Fargo, ND | HEI No. 6019-0138
June 29, 2023

MODELING AND ASSESSMENT REPORT

CITY OF MOORHEAD CLIMATE CHANGE RESILIENCY PLANNING
PREPARED FOR THE CITY OF MOORHEAD AND THE MPCA

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1 PURPOSE

This project assessed vulnerabilities in the City of Moorhead (City) resulting from increased rainfall intensities caused by ongoing climate change and resulted in a feasibility study evaluating alternatives that increase resilience of vulnerable areas of the community with low-income and people of color populations.

1.1 GOAL STATEMENT

The goals of this project were to 1) Develop climate change hydrology (CCH) for the City; 2) Utilize the City's existing InfoSWMM hydrologic/hydraulic model to analyze the impacts of the CCH; 3) Develop a prioritized summary of critical locations affecting private structures, public structures, critical infrastructure, sanitary sewer systems, transportation systems, and community spaces, such as parks, that are in need of infrastructure improvements and/or other mitigation measures to increase resiliency to the CCH; 4) Complete a feasibility study to evaluate alternatives to increase resilience in high priority areas. The project study area focuses on portions of Census Tracts 202.02, 203, and 204 that have been identified on the MPCA's "Understanding Environmental Justice in Minnesota" website as having at least 40% of people reporting income less than 185% of the federal poverty level. The project study area extends beyond the boundaries of the Census Tracts that are identified on the "Understanding Environmental Justice in Minnesota" website. The storm sewer systems from those extended areas flow through the identified Census Tracts before they outlet into the Red River of the North. These areas have been included in this study because they have known flooding issues that propagate through the storm sewer systems and impact the Census Tract areas identified for this project. Excluding these areas would result in an inaccurate assessment of impacts/risk within the identified Census Tracts and would unnecessarily limit the range of mitigation strategies.

1.2 HYDRAULIC AND HYDROLOGIC MODEL

The existing City of Moorhead storm water models were utilized to analyze the rainfall events and develop anticipated impacts to infrastructure. The existing model is a city-wide storm water management model (SWMM) using the InfoSWMM software. The SWMM model utilizes the EPASWMM engine to perform hydrologic and hydraulic routing computations. This model accounts for total stormwater runoff volume and develops discharge hydrographs that are routed through the storm sewer system. The model consists of sub-surface drainage and overland conveyance as well as surface storage in streets, low areas, and designed storm water detention areas. The study area extents are included in **Appendix 1**.

2 TASKS

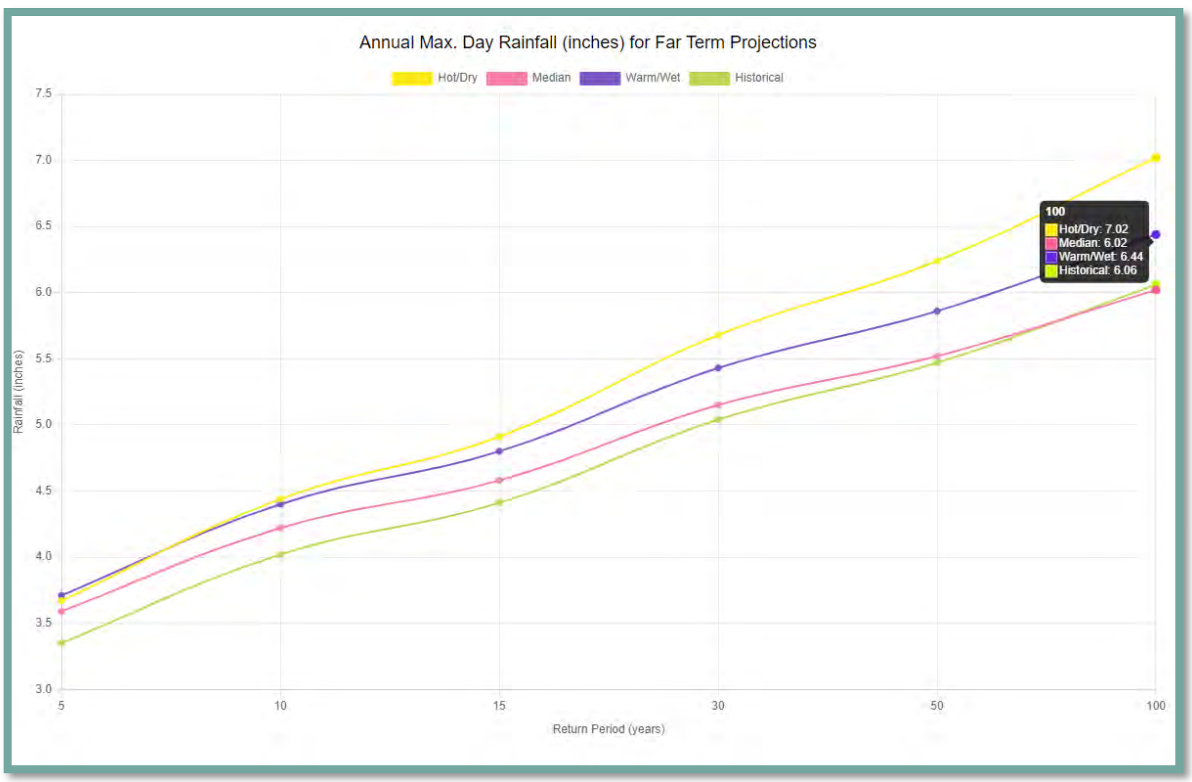
2.1 TASK 1: CLIMATE CHANGE HYDROLOGY DEVELOPMENT

To develop projected CCH, climate change information from sources including the Minnesota Department of Natural Resources, the University of Minnesota, the Climate Resilience Evaluation and Awareness Tool (CREAT) Climate Scenarios Projection Map [1], and other resources from the U.S. Climate Resilience Toolkit were evaluated.

2.1.1 PROJECTED RAINFALL

Climate change scenarios from the sources outlined above were compared to develop an approximate consensus of projected increases in rainfall depths due to climate change. The projected rainfalls outlined in the University of Minnesota's 2022 report titled "Equipping Municipalities with Climate Change Data to Inform Stormwater Management" [2] were not consistent with other data sources as they varied significantly across the study area and were nearly double the current NOAA Atlas 14 100-Yr, 24-Hr rainfall depths. These anomalies appeared to exist throughout the Red River Valley. Projected rainfalls for other areas of the state appeared to be in line with other data sources, but due to the discrepancies in the study area this data source was not used for this study. Ultimately the EPA National Stormwater Calculator (NSWC) [2] was selected as the data source for the project climate change hydrology. The NSWC was selected because the projections were consistent with projections provided by CREAT. The NSWC information used in this study is based on projected rainfall data estimates from March of 2022. The climate change projections in the NSWC are continuously being updated and at the time of this report show slightly different projects than in March of 2022. The project partners determined that using the "far term (2045-2074)" "Hot/Dry" climate change scenario provided a reasonable estimate for the predicted rainfall depths. According to the NSWC, the projected CCH 100-Yr, 24-Hr rainfall depth is approximately 7.02", and the historical 100-YR, 24-HR rainfall depth is 6.06" for Moorhead. The projected trendlines due to climate change from the NSWC are included in **Figure 1**. For comparison the historical 100-Yr, 24-Hr rainfall from the NSWC is less than current NOAA Atlas 14 100-Yr, 24-Hr depth of 6.5". To project the future rainfall depths relative to current rainfall depths, the study used the percent increase in the 100-Yr, 24-Hr rainfall depth based on the NSWC projections. Based on NSWC current and future rainfall depths for the 100-Yr, 24-Hr event, a 15.8% (7.02"/6.06") increase due to climate change was assumed. For all rainfalls utilized in this study, CCH rainfall depths were assumed to be 15.8% greater than present day rainfall depths.

Figure 1 - EPA National Stormwater Calculator Projected Future Rainfall Depths



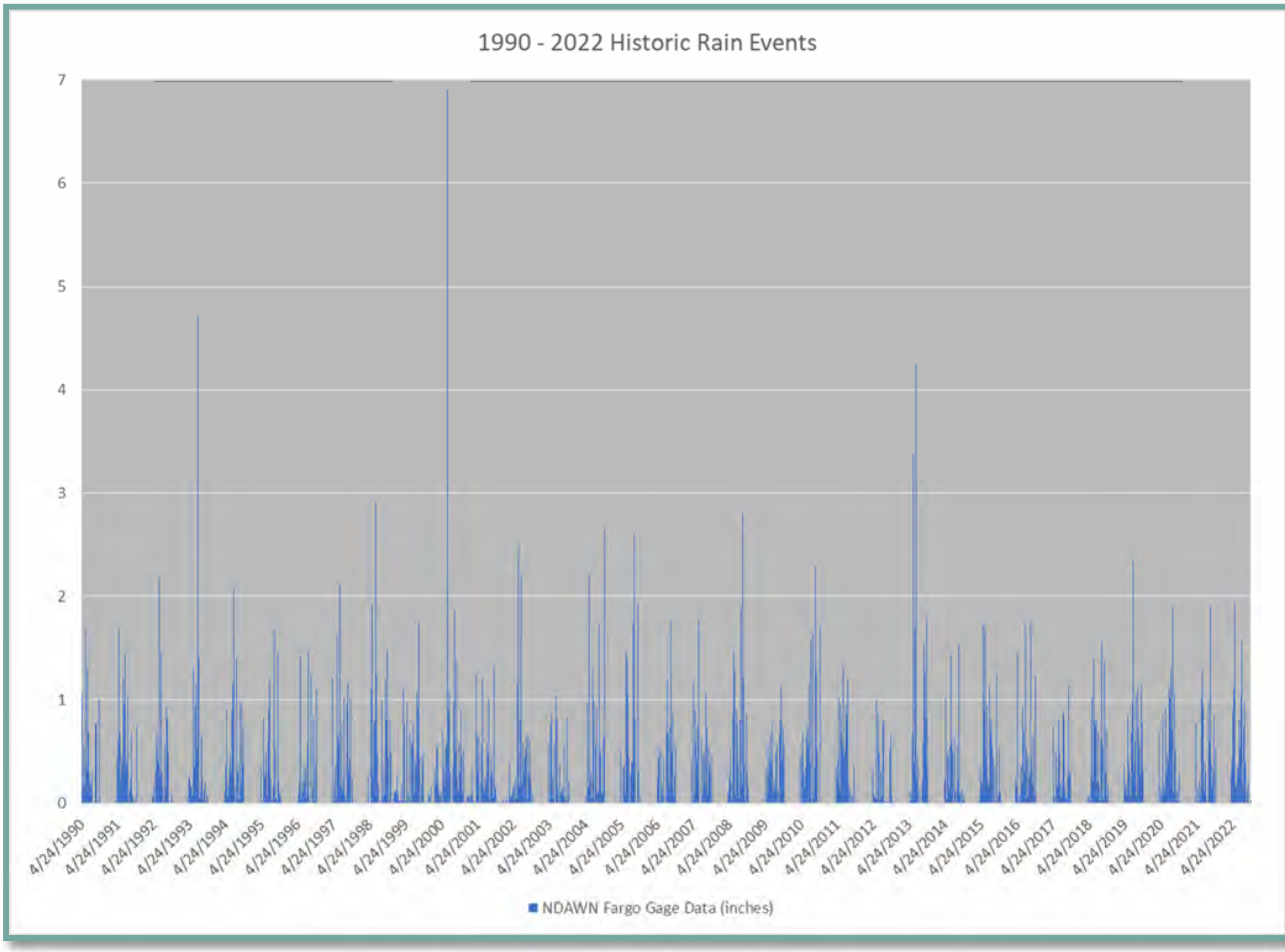
2.1.2 DRAINAGE LIMITATIONS AND STUDY APPROACH

The capacity of the existing storm sewer infrastructure in the City is limited by multiple geographical constraints. The clay soils in the Red River Valley are not conducive to infiltration, and therefore the majority of the rainfall runs off the landscape and must be conveyed to an outfall where it will discharge to a waterway. The lack of sufficiently available grade across the City impedes conveyance capacity of storm sewers. Flat available slopes often require large diameter storm sewers to convey relatively small rain events without surcharging to the surface. Additionally, due to flooding concerns from the Red River additional outfalls require expensive flood control structures and lift stations. Added penetrations through the line of flood protection along the Red River increases potential risks of riverine flooding. These factors combined result in limited outfall capacity and undersized storm sewer. The approach of this analysis was to determine commonly experienced rainfall events that may result in impacts to citizens. Prior studies conducted on the city storm sewer system have indicated that large scale events such as a 100-Yr,24-Hr rainfall results in impacts to nearly all residents regardless of location within the city. A 100-Yr event for all intents and purposes will overwhelm the storm sewer and results in runoff surcharging and surface flooding flowing in multiple directions to adjacent subcatchments. Conversely, by analyzing more common, but impactful, events better serves to highlight areas within the study area where direct drainage to the intended storm sewer is under performing. This allows for more economical and targeted improvements allowing for broader improvements to a larger portion of the City.

2.1.3 STUDY RAINFALL EVENTS

To determine the common “impactful” rainfall events, historical rainfall data from the nearby North Dakota Agricultural Weather Network (NDAWN) [3] site was compiled. This data is displayed on **Figure 2**. In order to capture current climate trends, a period of record from 1990 to 2022 was used. Analysis of the data revealed that relatively few events over the period of record resulted in rainfalls greater than 2” and three events resulted in a rainfall greater than 4”. A sensitivity analysis using the SWMM model determined that events under 2” did not result in appreciable surface inundation. For these reasons the scope of the analysis was focused on 2”, 3” and 4” rainfall events. Although 4” rainfall events are not nearly as frequent as the 2” and 3” events, the 4” rainfall was included to exhibit the relative increase in impacts as rainfall depth increases within the study area. The equivalent projected CCH rainfall depths of 2.32”, 3.47” and 4.63”, were compared to the current 2”, 3”, and 4” events respectively. These future CCH depths were determined by applying the anticipated 15.8% percent increase based on the NWSC for the 100-year rainfall.

Figure 2 - NDAWN Daily Rainfall Fargo 1990-2022



2.2 TASK 2: CLIMATE CHANGE IMPACTS ANALYSIS

This task utilized the CCH generated in Task 1 to identify areas at risk of increased flooding within the study area. Using the SWMM model the projected CCH events were analyzed. Utilizing GIS-based tools and results from the SWMM model, inundation maps were developed to visually identify surface flooding, and raster data from GIS determined inundation depths within the study area. The results of this analysis were reviewed with City Staff and was compared to known, historic flood-prone areas to validate the model results. A public meeting and on-line survey were completed under this task. Public input further verified results of the analysis. Inundation maps comparing the current and projected CCH hydrology are included in **Appendix 2**.

2.3 TASK 3: CLIMATE CHANGE RISK ASSESSMENT

To develop a risk assessment, the inundation mapping completed in Task 2 was evaluated to determine potential impacts in each subcatchment. In general, the risk assessment includes consideration of the consequence (impacts) of flooding (e.g. the potential for structural damage, transportation impacts, sanitary sewer system inflow and sewer back-up, etc.) combined with the probability of flooding (based on the CCH).

Risk = Probability of Event Occurrence × Impacts of the Event

GIS data was used to identify various key community assets including public and private structures, critical infrastructure, sanitary sewer systems, transportation systems, and community spaces impacted within each area. The impacts to each of these categories of community assets was evaluated individually, and then the combined impacts were expressed as a weighted sum of the risk to the entire subcatchment.

2.3.1 IMPACT ASSESSMENT APPROACH

To provide a measurable and repeatable approach to the impact assessment, the limitations of the available data must be considered. The impact assessment is based on peak water surface inundation and the duration of inundation was not considered. The inundation mapping in areas with local low areas such as backyards that do not uniformly drain to an inlet result in disconnected pockets of inundation. Visual checks were made to remove structure impacts that were believed to be the result of anomalies in the LiDAR based elevation data. The structure footprints used in this study are an approximation derived from the LiDAR collection and are not surveyed boundaries of the actual structure. It was also assumed that if inundation touched the structure footprint it resulted in an impact regardless of if the inundation would result in damage to the structure. Similarly, there was insufficient data to approximate the volume of inflow to the sanitary sewer due to runoff. Sanitary sewer impacts were based on the potential for inflow due to inundation.

2.3.2 IMPACT ASSESSMENT FRAMEWORK

The flood impact assessment components used for this study are outlined below. The numerical values for each category of impacts were assigned to the subcatchment data set to develop the impact ratings.

- **Structure Impact Rating**
  - 0 – No Impacts
  - 1 – Secondary Structure Impacts (i.e. sheds)
  - 2 – Private Primary Structure Impacts (Houses, businesses, churches, etc.)
  - 3 – Public Structure Impacts (Courthouse/LEC, Schools, Post Office, Library, etc.)
- **Sanitary Sewer Impact Rating**
  - 0 – No Impacts
  - 1 – Manholes 0 – 3” inches of inundation
  - 2 – Manholes 3 – 6” inches of inundation
  - 3 – Manholes over 6” inches of inundation
- **Transportation Impact Rating**
  - 0 – No Flooding
  - 1 – Minor Flooding (flooding mainly in gutter or parking lanes)
  - 2 – Moderate Flooding (flooding partially in travel lanes)
  - 3 – Major Flooding (entire roadway width)
  - Functional Class Multiplier: Each Flood Rating (0-3) is multiplied by the functional class to result in a final score (0-12).
    - 1 – Local Street
    - 2 – Collector
    - 3 – Minor Arterial
    - 4 – Principal Arterial
- **Community Spaces (Parks, etc.)**
  - 0 – No Flooding
  - 1 – Greenspace Flooding
  - 2 – Playground Equipment Impacts
  - 3 – Structure Impacts

2.3.2.1 IMPACT WEIGHTING

Due to the variations in drainage area and density of infrastructure in each subcatchment, a system of weighting the impacts was created to better differentiate impact ratings. The impact weighting was a multiple step process. The first step was to determine all impacts for each category in a subcatchment. Next the highest impact for each category within a subcatchment was determined. For example, if a subcatchment had an impact to a secondary structure and a primary structure, the primary structure impact controlled and the subcatchment was rated as a 3 for the structure impact category. Due to the categories having different maximum point value, the impact ratings were taken as a percentage of total possible points in that category. In the case of transportation impacts, a collector street with total roadway flooding was assigned 6 points out of 12 possible. The percentage of total points for the transportation category would then be 50%. This percentage is then multiplied by the overall category impact category weight factor. The impact category weight factor for structure impacts is 40%, sanitary impacts account is 30%, transportation impacts are 20%, and community space impacts make up the remaining 10%.

The impacts of each area were determined by summing all the individual ratings from each category and multiplying the total by 100 to give a cumulative impact rating.

Structure impacts are out of a maximum of 3 points, equivalent to a public structure impact rating. Sanitary sewer impacts are also out of a maximum of 3 points, equivalent to a rating of a sanitary sewer manhole that is inundated 6 or more inches. Transportation impacts are out of a maximum 12 points since that is equivalent to a score of a principal arterial roadway with major flooding. Community spaces are out of a maximum of 3 points, equivalent to structure impacts within a community space.

Figures showing the raw impact rating of each subcatchment for the 3 CCH rainfall scenarios are included in **Appendix 3**.

2.3.3 RISK ASSESSMENT

Calculating risk is achieved by multiplying the occurrence probability of the rainfall event by the potential impacts from the rainfall event. The following sections summarize how the risk probability was determined.

2.3.3.1 PROBABILITY WEIGHTING

It was assumed that the probability of the 2”, 3”, and 4” rainfall events would remain unchanged for the projected future CCH events (i.e. the probability of a present day 2” rain would be the same as a future 2.32” rain). Applying this assumption, the current recurrence probability of a 2”, 3” and 4” rainfall event under existing conditions was determined and then applied to the projected CCH equivalent of these events (2.32”, 3.47” and 4.63”). The recurrence probabilities for the study events are summarized in **Table 1**. The derivation of these values is summarized in the following sections.

Table 1 - Rainfall Statistical Summary

Rainfall Depth	Recurrence Interval	Exceedance Probability
2”	1.1 – YR	91.6%
3”	4.98 – YR	20.2%
4”	14.56 – YR	6.9%

2.3.3.1.1 SYNTHETIC RAINFALL

The synthetic rainfall depths used in this study were obtained from the precipitation frequency estimates in NOAA Atlas 14 [3] for "Moorhead (21-5586)", Moorhead, Minnesota (National Oceanic Atmospheric Administration). Atlas 14 rainfall data provides the most recent point precipitation frequency estimates for the study area. The three rainfall events used in this study do not directly correlate to a recurrence interval presented in Atlas 14. To determine the probability of the 2", 3", and 4" rainfall events, the known probabilities from Atlas 14 rainfalls were utilized. For comparison purposes, the 24-Hr rainfall events with return periods ranging from 2-Year to 100-Year are included in **Table 2**.

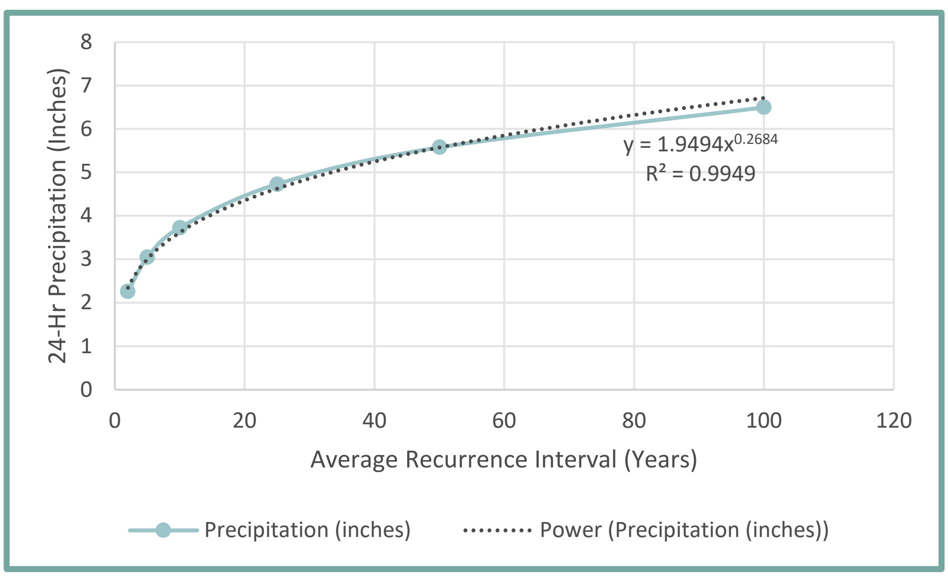
Table 2 – 24 Hour Atlas 14 Synthetic Rainfall Depths

Event	Rainfall Depth
2-Year	2.26"
5-Year	3.05"
10-Year	3.73"
25-Year	4.73"
50-Year	5.58"
100-Year	6.50"

2.3.3.2 AVERAGE RECURRENCE INTERVAL AND ANNUAL EXCEEDANCE PROBABILITY

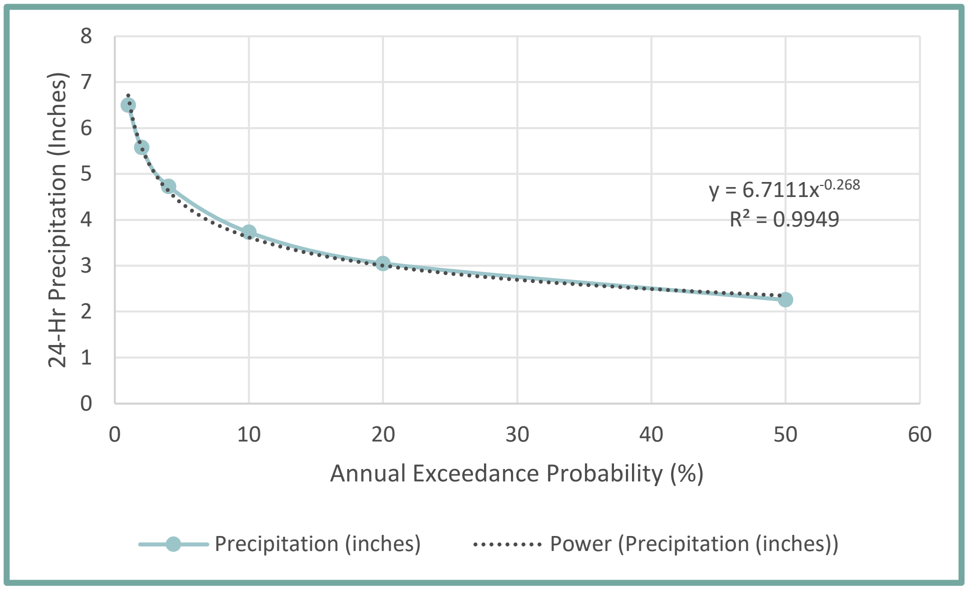
To determine the return period of the three study rainfall depths, the Atlas 14 annual maximum precipitation depths for each return period was plotted. Using a power function trendline yielded a formula which was used to find the average recurrence interval for the three rainfall events under current hydrologic conditions. The plot of the Atlas 14 annual maximum precipitation events and their corresponding return intervals are included as **Figure 3**. The calculated recurrence interval for a 2", 3", and 4" rainfall events are 1.1-yr, 4.98-yr, and 14.56-yr respectively.

Figure 3 - Moorhead Average Recurrence Intervals



Conversely, plotting the annual exceedance probability (%) versus the 24-hr annual maximum precipitation paired with a power trendline yields a formula that can be used to find the annual exceedance probability of the 2", 3" and 4" rainfall events for Moorhead. The plot of the annual exceedance is included as **Figure 4**. The annual exceedance probability for a 2" event using this formula is 91.6% while it is only 20.2% for a 3" rainfall and 6.9% for a 4" rainfall. Due to the relatively high probability of a 2" rainfall event, the risk analysis is largely controlled by the impacts related to the 2" event with CCH.

Figure 4 - Moorhead Annual Maximum Precipitation Frequency Estimates



2.3.4 RISK ASSESSMENT SUMMARY

To summarize the risk assessment a summary of the components is included below. **Figure 5** is an example workflow for determining a risk assessment for the 3" climate change event for an individual subcatchment. This assessment was completed for each subcatchment in the study area for each climate change event (2", 3", and 4" events)

Risk = Probability of Event Occurrence × Impact Rating

Probability of Event Occurrence = Exceedance Probability of a given event = 0.916 for the 2" event
= 0.202 for the 3" event
= 0.069 for the 4" event

Impact Rating = ∑(Percent of Maximum Potential Impact × Category Weighting Factor)

Percent of Maximum Potential Impact = Greatest impact recorded ÷ by the maximum possible impacts.

Weighting Factor = 40% for structure impacts
= 30% for sanitary sewer impacts
= 20% for transportation impacts
= 10% for community impacts

Figure 5 - Example Risk Assessment Workflow

2.3.5 PRIORITIZED FLOOD RISK AREAS

Combining the probability weighting with the impact assessment yields the final risk for each modeled subcatchment. The composite risk assessment figures for the CCH events and the existing storm sewer network are included in **Appendix 4**. These figures highlight the areas deemed to be at high flood risk and were targeted for system improvements to reduce impacts. The risk assessment figures were color coded based on areas consider to be low, slight, moderate, and high-risk. Generally high-risk areas included impacts to primary structures. The feasibility analysis focused on improvements that benefited the moderate and high-risk areas.

2.4 TASK 4: RISK REDUCTION FEASIBILITY ANALYSIS

This task used the flood risk assessment identified in Task 3 to develop feasibility analyses in the moderate and high risk areas. Using the SWMM model created under Task 2 of the project, an in-depth review of the existing storm sewer systems in the moderate and high-risk areas was completed to determine the limitations of the existing storm sewer systems. Alternatives for infrastructure improvements and/or other mitigation strategies were developed and assessed for each area to determine their feasibility from a cost and constructability perspective. Once completed, the most feasible alternatives were identified by the City and cost estimations were developed. Due to the interconnected nature of the surface and subsurface drainage patterns, the alternatives were not evaluated independently from one another, but rather as a holistic improvement for the entire system. Though the drainage systems in Moorhead are interconnected, the railroad tracks at Main and Center Avenues create a barrier clearly separating the north portion of the study area from the southern portion. For this reason, the proposed risk reduction improvements were grouped into the two areas listed below.

2.4.1 NORTH IMPROVEMENT AREA

The north improvement area has a unique drainage pattern in that storm water can outlet either directly to the Red River by running to the west or to Clay County Legal Drain 41 to the northeast. The existing storm sewer system primarily discharges directly to the Red River. By providing a storm water detention pond and connecting new trunk storm sewers to it, a large portion of the contributing area can be diverted to Drain 41. This provides a twofold benefit in that it shortens the distance to the outfalls and reduces the drainage area to the Red River outfalls. There is a large green space owned by the Moorhead School District that potentially could be utilized to construct an underground stormwater detention facility. There are also potential sites for rain gardens in the north improvement area that could provide green infrastructure to the storm drainage network. In addition to the proposed re-routing of the drainage area, proposed improvements at existing outfalls provide additional capacity to the storm sewer system to more efficiently move water and reduce surface flooding. The anticipated cost for the entire improvement plan for the North Improvement Area is approximately $61.5 million. Figures outlining the improvements and a comparison of inundation with and without the proposed improvements are in included in **Appendix 5**. Updated impact and risk assessments reflecting the proposed improvements are included as **Appendices 6 and 7**, respectively. A summary of the cost estimate is included in **Appendix 8**.

2.4.2 SOUTH IMPROVEMENT AREA

Due to dense development and the topography of the southern portion of the study area it is difficult to provide additional storm drainage capacity. Much of the drainage area east of US Highway 75 was routed east away from the Red River and south before being routed back to the west towards the outfall. This routing resulted in long storm sewer runs and additional losses to the hydraulic system. Proposed improvements along Main Avenue to an upsized outfall virtually eliminated the runoff from the high impervious downtown area of the city from being conveyed by the storm sewer in the residential area to the south. Additionally increasing capacity along trunk storm sewers at 6th and 16th Avenues south reduced the potential impacts around Minnesota State University Moorhead. There is a large green space owned by Concordia College that could be utilized to construct an underground stormwater detention facility. The additional of this stormwater detention facility results in a decrease in pipe size for the 16th Ave S improvement. The anticipated cost for the entire improvement plan for the South Improvement Area is approximately $58 million. Figures outlining the improvements and a comparison of inundation with and without the proposed improvements are included in **Appendix 5**. Updated impact and risk assessments reflecting the proposed improvements are included as **Appendices 6 and 7**, respectively. A summary of the cost estimate is included in **Appendix 8**.

3 CONCLUSION

This study has identified several locations within the study area that show an increased risk of flooding under a projected climate change scenario. These increased risks can result in impacts to the sanitary sewer system, transportation impacts (pedestrian and vehicular), impacts to public facilities, and impacts to residential structures.

The existing soils, lack of green space, and flat topography in the study area present unique challenges not seen in other parts of the state. The lack of infiltration capability of the soils results in a high runoff to rainfall percentage which produces higher volumes of runoff than other portions of the state. The smaller lot size and high housing density of the study areas also results in additional impervious area that increase the runoff to rainfall percentage. The flat topography produces an additional challenge in that the storm sewer must be installed at or close to minimum slopes. The flatter storm sewer slopes result in less capacity per diameter, thereby requiring larger pipes to convey the runoff. Although engineered rain gardens can be used to improve water quality, they provide little to no reduction in the volume of runoff due to the lack of infiltration capacity of the soils.

For the reasons listed above, improvements needed to increase the City's resilience to climate change are limited to providing stormwater detention where possible to temporarily store runoff so it can be released at a slower rate and increasing storm sewer capacity so it can convey higher volumes of water. These improvements are costly as they require replacing large sections of the existing storm sewer system that lies beneath the city streets. Although determined to be technically feasible, the alternatives presented in this report are conceptual and will require optimization. Additionally, final improvement plans should follow a phased implementation over several years to coincide with City capital improvement projects wherever possible.

4 REFERENCES

[1] US Environmental Protection Agency, "CREAT Climate Change Scenarios Projection Map," US Environmental Protection Agency, 15 March 2022. [Online]. Available: https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=3805293158d54846a29f750d63c6890e. [Accessed 15 March 2022].

[2] R. N. J. B. C. L. T. T. B. K. L. H. S. Pinkalla, "Equipping Municipalities with Climate Change Data to Inform Stormwater Management," University of Minnesota, Minneapolis, 2022.

[3] North Dakot Agricultural Weather Network, "NDAWN Center," North Dakota Agricultural Weather Network, 15 March 2022. [Online]. Available: https://ndawn.ndsu.nodak.edu/. [Accessed 15 March 2022].

[4] Natural Resources Conservation Service, "Technical Release 55: Urban Hydrology for Small Watersheds," 1986.

[5] Quantum Spatial, Inc., *LiDAR Collection,* Moorhead: NVG Geospatial, 2020.

APPENDIX 1

Location Map and Study Extents


Appendix 1
18th Ave N
18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
13th 1/2 St N
13th Ave N
7th St N
8th St N
9th St N
12th St N
13th St N
12th Ave N
15th St N
15 1/2 St N
16th St N
18th 1/2 St N
11th Ave N
10th Ave N
10th St N
9th Ave N
8th Ave N
7th Ave N
14th St N
17th St N
18th St N
19th St N
20th St N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
21st St N
24th
26th St N
28th St N
29th St N
M-252
M-424
Memorial Park Rd
3rd St N
4th St S
3rd St S
5th St S
6th St S
7th St N
8th St N
10th St N
11th St N
Center Ave
Main Ave
1st Ave S
21st St S
2888
75
10
N
Legend
Existing Storm Sewer
Model Subcatchments
Project Study Area
0 325 650 Feet
Moorhead Climate Resiliancy Study
Location Map and Study Extents
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/20/2023
Sheet: 1 of 1
HOUSTON engineering, inc.

Appendix 1
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
M-234
M-233
Park Dr
S River Dr
Elm St S
1st St S
2nd St S
3rd St S
4th St S
5th St S
6th St S
7th St S
9th St S
10th St S
10th St N
11th St N
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12th St S
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Dudley Ct S
14th St S
15th St S
16th St S
17th St S
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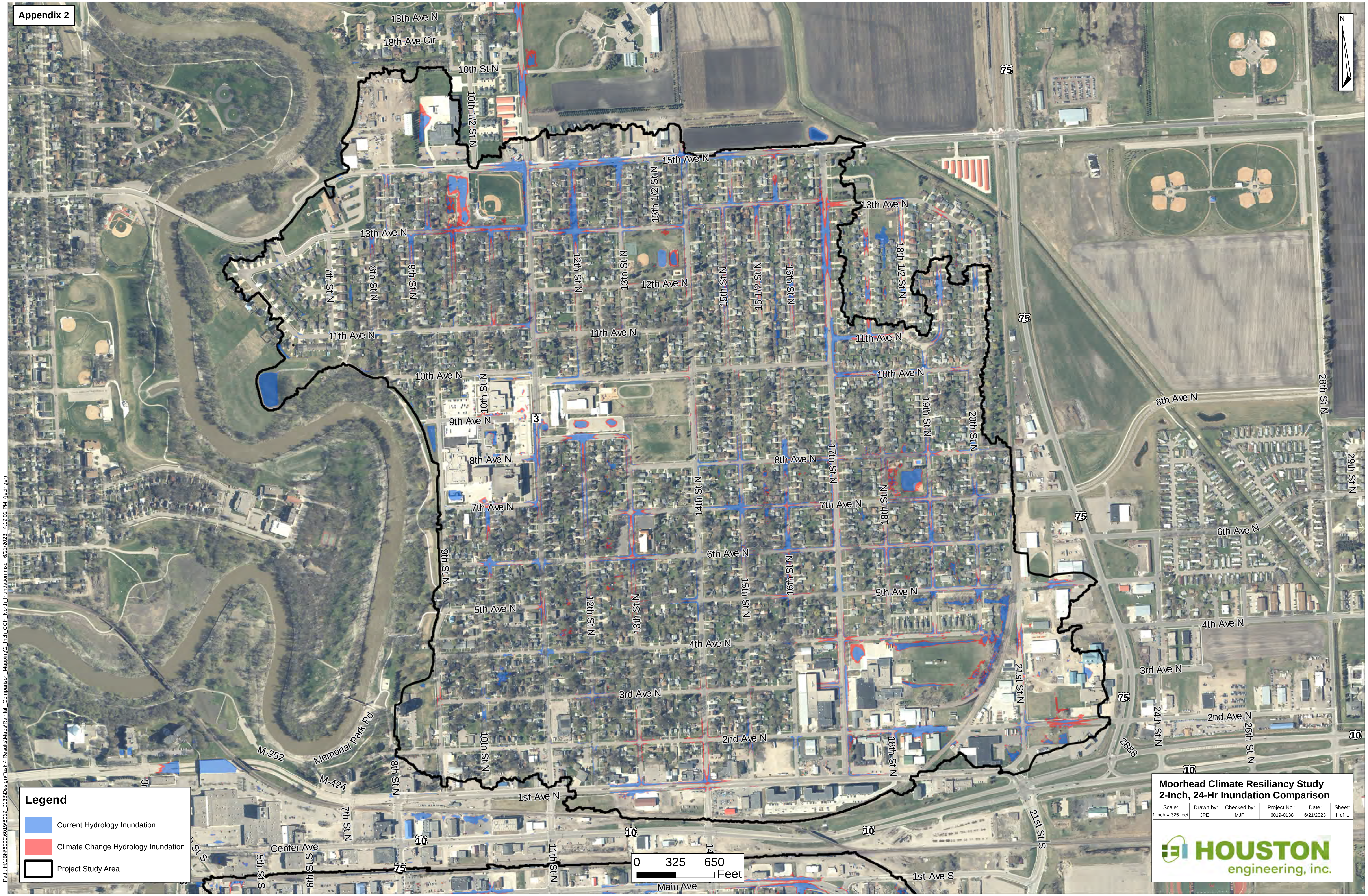
18th 1/2 St S
19th St S
19th 1/2 St S
20th St S
21st St S
22nd St S
23rd St S
24th St S
25th St S
26th St S
Birch Ln
Birch Cir
Oak Way
Walnut Cir S
Rensvold Blvd S
Maple Ln S
Willow Way S
Cedar Ln S
Birch Ln S
Appletree Ln S
10
75
1025
N
Legend
Existing Storm Sewer
Model Subcatchments
Project Study Area
0 325 650
Feet
Moorhead Climate Resiliency Study
Location Map and Study Extents
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/20/2023
Sheet: 1 of 1
HOUSTON engineering, inc.

APPENDIX 2

Climate Change Rainfall Inundation Comparison



Appendix 2
Legend
Current Hydrology Inundation
Climate Change Hydrology Inundation
Project Study Area
0 325 650 Feet
Moorhead Climate Resiliancy Study
2-Inch, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
18th Ave N
18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
13th Ave N
13th 1/2 St N
12th Ave N
11th Ave N
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9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
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M-424
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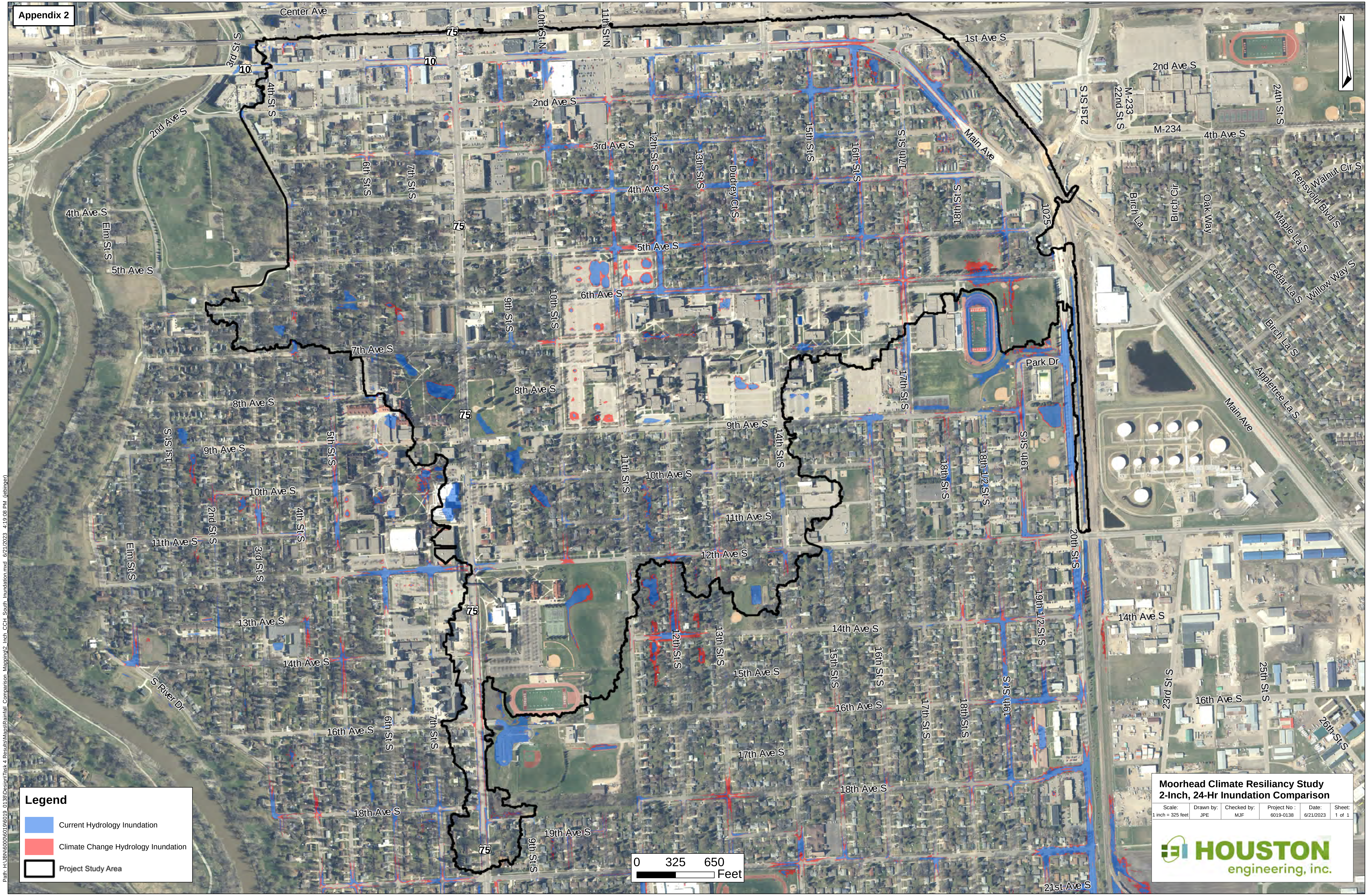

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Scale: 1 inch = 325 feet
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Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
Legend
Current Hydrology Inundation
Climate Change Hydrology Inundation
Project Study Area
0 325 650 Feet
N
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
M-234
S River Dr
Elm St S
1st St S
2nd St S
3rd St S
4th St S
5th St S
6th St S
7th St S
9th St S
10th St N
10th St S
11th St N
11th St S
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17th St S
18th St S
18th 1/2 St S
19th 1/2 St S
16th St S
20th St S
21st St S
22nd St S
23rd St S
24th St S
25th St S
26th St S
Dudrey Ct S
Birch La
Birch Cir
Oak Way
Walnut Cir S
Rensvold Blvd S
Maple La S
Cedar La S
Willow Way S
Birch La S
Appletree La S
75
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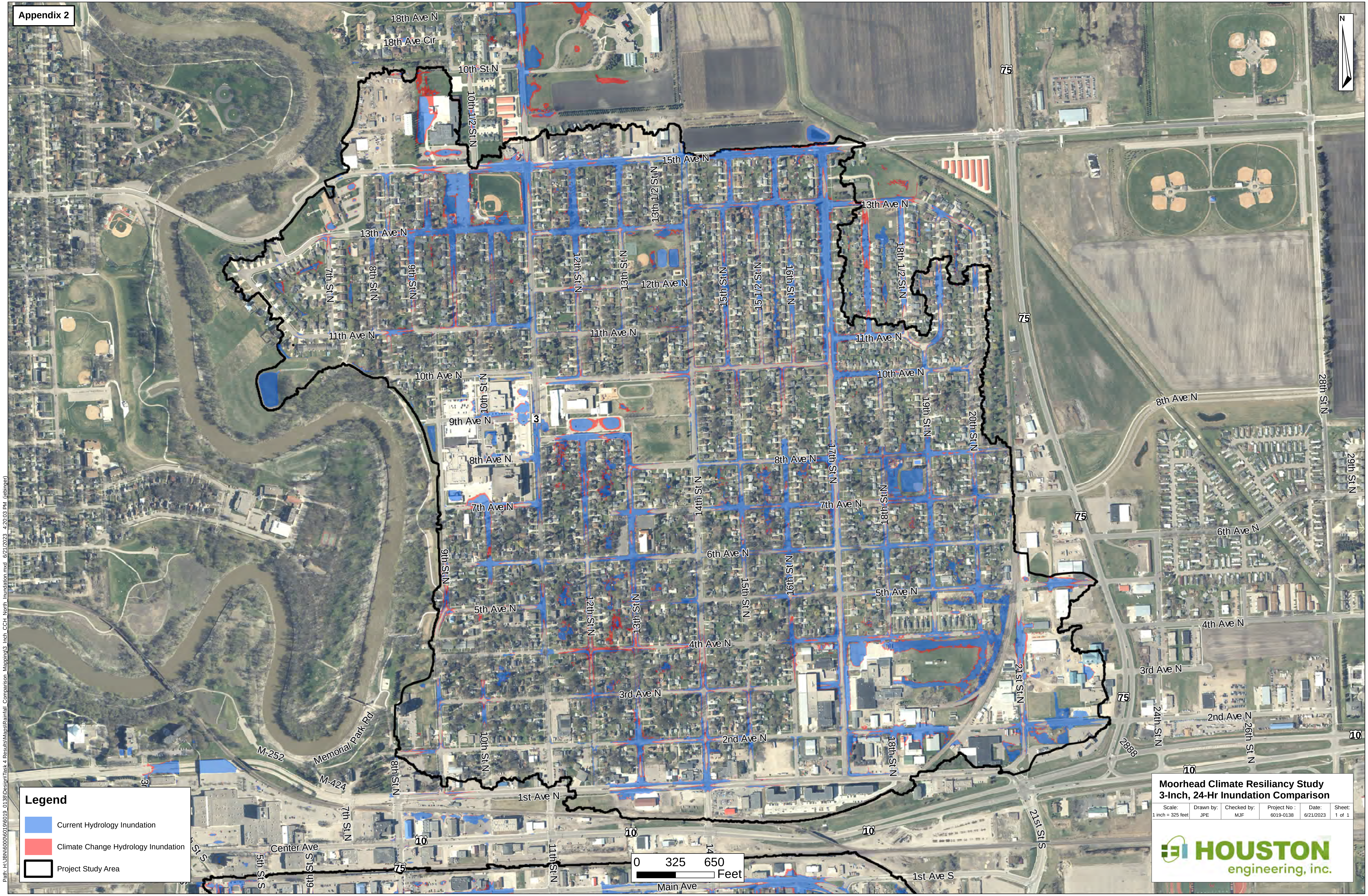
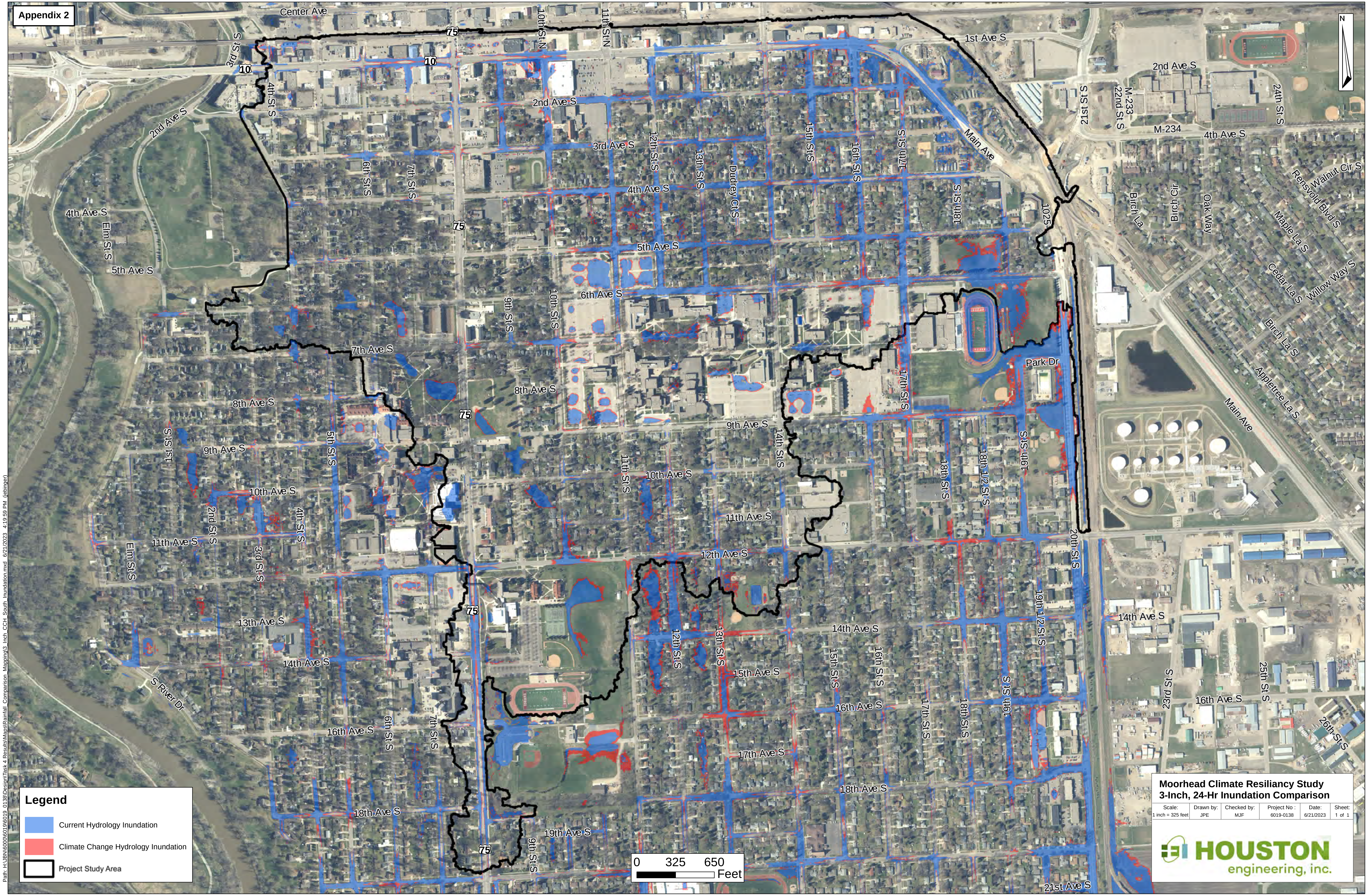

Appendix 2
Legend
Current Hydrology Inundation
Climate Change Hydrology Inundation
Project Study Area
0 325 650
Feet
Moorhead Climate Resiliancy Study
3-Inch, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No: 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
18th Ave N
18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
13th Ave N
12th Ave N
11th Ave N
10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
1st Ave S
Center Ave
Main Ave
7th St N
8th St N
9th St N
12th St N
13th St N
13th 1/2 St N
14th St N
15th St N
15 1/2 St N
16th St N
17th St N
18th St N
18th 1/2 St N
19th St N
20th St N
21st St N
21st St S
24th St N
26th St N
28th St N
29th St N
11th St N
Memorial Park Rd
M-252
M-424
75
10
2888
3


Appendix 2
Legend
Current Hydrology Inundation
Climate Change Hydrology Inundation
Project Study Area
Moorhead Climate Resiliancy Study
3-Inch, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No: 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
0 325 650 Feet
N
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
M-234
S River Dr
Elm St S
1st St S
2nd St S
3rd St S
4th St S
5th St S
6th St S
7th St S
9th St S
10th St S
11th St S
12th St S
13th St S
14th St S
15th St S
16th St S
17th St S
18th St S
18th 1/2 St S
19th St S
19th 1/2 St S
20th St S
21st St S
22nd St S
23rd St S
24th St S
25th St S
26th St S
10th St N
11th St N
Dudley Ct S
Birch La
Birch Cir
Oak Way
Walnut Cir S
Rensvold Blvd S
Maple La S
Cedar La S
Willow Way S
Birch La S
Appletree La S
75
10
1025


Appendix 2
18th Ave N
18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
13th Ave N
13th 1/2 St N
12th Ave N
11th Ave N
10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
Center Ave
Main Ave
1st Ave S
7th St N
8th St N
9th St N
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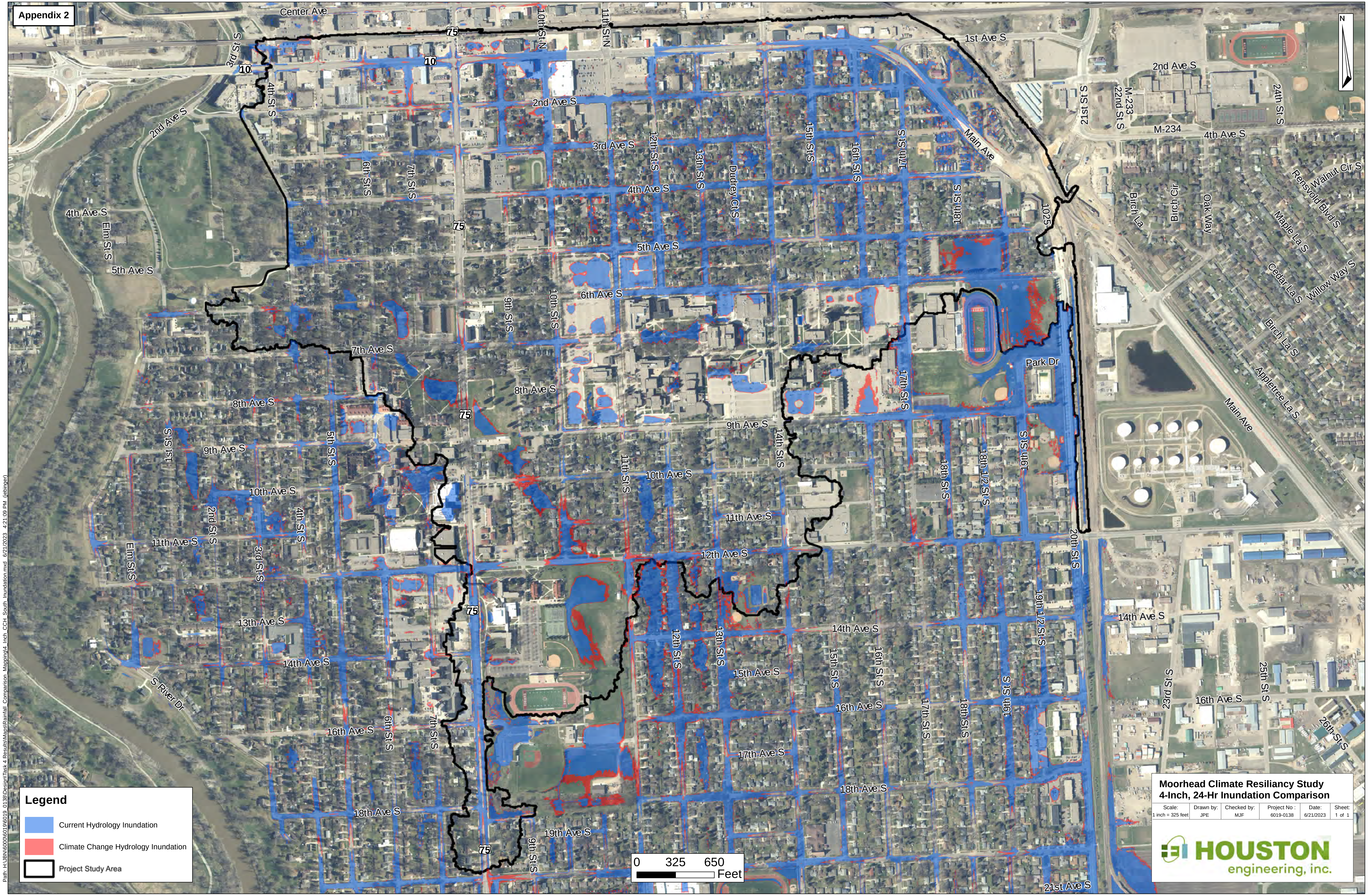
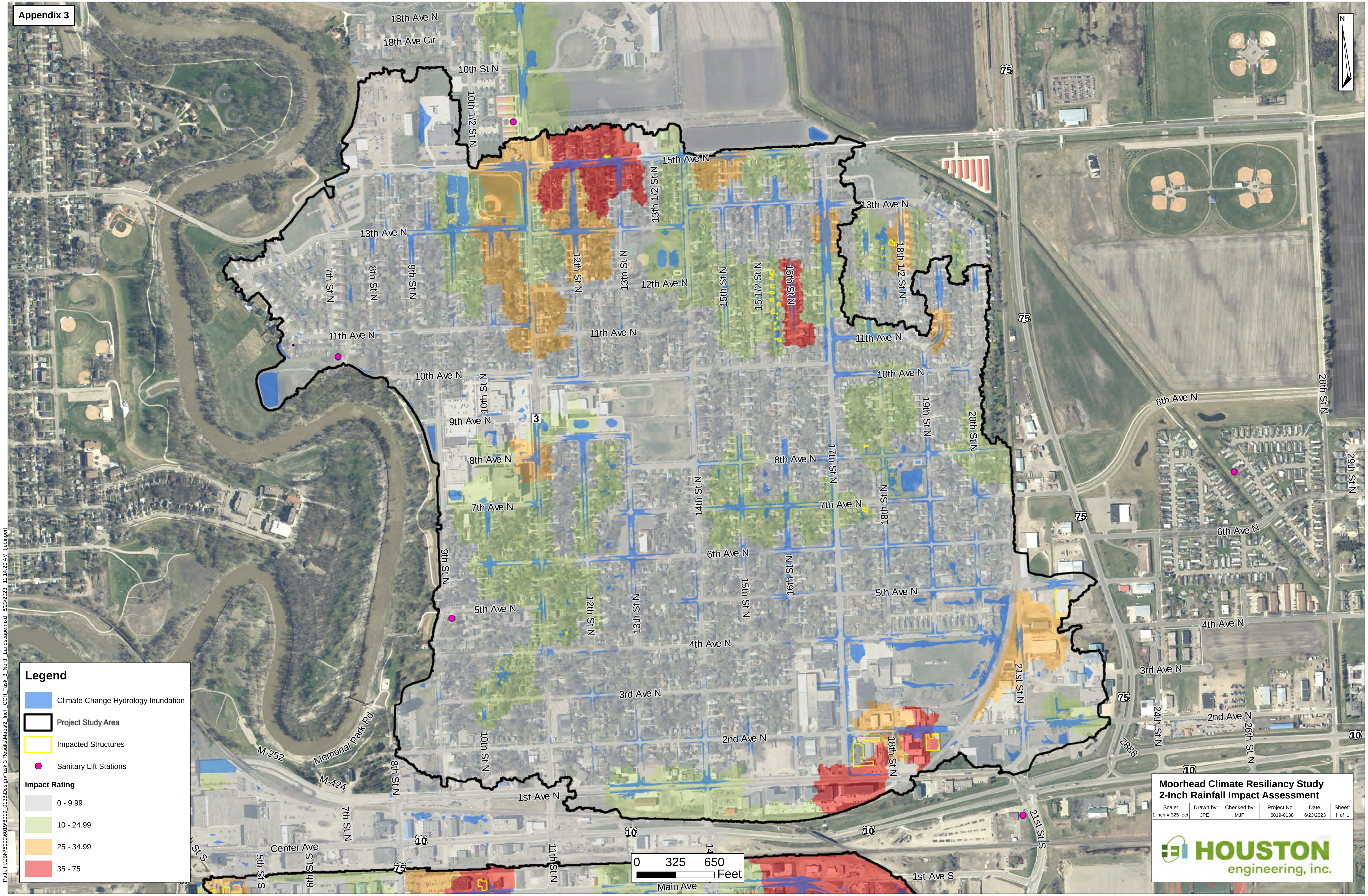
13th St N
14th St N
15th St N
15 1/2 St N
16th St N
17th St N
18th St N
18th 1/2 St N
19th St N
20th St N
21st St N
21st St S
24th St N
26th St N
28th St N
29th St N
11th St N
5th St S
6th St S
Memorial Park Rd
M-252
M-424
2888
Legend
Current Hydrology Inundation
Climate Change Hydrology Inundation
Project Study Area
0 325 650
Feet
Moorhead Climate Resiliancy Study
4-Inch, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.

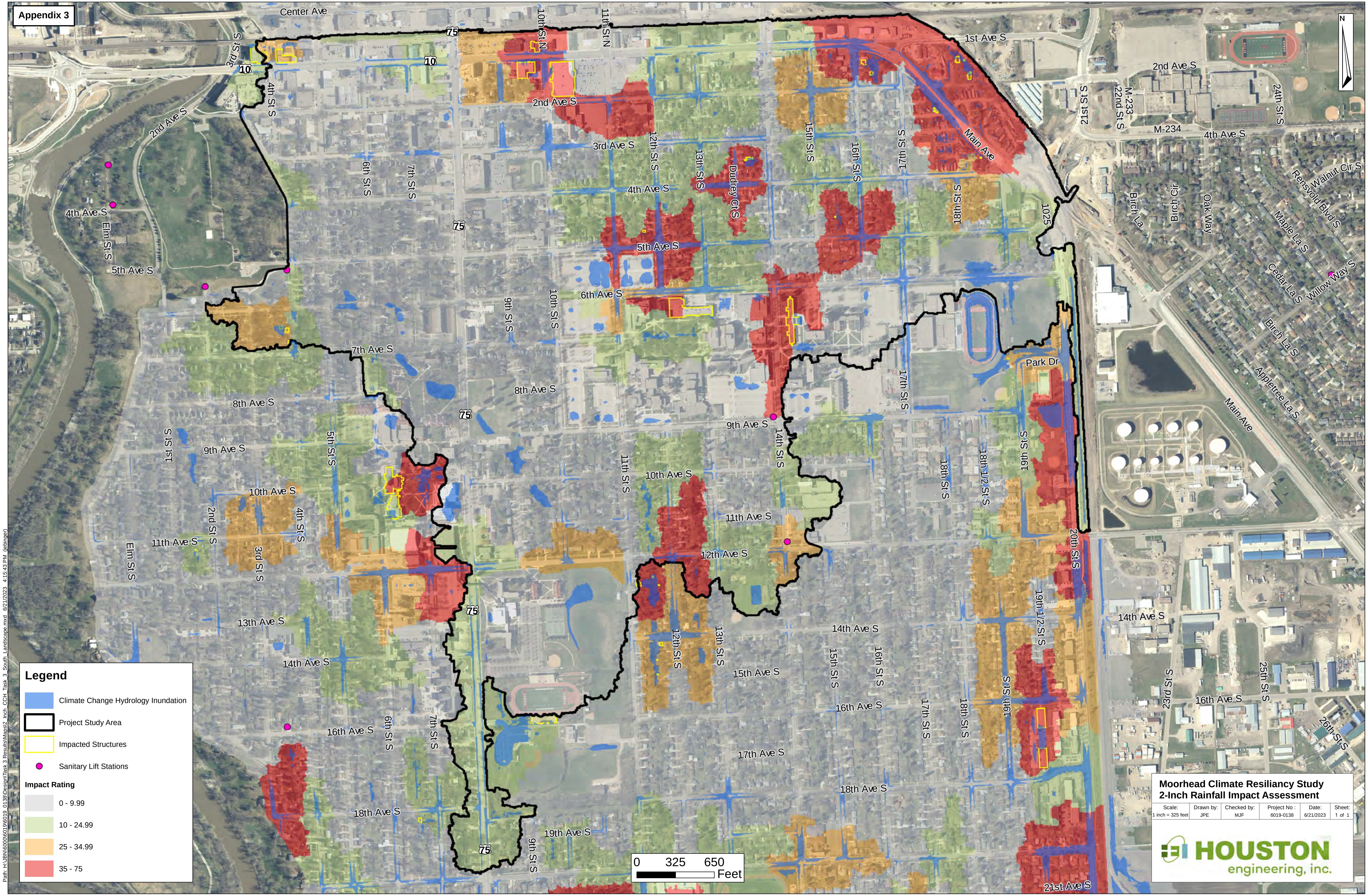

Appendix 2
Moorhead Climate Resiliency Study
4-Inch, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
Legend
Current Hydrology Inundation
Climate Change Hydrology Inundation
Project Study Area
0 325 650 Feet
N
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
S River Dr
M-234
M-233
Elm St S
1st St S
2nd St S
3rd St S
4th St S
5th St S
6th St S
7th St S
9th St S
10th St S
10th St N
11th St N
11th St S
12th St S
13th St S
Dudley Ct S
14th St S
15th St S
16th St S
17th St S
18th St S
18th 1/2 St S
19th St S
19th 1/2 St S
20th St S
21st St S
22nd St S
23rd St S
24th St S
25th St S
26th St S
Birch La
Birch Cir
Oak Way
Rensvold Blvd S
Walnut Cir S
Maple La S
Cedar La S
Willow Way S
Birch La S
Appletree La S
75
10
1025

APPENDIX 3

Existing Conditions CCH Impact Assessment

Appendix 3


Legend
Climate Change Hydrology Inundation
Project Study Area
Impacted Structures
Sanitary Lift Stations
Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
Moorhead Climate Resiliancy Study
2-Inch Rainfall Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/23/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
0 325 650 Feet
N
18th Ave N
18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
13th 1/2 St N
13th Ave N
18th 1/2 St N
7th St N
8th St N
9th St N
12th St N
13th St N
12th Ave N
15th St N
15 1/2 St N
16th St N
11th Ave N
10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
14th St N
17th St N
18th St N
19th St N
20th St N
21st St N
24th St N
26th St N
28th St N
29th St N
M-252
M-424
Memorial Park Rd
Center Ave
Main Ave
1st Ave S
5th St S
6th St S
7th St N
8th St N
11th St N
21st St S
2888
75
10
Path: H:\JBN\6000\6019\6019_0138\Design\Task 3 Results\Maps\2_Inch_CCH_Task_3_North_Landscape.mxd 6/23/2023 11:14:20 AM (lebinger)


Appendix 3
Moorhead Climate Resiliency Study
2-Inch Rainfall Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
Legend
Climate Change Hydrology Inundation
Project Study Area
Impacted Structures
Sanitary Lift Stations
Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
0 325 650 Feet
N
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
Dudrey Ct S
M-234
Elm St S
1st St S
2nd St S
3rd St S
4th St S
5th St S
6th St S
7th St S
8th St S
9th St S
10th St S
10th St N
11th St N
11th St S
12th St S
13th St S
14th St S
15th St S
16th St S
17th St S
18th St S
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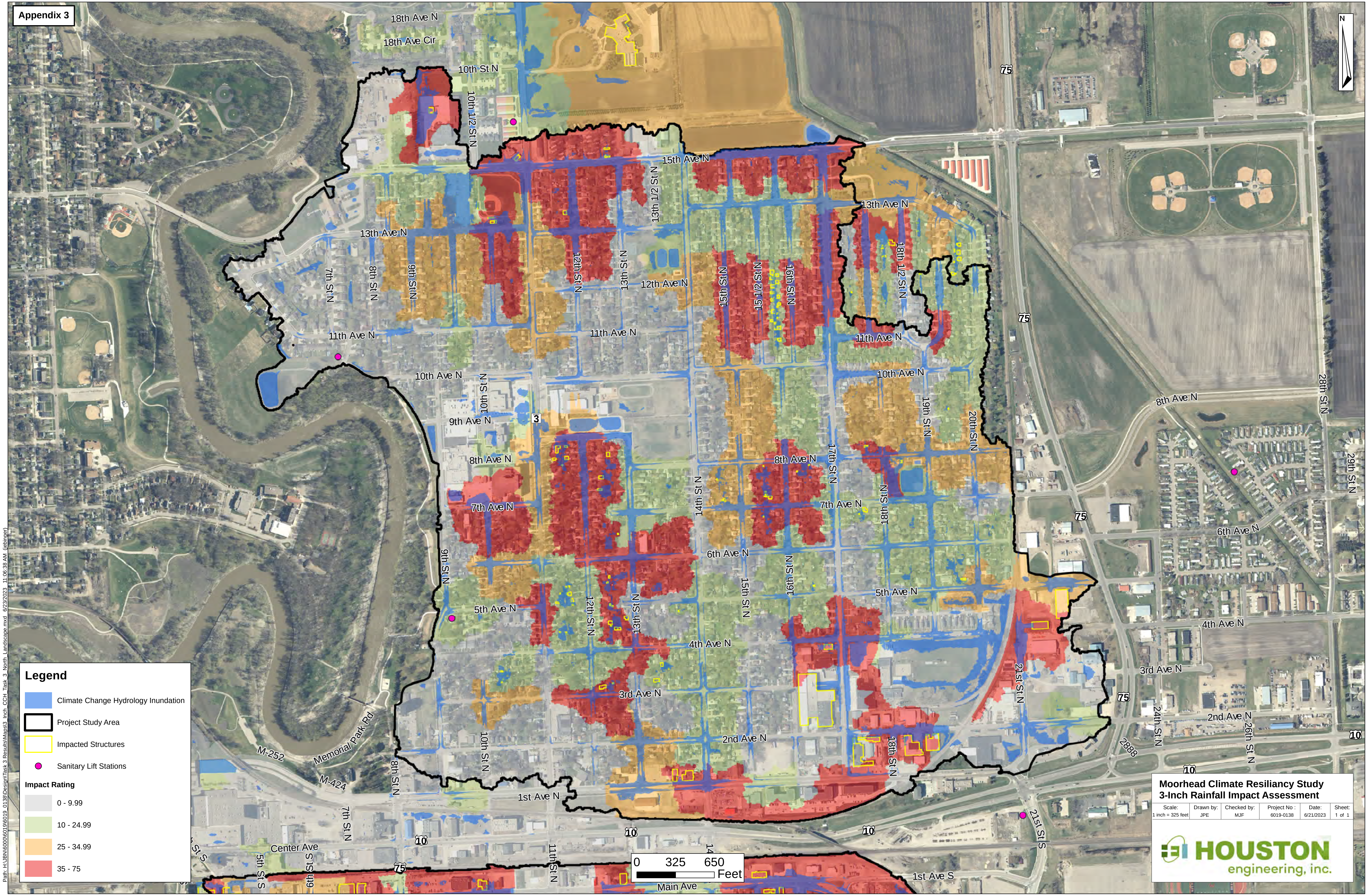
19th St S
19th 1/2 St S
20th St S
21st St S
22nd St S
23rd St S
24th St S
25th St S
26th St S
Birch La
Birch Cir
Oak Way
Maple La S
Cedar La S
Birch La S
Appletree La S
Rensvold Blvd S
Walnut Cir S
Willow Way S
10
75


Appendix 3
Legend
Climate Change Hydrology Inundation
Project Study Area
Impacted Structures
Sanitary Lift Stations
Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
Moorhead Climate Resiliancy Study
3-Inch Rainfall Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
0 325 650 Feet
N
18th Ave N
18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
13th 1/2 St N
13th Ave N
7th St N
8th St N
9th St N
12th St N
13th St N
12th Ave N
15th St N
15 1/2 St N
16th St N
18th 1/2 St N
11th Ave N
10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
Center Ave
Main Ave
1st Ave S
14th St N
17th St N
18th St N
19th St N
20th St N
21st St N
24th St N
26th St N
28th St N
29th St N
21st St S
5th St S
6th St S
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11th St N
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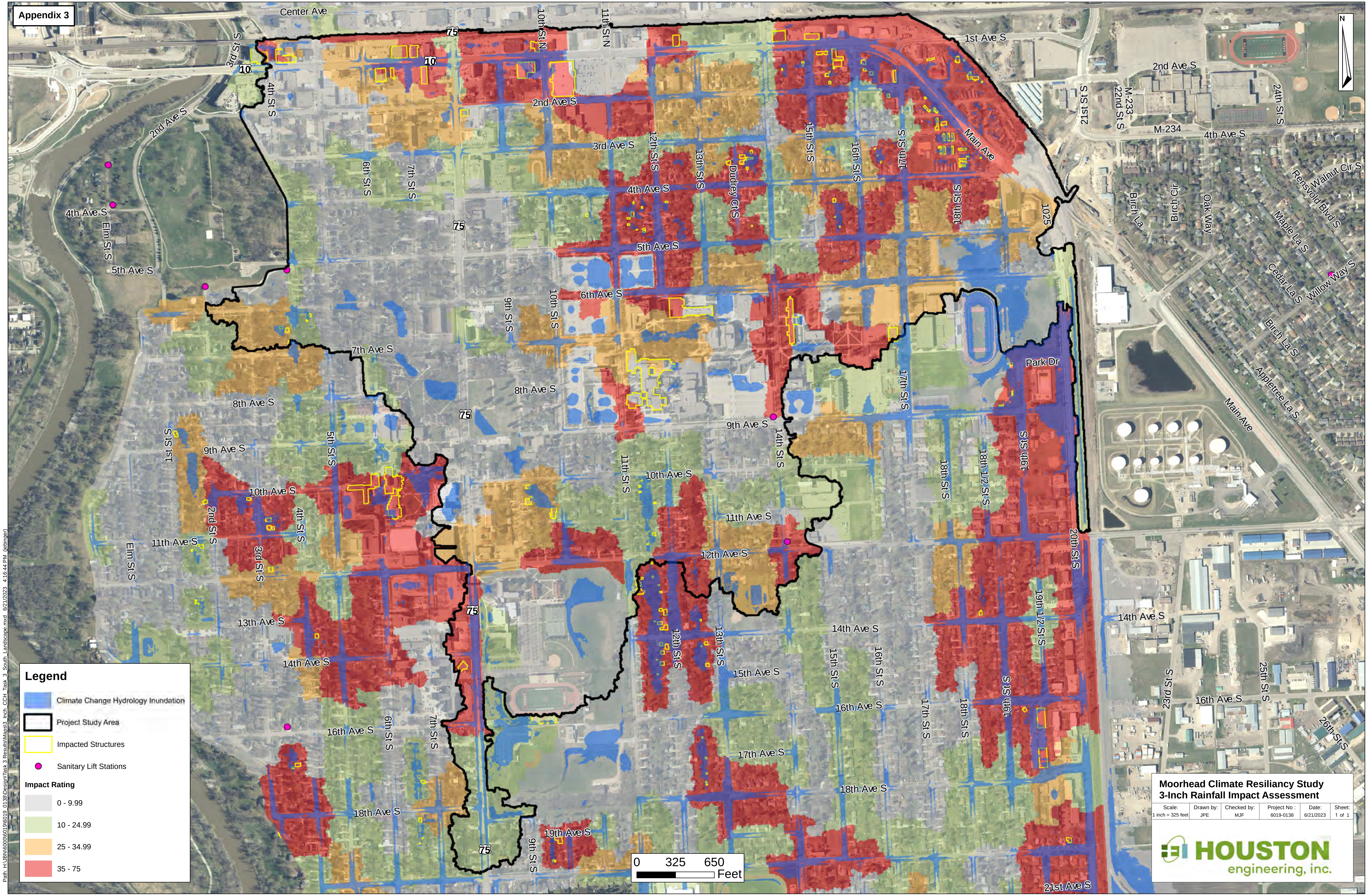
M-252
M-424
2888
75
10
3



Appendix 3
Legend
Climate Change Hydrology Inundation
Project Study Area
Impacted Structures
Sanitary Lift Stations
Impact Rating
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10 - 24.99
25 - 34.99
35 - 75
0 325 650
Feet
N
Moorhead Climate Resiliancy Study
3-Inch Rainfall Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
M-234
M-233
Elm St S
1st St S
2nd St S
3rd St S
4th St S
5th St S
6th St S
7th St S
9th St S
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11th St N
11th St S
12th St S
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14th St S
15th St S
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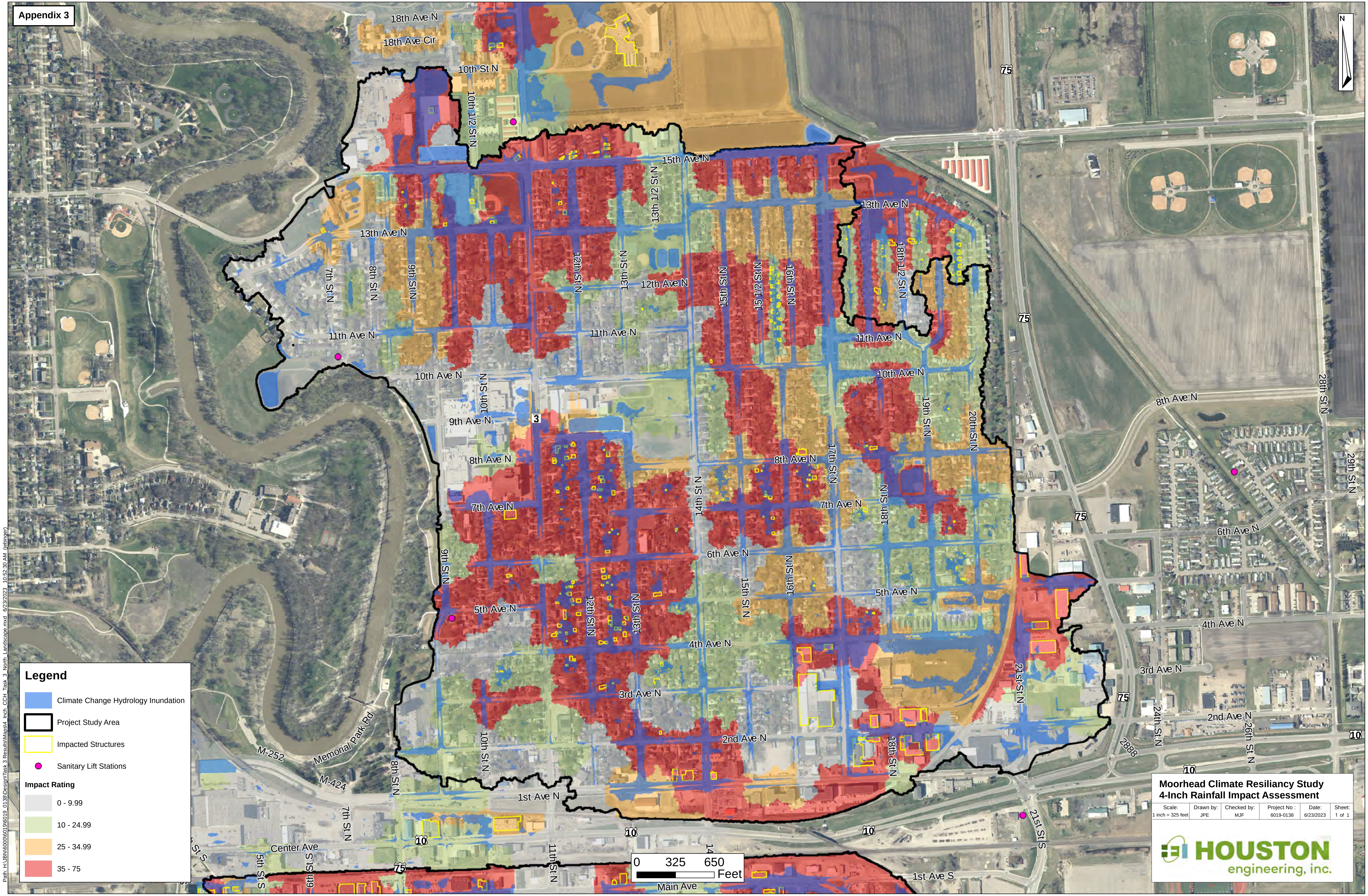
17th St S
18th St S
18th 1/2 St S
19th St S
19th 1/2 St S
20th St S
21st St S
22nd St S
23rd St S
24th St S
25th St S
26th St S
Dudrey Ct S
Birch La
Birch Cir
Oak Way
Maple La S
Cedar La S
Willow Way S
Birch La S
Appletree La S
Walnut Cir S
Rensvold Blvd S
1025
75
10


Appendix 3
Legend
Climate Change Hydrology Inundation
Project Study Area
Impacted Structures
Sanitary Lift Stations
Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
Moorhead Climate Resiliancy Study
4-Inch Rainfall Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/23/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
0 325 650 Feet
18th Ave N
18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
13th Ave N
13th 1/2 St N
12th Ave N
11th Ave N
10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
Center Ave
Main Ave
1st Ave S
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20th St N
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21st St S
24th St N
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2888
75
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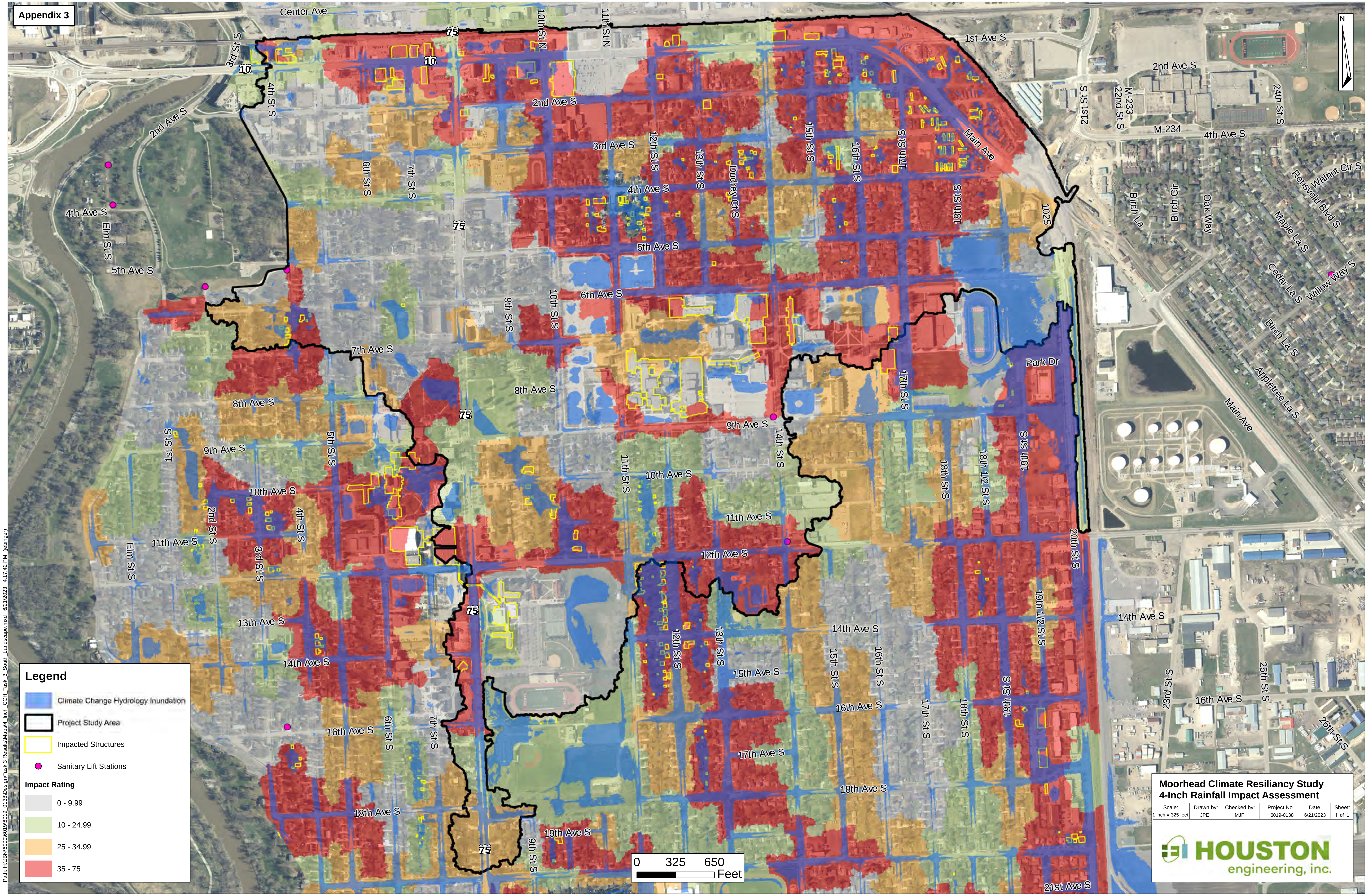
3



Appendix 3
Moorhead Climate Resiliancy Study
4-Inch Rainfall Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
Legend
Climate Change Hydrology Inundation
Project Study Area
Impacted Structures
Sanitary Lift Stations
Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
0 325 650
Feet
N
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
M-234
M-233
Elm St S
1st St S
2nd St S
3rd St S
4th St S
5th St S
6th St S
7th St S
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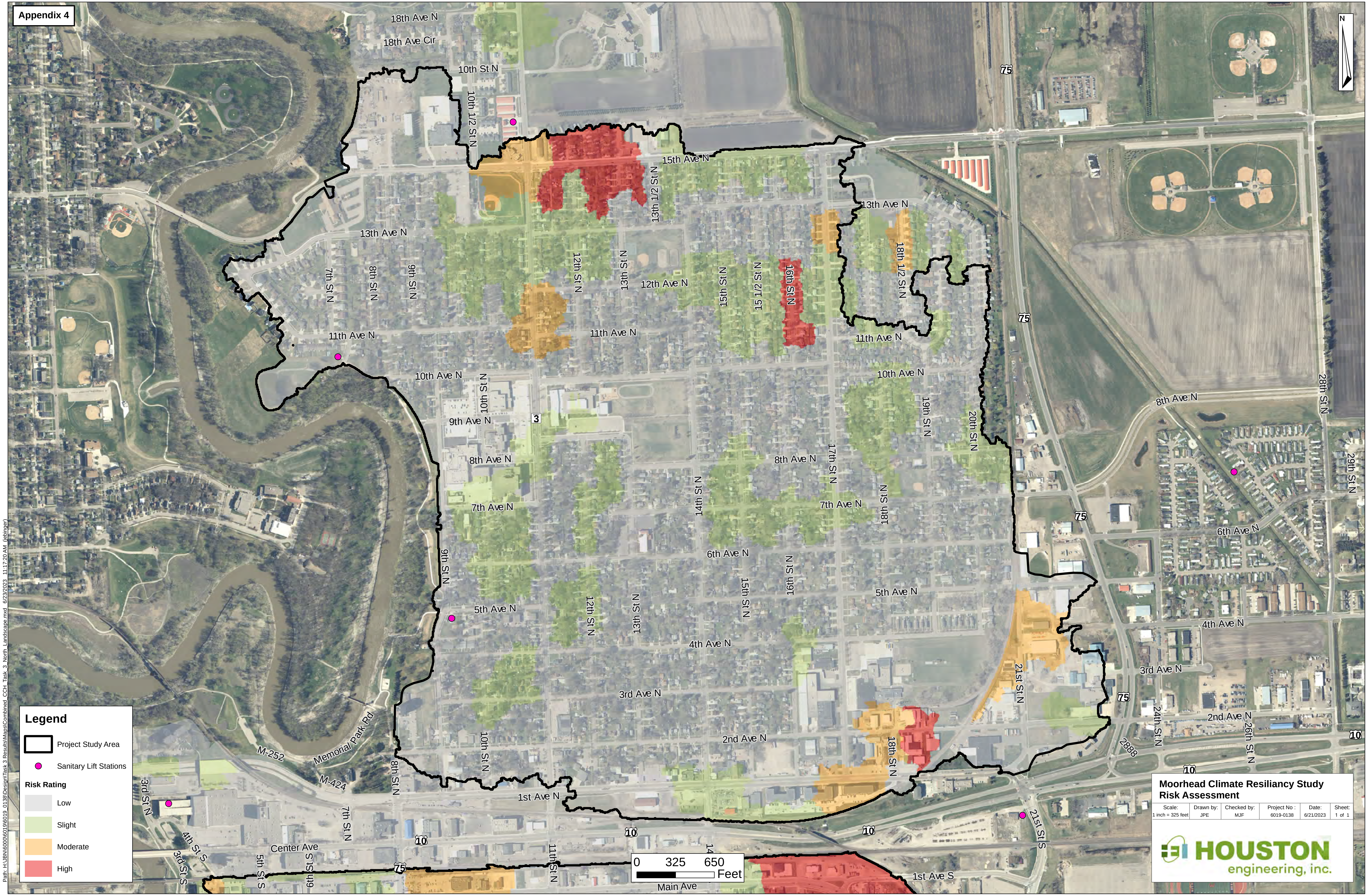
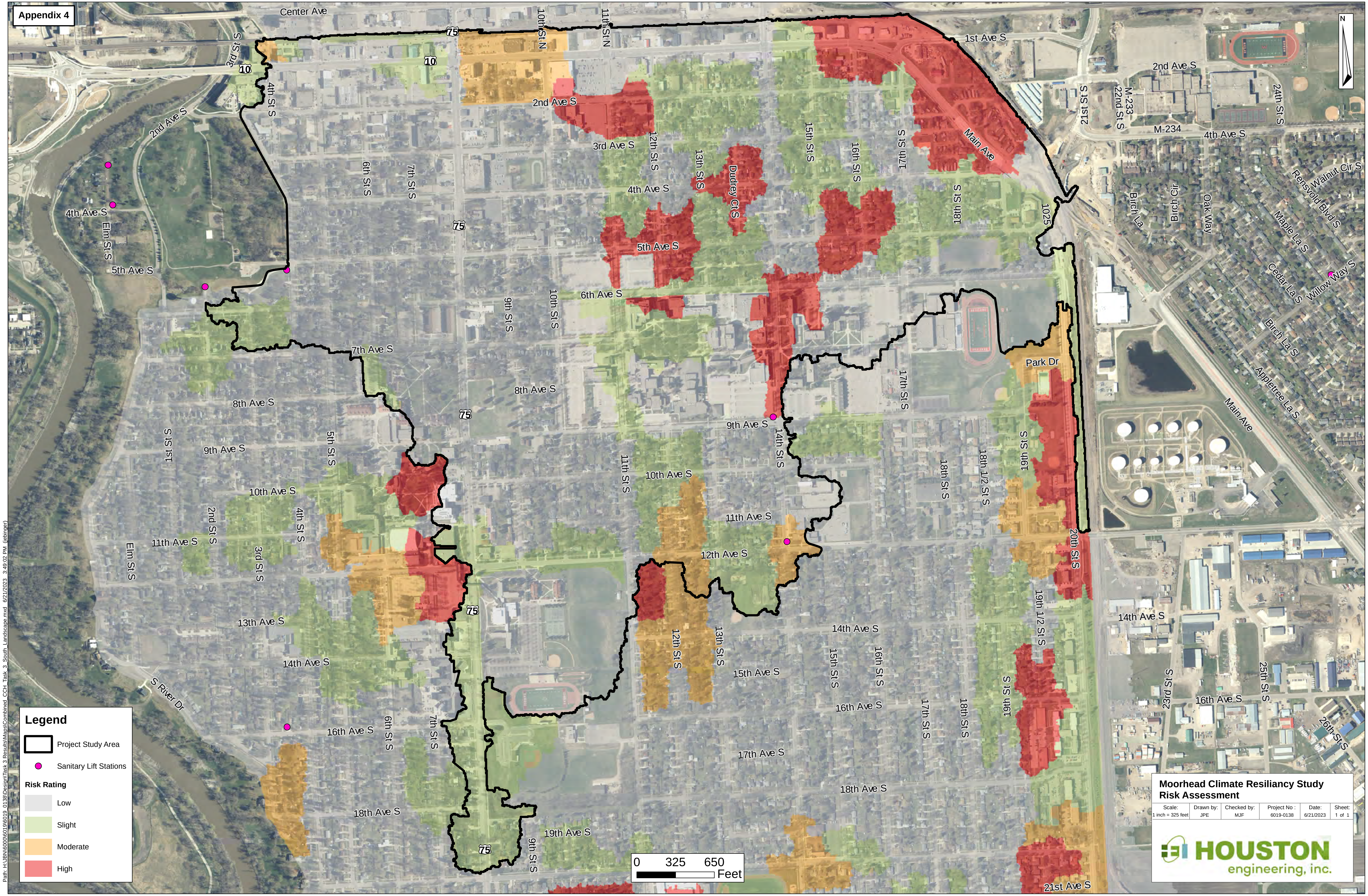
19th St S
19th 1/2 St S
20th St S
21st St S
22nd St S
23rd St S
24th St S
25th St S
26th St S
Dudley Ct S
Birch La
Birch Cir
Oak Way
Maple La S
Cedar La S
Birch La S
Appletree La S
Rensvold Blvd S
Walnut Cir S
Willow Way S
10
75
1025

APPENDIX 4

Existing Conditions CCH Risk Assessment



Appendix 4
Legend
Project Study Area
Sanitary Lift Stations
Risk Rating
Low
Slight
Moderate
High
0 325 650
Feet
N
Moorhead Climate Resiliancy Study
Risk Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
18th Ave N
18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
13th 1/2 St N
13th Ave N
12th Ave N
11th Ave N
10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
Main Ave
Center Ave
1st Ave S
7th St N
8th St N
9th St N
12th St N
13th St N
14th St N
15th St N
15 1/2 St N
16th St N
17th St N
18th St N
18th 1/2 St N
19th St N
20th St N
21st St N
24th St N
26th St N
28th St N
29th St N
21st St S
3rd St N
4th St S
3rd St S
5th St S
6th St S
11th St N
Memorial Park Rd
M-252
M-424
2888
75
10
3


Appendix 4
Moorhead Climate Resiliancy Study
Risk Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
Legend
Project Study Area
Sanitary Lift Stations
Risk Rating
Low
Slight
Moderate
High
0 325 650 Feet
N
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
S River Dr
M-234
Elm St S
1st St S
2nd St S
3rd St S
4th St S
5th St S
6th St S
7th St S
9th St S
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11th St N
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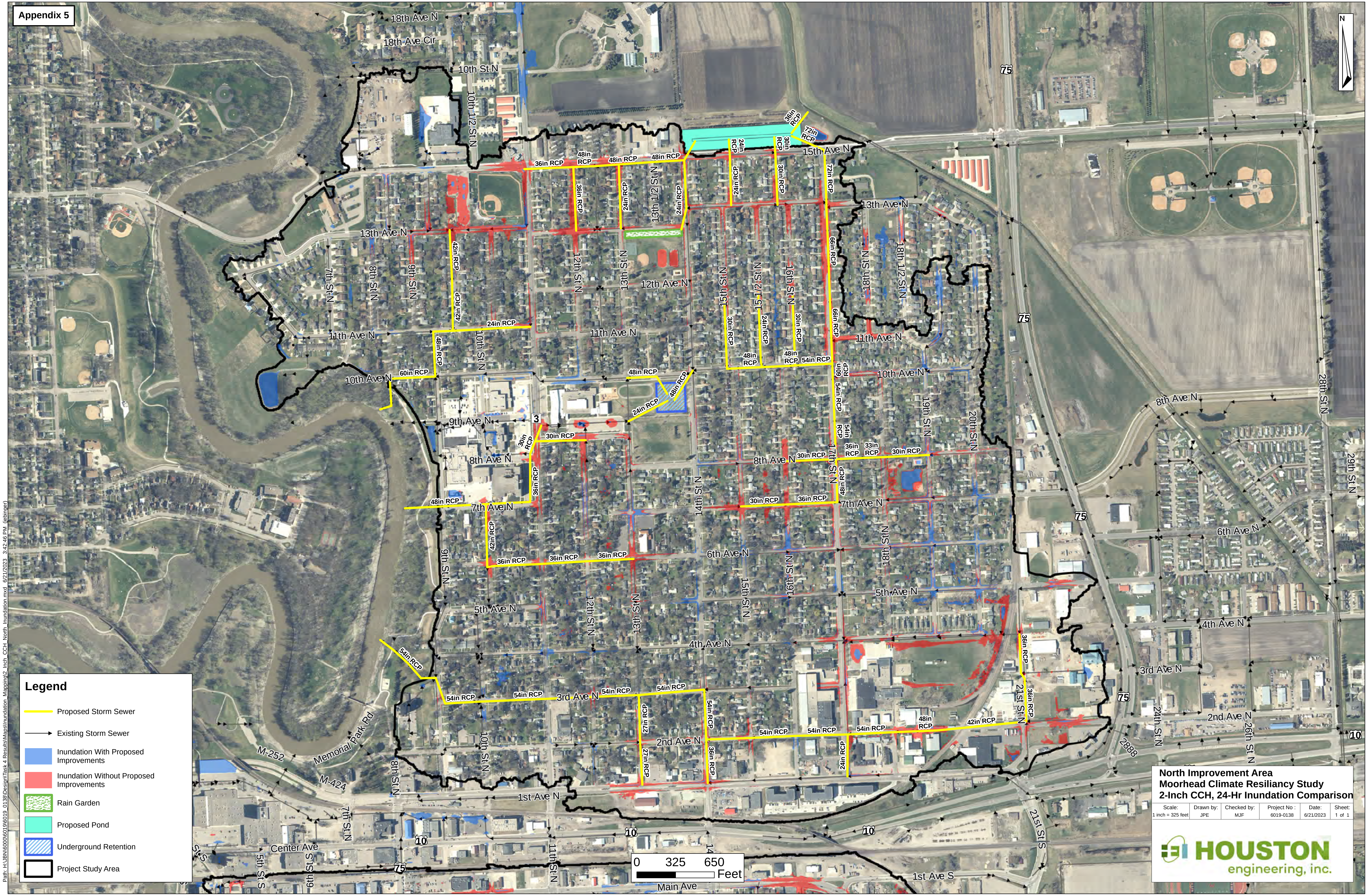
20th St S
21st St S
22nd St S
23rd St S
24th St S
25th St S
26th St S
Dudley Ct S
Birch La
Birch Cir
Oak Way
Maple La S
Cedar La S
Birch La S
Appletree La S
Willow Way S
Walnut Cir S
Rensvold Blvd S
75
10
1025

APPENDIX 5

Proposed Conditions Inundation Comparison

Appendix 5



North Improvement Area
Moorhead Climate Resiliancy Study
2-Inch CCH, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
Legend
Proposed Storm Sewer
Existing Storm Sewer
Inundation With Proposed Improvements
Inundation Without Proposed Improvements
Rain Garden
Proposed Pond
Underground Retention
Project Study Area
0 325 650 Feet
15th Ave N
13th Ave N
12th Ave N
11th Ave N
10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
18th Ave N
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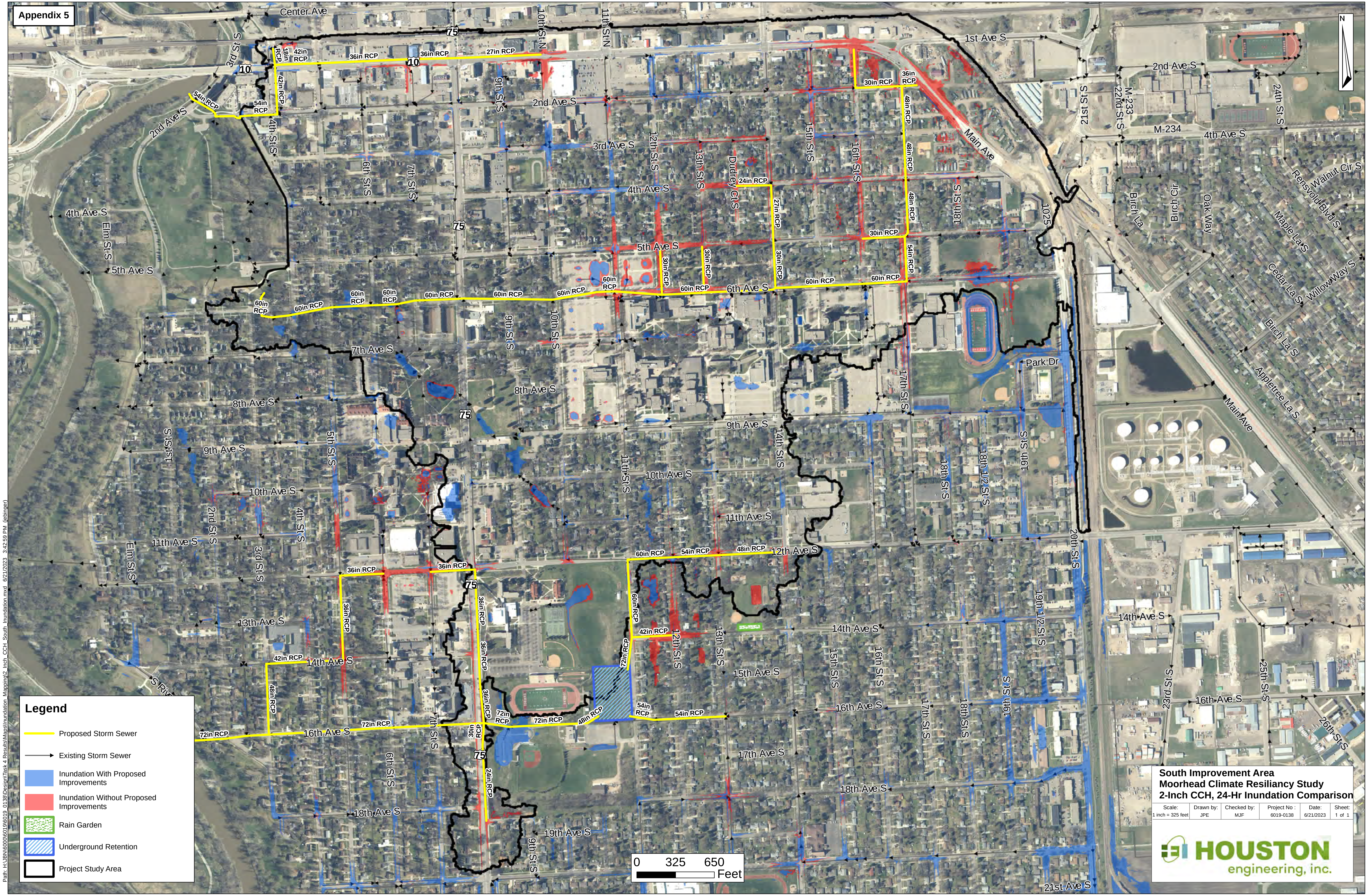
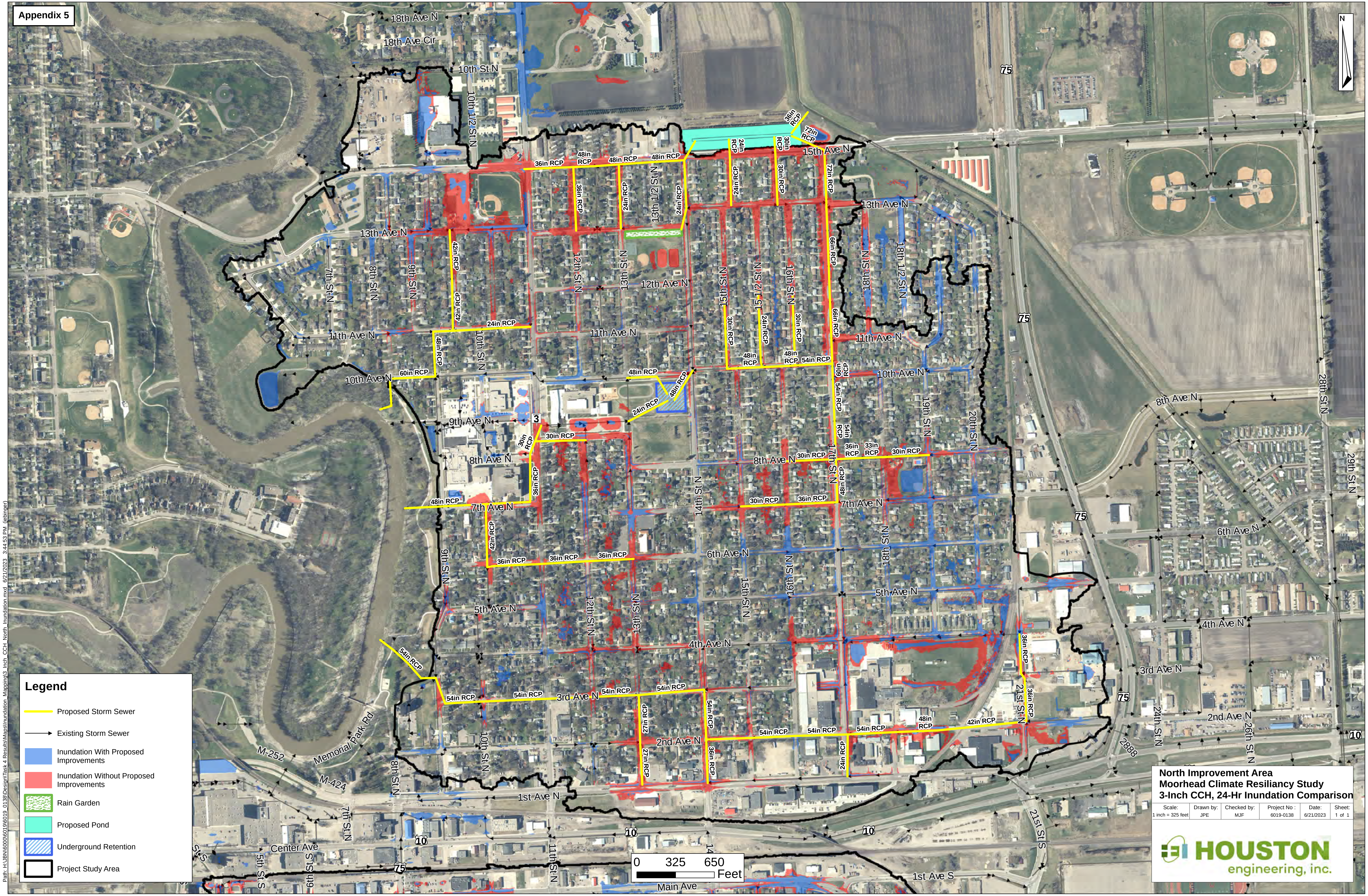
Center Ave
Main Ave
1st Ave S
Memorial Park Rd
M-252
M-424


Appendix 5
Legend
Proposed Storm Sewer
Existing Storm Sewer
Inundation With Proposed Improvements
Inundation Without Proposed Improvements
Rain Garden
Underground Retention
Project Study Area
South Improvement Area
Moorhead Climate Resiliancy Study
2-Inch CCH, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
0 325 650 Feet
N
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
60in RCP
72in RCP
54in RCP
48in RCP
42in RCP
36in RCP
30in RCP
27in RCP
24in RCP

Appendix 5


Legend
Proposed Storm Sewer
Existing Storm Sewer
Inundation With Proposed Improvements
Inundation Without Proposed Improvements
Rain Garden
Proposed Pond
Underground Retention
Project Study Area
North Improvement Area
Moorhead Climate Resiliancy Study
3-Inch CCH, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
0 325 650 Feet
18th Ave N
18th Ave Cir
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10th 1/2 St N
15th Ave N
13th Ave N
12th Ave N
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9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
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Center Ave
Main Ave
1st Ave S
7th St N
8th St N
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12th St N
13th St N
13th 1/2 St N
14th St N
15th St N
15 1/2 St N
16th St N
17th St N
18th St N
18th 1/2 St N
19th St N
20th St N
21st St N
21st St S
24th St N
26th St N
28th St N
29th St N
Memorial Park Rd
M-252
M-424
2888
75
10
24in RCP
30in RCP
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60in RCP
66in RCP
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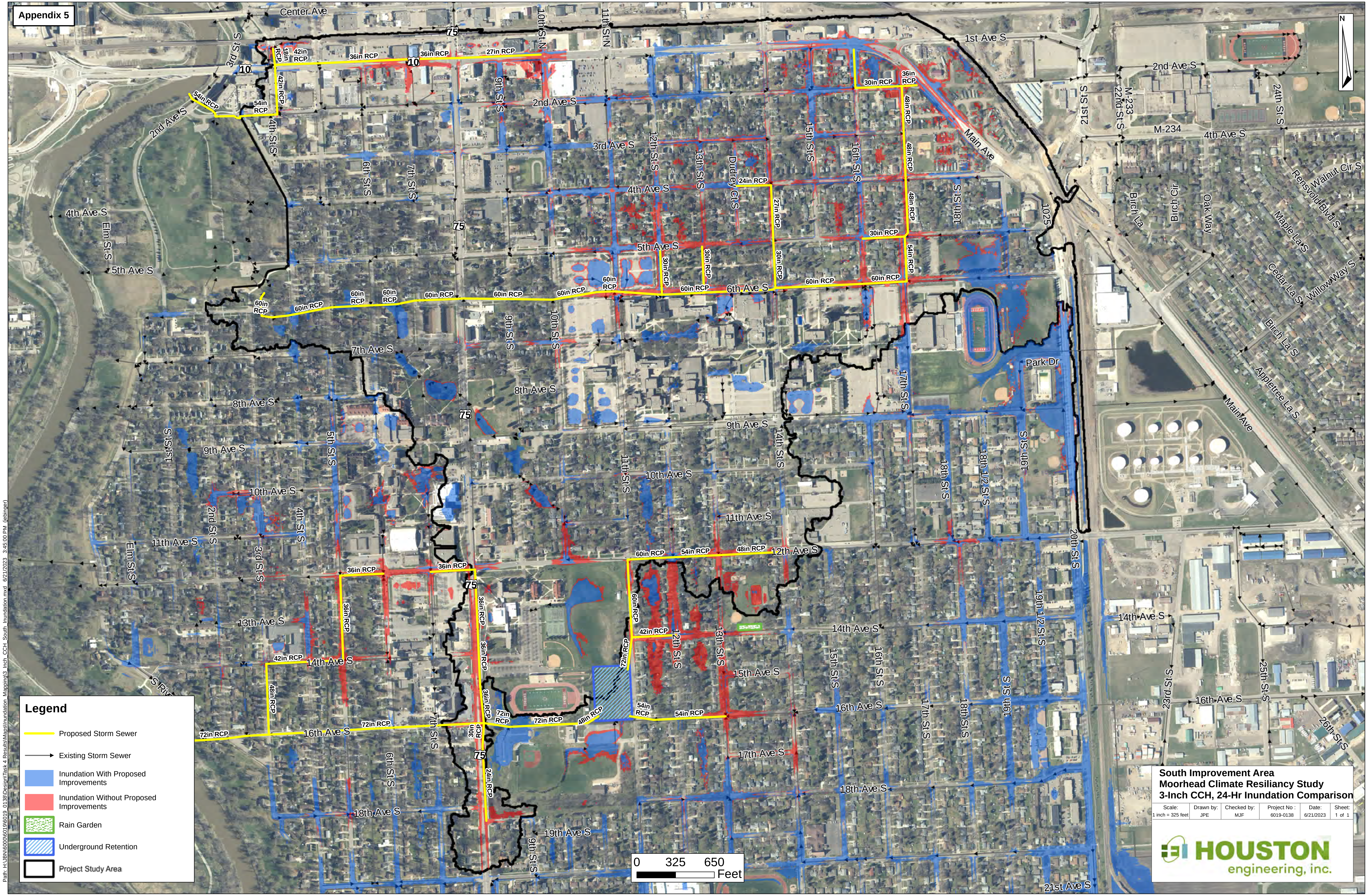
27in RCP
33in RCP


Appendix 5
Legend
Proposed Storm Sewer
Existing Storm Sewer
Inundation With Proposed Improvements
Inundation Without Proposed Improvements
Rain Garden
Underground Retention
Project Study Area
South Improvement Area
Moorhead Climate Resiliency Study
3-Inch CCH, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
0 325 650 Feet
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
36in RCP
60in RCP
72in RCP
48in RCP
54in RCP
42in RCP
30in RCP
24in RCP
27in RCP

Appendix 5


Legend
Proposed Storm Sewer
Existing Storm Sewer
Inundation With Proposed Improvements
Inundation Without Proposed Improvements
Rain Garden
Proposed Pond
Underground Retention
Project Study Area
0 325 650
Feet
18th Ave N
18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
13th Ave N
12th Ave N
11th Ave N
10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
Center Ave
Main Ave
1st Ave S
7th St N
8th St N
9th St N
11th St N
12th St N
13th St N
13th 1/2 St N
14th St N
15th St N
15 1/2 St N
16th St N
17th St N
18th St N
18th 1/2 St N
19th St N
20th St N
21st St N
21st St S
24th St N
26th St N
28th St N
29th St N
8th Ave N
6th Ave N
4th Ave N
3rd Ave N
2nd Ave N
Memorial Park Rd
M-252
M-424
2888
75
10
36in RCP
48in RCP
24in RCP
30in RCP
42in RCP
54in RCP
60in RCP
66in RCP
72in RCP
27in RCP
33in RCP
North Improvement Area
Moorhead Climate Resiliancy Study
4-Inch CCH, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
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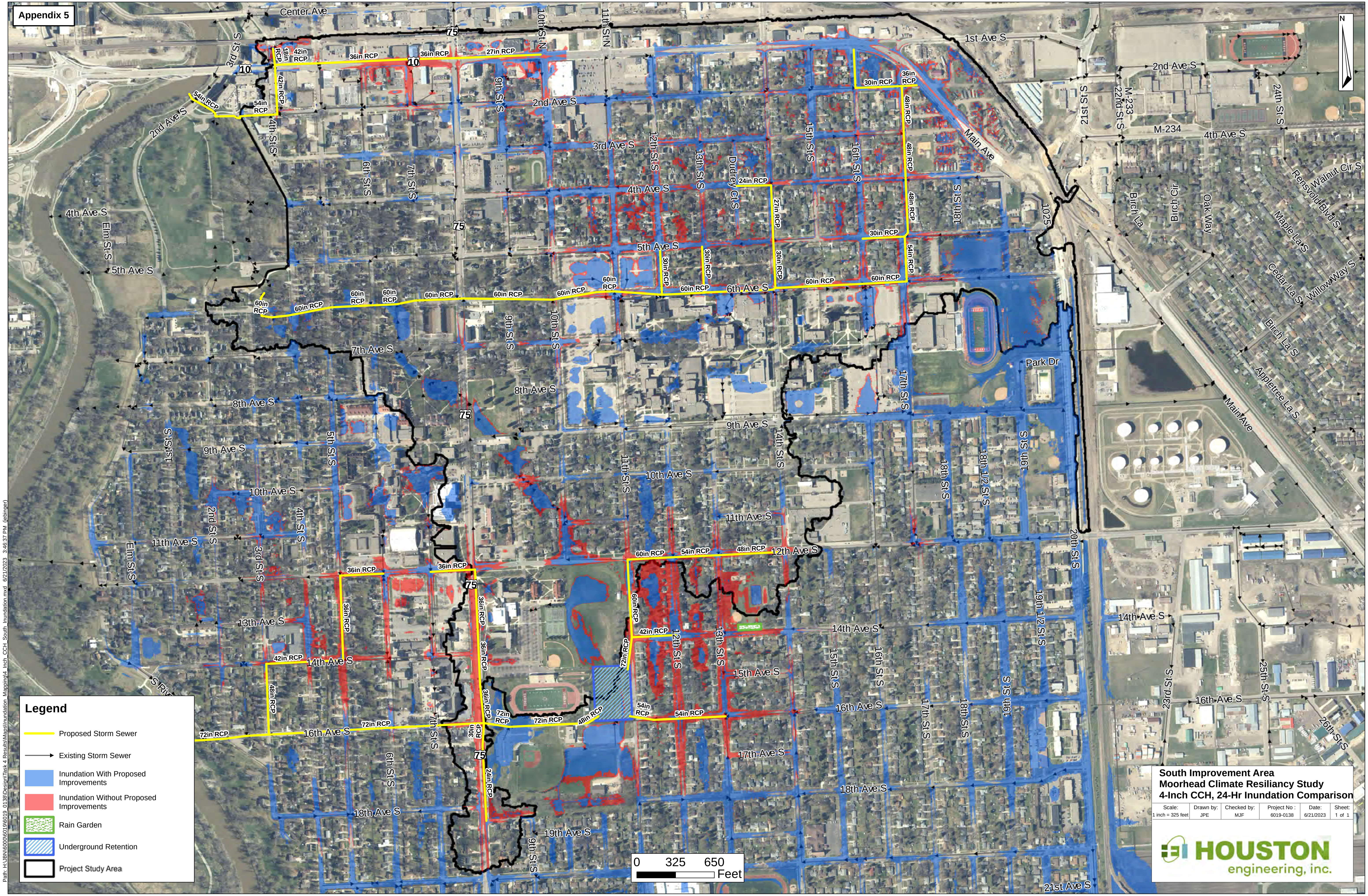
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.



Appendix 5
Legend
Proposed Storm Sewer
Existing Storm Sewer
Inundation With Proposed Improvements
Inundation Without Proposed Improvements
Rain Garden
Underground Retention
Project Study Area
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Feet
South Improvement Area
Moorhead Climate Resiliancy Study
4-Inch CCH, 24-Hr Inundation Comparison
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
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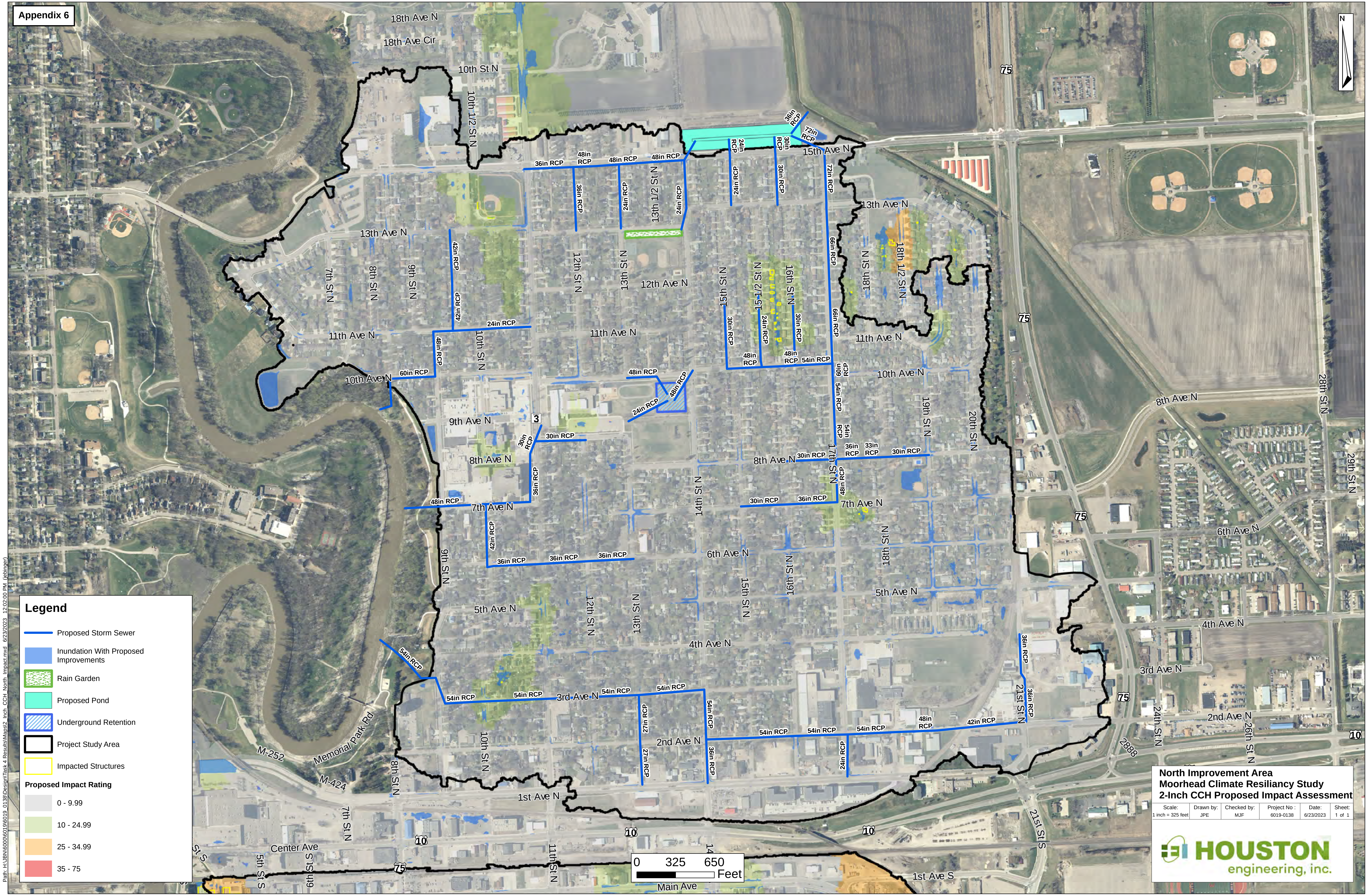
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.

APPENDIX 6

Proposed Conditions CCH Impact Assessment



Appendix 6
Legend
Proposed Storm Sewer
Inundation With Proposed Improvements
Rain Garden
Proposed Pond
Underground Retention
Project Study Area
Impacted Structures
Proposed Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
North Improvement Area
Moorhead Climate Resiliancy Study
2-Inch CCH Proposed Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/23/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
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18th Ave Cir
10th St N
10th 1/2 St N
15th Ave N
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12th Ave N
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10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
Center Ave
Main Ave
1st Ave S
7th St N
8th St N
9th St N
12th St N
13th St N
13th 1/2 St N
14th St N
15th St N
15 1/2 St N
16th St N
17th St N
18th St N
18th 1/2 St N
19th St N
20th St N
21st St N
24th St N
26th St N
28th St N
29th St N
21st St S
Memorial Park Rd
M-252
M-424
2888
75
10
36in RCP
48in RCP
42in RCP
24in RCP
30in RCP
60in RCP
54in RCP
66in RCP
72in RCP
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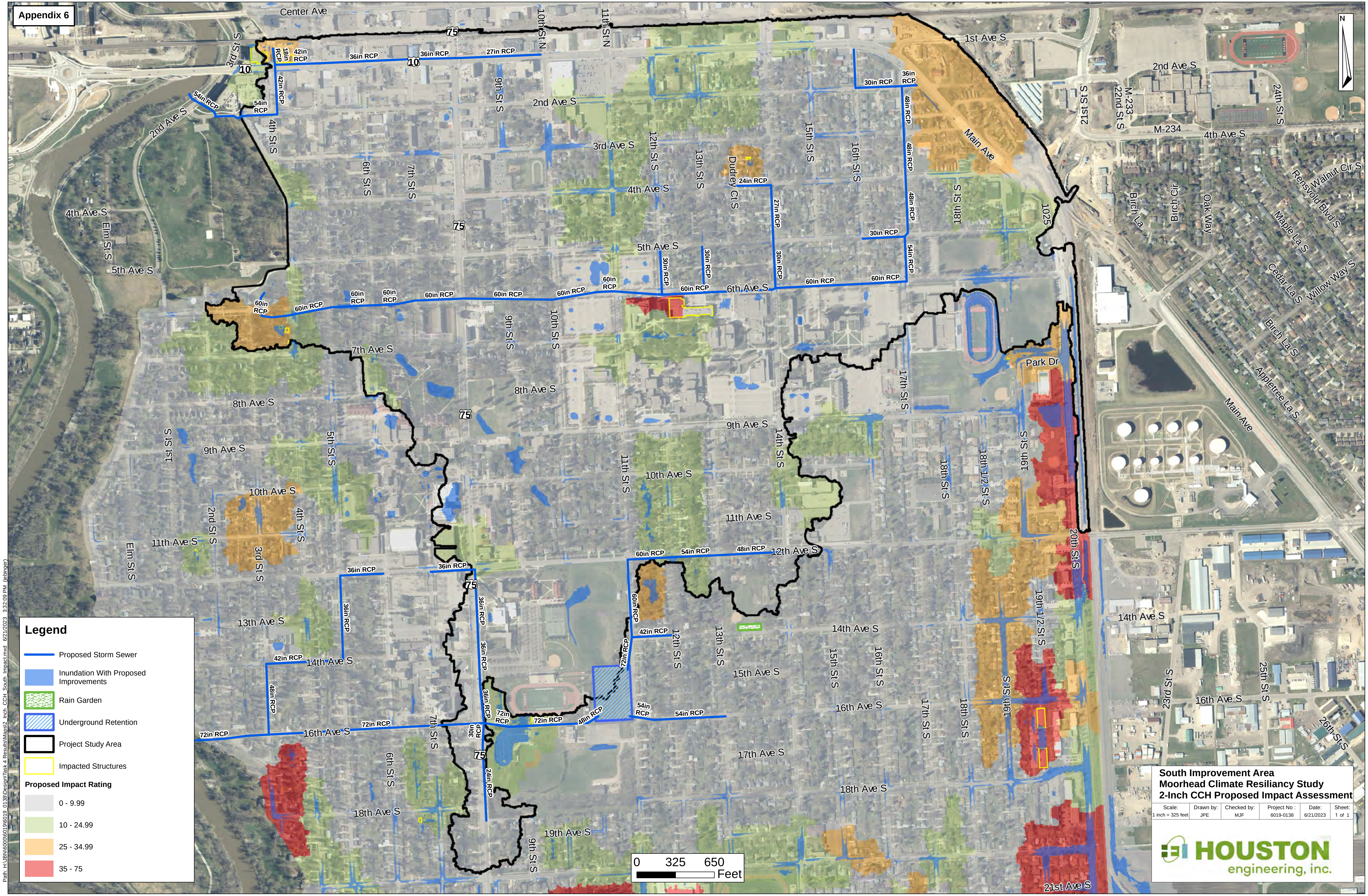
Appendix 6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Proposed Storm Sewer
Inundation With Proposed Improvements
Rain Garden
Underground Retention
Project Study Area
Impacted Structures
Proposed Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
South Improvement Area
Moorhead Climate Resiliency Study
2-Inch CCH Proposed Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
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2nd Ave S
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7th Ave S
8th Ave S
9th Ave S
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11th Ave S
12th Ave S
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16th Ave S
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20th St S
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22nd St S
23rd St S
24th St S
25th St S
26th St S
Dudley Ct S
Elm St S
Birch La
Birch Cir
Oak Way
Maple La S
Cedar La S
Birch La S
Appletree La S
Renwold Blvd S
Walnut Cir S
Willow Way S
75
10
1025
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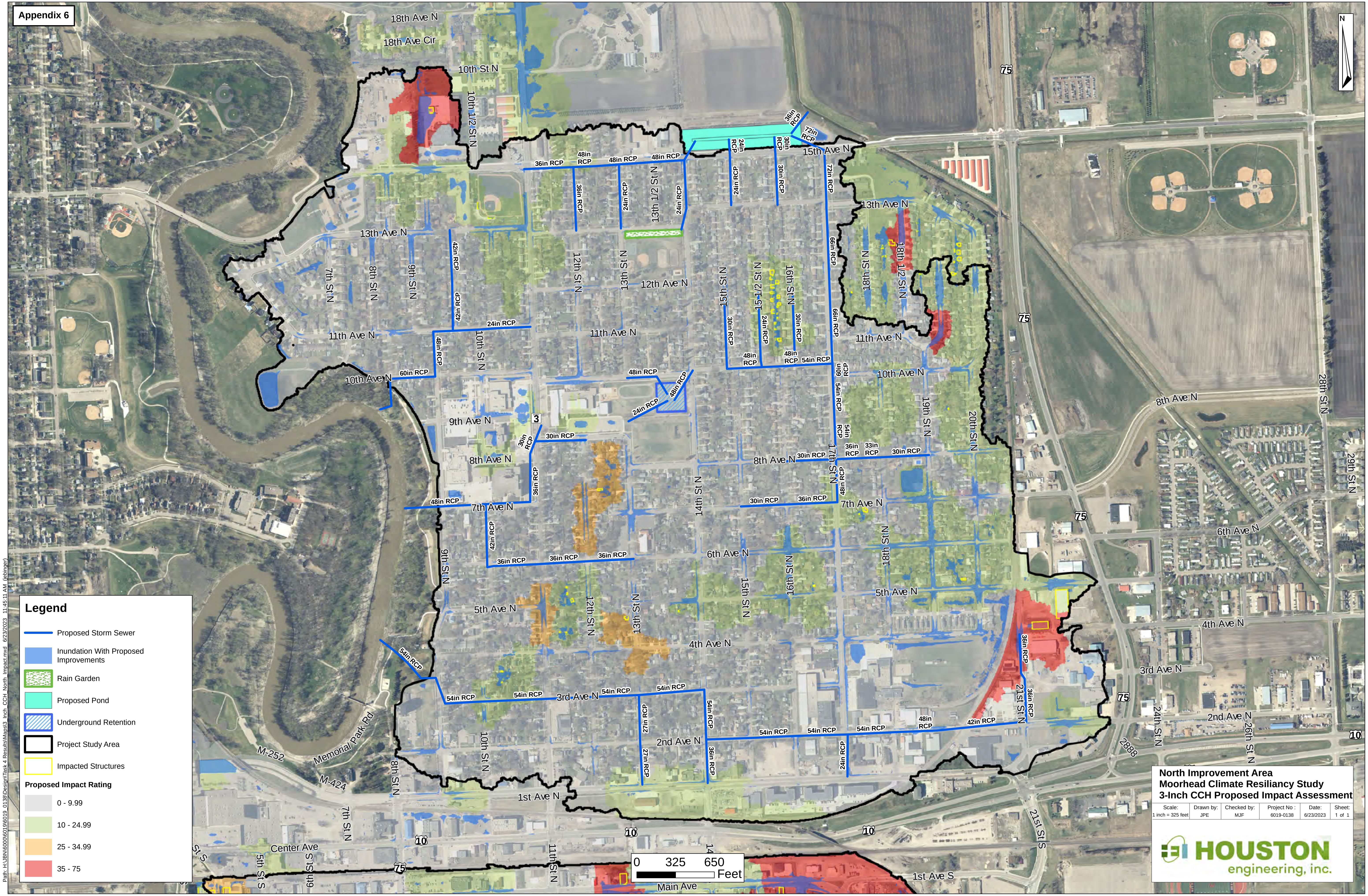
Appendix 6
Legend
Proposed Storm Sewer
Inundation With Proposed Improvements
Rain Garden
Proposed Pond
Underground Retention
Project Study Area
Impacted Structures
Proposed Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
North Improvement Area
Moorhead Climate Resiliancy Study
3-Inch CCH Proposed Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/23/2023
Sheet: 1 of 1
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12th Ave N
11th Ave N
10th Ave N
9th Ave N
8th Ave N
7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
Center Ave
Main Ave
1st Ave S
7th St N
8th St N
9th St N
12th St N
13th St N
13th 1/2 St N
14th St N
15th St N
15 1/2 St N
16th St N
17th St N
18th St N
18th 1/2 St N
19th St N
20th St N
21st St N
24th St N
26th St N
28th St N
29th St N
21st St S
Memorial Park Rd
M-252
M-424
2888
75
10
36in RCP
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60in RCP
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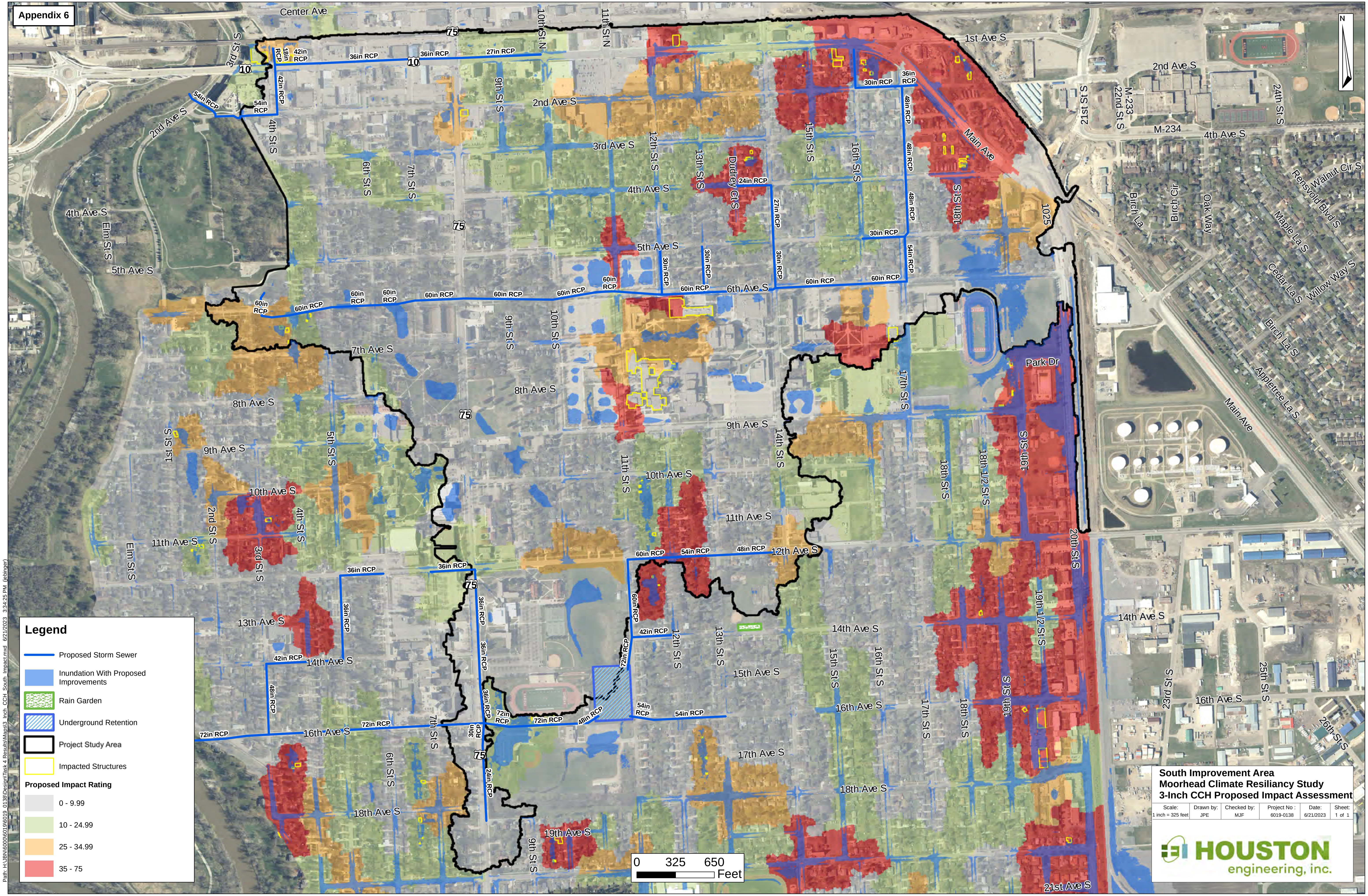
Appendix 6
Legend
Proposed Storm Sewer
Inundation With Proposed Improvements
Rain Garden
Underground Retention
Project Study Area
Impacted Structures
Proposed Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
0 325 650 Feet
South Improvement Area
Moorhead Climate Resiliency Study
3-Inch CCH Proposed Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
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4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
10th Ave S
11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
Dudley Ct S
M-234
Elm St S
Birch Cir
Oak Way
Maple La S
Cedar La S
Willow Way S
Birch La S
Appletree La S
Rensvold Blvd S
Walnut Cir S
60in RCP
54in RCP
48in RCP
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24in RCP
72in RCP
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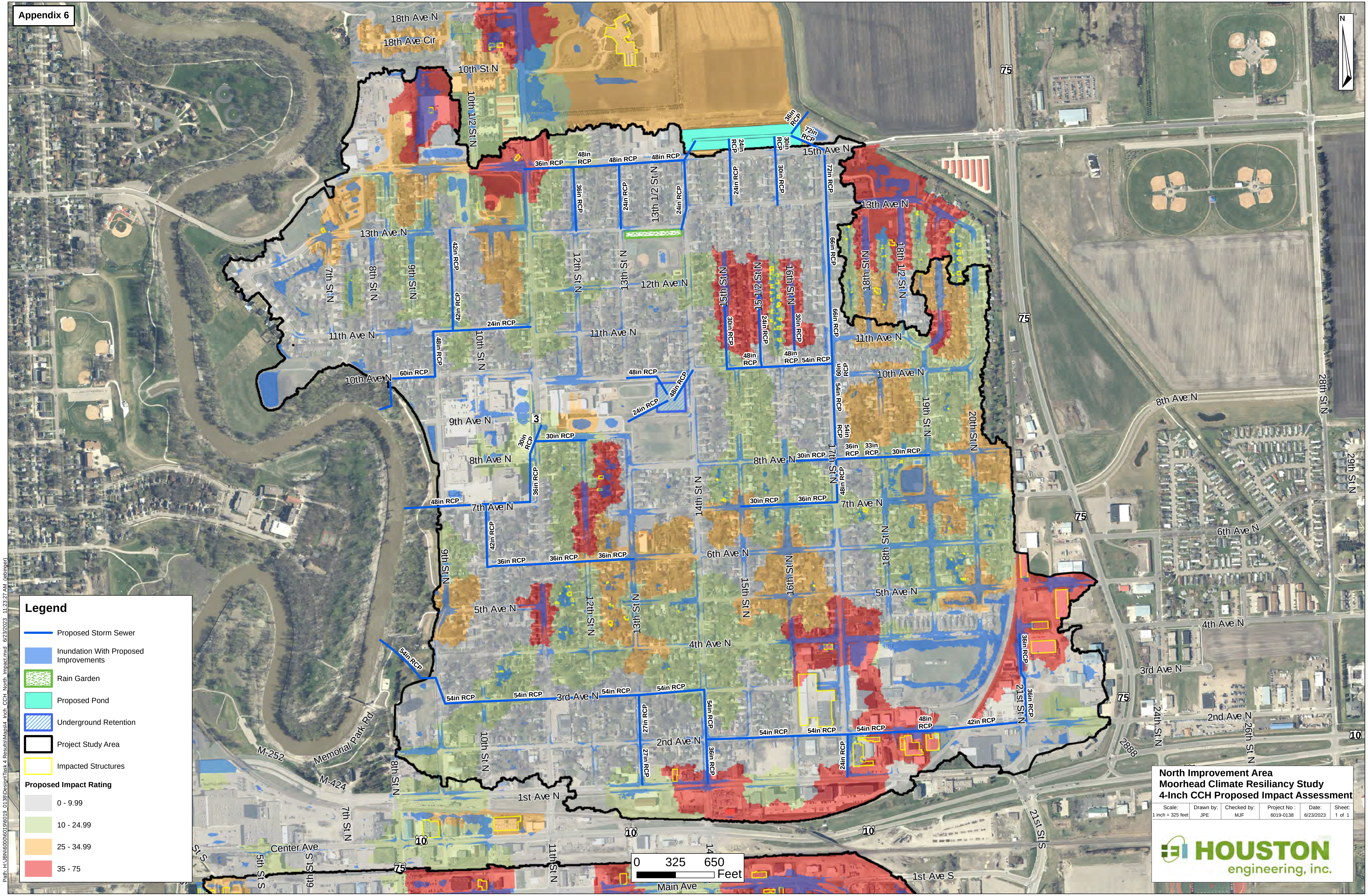
Appendix 6
Legend
Proposed Storm Sewer
Inundation With Proposed Improvements
Rain Garden
Proposed Pond
Underground Retention
Project Study Area
Impacted Structures
Proposed Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
North Improvement Area
Moorhead Climate Resiliancy Study
4-Inch CCH Proposed Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
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Sheet: 1 of 1
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18th Ave Cir
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10th 1/2 St N
15th Ave N
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12th Ave N
11th Ave N
10th Ave N
9th Ave N
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7th Ave N
6th Ave N
5th Ave N
4th Ave N
3rd Ave N
2nd Ave N
1st Ave N
Center Ave
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26th St N
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Memorial Park Rd
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36in RCP
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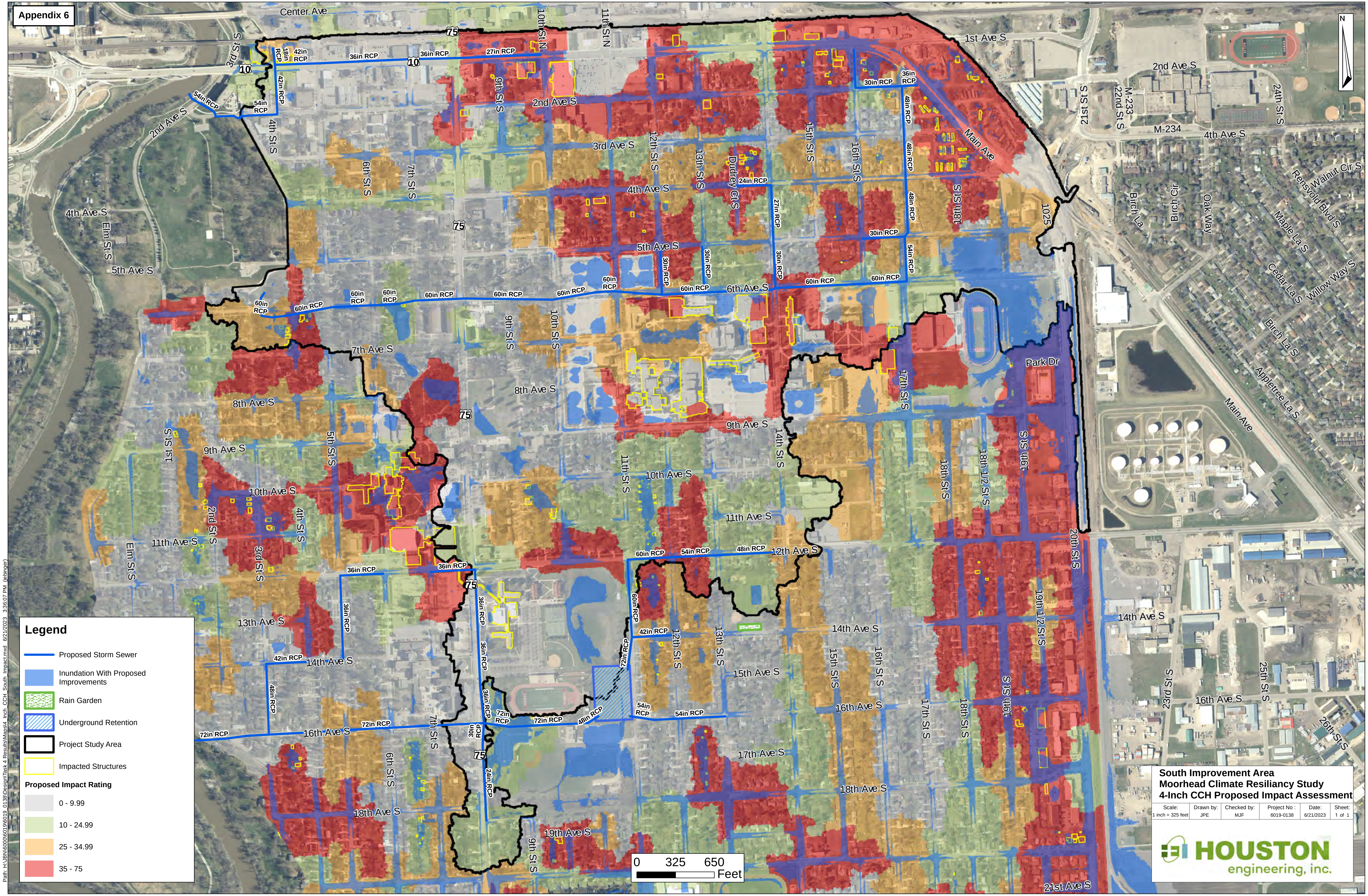

Appendix 6
South Improvement Area
Moorhead Climate Resiliancy Study
4-Inch CCH Proposed Impact Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No.: 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.
Legend
Proposed Storm Sewer
Inundation With Proposed Improvements
Rain Garden
Underground Retention
Project Study Area
Impacted Structures
Proposed Impact Rating
0 - 9.99
10 - 24.99
25 - 34.99
35 - 75
0 325 650 Feet
Center Ave
1st Ave S
2nd Ave S
3rd Ave S
4th Ave S
5th Ave S
6th Ave S
7th Ave S
8th Ave S
9th Ave S
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11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
M-234
Dudrey Cir S
Elm St S
1st St S
2nd St S
3rd St S
4th St S
5th St S
6th St S
7th St S
9th St S
10th St S
11th St S
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13th St S
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20th St S
21st St S
22nd St S
23rd St S
24th St S
25th St S
26th St S
Birch La
Birch Cir
Oak Way
Maple La S
Cedar La S
Willow Way S
Birch La S
Appletree La S
Walnut Cir S
Rensvold Blvd S
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48in RCP
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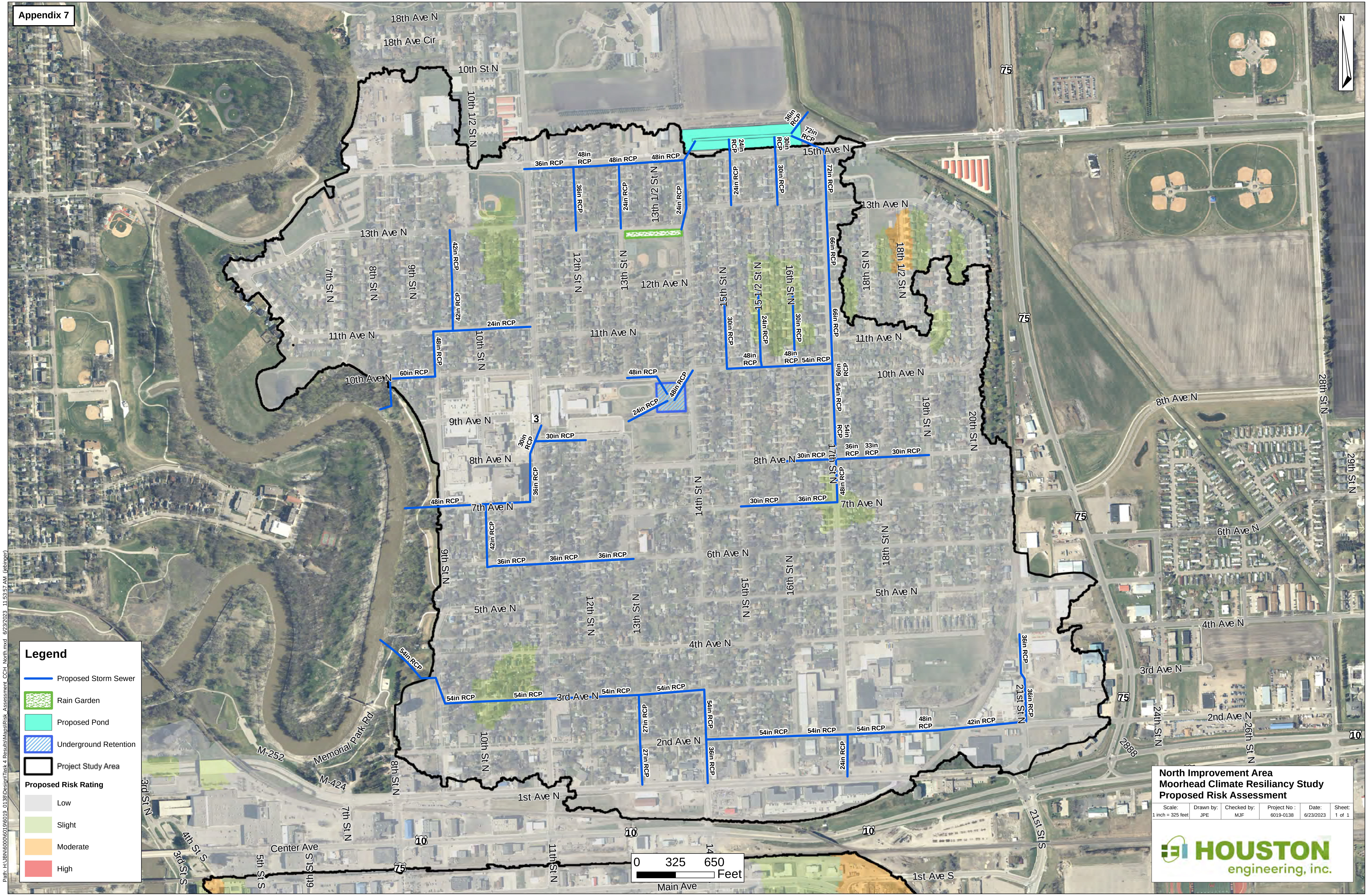
18in RCP

APPENDIX 7

PROPOSED CONDITIONS CCH RISK ASSESSMENT


Appendix 7
Legend
Proposed Storm Sewer
Rain Garden
Proposed Pond
Underground Retention
Project Study Area
Proposed Risk Rating
Low
Slight
Moderate
High
North Improvement Area
Moorhead Climate Resiliency Study
Proposed Risk Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/23/2023
Sheet: 1 of 1
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3rd Ave N
2nd Ave N
1st Ave N
Center Ave
Main Ave
1st Ave S
7th St N
8th St N
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12th St N
13th St N
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16th St N
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19th St N
20th St N
21st St N
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21st St S
Memorial Park Rd
M-252
M-424
36in RCP
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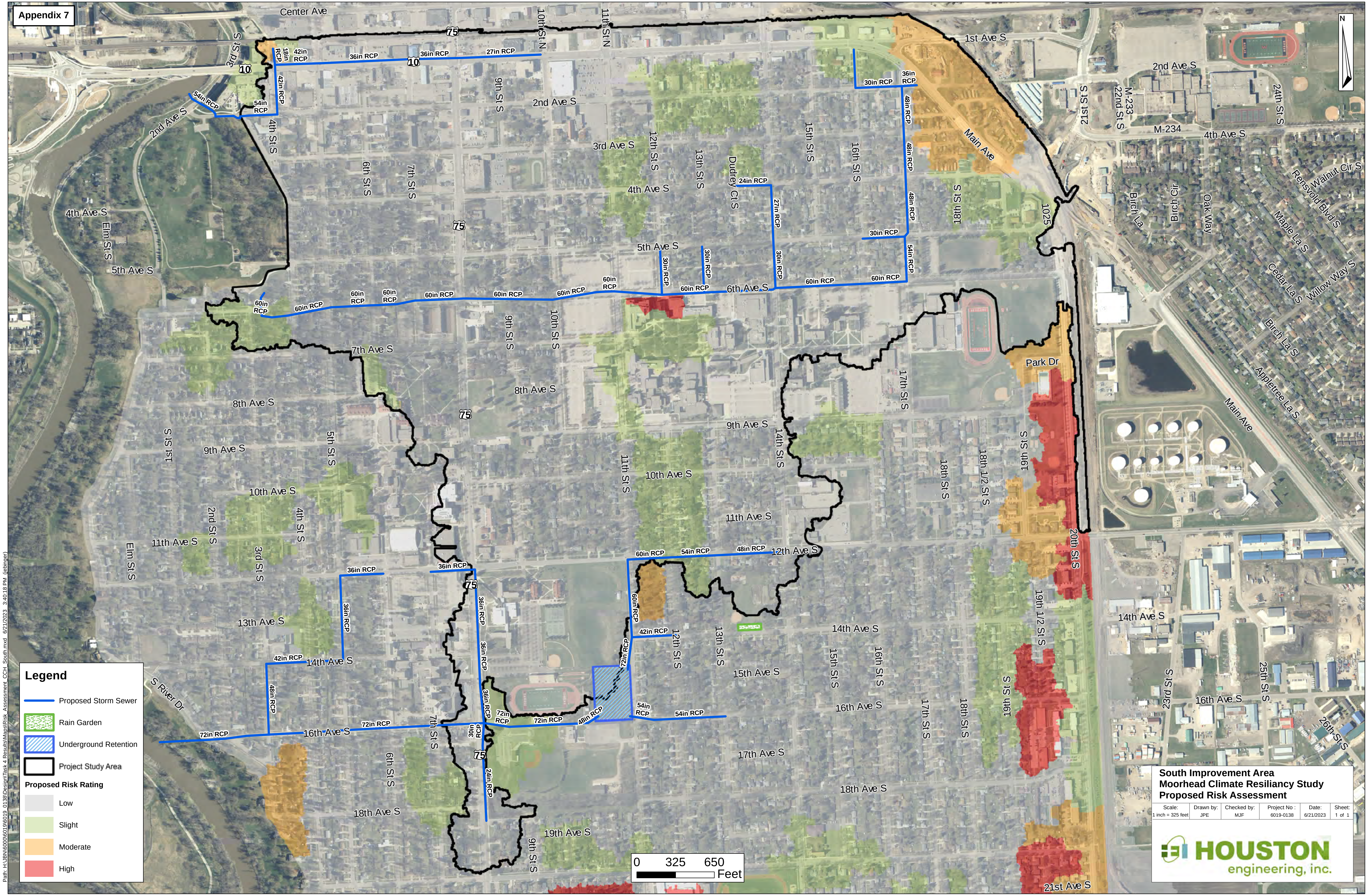

Appendix 7
Legend
Proposed Storm Sewer
Rain Garden
Underground Retention
Project Study Area
Proposed Risk Rating
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Slight
Moderate
High
0 325 650
Feet
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2nd Ave S
3rd Ave S
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6th Ave S
7th Ave S
8th Ave S
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11th Ave S
12th Ave S
13th Ave S
14th Ave S
15th Ave S
16th Ave S
17th Ave S
18th Ave S
19th Ave S
21st Ave S
Main Ave
Park Dr
S River Dr
10th St N
11th St N
Proposed 36in RCP
Proposed 60in RCP
Proposed 72in RCP
South Improvement Area
Moorhead Climate Resiliancy Study
Proposed Risk Assessment
Scale: 1 inch = 325 feet
Drawn by: JPE
Checked by: MJF
Project No : 6019-0138
Date: 6/21/2023
Sheet: 1 of 1
HOUSTON engineering, inc.

APPENDIX 8

Improvements Opinion of Probable Cost

Opinion of Probable Cost
City of Moorhead Climate Resilience Study
North Improvement Area

No.	Item	Units	Unit Price	Quantity	Total
1	Remove Storm Sewer	LF	$30	28,575	$857,250
2	Remove Catch Basin	EA	$750	540	$405,000
3	Remove Manhole	EA	$1,000	135	$135,000
4	24in RCP Storm Sewer	LF	$100	3,670	$367,000
5	27in RCP Storm Sewer	LF	$120	750	$90,000
6	30in RCP Storm Sewer	LF	$140	3,700	$518,000
7	33in RCP Storm Sewer	LF	$170	200	$34,000
8	36in RCP Storm Sewer	LF	$180	4,900	$882,000
9	42in RCP Storm Sewer	LF	$250	2,125	$531,250
10	48in RCP Storm Sewer	LF	$300	4,325	$1,297,500
11	54in RCP Storm Sewer	LF	$380	6,000	$2,280,000
12	60in RCP Storm Sewer	LF	$420	815	$342,300
13	66in RCP Storm Sewer	LF	$450	1,310	$589,500
14	72in RCP Storm Sewer	LF	$500	780	$390,000
15	60in Dia Storm Manhole	EA	$8,000	19	$152,000
16	72in Dia Storm Manhole	EA	$12,000	23	$276,000
17	84in Dia Storm Manhole	EA	$15,000	26	$390,000
18	96in Dia Storm Manhole	EA	$18,000	52	$936,000
19	108in Dia Storm Manhole	EA	$20,000	11	$220,000
20	120in Dia Storm Manhole	EA	$25,000	4	$100,000
21	Catch Basin	EA	$3,000	540	$1,620,000
22	Underground Retention System	LS	$1,250,000	1	$1,250,000
23	Lift Station & Gatewell Modifications	LS	$6,500,000	1	$6,500,000
24	Rain Garden	LS	$50,000	1	$50,000
				Storm Sewer Subtotal	**$20,212,800**
				Storm Sewer Contingencies (30%)	**$6,063,840**
				Storm Sewer Construction Total	**$26,276,640**
				Street Reconstruction Total (1,289,500 SF & $21/SF)	**$27,079,500**
				Total Construction Cost	**$53,356,140**
				Design, Staking, Insepction, and Testing (15%)	**$8,003,421**
				Total Project Cost	**$61,359,561**

Opinion of Probable Cost
City of Moorhead Climate Resilience Study
South Improvement Area

No.	Item	Units	Unit Price	Quantity	Total
1	Remove Storm Sewer	LF	$30	25,850	$775,500
2	Remove Catch Basin	EA	$750	496	$372,000
3	Remove Manhole	EA	$1,000	124	$124,000
4	18in RCP Storm Sewer	LF	$80	140	$11,200
5	24in RCP Storm Sewer	LF	$100	950	$95,000
6	27in RCP Storm Sewer	LF	$120	1,150	$138,000
7	30in RCP Storm Sewer	LF	$140	2,400	$336,000
8	36in RCP Storm Sewer	LF	$180	4,050	$729,000
9	42in RCP Storm Sewer	LF	$250	1,825	$456,250
10	48in RCP Storm Sewer	LF	$300	2,525	$757,500
11	54in RCP Storm Sewer	LF	$380	2,400	$912,000
12	60in RCP Storm Sewer	LF	$420	6,675	$2,803,500
13	72in RCP Storm Sewer	LF	$500	3,875	$1,937,500
14	60in Dia Storm Manhole	EA	$8,000	6	$48,000
15	72in Dia Storm Manhole	EA	$12,000	18	$216,000
16	84in Dia Storm Manhole	EA	$15,000	21	$315,000
17	96in Dia Storm Manhole	EA	$18,000	25	$450,000
18	108in Dia Storm Manhole	EA	$20,000	34	$680,000
19	120in Dia Storm Manhole	EA	$25,000	20	$500,000
20	Catch Basin	EA	$3,000	496	$1,488,000
21	Underground Retention System	LS	$3,000,000	1	$3,000,000
22	Lift Station Modifications	LS	$5,000,000	1	$5,000,000
23	Rain Garden	LS	$50,000	1	$50,000
				Storm Sewer Subtotal	**$21,194,450**
				Storm Sewer Contingencies (30%)	**$6,358,335**
				Storm Sewer Construction Total	**$27,552,785**
				Street Reconstruction Total (1,080,500 SF & $21/SF)	**$22,690,500**
				Total Construction Cost	**$50,243,285**
				Design, Staking, Insepction, and Testing (15%)	**$7,536,493**
				Total Project Cost	**$57,779,778**