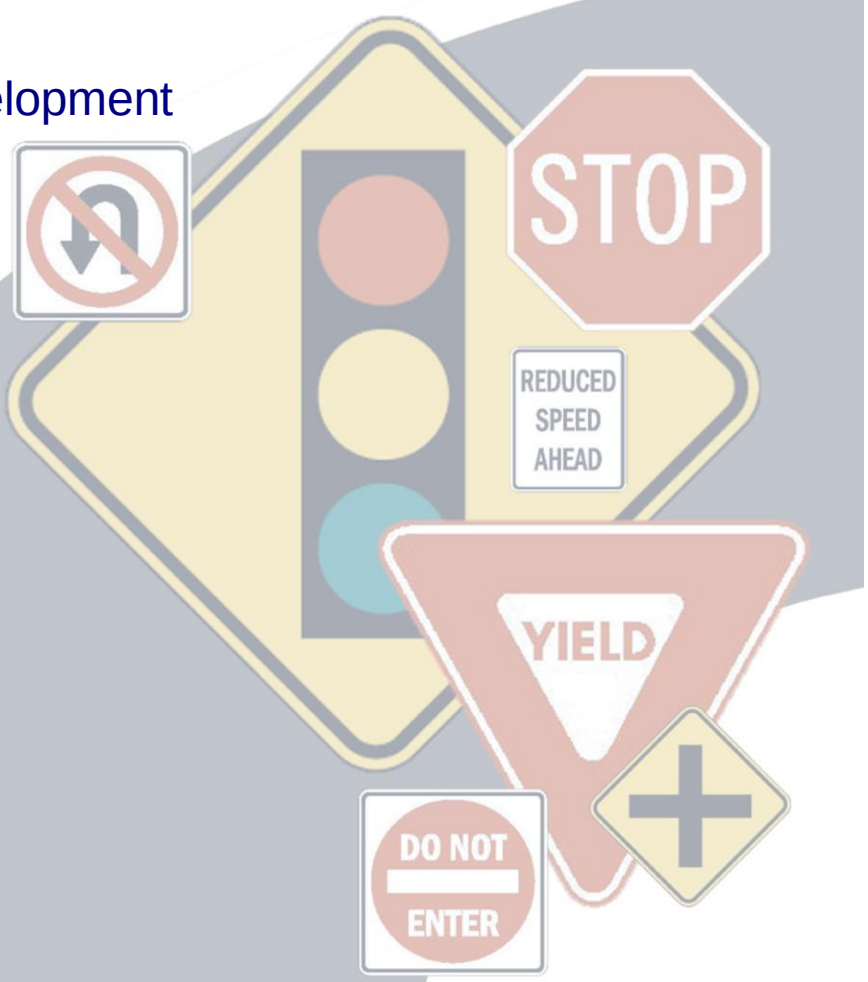
Traffic Impact and Access Study

Proposed
Interchange Mixed-Use Development
Whitney Road
Concord, New Hampshire

TFM Project #95830.00

February 17, 2020

Prepared for:
Interchange Development LLC



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Appendix

Volume 1 – Interchange Mixed Use Development
A1-N1: Trip Generation & Distribution
O1-V1: Analysis

Volume 2 – Whitney Road Extension
A2-P2: Trip Generation & Distribution, Analysis

Appendix Volume 1 – Interchange Mixed Use Development

Note: Volume 1 data (A1-N1) was previously approved by NHDOT as part of Trip Generation & Distribution Report for the Interchange Development Project

APPENDIX A1	Trip Generation & Composition Calculations • Phase 1 • Full Build
APPENDIX B1	Internal Trip Capture Calculations: AM & PM
APPENDIX C1	AM Distribution Calculations & Site Trip Diagrams: • Phase 1 • Full Build
APPENDIX D1	AM Volume Calculations
APPENDIX E1	AM Network Diagrams • 2019 Existing • 2021 NoBuild/2021 Build (Phase 1) • 2031 NoBuild/2031 Build (Full Build)
APPENDIX F1	PM Distribution Calculations & Site Trip Diagrams: • Phase 1 • Full Build
APPENDIX G1	PM Volume Calculations
APPENDIX H1	PM Network Diagrams • 2019 Existing • 2021 NoBuild/2021 Build (Phase 1) • 2031 NoBuild/2031 Build (Full Build)
APPENDIX I1	SAT Distribution Calculations & Site Trip Diagrams: • Phase 1 • Full Build
APPENDIX J1	SAT Volume Calculations
APPENDIX K1	SAT Network Diagrams • 2019 Existing • 2021 NoBuild/2021 Build (Phase 1) • 2031 NoBuild/2031 Build (Full Build)
APPENDIX L1	TMC Volume Counts • Intersection TMCs • NHDOT I93
APPENDIX M1	Gravity Model Calculations: Interchange Development
APPENDIX N1	ProRata Calculations Diverted Link Calculation

Appendix Volume 1 – Interchange Mixed Use Development

APPENDIX O1 AM Networks (Synchro & SIDRA)

1) 2019 Existing
2a) 2021 NoBuild
2b) 2021 Build [Phase 1]
3a) 2031 NoBuild
3b) 2031 Build [Full Build] Mit R1

APPENDIX P1 PM Networks (Synchro & SIDRA)

1) 2019 Existing
2a) 2021 NoBuild
2b) 2021 Build [Ph 1]
3a) 2031 NoBuild
3b) 2031 Build [IFB] Mit R1

APPENDIX Q1 SAT Networks (Synchro & SIDRA)

1) 2019 Existing
2a) 2021 NoBuild
2b) 2021 Build [Ph 1]
3a) 2031 NoBuild
3b) 2031 Build [IFB] Mit R1

APPENDIX R1 Mitigation – US4/Whitney Road

Signal Warrant Analysis
2d) 2021 Build [Ph 1] Signal (AM/PM/SAT)
3d) 2031 Build [IFB] Signal (AM/PM/SAT)
2c) 2021 Build [Ph 1] Roundabout (AM/PM/SAT)

APPENDIX S1 Mitigation – Boscawen Roundabout

3f) 2031 Build [IFB] Roundabout (AM/PM/SAT)
Comparison of Effects of Growth vs. IFB Site Trips
2z) 2021 PM Build [IFB]

APPENDIX T1 Mitigation – I93 Ramps

Turn Lane Warrant Analysis (2021 NoBuild)
2e) 2021 Build [Ph 1] Mit-Ramps
3e) 2031 Build [IFB] Mit-Ramps

APPENDIX U1 Crash Data

APPENDIX V1 Supplemental Analysis – Lane Utilization Sensitivity Analysis

Appendix Volume 2 – Whitney Road Extension

Note: Volume 2 data (A2-M2) was previously approved by NHDOT as part of Trip Generation & Distribution Report, however, volumes in D2/E2, G2/H2 & J2/K2 were updated per NHDOT comment.

APPENDIX A2	Trip Generation & Composition Calculations • Interchange Full Build • Whitney Extension Development
APPENDIX B2	Internal Trip Capture Calculations: AM & PM
APPENDIX C2	AM Distribution Calculations & Site Trip Diagrams: • Interchange Full Build • Whitney Extension Development • Whitney Road Extension Cut-thru Diagram
APPENDIX D2	AM Volume Calculations
APPENDIX E2	AM Network Diagrams • 2031 Build (WR Ext)
APPENDIX F2	PM Distribution Calculations & Site Trip Diagrams: • Interchange Full Build • Whitney Extension Development • Whitney Road Extension Cut-thru Diagram
APPENDIX G2	PM Volume Calculations
APPENDIX H2	PM Network Diagrams • 2031 Build (WR Ext)
APPENDIX I2	SAT Distribution Calculations & Site Trip Diagrams: • Interchange Full Build • Whitney Extension Development • Whitney Road Extension Cut-thru Diagram
APPENDIX J2	SAT Volume Calculations
APPENDIX K2	SAT Network Diagrams • 2031 Build (WR Ext)
APPENDIX L2	TMC Volume Counts • Sewalls Falls Road
APPENDIX M2	Gravity Model Calculations: Whitney Road Extension
APPENDIX N2	<u>AM Network</u> 4a) 2031 WRE Build 4b) 2031 WRE Build Mit
APPENDIX O2	<u>PM Network</u> 4a) 2031 WRE Build 4b) 2031 WRE Build Mit
APPENDIX P2	<u>SAT Network</u> 4a) 2031 WRE Build 4b) 2031 WRE Build Mit

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Traffic Impact and Access Study
Interchange Mixed-Use Development
Whitney Road, Concord, NH
17 February 2020

1. Introduction:

The purpose of this Traffic Impact and Access Study is to review vehicular impacts as a result of the proposed Interchange Mixed-Use Development in Concord, New Hampshire. The objectives of the study are:

- To use approved trip generation and distribution for the proposed development and perform capacity analysis for the identified study area.
- To determine the potential traffic impacts of the proposed development.
- To develop recommendations for roadway and operational improvements to US4 and Whitney Road to accommodate the proposed development's traffic impacts.

Proposal.
Interchange Development proposes to develop a 43-acre parcel at the corner of US Route 4 and Whitney Road in Concord, New Hampshire, into a multi-use commercial plaza anchored by an 80,000 sf supermarket with several pad-sites. The pad sites will be individually leased, with shared common parking areas. See Figure A on the following page for an overall site plan. The proposed Interchange Mixed Use Development project includes the following components:

- 79,895 sf supermarket
- 60,758 sf retail space
- 8,420 sf restaurants
- 2,400 sf bank
- 13,992 sf medical office
- 45,000 sf industrial

The project is proposed to be developed in three phases. Phase 1 consists of the North and South Site Driveways to provide access to the proposed development, the Supermarket, and the two retail pad sites to the north of the North Site Driveway.

79,895 sf supermarket
48,902 sf retail space

- Phase 2 includes development of the central block which is composed of the three pad sites to the south of the North Site Driveway with a retail and two medical office pad sites on the South Site Driveway.

  11,856 sf retail space
  8,420 sf restaurants
  2,400 sf bank
  13,992 sf medical office

- Phase 3 will finish the development with the industrial portion of the development.

  45,000 sf industrial

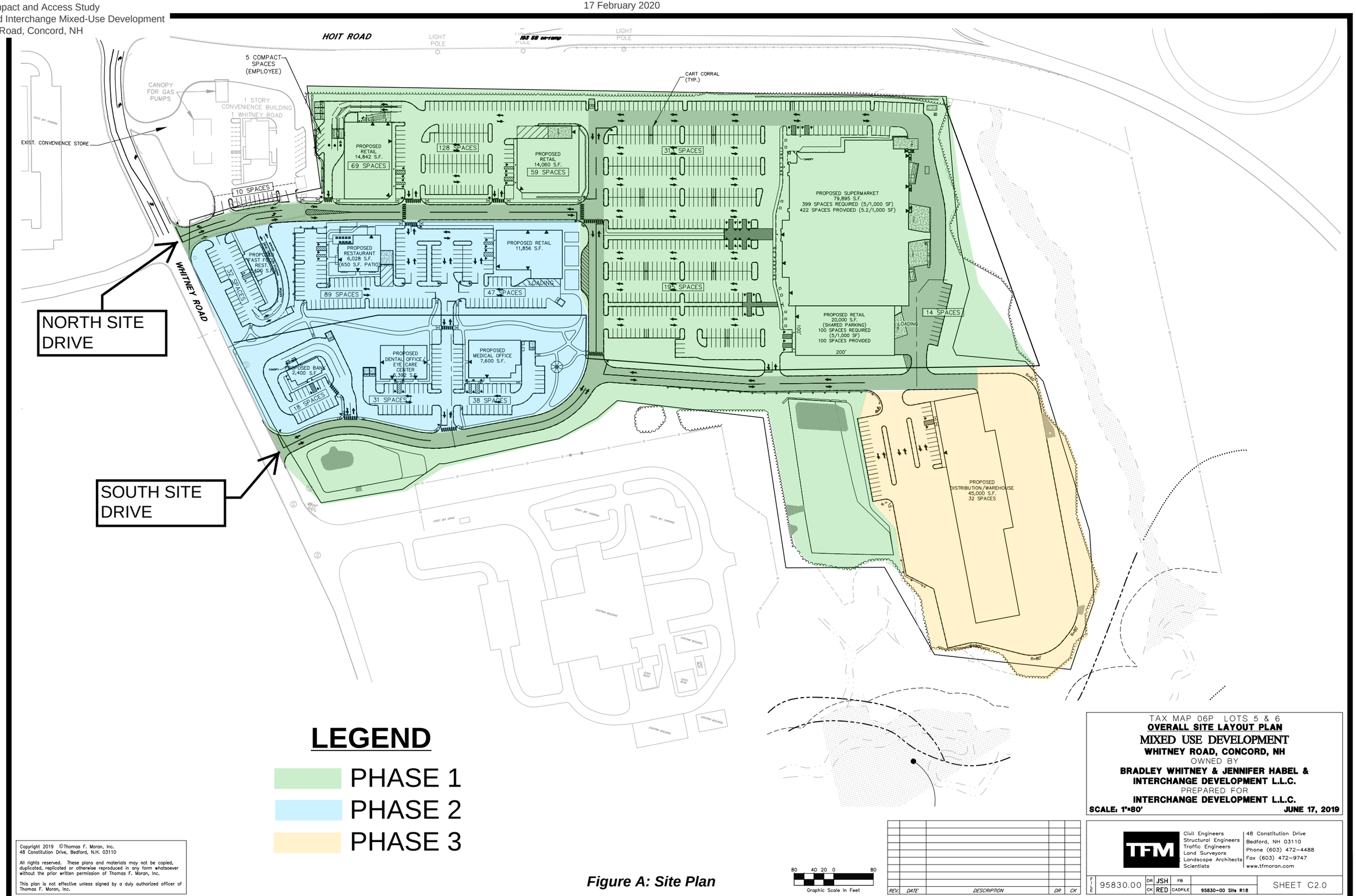


Figure A: Site Plan

This study compares the traffic with ("Build") and without ("No-Build") the development, assuming a 2021 opening year and 2031 future year conditions. The opening year for the project (2021) will include Phase 1 only while the future year (2031) includes all Phases 1-3.

Our evaluation includes conducting turning movement counts, estimating opening and future year traffic conditions by applying adjustments for seasonal and background growth, estimating the increase in traffic on the roadway network due to the proposed development, and evaluating the effect of the traffic associated with the development on the study area roadways and intersections. This report summarizes our findings and conclusions.

Scoping Meeting.
At our traffic scoping meeting held on August 21, 2019 with NHDOT and City Staff, it was agreed that this study would consider weekday AM, PM and Saturday peak hour conditions at the following intersections:

- US4 at Whitney Road/Old Boyce Road
- US4 at I93 Exit 17 ramps
- US4 at Hannah Dustin Road
- Boscawen Roundabout on US4
- Site Driveways on Whitney Road

See Figure B on the following page for an aerial map of the traffic network.

The weekday AM and PM and the weekend SAT peak hour scenarios were analyzed to coincide with the peak trip generation for the proposed land use. A background growth rate of 1.25% was used for US4 and 1% per year was used for all other roadways. Seasonal adjustments are per NHDOT Group 4.

Calculations for trip generation and distribution have been previously approved by the City and NHDOT in order to facilitate approval of the final Traffic Impact and Access Study for this Project. The approved data is included in this complete TIAS.

Figure B: Aerial Map of Traffic Network

2. Existing Conditions:

Description of Roadways:

US4 (Hoit Road). Within the study area, US4 is a state-maintained arterial roadway oriented in an east-west direction. Adjacent to the project, US4 is also known as Hoit Road and is a popular commuter route to Interstate 93 at the Exit 17 ramps. The roadway generally provides one travel lane in each direction with turn lanes provided at Whitney Road and Hannah Dustin Drive. The speed limit is 45 mph and passing is prohibited. There are no sidewalks in the area of Whitney Road or the ramps, but a sidewalk is provided on the south side of US4 from Hannah Dustin Drive westward almost to the Boscawen roundabout.

Whitney Road. Within the study area, Whitney Road is a City-maintained dead-end street oriented in the north-south direction. The roadway services industrial and commercial businesses with a gas station/convenience/coffee shop at the corner of US4 and Whitney Road. The roadway generally provides one travel lane in each direction. The speed limit is 30 mph and there are no sidewalks along the roadway.

I93 Ramps. Within the study area, the Exit 17 I93 ramps provide complete access between the interstate and US4. The ramps are a combination cloverleaf and diamond configuration to accommodate all NB-SB traffic to/from US4.

Description of Intersections:

US4 at Whitney Road / Old Boyce Road. Whitney Road and Old Boyce Road intersect US4 to form the northbound and southbound approaches, respectively, to this four-way unsignalized intersection. The northbound approach provides an exclusive right turn lane with approximately 160’ of queue storage capacity. A shared left/thru lane is provided to accommodate the other northbound movements. The southbound approach provides a single left/thru/right lane for all traffic. Northbound and southbound traffic are stop controlled.

US4 (Hoit Road) forms the eastbound and westbound approaches to the unsignalized intersection. The eastbound approach is a three-lane approach consisting of a 160’ exclusive left turn lane, a thru lane and a 250’ right turn pocket. The westbound approach is a two-lane approach which includes an exclusive left turn lane with about 160’ of delineated queue storage capacity.

No turning movements are restricted at the intersection, and each of the approaches accommodates two-way traffic. There are no sidewalks at this intersection.

Whitney Road at Site Driveway / Concord Crossing. The driveways for Concord Crossing and the existing gas station form the eastbound and westbound approaches, respectively, to this four-way unsignalized intersection. The eastbound approach is a single lane driveway and the westbound driveway has an exclusive right turn lane of 65’ queue storage capacity and a shared thru/left lane.

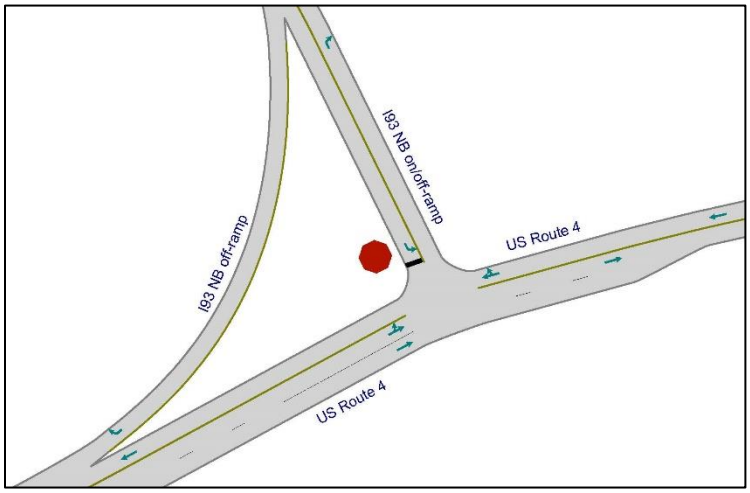
Whitney Road is the northbound and southbound approaches. Northbound is a single left/thru/right lane and southbound has an exclusive left turn lane with about 70’ of queue storage capacity and a shared thru/right lane.

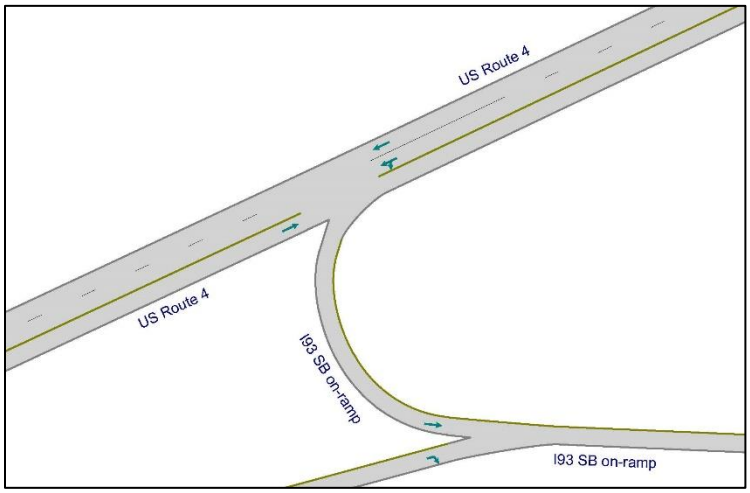
No turning movements are restricted at the intersection and each of the approaches accommodates two-way traffic. There are no sidewalks at the intersection.

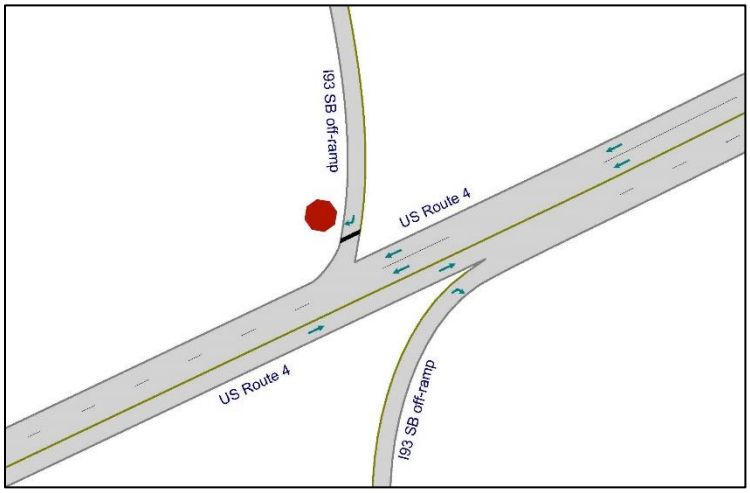
US4 at Harris Hill Connector (Existing Roundabout). Harris Hill Connector intersects US4 at the 3-leg Boscawen roundabout to form the northbound approach. The northbound leg has a left/thru lane that enters the roundabout and a bypass right turn with about 200' of queue storage capacity. US4 enters the roundabout from the east and west with a single lane. The 1-lane roundabout has single lane exits.

I93 Exit 17 Ramps. For the I93 off-ramps, the following intersection configurations are present:

- Lane added on US4 to accommodate I93 traffic, no stop control
  - I93 NB to US4 WB
  - I93 SB to US4 EB
- Stop sign
  - I93 NB to US4 EB
  - I93 SB to US4 WB
- Free right
  - US4 WB to I93 NB
  - US4 EB to I93 SB
- Left/thru Lane and thru lane
  - US4 EB to I93 NB
  - US4 WB to I93 SB





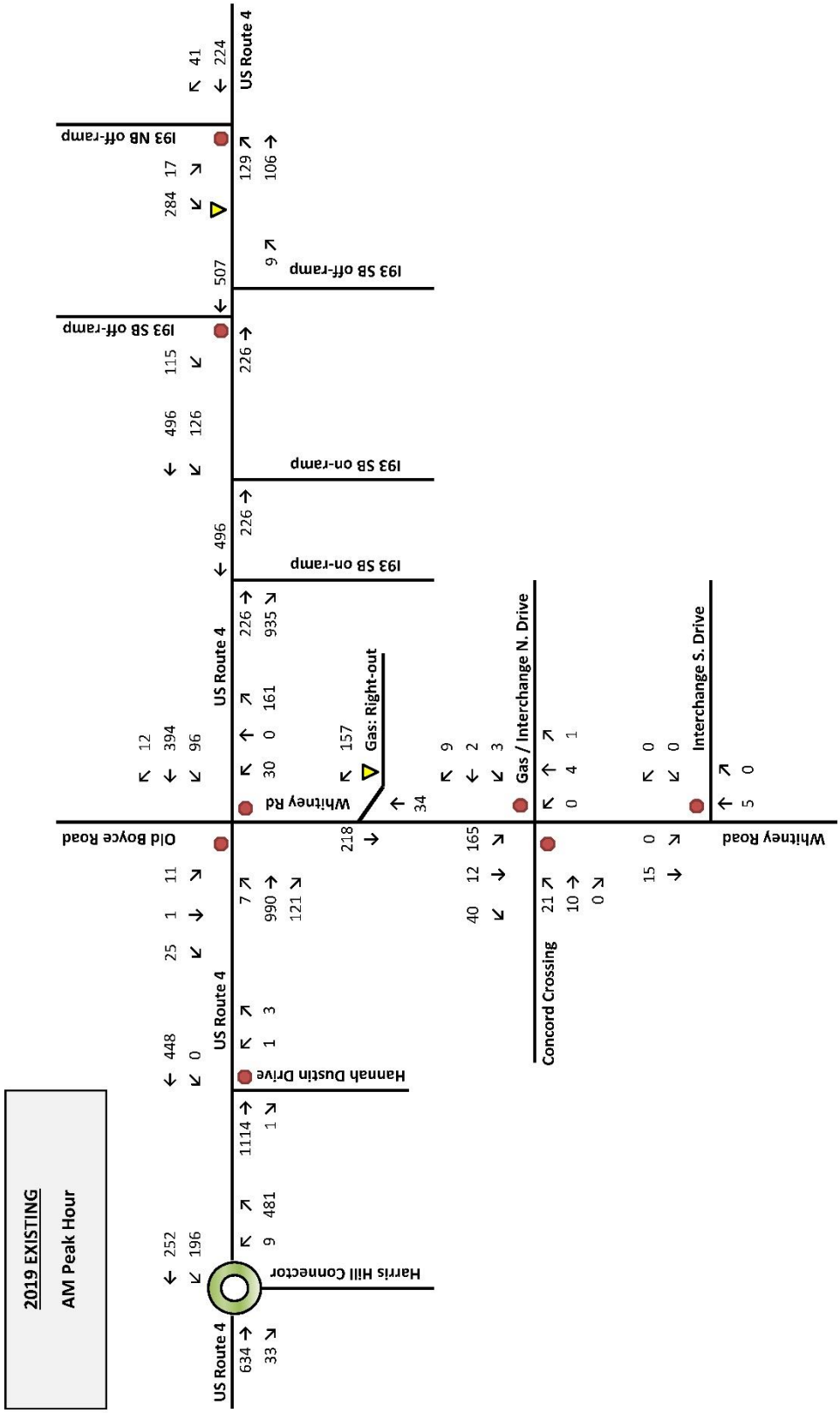


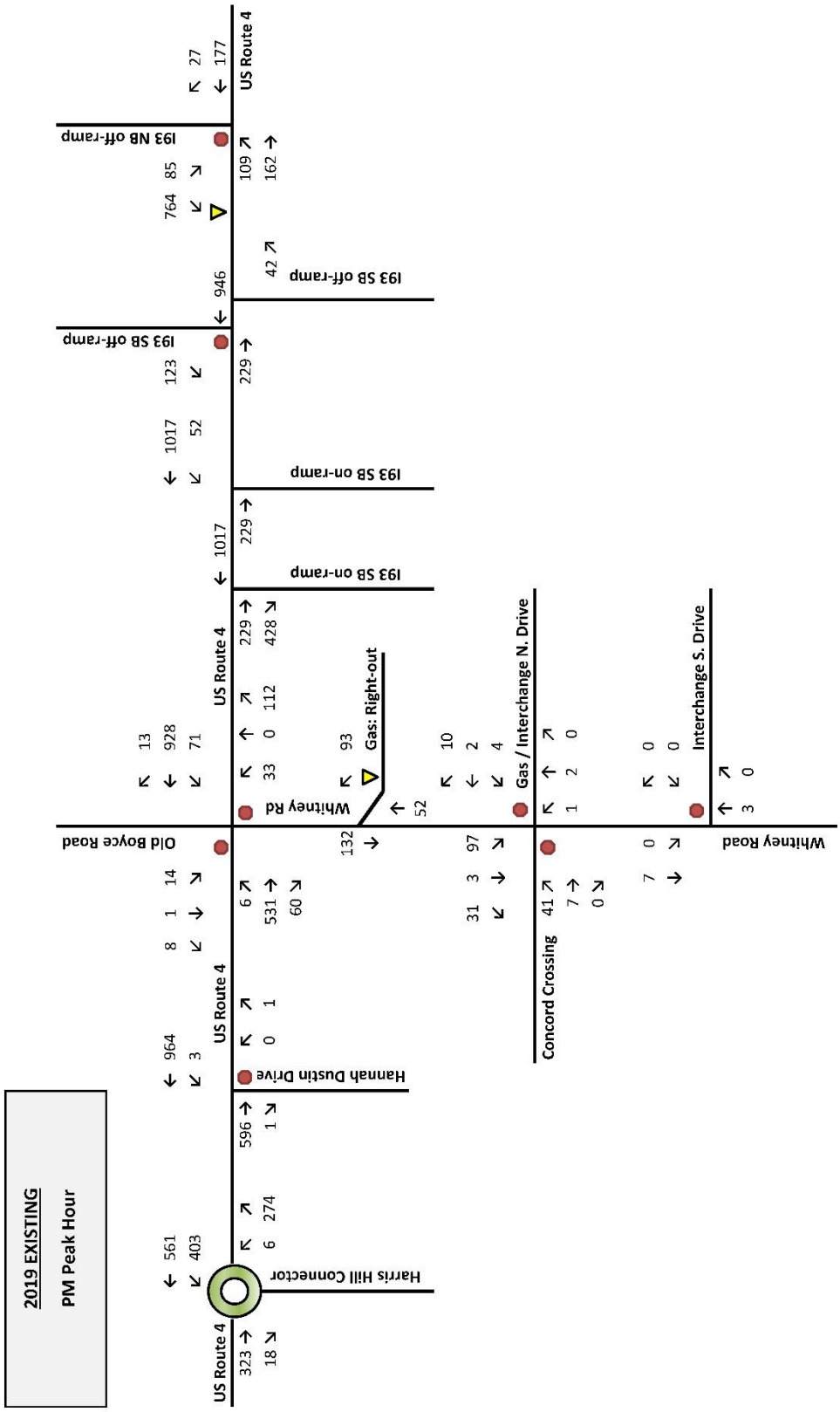
3. Existing Volumes:

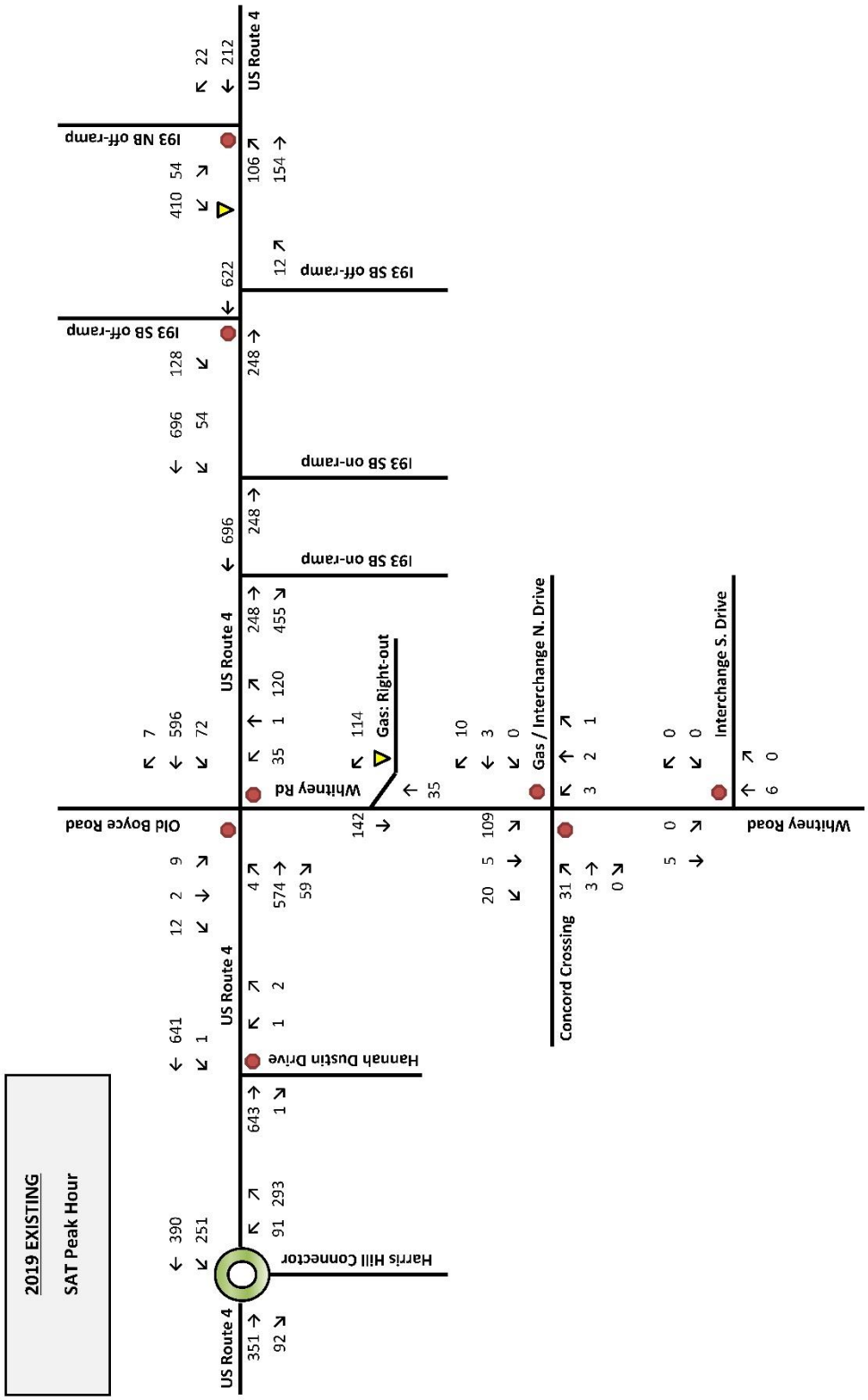
To quantify the existing peak hour traffic volumes within the study area, turning movement counts were taken during the following dates and times:

- **June 20, 2019** (7:00 AM to 9:00 AM, 4:00 PM to 6:00 PM) and **June 22, 2019** (11:00 AM to 1:00 PM)
    - US4 (Hoit Road) at Whitney Road / Old Boyce Road
    - US4 (Hoit Road) at I93 SB On-Off Ramps
    - US4 (Hoit Road) at I93 NB On-Off Ramps
- **August 3, 2019** (11:00 AM to 1:00 PM) and **August 6, 2019** (7:00 AM to 9:00 AM and 4:00 PM to 6:00 PM)
    - Whitney Road at Mobil South Entrance / Existing Driveway [Concord Crossing]
- **August 22, 2019** 7:00 AM to 9:00 AM and 4:00 PM to 6:00 PM) and **August 24, 2019** (11:00 AM to 1:00 PM)
    - Boscawen Roundabout: US4 (Hoit Road) at Harris Hill Connector
- At Hannah Dustin Road, turning movements not counted due to low volume - site trips were generated based on ITE averages for 5 single-family residences

See the following diagrams which are also in the Appendices.


2019 EXISTING
AM Peak Hour
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
Concord Crossing
Gas / Interchange N. Drive
Interchange S. Drive
Whitney Road
I93 SB on-ramp
I93 SB off-ramp
I93 NB off-ramp
US Route 4


2019 EXISTING
PM Peak Hour
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
I93 SB on-ramp
I93 SB off-ramp
I93 NB off-ramp
Concord Crossing
Gas / Interchange N. Drive
Interchange S. Drive
Whitney Road
323 18 561 403 964 3 8 1 14 6 596 1 6 274 0 1 531 60 132 93 52 10 31 3 97 2 4 41 7 0 1 2 0 7 0 0 0 3 0
13 928 71 1017 52 1017 123 946 764 85 27 177 229 229 229 428 112 0 33 109 162 42


2019 EXISTING
SAT Peak Hour
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
I93 SB on-ramp
I93 SB off-ramp
I93 NB off-ramp
Concord Crossing
Gas / Interchange N. Drive
Interchange S. Drive
Whitney Road
351 92
390 251
641 1
12 2 9
643 1
1 2
4
574 59
293 91
7 596 72
35 1 120 455
114
142
35
248
696
696 54 128
248
410 54
622
22 212
10 3 0
109 5 20
31 3 0
3 2 1
0 0
5 0
6 0
106 154
12

4. No-Build Volumes:

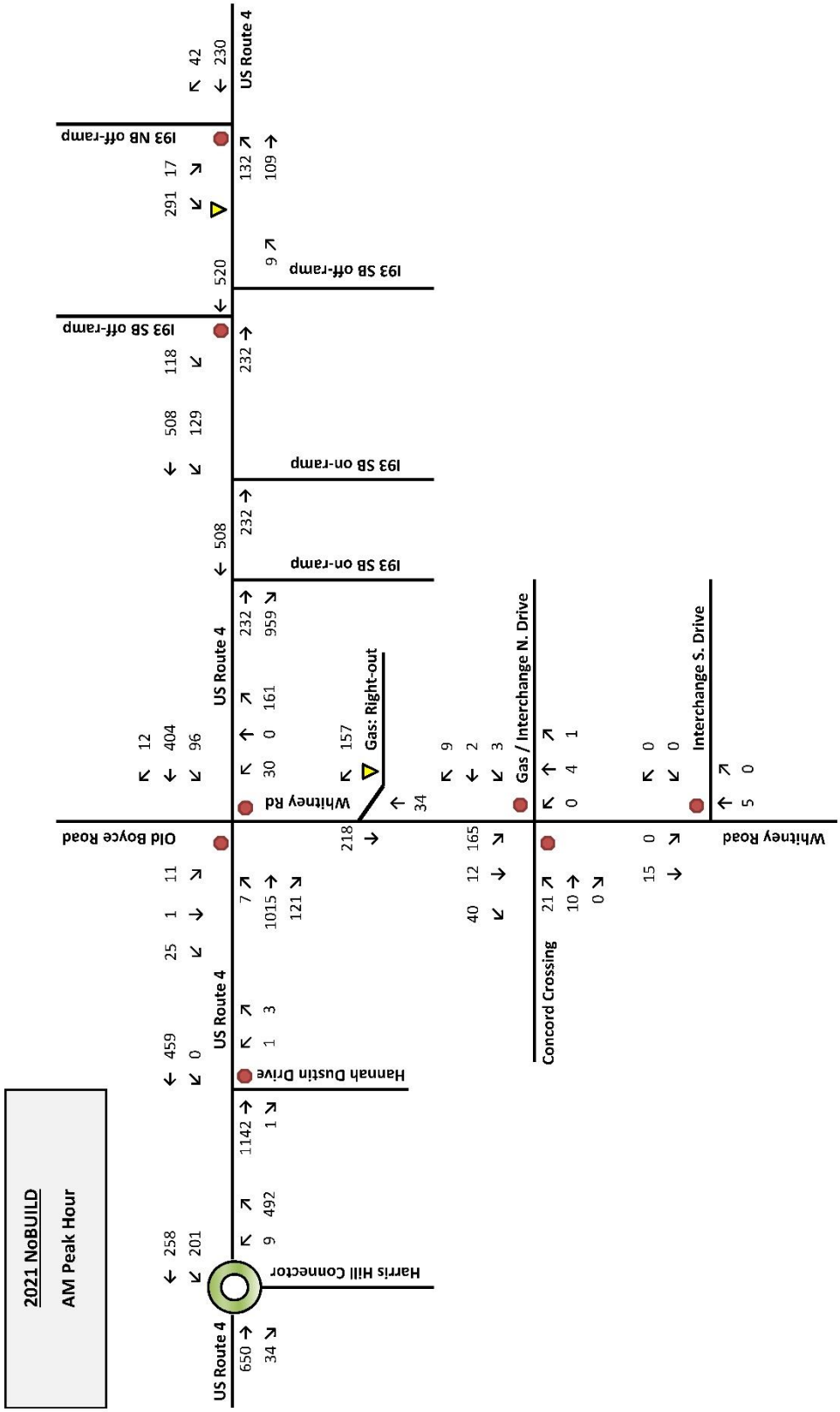
To establish no-build traffic volumes for the traffic study, the following adjustments were made to the turning movement data:

Seasonal Adjustment
To account for seasonal variations, the data is typically seasonally adjusted upward to reflect the estimated peak month traffic volume. The seasonal adjustments based on the 2018 monthly adjustment factors from the NHDOT for Group 4 Urban Highways shows that both June and August are peak months and have no adjustment factors (1.00).

Growth Factor
An annual growth factor of 1.25% has been applied to US4 and 1.0% for other roadways as agreed at the scoping meeting, based on NHDOT recommendations used in the high-level HDR feasibility report for Whitney Road Extension. Using these factors, the volume data was grown to reflect traffic volumes for opening year 2021 (phase one) and 2031 (all phases).

Other Proposed Developments
No “Other Developments” are included in the Interchange Project Analysis. However, at the Scoping Meeting, it was agreed to investigate an additional, separate scenario for the future year that would include traffic resulting from a possible extension of Whitney Road southward to Sewalls Falls Road. In addition to the Interchange Development full buildout, this separate case includes traffic generated by development of the vacant land south of the existing terminus of Whitney Road. Further description of this additional analysis is available in Section 14 of this TIAS.

No-Build Volume Diagrams
The following no-build volume diagrams for the opening and future year are also found in the Appendix.


2021 NoBUILD
AM Peak Hour
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
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Interchange S. Drive
Whitney Road
I93 SB on-ramp
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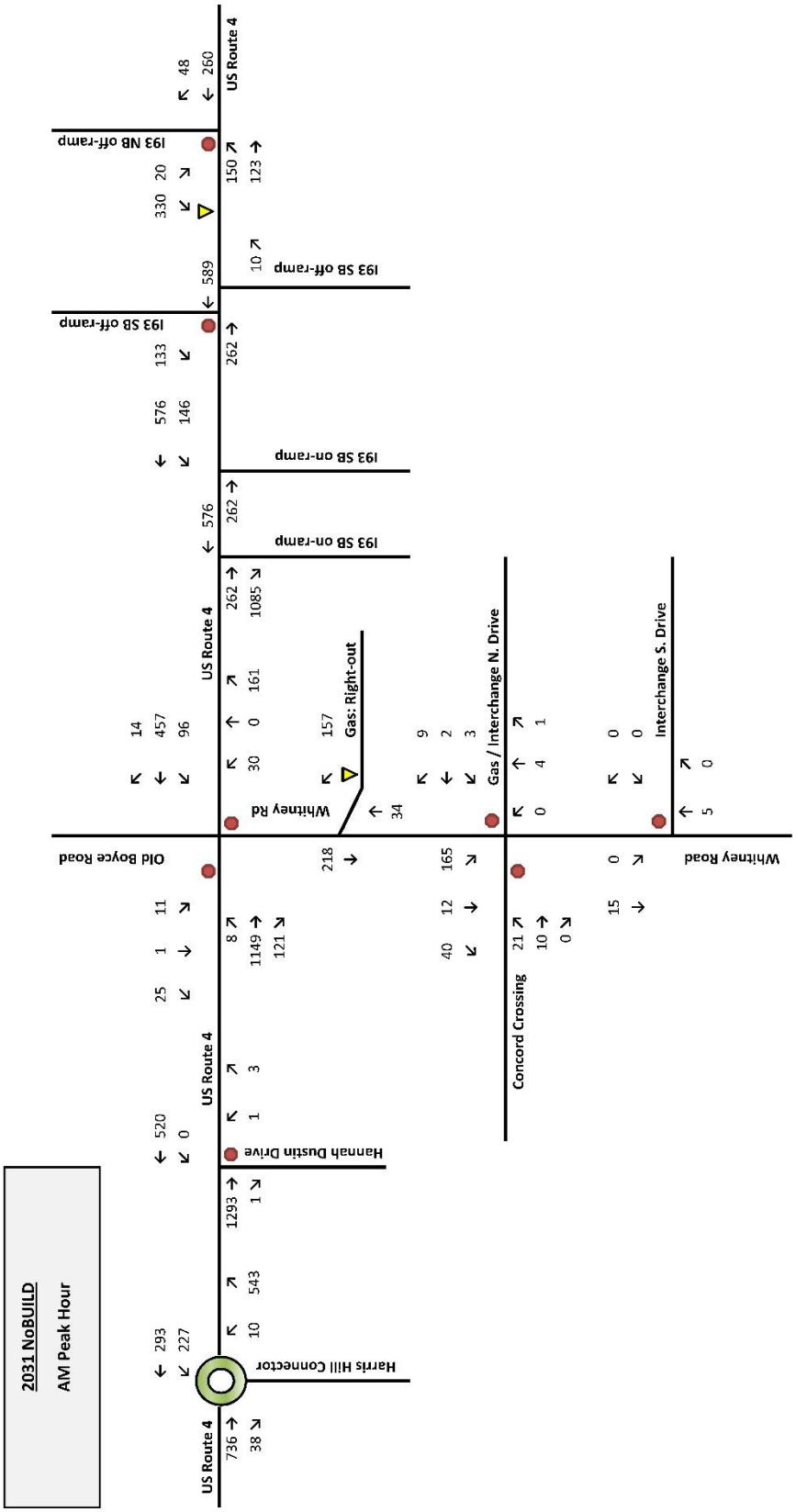
I93 NB off-ramp


2031 NoBUILD
AM Peak Hour
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
Gas / Interchange N. Drive
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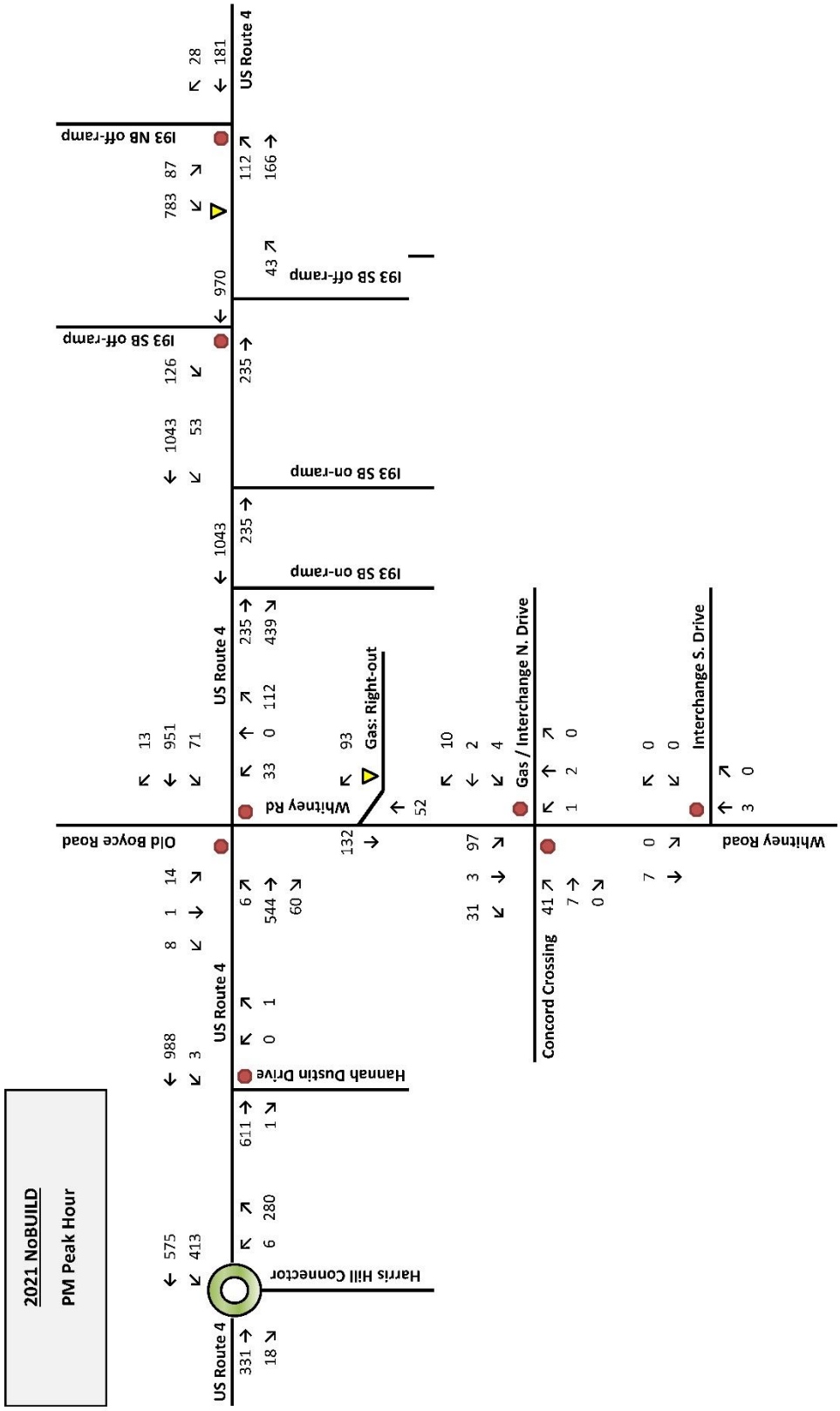
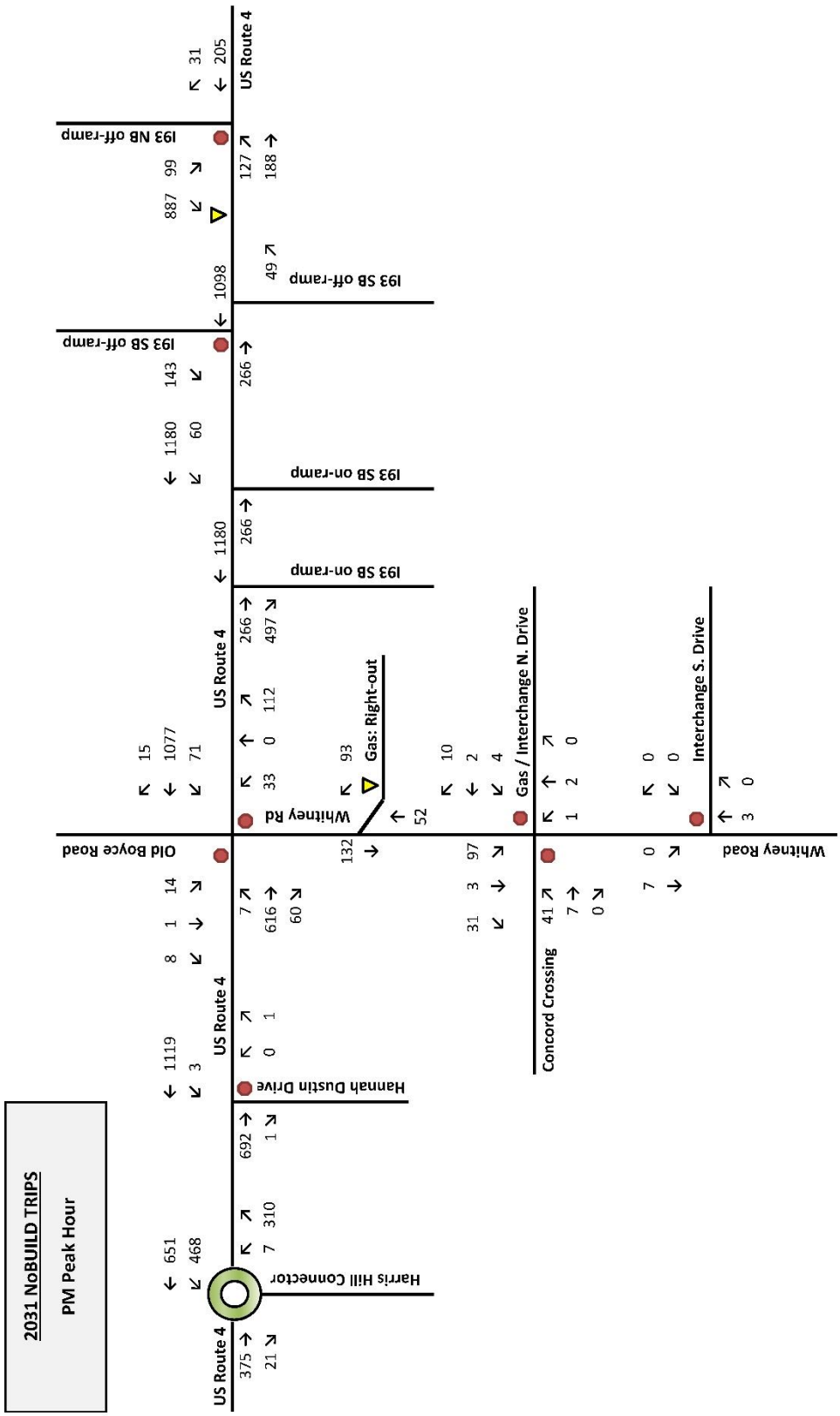
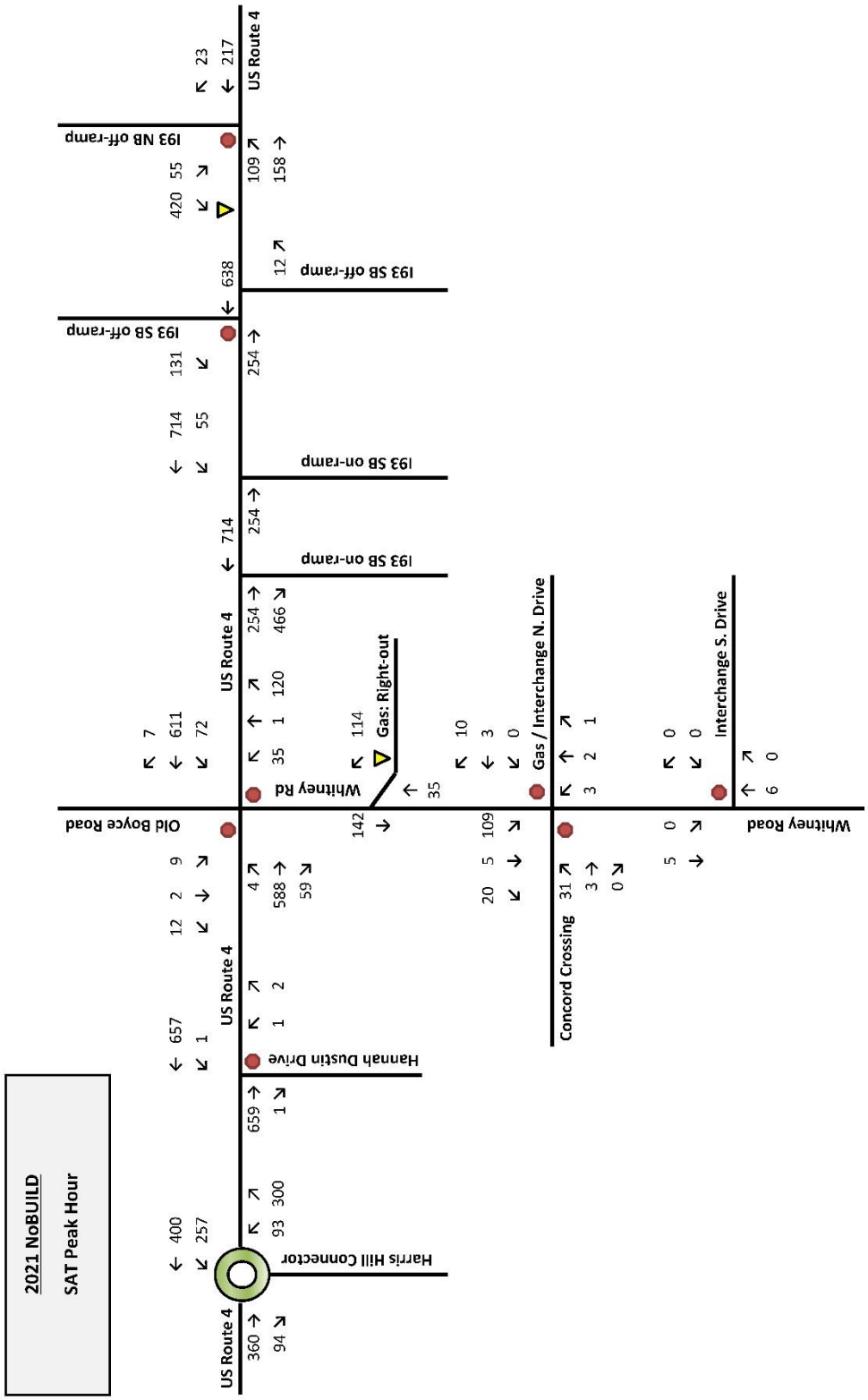
Whitney Road
Interchange S. Drive
193 SB on-ramp
193 SB off-ramp
193 SB off-ramp
193 NB off-ramp
193 SB off-ramp
US Route 4


2021 NoBUILD
PM Peak Hour
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
I93 SB on-ramp
I93 SB off-ramp
I93 NB off-ramp
Concord Crossing
Gas / Interchange N. Drive
Interchange S. Drive
Whitney Road


2031 NoBUILD TRIPS
PM Peak Hour
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
Gas / Interchange N. Drive
Concord Crossing
Interchange S. Drive
Whitney Road
I93 SB on-ramp
I93 SB off-ramp
I93 NB off-ramp


2021 NoBUILD
SAT Peak Hour
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
I93 SB on-ramp
I93 SB off-ramp
I93 NB off-ramp
I93 SB off-ramp
I93 SB on-ramp
US Route 4
Gas / Interchange N. Drive
Concord Crossing
Interchange S. Drive
Whitney Road
US Route 4
360 94
400 257
93 300
659 1
657 1
1 2
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638 420 55
109 158
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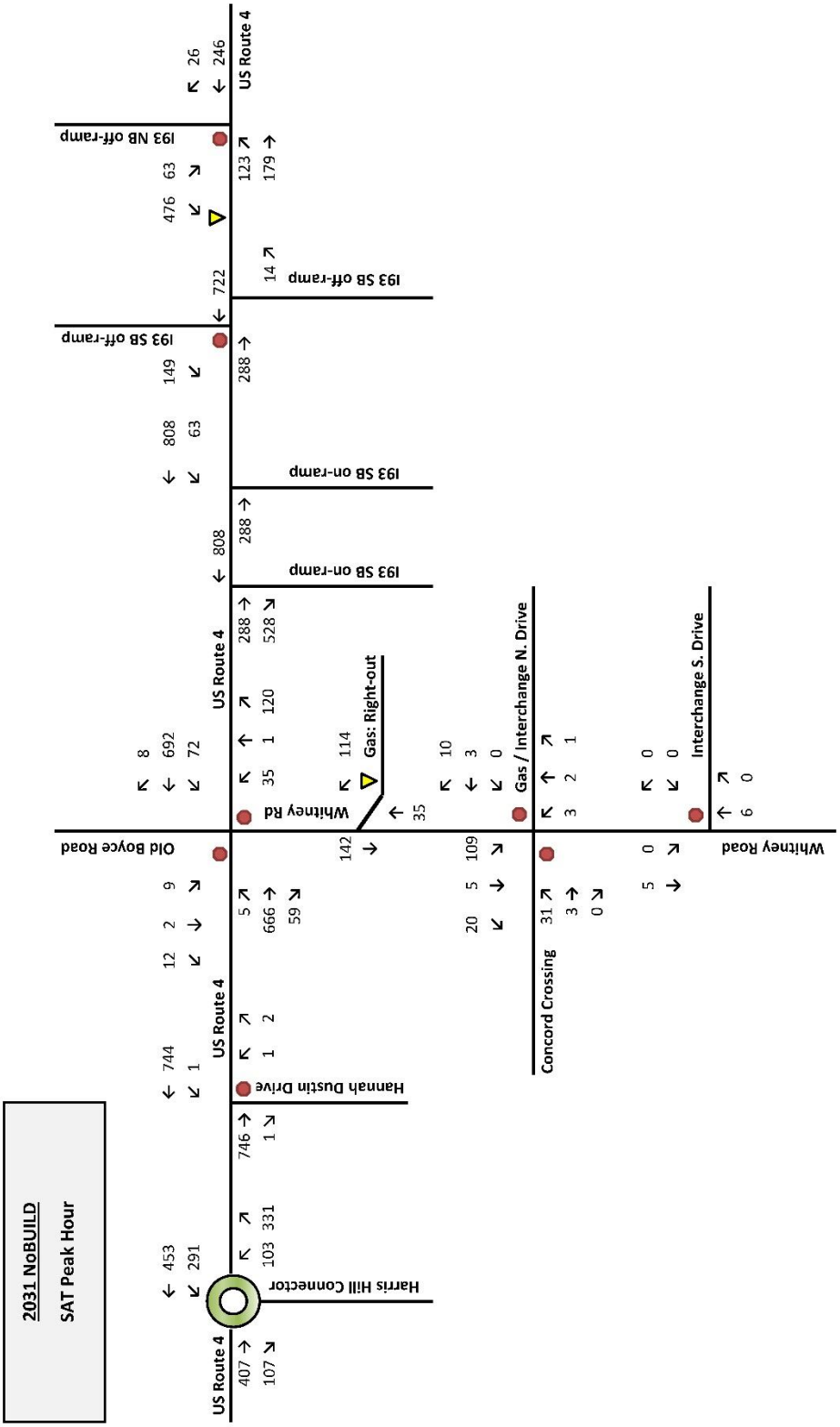
23 217


2031 NoBUILD
SAT Peak Hour
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Hannah Dustin Drive
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Interchange S. Drive
Whitney Road
193 SB on-ramp
193 SB off-ramp
193 NB off-ramp
407 107
291 453
331 103
746 1
744 1
2 1
12 2 9
5 666 59
142
35 1 120 288 528
114 35
8 692 72
808 288
10 3 0
20 5 109
31 3 0
3 2 1
5 0
0 0
6 0
808 63 149
288
722 476 63
26 246
123 179
14

5. Trip Generation:

This report uses standard trip generation rates published by the ITE (Institute of Transportation Engineers, Traffic Generation Manual, 10th Edition). ITE Land Use Codes shown in the following tables were used to calculate gross (unadjusted) trip generation for Phase 1 and Full Build of the Interchange development, respectively. See also "Other Developments", below.

Table 1 – Proposed Interchange Phase 1
Trip Generation by Land Use

Land Use	In	Out	Total
Proposed Supermarket (LUC 850)			
Weekday AM Peak Hour Adjacent Street	183	122	305
Weekday PM Peak Hour Adjacent Street	376	362	738
Saturday Midday Peak Hour	421	405	826
Proposed 48,902 sf Shopping Center/Retail (LUC 820)			
Weekday AM Peak Hour Adjacent Street	29	17	46
Weekday PM Peak Hour Adjacent Street	154	166	320
Saturday Midday Peak Hour	183	168	351
Total Proposed Trips before Trip Reductions*			
Weekday AM Peak Hour Adjacent Street	212	139	351
Weekday PM Peak Hour Adjacent Street	530	528	1058
Saturday Midday Peak Hour	604	573	1177

* No Internal Trip Capture reduction for multi-purpose trips was taken for Phase 1.

Table 2 – Proposed Interchange Full Build
Trip Generation by Land Use (Unadjusted)

Land Use	In	Out	Total
Proposed Supermarket (LUC 850)			
Weekday AM Peak Hour Adjacent Street	183	122	305
Weekday PM Peak Hour Adjacent Street	376	362	738
Saturday Midday Peak Hour	421	405	826
Proposed 71,429 sf Shopping Center/Retail (LUC 820)			
Weekday AM Peak Hour Adjacent Street	42	25	67
Weekday PM Peak Hour Adjacent Street	203	220	423
Saturday Midday Peak Hour	246	228	474
Proposed 13,992 sf Medical/Dental Office (LUC 720)			
Weekday AM Peak Hour Adjacent Street	30	9	39
Weekday PM Peak Hour Adjacent Street	13	15	48
Saturday Midday Peak Hour	25	18	43
Proposed 45,000 sf General Light Industrial (LUC 110)			
Weekday AM Peak Hour Adjacent Street	28	4	32
Weekday PM Peak Hour Adjacent Street	4	24	28
Saturday Midday Peak Hour	8	10	18
Total Proposed Trips before Trip Reductions*			
Weekday AM Peak Hour Adjacent Street	283	160	443
Weekday PM Peak Hour Adjacent Street	596	641	1237
Saturday Midday Peak Hour	700	661	1361

*See Tables 2 and 3 below for traffic volume reductions due to internal capture

Internal Trip Capture
Because the proposed development includes multiple uses, some of the traffic generation will be due to multi-purpose trips; that is, trips involving visits to more than one use on the same site; (e.g. office and restaurant, retail and office, etc.). This interaction, known as "Internal Trip Capture" reduces traffic generation on adjacent roadways below a simple summation of the individual uses. Internal Trip Capture reduction can be calculated by evaluating use pairs for the development, according to ITE and NCHRP 684 guidelines.

NCHRP 684 does not specifically address the interaction between retail uses (such as the supermarket and other retail), the ITE *Trip Generation Handbook 2nd edition* does, and recommends a 20% reduction of retail-to-retail. To incorporate this interaction for the mixed-use development, a conservative 10% capture rate was applied to the site for both Phase 1 and Full Build. It should be noted that no deduction was taken for trip interaction by the development with the existing gas/convenience store at Whitney Road. Therefore, the results in the tables below are likely to be somewhat conservative. Detailed calculations are in Appendix B1, pages 7 & 8. Tables 3a and 3b below show the effect of internal capture reduction for the development. The new trip calculations are in the Trip Generation section of Appendix A1, pages 3 & 5.

Table 3a – Net New Trips for Interchange Phase 1

	In	Out	Total
Unadjusted Trip Totals			
Weekday AM Peak Hour Adjacent Street	212	139	351
Weekday PM Peak Hour Adjacent Street	530	528	1058
Saturday Midday Peak Hour	604	574	1178
Total Trip Reductions (Internal Trip Capture)			
Weekday AM Peak Hour Adjacent Street **(9%)**	(19)	(14)	(33)
Weekday PM Peak Hour Adjacent Street **(12%)**	(63)	(63)	(126)
Saturday Midday Peak Hour **(12%)**	(73)	(70)	(143)
New (adjusted) Trip Totals			
Weekday AM Peak Hour Adjacent Street	193	125	318
Weekday PM Peak Hour Adjacent Street	467	465	932
Saturday Midday Peak Hour	531	504	1035

Table 3b – Net New Trips for Interchange Full-Build

	In	Out	Total
Unadjusted Trip Totals			
Weekday AM Peak Hour Adjacent Street	283	160	443
Weekday PM Peak Hour Adjacent Street	596	641	1237
Saturday Midday Peak Hour	700	661	1361
Total Trip Reductions (Internal Trip Capture)			
Weekday AM Peak Hour Adjacent Street **(9%)**	(25)	(15)	(40)
Weekday PM Peak Hour Adjacent Street **(12%)**	(72)	(77)	(149)
Saturday Midday Peak Hour **(12%)**	(85)	(80)	(165)
New (adjusted) Trip Totals			
Weekday AM Peak Hour Adjacent Street	258	145	403
Weekday PM Peak Hour Adjacent Street	524	564	1088
Saturday Midday Peak Hour	615	581	1196

6. Trip Composition:

The above trips are classified by ITE as primary, pass-by, and diverted-linked trips:

- A primary trip is made for the specific purpose of visiting the generator. A primary trip typically goes from its origin to the generator and then returns to the origin.
- Pass-by trip are attracted from traffic passing the site on a roadway that offers relatively direct access to the generator. For the purposes of this study, US4 and Whitney Road were considered to be sources for pass-by trips.
- A diverted-linked trip is attracted from existing traffic on other nearby roadways that require a diversion onto another roadway to access the generator. In this study, we considered I93, US3 and NH132 as the appropriate source for this traffic.

Trip composition for the proposed site development was calculated for each Land Use Code based on average percentage rates for Pass-By and Diverted-Linked trips published by the ITE Manual. Only primary trips were considered for the Medical Office and Industrial uses. Table 4 shows the breakdown of trip types associated with the Interchange development:

Table 4a: Site Trip Volumes for Interchange Phase 1

	Primary		Pass-By		Diverted Link		Total Trips to Site	New Trips On US4
	In	Out	In	Out	In	Out		
Weekday AM Peak Hour Adjacent Street	55	35	69	45	69	45	318	204
Weekday PM Peak Hour Adjacent Street	141	141	165	165	161	159	932	602
Weekend SAT Peak Hour Adjacent Street	158	150	176	167	197	187	1035	692

Table 4b: Site Trip Volumes for Interchange Full Build

	Primary		Pass-By		Diverted Link		Total Trips to Site	New Trips On US4
	In	Out	In	Out	In	Out		
Weekday AM Peak Hour Adjacent Street	112	50	73	48	73	47	403	282
Weekday PM Peak Hour Adjacent Street	172	212	180	180	172	172	1088	728
Weekend SAT Peak Hour Adjacent Street	209	195	190	180	216	206	1196	826

7. Trip Distribution & Assignment:

New site-generated trips associated with the Interchange Mixed-Use Development were distributed within the study area based on the following.

- *Primary Trips*
  To calculate primary trip distribution for the Interchange Development, a home-based gravity model was created to link Concord and other surrounding towns to the Interchange Development supermarket. Population for surrounding towns was based on 2018 OSI (NH Office of Strategic Initiatives) information. Concord population was divided into census tracts. Towns with origins located 30 minutes or more have been eliminated from the model since towns at that distance are likely to have much closer shopping options.

  Weighted populations were determined by applying friction factors for distance of travel (using 1/t, where t=travel time in minutes), and for the presence of other competing supermarkets along the path of travel, using a factor ranging from 0.25 to 1.00 all trips. Lower factors were applied to communities with more than one supermarket along the path of travel, and higher factors where there are no competing supermarkets.

  Route assignment was determined using the center of population for the town/tract, with an appropriate split over route the various route options when more than one was available. The weighted population and route assignment were then used to determine primary trip distribution across the study area.

- *Pass-By Trips*
  Pass-By trips were calculated using US4 as the source of Pass-By traffic since Whitney Road is a short dead-end road that effectively serves as a site driveway. Pass-By distribution was based pro-rata on directional traffic along US4 at the Whitney Road intersection.

- *Diverted-Linked Trips*
  Diverted-Linked trips were determined using the volumes for I93, US3 and NH132 as the source of DL traffic. Although the volume of traffic along I93 substantially outweighs all other traffic, it is likely that a small amount of traffic will divert to the site from US3 and NH132. Distribution of this traffic is pro-rata per NHDOT data. See Appendix N1. Distribution of DL traffic through the ramps was based pro-rata on directional I93 traffic. These trips act as Primary trips to/from I93 at the Whitney Road intersection, however they are assumed to continue their original direction of travel (NB or SB) at the I93/US4 ramp intersections.

Please refer to the Trip Distribution diagrams in Volume 1 Appendix for each trip type for the Interchange Development. Calculation worksheets and diagrams detailing the distribution of the site-generated trips are included in the following appendix sections.

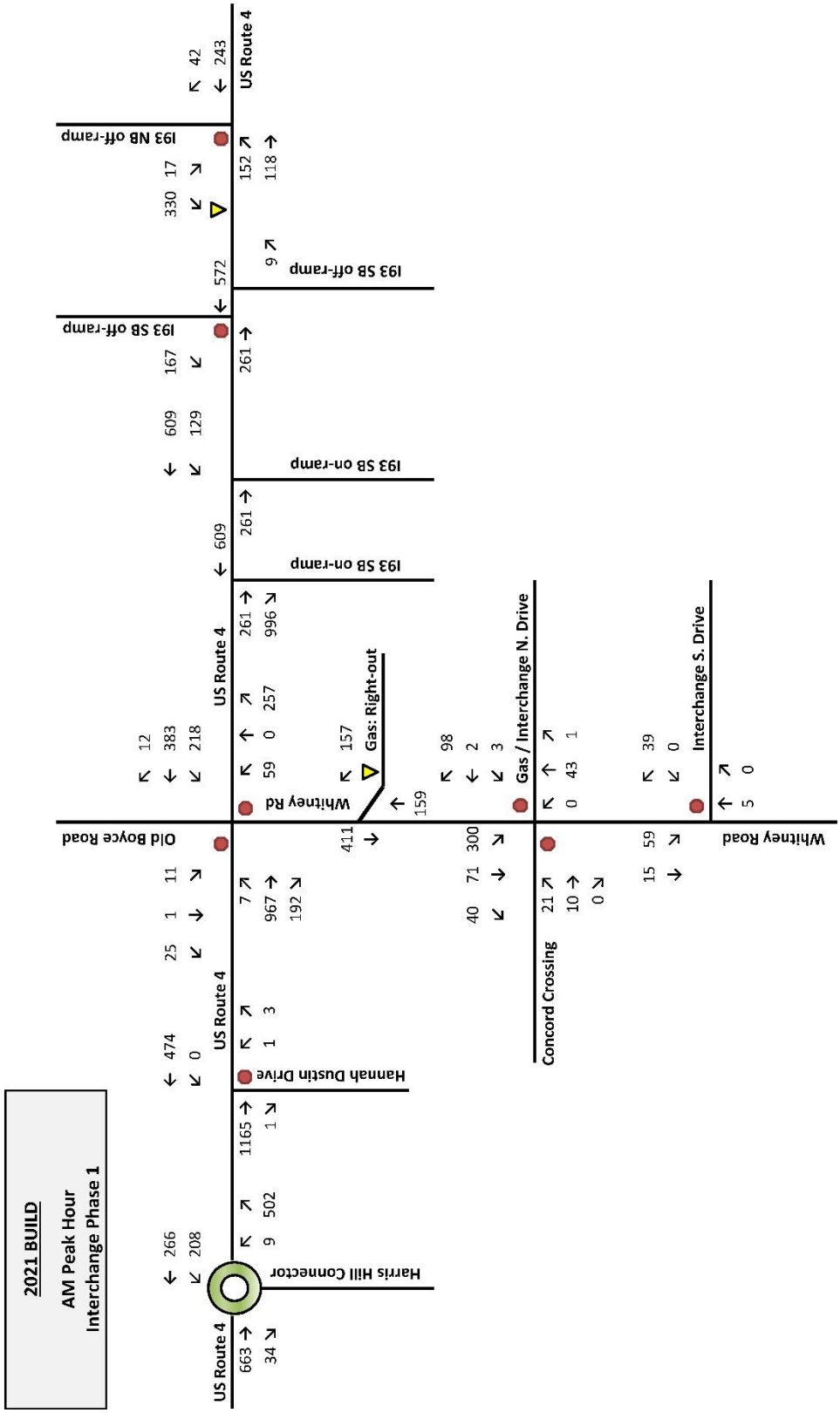
- <u>Volume 1, Appendix C1: AM Distribution Calculations & Site Trip Diagrams</u>
  - Pages 10-13: Distribution Calculations
  - Pages 14-16: Diagrams – % Primary/Pass-By/Diverted Link
  - Pages 17-20: Diagrams Phase 1– Total Site Trips/Primary/Pass-By/Diverted Link
  - Pages 21-24: Diagrams Full Build – Total Site Trips/Primary/Pass-By/Diverted Link

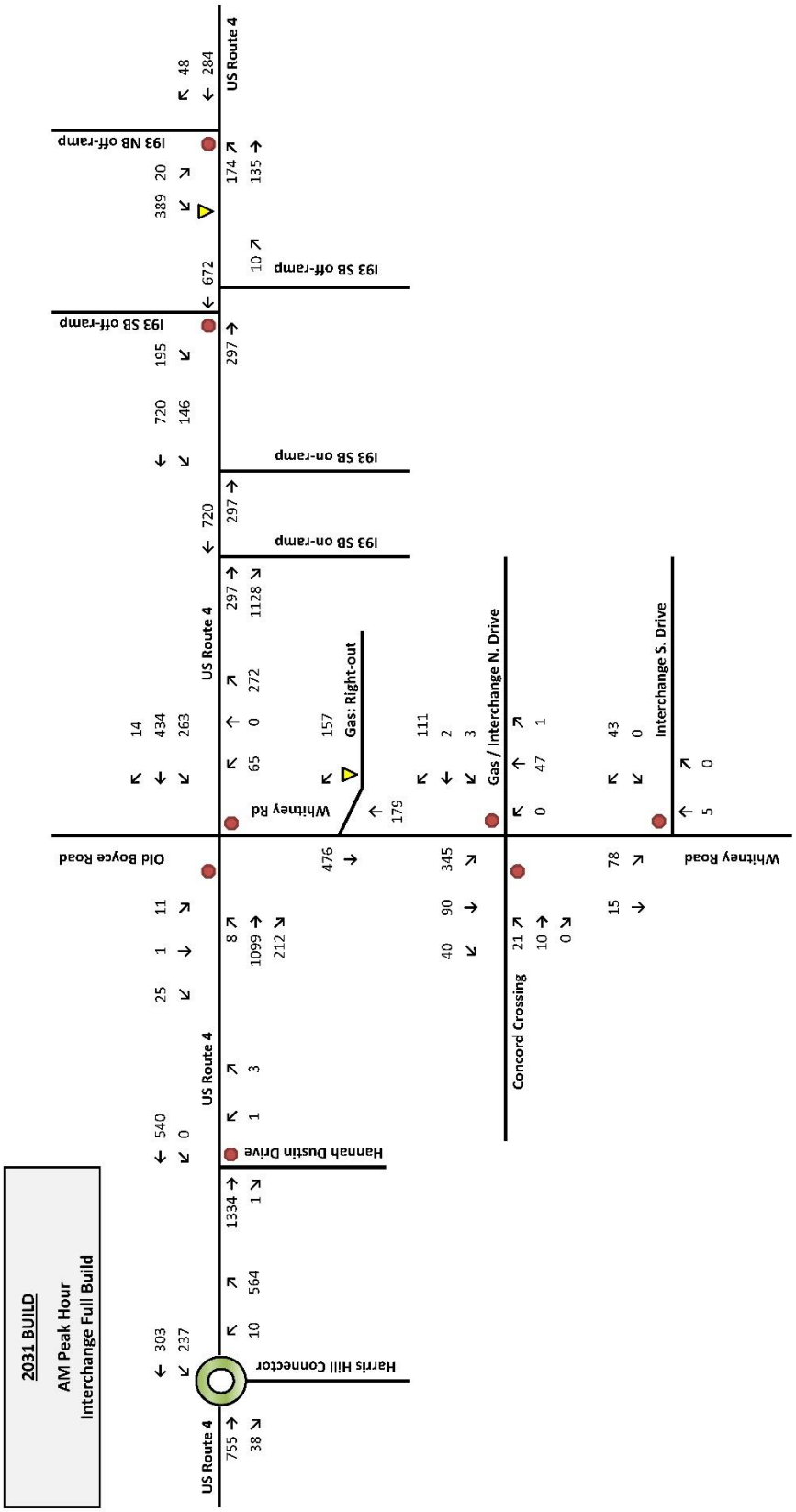
- Volume 1, Appendix F1: PM Distribution Calculations & Site Trip Diagrams
  - Pages 37-40: Distribution Calculations
  - Pages 41-43: Diagrams – % Primary/Pass-By/Diverted Link
  - Pages 44-47: Diagrams Phase 1– Total Site Trips/Primary/Pass-By/Diverted Link
  - Pages 48-51: Diagrams Full Build – Total Site Trips/Primary/Pass-By/Diverted Link

- Volume 1, Appendix I1: SAT Distribution Calculations & Site Trip Diagrams
  - Pages 64-67: Distribution Calculations
  - Pages 68-70: Diagrams – % Primary/Pass-By/Diverted Link
  - Pages 71-74: Diagrams Phase 1– Total Site Trips/Primary/Pass-By/Diverted Link
  - Pages 75-78: Diagrams Full Build – Total Site Trips/Primary/Pass-By/Diverted Link

8. Build Volumes:

The site trip distribution data was added to the no-build volumes throughout the study area to produce the build volumes. Network volume diagrams for Phase 1 Build & Full Build conditions are shown on the following pages and included in the Volume 1 Appendix, pages 33, 35, 60, 62, 87 & 89.


2021 BUILD
AM Peak Hour
Interchange Phase 1
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
193 SB on-ramp
193 SB off-ramp
193 NB off-ramp
Concord Crossing
Gas / Interchange N. Drive
Interchange S. Drive
Whitney Road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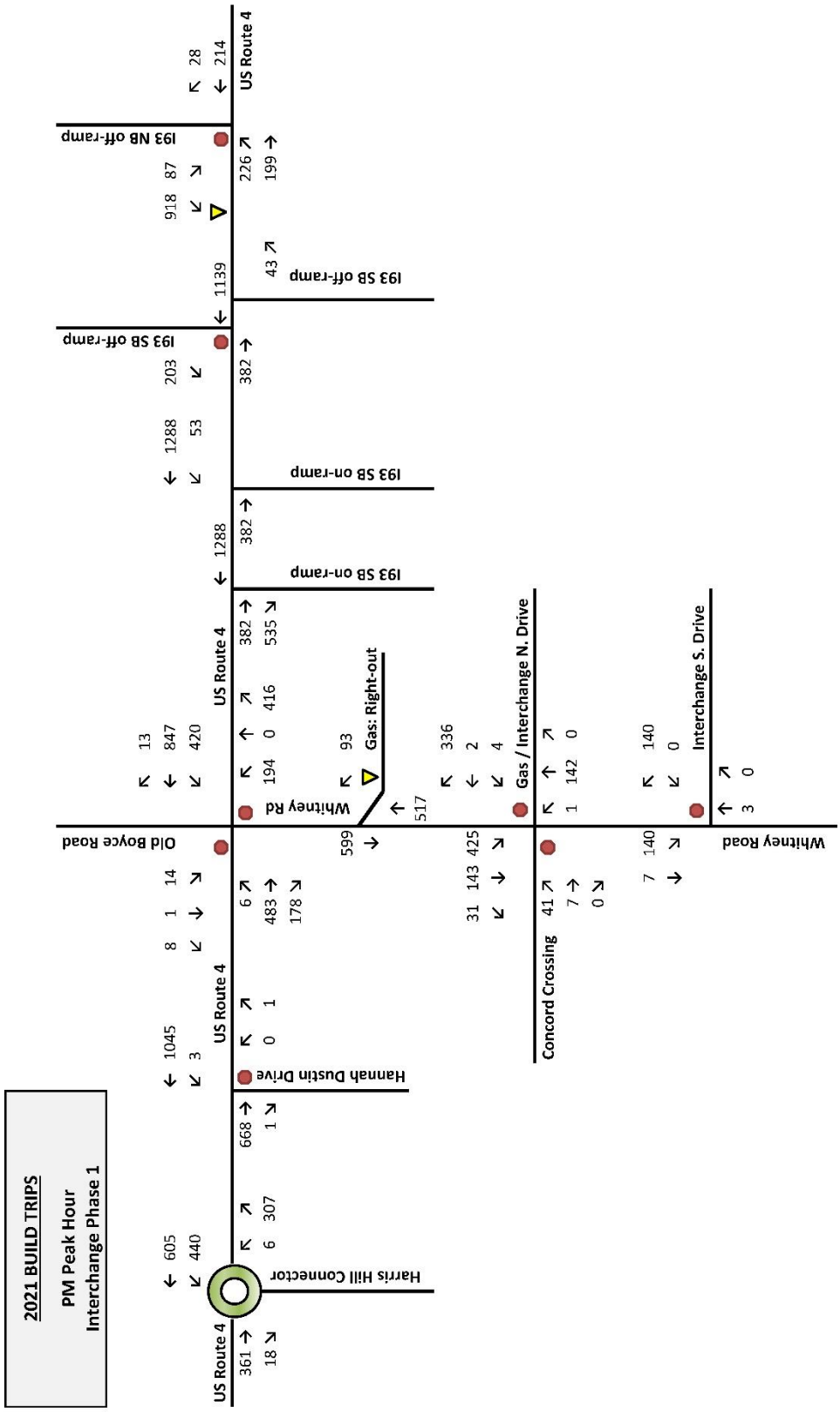
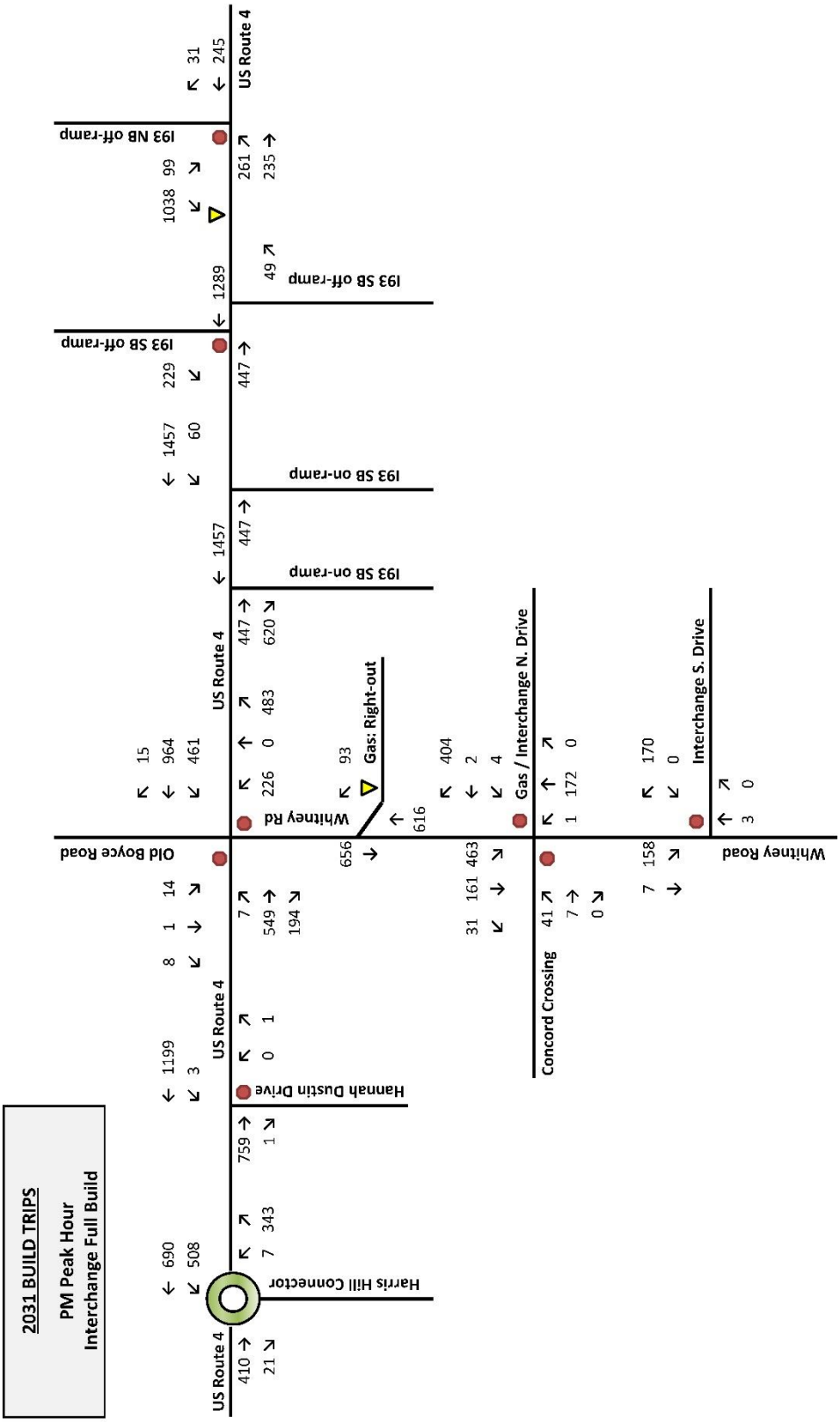
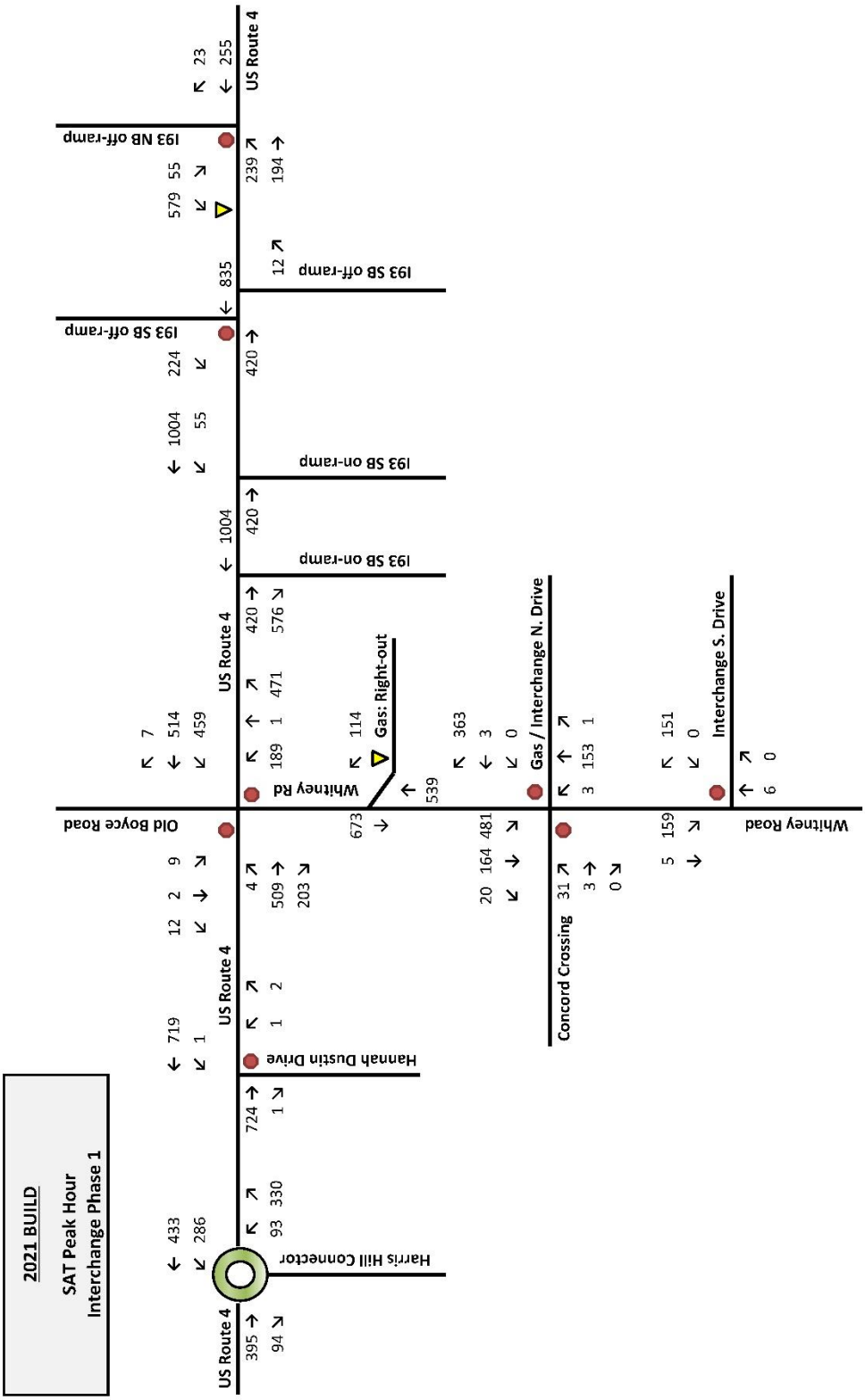
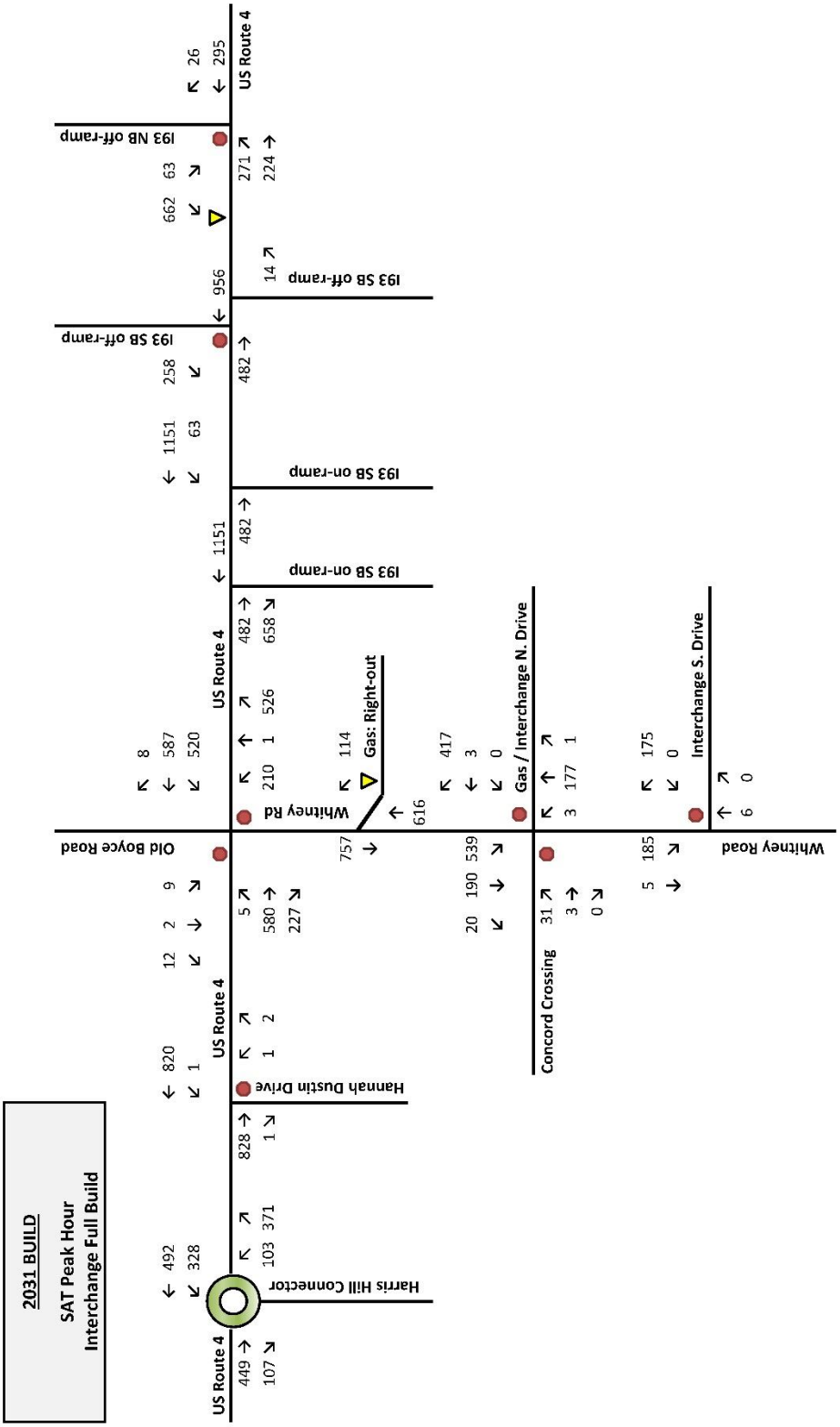
AM Peak Hour
Interchange Full Build
US Route 4
Harris Hill Connector
Hannah Dustin Drive
US Route 4
Old Boyce Road
Whitney Rd
Gas: Right-out
US Route 4
193 SB on-ramp
193 SB on-ramp
193 SB off-ramp
193 SB off-ramp
193 NB off-ramp
193 SB off-ramp
US Route 4
Concord Crossing
Gas / Interchange N. Drive
Whitney Road
Interchange S. Drive


2021 BUILD TRIPS
PM Peak Hour
Interchange Phase 1
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
I93 SB on-ramp
I93 SB off-ramp
I93 NB off-ramp
Concord Crossing
Gas / Interchange N. Drive
Interchange S. Drive
Whitney Road


2031 BUILD TRIPS
PM Peak Hour
Interchange Full Build
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
Concord Crossing
Gas / Interchange N. Drive
Interchange S. Drive
Whitney Road
I93 SB on-ramp
I93 SB off-ramp
I93 NB off-ramp


2021 BUILD
SAT Peak Hour
Interchange Phase 1
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Old Boyce Road
Whitney Rd
Gas: Right-out
Gas / Interchange N. Drive
Concord Crossing
Whitney Road
Interchange S. Drive
I93 SB on-ramp
I93 SB off-ramp
I93 NB off-ramp


2031 BUILD
SAT Peak Hour
Interchange Full Build
US Route 4
Harris Hill Connector
Hannah Dustin Drive
Whitney Rd
Gas: Right-out
Concord Crossing
Gas / Interchange N. Drive
Interchange S. Drive
Whitney Road
Old Boyce Road
US Route 4
US Route 4
193 SB on-ramp
193 SB on-ramp
193 SB off-ramp
193 SB off-ramp
193 SB off-ramp
193 NB off-ramp
US Route 4

9. Analysis Cases:

Existing & No-Build Cases

For Case 1, 2a and 3a, the level of service analysis was conducted with the existing lane geometry and traffic control at each intersection as shown in Figures C & D below.

1) 2019 Existing: Existing Volumes with Seasonal Adjustment
2a) 2021 No Build: Volumes with Growth to 2021
3a) 2031 No Build: Volumes with Growth to 2031

Figure C: Existing at US4 & Whitney Road

Figure D: Existing Roundabout at US4 & Harris Hill Connector

Build Cases

2b) 2021 Build [Ph1]: 2021 No-Build Volumes plus Interchange Phase 1 trips
For Case 2b, the level of service analysis was conducted with the existing lane geometry and traffic control at each intersection as shown in Figures C & D above and Figure E below. No improvements proposed.

3b) 2031 Build [IFB] Mit R1: 2031 No-Build Volumes plus Interchange Full Build (IFB) trips with a Proposed Roundabout at US4 & Whitney Road.
For Case 3b, the analysis was conducted with the existing lane geometry and traffic control at each intersection as shown in Figures D & E above for all intersections except US4 & Whitney Road is mitigated per Figure F on the following page.

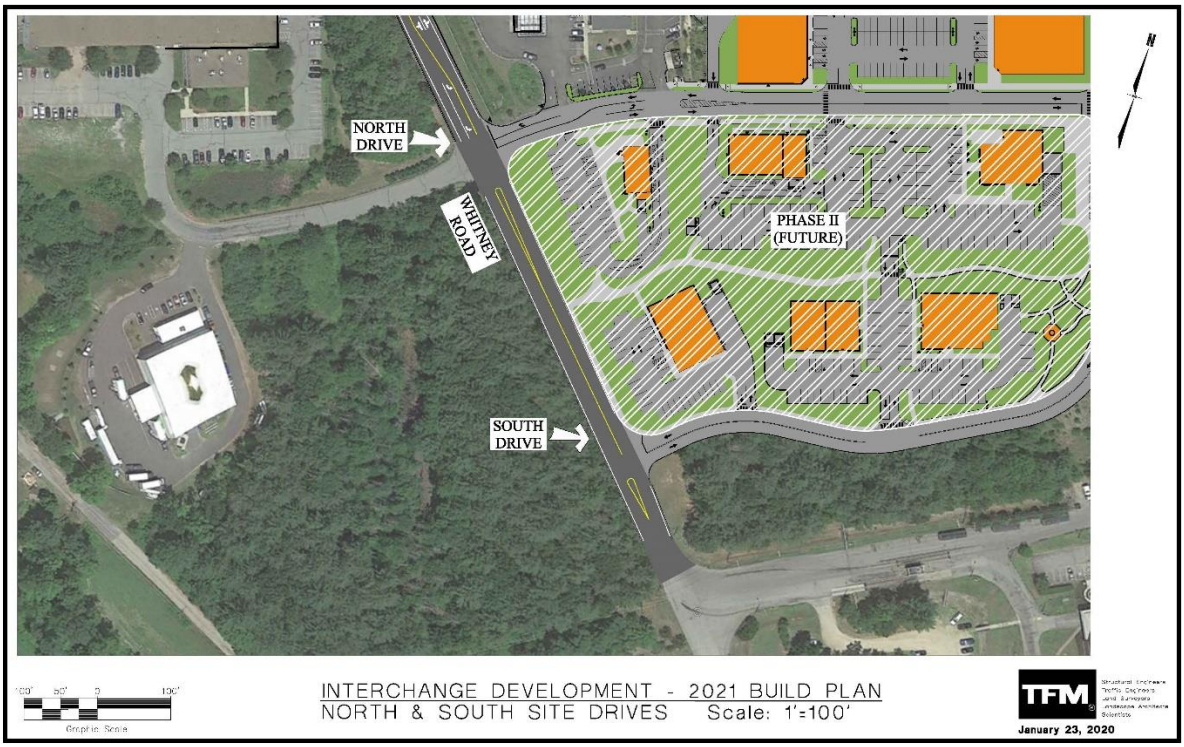


Figure E: Existing Conditions with Phase 1 Interchange Development

Mitigation Case: Roundabout – US4/Whitney Road Intersection

2c) 2021 Build [Ph1] Mit R1: 2021 Phase 1 Build Volumes with a Proposed Roundabout at US4 & Whitney Road
For Case 2c, the analysis was conducted with a proposed roundabout at the intersection as shown in Figure F below. All other intersections remain in existing conditions.

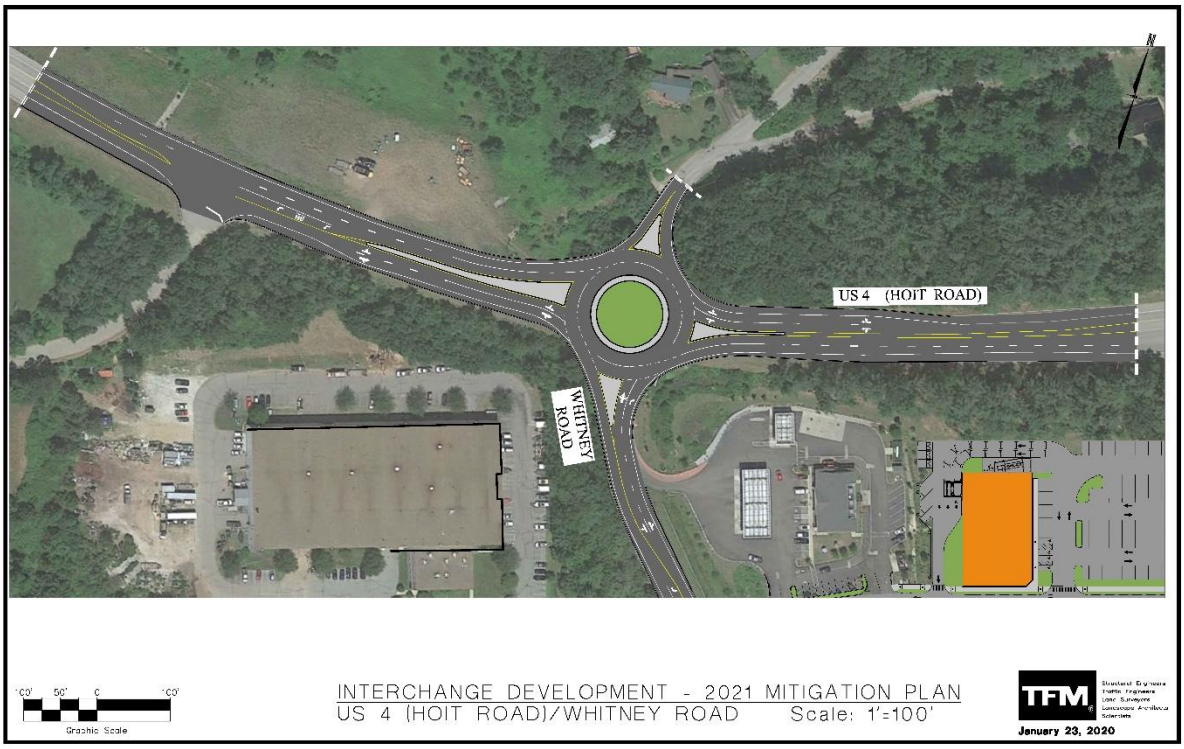


Figure F: Proposed Roundabout at US4 & Whitney Road

<u>Mitigation Case: Signal – US4/Whitney Road Intersection</u>

2d) 2021 Build [Ph1] Signal: 2021 Ph 1 Build volumes with conceptual traffic signal control

3d) 2031 Build [IFB] Signal: 2031 Full Build volumes with conceptual traffic signal control
For Case 2d and 3d, the analysis was conducted with a conceptual traffic signal at the intersection based on the figure in the HDR Whitney Road Corridor Planning Evaluation Memo as shown in Figure G below. All other intersections remain in existing conditions.

Figure G: Conceptual Signal at US4 & Whitney Road

10. Level of Service/Queue Analysis:

Level of Service Analysis:
Level of service (LOS) is a qualitative description of operational conditions within a traffic stream measured in terms of control delay, a function of capacity, degree of saturation, and delay associated with traffic signals and "STOP" signs. Control delay includes initial deceleration, delay approaching a control device, stopped delay, queue move-up time, and acceleration delay from a stopped condition. The relationship between control delay and LOS is shown in the following table.

Level of Service (LOS)	Signalized Control Delay (sec)	Unsignalized Control Delay (sec)
A	≤10.0	≤10.0
B	10.1 to 20.0	10.1 to 15.0
C	20.1 to 35.0	15.1 to 25.0
D	35.1 to 55.0	25.1 to 35.0
E	55.1 to 80.0	35.1 to 50.0
F	Over 80.0	Over 50.0

Study Area.
Analyses were performed for the study area intersections previously described, that is:

- US4 at Whitney Road/Old Boyce Road
- US4 at I93 Exit 17 ramps
- US4 at Hannah Dustin Road
- Boscawen Roundabout on US4
- Site Driveways on Whitney Road

Queue Analysis.
Vehicle queue lengths are determined by the capacity of the movement under study and the volume of traffic processed by the intersection during the analysis period. It is standard practice to report the 95th percentile queue, that is, the queue that will be exceeded no more than 5% of the time during the peak periods.

Methodology.
Trafficware "Synchro" v10.0 software was used to analyze stop controlled intersections (using HCM2010) and signalized intersections (using HCM2000) within the study area. SIDRA 8.0 software was used to analyze roundabouts at study area intersections. Level of service analysis was conducted for study area intersections during the weekday AM, PM and Saturday peak hours.

Analysis Results & Discussion.

US4/Whitney Road

As shown in Tables 5a-g, the Synchro models indicate that the US4/Whitney Road intersection operates at an overall LOS D without the Interchange development traffic. The intersection operation degrades to LOS E/F with the addition of the Interchange Phase 1 trips in 2021. Two mitigation options were reviewed for this intersection: a two-lane roundabout and a traffic signal with added thru and turning lanes on the US4 and Whitney Road approaches.

- Roundabout: The roundabout design includes two circulating lanes, a two-lane approach on US4 in each direction, a two-lane approach on Whitney Road northbound and a one lane approach on Old Boyce Road southbound. As shown in Tables 5b,5d, and 5f, the proposed roundabout lane configuration would produce B or better levels of service for all approaches in 2021 Build Conditions, and as shown in Tables 5c, 5e and 5g, LOS C or better in 2031 Full Build conditions.
- Traffic Signal: Alternatively, traffic signal control was considered for US4/Whitney Road in lieu of a roundabout. The signal design was taken from the recommendations contained in the 2019 HDR Whitney Road Corridor Planning Evaluation. The traffic contained in that analysis is comparable to the Interchange Full Build with Whitney Road Extension (see Section 14). In the HDR report, the signal is configured as follows:
  - Eastbound US4: exclusive left turn lane, two thru lanes, exclusive right turn lane
  - Westbound US4: two exclusive left turn lanes, one thru lane, one thru-right lane
  - Northbound Whitney Rd: exclusive left turn lane, thru-right lane, exclusive right turn lane
  - Southbound Old Boyce Road: exclusive left turn lane, thru-right lane

Tables 5b-5g below compare the operations of US4/Whitney Road assuming traffic signal control and a proposed roundabout. In general, the roundabout option provides better levels of service in all peak hours; roundabout queue lengths are up to 60% shorter than the signal queues; the roundabout would offer safety advantages over a signalized intersection, and carbon emissions are up to 75% less with a roundabout as opposed to traffic signal control (refer to “Effectiveness reports” in appendices).

These analyses are based on an even (50/50) lane utilization of the eastbound and northbound approaches. With a significant volume of downstream turning traffic heading to the I93 SB on-ramp, we also performed a sensitivity analysis using greater proportions of traffic favoring the right lanes (60/40 and 70/30) as shown in Appendix V1, pages 392 to 398.

In all cases, the 60/40 and 30/70 utilizations show similar benefits to the roundabout option over the signal option. In the future year AM case, the EB roundabout queue lengthens, however delays are reduced, and the other benefits (total volume processed, emissions, and safety) continue to favor the roundabout.

Table 5a: US4 at Whitney Road / Old Boyce Road *[Existing Stop Controlled Intersection]*

	2019 Existing (1)		2021 No Build (2a)		2021 Build (2b)		2031 No Build (3a)		2031 Build (3b)
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	
AM Overall	22.7	C	27.4	D	36.5	E	99.5	F	See Table 5c
PM Overall	8.2	A	8.9	A	785.6	F	15.0	B	See Table 5e
SAT Overall	4.9	A	5.1	A	624.1	F	6.7	A	See Table 5g

Table 5b: AM Peak Hour - 2021 Mitigation US4/Whitney Level of Service & Queues

2c) 2021 Build [Ph1] Mit R1 (Roundabout)					**2d) 2021 Build [Ph1] Signal**				
	v/c	Delay	LOS	Queue		v/c	Delay	LOS	Queue
AM OVERALL	**0.58**	**9.3**	**A**	**-**	**AM OVERALL**	**0.55**	**18.8**	**B**	**-**
					EB L	0.09	29.8	C	13
EB	0.58	10.8	B	128	EB T	0.74	18.8	B	313
					EB R	0.13	21.3	C	36
WB	0.26	5.3	A	32	WB L	0.62	30.3	C	76
					WB TR	0.27	10.7	B	98
					NB L	0.18	17.9	B	37
NB	0.33	12.1	B	34	NB TR	0.09	21.1	C	0
					NB R	0.08	15.7	B	16
SB	0.11	7.3	A	9	SB L	0.28	31.8	C	15
					SB TR	0.04	22.3	C	10
Environmental	**Summary**								
# Cars Served	2300				2131				
CO Emissions	0.37 (kg)				1.60 (kg)				
									*Queues expressed in feet

Table 5c: AM Peak Hour - 2031 Mitigation US4/Whitney Level of Service & Queues

3b) 2031 Build [IFB] Mit R1 (Roundabout)					**3d) 2031 Build [IFB] Signal**				
	v/c	Delay	LOS	Queue		v/c	Delay	LOS	Queue
AM OVERALL	**0.69**	**11.8**	**B**	**-**	**AM OVERALL**	**0.63**	**21.4**	**B**	**-**
					EB L	0.11	30.2	C	15
EB	0.69	14.2	B	242	EB T	0.85	22.8	C	390
					EB R	0.14	21.3	C	46
WB	0.31	5.8	A	39	WB L	0.75	35.8	D	108
					WB TR	0.31	11.1	B	115
					NB L	0.20	17.9	B	40
NB	0.41	15.3	C	44	NB TR	0.10	21.0	C	0
					NB R	0.08	15.7	B	20
SB	0.12	8.1	A	10	SB L	0.28	32.0	C	16
					SB TR	0.04	22.2	C	10
Environmental	**Summary**								
# Cars Served	2590				2404				
CO Emissions	0.43 (kg)				1.95 (kg)				
					*Queues expressed in feet				

Table 5d: PM Peak Hour - 2021 Mitigation Level of Service & Queue

2c) 2021 Build [Ph1] Mit R1 (Roundabout)					2d) 2021 Build [Ph1] Signal				
	v/c	Delay	LOS	Queue		v/c	Delay	LOS	Queue
PM OVERALL	**0.62**	**10.3**	**B**	**-**	**PM OVERALL**	**0.65**	**19.3**	**B**	**-**
					EB L	0.09	32.2	C	13
EB	0.41	8.9	A	53	EB T	0.49	19.8	B	126
					EB R	0.11	12.7	B	28
WB	0.62	11.5	B	158	WB L	0.76	32.3	C	130
					WB TR	0.60	15.4	B	212
					NB L	0.48	17.7	B	122
NB	0.40	9.3	A	52	NB TR	0.15	20.5	C	0
					NB R	0.13	12.3	B	33
SB	0.09	12.0	B	7	SB L	0.25	33.6	C	19
					SB TR	0.01	22.9	C	10
Environmental	**Summary**								
# Cars Served	2812				2580				
CO Emissions	0.43 (kg)				1.84 (kg)				
									*Queues expressed in feet

Table 5e: PM Peak Hour - 2031 Mitigation US4/Whitney Level of Service & Queues

3c) 2031 Build [IFB] Mit R1 (Roundabout)					3d) 2031 Build [IFB] Signal				
	v/c	Delay	LOS	Queue		v/c	Delay	LOS	Queue
PM OVERALL	**0.72**	**13.3**	**B**	**-**	**PM OVERALL**	**0.72**	**20.3**	**C**	**-**
					EB L	0.11	34.5	C	15
EB	0.47	10.1	B	72	EB T	0.53	20.7	C	150
					EB R	0.12	13.2	B	29
WB	0.72	15.3	C	306	WB L	0.76	33.3	C	150
					WB TR	0.64	15.6	B	248
					NB L	0.59	22.0	C	146
NB	0.54	12.6	B	97	NB TR	0.18	22.7	C	12
					NB R	0.19	13.4	B	58
SB	0.13	15.0	B	10	SB L	0.27	36.0	D	20
					SB TR	0.01	24.8	C	10
Environmental	**Summary**								
# Cars Served	3214				2922				
CO Emissions	0.51 (kg)				2.12 (kg)				
									*Queues expressed in feet

Table 5f: SAT Peak Hour - 2021 Mitigation Level of Service & Queue

2c) 2021 Build [Ph1] Mit R1 (Roundabout)					2d) 2021 Build [Ph1] Signal				
	v/c	Delay	LOS	Queue		v/c	Delay	LOS	Queue
SAT OVERALL	**0.47**	**9.0**	**A**	**-**	**SAT OVERALL**	**0.58**	**20.9**	**C**	**-**
					EB L	0.05	32.8	C	10
EB	0.44	9.5	A	62	EB T	0.50	20.6	C	146
					EB R	0.12	13.2	B	33
WB	0.47	8.3	A	69	WB L	0.84	38.3	D	184
					WB TR	0.37	13.7	B	137
					NB L	0.45	17.3	B	109
NB	0.42	9.5	A	59	NB TR	0.17	20.5	C	57
					NB R	0.15	12.4	B	41
SB	0.10	9.1	A	8	SB L	0.23	34.3	C	14
					SB TR	0.03	22.7	C	8
Environmental	**Summary**								
# Cars Served	2582				2381				
CO Emissions	0.37 (kg)				1.69 (kg)				
									*Queues expressed in feet

Table 5g: SAT Peak Hour - 2031 Mitigation US4/Whitney Level of Service & Queues

3c) 2031 Build [IFB] Mit R1 (Roundabout)					3d) 2031 Build [IFB] Signal				
	v/c	Delay	LOS	Queue		v/c	Delay	LOS	Queue
SAT OVERALL	**0.55**	**10.9**	**B**	**-**	**SAT OVERALL**	**0.64**	**21.2**	**C**	**-**
					EB L	0.07	36.0	D	12
EB	0.52	11.8	B	92	EB T	0.57	23.3	C	189
					EB R	0.13	15.0	B	40
WB	0.55	9.8	A	91	WB L	0.77	33.3	C	181
					WB TR	0.39	13.1	B	161
					NB L	0.53	21.2	C	134
NB	0.51	11.8	B	84	NB TR	0.19	23.4	C	63
					NB R	0.22	12.9	B	58
SB	0.11	10.7	B	9	SB L	0.25	37.7	D	15
					SB TR	0.03	25.5	C	8
Environmental	**Summary**								
# Cars Served	2912				2687				
CO Emissions	0.43 (kg)				1.95 (kg)				
									*Queues expressed in feet

Whitney Road/North Site Driveway/Concord Crossing

Table 6: Whitney Road at Interchange North Site Drive / Concord Crossing

	2019 Existing (1)		2021 No Build (2a)		2021 Build (2b)		2031 No Build (3a)		2031 Build (3b)	
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
AM Overall	7.0	A	7.0	A	7.5	A	7.0	A	7.7	A
PM Overall	7.5	A	7.5	A	27.4	D	7.5	A	49.8	E
SAT Overall	7.6	A	7.6	A	35.2	E	7.6	A	65.8	F

The North Site Driveway is currently serving traffic to and from an existing gas station and is located opposite the private driveway for Concord Crossing. Table 6 shows that the overall operation of the North Site Driveway is LOS A during the Weekday AM peak hour for all cases in 2019, 2021 and 2031. The overall intersection will operate at LOS D and LOS E in the 2021 Build PM and Saturday peak hour conditions, respectively. The overall intersection will operate at LOS E and LOS F in the 2031 Build PM and Saturday peak hour conditions, respectively.

The lower levels of service at the North Site Driveway are experienced by a low-volume eastbound left turn movement - exiting from the Concord Crossing driveway. In 2031, these left turns operate at LOS F in the PM and Saturday peak hours, while other turns operate at LOS A/B. The total delay of the eastbound left turns is minimal due to the low volume of traffic exiting the Concord Crossing driveway (about one vehicle per two minutes at peak).

Whitney Road/South Site Driveway

Table 7: Whitney Road at Interchange South Site Drive

	2019 Existing (1)		2021 No Build (2a)		2021 Build (2b)		2031 No Build (3a)		2031 Build (3b)	
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
AM Overall	-	-	-	-	6.4	A	-	-	6.6	A
PM Overall	-	-	-	-	7.9	A	-	-	8.0	A
SAT Overall	-	-	-	-	7.9	A	-	-	8.0	A

Table 7 shows that the proposed intersection of Whitney Road and the South Site Driveway will operate at LOS A in all cases with the existing lanes on Whitney Road and a proposed single lane westbound approach on the South Site Driveway.

US4/Hannah Dustin Drive

Table 8: US4 at Hannah Dustin Drive

	2019 Existing (1)		2021 No Build (2a)		2021 Build (2b)		2031 No Build (3a)		2031 Build (3b)	
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
AM Overall	0.1	A	0.1	A	0.1	A	0.1	A	0.1	A
PM Overall	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A
SAT Overall	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A

Due to the limit existing traffic on Hannah Dustin Drive, there is no change in intersection operations in Build conditions.

US4/Harris Hill Connector (Boscawen Roundabout)

Table 9: US4 at Harris Hill Connector (Boscawen Roundabout)

	2019 Existing (1)			2021 No Build (2a)			2021 Build (2b)			2031 No Build (3a)			2031 Build (3b)		
	v/c	**Delay**	**LOS**	**v/c**	**Delay**	**LOS**	**v/c**	**Delay**	**LOS**	**v/c**	**Delay**	**LOS**	**v/c**	**Delay**	**LOS**
AM Overall	0.74	8.2	A	0.76	8.8	A	0.78	9.3	A	0.89	13.4	B	0.92	15.3	C
PM Overall	0.80	11.6	B	0.82	12.4	B	0.86	14.6	B	0.93	19.3	C	0.99	27.0	D
SAT Overall	0.57	7.4	A	0.59	7.7	A	0.64	8.8	A	0.67	9.6	A	0.74	11.7	B

Table 9 shows that the existing roundabout at US4/Harris Hill Connector operates at LOS A in 2021 No Build and Build weekday AM and Saturday peak hour conditions and at LOS B in 2021 No Build and Build weekday PM peak hour conditions. For the weekday AM peak hour, Table 9 shows that the roundabout operates at LOS B under 2031 No Build and LOS C in 2031 Build conditions. For the Saturday peak hour, the roundabout operates at LOS A in 2031 No Build and LOS B in 2031 Build conditions. For the weekday PM peak hour, the roundabout operates at LOS C in 2031 No Build (v/c ratio of 0.93) and LOS D (v/c ratio of 0.99) in 2031 Build conditions. In the weekday PM peak hour, by 2031, the westbound approach will have even greater queues than currently observed due to the addition of Interchange Development traffic as well as the growth in background traffic.

We found that background traffic growth has a larger effect than Interchange traffic on delays and queues at the roundabout. In fact, background growth between 2021 and 2031 increases PM entering volumes by 13%, versus 8% from full build out of the Interchange Development. See Appendix S1, page 195 for diagram. Without background growth or the Whitney Road new extension, the roundabout would operate at a favorable LOS C in 2031 even in Interchange Full-Build conditions.

I93 Ramps

Table 10: US4 at I93 SB off-ramp

	2019 Existing (1)		2021 No Build (2a)		2021 Build (2b)		2031 No Build (3a)		2031 Build (3b)	
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
AM Overall	1.5	A	1.5	A	2.0	A	1.6	A	2.3	A
PM Overall	1.4	A	1.4	A	2.5	A	1.6	A	3.5	A
SAT Overall	1.5	A	1.5	A	2.5	A	1.7	A	3.2	A

Table 11: US4 at I93 NB on/off-ramp

	2019 Existing (1)		2021 No Build (2a)		2021 Build (2b)		2031 No Build (3a)		2031 Build (3b)	
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
AM Overall	2.7	A	2.7	A	2.9	A	2.8	A	3.1	A
PM Overall	4.6	A	4.6	A	7.6	A	5.3	A	12.5	B
SAT Overall	3.1	A	3.2	A	4.7	A	3.4	A	5.6	A

As shown in Tables 10 and 11, operating conditions were generally favorable for all scenarios at the I93 ramp intersections. At the northbound off-ramp, the SB left turn does experience a 70 sec delay in 2031 Build weekday PM conditions, however, the v/c ratio is 0.77 and the 95th percentile queue is estimated at six cars, therefore, there is little chance of backup onto the highway.

When analyzing left turn lane warrants for US4 at the I93 ramps (see Section 11. Lane Warrant Analysis), we found that all left turn on-ramp movements meet the thresholds for left turn treatment under 2021 No Build volumes. Theoretically, this could be satisfied by re-striping the left-most (inner) lanes to left-turn-only and tapering the through movements into the right lane. However, doing so does not create any operational advantage in terms of delay or capacity, the warrants are already met under existing conditions, and conditions are not significantly affected by development traffic. We based all opening and future year runs in this report on existing lane markings.

11. Turn Lane Warrant Analysis:

Lane warrant analysis was performed per NCHRP 457 for left turn lanes on US4 westbound at the existing I93 SB on-ramp and US4 eastbound at the NB on-ramp. Currently, both intersections are striped with a left-thru and a thru lane along US4. The calculations are for a 2-lane roadway at 85th percentile road speeds of 45 mph. See the calculation tables in the Appendix T1.

Left Turns. Figure 2-5, "Guidelines for determining the need for a major-road left-turn bay at a two-way stop-controlled intersection" shows that in the 2021 No Build scenario (i.e. without any Interchange Development), left turn treatments are warranted in all peak hour scenarios at both intersections.

If it is intended to meet the lane warrant conditions at the two on-ramp intersections, the left/thru lanes at these intersections could be re-striped to provide for exclusive left turns (markings are there already for the thru-only lane). Existing signage should be replaced to reflect the new lane usage.

12. Signal Warrant Analysis:

A signal warrant analysis was performed at the intersection of US4 and Whitney Road in accordance with MUTCD. Using the 12-hour count data that was collected on Wednesday May 30, 2018, the warrants were evaluated based on 2021 No Build conditions. In this case without any proposed developments, warrants 1B, 2 & 3 were met as shown in the table below. The calculated average daily trips for Interchange Phase 1 was added to the 2021 volumes and in this scenario, all three traffic volume warrants are also satisfied. See the signal warrant calculations in the Appendix Volume 1, Appendix R1.

MUTCD Warrants

2021 No Build										
		Approach Volumes (vph)			Volumes Used		MUTCD Warrants*			
Wednesday		US4		Whitney Rd						
Hour Begin		EB	WB	NB	Major St	Minor St	1A**	1B**	2**	3**
6:00	AM	790	357	146	1147	146	N	**Y**	**Y**	N
7:00	AM	1226	575	186	1801	186	N	**Y**	**Y**	**Y**
8:00	AM	752	495	140	1247	140	N	**Y**	**Y**	N
9:00	AM	537	530	117	1067	117	N	**Y**	N	N
10:00	AM	448	651	107	1099	107	N	**Y**	N	N
11:00	AM	442	402	105	844	105	N	**Y**	N	N
12:00	PM	727	439	113	1166	113	N	**Y**	N	N
1:00	PM	536	479	115	1015	115	N	**Y**	N	N
2:00	PM	575	647	139	1222	139	N	**Y**	**Y**	N
3:00	PM	681	829	143	1510	143	N	**Y**	**Y**	N
4:00	PM	710	1056	166	1766	166	N	**Y**	**Y**	**Y**
5:00	PM	565	1041	124	1606	124	N	**Y**	**Y**	N
[Hours Met] of [# Hours Required]=							0 of 8	12 of 8	7 of 4	2 of 1
Warrant Met:							**No**	**Yes**	**Yes**	**Yes**

13. Crash Analysis:

Crash data from NHDOT is included in Appendix U1, which is representative of the intersection-related accidents reported to the Department within the study area. The data shows that the number of accidents reported is only slightly less than the number of accidents that would be expected for an intersection of the same size as the intersection studied.

The crash data for the most recent 3-year period available (2015-2017) is summarized in the following table:

Table 12 – Crash Frequency

Location	Number of Crashes		Severity			Peak Hours
	Total	Average per Year				
US4 & Whitney Road	(3 years)	Annual	PD	PI	F	# (%) During Peak Hours
Actual Crashes*	8	2.7	2.7	0.7	0	1 (38%)
Expected Crashes**	9	3	--	--	--	---

*- based on NHDOT reported crashes 2015-2017
2015: 3 intersection accidents on Whitney Road (6 vehicles)
2016: 3 intersection accidents on Whitney/Old Boyce (7 vehicles)
2017: 2 intersection accident on Whitney Road (4 vehicles)

**- Based on Average Crash Rates, per Million Entering Vehicles (MassDot June 26, 2018) for unsignalized intersection: 0.57 crashes. [US4 at the Merrimack River 2018 ADT is = 14,159]

Note: NH does not have a published statewide average for accidents. MassDOT has worked with UMass Lowell to calibrate the crash modification factors for their state, therefore those values were used as a check for expected crashes at the study intersection.

14. Whitney Road Extension (Future Concept):
At the Scoping Meeting, it was agreed to investigate an additional scenario for future year conditions that includes traffic from a possible City extension of Whitney Road southward to Sewalls Falls Road. That scenario includes, in addition to Interchange buildout traffic, traffic generated by development of the approximately 100 acres currently owned by Newspapers of New England (Concord Monitor land), and 40 acres currently owned by the Regional Solid-Waste Resource Recovery Cooperative (Coop land) south of the existing terminus of Whitney Road.

Although these 140 acres are currently zoned “Industrial”, based on discussions with City staff, a hypothetical mixed-use development (Whitney Extension Development) was assumed to be located on these properties to provide a reasonably conservative estimate of potential future traffic generation. This development does not result from any specific intentions or proposals by the current landowners.

Whitney Extension Development (WED)
The Whitney Road Extension development was assumed to include the following components:

- ITE LUC 221 - Multifamily Housing (Mid-Rise): 350 Apartment Units
- ITE LUC 710 - General Office: 140,000 sf
- ITE LUC 130 - Industrial Park: 175,000 sf
- ITE LUC 760 – R&D Center: 115,000 sf (existing Concord Monitor Building)

In addition to the above, an allowance of 500 vehicles per day was included to represent “cut-through” trips on Whitney Road extension, consistent with the previous HDR analysis. This represents traffic using the new roadway extension with origins and destinations outside the study area.

The Mixed-Use Development concept for the Whitney Road Extension case is the result of several planning meetings with City staff. Although the zoning is currently “Industrial”, given the limited demand for raw industrial land in the foreseeable future, the City believes this prime riverfront land is better suited for a Mixed-Use development, which would include commercial, residential and light industrial components. The types and sizes of the trip generators used in this study were based on a conceptual layout plan reviewed by City staff that reflects a dense, but reasonable, build-out scenario.

The potential Whitney Road Extension is envisioned as a two-lane extension of Whitney Road from its current terminus at 14 Whitney Road south to Sewalls Falls Road. There will be access points on the east side for development of the Coop land and on the west side for the Concord Monitor land. While the exact nature and location of these future driveways is not known at this time, the volumes presented in this TIAS can guide the eventual design of these future intersections.

In the event Whitney Road Extension is constructed, the anticipated traffic, including through traffic and future development traffic will cause the intersection of Sewalls Falls Road and Whitney Road Extension to operate at LOS A in all future year 2031 Build conditions.

In the following tables, we summarize the effect of the WED traffic volumes on the Interchange Development Full Build proposal, and the combined effect of this interaction and resulting traffic volumes on all study area intersections.

These tables show that the US4/Whitney roundabout recommended for the Interchange Development will also accommodate the additional traffic related to the potential extension of Whitney Road, although in the 70/30 unbalanced lane utilization case, the 2031 AM scenario does approach failure.

WRE Analysis Cases

3b) 2031 Build R1 [IFB]: 2031 No-Build Volumes plus Interchange Full Build (IFB) with Roundabout at US4 & Whitney Road.
For Case 3b, the analysis was conducted with the intersections as shown in Figure E & Figure F in Section 9.

4a) 2031 WRE Build [IFB+WRE]: 2031 Interchange Full Build Volumes and Mitigation plus Whitney Extension Development (WED).
For Case 4a, the analysis was conducted with the intersections as shown in Figure E & Figure F in Section 9. No additional improvements proposed.

4b) 2031 WRE Build [IFB+WED] Mit R2: 2031 Interchange Full Build Volumes and Mitigation plus Whitney Extension Development (WED) and WRE Mitigation.
For Case 4b, the analysis was conducted with the intersections as shown in Figure F in Section 9. Additional improvements in this analysis include a single lane roundabout at the Interchange North Site Drive per Figure H below and an additional westbound thru lane at the Boscawen Roundabout per Figure I below.

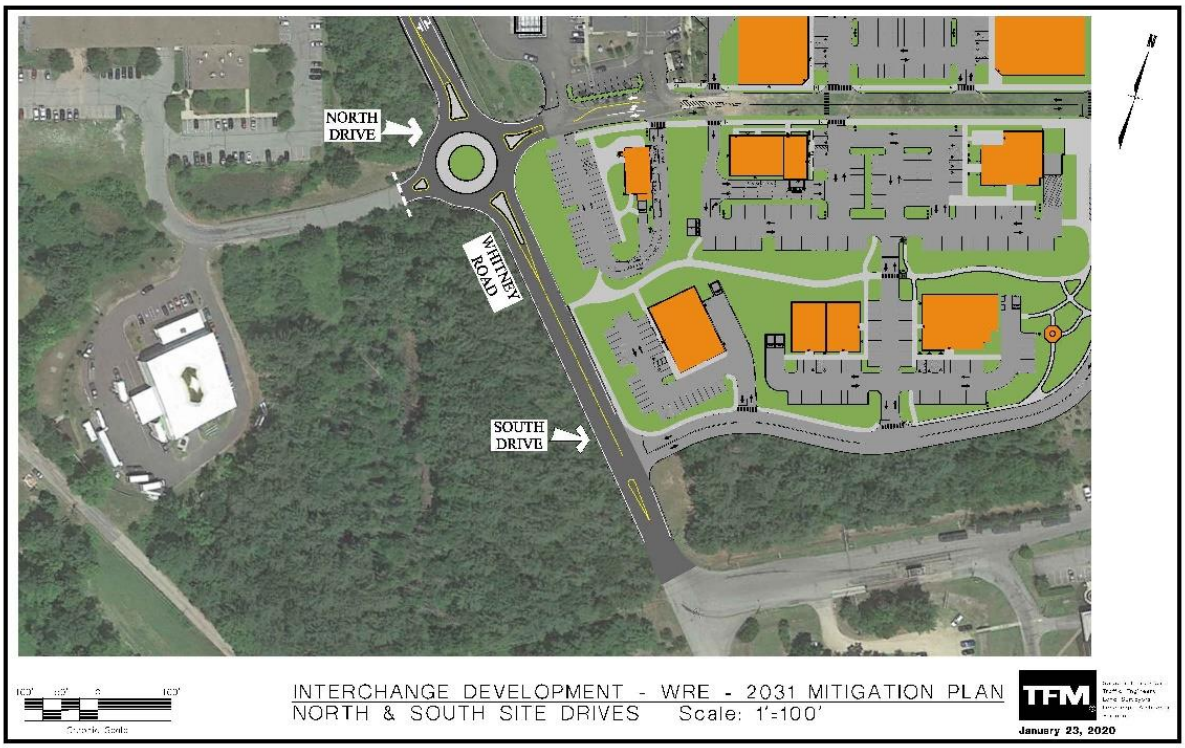


Figure H: Proposed Roundabout at North Site Drive

Figure I: Roundabout Mitigation at Boscawen for Future Whitney Road Extension Development.

Analysis Results

WRE Table 13: US4 at Whitney Road / Old Boyce Road *[Prop. US4 Roundabout]*

	2031 IFB Build (3b)			2031 WRE Build (4a)			2031 WRE Build MIT (4b)		
	v/c	**Delay**	**LOS**	**v/c**	**Delay**	**LOS**	**v/c**	**Delay**	**LOS**
AM Overall	0.69	12.3	B	0.80	16.1	C	Same as 4(a)		
PM Overall	0.72	13.9	B	0.74	14.7	B			
SAT Overall	0.69	11.7	B	0.57	11.7	B			

WRE Table 14: Whitney Road at Interchange North Site Drive / Concord Crossing *[3b & 4a Existing Stop Controlled Intersection, 4b Prop. Roundabout]*

	2031 IFB Build (3b)		2031 WRE Build (4a)		2031 WRE Build MIT (4b)		
	Delay	**LOS**	**Delay**	**LOS**	**v/c**	**Delay**	**LOS**
AM Overall	7.7	A	6.9	A	0.51	7.1	A
PM Overall	49.8	E	77.8	F	0.57	10.4	B
SAT Overall	65.8	F	79.4	F	0.64	10.8	B

WRE Table 15: Whitney Road at Interchange South Site Drive

	2031 IFB Build (3b)		2031 WRE Build (4a)		2031 WRE Build MIT (4b)	
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
AM Overall	6.6	A	2.4	A	Same as 4(a)	
PM Overall	8.0	A	5.1	A		
SAT Overall	8.0	A	5.7	A		

WRE Table 16: US4 at Hannah Dustin Drive

	2031 IFB Build (3b)		2031 WRE Build (4a)		2031 WRE Build MIT (4b)	
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
AM Overall	0.1	A	0.1	A	Same as 4(a)	
PM Overall	0.0	A	0.0	A		
SAT Overall	0.0	A	0.0	A		

WRE Table 17: US4 at Harris Hill Connector (Boscawen Roundabout)

	2031 IFB Build (3b)			2031 WRE Build (4a)			2031 WRE Build MIT (4b)		
	v/c	**Delay**	**LOS**	**v/c**	**Delay**	**LOS**	**v/c**	**Delay**	**LOS**
AM Overall	0.92	15.3	C	0.93	15.9	C	0.93	15.1	C
PM Overall	0.99	27.0	D	0.99	27.4	D	0.60	7.5	A
SAT Overall	0.74	11.7	B	0.74	11.6	B	0.71	8.1	A

Table 19: US4 at I93 NB on/off-ramp

	2031 IFB Build (3b)		2031 WRE Build (4a)		2031 WRE Build MIT (4b)	
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
AM Overall	3.1	A	3.3	A	Same as 4(a)	
PM Overall	12.5	B	17.7	C		
SAT Overall	5.6	A	6.3	A		

Table 20: Sewalls Falls Road at Whitney Road Extension

	2031 IFB Build (3b)		2031 WRE Build (4a)		2031 WRE Build MIT (4b)	
	Delay	**LOS**	**Delay**	**LOS**	**Delay**	**LOS**
AM Overall	-	-	2.7	A	Same as 4(a)	
PM Overall	-	-	2.9	A		
SAT Overall	-	-	3.1	A		

The above analyses assume even (50/50) lane utilization of the eastbound and northbound approach lanes. We also performed a sensitivity analysis with greater volumes favoring the right lanes (60/40 and 70/30) due to downstream traffic heading to the I93 SB on-ramp.

In opening year AM and all PM, and SAT cases, the 60/40 and 70/30 utilizations show similar benefits for the roundabout option over the signal option. In the future year AM case, the EB roundabout queue lengthens, however the other benefits (total volume processed, emissions, and safety) continue to favor the roundabout.

15. Recommendations:

US4/Whitney Road

The results of the capacity analysis show that the US4/Whitney Road intersection will require the construction of either a roundabout or traffic signal with added lanes on US4 and Whitney Road in order to accommodate the proposed Interchange Development traffic. In addition to its recognized safety advantages, a roundabout was shown to generally operate at better levels of service, with shorter queues and delays, and generate less carbon emissions than the traffic signal option. Our analysis shows that the roundabout will also accommodate the potential Whitney Road Extension development, although it does show some sensitivity to EB lane utilization ratio. Therefore, it is recommended that a two-lane roundabout be installed at US4/Whitney Road in the opening year.

Whitney Road/Site Driveways

The proposed South Site Driveway at Whitney Road is expected to operate at favorable levels of service in all peak hours. The existing Concord Crossing driveway opposite the North Site Driveway will experience increased delays due to the Interchange Development traffic, and these delays will increase further if Whitney Road Extension is built. We recommend construction of a single-lane roundabout the North Site Drive intersection if the City decides to move forward with the Whitney Road Extension.

We considered earlier construction of this roundabout as part of the Interchange Development; however, this will increase total delays for all intersection traffic, which should be weighed against minor benefits to the exiting Concord Crossing traffic. However, the timing of this roundabout can be reassessed after Phase I is complete and determine if actual traffic conditions warrant an earlier implementation.

US4/Harris Hill Connector (Boscawen Roundabout)

The existing roundabout at US4/Harris Hill Connector was found to operate at acceptable levels of service in all cases; however, by 2031, in the weekday PM peak hour, the westbound approach is near capacity and will experience greater delays than currently observed.

We considered the effect of second westbound through lane through the roundabout, which would significantly improve PM peak hour operations and queues, however, this improvement would have little effect in the weekday AM peak hour on eastbound delays and queues with or without Interchange Development traffic.

We found that background traffic growth has a larger effect than Interchange traffic on delays and queues at the roundabout. In fact, background growth between 2021 and 2031 increases PM entering volumes by 13%, versus 8% from full build out of the Interchange Development. Without background growth or the Whitney Road new extension, the roundabout would operate at a favorable LOS C in 2031 even in Interchange Full-Build conditions.

Since the addition of a second westbound lane through the Boscawen roundabout would primarily serve to accommodate regional traffic growth, we recommend that consideration be given to adding this improvement to the NHDOT Ten-Year Plan.

I93 Ramps

For the I93 ramp intersections, operating conditions were generally favorable for all scenarios. Left turn lane warrant calculations show that NB and SB on-ramp left turn movements do meet

the thresholds for left turn treatment on US4 under 2021 No Build volumes. This could be satisfied by re-striping the left-most (or “inside lane”) lane to left turn only and taper all thru movements to the right lane (“outside lane”). We also understand the NHDOT is considering changing the SB on-ramp configuration as a safety improvement to reduce turning traffic speed.

However, these improvements do not create any operational advantages in terms of delay or capacity and the conditions are not significantly affected by the proposed Interchange development traffic. We therefore see these items as discretionary issues for NHDOT.

Summary

Based on the foregoing, we find that the roadway network, with the phased mitigation measures discussed herein, can safely accommodate the traffic generated by the Interchange Phase 1 and Full Buildout development proposals.

We also find that the US4/Whitney Road roundabout recommended for the Interchange Development can accommodate the additional traffic related to the potential southward extension of Whitney Road, should that project come to fruition as anticipated.

Respectfully Submitted,
TFMORAN, INC.

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