APPENDIX I

Maple Grove, MN | HEI No. 5555_251
February 29, 2016

FUTURE LAND USE CONDITIONS HYDROLOGY & HYDRAULICS ANALYSIS FOR UPPER RICE CREEK

RCWD
RICE CREEK WATERSHED DISTRICT

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Acronyms and Abbreviations List

ACD	Anoka County Ditch
ASSA	Autodesk Storm and Sanitary Analysis
BMP	Best Management Practices
cfs	Cubic feet per second
CN	Curve Number
DWMP	District Wide Modeling Program
FEMA	Federal Emergency Management Agency
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HEI	Houston Engineering, Inc.
HSG	Hydrologic Soil Group
JD	Judicial Ditch
MCPLU	Metropolitan Council Planned Land Use
MLCCS	Minnesota Land Cover Classification System
NRCS	Natural Resources Conservation Service
PR	Planning Region
RCWD	Rice Creek Watershed District
SCS	Soil Conservation Service
SWMM	Storm Water Management Model
Tc	Time of Concentration
TM	Technical Memorandum
TR-55	Technical Release 55
WMP	Watershed Management Plan

1 INTRODUCTION

1.1 Background

The District Wide Modeling Program (DWMP) initiated by the Rice Creek Watershed District (District) in 2008 is focused on developing 1) methods and procedures; 2) information and data; and 3) water quality, hydrologic and hydraulic models (collectively termed “technical resources”) for use in addressing hydrology, hydraulic, and water quality issues. A summary report of the DWMP was prepared upon completion of the initial modeling and reporting (HEI, 2012B). Within the summary report, Table 1 shows the specific goals and technical objectives of the DWMP. A number of technical resources have been developed throughout the DWMP and a summary of these can be found in Tables 3-6 in the report summary (HEI, 2012B). This report continues the development of additional technical resources.

The District has and continues to use these technical resources to develop the information needed to support decision-making by District staff and the Board of Managers (Board). The technical resources are commonly relied upon internal to the District for supporting decisions related to the sizing of culverts and bridges crossing public drainage systems and roads; assessing the ability of a water conveyance system to transport flow; conceptualizing and design of water projects to reduce flooding and improve water quality; developing floodplain boundaries; and evaluating the effectiveness of and need for modifications to the District rules. These same technical resources are commonly shared with and provided to the development community, cities, transportation authorities, and counties for their use in addressing water quality, hydraulic, and hydrology issues. The technical resources have resulted in considerable public value, including the ability to quickly and effectively respond to challenging technical questions, through better knowledge and improved solutions, and via a reduction in public expenditures through reuse of the resources.

Through previous DWMP analysis an improved understanding of the rate, volume, and timing of water movement throughout the District has been realized. Because of this improved understanding the District has come to recognize the importance of key resources and specific watersheds in their role in causing flooding and flood damages. Specifically, the analysis showed that lakes (Baldwin, Rice, Reshenau, Marshan, Peltier, and George Watch) collectively known as the Anoka chain of lakes are instrumental in providing flood storage, thereby reducing the risk of downstream flooding along Rice Creek within Shoreview, Arden Hills, Mounds View, New Brighton, and Fridley. The previous analysis also showed that existing flooding problems are in part caused by the accelerated rate and volume of runoff from Ramsey County Ditches No. 2, 3, 4, and 5, and land located immediately adjacent to lower Rice Creek. The District used the technical resources to establish the goal of removing an estimated 2,500 acre-feet of runoff volume from the peak window of the inflow to Long Lake (HEI, 2012a). The District also established a more stringent standard for controlling the rate of runoff for land located downstream from Baldwin Lake, as a means of working toward this goal.

Development patterns and trends have resulted in differing amounts of impervious (i.e. hard and not susceptible to infiltration) surfaces (e.g. roads, building roof tops, and parking lots) within the District. Much of the land area downstream of Baldwin Lake is already developed and therefore has a larger proportion of impervious surface than land contributing runoff to the Anoka chain of lakes and upstream. An increased amount of impervious surfaces in these areas has also occurred as a result of development adjacent to the major arteries of the transportation system including I-35E and I-35W. Development (and redevelopment) is expected to continue throughout the District. The greatest amount of area available for development is upstream of and contributing runoff to the Anoka chain of lakes. Much of this land exhibits a groundwater elevation near the land surface and soils high in organic content. Both of these factors appear to limit the amount of area for stormwater management practices which function by reducing runoff volume.

1.2 Project Purposes

The currently available technical resources developed through the DWMP reflect the existing development patterns, locations, and amounts of impervious surfaces within the District. Because of the focus on and concern about flooding and flood damages the Board authorized the development of technical resources reflecting the probable future development patterns, locations, and amounts of impervious surfaces through the issuance of Task Order 2015-022. Specifically, the task order authorized the development of information, data, and hydrologic and hydraulic models (i.e. future conditions models) reflecting the probable future development patterns, locations, and amounts of impervious surfaces reflected in various municipal and regional government land use plans.

The primary purpose for completing this work as expressed by the Board is being proactive in the development of information, which can used and shared to minimize and reduce the risk of future flooding and flood damages within the District. Using this knowledge, the District can decide upon and use the most appropriate methods for minimizing this risk. These methods include providing financial incentives to partners for the construction of cooperative projects, construction of projects by the District itself, and modification and utilization of the District's regulatory program.

This report presents the results of the future conditions modeling analysis, which primarily reflects potential land use changes into the foreseeable future, upstream of Baldwin Lake. Included within this report is information about the:

- Effects of future land use changes and specifically development and the associated change in the amount of impervious area on peak discharges and runoff volumes;

- Identification of potential future flood and flood damage regional problem areas;
- The ability of the current District standards for rate control and water quality treatment to mitigate potential future flooding and flood damages;
- Adequacy and the role of key storage locations like the Anoka chain of lakes, in mitigating potential flooding when the area develops;
- Ability of a rule-based approach to address future flooding and flood damages and the implications of such a rule;
- Probable changes in the rate, volume and timing of runoff; and
- Possible changes in the rate and volume of runoff from one community to the next.

The information contained within this report is expected to be used by the District to guide several policy discussions, including the identification and implementation of the most cost effective methods to minimize the risk of future flooding and flood damages. These technical resources are also expected to be shared with the municipalities located within the District providing them with valuable information and tools for their use.

1.3 Analysis Scale

The technical resources developed as a result of this work are consistent with the District's role as a regional water manager. The analysis and results cannot possibly identify every potential flood problem area, including those at a very small scale such as a given parcel or development site. However, the technical resources do provide a framework for subsequent analysis at a more detailed scale, when needed in the future.

2 MODEL DEVELOPMENT

From 2009-2011, the District oversaw the DWMP, under which existing condition hydrologic and hydraulic models were developed or updated for the entire District. These models were developed using multiple modeling programs. Details on the development of the existing condition models can be found in the DWMP documentation and throughout the accompanying technical resources (HEI, 2012b). The existing condition models were used as the basis for the development of the future condition models. The future condition modeling methodology was primarily developed in an initial technical memorandum at the onset of this project (HEI, 2015). Additional methodology is described in the following sections. This section of the report serves as documentation for the model development, including modeling methods and data sources.

2.1 Model Boundaries

The eight future condition model boundaries are shown in **Figure 1**. The models developed encompass the Upper Rice Creek, Hardwood Creek, Clearwater Creek Planning Regions as well as a portion of the Middle Rice Creek Planning Region. All of the models ultimately contribute to the Anoka chain of lakes. The eight individual model areas are listed in **Table 1**, along with the modeling software used for each area. The future condition models were built using the same software as the existing condition models.

Table 1. Model development software for each model area.

Modeling Software	Model Area
Autodesk Storm & Sanitary Analysis	ACD 10, 22, 32
	ACD 15 & JD 4
	ACD 31
	ACD 46
InfoSWMM	ACD25
	Hardwood Creek (JD 2)
	Clearwater Creek (JD 3)
	Rice Creek Direct Drainage

2.2 Modeling Software

The models were developed using two different software packages as denoted in **Table 1**: Autodesk Storm and Sanitary Analysis (ASSA) 2015 and InfoSWMM. The ASSA 2015 models were built using version 9.1.140.1; the InfoSWMM models were built using version 13.0 SP2. The model data are also being structured in ArcGIS File Geodatabases, utilizing ArcGIS version 10.3.0.4322.

2.3 Model Coordinate System and Datum

All of the models were developed in the NAD83 Minnesota State Plane FIPS 2203 Feet horizontal coordinate system and the NAVD88 vertical datum. These systems match the existing models developed under the DWMP.

2.4 Modeling Methodology

The model hydrology determines the overall volume of water that leaves the landscape, as well as the rate and timing at which the runoff is contributed to the hydraulic network. The volume and rate of runoff depends on a variety of watershed characteristics (size, land cover, initial moisture, etc.), as well as the intensity and duration of the rain event(s) applied to the model.

The future condition models all utilize the Natural Resources Conservation Service (NRCS) TR-20 hydrology method; this methodology is consistent with the existing condition models. Infiltration is accounted for within this method (i.e. no additional infiltration methods are used). The TR-20 method requires several catchment hydrology inputs, primarily composite curve number (CN) and time of concentration (Tc). The general process used for developing the future condition models' catchment hydrology from the existing condition models is:

1. Obtain data for anticipated future land use/land cover throughout the District;
2. Utilize the future land use/land cover data and a classification system to develop future condition hydrology datasets for:
    a. Pervious CN;
    b. Impervious percentage; and
    c. Composite CN.
3. Perform area-weighted calculations on the composite CN data and assign composite CN values to each catchment within each model.
4. Utilize the existing condition models Tc values for each catchment in the future condition models (i.e. assume that Tc does not change for each catchment, from existing to future condition).

This process is described in further detail in the following sections.

The model hydraulics determine how the runoff generated from the catchments travels through the stormwater network and is stored and discharged in various locations. The rate and timing depend on a variety of hydraulic parameters including conveyance sizes, shapes, materials, lengths, and head loss components. Storage volumes located throughout the model dictate retention times and flood estimation. In general, the existing model network hydraulics did not change during the future model development. Additional hydraulic features were added in the future condition models to simulate the District rules as they apply to catchment runoff. These are described further in **Sections 2.4.3** and **2.4.4**.

2.4.1 Catchment Delineation

The catchment boundaries for the future condition models are based on the initial catchments developed for the existing condition models. The future condition models assume that overall drainage patterns, and therefore catchments, will remain the same and that only land use within the catchments will change.

In the future condition models, catchments were spatially broken up for modeling purposes in order to simulate the application of the District rules. This process is described further in **Section 2.4.3**.

2.4.2 Land Use Changes

During the development of the existing condition models, a classification system was created to map:

- Impervious percentage based on land use; and
- Pervious CN value based on a combination of land use and hydrologic soil group (HSG).

This classification system developed specific impervious percentages for each of the land use categories utilized by the Minnesota Land Cover Classification System (MLCCS) land cover data set. This data categorizes urban and built-up areas in terms of land cover rather than land use. Also established were 14 generalized land use codes applied to each of the MLCCS classifications, that when combined with a specific HSG, determine its pervious CN (HEI, 2012b). During prior District future model development, this classification system was extended to include the Metropolitan Council Planned Land Use (MCPLU) data (HEI, 2012b). The Met Council routinely compiles individual land use plans and plan amendments from communities within the seven-county Twin Cities metropolitan area into a single regional data layer. The extended classification system results in a methodology for converting both existing and future land use/land cover data into data that can be utilized for hydrologic modeling.

The changes in hydrology from existing to future condition are based entirely on the changes in land use. For modeling purposes, the land use change results in a change in impervious percentages; a combination of the land use change and underlying soils results in a change in pervious CN. Impervious percentage and pervious CN combine to form the composite CN utilized by the models.

To estimate future land use conditions, the MCPLU data for 2030 was utilized (Met Council, 2015). Because the MCPLU data is land use, rather than land cover, it does not include specific data pertaining to lakes and wetlands. For modeling purposes, these areas are important because they are considered 100% impervious (i.e. rainfall that lands on these areas immediately contributes to the waterbody or wetland). To accurately utilize the MCPLU data for hydrologic purposes, the MCPLU was modified to include waterbodies and wetlands. The modification was made using the MLCCS data set. MLCCS areas within the District with classifications that reflect waterbodies or wetlands were overlaid onto the MCPLU to modify the data set. The classification system described earlier was then utilized to develop impervious percentage and pervious curve number data sets for the District. These two data sets were combined to form a composite CN data set (assuming impervious areas have a CN of 98). The composite CN data set was used with the model catchments to determine area-weighed composite CN values for each catchment.

2.4.3 Simulating Rule C.6 Water Quality Treatment

District Rule C.6 indicates that new or reconstructed impervious surface is subject to a water quality treatment standard. The treatment standard is:

$$\text{Required Water Quality Treatment Volume (ft}^3\text{)} = \text{Area of New or Reconstructed Impervious Surface (ft}^2\text{)} \times 1.1\ \text{(in)} \div \text{TP Removal Factor from Table C1} \div 12\ \text{(in/ft)}$$

For future condition modeling purposes, the TP removal factor was assumed to be 1.0, consistent with infiltration as the standard treatment type. A TP removal factor of 1.0 represents the maximum required water quality treatment volume and is therefore the most conservative estimate (RCWD, 2016).

Various factors (soil type, presence of contamination, depth to groundwater, etc.) determine if infiltration is suitable. Soil type was used as the metric for determining if infiltration is feasible within a model catchment. The HSG dataset was used to analyze each model catchment for infiltration potential (NRCS, 2015). Catchments were determined to be suitable for infiltration if 50% or greater of the catchment area consisted of type A or B soils. The infiltration determination for all of the catchments in each model is shown in **Figure 2**. The water quality treatment rule was only applied to catchments that:

1. Indicated they were suitable for infiltration; and
2. Showed an increase in impervious from existing to future condition (i.e. triggered Rule C.6).

To simulate the Rule C.6 treatment standard in the future condition modeling, the change in impervious surface from existing to future condition (assumed to be the increase in newly constructed or redeveloped impervious surface) was broken out into a separate catchment. This new impervious catchment was assumed to have a composite CN of 98 (100% impervious) and was given the same Tc as the existing catchment it was created from. A composite CN was recalculated for the remainder of the catchment (not subject to the rule). A diagramed example of this can be found in **Figure 3.**

The catchment representing the new impervious was then routed directly into an infiltration basin. The basin was sized to retain the volume dictated by the rule (1.1 inches over all new impervious area). The retaining of this volume in the infiltration basin simulates the infiltration itself. The outlet was sufficiently sized (broad crested weir) so as not to impede the catchment runoff once the required infiltration volume has been retained. The infiltration basin overflows was then routed to an artificial stormwater basin to simulate Rule C.7 (described in **Section 2.4.4**). The runoff from the remaining portion of the catchment (not subject to the rule) was routed directly to the artificial stormwater basin. See **Figure 3** for additional details.

2.4.4 Simulating Rule C.7 Peak Stormwater Runoff Control

District Rule C.7 indicates that peak stormwater runoff rates for a proposed project at the project site boundary, in aggregate, must not exceed existing peak runoff rates for the 2-, 10-, and 100-year, 24-hour rainfall events. For future condition modeling purposes this is assumed to mean that the peak discharge leaving a specific catchment within a given model will not increase compared to the existing condition. To simulate this in the future condition model, the runoff from each catchment was routed through an artificial storage basin before being released to the existing hydraulic network. The storage basin and its outlet were designed to limit the peak discharge to the existing hydraulic network to within +10% of the existing condition. The artificial storage basins were designed based on guidance from the NRCS Technical Release 55 (TR-55) (NRCS, 1986), which provides a nomograph that can be used to size storage for peak discharge buffering. This nomograph is shown in **Figure 4**.

The artificial storage basin outlet channel leading to the existing hydraulic network was also sized to limit discharge to the existing condition. Sizing was based on Manning's equation, assuming full flow of a rectangular channel. Iterations on the artificial storage basin sizing were performed using the 100-year, 24-hour storm event. This makes the assumption that the peak control achieved by the basins for the 100-year, 24-hour event also applies to the 10- and 2-year events. The iterations were performed until the outflow was within +10% of the existing condition. In some cases, peak outflow was reduced. In this cases, the outflow was allowed to pass unimpeded into the existing hydraulic network.

2.4.5 Future Modeling Methods Overview

As discussed earlier, a general example of the future condition modeling modification is shown in **Figure 3.** This figure gives an example of the modification made at the catchment scale to simulate the change from the existing condition to the future condition with the application of Rule C.6 and C.7.

In this example, the existing catchment is 50% pervious and 50% impervious, the entire existing catchment routes directly to the existing hydraulic network. In the future condition, 25% of the original pervious area has now become new impervious (subject to Rule C.6); therefore it is routed through an infiltration basin that simulates the rule. All of the runoff (including that which passes through the infiltration basin) is then routed through the artificial storage basin (stormwater pond) where the flow is mitigated, subject to Rule C.7. The flow then passes through to the existing hydraulic network.

2.5 Boundary Conditions

Flow conveyed through the future condition models eventually outlets at various locations. These points are known as outfalls. Often these outfalls apply constraints to the models, also known as boundary conditions, which affect the modeling results. These boundary conditions can be static or time varying. The primary boundary condition for the future condition models is Rice Creek. Each of the branch models feed into Rice Creek and often, the water surface elevation of Rice Creek can cause tailwater effects that back up into each branch model.

2.5.1 Rice Creek Boundary Condition

Each of the branch models and the direct drainage model collect water and eventually discharge into Rice Creek, which is itself simulated using a Hydrologic Engineering Centers River Analysis System (HEC-RAS) hydraulic model. Because the branch models and Rice Creek interact, it is crucial to establish a boundary condition between them using an iterative process. The direct drainage model behaves differently and is discussed further in **Section 2.5.2**. The process by which the Rice Creek boundary condition was established for each of the branch models was:

1. Run the branch models with a free discharge boundary condition at each models' outfall to Rice Creek and extract the event hydrographs at each outfall.
2. Establish a steady-state initial condition for the Rice Creek HEC-RAS model and input the branch model event hydrographs into HEC-RAS model as an unsteady-state run.
3. Extract the stage time series from the HEC-RAS model at each branch model inflow locations and utilize these as the branch model boundary condition. Adjust the starting water surface elevations near the outfall of the branch models based on the boundary conditions (i.e. allow water from Rice Creek to back up into the branch models) and rerun the branch models.
4. Repeat steps 2-3 until no significant change occurs in the Rice Creek HEC-RAS model profile from one iteration to the next.

The process for establishing the branch model boundary conditions required two iterations to ensure stability within the Rice Creek HEC-RAS model. Separate time series boundary conditions were established for each of the three storm events (2-, 10-, and 100-year, 24-hour) and for both the existing and future condition.

2.5.2 Rice Creek Direct Drainage

One of the eight models that contributes to the Rice Creek HEC-RAS is the direct drainage model (**Figure 1**). This model represents mainly wetlands and lakesheds that are located adjacent to Rice Creek. These areas contribute direct runoff to Rice Creek. Because these areas have no defined outlet channel, their model drainage to Rice Creek is not subject to a defined boundary condition. The direct drainage model has 13 outfall locations that discharge into Rice Creek. Because these outfalls are not subject to a boundary condition, there is no need to perform the iterations described in **Section 2.5.1**. Therefore discharge at these outfalls was directly input into the Rice Creek HEC-RAS model.

2.6 Rainfall Events

Three different rainfall events were used in the modeling process, including the 2-, 10-, and 100-year 24-hour Atlas 14 storm events. In 2014, the DWMP was updated to include the Atlas 14 storm events (HEI, 2014). With the improved spatial resolution provided by Atlas 14, the rainfall depths vary across the District for each event. The total depths used for each event and model are given in **Table 2**. The same total depths were used for both the existing and future condition models. The storm events utilize a standard Soil Conservation Service (SCS) Type II unit rainfall distribution.

Table 2. Rainfall events used in models.

Drainage System	2-Year Rainfall (in)	10-Year Rainfall (in)	100-Year Rainfall (in)
Anoka County Ditch 10-22-32	2.8	4.2	7.1
Anoka County Ditch 15/Anoka County – Washington County Judicial Ditch 4	2.8	4.1	7.0
Anoka County Ditch 25	2.8	4.2	7.2
Anoka County Ditch 31	2.8	4.2	7.0
Anoka County Ditch 46	2.8	4.2	7.0
Washington Judicial Ditch 2 (Hardwood Creek)	2.8	4.2	7.1
Anoka Washington Judicial Ditch 3 (Clearwater Creek)	2.8	4.2	7.2
Upper Rice Creek	2.8	4.2	7.1

2.7 Job Control

Job control settings determine how the model simulations are run and how the model engines carry out the calculations. The job control setting are very often modified throughout model development to increase the resolution and stability of the modeling.

The majority of the job control settings remain unchanged from those developed during the DWMP for each model (HEI, 2012b). This is to ensure consistency between the original existing condition models and the newly develop future condition models. Each model was run for a period of seven days. This time period encompasses the peak flows as well as the majority of the falling limb of the hydrograph (storm volume). This results in a consistent 7-day runoff volume for comparison between models, conditions, and locations. The model runs were performed at a calculation time step determined to provide model hydraulic continuity and resolution and reduce continuity error to an acceptable percentage (generally ±2%). The calculation time step for each model may vary but generally range from 5 to 15 seconds for each of the future condition models.

3 RESULTS AND ANALYSIS

3.1 Results Overview

The results of the modeling analysis are expected to reflect the probable changes in hydrologic and hydraulic characteristics within the District resulting from the predicted land use changes and estimated increase in the amount of impervious surface. Peak discharge, the amount of time for the flood peak to move downstream, runoff volume, and maximum water level are the characteristics used to describe the hydrologic and hydraulic changes. The locations and amounts of impervious surface are based on planning level information reflecting local zoning controlled by the cities. Although the amounts and locations of impervious surface in the future may differ from the city planning documents, the results of this analysis are expected to remain useful in guiding water management decisions.

The changes in peak discharge, runoff volume (7-day), and maximum water level are presented at many locations important to the District as a regional water manager. These locations include the most downstream locations for each planning region and modeled area, where inspections are completed annually, bridge and culvert locations (crossings), where the District owns facilities, and within floodplain (1% chance) areas. A summary of the results for each type of location is included within this section of the report. Analysis of the implications for Rice Creek upstream and downstream from Baldwin Lake are also included in this section.

As described in **Section 1**, the estimated amount of impervious surface is based on the existing and future land use categories. No effort has been made to categorize the impervious area as being part of a transportation system or future development. Nor has any effort been made to quantify the amount of area which may be reconstructed in the future (versus new development). Therefore, the estimated future water quality treatment volume is based on the development treatment standard of 1.1 inches over new impervious surface. **Table 3** shows the estimated impervious area for each model, for both existing and future conditions. The data is reported as total areas, percentage of the model area, and percent change from existing to future condition. This data is also presented graphically across the model areas in **Figure 5,** showing a side-by-side comparison of the existing and future impervious areas, and in **Figure 6**, which shows the areas of greatest change in imperviousness. Areas showing the greatest impervious percentage increase are within the Cities of Lino Lakes and Hugo (Hardwood Creek), Forest Lake (JD 4), Columbus (ACD 10-22-32, ACD 31, ACD 46), and Blaine (ACD 10-22-32). For reference, the model areas are shown in relationship to the Metropolitan Urban Service Area (MUSA) boundary in **Figure 7**. This represents the area that is expected to be serviced by the Metropolitan Council in 2030, the same projection as the land uses used in the future condition modeling.

Table 3. Existing and future imperviousness for District branch models.

Branch Model	Existing Impervious Area (acres)	Future Impervious Area (acres)	Change in Impervious (acres)	Existing Impervious % (area-weighted average)	Future Impervious % (area-weighted average)	Change in Impervious % (area-weighted average)
Anoka County Ditch 10-22-32	578	1176	598	13	26	13
Anoka County Ditch 15/Anoka County – Washington County Judicial Ditch 4	394	1079	685	10	26	16
Anoka County Ditch 25	1140	1477	337	26	34	8
Anoka County Ditch 31	134	329	195	9	21	13
Anoka County Ditch 46	177	381	204	7	15	8
Washington Judicial Ditch 2 (Hardwood Creek)	1972	4025	2053	11	22	11
Anoka Washington Judicial Ditch 3 (Clearwater Creek)	9650	12170	2520	35	45	9
Upper Rice Creek Direct Drainage	7665	9454	1789	37	46	9

The District uses multiple "tools" for managing water. These tools include the policies described with the Water Management Plan (WMP), the use of financial incentives provided as project cost share to cities and landowners, the completion of projects lead by the District, and the regulatory program. Rule C.6 Water Quality Treatment and Rule C.7 Peak Stormwater Runoff Control impose specific standards on the creation of new impervious surfaces. The peak rate of runoff in aggregate must not exceed the existing peak rates for the 2-, 10-, and 100-year, 24-hour precipitation events for land located upstream of Baldwin Lake; the peak rate must be reduced by 20% for land located downstream of Baldwin Lake. Development projects are required to provide water quality treatment in the amount of 1.1-inches for reconstructed or new impervious area. Public linear projects (roads) are required to provide water quality treatment in the amount of 0.75-inches for reconstructed or new impervious area. A removal factor is applied to the treatment volume if treatment occurs by methods other than those which provide volume control.

Infiltration has traditionally been the preferred method for reducing runoff volumes within the District. The feasibility of using infiltration varies considerably across the District. Infiltration is feasible where the soils are free from contamination, the underlying aquifer is not used as a public water supply, the soils are sufficiently porous (e.g. sands), and the depth to groundwater below the land surface equals or exceeds three feet. The results of the modeling analysis includes assumptions about the general areas (model catchments) within the District considered feasible for infiltration based only on suitable soil types. Based on the modeling methodology described in **Section 2.4**, **Figure 2** shows model catchments where infiltration was considered feasible based solely on the soil types (HSG A or B). **Table 4** also provides an estimate of the amount of area within each model where infiltration is feasible as well as an overall percentage of each model suited for infiltration. The modeling analysis assumes runoff volume reduction in those catchments where infiltration is feasible. Water quality treatment for the remaining areas is expected to be accomplished through non-volume control means. Therefore, the modeling analysis assumes no volume reduction for the future condition in catchments indicated “not suitable” in **Figure 2**. It is important to note that these infiltration estimates are planning level estimates only and could be subject to change as more information becomes available regarding infiltration potential.

The areas with the greatest infiltration potential (by area) include the eastern portions of Hardwood and Clearwater Creeks (JD2 and JD 3, respectively) as well as eastern portions of ACD 10-22-32 and large portions of ACD 31 and ACD 46. The added runoff volume has potential downstream flood implications, including lands located along Rice Creek and surrounding the Anoka Chain of Lakes.

Table 4. Model areas estimated to be feasible for infiltration, based on soil types.

Branch Model	Total Area (acres)	Infiltration Feasible Area (acres)	Infiltration Feasible Area (%)
Anoka County Ditch 10-22-32	4459	2621	59%
Anoka County Ditch 15/Anoka County – Washington County Judicial Ditch 4	4149	279	7%
Anoka County Ditch 25	4383	1015	23%
Anoka County Ditch 31	1548	1398	90%
Anoka County Ditch 46	2595	1072	41%
Washington Judicial Ditch 2 (Hardwood Creek)	18363	7870	43%
Anoka Washington Judicial Ditch 3 (Clearwater Creek)	27292	11413	42%
Upper Rice Creek Direct Drainage	20635	4220	20%

The primary purposes of this analysis are to understand the hydrologic and water management implications of future development and to assess whether the current standards for rate control and water quality treatment (achieved solely through infiltration) are sufficient for managing the probable hydrologic changes. Some consideration by the Board as to the philosophy behind the rule seems appropriate when reviewing this report. Specifically, is the purpose of the regulatory program primarily to:

1. Reasonably ensure that the peak discharges, runoff volumes, and maximum water levels are no greater than the existing condition following development (i.e. do they maintain existing conditions without making things worse)?
2. Mitigate to the extent possible future increases in the peak discharges, runoff volumes, and maximum water levels, using the existing rule combined with other tools available to the Board of Managers?

Should the modeling analysis show an increase in the peak discharges, runoff volumes, and maximum water levels in the future, the Board may considering one or more of the following:

1. Use the regulatory program as the primary tool and modify the current rule to reasonably ensure that the peak discharges, runoff volumes, and maximum water levels do not increase with future development; and/or
2. Maintain or modify the current rule allowing for some increase in runoff volumes and maximum water levels along with an increase the development and implementation of regional projects or a modified cost share amount to better incentivize cooperative projects.

3.2 Considerations for Assessing Model Results

In reviewing the modeling results presented in the following sections, several aspects should be considered in combination. Additionally, there are several modeling assumptions that should also be considered.

In assessing the potential impacts of future land use changes, several forms of hydrologic and hydraulic data have been reviewed. These include:

- Changes in the amount of runoff volume and peak flow rate at the outlets of Planning Regions (PRs), branch model outlets, District inspection locations, and District Facility locations. Each of these groups of evaluation point offer varying degrees of resolution helpful in pinpoint potential problem areas.
- Changes in the maximum water elevation for the various branch models. This information can be used to identify patterns throughout the system that indicates how the system reacts to the future condition. These areas can be qualitatively assessed and categorized.
- Changes in road crossings and potential roadway overtopping. This information can be used to identify potential future flood damage and also assist the District in facilitating discussion with road authorities about future replacements and damage awareness.
- Changes in peak flow and volume from one community to another. These locations are important metrics which the District can utilize to assess and manage stormwater regionally
- Changes in the available live storage within the Anoka chain of lakes. Evaluating the amount of storage utilized within the chain of lakes identifies potential flooding problems near the lake as well as evaluates the chain of lakes potential to buffer flooding downstream of Baldwin Lake.
- Changes in water elevations along rice creek, particularly key locations such as Long Lake.

There are some key concepts that are important to keep in mind when reviewing the future condition modeling results. These concepts are:

- The future condition modeling makes assumption about where infiltration is feasible and it is generalized to the individual catchment scale (**Figure 2**). Only 36% of the branch model area was assumed to be suitable for infiltration and therefore simulates the water quality rule (C.6).

- If the model approximated infiltration is not realized (i.e. less area is treated for infiltration in reality than in the modeling), volume estimates and percent changes presented in this report will go up.
- The existing condition model does include the current District rules. The rules are included to the extent that they are reflected in the existing land use and hydraulic network.
- The future condition land use conditions were not modeled without the rule, therefore the results of the modeling do not explicitly assess the effects of the rule.
- The rule standards are for rate and volume control.
- Water level increases less than 0.5 feet are not necessarily considered significant because they fall outside of typical model tolerances. This is consistent with FEMA modeling guidance.
- Just because the model indicates an elevation increase doesn't mean there is a future flood problem at that location. In fact, sometimes increases can be a positive indicator, particularly if it means the system is retaining water for a period and drawing it out slower.
- The modeling results presented in this report do not include any land use changes below the Anoka chain of lakes.
- The modeling results, particularly within the localized upstream portions (branch models), is not meant to be completely comprehensive. The primary focus on this model reporting is Rice Creek.
- More detailed analysis of each of the branch models is possible and should be a future consideration.

3.3 Runoff and Flow Overview

The causes of the increased runoff and peak flows (land use and impervious percentage change) seen in the modeling are presented in **Section 3.1.** The following sections present some of the results of this increased runoff volume at important locations throughout the District. Specifically, this section presents the results of the future condition modeling in terms of changes in peak flow (discharge) and changes in 7-day runoff volumes passing through various important locations throughout the District. The following evaluation locations identified and reported in this section include:

1. Planning Region Outlets;
2. Branch Model Outlets;
3. District Inspection Locations; and
4. District Facility Locations.

The following sections present tables and figures that indicate existing and future peak flows and volumes as well as percent change in peak flows and volumes. The percent changes have been color-coded to indicate severity of change from existing to future condition.

Some caution is warranted when reviewing and interpreting the results. Although the results show increases in the peak discharge and 7-day runoff volumes, these increases may or may not be a problem. For example, the 2-year, 24-hour peak discharge has been used by the District to assess public drainage system function. The 10- and 100-year 24-hour peak discharge have been used to assess adequacy of the conveyance system and to establish floodplain boundaries, respectively. An increase in the 2-year, 24-hour peak discharge may or may not reduce the quality of drainage. Drainage system performance would not be diminished even with an increase in discharge if drainage from adjacent land remains unimpeded and the water remains with the conveyance system.

3.3.1 Planning Region Outlets

Five Planning Regions (PR) have been established in the RCWD. They are Hardwood Creek, Clearwater Creek, Upper Rice Creek, Middle Rice Creek, and Lower Rice Creek. The PRs were determined based on hydrologic boundaries and generally reflect groupings of similar resources (e.g. urban shallow lakes, big lakes, chain of lakes) and other landscape characteristics. The PRs are used to help orient the District or stakeholders when discussing resources, issues, or focusing on activities. PRs are not used as a means to set standards or rules. Instead, they reflect an organizational structure which acknowledges general regional similarities within the District.

The five PRs are shown in **Figure 8**. The outlets of the Clearwater Creek and Hardwood Creek PRs is at their confluences with Rice Creek. The outlets of the Upper Rice Creek and the Middle Rice Creek PRs are along Rice Creek itself. The outlet of the Lower Rice Creek PR is at the Rice Creek confluence with the Mississippi River. **Table 5** and **Table 6** show the peak discharge changes and 7-day volume changes between the existing and future condition. The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

The most substantial changes occur at the outlets of both Hardwood Creek and Clearwater Creek. Very little change is seen at the outlet of the Lower Rice Creek PR, demonstrating the effect that the Anoka chain of lakes, Long Lake, and Locke Lake have in mitigating peak discharge impacts.

Table 5. Planning Region peak discharge changes from existing to future condition.

Planning Region	2-Year, 24-Hour Precipitation Event			10-Year, 24-Hour Precipitation Event			100-Year, 24-Hour Precipitation Event		
	Peak Discharge (cfs)		Percent Change (%)*	Peak Discharge (cfs)		Percent Change (%)*	Peak Discharge (cfs)		Percent Change (%)*
	Existing Condition	Future Condition		Existing Condition	Future Condition		Existing Condition	Future Condition	
Upper Rice Creek	184	188	2%	319	315	-1%	523	527	1%
Hardwood Creek	90	133	48%	191	262	37%	644	762	18%
Clearwater Creek	192	279	45%	333	402	21%	563	590	5%
Middle Rice Creek	116	140	21%	296	366	24%	713	824	16%
Lower Rice Creek	339	339	0%	700	701	0%	1583	1583	0%

*The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

Table 6. Planning Region 7-day volume changes from existing to future condition.

Planning Region	2-Year, 24-Hour Precipitation Event			10-Year, 24-Hour Precipitation Event			100-Year, 24-Hour Precipitation Event		
	Volume* (ac-ft)		Percent Change (%)**	Volume* (ac-ft)		Percent Change (%)**	Volume* (ac-ft)		Percent Change (%)**
	Existing Condition	Future Condition		Existing Condition	Future Condition		Existing Condition	Future Condition	
Upper Rice Creek	943	1048	11%	1830	1986	9%	3778	3990	6%
Hardwood Creek	613	1036	69%	1483	2138	44%	3880	4900	26%
Clearwater Creek	522	784	50%	1092	1482	36%	2650	3209	21%
Middle Rice Creek	1187	1378	16%	3153	3764	19%	7627	8514	12%
Lower Rice Creek	2721	2836	4%	6305	6702	6%	14591	15116	4%

*Volume for the 24-hour event is the volume over a 7 day period following the start of a 24-hour event

** The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

3.3.2 Branch Model Outlets

The next level of resolution beyond the PRs is the actual branch models themselves. In some cases (i.e. Hardwood Creek and Clearwater Creek) the models coincide entirely with a PR. However, PRs such as Upper Rice Creek and Middle Rice Creek, the branch model outlet data provides additional insight into what is causing peak flow and volume increases at the PR outlets. Each of the individual branch model outlets are shown in **Figure 9**. **Table 7** and **Table 8** show the peak discharge changes and 7-day volume changes between the existing and future condition. The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

Some of the most substantial changes are at the outlets of ACD 31 and ACD 10-22-32. However, it's important to note that the greatest volumes, both existing and future, still occur at the outlets of both Hardwood Creek and Clearwater Creek. This is due to the sheer size of the JD 2 and JD 3 watersheds. **Table 7** indicates a consistent decrease in the peak discharges for the outlets in the Rice Creek Direct Drainage model. These outlets generally represent a single catchment draining to a lake. The methodology utilized for simulating Rule C.7 to buffer peak runoff from a catchment creates an artificial storage basin to perform this buffering (**Section 2.4.4**). This methodology tends to oversize the simulated artificial storage basin for large catchments with large existing peak discharges. Such is the case with those draining directly to Rice Creek and the adjacent lakes. This is because these are essentially runoff hydrographs entering the lake. The decrease in peak discharge reported in **Table 7** is not expected to have much effect on the modeling because they are directly draining to lakes where they undergo peak discharge buffering as well.

Table 7. Branch model outlet peak discharge changes from existing to future condition.

Location	2-Year, 24-Hour Precipitation Event			10-Year, 24-Hour Precipitation Event			100-Year, 24-Hour Precipitation Event		
	Peak Discharge (cfs)		Percent Change (%)**	Peak Discharge (cfs)		Percent Change (%)**	Peak Discharge (cfs)		Percent Change (%)**
	Existing Condition	Future Condition		Existing Condition	Future Condition		Existing Condition	Future Condition	
ACD 31	15	26	78%	44	61	40%	112	117	5%
ACD 46	39	49	23%	130	139	7%	406	415	2%
JD 4	68	94	38%	125	151	20%	248	268	8%
Hardwood Creek/JD 2	90	133	48%	191	262	37%	644	762	18%
Clearwater Creek/JD 3	192	279	45%	333	402	21%	563	590	5%
ACD 10-22-32	43	74	75%	97	153	58%	230	258	12%
ACD 25*	908	776	-15%	1651	1741	5%	3250	2990	-8%

*Combined Flow into Reshanau Lake

** The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

Table 8. Branch model outlet 7-day volume changes from existing to future condition.

Location	2-Year, 24-Hour Precipitation Event			10-Year, 24-Hour Precipitation Event			100-Year, 24-Hour Precipitation Event		
	Volume** (ac-ft)		Percent Change (%)***	Volume** (ac-ft)		Percent Change (%)***	Volume** (ac-ft)		Percent Change (%)***
	Existing Condition	Future Condition		Existing Condition	Future Condition		Existing Condition	Future Condition	
ACD 31	17	34	101%	70	98	41%	255	298	17%
ACD 46	50	65	29%	143	168	18%	405	447	10%
JD 4	223	329	48%	483	630	31%	1220	1433	17%
Hardwood Creek/JD 2	613	1036	69%	1483	2138	44%	3880	4900	26%
Clearwater Creek/JD 3	522	784	50%	1092	1482	36%	2650	3209	21%
ACD 10-22-32	87	189	117%	251	430	71%	764	1087	42%
ACD 25	211	290	38%	397	485	22%	522	605	16%

*Combined Flow into Reshanau Lake

**Volume for the 24-hour event is the volume over a 7 day period following the start of a 24-hour event

***The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

3.3.3 District Inspection Locations

Annual inspection locations have been identified at key locations throughout the District. These are locations in which the District Inspector performs an annual Spring Drainage Inspection during the peak snowmelt runoff. These spring inspections not only identify immediate maintenance and repair needs throughout the District watercourses, but also provide insight into potential problem areas which may lead to flooding during larger rainfall or snowmelt events. Because of this potential for damage during larger events, it is useful to evaluate future condition modeling impacts at these locations. **Figure 10** shows the inspection locations included within the future condition modeling areas.

Table 9 and **Table 10** show the peak discharge changes and 7-day volume changes, respectively, between the existing and future condition. Inspection locations are labeled on the figure and correspond to Map ID values in the tables. The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

The results indicate that the most significant increases occur within RW1D 1, to the east of Bald Eagle Lake (IP4, IP5, IP6, and IP7). Other notable increases include JD 4 (IP11) and ACD 10-22-32 (IP17).

Table 9. District inspection location peak discharge changes from existing to future condition.

Map ID	Location	2-Year, 24-Hour Precipitation Event			10-Year, 24-Hour Precipitation Event			100-Year, 24-Hour Precipitation Event		
		Peak Discharge (cfs)		Percent Change (%)**	Peak Discharge (cfs)		Percent Change (%)**	Peak Discharge (cfs)		Percent Change (%)**
		Existing Condition	Future Condition		Existing Condition	Future Condition		Existing Condition	Future Condition	
IP1	Priebe Lake Outlet*	-	-	-	-	-	-	-	-	-
IP2	Halls Marsh Outlet*	-	-	-	-	-	-	-	-	-
IP3	RCD 11 several locations	52	64	24%	84	89	6%	106	111	4%
IP4	RW1D 1 at Hugo Rd	34	35	3%	65	66	1%	100	101	0%
IP5	RW1D 1 at Buffalo St	17	28	63%	32	37	17%	44	49	11%
IP6	RW1D 1 at Portland Ave	17	28	64%	32	37	17%	44	49	11%
IP7	RW1D 1 at County Road 7	14	33	131%	37	52	39%	64	71	11%
IP8	Bald Eagle Lake Outlet Dam	6	9	63%	17	22	28%	46	51	10%
IP9	WJD #7 Outlet	68	92	35%	234	379	62%	1014	1276	26%
IP10	WJD 5 at 200th St. N.*	-	-	-	-	-	-	-	-	-
IP11	AWJD 4 at 145th St	9	20	124%	31	40	26%	60	63	5%
IP12	AWJD 4 at Branch 3 Tile Outlet	28	29	3%	34	33	-3%	51	52	1%
IP13	AWJD 4 West of Freeway Drive	56	78	38%	95	114	20%	150	169	13%
IP14	ACD 46 at Camp Three Road	2	4	60%	6	9	43%	26	27	5%
IP15	Lake Drive near Mastell Bros.	6	16	160%	29	45	58%	82	93	14%
IP16	Rondeau Lake Outlet Channel	21	21	0%	34	34	-1%	47	48	2%
IP17	ACD 10-22-32 at Carl St.	24	51	106%	63	76	21%	89	93	5%
IP18	Howard Lake Outlet	26	26	2%	46	48	4%	109	112	3%
IP19	35W Crossing Lino Lakes	184	188	2%	319	315	-1%	523	527	1%
IP20	County Road J	118	142	20%	311	379	22%	802	912	14%
IP21	Lexington Ave.	119	143	20%	313	381	22%	820	931	14%
IP22	County Road I	161	161	0%	350	383	10%	838	939	12%
IP23	35W Crossing Arden Hills	188	188	0%	413	413	0%	837	938	12%
IP24	Long Lake Inlet Trestle	241	241	0%	482	482	0%	870	944	9%
IP25	Long Lake Road	317	318	0%	658	659	0%	1196	1201	0%
IP26	Mississippi Street	317	318	0%	658	659	0%	1196	1201	0%
IP27	Central Ave. NE	326	326	0%	670	671	0%	1230	1230	0%
IP28	Silver Lake Road	322	322	0%	664	665	0%	1203	1207	0%
IP29	Highway 65	329	329	0%	675	675	0%	1253	1253	0%
IP30	University Ave.	380	380	0%	745	745	0%	1578	1578	0%

Map ID	Location	2-Year, 24-Hour Precipitation Event Peak Discharge (cfs) Existing Condition	Future Condition	Percent Change (%)**	10-Year, 24-Hour Precipitation Event Peak Discharge (cfs) Existing Condition	Future Condition	Percent Change (%)**	100-Year, 24-Hour Precipitation Event Peak Discharge (cfs) Existing Condition	Future Condition	Percent Change (%)**
IP31	Locke Lake Dam / Manomin Park	339	339	0%	700	701	0%	1583	1583	0%

*Results are not available. Location does not have a corresponding modeling node

** The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

Table 10. District inspection location 7-day volume changes from existing to future condition.

Map ID	Location	2-Year, 24-Hour Precipitation Event Volume** (ac-ft) Existing Condition	Future Condition	Percent Change (%)***	10-Year, 24-Hour Precipitation Event Volume** (ac-ft) Existing Condition	Future Condition	Percent Change (%)***	100-Year, 24-Hour Precipitation Event Volume** (ac-ft) Existing Condition	Future Condition	Percent Change (%)***
IP1	Priebe Lake Outlet*	-	-	-	-	-	-	-	-	-
IP2	Halls Marsh Outlet*	-	-	-	-	-	-	-	-	-
IP3	RCD 11 several locations	25	34	35%	58	73	25%	147	172	17%
IP4	RW1D 1 at Hugo Rd	135	287	113%	395	528	34%	697	735	5%
IP5	RW1D 1 at Buffalo St	102	249	143%	323	451	39%	513	550	7%
IP6	RW1D 1 at Portland Ave	102	249	144%	324	453	40%	516	553	7%
IP7	RW1D 1 at County Road 7	58	155	169%	180	331	83%	486	659	36%
IP8	Bald Eagle Lake Outlet Dam	67	97	45%	198	233	17%	574	623	9%
IP9	WJD #7 Outlet	369	586	59%	935	1279	37%	2537	3115	23%
IP10	WJD 5 at 200th St. N.*	-	-	-	-	-	-	-	-	-
IP11	AWJD 4 at 145th St	18	52	191%	91	144	58%	318	394	24%
IP12	AWJD 4 at Branch 3 Tile Outlet	99	129	30%	162	200	23%	311	364	17%
IP13	AWJD 4 West of Freeway Drive	199	298	50%	432	570	32%	1101	1300	18%
IP14	ACD 46 at Camp Three Road	2	5	107%	9	14	48%	33	42	29%
IP15	Lake Drive near Mastell Bros.	6	18	197%	24	46	93%	81	121	48%
IP16	Rondeau Lake Outlet Channel	239	217	-9%	374	348	-7%	319	257	-20%
IP17	ACD 10-22-32 at Carl St.	60	127	111%	178	299	68%	546	743	36%
IP18	Howard Lake Outlet	294	301	2%	516	532	3%	1123	1151	2%
IP19	35W Crossing Lino Lakes	943	1048	11%	1830	1986	9%	3778	3990	6%
IP20	County Road J	1428	1597	12%	3732	4282	15%	9015	9806	9%
IP21	Lexington Ave.	1462	1630	11%	3809	4352	14%	9283	10067	8%

Map ID	Location	2-Year, 24-Hour Precipitation Event Volume** (ac-ft) Existing Condition	Future Condition	Percent Change (%)***	10-Year, 24-Hour Precipitation Event Volume** (ac-ft) Existing Condition	Future Condition	Percent Change (%)***	100-Year, 24-Hour Precipitation Event Volume** (ac-ft) Existing Condition	Future Condition	Percent Change (%)***
IP22	County Road I	1581	1744	10%	4106	4627	13%	10009	10743	7%
IP23	35W Crossing Arden Hills	1621	1781	10%	4210	4721	12%	10261	10969	7%
IP24	Long Lake Inlet Trestle	1688	1844	9%	4355	4848	11%	10563	11234	6%
IP25	Long Lake Road	2524	2650	5%	5939	6367	7%	13714	14274	4%
IP26	Mississippi Street	2523	2649	5%	5935	6362	7%	13697	14254	4%
IP27	Central Ave. NE	2566	2690	5%	6039	6461	7%	13955	14501	4%
IP28	Silver Lake Road	2541	2666	5%	5976	6402	7%	13793	14348	4%
IP29	Highway 65	2622	2746	5%	6165	6585	7%	14244	14787	4%
IP30	University Ave.	2716	2838	4%	6355	6769	7%	14635	15167	4%
IP31	Locke Lake Dam / Manomin Park	2719	2835	4%	6305	6702	6%	14592	15116	4%

*Results are not available. Location does not have a corresponding modeling node

**Volume for the 24-hour event is the volume over a 7 day period following the start of a 24-hour event

*** The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

3.3.4 District Facility Locations

In addition to the public drainage systems, other water resource management facilities which are primarily water level control structures, water quality treatment facilities, and fish barriers are owned and operated by the District. Similar to the District inspection locations, it is useful to evaluate future condition modeling impacts at these locations. **Figure 11** shows the District facility locations included within the future condition modeling areas. **Table 11** and **Table 12** show the peak discharge changes and 7-day volume changes, respectively, between the existing and future condition. District facilities are labeled on the figure and correspond to Map ID values in the tables. The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

The results indicate that the most significant increases occur within Hardwood Creek (JD 2), particularly at the Wick Conservation easement (F13) located in the downstream portion of Hardwood Creek.

Table 11. District facility location peak discharge changes from existing to future condition.

Map ID	Location	2-Year, 24-Hour Precipitation Event			10-Year, 24-Hour Precipitation Event			100-Year, 24-Hour Precipitation Event		
		Peak Discharge (cfs)		Percent Change (%)**	Peak Discharge (cfs)		Percent Change (%)**	Peak Discharge (cfs)		Percent Change (%)**
		Existing Condition	Future Condition		Existing Condition	Future Condition		Existing Condition	Future Condition	
F1	WALLS BROS. WETLAND RESTORATION*	-	-	-	-	-	-	-	-	-
F2	HARDWOOD CREEK PROFILE STUDY	18	22	23%	49	69	41%	172	200	16%
F3	LONG LAKE OUTLET PROJECT	5	6	16%	6	7	10%	8	8	9%
F4	HWY. 61/JD NO.1 TREATMENT BASIN*	-	-	-	-	-	-	-	-	-
F5	PRIEBE LAKE OUTFALL PROJECT*	-	-	-	-	-	-	-	-	-
F6	LONG LAKE SEDIMENTATION BASIN	436	436	0%	803	804	0%	1404	1404	0%
F7	LOCKE LAKE RESTORATION AND SEDIMENTATION BASIN*	-	-	-	-	-	-	-	-	-
F8	HALL'S MARSH OUTLET STRUCTURE*	-	-	-	-	-	-	-	-	-
F9	RONDEAU LAKE OUTLET CHANNEL	20	21	0%	33	33	-2%	47	48	2%
F10	MALMSTROM CONSERVATION EASEMENT (JD #2)	21	23	11%	53	65	22%	168	185	10%
F11	EAGLE BROOK CHURCH (LINO LAKES) EASEMENT*	-	-	-	-	-	-	-	-	-
F12	BREDAHL CONSERVATION EASEMENT (JD #2)	73	93	28%	237	382	61%	1032	1300	26%
F13	WICK CONSERVATION EASEMENT (JD #2)	78	151	95%	192	260	35%	640	767	20%
F14	RWJD1 FISH BARRIER	34	35	3%	65	66	1%	100	101	0%

*Results are not available. Location does not have a corresponding modeling node

**The percent changes have been relatively color-coded to indicate magnitude of change from existing to future condition. Increases are indicated in increasingly darker shades of red while decreases are indicated in increasingly darker shades of blue.

Table 12. District facility location 7-day volume changes from existing to future condition.

Map ID	Location	2-Year, 24-Hour Precipitation Event			10-Year, 24-Hour Precipitation Event			100-Year, 24-Hour Precipitation Event		
		Volume** (ac-ft)		Percent Change (%)	Volume** (ac-ft)		Percent Change (%)	Volume** (ac-ft)		Percent Change (%)
		Existing Condition	Future Condition		Existing Condition	Future Condition		Existing Condition	Future Condition	
F1	WALLS BROS. WETLAND RESTORATION*	-	-	-	-	-	-	-	-	-
F2	HARDWOOD CREEK PROFILE STUDY	85	158	86%	193	269	40%	431	589	37%
F3	LONG LAKE OUTLET PROJECT	55	62	11%	65	74	14%	87	97	12%
F4	HWY. 61/JD NO.1 TREATMENT BASIN*	-	-	-	-	-	-	-	-	-
F5	PRIEBE LAKE OUTFALL PROJECT*	-	-	-	-	-	-	-	-	-
F6	LONG LAKE SEDIMENTATION BASIN	2541	2696	6%	6047	6538	8%	14089	14757	5%
F7	LOCKE LAKE RESTORATION AND SEDIMENTATION BASIN*	-	-	-	-	-	-	-	-	-
F8	HALL'S MARSH OUTLET STRUCTURE*	-	-	-	-	-	-	-	-	-
F9	RONDEAU LAKE OUTLET CHANNEL	239	217	-9%	374	348	-7%	319	256	-20%
F10	MALMSTROM CONSERVATION EASEMENT (JD #2)	77	151	95%	184	260	41%	415	571	38%
F11	EAGLE BROOK CHURCH (LINO LAKES) EASEMENT*	-	-	-	-	-	-	-	-	-
F12	BREDAHL CONSERVATION EASEMENT (JD #2)	364	585	61%	934	1281	37%	2545	3128	23%
F13	WICK CONSERVATION EASEMENT (JD #2)	545	937	72%	1358	1977	46%	3634	4589	26%
F14	RWJD1 FISH BARRIER	135	287	113%	395	528	34%	697	735	5%

*Results are not available. Location does not have a corresponding modeling node

**Volume for the 24-hour event is the volume over a 7 day period following the start of a 24-hour event

3.4 Branch Model Assessment

Another way of assessing modeling results and the impacts of future land use changes is by looking at general trends in changes in the maximum water surface elevation across the District. Looking at these changes for different size events can be indicative of how the system is functioning. For example, large changes in peak water elevations for sequential nodes upstream of a culvert may indicate that the culvert is undersized to handle anticipated future flows for certain storm events. Likewise, if the modeling indicates large peak water surface changes at storage areas located near current flooding problem areas, it is likely that the problems may become worse as future development occurs.

This section presents District-wide mapping of the changes in the peak water surface elevation that occur from the existing to the future condition. Water surface elevation changes area shown for all of the storage and junction nodes that exist in the branch models. Mapping is presented for the 2-, 10-, and 100-year, 24-hour events and is shown in **Figure 12, Figure 13,** and **Figure 14**. Each of the three maps has labels identifying areas where a qualitative assessment has been made about how the systems are reacting to the increased flow and volume indicated in the modeling. **Table 13** includes descriptions of the locations and general discussion of each of these areas as well as a relative likelihood that this area will become a problem in the future. The problems identified generally fall into three distinct categories:

- Insufficient conveyance;
- Insufficient or improper storage; or
- A combination of conveyance and storage.

Table 13. Qualitative assessment of changes in maximum water elevation throughout the branch models.

Comment ID	Location	Relative Problem Likelihood	Discussion
2-Year, 24-Hour Event			
2A	ACD 31 Main Trunk	Low	Repair of the public drainage system will likely mitigate some of the peak water surface increases.
2B	ACD 10-22-32 Main Trunk	Low	The extent and relative change in the peak water surface is actually greater for the 2-year rainfall than the 100-year. This is because the flows stay entirely within the channel for the 2-year event. This is an example of why repair of the open channel was so critical in this drainage system.
2C	JD 2 Main Trunk	Low	This location had little change for the 100-year rainfall, but substantial increase for the 2-year. This is likely because flows are confined within the channel for the 2-year event, and is not necessarily reflective of inadequate performance.
2D	R/W JD 1 Main Trunk	Low	This location also had relatively small changes for the 100-year but larger for the 2-year. This is likely due to the CR 71

Comment ID	Location	Relative Problem Likelihood	Discussion
			culvert, which is sized to convey flows for a rainfall event somewhere between the 2-year and 100-year event.
10-Year, 24-Hour Event			
10A	ACD 10-22-32 Main Trunk	Low	As this area develops, the drainage system will likely be substantially modified and may be placed into storm sewer. Municipal conveyance (which are typically based on the 10-year rainfall) needs to account for increased flows as a result of watershed-wide development.
100-Year, 24-Hour Event			
100A	ACD 31 Main Trunk	Moderate	Culvert under Kettle River Boulevard is the control. Some potential structure inundation near Kettle River Boulevard.
100B	ACD 10-22-32 Main Trunk	Low	Culvert under I-35W is the control. No damage is likely to result - ditch section here is deep.
100C	JD 4 Main Trunk	Low	It appears that the new realignment channel is adequate to convey future flows.
100D	Upstream of JD 4 Main Trunk tile	Moderate	This developing area is served only by a small diameter (12") tile. Additional conveyance and/or storage is required to enable the zoned land use (similar to ACD 55).
100E	JD 2 upstream of Elmcrest Ave.	High	Existing structure inundation in this location may be exacerbated. Increasing the culvert sizes under 165th Ave. may assist in mitigating this issue.
100F	JD 2 upstream of Hwy. 61	Low	No structures are currently inundated in this area, and a peak flood elevation increase of less than 1-foot will not likely change that. This area contains a substantial volume of flood storage.
100G	JD 3 Main Trunk	Low	No structures are in close proximity to the existing floodplain. However, changes in floodplain may have some effect on development of adjacent lots.
100H	Former ACD 47	Low	No structures are in close proximity to the existing floodplain. However, changes in floodplain may have some effect on development of adjacent lots.
100I	ACD 55 & 72	Moderate	Development is challenged by the lack of an adequate outlet. City of Lino Lakes is currently developing a plan to address these challenges.
100J	JD 3 Main Trunk	Low	The floodplain is not in close proximity to any structures, and is not likely to impact development.
100K	R/W JD 1 Main Trunk	High	Flow is restricted by the County Road 71 culvert. The floodplain does not appear to inundate any structures currently, but does inundate an adjacent golf course. Increasing the flood elevation by over a foot may put some structures in the floodplain. This is a major flood storage location in this region. Increasing the size of the CR 71 culvert may alleviate some of this concerns, but downstream capacity needs to be verified in detail.

3.5 Potential Road Crossing Impacts

Crossing locations are points where the public drainage system or public waterways pass underneath roadways. Roadway crossings are a useful evaluation points because not only are they most likely to be damaged during a flood, they are also the source for the majority of the hydraulic head in the District's public drainage system during flooding events. Most of the public roadway crossings throughout the District utilize culverts which are sufficiently sized to convey flood flows. However, the public drainage system Repair Reports have indicated that some private crossings (including driveways and field approaches) are undersized and incapable of conveying flood flows resulting from rainfalls as low as the 2-year, 24-hour rainfall event. Analyzing the anticipated future changes in peak elevation at these crossings can both identify potential future flood damage and also assist the District in facilitating discussion with road authorities about future replacements and damage awareness.

The DWMP Summary indicates roadway crossing (critical structures) data within each planning region (HEI, 2012b). Included in this data is overtopping elevations for the roadways. These tables have been adapted for this report and are included in **Appendix A**. The tables include a comparison of the overtopping elevation to the 2-, 10-, and 100-year peak water surface elevations for both the existing and future condition. The tables also indicate which roads are overtopped during each storm event, for both conditions (existing and future). The roadway overtopping for various conditions (existing and future) and events is shown in **Figure 15**.

The following is a summary of important anticipated roadway crossing impacts based on the results of the future condition modeling.

- There are three roadway crossings for Hardwood Creek (JD 2) to the east of I-35E that may experience overtopping during the 100-year, 24-hour event under future conditions. The most important of these includes the I-35E crossing itself.
- The Hardwood Creek crossing at 165th Street North indicates new overtopping for the 10-year, 24-hour event under future conditions.
- Goodview Avenue, to the southeast of Oneka Ridge Golf Course, shows anticipated roadway overtopping during the 100-year, 24-hour event under future conditions.
- The bike path upstream of the Rice Creek Lexington Avenue crossing indicates overtopping during the future condition 100-year, 24-hour event. However, overtopping does not occur at Lexington Avenue itself.
- Eight additional roadway overtopping locations are shown in **Figure 15** (red and green dots) where 10- and/or 100-year, 24-hour event overtopping is currently predicted under existing conditions.

3.6 Intercommunity Flow Rates

Intercommunity flow rates are defined as locations within the District where stormwater conveyed through the public drainage system flows from one municipality to another. Through its Watershed Management Plan (WMP), the District identifies intercommunity flow points as Regional Assessment Locations (RALs). These are relatively easy locations to quantify stormwater discharge but they are important metrics which the District can utilize to assess and manage stormwater regionally. Locations of intercommunity flow rates throughout the entire District were identified in Figure 10 of the DWMP Summary (HEI, 2012b). A summary of the anticipated effects of future hydrologic conditions on intercommunity flow rates is provided in **Table 14**. The peak flow rates are presented as is the percent change (increase or decrease) from the existing to the future condition. The changes have been color-coded to indicate increases (red) and decreases (green).

It is important to note that the assessment of the intercommunity flows during the future condition only takes into account model conveyances (pipes, channels, etc.) that cross municipality borders. Many catchments within the models span multiple municipality boundaries and this assessment does not consider intercommunity flows within these catchments.

The most significant increases in intercommunity flow rates occur along a private open channel between Grant and Dellwood and from Forest Lake to Columbus along the main trunk of Anoka Washington JD 4. These increases are caused by a significant increase in anticipated impervious surface upstream of Pine Tree Lake.

Branch 4 of ACD 10-22-32 between Columbus and Lino Lakes indicates a large percent increase, however, this only has about 400 contributing acres, most of which is wetland; the large increase is due to increased impervious (land use) within this small area.

Additionally, some areas do see reductions in peak flows, likely due to modeled changes in land use in the upstream portions of these crossings or due to application of Rule C.7 for buffering peak discharge. Additional analysis working with the municipalities is needed to ensure the downstream conveyance system is adequate to manage these discharges.

Table 14. Intercommunity flow comparison, existing to future condition.

Discharging City	Receiving City	Watercourse	Peak Flows (cfs)						Peak Flow Comparison		
			2-Year Existing	2-Year Future	10-Year Existing	10-Year Future	100-Year Existing	100-Year Future	2-Year	10-Year	100-Year
Centerville	Lino Lakes	AWJD 3 Main Trunk	192	279	333	402	564	590	45%	21%	5%
Columbus	Lino Lakes	Rice Creek	168	189	306	326	583	594	13%	6%	2%
Columbus	Lino Lakes	ACD 10-22-32 Branch 4	0.14	0.56	1.90	3.09	4.59	4.73	300%	63%	3%
Columbus	Lino Lakes	ACD 10-22-32 Main Trunk	3	3	9	10	19	20	21%	13%	4%
Dellwood	White Bear Township	RWJD 1 Main Trunk	15	30	34	44	51	61	93%	32%	18%
Forest Lake	Columbus	AWJD 4 Branch 4	15	13	21	20	40	39	-16%	-4%	-1%
Forest Lake	Columbus	AWJD 4 Branch 3	5	4	8	7	11	12	-11%	-11%	8%
Forest Lake	Columbus	AWJD 4 Main Trunk	7	21	47	60	97	113	202%	28%	16%
Forest Lake	Columbus	Rice Creek	12	12	24	24	46	45	0%	0%	0%
Forest Lake	Hugo	AWJD 2 Main Trunk	72	97	224	366	963	1142	34%	64%	19%
Grant	Dellwood	Private Open Channel	14	33	36	48	55	57	138%	32%	4%
Grant	Dellwood	Private Open Channel	1	4	4	16	30	51	340%	275%	70%
Hugo	Forest Lake	AWJD 2 Main Trunk	41	56	130	261	692	955	34%	101%	38%
Hugo	Grant	Private Open Channel	18	32	36	67	82	77	82%	88%	-6%
Hugo	Lino Lakes	AWJD 2 Main Trunk	78	145	192	262	641	767	88%	36%	20%
Hugo	Lino Lakes	AWJD 3 Main Trunk	134	167	222	247	327	354	24%	12%	8%
Lino Lakes	Centerville	AWJD 3 Main Trunk	148	224	271	370	509	581	52%	37%	14%
Lino Lakes	Circle Pines	Rice Creek	116	140	296	366	713	824	21%	24%	16%
Lino Lakes	Hugo	AWJD 3 Branch 4	36	37	41	42	48	49	3%	3%	2%
Lino Lakes	Hugo	AWJD 3 Branch 1	19	17	34	37	66	74	-11%	10%	11%
White Bear Lake	White Bear Township	RCD 11 Main Trunk	10	8	19	19	39	41	-17%	2%	7%

3.7 Rice Creek Analysis

3.7.1 Upstream of the Anoka Chain of Lakes

The future condition effects in the Upper Rice Creek, Hardwood Creek, and Clearwater Creek can be assessed collectively by examining the changes in the Anoka chain of lakes. All three of these PRs outlet into Peltier Lake. By analyzing the inflow and outflow hydrographs of Peltier Lake an assessment can be made for the PRs upstream of the Anoka chain of lakes. The inflow hydrographs for existing and future conditions into Peltier Lake are shown in **Figures 16** and **Figure 17,** respectively. The peak discharge values and 7-day volume values are also shown in **Table 5** and **Table 6** location in **Section 3.3.1**.

In examining the tables and hydrographs for both existing and future conditions it can be seen that Hardwood Creek and Clearwater Creek both have increases in peak discharge and in volume for all of the analyzed events. This is anticipated due to the large increase in impervious surface (**Figure 5** and **Figure 6**).The Upper Rice Creek PR has slight changes in peak discharge for all of the events, and smaller increases in volume when compared to the other two PRs. In general, the shape of the inflow hydrographs are the same for existing and future, with the exception of the future conditions hydrographs being larger in magnitude. The hydrographs also show that there is a greater peak discharge and volume existing Peltier Lake into the downstream lakes and ultimately Rice Creek itself.

3.7.2 Anoka Chain of Lakes

The Anoka chain of lakes acts to buffer upstream storm runoff by utilizing the storage that is available in the lakes. The live storage is the storage available above the normal water level up to the lake flood elevation, which is defined by the 100-year 10-day snowmelt event on the chain of lakes. **Table 15** shows the water surface elevations, total storage, live storage, and utilized storage for the 100-year 10-day event and the analyzed 100-year 24-hour existing and future rainfall events. The normal water level shown in the table is based on the 2-year recurrence interval from the lake level frequency analysis (HEI, 2011). Peak water surface elevations are presented for the 100-year, 10-day, which is considered the flooding elevation. Also presented are the 100-year, 24-hour elevations for the existing and future condition. The total storage is the volume of water stored for each condition. The live storage is the volume utilized above the normal water level. Once all of the available live storage has been utilized, flooding is expected to occur. The percentage of utilized live storage is presented and color-coded.

The table shows that for the analyzed 100-year 24-hour event the existing and future water surface elevations would closely approach but not exceed the 100-year 10-day snowmelt elevations. The amount of utilized storage compared to the snowmelt event ranges from 80% to 98%. The chain of lakes future conditions utilized storage values increase by 3% to 5% when compared to the existing condition events. Within modeling tolerance, the data indicates that the storage in some of the lakes (Centerville and Peltier) is essentially used up during the future condition. The 100-year, 24-hour precipitation event, under future conditions, utilizes approximately the same amount of storage in the chain of lakes as the existing condition 100-year, 10-day snowmelt, which is the critical duration event. This presents a potential flooding problem around the Anoka chain of lakes.

Table 15. Anoka chain of lakes storage utilization under existing and future conditions. Elevations in NAVD 88 datum.

Lake	Normal Water Level 2-year Recurrence Interval	Peak Water Surface Elevation			Total Storage				Live Storage			Utilized Storage	
		Existing 100-year, 10-day (feet)	Existing 100-year, 24-hr (feet)	Future 100-year, 24-hr (feet)	Normal Water Level (ac-ft)	Existing 100-year, 10-day (ac-ft)	Existing 100-year, 24-hr (ac-ft)	Future 100-year, 24-hr (ac-ft)	Existing 100-year, 10-day (ac-ft)	Existing 100-year, 24-hr (ac-ft)	Future 100-year, 24-hr (ac-ft)	Existing 100-year, 24-hr (ac-ft)	Future 100-year, 24-hr (ac-ft)
Peltier Lake	885.7	887.46	887.11	887.3	4321	5650	5351	5517	1328	1029	1195	95%	98%
George Watch Lake	882.5	886.81	885.42	885.79	3234	7179	5796	6162	3946	2563	2928	81%	86%
Centerville Lake	885.5	887.2	886.78	886.9	5573	6411	6198	6258	838	625	685	97%	98%
Marshan Lake	882.5	886.71	885.31	885.68	1251	2670	2166	2300	1420	915	1049	81%	86%
Reshanau Lake	882.4	886.7	885.29	885.67	2489	4152	3581	3732	1663	1092	1243	86%	90%
Rice Lake	882.5	886.7	885.29	885.67	3034	5993	4922	5206	2959	1889	2172	82%	87%
Baldwin Lake	882.3	886.61	885.24	885.61	1061	2415	1933	2061	1355	872	1000	80%	85%
Total					**20963**	**34470**	**29947**	**31236**	**13509**	**8985**	**10272**		

***Total storage is the volume within the lake between the normal water level and the 100-year, 10-day flood elevation.**

****Live storage is the volume within the lake between the normal water level and the maximum elevation resulting from the precipitation event.**

*** Live storage is less for the 10-day event because the lake.

3.7.3 Downstream of the Anoka Chain of Lakes and Long Lake

In order to quantify the value of the chain of lakes, the changes along Rice Creek downstream of the chain of lakes and Long Lake can be assessed. This portion of Rice Creek can be broken up into two sections, between Baldwin Lake and Long Lake, and below Long Lake.

There are many inspection points along this portion of Rice Creek where the peak discharge and 7-day volume can be assessed. The inspection point results are shown in

Table 9 and **Table 10.** Between Baldwin Lake and Long Lake there are 5 inspection points (IP20 – IP24) shown on **Figure 10**. For these locations, there are increases in peak discharge for the upstream reporting locations transitioning to no change at the downstream reporting locations near Long Lake. These locations also see an increase in volume ranging in increases from 6% to 15% for all analyzed events. Below Long Lake there are 7 inspection points (IP25 – IP31). For these locations there are no increases in peak discharge and slight increases in volume ranging from 4% to 7% for all analyzed events.

This analysis shows that there are no peak discharge changes at Long Lake, however there is an increase in 7-day volume. The inflow and outflow hydrographs for existing and future conditions into Long Lake are shown in **Figure 18** and **Figure 19**, respectively. These hydrographs include the Lower Rice Creek branch models (not modified for this project) as well as the inflow from Rice Creek itself (originating from the Anoka chain of lakes and the areas modeled in this project). These hydrographs depict the change in volume mainly occurs on the trailing limb of the hydrograph. One conclusion that can be drawn from this is that the Anoka chain of lakes buffers the increased runoff upstream and delays the timing of this volume reaching Long Lake until several days after the local runoff reaches the Long Lake.

3.7.4 Additional Storage/Volume Control to Achieve No Net Increase

It is possible to estimate the necessary additional volume control required for each branch model, if the desired goal for the future condition is that outlet volume does not increase compared to the existing condition (for a 2-year, 24-hour event, 2.8-inches). Volume control is typically achieved as an ancillary benefit through Rule C.6 and is based on 1.1-inches of runoff from new and reconstructed impervious surfaces for new development (the requirement for public linear projects is 0.75 inches). The future condition C.6 rule benefit can be shown. Additionally, the change in outflow volume, from existing to future condition can be compared to both the overall area of the branch model as well as the area of the branch model suitable for infiltration. Doing so for the 2-year, 24-hour storm event gives an estimate of additional volume reduction (in runoff depth) necessary across each branch model.

This is shown in **Table 16**. The second column represents the depth, out of 1.1 inches, controlled by the rule for the future condition, over the entire branch model. The third column represents the additional runoff depth capture required to maintain existing runoff volume conditions, if the entire model area is utilized for volume control during the 2.8-inch (2-year) event. The fourth column is similar to the third column, but if only infiltration suitable areas were used (**Figure 2**). What this comparison shows is the relative volume control depth for each branch model that would be required to retain the volume for smaller storm events (2-year) under future conditions. A relative comparison of the third and fourth column indicates how much of that additional control can be achieved by infiltration and how much would require control through other means, such as water reuse. For example, ACD 31 could achieve most of its additional control from infiltration, while ACD 15 JD4 would require primarily other means.

Table 16. Additional infiltration required in each branch model for future condition volume control.

Branch Model	Average Depth Controlled by Rule C.6 averaged for area (in)	Additional Depth Control Required for 2-year Event (2.8 inches) over entire area (in)	Additional Depth Control Required for 2-year Event (2.8 inches) only on infiltratible area (in)	Ratio of infiltration area only depth control to total area depth control
Anoka County Ditch 10-22-32	0.15	0.27	0.46	1.7
Anoka County Ditch 15/Anoka County – Washington County Judicial Ditch 4	0.18	0.31	4.56	14.7
Anoka County Ditch 25	0.08	0.22	0.94	4.3
Anoka County Ditch 31	0.14	0.13	0.15	1.2
Anoka County Ditch 46	0.09	0.07	0.16	2.3
Washington Judicial Ditch 2 (Hardwood Creek)	0.12	0.28	0.64	2.3
Anoka Washington Judicial Ditch 3 (Clearwater Creek)	0.10	0.12	0.28	2.3

3.8 Regulatory Floodplain Impacts

The floodplain boundary is one means of representing the area with a potential flood risk. The elevation used to establish the floodplain is determined through modeling. The event that results in the highest elevation is used to map the floodplain boundary. Within the District these events are the runoff amount resulting from a 100-year, 10-day or 100-year, 24-hour snowmelt or precipitation event, respectively. The event is assumed to occur simultaneously across the District.

To assess the potential change in the floodplain elevation, the change in water surface elevation at locations throughout the District were mapped and compared to the 2015 District regulatory floodplain. This comparison is shown in **Figure 20**. The figure shows the current regulatory floodplain boundaries within each branch model as well as the branch model boundaries. The figure also shows the detailed model nodes within each branch model, used to set the regulatory floodplain elevations. Nodes that indicate a decrease are not shown. The color-coding of the nodes indicates the comparison to the existing regulatory floodplain elevation. White nodes indicate less than

0.1 foot of change. This amount of change is likely within the model error and would not normally trigger a floodplain revision. Green nodes indicate changes of 0.1 to 0.5 feet. Red nodes indicate regulatory floodplain changes of greater than 0.5 feet. These are locations where the increase may be problematic in the future, and should be discussed with the Cities. Rice Creek cross sections were also reviewed and the 100-year, 24-hour maximum water elevations compared to the regulatory floodplain elevations. All of the changes in Rice Creek are less than 0.1 feet and are also shown on the map.

The most significant changes to the regulatory floodplain occur near the outlet of Clearwater Creek (JD 3). This area currently does not have substantial floodplain mapping. Another significant area is the outlet to ACD 10-22-32. Lesser impacts occur along Hardwood Creek (JD 2) and throughout ACD 15 JD4.

4 DISCUSSION

The future condition modeling results presented in this report amount to a substantial amount of data, any subset of which can be used can be used to analyze a range of issues within the District. It is important, however to return to the focus of the project, presented in **Section 1.2**. The following is a summary of important results from this project, as they relate to the project goals and purpose.

1. The anticipated future land use changes in areas draining to the Anoka chain of lakes do not show significant effects at the inflow to Long Lake. These would-be effects are substantially buffered by the storage within the Anoka chain of lakes and the minor effect that exit Baldwin Lake, dissipate before reaching Long Lake. This modeling does not include anticipated future land use changes below Baldwin Lake.
2. The anticipated future land use changes in areas draining to the Anoka chain of lakes do increase both peak discharge and 7-day volume into the Anoka chain of lakes. This serves to increase the utilizable live storage by 3-5%. While none of these live storage increase indicate flood damage risk based on the 100-year, 10-day maximum water elevation, several lakes (Centerville and Peltier) are estimated to come within 2% of the utilizable live storage before flood damage may occur.
3. The future land use conditions will result in some increased intercommunity flows, particularly within ACD 10-22-32 and JD 4. Cities that experience increases in intercommunity flow rates include Columbus, Lino Lakes, Grant, and Dellwood.
4. Despite the simulation of District Rules C.6 and C.7, increases in peak flow and 7-day runoff volume occur at the outlet of all of the branch models. Mitigation of this is tied to not only increase in the amount of impervious area and suitability of infiltration, but also drainage area size. For example, Clearwater Creek makes up a sizeable portion of the modeled contributing area and has a fairly large increase in impervious surface, but its high infiltration suitability (see **Table 4** and **Figure 2**) helps to reduce its volume outflow and demonstrates a fairly good application of the District Rules. Hardwood Creek, in contrast, has similar drainage size and impervious increase, but its low infiltration suitability results in relatively poorer application of volume control by infiltration; this would suggest that volume reduction may be necessary through other means within this model area.
5. Multiple locations identified as District Inspection Locations, District Facility Locations, Road Crossings, and throughout the branch models show significant increases in peak flow, maximum water elevation, and 7-day runoff volumes. Many of these locations are well-suited to handle these increases, however several may need to be addressed in the future. These include ditches that may need widening, culverts that require upsizing, and potential flood locations that may require additional protection or mitigation.

Addressing these problems could occur through a variety of implementation strategies including site level volume reduction, inline storage, District initiated projects, or District Rule modification.

6. If future land use development changes occur as modeled, District regulatory floodplain elevations will be expected to increase for all locations upstream of Long Lake. This based on high water elevation increases from precipitation events.

5 RECOMMENDATIONS

Based upon local municipality and Metropolitan Council land use projections, areas of the District are expected to develop considerably in the future. The rate of development remains uncertain, but the analysis presented in this report represents reasonably foreseeable future conditions. The increase in the amount of impervious surface associated with development always results in increases in stormwater that needs to be managed. The future urban development within the District is no exception and shows increases in peak discharge, total runoff volumes, and floodplain elevations. Generally, these increases occur homogeneously throughout the District.

One of the roles of the District is as a regional water manager. The results of this analysis are focused on regional changes in peak discharge, runoff volume, and water surface elevations. Important regional information including the amount of water flowing from one City to the next, water elevations where rivers and streams bisect roads, hydrologic changes at the most downstream locations within the planning regions and along Rice Creek, and floodplain elevations are the focus of this report. One of the next steps is sharing this information with those potentially affected, including municipalities within the District, the Counties, and the road authorities to discuss the implications of these results in managing water in the future. The planning for some of these changes seems relatively easy. For example, a culvert size may need increasing in the future to safely convey the increased flows.

The results of this modeling analysis should not be expected to “detect” the presence of all of the localized future flooding problems. These problems are often a consequence of the size of the conveyance system (e.g., pipes and open channels) used to move water. Other than the public drainage systems, these systems are largely managed by the municipality. Sharing these results with the municipalities is one means of assessing and beginning to define where future localized flooding may occur, thereby providing municipalities with an opportunity to plan for these increased flows.

The primary purpose for completing this work, as expressed by the Board, is being proactive in the development of information which can used and shared to minimize and reduce the risk of future flooding and flood damages within the District. Using this knowledge, the District can decide upon and use the most appropriate methods for minimizing this risk. These methods include providing financial incentives to partners for the construction of cooperative projects, construction of projects by the District itself, and modification and utilization of the District’s regulatory program. However, the direction necessary to achieve this purpose depends in part upon goals yet to be decided upon by the Board. Specifically, the desired approach depends upon the answer to the following:

- Is it the Board’s goal to maintain future peak discharges, runoff volumes and water levels at the existing condition (with no change)[1]? or
- Is it the Board’s goal to allow some manageable increases in future peak discharges, runoff volumes and water levels compared to the existing condition?

An answer to this question relies largely on whether the increases in future peak discharges, runoff volumes, and water level increases result in flood damages. In the absence of knowledge about the economic impacts of the future flood damages and the resulting cost of mitigation, an answer is not currently possible.

The results of this analysis, however, can be used by the Board to begin guiding decisions. The primary decision is developing and establishing a measured approach to address the future increases in peak discharges, runoff volumes, and water levels. Specifically, how should the various tools represented by the District’s regulatory program, cost share programs, and capital improvement projects be utilized and where should emphasis be placed?

When the results of the future condition modeling analysis are viewed from a regional perspective (i.e. along Rice Creek as a system), recommendations ultimately focus on developing measures to address the changes in discharge and volume throughout the District. The standard for peak stormwater runoff control (Rule C.7) is a key component of the rule. The standard for water quality treatment and the preference for volume reduction (Rule C.6), although focused on improving water quality does, result in incidental flood reduction benefits, primarily for small precipitation events (e.g. 2-year return period).

The future development conditions were not modeled without the current District rules, but it is reasonable to assume the standard for peak stormwater runoff control (Rule C.7) is effective and that some incidental volume reduction resulting from the water quality treatment requirement (Rule C.6) occurs. The current rule does mitigate some of the potential development effects, but this mitigation alone is not sufficient enough to maintain future peak discharges, runoff volumes, and water levels at existing conditions.

The Board has several tools available for managing the regionally anticipated increases in peak discharges, runoff volumes, and water levels (**Table 17**). The recommendation includes using all of the tools available to the District including considering modifying the rules and regulations, means for providing financial incentives, and leading the development and construction of projects. The options available to the District include:

[1] From a practical technical perspective, maintaining future runoff volumes at existing conditions can perhaps be accomplished for small precipitation events (using something like standard C.6 Water Quality Treatment), but is not realistic for larger precipitation events.

1. Consider managing the floodplain elevations based on future condition modeling results within the regulatory program. The Federal Emergency Management Agency (FEMA) allows the setting of floodplain elevations based on future conditions, however, this should be discussed with the municipalities within the District. The municipalities are responsible for the local floodplain ordinance. Although the District should discuss this with the municipalities, it is not likely that a district-wide floodplain update would occur based on the future conditions. The District could start using the future condition elevations in their regulatory program, but the challenge is that development won't occur for years and implementing this now will result in a greater challenge in managing floodplains because of differing elevations used by the District and municipalities.
2. Use the District regulatory program and modify the standards within the District rules. These options include:
    a. No modification of the current standard for peak stormwater runoff control (Rule C.7) and the water quality treatment requirement (Rule C.6) and no modification to other programs or capital improvement efforts (use only a regulatory approach). The results of the analysis show that this approach will result in an increase in peak discharge, runoff volumes, and water levels. As discussed above, not changing the current rule is an option, but it should be emphasized that the future condition modeling indicates that the current rules are likely not sufficient to maintain necessary storage within the chain of lakes. The modeling indicates that storm events under the future condition have the possibility of utilizing all of the available storage in the Anoka chain of lakes. There is no "safety factor" because the amount of storage within the Anoka Chain of Lakes is completely utilized. The analysis also shows increases in the duration of flows, because of the increase in volumes, which has proven to lead to problems throughout the District, particularly where conveyance systems are in disrepair or channels have shown stability problems. This approach is not recommended, as it is unresponsive to a potential future problem;
    b. No modification of the current standard for peak stormwater runoff control (Rule C.7) and the water quality treatment requirement (Rule C.6) but make modifications to other programs and develop capital improvements to encourage regional rate and volume control projects. The District Engineer recommends considering this approach only after completing additional technical analysis to evaluate the feasibility, effectiveness, and practicality of an alternative standard for peak stormwater runoff control (Rule C.7) (see c. below);
    c. Consider modifying the current standard for peak stormwater runoff control (Rule C.7) and the water quality treatment requirement (Rule C.6). Specifically evaluate the effectiveness of alternative standards for peak stormwater runoff control upstream of Baldwin Lake and relax the preference for volume control through infiltration, to more easily allow for water reuse. This

option should be evaluated in combination with modifications to providing financial incentives and the use of regional capital improvement projects.

3. Modify financial incentive programs and focus efforts on the development and construction of regional Best Management Practices (BMP) and projects to reduce rate and volume control. This is recommended regardless of possible modifications to the rule; and
4. Engage municipalities by sharing the results of this study, to consider and incorporate them into the regional water planning efforts, including the development of their local surface water management plans (WMP).

Ultimately, the District Engineer's recommendation depends on the Board's goal for the regulatory program and how they wish it to work in conjunction with other District programs such as the Urban Stormwater Remediation Cost-Share Program. The District Engineer assumes that the Board would like to utilize multiple tools to mitigate the potential future impacts rather than a single tool such as a regulatory program.

Regardless of the Board's decision based on the recommendations, future steps include discussion with the cities regarding intercommunity flows, potential crossing impacts, and future impacts to floodplains. Depending on the results, some additional modeling should be completed to determine feasibility of new rate standards and how to apply them. Additionally, the Board should begin considering a mechanism for incentivizing regional rate or volume control projects through cities or other development.

Table 17. Existing tools for mitigating the future increases in peak discharge, runoff volumes, and water levels within the District.

Tool	Category	Description	Recommendation
Rules and Regulations	Local Floodplain Ordinances	Municipal ordinance intended to implement the National Flood Insurance Program and manage flood hazard mapping program.	Consider managing the floodplain elevations based on future condition modeling results within the regulatory program. The Federal Emergency Management Agency (FEMA) allows the setting of floodplain elevations based on future conditions, however, this should be discussed with the cities within the District. The cities could implement the FEMA program. Although the District should discuss this with the cities, it is not likely that a district-wide floodplain update would occur based on the future conditions. The District could start using the future condition elevations in their regulatory program, but the challenge is that development won't occur for years and implementing this now will result in a greater challenge in managing floodplains.
	District Rule C.6, Water Quality Treatment	Treatment of 0.75 inches and 1.1 inches of runoff from reconstructed and new impervious surface to treat water quality, but provides some incidental volume reduction with mitigation for small precipitation events.	Modify current standard to create flexibility for volume control (remove preference for infiltration, and encourage volume control through stormwater reuse in the regulatory program).
	District Rule C.7, Peak Stormwater Rate Control	Requires reduction in the peak rate of runoff for the 2-, 10-, and 100-year precipitation events to the pre-developed rates, expect downstream of Baldwin Lake which requires reduction to 80% of the pre-development levels.	Evaluate effectiveness of a rate control rule similar to the Flood Management Zone for the drainage area downstream of Baldwin Lake (i.e. future conditions peak discharge rate for the 2-, 10-, and 100-year precipitation events controlled to 80% of existing condition or alternative such as City of Hugo 0.1cfs/square mile for the 24-hour, 100-year precipitation event).
	District Rule E, Floodplain Alteration	Focused on preventing flood damages by managing the floodplain. The District currently maintains a set of regulatory floodplain elevations which differ from the FEMA elevations.	Do not modify.
Water Management Planning	Intercommunity Flow Rates	The District approves local surface water management plans, prepared by the municipalities.	Engage municipalities in a discussion about whether the estimated increases are problematic and how these may be addressed.

Tool	Category	Description	Recommendation
Financial Incentives through Cost Share Programs	Urban Stormwater Remediation Cost Share Program	Funding is intended for projects that provide stormwater quality treatment and/or runoff volume or peak runoff rate control. Projects must not be required by a RCWD permit, or if required, the proposed outcomes should exceed RCWD permit requirements. Cost-sharing will be limited to 50% of estimated project costs or bid cost, whichever is lower, not to exceed $50,000 per project.	Modify the program to encourage and incentivize regional Best Management Practices for rate control and volume control that contribute to downstream flood peak increases (e.g. lower Hardwood Creek).
Capital Improvements by Cities	Urban Best Management Practice Cost Share Program	Construction of regional projects for rate control and volume reduction.	Provide financial and technical assistance to encourage regional Best Management Practices for rate control and volume control that contribute to downstream flood peak increases (e.g. lower Hardwood Creek).
Capital Improvements by District	Direct Funding	Construction of regional projects for rate control and volume reduction.	Focus on regional rate control and volume control that contribute to downstream flood peak increases (e.g. lower Hardwood Creek).

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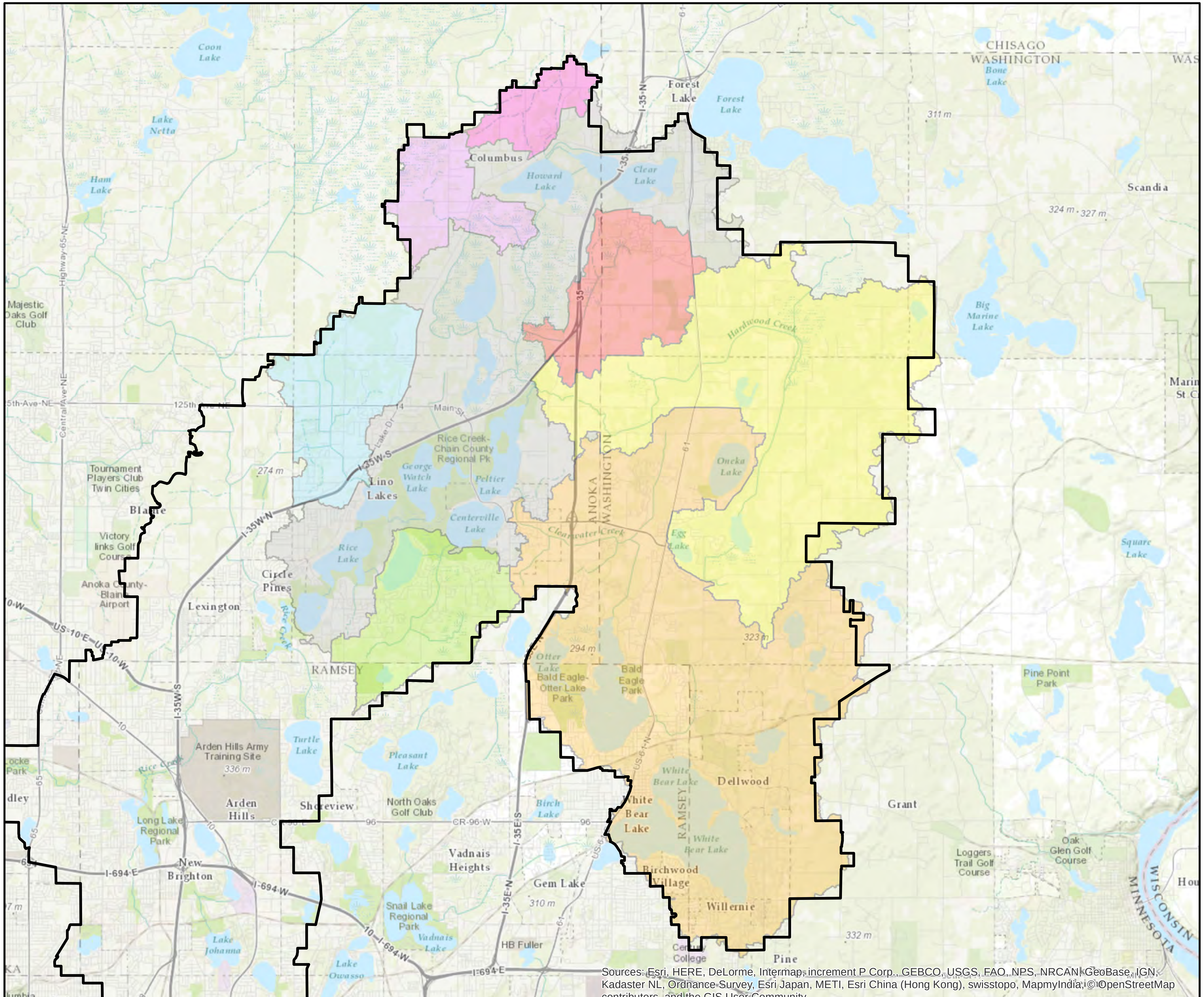
FIGURES

Rice Creek Watershed District Future Condition Modeling

Model Boundaries



RCWD Boundary

Model Boundaries

Model Name

- ACD 10 22 32
- ACD 15 JD 4
- ACD 25
- ACD 31
- ACD 46
- Hardwood Creek (JD 2)
- Clearwater Creek (JD 3)
- Rice Creek Direct Drainage

N W E S

0 0.75 1.5 3 4.5 6 Miles

Sources: RCWD

Figure 1: Future Condition Model Boundaries

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	JDJ		5555-251	1/21/16	1 of 1

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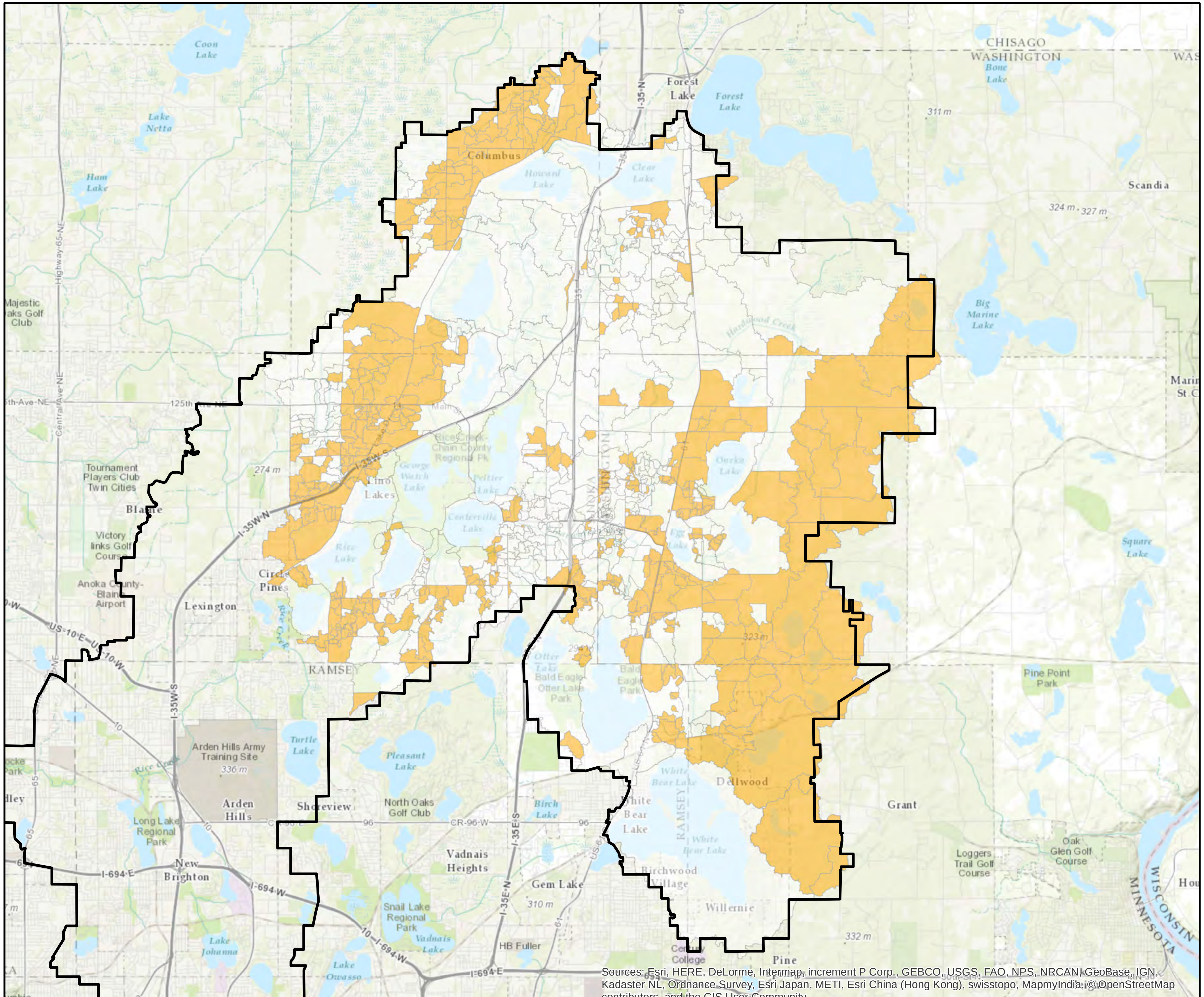
Rice Creek Watershed District Future Condition Modeling

Soil Infiltration Potential



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

RCWD Boundary

Catchment Soils Suitable for Infiltration

Yes

No

N E S W

0 0.75 1.5 3 4.5 6 Miles

Sources: RCWD

Figure 2: Soil Infiltration Potential

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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Rice Creek
Watershed District
Future Condition Modeling
Simulated Rule Modeling Example

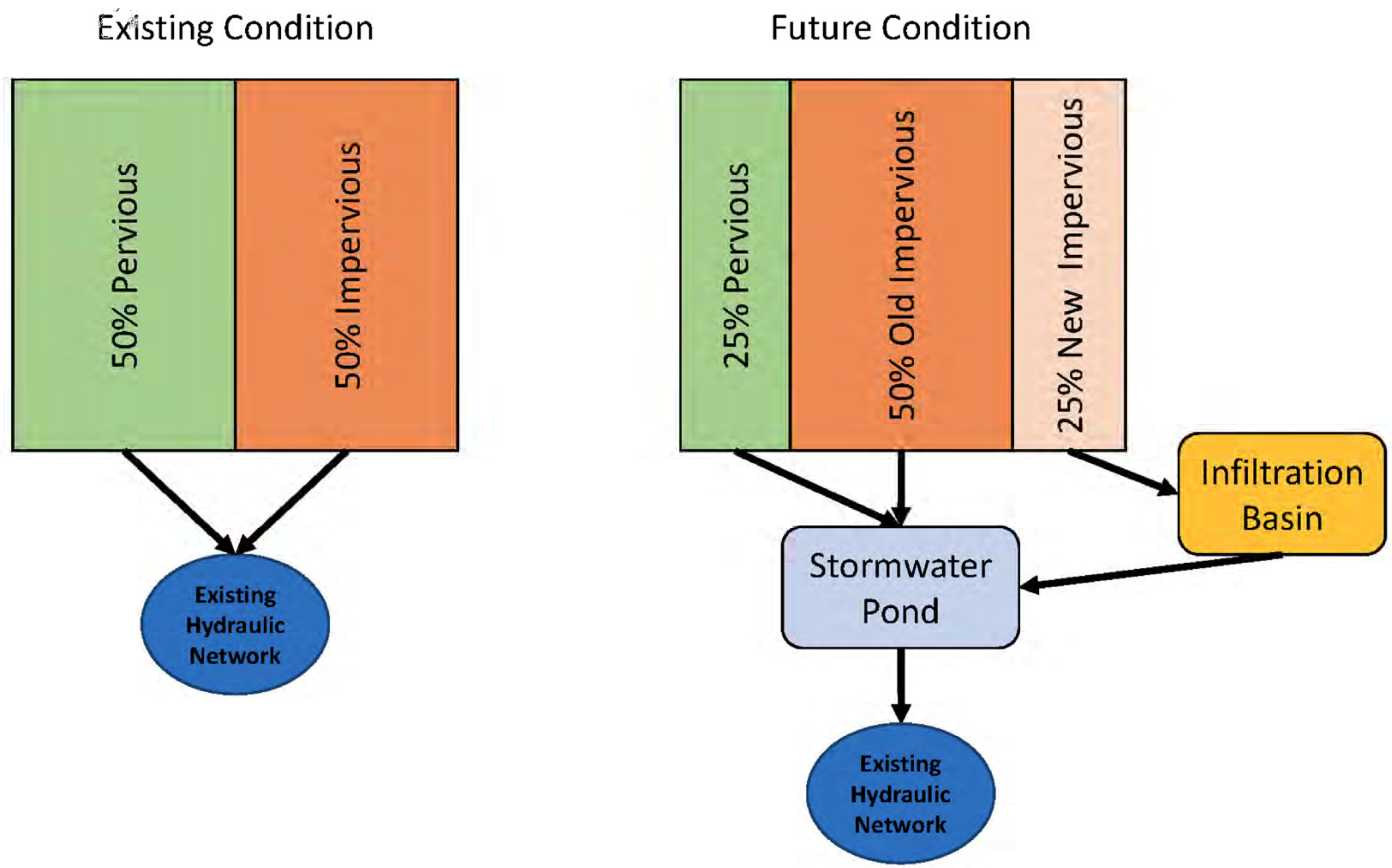

Figure 3: Simulated Rule Modeling Example

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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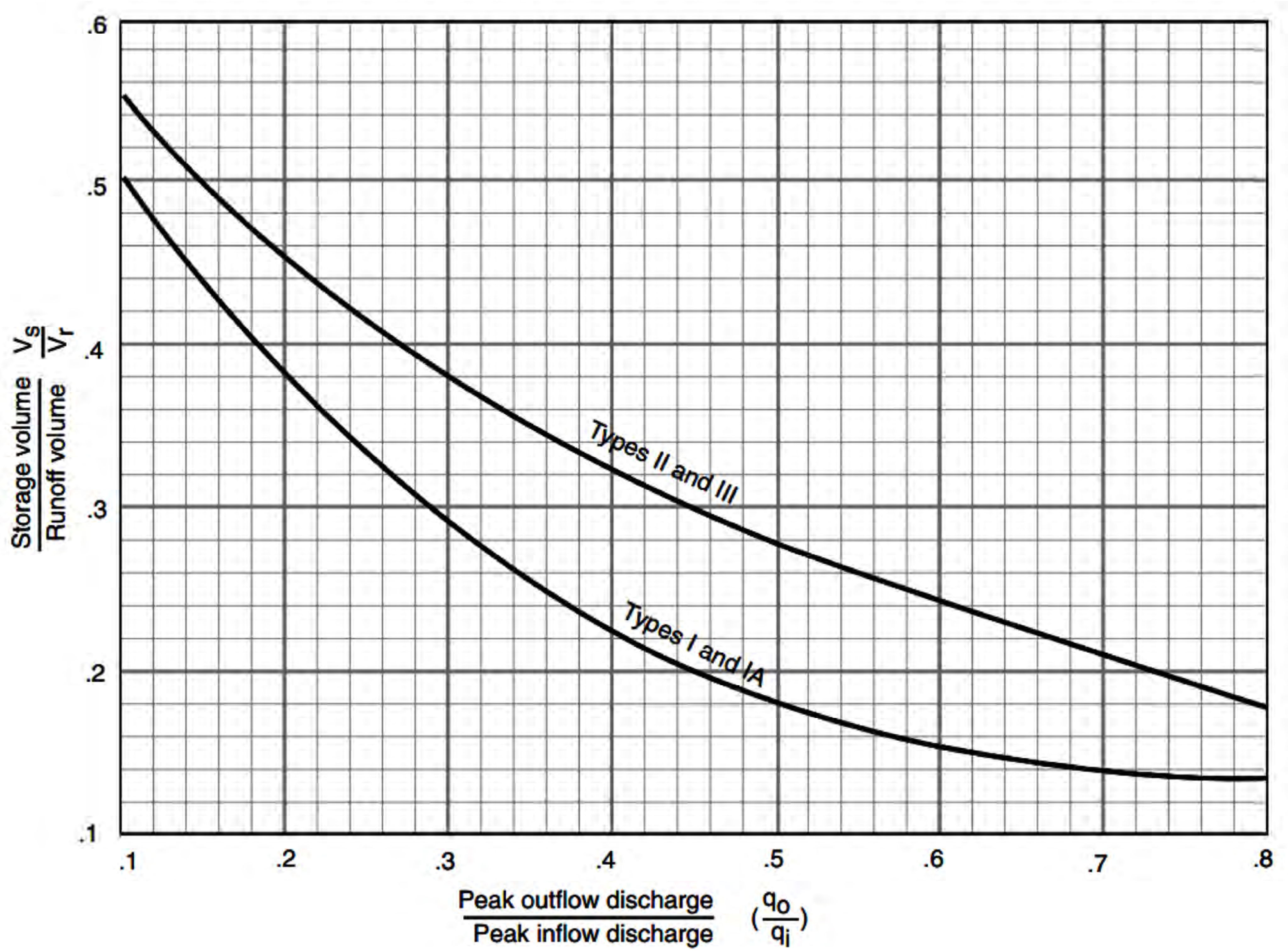
Rice Creek
Watershed District
Future Condition Modeling
Rule C.7 Storage Sizing Nomograph



Source: NRCS, 1986

Figure 4: Rule C.7 Storage Sizing Nomograph

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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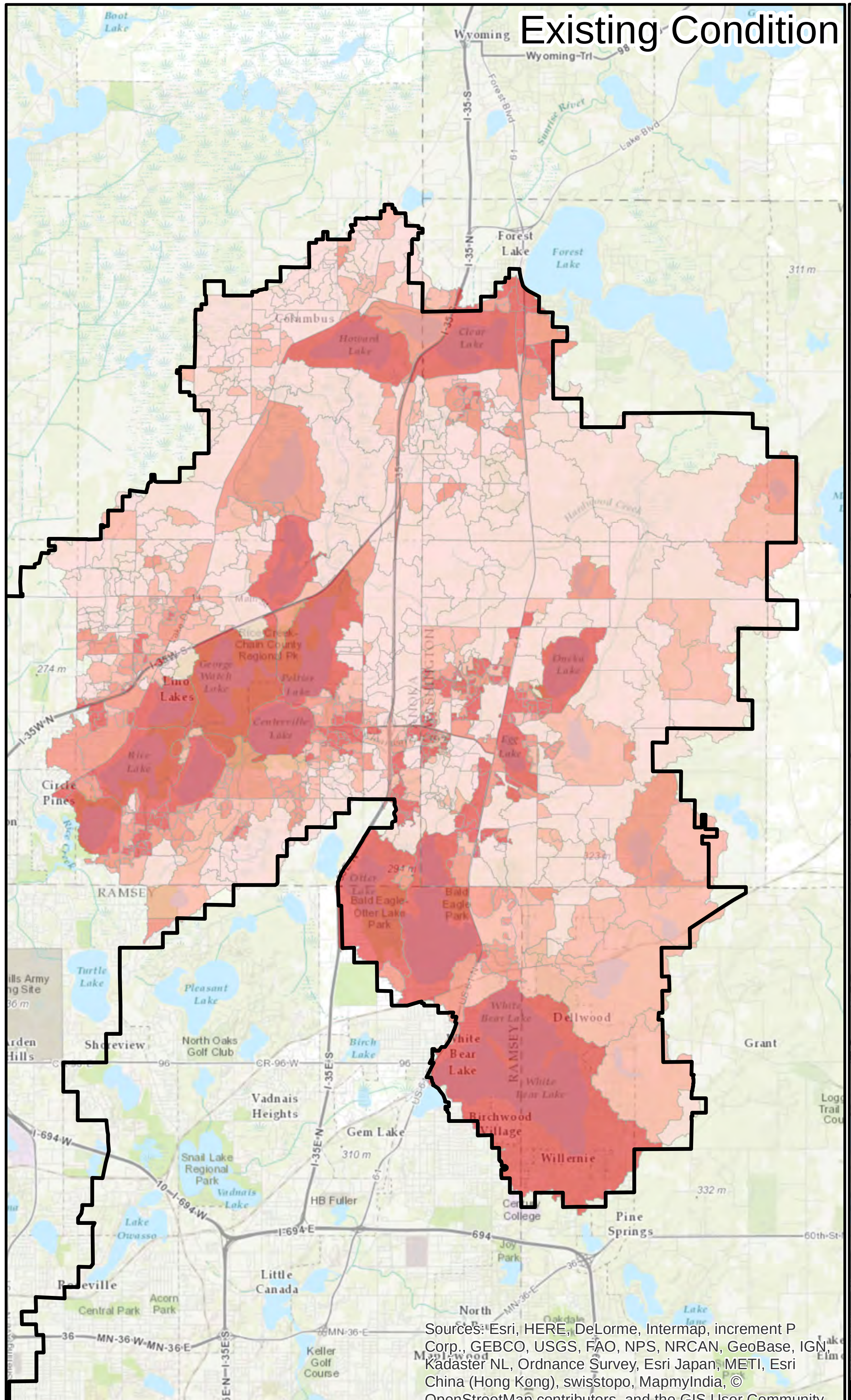
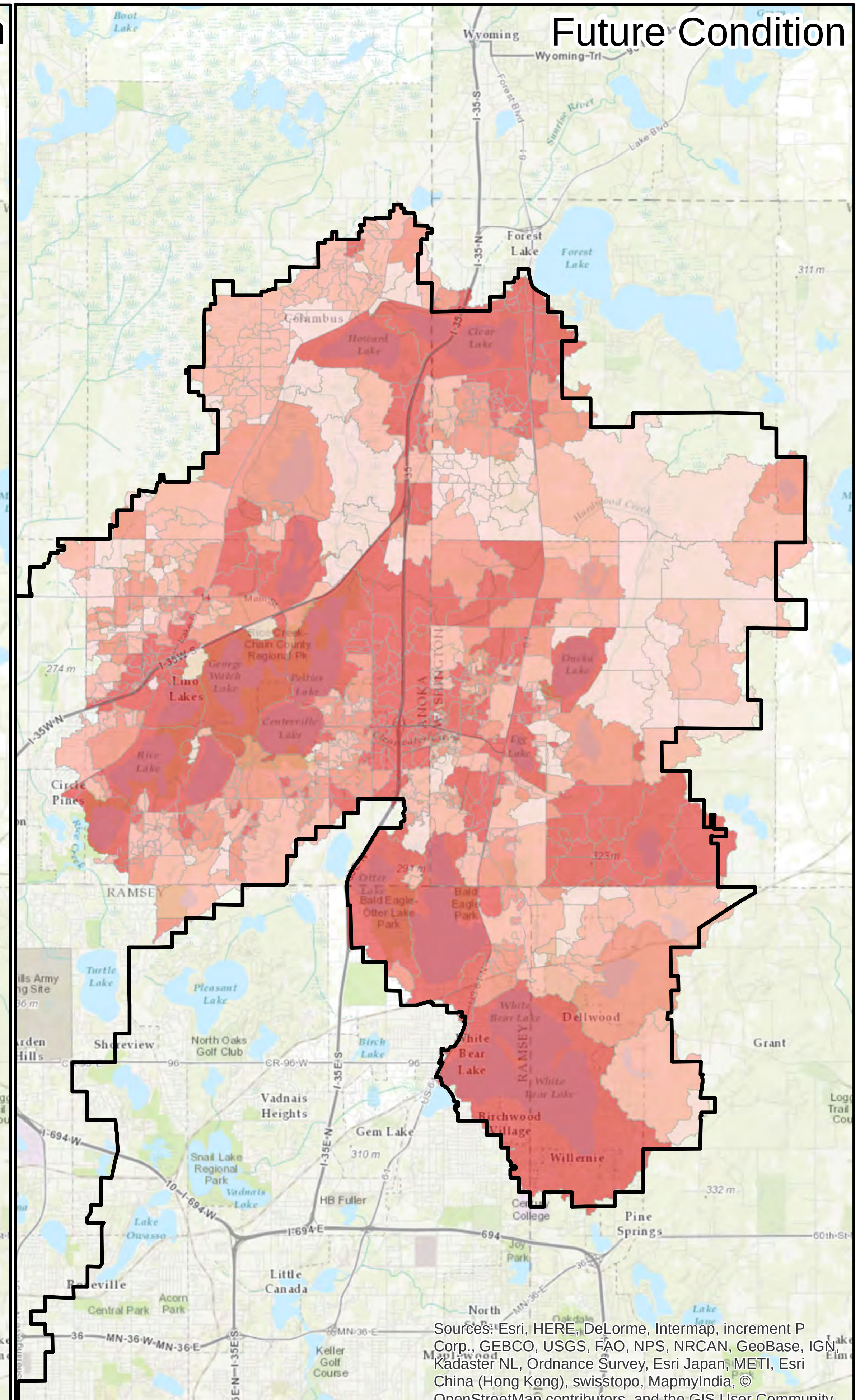
Rice Creek Watershed District Future Condition Modeling

Existing and Future Condition Model Imperviousness





RCWD Boundary

Impervious %

- 0 - 12
- 13 - 26
- 27 - 46
- 47 - 100

N W E S

0 1 2 4 6 8 Miles

Sources: RCWD

Figure 5: Model Imperviousness

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	JDJ		5555-251	1/21/16	1 of 1

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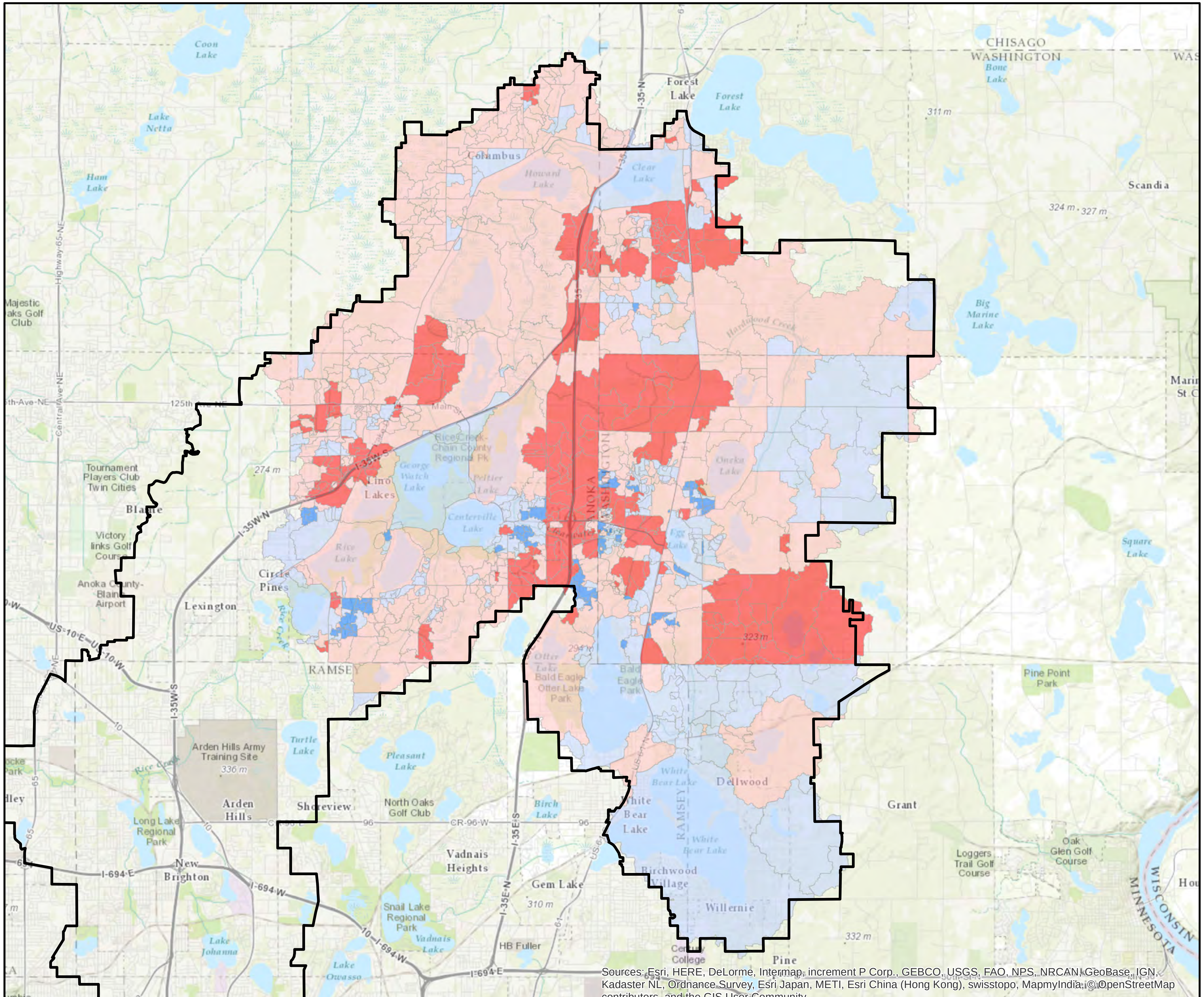
Rice Creek Watershed District Future Condition Modeling

Existing and Future Condition Model Imperviousness Change



RCWD Boundary

Change in Imperviousness

- > 25% reduction
- 25% - 0% reduction
- 0% - 25% increase
- >25% increase

N S E W

0 0.75 1.5 3 4.5 6 Miles

Sources: RCWD

Figure 6: Model Imperviousness Change

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	JDJ		5555-251	1/21/16	1 of 1

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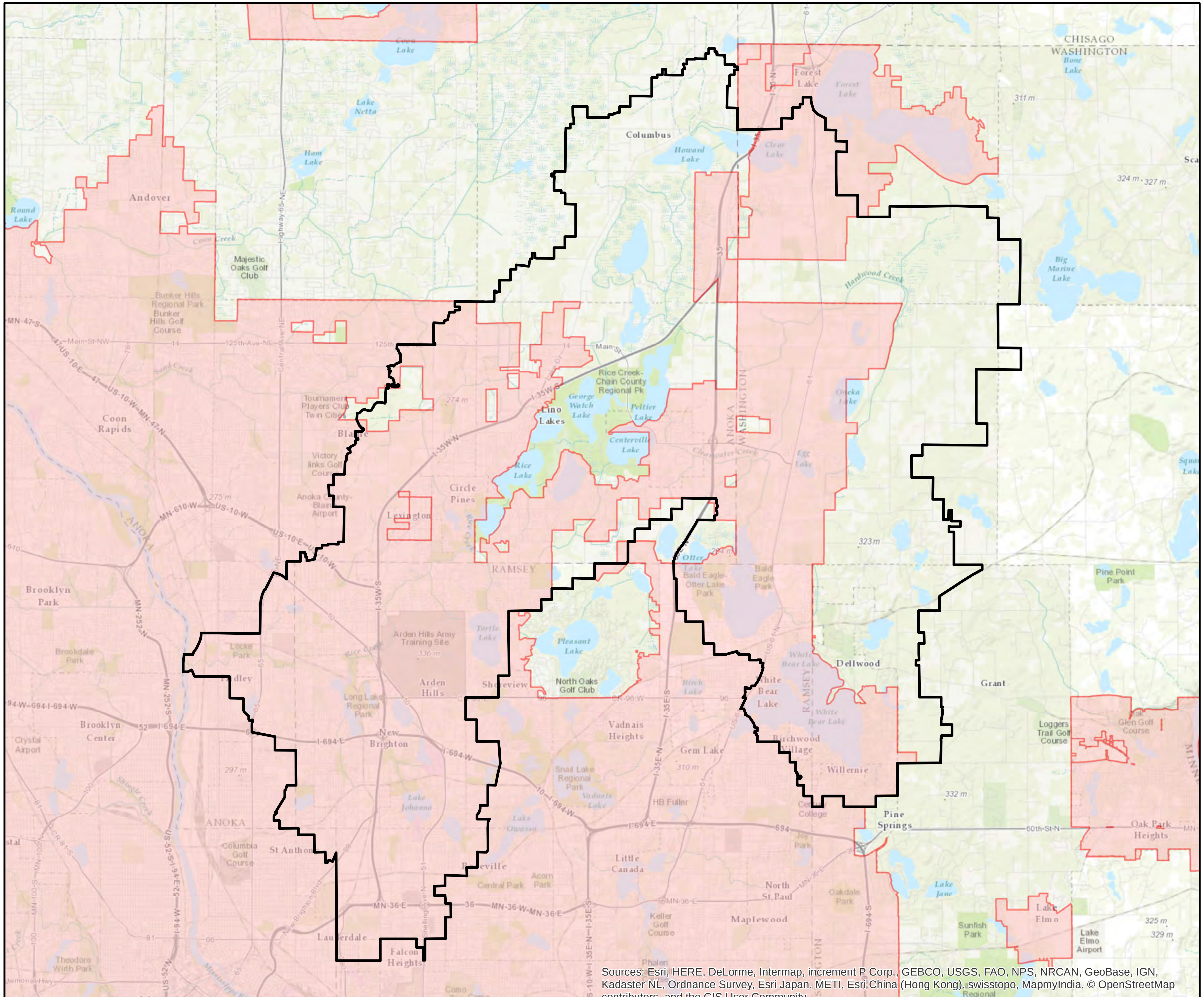
Rice Creek Watershed District Future Condition Modeling

Existing and Future Condition Metropolitan Urban Service Areas (MUSA) Boundary



RCWD Boundary

MUSA 2030 Boundary

N
W E
S

0 0.75 1.5 3 4.5 6 Miles

Sources: RCWD

Figure 7: Model Imperviousness Change

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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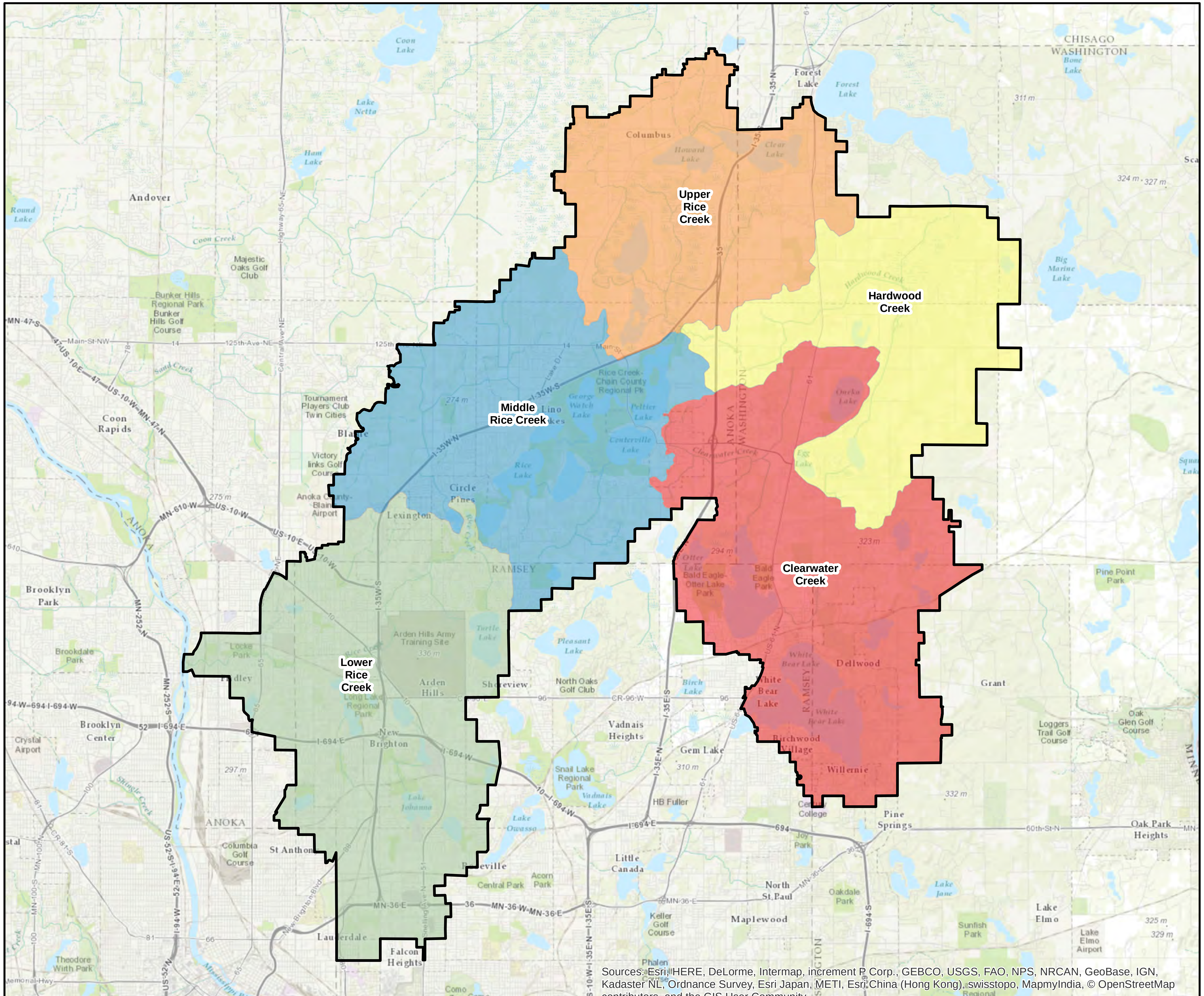
Rice Creek Watershed District Future Condition Modeling

District Planning Regions



RCWD Boundary

Planning Regions

- Clearwater Creek
- Hardwood Creek
- Lower Rice Creek
- Middle Rice Creek
- Upper Rice Creek

N W E S

0 0.75 1.5 3 4.5 6 Miles

Sources: RCWD

Figure 8: District Planning Regions

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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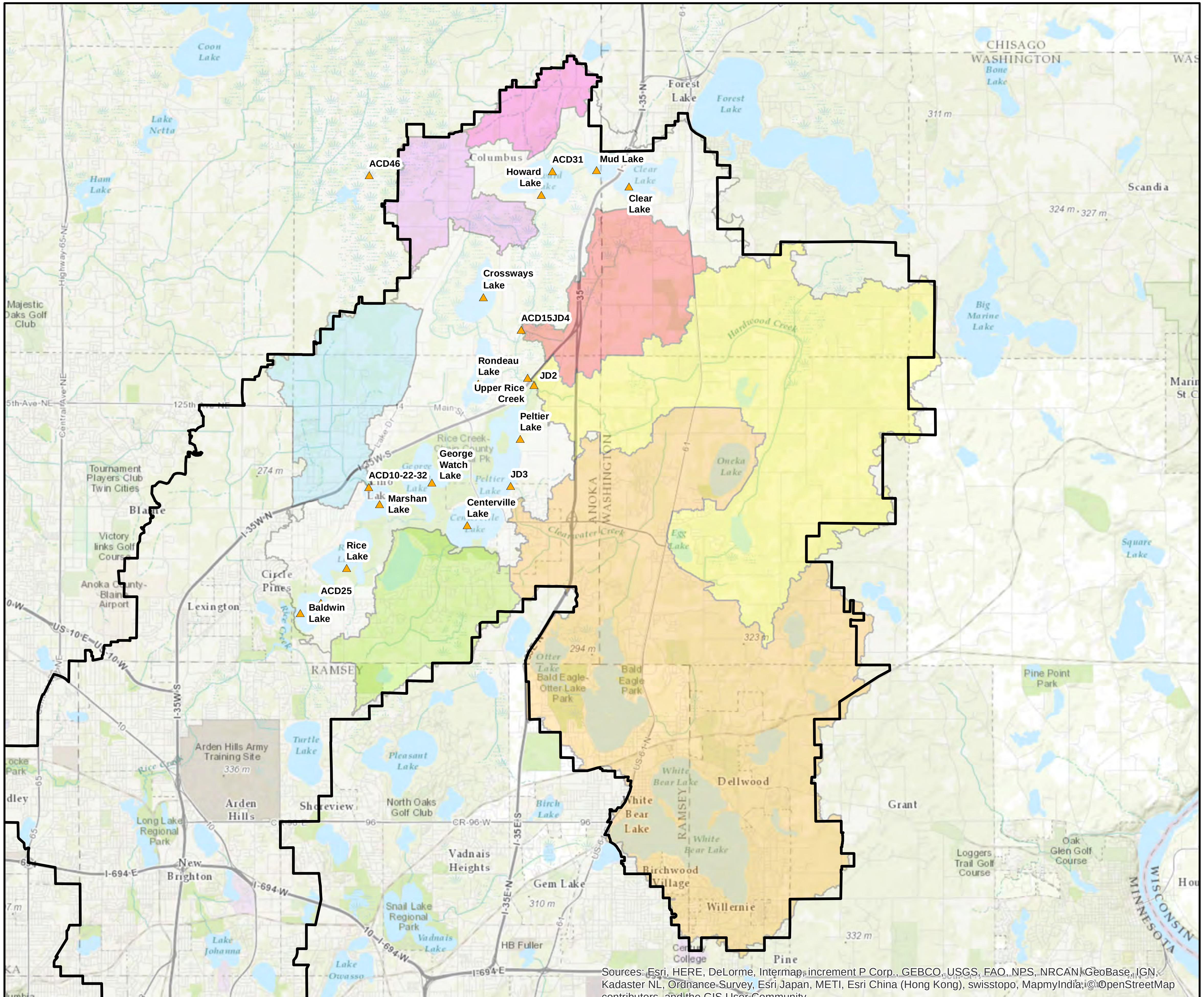
Rice Creek Watershed District Future Condition Modeling

Branch Model Outlets



RCWD Boundary

Model Outlets

Model Boundaries

- ACD 10 22 32
- ACD 15 JD 4
- ACD 25
- ACD 31
- ACD 46
- JD 2
- JD 3
- Rice Creek Direct Drainage

N W E S

0 0.75 1.5 3 4.5 6 Miles

Sources: RCWD

Figure 9: Branch Model Outlets

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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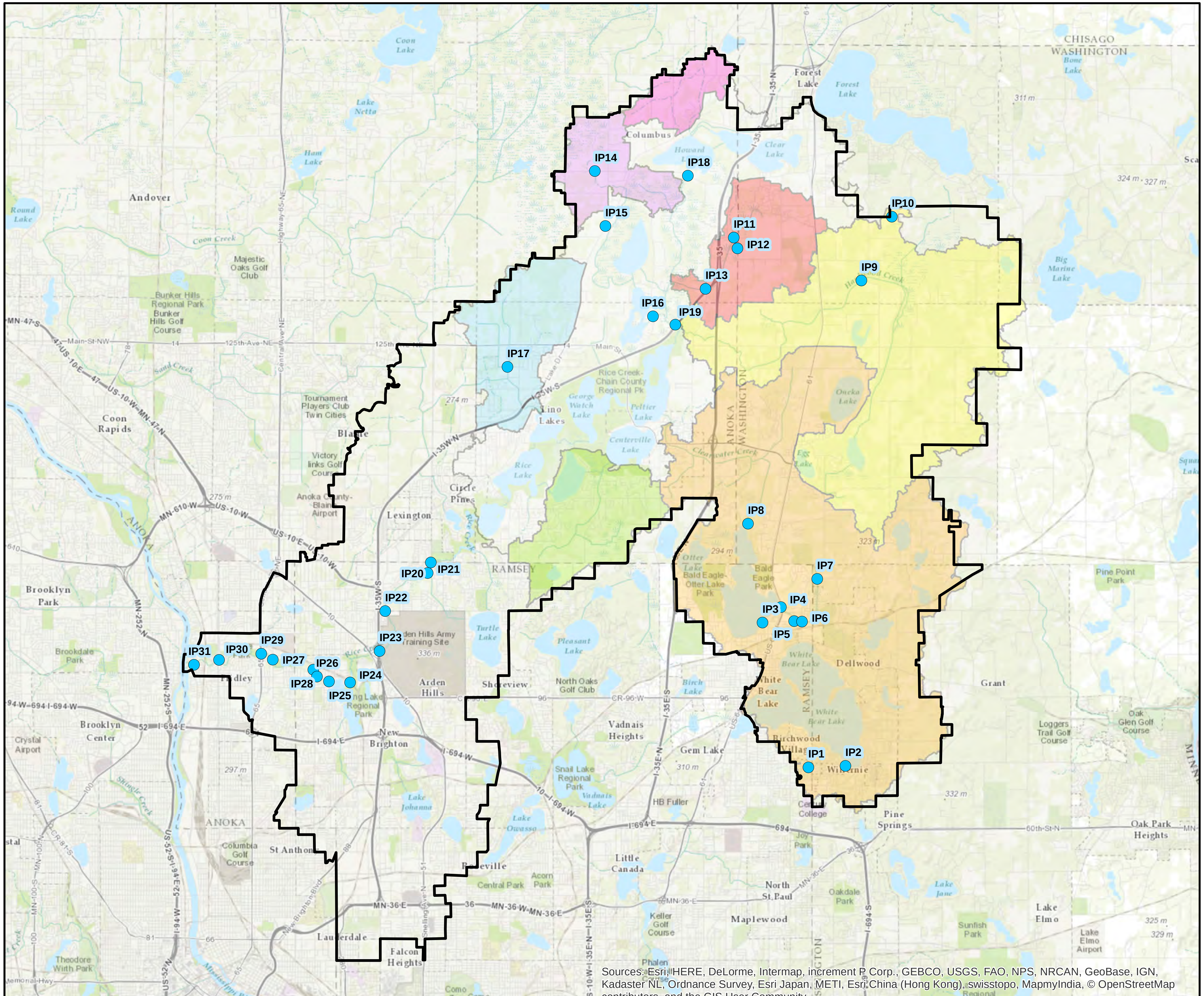
Rice Creek Watershed District Future Condition Modeling

District Inspection Locations



RCWD Boundary

District Inspection Locations

Model Boundaries

ACD 10 22 32

ACD 15 JD 4

ACD 25

ACD 31

ACD 46

JD 2

JD 3

Rice Creek Direct Drainage

N W E S

0 0.75 1.5 3 4.5 6 Miles

Sources: RCWD

Figure 10: District Inspection Locations

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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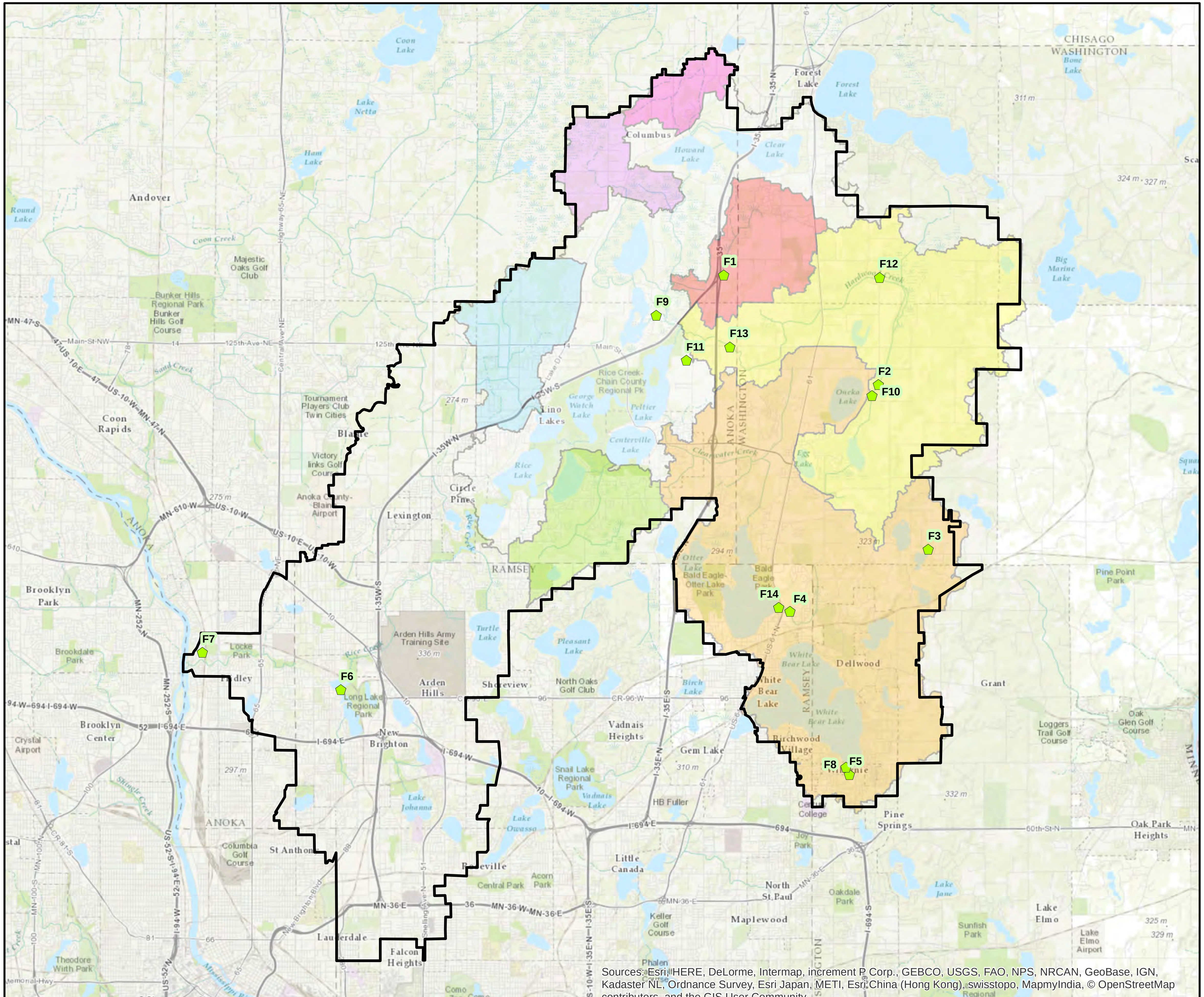

Rice Creek Watershed District Future Condition Modeling

District Facility Locations

RCWD Boundary

District Facility Locations

Model Boundaries

- ACD 10 22 32
- ACD 15 JD 4
- ACD 25
- ACD 31
- ACD 46
- JD 2
- JD 3
- Rice Creek Direct Drainage

N E S W

0 0.75 1.5 3 4.5 6 Miles

Sources: RCWD

Figure 11: District Facility Locations

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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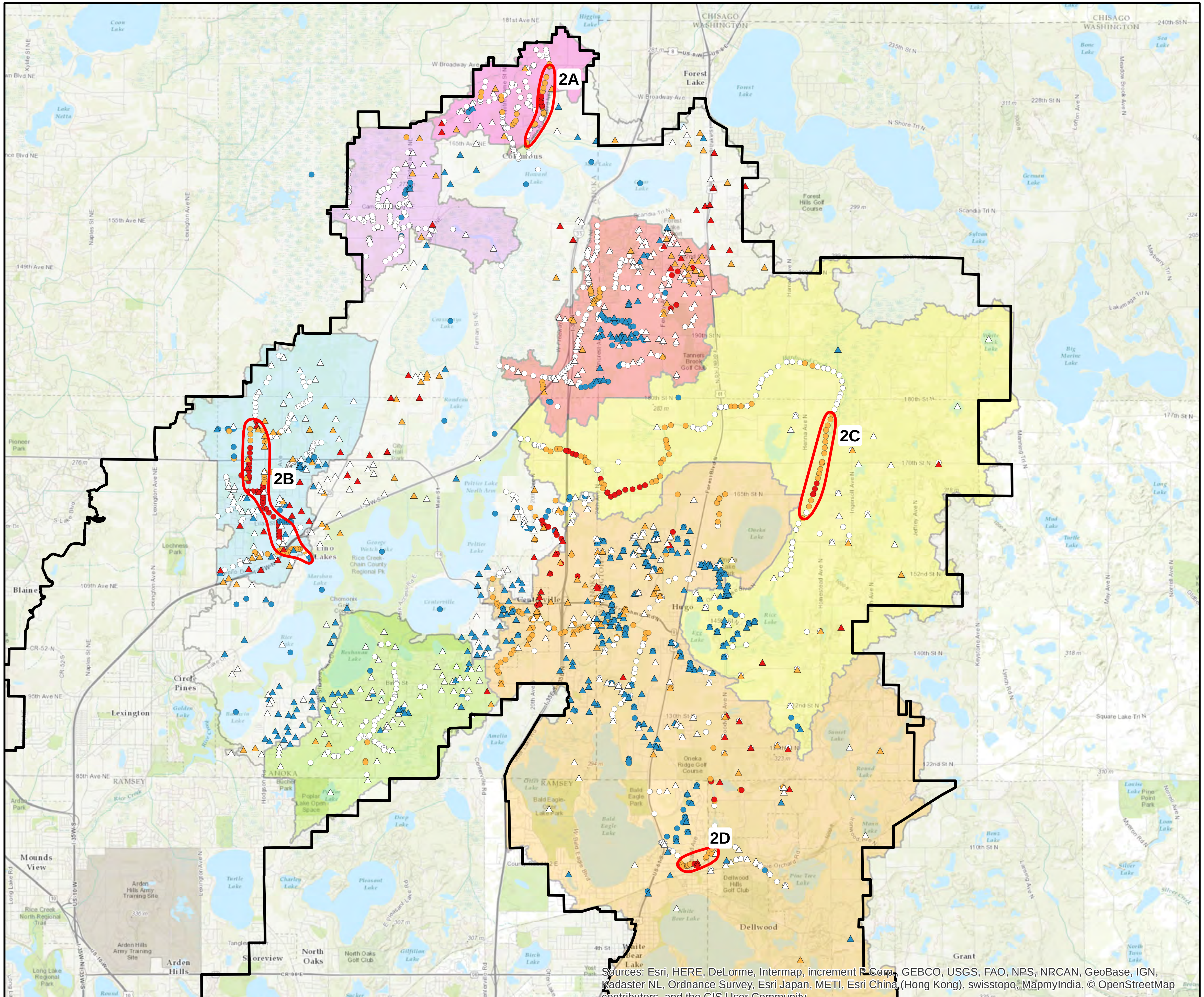

Rice Creek Watershed District Future Condition Modeling

Maximum Elevation Changes 2-Year, 24-Hour Storm Event

RCWD Boundary

Model Boundaries

- ACD 10 22 32
- ACD 15 JD 4
- ACD 25
- ACD 31
- ACD 46
- JD 2
- JD 3
- Rice Creek Direct Drainage

Storage Nodes

Max Elevation Change

- < 0 (reduction)
- 0 - 0.5 ft
- 0.5 - 1.0 ft
- > 1.0 ft

Junction Nodes

Max Elevation Change

- < 0 (reduction)
- 0 - 0.5 ft
- 0.5 - 1.0 ft
- > 1.0 ft

N W E S

0 0.5 1 2 3 4 Miles

Sources: RCWD

Figure 12: Maximum Elevation Changes, 2-Year Event

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	JDJ		5555-251	1/21/16	1 of 1

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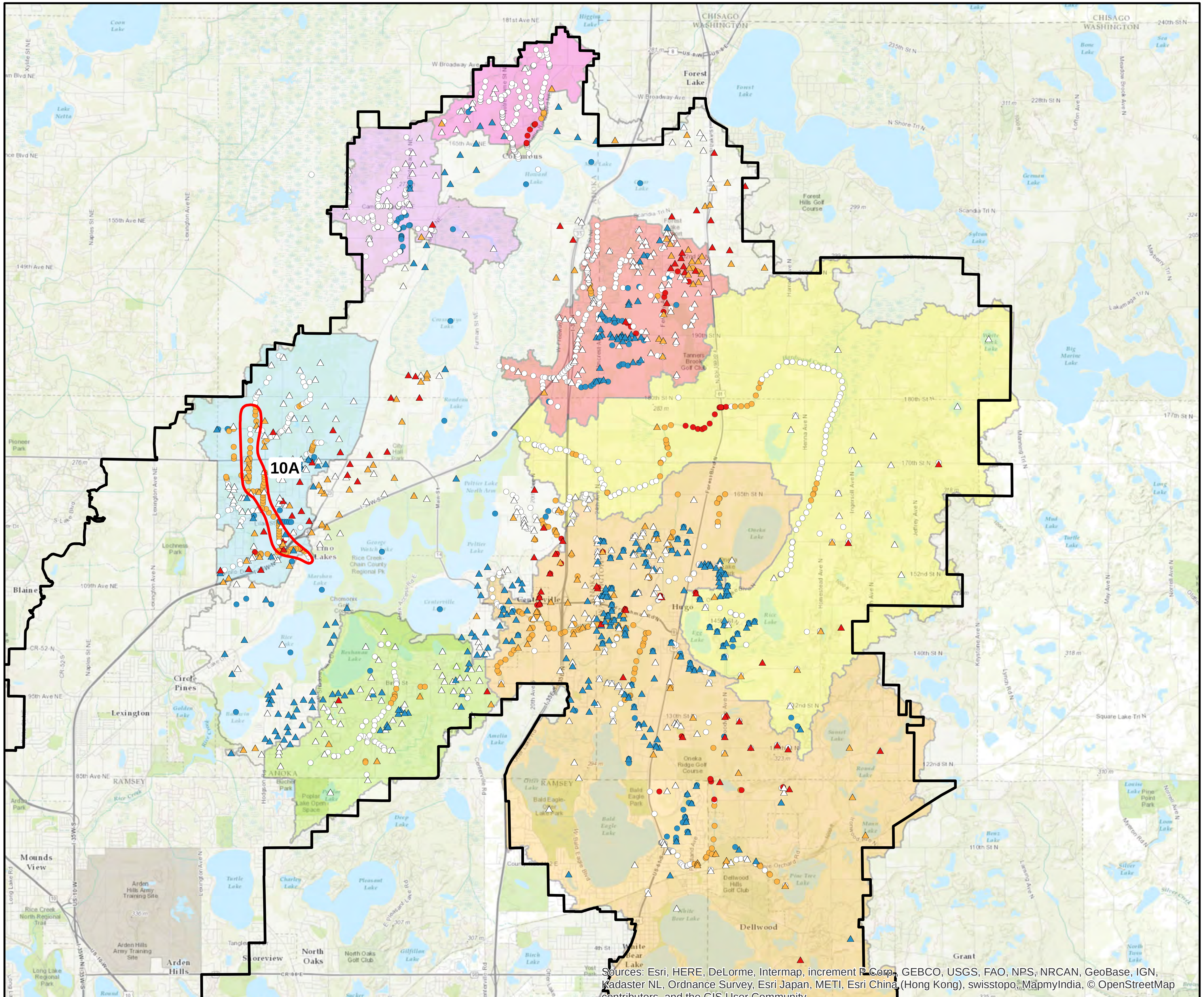
Rice Creek Watershed District Future Condition Modeling

Maximum Elevation Changes 10-Year, 24-Hour Storm Event



RCWD Boundary

Model Boundaries

- ACD 10 22 32
- ACD 15 JD 4
- ACD 25
- ACD 31
- ACD 46
- JD 2
- JD 3
- Rice Creek Direct Drainage

Storage Nodes

Max Elevation Change

- < 0 (reduction)
- 0 - 0.5 ft
- 0.5 - 1.0 ft
- > 1.0 ft

Junction Nodes

Max Elevation Change

- < 0 (reduction)
- 0 - 0.5 ft
- 0.5 - 1.0 ft
- > 1.0 ft

N W E S

0 0.5 1 2 3 4 Miles

Sources: RCWD

Figure 13: Maximum Elevation Changes, 10-Year Event

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	JDJ		5555-251	1/21/16	1 of 1

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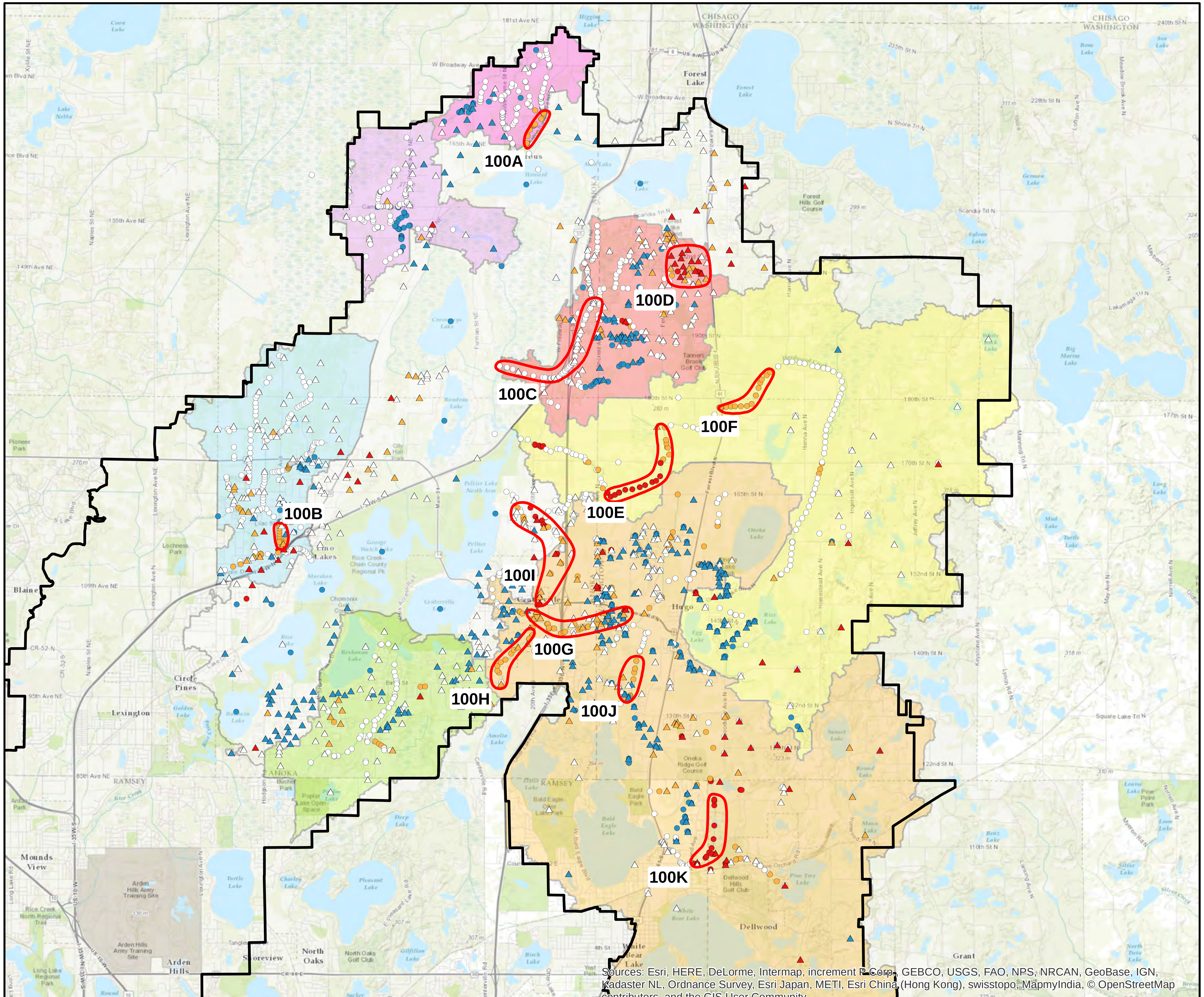

Rice Creek Watershed District Future Condition Modeling

Maximum Elevation Changes 100-Year, 24-Hour Storm Event

RCWD Boundary

Model Boundaries

- ACD 10 22 32
- ACD 15 JD 4
- ACD 25
- ACD 31
- ACD 46
- JD 2
- JD 3
- Rice Creek Direct Drainage

Storage Nodes

Max Elevation Change

- < 0 (reduction)
- 0 - 0.5 ft
- 0.5 - 1.0 ft
- > 1.0 ft

Junction Nodes

Max Elevation Change

- < 0 (reduction)
- 0 - 0.5 ft
- 0.5 - 1.0 ft
- > 1.0 ft

N W E S

0 0.5 1 2 3 4 Miles

Sources: RCWD

Figure 14: Maximum Elevation Changes, 100-Year Event

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	JDJ		5555-251	1/21/16	1 of 1

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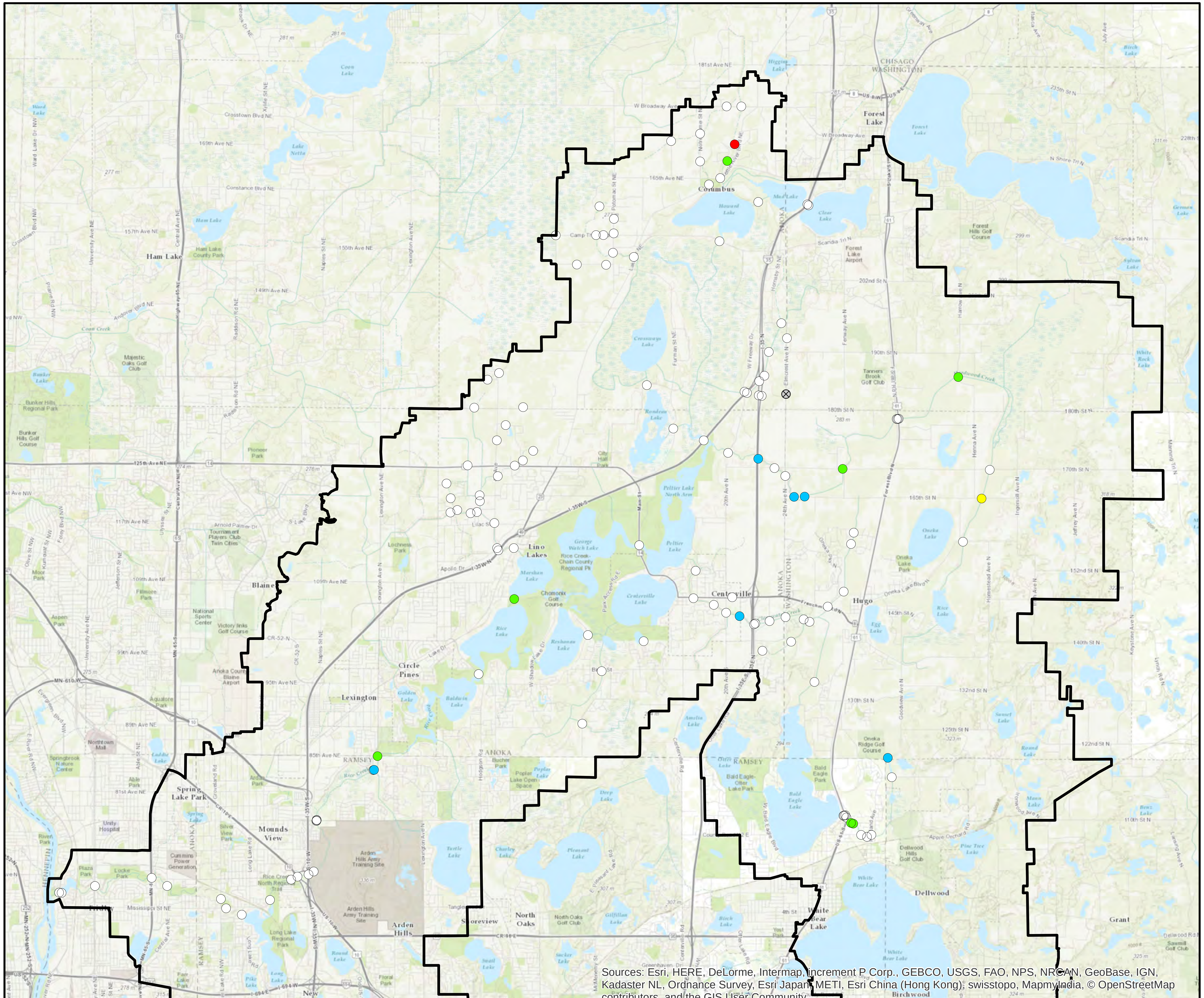

Rice Creek Watershed District Future Condition Modeling

Roadway Crossing Impacts

RCWD Boundary

Roadway Crossing Impacts

- Overtopping at Future 100-year events
- Overtopping at Existing and Future 100-year events
- Overtopping at Future 10-year, Existing and Future 100-year events
- Overtopping at Existing and Future 10-year and 100-year events
- Does not overtop
- No Data

N S W E

0 0.5 1 2 3 4 Miles

Sources: RCWD

Figure 15: Roadway Crossing Impacts

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	JDJ		5555-251	1/21/16	1 of 1

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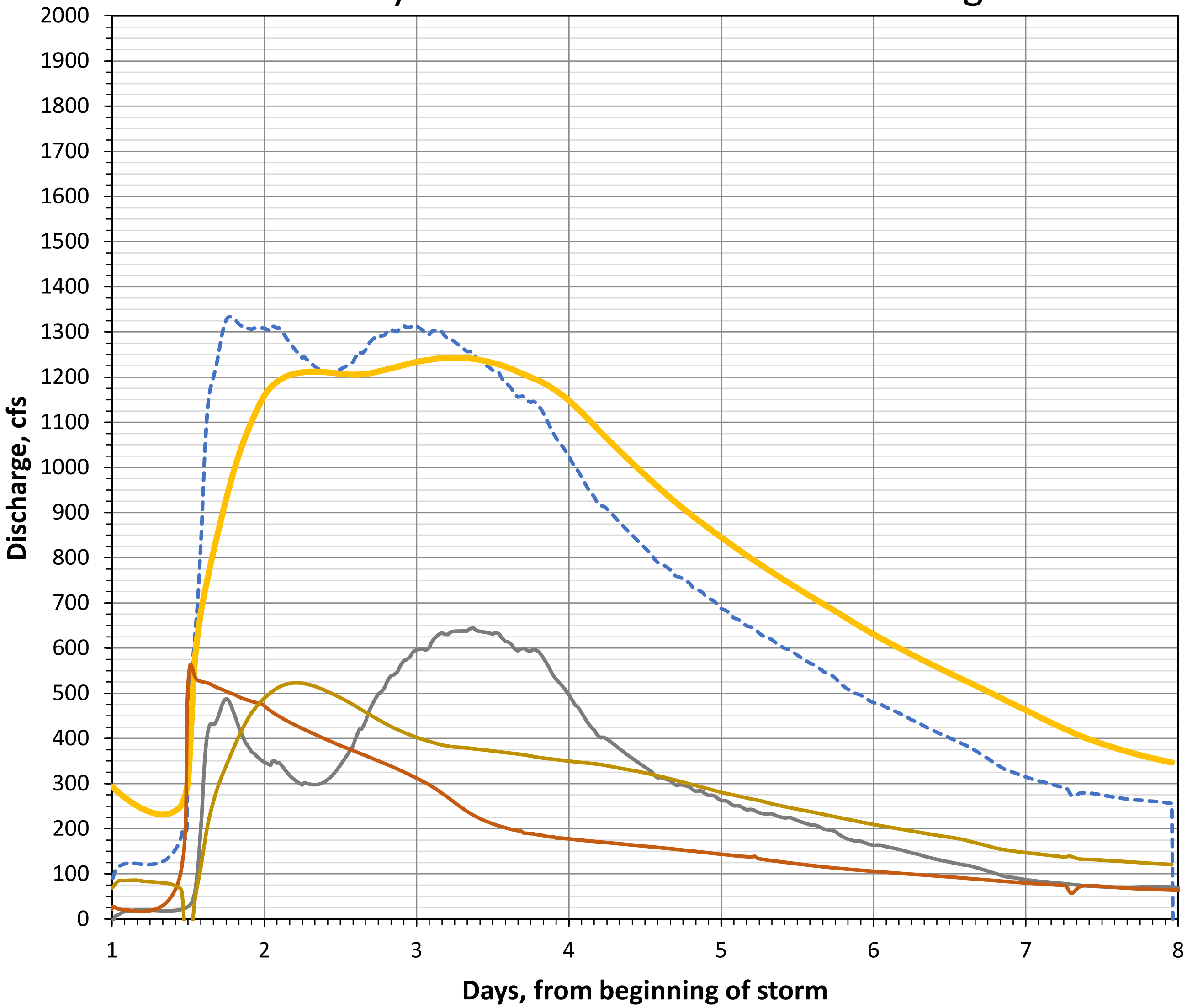
Figure 16

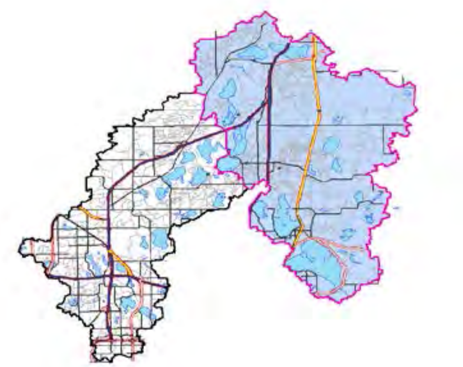
Peltier Lake Synthetic Event Discharge Hydrographs
Tributary Inflows and Lake Outflow
100-year 24-hr rainfall event - Existing Condition



Rice Creek Watershed District
Hydrologic and hydraulic model output from District-Wide modeling program 2010. For supplemental information please see the respective model submittal package.

Rice Creek
at Peltier Lake Dam

Total Drainage Area - 101.6 sq. miles

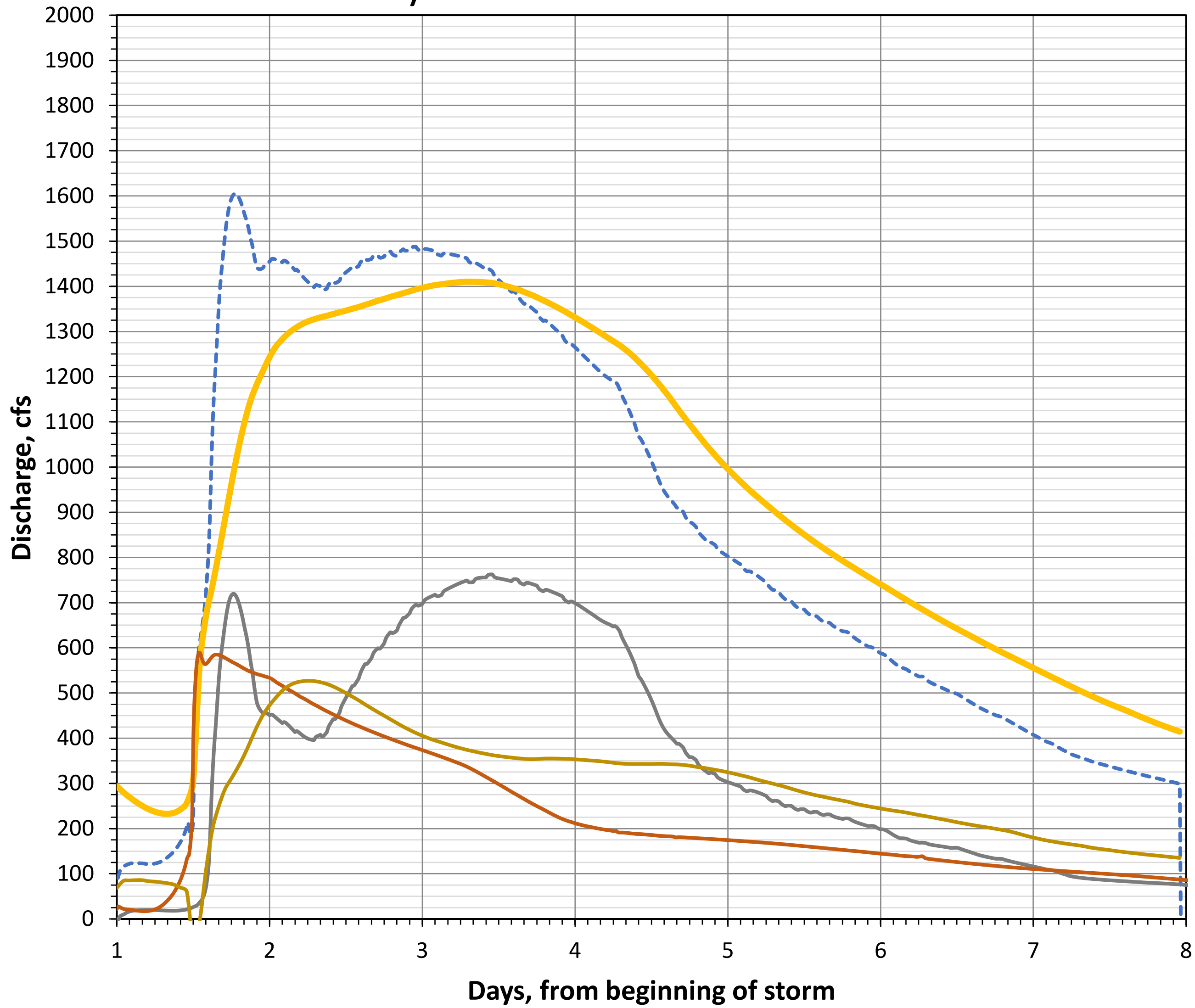


Legend

- Peltier Lake Combined Inflow
- Peltier Lake Outflow
- Hardwood Creek Inflow
- Clearwater Creek Inflow
- Upper Rice Creek Inflow

Figure 17

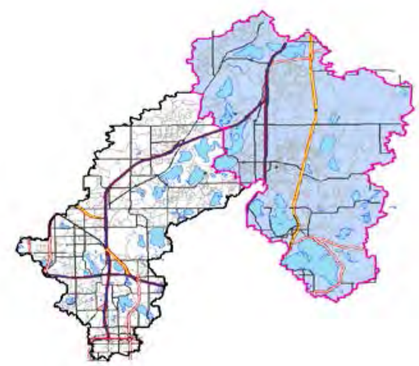
Peltier Lake Synthetic Event Discharge Hydrographs
Tributary Inflows and Lake Outflow
100-year 24-hr rainfall event - Future Condition



Rice Creek Watershed District
Hydrologic and hydraulic model output from District-Wide modeling program 2010. For supplemental information please see the respective model submittal package.

Rice Creek
at Peltier Lake Dam

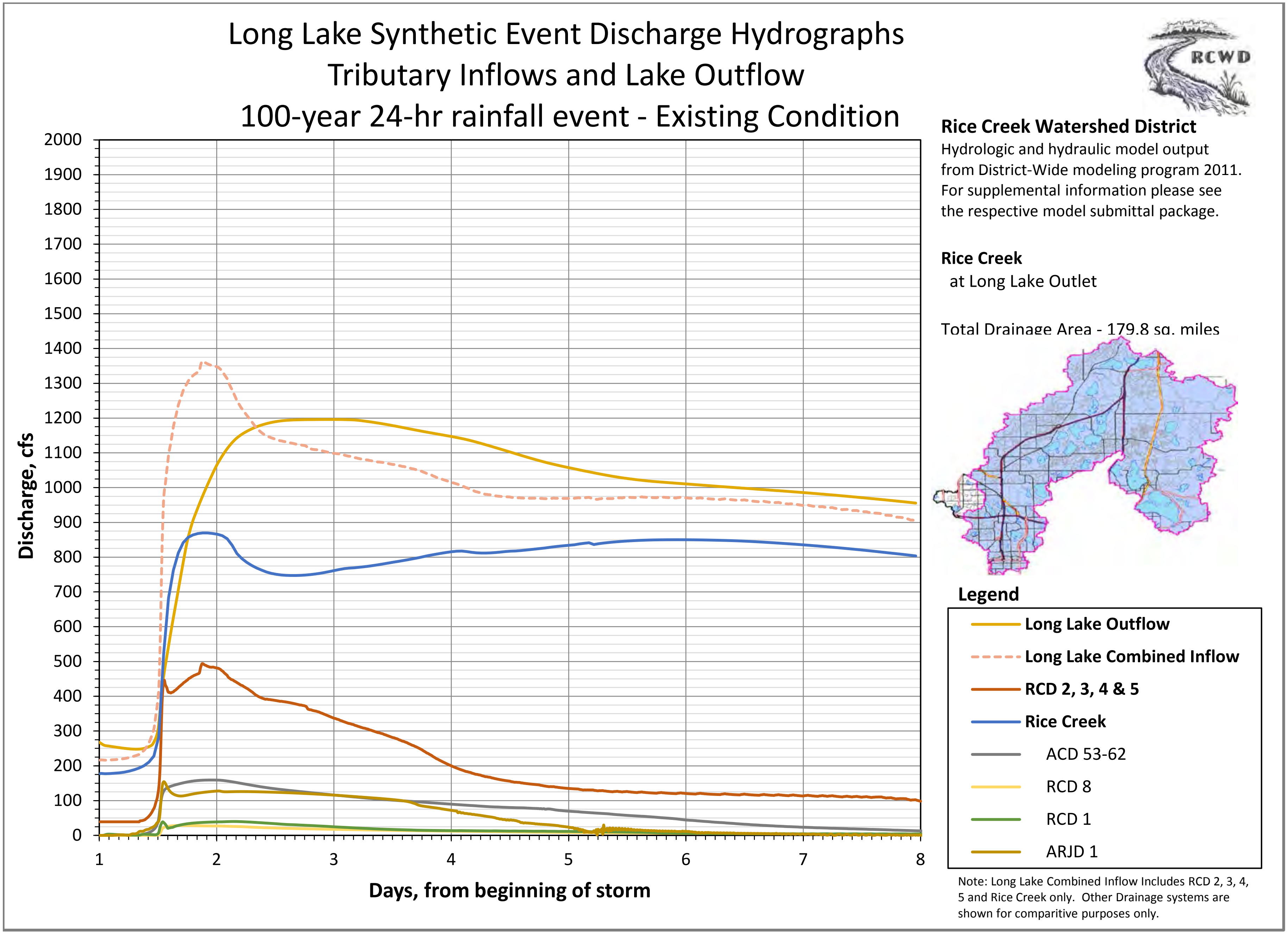
Total Drainage Area - 101.6 sq. miles



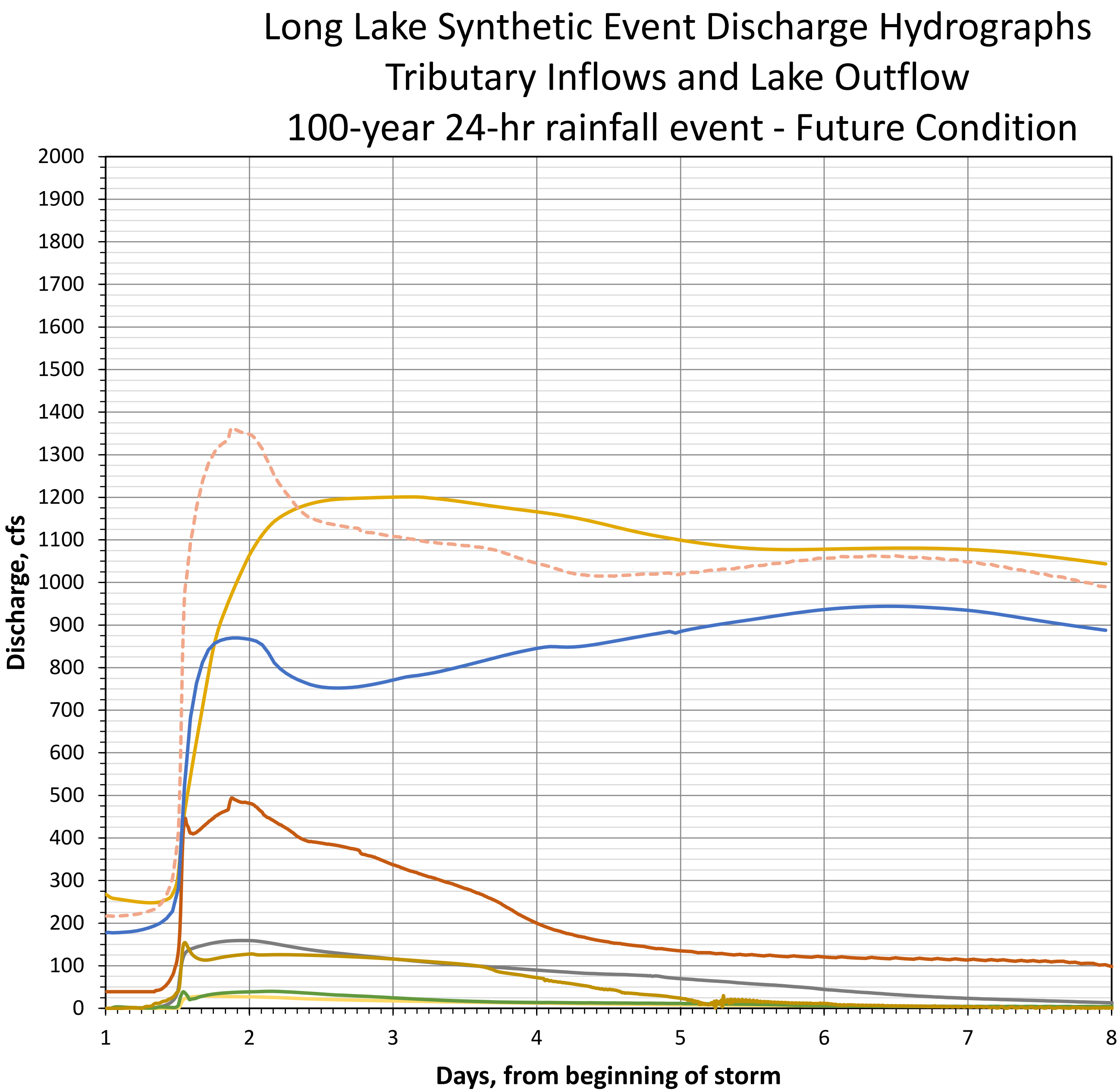
Legend

- Peltier Lake Combined Inflow
- Peltier Lake Outflow
- Hardwood Creek Inflow
- Clearwater Creek Inflow
- Upper Rice Creek Inflow

Figure 18



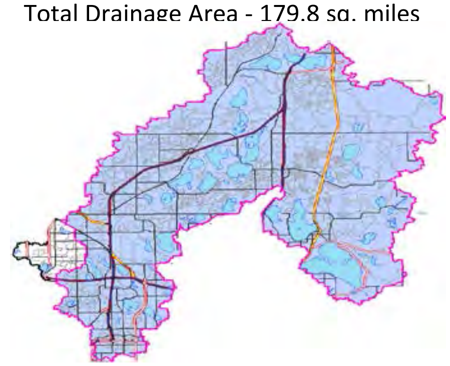
Long Lake Synthetic Event Discharge Hydrographs
Tributary Inflows and Lake Outflow
100-year 24-hr rainfall event - Existing Condition
RCWD
Rice Creek Watershed District
Hydrologic and hydraulic model output from District-Wide modeling program 2011. For supplemental information please see the respective model submittal package.
Rice Creek
at Long Lake Outlet
Total Drainage Area - 179.8 sq. miles
Discharge, cfs
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
Days, from beginning of storm
Legend
Long Lake Outflow
Long Lake Combined Inflow
RCD 2, 3, 4 & 5
Rice Creek
ACD 53-62
RCD 8
RCD 1
ARJD 1
Note: Long Lake Combined Inflow Includes RCD 2, 3, 4, 5 and Rice Creek only. Other Drainage systems are shown for comparitive purposes only.



Rice Creek Watershed District
Hydrologic and hydraulic model output from District-Wide modeling program 2011. For supplemental information please see the respective model submittal package.

Rice Creek
at Long Lake Outlet

Total Drainage Area - 179.8 sq. miles



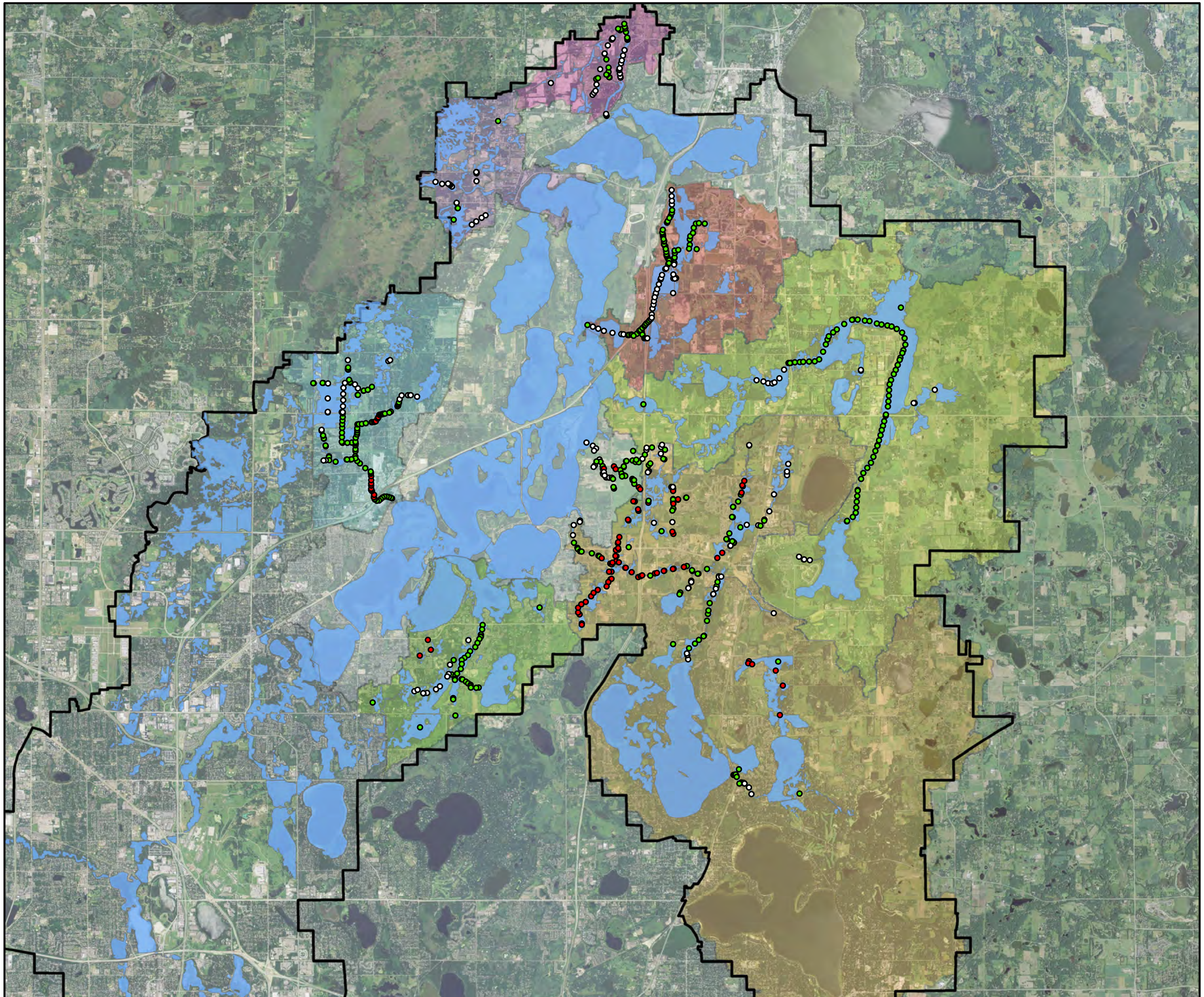
Legend

- **Long Lake Outflow**
- **Long Lake Combined Inflow**
- **RCD 2, 3, 4 & 5**
- **Rice Creek**
- ACD 53-62
- RCD 8
- RCD 1
- ARJD 1

Note: Long Lake Combined Inflow Includes RCD 2, 3, 4, 5 and Rice Creek only. Other Drainage systems are shown for comparitive purposes only.

Rice Creek Watershed District Future Condition Modeling

Estimated Regulatory Floodplain Increase



RCWD Boundary

Model Boundaries

- ACD 10 22 32
- ACD 15 JD 4
- ACD 25
- ACD 31
- ACD 46
- JD 2
- JD 3
- Rice Creek Direct Drainage

Current Regulatory Floodplain (2015)

Estimated Floodplain Increase (ft)

- < 0.1 ft
- 0.1 - 0.5 ft
- >0.5 ft

N E S W

0 0.5 1 2 3 4 Miles

Sources: RCWD

Figure 20: Estimated Regulatory Floodplain Increase

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
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APPENDIX A – CRITICAL STRUCTURE MAXIUMUM WATER ELEVATIONS

Clearwater Creek Planning Region Critical Structures

Clearwater Creek / JD 3 Public Drainage System

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation					
									2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
0+01	J3MT_002	Main Trunk	2 - 8'x10'x42' RCBC	Peltier Lake Drive	160.0	885.40	885.27	896.0	887.1	887.5	887.7	888.1	888.7	888.8
16+41	J3MT_009	Main Trunk	2 - 5.83'x8.37'x130' RCPA	Main St. / County Road 14	82.6	892.44	892.17	904.1	895.3	896.2	896.6	897.1	897.7	898.1
37+06	J3MT_015	Main Trunk	2 - 78"x67' RCP	Brian Drive	66.4	892.99	892.50	901.1	897.0	897.9	898.4	899.0	899.8	900.3
50+51	J3MT_019	Main Trunk	2 - 5.83'x8.37'x148' RCPA	20th Ave. S / County Road 54	82.6	894.47	894.46	903.1	897.8	898.7	899.2	899.9	900.8	901.4
63+17	J3MT_022	Main Trunk	6.5'x10.03'x80' RCPA	Farm Road	51.7	894.60	894.59	902.2	898.5	899.3	899.7	900.7	901.9	902.5
79+71	J3MT_025	Main Trunk	6.5'x10.03'x230' RCPA	Interstate 35E	51.7	895.00	894.72	908.9	899.7	900.5	901.3	902.0	903.5	904.2
81+04	J3MT_027	Main Trunk	6.6'x9.75'x100' RCPA	Frontage Road	51.7	895.29	985.00	907.3	900.5	901.2	902.1	902.7	904.3	904.9
94+35	J3MT_029	Main Trunk	96"x184' RCP	Otter Lake Road	50.3	895.96	895.96	909.3	901.3	902.0	903.0	903.6	905.3	906.2
109+51	J3MT_031	Main Trunk	Approx. 60' single span bridge	Victor Hugo Boulevard	~407	897.80	897.80	912.4	901.6	902.4	903.6	904.3	906.3	906.9
129+58	J3MT_033	Main Trunk	Approx. 60' single span bridge	Valjean Boulevard	~407	898.92	898.90	909.5	903.3	903.8	904.8	905.4	907.5	907.8
136+02	J3MT_035	Main Trunk	Approx. 60' single span bridge	Everton Ave. N	~407	899.97	899.95	908.5	903.3	903.9	904.9	905.4	907.5	907.9
211+72	J3MT_046	Main Trunk	Approx. 60' single span bridge	Fable Hill Parkway	~900	902.85	902.75	911.8	904.4	904.9	905.7	906.3	908.2	908.7
23+99	SJ3BR3_003	Branch 1	48"x62' RCP*	Elmcrest Ave N.	12.6	904.77	904.75	913.0	906.4	906.9	908.1	909.3	910.6	910.7
24+91	SJ3BR4_010	Branch 4	30"x51' RCP*	Elmcrest Ave N.	12.6	904.31	904.19	913.9	908.8	909.0	909.6	909.8	910.7	910.9
57+61	SJ3BR4_013	Branch 4	36"x336' RCP*	Clearwater Creek Drive	7.1	908.47	908.23	923.0	910.9	910.9	911.4	911.5	912.9	912.7
14+05	SJ3BR3_001	Branch 3	60"x233' RCP	CSAH 8 / Frenchman Road	19.6	901.65		913.0	905.2	905.5	906.0	906.4	908.4	909.0
20+44	SJ3BR3_003	Branch 3	6'x15'x225' RCBC	Oneka Parkway	90.0	901.90	900.00	914.3	906.4	906.9	908.1	909.3	910.6	910.7
80+21	SJ3BR3_051	Branch 3	42"x173' RCP	157th St. N	9.6	907.19	906.70	915.0	910.0	911.1	911.3	912.1	913.1	913.9
90+78	J3BR3_022	Branch 3	42"x125' RCP	159th St. N	9.6	907.75	907.20	915.0	910.2	911.3	911.4	912.3	913.1	914.0

Ramsey-Washington Judicial Ditch 1 Public Drainage System

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation					
									2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
3+44	J_MT_002	Main Trunk	2 - 3'x8'x40' RCBC	Hugo Road	48.0	910.35	910.30	915.5	911.8	911.8	912.4	912.5	913.1	913.1
4+32	J_MT_004	Main Trunk	7.83'x9'x42' RCPA	BNSF Railroad	56.0	910.27	910.91	925.0	912.5	912.6	913.2	913.3	914.0	914.0
5+52	STOR_MT_006	Main Trunk	42"x97' RCP	U.S. Highway 61	9.6	909.00	909.23	921.5	912.9	913.0	914.7	914.7	917.4	917.5
7+88	STOR_MT_008	Main Trunk	54"x72' CMP	Meehan Drive	15.9	909.00	909.33	921.3	913.0	913.0	914.8	914.8	917.4	917.4
15+32	J_MT_011	Main Trunk	2 - 48"x30' CMP	Cantwell Avenue	25.1	910.05	909.78	915.3	913.0	913.1	914.8	914.9	917.4	917.4
17+49	J_MT_014	Main Trunk	2.67'x6'x50' RCPA	Taylor Avenue	12.0	910.80	909.82	916.6	913.2	913.7	915.0	915.1	917.5	917.5
31+10	J_MT_019	Main Trunk	42"x100' RCP	CSAH 8	9.6	911.42	911.66	918.8	914.2	914.9	915.4	915.5	917.5	917.6
37+82	J_MT_023	Main Trunk	48"x38' RCP	Grand Ave.	12.6	910.58	911.54	918.5	914.9	915.6	915.8	916.2	917.6	917.6
42+29	J_MT_024	Main Trunk	30"x95' RCP	Portland Ave. / County Road 71	4.9	912.53	912.08	922.5	915.4	916.8	917.4	918.3	919.5	920.5
	J_P2_001	Private	36"x80' CMP	117th St. N / County Road 7	7.1	916.07	915.65	926.7	917.9	919.3	919.7	921.2	923.2	924.5
	J_P2_006	Private	36"x56' RCP	Goodview Ave.	7.1	918.05	917.89	926.5	919.8	920.5	921.0	923.5	925.7	926.5

ACD55 Public Drainage System

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation					
									2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
17+95	SA55MT_005	Main Trunk	42"x72' RCP	Main Street / County Road 14	9.6	897.52	897.23	905.1	898.7	900.2	899.9	902.1	902.4	904.4

Notes:

a. Cells highlighted in gray are elevations greater than the overtopping elevation

b. Culvert dimensions are as reflected in the models.

*Recent survey - modeled structure was an estimate.

Hardwood Creek Planning Region Critical Structures

Hardwood Creek / JD 2 Public Drainage System

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation					
									2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
	JMT_004	Hardwood	5'x10'x33' RCBC	20th Ave. N / County Road 54	50.0	883.25	883.10	893.3	886.1	886.5	887.0	887.4	890.2	891.5
	JMT_018	Hardwood	2 - 4.5'x7.33' x153'RCPA	Interstate 35E	51.2	888.79	888.00	897.2	892.0	893.6	893.8	894.3	897.1	897.6
	JMT_023	Hardwood	2 - 6'x8'x104' RCBC	80th St. E	96.0	892.60	892.28	904.6	895.1	895.8	896.3	896.7	899.4	900.1
	JMT_027	Hardwood	7'x12'x74' RCBC	Elmcrest Ave / 24th Ave. N	84.0	894.46	894.13	908.7	899.1	899.5	899.5	900.1	902.1	902.8
	JMT_035	Hardwood	96"x60' RCP	165th St. N - west crossing	50.3	898.99	899.14	910.4	902.6	904.7	905.0	905.5	909.3	910.6
0+30	JMT_041	Main Trunk	96"x60' RCP	165th St. N - east crossing	50.3	901.86	901.42	914.1	905.5	907.9	908.3	908.5	912.4	914.4
50+65	JMT_052	Main Trunk	2 - 84"x58' RCP	170th St. N	77.0	904.72	903.91	912.8	908.1	909.0	910.6	911.3	913.8	914.7
140+21	JMT_076	Main Trunk	Approx. 20' single span bridge	Forest Road	~160	908.33	908.77	918.4	913.0	913.3	913.9	915.2	917.7	918.2
140+80	JMT_078	Main Trunk	Approx. 45' single span bridge	Railroad / Bikepath	~459	906.70	908.40	923.0	913.1	913.3	913.9	915.2	917.8	918.4
142+00	JMT_080	Main Trunk	2 - 8'x10'x55' RCBC	U.S. Highway 61	160.0	908.25	908.07	923.0	913.0	913.3	914.0	915.3	918.1	919.0
215+46	JMT_096	Main Trunk	9'x10'x72' RCBC	Harrow Ave.	90.0	909.09	909.08	919.3	916.7	917.0	917.8	918.2	919.5	919.9
337+96	JMT_123	Main Trunk	10'x10'x96' RCBC	170th St. N / County Road 4	100.0	911.80	911.86	926.7	918.7	919.6	920.3	920.7	921.7	922.2
365+11	JMT_132	Main Trunk	7'x14'x61 RCBC	165th St. N	98.0	912.97	912.75	921.0	919.1	920.2	920.8	921.4	922.1	922.5
409+11	JMT_142	Main Trunk	6'x14'x47' RCBC	157th St. N	84.0	914.72	914.72	924.1	921.3	921.6	922.5	922.8	923.9	924.0

Notes:

a. Cells highlighted in gray are elevations greater than the overtopping elevation

b. Culvert dimensions are as reflected in the models.

Upper Rice Creek Planning Region Critical Structures

ACD 31 Public Drainage System

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation					
									2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
38+81	AC31MT_005	Main Trunk	36"x88' CMP	Kettle River Blvd. (C.R. 62)	7.1	886.80	886.73	899.7	889.5	890.2	891.3	892.9	896.8	897.6
56+46	AC31MT_012	Main Trunk	36"x52' HDPE	167th Ave.	7.1	891.55	891.41	896.1	892.6	893.2	893.9	895.0	896.9	897.7
75+31	AC31MT_021	Main Trunk	18"x24' RCP	170th Ave.	1.8	893.22	892.99	897.5	895.4	897.1	898.1	898.4	898.7	898.7
110+77	AC31MT_035	Main Trunk	48"x65' CMP	W. Broadway Ave. (CSAH 18)	12.6	895.83	895.38	903.9	898.3	899.0	899.7	900.2	901.3	901.6
60+40	AC31B1_017	Branch 1	27"x43"x49' CMPA	W. Broadway Ave. (CSAH 18)	7.1	899.75	899.51	904.2	901.1	901.4	901.6	901.8	902.2	902.2
52+96	AC31B2_015	Branch 2	24"x50' CMP	Notre Dame St.	3.1	901.01	901.35	906.9	901.5	902.0	903.2	903.4	904.4	904.4
0+53	AC31B6_001	Branch 6	36"x53' CMP	Furman St.	7.1	900.45	899.75	907.1	901.7	902.1	903.3	903.4	904.6	904.6
9+16	AC31P1_006	Private	36"x110' CMP	Kettle River Blvd. (C.R. 62)	7.1	892.44	892.03	906.6	893.6	893.8	894.1	894.4	895.7	895.7
33+69	AC31P1_019	Private	36"x51' CMP	Notre Dame St.	7.1	895.89	896.09	903.1	897.9	898.1	898.3	898.3	901.2	901.2

ACD 46 Public Drainage System

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation					
									2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
81+15	AC46MT_008	Main Trunk	48"x153' RCP	Lake Dr. (CSAH 23)	12.6	889.53	888.47	908.0	891.3	891.7	893.0	893.3	895.1	895.5
102+67	AC46MT_013	Main Trunk	48"x82' CMP	Potomac St. (CR 19)	12.6	894.90	894.00	905.5	896.9	897.2	898.4	898.4	900.1	900.0
188+42	AC46MT_046	Main Trunk	24"x42' CMP	161st Ave.	3.1	903.03	902.74	906.2	903.4	903.6	903.7	904.0	904.5	904.7
37+18	AC46B1_011	Branch 1	15"x29' CMP	Camp 3 Road	1.2	902.14	901.81	906.1	902.6	902.7	903.0	903.1	903.3	903.3
12+41	AC46B2_006	Branch 2	24"x41' CMP	153rd Ave. NE	3.1	898.62	898.24	903.7	899.8	900.1	900.8	901.1	901.6	901.7
24+35	AC46B3_009	Branch 3	18"x42' CMP	Camp 3 Road	1.8	902.99	902.38	906.2	903.5	903.7	904.0	904.0	905.2	905.3
47+76	AC46B3_024	Branch 3	36"x50' RCP	Potomac St. (CR 19)	7.1	904.19	904.27	908.5	904.8	904.7	905.3	905.3	906.0	906.1
1+91	AC46B4_002	Branch 4	24"x43' RCP	Potomac St. (CR 19)	3.1	903.84	903.44	907.3	904.1	904.3	904.7	904.8	905.7	905.8
8+48	AC46B5_005	Branch 5	36"x62' CMP	153rd Ave.	7.1	896.97	897.02	905.6	899.2	899.2	900.3	900.1	901.5	901.3
13+54	AC46P1_005	Private	36"x42' CMP	Camp 3 Road	7.1	900.05	899.56	905.2	900.6	900.8	901.1	901.3	902.4	902.5

ACD 15/JD 4 Public Drainage System

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation					
									2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
11+75	B3_05DP	Branch 3	24"x35"x42' RC Arch	Elmcrest Ave.	4.9	892.67	891.55	895.5	892.8	892.8	892.9	892.9	893.1	893.2
10+28	B4_04J	Branch 4	30"x116' RCP	I-35E SB	4.9	887.13	886.74	898.2	890.3	890.4	890.8	891.0	892.0	892.2
12+53	B4_06DP	Branch 4	30"x115" RCP	I-35E NB	4.9	887.40	886.91	897.3	890.9	891.0	891.4	891.7	893.1	893.3
	B4i_15J	Branch 4	24"x34' CMP	Elmcrest Ave.	3.1	896.91	896.98		899.0	898.8	900.3	900.1	904.8	904.6
46+89	MT16J	JD 4 Main Trunk	72"x150' RCP	Freeway Dr. (C.R. 54)	28.3	885.26	884.97	899.2	888.8	889.2	889.5	889.9	890.5	890.8
49+16	MT19DP	JD 4 Main Trunk	72"x126' RCP	I-35W	28.3	885.26	885.21	894.2	889.0	889.4	889.8	890.1	890.8	891.1
64+88	MT26J	JD 4 Main Trunk	54"x88"x119' RC Arch	I-35E SB	28.3	885.88	885.65	896.2	889.7	890.1	890.4	890.7	891.4	891.6
70+44	MT30DP	JD 4 Main Trunk	54"x88"x150' RC Arch	I-35E NB	28.3	886.24	886.01	897.9	889.8	890.2	890.6	890.9	891.8	892.1
93+93	MT40J	JD 4 Main Trunk	6' Bridge	141st St.	36.0	886.62	886.93	894.5	890.6	890.9	891.2	891.6	892.6	892.8
122+69	MT50DP	JD 4 Main Trunk	48"x40' RCP	145th St.	12.6	889.43	889.11	895.7	891.4	892.0	892.5	892.8	893.6	893.7

Notes:

a. Cells highlighted in gray are elevations greater than the overtopping elevation

b. Culvert dimensions are as reflected in the models.

Upper Rice Creek Planning Region Critical Structures

Rice Creek

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation 2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
1595+56	Rice Creek	blw Clear Lake	42"x36.5' CMP	Eureka Avenue, Clear Lake Outlet	9.6	888.14	887.67	892.8	889.7	889.7	890.5	890.5	891.6	891.6
1594+55	Rice Creek	blw Clear Lake	48"x185' RCP	Interstate 35W	12.6	887.21	886.88	899.8	889.5	889.5	889.5	889.5	890.7	890.7
1546+57	Rice Creek	blw Mud Lake	36"x58"x50' CMPA w/ Riser	Field Road, Mud Lake Outlet	11.4	887.74	885.10	893.7	888.1	888.2	888.7	888.8	889.9	890.0
1490+33	Rice Creek	Upper abv Rondea	10'x6'x104.5' RCP Box	Lake Drive, Howard Lake Outlet	60.0	886.25	885.75	896.0	888.0	888.1	888.6	888.6	889.3	889.4
1257+69	Rice Creek	Upper blw Rondea	3x10'x6'x138' RCP Box	Interstate 35W	180.0	880.32	880.10	894.3	886.1	886.3	886.7	886.8	887.6	887.7
		Crossways Lake Outlet	24"x48' CMP	North Rondeau Lake Drive	3.1	886.44	885.84	893.4	887.3	887.3	887.2	887.2	887.8	887.8
		Rondeau Lake Outlet	36"x58"x39' RCPA	East Rondeau Lake Drive	11.4	884.54	884.35	889.1	886.2	886.3	886.8	886.8	887.5	887.6

Notes:

a. Cells highlighted in gray are elevations greater than the overtopping elevation

b. Culvert dimensions are as reflected in the models.

Middle Rice Creek Planning Region Critical Structures

ACD 25 Public Drainage System

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation 2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
13+50	ACD25_BR1_04	Branch1	24"x60' CSP	Holly Drive N.	3.14	889.91	890.04	898.9	891.9	892.1	892.6	892.8	893.1	893.7
3+26	ACD25_MT_02	Main Trunk	36"x91' RCP	Blackduck Drive	7.07	879.95	879.65	886.6	882.5	882.6	883.2	883.6	885.3	885.8
51+28	ACD25_MT_10	Main Trunk	54"x88"x87' RCPA	Birch St. (C.R. 34)	28.27	883.38	883.36	891.4	884.8	885.0	885.3	885.6	886.6	887.1
	L_SHE_001	Sherman Outlet	18"x22' CSP 30"x22' RCP	Sherman Lake Outlet	1.77 4.91	884.47 883.45	884.41 883.04	887.6	884.0	884.2	884.4	884.6	885.4	885.8

ACD 10-22-32 Public Drainage System

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation 2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
3+22	ACD32_MT_33	Branch 1	36"x301' RCP	Palomino Lane	7.07	893.59	891.38	899.0	894.4	894.4	894.4	894.4	895.4	895.8
7+51	ACD32_MT_35	Branch 1	27"x43"x308' RCPA	Apaloosa Lane	7.07	893.47	892.83	898.6	894.1	894.2	894.5	894.6	895.5	895.9
26+38	ACD32_BR11A_03	Branch 1	36"x105' RCP	Palomino Lane/Storm Sewer	7.07	893.66	893.22	903.0	895.5	895.6	895.8	895.9	896.6	897.2
37+16	ACD32_BR11A_06	Branch 1	36"x65"x74' RCPA	Century Trail	15.90	895.15	894.75	900.6	895.6	895.9	896.1	896.4	897.2	897.4
51+27	ACD32_BR11A_12	Branch 1	12"x59' PVC	Robinson Dr.	0.79	894.91	894.01	899.3	895.6	896.0	896.5	897.1	897.4	897.5
2+92	ACD32_MT_38	Branch 1a	24"x73' RCP	Mustang Lane	3.14	895.14	894.60	901.2	895.3	895.5	895.7	895.9	897.1	897.2
29+63	ACD32_BRPen_12	Branch 2	27"x43"x73' RCPA	4th Avenue	7.07	896.19	896.07	902.4	896.9	897.2	897.8	898.3	899.4	899.8
50+34	ACD32_BRPen_32	Branch 2	42"x144' RCP	Main Street (CR 14)	9.62	899.46	898.33	904.8	899.9	900.2	900.7	901.0	902.3	902.6
58+58	ACD32_BRPen_34	Branch 2	(2) 30"x62' CMP	Woodduck Trail	4.91	900.32	899.88	905.2	900.8	901.2	901.3	901.8	902.5	902.8
76+28	ACD32_BRPen_44	Branch 2	18"x27' CMP 12"x27' CMP	Pin Oak Lake Outlet	1.77 0.79	902.66	902.39	905.4	902.9	903.3	903.4	903.7	904.1	904.5
32+86	ACD32_BR14_13	Branch 4	18"x45' CMP	4th Street	1.77	899.95	899.40	905.0	901.0	901.4	901.9	902.0	903.0	903.2
49+22	ACD32_BR14_19	Branch 4	24"x81' RCP	Andall Street	3.14	900.92	900.27	905.6	901.7	902.0	902.4	902.6	903.4	903.6
72+76	ACD32_BR14_27	Branch 4	24"x34' RCP	Pine Street	3.14	902.80	901.99	906.5	903.0	903.2	903.5	903.7	904.4	904.4
14+24	ACD32_MT_06	Main Trunk	6'x4'x91' RC Box	Lake Drive (CR 23)	24.00	884.43	883.96	901.0	886.3	887.1	887.6	888.6	889.8	890.3
30+21	ACD32_MT_14	Main Trunk	72"x199' RCP	Interstate 35W	28.27	886.81	886.19	902.0	889.3	890.1	890.5	891.3	892.3	892.8
32+32	ACD32_MT_16	Main Trunk	72"x167' RCP	Apollo Drive (CR 12)	33.18	886.64	886.97	901.5	889.5	890.4	890.9	891.9	893.3	894.0
55+94	ACD32_MT_28	Main Trunk	72"x123' CMP	Lilac Street (CR 153)	28.27	888.41	888.73	901.0	891.1	892.3	893.0	893.8	895.2	895.7
82+26	ACD32_BR12_03	Main Trunk	60"x165' RCP	Airport Runway	19.63	888.92	889.54	899.1	891.8	893.0	893.6	894.3	895.2	895.7
87+93	ACD32_BR12_06	Main Trunk	72"x72' RCP	Carl Street	28.27	889.76	889.73	897.2	892.0	893.2	893.8	894.5	895.3	895.8
126+82	ACD32_BR12_19	Main Trunk	52"x96"x95' RCPA	Main Street (CR 14)	28.27	890.50	890.55	900.6	892.6	893.7	894.3	894.9	895.5	896.0
186+12	ACD32_BR12_33	Main Trunk	24"x41' RCP	Pine Street	3.14	899.22	898.71	902.7	899.9	899.9	900.5	900.6	901.9	902.0
216+06	ACD32_BR12_39	Main Trunk	12"x23' HDPE	137th Avenue	0.79	900.03	899.86	904.0	900.8	901.1	901.4	901.8	902.5	902.8
230+57	ACD32_BR15_02	Main Trunk	24"x63' RCP	Jodrell Street	3.14	900.63	901.18	907.3	900.8	901.2	901.5	901.9	902.7	903.1

Notes:

a. Cells highlighted in gray are elevations greater than the overtopping elevation

b. Culvert dimensions are as reflected in the models.

Middle Rice Creek Planning Region Critical Structures

Rice Creek

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation 2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
1107+98	Rice Creek	blw Peltier Lake	138' Weir	Peltier Lake Dam		884.78		884.8	885.7	885.9	886.2	886.4	887.1	887.3
1099+02	Rice Creek	blw Peltier Lake	91' Single Span Bridge,17'(h),55'(w)	Main Street	1416.86	874.04	872.31	889.8	881.3	881.6	883.2	883.5	885.4	885.8
907+96	Rice Creek	blw Marshan	63' Three Span Bridge,11.5'(h),45'(w)	Aqua Lane, Marshan Lake Outlet	485.38	875.64	875.55	883.9	881.2	881.5	883.0	883.3	885.3	885.7
816+08	Rice Creek	blw Rice Lake	66' Single Span Bridge, 9'(h),90'(w)	Hodgson Road, Rice Lake Outlet	603.77	874.57	876.69	888.0	881.2	881.5	883.0	883.3	885.3	885.6

Notes:

a. Cells highlighted in gray are elevations greater than the overtopping elevation

b. Culvert dimensions are as reflected in the models.

Lower Rice Creek Planning Region Critical Structures

Rice Creek

Station	Upstream Node Name	Reach	Size and Type	Description	Opening Area (sq ft)	Upstream Invert Elevation (feet)	Downstream Invert Elevation (feet)	Overtopping Elevation (feet)	Upstream Elevation 2-Year Existing (feet)	2-Year Future (feet)	10-Year Existing (feet)	10-Year Future (feet)	100-Year Existing (feet)	100-Year Future (feet)
636+54	Rice Creek	blw Baldwin Lake	17' Single Span Bridge,10'(h),75'(w)	85th Avenue	164.59	874.56	874.41	883.9	879.5	879.9	881.5	882.0	884.4	884.8
620+40	Rice Creek	blw Baldwin Lake	20' Single Span Bridge,8'(h), 23'(w)	Bike Trail Wooden Bridge	149.16	875.17	874.89	883.5	879.0	879.3	880.9	881.3	883.0	883.5
619+56	Rice Creek	blw Baldwin Lake	36' Single Span Bridge,13'(h),68'(w)	Lexignton Avenue	385.42	874.80	875.09	885.9	878.8	879.1	880.7	881.0	882.4	882.6
508+70	Rice Creek	blw Baldwin Lake	60' Double SpanBridge,6'(h),13'(w)	Pipe Crossing 1	348.05	869.56	869.56	885.3	876.2	876.2	877.9	878.0	880.5	881.0
508+35	Rice Creek	blw Baldwin Lake	40' Double Span Bridge,7'(h),16'(w)	Pipe Crossing 2	237.22	870.01	870.01	884.8	876.2	876.2	877.9	878.0	880.4	880.9
507+60	Rice Creek	blw Baldwin Lake	45' Single Span Bridge,9 (h),74'(w)	County Road I	323.74	872.11	871.89	884.7	876.1	876.1	877.8	877.8	880.1	880.5
488+60	Rice Creek	blw Baldwin Lake	(2) 8'x10'x133.6' RCP Box	Ammunition Plant Entrance	160.00	871.09	870.77	884.4	873.4	873.4	875.4	875.4	878.3	878.9
442+73	Rice Creek	blw Baldwin Lake	(2) 8'x10'x179' RCP Box	Interstate 35W	160.00	870.37	870.01	881.8	872.8	872.8	874.7	874.7	877.4	878.0
432+31	Rice Creek	blw Baldwin Lake	(2) 8'x10'x208' RCP Box	County Road 10	160.00	868.94	868.64	880.2	871.5	871.5	873.4	873.4	875.8	876.3
425+56	Rice Creek	blw Baldwin Lake	(3) 12'x8'x128' RCP Box	County Road 77	288.00	867.96	866.96	878.9	870.6	870.6	872.5	872.5	874.1	874.5
375+72	Rice Creek	blw Baldwin Lake	(2) 11'x7'x57' CMPA	Park Trial Crossing	123.40	860.69	860.73	877.3	868.3	868.3	870.1	870.1	872.4	872.9
332+80	Rice Creek	blw Long Lake	45' Single Span Bridge,5'(h),50'(w)	Long Lake Road, Long Lake Outlet	204.61	863.32	863.75	873.3	866.6	866.6	867.9	867.9	870.0	870.1
311+03	Rice Creek	blw Long Lake	(3) 7.3'x11.4'x93' RCPA	Mississippi Street	175.86	860.53	859.81	869.3	863.6	863.6	865.3	865.3	867.4	867.4
293+76	Rice Creek	blw Long Lake	(3) 10'x6'x73.5' RCP Box	Silver Lake Road	180.00	857.57	857.40	866.6	860.5	860.5	862.0	862.0	863.8	863.8
219+70	Rice Creek	blw Long Lake	(2) 12'x10'x54' RCP Box	Central Avenue	240.00	843.63	844.15	863.3	848.2	848.2	849.7	849.7	851.5	851.5
191+55	Rice Creek	blw Long Lake	(2) 12'x10'x168' RCP Box	Highway 65	240.00	840.18	840.16	861.4	843.6	843.6	845.5	845.5	847.9	847.9
57+79	Rice Creek	blw Long Lake	(2) 10'x10' RCP Box	University Avenue	200.00	820.38	819.65	843.9	824.1	824.1	826.2	826.2	829.9	829.9
14+66	Rice Creek	blw Locke Lake	(2) 9'x9'x42' RCP Box, lift gates	Locke Lake Dam	162.00	808.00	807.50	824.3	811.0	811.0	814.2	814.2	821.4	821.4
11+94	Rice Creek	blw Locke Lake	48' Single Span Bride,14'(h),102'(w)	East River Road	669.52	804.83	806.58	826.9	810.5	810.5	814.3	814.3	820.3	820.3

Notes:

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b. Culvert dimensions are as reflected in the models.