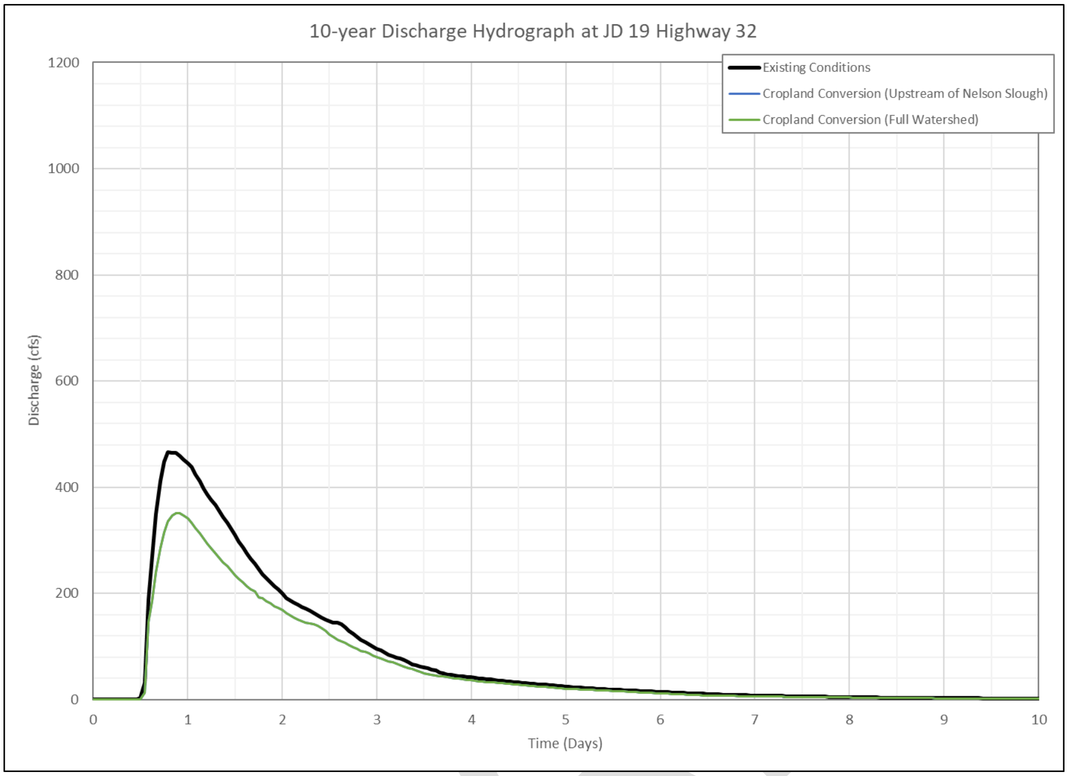
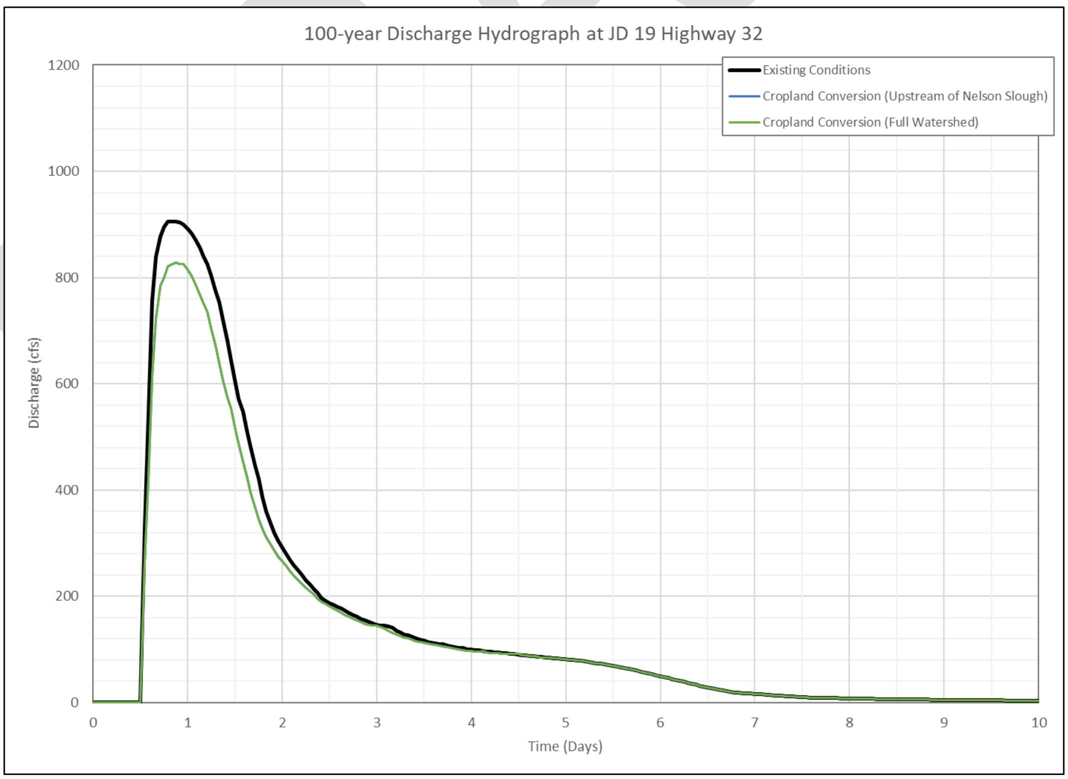
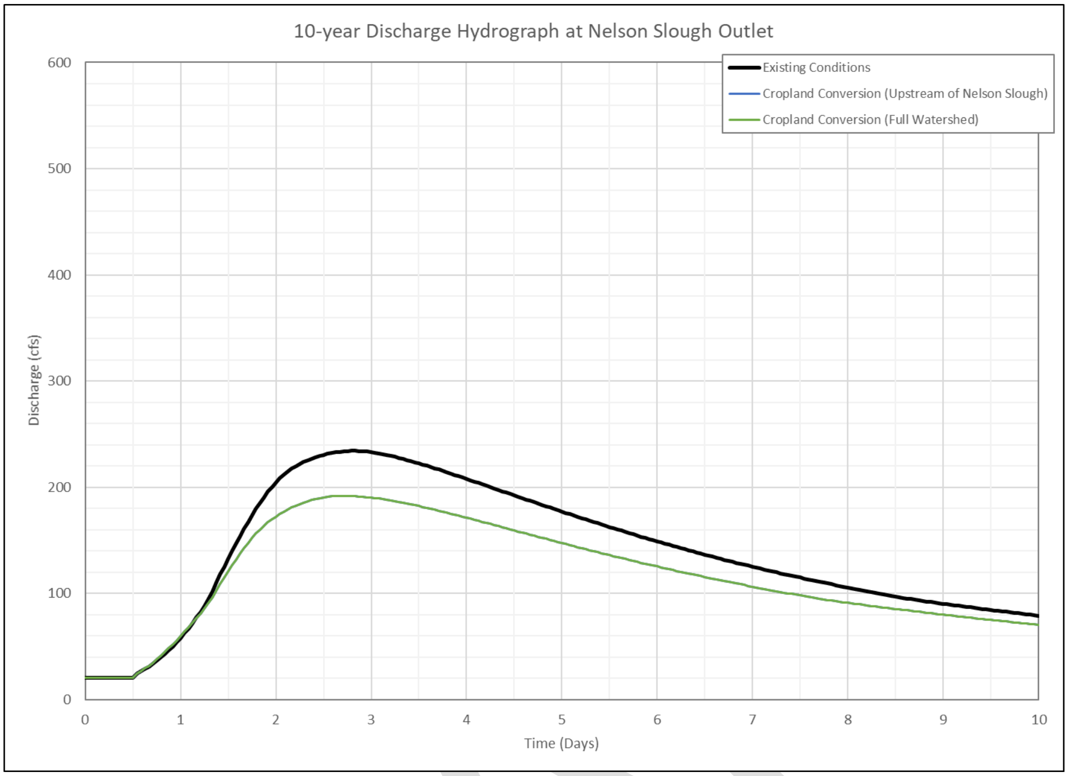
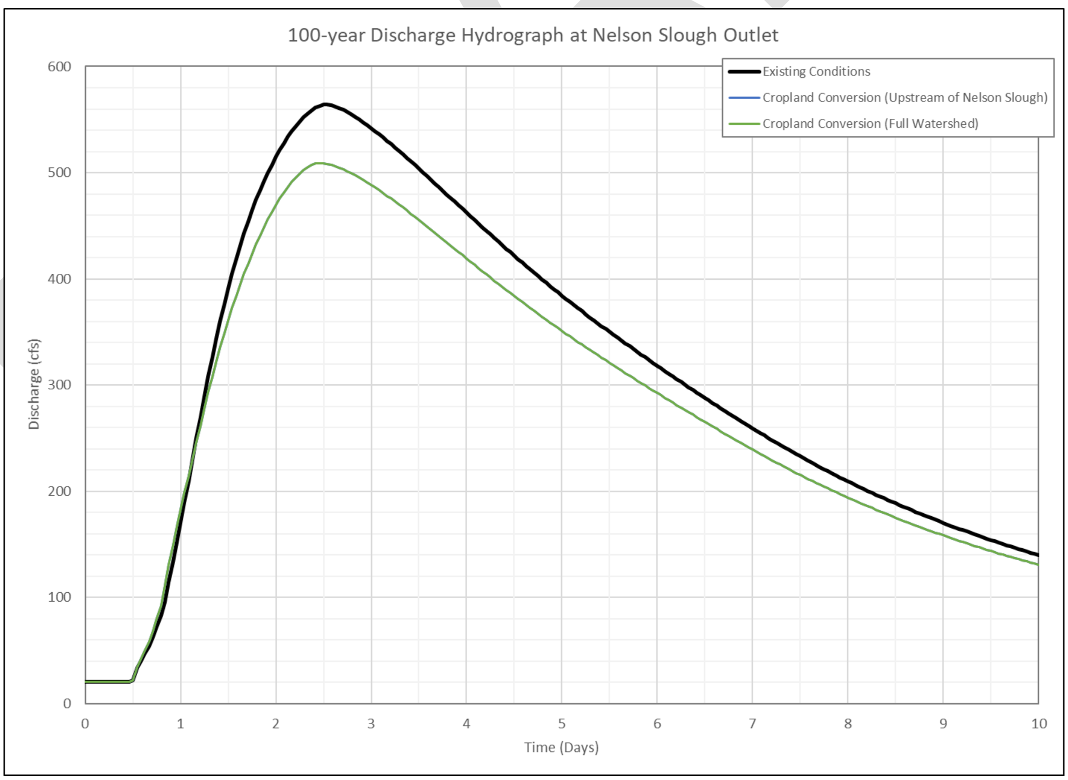
A.2 REDUCE RUNOFF VOLUME - HYDROGRAPHS







10-year Discharge Hydrograph at Nelson Slough Outlet
Existing Conditions
Cropland Conversion (Upstream of Nelson Slough)
Cropland Conversion (Full Watershed)
Discharge (cfs)
0
100
200
300
400
500
600
0
1
2
3
4
5
6
7
8
9
10
Time (Days)



100-year Discharge Hydrograph at Nelson Slough Outlet
Existing Conditions
Cropland Conversion (Upstream of Nelson Slough)
Cropland Conversion (Full Watershed)
Discharge (cfs)
0
100
200
300
400
500
600
0
1
2
3
4
5
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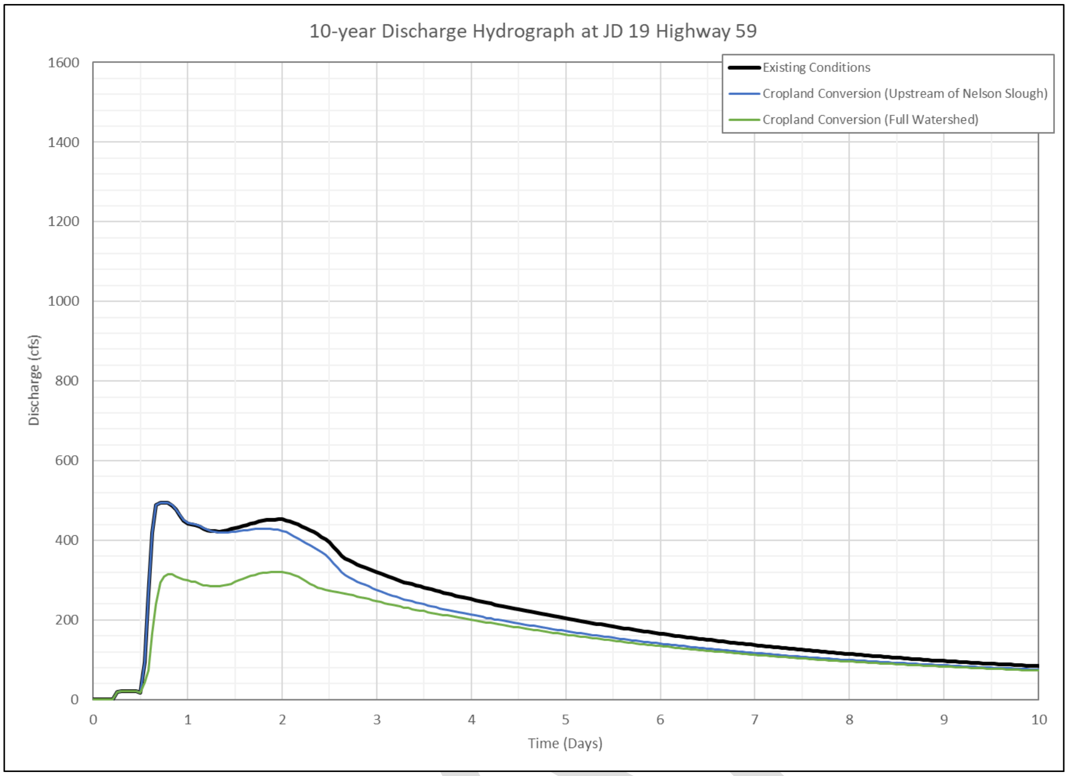
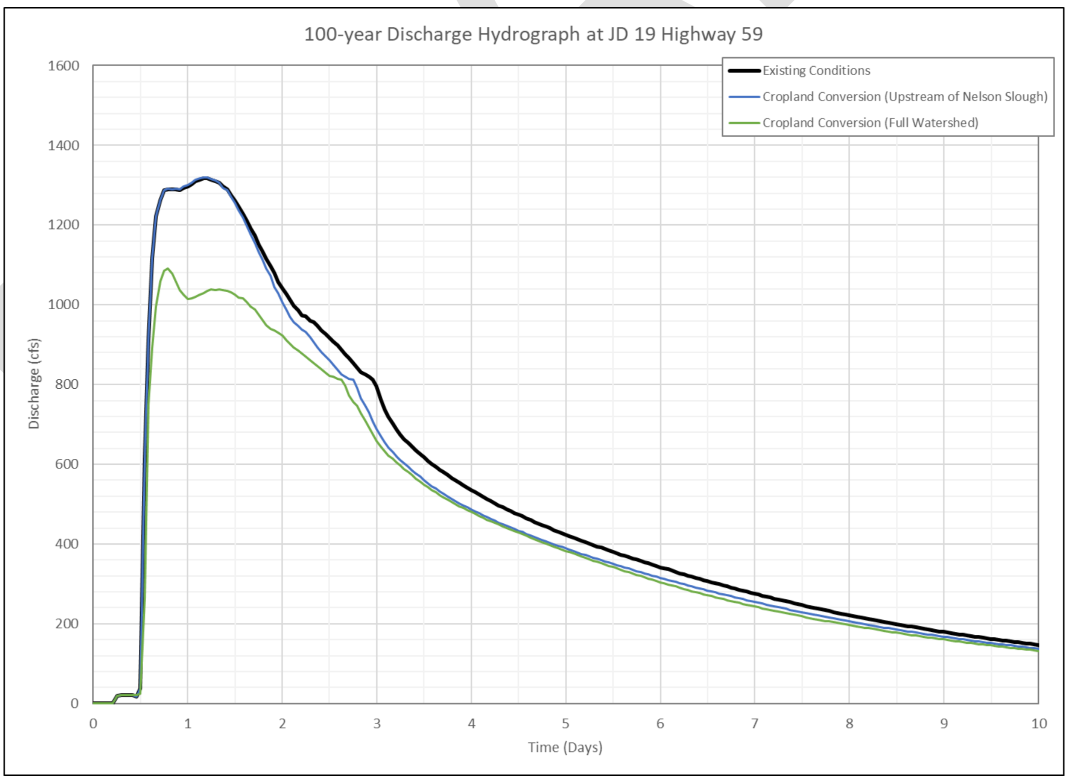
7
8
9
10
Time (Days)


10-year Discharge Hydrograph at JD 19 Highway 59
Existing Conditions
Cropland Conversion (Upstream of Nelson Slough)
Cropland Conversion (Full Watershed)
Discharge (cfs)
Time (Days)
0
200
400
600
800
1000
1200
1400
1600
0 1 2 3 4 5 6 7 8 9 10


100-year Discharge Hydrograph at JD 19 Highway 59
Existing Conditions
Cropland Conversion (Upstream of Nelson Slough)
Cropland Conversion (Full Watershed)
Discharge (cfs)
Time (Days)
0
200
400
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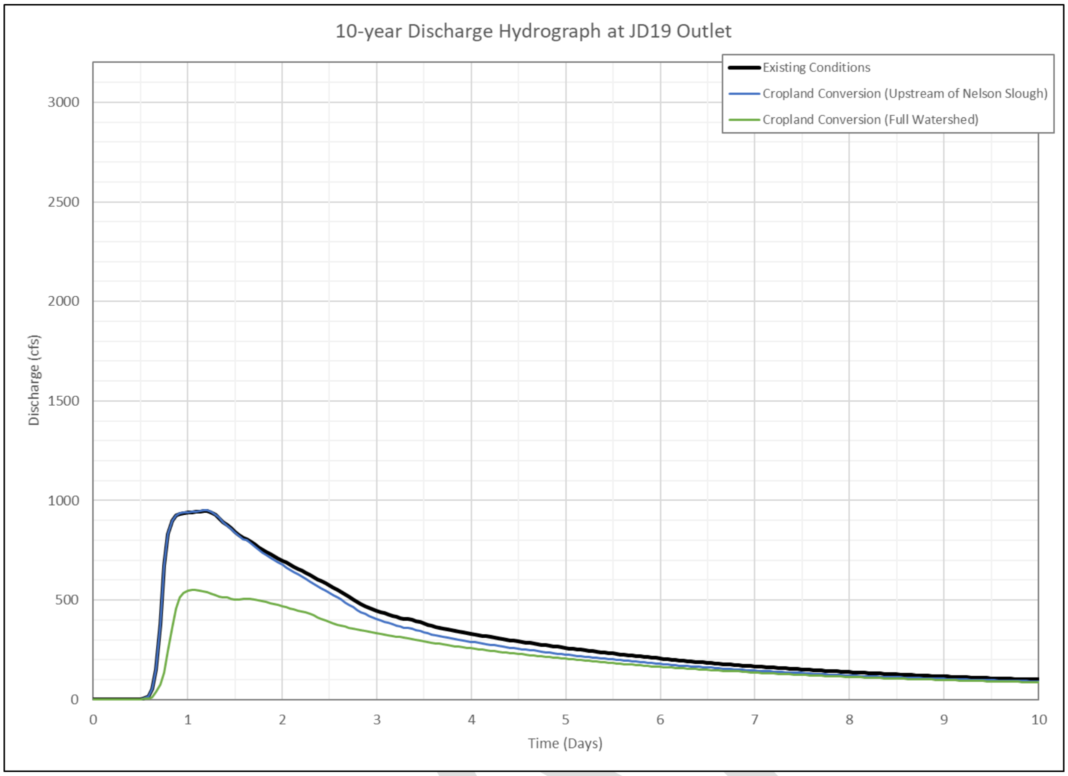
1600
0 1 2 3 4 5 6 7 8 9 10


10-year Discharge Hydrograph at JD19 Outlet
Existing Conditions
Cropland Conversion (Upstream of Nelson Slough)
Cropland Conversion (Full Watershed)
Discharge (cfs)
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2500
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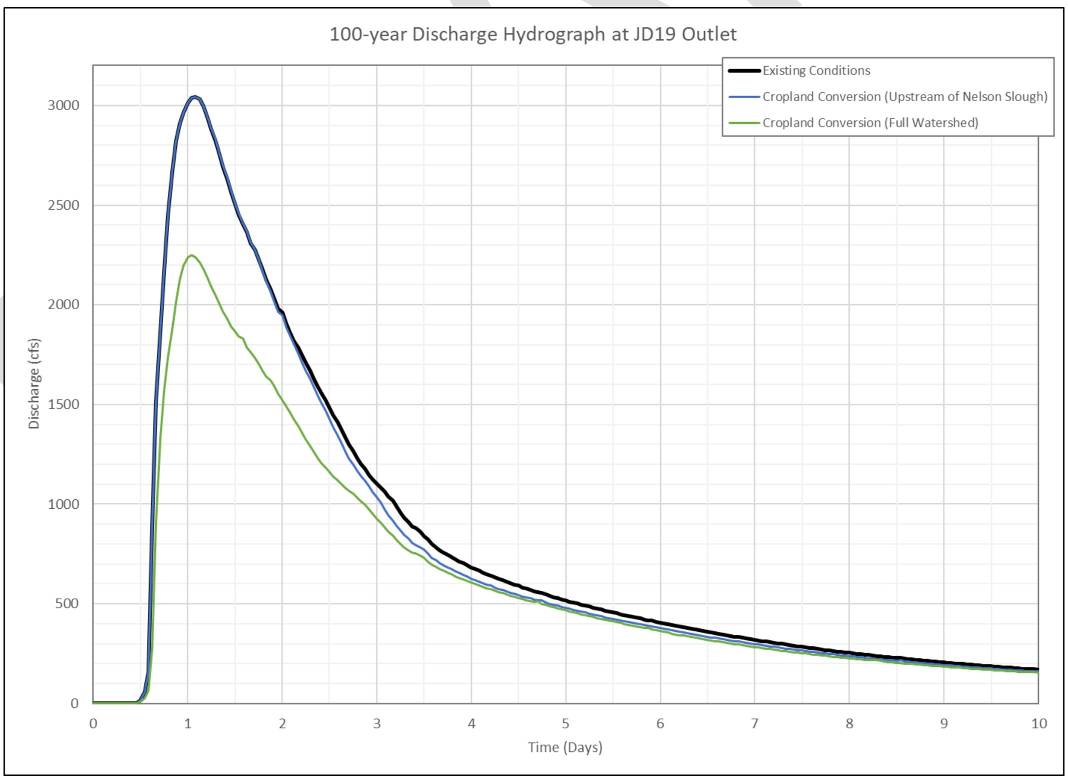
8
9
10
Time (Days)


100-year Discharge Hydrograph at JD19 Outlet
Existing Conditions
Cropland Conversion (Upstream of Nelson Slough)
Cropland Conversion (Full Watershed)
Discharge (cfs)
0
500
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2500
3000
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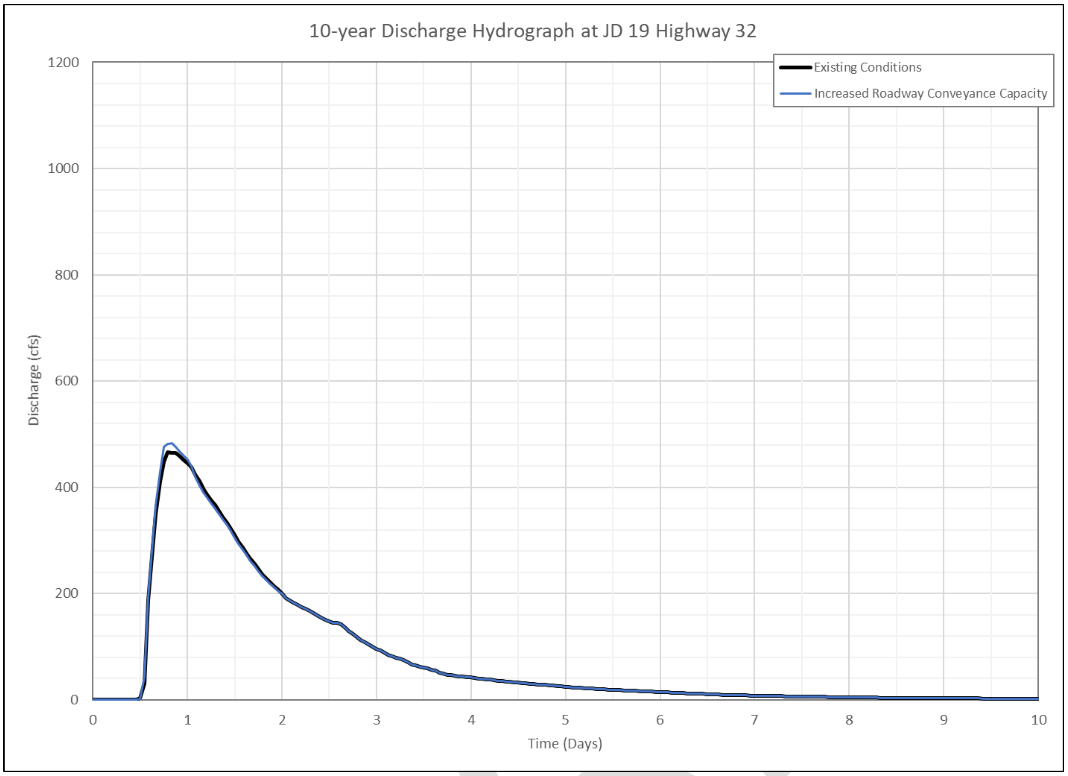
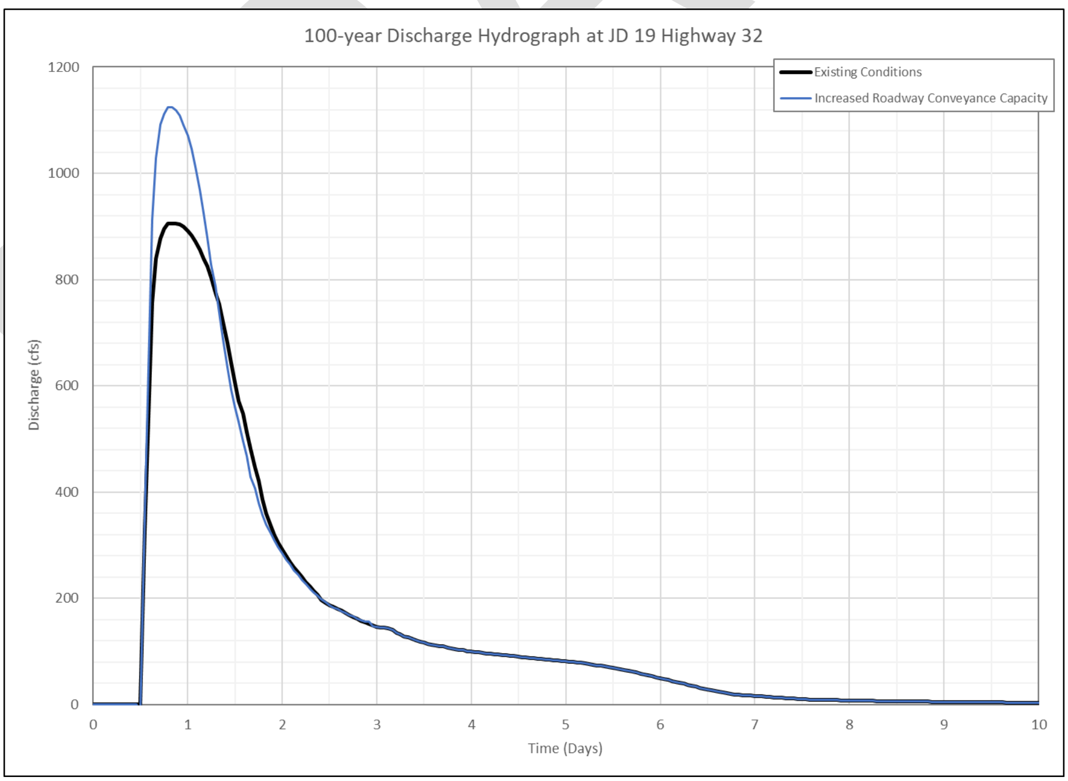
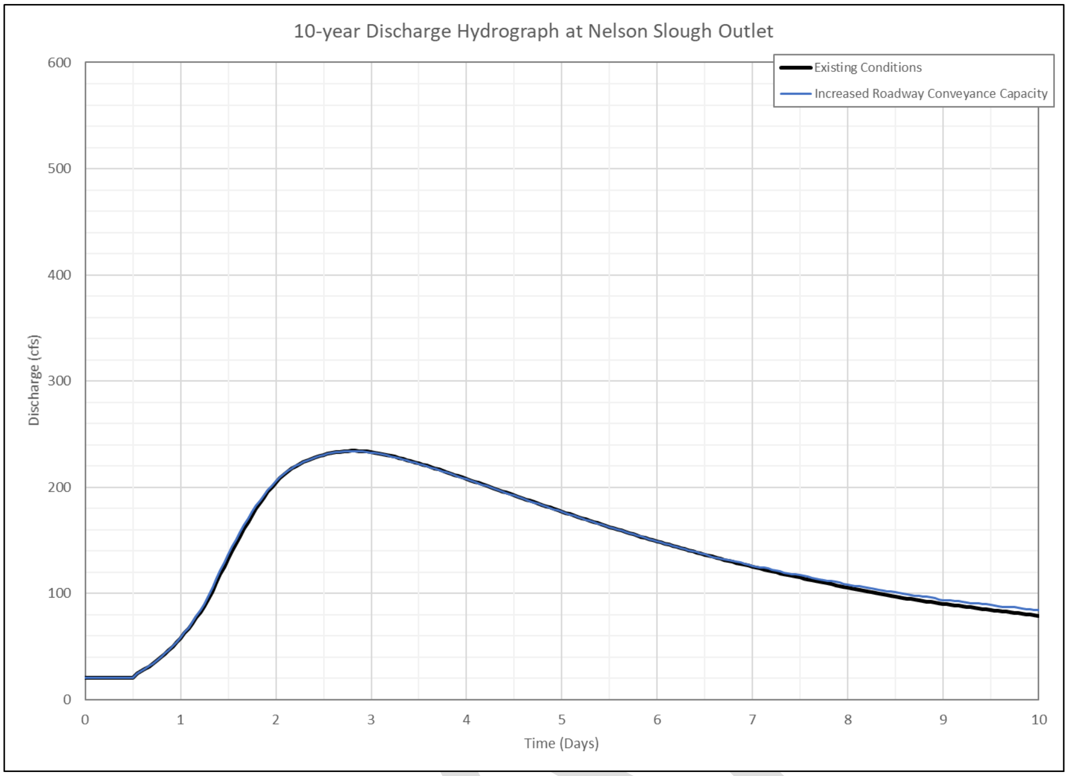
Time (Days)

A.3 INCREASE CONVEYANCE CAPACITY - HYDROGRAPHS






10-year Discharge Hydrograph at Nelson Slough Outlet
Existing Conditions
Increased Roadway Conveyance Capacity
Discharge (cfs)
0
100
200
300
400
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Time (Days)
0
1
2
3
4
5
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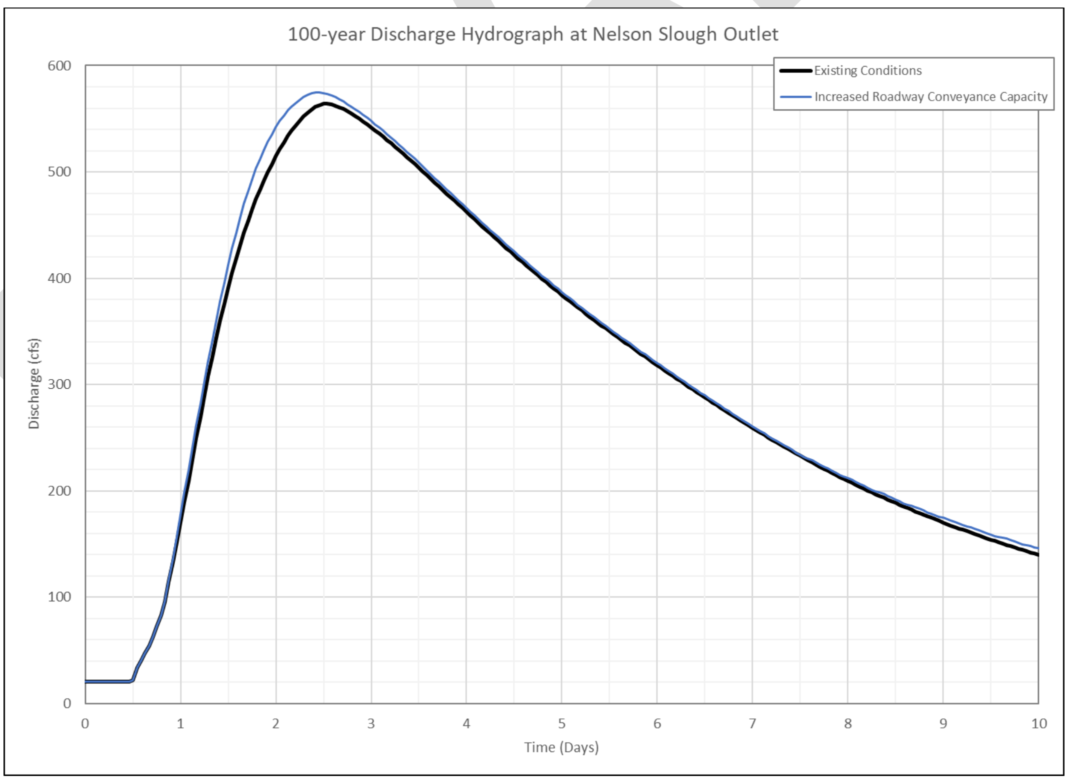
100-year Discharge Hydrograph at Nelson Slough Outlet
Existing Conditions
Increased Roadway Conveyance Capacity
Discharge (cfs)
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Time (Days)
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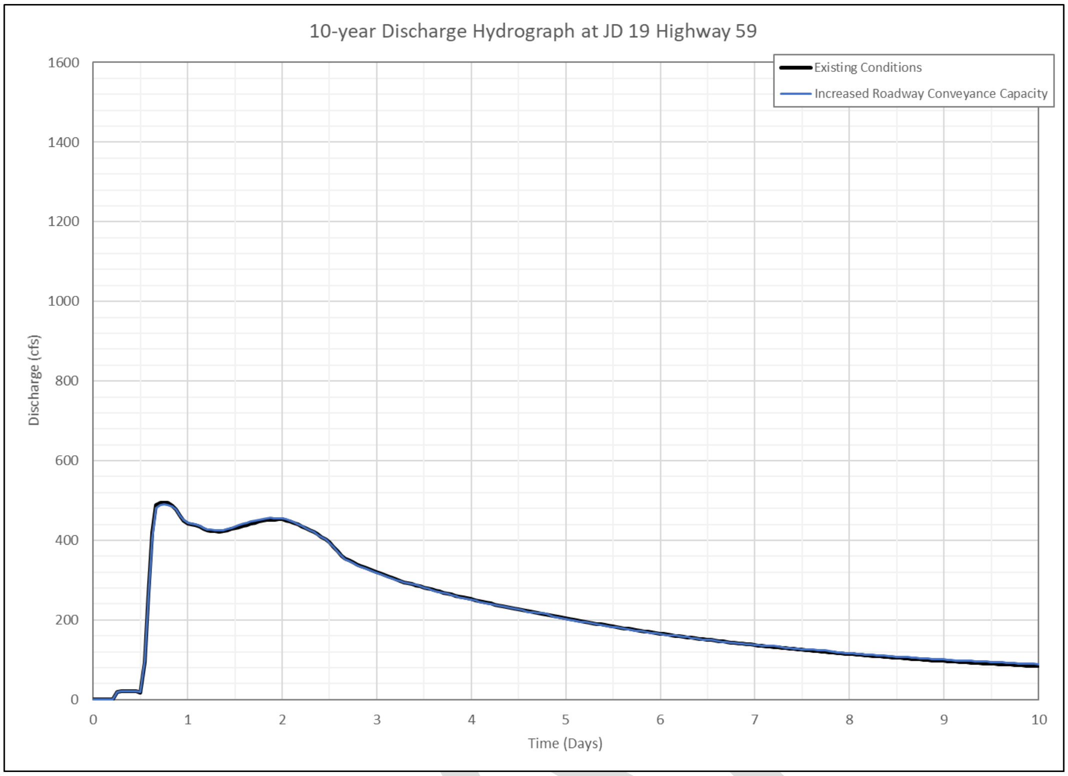

10-year Discharge Hydrograph at JD 19 Highway 59
Existing Conditions
Increased Roadway Conveyance Capacity
Discharge (cfs)
Time (Days)
0
200
400
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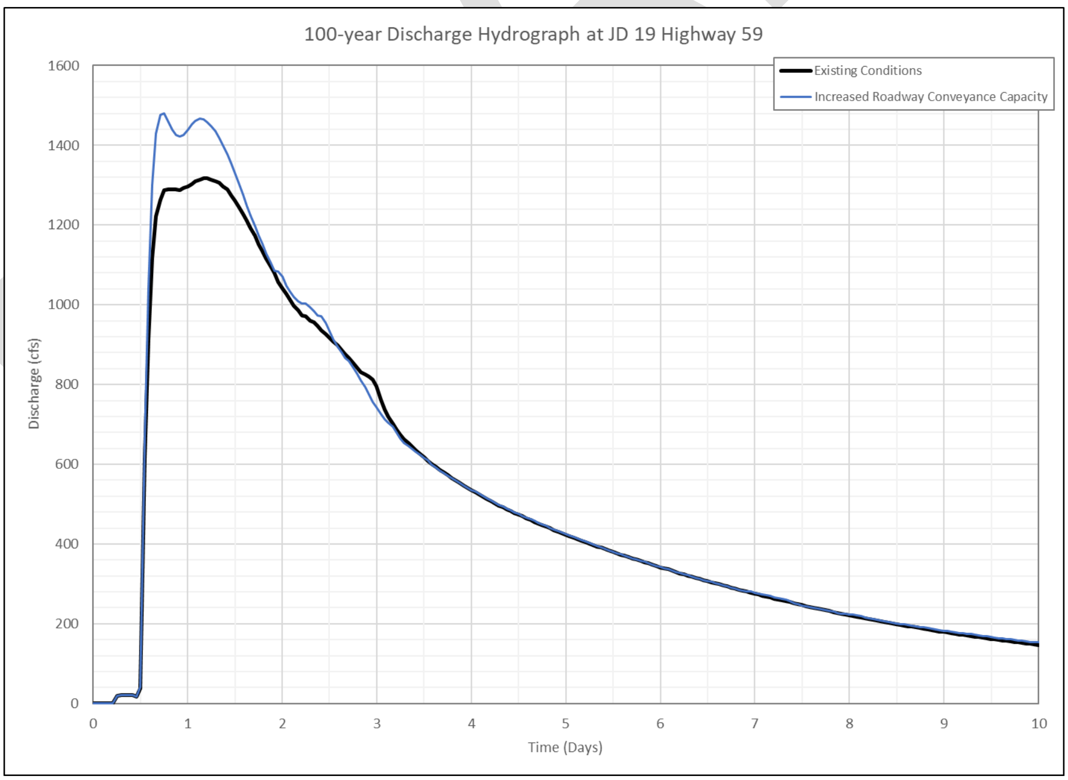

100-year Discharge Hydrograph at JD 19 Highway 59
Existing Conditions
Increased Roadway Conveyance Capacity
Discharge (cfs)
Time (Days)
0
200
400
600
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0
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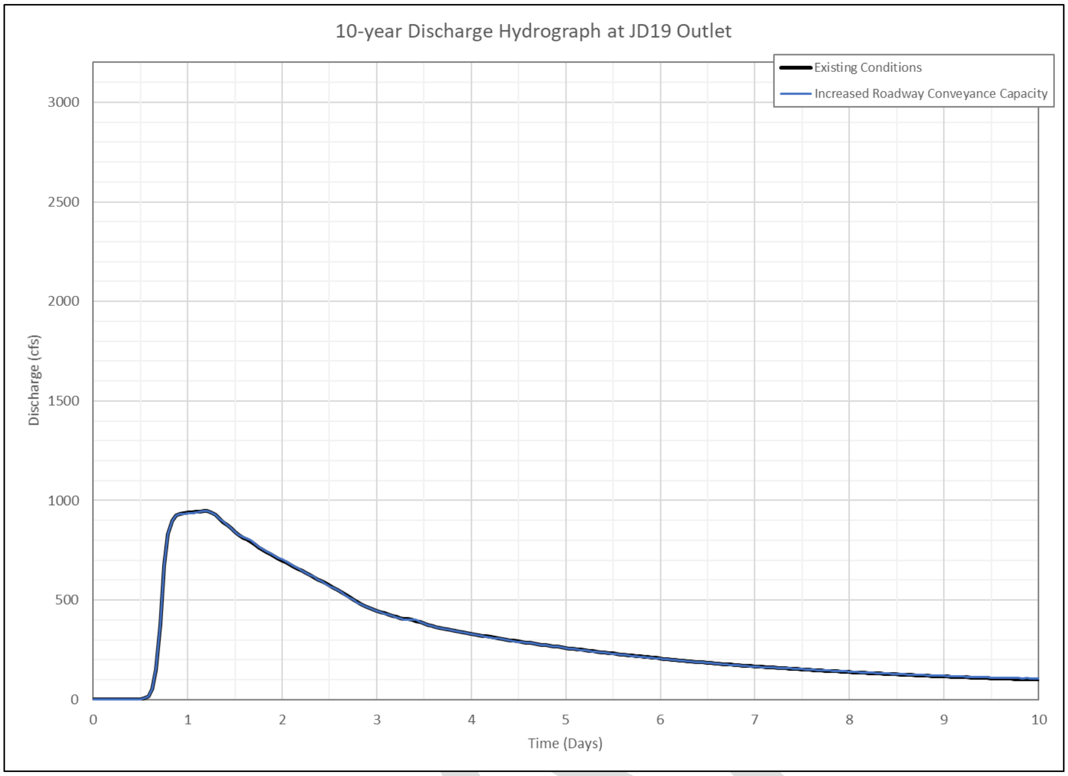
10-year Discharge Hydrograph at JD19 Outlet
Existing Conditions
Increased Roadway Conveyance Capacity
Discharge (cfs)
3000
2500
2000
1500
1000
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6
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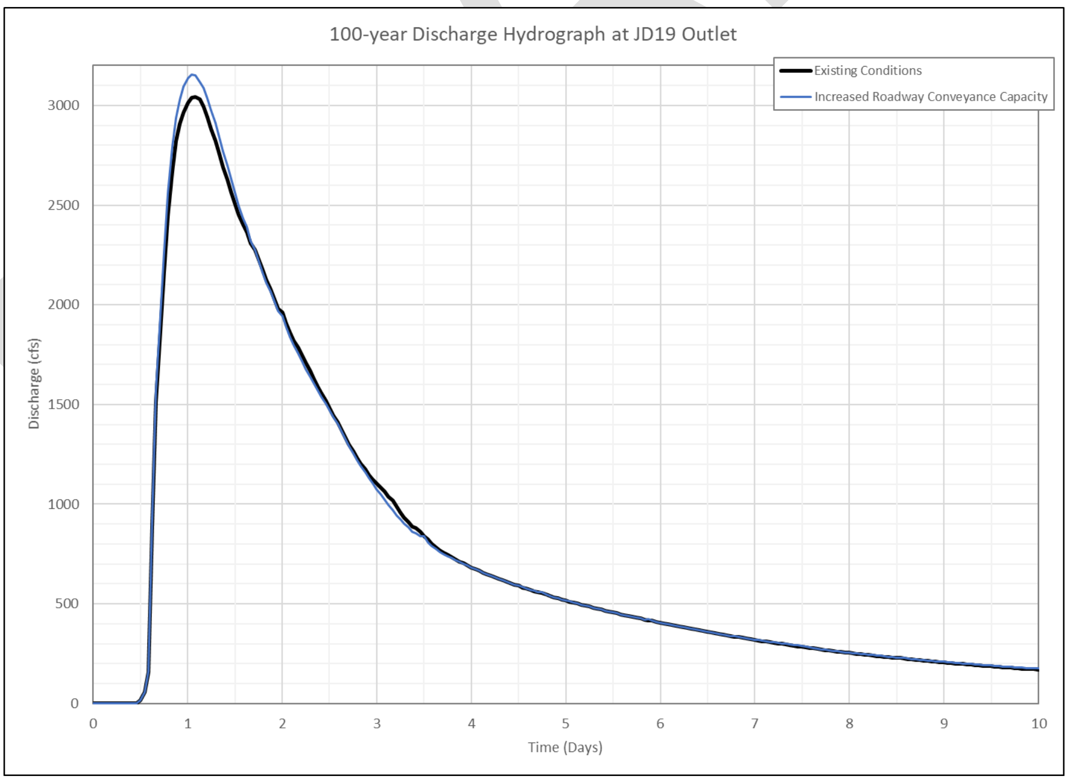
8
9
10
Time (Days)


100-year Discharge Hydrograph at JD19 Outlet
Existing Conditions
Increased Roadway Conveyance Capacity
Discharge (cfs)
3000
2500
2000
1500
1000
500
0
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1
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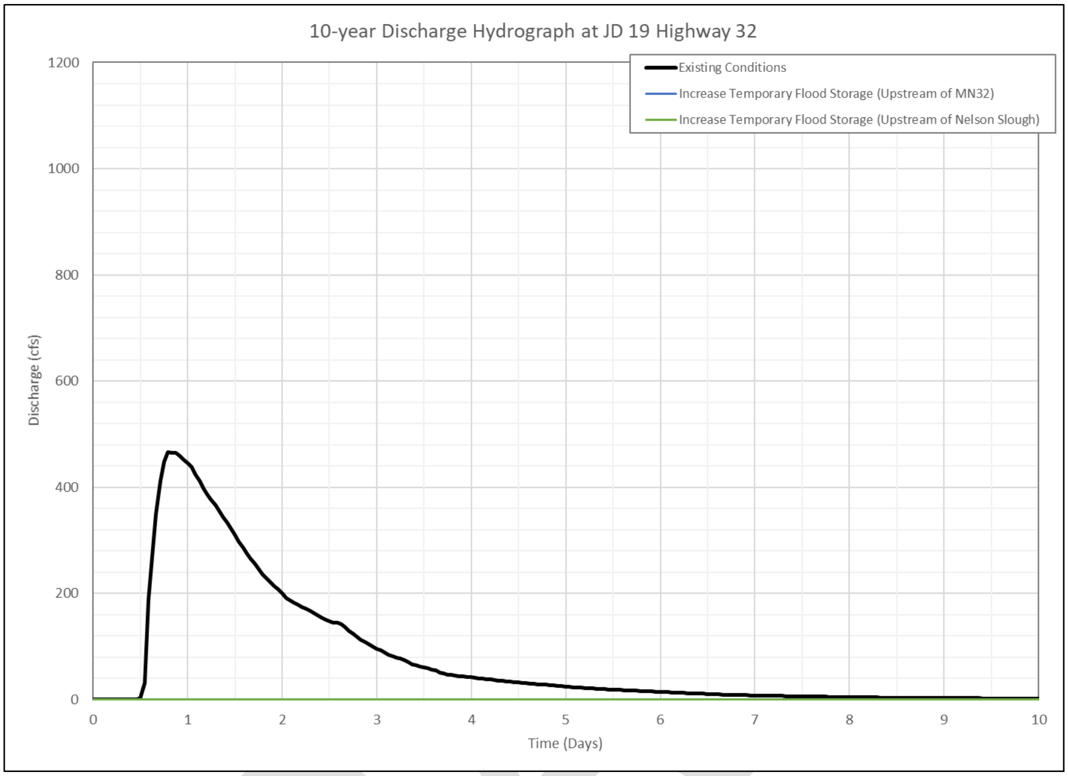
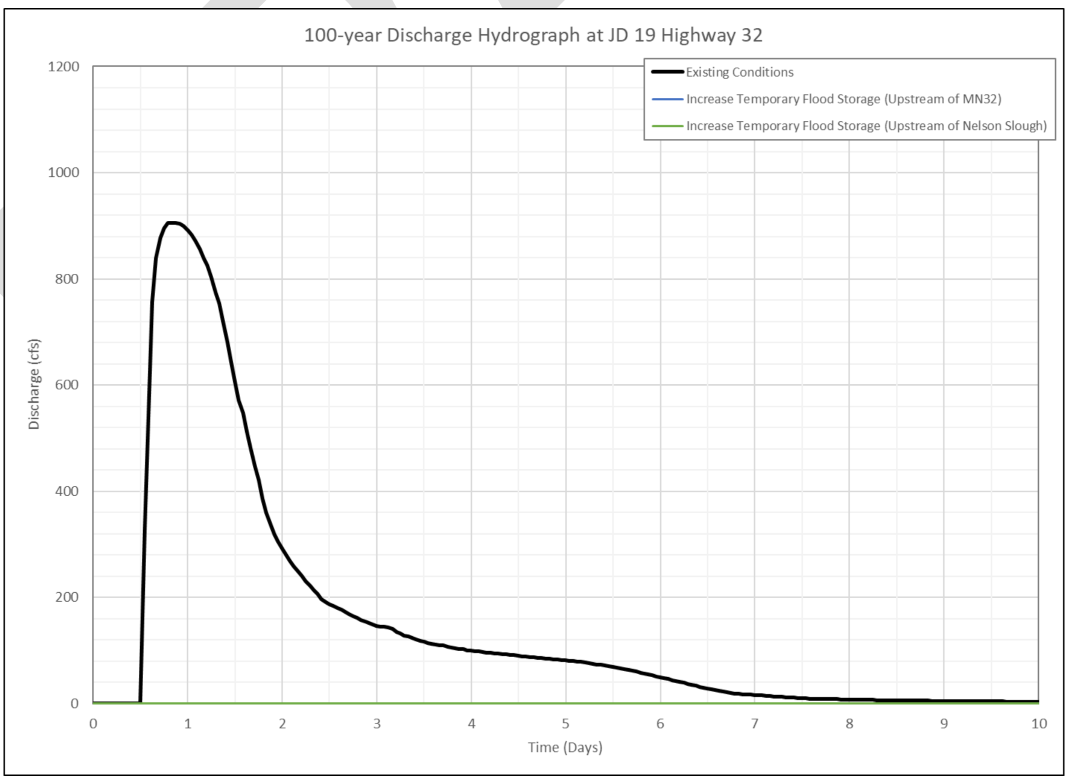
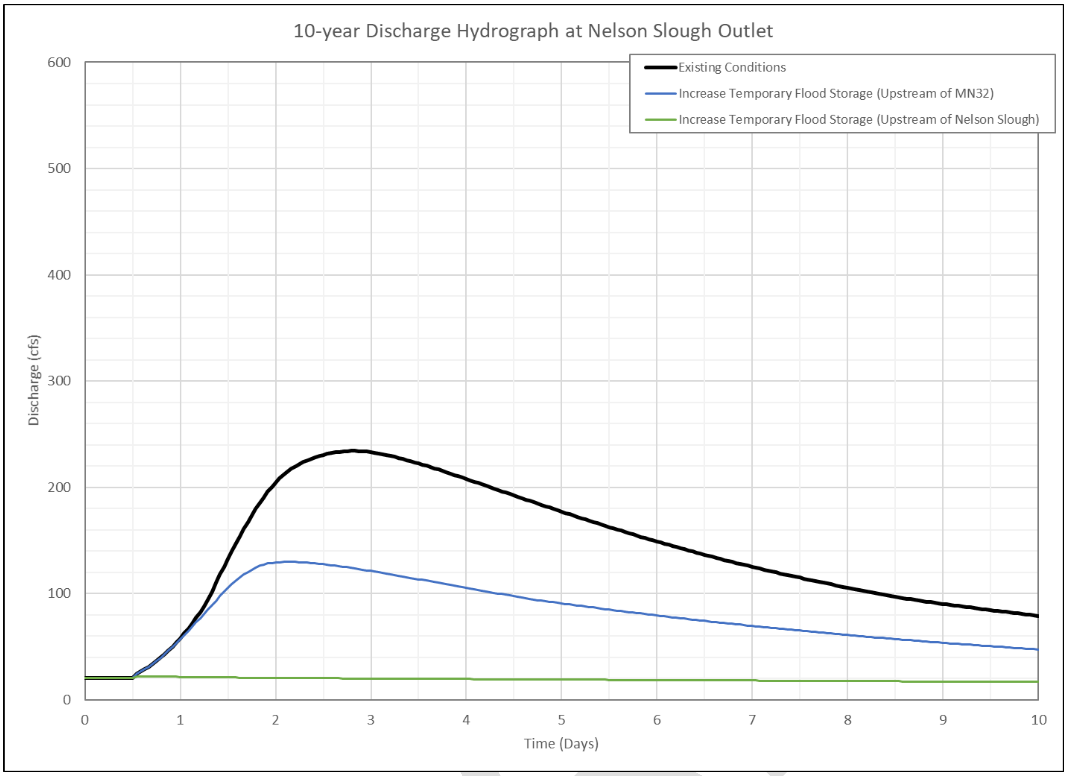
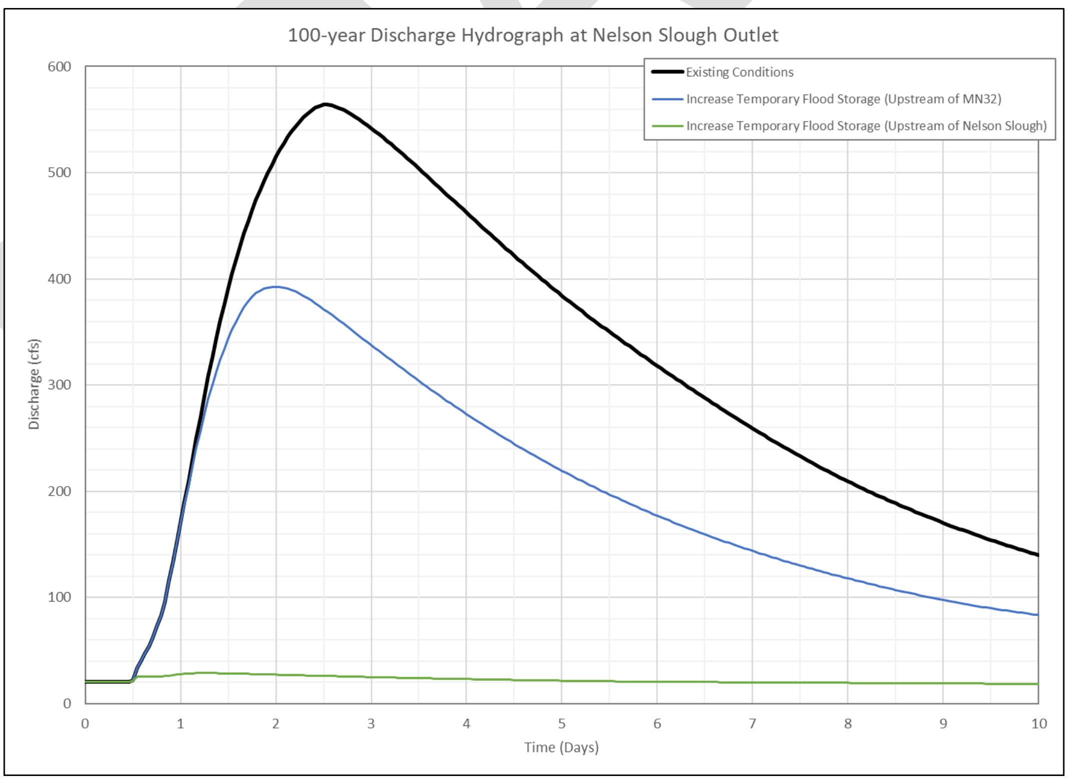
9
10
Time (Days)

A.4 INCREASE TEMPORARY FLOOD STORAGE – HYDROGRAPHS






10-year Discharge Hydrograph at Nelson Slough Outlet
Existing Conditions
Increase Temporary Flood Storage (Upstream of MN32)
Increase Temporary Flood Storage (Upstream of Nelson Slough)
Discharge (cfs)
Time (Days)
0
100
200
300
400
500
600
0
1
2
3
4
5
6
7
8
9
10


100-year Discharge Hydrograph at Nelson Slough Outlet
Existing Conditions
Increase Temporary Flood Storage (Upstream of MN32)
Increase Temporary Flood Storage (Upstream of Nelson Slough)
Discharge (cfs)
Time (Days)
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200
300
400
500
600
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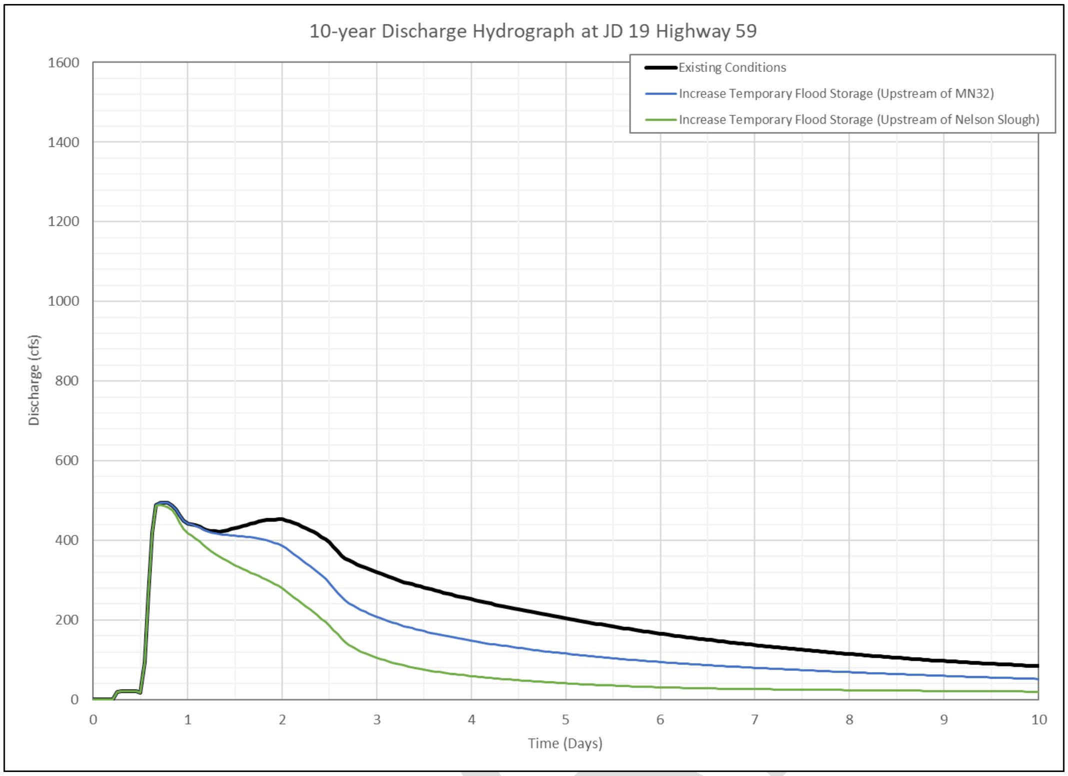
6
7
8
9
10



10-year Discharge Hydrograph at JD 19 Highway 59
Existing Conditions
Increase Temporary Flood Storage (Upstream of MN32)
Increase Temporary Flood Storage (Upstream of Nelson Slough)
Discharge (cfs)
Time (Days)
0
200
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1000
1200
1400
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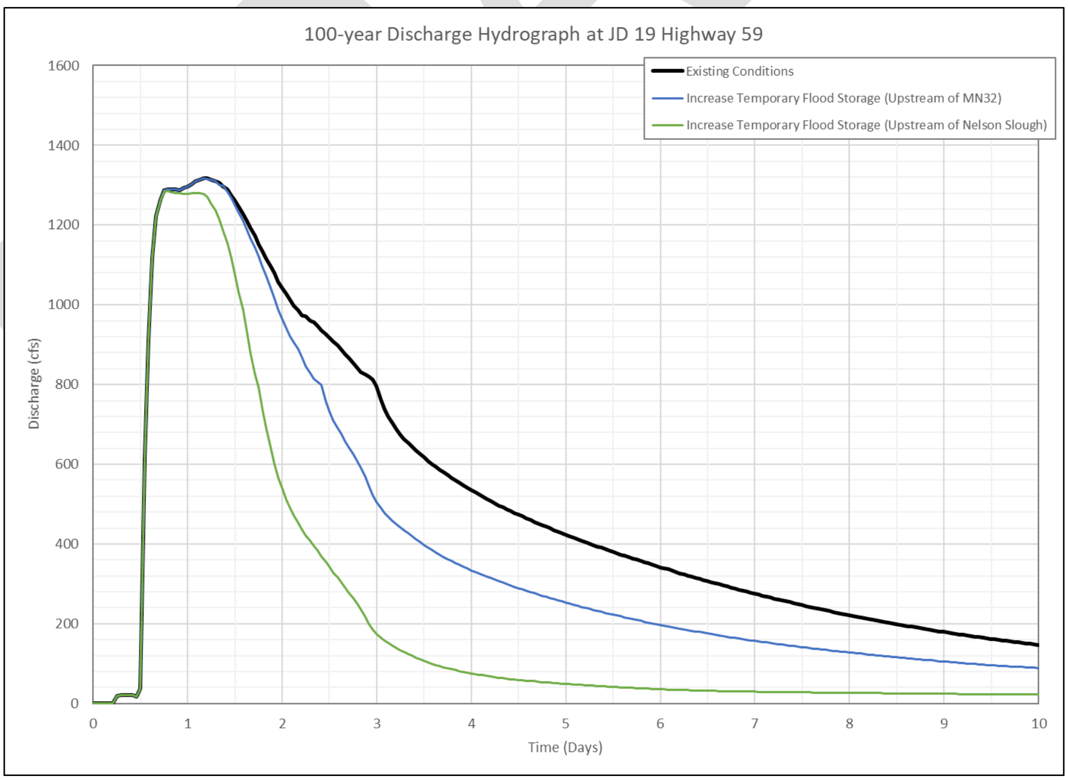
6
7
8
9
10



100-year Discharge Hydrograph at JD 19 Highway 59
Existing Conditions
Increase Temporary Flood Storage (Upstream of MN32)
Increase Temporary Flood Storage (Upstream of Nelson Slough)
Discharge (cfs)
Time (Days)
0
200
400
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1000
1200
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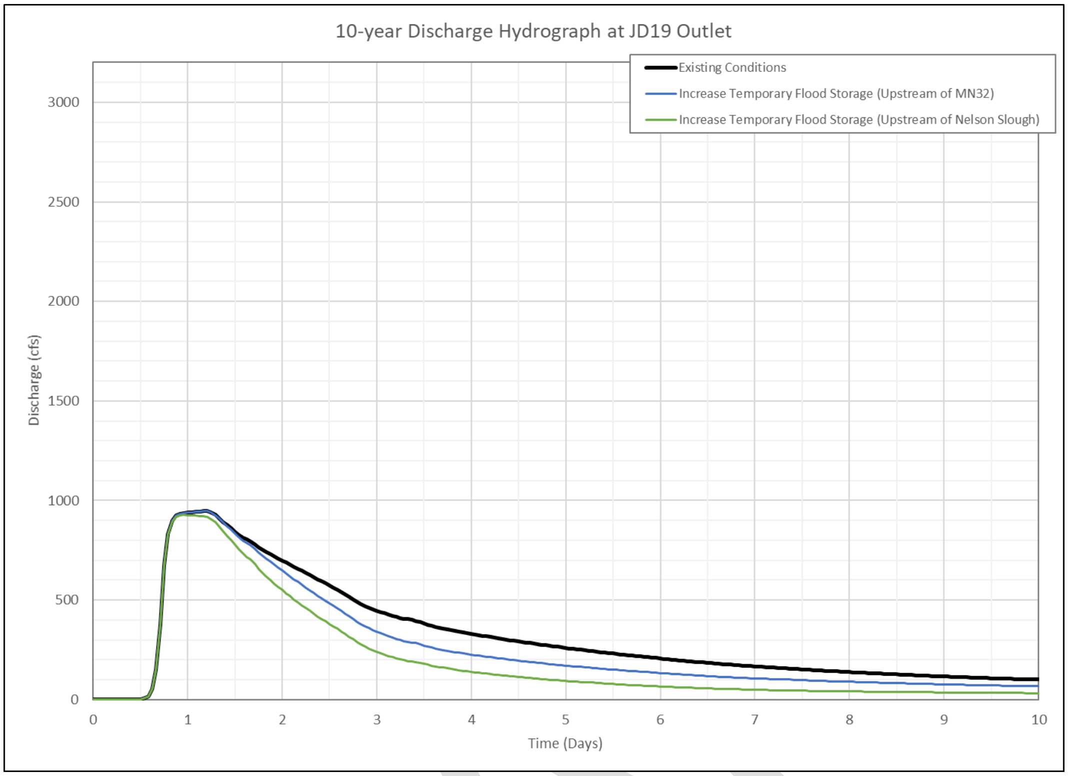
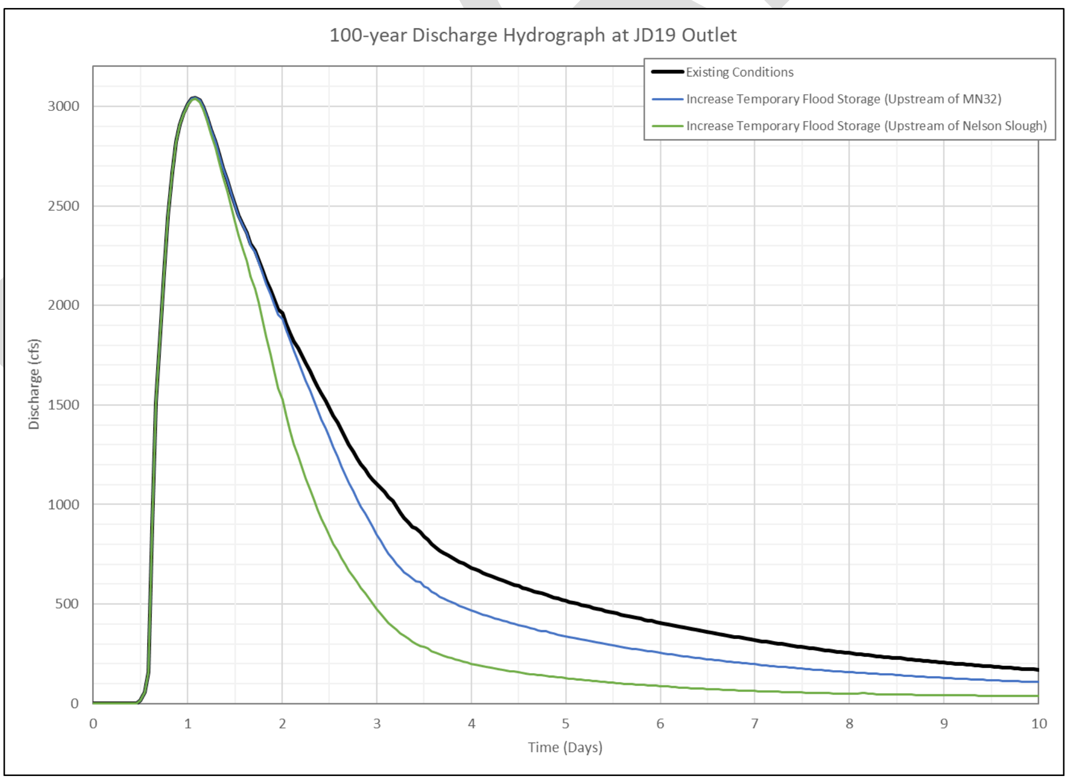
6
7
8
9
10


10-year Discharge Hydrograph at JD19 Outlet
Existing Conditions
Increase Temporary Flood Storage (Upstream of MN32)
Increase Temporary Flood Storage (Upstream of Nelson Slough)
Discharge (cfs)
Time (Days)
0
500
1000
1500
2000
2500
3000
0 1 2 3 4 5 6 7 8 9 10


100-year Discharge Hydrograph at JD19 Outlet
Existing Conditions
Increase Temporary Flood Storage (Upstream of MN32)
Increase Temporary Flood Storage (Upstream of Nelson Slough)
Discharge (cfs)
Time (Days)
0
500
1000
1500
2000
2500
3000
0 1 2 3 4 5 6 7 8 9 10

APPENDIX B

Figure B.1: Identified Alternatives – Reporting Locations
B.2 Alternative 1 – Drainage Improvement – Hydrographs
B.3 Alternatives 2-7 – Impoundment Site Alternatives – Hydrographs

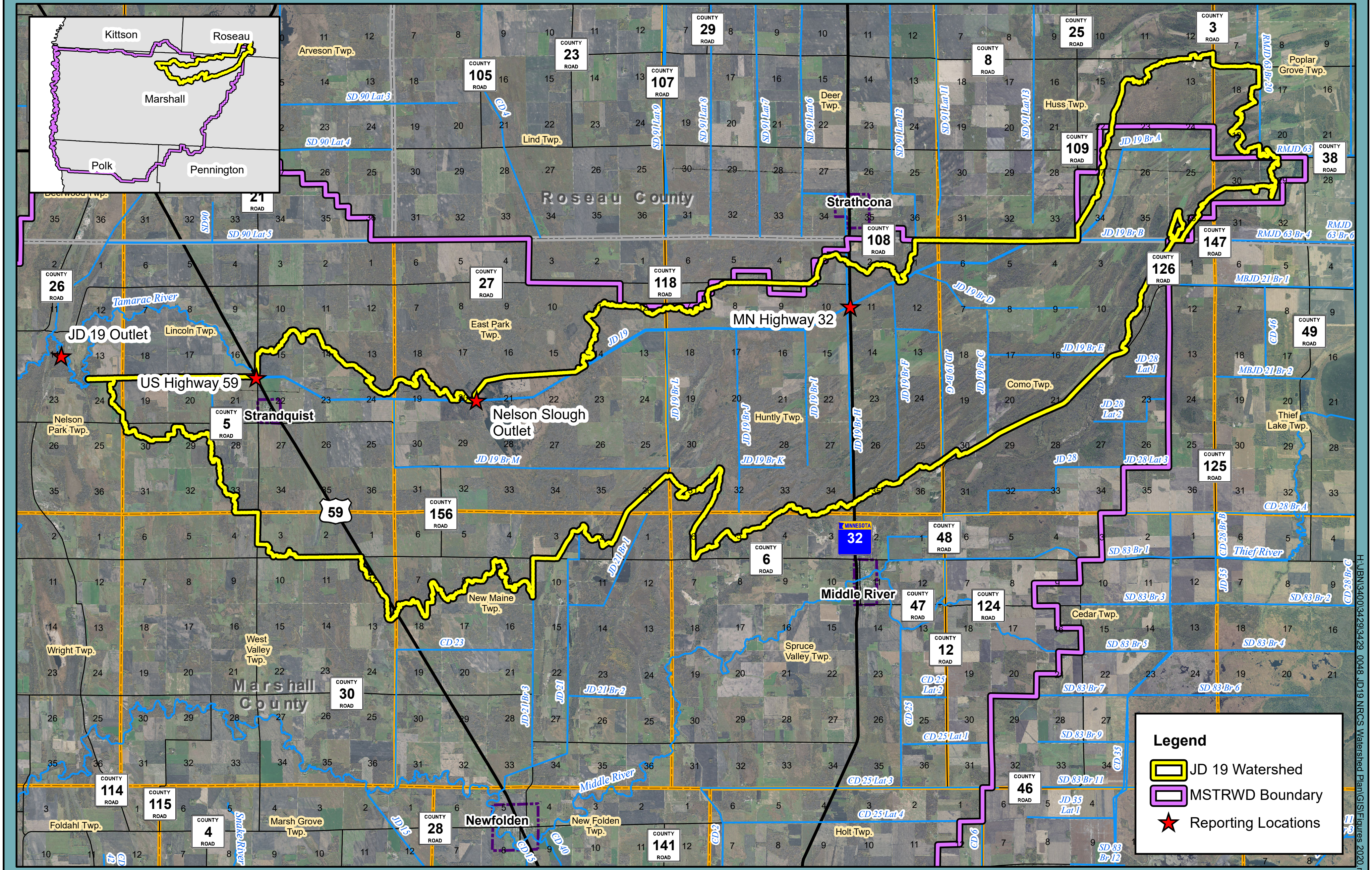


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Fig. B.1

Figure B.1: Identified Alternatives - Reporting Locations

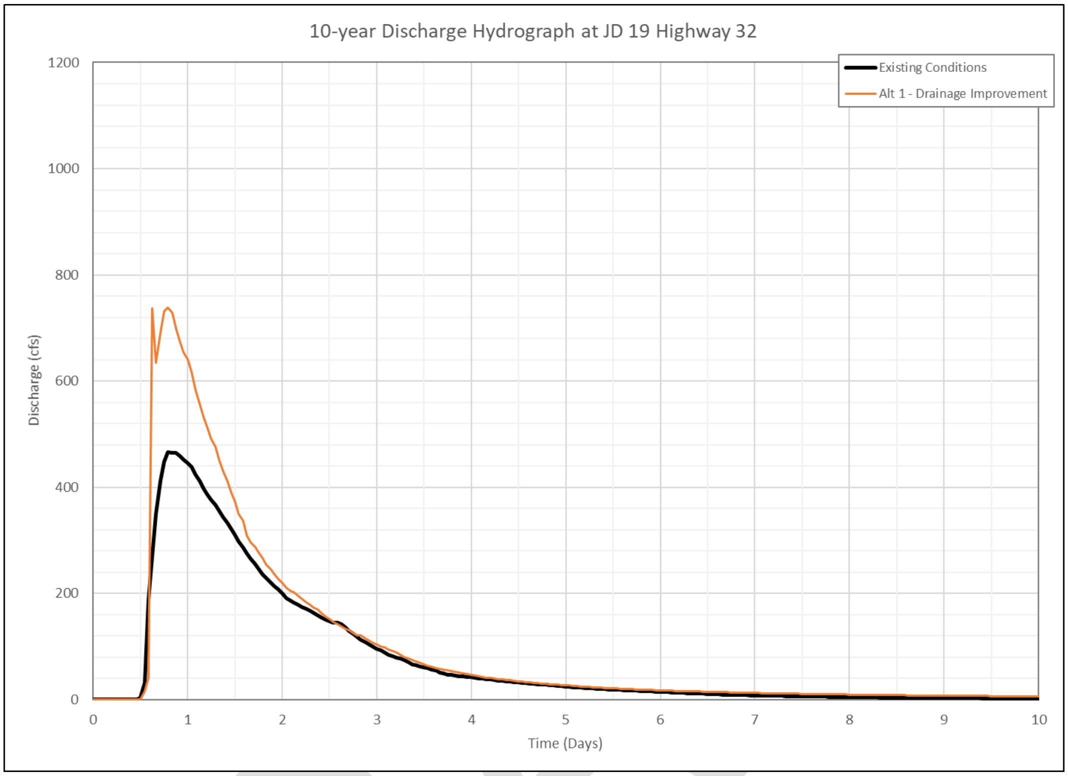
Judicial Ditch #19 Watershed Plan
Screening of Alternatives for Detailed Review
Middle-Snake-Tamarac Rivers Watershed District

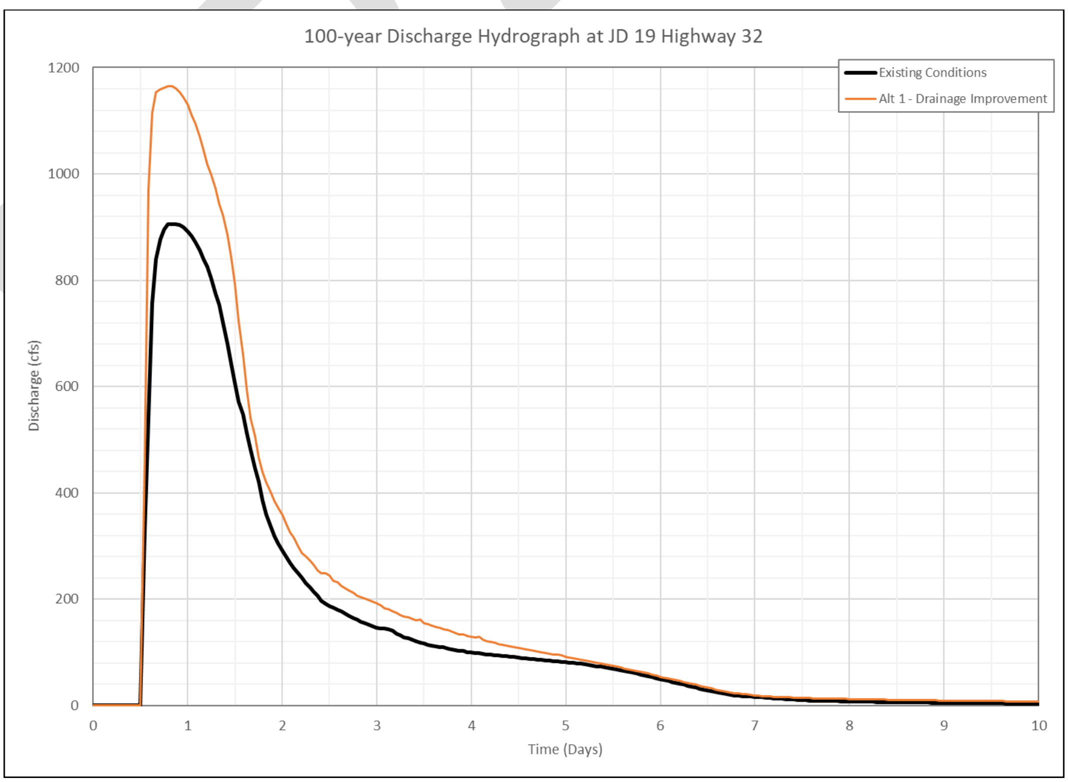
N W E S

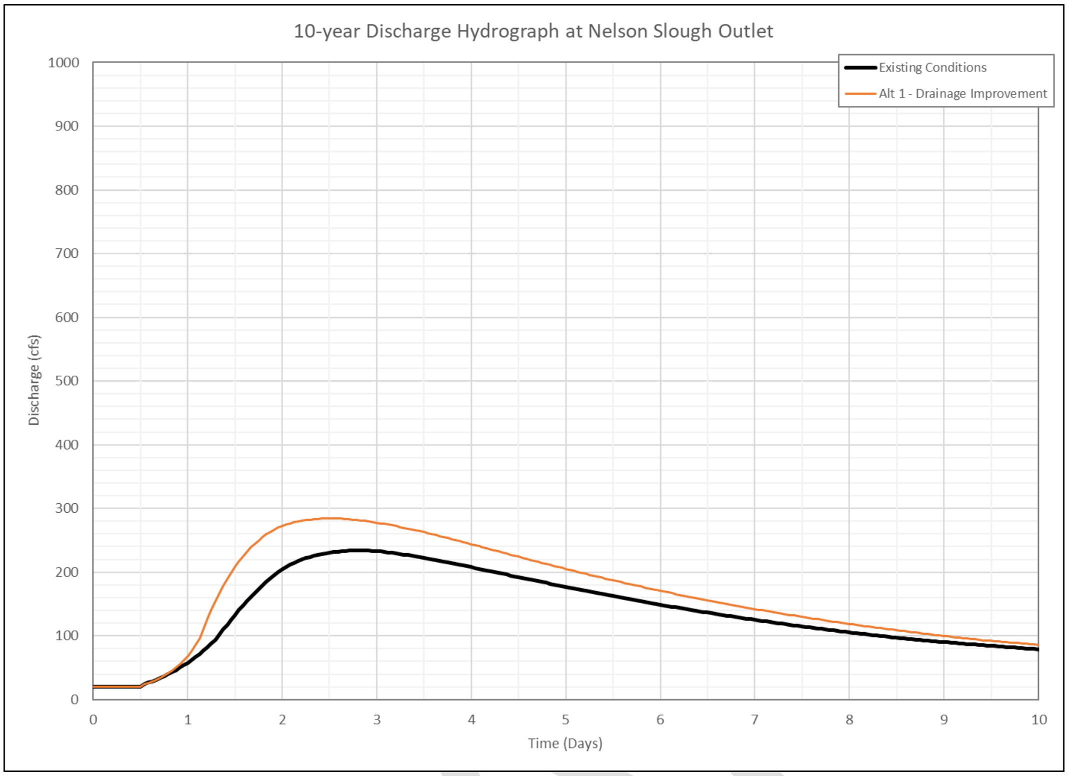
0 1 2 4 Miles

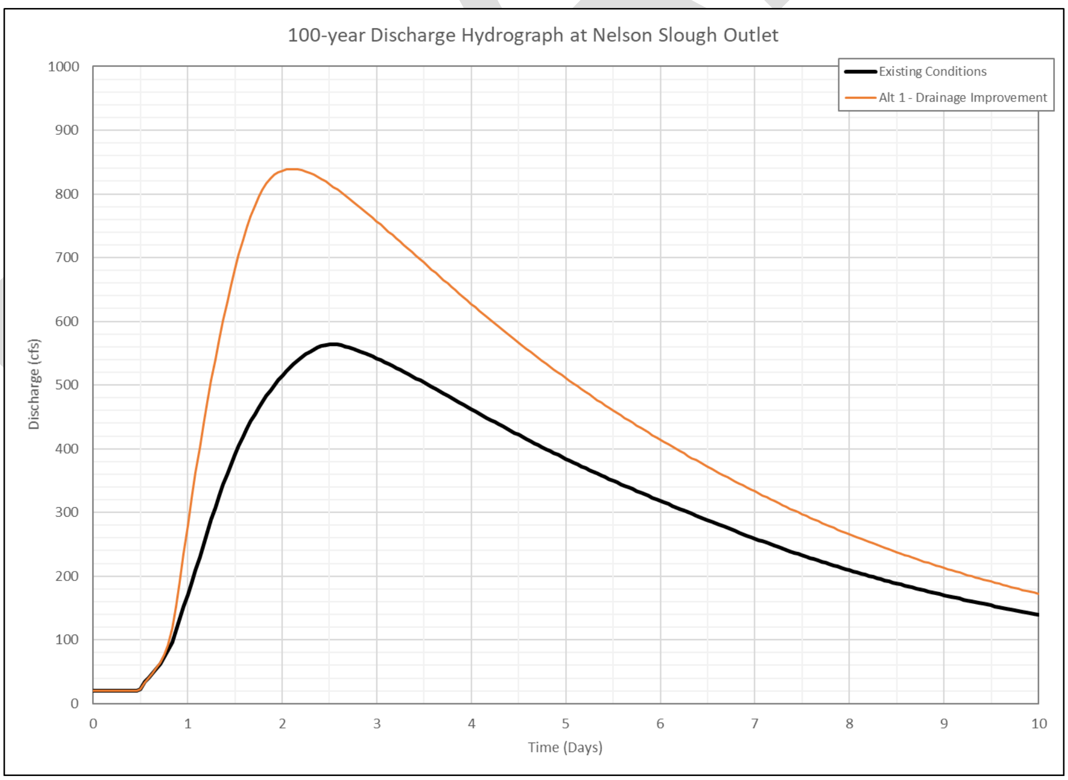
Houston Engineering Inc.

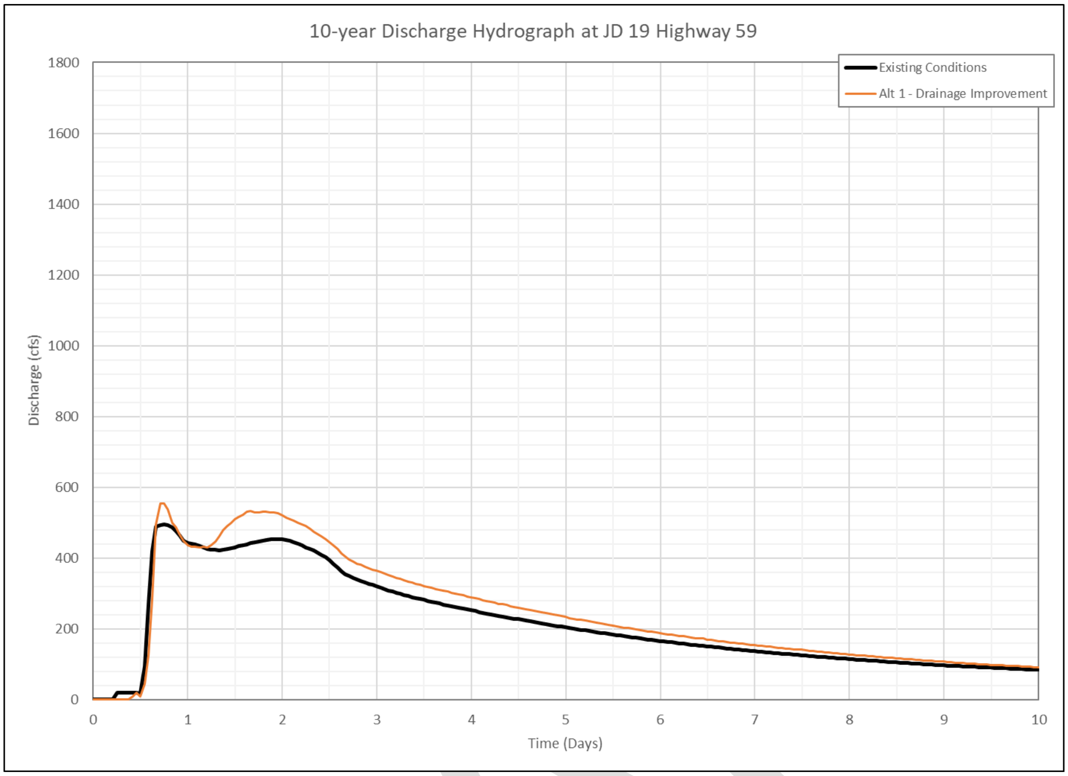
B.2 ALTERNATIVE 1 – DRAINAGE IMPROVEMENT – HYDROGRAPHS

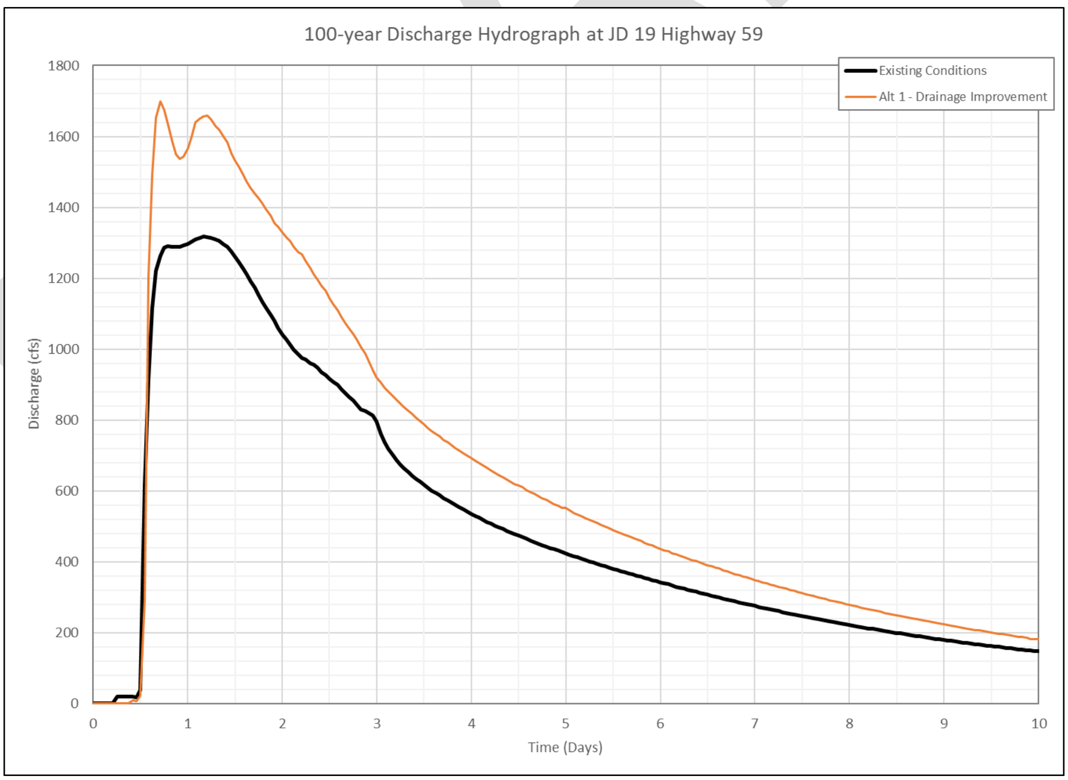


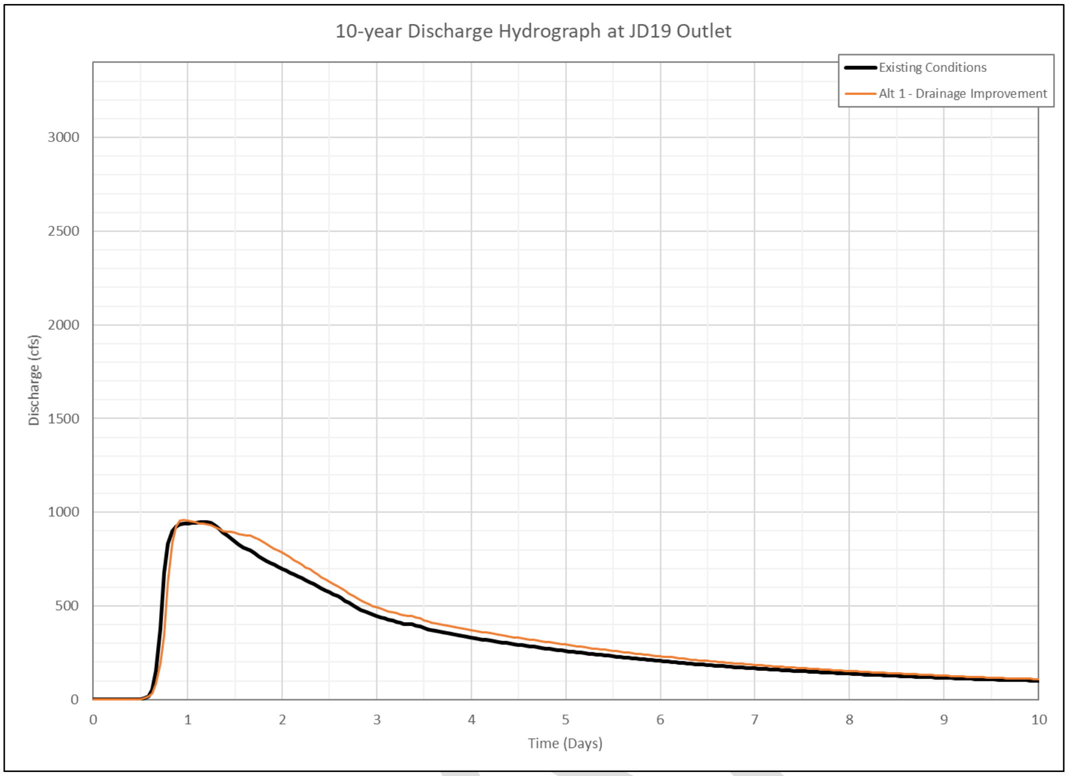


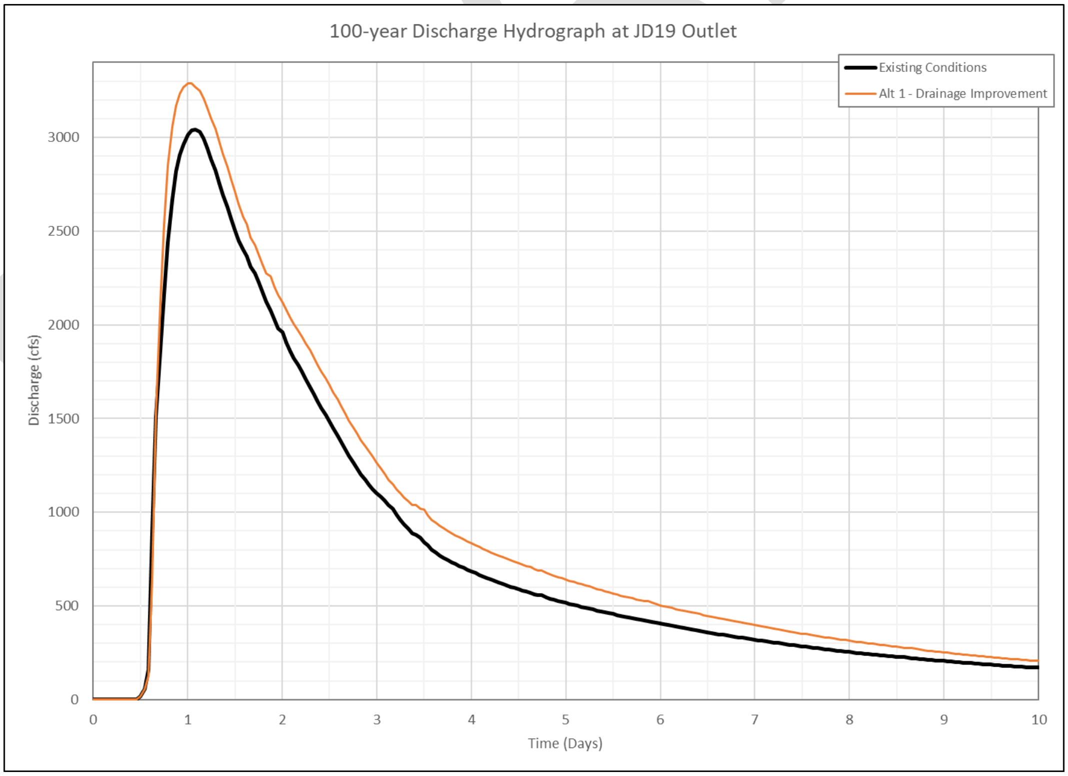

10-year Discharge Hydrograph at Nelson Slough Outlet
Existing Conditions
Alt 1 - Drainage Improvement
Discharge (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
Time (Days)


100-year Discharge Hydrograph at Nelson Slough Outlet
Existing Conditions
Alt 1 - Drainage Improvement
Discharge (cfs)
1000
900
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
Time (Days)

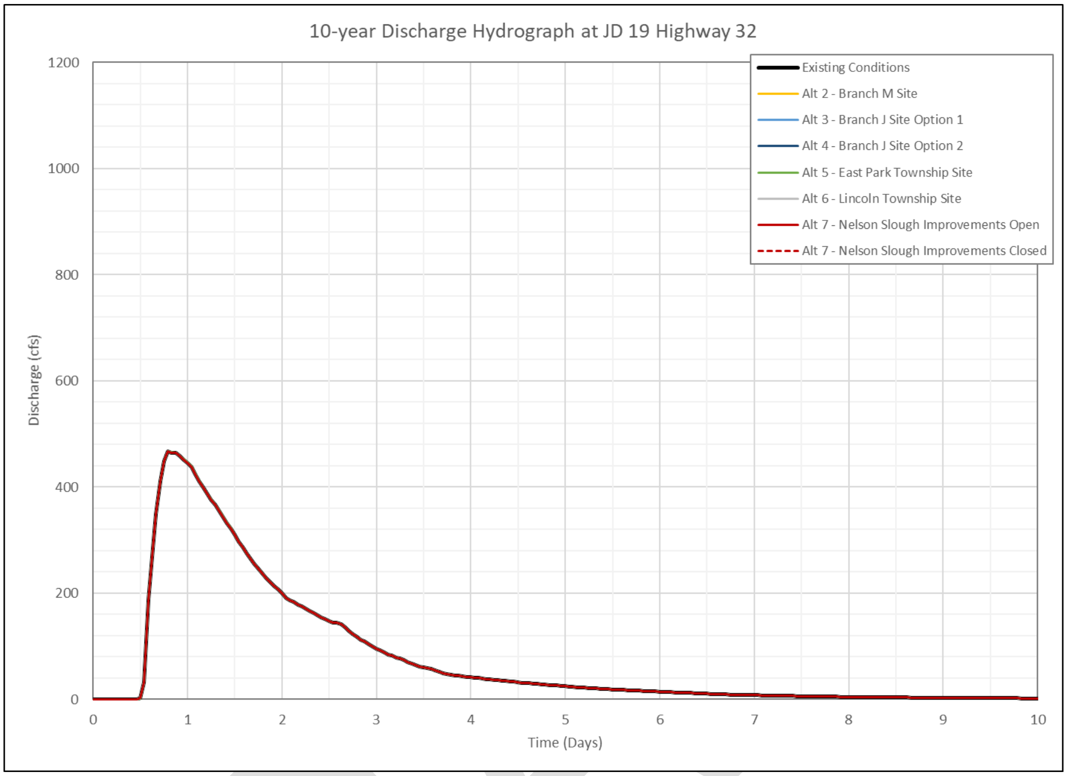

10-year Discharge Hydrograph at JD 19 Highway 59
Existing Conditions
Alt 1 - Drainage Improvement
Discharge (cfs)
1800
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
9
10
Time (Days)

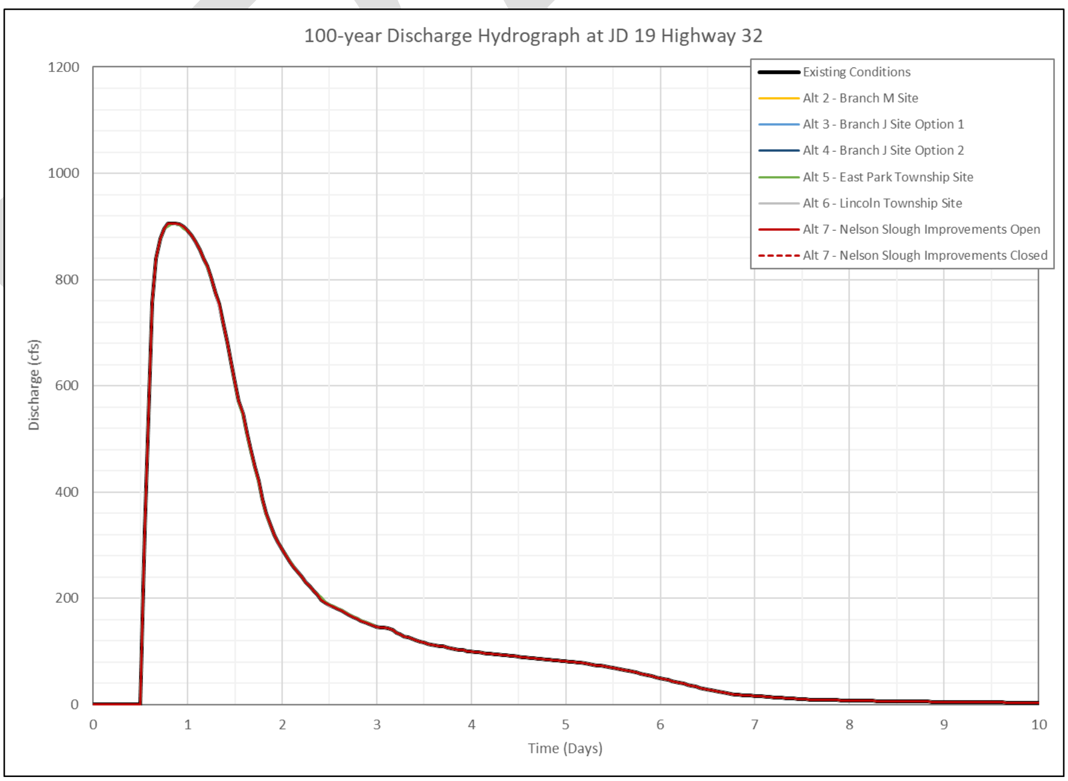

100-year Discharge Hydrograph at JD 19 Highway 59
Existing Conditions
Alt 1 - Drainage Improvement
Discharge (cfs)
1800
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
9
10
Time (Days)

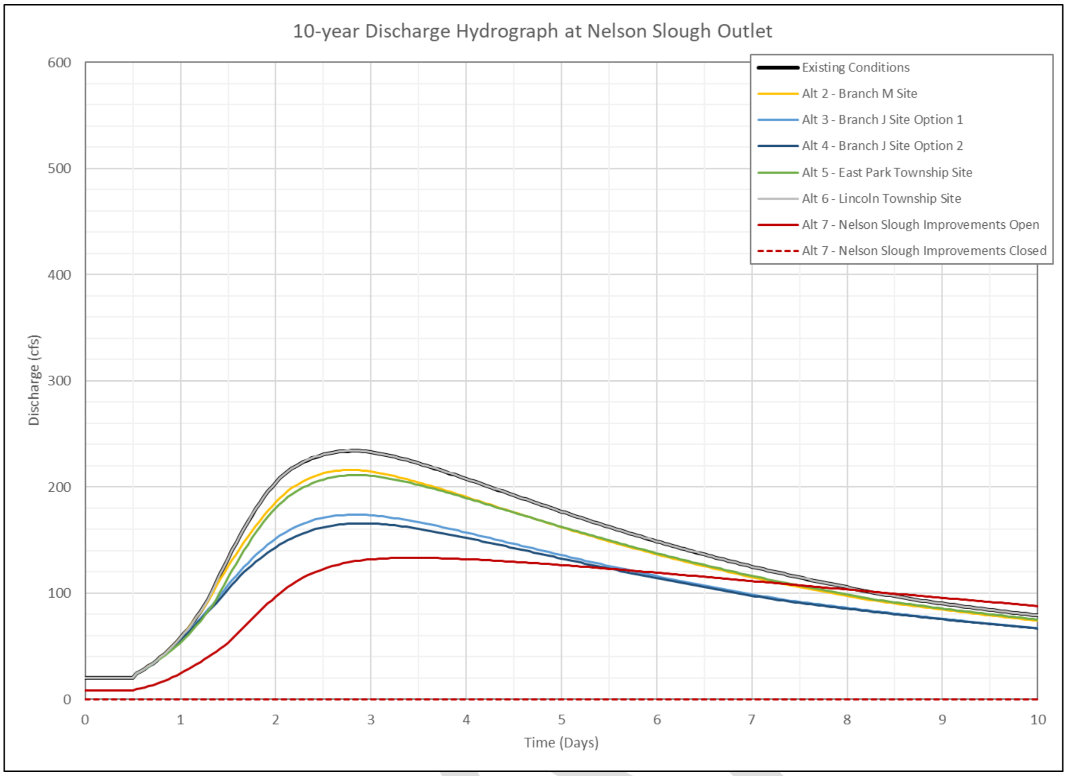

10-year Discharge Hydrograph at JD19 Outlet
Existing Conditions
Alt 1 - Drainage Improvement
Discharge (cfs)
3000
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
8
9
10
Time (Days)


100-year Discharge Hydrograph at JD19 Outlet
Existing Conditions
Alt 1 - Drainage Improvement
Discharge (cfs)
3000
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
8
9
10
Time (Days)

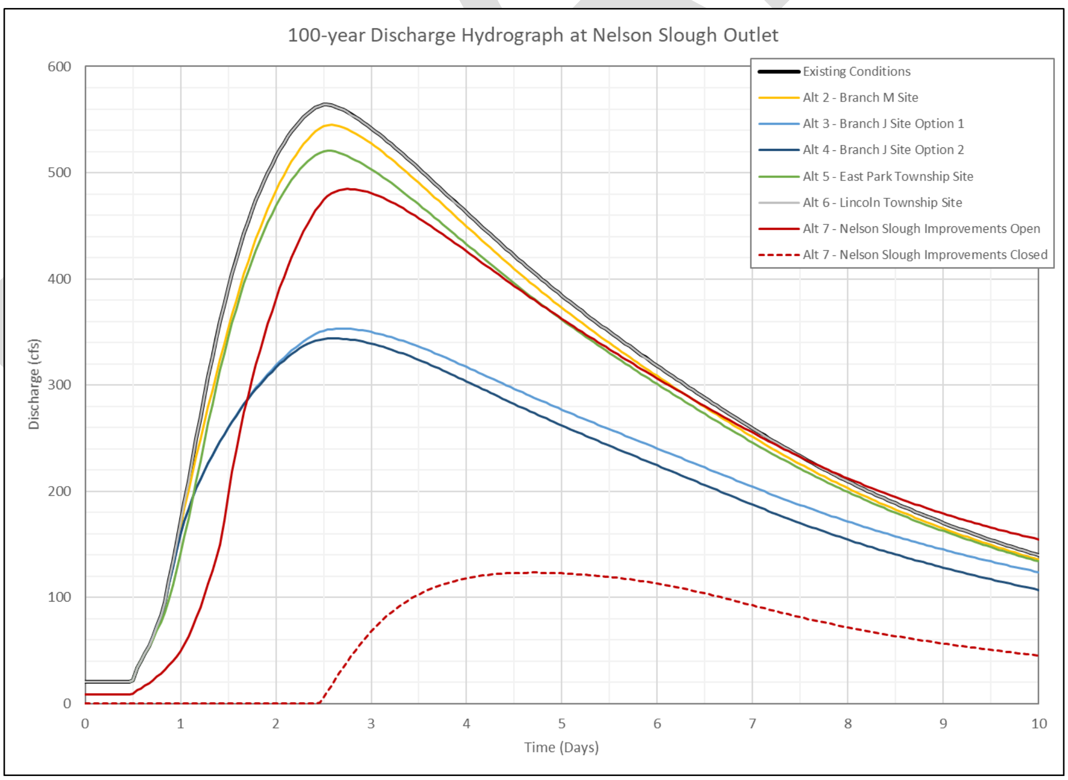
B.3 ALTERNATIVES 2-7 – IMPOUNDMENT SITE ALTERANTIVES – HYDROGRAPHS



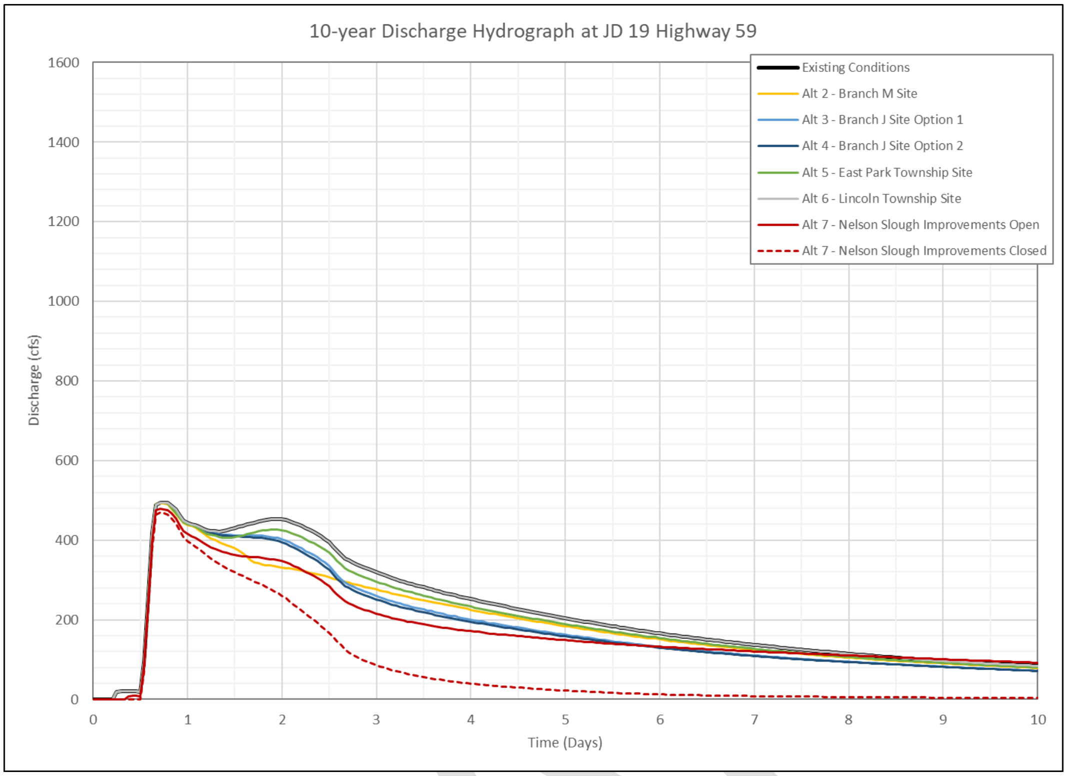


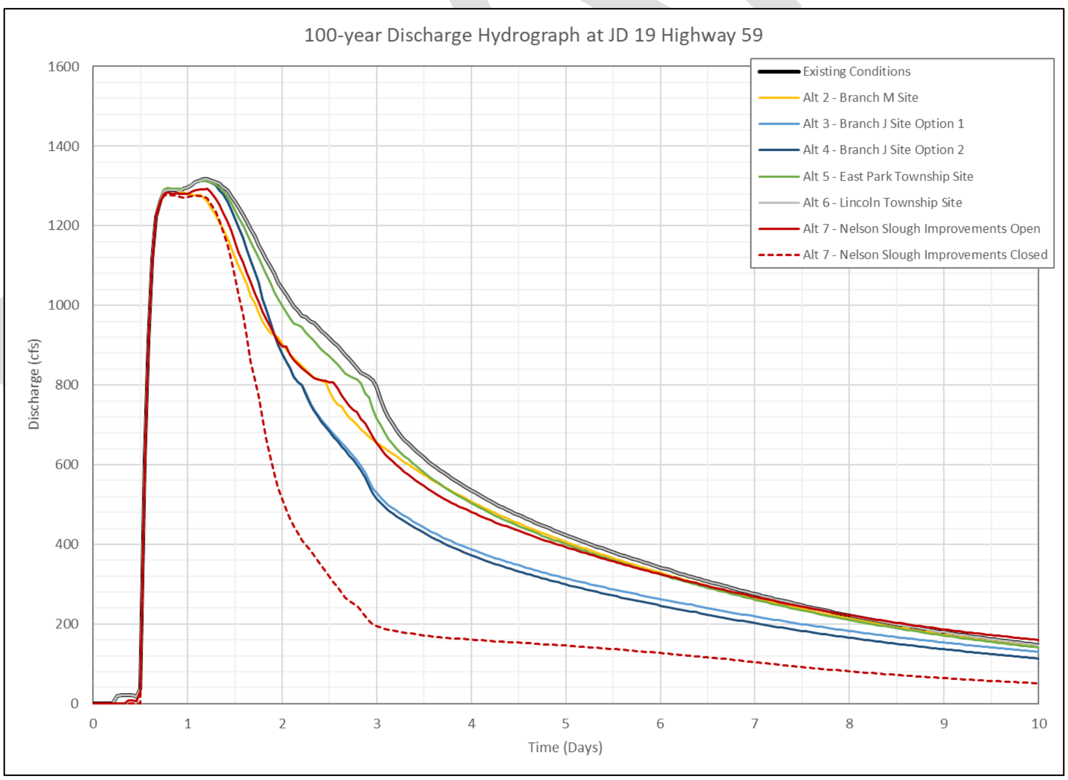


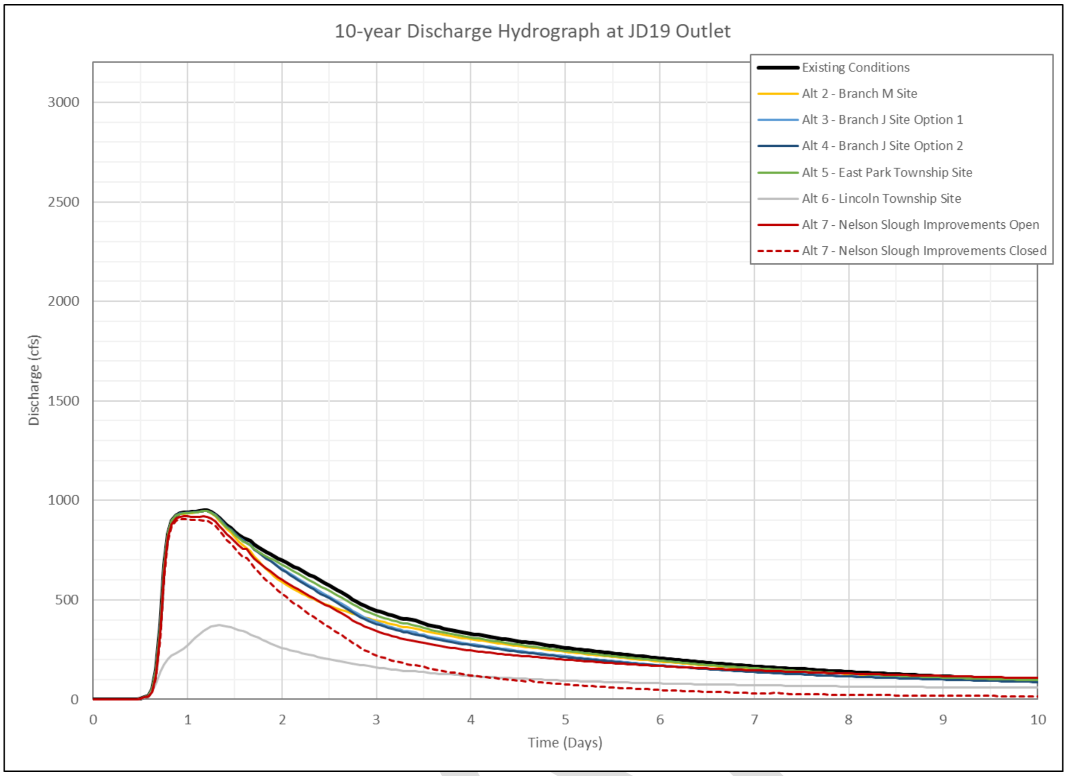
10-year Discharge Hydrograph at Nelson Slough Outlet
Discharge (cfs)
Time (Days)
0
100
200
300
400
500
600
0
1
2
3
4
5
6
7
8
9
10
Existing Conditions
Alt 2 - Branch M Site
Alt 3 - Branch J Site Option 1
Alt 4 - Branch J Site Option 2
Alt 5 - East Park Township Site
Alt 6 - Lincoln Township Site
Alt 7 - Nelson Slough Improvements Open
Alt 7 - Nelson Slough Improvements Closed



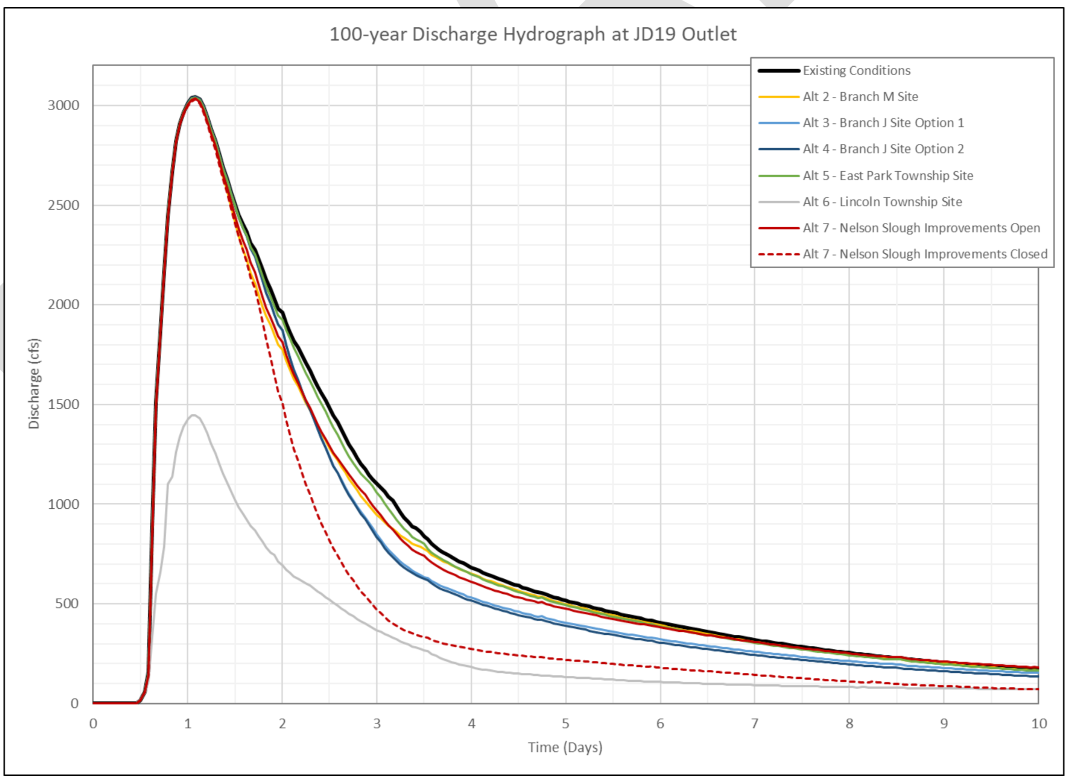
100-year Discharge Hydrograph at Nelson Slough Outlet
Discharge (cfs)
Time (Days)
0
100
200
300
400
500
600
0
1
2
3
4
5
6
7
8
9
10
Existing Conditions
Alt 2 - Branch M Site
Alt 3 - Branch J Site Option 1
Alt 4 - Branch J Site Option 2
Alt 5 - East Park Township Site
Alt 6 - Lincoln Township Site
Alt 7 - Nelson Slough Improvements Open
Alt 7 - Nelson Slough Improvements Closed


10-year Discharge Hydrograph at JD 19 Highway 59
Discharge (cfs)
0
200
400
600
800
1000
1200
1400
1600
Time (Days)
0
1
2
3
4
5
6
7
8
9
10
Existing Conditions
Alt 2 - Branch M Site
Alt 3 - Branch J Site Option 1
Alt 4 - Branch J Site Option 2
Alt 5 - East Park Township Site
Alt 6 - Lincoln Township Site
Alt 7 - Nelson Slough Improvements Open
Alt 7 - Nelson Slough Improvements Closed


100-year Discharge Hydrograph at JD 19 Highway 59
Discharge (cfs)
0
200
400
600
800
1000
1200
1400
1600
Time (Days)
0
1
2
3
4
5
6
7
8
9
10
Existing Conditions
Alt 2 - Branch M Site
Alt 3 - Branch J Site Option 1
Alt 4 - Branch J Site Option 2
Alt 5 - East Park Township Site
Alt 6 - Lincoln Township Site
Alt 7 - Nelson Slough Improvements Open
Alt 7 - Nelson Slough Improvements Closed



10-year Discharge Hydrograph at JD19 Outlet
Discharge (cfs)
Time (Days)
0
500
1000
1500
2000
2500
3000
0
1
2
3
4
5
6
7
8
9
10
Existing Conditions
Alt 2 - Branch M Site
Alt 3 - Branch J Site Option 1
Alt 4 - Branch J Site Option 2
Alt 5 - East Park Township Site
Alt 6 - Lincoln Township Site
Alt 7 - Nelson Slough Improvements Open
Alt 7 - Nelson Slough Improvements Closed



100-year Discharge Hydrograph at JD19 Outlet
Discharge (cfs)
Time (Days)
0
500
1000
1500
2000
2500
3000
0
1
2
3
4
5
6
7
8
9
10
Existing Conditions
Alt 2 - Branch M Site
Alt 3 - Branch J Site Option 1
Alt 4 - Branch J Site Option 2
Alt 5 - East Park Township Site
Alt 6 - Lincoln Township Site
Alt 7 - Nelson Slough Improvements Open
Alt 7 - Nelson Slough Improvements Closed