V. CONDITIONS OF APPROVAL

A. Purpose

On October 17, 2023, the Pima County Board of Supervisors approved the Thornydale Sumter Specific Plan. The approval was subject to several conditions that have been incorporated into this final Specific Plan document and are provided in Section V.B, below. If the Specific Plan is amended in the future, this section, *"Conditions of Approval"*, will be updated to document all changes and any additional conditions of approval that may be associated with each amendment. This will provide an ongoing record of the overall Specific Plan, including all associated amendments and revisions, throughout the life of the project in a single location.

B. Board of Supervisors Conditions of Approval

1. Not more than 60 days after the Board of Supervisors approves the specific plan, the owner(s) shall submit to the Planning Director the specific plan document, including the following conditions and any necessary revisions of the specific plan document reflecting the final actions of the Board of Supervisors, and the specific plan text and exhibits in an electronic and written format acceptable to the Planning Division.

   Reference: (no other reference within this Specific Plan)

2. In the event of a conflict between two or more requirements in this specific plan, or conflicts between the requirements of this specific plan and the Pima County Zoning Code, the specific plan shall apply. The specific plan does not regulate Building Codes.

   Reference: Section III.A: Administration and Interpretation

3. This specific plan shall adhere to all applicable Pima County regulations that are not explicitly addressed within this specific plan. The specific plan's development regulations shall be interpreted to implement the specific plan or relevant Pima County regulations.

   Reference: Section III.A: Administration and Interpretation

4. Transportation conditions:
   A. A Traffic Impact Study (TIS) shall be submitted for review and approval by the Department of Transportation with the submittal of the development plan. The commercial component to the site shall be included in the TIS. Off-site improvements determined necessary as a result of the TIS shall be provided by the property owner.
   B. The property owner shall dedicate 45 feet of right-of-way for Thornydale Road.

C. Corner spandrel right-of-way dedication shall be provided by the property owner(s) at the southwest corner of the project boundary adjacent to the Thornydale Road and Sumter Drive intersection prior to development plan or subdivision plat approval. A curve radius of twenty-five (25) feet is required.
D. A multi-use path shall be constructed to Pima County standards along the west side of Thornydale Road from Thornydale Road/Linda Vista intersection to the North Ranch subdivision. A second multi-use path shall be constructed along the north side of Sumter Drive from the Thornydale Road/Sumter Drive intersection to the west end of the driveway access including any handicap access ramps required at the two intersections. The design of the multi-use paths shall be determined at the time of permitting and as approved by the Department of Transportation.
E. Gated entries shall meet the requirements of the Subdivision and Development Street Standards.
F. A northbound right-turn lane at the project's driveway entrance on Thornydale Road shall be constructed to Pima County standards.

Reference: Section II.E: Transportation and Circulation

5. Flood Control District conditions:
   A. Conditional Letter of Map Revision (CLOMR) and a Letter of Map Revision (LOMR) are required. The CLOMR shall be approved by FEMA prior to start of grading.
   B. Drainage infrastructure, bank protection and open space for drainage shall be maintained by the property owner.
   C. Encroachment into mapped Regulated Riparian Habitat and the FEMA floodplain not shown on the approved Preliminary Development Plan (PDP) is prohibited.
   D. Disturbance of Regulated Riparian Habitat will be mitigated with like density to the habitat disturbed. The mitigation plantings shall be located within and surrounding the disturbance caused by construction of the basins.
   E. This project shall comply with detention and retention requirements at the time of site permitting. During permitting if the site plan follows the drainage concept approved at the time of rezoning a Detention Waiver will be accepted by the Floodplain Administrator.
   F. First Flush retention shall be provided in Low Impact Development practices distributed thought the site and shall provide a maximum 9” depressed area for stormwater harvesting to supplement irrigation in the landscape buffers.
   G. At the time of development, the developer shall be required to select a combination of Water Conservation Measures from Table B such that the point total equals or exceeds 15 points and includes a combination of indoor and outdoor measures.

Reference: Section II.D: Hydrology; Section II.A: Land Use Proposal; Section II.C.4.c: Restoration; Section II.C.4.d: Retention Basin; Section II.F.2: Water

6. Regional Wastewater Reclamation conditions:
   A. The owner(s) shall construe no action by Pima County as a commitment of capacity to serve any new development within the rezoning area until Pima County executes an agreement with the owner(s) to that effect.

B. The owner(s) shall obtain written documentation from the Pima County Regional Wastewater Reclamation Department (PCRWRD) that treatment and conveyance capacity is available for any new development within the rezoning area, no more than 90 days before submitting any tentative plat, development plan, preliminary sewer layout, sewer improvement plan, or request for building permit for review. Should treatment and/or conveyance capacity not be available at that time, the owner(s) shall enter into a written agreement addressing the option of funding, designing and constructing the necessary improvements to Pima County's public sewerage system at his or her sole expense or cooperatively with other affected parties. All such improvements shall be designed and constructed as directed by the PCRWRD.
C. The owner(s) shall time all new development within the rezoning area to coincide with the availability of treatment and conveyance capacity in the downstream public sewerage system.
D. The owner(s) shall connect all development within the rezoning area to Pima County's public sewer system at the location and in the manner specified by the PCRWRD in its capacity response letter and as specified by PCRWRD at the time of review of the tentative plat, development plan, preliminary sewer layout, sewer construction plan, or request for building permit.
E. The owner(s) shall fund, design and construct all off-site and on-site sewers necessary to serve the rezoning area, in the manner specified at the time of review of the tentative plat, development plan, preliminary sewer layout, sewer construction plan or request for building permit.
F. The owner(s) shall complete the construction of all necessary public and/or private sewerage facilities as required by all applicable agreements with Pima County, and all applicable regulations, including the Clean Water Act and those promulgated by ADEQ, before treatment and conveyance capacity in the downstream public sewerage system will be permanently committed for any new development within the rezoning area.

Reference: (no other reference within this Specific Plan)

7. Environmental Planning conditions:
   A. The property owner/developer shall achieve compliance with the Maeveen Marie Behan Conservation Lands System (CLS) Conservation Guidelines by providing a total of 45.6 acres as Natural Open Space (NOS). Should the developed area be reduced from that which is reflected in the approved Specific Plan, the property owner shall provide a minimum of four (4) acres of natural open space for every acre disturbed in order to achieve full compliance with the CLS Conservation Guidelines. No less than 6.5 acres of NOS will be provided onsite and will conform to the approximate location and configuration shown on the approved Specific Plan. The difference between the total acres of NOS and NOS provided onsite will be provided off-site. Off-site NOS must conform to the CLS Off-site Mitigation Policies found in Pima Prospers (Section 3.4 Environmental Element, Policy 11: "Conservation Lands System Mitigation Lands) and must comply with all of the following:

- Off-site NOS is acceptable to the Pima County Planning Official or their designee; and
- Prior to the approval of the tentative plat, off-site NOS will be permanently protected as natural open space by a separately recorded legal instrument acceptable to the Pima County Planning Official or their designee.

Reference: Section I.B: Pima Prospers Amendment; Section II.E.5: Transportation and Circulation

B. Upon the effective date of the Ordinance, the owner(s)/developer(s) shall have a continuing responsibility to remove invasive non-native species from the property, including those listed below. Acceptable methods of removal include chemical treatment, physical removal, or other known effective means of removal. This obligation also transfers to any future owners of property within the rezoning site and Pima County may enforce this rezoning condition against the property owner. Invasive Non-Native Plant Species Subject to Control:

Ailanthus altissima	Tree of Heaven
Alhagi pseudalhagi	Camelthorn
Arundo donax	Giant reed
Brassica tournefortii	Sahara mustard
Bromus rubens	Red brome
Bromus tectorum	Cheatgrass
Centaurea melitensis	Malta starthistle
Centaurea solstitalis	Yellow starthistle
Cortaderia spp.	Pampas grass
Cynodon dactylon	Bermuda grass (excluding sod hybrid)
Digitaria spp.	Crabgrass
Elaeagnus angustifolia	Russian olive
Eragrostis spp.	Lovegrass (excluding E. intermedia, plains lovegrass)
Melinis repens	Natal grass
Mesembryanthemum spp.	Iceplant
Oncosiphon pilulifer	Stinknet
Peganum harmala	African rue
Pennisetum ciliare	Buffelgrass
Pennisetum setaceum	Fountain grass
Rhus lancea	African sumac
Salsola spp.	Russian thistle
Schinus spp.	Pepper tree
Schismus arabicus	Arabian grass
Schismus barbatus	Mediterranean grass
Sorghum halepense	Johnson grass
Tamarix spp.	Tamarisk

Reference: Section II.C.8: Invasive Non-Native Species

8. Cultural Resources condition: In the event that human remains, including human skeletal remains, cremations, and/or ceremonial objects and funerary objects are found during excavation or construction, ground disturbing activities must cease in the immediate vicinity of the discovery. State laws ARS 41-865 and ARS 41-844, require that the Arizona State Museum be notified of the discovery at (520) 621-4795 so that cultural groups who claim cultural or religious affinity to them can make appropriate arrangements for the repatriation and reburial of the remains. The human remains will be removed from the site by a professional archaeologist pending consultation and review by the Arizona State Museum and the concerned cultural groups.

   Reference: (no other reference within this Specific Plan)

9. Adherence to the specific plan document as approved at the Board of Supervisor's public hearing.

   Reference: (no other reference within this Specific Plan)

10. Water conservation conditions:
    A. The owner(s) shall incorporate EPA WaterSense fixtures in all dwelling units. WaterSense requirements include, but are not limited to, the following low water use items:
       - Toilets
       - Showerheads
       - Bathroom faucets
       - Irrigation systems, including irrigation controllers

    B. The owner(s) shall not landscape or irrigate any portion of the Natural Undisturbed Open Space, as designated on the PDP. This condition does not limit the owner(s) ability to restore the previously disturbed areas of the Natural Undisturbed Open Space, as coordinated with Pima County Flood Control District.
    C. The project shall only include Xeriscape landscaping with native and/or desert adaptive vegetation that is drought tolerant, and it will use a water efficient drip irrigation system.
    D. The owner(s) shall grade the project's common areas to capture onsite stormwater runoff to promote passive rainwater harvesting.
    E. The owner(s) shall design the site so that stormwater runoff from the building and covered parking is directed into interior common area landscaping areas to promote passive rainwater harvesting, as shown on the attached Enclosure A.
    F. The project shall not include non-functional natural turf grass. Artificial turf may be substituted for natural turf.
    G. The project shall not include any fountains and water features in common areas.
    H. The owner(s) shall install dedicated irrigation meter(s) to monitor landscaping water use separate from residential potable use.

I. The owner(s) shall install a leak detector for each multi-family building to help identify and remediate water overuse and/or water leaks.
J. The owner(s) shall design and construct the community pools to drain into the sanitary sewer system.

Reference: Section II.C.7: Water Conservation

11. In the event the subject property is annexed, the property owner shall adhere to all applicable conditions, including, but not limited to, development conditions which require financial contributions to, or construction of infrastructure, including without limitation, transportation, flood control, or sewer facilities.

    Reference: (no other reference within this Specific Plan)

12. The property owner shall execute the following disclaimer regarding the Private Property Rights Protection Act rights: "Property Owner acknowledges that neither the rezoning of the Property nor the conditions of rezoning give Property Owner any rights, claims or causes of action under the Private Property Rights Protection Act (Arizona Revised Statutes Title 12, chapter 8, article 2.1). To the extent that the rezoning or conditions of rezoning may be construed to give Property Owner any rights or claims under the Private Property Rights Protection Act, Property Owner hereby waives any and all such rights and/or claims pursuant to A.R.S. § 12-1134(1)."

    Reference: (no other reference within this Specific Plan)

VI. REFERENCES

Pima County. "*PimaMaps*." Pima County, Arizona.

Pima County. *"Pima Prospers."* Pima County, Arizona, adopted May 19, 2015.

Pima County. "*Title 18 – Zoning*." Pima County, Arizona, Municipal Code, http://library.amlegal.com/nxt/gateway.dll/Arizona/pimacounty_az/title18zoning?f=templates$fn=default.htm$3.0$vid=amlegal:pimacounty_az.

Appendix A

Property Survey

LEGEND

- FOUND MONUMENTATION AS NOTED
- FOUND BRASS CAP IN CONCRETE (BCSM) AS NOTED
- SET 1/2" DIAM. REBAR AND BRASS TAG, LS 11758
- NOTHING FOUND OR SET
- ( ) RECORD BEARING AND OR DISTANCE, NORTH RANCH BK. 39, PG. 58, AND BK. 42, PG. 55, MAPS AND PLATS
- < > RECORD BEARING AND OR DISTANCE, HACIENDAS DE LA CAROLINA BK. 56, PG. 64, MAPS AND PLATS
- [ ] UNRECORDED BEARING AND OR DISTANCE, RLS 4252, 08/1987
- { } RECORD BEARING AND OR DISTANCE, RLS 12537, SN 20173490069

NOTES

BASIS OF BEARING WAS N 00°32'01" W ALONG THE CENTER LINE MONUMENTATION OF N THORNEYDALE ROAD.

BASIS OF ELEVATION WAS BASED ON NAVD88 PER NGS CORS NETWORK.

MONUMENTS FOUND WERE ACCEPTED BASED ON A PARTIAL RETRACEMENT AND BREAKDOWN FOR THE SW 1/4 OF SECTION 17.

REFERENCE IS MADE TO AN UNRECORDED OF SURVEY; BY LAWRENCE D. DADISMAN, RLS 4252, DATED 08/1987.

REFERENCE IS MADE TO RECORD OF SURVEY; BY FREDRICK J. STURNIOLO, RLS 12537, SEQUENCE NUMBER 20173490069, DATED 12/2017.

REFERENCE IS MADE TO MOUNTAIN VISTA RIDGE; BY PERRY ENGINEERING, SEQUENCE NUMBER 20183340400, MAPS AND PLATS, DATED 10/2018.

REFERENCE IS MADE TO NORTH RANCH LOTS 1 THROUGH 187; BY CELLA BARR ASSOCIATES, BOOK 39, PAGE 58, MAPS AND PLATS, DATED 10/1986.

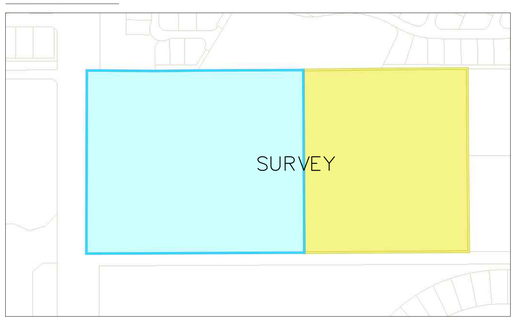
REFERENCE IS MADE TO NORTH RANCH LOTS 545 THROUGH 688; BY CELLA BARR ASSOCIATES, BOOK 42, PAGE 55, MAPS AND PLATS, DATED 10/1988.

REFERENCE IS MADE TO NORTH STAR ESTATES LOTS 1 THROUGH 98; BY RICK ENGINEERING COMPANY, BOOK 46, PAGE 82, MAPS AND PLATS, DATED 11/1994.

REFERENCE IS MADE TO HACIENDAS DE LA CAROLINA; BY ROGERS CIVIL ENGINEERING, BOOK 56, PAGE 64, MAPS AND PLATS, DATED 12/2002.

THIS SURVEY WAS PERFORMED FOR THE OWNER OF AP# 224-44-0570.

LOCATION MAP



SURVEYORS CERTIFICATE

I HEREBY CERTIFY THAT THIS SURVEY AND PLAT WAS MADE UNDER MY DIRECTION AND SUPERVISION DURING JANUARY 2022.

REGISTERED LAND SURVEYOR
CERTIFICATE
11758
RONALD E. STOLL
01-27-22
ARIZONA U.S.A.

RONALD E. STOLL, LS 11758

JOB NO. 3055

SHEET 1 OF 1

A PORTION OF THE

SW 1/4 OF S 17

T 12 S R 13 E G. & S.R.M.

PIMA COUNTY, ARIZONA

RECORD OF SURVEY

RES LAND SURVEYS, INC. 1910 E. 14TH STREET TUCSON, ARIZONA 85719

Appendix B

AGFD Best Management Practices for Saguaro Translocation and Replanting

BEST MANAGEMENT PRACTICES
FOR
SAGUARO TRANSLOCATION AND REPLANTING

Arizona Game and Fish Department

January 2019

The Arizona Game and Fish Department Mission:
To conserve Arizona's diverse wildlife resources and manage for safe, compatible outdoor recreation opportunities for current and future generations.

ABSTRACT
The *Best Management Practices for Saguaro Translocation and Replanting* (BMPs) provide information to help reduce impacts to saguaros from development in Arizona. They include recommendations on: 1) planning saguaro transplanting, 2) preparing saguaros for transplanting, 3) transplanting saguaros, 4) post-care of saguaros, and 5) research opportunities.

ACKNOWLEDGEMENTS
These BMPs were compiled by Arizona Game and Fish Department (AGFD) employees. The BMPs were developed from a detailed review of the literature and subsequent discussions with saguaro experts.

RECOMMENDED CITATION
Arizona Game and Fish Department. 2019. *Best Management Practices for Saguaro Translocation and Replanting.*

TABLE OF CONTENTS

EXECUTIVE SUMMARY

These Best Management Practices (BMPs) are recommendations and protocols to be used by developers and local permitting agencies in Arizona, and as a resource for other parties involved in the permitting process. Local governments are encouraged to integrate the BMPs described herein within their permitting process. The Arizona Game and Fish Department (AGFD), acting on behalf of the Arizona Game and Fish Commission, encourage the use of these BMPs to mitigate impacts to saguaros and wildlife species that depend on these cacti.

The document is organized around five basic project development steps:

1. Planning Saguaro Transplanting
2. Preparing Saguaros for Extraction
3. Transplanting Saguaros
4. Post-Planting Care of Saguaros
5. Research Opportunities

The BMPs do not duplicate or supersede any/or other legal requirements. This document does not mandate or limit the types of studies, mitigations, or alternatives an agency may decide to require.

INTRODUCTION

Transplanting a saguaro is a relatively simple mechanical process, but a more complicated biological process. Saguaros are long living cacti uniquely adapted to the Sonoran Desert's extreme environmental conditions. Saguaros have evolved thicker skins on their sides that are exposed to the most intense rays of the sun (Mazier & Schatt 1998, Mielke et. al. 2012). They have an extensive and mostly shallow root system that takes advantage of the infrequent and limited rainfall events in the desert and can store large quantities of water in their stems. Saguaros can weigh over 100 pounds per linear foot (Elliot 2003). These giant cacti are also more fragile than they appear. Their tremendous weight can actually crush and damage internal tissues if not moved with great care, and damage to their skin can leave openings for the entry of pathogens (Emming 2007, Mielke et. al. 2012). It is estimated that 80 percent of the roots are lost as the saguaro is extracted from the ground, and 30 to 50 percent of its stored water can be lost during the translocation process (Emming 2007).

Success of saguaro transplant survival is inversely related to size. Saguaros less than two feet almost always survive. Those over 25 feet rarely survive (Elliot 2003). Transplanting success is much higher with "spears" (saguaros without arms) less than 10 feet tall (Desert Botanical Garden 2010). There are two published studies that evaluate saguaro transplant survival over periods ranging from four to eleven years at five different sites (Harris et. al. 2004, Mielke et. al. 2012). Overall survival from these studies ranged from 66 to 78 percent. Survival rates and health were significantly affected by the height of the saguaro, whether or not it had arms, and the depth to which it was replanted as judged from the presence or absence of the stem's taper at its base. The results of these studies are summarized in Appendix 12.1.

Upon reviewing the extant literature, the Arizona Game and Fish Department (Department) recognized there was a lack of consensus on definitive guidelines for the translocation of saguaros. Therefore, the Department developed these Best Management Practices (BMPs) from a thorough review of the literature and subsequent discussions with several of the experts (see Appendix 12.2).

The main body of these guidelines presents the BMPs, the facts and discussion of how the BMP was derived, and the pertinent citations. At the very end of this document (Appendix 12.8) a summary version of the BMPs is included. This summary is designed to be printed and handed out to staff as needed for improved project implementation.

While some of the following recommendations are critical, the value of other recommendations may be less obvious and more incremental. The Department believes applying as many of these BMPs as possible will result in overall improvement in the survival of transplanted saguaros.

Although the primary purpose of these guidelines is to assist with the successful translocation of saguaro cacti, the Department recommends that all efforts should be made to avoid moving these cacti if at all possible. Mitigation by avoidance is the best method to minimize any negative impact (Thorton 2017). Careful planning and adjustments to the footprint of an activity or project might be able to avoid the necessity of removing the saguaro.

PLANNING THE SALVAGE/TRANSPORTATION

The relocation of a few dozen saguaros may require only a moderate amount of planning. The relocation of hundreds of saguaros, as might occur with large projects spanning many miles or acres, will require meticulous planning to ensure major logistical variables that impact time, costs, and desired results are considered. This section details the items that should be considered prior to translocation.

Permitting

In Arizona, the Department of Agriculture (AZDA) must be contacted whenever moving or destroying saguaros. Be sure to check with the local office for current rules and timelines to obtain the required permit.
More information is available at: https://agriculture.az.gov/plantsproduce/native-plants.

Survey, Marking, and Data Collection for each Saguaro

A thorough survey of the project area is recommended to identify and quantify the saguaros that will need to be moved. If monitoring or research activities are envisioned, saguaros that may not need to be moved should also be identified because some of these may be selected as control specimens. Those saguaros identified should be physically tagged, photographed (from all four cardinal directions), and the pertinent data recorded (Appendix 12.3a). Data collection apps and digital photography can be used to facilitate the recording process, and the multiple photographs may be useful for assessing future mortality causes. The required AZDA Native Plant Law (AZNPL) tag as well as the unique ID number tag should be affixed on the north side of the saguaro using long zip-lock plastic ties. The ties should be loose enough to allow growth, and can be cut and re-adjusted in the future if they threaten to cut into the stem. The zip-lock tie and tags should be placed 1 foot above the natural ground level. Although some workers use white correction fluid to mark cacti, these marks fade with time and are not recommended. Data recorded should include geo-coordinates, the unique ID number, height, number and length of arms, diameter-at-breast-height (DBH)[1], whether or not the saguaro has nurse tree shading, overall condition (see Appendix 12.3b), and any other special observations (e.g., stem cavities, notable damage, etc.) The multiple photographs will provide additional backup information.

Nearly every expert contacted thought it was important that saguaros be replanted to the same cardinal orientation (Byrd 2017, Desert Botanical Garden 2010, Elliot 2003, Emming 2017, Kelly 2005, Kelly and Grumbles 2009, Mielke et. al. 2012, NRCS 2009, Tucson Saguaro and

[1] DBH measurements are recommended after multiple BMPs (initial identification; after rehydration but prior to extraction; when the saguaro is actually removed from the ground; after the saguaro has been replanted; and 10 days after each supplemental watering or rainfall event that exceeds ¼ inch). A large sliding caliper is recommended to take the DBH measurement, and the measurement points can be marked with white correction fluid (this can be refreshed when necessary). These DBH measurements will be used to monitor the re-establishment of the saguaro, and in particular, to determine when the roots become functional again and can intake water and nutrients. This activity will cause the stem to swell (increase in diameter). This increase in stem diameter, when documented during the post-translocation monitoring phase, will be used to declare when a transplant has been initially successful. Because some of the shorter saguaros may not reach "breast" height, measurements should be taken at 4 feet 3 inches from the ground level, or 15 inches from the top, whichever is closest to the ground.

Succulent Society 2013). The north and east sides have more tender skin, and can easily sunburn if they end up facing the more radiant south and west directions after being replanted (Desert Botanical Garden 2004). Sunburn can scar the saguaro skin and cause permanent blemishes or even rot.

Studies (Harris et. al. 2004, Mielke et. al. 2012) also support the importance of the saguaro being replanted at the same depth at which it was growing. The recommendation to attach the tags on the north side of the saguaro at one foot above ground level is to facilitate the implementation of both of these BMPs: replant the saguaro facing the same direction, and to the same depth, at which it was growing.

Planning and Scheduling

Meticulous planning and scheduling of any sizeable salvage and transplant operation is critical. The Department recommends developing a detailed calendar indicating the order that each saguaro will be moved during each week and season; and whether the saguaro can be "once-moved" (i.e., extracted and loaded onto the cradle, transported to the new permanent site, and then directly re-planted from the cradle, NRCS 2009), or whether some/all saguaros will have to be placed in a temporary nursery storage setting. A uniquely important consideration in the overall implementation plan will be, based on the number of cacti to be moved, how many cradle/truck rigs will be needed. Beyond the numbers of saguaros to be moved and the timeline envisioned, there are other major logistical variables that impact time, costs, and final results. When developing your schedule/calendar, consider the following variables:

Seasonal Considerations

Saguaros can be successfully transplanted throughout the year. Spring is the most ideal season. The dry weather and soil conditions are less conducive to tissue rot, and the warmer temperatures promote active root growth and faster re-establishment (Kelly and Grumbles 2009, NRCS 2009). The 60°F night time temperature threshold can be used to define the startup of the optimal spring planting season (Kelly 2005). Many experts extend the planting season throughout the summer (Kelly and Grumbles 2009), but some caution that the extreme temperatures can be stressful, and the monsoons can result in excess soil moisture which promotes root rot (NRCS 2009). Planting can continue into the fall and winter months, with the understanding that new root growth might be delayed during these cooler months. Given that the saguaro can rely upon its stored water during these times, this is not viewed as detrimental (Emming 2017, Kelly and Grumbles 2009, NRCS 2009). Some advantages of winter planting include decreased chance of sunburn and less heat stress on both saguaros and human workers. However, transplanting should be avoided during fall and winter days when soils are saturated by rainfall, and saguaros should have a month in dry soil prior to any supplemental watering (see *Watering of Transplanted Saguaros*). If transplanting cannot be avoided during these more adverse, wet conditions, this should be noted in the record for any saguaros affected so it can be considered when assessing future survival rates.

Transplantation of Legacy Saguaros

If legacy saguaros (those over 15 feet tall and/or with multiple arms) are to be translocated, they should be given special consideration in the implementation plan. These giant saguaros should be

transplanted during the optimal spring months if at all possible. The methods used to extract saguaros (see Excavation of the Saguaro) tend to result in similar size root balls whether the cactus is 5, 10, 15 or even 20 feet tall. These large saguaros that have less roots per total mass should be moved during the most ideal transplant season so their roots have the longest growing season to re-establish. Survival rates can also be improved if the translocation is scheduled as a "once-move."

Although survival rates for these legacy saguaros are much lower and in some respects may not justify the cost of transplanting, the effort is sometimes still warranted to mitigate their outright destruction. When identifying legacy saguaros for translocation, it should be recognized that saguaros with arms longer than 7-8 feet, central stem lengths greater than 25 feet, and more than 7-8 arms are likely nearing the end of their lifespans. Those that are thinning and balding at the tops with spine loss, numerous bird holes, or other obvious damage and blemishes are also poor candidates (Emming 2017).

Allowing Sufficient Time for Handling Saguaros

When translocating saguaros, adequate time and care is important to achieve high survival rates. Salvage activities should allow ample time to handle saguaros, especially those that exceed ten feet in height. A minimum of an hour is required to remove a 10 foot saguaro, a minimum of one and a half hours is required if it has up to two short arms (NRCS 2009). Taller, multi-arm saguaros will require even more time.

Selection of Transplant Sites

Transplant sites should be as similar to the original site as possible: light exposure, freeze potential, soil type and texture, cardinal orientation and other abiotic factors (Kelly 2005). Select slightly raised (mounded) planting sites and avoid those where water can accumulate and keep the soil too wet (Emming 2017).

Elevational Concerns

Saguaros can grow at elevations to 4000 - 5000 feet in favorable microhabitats. When saguaros are transplanted at elevations above 2800 feet, aspect (the direction the slope is facing) becomes an important consideration. In these settings, care should be taken to place the plants on the warmer south- and west-facing slopes; north-facing slopes should be avoided. If planting on a north-facing slope is unavoidable, the plants should be placed near the top of the slope rather than near the base (Mielke et. al. 2012). The reason for the preferred selection of the upper slopes probably relates to the phenomenon of cold air drainage. This occurs on cold, still winter nights when the denser cold air flows off the slopes towards the valleys and mountain bases and can result in temperature differentials of 5-10°F within 100-200 feet of elevational change. These temperature changes can be the difference in survival of younger saguaros, or possible frost damage to mature saguaros (Emming 2017).

Acquisition/Scheduling of Equipment, Supplies, and Labor

An important consideration in the overall implementation plan will be acquiring and scheduling the equipment, supplies, and labor needed. This includes equipment such as special cradles and hydraulic lifts (saguaro "rigs") for moving saguaros; flat-bed trailers for moving the smaller spears; optional towable cherry-picker lift (for padding and securing arms prior to extraction,

measuring plumb and/or attaching guy wires to the taller saguaros for support after re-planting); water tank trucks and ATVs, as well as jet-spray and octopus hose systems for watering; hand tools (shovels, picks and digging bars, pneumatic diggers, various size pruners and pruning saws, etc.); calipers for measuring DBH; support stakes and guy wires; cutting tool disinfectant; and treatment chemicals and applicators (see Appendix 12.4). The number and availability of specialized cradle/truck rigs are expected to be a key limiting factor in the scheduling/implementation plan.

Pre-Extraction and Post-planting Watering

Identifying the watering methods to be used and the equipment needed, as well as acquiring and scheduling the use of the equipment, should be detailed in the implementation plan. Different methods might be required under different circumstances and available access to the translocated saguaros. This planning activity also includes locating historical rainfall data, designing the rain gauge network for the project(s) area, and determining trigger values (amount of rainfall) for supplemental watering if precipitation falls below the long-term average. Additional information is provided under the sections entitled HYDRATION OF SAGUAROS PRIOR TO EXTRACTION and *Watering of Transplanted Saguaros*.

Monitoring and/or Research Activities.

Monitoring the translocated saguaros should be conducted for a minimum of 5 years and preferably 10 or more. Saguaros are long living cacti and their ability to use their stored water can maintain an appearance of life even as they slowly die over an extended period of time. Specific data to be collected, the number to be monitored, and even identification of specific individuals should be determined prior to project implementation. Additionally, if research activities are planned, the protocols should be prepared and sample sizes determined prior to commencement of transplanting.

HYDRATION OF SAGUAROS PRIOR TO EXTRACTION

The saguaro's ability to store large quantities of water is an adaption that allows them to survive extended dry periods in the desert. Watering saguaros prior to transplantation seeks to maximize the benefits of this adaptation. Dehydrated saguaros do not fare well through the transplant process. The condition of the saguaro will determine if watering is necessary prior to extraction. Generally, if a saguaro appears fully hydrated and is in superb condition (i.e. appears full with its ribs apart and signs of growth such as new arms starting, new spines, or growth at the apex or tips (Saguarobylin_dot_com 2009, Desert Botanical Garden 2004, Harris et. al. 2004), then watering is not necessary. However, if the saguaro is dehydrated (shrunken ribs, pinched tips), and/or the hot season is approaching, then it should be well watered at least once prior to extraction. Even the healthiest saguaros lose 30 to 50 percent of their mass after a move (Emming 2007). Fully hydrating a saguaro before the move creates a reserve the plant can use while regenerating the 80 percent or more of the roots it will lose when excavated.

Two different methods are reported in the literature for rehydrating saguaros prior to extraction. One recommends watering two times, several weeks before extraction, and the other recommends a slow watering to a depth of 12 inches, two weeks before removal (Mielke et. al. 2012). Another method for watering saguaros (NRCS 2009) is to apply water over the shallow, widespread roots to a depth of 4-5 inches (see *Water Application Methods* for equipment needed). A soil moisture probe can be used to verify the water penetration depth. Given that the naturally growing saguaro prior to extraction still has its extensive, shallow root system intact, it would seem that application of water over this widespread root system (to the 4-5 inch depth) would be the most advantageous method. One watering would be the minimum application; two being preferable.

Although a baseline DBH[1] should have been collected when the saguaro was first inventoried, there may have been a considerable time lapse between then and this pre-extraction step. Accordingly, a new measurement should be taken just prior to this rehydration watering, with a follow-up DBH taken 10 days after the final watering (whether one or two are applied). An increase in DBH indicates that water uptake has occurred.

EXTRACTION OF THE SAGUARO

Handling Saguaros

Saguaros less than six feet tall can be moved relatively easily using a hand-cart (dolly) with never flat, pneumatic tires, a wheelbarrow depending on length of the saguaro, or slings if adequate workers are available. Depending on the height and girth, 5-6 foot saguaros can weigh between 300 to 600 pounds. Sufficient padding should be used so that no damage to the spines and trunk occur, and the saguaro should be well secured to the dolly. When placed on a transport vehicle or flatbed trailer, extra padding should be used to cushion the side and spines lying on the bed of the truck, and the spears should be secured so that they do not bounce. Saguaros can be stacked 2-3 high, depending on size, if sufficient padding is used (Byrd 2017). They should also be covered to prevent sunburn.

Saguaros taller than six feet are best handled with a special cradle for support and usually a hydraulic system for lifting and tilting (NRCS 2009). Prior to excavation, pad the trunk and arms generously with old carpeting, foam rubber, pillows, etc. and secure with cordage. A cherry-picker lift could be helpful for reaching the higher portions of the saguaros. It is important to support the entire stem length as well as any arms longer than three feet; the saguaro should be firmly attached to the cradle device for safety. Saguaros can break easily by tilting when unsupported, as well as the jarring from transport (Emming 2007, Mielke et. al. 2012). A dropped saguaro will likely die from internal damage, even if it can be erected again.

These special saguaro cactus "rigs" have been largely designed and constructed by the commercial nursery industry. A review of these designs is recommended. It is likely that many different ideas have been used and careful selection or even combining the various features might well yield a more "ideal" design and contribute to the survival of transported saguaros.

Excavation of the Saguaro

Prior to excavation, verify that the AZNPL and unique ID tag are attached one foot above ground level on the north side of the cactus. These will serve as reference marks for replanting. The DBH[1] should be re-measured and recorded. Some useful tools for extraction include shovel, railroad pick, digging bars, various types of saws with easily replaced blades (e.g., bow saw, pruning saw), various sizes of pruning shears, and sometimes power demolition hammers.

About two feet from the outside of the saguaro, begin digging a trench around the saguaro (Desert Botanical Garden 2010, Emming 2007, Kelly 2005, Mielke et. al. 2012). Whenever there is an opportunity to preserve a longer lateral root (i.e., it can be detected from the surface; the soil is particularly loose, or the root becomes exposed during the excavation), it should be taken. Lateral roots can also be found by starting a shallow excavation further from the stem (e.g., three feet) and then working back towards the stem to free the root prior to the deeper digging at the two foot radius to remove the tap root. For saguaros less than two feet tall, it is advised to remove the entire root mass, and to remove as much as possible for saguaros that range from 2 to 6 feet tall. Saguaro roots seem to be rather brittle; therefore considerable care is required during excavation (Peachey 2017).

Unlike other cacti, saguaros have a prominent tap root (Kelly 2005), although it rarely exceeds three feet in length, even on a 20 foot tall saguaro (Desert Botanical Garden 2004, Peachey 2017). If soil conditions allow for a deeper excavation and removal of more of the tap root, this should be done (Byrd 2017, Emming 2017). The minimum length for the excavated taproot is 18 inches.

Root Trimming and Treatments

After careful excavation, trimming and treatment of the roots is the second most important action for achieving a successful transplant. Not only does the saguaro lose the majority of its root system from the excavation process, but the saguaro also has a proclivity to suffer from root rot. The ability of the saguaro to regenerate new, healthy roots is critical for both moisture and nutrient absorption, and eventual stability of the cactus. Regrowth of roots is extremely slow, and likely mimics stem elongation. New root growth emerges along the trimmed remnants, not from the tips (Peachey 2017). Longer roots have more surface area from which to generate new feeder

roots, and longer roots may be better able to seal off any root rot from damaged ends well before the necrosis reaches the root base near the main trunk (Emming 2017).

After the saguaro has been lifted from the hole, any damaged parts of roots should be carefully trimmed away (Kelly 2005). Cuts should be above (stem side) the damage point, and should be clean and square (Cactusbylin_dot_com 2009, Kelly 2005). It is recommended that a minimum of 12-18 inches of solid, healthy lateral root, and as much of the tap root as possible, be retained (Emming 2017, Tucson Cactus and Succulent Society 2013). All tools such as knives, pruners and saws should be sharp and sterile. Use a 10 percent household bleach solution to clean tools between individual saguaros (Emming 2017).

The trimmed roots should be well dusted with a fungicide and bactericide (Desert Botanical Garden 2004, Elliot 2003, Kelly and Grumbles 2009, Mazier Undated, NRCS 2009). Agri-Mycin® 17 (an agricultural streptomycin, see Appendix 12.5) is the recommended bactericide Mazier and Schatt 1998). Bordeaux Mix has been suggested as a fungicide (Thorton 2017) as most of the previously used products have been removed from the market. Sulfur powder can be used as a last resort, but may not be very effective against white fungi (Peachey 2017, Thorton 2017). A photo of the roots, with a legible measuring stick, should be taken following excavation and treatment.

Air Drying Roots

Most experts recommend that the roots have time to air-dry (Desert Botanical Garden 2004, Harris et. al. 2004, Kelly 2005). One to two weeks is the general consensus, and the roots should be shaded during this period (Harris et. al. 2004). Shade cloth can be used if necessary (Emming 2017). Air-drying allows the recently traumatized and trimmed roots to form a protective callus, which prevents the entry of pathogens that cause root rot. This BMP can be readily accommodated for small projects where only a few saguaros are moved. However, when dozens or hundreds are being moved, this drying period is not always feasible as there may be a limited number of hydraulic cradles which cannot be left holding a saguaro for the extra days recommended for air-drying. In these situations, the Department recommends that the larger, more logistically challenging saguaros are transplanted using the "once-move" process (i.e., loaded onto the cradle, transported to the new site, and then directly re-planted from the cradle). Smaller saguaros, especially spears, can be stacked on flatbed trailers and left for the recommended time (under shade).

When scheduling conflicts preclude the recommended air-drying time, some techniques that may help mitigate this insufficient time are:

(1) use of fungicide and/or sulfur powder;
(2) utilizing weekend time (or other non-work days) for extra drying time as much as possible;
(3) recognize that the moving wind around the open air roots during transport could facilitate drying; and
(4) consider the use of blowers to hasten drying time (Note: this method has not been documented and would best be employed under an experimental protocol.) If this technique is used, it will be important to record how long the blowers were used on each

cactus so the data can be analyzed to determine if this technique is beneficial or detrimental to the survival of saguaros.

Because the recommended air-drying time will not always be possible, it is imperative that records kept for each saguaro note the actual air-drying time as precisely as possible (time in hours are best, but time in quarter-day increments might also suffice). If chemical treatments or forced air blowers are used, this too should be noted. With these data and continued monitoring, it should be possible to better correlate air-drying time with survival rates and to determine the best techniques and ideal time frames.

There is some suggestion (based on a dissertation study by Caldwell completed in 1966), that the callus process might happen much quicker that commonly assumed[2]. However, there has been no further investigation of this phenomenon since the time of that study, so the BMP remains at 1-2 weeks.

Cover Saguaros during Transport

Once the saguaro has been removed from the ground, it is important to protect it from sunburn. Unprotected saguaros can burn under a hot sun in minutes or hours (Elliot 2003). Whether reclined in the cradle, loaded onto a transport vehicle or trailer, or actually being transported, all parts of the saguaro, including the roots, should be covered with carpet, 30 percent shade cloth, or some other protective cover, such as a tarp. The coverage must also be well secured so that it does not blow open during highway travel and expose any part of the cactus to possible sunburn.

[2] The dissertation research identified groups of complex organic molecules that combined to produce protective compounds that could kill or inhibit invading organisms. These compounds also rapidly built physical barriers to seal off the damaged areas. This process appears to be an evolved mechanism to protect the fluids stored within a succulent saguaro from a sudden breach, and to do this quickly. While the complete process and the specific contributions of various identified chemicals have not been determined, rapid color changes indicate that these responses occur within hours, even if the final lignification takes additional time. It seems that the response to trauma is first the chemical formation of "biocides" to combat foreign elements, quickly followed by the formation of physical barriers, and the eventual creation of lignified structural layers that permanently wall off the damaged parts (Peachey 2017).

TEMPORARY STORAGE

Storing saguaros should only be done when absolutely necessary. Immediate transfer of these cacti to their permanent location reduces the amount of mechanical handling and probability of damage to the plant, and ensures the best survival rate (NRCS 2009). This "once-move" approach is especially important when transplanting the larger and/or multi-arm saguaros. The need for temporary storage, locations, and durations are key factors that should be addressed during the planning stage of a transplanting project.

Locations selected for temporary storage areas should be open to allow good air circulation. The saguaros should be both properly oriented using the tags placed on the north side and covered with 30 percent shade cloth to prevent sunburn. The saguaros must remain in an upright position. Pea-gravel is the recommended backfill (see Backfill and Backfilling). If the pea-gravel is well packed, saguaros up to 12 feet tall (with or without arms) and spears (saguaros without arms) up to 15 should not require additional support. Saguaros over 12 feet tall with arms, and any saguaros over 15 feet tall should be supported with guy wires and stakes. The Pima County Native Plant Nursery has maintained saguaros in a storage setting for two years (Byrd 2017).

RE-PLANTING THE SAGUARO

The ideal time period to transplant saguaros is the spring. The dry weather and soil conditions are not conducive to tissue rot, and the warmer temperatures promote active root growth and faster establishment (Kelly and Grumbles 2009, NRCS 2009). The 60°F night time temperature threshold can be used to define the startup of this optimal planting season (Kelly 2005). Many experts extend this planting season throughout the summer (Kelly and Grumbles 2009), while some caution that the extreme temperatures can be stressful, and the monsoons can result in excess soil moisture which promotes root rot (NRCS 2009). Most knowledgeable persons also concur that saguaros can be planted essentially throughout the year, although the days when the soils are saturated by rains (summer or winter) might best be avoided. It is acknowledged that during late fall, winter and early spring periods, unless the weather is unseasonably warm, the newly transplanted saguaros might remain dormant, without any new root growth, for several months. Given that the saguaro can rely on its stored water during these times, this is not viewed as detrimental (Emming 2017, Kelly and Grumbles 2009, NRCS 2009).

Hole Preparation

Excavate the new hole to a width twice as wide as the extant root ball (Desert Botanical Garden 2004, Mazier & Schatt 1998). If longer lengths of lateral roots were successfully excavated without excessive damage, those longer than 18-24 inches can be buried in a trench dug to accommodate them (i.e., like laying pipe), rather than expanding the diameter of the entire hole (Emming 2017). It is highly recommended that saguaros are replanted no deeper (or within 1-2 inches) than their original level in the ground (Byrd 2017, Saguarobylin_dot_com 2009, Desert Botanical Garden 2004, Desert Botanical Garden 2010, Emming 2007, Kelly 2005, Mazier & Schatt 1998, Mazier Undated, NRCS 2009). Although there are some commercial planters that plant the stem deeper for added stability, this results in roots being significantly deeper in the ground and beyond the penetration range of most desert rains (Elliot 2003, Mazier & Schatt 1998). In addition, the stems are not designed to be in contact with the soil above the natural growth level, and have a tendency to develop rot. The most compelling reason, however, to replant at the original ground level, is the transplant success documented in a study of ADOT saguaro translocations (Mielke et. al. 2012)[3].

The translocated saguaros should have a zip-lock tie near the base that is one foot above the original ground level (this tie should also hold the AZNPL tag and the unique ID tag that mark

[3] Based on this study that evaluated the transplant success of saguaros moved during four ADOT highway projects, there was a significant survival and health benefit to saguaros that were planted at or near to their original ground level as judged by the presence or absence of a taper at the base of the stem. At one of the study sites (SR86), saguaros that showed a taper were judged to be in good condition 3x more than those without. Combining the data from the three other study sites (which rated saguaros health as good, fair and poor), there is additional evidence that replanting to the original ground level depth is beneficial. When both good and fair condition percentages are considered at the other three sites, there was a consistent 12+% improvement for the saguaros that exhibited a taper. The benefits were more pronounced when looking at the average percent results across the three sites for each individual category:

	Good Condition	Fair Condition	Poor Condition
With taper (planted near original depth)	78%	15%	9%
Without taper (deeper than original depth)	48%	33%	45%

the north side of the saguaro). This one-foot distance marker, along with the vertical length of the extant root mass, including the tap root, can be used to measure precisely how deep the hole should be (after subtracting the extra foot). Soil at the bottom of the hole should be able to promote good drainage (i.e., a sandy type soil). If it's too hard and compact (i.e., a clay type soil), it can be broken up and/or some sand or gravel added, but should then be re-tamped to the proper depth as calculated (Saguarobylin_dot_com 2009).

If the zip-lock tie marking the one foot distance above ground level has been removed from the saguaro stem, it may be possible to still see the original soil line, or use the butt or the taper of the stem at the base to approximate the original ground level.

Final Inspection and Placement of Saguaro in the Hole

In addition to using the zip-lock tie to determine the proper depth to replant the saguaro, the tags held by the zip-lock marking the north side should be used to turn the saguaro to face north once again. If the north marking tag has been lost, the north side may be determined by:

(1) Saguaros generally have a sloping top that is oriented to the south, and
(2) The north side of the saguaro is a lighter green color than the south side (Saguarobylin_dot_com 2009).

If for any reason the north side cannot be identified, this should be documented and the replanted saguaro should be covered with a shade cloth (Emming 2017).

Prior to lowering the saguaro into the hole, the roots should be re-examined to determine if they are suitably callused, and/or if there has been any new damage or deterioration. Any new damage should be trimmed away, and any other pertinent observations should be recorded. The root mass should again be dusted/sprayed with additional fungicide (including Bordeaux mix) and anti-bactericide (NRCS 2009, Thorton 2017). Use of a root stimulating hormone (indole acetic or buteric acid) has also been suggested (Thorton 2017). With the saguaro still attached to the cradle for both support and safety, either visually, or using a plumb line (and a ladder or the cherry-picker lift), assure the saguaro is vertically straight and balanced. To avoid crushing the excavated tap root with the weight of the saguaro, it is imperative that the saguaro is still supported on the cradle as the pea-gravel backfill is added and tamped around the roots until there is a sufficient quantity of compacted backfill to support the cactus.

Backfill and Backfilling

Pea gravel is recommended for the backfill material (Byrd 2017). Given that root rot is probably the most significant detrimental factor to overcome, and the likelihood that "once-move" and other time constraints in a large scale transplant operation will often preclude the recommended one to two weeks for air-drying roots, the extra drainage inherent with the pea-gravel medium is considered to be the best backfill choice to avoid prolonged, excessively moist conditions. No other amendments are recommended.

To avoid crushing the tap root, it is important that the saguaro is supported on the cradle as it is lowered to the proper depth into the hole. The pea gravel backfill should be incrementally added and firmly compacted around the saguaro. This is best accomplished by adding 3-5 inches of pea gravel, tamping it down, and repeating this process until the hole is filled (Elliot 2003, Emming 2007, Mielke et. al. 2012). A 3x3 inch tamping rod, preferably with a rounded tip, is

recommended. Caution should be used when tamping to avoid striking or otherwise damaging the carefully trimmed, treated and callused roots. Fresh wounds can easily defeat all the previous efforts to avoid root rot. Accidental damage should not be ignored; rather, that area should be re-excavated, trimmed again, and treated with fungicide, bactericide and/or extra sulfur. Another technique rather than tamping (which as just noted could strike and damage a root) is to use a heavy bar inserted into the fill to agitate and settle the fill material with circular or back and forth motions (Peachey 2017). Once the roots are adequately covered, some of the native soil can be used to cover the top few inches of the hole and tamped down. If the soil seems particularly heavy (clayey), some river sand can be added. This finer fill material will slowly work its way into the upper interstices of the pea gravel and serve to lock some of the gravel together and provide extra support (Peachey 2017).

If any native soil is used as backfill (even though this is not recommended as a BMP), it is especially important to remove any rocks or caliche chunks over three inches (Mazier & Schatt 1998) in diameter. These larger rocks, as they are tamped down in the hole, could easily damage roots with which they might be in contact.

Stem Cone and Retention Basins

Create a tapered mound or cone of soil around the base of the saguaro to divert water away from the stem (Elliot 2003). This precludes excess accumulation of water around the stem that could promote rot, and/or prevents the spores of pathogens from contact with the stem base. The cone is not compacted so it will eventually erode away (see Appendix 12.6).

Some of the excavated dirt should be used to create a water-collecting basin around the saguaro. These basins should be three times the diameter of the saguaro, with a 4-6 inch berm around the basin circumference to retain water. This basin will capture some rainfall, but is primarily intended to assure the most efficient usage of supplemental water. A similar technique identified by Mazier & Schatt (1998) is to dig a donut-shaped canal around the saguaro starting about 18 inches from the stem. This design will also facilitate the efficient use of supplemental water, but will also be able to capture some additional runoff water from rainfall events. Note that using pea-gravel as backfill (instead of using the native soil excavated from the hole) will also promote the infiltration of water into the excavated area.

Temporary Support of Transplanted Saguaros

After transplantation, the biomass of a saguaro is now supported by about 20 percent of a recently traumatized root mass (especially the loss of most of the extended lateral support roots) in freshly disturbed soil or pea gravel that has just been tamped down. When this situation is combined with the cost and effort involved in the transplant process, it makes sense to provide additional temporary support which can augment the survival rate of the cactus.

Experience at the Pima County Native Plant Nursery indicates that saguaros less than 12 feet do not require additional support if the backfill is well tamped. This height can be extended to 15 feet for spears (saguaros with no arms). Accordingly, saguaros over 15 feet tall or those between 12-15 feet with arms should have additional support or bracing (Byrd 2017, Emming 2017).

The preferred support system consists of three guy wires strung through sections of fiber-

reinforced hose or tree straps. Galvanized wire rope (1/8 inch wire with 2000 lb breaking strength) is recommended. Sections of hose are placed around the plant two thirds up from the base of the saguaro; the cherry-picker lift or ladders may be useful to facilitate attachment of the collar and guy wires, especially on taller saguaros. Triangulate the three guy wires from the hose sections surrounding the plant column and stake them into the ground using 24-inch #4 rebar. Ensure that the collar is not too tight around the stem. As the saguaro settles, and after watering, the guy wires can be re-adjusted to maintain a balanced tension if necessary. Guy wires should be flagged at 5-6 feet above ground level as a safety measure (see Appendix 12.6).

Note that the cactus should be well balanced and able to stand by itself. The guy wire support is to prevent tilting in any direction until such time as re-rooting stabilizes the cactus. Once the guy wires are attached and staked and it has been verified that the replanted saguaro is stable, the cactus can be detached from the support cradle. If a saguaro falls over, it will likely perish from internal damage even if it is erected again. A falling saguaro also poses grave danger to workers (Emming 2007).

The support system should be left in place for two growing seasons. In order to stabilize, the saguaro must replace much of the estimated 80 percent of its roots (especially the extensive laterals) that were truncated during excavation. This is very unlikely to be accomplished in two growing seasons, and will probably require much longer. Peachey (2017) believes that roots grow and extend at a pace similar to stems and arms. In addition, damage to saguaros is not always readily apparent, especially if internal. Having the support system will help keep the saguaro upright as it heals and re-establishes. For longer term projects, especially those that are being actively monitored, there is also no reason that the support systems cannot be left longer on selected saguaros that might benefit from this additional time. Once the system is in place, there is little to no additional cost.

The use of 2x4 supports that are covered with carpet at the point of contact with the stem are not recommended. Not only do the boards press against the stem and damage the spines (sometimes excessively as the saguaro settles into the soil), but the carpet can retain moisture which promotes decay where it is in contact with the stem. The guy wire system is also less expensive than the 2x4 support system.

Re-Measure the DBH[1] and take New Photos

Prior to removal from the point-of-origin location and after the saguaro was rehydrated by supplemental watering (if necessary), the diameter at breast height (DBH) was measured and recorded. Now that the saguaro has been replanted (whether as a once-move, or after any length of time in temporary storage), the DBH should again be measured. These data will indicate if the saguaro has lost mass during the move (and/or storage), and serve as the baseline measure for monitoring new water uptake and transplant success. New photos should also be taken to document the saguaro transplantation.

POST-PLANTING CARE AND MONITORING

Use of Shade Cloth

It is recommended to use shade cloth to provide additional protection and reduce stress on newly transplanted saguaros (Byrd 2017, Saguarobylin_dot_com 2009, Desert Botanical Garden 2010, Emming 2007, Emming 2017, Kelly and Grumbles 2009, Mielke et. al. 2012, Thorton 2017, Tucson Saguaro and Succulent Society 2013). Cover each transplanted saguaro with 30 percent shade cloth, secured around the stem and arms with cordage and completely covering the southern and western exposures (i.e., shade cloth seams should be on the north side). The cloth should be left covering the saguaro through the first summer season. Care should be taken that folds and overlaps in the cloth do not effectively double or triple the protection. Any lightening of the skin to a paler green or yellowish to white color is an indication of sun burn. Such areas should be covered immediately with 30 percent shade cloth.

Watering of Transplanted Saguaros

Saguaros' ability to store large quantities of water is an adaption that allows them to survive extended dry periods in the desert. The previous BMP to make sure they are well hydrated prior to transplantation seeks to maximize the benefits of this adaptation. The saguaro should be re-planted into dry ground, backfilled with well compacted pea gravel, and not watered immediately to "settle" the backfill. If any rot starts in the root area from mechanical damage or stress from the transplantation, the dry, well drained, backfill should be conducive for the natural defenses of the cactus to deal with the problem (Elliott 2003). Recommended watering regimes will vary by season and transplantation date. Initiate post-transplant saguaro watering according to the following guidelines:

- The newly replanted saguaro has lost perhaps 80 percent of its roots. Saguaro roots are known to be very susceptible to root rot (facilitated by damaged roots and excessive moisture). The initial post-transplant watering regime should emphasize avoiding prolonged excessively moist conditions by providing intermittent watering in well drained (pea gravel) conditions.
- Saguaros transplanted in the spring, summer, or early fall months should remain in the dry backfill soil for 2 to 4 weeks before initial watering begins. Two weeks are sufficient for those whose roots were allowed the recommended two weeks air drying time; the additional weeks in dry soil are given (proportionately) to those saguaros that received less or effectively no air drying time.
- If saguaros are transplanted in the later fall or early winter, they should have a full month of dry soil time to reduce any onset of root rot, but can receive an initial watering after this dry period if there has been no rainfall. Although virtually all experts concur that transplanted saguaros should receive supplemental water, many caution against watering during the winter months, because root development and activity is generally inhibited by the cooler weather, and the cool, moist conditions may facilitate root rot. However, it is also not advisable that a newly transplanted saguaro should stand without any water for many months. The recommended schedule is to provide some water for those saguaros which are disposed to use it, but also long enough periods between watering to deter the continued development of any root rot that might start.

- Once air temperatures reach about 90°F, watering should begin according to the Water Schedule. (Note: the temperature guideline provided (60°F ground temperature and 90°F air temperatures) are general guidelines. In reality, natural processes operate on a continuum; not an absolute on-off switch. If a given saguaro is ready to grow roots, it can only do so if soil moisture is available.

Water Schedule

In the spring and summer, the watering schedule should be once every three weeks, especially during the first season as soil dries in 7 to 14 days (Desert Botanical Garden 2004, Mielke et. al. 2012, NRCS 2009). When temperatures exceed 110°F, watering may need to be increased to once every two weeks (Emming 2017, Mazier, no date).

Water schedules during non-summer months are more variable. It must be recognized that some winters are much warmer or cooler than the normative years, and that saguaros are well adapted to the winter rains in Arizona. The BMP is to try to simulate the average rainfall for the locale, based on available climate records and/or monitored by a rain gauge network established throughout the project area. If winter rains (as measured by the rain gauge network) are near the historic record norms, then supplemental watering is not needed. However, if winter months have little to no rain, and/or the temperatures are unseasonably warm, then supplemental water can be applied, but no more frequently than once per month. Saguaros may or may not be able to take advantage of this extra moisture. Because their roots are known to be active at night time air temperatures above 60°F, if day time air temperatures still reach into the 70°s or 80°s, the desert soils tend to absorb this heat which might stimulate root activity near the surface. A monthly watering, even if not utilized by the saguaro, is very unlikely to cause the development of root rot which is promoted by more chronic soil moisture. The widely spaced watering should not be detrimental to a healthy saguaro. Even in the event that there is some extant rot root as a result of the transplant process, the occasional watering is not expected to encourage the significant spread of this rot. This is because the wet conditions will not be prolonged, especially with the extra drainage provided by the pea gravel backfill.

There are other factors that can modify watering frequency. Spring, summer and/or winter rains, depending on the quantity, can substitute for one or more of the watering intervals. A distribution of rain gauges throughout the replant areas (existing network available via county flood control maps or installed network for the project) can be used to determine where and how much rain has fallen, and these data can be used to adjust the watering plan. Soil texture is another consideration. Sandy soils have poor water retention properties while clay soils hold water. This becomes an important factor as the roots grow from the well-drained pea gravel backfill into the surrounding native soil.

Water Application Methods

There are a variety of methods to apply water to accommodate different conditions within the project area. These methods are:

Jet-spray Tank Truck

Low-pressure jet-spray is a hose that extends from a tank truck that can quickly saturate soils to a depth of 4 to 5 inches (NRCS 2009). The hose system would allow one or more

workers to walk from saguaro to saguaro; the jet spray would allow the required water to be applied to each unit quickly.

ATV Tank
In settings where the truck/hose system does not have good access to some of the saguaros, a similar system can be mounted on an ATV equipped with a water tank. This more mobile ATV delivery system would require frequent refilling from a larger tank truck.

Octopus Hose Systems
Octopus hose systems are designed to operate from a manifold attached to a tank truck. Five to ten hoses can be run to as many saguaros, which are then watered simultaneously for a specified time. This system would best be used in conjunction with small basins prepared at the base of each saguaro.

(Note: Drip systems are ***not*** recommended. Drip systems are generally used to maintain soil moisture over an extended or even continuous period of time. Such an approach does not mimic natural precipitation events in the Arizona desert. This prolonged moisture regime might facilitate root rot.)

Ultimately, which ever system(s) is used, the appropriate amount of time to deliver a known number of gallons and to what depth this water penetrates must be determined. The number of gallons applied can be determined by using flow meters on the hoses.

Water Quantity
The Tucson Cactus and Succulent Society applied two gallons every two weeks to 2 to 3 foot saguaros (Thorton 2017), similar to a more moderate recommendation of 10 to 30 gallons every three weeks, depending on size of saguaro (Emming 2017). A very general rule of thumb is one gallon per linear foot of the cactus, including the arms, for each watering.

Initially, the trimmed root mass might be some 24 to 36 inches wide, and 12 to 24 inches deep. The first watering must penetrate to this area. This can only be determined by applying a measured volume of water to an area, and then either using a soil moisture meter, or digging a trench in an adjacent test area (e.g., an excavated hole backfilled with pea gravel) to observe the actual moisture penetration level. Several repeats of this experimental measuring (preferably using both methods), should yield a useful approximation of the amount of water (in gallons) that needs to be applied. Once this quantity has been ascertained, flow meters can be attached to hoses to measure how many gallons pass through in a given time period.

As the roots begin to expand laterally and grow nearer to the surface (over multiple growing seasons), the water application should strive to meet the 4 to 5 inch penetration level, over a broader area. This can be easily verified with soil moisture meters.

Although most experts agree that supplemental watering is beneficial to saguaro transplants, it is worth reiterating that most desert plants are more tolerant of too little water than too much (Kelly and Grumbles 2009). Supplemental watering and the concern of over-watering or facilitation of

root rot conditions should also be considered from the viewpoint of whether or not it is a chronic shift from natural conditions. Desert conditions are characterized as normally dry. Sometimes, even in the winter months, there are periods of considerable rainfall which may extend for a week or two. Providing very frequent and/or excessive supplemental water (e.g., via a drip system) would be a departure from typical desert conditions. A moderate or even heavy watering once a month, even during the winter months when the roots may or may not be active, is not a departure from typical desert conditions.

Duration

Most experts recommend that transplanted saguaros be watered at least through the first summer season, and often for another one to two years. However, a 10-year study of transplanted saguaros in the Tucson area determined that the impact of transplantation on water uptake by saguaros persisted for four years (Harris et. al. 2004). Accordingly, the Department recommends supplemental watering for at least four years from the transplant date.

Monitoring DBH

A diameter at breast height (DBH) measurement should have been taken prior to extraction and immediately post-transplant. For the duration of the post-transplant monitoring, DBHs should be recorded 10 days after each watering or rainfall event that exceeds a quarter of an inch. If the roots are starting to function and water uptake has occurred, the diameter of the saguaro will increase. Although most successful transplants should show increasing girth by the end of their first growing season, saguaros that are planted at less optimal times of the year (e.g., winter), or less vigorous individuals, might have a tendency to lag behind with root development and overall reestablishment (Emming 2017). Specific site conditions can also be expected to influence response time. Saguaros that show no increased girth (despite supplemental watering) after the second full growing season should be flagged as likely failures, but still receive supplemental care and monitoring as long as other cohorts are, or until there are obvious signs of rot or death. If the circumference of the saguaro increases, this can only result from growth which does require the uptake of water and nutrients, which in turn means that the roots are functioning. This definitive increase in circumference will define that the transplant has been successful[4]. A healthy saguaro will appear full with its ribs apart. Other indicators of growth include new arms or spines, or growth at the apices (ends) that can be pushing against the shade cloth (Byrd 2017, Saguarobylin_dot_com 2009, Desert Botanical Garden 2010, Kelly and Grumbles 2009).

Although DBH can be measured with a flexible tape measure, it will be quicker and more accurate to use a larger sliding caliper (e.g., a Haglof Mantax or similar device). The precise measuring points can be marked with white correction fluid (and renewed when these marks

[4] One reviewer (Peachey 2017) pointed out that an ongoing study of saguaros on Tumamoc Hill in Tucson which continuously measures the diameter of subject saguaros has found that there seems to be two minimum diameter low points each year and that the resultant sine-waves for each saguaro differs from the others. Accordingly, he questions whether the DBH measurements will truly be indicative of saguaro re-establishment and growth. However, there will be many DBH measurements for each saguaro over the duration of the project monitoring years. There should be adequate measurements to account for these suggested sine-wave fluctuations. More importantly, each individual saguaro is only being measured against itself as a long-term trend indicator. It can only continue to grow if the roots are functioning to uptake water and nutrients.

show signs of fading). The problem with using a measuring tape is that it must be carefully worked down through the spines to be truly accurate.

Other Post-Planting Management Practices

Do not cultivate and otherwise disturb the area around the trunk (up to seven feet diameter) to avoid damaging shallow roots. Do not mulch with any material that reflects or intensifies light. Do not cover soil with plastic sheets (Elliott 2003, Kelly and Grumbles 2009). Fertilization is generally not necessary.

PESTS AND DISEASES

Rots result from various forms of injury. Bacterial soft rot (*Erwinia carnegiana*) is a primary disease of saguaro and control measures include removal of the soft, black rotting tissue and treating with a 10 percent household bleach solution (Kelly and Grumbles 2009). Powdered sulfur can also be dusted into the wounds of saguaros as a healing aid. Sometimes an infection can develop in a saguaro through an injury or as a result of frost damage. It may be long after the actual event, but brownish or black ooze coming out of the trunk will indicate a problem. If the problem results from a localized injury, the suggested treatment can be successful. Sometimes, however, the problem is systematic (e.g., the plant has actually been killed by a hard freeze) and the emergent ooze is the first manifestation that the saguaro is standing but already dead (Desert Botanical Garden 2010).

In addition to the bacteria-caused soft rot, saguaros are also affected by wood-rotting "white" fungi. *Poria carnegiea* and *Phellinus texanus* are two types of fungi known to attack the lignin rich parts of the saguaro: woody roots and the butt (base) portion of the stem. It is most commonly found on mature plants and rarely on those less than 12 feet tall. *P. carnegiea* was found to be associated with 68 percent of saguaro wind-throws surveyed from 1961-1966 in the eastern section of Saguaro National Park (Lindsey 1975, Peachey 2017).

RECOMMENDED RESEARCH STUDIES

The topics listed below were identified while reviewing expert opinions and trying to resolve conflicts between various ideas and recommendations during development of the BMPs. The Department encourages further evaluation of these topics, especially when a large number of saguaros are proposed for transplanting. If such studies are to be incorporated into the project, work with AGFD's Research Branch and university/institutional experts to develop a detailed experimental protocol. Results from these studies could be used to improve these BMPs.

Ideal Root Length

Experts have suggested various lengths to which roots should be trimmed; these can generally be grouped into shorter (6-12 inches), longer (12-24 inches) and some extra-long (>24 inches) if they can be extracted without significant damage. Keeping track of final roots lengths for each saguaro, and monitoring the survival, health, and growth of transplanted saguaros in your project will help to determine which length is more advantageous. It may require sacrificing (or partially excavating) some of the transplanted saguaros to obtain information on the actual growth and condition of the roots.

Artificial Acceleration of Root Drying

Allowing time for the roots to air dry and callus after being extracted from the ground is a standard recommendation. Minimum times were 2 to 4 days; others were 1 to 2 weeks. It was also recommended, especially for larger saguaros, that they be removed from the ground and replanted in a "once-move" manner. Trying to follow both of these recommendations, along with it being prohibitive to leave a saguaro on the cradle for an extended period of time (even several days) because the equipment is needed for the next saguaro, leads to a conflict. To better inform these BMPs, a study should be designed to determine the most beneficial duration for drying, and whether alternative methods of drying are effective (i.e. can fans or blowers be used to artificially accelerate root drying; is the result physiologically and functionally the same or similar enough).

Use of a Root Growth Hormone

Although only one expert specifically recommended the use of a root growth hormone (indole acetic or buteric acid), given that nearly 80 percent of the root mass is lost during excavation, anything that accelerates the growth of new roots post-transplant so that the saguaro can uptake more water and nutrients and re-anchor itself, seems logical. This is why supplemental watering is recommended. Application of root hormones is a common horticultural practice for transplants. There is, however, some debate on this matter, which is summarized in an article in Appendix 12.7. It is recommended that a research protocol be developed to ascertain if the application of root hormones are beneficial when transplanting saguaros. Note that the protocol may include the sacrifice of some transplanted saguaros as a direct method of evaluating root growth.

Evaluation of Watering Methods

There are wide ranging opinions on when and how, and how much, to water transplanted saguaros, although virtually all experts agree this is beneficial. An experimental protocol should be developed and implemented to statistically determine the following:

1) When watering should begin?
2) What is the ideal frequency and what parameters should be used to guide the frequency?
3) Which seasons should or should not be emphasized, again with guiding parameters such as rainfall and temperature?
4) What quantities of water should be applied?
5) What are the best application methods, e.g., jet spray, hose, drip, use of small basins, etc.?

In any project that involves a large number of saguaros, it should be possible to design a robust experimental protocol.

Alternate Method of Staking Saguaros

There is an alternative method for staking saguaros from those presented in these BMPs that was described in an early edition of Lyle Benson's "Cacti of Arizona" (Thorton 2017). It states, "When the plant is first moved drive three or four pieces of pipe into the hole the saguaro is to occupy. Anchor roots may be wired to the pipes after wrapping with burlap where the wire goes around the roots. Use plain 9 or 12 gauge wire and it will rust away by the time the plant is able to support itself." This method would negate the necessity of removing guy wires after the saguaro is established and avoid the risk of injury from people running into guy wires. The pipe can be substituted with #4 rebar. This technique, if it can be demonstrated to facilitate the stability of larger saguaros, offers an easier, less expensive, and safer way to provide additional support. A suitable number of transplanted saguaros, taller than 15 feet, should be evaluated to determine if this method is advantageous.

Necropsy Saguaros

Transplants are never 100 percent successful. Root rot and the development of new roots in the absence of root rot are important factors that influence the survival of transplanted saguaros. The necropsy of dying saguaros might shed considerable light on what is actually going on within the normally unobservable root zone.

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APPENDICES

12.1 Summary of Studies
12.2 Technical Reviewers and Contributors
12.3a Data Collection Information Fields
12.3b Proposed Saguaro Condition Rankings
12.4 Partial Equipment List and Web-links
12.5 Agri-Mycin® 17
12.6 Planting Design from ADOT
12.7 Article Discounting Vitamin B-1 for Root Stimulation
12.8 Summary Version of BMPs (printable for handouts)

- Planning and Other Activities prior to Saguaro Removal
- Removal, Transport and Temporary Storage
- Re-Planting the Saguaro
- Post Planting Care

Summary of Saguaro Survival and Health Condition by Height Class from 2 Long-Term Studies

HEIGHT	HEIGHT	Tucson Study	ADOT	SR86 Covered Wells		SR87 Tombstone		SR188 Resort to Devore		US93 Kaiser Spring	
(meters)	(feet)	9 years	Studies:	4.5 years		11 years		4 years		8 years	
		survival %	HEIGHT	survival %	condition	survival %	condition	survival %	condition	survival %	condition
	overall:	66%		66% (1)		68%		72%		78%	
0.1 - 0.9	4 in - 3 ft	76									
1.0 - 1.9	3ft 3in - 6ft 3in	80	0 - 6ft	68	good	63	good	91	good	76	excel-good
2.0 - 3.9	6ft 6in - 12ft 9in	71	6 - 12ft	64	good	93	good	70	good-fair	71	good
4.0 - 4.9	13ft 1 in - 16ft	56									
			12 -20ft	55	fair	64	good-fair	78	good-fair	63	good-fair
5.0 - 6.9	16 ft 5in-22ft 8 in	55	>20	57	fair-poor	n/a		56	fair-poor	n/a	
>7.0	>23ft	40									
		with arms		88	fair-poor	23	dead	20,41,19,20	Gd,Fr,Pr,Dd	35,18,12,35	Gd,Fr,Pr,Dd
		without arms		58	good	7	dead	68,15,6,6	Gd,Fr,Pr,Dd	73,9	Ex-Gd, Pr-Dd
		with tapered base		63	good	72,21,5	Gd, Fr,Pr	84,6,3	Gd,Fr,Pr	79,17,1	Gd,Fr,Pr
		without tapered base		19	good	53,30,16	Gd,Fr,Pr	29,47,22	Gd,Fr,Pr	61,22,7,10	Gd,Fr,Pr,Dd
							Gd=Good; Fr=Fair; Pr=Poor; Dd= Dead				

(1) poorest survival of the 4 sites, but also received lowest amount of rainfall relative to long term average.

Tucson Study: Harris, Lisa K., Elizabeth A. Pierson, Carianne Funicelli, William W. Shaw, Susana Morales, Kelly Hutton, and Jennifer Ashbeck. 2004. Long-term Study of Preserved and Transplanted Saguaros in an Urban Housing and Golf Course Development. Desert Plants 20(1):33-42.

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Appendix 12.2 – Technical Reviewers and Contributors

Jessie Byrd. Manager, Pima County Native Plant Nursery. Tucson, AZ. Jessie.Byrd@pima.gov

Jan Emming. Destination: Forever Ranch and Gardens, Yucca, AZ. www.dfranch.com, jan@dfranch.com

Lisa Harris. President, Harris Environmental Group, Inc. Tucson, AZ. lharris@heg-inc.com

William Peachey. Tucson, AZ. williampeachey@cox.net

William Thorton. Tucson Cactus and Succulent Society, Tucson AZ. cactusworld@msn.com

B. Dean Treadwell Arizona Game and Fish Department (primary author)

Appendix 12.3a – Data Collection Information Fields

The following are data fields for information that should be collected for every saguaro cactus. Additional fields can be added as required. It is anticipated that a smart device app will be developed to facilitate data collection, storage and management.

Unique ID Number (this number should also be recorded on a tag and affixed to the cactus)
Geo-coordinate location of cactus (and geo-coordinate datum).
Height Number of arms and length of each arm.
Condition (see Appendix 12.3b for proposed condition rankings).
Other observations (e.g., color, especially if abnormal; number of holes; damage, etc).
Photos (from all 4 cardinal directions) and any particular close-ups if necessary.
DBH (diameter-at-breast-height)
[Measured at 4 feet, 3 inches from ground level, or 15 inches from top, whichever is closest to the ground]
Stem ridge (pleat) angle
Nurse tree Setting Yes/No Photo (if Yes)
Dates Information Recorded

Pre-Removal Hydration: Dates (may be multiple) Amount of Water

Extraction: Date Time (24 hr basis)
Length of Roots (after trimming) Lateral (1, 2, 3, etc) Length
Tap Root Length
Photos of Roots (with legible measuring stick)
Root Treatments Agri-Mycin Fungicide Sulfur
Root Air-Dry Time Start: Finish: Total Hours:

Temporary Nursery Storage Yes/No If Yes: Date/Time IN Date/Time OUT

Re-Plant Date Time
New Geo-Coordinates (and datum)
Confirm Planting Depth (based on original depth)
Confirm Orientation (based on original orientation)
Any Additional Root Treatments (trimming to remove damage)
Agri-Mycin Fungicide Sulfur
DBH Measurement Pleat Angle Measurement
Photos (from 4 cardinal directions)

Support System Use Yes/ No Date Photo

Supplemental Water Dates (may be multiple) Time Amount of Water
Re-Measure DBH / Pleat Date (10 days after watering) Time Diameter

Misc Observations Date (can be any time cactus is visited) Notes

Annual Monitoring Date Condition

Appendix 12.3b – Proposed Saguaro Condition Rankings

Score	Condition	Description
0	Dead	Dry, brown, no green tissue
1	Imminent Mortality	Dry, brown base, no green tissue connecting base and upper green, partly green or yellow tissue.
2	Poor	Yellowish color, evident damage or rot on skin, appearance of wrinkling or wilting. Retains tissue connection to base. Thin. Leaning. Top of main stem shrunken or leaning.
3	Fair	Generally green, holes or marks with some indication of rot. Skin generally uneven in texture. Lacking girth.
4	Good	Green throughout, some holes or marks, but no evidence of rot. Skin generally even and smooth, appearance generally plump.
5	Excellent	Vibrant green, few holes or marks, no evidence of rot or damage. Plump. Evidence of new growth.

Appendix 12.4 – Partial Equipment List and Web-links

- Saguaro cradles and hydraulics (attached to truck; attached to backhoe). Review various designs and select best features. Determine number of units required based on moving plan and other logistics.
- Padding material (old carpet, foam, etc) and cordage.
- Hand Tools (extraction and planting): shovels, picks, digging bars, pneumatic diggers, tamping rod.
- Hand Tools (trimming): knives, pruners, pruning saws (various).
- Plumb bob and cord; ladders; calipers and diameter measuring tapes: large sliding caliper (e.g., a Haglof Mantax or similar device); white correction fluid; large zip ties for affixing tags.
- Shade cloth (30%).
- Hand truck, wheelbarrow (both with never flat tires), slings (all for moving smaller cacti).
- Wire Support Rigging: wire (1/8th inch galvanized wire rope, 2000 lb breaking strength), fiber reinforced hose, 24" #4 rebar stakes, sledge hammer, flagging to mark guy wires, ladders.
  Other options:
  http://www.treestaking.com/?gclid=EAIaIQobChMIrNOXiLnr1gIVBIxpCh1syQxbEAMYASAAEgJprfD_BwE
  https://www.amleo.com/better-bilt-earth-anchor/p/VP-BBEA/
- Ag Chemicals: Agri-Mycin® 17, fungicide (Bordeaux Mix), powdered sulfur, applicators, protective gear. Bleach and container for sterilizing cutting tools.
- Pea gravel for backfilling.
- Water tank trucks; hoses and/or sprayers; hose-end flow meters; water moisture meters; rain gauges.
- Towable cherry-picker lift (attach padding, determining plumb, attach support wires)
  http://www.towbehindboomlifts.com/
  [for illustrative purposes; not a brand or company recommendation]

Appendix 12.5 – Agri-Mycin® 17

Agri-Mycin® 17

FUNGICIDE

Protect Ornamentals with Agri-Mycin® 17.

For years, Agri-Mycin® 17 has been the industry standard bactericide. It provides effective, economical control for three to four days. Its specific mode of action is unique to streptomycin and is an essential part of any bacterial disease control program.

SETTING THE STANDARD IN DISEASE CONTROL

- PROTECTION – Superior protection against certain diseases including leaf rot, bacterial stem rot, bacterial wilt and crown gall roses
- COMPATIBLE – Compatible with most commonly used pesticides
- GENTLE – Easy on target crop

EPA REG. NO.	55146-96
ACTIVE INGR.	streptomycin sulfate *(22.4%)*
FORMULATION	water soluble powder
CHEM. FAMILY	glucopyranosyl antibiotic
FRAC NO.	25
REI	12 hours
PACKAGE SIZE	10 x 2 lb bag
APPLICATION	spray, dip

FIELD-GROWN NURSERY
CONTAINER-GROWN NURSERY
GREENHOUSE
OMRI LISTED
CAUTION

Nufarm

Agri-Mycin® 17

FUNGICIDE

KEY USES

Chrysanthemums
Dieffenbachia cuttings
Philodendron
Roses

KEY DISEASES CONTROLLED

(See product label for complete list)
Leaf rot *(philodendron)*
Bacterial stem rot *(dieffenbachia cuttings)*
Bacterial wilt *(chrysanthemums)*
Crown gall roses *(New Jersey area)*

APPLICATION RECOMMENDATIONS

DISEASE AND CROP	RECOMMENDED CONCENTRATION	FIRST SPRAY	FOLLOW-UP SPRAY SCHEDULE
Bacterial leaf rot *(philodendron)*	200 ppm	Apply as a preventive or at first signs of water-soaked areas on leaf.	Apply every 4–5 days.
	For curative action	Remove all rotted leaves from plant and then spray at 200 ppm every 4 days.	
Bacterial stem rot *(dieffenbachia cuttings)*	200 ppm	Soak cuttings in streptomycin solution for 20 minutes; plant cuttings in sterilized rooting medium.	
	100 ppm	To check spread of stem rot in stock plants, use 100 ppm streptomycin spray every 5–7 days.	
Bacterial wilt *(chrysanthemums)*	50 ppm	Soak plant cuttings in streptomycin solution for 4 hours; plant as usual.	
Crown gall roses *(New Jersey area)*	200 ppm	Remove infected plant. Cut out gall tissue. Soak the plant root system and cut surfaces of the infected area in streptomycin solution for 15 minutes. Replant rose bushes in soil free of crown gall organisms.	
	50 ppm	Use 50 ppm streptomycin in watering solution and in foliar sprays applied weekly starting one week after planting as an adjunct to this treatment.	

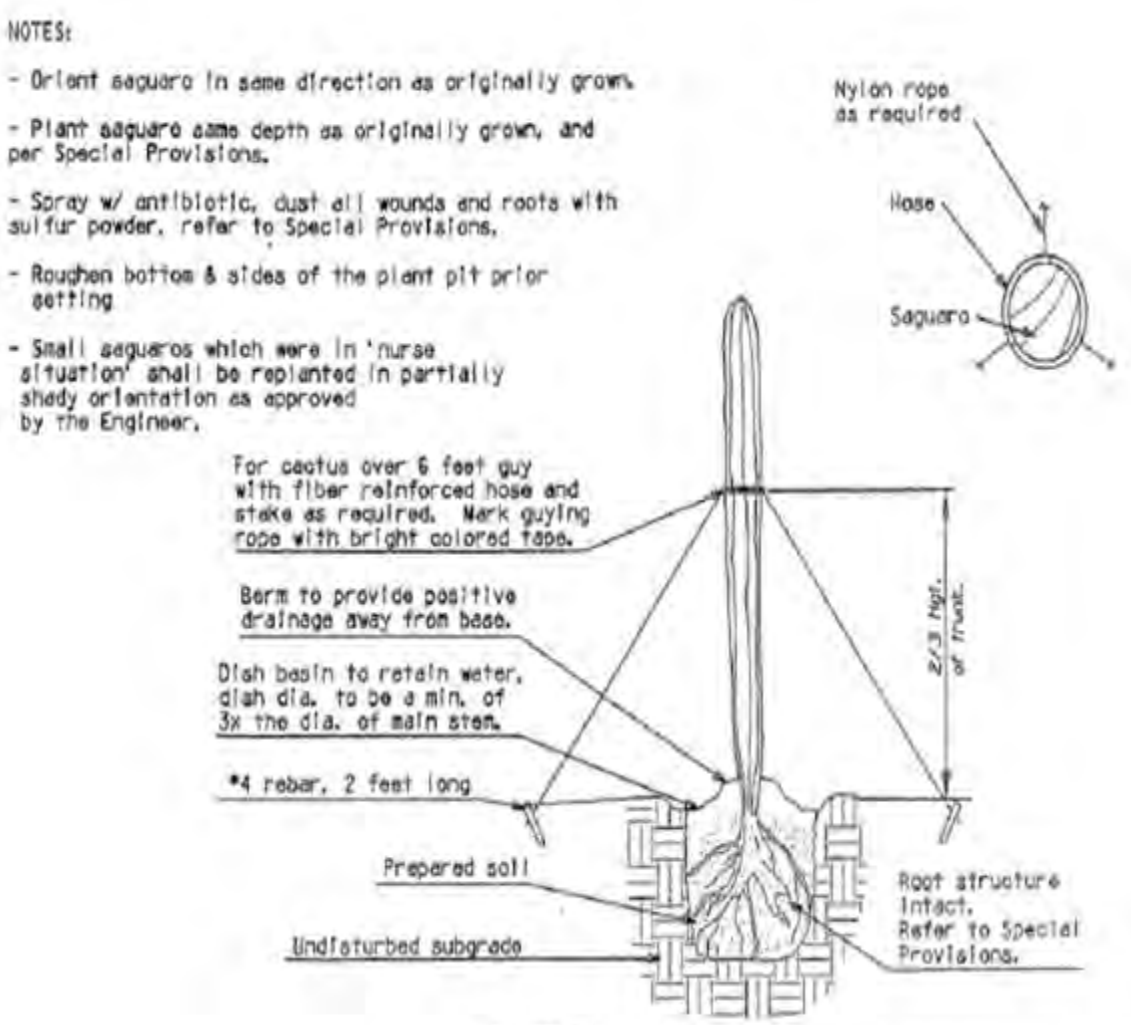
See label for complete application rates and recommendations.

MIXING INSTRUCTIONS

CONCENTRATION DESIRED	QUANTITY PER VOLUME OF WATER		
Parts per million	10 gals	50 gals	100 gals
50	0.4 oz	2.0 oz	4.0 oz
60	0.48 oz	2.4 oz	4.8 oz
100	0.8 oz	4.0 oz	8.0 oz
200	1.6 oz	8.0 oz	16.0 oz

See label for complete mixing instructions.

Appendix 12.6 – Planting Design from ADOT



(ADOT 2002: 39-40)

Mielke, Judy, Tisha Curella, Jenni James and Wayne Colebank. 2012. Evaluation of Salvage and Replanted Native Plants on ADOT Projects. Final Report No. FHWA-AZ-12-587 for ADOT Contract No. T0749A0029. Logan Simpson Design, Inc. Tempe, AZ. 115 p. https://apps.azdot.gov/adotlibrary/publications/project_reports/PDF/AZ587.pdf.

Appendix 12.7 – Article Discounting Vitamin B-1 for Root Stimulation

DYNA-GRO
ADVANCED SCIENCE SIMPLIFIED

HOME ABOUT PRODUCTS DG UNIVERSITY NEWS FIND A STORE CONTACT

< Previous

Vitamin B-1 Myth

Plants manufacture vitamins and hormones used to regulate their growth. In many instances, supplying these hormones, auxins and vitamins to plants can stimulate the growth of roots and foliage, regulate growth, internodal spacing and promote flowering. While many of these occur naturally in plants, man-made versions which have the effect of naturally occurring plant hormones can the same effect as those naturally occurring hormones, auxins & vitamins.

You can find vitamin B-1 on the shelves in many garden centers. Typical claims are that applying vitamin B-1 to new plantings helps to overcome transplant shock. Is there any truth to this claim or is this merely another horticultural myth?

Studies at the University of California, Davis conclude that there is no basis to support the claim that vitamin B-1 benefits plants by stimulating root growth or reducing transplant shock as many advertisements claim.

Jeff Schalau, an extension agent with the Arizona Cooperative Extension, Yavapai County wrote: "Application of vitamin B-1 (thiamine) to root systems of whole plants does not stimulate root growth. This myth arose from early work on plant growth regulators, called auxins, which were mixed with vitamin B-1. . . Various studies using both woody plants and annual flowers and crops failed to demonstrate that vitamin B-1 treatments provide any subsequent growth response."

Robert Cox, Horticulture Agent, Colorado State University Cooperative Extension wrote: "Several studies using (a variety of herbaceous and woody plants) have failed to demonstrate

http://dyna-gro.com/vitamin-b-1-myth/ 10/2/2017

that vitamin B-1 treatments provide any type of growth response. While root stimulator products are not necessary for transplant success, if you do use one, make sure it contains a rooting hormone and fertilizer rather than just vitamin B-1. The vitamin B-1 is for marketing purposes rather than actual effect."

An independent study to test the claim that vitamin B-1 applied to plants result in better foliage or root growth was conducted by the editors of *Sunset Magazine*, the results of which were published in the magazine. Starting with fast growing bedding plants, six different treatments were used:

1. B-1 alone
2. B-1 with phosphorous
3. B-1 with 3-10-3 fertlizer
4. B-1 with 10-10-10 fertilizer
5. 10-10-10 fertilizer alone
6. Plain water

The results at two weeks showed new leaves and growth on all plants except those given vitamin B-1 alone. The B-1 only plants showed no growth at all. The plants in treatment 5 (fertilizer alone) were blooming after four weeks. Those receiving B-1 with fertilizer (treatments 2, 3 & 4) took two more weeks to bloom. After six weeks, fertilized plants had better color, more blooms and more foliage. The shocking conclusion: **Plants that received only water out performed those receiving solutions treated with B-1!** Lesson: stick with water and nutrients. Skip vitamin B-1.

As a result of in-house testing of vitamin B-1, Almaden Valley Nursery, a retail garden center, pulled vitamin B-1 products from their retail shelves, refusing to subject their customers to another snake oil product. These studies should convince you that proper nutrition applications are the best bet for healthy plants.

What can you do to promote root growth?

For propagation of vegetative cuttings or promoting root growth when transplanting, there are effective options. Both IBA (Indole-3-butyric acid) and NAA (1-Naphthalene acetic acid) are auxins that stimulate root growth. Some B-1 products contain one or both of these auxins which will be beneficial when transplanting. One "Super ..." product consists of NAA and B-1 despite claims of more vitamins and hormones than exist in nature.

NAA is particularly effective in inducing root growth on cuttings because its primary effect is to enhance lateral root growth rather than primary root growth. However, NAA, like IBA suppresses top growth of plants and, therefore, should not be used on a continuing basis. One or two applications after transplanting rooted cuttings or other plants into new containers or the ground will suffice to promote lateral root growth. The plant can take over from there with its naturally generated hormones and auxins. For optimum results, insure that your plants are receiving complete nutrition*, adequate water and proper levels of light.

Dyna-Gro™ KLN Concentrate™ and Root-Gel® contain both IBA and NAA and are very effective for vegetative propagation and stimulating root growth at any time. KLN Concentrate™ is most effective on herbaceous cuttings in general while Root-Gel® is often more effective for more difficult to root, woody cuttings. In addition, Dyna-Gro™ Pro-TeKt®: The Silicon Solution® has produced 100% success rate in rooting vegetative cuttings without the application of any auxins or hormones. Combined with KLN Concentrate™, the two are even more effective used as a drench into the rooting medium before or after sticking the cuttings.

Appendix 12.8 Summary Version of BMPs

The following summary version of the Best Management Practices is designed to be printed and handed out to staff as needed for improved project implementation. The BMPs are divided into four sections:

- **Planning and Other Activities prior to Saguaro Removal**
- **Removal, Transport and Temporary Storage**
- **Re-Planting the Saguaro**
- **Post-Planting Care**

Planning and Other Activities Prior to Saguaro Removal

Identification of Individual Cacti. Every cactus to be moved needs to be identified and tagged. Minimum identification data includes a unique ID number, geo-coordinates, height, number of arms, whether or not in nurse tree setting, overall condition, and DBH (diameter at breast height). The DBH is measured at 4 feet, 3 inches from the ground level, or 15 inches from the top, whichever is closest to the ground, using a large sliding caliper. Photos should be taken. Tagging should include the AZ Dept. of Ag NPL and unique ID tag, affixed on the north side of the cactus, using zip-lock ties at a distance of 1 foot above natural ground level.

Planning. Meticulous planning of the salvage and transplant operation is critical. Beyond the numbers of cacti to be moved, there are major logistical variables that impact time, costs and final results. These include the timeline for the project itself; Dept. of Ag. Permits and tags; seasons to transplant the cacti (or will temporary storage be required); special time and handling considerations (i.e., once-move technique) for legacy cacti (those over 15 feet and/or with multiple arms); acquisition or scheduling of equipment, and treatment chemicals; labor requirements (number of specialized hydraulic saguaro cradles needed); time for air-drying roots; pre-removal and post-transplant irrigation needs, watering methods and equipment; long-term monitoring plan; implementation of research studies if planned, etc. Planning also includes identification/assignment of replanting sites for each cactus (including elevation concerns if planting saguaros above 2800 feet).

Seasonal Considerations. The saguaro cactus can be successfully transplanted throughout the year. The ideal season to transplant saguaros is the spring. The warmer weather promotes root growth and faster re-establishment. Transplanting can be done during the hotter summer months, but is less ideal because of the added stress on the cactus from the extreme heat. Summer times with heavy monsoon rains should be avoided due to excessive soil moisture that can promote root rot. Planting can continue into the fall and winter, with the understanding that new root growth might be delayed during these cooler months. Cacti transplanted during the cooler months should have up to a month in dry soil prior to any supplemental watering (if applied). Advantages of winter planting include decreased chance of sunburn, and less heat stress on both cacti and human workers. It is recommended that if larger, legacy cacti are being transplanted, they should be prioritized for the spring months if possible.

Re-Hydration of Cacti prior to Extraction. Unless the cactus is judged to be in superb condition, it should be watered prior to extraction. A healthy saguaro will appear full with its ribs apart. There should also be signs of growth such as new arms starting, new spines, or growth at the apex (tips) of the plant. The cactus will lose 80% of its roots, and 30-50% of its total biomass during the transplant process. The cactus should be watered, preferably two times, several weeks prior to extraction. Given that the native growing saguaro prior to excavation still has its extensive, shallow root system intact, a jet hose can be used to apply water over these widespread roots to a depth of 4-6 inches. The very minimum recommended is a slow watering to a depth of 12 inches, two weeks before removal. A soil moisture probe can be used to verify the water penetration depth. Ten days after watering, the DBH should be measured and compared to the original measurement recorded when the cactus was inventoried. An increase in the DBH indicates that water uptake has occurred.

Removal, Transport and Temporary Storage

Handling Saguaros. Saguaros less than six feet tall can be moved relatively easily using a hand-cart (dolly) with pneumatic (preferably never flat tires), wheelbarrow or slings if adequate workers are available. Depending on the height and girth, these 5-6 foot cacti can weigh 300-600 pounds. Sufficient padding should be used so that no damage to the spines and trunk occur, and the cactus should be well secured to the dolly. Adequate padding should be used to cushion the side and spines lying on the bed of the truck or trailer, and these spears should be tied down so they do not bounce. Cacti can be stacked 2-3 high, depending on size, if sufficient padding is used. They should also be covered with shade cloth to prevent sunburn.

Saguaros taller than 6 feet are best handled with a special cradle for support and usually a hydraulic system for lifting and tilting. Prior to moving, while the cactus is still upright, pad trunk and arms generously; then secure the wrapped carpet with cordage. Arms more than three feet in length should also be supported and the cactus should be firmly attached to the cradle device for safety.

Excavation of the Cactus. Prior to excavation, verify that the north direction tag is attached with a zip-lock band placed 1 foot above ground level. Record the DBH. For cacti taller than 6 feet, start digging the trench around the cactus at the two foot radius from the outside of the stem. If lateral roots can be easily exposed, longer lengths can be retained. Undercut the cactus to sever the tap root at no less than 18 inches; if removing from a sandy soil, even more of the tap root can sometimes be extracted. For cacti less than two feet tall, the goal is to remove the entire root mass, and to remove as much as possible for cacti that range from 2 – 6 feet tall. Considerable care is important because saguaro roots can be very brittle.

Root Trimming and Treatments after cactus has been removed from the hole. After a careful excavation, trimming and treatment of the roots may be the next most important action towards achieving a successful transplant. Not only does the saguaro lose the majority of its root system from the excavation process, it also has the proclivity to suffer from root rot. Any damaged parts of roots should be carefully trimmed away. All tools such as knives, pruners and saws should be sharp and sterile. Use a 10% household bleach solution to clean tools between individual cacti. Retain 12-18 inches of solid, healthy lateral roots, and longer if possible. All of the tap root that was removed without damage should also be retained. The trimmed roots should be well dusted with a fungicide and Agri-Mycin® 17. Sulfur powder can be used as a last resort, but may not be very effective against white fungi. A photo of the roots should be taken following excavation. The photo should include a legible measuring stick.

Air Drying Roots. Ideally, the freshly trimmed roots should have 1-2 weeks to air-dry in the shade. This process allows the recently traumatized roots time to form a protective callus, which helps prevent the entry of pathogens and subsequent root rot. For small projects moving only a few saguaros, this BMP can be readily accommodated. However, when dozens or hundreds are being moved, with a limited number of hydraulic cradles, this length of time is unlikely to be available. A single large saguaro cannot be allowed to sit on the cradle for a week or more. Additionally, the large "legacy saguaros" are best transplanted using a "once-move" method. This also precludes the recommended drying time. Smaller saguaros, especially spears, can be stacked on a flatbed trailer and left for the recommended air-drying period (under shade). Some techniques that may help mitigate insufficient air-dry time are: (1) use of fungicide and/or sulfur powder; (2) utilizing weekend time for extra drying days as much as possible; (3) recognize that the moving wind around the open air roots during transport should facilitate drying; and (4) consider the use of blowers to hasten drying time. Because all translocated saguaros are unlikely to

receive the BMP recommended air-dry time, it becomes very important to keep accurate records of how long (probably in hours) each individual cactus is allowed to have its roots exposed to the air (and/or drying fans if used). When large numbers of cacti are transplanted, this information will help to analyze the impact of varying air-drying times on the survival of the cacti.

Cover cacti during transport. All parts of the cactus, including the roots, should be covered with carpet, other protective covering, or 30% shade cloth during transport. The coverage must be well secured for any required highway travels so that it does not blow open and expose the cactus to possible sunburn.

Temporary Storage. Storing saguaro cacti should only be done when absolutely necessary. Immediate transfer of plants to their permanent location reduces the amount of mechanical handling and probability of damage to the plant, and ensures the best survival rate. This "once-move" approach is especially important when transplanting the larger and/or multi-arm cacti. The need for temporary storage, locations, and durations are key factors that should be addressed during the planning stage of a transplanting project. Storage areas should be open to allow good air circulation. The cacti should be both properly oriented using the tag placed on the north side, and covered with shade cloth (30%) to prevent sunburn. The cacti must remain in an upright position. Pea-gravel is the recommended backfill. If this backfill is well packed, cacti up to 12 feet tall (with or without arms) and spears (cacti without arms) up to 15 feet should not require additional support. Cacti taller than 12 feet with arms and any cacti taller than 15 feet should be supported with guy wires and stakes. Saguaros have been kept in nursery storage for two years.

Re-Planting the Saguaro

Select an advantageous aspect when planting at elevations above 2800 feet. In these settings, the saguaro should be planted on south- and west-facing slopes; north-facing slopes should be avoided. If planting on a north-facing slope is unavoidable, the plants should be placed near the top of the slope rather than near the base.

Hole Preparation: width and depth. Excavate the new hole to a width twice as wide as the extant root ball. If longer lengths of some lateral roots were successfully excavated without excessive damage, those longer than 18-24 inches can be buried in a trench dug especially to accommodate them (i.e., like laying pipe), rather than expanding the diameter of the entire hole. The saguaro should be replanted no deeper (or within 1-2 inches) than its original level in the ground. The zip-lock tie placed 1 foot above the original ground level, along with the vertical length of the extant root mass, including the tap root, can be used to measure precisely how deep the hole should be (after subtracting the extra foot). The soil at the bottom of the hole should be able to promote good drainage (a sandy type soil). If it's too hard and compact (a clay type soil) it can be broken up and/or some sand or gravel added, but should then be re-tamped to the proper depth as calculated.

Proper Re-orientation and final steps before backfilling the hole. Using the tag attached on the north side of the cactus, orient the cactus to face north once again. Prior to lowering the cactus into the hole, trim off any damaged roots, and again dust/spray the root mass with additional fungicide and anti-bactericide. Use of a root stimulating hormone (indole acetic or buteric acid) has been suggested. Either visually, or using a plumb line, assure the cactus is vertically straight and balanced. Note the cactus is still attached to the cradle for support and safety. If the cactus is simply lowered into the hole, its massive weight is likely to crush the tap root which could very well result in rot. If the cactus is lowered into the hole and supported by the cradle as the hole is backfilled, damage to the tap root can be avoided.

Backfill. Pea gravel is recommended for the backfill material. If properly tamped and packed, it provides the necessary support for the cactus. It also drains well and precludes excessively wet conditions around the recently traumatized roots that may or may not have received sufficient air-dry time.

Tamping backfill around the cactus and its trimmed roots. The backfill must be firmly compacted around the plant. This is best accomplished by adding a few inches of pea gravel, tamping it down well, and repeating this process until the hole is filled. As this is done, the cactus should still be supported to avoid crushing the tap root. Caution should be used when tamping to avoid striking or otherwise damaging the carefully trimmed, treated and callused roots. Fresh wounds could easily defeat all the previous efforts to avoid rot root. Any accidental damage should not be ignored; rather, that area should be dug out, trimmed again, and treated with fungicide, bactericide and/or extra sulfur. Another suggestion, instead of tamping (which as just noted could strike and damage a root) is to use a heavy bar inserted into the fill to agitate the fill material with circular and/or back and forth motions.

Build a stem cone and water retention basin around the base of the stem. The stem cone or tapered mound will divert water away from the stem and prevent accumulation of excess water and possibly pathogen spores from contact with the stem. The water retention basin should be 3 times the diameter of the stem, with a 4-6 inch berm to retain the water. This basin will capture some rainfall, but is primarily intended to assure the most efficient usage of supplemental water. A similar technique is to dig a donut-shaped canal around the saguaro starting about 18 inches from the stem. This design will also facilitate the efficient use of supplemental water, and will be able to capture some additional runoff water from

rainfall events. Note that using pea-gravel as backfill (instead of using the native soil excavated from the hole) will also promote the infiltration of water into the area excavated.

Additional Temporary Support – Staking the Taller Transplanted Saguaros. Any saguaro over 15 feet tall and 12-15 foot saguaros with arms should have additional support. The preferred support system consists of three guy wires strung through sections of fiber-reinforced hose. 1/8th inch galvanized wire rope (2000 lb breaking strength) is recommended. Sections of hose are placed around the plant two thirds up from the base. Triangulate the three guy wires from the hose sections surrounding the plant column and stake them into the ground using 24 inch #4 rebar. Guy wires should be flagged at 5-6 feet above ground level as a safety measure. The support system should be left in place for at least two growing seasons. Once staking is complete, the cactus can be detached from the cradle. The use of 2x4 supports, covered with carpet at the point of contact with the stem are not recommended.

Re-measure DBH. This measure will indicate if the cactus has loss mass during the move (and/or storage) and serve as the baseline measure to monitor new water uptake and transplant success. New photos should be taken.

Use Shade Cloth. Cover each newly transplanted saguaro with 30% shade cloth, secured around the stem and arms with cord and completely covering the southern and western exposures. Leave the cloth on through the first summer season. Care should be taken that folds and overlaps in the cloth do not effectively double or triple the protection.

Post-Planting Care

Watering newly transplanted saguaros. Plant the cactus into dry ground, backfill with pea gravel, and do not water immediately to "settle" the backfill. Recommended watering regimes will vary by season and transplantation date. Initiate post-transplant saguaro watering according to the following guidelines:

- The newly replanted saguaro has loss perhaps 80% of its roots. Saguaro roots are known to be very susceptible to root rot (facilitated by damaged roots and excessive moisture). The initial post-transplant watering regime should emphasize avoiding prolonged excessively moist conditions by providing intermittent watering in well drained (pea gravel) conditions.
- Saguaros transplanted in the spring, summer, or early fall months should remain in the dry backfill soil for 2-4 weeks before initial watering begins. Two weeks are sufficient for those whose roots were allowed the recommended two weeks air drying time; the additional weeks in dry soil are given (proportionately) to those cacti that received less or effectively no air drying time.
- If saguaros are transplanted in the later fall or early winter, they should have a full month of dry soil time to reduce any onset of root rot, but can receive an initial watering after this dry period if there has been no rainfall. Root development and activity is generally inhibited by the cooler weather, and the cool, moist conditions may facilitate root rot. However, it is also not advisable that a newly transplanted saguaro should stand without any water for many months. The recommended schedule is to provide some water for those cacti which are disposed to use it, but also long enough periods between watering to deter the continued development of any root rot that might start.
- Watering should definitely be regular once air temperatures have regained about 90°F, when roots are actively growing.

Water Schedule

Saguaros should be watered once every three weeks; especially during the first summer (soil dries in 7 to 14 days). When temperatures exceed 110°F, watering may be increased to every two weeks.

Water schedules during non-summer months are more variable. It must be recognized that some winters are much warmer or cooler than the normative years, and that saguaros are well adapted to the winter rains in Arizona. The BMP is to try to simulate the average rainfall for the locale, based on available climate records and monitored by a rain gauge network established throughout the project area. If winter rains (as measured by the rain gauge network) are near the historic record norms, then supplemental watering is not needed. If the winter months have little to no rain, and/or the temperatures are unseasonably warm, then supplemental water can be applied, but no more frequently than once per month. Saguaros may or may not be able to take advantage of this extra moisture since their roots are known to be inactive until night time air temperatures are above 60°F. However, if day time air temperatures still reach into the 70s or 80s, the desert soils tend to absorb this heat which might also stimulate root activity near the surface. A monthly watering, even if not utilized by the saguaro, is very unlikely to cause the development of root rot which is promoted by more chronic soil moisture.

There are other factors that can modify watering frequency. Spring, summer and/or winter rains, depending on the quantity, can substitute for one or more of the watering intervals. A distribution of rain gauges throughout the replant areas can be used to determine where, and how much, rain has fallen. This data can be used to adjust the watering plan. Soil texture is another consideration. Sandy soils have poor water retention properties where clay soils hold water well. This becomes an important factor as the roots grow from the well-drained pea gravel backfill into the surrounding native soil.

Water Application Methods

There are a variety of methods to apply water to accommodate different conditions within the project area. These methods are:

Low-pressure Jet-spray Tank Truck

This is a hose that extends from a tank truck that can quickly saturate soils to a depth of 4-5 inches. The hose system would allow one or more workers to walk from saguaro to saguaro; the jet spray would allow the required water to be applied to each unit quickly.

Octopus Hose Systems

Octopus hose systems are designed to operate from a manifold attached to a tank truck. Five to ten hoses can be run to as many saguaros which are watered simultaneously for a specified time once the manifold is opened. This system would best be used in conjunction with small basins prepared at each saguaro.

ATV Tank

In settings where the truck/hose system does not have good access to some of the saguaros, a similar mini-system can be mounted on at ATV equipped with a water tank. This more mobile delivery system would require frequent refilling from a larger tank truck.

(Note: Drip systems are ***not*** recommended. Drip systems are generally used to maintain soil moisture over an extended or even continuous period of time. Such an approach does not mimic natural precipitation events in the Arizona desert. This prolonged moisture regime might facilitate root rot.)

Water Quantity

A general rule is one gallon of water per linear foot of cactus, including the arms, for each watering.

Duration

Provide supplemental watering for at least 4 years from the transplant date.

Use the DBH to Monitor Cactus. DBH measurements have been recorded both prior to extraction and immediately post-transplanting, and 10 days after each supplemental watering, or rainfall event that exceeds one quarter inch. A large sliding caliper (e.g., a Haglof Mantax) is recommended. The precise measuring points can be marked with white correction fluid (and renewed when these marks shown signs of fading).

If the roots are functioning, the diameter of the saguaro will increase. Although most successful transplants should show increasing girth by the end of their first growing season, saguaros that are planted at less optimal times of the year (e.g., winter), or just certain individuals, might have a tendency to lag behind with root development and overall reestablishment. Saguaros that show no increased girth after the second full growing season can be flagged as likely failures, but should still receive supplemental care and monitoring as long as other cohorts are, or until there are obvious signs of rot or death. If the circumference of the saguaro increases, this can only result from growth which does require the uptake of water and nutrients, which in turn means that the roots are functioning. Thus a definitive increase in circumference will define that the transplant has been successful. Other indicators of growth include new arms or spines, or growth at the apices (ends) that can be pushing against the shade cloth.

Other Post-Planting Management Practices

Do not cultivate and otherwise disturb area around the trunk (up to seven feet diameter) to avoid damaging shallow roots. Do not mulch with any material that reflects or intensifies light. Do not cover soil with plastic sheets. Fertilization is generally not necessary.

Appendix C

Hydrologic and Hydraulic Analyses for North Ranch Wash

Hydrologic and Hydraulic Analyses for North Ranch Wash
Northeast Corner of Thornydale and Sumter
T12S, R13E, Section 17
Pima County, Arizona

Prepared For:

Mr. Zachary Channing
ZDC Properties, LLC
18381 Long Lake Drive
Boca Raton, FL 33496

Prepared By:
Arroyo Engineering, LLC
2118 E. 10th Street
Tucson, Arizona 85719

June 2022

ARROYO ENGINEERING, LLC
Water Resources & Civil Engineering Consultants

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TABLES

I. INTRODUCTION

A. Project Site

This Drainage Report has been prepared in support of a rezoning application and site plan for the project site prepared by Baker and Associates Engineering, Inc. (BAE).

The property site is located within unincorporated Pima County at the northeast corner of the intersection of Thornydale Road and Sumter Drive within Township 12S, Range 13E, Section 17. The project site is partially developed. The project site is bordered by North Ranch subdivision (M&P 39/58) to the north, two residential properties to the east, Thornydale Road to the west, and Sumter Drive to the south. A Location Map is provided in Appendix A.

B. Project Understanding and Approach

Two watercourses, regulated by both Pima County and the Federal Emergency Management Agency (FEMA), are located on the project site. The two watercourses combine to form a single FEMA 100-year floodplain for the North Ranch Wash, which is designated as "Zone A." By definition, Zone A is a floodplain determined by approximate methods. Consequently, there are no site-specific hydrologic data, hydraulic model, or floodplain mapping which can be used to define the onsite floodplain at a level of detail required for site development. New hydrologic analyses and new hydraulic model have been completed to define the existing and proposed 100-year floodplain on the site.

C. Purpose of Report

The initial purpose of the hydrologic and hydraulic analyses is to support the rezoning application for the project site. Because of the subsequent development requirements related to the site plan (for submittal to Pima County) and a Conditional Letter of Map Revisions (CLOMR) (for submittal to FEMA), the analyses have been completed at a level of detail appropriate for use as part of future submittals. In addition, the hydraulic model will extend beyond the southern property line to near Linda Vista Boulevard because of potential mapping needs as part of the CLOMR.

D. Existing Studies

Hydrologic and hydraulic modeling was completed for the North Ranch Wash as part of the North Ranch Wash Floodplain Study (Technical Data Notebook [TDN], Arroyo Engineering and SCE Engineering, March 14, 2019). The North Ranch Wash study area includes the entire North Ranch Wash watershed located upstream of the North Ranch subdivision. The Thornydale/Sumter project site is located south of the North Ranch subdivision, outside of the North Ranch Wash study area.

The 2019 TDN was approved by the Pima County Regional Flood Control District (RFCD) and the Town of Oro Valley. The TDN was subsequently modified and approved by FEMA on June 23, 2021 as Letter of Map Revision 20-09-1981P.

E. Report Requirements

This Drainage Report has been prepared in accordance with Pima County Regional Flood Control District Technical Policy TECH-114, "Requirements for Content of Hydrologic and Hydraulic Drainage Reports," (revised date 11/2/2015). This report is limited to only address drainage conditions specific to the North Ranch Wash.

II. EXISTING CONDITIONS

A. North Ranch Wash

Two watercourses, regulated by both Pima County and FEMA, are located on the project site. The onsite watercourses are two branches of the North Ranch Wash. The watercourses are referenced as the "west branch" (NR-W) and "east branch" (NR-E) within this report.

B. FEMA Floodplains

The FEMA floodplain on the project site is shown on Flood Insurance Rate Map 04019C2270L (FEMA, June 16, 2011). The two onsite watercourses combine to form a single FEMA 100-year floodplain for the North Ranch Wash, which is designated as "Zone A." Zone A is a "special flood hazard area subject to inundation by the 1% annual chance flood, no base flood elevations determined."

C. Existing Studies

Hydrologic and hydraulic modeling was completed for the North Ranch Wash as part of the North Ranch Wash Floodplain Study (Technical Data Notebook [TDN], Arroyo Engineering and SCE Engineering, March 14, 2019). The North Ranch Wash study area includes the entire North Ranch Wash watershed located upstream of the North Ranch subdivision. The Thornydale/Sumter project site is located south of the North Ranch subdivision, outside of the North Ranch Wash study area.

The 2019 TDN was approved by the Pima County Regional Flood Control District (RFCD) and the Town of Oro Valley. The TDN was subsequently modified and approved by FEMA on June 23, 2021 as Letter of Map Revision 20-09-1981P.

III. PROPOSED CONDITIONS

For proposed conditions, onsite flow corridors along the west branch and the east branch of the North Ranch Wash will generally be maintained along their natural flow paths. For onsite portions of the west branch, the 100-year flow is split into two separate flow paths under existing conditions. For proposed conditions, the east flow path will be eliminated and all west-branch flows will be directed into the western flow path.

The footprint o the proposed development is shown on the Developed Conditions Floodplain Map in Appendix A. Where areas of the proposed development encroach into the 100-year floodplain and/or the erosion hazard setback, bank protection is proposed. For the areas of proposed bank protection, the proposed 100-year floodplain boundaries will lie along the limits of the bank protection. For the areas that remain natural, the floodplain boundaries generally correspond to the existing conditions floodplain boundaries.

IV. HYDROLOGIC AND HYDRAULIC ANALYSIS

A. Hydrology

1. Offsite North Ranch Wash

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A hydrologic and hydraulic analysis for the North Ranch Wash, located north of the North Ranch subdivision, was previously completed to determine 100-year peak discharges, flood depths, and floodplain boundaries using FLO-2D (North Ranch Floodplain Study, 2019). The Watershed Map from the 2019 study is provided in Appendix A.

The 100-year discharges were calculated at various locations within the North Ranch Wash study area. Exhibit 4 from the 2019 North Ranch Floodplain Study is provided in Appendix A to display the calculated 100-year discharges for the recording cross sections located at the downstream limit of the study area. These discharges, which flow through the North Ranch subdivision and then across the project site within the two onsite watercourses, are summarized in the following table.

North Ranch Wash FEMA 100-Year Discharges			
Location Downstream limit of FIS	Concentration Pt. (for this project)	Recording Section	Q_{100} (cfs)
West branch	NR-W	212	303
East branch	NR-E	210	531

2. Onsite North Ranch Wash

The west branch and the east branch of the North Ranch Wash flow through the North Ranch subdivision, combine with onsite flows from the North Ranch subdivision, and then enter the project site along the north property line. The flows from the North Ranch subdivision enter the watercourses both by direct discharge and detention basin outflows.

The 100-year peak discharges along the west branch and the east branch of the North Ranch Wash for locations on and near the project site were determined by combining hydrographs from the upstream North Ranch Wash and the downstream flows from both the North Ranch subdivision and the onsite contributions from the project site.

For the upstream flows from the North Ranch Wash, 100-year hydrographs were obtained from the FLO-2D model (North Ranch Floodplain Study, 2019).

For the downstream flows from the North Ranch subdivision and the project site, hydrologic calculations were performed and hydrographs generated using the web-based PC-Hydro 7.1, in accordance with guidelines from the PC-Hydro User Guide (Pima County Regional Flood Control District, 2019; Arroyo Engineering, 2007). Hydrologic data sheets are included in Appendix B. Watersheds are shown on the project maps in Appendix A.

Hydrograph summations did not include any peak-flow reduction effects from the North Ranch detention basins. From an evaluation of the offsite and onsite hydrographs, it was determined that the difference in the time to peak for 1) the offsite flows (3.3 hours) in North Ranch Wash and 2) the local flows (15 minutes) from the North Ranch subdivision and the project site were so large that the offsite flows and the onsite runoff contributions are mutually exclusive. In other words, the local flows have no effect on the regional peak flows along the North Ranch Wash.

The hydrograph analyses are included in Appendix B. Summary tables are provided as follows.

Summary of Hydrograph Contributing Flows to the North Ranch Wash				
Location	Conc. Pt.	Hydrograph Q_{100} (cfs)	Time to Peak (hrs)	Hydrograph Duration (hrs)
NR Wash – West Branch	NR-W	303	3.37	>4.5
NR subdivision	W-1	47	0.27	1.5
NR subdivision	W-2	105	0.25	1.5
Project site (local)	W-3 (local)	49	0.23	1.0
NR Wash – East Branch	NR-E	531	3.28	>4.5
NR subdivision	NR-E1(local)	37	0.25	1.5
NR subdivision	E-1	74	0.23	1.5
Project site (local)	NR-E3(local)	22	0.25	1.5

Summary of Hydrograph Summations for North Ranch Wash		
Location	Conc. Pt.	Hydrograph Q_{100} (cfs)
NR Wash – West Branch	NR-W	303
	NR-W1	303
	NR-W2	303
	NR-W3	303
NR Wash – East Branch	NR-E	531
	NR-E1	531
	NR-E2	531
	NR-E3	531

B. Hydraulics

1. Floodplain Mapping

Detailed hydraulic models were prepared, using RiverCAD and HEC-RAS software, for onsite watercourses. Concentration points and 100-year floodplains are shown on the Existing Conditions Floodplain Map and Developed Conditions Floodplain Map provided in Appendix A. HEC-RAS summary output sheets are included in Appendix C. HEC-RAS input files are provided separately.

C. Erosion Hazard Setbacks

In accordance with Pima County regulations, erosion hazard setbacks along regulatory watercourses are based on the corresponding 100-year discharge. Setbacks for the project site are listed as follows:

Erosion Hazard Setbacks for North Ranch Wash		
Concentration Point	Q_{100} (cfs)	Setback (ft)
NR-W3	303	25
NR-E3	531	50

V. REFERENCES

Arroyo Engineering and SCE Engineering, *North Ranch Wash Floodplain Study Technical Data Notebook*, March 14, 2019.

Federal Emergency Management Agency, *Flood Insurance Study for Pima County and Incorporated Areas, Arizona,* June 16, 2011.

Perry Engineering, *Tentative Plat for Mountain Vista Ridge*, August 14, 2018.

Pima County Regional Flood Control District, *Design Standards for Stormwater Detention and Retention*, November, 2015.

Pima County Regional Flood Control District, *PC-Hydro User Guide,* 2019; Arroyo Engineering, 2007.

U.S. Army Corps of Engineers, Hydrologic Engineering Center, *HEC-RAS River Analysis Systems*, Version 3.1.3, May 2005.

Appendix A. Exhibits

Location Map

Legend

- Parcels

Notes:

5/16/2022

800.0 0 400.00

Feet

This map is static output from an internet mapping site and no warranty is expressed or implied as to the accuracy, reliability, currency or completeness of the data, and is for reference only

CI=2'
NAVD88

0 300 600

SCALE

North Ranch Wash

NR-W
303 cfs

NR-E
531 cfs

North Ranch Subdivision

W-1
47 cfs

NR-W1
303 cfs

Thornydale Rd.

W-2
105 cfs

E-1
74 cfs

Basin E

Basin W

NR-E1
531 cfs

NR-W2
303 cfs

NR-E2
531 cfs

Project Site

NR-W3
303 cfs

NR-E3
531 cfs

Sumter Drive

Mountain Vista Ridge

LEGEND

Local watershed boundary

Flow arrow

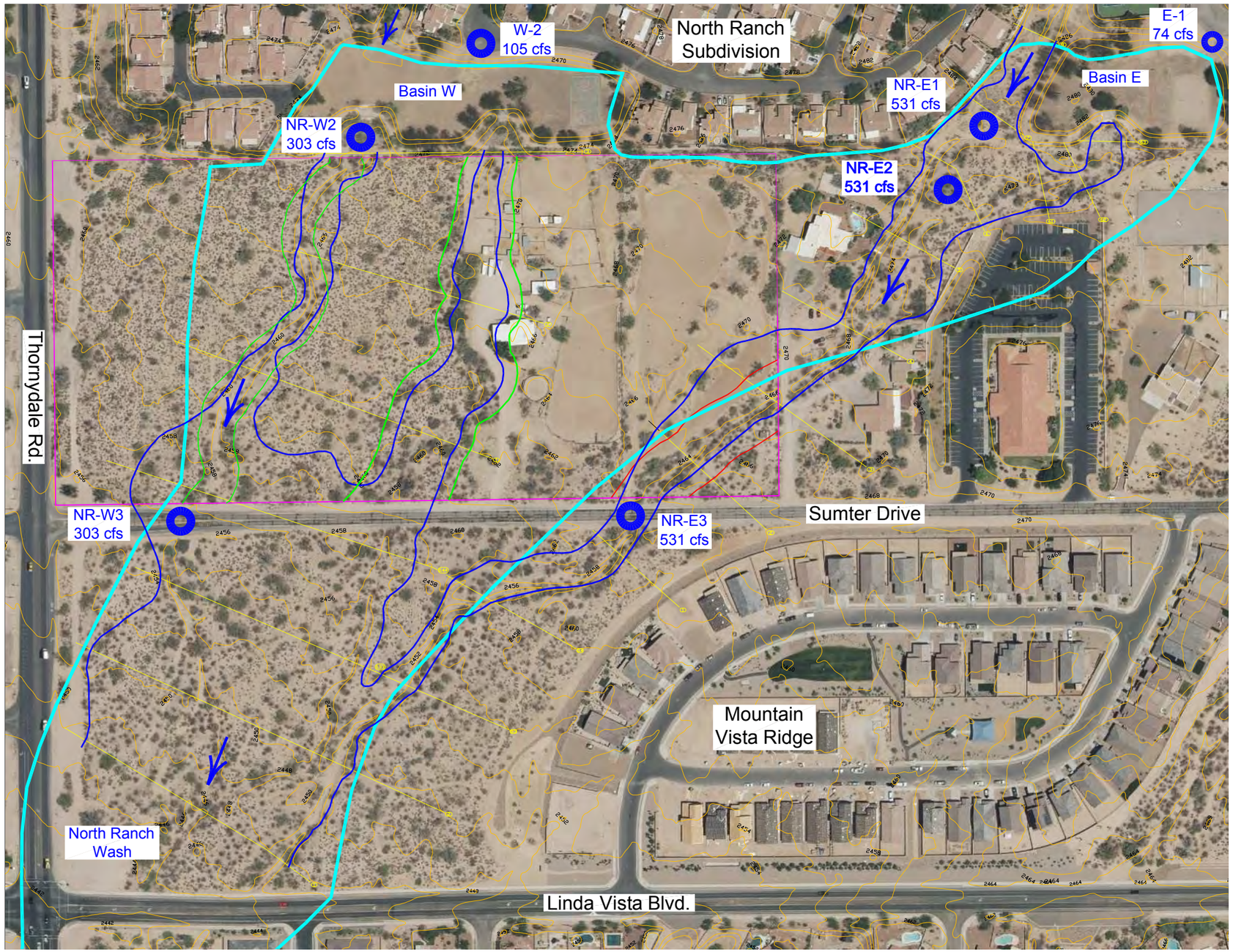
Project site

E-1
73 cfs — Concentration point with 100-year discharge

NR-E
531 cfs — 100-year discharge at FLO-2D recording section
(North Ranch Floodplain Study, Arroyo Engineering, March 2019)

ARROYO ENGINEERING, LLC
Water Resources & Civil Engineering Consultants

EXISTING CONDITIONS HYDROLOGY MAP



CI=2'
NAVD88

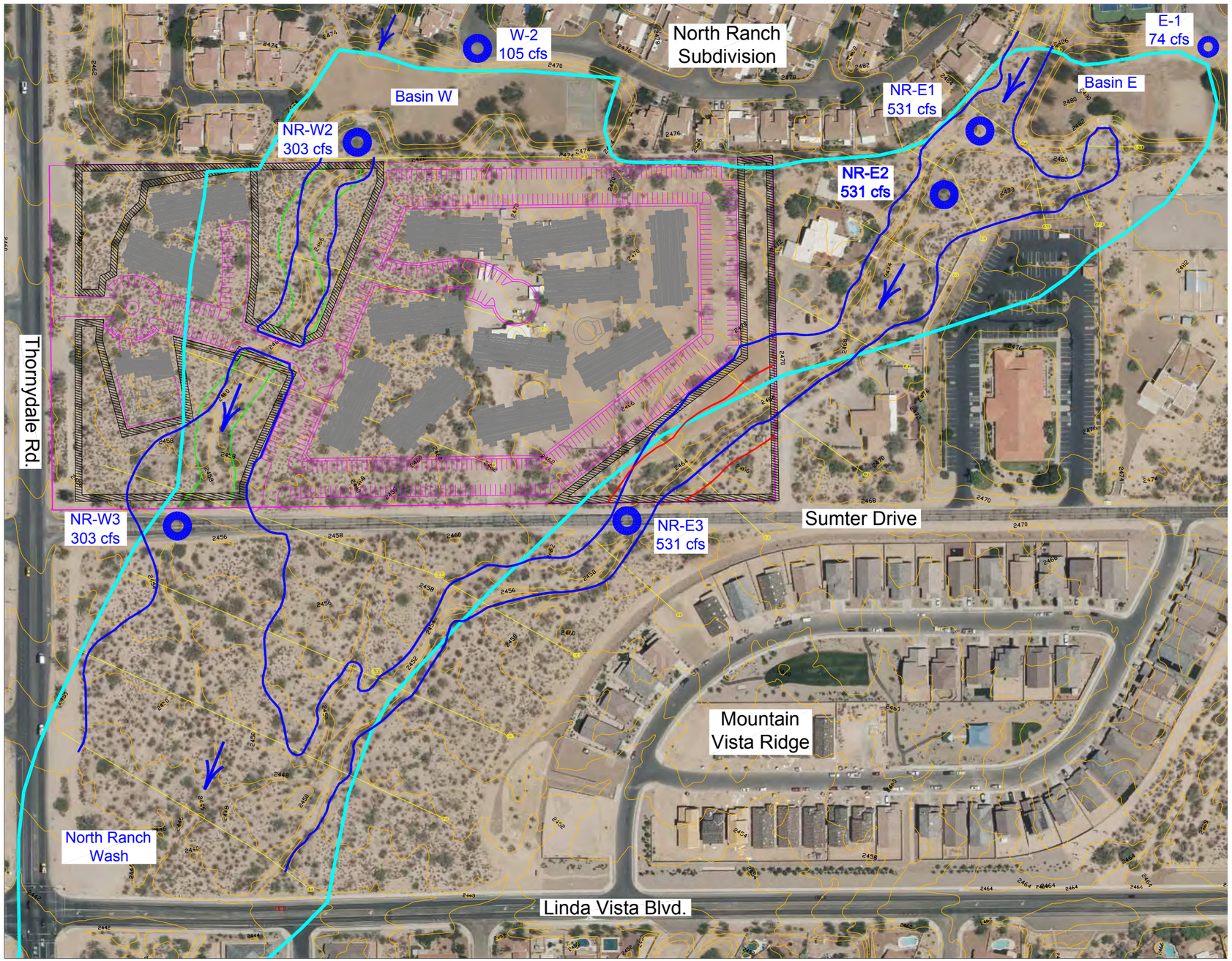
0 200 400
SCALE

LEGEND

- 100-year existing floodplain
- FEMA 100-year floodplain (Zone A)
- 25-ft erosion hazard setback
- 50-ft erosion hazard setback
- HEC-RAS cross section
- Project boundary
- Flow arrow
- NR-E3 531 cfs — Conc. point with 100-year discharge

ARROYO ENGINEERING, LLC
Water Resources & Civil Engineering Consultants

EXISTING CONDITIONS FLOODPLAIN MAP



CI=2'
NAVD88

0 200 400
SCALE

LEGEND

- 100-year developed floodplain
- FEMA 100-year floodplain (Zone A)
- 25-ft erosion hazard setback
- 50-ft erosion hazard setback
- HEC-RAS cross section
- Project site, with proposed footprint
- Flow arrow
- NR-E3 531 cfs — Conc. point with 100-year discharge

ARROYO ENGINEERING, LLC
Water Resources & Civil Engineering Consultants

DEVELOPED CONDITIONS FLOODPLAIN MAP

Appendix B. Hydrology

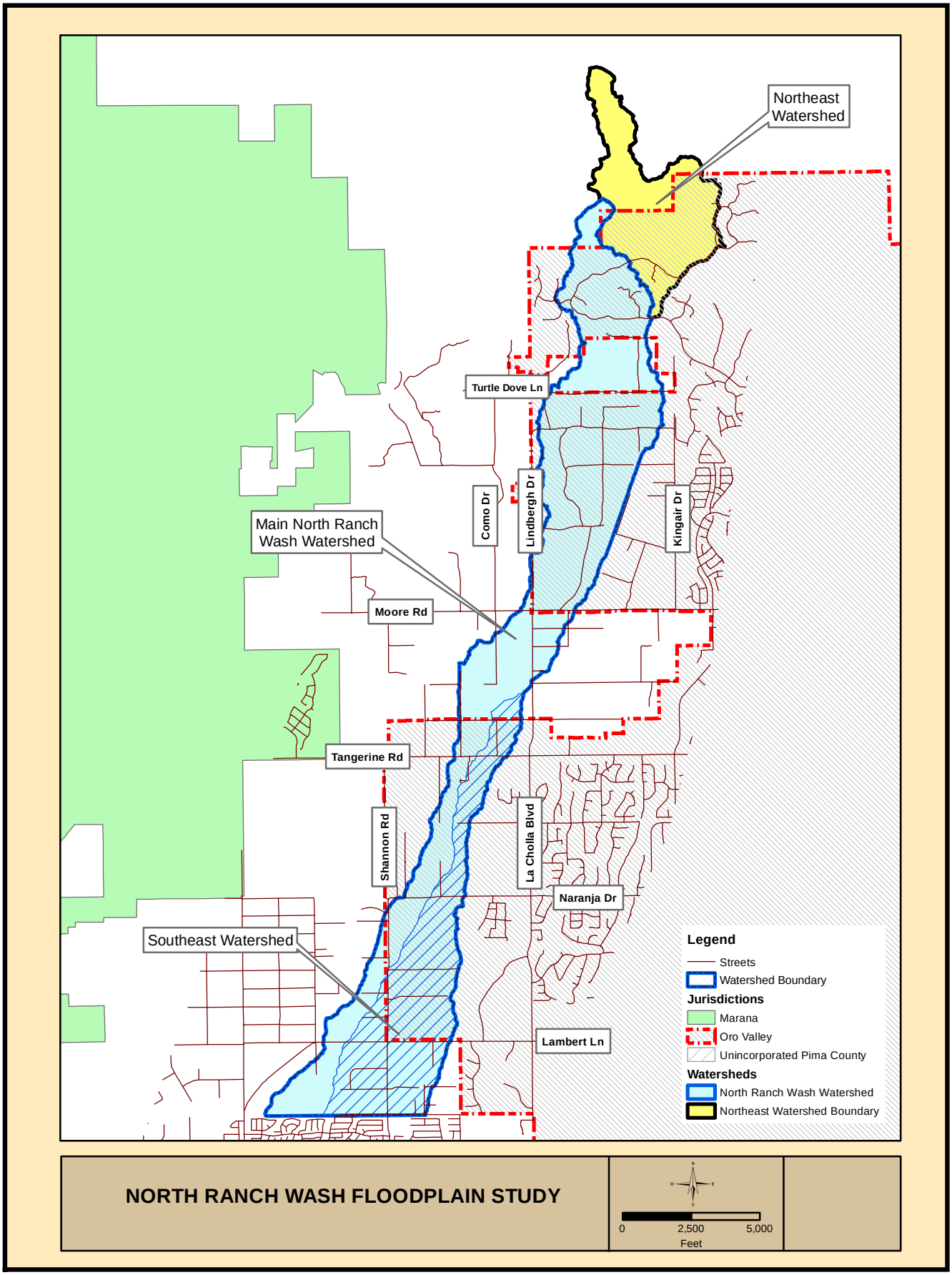


Figure 1.1 Watershed Map for Study Area

N
W E
S
0 300 600 Ft
Contour Interval=2'

Camino Alto
Camino Christy
Shannon Rd
Thornydale Rd
Lambert Lane
Pecos Way
PIMA COUNTY
ORO VALLEY

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control District makes no claims regarding the accuracy of the information depicted herein.

This product is subject to the GIS Division Disclaimer and Use Restrictions.

NORTH RANCH WASH FLOODPLAIN STUDY
100-YEAR FLOODPLAIN MAPS (SHEET 4 OF 4)

Date: 4/4/19

PIMA COUNTY FLOOD CONTROL
Pima County Regional Flood Control District
201 N Stone 9th Floor
Tucson, Arizona 85701-1207
(520) 724-4600
http://www.fcd.pima.gov

ARROYO ENGINEERING, LLC
Water Resources & Civil Engineering Consultants
2118 E. 10th Street
Tucson, Arizona 85719
Ph: 520.882.0206

SCE ENGINEERING
501 E 4th Street
Tucson AZ 85705
Ph: 520.405.7353

Legend

- FLO-2D Computational Boundary
- FEMA Floodplain Limiits
- 2910 Existing Contours
- Jurisdiction Boundary
- Flood Limits
- WSE Contour
- Q=xx cfs ## FLO-2D Recording Cross Section (No. and Q)

Flow Depth Legend

- >0.2 ft - 0.5 ft
- >0.5 ft - 1.0 ft
- >1.0 ft - 2.0 ft
- >2.0 ft - 3.0 ft
- >3.0 ft

Registered Professional Engineer
CERTIFICATE NO
23987
EDITH GRIFFITH METTEY
4-4-19
ARIZONA U.S.A.

Registered Professional Engineer (Civil)
CERTIFICATE NO
25331
LARRY L. ROBERTS
4-4-19
ARIZONA U.S.A.
Expires 3-31-2022

North Ranch Wash FLO-2D
HYDCROSS.OUT

THE MAXIMUM DISCHARGE FROM CROSS SECTION 210 IS: 531.47 CFS
AT TIME: 3.28 HOURS
THE TOTAL VOLUME OF DISCHARGE IS: 60.15 AF

HYDROGRAPH AND AVERAGE FLOODPLAIN HYDRAULICS FOR CROSS SECTION NO: 210

VELOCITY = AVERAGE CROSS SECTION VELOCITY = DISCHARGE DIVIDED BY AVERAGE DEPTH AND TOTAL WIDTH
RESOLVED VEL = AVERAGE OF THE SUM OF THE MAGNITUDE OF THE RESOLVED VELOCITY VECTORS FOR EACH CROSS SECTION ELEMENT (FOR ONLY ONE CELL = RESOLVED VELOCITY VECTOR AND ALWAYS POSITIVE)

TIME (HRS)	TOPWD (FT)	DPTH (FT)	WSEL (FT/FT)	VELOCITY (FPS)	RES. VEL (FPS)	DISCHARGE (CFS)
0.50	0.00	0.00	0.00	0.00	0.13	0.00
1.00	0.00	0.00	2510.88	0.00	0.10	0.00
1.50	248.53	0.06	2510.93	1.81	0.45	24.86
2.00	223.68	0.16	2511.03	3.05	0.75	106.26
2.50	198.82	0.15	2511.02	3.41	0.79	98.84
3.00	223.68	0.30	2511.18	3.83	1.10	256.05
3.50	248.53	0.49	2511.37	3.96	1.56	486.26
4.00	223.68	0.37	2511.25	4.03	1.33	332.24
4.50	173.97	0.27	2511.15	4.77	1.30	226.62

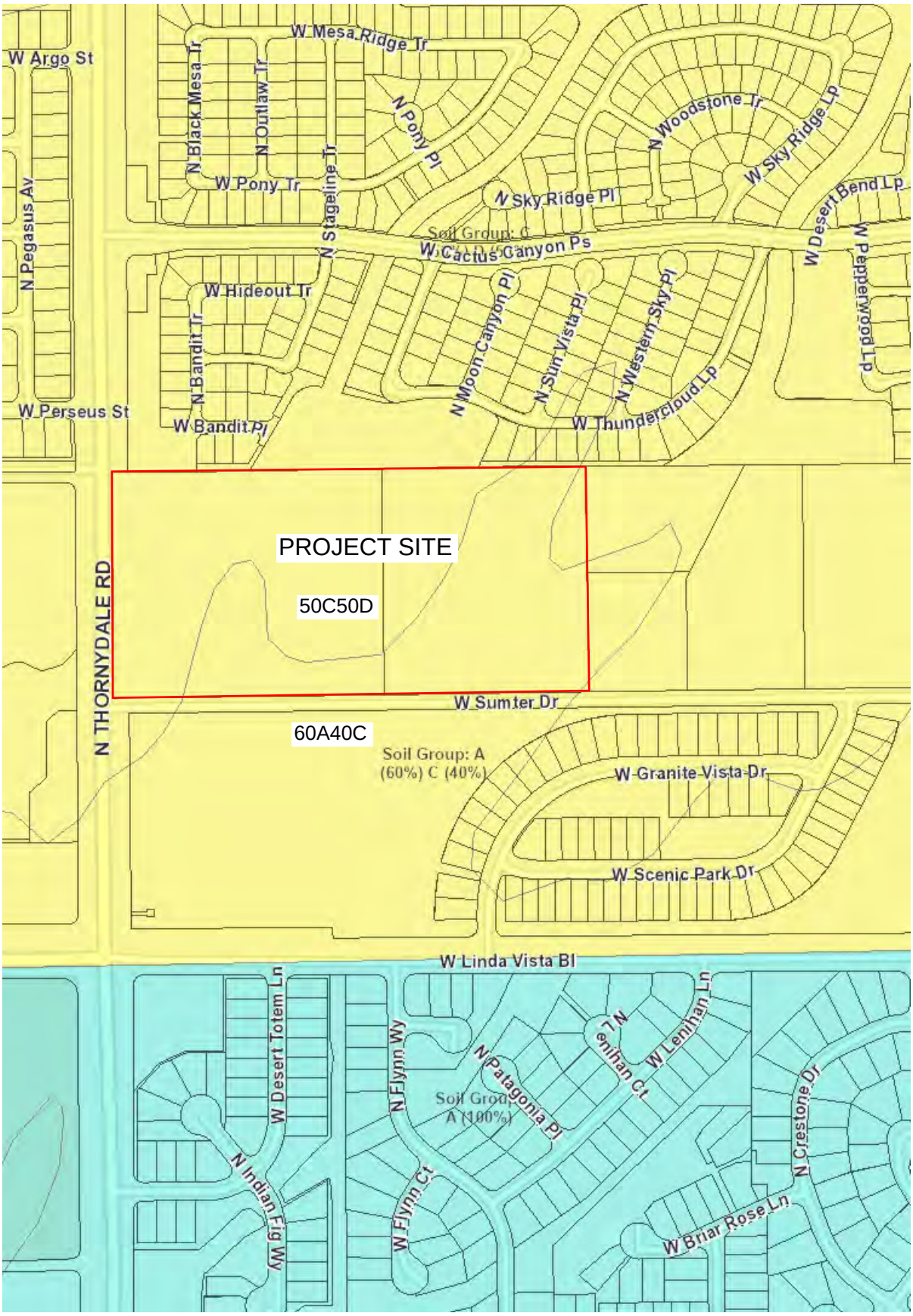
THE MAXIMUM DISCHARGE FROM CROSS SECTION 212 IS: 303.01 CFS AT TIME: 3.37 HOURS
THE TOTAL VOLUME OF DISCHARGE IS: 30.48 AF

HYDROGRAPH AND AVERAGE FLOODPLAIN HYDRAULICS FOR CROSS SECTION NO: 212

VELOCITY = AVERAGE CROSS SECTION VELOCITY = DISCHARGE DIVIDED BY AVERAGE DEPTH AND TOTAL WIDTH
ESOLVED VEL = AVERAGE OF THE SUM OF THE MAGNITUDE OF THE RESOLVED VELOCITY VECTORS FOR EACH CROSS SECTION ELEMENT (FOR ONLY ONE CELL = RESOLVED VELOCITY VECTOR AND ALWAYS POSITIVE)

TIME (HRS)	TOPWD (FT)	DPTH (FT)	WSEL (FT/FT)	VELOCITY (FPS)	RES. VEL (FPS)	DISCHARGE (CFS)
0.50	0.00	0.00	0.00	0.00	0.13	0.00
1.00	0.00	0.00	2496.01	0.00	0.25	0.00
1.50	521.91	0.07	2496.08	2.63	1.01	101.33
2.00	447.35	0.06	2496.07	2.61	1.11	74.22
2.50	397.65	0.05	2496.06	2.46	0.96	44.91
3.00	422.50	0.06	2496.07	2.89	1.13	71.89
3.50	422.50	0.13	2496.14	4.98	1.95	282.61
4.00	347.94	0.09	2496.10	4.89	1.72	151.58
4.50	323.09	0.06	2496.07	4.21	1.36	82.69

Hydrologic Soil Groups



Legend

- Parcels
- Hydrologic Soils Group
  - Soil Group: A 100%
  - Soil Group: B 100%
  - Soil Group: C 100%
  - Soil Group: D 100%
  - Soil Group: Mixed

Notes:

5/16/2022

800.0 0 400.00

Feet

Pima County GIS

This map is static output from an internet mapping site and no warranty is expressed or implied as to the accuracy, reliability, currency or completeness of the data, and is for reference only

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Baker and Associates Engineering, Inc.	Prepared by:	LKR
Project Name:	W-1	Date:	05/11/2022
Concentration Point:	W-1	Job #	
Watershed Area:	7 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	15	1270	0.0118	0.04

Length of Watercourse (Lc):	1270	feet	Mean Slope:	0.0118	
Length to Cen. of Gravity (Lca):	635	feet	Weighted Basin Fac:	0.04	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	30	

RETURN PERIOD: 100-years NOAA Data Obtained: 2022-05-11 09:09:25 AM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.385 Longitude: -111.0428

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.85	1.29	1.6	2.15	2.66	2.96	3.11	3.38	3.62	4.55

Soil Type	Percent	Curve # (CN)	Runoff Coef. (C)
B	-	-	-
C	50	87.3	0.552
D	50	90.3	0.639
Imp.	55	99	0.956

Weighted Runoff Coef. (Cw):	0.79	
Time of Concentration:	7.8	min
Rainfall Intensity (i) @ Tc:	8.41	in/hr
Runoff Supply Rate (q) @ Tc:	6.68	in/hr
PEAK DISCHARGE:	47.1	cfs

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Baker and Associates Engineering, Inc.	Prepared by:	LKR
Project Name:	W-2	Date:	05/11/2022
Concentration Point:	W-2	Job #	
Watershed Area:	14.8 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	20	1272	0.0157	0.04

Length of Watercourse (Lc):	1272	feet	Mean Slope:	0.0157	
Length to Cen. of Gravity (Lca):	636	feet	Weighted Basin Fac:	0.04	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	30	

RETURN PERIOD: 100-years NOAA Data Obtained: 2022-05-11 09:09:25 AM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.385 Longitude: -111.0428

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.85	1.29	1.6	2.15	2.66	2.96	3.11	3.38	3.62	4.55

Soil Type	Percent	Curve # (CN)	Runoff Coef. (C)
B	-	-	-
C	50	87.3	0.552
D	50	90.3	0.639
Imp.	55	99	0.956

Weighted Runoff Coef. (Cw):	0.79	
Time of Concentration:	6.9	min
Rainfall Intensity (i) @ Tc:	8.87	in/hr
Runoff Supply Rate (q) @ Tc:	7.04	in/hr
PEAK DISCHARGE:	105	cfs

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Baker and Associates Engineering, Inc.	Prepared by:	LKR
Project Name:	W-3 local	Date:	05/11/2022
Concentration Point:	W-3-local	Job #	
Watershed Area:	8 Acres	Watershed Type	Undeveloped-Valley

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	12	732	0.0164	0.035

Length of Watercourse (Lc):	732	feet	Mean Slope:	0.0164	
Length to Cen. of Gravity (Lca):	366	feet	Weighted Basin Fac:	0.035	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	30	

RETURN PERIOD: 100-years NOAA Data Obtained: 2022-05-11 09:09:25 AM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.385 Longitude: -111.0428

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.85	1.29	1.6	2.15	2.66	2.96	3.11	3.38	3.62	4.55

Soil Type	Percent	Curve # (CN)	Runoff Coef. (C)
B	-	-	-
C	50	87.3	0.552
D	50	90.3	0.639
Imp.	0	99	0.956

Weighted Runoff Coef. (Cw):	0.6	
Time of Concentration:	5	min
Rainfall Intensity (i) @ Tc:	10.2	in/hr
Runoff Supply Rate (q) @ Tc:	6.07	in/hr
PEAK DISCHARGE:	48.9	cfs

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Baker and Associates Engineering, Inc.	Prepared by:	LKR
Project Name:	E1	Date:	05/11/2022
Concentration Point:	E-1	Job #	
Watershed Area:	9.6 Acres	Watershed Type	Medium Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	14	950	0.0147	0.04

Length of Watercourse (Lc):	950	feet	Mean Slope:	0.0147	
Length to Cen. of Gravity (Lca):	475	feet	Weighted Basin Fac:	0.04	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	30	

RETURN PERIOD: 100-years NOAA Data Obtained: 2022-05-11 09:09:25 AM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.385 Longitude: -111.0428

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.85	1.29	1.6	2.15	2.66	2.96	3.11	3.38	3.62	4.55

Soil Type	Percent	Curve # (CN)	Runoff Coef. (C)
B	-	-	-
C	50	87.3	0.552
D	50	90.3	0.639
Imp.	55	99	0.956

Weighted Runoff Coef. (Cw):	0.79	
Time of Concentration:	5.7	min
Rainfall Intensity (i) @ Tc:	9.57	in/hr
Runoff Supply Rate (q) @ Tc:	7.6	in/hr
PEAK DISCHARGE:	73.5	cfs

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Baker and Associates Engineering, Inc.	Prepared by:	LKR
Project Name:	NR-E1 local	Date:	05/11/2022
Concentration Point:	NR-E1 local	Job #	
Watershed Area:	7 Acres	Watershed Type	Low Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	24	1520	0.0158	0.035

Length of Watercourse (Lc):	1520	feet	Mean Slope:	0.0158	
Length to Cen. of Gravity (Lca):	760	feet	Weighted Basin Fac:	0.035	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	30	

RETURN PERIOD: 100-years NOAA Data Obtained: 2022-05-11 09:09:25 AM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.385 Longitude: -111.0428

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.85	1.29	1.6	2.15	2.66	2.96	3.11	3.38	3.62	4.55

Soil Type	Percent	Curve # (CN)	Runoff Coef. (C)
B	-	-	-
C	50	87.3	0.552
D	50	90.3	0.639
Imp.	5	99	0.956

Weighted Runoff Coef. (Cw):	0.61	
Time of Concentration:	7.5	min
Rainfall Intensity (i) @ Tc:	8.56	in/hr
Runoff Supply Rate (q) @ Tc:	5.25	in/hr
PEAK DISCHARGE:	37	cfs

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Generated using methonds provided by Pima County Regional Flood Control District

Client:	Baker and Associates Engineering, Inc.	Prepared by:	LKR
Project Name:	NR-E3 local	Date:	05/11/2022
Concentration Point:	NR-E3 local	Job #	
Watershed Area:	4.1 Acres	Watershed Type	Low Density Urbanized

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	16	1168	0.0137	0.035

Length of Watercourse (Lc):	1168	feet	Mean Slope:	0.0137	
Length to Cen. of Gravity (Lca):	584	feet	Weighted Basin Fac:	0.035	
Veg. Cover Type(s):	Desert Brush		Veg. Cover Density:	30	

RETURN PERIOD: 100-years NOAA Data Obtained: 2022-05-11 09:09:25 AM

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.385 Longitude: -111.0428

Duration:	5-min	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in):	0.85	1.29	1.6	2.15	2.66	2.96	3.11	3.38	3.62	4.55

Soil Type	Percent	Curve # (CN)	Runoff Coef. (C)
B	-	-	-
C	50	87.3	0.552
D	50	90.3	0.639
Imp.	1	99	0.956

Weighted Runoff Coef. (Cw):	0.6	
Time of Concentration:	6.7	min
Rainfall Intensity (i) @ Tc:	8.94	in/hr
Runoff Supply Rate (q) @ Tc:	5.35	in/hr
PEAK DISCHARGE:	22.1	cfs

North Ranch Wash - West Branch Additive Hydrographs

Concentration Point		W-1	NR-W			W-2			W-3 local	
Return Period		100-Yr	100-Yr			100-Yr			100-Yr	
Time of Concentration (min)		7.84				6.86			5	
Time to Peak (hr		0.27	3.37			0.25			0.23	
					1	= Lag (min)		2	= Lag (min)	
					418	= Distance (ft)		733	= Distance (ft)	
					5	= velocity (ft/s)		5	= velocity (ft/s)	
Concentration Poin		W-1	NR-W	NR-W1	NR-W1	W-2	NR-W2	NR-W2	W-3 local	NR-W3
Q_{100} peak		46	303	303	303	104	303	303	48	303
		(A)	(B)	(A+B)	(A)	(B)	(A+B)	(A)	(B)	(A+B)
Time (min	Time (hr)	Discharge (cfs)			Discharge (cfs)			Discharge (cfs)		
0	0.00	0	0	0		0	0		0	0
1	0.02	1		1	0	2	2		1	1
2	0.03	2		2	1	5	6	0	3	3
3	0.05	4		4	2	9	11	2	5	7
4	0.07	6		6	4	14	18	6	8	13
5	0.08	8		8	6	20	26	11	11	22
6	0.10	11		11	8	26	34	18	14	32
7	0.12	14		14	11	33	44	26	18	44
8	0.13	17		17	14	40	54	34	21	56
9	0.15	20		20	17	48	65	44	26	70
10	0.17	23		23	20	57	77	54	31	85
11	0.18	27		27	23	67	91	65	37	101
12	0.20	32		32	27	78	106	77	42	119
13	0.22	37		37	32	89	121	91	46	137
14	0.23	41		41	37	98	135	106	48	154
15	0.25	45		45	41	104	146	121	45	166
16	0.27	46		46	45	99	144	135	42	177
17	0.28	44		44	46	93	140	146	39	185
18	0.30	42		42	44	87	131	144	36	180
19	0.32	39		39	42	81	123	140	33	173
20	0.33	37		37	39	76	115	131	31	162
21	0.35	34		34	37	70	107	123	28	151
22	0.37	32		32	34	65	99	115	26	141
23	0.38	30		30	32	61	92	107	24	131
24	0.40	28		28	30	56	86	99	22	121
25	0.42	26		26	28	52	80	92	20	112
26	0.43	24		24	26	48	74	86	18	104
27	0.45	22		22	24	44	68	80	16	96
28	0.47	20		20	22	40	62	74	15	88
29	0.48	19		19	20	37	57	68	13	81
30	0.50	17	0	17	19	33	52	62	12	74
31	0.52	16		16	17	30	48	57	11	68
32	0.53	14		14	16	27	43	52	9	61
33	0.55	13		13	14	25	39	48	8	56
34	0.57	12		12	13	23	36	43	8	51
35	0.58	11		11	12	20	32	39	7	46
36	0.60	10		10	11	18	29	36	6	42
37	0.62	9		9	10	17	27	32	6	38
38	0.63	8		8	9	15	24	29	5	34
39	0.65	8		8	8	14	22	27	5	31
40	0.67	7		7	8	13	20	24	4	29
41	0.68	6		6	7	12	18	22	4	26
42	0.70	6		6	6	10	17	20	4	24
43	0.72	5		5	6	10	15	18	3	22
44	0.73	5		5	5	9	14	17	3	20
45	0.75	4		4	5	8	13	15	3	18
46	0.77	4		4	4	8	12	14	2	16
47	0.78	4		4	4	7	11	13	2	15
48	0.80	3		3	4	6	10	12	2	14
49	0.82	3		3	3	6	9	11	2	13
50	0.83	3		3	3	5	9	10	2	12
51	0.85	3		3	3	5	8	9	2	11
52	0.87	3		3	3	5	7	9	1	10
53	0.88	2		2	3	4	7	8	1	9
54	0.90	2		2	2	4	6	7	1	9
55	0.92	2		2	2	4	6	7	1	8
56	0.93	2		2	2	3	5	6	1	7
57	0.95	2		2	2	3	5	6	1	7
58	0.97	2		2	2	3	5	5	1	6
59	0.98	1		1	2	3	4	5	1	6
60	1.00	1	0	1	1	3	4	5	1	5
90	1.50	0	101	101	0	0	0	1	0	1
91	1.52	0		0	101	0	102	1	0	1
92	1.53	0		0	0	0	1	0	0	0
93	1.55	0		0	0	0	1	102	0	102
	2		74	74	74		74	74		74
	2.5		45	45	45		45	45		45
	3		72	72	72		72	72		72
	3.37		303	303	303		303	303		303
	3.5		283	283	283		283	283		283
	4		152	152	152		152	152		152
	4.5		83	83	83		83	83		83

North Ranch Wash - East Branch Additive Hydrographs

Concentration Point		NR-E1 local	NR-E			E-1			NR-E3 local	
Return Period		100-Yr	100-Yr			100-Yr			100-Yr	
Time of Concentration (min)		7.49				5.73			6.72	
Time to Peak (hr		0.25	3.28			0.23			0.25	
								3	= Lag (min)	
								877	= Distance (ft)	
								5	= velocity (ft/s)	
Concentration Poin		NR-E1 local	NR-E	NR-E1	NR-E1	E-1	NR-E2	NR-E2	NR-E3 local	NR-E3
Q_{100} peak		36	531	531	531	73	531	531	22	531
		(A)	(B)	(A+B)	(A)	(B)	(A+B)	(A)	(B)	(A+B)
Time (min	Time (hr)	Discharge (cfs)			Discharge (cfs)			Discharge (cfs)		
0	0.00	0	0	0	0	0	0		0	0
1	0.02	1		1	1	1	2		0	0
2	0.03	2		2	2	4	5		1	1
3	0.05	3		3	3	7	10	0	2	2
4	0.07	5		5	5	11	16	2	3	5
5	0.08	7		7	7	15	22	5	4	10
6	0.10	9		9	9	20	29	10	6	16
7	0.12	11		11	11	25	36	16	7	23
8	0.13	14		14	14	31	44	22	9	30
9	0.15	16		16	16	37	53	29	10	39
10	0.17	19		19	19	44	63	36	12	48
11	0.18	22		22	22	52	74	44	14	59
12	0.20	26		26	26	60	86	53	17	70
13	0.22	30		30	30	67	97	63	19	82
14	0.23	33		33	33	73	106	74	21	95
15	0.25	36		36	36	70	106	86	22	108
16	0.27	36		36	36	65	101	97	21	118
17	0.28	34		34	34	61	95	106	19	126
18	0.30	32		32	32	57	89	106	18	124
19	0.32	30		30	30	53	82	101	17	118
20	0.33	28		28	28	48	76	95	16	111
21	0.35	26		26	26	45	71	89	15	103
22	0.37	24		24	24	41	66	82	14	96
23	0.38	23		23	23	38	61	76	13	89
24	0.40	21		21	21	35	56	71	12	82
25	0.42	20		20	20	32	52	66	11	77
26	0.43	18		18	18	29	47	61	10	71
27	0.45	17		17	17	27	43	56	9	65
28	0.47	15		15	15	24	39	52	8	60
29	0.48	14		14	14	22	36	47	8	55
30	0.50	13	0	13	13	20	32	43	7	50
31	0.52	12		12	12	18	29	39	6	46
32	0.53	11		11	11	16	27	36	6	41
33	0.55	10		10	10	14	24	32	5	38
34	0.57	9		9	9	13	22	29	5	34
35	0.58	8		8	8	12	20	27	4	31
36	0.60	7		7	7	11	18	24	4	28
37	0.62	7		7	7	10	16	22	3	25
38	0.63	6		6	6	9	15	20	3	23
39	0.65	6		6	6	8	13	18	3	21
40	0.67	5		5	5	7	12	16	3	19
41	0.68	5		5	5	6	11	15	2	17
42	0.70	4		4	4	6	10	13	2	15
43	0.72	4		4	4	5	9	12	2	14
44	0.73	4		4	4	5	9	11	2	13
45	0.75	3		3	3	5	8	10	2	12
46	0.77	3		3	3	4	7	9	2	11
47	0.78	3		3	3	4	7	9	1	10
48	0.80	3		3	3	4	6	8	1	9
49	0.82	2		2	2	3	6	7	1	8
50	0.83	2		2	2	3	5	7	1	8
51	0.85	2		2	2	3	5	6	1	7
52	0.87	2		2	2	3	4	6	1	7
53	0.88	2		2	2	2	4	5	1	6
54	0.90	2		2	2	2	4	5	1	6
55	0.92	2		2	2	2	3	4	1	5
56	0.93	1		1	1	2	3	4	1	5
57	0.95	1		1	1	2	3	4	1	4
58	0.97	1		1	1	2	3	3	1	4
59	0.98	1		1	1	1	3	3	1	4
60	1.00	1	0	1	1	1	2	3	1	4
90	1.50	0	25	25	25	0	25	0	0	1
91	1.52	0		0	0	0	0	0	0	0
92	1.53	0		0	0	0	0	0	0	0
93	1.55	0		0	0	0	0	25	0	25
	2		106	106	106		106	106		106
	2.5		99	99	99		99	99		99
	3		256	256	256		256	256		256
	3.28		531	531	531		531	531		531
	3.5		486	486	486		486	486		486
	4		332	332	332		332	332		332
	4.5		227	227	227		227	227		227

Appendix C. Hydraulics

HEC-RAS Profile: PF 1

River	Reach	River Sta	Plan	Q Total	W.S. Elev
				(cfs)	(ft)
West Branch	2	3	existing	303	2469.1
West Branch	2	3	developed	303	2469.1
West Branch	2	2	existing	303	2465.4
West Branch	2	2	developed	303	2465.6
West Branch	2	1	existing	303	2460.7
West Branch	2	1	developed	303	2461.2
West Branch	2	0.44	existing	303	2457.1
West Branch	2	0.44	developed	303	2457.1
West Branch	2	0.33	existing	303	2453.1
West Branch	2	0.33	developed	303	2453.1
North Ranch Wash	1	2	existing	834	2450.6
North Ranch Wash	1	2	developed	834	2450.6
North Ranch Wash	1	1	existing	834	2447.3
North Ranch Wash	1	1	developed	834	2447.3
East trib	5	63	existing	74	2481.5
East trib	5	63	developed	74	2481.5
East trib	5	62	existing	74	2479.2
East trib	5	62	developed	74	2479.2
East trib	5	61	existing	74	2478.9
East trib	5	61	developed	74	2478.9
East Branch	4	8	existing	531	2482.9
East Branch	4	8	developed	531	2482.9
East Branch	4	7	existing	531	2480.0
East Branch	4	7	developed	531	2480.0
East Branch	3	6	existing	531	2477.2
East Branch	3	6	developed	531	2477.2
East Branch	3	5	existing	531	2474.7
East Branch	3	5	developed	531	2474.7

HEC-RAS Profile: PF 1 (Continued)

River	Reach	River Sta	Plan	Q Total	W.S. Elev
				(cfs)	(ft)
East Branch	3	4	existing	531	2471.0
East Branch	3	4	developed	531	2471.0
East Branch	3	3	existing	531	2468.6
East Branch	3	3	developed	531	2468.6
East Branch	3	2	existing	531	2466.4
East Branch	3	2	developed	531	2466.4
East Branch	3	1	existing	531	2462.4
East Branch	3	1	developed	531	2462.4
East Branch	3	0.4	existing	531	2457.5
East Branch	3	0.4	developed	531	2457.5
East Branch	3	0.3	existing	531	2454.0
East Branch	3	0.3	developed	531	2454.0

HEC-RAS Profile: PF 1

River	Reach	River Sta	Plan	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Max Chl Dpth	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft/s)	(ft)	(sq ft)	(ft)	
West Branch	2	3	existing	303	2468.0	2469.1	4.7	1.1	68	108	1.0
West Branch	2	3	developed	303	2468.0	2469.1	4.8	1.1	63	85	1.0
West Branch	2	2	existing	303	2463.8	2465.4	3.1	1.6	116	192	0.6
West Branch	2	2	developed	303	2463.8	2465.6	3.6	1.9	84	85	0.6
West Branch	2	1	existing	303	2459.4	2460.7	4.2	1.4	79	180	1.0
West Branch	2	1	developed	303	2459.4	2461.2	5.0	1.9	61	76	1.0
West Branch	2	0.44	existing	303	2456.4	2457.1	0.4	1.6	169	437	0.1
West Branch	2	0.44	developed	303	2456.4	2457.1	3.0	1.6	101	349	1.0
West Branch	2	0.33	existing	303	2452.0	2453.1	3.4	1.1	91	182	0.9
West Branch	2	0.33	developed	303	2452.0	2453.1	3.8	1.1	83	172	0.9
North Ranch Wash	1	2	existing	834	2448.6	2450.6	3.9	1.9	274	450	0.8
North Ranch Wash	1	2	developed	834	2448.6	2450.6	3.9	1.9	274	450	0.8
North Ranch Wash	1	1	existing	834	2445.1	2447.3	6.3	2.1	189	291	1.1
North Ranch Wash	1	1	developed	834	2445.1	2447.3	6.3	2.1	189	291	1.1
East trib	5	63	existing	74	2480.8	2481.5	3.6	0.7	21	53	1.0
East trib	5	63	developed	74	2480.8	2481.5	3.6	0.7	21	53	1.0
East trib	5	62	existing	74	2478.5	2479.2	3.8	0.8	19	43	1.0
East trib	5	62	developed	74	2478.5	2479.2	3.8	0.8	19	43	1.0
East trib	5	61	existing	74	2477.4	2478.9	1.4	1.5	54	71	0.3
East trib	5	61	developed	74	2477.4	2478.9	1.4	1.5	54	71	0.3
East Branch	4	8	existing	531	2481.2	2482.9	6.4	1.7	83	67	1.0
East Branch	4	8	developed	531	2481.2	2482.9	6.4	1.7	83	67	1.0
East Branch	4	7	existing	531	2478.8	2480.0	5.6	1.3	95	101	1.0
East Branch	4	7	developed	531	2478.8	2480.0	5.6	1.3	95	101	1.0
East Branch	3	6	existing	531	2474.7	2477.2	5.6	2.5	107	113	1.0
East Branch	3	6	developed	531	2474.7	2477.2	5.6	2.5	107	113	1.0
East Branch	3	5	existing	531	2471.3	2474.7	6.8	3.4	111	125	1.0
East Branch	3	5	developed	531	2471.3	2474.7	6.8	3.4	111	125	1.0
East Branch	3	4	existing	531	2468.7	2471.0	6.3	2.3	84	67	1.0
East Branch	3	4	developed	531	2468.7	2471.0	6.3	2.3	84	67	1.0
East Branch	3	3	existing	531	2466.0	2468.6	4.8	2.6	121	151	0.8
East Branch	3	3	developed	531	2466.0	2468.6	4.8	2.6	121	151	0.8
East Branch	3	2	existing	531	2463.7	2466.4	5.8	2.7	102	100	0.9
East Branch	3	2	developed	531	2463.7	2466.4	5.8	2.7	102	100	0.9
East Branch	3	1	existing	531	2459.0	2462.4	6.5	3.4	82	61	1.0
East Branch	3	1	developed	531	2459.0	2462.4	6.5	3.4	82	61	1.0
East Branch	3	0.4	existing	531	2454.8	2457.5	5.5	2.7	97	89	0.9
East Branch	3	0.4	developed	531	2454.8	2457.5	5.5	2.7	97	89	0.9
East Branch	3	0.3	existing	531	2451.3	2454.0	6.3	2.7	84	68	1.0
East Branch	3	0.3	developed	531	2451.3	2454.0	6.3	2.7	84	69	1.0

Appendix D

Biological Impact Report

Biological Impact Report
Thornydale and Sumter
NE#22037

Prepared for:
Mr. Zach Channing
ZDC Properties, LLC
18381 Long Lake Drive
Boca Raton, FL 33496

Prepared by:
Novak Environmental, Inc.
4574 N. 1st Avenue
Tucson, Arizona 85718
(520) 206-0591

For questions regarding this report please contact: Karen Cesare, RLA
karen@novakenvironmental.com

TABLE OF CONTENTS

BIOLOGICAL IMPACT REPORT
Thornydale and Sumter Rezoning

August 17, 2022

I. INTRODUCTION

This Biological Impact Report is for an approximately 17.88-acre site on the northeast corner of N. Thornydale Road and W Sumter Drive in Pima County, Arizona, including parcels 224-44-0570 and 224-44-058A. The owner is seeking to rezone the property through a Specific Plan. The property is in Sections 17, T12S, R13E, G. & S.R.M., Pima County, Arizona (see Figure 1).

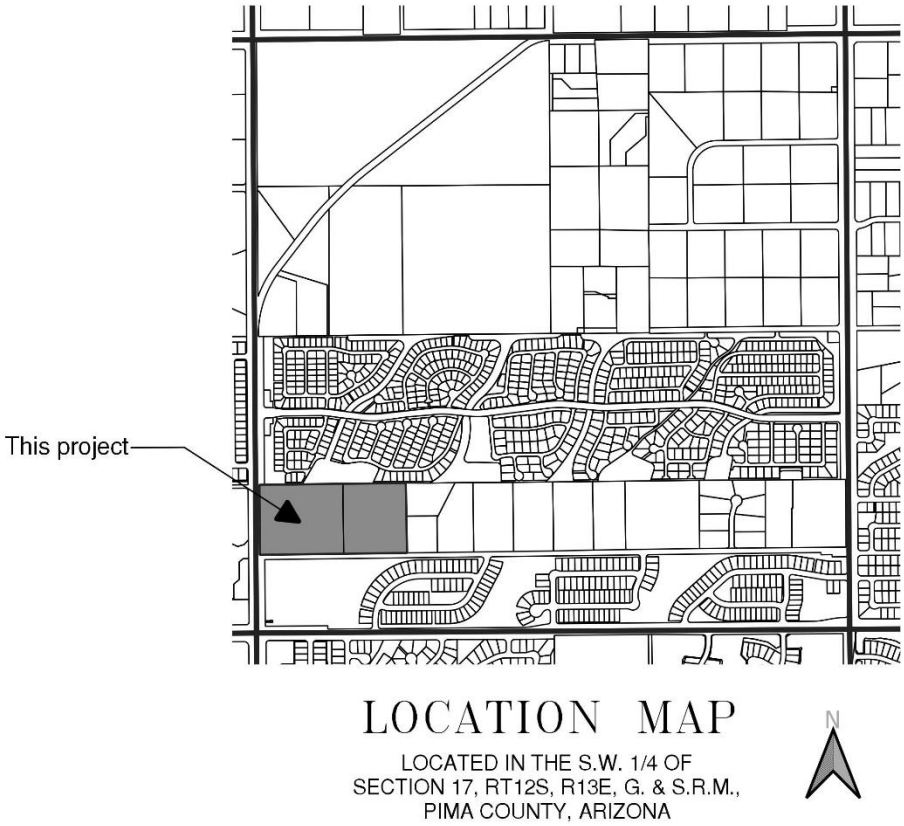


Figure 1. Location Map
2 Parcels (224-44-0570 and 224-44-058A)
Section 17, T12S, R13E, G. & S.R.M., Pima County, Arizona

This required Biological Impact Report will present responses, as they pertain to the subject property, to all questions set forth in the Pima County Development Services Biological Impact Report Guidelines, March 2010.

II. LANDSCAPE RESOURCES

1. Identify whether the proposed site occurs wholly or partially within any Maeveen Marie Behan Conservation Lands System Category including Important Riparian Areas and Special Species Management Areas.

Yes, the site is located in CLS Category Special Species Management Area, Multiple Use Management Area, and portions of the site are within the CLS Category Important Riparian Area Xeroriparian C.

2. Identify whether the proposed project occurs in the vicinity of any of the six general areas identified as Critical Landscape Linkages.

This project occurs to the southwest of Critical Landscape Linkage area number 1, and southeast of Critical Landscape Linkage area number 2.

3. If the property is a Habitat Protection or Community Open Space priority acquisition property, as displayed on SDCP MapGuide, identify which designation applies to the site and comment on the status of communications, if any, between the owner and Pima County regarding the County's potential acquisition of the property.

This site is included as a priority acquisition for either Habitat Protection. There have been no communications between the owner and Pima County regarding acquisition and none are planned.

III. SPECIES-SPECIFIC INFORMATION (including Pertinent Federally-Threatened and Endangered Species)

Cactus Ferruginous Pygmy-owl:

1. Does the proposed project site occur within Survey Zone 1 for the cactus ferruginous pygmy-owl?

Yes, it is within the Pygmy-Owl Survey Zone 1.

2. Has the proposed project site been surveyed for pygmy-owls?

a. If yes, disclose the dates when surveys were done and provide a summary of the results.

b. If no, are surveys planned in the future?

No. The project site has not been surveyed for pygmy-owls; there are no surveys planned in the future. The site has been mostly cleared of vegetation.

Western Burrowing Owl:

1. ***Does the proposed project site occur within the Priority Conservation Area for the Western Burrowing Owl?***

   No.

2. Has the proposed project site been surveyed for burrowing owls?

a. If yes, disclose the dates when surveys were done and provide a summary of the results.

b. If no, are surveys planned in the future?

No. The project site has not been surveyed for Western Burrowing Owls; there are no surveys planned in the future.

Pima Pineapple Cactus

1. Does the proposed project site occur within the Priority Conservation Area for the Pima pineapple cactus?

No.

2. Have Pima pineapple cactus been found on the proposed project site?

No. No Pima pineapple cacti have been found on the project site.

3. Has the proposed project site been surveyed for Pima pineapple cactus?

a. If yes, disclose the date when surveys were done and provide a summary of the results.

b. If no, are surveys planned in the future?

No. The project site has not been surveyed for Pima pineapple cactus; no surveys are planned in the future.

<u>Needle-Spined Pineapple Cactus:</u>

1. Does the proposed project site occur within the Priority Conservation Area for the needle-spined pineapple cactus?

No.

2. Have needle-spined pineapple cactus been found on the proposed project site?

No needle-spined pineapple cactus have been found on the project site.

3. Has the proposed project site been surveyed for needle-spined pineapple cactus?

a. If yes, disclose the date when surveys were done and provide a summary of the results.

b. If no, are surveys planned in the future?

No. The project site has not been surveyed for needle-spined pineapple cactus; no surveys are planned in the future.

IV. SAGUAROS AND IRONWOODS

Portions of the property have been disturbed for a single family residence with equestrian facilities. The undisturbed portions contain both saguaros and ironwoods. See site analysis information for details.

V. SUMMARY

This report presents a Biological Impact Report for the Thornydale and Sumter Rezoning, an approximately 17.88-acre parcel located in Pima County. This Biological Impact Report, required as part of the Specific Plan request, presents responses to all questions set forth in the Pima County Development Services Biological Impact Report Guidelines, March 2010. The findings indicate that this site is within areas of concern included in the report guidelines. The developer is aware of the CLS Guidelines for conservation and is working with the County to present a plan, including off-site mitigation, that is in compliance with these guidelines.

Appendix E

Traffic Impact Study

NEC Thornydale-Sumter Residential

Traffic Impact Study

Prepared for submittal to:

Pima County, AZ

Prepared by:

M Esparza Engineering, LLC
2934 W. Salvia Drive
Tucson, AZ 85745

August 23, 2022
Updated October 18, 2022
Updated May 9, 2023
Updated June 26, 2023
Updated July 20, 2023

NEC Thornydale-Sumter Residential
Traffic Impact Study

Prepared for:

Pima County, Arizona

Prepared by:
M Esparza Engineering, LLC
2934 W. Salvia Drive
Tucson, AZ 85745

Phone: (520) 207-3358
Project No. 2022.12
Marcos Esparza, P.E., Principal

August 23, 2022
Updated October 18, 2022
Updated May 9, 2023
Updated June 26, 2023
Updated July 20, 2023

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List of Exhibits

1. Introduction and Summary

Purpose of Report and Study Objectives

This updated traffic impact study (TIS) addresses traffic operations and roadway design for a proposed residential development east of Thornydale Road and north of Sumter Drive. The project is in unincorporated Pima County. The current zoning is SR (Suburban Ranch). This TIS is provided to support a rezoning application to revise the zoning to Specific Plan.

Exhibit 1 shows the preliminary development plan (also provided in the appendix). Exhibit 2 shows the site location.

The project has been updated to reduce the number of multifamily residential units from 340 units to 270 units. The updated preliminary development plan shows seven three-story apartment buildings with thirty units in each building and three two-story buildings with twenty units in each building. The preliminary development plan also shows a two-story "clubhouse/retail" 8,000 square foot building on the east side of the project that, in addition to being the offices for the apartments, will include 3,000 square feet of amenity-commercial space (likely a beauty salon or personal trainer). There are regulated riparian habitat areas that separate one of the apartment buildings and the office building from the remaining buildings.

The objectives of this study are to determine the traffic impacts of the proposed development on the adjacent roadway system and to recommend any needed improvements to maintain efficient and safe traffic operations. The specific study objectives are as follows:

- Evaluate the intersections of Thornydale Road/Linda Vista Boulevard, Thornydale Road/Sumter Drive, Thornydale Road/Le Mirage Apartments Driveway, and Shannon Road/Sumter Drive with and without the project and recommend any needed improvements.
- Evaluate the roadways Linda Vista Boulevard, Sumter Drive, Thornydale Road and Shannon Road adjacent to the project, and recommend any needed improvements.
- Evaluate the appropriateness of the proposed driveway locations.

The project will generate an estimated 1,860 daily trips with 112 AM peak hour trips and 143 PM peak hour trips. Based on the projected trip generation, this report includes the required analysis for a Category 1 Traffic Impact Study. This report analyzes existing, future "without project" and future "with project" conditions at the site access drives and at adjacent signalized intersections and/or major unsignalized street intersections. For the purposes of this study, the analysis for the future year conditions estimates buildout in 2025.

Executive Summary

Development Description

The preliminary development plan of the proposed development includes 270 multi-family residential units. There is an 8,000 square foot building on the east side of the project that, in addition to being the offices for the apartments, will include 3,000 square feet of amenity-commercial space (likely a beauty salon or personal trainer). Access to the site is proposed from Thornydale Road and Sumter Drive.

Based on trip rates for multi-family residential units and the anticipated commercial use (Hair Salon) from the Institute of Transportation Engineering (ITE) *Trip Generation Manual 11th Edition*, the project will add approximately 1,860 daily trips with 112 AM peak hour trips and 143 PM peak hour trips to the roadway system.

The west driveway on Thornydale Road would be located opposite the driveway to the Le Mirage Apartments. The south driveway is shown on the preliminary development plan to be approximately 771 feet from Thornydale Road.

The spacing of project driveways will meet Pima County driveway spacing and corner clearance guidelines as defined in the Pima County Subdivision and Development Street Standards.

Existing traffic volumes near the project show that all study area intersections operate at acceptable levels of service (LOS D or better).

Exhibit 1 Preliminary Development Plan

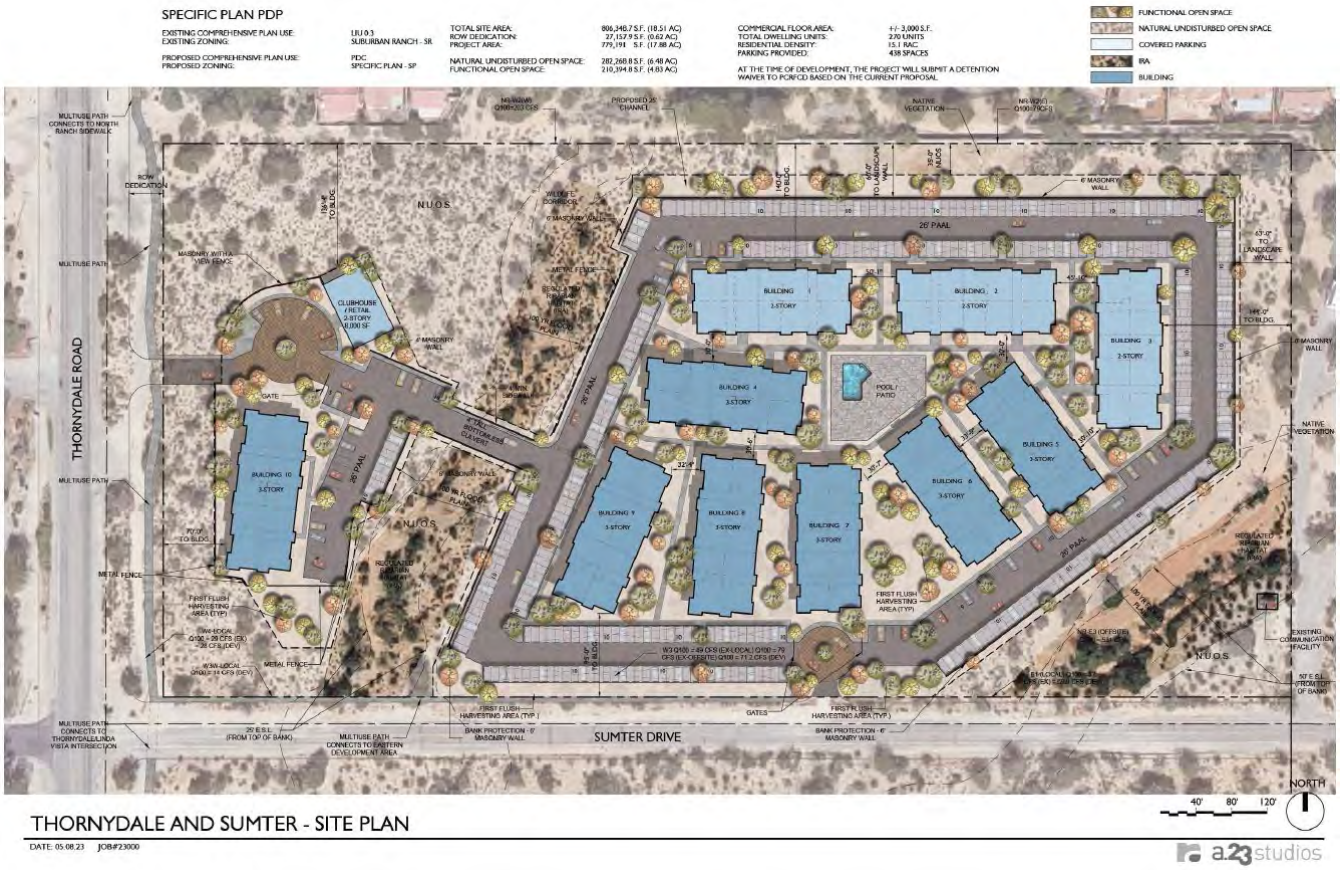
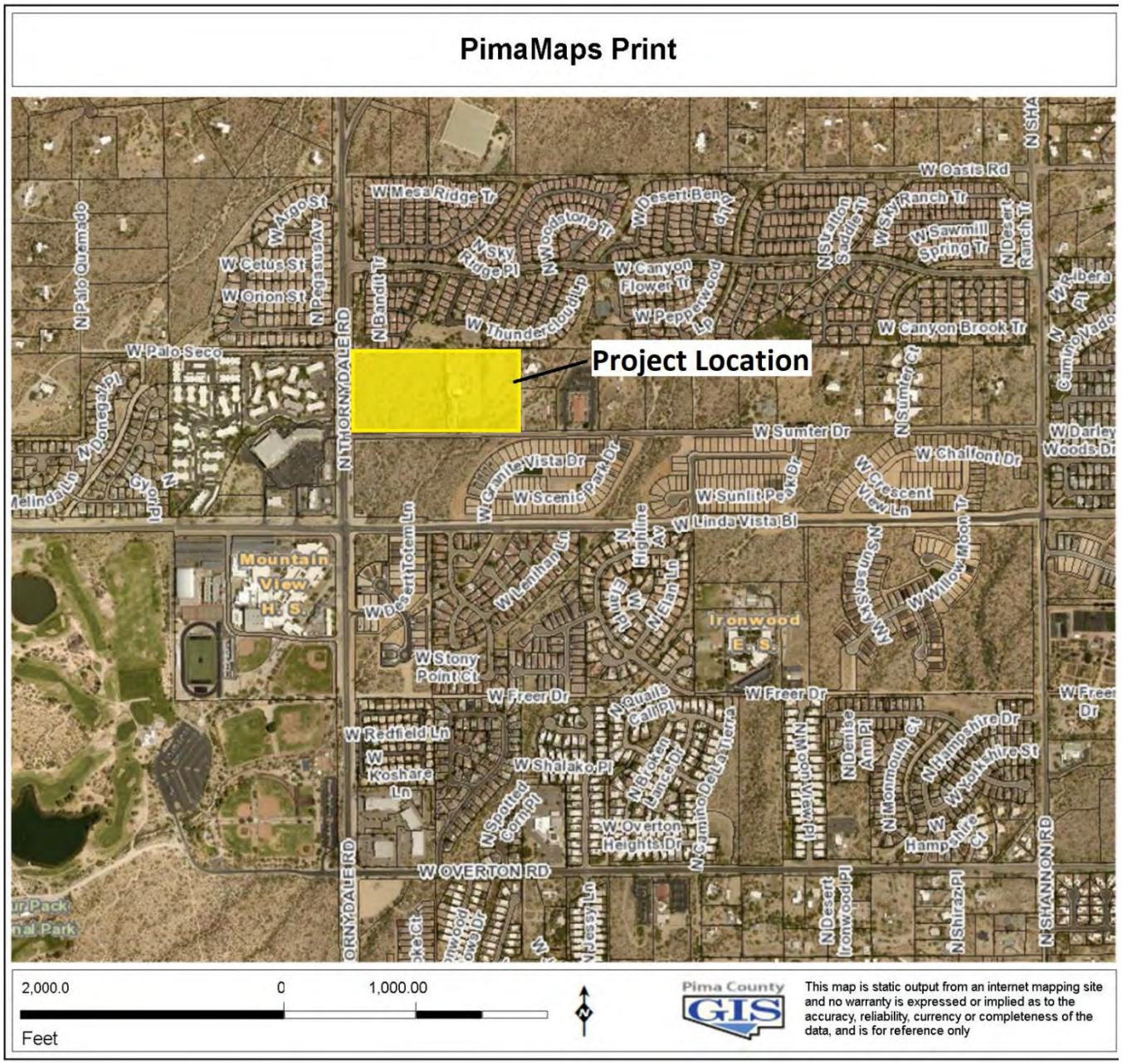


Exhibit 2 Site Location



Summary of Conclusions and Recommendations

The following is a summary of conclusions and recommendations for the roadways within and surrounding the project site.

Conclusions

1. Turn lanes on Thornydale Road and on Sumter Drive at the project driveways are not warranted based on Pima County turn lane warrant criteria. However, although the northbound turn lane on Thornydale Road is not warranted, the developer will construct a northbound turn lane into the project driveway to address concurrency issues related to the over-capacity concerns on Thornydale Road.
2. The westbound left turn movement and eastbound approach at Thornydale Road/Sumter may experience LOS E during the PM peak hour. It is not unusual for drivers entering major roadways like Thornydale Road to experience moderate to high delays during peak periods. The eastbound and westbound approaches on Sumter Road at Thornydale Road will likely operate with less delay during the non-peak hours. No mitigation is recommended for these movements. All other movements at the other project intersections will operate at LOS D or better through the year 2025 with the project.
3. The project will generate an estimated 1,860 daily trips with 112 AM peak hour trips and 143 PM peak hour trips. These trips will be distributed to and from the project site at two driveways, one on Thornydale Road and one on Sumter Drive.
4. The driveway spacings and corner clearances will meet Pima County minimum spacing standards.
5. The developer is providing off-site improvements for the project to address the County's transportation concurrency concerns.

Recommendations

1. Construct the project driveways to Pima County standards, with one ingress and one egress lane at both driveway access locations.
2. The northbound right turn lane on Thornydale Road at the west project driveway will be constructed to the Pima County minimum length (110 feet) with the gap and taper designed to Pima County turn lane design standards.
3. Ensure that there is acceptable sight distance to and from the project entrances.
4. Provide stop signs for traffic exiting the project driveways.
5. The developer will construct a shared-use path from an existing sidewalk along the North Ranch development to Linda Vista Boulevard along the east side of Thornydale Road. A shared use path will also be constructed by the developer along Sumter Drive. The path on Sumter Drive shall be constructed from the west side of the access location on Sumter Drive to its intersection with the shared-use path along Thornydale Road, as shown on the preliminary development plan. This off-site improvement is to be constructed to address concurrency concerns. The shared-use paths will be designed and built to Pima County standards.
6. Subdivision design should conform to current Pima County standards.
7. All new traffic signs and markings must comply with the current *Manual on Uniform Traffic Control Devices* and local requirements.

2. Proposed Development

Site Location

The project is a multi-family residential development east of Thornydale Road and north of Sumter Drive. The project is in unincorporated Pima County. The site location is shown in Exhibit 2.

Land Use and Intensity

The project includes two hundred and seventy multi-family residential units. There is also an 8,000 square foot building on the east side of the project that, in addition to being the offices for the apartments, will include 3,000 square feet of amenity-commercial space (likely a beauty salon or personal trainer).

Site Plan

The updated preliminary development plan shows seven three-story apartment buildings with thirty units in each building and three two-story buildings with twenty units in each building. There is also an 8,000 square foot building on the east side of the project that, in addition to being the offices for the apartments, will include 3,000 square feet of amenity-commercial space (likely a beauty salon or personal trainer). There are regulated riparian habitat areas that separate one of the apartment buildings and the office building from the remaining buildings.

Access Geometrics

The driveways should be constructed to Pima County standards. The project will have full access with one ingress and one egress lane at both driveways.

Development Phasing and Timing

For the purpose of this study, we have assumed a horizon buildout year of 2025 to better prepare for potential mitigation recommendations.

3. Study Area Conditions

Study Area

The study area includes Thornydale Road, Sumter Drive and Shannon Road A Category I TIS is required for this project, and the study area for a Category I TIS includes site access driveways and adjacent signalized intersections and/or major unsignalized street intersections within a quarter mile. For this project, the intersections within this area are Thornydale Road/Linda Vista Boulevard, Thornydale Road/Sumter Drive, and Shannon Road/Sumter Drive. A driveway on Thornydale Road will be located opposite the driveway to the Le Mirage Apartments and the driveway on Sumter Drive will be approximately 771 feet from Thornydale Road.

Area of Significant Traffic Impact

The significant impact from the project will be along the roadways adjacent to the project site.

Influence Area

The influence area includes the area in the vicinity of the project.

Existing Land Use

The project site is mostly vacant with one single family residential horse property, and zoned SR (Suburban Ranch). Mountain View High School is on the southwest corner of Thornydale Road/Linda Vista Boulevard. The Le Mirage Apartments are on the west side of Thornydale immediately west of the project. The Thornydale Plaza shopping center is southwest of the project. There are residential subdivisions to the north, south and west of the project site. Other major uses in the area include the Ironwood Elementary School south of the project area and The Church of Jesus Christ of Latter-Day Saints on Sumter Drive, east of Thornydale Road.

Site Accessibility

Access to the project will be via one ingress/egress driveway on Thornydale Road and one ingress/egress driveway on Sumter Drive.

Existing and Future Area Roadway System

Thornydale Road, Linda Vista Boulevard, Sumter Drive and Shannon Road will provide the primary regional access to the project site. They are all two-lane roadways, with Thornydale Road having a two-way, left turn lane along the frontage of the property. Linda Vista Boulevard, from a quarter mile west of Thornydale Road to Thornydale Road, also has a two-way, left turn lane along the frontage of Mountain View High School. It continues with the center turn lane east of Thornydale Road to Shannon Road. The Mountain Vista Ridge residential project (two-hundred single family residential lots) is near buildout on the south side of Sumter Drive, which is a two-lane undivided collector road from Thornydale Road to Shannon Road. Shannon Road also is a two-lane undivided collector road in the vicinity of the project.

The Pima Association of Governments (PAG) FY 2022-2026 Transportation Improvement Program (TIP) does not have any projects that are approved for funding in its project list.

Site Circulation

The preliminary development plan shows a roadway connecting the western area of the site to the eastern area. This road will be constructed with a bridge over the riparian area on-site.

4. Analysis of Existing Conditions

Physical Characteristics

Roadway Characteristics

Exhibit 3 is an inventory of the physical features of the project area roads. The following describes the roadway features of the study area roads.

Thornydale Road – is a nine-mile north/south paved roadway from its northern paved terminus north of Moore Road to its southern terminus at River Road. It is a two-lane arterial road with a two-way left turn lane in the vicinity of the project. It is classified as a medium volume arterial with a 150-foot right of way in the Pima County Major Streets Plan and as a Scenic, Major Route in the Pima County Scenic Routes Plan. It is also classified as an urban minor arterial on the Federal Functional Classification System map.

Near the project, Thornydale Road has a 40-mph speed limit. It has paved shoulders along the project frontage. It is classified as a minor arterial. There are some sidewalks on the east side between Pecos Drive and Linda Vista Boulevard. There are no bike routes along the frontage of the project site.

Sun Shuttle Route 412 (Thornydale/River) runs along Thornydale Road with a stop at Thornydale/Linda Vista.

Shannon Road - is a two-lane arterial road with a two-way left turn lane in the vicinity of the project. It is classified as a low volume arterial with a 90-foot right of way in the Pima County Major Streets Plan and as a Scenic, Major Route in the Pima County Scenic Routes Plan. It is also classified as an urban minor arterial on the Federal Functional Classification System map.

Its speed limit is 40 mph. There are no sidewalks, bike lanes or bus routes along the project frontage.

Linda Vista Boulevard – Linda Vista Boulevard is a two-lane east-west paved roadway. It is classified as a medium volume arterial with a 150-foot right of way in the Pima County Major Streets Plan west of Shannon Road and as a low volume arterial with a 90-foot right of way east of Shannon Road. Between Thornydale Road and Shannon Road, it is also classified as a Scenic, Major Route in the Pima County Scenic Routes Plan. It is also classified as an urban minor collector on the Federal Functional Classification System map.

West of Thornydale Road, Linda Vista Boulevard has a two-way left turn lane. East of Thornydale Road, the road continues with a two-way left turn lane to Shannon Road. It continues as a local road at Shannon Road to the east. West of Thornydale Road, the posted speed limit is 25 mph and east of Thornydale Road, the posted speed limit is 35 mph.

There are sidewalks and bike lanes along Linda Vista Boulevard within the study area.

Sumter Drive - is a two-lane east-west undivided road between Thornydale Road and Shannon Road. It is classified as an urban minor arterial on the Federal Functional Classification System map. Its speed limit is 35 mph. There are no sidewalks, bike lanes or bus routes along the project frontage. It provides local access to residential uses and a church on the north side of Sumter Drive.

Existing Intersections

This study analyses conditions at the existing intersections of Thornydale Road/Linda Vista Boulevard, Thornydale Road/Sumter Drive, and Shannon Road/Sumter Drive.

Thornydale Road/Linda Vista Boulevard is a four-leg signalized intersection. There is a lagging left turn phase for the north and south movements. Each approach has a left turn lane. The northbound, southbound, and eastbound approaches have a through lane and a right turn lane; the westbound approach has a shared through/right turn lane. There are crosswalks on each leg of the intersection.

Thornydale Road/Sumter Drive is a four-leg unsignalized intersection. Each approach has one through lane. The west leg is an entrance to the Thornydale Plaza Shopping Center. The west leg has a shared left/through/right lane. The east and north legs have a left turn lane and a shared through/right turn lane. The north and south legs turn left from the two-way left turn lane on Thornydale Road. The south leg has an exclusive right turn lane.

Shannon Road/Sumter Drive is a four-leg unsignalized intersection with stop control on both legs of Sumter Drive. The east and west legs are stop sign controlled. The west leg has a 100-foot left turn lane and a shared through/right turn lane. The two-way left turn lane on Shannon Road provides for a separate turn lane on the Shannon Road approaches.

Exhibits 4-5 are aerial photographs of the closest intersections to the project on Thornydale Road.

Exhibit 3 Roadway Inventory

Street	*Weekday Daily Volume*	*Data Year*	*Source*	*ROW Width (ft)*	*No. Thru Lanes*	*Speed Limit*	*Sidewalks*	*Bike Route*	*Daily Capacity at LOS D**
Thornydale Road									
Pecos Drive to Linda Vista	15,213	2022	FDS	100-145	2	40	Some, East Side	No	16,730
Linda Vista to Overton	19,514	2021	PAG	150	2	40	No	No	16,730
Shannon Road									
Lambert to Linda Vista	3,890	2021	PAG	100-160	2	40	No	No	12,740
Linda Vista to Overton	7,699	2021	PAG	110	2	40	No	No	12,740
Sumter Road									
Thornydale Road to Shannon Road	679	2022	PAG	45	2	35	No	No	10,660
Linda Vista Boulevard									
Camino de Oeste to Thornydale Road	10,976	2021	PAG	120-150	2	25-35	South Side by MV High Sch	Yes	13,990
Thornydale Road to Shannon Road	2,935	2021	PAG	105-135	2	35	Yes	Yes	13,990

*Generalized Annual Average Daily Volumes for Florida's Urbanized Areas, *from 2020 FDOT Quality/Level of Service Handbook Tables.*

Transit Service

Sun Shuttle Route 412 runs along Thornydale Road and Linda Vista Boulevard with a stop at the southwest corner of Thornydale/Linda Vista with ninety-minute headways. Besides this shuttle service, there is no fixed route service within the study area.

Pedestrian/Bicycle Facilities

With few exceptions, the roadways within the study area have shoulders with no sidewalks or bike lanes. There is a separated walking path along the north side of Mountain View High School on Linda Vista Boulevard. There are sidewalks along Linda Vista Boulevard between Thornydale Road and Shannon Road.

Exhibit 4 Thornydale/Linda Vista

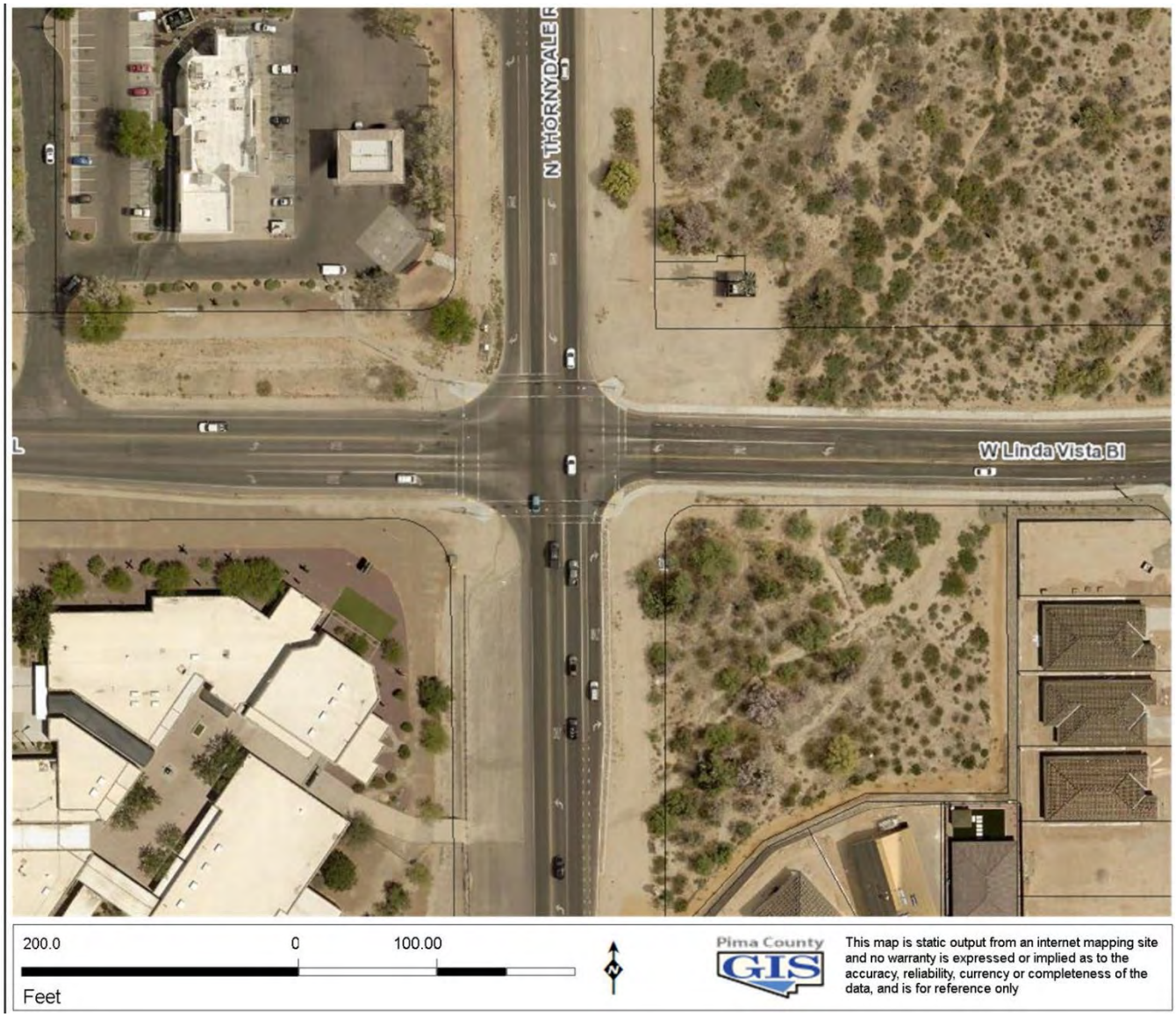
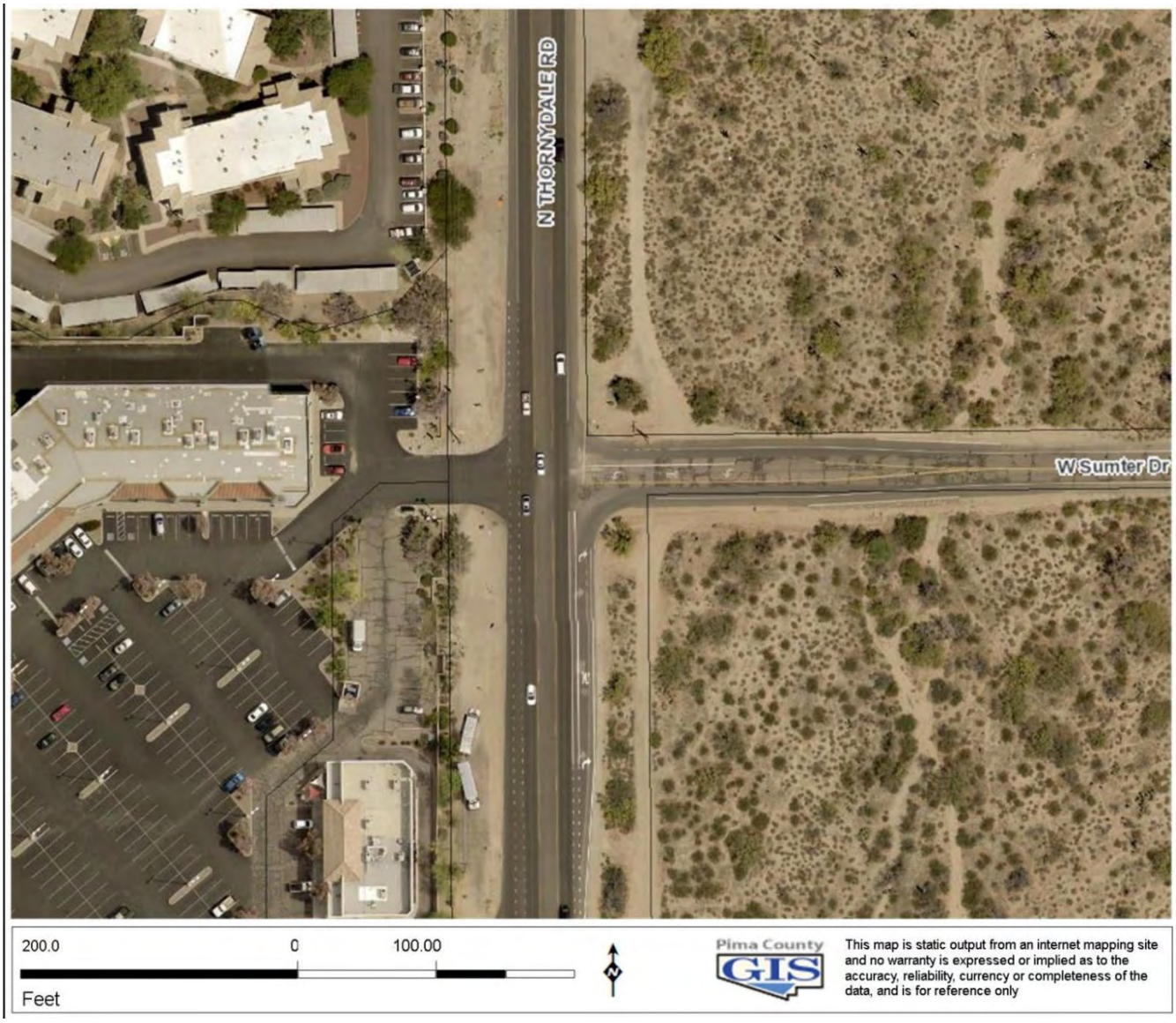


Exhibit 5 Thornydale/Sumter



Traffic Volumes

Daily traffic volumes from 2021 and 2022 for several of the roadway segments are available on Pima Association of Governments' website. A weekday count on Thornydale Road north of Sumter Drive was recorded by Field Data Services (FDS) of Arizona in March 2022.

Peak period turning movement counts were collected by FDS at Thornydale Road/Sumter Drive, Thornydale Road/Le Mirage Apartments intersection and at Shannon Road/Sumter Drive in March 2022. Year 2021 turning movement counts at Thornydale/Linda Vista are available on PAG's website. The peak hour intersection volumes are shown in Exhibit 6.

Level of Service

Level of service is a qualitative description of how well a roadway or intersection operates under prevailing traffic conditions based on traffic volumes and capacity. A grading system of A through F, like academic grades, is utilized. LOS A is free-flowing traffic, whereas LOS F is forced flow and extreme congestion. LOS D is generally accepted as the standard in urbanized areas although LOS E is sometimes accepted in more congested areas. Segment performance has been estimated using the planning methods contained in the Florida Department of Transportation (FDOT) Level of Service Handbook. Current performance of the intersections was analyzed using the Synchro analysis software.

It should also be noted that for projects in urban or suburban areas, performance is more dependent on peak hour intersection operations than daily roadway segment volumes.

Roadway Performance

Two lane roadways have a LOS D daily volume threshold of between 10,660 and 16,730 vehicles per day, depending on speed limit and the presence of turn lanes. Based on the recorded traffic volumes shown in Exhibit 3, the daily volumes on Thornydale Road north of Linda Vista approach the LOS D daily volume threshold, and the daily volumes on Thornydale Road south of Linda Vista exceed the LOS D daily threshold volumes. All other project area roadways operate below their LOS D daily volume thresholds.

Intersection Performance

The project area intersections were analyzed for both the AM and PM peak hour conditions and the results are provided in Exhibit 7. All study area intersections currently operate at acceptable levels of service (LOS D or better).

Crash History

Collision data for the project intersections and adjacent roadway segments were provided by ADOT. Recorded collision data from 2017 through 2021 are shown in a summary in Exhibit 8 and 9. Only intersections or roadway segments with three or more crashes during the five-year period are shown.

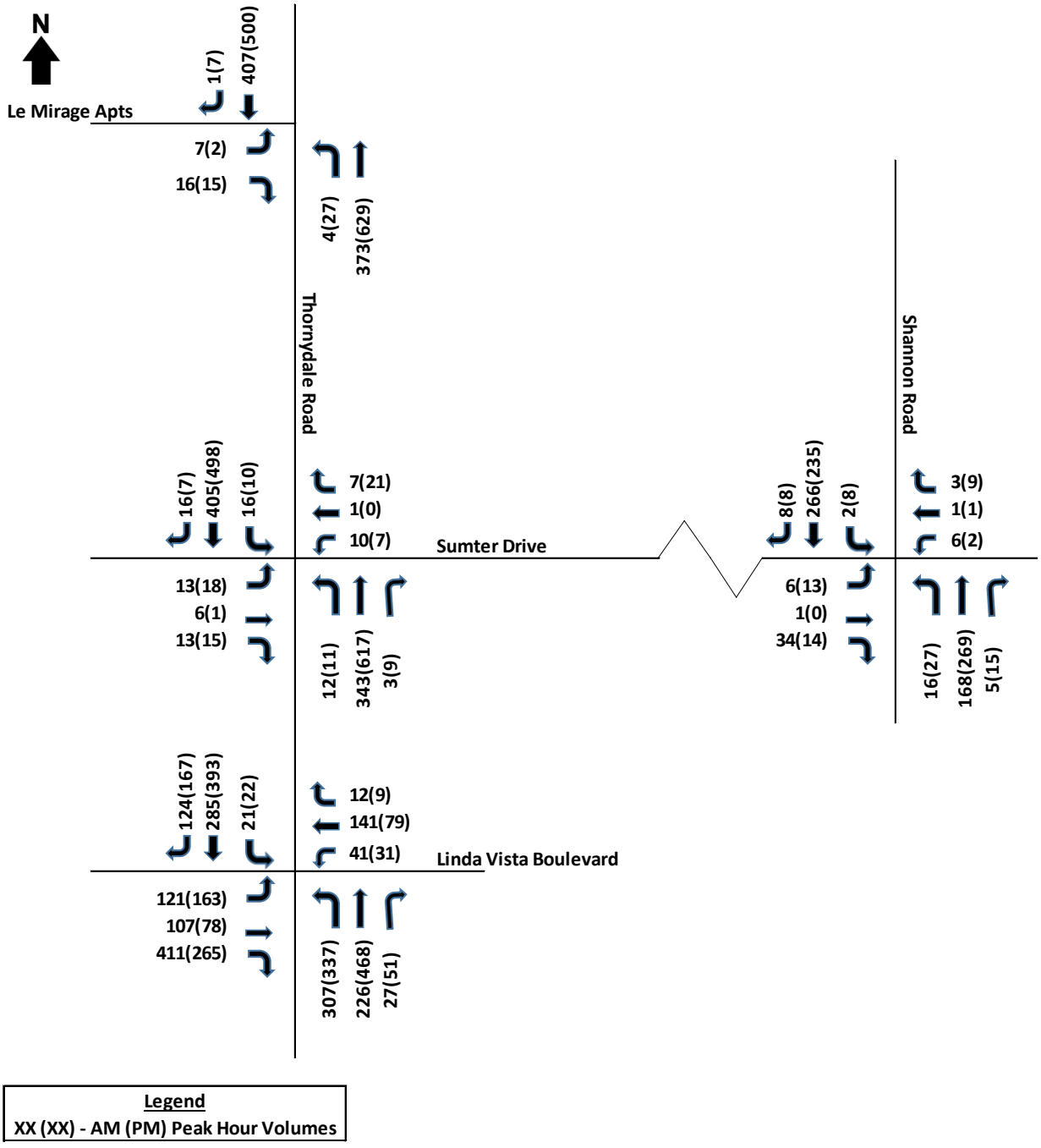
Crash rates over 1.0 crash per million entering-vehicles (MEV) for intersections, or per million vehicle-miles (MVM) for roadways usually indicate a need to review mitigating measures to reduce the rate.

All intersections and roadway segments are below the 1.0 MEV or 1.0 MVM crash rate over the five-year period.

The predominant crash types at the Thornydale/Linda Vista intersection were left turn (ten) and rear end (five. Most (fourteen) of the crashes were non-injury crashes. There were only three crashes at the Thornydale/Sumter crashes during the five-year period.

The Thornydale Road segment south of Linda Vista Road had the highest number (fifteen) of crashes during the five-year period, with the majority being rear-end crashes (ten). Thirteen of these crashes were non-injury crashes.

Exhibit 6 Existing Project Area Traffic Volumes



Legend
XX (XX) - AM (PM) Peak Hour Volumes

Exhibit 7 Current Intersection Performance

	Thornydale/Linda Vista			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left	17.4	C	16.9	B
Through	12.8	B	13.2	B
Right	14.7	B	11.8	B
Approach	*14.9*	*B*	*13.7*	*B*
Westbound				
Left	14.6	B	14.3	B
Through/Right	13.8	B	13.4	B
Approach	*13.9*	*B*	*13.6*	*B*
Northbound				
Left	22.6	C	21.8	C
Through	14.6	B	14.9	B
Right	12.4	B	9.9	A
Approach	*18.9*	*B*	*17.3*	*B*
Southbound				
Left	11.4	B	15.8	B
Through/Right*	14.7	B	15.1	B
Right	12.7	B	12.1	B
Approach	*13.9*	*B*	*14.3*	*B*
Intersection	***15.7***	***B***	***15.3***	***B***

	Thornydale/Sumter			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left/Through/Right	17.2	C	29	D
Westound				
Left	21	C	32.7	D
Through/Right	11.5	B	13.3	B
Northbound				
Left	8.3	A	8.5	A
Southbound				
Left	8.1	A	8.9	A

	Shannon/Sumter			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left	13.4	B	15.5	C
Through/Right	10.3	B	9.8	A
Westbound				
Left/Through/Right	12.7	B	11.3	B
Northbound				
Left	7.9	A	7.9	A
Southbound				
Left	7.6	A	7.9	A

	Thornydale/Le Mirage Apts			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left/Right	13.5	B	14.5	B
Northbound				
Left	8.2	A	8.7	A

Exhibit 8 Collision History - Intersections

Thornydale/Sumter							
Crash Type	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**	**%**
Angle	1					1	**33%**
Rear End	1					1	**33%**
Sideswipe	1					1	**33%**
Total	**3**	**0**	**0**	**0**	**0**	**3**	
Crash Rate (per MEV)	**0.51**	**0.00**	**0.00**	**0.00**	**0.00**	**0.10**	
Severity						**Total**	**%**
Bodily Injury	1					**1**	**33%**
Property Damage	2					**2**	**67%**

Thornydale/Linda Vista							
Crash Type	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**	**%**
Angle					1	1	**5%**
Left Turn	1	3		3	3	10	**48%**
Rear End	2	3				5	**24%**
Sideswipe		2			1	3	**14%**
Other			1		1	2	**10%**
Total	**3**	**8**	**1**	**3**	**6**	**21**	
Crash Rate (per MEV)	**0.34**	**0.90**	**0.11**	**0.34**	**0.68**	**0.47**	
Severity						**Total**	**%**
Bodily Injury	1	2		1	3	**7**	**33%**
Property Damage	2	6	1	2	3	**14**	**67%**
Note: MEV = Million Entering Vehicles							

Exhibit 9 Collision History - Roadways

Thornydale Road: Linda Vista to 1/2 Mile North							
Crash Type	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**	**%**
Angle		1			1	2	**25%**
Rear End		1	1	1		3	**38%**
Sideswipe				1		1	**13%**
Other					1	1	**13%**
Rear to Rear		1				1	**13%**
Total	**0**	**3**	**1**	**2**	**2**	**8**	
Crash Rate (per MVM)	**0.00**	**1.08**	**0.36**	**0.72**	**0.72**	**0.58**	
Severity						**Total**	**%**
Bodily Injury		3	1	2	1	**7**	**88%**
Property Damage					1	**1**	**13%**

Thornydale Road: Linda Vista to 1/2 Mile South

Crash Type	2017	2018	2019	2020	2021	Total	%
Angle				1		1	**7%**
Left Turn				1	1	2	**13%**
Rear End	2	3	2		3	10	**67%**
Head On	1					1	**7%**
Sideswipe					1	1	**7%**
Rear to Rear						0	**0%**
Total	**3**	**3**	**2**	**2**	**5**	**15**	
Crash Rate (per MVM)	**0.84**	**0.84**	**0.56**	**0.56**	**1.40**	**0.84**	
Severity						**Total**	**%**
Bodily Injury		1	1			**2**	**13%**
Property Damage	3	2	1	2	5	**13**	**87%**
Note: MVM = Million Vehicle Miles							

5. Projected Traffic

Site Traffic Forecasting

The future traffic from the project is estimated using the trip rates contained in the Institute of Traffic Engineers' *Trip Generation Manual, 11th Edition* for the various land uses. Trip generation is the mathematical product of land use intensity (building square footage, number of units, etc.) and the trip generation rate. The result is the total number of one-way trips expected to be generated by the project. These trips represent the number of vehicles estimated to enter and leave the project site.

Trip Generation

Exhibit 10 provides the ITE average trip rates and trip generation for the proposed uses during the average weekday. The exhibit shows the number of trips generated by the project for the three-time periods (weekday, weekday AM peak hour, and weekday PM peak hour) at build out of the project. The lane use "Hair Salon" does not have rates for the average weekday. We assumed that the "personal trainer space" would have a similar trip generation rate as the hair salon as trips to personal trainer services will likely require reservations similar to hair salons. We estimated the daily trips for this lane use by multiplying the average peak hour trips (4 trips) by ten.[1]

Exhibit 10 Trip Generation

				Trip Generation Average Rates					
				Weekday AM		Weekday PM		Avg Weekday	
Land Use	*Unit*	*No. Units*	*ITE Categ.*	*In*	*Out*	*In*	*Out*	*In*	*Out*
Multi Family Detached Unit	Units	270	220	0.4		0.51		6.74	
Low Rise				24%	76%	63%	37%	50%	50%
Hair Salon	Units	3	918	1.21		1.45		No Weekday Rates	
				50%	50%	17%	83%		

				Trip Generation					
				Weekday AM		Weekday PM		Avg Weekday	
Land Use	*Unit*	*No. Units*	*ITE Categ.*	*In*	*Out*	*In*	*Out*	*In*	*Out*
Multi Family Detached Unit	1000 SF	270	220	108		138		1,820	
Low Rise				26	82	87	51	910	910
Hair Salon	1000 SF	3	918	4		4		40	
				2	2	1	4	20	20
Total Trip Generation				112		143		1,860	
				28	84	88	55	930	930

Note: AM, PM Rates based on Peak Hour of Adjacent Street Traffic (7-9 AM; 4-6 PM)
There are no weekday rates for the lane use "Hair Salon" in the ITE Trip Generation Manual. We estimated that the number of weekday trips by multiplying the peak hour trips by 10.

[1] The most recent Pima County review of the previous updated TIS requested that we apply the most conservative land use listed in the specific plan document for the 3,000 square foot space in the 8,000 square foot building. Of those land uses listed, only "hair salon" and "small office building" are provided in the ITE Trip Generation Manual. The estimated trip generation for a 3,000 square foot "small office building" results in an estimated 5 AM peak hour trips, 6 PM peak hour trips and 43 weekday trips. The difference in trips between the two land uses is inconsequential, and the developer is expecting the land use to be more like a personal trainer/hair salon. Therefore we did not revise the report and the impact of the changes in trips would be trivial.

Pass-By Trips

No pass-by trips were assumed for the trip generation.

Trip Distribution and Assignment

Trips generated by this project have been distributed to the surrounding roadway network and the project intersections as shown in Exhibit 11.

Trips were distributed 60% toward Thornydale Road and 40% to Shannon. These trips were then distributed 60% to the south and 40% to the north.

Non-Site Traffic Forecasting

Background traffic volumes were estimated for the project area intersections and roadways. We assumed a 2% per year growth rate for existing volumes at the project area intersection based on historical traffic data available on Pima County's and Pima Association of Governments' websites.

The background, or "No Project," volumes for the year 2025 are shown in Exhibit 12.

Total Traffic

The total traffic volumes are the site traffic volumes added to the projected traffic volumes for the year 2025. The total traffic volumes are shown in Exhibit 13.

Exhibit 11 Site Trips

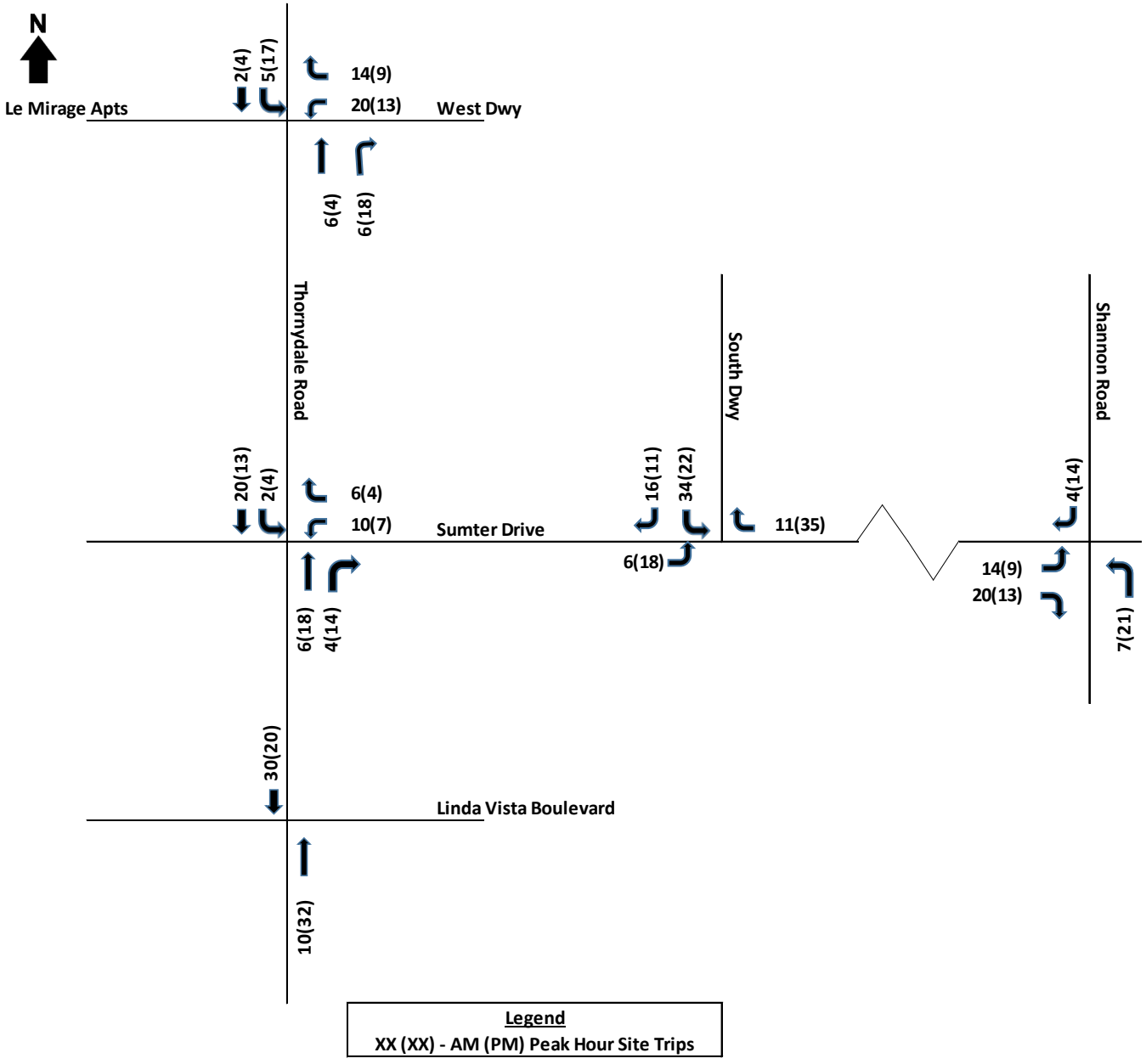
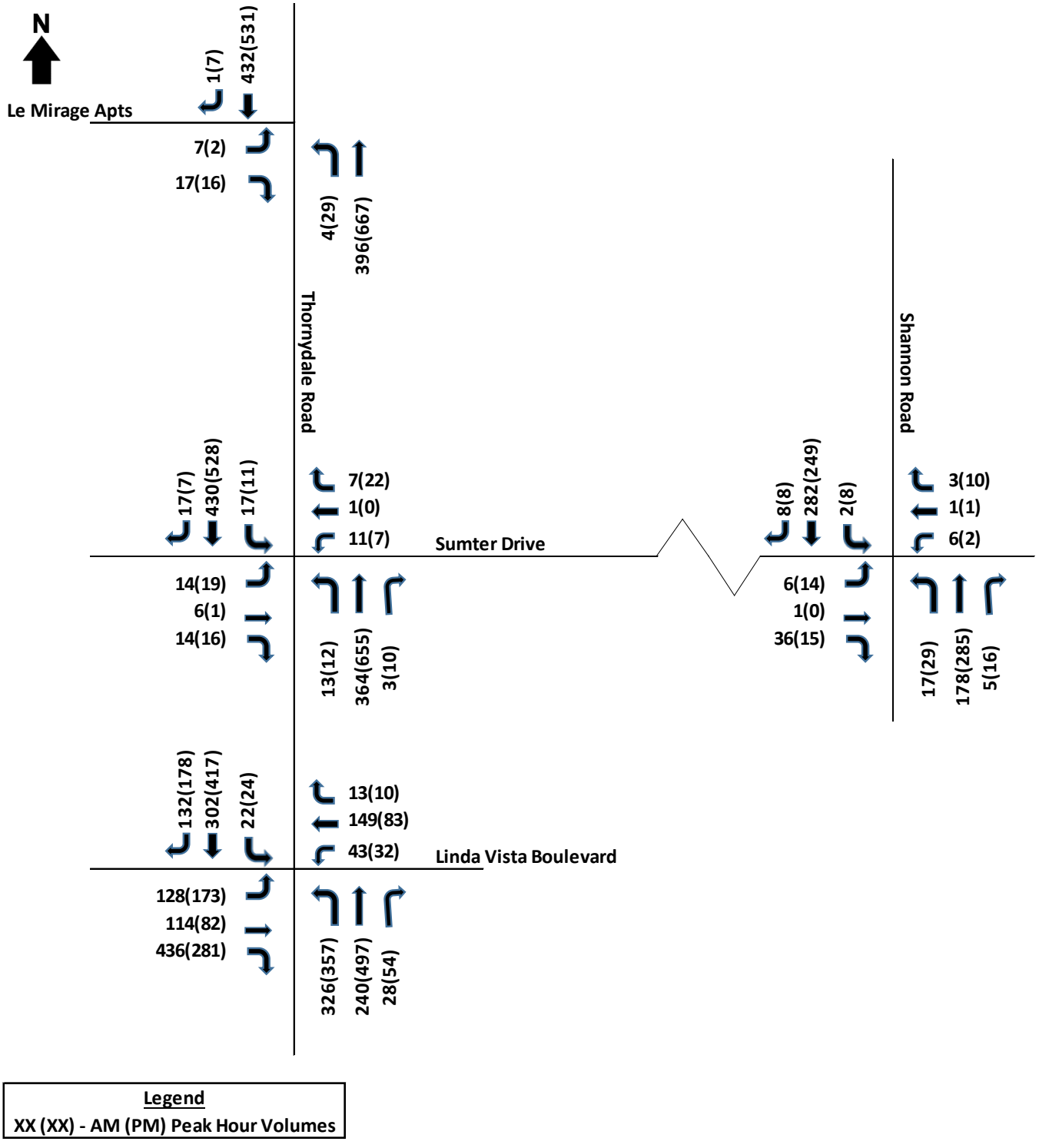
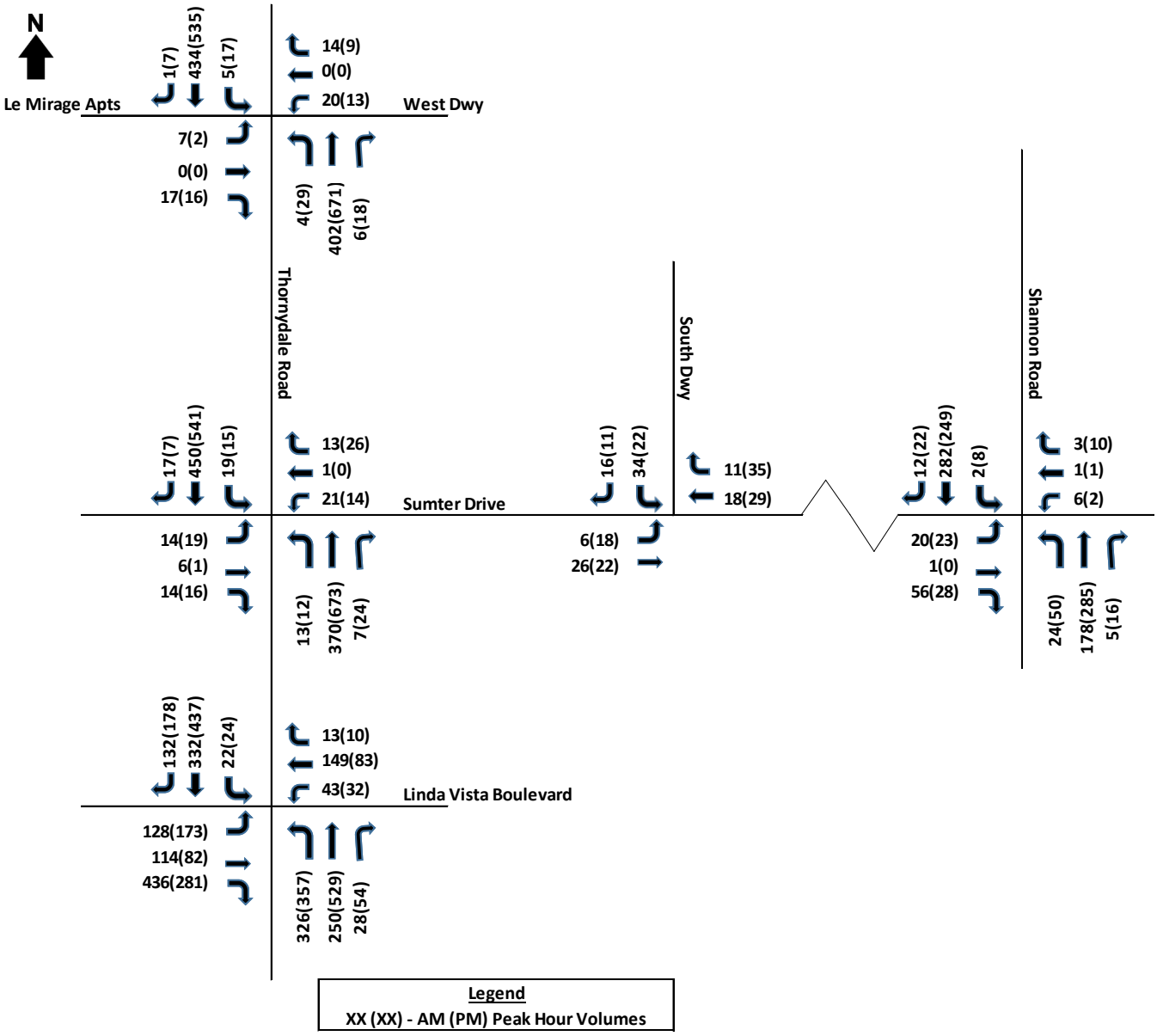


Exhibit 12 Peak Hour Background Traffic at 2025



Legend
XX (XX) - AM (PM) Peak Hour Volumes

Exhibit 13 Total Peak Hour Traffic at 2025



6. Traffic and Improvement Analysis

Site Access

The driveways should be constructed to Pima County standards. It is recommended that both driveways provide one entering lane and one exit lane. Both driveways should be controlled by a stop sign.

Level of Service Analysis

By the year 2025, the operational impacts of the project at the project intersections are projected to be minor. Roadway daily volumes and intersection levels of service are provided for the future years in this section.

Roadway Performance

The regional growth estimate of 2% per year was applied to the existing roadway segment volumes along with the estimated site traffic to analyze future segment performance at 2025 using the FDOT generalized tables. The future daily volumes are shown in Exhibit 14.

As a two-lane roadway, Thornydale road south of Linda Vista Road will continue to be over its LOS D capacity based on its daily volumes without and with the project. The addition of weekday site trips on Thornydale Road between Pecos Drive to Linda Vista will increase daily traffic volumes to just above the LOS D threshold. All other segments will operate at LOS D or better based on daily volumes even with the project.

Exhibit 14 Future Roadway Performance at 2025

Street	*Daily Capacity at LOS D**	*2025 ADT No Project*	*Site Trips*	*2025 ADT With Project*	*Over LOS D Capacity (No Project)*	*Over LOS D Capacity (With Project)*
Thornydale Road						
Pecos Drive to Linda Vista	16,730	16,140	670	16,810	No	Yes
Linda Vista to Overton	16,730	21,120	670	21,790	Yes	Yes
Shannon Road						
Lambert to Linda Vista	12,740	4,210	446	4,656	No	No
Linda Vista to Overton	12,740	8,330	446	8,776	No	No
Sumter Road						
Thornydale Road to Shannon Road	10,660	720	1,302	2,022	No	No
Linda Vista Boulevard						
Camino de Oeste to Thornydale Road	13,990	11,880	0	11,880	No	No
Thornydale Road to Shannon Road	13,990	3,180	0	3,180	No	No

*Generalized Annual Average Daily Volumes for Florida's Urbanized Areas, *from 2020 FDOT Quality/Level of Service Handbook Tables.*

Intersection Performance

The project intersections were analyzed without and with the project site trips for the year 2025. Results for the "with project" and "without project" scenarios are shown in Exhibits 15 and 16.

Without the project in 2025, the westbound left turn lane movement at the Sumter/Thornydale intersection will operate at LOS E during the PM peak hour and will continue to do so with the project trips added.

The westbound left and the eastbound approach at the Thornydale access is projected to operate at LOS E.

It is not unusual for drivers entering major roadways like Thornydale Road to experience moderate to high delays during peak periods. The eastbound and westbound approaches on Sumter Road at Thornydale Road will likely operate with less delay during the non-peak hours. No mitigation is recommended for these movements.

All movements at the other study area intersections will operate at LOS D or better through the year 2025.

Exhibit 15 Peak Hour LOS Results – No Project, Year 2025

	Thornydale/Linda Vista			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left	18.6	B	17.9	B
Through	13.3	B	13.7	B
Right	15.4	B	12	B
Approach	*15.7*	*B*	*14.1*	*B*
Westbound				
Left	15.3	B	14.9	B
Through/Right	14.4	B	13.9	B
Approach	*14.6*	*B*	*14.2*	*B*
Northbound				
Left	27.4	C	27	C
Through	15.7	B	17.4	B
Right	13.1	B	10.5	B
Approach	*22*	*C*	*20.8*	*C*
Southbound				
Left	12	B	17.2	B
Through/Right*	16.3	B	17.3	B
Right	13.6	B	13	B
Approach	*15.3*	*B*	*16*	*B*
Intersection	***17.3***	***B***	***17.4***	***B***

	Thornydale/Sumter			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left/Through/Right	18.3	C	33.8	D
Westound				
Left	22.9	C	37.1	E
Through/Right	11.8	B	13.8	B
Northbound				
Left	8.4	A	8.6	A
Southbound				
Left	8.2	A	9.1	A

	Shannon/Sumter			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left	13.9	B	16.3	C
Through/Right	10.5	B	10	B
Westbound				
Left/Through/Right	13.1	B	11.5	B
Northbound				
Left	8	A	7.9	A
Southbound				
Left	7.7	A	7.9	A

	Thornydale/Le Mirage Apts			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left/Right	14	B	15.2	C
Northbound				
Left	8.3	A	8.8	A

Exhibit 16 Peak Hour LOS Results – With Project, Year 2025

	Thornydale/Linda Vista			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left	19.6	B	18.4	B
Through	14.1	B	14	B
Right	15.3	B	12.1	B
Approach	*15.9*	*B*	*14.4*	*B*
Westbound				
Left	16.2	B	15.3	B
Through/Right	15.2	B	14.3	B
Approach	*15.4*	*B*	*14.5*	*B*
Northbound				
Left	29.7	C	29.8	C
Through	16.7	B	19.5	B
Right	13.8	B	10.5	A
Approach	*23.6*	*C*	*22.9*	*C*
Southbound				
Left	12.2	B	18.2	B
Through/Right*	19	B	18.2	B
Right	14	B	13	B
Approach	*17.3*	*B*	*16.7*	*B*
Intersection	***18.5***	***B***	***18.6***	***B***

	Thornydale/Sumter			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left/Through/Right	19.3	C	37.9	E
Westound				
Left	25.9	D	43.2	E
Through/Right	11.6	B	14.2	B
Northbound				
Left	8.5	A	8.7	A
Southbound				
Left	8.2	A	9.2	A

	Shannon/Sumter			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left	14.7	B	18	C
Through/Right	10.7	B	10.1	B
Westbound				
Left/Through/Right	13.8	B	11.8	B
Northbound				
Left	8	A	8	A
Southbound				
Left	7.7	A	7.9	A

	Thornydale/Le Mirage Apts/West Dwy			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left/Through/Right	14.4	B	15.8	C
Westbound				
Left/Through/Right	18	C	33.1	D
Northbound				
Left	8.3	A	8.8	A
Southbound				
Left	8.2	A	9.2	A

	Sumter/South Dwy			
	AM		PM	
	Delay (sec/veh)	LOS	Delay (sec/veh)	LOS
Eastbound				
Left	7.3	A	7.4	A
Southbound				
Left/Right	8.9	A	9.1	A

Turn Lane Warrants

We applied turn lane warrants from the *Pima County Subdivision and Development Street Standards*. They are based on the daily volume of the street where a potential turn lane may be and the peak hour turning volumes. The warrants for turn lanes also consider the posted speed limit on the street from which the turn would originate.

The Pima County left turn lane warrant criteria and right turn lane warrant criteria are shown in Exhibits 17 and 18.

Based on the volumes shown in the exhibits, neither an eastbound left turn on Sumter Drive nor a northbound right turn lane will be warranted on Sumter Drive or on Thornydale Road at the project driveways. However, although the northbound turn lane on Thornydale Road is not warranted, the developer will construct a northbound turn lane into the project driveway to address concurrency issues related to the over-capacity concerns on Thornydale Road. For this right turn lane, it be constructed to the Pima County minimum length (110 feet) with the gap and taper designed to Pima County turn lane design standards.

Exhibit 17 Pima County Left Turn Warrants

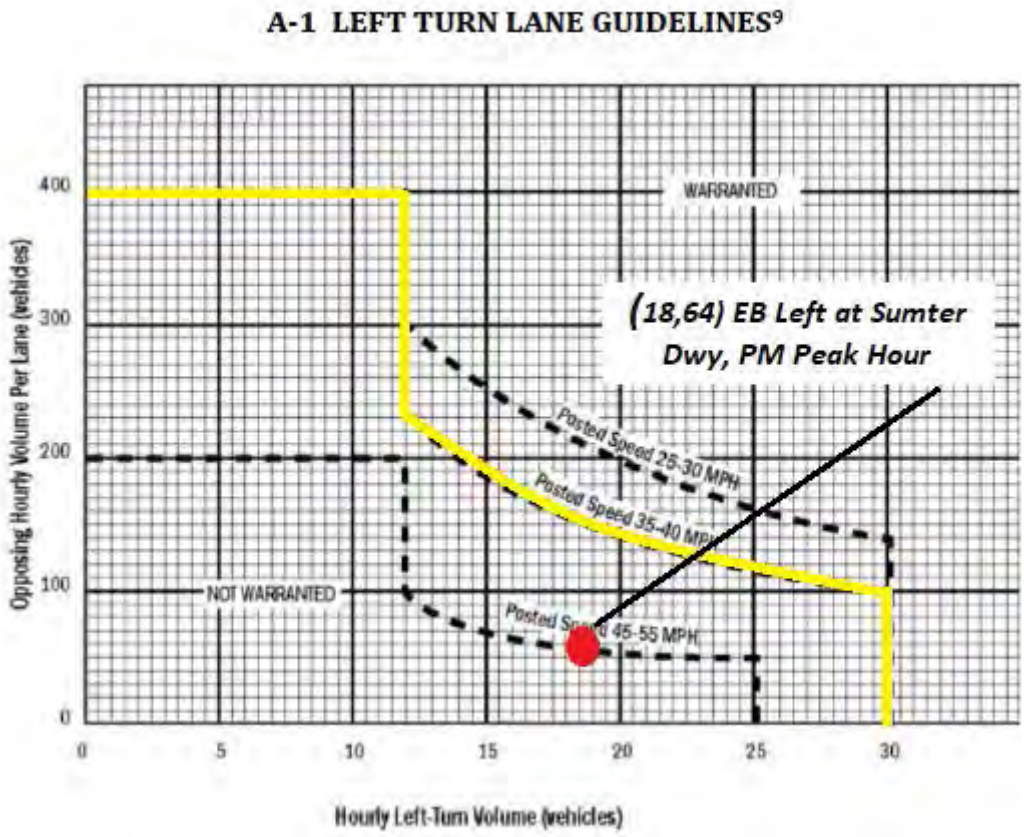
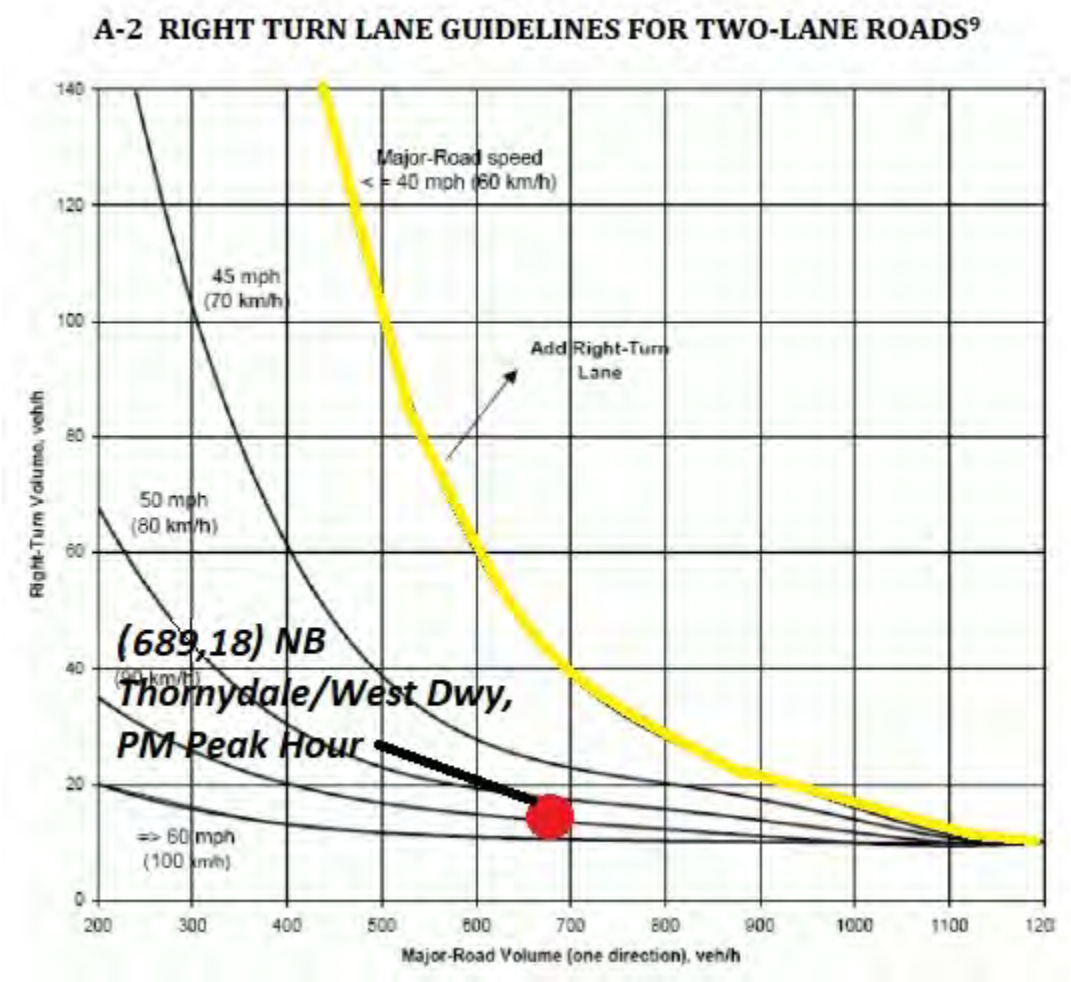


Exhibit 18 Pima County Right Turn Warrants on Two-Lane Roads



Turn Lane Storage Lengths

The Synchro intersection analysis results include projected queue lengths (95th percentile) based on the projected traffic volumes at the intersections. The calculated queue lengths for existing turn lanes and the warranted turn lanes for the 2025 With Project condition are shown in Exhibit 19. The existing storage lengths will serve the projected traffic queues through the year 2025.

Exhibit 19 Turn Lane Storage Length Recommendations

Existing Turn Lanes

		95th Percentile Queue Length (ft)		
Intersection	**Lane**	**AM Peak Hour**	**PM Peak Hour**	**Existing Storage Length (ft.)**
Thornydale/Linda Vista	EB Left	89	112	150
	EB Right	142	79	150
	WB Left	32	27	125
	NB Left	145	174	280
	NB Right	0	6	150
	SB Left	11	13	125
	SB Right	18	37	325
Thornydale/Sumter	WB Left	<25	<25	110
	NB Left	<25	<25	TWLTL
	NB Right	<25	<25	180
	SB Left	<25	<25	TWLTL
Shannon/Sumter	EB Left	<25	<25	100
	NB Left	<25	<25	TWLTL
	SB Left	<25	<25	TWLTL

Sight Distance

The project driveways and intersections should be designed to allow for acceptable sight distance. Sight distance is typically shown on the development plan and improvement drawings. The guidelines for sight distance are provided in Pima County's Roadway Design Manual.

Adequacy of Location and Design of Driveway Access

The preliminary development plan shows that the corner clearances and driveway spacings for the driveways on Thornydale Road and on Sumter Drive will meet the County minimum standards. The spacing for the driveway on Sumter Drive is more than 150 feet (minimum spacing for the 35 mph roads) and the driveway spacing on Thornydale Road is more than 230 feet.

The development will have gated access. Pima County includes guidance on the placement of gates at the entrances to residential developments in their *Subdivision and Development Street Standards*:

> "Gated entrances shall be allowed for commercial/industrial developments such as apartments where on-site parking areas are privately maintained and for residential subdivisions with private streets. Gated entries shall meet the following requirements:
>
> - Stopping locations (keypads, card-readers, guard shacks, etc.) shall be set back from the right-of-way of the cross street to avoid interfering with through traffic and to provide protection for entering vehicles.
> - The gate may not encroach into the travel lane when open.

- Each side of a median-divided roadway/driveway shall be at least 16 feet wide to provide accessibility of emergency vehicles.
- Any equipment or obstructions such as keypads or card-readers shall be installed in a median island.
- The design of the entrance shall allow vehicles that do not go past the gate to turn around without interfering with other traffic.
- The turnaround area shall be located within the development boundary outside of the collector or arterial right-of-way.

Gate Queuing Analysis

Using a basic Poisson distribution methodology, it is possible to estimate the average queue at a gate. The entering volume of 53 entering volumes per hour at the Sumter Road driveway was applied to this analysis. Based on the number of entering vehicles, it is likely that the entry will remain open during the highest peak and allow two to three vehicles in per entry "call." This would allow the second (or third) vehicle to enter without activating the gate. Given this assumption, the entering volume applied in this analysis is 27 vehicles (half of the projected entering vehicles). We also assume that it takes an average of 30 seconds for a driver to activate the gate and to enter. The following queue equation is applied:

$$E(n) = \rho/(1-\rho) = \lambda/(\mu - \lambda),$$

Where:

λ = arrival rate, in this case 27 vehicles/hour, or 0.45/minute,
μ = service rate, in this case 30 seconds per vehicle/hour, or 2 vehicles/minute,
$\rho = \lambda/\mu = 0.23$. This is the traffic intensity, or utilization factor.

This equation estimates the average number of queued vehicles plus the vehicle entering the gate.

The average number of vehicles in the queue is then:

$0.23/(1-0.23) = 0.30$ vehicle on average at the gate.

The probability that there will be three vehicles at the gate is:

$P(3) = \rho^3 \text{ X } P(0)$, where P(0) is the probability of no queue, and $P(0) = 1-\rho = 0.77$,

$= 0.23^3 \text{ X } 0.77 = 0.01$, or a 1% probability of a queue of 3 vehicles.

The probability of four or more vehicles queued decreases rapidly, so it can be estimated that there is a 99% probability that entering vehicles will not back up to the street if storage for at least four vehicles is provided between the gate and the street. For this reason, it is recommended that there be enough space for three to four vehicles to queue before the gate keypad. Because there are fewer vehicles entering at the Thornydale entrance, this analysis would apply to that location also.

Alternative Modes Considerations

The internal streets will contain sidewalks, accommodating pedestrian needs.

The developer is providing off-site improvements for the project to address the County's transportation concurrency concerns. The developer has agreed to provide a separated shared-use path on the east side of Thornydale Road that will begin at the existing sidewalk along the frontage of the North Ranch development and continue to Linda Vista Boulevard. A shared use path will also be constructed by the developer along Sumter Drive. The path on Sumter Drive shall be constructed from the west side of the access location on Sumter Drive to its intersection with the shared-use path along Thornydale Road, as shown on the preliminary development plan.

Traffic Control Needs

Stop signs are recommended for traffic control at the project driveways at their entrances to Thornydale Road and Sumter Drive. Sign construction and placement should comply with the MUTCD and local policies.

Traffic Signal Warrants

Traffic volumes at the project driveways are not expected to warrant traffic signals.

7. Conclusions and Recommendations

Conclusions

1. Turn lanes on Thornydale Road and on Sumter Drive at the project driveways are not warranted based on Pima County turn lane warrant criteria. However, although the northbound turn lane on Thornydale Road is not warranted, the developer will construct a northbound turn lane into the project driveway to address concurrency issues related to the over-capacity concerns on Thornydale Road.
2. The westbound left turn movement and eastbound approach at Thornydale Road/Sumter may experience LOS E during the PM peak hour. It is not unusual for drivers entering major roadways like Thornydale Road to experience moderate to high delays during peak periods. The eastbound and westbound approaches on Sumter Road at Thornydale Road will likely operate with less delay during the non-peak hours. No mitigation is recommended for these movements. All other movements at the other project intersections will operate at LOS D or better through the year 2025 with the project.
3. The project will generate an estimated 1,860 daily trips with 112 AM peak hour trips and 143 PM peak hour trips. These trips will be distributed to and from the project site at two driveways, one on Thornydale Road and one on Sumter Drive.
4. The driveway spacings and corner clearances will meet Pima County minimum spacing standards.
5. The developer is providing off-site improvements for the project to address the County's transportation concurrency concerns.

Recommendations

1. Construct the project driveways to Pima County standards, with one ingress and one egress lane at both driveway access locations.
2. The northbound right turn lane on Thornydale Road at the west project driveway will be constructed to the Pima County minimum length (110 feet) with the gap and taper designed to Pima County turn lane design standards.
3. Ensure that there is acceptable sight distance to and from the project entrances.
4. Provide stop signs for traffic exiting the project driveways.
5. The developer will construct a shared-use path from an existing sidewalk along the North Ranch development to Linda Vista Boulevard along the east side of Thornydale Road. A shared use path will also be constructed by the developer along Sumter Drive. The path on Sumter Drive shall be constructed from the west side of the access location on Sumter Drive to its intersection with the shared-use path along Thornydale Road, as shown on the preliminary development plan. This off-site improvement is to be constructed to address concurrency concerns. The shared-use paths will be designed and built to Pima County standards.
6. Subdivision design should conform to current Pima County standards.
7. All new traffic signs and markings must comply with the current *Manual on Uniform Traffic Control Devices* and local requirements.

Appendix

- Preliminary Development Plan
- Traffic Counts
- Capacity Analysis Worksheets

SPECIFIC PLAN PDP

EXISTING COMPREHENSIVE PLAN USE:	LIU 0.3	TOTAL SITE AREA:	806,348.7 S.F. (18.51 AC)	COMMERCIAL FLOOR AREA:	+/- 3,000 S.F.
EXISTING ZONING:	SUBURBAN RANCH - SR	ROW DEDICATION:	27,157.9 S.F. (0.62 AC)	TOTAL DWELLING UNITS:	270 UNITS
		PROJECT AREA:	779,191 S.F. (17.88 AC)	RESIDENTIAL DENSITY:	15.1 RAC
PROPOSED COMPREHENSIVE PLAN USE:	PDC			PARKING PROVIDED:	438 SPACES
PROPOSED ZONING:	SPECIFIC PLAN - SP	NATURAL UNDISTURBED OPEN SPACE:	282,268.8 S.F. (6.48 AC)		
		FUNCTIONAL OPEN SPACE:	210,394.8 S.F. (4.83 AC)		

AT THE TIME OF DEVELOPMENT, THE PROJECT WILL SUBMIT A DETENTION WAIVER TO PCRFCD BASED ON THE CURRENT PROPOSAL

- FUNCTIONAL OPEN SPACE
- NATURAL UNDISTURBED OPEN SPACE
- COVERED PARKING
- IRA
- BUILDING

THORNYDALE AND SUMTER - SITE PLAN

DATE: 05.08.23 JOB#23000

a.23 studios

Project: **Thornydale/Linda Vista**

Date: **Thursday, September 23, 2021**

Count | 0:15

Count Starts at

	7:00 AM	NB Thornydale			SB Thornydale			EB Linda Vista			WB Linda Vista									
	END	Left			Left		Right	Left		Right	Left		Right	TOTALS					END	
	Time	Turn	THRU	Right	Turn	THRU	Turn	Turn	THRU	Turn	Turn	THRU	Turn	NB	SB	EB	WB	Total	Time	
	7:15 AM	58	69	8	6	86	36	44	23	76	17	25	3	135	128	143	45	451	7:15 AM	
	7:30 AM	37	65	4	12	110	30	42	26	82	12	32	5	106	152	150	49	457	7:30 AM	
	7:45 AM	57	102	6	10	122	33	58	36	102	11	47	9	165	165	196	67	593	7:45 AM	
	8:00 AM	93	99	7	5	118	43	55	21	89	5	39	6	199	166	165	50	580	8:00 AM	
	8:15 AM	91	92	9	9	123	86	46	21	126	9	28	3	192	218	193	40	643	8:15 AM	
	8:30 AM	60	88	4	8	80	31	45	27	86	15	24	3	152	119	158	42	471	8:30 AM	
	8:45 AM	35	84	5	9	118	13	35	12	59	10	19	6	124	140	106	35	405	8:45 AM	
	9:00 AM	39	84	9	5	108	26	37	12	40	4	15	2	132	139	89	21	381	9:00 AM	
7:00 AM	8:00 AM	245	335	25	33	436	142	199	106	349	45	143	23	605	611	654	211	2081	7:00 AM	8:00 AM
7:15 AM	8:15 AM	278	358	26	36	473	192	201	104	399	37	146	23	662	701	704	206	2273	7:15 AM	8:15 AM
7:30 AM	8:30 AM	301	381	26	32	443	193	204	105	403	40	138	21	708	668	712	199	2287	7:30 AM	8:30 AM
7:45 AM	8:45 AM	279	363	25	31	439	173	181	81	360	39	110	18	667	643	622	167	2099	7:45 AM	8:45 AM
8:00 AM	9:00 AM	225	348	27	31	429	156	163	72	311	38	86	14	600	616	546	138	1900	8:00 AM	9:00 AM
7:00 AM	9:00 AM	470	683	52	64	865	298	362	178	660	83	229	37	1205	1227	1200	349	3981	7:00 AM	9:00 AM
														0.89	0.77	0.91	0.74			
2022		307	389	27	33	452	197	208	107	411	41	141	21							
Adjusted 2022		307	226	27	21	285	124	121	107	411	41	141	12							
2025 NP		326	240	28	22	302	132	128	114	436	43	149	13							
Site Trips			10			30														
2025 WP		326	250	28	22	332	132	128	114	436	43	149	13							

Count Starts at

	4:00 PM	NB Thornydale			SB Thornydale			EB Linda Vista			WB Linda Vista									
	END	Left			Left		Right	Left		Right	Left		Right	TOTALS					END	
	Time	Turn	THRU	Right	Turn	THRU	Turn	Turn	THRU	Turn	Turn	THRU	Turn	NB	SB	EB	WB	Total	Time	
	4:15 PM	69	100	10	5	115	28	37	15	64	5	17	5	179	148	116	27	470	4:15 PM	
	4:30 PM	80	132	14	4	123	37	42	9	51	4	25	4	226	164	102	33	525	4:30 PM	
	4:45 PM	88	102	14	5	97	38	47	16	42	6	18	3	204	140	105	27	476	4:45 PM	
	5:00 PM	68	107	7	4	91	37	30	17	48	9	14	5	182	132	95	28	437	5:00 PM	
	5:15 PM	76	111	11	7	90	43	30	17	60	8	15	2	198	140	107	25	470	5:15 PM	
	5:30 PM	83	114	9	5	110	40	42	18	71	6	20	2	206	155	131	28	520	5:30 PM	
	5:45 PM	101	110	12	5	104	37	45	16	79	5	26	3	223	146	140	34	543	5:45 PM	
	6:00 PM	70	124	18	5	81	44	43	25	50	11	16	2	212	130	118	29	489	6:00 PM	
4:00 PM	5:00 PM	305	441	45	18	426	140	156	57	205	24	74	17	791	584	418	115	1908	4:00 PM	5:00 PM
4:15 PM	5:15 PM	312	452	46	20	401	155	149	59	201	27	72	14	810	576	409	113	1908	4:15 PM	5:15 PM
4:30 PM	5:30 PM	315	434	41	21	388	158	149	68	221	29	67	12	790	567	438	108	1903	4:30 PM	5:30 PM
4:45 PM	5:45 PM	328	442	39	21	395	157	147	68	258	28	75	12	809	573	473	115	1970	4:45 PM	5:45 PM
5:00 PM	6:00 PM	330	459	50	22	385	164	160	76	260	30	77	9	839	571	496	116	2022	5:00 PM	6:00 PM
4:00 PM	6:00 PM	635	900	95	40	811	304	316	133	465	54	151	26	1630	1155	914	231	3930	4:00 PM	6:00 PM
														0.94	0.92	0.89	0.85			
2022		337	468	51	22	393	167	163	78	265	31	79	9							
2025 NP		357	497	54	24	417	178	173	82	281	32	83	10							
Site Trips			32			20														
2025 WP		357	529	54	24	437	178	173	82	281	32	83	10							

Intersection Turning Movement
Prepared by:

FIELD DATA SERVICES OF ARIZONA, INC.
520.316.6745

veracitytrafficgroup

N-S STREET:	Thornydale Rd	DATE:	03/24/22	LOCATION:	Tucson
E-W STREET:	Sumter Dr	DAY:	THURSDAY	PROJECT#	22-1178-001

	NORTHBOUND			SOUTHBOUND			EASTBOUND			WESTBOUND			
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
LANES:	0	1	1	0	1	0	0	1	0	1	1	0	
6:00 AM													
6:15 AM													
6:30 AM													
6:45 AM													
7:00 AM	0	54	1	4	54	2	3	2	2	0	1	1	124
7:15 AM	3	77	1	5	84	2	3	1	2	4	0	2	184
7:30 AM	3	101	0	6	100	0	2	0	0	4	0	3	219
7:45 AM	3	94	1	4	86	1	4	1	3	4	0	3	204
8:00 AM	6	79	1	7	100	2	3	1	4	4	1	2	210
8:15 AM	1	78	0	2	110	4	4	1	4	1	0	1	206
8:30 AM	2	92	1	3	109	9	2	3	2	1	0	1	225
8:45 AM	1	108	3	1	73	3	2	1	3	0	1	5	201
9:00 AM													
9:15 AM													
9:30 AM													
9:45 AM													
10:00 AM													
10:15 AM													
10:30 AM													
10:45 AM													
11:00 AM													
11:15 AM													
11:30 AM													
11:45 AM													

TOTAL	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
Volumes	19	683	8	32	716	23	23	10	20	18	3	18	1573
Approach %	2.68	96.20	1.13	4.15	92.87	2.98	43.40	18.87	37.74	46.15	7.69	46.15	
App/Depart	710	/	724	771	/	754	53	/	50	39	/	45	

AM Peak Hr Begins at: 745 AM

PEAK													
Volumes	12	343	3	16	405	16	13	6	13	10	1	7	845
2025 NP	13	364	3	17	430	17	14	6	14	11	1	7	
Site Trips		6	4	2	20					10		6	
2025 WP	13	370	7	19	450	17	14	6	14	21	1	13	
Approach %	3.35	95.81	0.84	3.66	92.68	3.66	40.63	18.75	40.63	55.56	5.56	38.89	
PEAK HR. FACTOR:		0.913			0.903			0.889			0.643		0.939

CONTROL: 2-Way Stop (EB & WB)
COMMENT 1:
GPS: 32.382641, -111.046921

Intersection Turning Movement

FIELD DATA SERVICES OF ARIZONA, INC.
520.316.6745

veracitytrafficgroup

N-S STREET:	Thornydale Rd 0	DATE:	03/24/22	LOCATION:	Tucson
E-W STREET:	Sumter Dr	DAY:	THURSDAY	PROJECT#	22-1178-001

	NORTHBOUND			SOUTHBOUND			EASTBOUND			WESTBOUND			
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
LANES:	0	1	1	0	1	0	0	1	0	1	1	0	
1:00 PM													
1:15 PM													
1:30 PM													
1:45 PM													
2:00 PM													
2:15 PM													
2:30 PM													
2:45 PM													
3:00 PM													
3:15 PM													
3:30 PM													
3:45 PM													
4:00 PM	2	149	4	1	130	2	7	1	8	3	0	4	311
4:15 PM	2	137	2	0	131	1	7	1	4	0	0	2	287
4:30 PM	3	147	5	3	131	1	5	0	2	2	0	3	302
4:45 PM	3	162	4	2	133	2	1	0	1	0	0	5	313
5:00 PM	4	147	0	4	107	1	7	0	7	2	0	6	285
5:15 PM	1	161	0	1	127	3	5	1	5	3	0	7	314
5:30 PM	0	159	0	2	111	4	8	0	3	5	0	5	297
5:45 PM	1	152	5	4	127	0	2	0	2	1	0	2	296
6:00 PM													
6:15 PM													
6:30 PM													
6:45 PM													

TOTAL	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
Volumes	16	1214	20	17	997	14	42	3	32	16	0	34	2405
Approach %	1.28	97.12	1.60	1.65	96.98	1.36	54.55	3.90	41.56	32.00	0.00	68.00	
App/Depart	1250	/	1290	1028	/	1045	77	/	40	50	/	30	

PM Peak Hr Begins at: 430 PM

PEAK													
Volumes	11	617	9	10	498	7	18	1	15	7	0	21	1214
2025 NP	12	655	10	11	528	7	19	1	16	7	0	22	
Site Trips		18	14	4	13					7		4	
2025 WP	12	673	24	15	541	7	19	1	16	14	0	26	
Approach %	1.73	96.86	1.41	1.94	96.70	1.36	52.94	2.94	44.12	25.00	0.00	75.00	

PEAK HR. FACTOR:	0.942	0.940	0.607	0.700	0.967

CONTROL: 2-Way Stop (EB & WB)
COMMENT 1: 0
GPS: 32.382641, -111.046921

Intersection Turning Movement
Prepared by:

FIELD DATA SERVICES OF ARIZONA, INC.
520.316.6745

veracitytrafficgroup

N-S STREET:	Thornydale Rd	DATE:	03/24/22	LOCATION:	Tucson
E-W STREET:	Le Mirage Apt. Driveway	DAY:	THURSDAY	PROJECT#	22-1178-002

	NORTHBOUND			SOUTHBOUND			EASTBOUND			WESTBOUND			
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
LANES:	0	1	0	0	1	0	0	1	0	0	0	0	
6:00 AM													
6:15 AM													
6:30 AM													
6:45 AM													
7:00 AM	2	56	0	0	59	0	3	0	1	0	0	0	121
7:15 AM	1	81	0	0	85	0	1	0	6	0	0	0	174
7:30 AM	3	103	0	0	96	1	1	0	10	0	0	0	214
7:45 AM	2	99	0	0	83	1	1	0	8	0	0	0	194
8:00 AM	2	82	0	0	105	1	0	0	4	0	0	0	194
8:15 AM	1	82	0	0	109	0	2	0	7	0	0	0	201
8:30 AM	0	95	0	0	117	0	3	0	4	0	0	0	219
8:45 AM	1	114	0	0	76	0	2	0	1	0	0	0	194
9:00 AM													
9:15 AM													
9:30 AM													
9:45 AM													
10:00 AM													
10:15 AM													
10:30 AM													
10:45 AM													
11:00 AM													
11:15 AM													
11:30 AM													
11:45 AM													

TOTAL	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
Volumes	12	712	0	0	730	3	13	0	41	0	0	0	1511
Approach %	1.66	98.34	0.00	0.00	99.59	0.41	24.07	0.00	75.93	####	####	####	
App/Depart	724	/	725	733	/	771	54	/	0	0	/	15	

AM Peak Hr Begins at: 800 AM

PEAK													
Volumes	4	373	0	0	407	1	7	0	16	0	0	0	808
2025 NP	4	396	0	0	432	1	7	0	17	0	0	0	
Site Trips		6	6	5	2					20		14	
2025 WP	4	402	6	5	434	1	7	0	17	20	0	14	
Approach %	1.06	98.94	0.00	0.00	99.75	0.25	30.43	0.00	69.57	####	####	####	
PEAK HR. FACTOR:		0.820			0.872			0.639			0.000		0.922

CONTROL:	1-Way Stop (EB)
COMMENT 1:	
GPS:	32.383737, -111.046926

Intersection Turning Movement

FIELD DATA SERVICES OF ARIZONA, INC.
520.316.6745

veracitytrafficgroup

N-S STREET:	Thornydale Rd 0	DATE:	03/24/22	LOCATION:	Tucson
E-W STREET:	Le Mirage Apt. Driveway	DAY:	THURSDAY	PROJECT#	22-1178-002

	NORTHBOUND			SOUTHBOUND			EASTBOUND			WESTBOUND			
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
LANES:	0	1	0	0	1	0	0	1	0	0	0	0	
1:00 PM													
1:15 PM													
1:30 PM													
1:45 PM													
2:00 PM													
2:15 PM													
2:30 PM													
2:45 PM													
3:00 PM													
3:15 PM													
3:30 PM													
3:45 PM													
4:00 PM	6	154	0	0	128	1	1	0	5	0	0	0	295
4:15 PM	3	143	0	0	130	2	1	0	2	0	0	0	281
4:30 PM	5	150	0	0	130	2	1	0	5	0	0	0	293
4:45 PM	6	162	0	0	136	3	0	0	1	0	0	0	308
5:00 PM	5	155	0	0	107	2	1	0	5	0	0	0	275
5:15 PM	11	162	0	0	127	0	0	0	4	0	0	0	304
5:30 PM	13	159	0	0	109	1	2	0	8	0	0	0	292
5:45 PM	8	148	0	0	125	1	1	0	6	0	0	0	289
6:00 PM													
6:15 PM													
6:30 PM													
6:45 PM													

TOTAL	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
Volumes	57	1233	0	0	992	12	7	0	36	0	0	0	2337
Approach %	4.42	95.58	0.00	0.00	98.80	1.20	16.28	0.00	83.72	####	####	####	
App/Depart	1290	/	1240	1004	/	1028	43	/	0	0	/	69	

PM Peak Hr Begins at: 430 PM

PEAK													
Volumes	27	629	0	0	500	7	2	0	15	0	0	0	1180
2025 NP	29	667	0	0	531	7	2	0	16	0	0	0	
Site Trips		4	18	17	4					13		9	
2025 WP	29	671	18	17	535	7	2	0	16	13	0	9	
Approach %	4.12	95.88	0.00	0.00	98.62	1.38	11.76	0.00	88.24	####	####	####	
PEAK HR. FACTOR:		0.948			0.912			0.708			0.000		0.958

CONTROL: 1-Way Stop (EB)
COMMENT 1: 0
GPS: 32.383737, -111.046926

Intersection Turning Movement
Prepared by:

FIELD DATA SERVICES OF ARIZONA, INC.
520.316.6745

veracitytrafficgroup

N-S STREET:	Shaonnon Rd	DATE:	03/24/22	LOCATION:	Tucson
E-W STREET:	Sumter Dr	DAY:	THURSDAY	PROJECT#	22-1178-003

	NORTHBOUND			SOUTHBOUND			EASTBOUND			WESTBOUND			
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
LANES:	0	1	0	0	1	0	0	1	0	0	1	0	
6:00 AM													
6:15 AM													
6:30 AM													
6:45 AM													
7:00 AM	2	23	1	1	43	1	2	0	5	2	0	4	84
7:15 AM	3	21	0	1	51	3	3	0	9	0	0	0	91
7:30 AM	4	40	1	0	75	3	1	0	8	1	0	1	134
7:45 AM	4	52	1	0	69	1	1	1	8	2	1	0	140
8:00 AM	4	36	2	1	71	2	1	0	12	2	0	0	131
8:15 AM	4	40	1	1	51	2	3	0	6	1	0	2	111
8:30 AM	2	36	1	1	52	0	2	1	10	3	0	2	110
8:45 AM	5	48	0	2	51	1	3	0	4	0	0	2	116
9:00 AM													
9:15 AM													
9:30 AM													
9:45 AM													
10:00 AM													
10:15 AM													
10:30 AM													
10:45 AM													
11:00 AM													
11:15 AM													
11:30 AM													
11:45 AM													

TOTAL	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
Volumes	28	296	7	7	463	13	16	2	62	11	1	11	917
Approach %	8.46	89.43	2.11	1.45	95.86	2.69	20.00	2.50	77.50	47.83	4.35	47.83	
App/Depart	331	/	323	483	/	536	80	/	16	23	/	42	

AM Peak Hr Begins at: 730 AM

PEAK													
Volumes	16	168	5	2	266	8	6	1	34	6	1	3	516
2025 NP	17	178	5	2	282	8	6	1	36	6	1	3	
Site Trips	7					4	14		20				
2025 WP	24	178	5	2	282	12	20	1	56	6	1	3	
Approach %	8.47	88.89	2.65	0.72	96.38	2.90	14.63	2.44	82.93	60.00	10.00	30.00	
PEAK HR. FACTOR:		0.829			0.885			0.788			0.833		0.921

CONTROL: 2-Way Stop (EB & WB)
COMMENT 1:
GPS: 32.382712, -111.029769

Intersection Turning Movement

FIELD DATA SERVICES OF ARIZONA, INC.
520.316.6745

veracitytrafficgroup

N-S STREET:	Shaonnon Rd 0	DATE:	03/24/22	LOCATION:	Tucson
E-W STREET:	Sumter Dr	DAY:	THURSDAY	PROJECT#	22-1178-003

	NORTHBOUND			SOUTHBOUND			EASTBOUND			WESTBOUND			
	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
LANES:	0	1	0	0	1	0	0	1	0	0	1	0	
1:00 PM													
1:15 PM													
1:30 PM													
1:45 PM													
2:00 PM													
2:15 PM													
2:30 PM													
2:45 PM													
3:00 PM													
3:15 PM													
3:30 PM													
3:45 PM													
4:00 PM	5	51	4	0	59	2	3	0	4	1	0	1	130
4:15 PM	4	82	4	1	55	1	0	0	4	2	0	0	153
4:30 PM	7	69	4	0	61	0	2	0	3	0	0	1	147
4:45 PM	5	62	3	2	68	2	6	0	4	1	0	2	155
5:00 PM	7	66	6	2	50	1	2	0	4	0	0	3	141
5:15 PM	10	64	5	1	67	0	3	0	3	1	1	3	158
5:30 PM	5	77	1	3	50	5	2	0	3	0	0	1	147
5:45 PM	4	54	4	0	54	3	4	0	4	2	0	0	129
6:00 PM													
6:15 PM													
6:30 PM													
6:45 PM													

TOTAL	NL	NT	NR	SL	ST	SR	EL	ET	ER	WL	WT	WR	TOTAL
Volumes	47	525	31	9	464	14	22	0	29	7	1	11	1160
Approach %	7.79	87.06	5.14	1.85	95.28	2.87	43.14	0.00	56.86	36.84	5.26	57.89	
App/Depart	603	/	558	487	/	500	51	/	40	19	/	62	

PM Peak Hr Begins at: 445 PM

PEAK													
Volumes	27	269	15	8	235	8	13	0	14	2	1	9	601
2025 NP	29	285	16	8	249	8	14	0	15	2	1	10	
Site Trips	21					14	9		13				
2025 WP	50	285	16	8	249	22	23	0	28	2	1	10	
Approach %	8.68	86.50	4.82	3.19	93.63	3.19	48.15	0.00	51.85	16.67	8.33	75.00	
PEAK HR. FACTOR:	0.937			0.872			0.675			0.600			0.951

CONTROL:	2-Way Stop (EB & WB)
COMMENT 1:	0
GPS:	32.382712, -111.029769

Prepared by: Field Data Services of Arizona/Veracity Traffic Group (520) 316-6745

Volumes for: Thursday, March 24, 2022 City: Tucson Project #: 22-1178-004

Location: Thornydale Rd north of Sumter Dr

AM Period	NB		SB		EB	WB		PM Period	NB		SB		EB	WB	
00:00	13		7					12:00	135		167				
00:15	6		8					12:15	141		128				
00:30	6		5					12:30	157		120				
00:45	13	38	5	25			63	12:45	142	575	136	551			1126
01:00	3		4					13:00	132		143				
01:15	4		3					13:15	151		155				
01:30	7		6					13:30	158		151				
01:45	5	19	2	15			34	13:45	134	575	145	594			1169
02:00	1		4					14:00	128		126				
02:15	4		1					14:15	164		131				
02:30	3		4					14:30	144		140				
02:45	4	12	2	11			23	14:45	156	592	141	538			1130
03:00	5		5					15:00	148		141				
03:15	4		3					15:15	135		135				
03:30	7		4					15:30	150		137				
03:45	5	21	8	20			41	15:45	159	592	139	552			1144
04:00	12		7					16:00	160		133				
04:15	7		11					16:15	146		132				
04:30	12		10					16:30	155		135				
04:45	16	47	17	45			92	16:45	168	629	137	537			1166
05:00	15		19					17:00	160		112				
05:15	18		28					17:15	173		131				
05:30	37		36					17:30	172		117				
05:45	33	103	38	121			224	17:45	156	661	131	491			1152
06:00	42		48					18:00	147		116				
06:15	47		47					18:15	133		119				
06:30	63		63					18:30	98		92				
06:45	63	215	71	229			444	18:45	112	490	111	438			928
07:00	58		60					19:00	119		77				
07:15	82		91					19:15	98		78				
07:30	106		106					19:30	93		58				
07:45	101	347	91	348			695	19:45	83	393	52	265			658
08:00	84		109					20:00	75		65				
08:15	83		116					20:15	85		50				
08:30	95		121					20:30	80		60				
08:45	115	377	77	423			800	20:45	55	295	42	217			512
09:00	101		136					21:00	50		47				
09:15	106		129					21:15	66		44				
09:30	110		133					21:30	44		37				
09:45	104	421	140	538			959	21:45	32	192	25	153			345
10:00	127		157					22:00	36		31				
10:15	100		142					22:15	31		24				
10:30	112		151					22:30	26		22				
10:45	124	463	128	578			1041	22:45	26	119	21	98			217
11:00	145		146					23:00	10		16				
11:15	131		147					23:15	15		9				
11:30	149		139					23:30	15		15				
11:45	148	573	148	580			1153	23:45	9	49	8	48			97
Total Vol.		2636		2933			**5569**			5162		4482			**9644**

GPS Coordinates: 32.383157, -111.046931

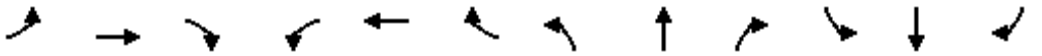
Daily Totals

NB	SB	EB	WB	Combined
7798	7415			**15213**

	AM			PM		
Split %	47.3%	52.7%	**36.6%**	53.5%	46.5%	**63.4%**
Peak Hour	11:45	11:15	**11:15**	16:45	13:00	**16:30**
Volume	581	601	**1164**	673	594	**1171**
P.H.F.	0.93	0.90	**0.96**	0.97	0.96	**0.96**

HCM 6th Signalized Intersection Summary
5: Thornydale/Thornydale Road & Linda Vista

05/04/2022



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	121	107	411	41	141	12	307	226	27	21	285	124
Future Volume (veh/h)	121	107	411	41	141	12	307	226	27	21	285	124
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.99	0.97		0.91	0.95		0.92
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	133	118	452	55	191	16	345	254	30	27	370	161
Peak Hour Factor	0.91	0.91	0.91	0.74	0.74	0.74	0.89	0.89	0.89	0.77	0.77	0.77
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	385	538	618	356	489	41	438	523	405	582	590	461
Arrive On Green	0.29	0.29	0.29	0.29	0.29	0.29	0.11	0.28	0.28	0.14	0.32	0.32
Sat Flow, veh/h	1165	1870	1563	837	1700	142	1781	1870	1446	1781	1870	1462
Grp Volume(v), veh/h	133	118	452	55	0	207	345	254	30	27	370	161
Grp Sat Flow(s),veh/h/ln	1165	1870	1563	837	0	1842	1781	1870	1446	1781	1870	1462
Q Serve(g_s), s	4.8	2.2	6.4	2.5	0.0	4.2	1.9	5.3	0.7	0.0	7.8	3.9
Cycle Q Clear(g_c), s	9.0	2.2	6.4	4.7	0.0	4.2	1.9	5.3	0.7	0.0	7.8	3.9
Prop In Lane	1.00		1.00	1.00		0.08	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	385	538	618	356	0	530	438	523	405	582	590	461
V/C Ratio(X)	0.35	0.22	0.73	0.15	0.00	0.39	0.79	0.49	0.07	0.05	0.63	0.35
Avail Cap(c_a), veh/h	501	725	774	439	0	714	613	946	731	582	765	598
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	16.9	12.6	12.0	14.4	0.0	13.3	18.0	13.9	12.3	11.4	13.6	12.2
Incr Delay (d2), s/veh	0.5	0.2	2.7	0.2	0.0	0.5	4.5	0.7	0.1	0.0	1.1	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.2	0.9	3.4	0.4	0.0	1.5	3.3	1.8	0.2	0.2	2.6	1.0
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	17.4	12.8	14.7	14.6	0.0	13.8	22.6	14.6	12.4	11.4	14.7	12.7
LnGrp LOS	B	B	B	B	A	B	C	B	B	B	B	B
Approach Vol, veh/h		703			262			629			558	
Approach Delay, s/veh		14.9			13.9			18.9			13.9	
Approach LOS		B			B			B			B	

Timer - Assigned Phs	1	2		4	5	6		8				
Phs Duration (G+Y+Rc), s	11.1	17.5		17.9	9.4	19.2		17.9				
Change Period (Y+Rc), s	4.5	4.5		4.5	4.5	4.5		4.5				
Max Green Setting (Gmax), s	5.0	23.5		18.0	9.5	19.0		18.0				
Max Q Clear Time (g_c+I1), s	2.0	7.3		11.0	3.9	9.8		6.7				
Green Ext Time (p_c), s	0.0	1.2		1.8	0.5	1.8		1.0				

Intersection Summary		
HCM 6th Ctrl Delay		15.7
HCM 6th LOS		B

Intersection	
Int Delay, s/veh	1.4

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	13	6	13	10	1	7	12	343	3	16	405	16
Future Vol, veh/h	13	6	13	10	1	7	12	343	3	16	405	16
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	110	-	-	100	-	180	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	89	89	89	64	64	64	91	91	91	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	15	7	15	16	2	11	13	377	3	18	450	18

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	906	901	459	909	907	377	468	0	0	380	0	0
Stage 1	495	495	-	403	403	-	-	-	-	-	-	-
Stage 2	411	406	-	506	504	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	257	278	602	256	276	670	1094	-	-	1178	-	-
Stage 1	556	546	-	624	600	-	-	-	-	-	-	-
Stage 2	618	598	-	549	541	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	246	270	602	240	269	670	1094	-	-	1178	-	-
Mov Cap-2 Maneuver	246	270	-	240	269	-	-	-	-	-	-	-
Stage 1	549	538	-	617	593	-	-	-	-	-	-	-
Stage 2	599	591	-	521	533	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	17.2	16.8	0.3	0.3
HCM LOS	C	C		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	WBLn2	SBL	SBT	SBR
Capacity (veh/h)	1094	-	-	331	240	565	1178	-	-
HCM Lane V/C Ratio	0.012	-	-	0.109	0.065	0.022	0.015	-	-
HCM Control Delay (s)	8.3	-	-	17.2	21	11.5	8.1	-	-
HCM Lane LOS	A	-	-	C	C	B	A	-	-
HCM 95th %tile Q(veh)	0	-	-	0.4	0.2	0.1	0	-	-

Intersection	
Int Delay, s/veh	1.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	6	1	34	6	1	3	16	168	5	2	266	8
Future Vol, veh/h	6	1	34	6	1	3	16	168	5	2	266	8
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	100	-	-	-	-	-	100	-	-	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	79	79	79	83	83	83	83	83	83	89	89	89
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	8	1	43	7	1	4	19	202	6	2	299	9

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	554	554	304	573	555	205	308	0	0	208	0	0
Stage 1	308	308	-	243	243	-	-	-	-	-	-	-
Stage 2	246	246	-	330	312	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	443	440	736	430	440	836	1253	-	-	1363	-	-
Stage 1	702	660	-	761	705	-	-	-	-	-	-	-
Stage 2	758	703	-	683	658	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	435	433	736	399	433	836	1253	-	-	1363	-	-
Mov Cap-2 Maneuver	435	433	-	399	433	-	-	-	-	-	-	-
Stage 1	691	659	-	750	694	-	-	-	-	-	-	-
Stage 2	742	692	-	641	657	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	10.8	12.7	0.7	0.1
HCM LOS	B	B		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	EBLn2	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1253	-	-	435	722	478	1363	-	-
HCM Lane V/C Ratio	0.015	-	-	0.017	0.061	0.025	0.002	-	-
HCM Control Delay (s)	7.9	-	-	13.4	10.3	12.7	7.6	-	-
HCM Lane LOS	A	-	-	B	B	B	A	-	-
HCM 95th %tile Q(veh)	0	-	-	0.1	0.2	0.1	0	-	-

Intersection	
Int Delay, s/veh	0.4

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	7	0	16	0	0	0	4	373	0	0	407	1
Future Vol, veh/h	7	0	16	0	0	0	4	373	0	0	407	1
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	-	150	-	-	150	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	8	0	17	0	0	0	4	405	0	0	442	1

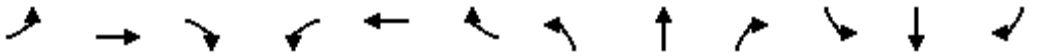
Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	856	856	443	864	856	405	443	0	0	405	0	0
Stage 1	443	443	-	413	413	-	-	-	-	-	-	-
Stage 2	413	413	-	451	443	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	278	295	615	274	295	646	1117	-	-	1154	-	-
Stage 1	594	576	-	616	594	-	-	-	-	-	-	-
Stage 2	616	594	-	588	576	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	277	294	615	266	294	646	1117	-	-	1154	-	-
Mov Cap-2 Maneuver	277	294	-	266	294	-	-	-	-	-	-	-
Stage 1	592	576	-	614	592	-	-	-	-	-	-	-
Stage 2	614	592	-	571	576	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	13.5	0	0.1	0
HCM LOS	B	A		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1117	-	-	448	-	1154	-	-
HCM Lane V/C Ratio	0.004	-	-	0.056	-	-	-	-
HCM Control Delay (s)	8.2	-	-	13.5	0	0	-	-
HCM Lane LOS	A	-	-	B	A	A	-	-
HCM 95th %tile Q(veh)	0	-	-	0.2	-	0	-	-

HCM 6th Signalized Intersection Summary
5: Thornydale/Thornydale Road & Linda Vista

05/04/2022



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	163	78	265	31	79	9	337	468	51	22	393	167
Future Volume (veh/h)	163	78	265	31	79	9	337	468	51	22	393	167
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.98	0.99		0.98	0.98		0.93	0.98		0.93
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	183	88	298	36	93	11	359	498	54	24	427	182
Peak Hour Factor	0.89	0.89	0.89	0.85	0.85	0.85	0.94	0.94	0.94	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	438	496	584	383	434	51	457	668	527	391	624	490
Arrive On Green	0.26	0.26	0.26	0.26	0.26	0.26	0.11	0.36	0.36	0.08	0.33	0.33
Sat Flow, veh/h	1275	1870	1561	989	1638	194	1781	1870	1476	1781	1870	1469
Grp Volume(v), veh/h	183	88	298	36	0	104	359	498	54	24	427	182
Grp Sat Flow(s),veh/h/ln	1275	1870	1561	989	0	1832	1781	1870	1476	1781	1870	1469
Q Serve(g_s), s	6.0	1.7	1.8	1.3	0.0	2.0	1.8	10.7	1.1	0.0	9.1	4.3
Cycle Q Clear(g_c), s	8.0	1.7	1.8	3.0	0.0	2.0	1.8	10.7	1.1	0.0	9.1	4.3
Prop In Lane	1.00		1.00	1.00		0.11	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	438	496	584	383	0	485	457	668	527	391	624	490
V/C Ratio(X)	0.42	0.18	0.51	0.09	0.00	0.21	0.79	0.75	0.10	0.06	0.68	0.37
Avail Cap(c_a), veh/h	599	732	782	508	0	717	641	956	755	434	765	601
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	16.3	13.0	11.1	14.2	0.0	13.2	17.5	13.0	9.9	15.7	13.2	11.6
Incr Delay (d2), s/veh	0.6	0.2	0.7	0.1	0.0	0.2	4.3	1.9	0.1	0.1	1.9	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.6	0.6	1.9	0.3	0.0	0.7	3.4	3.5	0.3	0.2	3.1	1.1
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	16.9	13.2	11.8	14.3	0.0	13.4	21.8	14.9	9.9	15.8	15.1	12.1
LnGrp LOS	B	B	B	B	A	B	C	B	A	B	B	B
Approach Vol, veh/h		569			140			911			633	
Approach Delay, s/veh		13.7			13.6			17.3			14.3	
Approach LOS		B			B			B			B	

Timer - Assigned Phs	1	2		4	5	6		8				
Phs Duration (G+Y+Rc), s	8.4	20.9		16.7	9.4	19.8		16.7				
Change Period (Y+Rc), s	4.5	4.5		4.5	4.5	4.5		4.5				
Max Green Setting (Gmax), s	5.0	23.5		18.0	9.7	18.8		18.0				
Max Q Clear Time (g_c+I1), s	2.0	12.7		10.0	3.8	11.1		5.0				
Green Ext Time (p_c), s	0.0	2.3		1.5	0.6	1.9		0.5				

Intersection Summary												
HCM 6th Ctrl Delay			15.3									
HCM 6th LOS			B									

Intersection	
Int Delay, s/veh	1.9

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	18	1	15	7	0	21	11	617	9	10	498	7
Future Vol, veh/h	18	1	15	7	0	21	11	617	9	10	498	7
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	110	-	-	100	-	180	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	61	61	61	70	70	70	94	94	94	94	94	94
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	30	2	25	10	0	30	12	656	10	11	530	7

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	1256	1246	534	1249	1239	656	537	0	0	666	0	0
Stage 1	556	556	-	680	680	-	-	-	-	-	-	-
Stage 2	700	690	-	569	559	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	148	174	546	150	175	465	1031	-	-	923	-	-
Stage 1	515	513	-	441	451	-	-	-	-	-	-	-
Stage 2	430	446	-	507	511	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	136	170	546	140	171	465	1031	-	-	923	-	-
Mov Cap-2 Maneuver	136	170	-	140	171	-	-	-	-	-	-	-
Stage 1	509	507	-	436	446	-	-	-	-	-	-	-
Stage 2	398	441	-	477	505	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	29	18.2	0.1	0.2
HCM LOS	D	C		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	WBLn2	SBL	SBT	SBR
Capacity (veh/h)	1031	-	-	205	140	465	923	-	-
HCM Lane V/C Ratio	0.011	-	-	0.272	0.071	0.065	0.012	-	-
HCM Control Delay (s)	8.5	-	-	29	32.7	13.3	8.9	-	-
HCM Lane LOS	A	-	-	D	D	B	A	-	-
HCM 95th %tile Q(veh)	0	-	-	1.1	0.2	0.2	0	-	-

Intersection	
Int Delay, s/veh	1.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	13	0	14	2	1	9	27	269	15	8	235	8
Future Vol, veh/h	13	0	14	2	1	9	27	269	15	8	235	8
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	100	-	-	-	-	-	100	-	-	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	68	68	68	60	60	60	94	94	94	87	87	87
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	19	0	21	3	2	15	29	286	16	9	270	9

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	654	653	275	655	649	294	279	0	0	302	0	0
Stage 1	293	293	-	352	352	-	-	-	-	-	-	-
Stage 2	361	360	-	303	297	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	380	387	764	379	389	745	1284	-	-	1259	-	-
Stage 1	715	670	-	665	632	-	-	-	-	-	-	-
Stage 2	657	626	-	706	668	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	363	375	764	360	377	745	1284	-	-	1259	-	-
Mov Cap-2 Maneuver	363	375	-	360	377	-	-	-	-	-	-	-
Stage 1	699	665	-	650	617	-	-	-	-	-	-	-
Stage 2	628	612	-	682	663	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	12.5	11.3	0.7	0.3
HCM LOS	B	B		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	EBLn2	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1284	-	-	363	764	591	1259	-	-
HCM Lane V/C Ratio	0.022	-	-	0.053	0.027	0.034	0.007	-	-
HCM Control Delay (s)	7.9	-	-	15.5	9.8	11.3	7.9	-	-
HCM Lane LOS	A	-	-	C	A	B	A	-	-
HCM 95th %tile Q(veh)	0.1	-	-	0.2	0.1	0.1	0	-	-

Intersection	
Int Delay, s/veh	0.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	2	0	15	0	0	0	27	629	0	0	500	7
Future Vol, veh/h	2	0	15	0	0	0	27	629	0	0	500	7
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	-	150	-	-	150	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	71	71	71	92	92	92	95	95	95	91	91	91
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	3	0	21	0	0	0	28	662	0	0	549	8

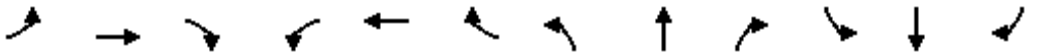
Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	1271	1271	553	1282	1275	662	557	0	0	662	0	0
Stage 1	553	553	-	718	718	-	-	-	-	-	-	-
Stage 2	718	718	-	564	557	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	145	168	533	142	167	462	1014	-	-	927	-	-
Stage 1	517	514	-	420	433	-	-	-	-	-	-	-
Stage 2	420	433	-	510	512	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	142	163	533	133	162	462	1014	-	-	927	-	-
Mov Cap-2 Maneuver	142	163	-	133	162	-	-	-	-	-	-	-
Stage 1	503	514	-	408	421	-	-	-	-	-	-	-
Stage 2	408	421	-	490	512	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	14.5	0	0.4	0
HCM LOS	B	A		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1014	-	-	403	-	927	-	-
HCM Lane V/C Ratio	0.028	-	-	0.059	-	-	-	-
HCM Control Delay (s)	8.7	-	-	14.5	0	0	-	-
HCM Lane LOS	A	-	-	B	A	A	-	-
HCM 95th %tile Q(veh)	0.1	-	-	0.2	-	0	-	-

HCM 6th Signalized Intersection Summary
5: Thornydale/Thornydale Road & Linda Vista

06/23/2023



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	128	114	436	43	149	13	326	240	28	22	302	132
Future Volume (veh/h)	128	114	436	43	149	13	326	240	28	22	302	132
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.99	0.97		0.91	0.95		0.92
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	141	125	479	58	201	18	366	270	31	29	392	171
Peak Hour Factor	0.91	0.91	0.91	0.74	0.74	0.74	0.89	0.89	0.89	0.77	0.77	0.77
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	375	548	645	344	495	44	436	518	401	581	585	457
Arrive On Green	0.29	0.29	0.29	0.29	0.29	0.29	0.12	0.28	0.28	0.15	0.31	0.31
Sat Flow, veh/h	1152	1870	1563	811	1689	151	1781	1870	1445	1781	1870	1461
Grp Volume(v), veh/h	141	125	479	58	0	219	366	270	31	29	392	171
Grp Sat Flow(s),veh/h/ln	1152	1870	1563	811	0	1841	1781	1870	1445	1781	1870	1461
Q Serve(g_s), s	5.5	2.5	6.8	2.9	0.0	4.7	3.4	6.0	0.8	0.0	8.9	4.5
Cycle Q Clear(g_c), s	10.1	2.5	6.8	5.3	0.0	4.7	3.4	6.0	0.8	0.0	8.9	4.5
Prop In Lane	1.00		1.00	1.00		0.08	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	375	548	645	344	0	539	436	518	401	581	585	457
V/C Ratio(X)	0.38	0.23	0.74	0.17	0.00	0.41	0.84	0.52	0.08	0.05	0.67	0.37
Avail Cap(c_a), veh/h	461	688	762	405	0	677	572	899	694	581	727	568
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	17.9	13.1	12.2	15.1	0.0	13.9	19.0	14.9	13.1	12.0	14.6	13.1
Incr Delay (d2), s/veh	0.6	0.2	3.3	0.2	0.0	0.5	8.5	0.8	0.1	0.0	1.7	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.4	1.0	3.9	0.5	0.0	1.7	4.1	2.1	0.2	0.2	3.1	1.2
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	18.6	13.3	15.4	15.3	0.0	14.4	27.4	15.7	13.1	12.0	16.3	13.6
LnGrp LOS	B	B	B	B	A	B	C	B	B	B	B	B
Approach Vol, veh/h		745			277			667			592	
Approach Delay, s/veh		15.7			14.6			22.0			15.3	
Approach LOS		B			B			C			B	

Timer - Assigned Phs	1	2		4	5	6		8				
Phs Duration (G+Y+Rc), s	12.0	18.1		18.8	10.3	19.8		18.8				
Change Period (Y+Rc), s	4.5	4.5		4.5	4.5	4.5		4.5				
Max Green Setting (Gmax), s	5.0	23.5		18.0	9.5	19.0		18.0				
Max Q Clear Time (g_c+I1), s	2.0	8.0		12.1	5.4	10.9		7.3				
Green Ext Time (p_c), s	0.0	1.3		1.8	0.5	1.8		1.1				

Intersection Summary												
HCM 6th Ctrl Delay			17.3									
HCM 6th LOS			B									

Intersection	
Int Delay, s/veh	1.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	14	6	14	11	1	7	13	364	3	17	430	17
Future Vol, veh/h	14	6	14	11	1	7	13	364	3	17	430	17
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	11	-	-	100	-	180	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	89	89	89	64	64	64	91	91	91	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	16	7	16	17	2	11	14	400	3	19	478	19

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	962	957	488	965	963	400	497	0	0	403	0	0
Stage 1	526	526	-	428	428	-	-	-	-	-	-	-
Stage 2	436	431	-	537	535	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	235	258	580	234	256	650	1067	-	-	1156	-	-
Stage 1	535	529	-	605	585	-	-	-	-	-	-	-
Stage 2	599	583	-	528	524	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	225	251	580	218	249	650	1067	-	-	1156	-	-
Mov Cap-2 Maneuver	225	251	-	218	249	-	-	-	-	-	-	-
Stage 1	528	521	-	597	577	-	-	-	-	-	-	-
Stage 2	580	575	-	499	516	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	18.3	18.2	0.3	0.3
HCM LOS	C	C		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	WBLn2	SBL	SBT	SBR
Capacity (veh/h)	1067	-	-	308	218	541	1156	-	-
HCM Lane V/C Ratio	0.013	-	-	0.124	0.079	0.023	0.016	-	-
HCM Control Delay (s)	8.4	-	-	18.3	22.9	11.8	8.2	-	-
HCM Lane LOS	A	-	-	C	C	B	A	-	-
HCM 95th %tile Q(veh)	0	-	-	0.4	0.3	0.1	0.1	-	-

Intersection	
Int Delay, s/veh	1.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	6	1	36	6	1	3	17	178	5	2	282	8
Future Vol, veh/h	6	1	36	6	1	3	17	178	5	2	282	8
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	100	-	-	-	-	-	100	-	-	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	79	79	79	83	83	83	83	83	83	89	89	89
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	8	1	46	7	1	4	20	214	6	2	317	9

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	586	586	322	606	587	217	326	0	0	220	0	0
Stage 1	326	326	-	257	257	-	-	-	-	-	-	-
Stage 2	260	260	-	349	330	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	422	422	719	409	422	823	1234	-	-	1349	-	-
Stage 1	687	648	-	748	695	-	-	-	-	-	-	-
Stage 2	745	693	-	667	646	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	414	415	719	377	415	823	1234	-	-	1349	-	-
Mov Cap-2 Maneuver	414	415	-	377	415	-	-	-	-	-	-	-
Stage 1	676	647	-	736	684	-	-	-	-	-	-	-
Stage 2	728	682	-	623	645	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	11	13.1	0.7	0.1
HCM LOS	B	B		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	EBLn2	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1234	-	-	414	705	455	1349	-	-
HCM Lane V/C Ratio	0.017	-	-	0.018	0.066	0.026	0.002	-	-
HCM Control Delay (s)	8	-	-	13.9	10.5	13.1	7.7	-	-
HCM Lane LOS	A	-	-	B	B	B	A	-	-
HCM 95th %tile Q(veh)	0.1	-	-	0.1	0.2	0.1	0	-	-

Intersection	
Int Delay, s/veh	0.4

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	7	0	17	0	0	0	4	396	0	0	432	1
Future Vol, veh/h	7	0	17	0	0	0	4	396	0	0	432	1
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	-	150	-	-	150	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	8	0	18	0	0	0	4	430	0	0	470	1

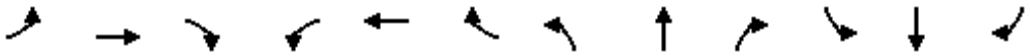
Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	909	909	471	918	909	430	471	0	0	430	0	0
Stage 1	471	471	-	438	438	-	-	-	-	-	-	-
Stage 2	438	438	-	480	471	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	256	275	593	252	275	625	1091	-	-	1129	-	-
Stage 1	573	560	-	597	579	-	-	-	-	-	-	-
Stage 2	597	579	-	567	560	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	255	274	593	243	274	625	1091	-	-	1129	-	-
Mov Cap-2 Maneuver	255	274	-	243	274	-	-	-	-	-	-	-
Stage 1	571	560	-	595	577	-	-	-	-	-	-	-
Stage 2	595	577	-	549	560	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	14	0	0.1	0
HCM LOS	B	A		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1091	-	-	428	-	1129	-	-
HCM Lane V/C Ratio	0.004	-	-	0.061	-	-	-	-
HCM Control Delay (s)	8.3	-	-	14	0	0	-	-
HCM Lane LOS	A	-	-	B	A	A	-	-
HCM 95th %tile Q(veh)	0	-	-	0.2	-	0	-	-

HCM 6th Signalized Intersection Summary
5: Thornydale/Thornydale Road & Linda Vista

06/23/2023



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	173	82	281	32	83	10	357	497	54	24	417	178
Future Volume (veh/h)	173	82	281	32	83	10	357	497	54	24	417	178
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.99	0.98		0.93	0.98		0.93
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	194	92	316	38	98	12	380	529	57	26	453	193
Peak Hour Factor	0.89	0.89	0.89	0.85	0.85	0.85	0.94	0.94	0.94	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	433	506	610	375	441	54	451	667	526	380	621	487
Arrive On Green	0.27	0.27	0.27	0.27	0.27	0.27	0.12	0.36	0.36	0.09	0.33	0.33
Sat Flow, veh/h	1268	1870	1562	970	1631	200	1781	1870	1476	1781	1870	1468
Grp Volume(v), veh/h	194	92	316	38	0	110	380	529	57	26	453	193
Grp Sat Flow(s),veh/h/ln	1268	1870	1562	970	0	1831	1781	1870	1476	1781	1870	1468
Q Serve(g_s), s	6.8	1.8	1.7	1.5	0.0	2.3	3.3	12.3	1.3	0.0	10.3	4.9
Cycle Q Clear(g_c), s	9.0	1.8	1.7	3.3	0.0	2.3	3.3	12.3	1.3	0.0	10.3	4.9
Prop In Lane	1.00		1.00	1.00		0.11	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	433	506	610	375	0	495	451	667	526	380	621	487
V/C Ratio(X)	0.45	0.18	0.52	0.10	0.00	0.22	0.84	0.79	0.11	0.07	0.73	0.40
Avail Cap(c_a), veh/h	562	696	769	473	0	681	590	909	717	396	735	577
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	17.2	13.5	11.3	14.8	0.0	13.7	18.5	14.0	10.4	17.1	14.2	12.4
Incr Delay (d2), s/veh	0.7	0.2	0.7	0.1	0.0	0.2	8.5	3.5	0.1	0.1	3.1	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.9	0.7	2.1	0.3	0.0	0.8	4.2	4.4	0.3	0.2	3.8	1.3
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	17.9	13.7	12.0	14.9	0.0	13.9	27.0	17.4	10.5	17.2	17.3	13.0
LnGrp LOS	B	B	B	B	A	B	C	B	B	B	B	B
Approach Vol, veh/h		602			148			966			672	
Approach Delay, s/veh		14.1			14.2			20.8			16.0	
Approach LOS		B			B			C			B	

Timer - Assigned Phs	1	2		4	5	6		8				
Phs Duration (G+Y+Rc), s	9.0	21.7		17.6	10.2	20.5		17.6				
Change Period (Y+Rc), s	4.5	4.5		4.5	4.5	4.5		4.5				
Max Green Setting (Gmax), s	5.0	23.5		18.0	9.5	19.0		18.0				
Max Q Clear Time (g_c+I1), s	2.0	14.3		11.0	5.3	12.3		5.3				
Green Ext Time (p_c), s	0.0	2.2		1.5	0.5	1.8		0.5				

Intersection Summary												
HCM 6th Ctrl Delay			17.4									
HCM 6th LOS			B									

Intersection	
Int Delay, s/veh	2.2

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	19	1	16	7	0	22	12	655	10	11	528	7
Future Vol, veh/h	19	1	16	7	0	22	12	655	10	11	528	7
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	110	-	-	100	-	180	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	61	61	61	70	70	70	94	94	94	94	94	94
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	31	2	26	10	0	31	13	697	11	12	562	7

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	1334	1324	566	1327	1316	697	569	0	0	708	0	0
Stage 1	590	590	-	723	723	-	-	-	-	-	-	-
Stage 2	744	734	-	604	593	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	131	156	524	132	158	441	1003	-	-	891	-	-
Stage 1	494	495	-	417	431	-	-	-	-	-	-	-
Stage 2	407	426	-	485	493	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	119	152	524	122	154	441	1003	-	-	891	-	-
Mov Cap-2 Maneuver	119	152	-	122	154	-	-	-	-	-	-	-
Stage 1	488	489	-	412	425	-	-	-	-	-	-	-
Stage 2	373	420	-	453	487	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	33.8	19.4	0.2	0.2
HCM LOS	D	C		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	WBLn2	SBL	SBT	SBR
Capacity (veh/h)	1003	-	-	183	122	441	891	-	-
HCM Lane V/C Ratio	0.013	-	-	0.322	0.082	0.071	0.013	-	-
HCM Control Delay (s)	8.6	-	-	33.8	37.1	13.8	9.1	-	-
HCM Lane LOS	A	-	-	D	E	B	A	-	-
HCM 95th %tile Q(veh)	0	-	-	1.3	0.3	0.2	0	-	-

Intersection	
Int Delay, s/veh	1.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	14	0	15	2	1	10	29	285	16	8	249	8
Future Vol, veh/h	14	0	15	2	1	10	29	285	16	8	249	8
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	100	-	-	-	-	-	100	-	-	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	68	68	68	60	60	60	94	94	94	87	87	87
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	21	0	22	3	2	17	31	303	17	9	286	9

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	692	691	291	694	687	312	295	0	0	320	0	0
Stage 1	309	309	-	374	374	-	-	-	-	-	-	-
Stage 2	383	382	-	320	313	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	358	368	748	357	370	728	1266	-	-	1240	-	-
Stage 1	701	660	-	647	618	-	-	-	-	-	-	-
Stage 2	640	613	-	692	657	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	340	357	748	338	359	728	1266	-	-	1240	-	-
Mov Cap-2 Maneuver	340	357	-	338	359	-	-	-	-	-	-	-
Stage 1	684	655	-	631	603	-	-	-	-	-	-	-
Stage 2	608	598	-	667	652	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	13	11.5	0.7	0.2
HCM LOS	B	B		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	EBLn2	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1266	-	-	340	748	579	1240	-	-
HCM Lane V/C Ratio	0.024	-	-	0.061	0.029	0.037	0.007	-	-
HCM Control Delay (s)	7.9	-	-	16.3	10	11.5	7.9	-	-
HCM Lane LOS	A	-	-	C	B	B	A	-	-
HCM 95th %tile Q(veh)	0.1	-	-	0.2	0.1	0.1	0	-	-

Intersection	
Int Delay, s/veh	0.5

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	2	0	16	0	0	0	29	667	0	0	531	7
Future Vol, veh/h	2	0	16	0	0	0	29	667	0	0	531	7
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	-	150	-	-	150	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	71	71	71	92	92	92	95	95	95	91	91	91
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	3	0	23	0	0	0	31	702	0	0	584	8

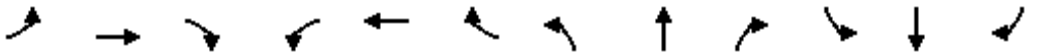
Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	1352	1352	588	1364	1356	702	592	0	0	702	0	0
Stage 1	588	588	-	764	764	-	-	-	-	-	-	-
Stage 2	764	764	-	600	592	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	127	150	509	125	149	438	984	-	-	895	-	-
Stage 1	495	496	-	396	413	-	-	-	-	-	-	-
Stage 2	396	413	-	488	494	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	124	145	509	117	144	438	984	-	-	895	-	-
Mov Cap-2 Maneuver	124	145	-	117	144	-	-	-	-	-	-	-
Stage 1	479	496	-	383	400	-	-	-	-	-	-	-
Stage 2	384	400	-	466	494	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	15.2	0	0.4	0
HCM LOS	C	A		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	984	-	-	378	-	895	-	-
HCM Lane V/C Ratio	0.031	-	-	0.067	-	-	-	-
HCM Control Delay (s)	8.8	-	-	15.2	0	0	-	-
HCM Lane LOS	A	-	-	C	A	A	-	-
HCM 95th %tile Q(veh)	0.1	-	-	0.2	-	0	-	-

HCM 6th Signalized Intersection Summary
5: Thornydale/Thornydale Road & Linda Vista

06/23/2023



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	128	114	436	43	149	13	326	250	28	22	332	132
Future Volume (veh/h)	128	114	436	43	149	13	326	250	28	22	332	132
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.99	0.98		0.91	0.96		0.92
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	141	125	479	58	201	18	366	281	31	29	431	171
Peak Hour Factor	0.91	0.91	0.91	0.74	0.74	0.74	0.89	0.89	0.89	0.77	0.77	0.77
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	363	539	660	334	487	44	432	513	396	598	589	461
Arrive On Green	0.29	0.29	0.29	0.29	0.29	0.29	0.13	0.27	0.27	0.17	0.32	0.32
Sat Flow, veh/h	1152	1870	1563	811	1689	151	1781	1870	1443	1781	1870	1462
Grp Volume(v), veh/h	141	125	479	58	0	219	366	281	31	29	431	171
Grp Sat Flow(s),veh/h/ln	1152	1870	1563	811	0	1841	1781	1870	1443	1781	1870	1462
Q Serve(g_s), s	5.7	2.6	6.2	3.0	0.0	4.9	4.4	6.5	0.8	0.0	10.5	4.6
Cycle Q Clear(g_c), s	10.6	2.6	6.2	5.6	0.0	4.9	4.4	6.5	0.8	0.0	10.5	4.6
Prop In Lane	1.00		1.00	1.00		0.08	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	363	539	660	334	0	531	432	513	396	598	589	461
V/C Ratio(X)	0.39	0.23	0.73	0.17	0.00	0.41	0.85	0.55	0.08	0.05	0.73	0.37
Avail Cap(c_a), veh/h	437	660	761	386	0	650	542	862	665	598	682	533
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	19.0	13.8	12.3	16.0	0.0	14.7	19.7	15.8	13.7	12.2	15.5	13.6
Incr Delay (d2), s/veh	0.7	0.2	3.0	0.2	0.0	0.5	10.0	0.9	0.1	0.0	3.4	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.5	1.0	4.0	0.5	0.0	1.8	4.5	2.3	0.2	0.2	4.0	1.3
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	19.6	14.1	15.3	16.2	0.0	15.2	29.7	16.7	13.8	12.2	19.0	14.0
LnGrp LOS	B	B	B	B	A	B	C	B	B	B	B	B
Approach Vol, veh/h		745			277			678			631	
Approach Delay, s/veh		15.9			15.4			23.6			17.3	
Approach LOS		B			B			C			B	

Timer - Assigned Phs	1	2		4	5	6		8				
Phs Duration (G+Y+Rc), s	13.3	18.5		19.2	11.2	20.6		19.2				
Change Period (Y+Rc), s	4.5	4.5		4.5	4.5	4.5		4.5				
Max Green Setting (Gmax), s	5.0	23.5		18.0	9.9	18.6		18.0				
Max Q Clear Time (g_c+I1), s	2.0	8.5		12.6	6.4	12.5		7.6				
Green Ext Time (p_c), s	0.0	1.3		1.6	0.4	1.6		1.1				

Intersection Summary			
HCM 6th Ctrl Delay		18.5	
HCM 6th LOS		B	

Intersection	
Int Delay, s/veh	2

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	14	6	14	21	1	13	13	370	7	19	450	17
Future Vol, veh/h	14	6	14	21	1	13	13	370	7	19	450	17
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	110	-	-	100	-	-	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	89	89	89	64	64	64	91	91	91	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	16	7	16	33	2	20	14	407	8	21	500	19

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	1002	995	510	1002	1000	411	519	0	0	415	0	0
Stage 1	552	552	-	439	439	-	-	-	-	-	-	-
Stage 2	450	443	-	563	561	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	221	245	563	221	243	641	1047	-	-	1144	-	-
Stage 1	518	515	-	597	578	-	-	-	-	-	-	-
Stage 2	589	576	-	511	510	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	208	237	563	205	235	641	1047	-	-	1144	-	-
Mov Cap-2 Maneuver	208	237	-	205	235	-	-	-	-	-	-	-
Stage 1	511	506	-	589	570	-	-	-	-	-	-	-
Stage 2	561	569	-	481	501	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	19.3	20.2	0.3	0.3
HCM LOS	C	C		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	WBLn2	SBL	SBT	SBR
Capacity (veh/h)	1047	-	-	289	205	571	1144	-	-
HCM Lane V/C Ratio	0.014	-	-	0.132	0.16	0.038	0.018	-	-
HCM Control Delay (s)	8.5	-	-	19.3	25.9	11.6	8.2	-	-
HCM Lane LOS	A	-	-	C	D	B	A	-	-
HCM 95th %tile Q(veh)	0	-	-	0.5	0.6	0.1	0.1	-	-

Intersection	
Int Delay, s/veh	2.3

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	20	1	56	6	1	3	24	178	5	2	282	12
Future Vol, veh/h	20	1	56	6	1	3	24	178	5	2	282	12
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	100	-	-	-	-	-	100	-	-	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	79	79	79	83	83	83	83	83	83	89	89	89
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	25	1	71	7	1	4	29	214	6	2	317	13

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	606	606	324	639	609	217	330	0	0	220	0	0
Stage 1	328	328	-	275	275	-	-	-	-	-	-	-
Stage 2	278	278	-	364	334	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	409	411	717	389	410	823	1229	-	-	1349	-	-
Stage 1	685	647	-	731	683	-	-	-	-	-	-	-
Stage 2	728	680	-	655	643	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	398	401	717	343	400	823	1229	-	-	1349	-	-
Mov Cap-2 Maneuver	398	401	-	343	400	-	-	-	-	-	-	-
Stage 1	669	646	-	713	667	-	-	-	-	-	-	-
Stage 2	706	664	-	588	642	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	11.7	13.8	0.9	0.1
HCM LOS	B	B		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	EBLn2	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1229	-	-	398	707	423	1349	-	-
HCM Lane V/C Ratio	0.024	-	-	0.064	0.102	0.028	0.002	-	-
HCM Control Delay (s)	8	-	-	14.7	10.7	13.8	7.7	-	-
HCM Lane LOS	A	-	-	B	B	B	A	-	-
HCM 95th %tile Q(veh)	0.1	-	-	0.2	0.3	0.1	0	-	-

Intersection	
Int Delay, s/veh	1.1

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	7	0	17	20	0	14	4	402	6	5	434	1
Future Vol, veh/h	7	0	17	20	0	14	4	402	6	5	434	1
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	-	150	-	-	150	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	92	92	92	92	92	92	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	8	0	18	22	0	15	4	437	7	5	472	1

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	939	935	473	941	932	441	473	0	0	444	0	0
Stage 1	483	483	-	449	449	-	-	-	-	-	-	-
Stage 2	456	452	-	492	483	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	244	265	591	243	266	616	1089	-	-	1116	-	-
Stage 1	565	553	-	589	572	-	-	-	-	-	-	-
Stage 2	584	570	-	558	553	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	236	263	591	234	264	616	1089	-	-	1116	-	-
Mov Cap-2 Maneuver	236	263	-	234	264	-	-	-	-	-	-	-
Stage 1	563	551	-	587	570	-	-	-	-	-	-	-
Stage 2	567	568	-	538	551	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	14.4	18	0.1	0.1
HCM LOS	B	C		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1089	-	-	411	314	1116	-	-
HCM Lane V/C Ratio	0.004	-	-	0.063	0.118	0.005	-	-
HCM Control Delay (s)	8.3	-	-	14.4	18	8.2	-	-
HCM Lane LOS	A	-	-	B	C	A	-	-
HCM 95th %tile Q(veh)	0	-	-	0.2	0.4	0	-	-

Intersection	
Int Delay, s/veh	4.4

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Traffic Vol, veh/h	6	26	19	11	34	16
Future Vol, veh/h	6	26	19	11	34	16
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	50	-	-	-	0	-
Veh in Median Storage, #	-	0	0	-	0	-
Grade, %	-	0	0	-	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	7	28	21	12	37	17

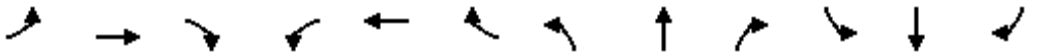
Major/Minor	Major1		Major2		Minor2	
Conflicting Flow All	33	0	-	0	69	27
Stage 1	-	-	-	-	27	-
Stage 2	-	-	-	-	42	-
Critical Hdwy	4.12	-	-	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	2.218	-	-	-	3.518	3.318
Pot Cap-1 Maneuver	1579	-	-	-	936	1048
Stage 1	-	-	-	-	996	-
Stage 2	-	-	-	-	980	-
Platoon blocked, %			-	-	-	
Mov Cap-1 Maneuver	1579	-	-	-	932	1048
Mov Cap-2 Maneuver	-	-	-	-	932	-
Stage 1	-	-	-	-	992	-
Stage 2	-	-	-	-	980	-

Approach	EB	WB	SB
HCM Control Delay, s	1.4	0	8.9
HCM LOS			A

Minor Lane/Major Mvmt	EBL	EBT	WBT	WBR	SBLn1
Capacity (veh/h)	1579	-	-	-	966
HCM Lane V/C Ratio	0.004	-	-	-	0.056
HCM Control Delay (s)	7.3	-	-	-	8.9
HCM Lane LOS	A	-	-	-	A
HCM 95th %tile Q(veh)	0	-	-	-	0.2

HCM 6th Signalized Intersection Summary
5: Thornydale/Thornydale Road & Linda Vista

06/23/2023



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	173	82	281	32	83	10	357	529	54	24	437	178
Future Volume (veh/h)	173	82	281	32	83	10	357	529	54	24	437	178
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.99	0.98		0.93	0.98		0.93
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	194	92	316	38	98	12	380	563	57	26	475	193
Peak Hour Factor	0.89	0.89	0.89	0.85	0.85	0.85	0.94	0.94	0.94	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	427	503	613	370	438	54	446	678	535	364	628	493
Arrive On Green	0.27	0.27	0.27	0.27	0.27	0.27	0.12	0.36	0.36	0.10	0.34	0.34
Sat Flow, veh/h	1268	1870	1561	970	1631	200	1781	1870	1478	1781	1870	1469
Grp Volume(v), veh/h	194	92	316	38	0	110	380	563	57	26	475	193
Grp Sat Flow(s),veh/h/ln	1268	1870	1561	970	0	1831	1781	1870	1478	1781	1870	1469
Q Serve(g_s), s	6.9	1.9	1.5	1.5	0.0	2.3	3.7	13.5	1.3	0.0	11.2	5.0
Cycle Q Clear(g_c), s	9.2	1.9	1.5	3.4	0.0	2.3	3.7	13.5	1.3	0.0	11.2	5.0
Prop In Lane	1.00		1.00	1.00		0.11	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	427	503	613	370	0	492	446	678	535	364	628	493
V/C Ratio(X)	0.45	0.18	0.52	0.10	0.00	0.22	0.85	0.83	0.11	0.07	0.76	0.39
Avail Cap(c_a), veh/h	550	683	763	463	0	668	535	891	704	375	758	596
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	17.6	13.9	11.4	15.2	0.0	14.0	18.9	14.3	10.4	18.2	14.6	12.5
Incr Delay (d2), s/veh	0.8	0.2	0.7	0.1	0.0	0.2	10.9	5.2	0.1	0.1	3.6	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.9	0.7	2.2	0.3	0.0	0.8	4.6	5.1	0.3	0.2	4.1	1.3
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	18.4	14.0	12.1	15.3	0.0	14.3	29.8	19.5	10.5	18.2	18.2	13.0
LnGrp LOS	B	B	B	B	A	B	C	B	B	B	B	B
Approach Vol, veh/h		602			148			1000			694	
Approach Delay, s/veh		14.4			14.5			22.9			16.7	
Approach LOS		B			B			C			B	

Timer - Assigned Phs	1	2		4	5	6		8				
Phs Duration (G+Y+Rc), s	9.2	22.4		17.8	10.5	21.0		17.8				
Change Period (Y+Rc), s	4.5	4.5		4.5	4.5	4.5		4.5				
Max Green Setting (Gmax), s	5.0	23.5		18.0	8.5	20.0		18.0				
Max Q Clear Time (g_c+I1), s	2.0	15.5		11.2	5.7	13.2		5.4				
Green Ext Time (p_c), s	0.0	2.2		1.5	0.3	2.0		0.5				

Intersection Summary												
HCM 6th Ctrl Delay			18.6									
HCM 6th LOS			B									

Intersection	
Int Delay, s/veh	2.6

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	19	1	16	14	0	26	12	673	24	15	541	7
Future Vol, veh/h	19	1	16	14	0	26	12	673	24	15	541	7
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	110	-	-	100	-	180	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	61	61	61	70	70	70	94	94	94	94	94	94
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	31	2	26	20	0	37	13	716	26	16	576	7

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	1386	1380	580	1368	1357	716	583	0	0	742	0	0
Stage 1	612	612	-	742	742	-	-	-	-	-	-	-
Stage 2	774	768	-	626	615	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	120	144	514	124	149	430	991	-	-	865	-	-
Stage 1	480	484	-	408	422	-	-	-	-	-	-	-
Stage 2	391	411	-	472	482	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	107	140	514	114	144	430	991	-	-	865	-	-
Mov Cap-2 Maneuver	107	140	-	114	144	-	-	-	-	-	-	-
Stage 1	474	475	-	403	417	-	-	-	-	-	-	-
Stage 2	353	406	-	438	473	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	37.9	24.4	0.1	0.2
HCM LOS	E	C		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	WBLn2	SBL	SBT	SBR
Capacity (veh/h)	991	-	-	167	114	430	865	-	-
HCM Lane V/C Ratio	0.013	-	-	0.353	0.175	0.086	0.018	-	-
HCM Control Delay (s)	8.7	-	-	37.9	43.2	14.2	9.2	-	-
HCM Lane LOS	A	-	-	E	E	B	A	-	-
HCM 95th %tile Q(veh)	0	-	-	1.5	0.6	0.3	0.1	-	-

Intersection	
Int Delay, s/veh	2.2

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	23	0	28	2	1	10	50	285	16	8	249	22
Future Vol, veh/h	23	0	28	2	1	10	50	285	16	8	249	22
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	100	-	-	-	-	-	100	-	-	100	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	68	68	68	60	60	60	94	94	94	87	87	87
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	34	0	41	3	2	17	53	303	17	9	286	25

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	744	743	299	755	747	312	311	0	0	320	0	0
Stage 1	317	317	-	418	418	-	-	-	-	-	-	-
Stage 2	427	426	-	337	329	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	331	343	741	325	341	728	1249	-	-	1240	-	-
Stage 1	694	654	-	612	591	-	-	-	-	-	-	-
Stage 2	606	586	-	677	646	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	310	326	741	295	324	728	1249	-	-	1240	-	-
Mov Cap-2 Maneuver	310	326	-	295	324	-	-	-	-	-	-	-
Stage 1	665	649	-	586	566	-	-	-	-	-	-	-
Stage 2	565	561	-	635	641	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	13.7	11.8	1.1	0.2
HCM LOS	B	B		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	EBLn2	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1249	-	-	310	741	551	1240	-	-
HCM Lane V/C Ratio	0.043	-	-	0.109	0.056	0.039	0.007	-	-
HCM Control Delay (s)	8	-	-	18	10.1	11.8	7.9	-	-
HCM Lane LOS	A	-	-	C	B	B	A	-	-
HCM 95th %tile Q(veh)	0.1	-	-	0.4	0.2	0.1	0	-	-

Intersection	
Int Delay, s/veh	1.2

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	2	0	16	13	0	9	29	671	18	17	535	7
Future Vol, veh/h	2	0	16	13	0	9	29	671	18	17	535	7
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	-	150	-	-	150	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	71	71	71	92	92	92	95	95	95	91	91	91
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	3	0	23	14	0	10	31	706	19	19	588	8

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	1413	1417	592	1420	1412	716	596	0	0	725	0	0
Stage 1	630	630	-	778	778	-	-	-	-	-	-	-
Stage 2	783	787	-	642	634	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	115	137	506	114	138	430	980	-	-	878	-	-
Stage 1	470	475	-	389	407	-	-	-	-	-	-	-
Stage 2	387	403	-	463	473	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	108	130	506	105	131	430	980	-	-	878	-	-
Mov Cap-2 Maneuver	108	130	-	105	131	-	-	-	-	-	-	-
Stage 1	455	465	-	377	394	-	-	-	-	-	-	-
Stage 2	366	390	-	433	463	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	15.8	33.1	0.4	0.3
HCM LOS	C	D		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	980	-	-	359	152	878	-	-
HCM Lane V/C Ratio	0.031	-	-	0.071	0.157	0.021	-	-
HCM Control Delay (s)	8.8	-	-	15.8	33.1	9.2	-	-
HCM Lane LOS	A	-	-	C	D	A	-	-
HCM 95th %tile Q(veh)	0.1	-	-	0.2	0.5	0.1	-	-

Intersection	
Int Delay, s/veh	3.2

Movement	EBL	EBT	WBT	WBR	SBL	SBR
Lane Configurations						
Traffic Vol, veh/h	18	22	29	35	22	11
Future Vol, veh/h	18	22	29	35	22	11
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	50	-	-	-	0	-
Veh in Median Storage, #	-	0	0	-	0	-
Grade, %	-	0	0	-	0	-
Peak Hour Factor	92	92	92	92	92	92
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	20	24	32	38	24	12

Major/Minor	Major1		Major2		Minor2	
Conflicting Flow All	70	0	-	0	115	51
Stage 1	-	-	-	-	51	-
Stage 2	-	-	-	-	64	-
Critical Hdwy	4.12	-	-	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	2.218	-	-	-	3.518	3.318
Pot Cap-1 Maneuver	1531	-	-	-	881	1017
Stage 1	-	-	-	-	971	-
Stage 2	-	-	-	-	959	-
Platoon blocked, %		-	-	-		
Mov Cap-1 Maneuver	1531	-	-	-	870	1017
Mov Cap-2 Maneuver	-	-	-	-	870	-
Stage 1	-	-	-	-	958	-
Stage 2	-	-	-	-	959	-

Approach	EB	WB	SB
HCM Control Delay, s	3.3	0	9.1
HCM LOS			A

Minor Lane/Major Mvmt	EBL	EBT	WBT	WBR	SBLn1
Capacity (veh/h)	1531	-	-	-	914
HCM Lane V/C Ratio	0.013	-	-	-	0.039
HCM Control Delay (s)	7.4	-	-	-	9.1
HCM Lane LOS	A	-	-	-	A
HCM 95th %tile Q(veh)	0	-	-	-	0.1

Queues
5: Thornydale/Thornydale Road & Linda Vista

06/23/2023

Lane Group	EBL	EBT	EBR	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR
Lane Group Flow (vph)	141	125	479	58	219	366	281	31	29	431	171
v/c Ratio	0.60	0.29	0.66	0.20	0.50	0.67	0.28	0.04	0.06	0.75	0.30
Control Delay	29.8	18.5	12.5	18.0	21.3	20.9	10.0	0.1	8.7	26.8	4.0
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	29.8	18.5	12.5	18.0	21.3	20.9	10.0	0.1	8.7	26.8	4.0
Queue Length 50th (ft)	41	34	72	15	60	49	35	0	6	116	0
Queue Length 95th (ft)	89	69	142	32	88	#145	138	0	11	185	18
Internal Link Dist (ft)		1014			1036		836			593	
Turn Bay Length (ft)	150		150	125		280		150	125		325
Base Capacity (vph)	363	671	740	453	666	572	1044	911	503	693	650
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.39	0.19	0.65	0.13	0.33	0.64	0.27	0.03	0.06	0.62	0.26

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.

Queues
5: Thornydale/Thornydale Road & Linda Vista

06/23/2023

Lane Group	EBL	EBT	EBR	WBL	WBT	NBL	NBT	NBR	SBL	SBT	SBR
Lane Group Flow (vph)	194	92	316	38	110	380	563	57	26	475	193
v/c Ratio	0.59	0.19	0.47	0.12	0.24	0.68	0.51	0.06	0.07	0.73	0.31
Control Delay	26.2	17.1	8.2	16.7	16.4	22.8	14.1	1.0	7.7	24.5	4.3
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	26.2	17.1	8.2	16.7	16.4	22.8	14.1	1.0	7.7	24.5	4.3
Queue Length 50th (ft)	57	24	37	10	27	56	92	0	4	131	0
Queue Length 95th (ft)	112	53	79	27	55	#174	#322	6	13	#286	37
Internal Link Dist (ft)		1014			1036		836			593	
Turn Bay Length (ft)	150		150	125		280		150	125		325
Base Capacity (vph)	492	726	682	505	717	565	1110	962	365	806	726
Starvation Cap Reductn	0	0	0	0	0	0	0	0	0	0	0
Spillback Cap Reductn	0	0	0	0	0	0	0	0	0	0	0
Storage Cap Reductn	0	0	0	0	0	0	0	0	0	0	0
Reduced v/c Ratio	0.39	0.13	0.46	0.08	0.15	0.67	0.51	0.06	0.07	0.59	0.27

Intersection Summary

95th percentile volume exceeds capacity, queue may be longer.
Queue shown is maximum after two cycles.