TABLE OF CONTENTS

1 INTRODUCTION .................................................................................................................. 1

2 EXISTING AND PROPOSED DRAINAGE PATTERNS AND IMPROVEMENTS ... 4
    2.1 EXISTING DRAINAGE PATTERNS ................................................................. 4
    2.2 PROPOSED DRAINAGE PATTERNS AND IMPROVEMENTS ...................... 4

3 HYDROLOGIC CRITERIA, METHODOLOGY, AND RESULTS ....................... 5
    3.1 HYDROLOGIC CRITERIA ........................................................................... 5
    3.2 HYDROLOGIC METHODOLOGY ............................................................... 5
    3.3 DESCRIPTION OF HYDROLOGIC MODELING SOFTWARE .................... 5
    3.4 HYDROLOGY RESULTS .......................................................................... 6

4 CONCLUSION .................................................................................................................... 7

5 REFERENCES ..................................................................................................................... 8

FIGURES

Figure 1. Location Map ................................................................................................. 2
Figure 2. Vicinity Map ................................................................................................. 3

TABLES

Table 1. Hydrology Criteria ............................................................................................ 5
Table 2. Summary of Rational Method Results ................................................................. 6

APPENDICES

Appendix A Exhibits
Appendix B Existing Condition Rational Method Results
Appendix C Proposed Condition Rational Method Results
Appendix D Reference Materials
1 INTRODUCTION

Nolte Vertical Five (NV5) has been retained by Arrowhead Villas Mutual Service Company (MSC) to perform supporting hydrologic and hydraulic analyses for the proposed Storage Tank Improvements Project (Project). The proposed Project entails the construction of two bolted steel water storage tanks at a site that previously contained two water storage tanks. The site is located west of the intersection of Sycamore Drive and Altamont Court, north of the existing storage tank and Sycamore Street, and south of Altamont Court. Refer to Figure 1 and Figure 2 for the Project’s Location and Vicinity Maps, respectively. In its existing conditions, the project site consists of a pump house and concrete foundation, gate and fence posts, and above- and below-ground piping and appurtenances. These existing structures will be removed prior to the construction of the proposed improvements.

This report has been prepared in accordance with the methodology presented within the San Bernardino Hydrology Manual (dated August 1986). To this end, the 100-year design storm event was used to quantify the hydrologic impacts of the project under existing and proposed conditions. The following sections discuss the comprehensive analysis in further detail.

The Project area lies within the San Bernardino National Forest within FEMA Flood Insurance Rate Map (FIRM) Panel 06071C7956H, with an effective date of August 28, 2008. The project is located within a FEMA designated “other flood areas” Zone D which is an area “which flood hazards are undetermined, but possible”. Please refer to Exhibit 1, FIRMette Map, in Appendix A.
Figure 1. Location Map
Figure 2. Vicinity Map
2  EXISTING AND PROPOSED DRAINAGE PATTERNS AND IMPROVEMENTS

The following sections provide descriptions of the existing and proposed drainage patterns and improvements for the Project.

2.1  Existing Drainage Patterns

The Project site’s watershed consists of one drainage basin, Basin 100, and is comprised of three sub-basins totaling approximately 0.40 acres. The land cover for the watershed is comprised of trees, asphalt, and natural ground with an average slope of 0.22 ft/ft. The Project on-site area, Sub-Basin 102, consists of a pump house and concrete foundation, gate and fence posts, and above- and below-ground piping and appurtenances. The total impervious area for the watershed is approximately 1,023 sq.ft. which includes a portion of Sycamore Drive. The storm water runoff generated from the upgradient off-site area, Sub-Basin 104, will flow north onto the project site area as sheet flow and combine with the on-site runoff. Runoff will continue northward down a slope through Sub-Basin 100 onto Altamont Court. These flows eventually reach Lake Arrowhead, approximately 0.9 miles downstream, which is part of the Deep Creek Watershed within the Mojave Hydrologic Unit (HU). Refer to Exhibit 2 for the existing conditions drainage map included in Appendix A.

2.2  Proposed Drainage Patterns and Improvements

Proposed Project improvements consists of the construction of two bolted steel water storage tanks at a site that previously contained two water storage tanks. The redevelopment activities will take place in the project site area, Sub-Basin 102. The proposed condition watershed is approximately 0.4 acres in size and will maintain the existing drainage patterns. Storm water runoff generated in Sub-Basin 104 will continue to drain onto the project site area where it will combine with the runoff generated in Sub-Basin 102 and sheet flow northward down the slope onto Altamont Court. Refer to Exhibit 3 for the proposed conditions drainage map included in Appendix A. Conservatively, this drainage study assumed ultimate build-out conditions which includes both steel water storage tanks. The total impervious area for the project’s watershed is approximately 3,097 sq.ft. in the ultimate build-out conditions.
3 HYDROLOGIC CRITERIA, METHODOLOGY, AND RESULTS

3.1 Hydrologic Criteria
The drainage basins were delineated using available topography (NV5, 2015) and the proposed grading layout for the project. Table 1 summarizes the key hydrology assumptions and criteria used for the hydrologic modeling.

Table 1. Hydrology Criteria

<table>
<thead>
<tr>
<th>Existing and Proposed Hydrology Design Storm:</th>
<th>100-Year Storm Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Type:</td>
<td>Hydrologic Soil Group Type “A” (1986 San Bernardino Hydrology Manual, Figure C-11, Hydrologic Soils Group Map for Southcentral Area).</td>
</tr>
<tr>
<td>Land Use/Runoff Coefficients:</td>
<td>The project site previously consisted of a potable water storage tank but now is currently vacant. The Project proposes construction of two storage tanks. The runoff coefficients for the analysis were based on impervious percentages.</td>
</tr>
<tr>
<td>Rainfall Intensity:</td>
<td>Based on intensity-duration-frequency relationships (Figures B-3 and B4) presented in the 1986 San Bernardino Hydrology Manual.</td>
</tr>
<tr>
<td>Topography:</td>
<td>The horizontal datum used was the North American Datum (NAD) 1983 and the vertical datum was the North American Vertical Datum (NAVD) 1988.</td>
</tr>
</tbody>
</table>

3.2 Hydrologic Methodology
The hydrologic methodology for the Project uses the Modified Rational Method to determine the storm flows for the design of the storm drain improvements. The goal of the Project hydrologic analysis was to:

- Determine pre- and post-development storm flows for the sizing of the on-site storm drain system facilities.
- A comparative analysis was performed between the existing runoff and proposed design storm runoff at Altamont Court. For results of the analysis refer to Appendices B and C for the Rational Method result files. Summaries for the flows are provided in Table 2.
- The existing and proposed conditions hydrology models were based on the existing topography and the proposed site plan and grading for the site.

3.3 Description of Hydrologic Modeling Software
The Rational Method was used to determine the 100-year storm flow. The Advanced Engineering Software (AES) HydroWIN version 2014, Rational Method Analysis for San Bernardino County was used to perform the hydrologic calculations.
The AES Rational Method Hydrology Program is a computer-aided design program where the user develops a node-link model of the watershed. Developing independent node link models for each interior watershed and linking these sub-models together at confluence points creates the node link model. The intensity-duration-frequency relationships are applied to each of the drainage areas in the model to get the peak flow rates at each point of interest. The model follows the 1986 San Bernardino Hydrology Manual (Manual) methodology.

### 3.4 Hydrology Results

Project hydrology results were used to verify that the project does not adversely impact existing downstream properties.

Table 2 summarizes the runoff for existing and proposed conditions at the drainage outfall points of the project.

**Table 2. Summary of Rational Method Results**

<table>
<thead>
<tr>
<th>Drainage Basin</th>
<th>Existing Condition Tributary Area</th>
<th>Existing Condition 100-Year Flow</th>
<th>Existing $t_c$</th>
<th>Proposed Condition Tributary Area</th>
<th>Proposed Condition 100-Year Flow</th>
<th>Proposed $t_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ac)</td>
<td>(cfs)</td>
<td>(min)</td>
<td>(ac)</td>
<td>(cfs)</td>
<td>(min)</td>
</tr>
<tr>
<td>100</td>
<td>0.4</td>
<td>3.31</td>
<td>6.14</td>
<td>0.4</td>
<td>3.34</td>
<td>6.12</td>
</tr>
<tr>
<td>Total</td>
<td>0.4</td>
<td>3.31</td>
<td></td>
<td>0.4</td>
<td>3.34</td>
<td></td>
</tr>
</tbody>
</table>

Results show an increase of 0.03 cfs (0.91%) in the 100-year discharge generated from the project site between the existing and proposed conditions. The increase in flow rate can be attributed to the increased impervious area from the proposed two bolted steel water storage tanks. The average travel time in the existing and proposed conditions are 6.14 minutes and 6.12 minutes, respectively. The average travel time in the proposed condition decreased by 0.02 minutes. This minor increase in the 100-year flow will not adversely affect downstream flooding conditions.
4 CONCLUSION

This drainage report has been prepared in support of hydrologic and hydraulic analyses for the proposed Storage Tank Improvements Project. The purpose of this report is to provide peak discharges for use in comparing the existing and proposed conditions storm water discharge. There is an increase of 0.03 cfs during a 100-year storm event due to the proposed improvements. This minor increase will not adversely affect downstream flooding conditions.
5 REFERENCES

Appendices
Appendix A
Exhibits
Appendix B
Existing Condition Rational Method Results
**RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE**

(Reference: 1986 SAN BERNARDINO CO. HYDROLOGY CRITERION)

(c) Copyright 1983-2014 Advanced Engineering Software (aes)

Analysis prepared by:

NV5
15092 Avenue of Science
San Diego, CA 92128

-----------------------------------------------------------------------
**DESCRIPTION OF STUDY**
-----------------------------------------------------------------------

ARROWHEAD VILLAS MSC
EXISTING CONDITION
100-YEAR STORM EVENT

-----------------------------------------------------------------------
FILE NAME: 100EX100.DAT
TIME/DATE OF STUDY: 10:36 10/10/2019
-----------------------------------------------------------------------
USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:

"TIME-OF-CONCENTRATION MODEL"

-----------------------------------------------------------------------
USER SPECIFIED STORM EVENT (YEAR) = 100.00
SPECIFIED MINIMUM PIPE SIZE (INCH) = 18.00
USER SPECIFIED GRADIENTS (DECIMAL) TO USE FOR FRICTION SLOPE = 0.50
USER-DEFINED LOGARITHMIC INTERPOLATION FOR RAINFALL:
10-YEAR STORM 60-MINUTE INTENSITY (INCH/HOUR) = 1.50
100-YEAR STORM 60-MINUTE INTENSITY (INCH/HOUR) = 2.150
COMPUTED TRAVEL TIME THRU INTENSITY DATA:
STORM EVENT = 100.00 1-HOUR INTENSITY (INCH/HOUR) = 2.1500
SLOPE OF INTENSITY DURATION CURVE = 0.7000

*ANTECEDENT MOISTURE CONDITION (AMC) III ASSUMED FOR RATIONAL METHOD*

USER-SPECIFIED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL:

*USER-SPECIFIED MINIMUM TOPOGRAPHIC SLOPE ADJUSTMENT NOT SELECTED

-----------------------------------------------------------------------
END OF SUBAREA CHANNEL HYDRAULICS:
LOWEST FLOWPATH FROM NODE 106.00 TO NODE 100.00 = 140.00 FEET.

**FLOW PROCESS FROM NODE 106.00 TO NODE 100.00 IS CODE = 21**

-----------------------------------------------------------------------
**RATIONAL METHOD INITIAL SUBAREA ANALYSIS**

INITIAL SUBAREA FLOW-LENGTH (FEET) = 90.00
ELEVATION DATA: UPSTREAM (FEET) = 5852.00 DOWNSTREAM (FEET) = 5840.00

-----------------------------------------------------------------------
**FLOW PROCESS FROM NODE 104.00 TO NODE 102.00 IS CODE = 51**

-----------------------------------------------------------------------
**RATIONAL METHOD INITIAL SUBAREA ANALYSIS**

INITIAL SUBAREA FLOW-LENGTH (FEET) = 90.00
ELEVATION DATA: UPSTREAM (FEET) = 5852.00 DOWNSTREAM (FEET) = 5840.00

-----------------------------------------------------------------------
**FLOW PROCESS FROM NODE 106.00 TO NODE 100.00 IS CODE = 21**

-----------------------------------------------------------------------
**RATIONAL METHOD INITIAL SUBAREA ANALYSIS**

INITIAL SUBAREA FLOW-LENGTH (FEET) = 90.00
ELEVATION DATA: UPSTREAM (FEET) = 5852.00 DOWNSTREAM (FEET) = 5840.00

-----------------------------------------------------------------------
TRAVEL TIME COMPUTED USING ESTIMATED FLOW (CFS) = 2.59
TRAVEL TIME THRU SUBAREA BASED ON VELOCITY (FEET/SEC.) = 2.86
AVERAGE FLOW DEPTH (FEET) = 0.02 TRAVEL TIME (MIN.) = 0.38
Tc (MIN.) = 6.14
SUBAREA AREA (ACRES) = 0.18 SUBAREA RUNOFF (CFS) = 1.60
EFFECTIVE AREA (ACRES) = 0.37 AREA-AVERAGED Fm (INCH/HR) = 0.68
AREA-AVERAGED Fp (INCH/HR) = 0.75 AREA-AVERAGED Ap = 0.91
TOTAL AREA (ACRES) = 0.4 PEAK FLOW RATE (CFS) = 3.31
END OF SUBAREA CHANNEL FLOW HYDRAULICS:
DEPTH (FEET) = 0.02 FLOW VELOCITY (FEET/SEC.) = 3.30
LONGEST FLOWPATH FROM NODE 106.00 TO NODE 100.00 = 205.00 FEET.
================================================================================================
END OF STUDY SUMMARY:
TOTAL AREA (ACRES) = 0.4 TC (MIN.) = 6.14
EFFECTIVE AREA (ACRES) = 0.37 AREA-AVERAGED Fm (INCH/HR) = 0.68
AREA-AVERAGED Fp (INCH/HR) = 0.75 AREA-AVERAGED Ap = 0.905
PEAK FLOW RATE (CFS) = 3.31
================================================================================================
END OF RATIONAL METHOD ANALYSIS
Appendix C
Proposed Condition Rational Method Results
Tc = K*(LENGTH** 3.00)/(ELEVATION CHANGE)**0.2

100 YEAR RAINFALL INTENSITY(INCH/HR) = 12.242

USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:

USER SPECIFIED STORM EVENT(YEAR) = 100.00

SPECIFIED MINIMUM PIPE SIZE(INCH) = 18.00

MANNING'S FACTOR = 0.025

MAXIMUM DEPTH(FEET) = 2.00

AREA-AVERAGE Fp(INCH/HR) = 0.74

AREA-AVERAGE Ap = 0.500

END OF SUBAREA CHANNEL FLOW HYDRAULICS:

DEPTH(FEET) = 0.03
FLOW VELOCITY(FEET/SEC.) = 1.32

LONGEST FLOWPATH FROM NODE 106.00 TO NODE 104.00 = 140.00 FEET.
SUBAREA AVERAGE PERVIOUS AREA FRACTION, $A_p = 1.00$

TRAVEL TIME COMPUTED USING ESTIMATED FLOW (CFS) = 2.62

TRAVEL TIME THRU SUBAREA BASED ON VELOCITY (FEET/SEC.) = 2.89

AVERAGE FLOW DEPTH (FEET) = 0.02

TRAVEL TIME (MIN.) = 0.37

$T_c$ (MIN.) = 6.12

SUBAREA AREA (ACRES) = 0.18

SUBAREA RUNOFF (CFS) = 1.60

EFFECTIVE AREA (ACRES) = 0.37

AREA-AVERAGED $F_m$ (INCH/HR) = 0.60

AREA-AVERAGED $F_p$ (INCH/HR) = 0.75

AREA-AVERAGED $A_p$ = 0.80

TOTAL AREA (ACRES) = 0.4

PEAK FLOW RATE (CFS) = 3.34

END OF SUBAREA CHANNEL FLOW HYDRAULICS:

DEPTH (FEET) = 0.02

FLOW VELOCITY (FEET/SEC.) = 3.33

LONGEST FLOWPATH FROM NODE 106.00 TO NODE 100.00 = 205.00 FEET.

END OF STUDY SUMMARY:

TOTAL AREA (ACRES) = 0.4

$T_c$ (MIN.) = 6.12

EFFECTIVE AREA (ACRES) = 0.37

AREA-AVERAGED $F_m$ (INCH/HR) = 0.60

AREA-AVERAGED $F_p$ (INCH/HR) = 0.75

AREA-AVERAGED $A_p$ = 0.797

PEAK FLOW RATE (CFS) = 3.34

END OF RATIONAL METHOD ANALYSIS
Appendix D
Reference Materials