

## Engineer's Report

# 100-Year Floodplain Vulnerability Evaluation (Climate Adaptation)

Prepared for  
Riley Purgatory Bluff Creek Watershed District



September 2016



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Cover photographs are of Riverview Road and a Bluff Creek trail crossing located west of Lake Drive West taken 6/20/2014 by RPBCWD staff.

## Certifications

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.



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Scott Sobiech PE #: 41338

September 7, 2016

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Date



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Brandon Barnes PE #: 49540

September 7, 2016

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Date

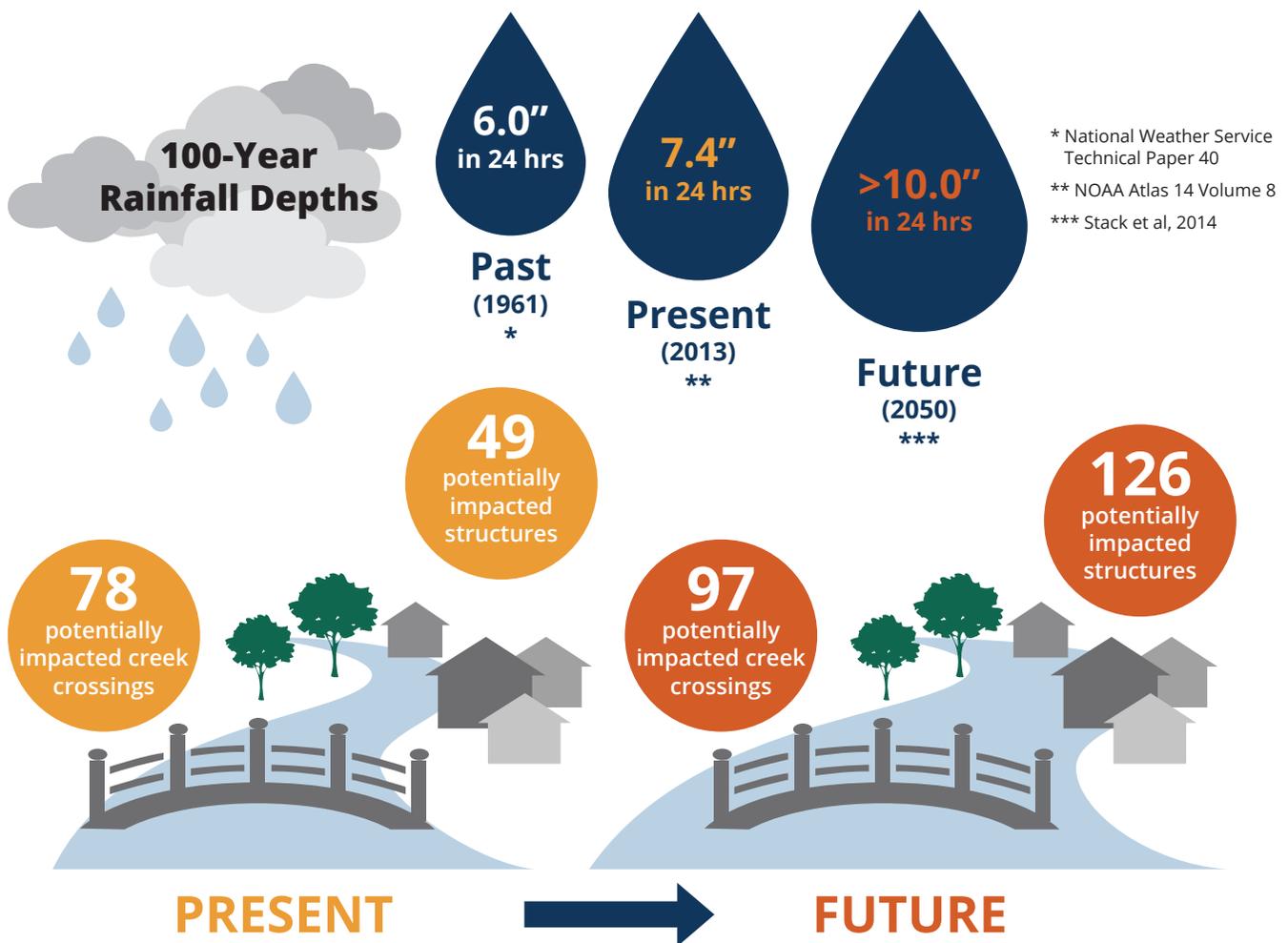
# FLOODPLAIN VULNERABILITY EVALUATION

## Using RPBCWD Hydrologic & Hydraulic (H&H) Model

RPBCWD uses H&H models to estimate the amount of runoff generated during a rainfall event and calculate water surface elevations along the creeks and lakes within the watershed. Simulations for the the 100-year 24-hour rainfall event are used to calculate the elevation of the 100-year floodplain and evaluate flood-risk.

### Estimating Vulnerability due to Changing Rainfall

The 100-year rainfall depths are estimated to increase. Future estimated rainfall depths were simulated with the H&H models to evaluate areas of resiliency within the watershed (i.e., flood-risk to structures and creek crossings is not sensitive to change in rainfall depths).



### Estimating Flood-Risk

Flood-risk figures were developed in partnership with local municipalities to inform communities of current flood-risk and estimated future flood-risk within the watershed. These figures provide the RPBCWD and municipalities a water management tool that considers how future changes to rainfall depth can impact infrastructure, but also can be used to determine where flood mitigation might be needed.

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## 1.0 Introduction

The Riley-Purgatory-Bluff Creek Watershed District (RPBCWD or District) works to protect public health and welfare and to provide for the prudent use of natural resources through planning, flood control, and conservation projects. One tool the District uses for flood control to quantify flood-risk along each creek and on water bodies is a hydrologic and hydraulic (H&H) model. In 2015, RPBCWD completed updates to the H&H models of Purgatory Creek, Riley Creek, and Bluff Creek (reference [1]).

The H&H models simulate NOAA's revised precipitation frequency estimates published in Atlas 14 (reference [2]). These estimates serve as an update to the U.S. Weather Bureau's Technical Paper 40 (TP 40, reference [3]) published in 1961 and, reflect the results of statistical analyses performed for a much longer period of recorded precipitation data. The Atlas 14 information show significant increases in rainfall amounts in the Twin Cities area where the 100-year, 24-hour rainfall depth increased by approximately 25% when compared to TP 40. As a result of these updates, flood-risk was identified in previously unaffected areas.

While the District was completing updates to the H&H models, recent work completed by Latham Stack and Michael Simpson (reference [4]) provides information required to consider long-term extreme weather trends in the Twin Cities area. One of the main outcomes was readily available precipitation data for use in climate adaptation assessments. The study of long-term extreme weather trends found that precipitation amounts are predicted to increase significantly over what is historically used in floodplain assessments and infrastructure design. Three mid-21<sup>st</sup> century estimates for the 100-year 24-hour rainfall event were identified an optimistic (i.e., lower estimate), moderate, and pessimistic (i.e., upper estimate).

The optimistic estimate for the mid-21<sup>st</sup> century 100-year 24-hour rainfall estimate was approximately 7.3 inches, which is similar to the current mean 100-year rainfall depth published in Atlas 14 (7.4 inches). The information also suggests moderate estimate is 10.2 inches, which is similar to the upper limits of the Atlas 14 90-percent confidence limits. This moderate estimate for the 100-year 24-hour event also corresponds to the pessimistic estimate for the mid-21<sup>st</sup> century 10-year, 24-hour event, and the typical return period used to design infrastructure.

Typically evaluation of adaptation for future change within the watershed includes an estimate of both future rainfall estimates as well as future land use within a watershed. However, the District's regulatory program includes rules that require no increase in discharge rate post-development using the mean Atlas 14 100-year precipitation depth (7.4 inches). Therefore, this analysis only included assessing the potential flood-risk resulting from increased precipitation amounts.

The following sections include a brief description of the updates to the model and discussion of simulated rainfall events (Section 2), resiliency evaluation (Section 3), and conclusions (Section 4).

## 2.0 Model Modifications & Rainfall Events

The H&H models of Riley, Bluff and Purgatory Creeks were developed to simulate the mean 100-year rainfall depth published in Atlas 14 (7.4-inches). During larger rainfall events, stormwater will overtop roadways and discharge through areas previously unaccounted for in the models. Therefore the models were enhanced to accurately simulate the floodplain. Modifications to the model included addition overland flow paths and road overflows. These added overland flow paths were defined based on the Minnesota Department of Natural Resources' (MNDNR) 2011 LiDAR elevations (reference [5]).

The updated models were used to simulate several rainfall events. The uncertainty in the 100-year water surface elevations was evaluated considering the 90-percent confidence limits published in Atlas 14 (see Figure 1). For the RPBCWD, the mean 100-year rainfall depth published in Atlas 14 is 7.4-inches, and the 90-percent confidence limits are 5.5 and 10.0-inches. In other words, there is a 90-percent probability that the actual 100-year rainfall depth is greater than 5.5-inches and less than 10.0-inches.

The Atlas 14 2-, 10-, 25-, 50-, 100- and 500-year, 24-hour events were also simulated to evaluate system resiliency along the creeks. Only 24-hour duration rainfall events were analyzed, no snowmelt or other design storm events were evaluated.

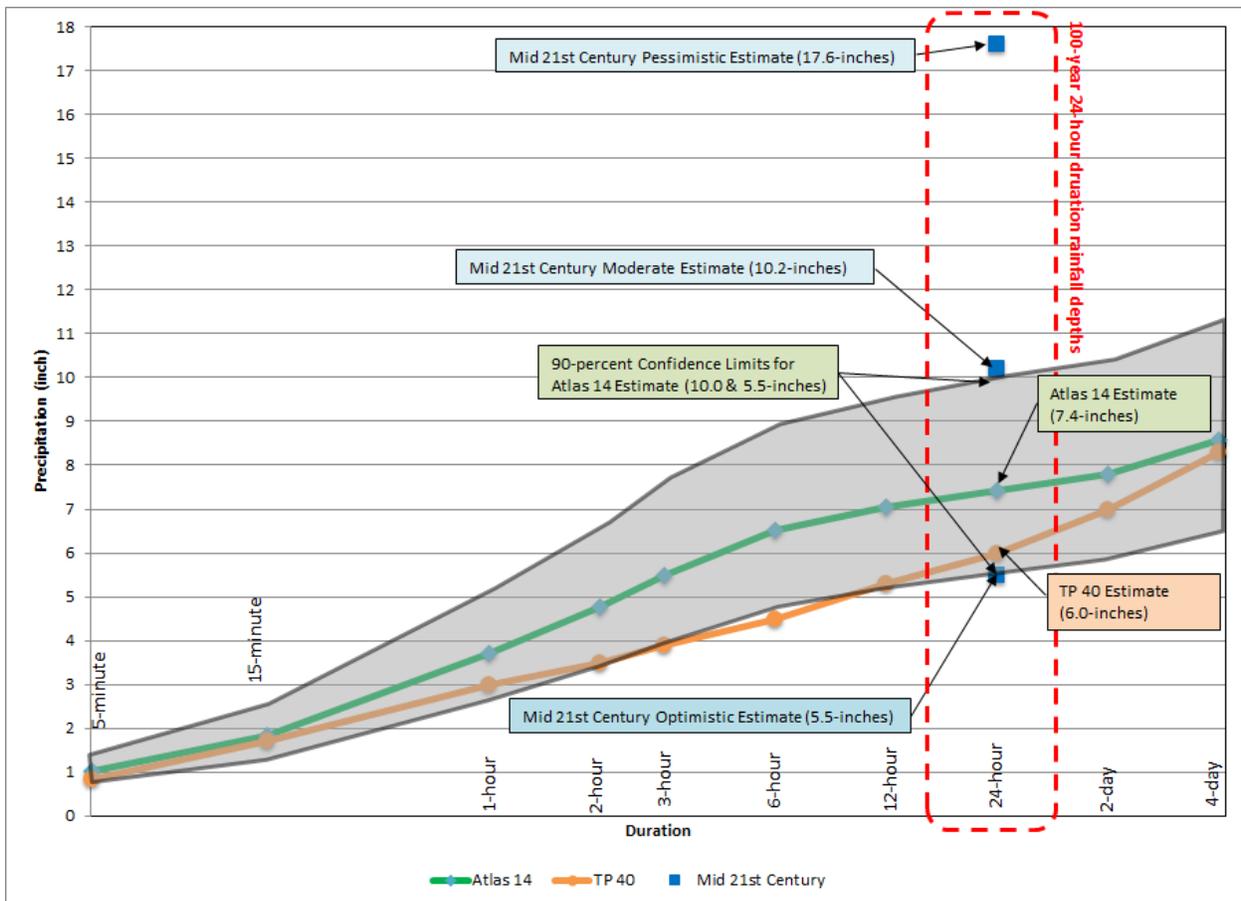


Figure 2-1 100-year, 24-hour Duration Rainfall Depth Comparison

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The rainfall depth associated with the upper, or 95-percent, confidence limit (10.0-inches) is similar to the moderate mid-21<sup>st</sup> century estimates for the 100-year 24-hour event (10.2-inches). Therefore, model results for the upper confidence limit were used to evaluate vulnerability of existing infrastructure along the creeks to potential future increases in rainfall depths. The pessimistic outlook for the 100-year 24-hour rainfall by the mid-21<sup>st</sup> century is 17.6 inches, but was not simulated for this analysis.

## 3.0 Resiliency Evaluation

Model results were used to develop flood-risk figures to illustrate the current and potential future flood-risk along the creeks. The evaluation identified current and potential estimated future impacts to creek crossings and structures. Assessment results identified resilient areas (i.e., flood-risk to structures and crossings was not sensitive to change in rainfall depths), and areas where flood elevations are sensitive to rainfall depths. During the development of flood-risk figures input was provided by RPBCWD Technical Advisory Committee (TAC) members and was considered when preparing final figures. Four sets of flood-risk figures were developed, and are described in the following sections.

### 3.1 Water-Surface Profiles

The water surface profiles along the three creeks were updated to show the 90-percent confidence limits for in the 100-year 24-hour water surface profile based on the uncertainty associated with the Atlas 14 mean 100-year 24-hour rainfall depth. The lower confidence limit, or 5-percent limit is 5.5-inches (i.e., there is a 5-percent probability that the current 100-year 24-hour rainfall depth is less than 5.5-inches). The upper confidence limit, or 95-percent limit is 10.0-inches (i.e., there is a 95-percent probability that the 100-year 24-hour rainfall depth is less than 10.0-inches). The upper confidence limit is similar to the potential mid-21<sup>st</sup> century moderate estimate for the 100-year 24-hour rainfall (10.2-inches). The uncertainty range is shown as a shaded band around the 100-year, 24-hour water surface profile. The updated water surface profiles are located in Appendix A.

### 3.2 Variability in the 100-year 24-hour Inundation Area

The inundation areas for the mean Atlas 14 100-year 24-hour rainfall event and 90-percent confidence limits were delineated to illustrate the uncertainty in the 100-year 24-hour floodplain. The upper confidence limit (10.0-inches) is similar to the moderate estimate for the mid-21<sup>st</sup> century. The 100-year, 24-hour figures are located in Appendix B.

A vulnerability assessment was completed to identify potential structures and creek crossings that could be impacted by the potential increase in rainfall depth. Simulation results can be used to identify areas that are currently flood-prone and help in planning for future climate conditions since the moderate mid-21<sup>st</sup> century estimate for the 100-year, 24-hour event (10.2 inches) and the current upper confidence limit for the 100-year, 24-hour event (10.0 inches) are similar in magnitude.

Structures potentially impacted were initially identified by intersecting the 2011 LiDAR derived building footprints (reference [5]) with the inundation extents. Structures identified along the creeks and lakes were reviewed using 2015 aerial imagery (reference [6]). The number of structures impacted by the lower confidence limit (5.5-inches), upper confidence limit (10.0-inches), and the mean Atlas 14 100-year 24-hour event (7.4-inches) are summarized in Table 3-1.

**Table 3-1 Summary of Structures Potentially Impacted by the Atlas 14 100-year, 24-hour event**

	<b>Lower Confidence Limit (5.5-inch 24-hour event)</b>	<b>Mean Atlas 14 100-year event (7.4-inch 24-hour event)</b>	<b>Upper Confidence Limit (10.0-inch 24-hour event)</b>
Purgatory Creek	12	43	108
Riley Creek	0	0	1
Bluff Creek	1	6	17

NOTE: Structures were identified based on available topographic data. A field survey was not complete to verify impacts to identified structures.

All creek crossings within the study boundary were reviewed to determine whether or not the crossing would be inundated. The number of crossings potentially impacted by the 100-year, 24-hour events are summarized in Table 3-2.

**Table 3-2 Summary of Creek Crossings Potentially Impacted by Atlas 14 100-year, 24-hour event**

	<b>Lower Confidence Limit (5.5-inch 24-hour event)</b>	<b>Mean Atlas 14 100-year event (7.4-inch 24-hour event)</b>	<b>Upper Confidence Limit (10.0-inch 24-hour event)</b>
Purgatory Creek	36	52	62
Riley Creek	7	9	14
Bluff Creek	15	17	21

NOTE: Crossings were identified based on available topographic data. A field survey was not complete to verify impacts to identified crossings.

### 3.3 Annual Flood-Risk

Annual flood-risk is the probability that a location will be inundated during a 1-year period. Inundation extents for the 2-, 10-, 25-, 50-, 100- and 500-year, 24-hour events were delineated, and processed to illustrate the annual flood-risk along the creek. The return period is related to annual flood-risk as shown in Table 3-3. Annual flood-risk for identified structures was estimated based on the processed simulation results. The annual flood-risk at creek crossings was determined based on the smallest simulated event to inundate the crossing. The annual flood-risk figures are located in Appendix C.

**Table 3-3 Rainfall Event Return Period and Corresponding Annual Flood-Risk**

<b>Return Period</b>	<b>Annual Flood-Risk (%)</b>
2-year	50%
10-year	10%
25-year	4%
50-year	2%
100-year	1%
500-year	0.2%

### 3.4 Flood-Risk over 30-year Period

The final set of figures created show the flood-risk over a 30-year period. Similar to the annual flood-risk figures, these figures were developed based on the potential inundation extents for the 2-, 10-, 25-, 50-, 100- and 500-year, 24-hour events. Simulation results were processed in GIS to determine the flood-risk over a 30-year period. For example, if the annual flood-risk for a structure is 1-percent, then there is a 26-percent probability of that structure being impacted during a 30-year period. The annual flood-risk is related to flood-risk over a 30-year period as shown in Table 3-4. The 30-year flood-risk figures are located in Appendix D.

**Table 3-4 Comparison of annual and 30-year flood-risk probabilities for various rainfall event return periods.**

<b>Return Period</b>	<b>Annual Flood-Risk (%)</b>	<b>30-Year Flood-Risk (%)</b>
2-year	50%	99.99%
10-year	10%	96%
25-year	4%	71%
50-year	2%	45%
100-year	1%	26%
500-year	0.2%	6%

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## 4.0 Conclusions

The flood-risk figures were developed in partnership with local municipalities and considered comments from RPBCWD TAC members. The figures can be used to inform communities of current flood-risk and potential future flood-risk within the watershed. This information provides the RPBCWD and municipalities a water management tool that looks at how future climate change could potentially impact infrastructure but also helps the District and municipalities to determine where flood mitigation might be needed.

Data sets used for model development are not always complete or error-free. RPBCWD TAC members provided comments regarding areas where additional detail in the model and flood-risk reduction figures would provide benefit for local planning purposes. As additional information is collected or provided by the municipalities, the number of potential flood-prone structures identified may be affected. In addition, no survey data was collected to verify flood-prone structures. However, surveys should be completed in the feasibility study phase of flood-risk mitigation projects to better address the cost-benefit relationship of specific projects.

RPBCWD TAC members commented that the model and mapping will be helpful and would like to further engage with the District to build on the initial model and further enhance it. It is recommended that the District coordinate with each municipality regarding how to enhance the current model.

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## 5.0 References

- [1] Barr Engineering Co., "Model Documentation Report Riley, Purgatory, and Bluff Creeks Hydrologic/Hydraulic Model Update. Prepared for Riley Purgatory Bluff Creek Watershed District," December, 2015.
- [2] S. Perica, D. Martin, S. Pavlovic, I. Roy, M. St. Laurent, C. Trypaluk, D. Unruh, M. Yekta and G. Bonnin, "NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States," NOAA, National Weather Service, Silver Spring, MD, 2013.
- [3] National Weather Service, "Technical Paper 40: Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years," U.S. Department of Commerce, Washington D.C., 1961.
- [4] Stack LJ, Simpson MH, Gruber J, Moore TL, Yetka L, Eberhard L, Gulliver J, Smith J, Mamayek T, Anderson M and Rhoades J, "Long-term climate information and forecasts supporting stakeholder-driven adaptation decisions for urban water resources: Response to climate change and population growth. Final project report: Sectoral Applications Research Program FY2011," Climate Program Office, National Oceanic and Atmospheric Administration, 2014.
- [5] Furgo Horizons Inc. and the MnDNR, "Lidar Elevation Twin Cities Metro Region," MnDNR, St. Paul, 2011.
- [6] Farm Service Agency, *Aerial Photography Field Office (USDA-FSA-APFO) Aerial Photography*, U.S. Department of Agriculture, 2015.