



The Hills Shire

Castle Hill South Traffic Study

Traffic Assessment Report

December 2017

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Traffic Assessment Report

Quality Assurance Statement

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1.Introduction

1.1 Background

The construction of the Sydney Metro Northwest line between Chatswood and Rouse Hill includes a major bus-rail interchange at Castle Hill. These major public transport facilities have provided the Hills Shire Council (**Council**) with the opportunity to plan for increased residential density within an 800m radius from the proposed Castle Hill Station.

Council has engaged TDG in association with Gennaoui Consulting to undertake a traffic study to assess the implications of potential developments within the Castle Hill South area, with particular emphasis on accessibility, roadway capacity and intersection operations.

1.2 Site Location and Study Area

The study area shown in **Figure 1** is generally bounded by Old Northern Road to the west, Old Northern Road and Brisbane Road to the north, Francis Street to the south, and Cecil Avenue to the east.

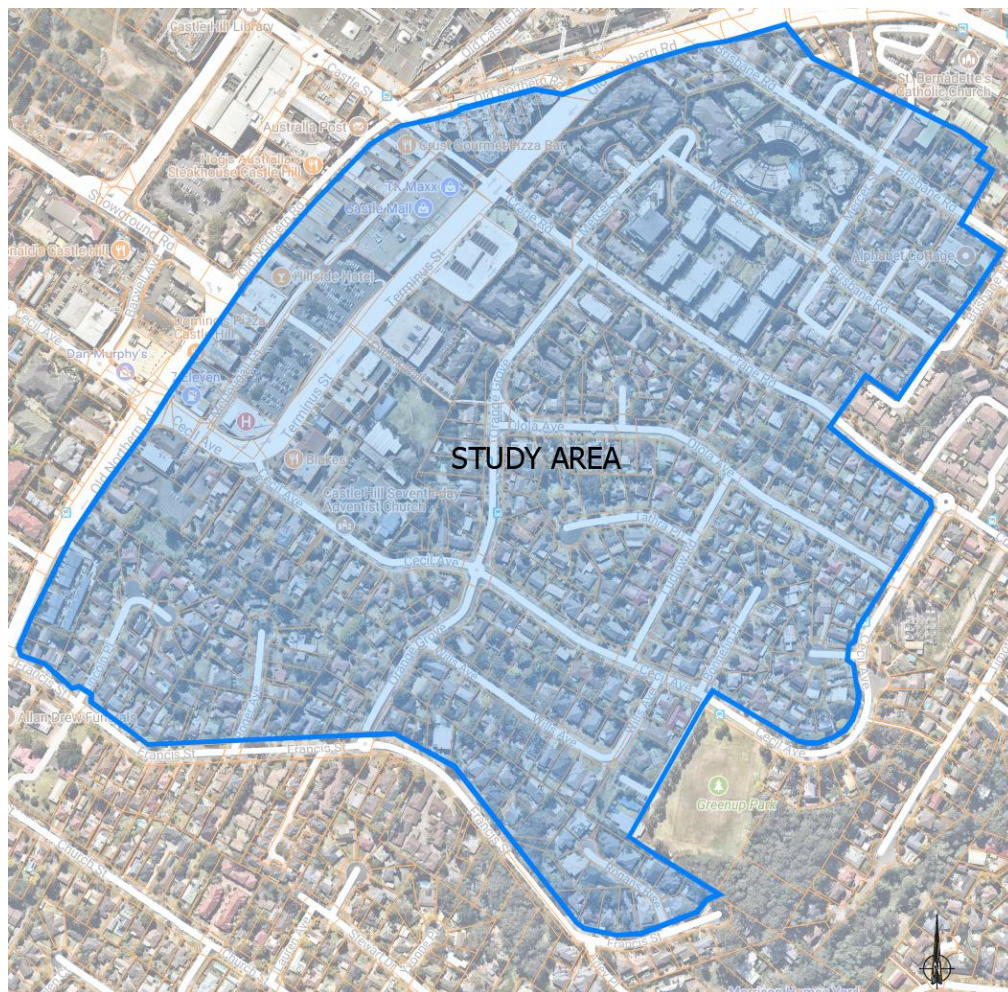


Figure 1: Study Area

1.3 Project Objectives

- Improve safety and efficiency of access to side streets; and
- Improve local and through access by controlling or limiting access points.

1.4 Project Scope and Methodology

The project identifies possible road widening options, intersection improvements such as turn lanes, and appropriate traffic controls for all roads and critical intersections within the study area illustrated in Figure 1. Intersection configuration options include traffic signals or roundabouts. The study was carried out in the following three stages:

1.4.1 Stage 1 – Data Collection

- Recording data and collation of data;
- Review of all available relevant reports;
- Carry out traffic volume counts at a number of critical intersections to supplement existing information;
- Obtain the potential land uses within the study area including the potential number of additional residential units from Council's planning department.

1.4.2 Stage 2 – Future Traffic Conditions

- Determine trip generation of all potential developments;
- Assign traffic generation to the existing road network to establish future traffic volumes along the main arterial, sub-arterial and collector roads within the study area, and of critical intersections;
- Assessment of roadway capacity and SIDRA analysis of all critical intersections to establish intersection capacity, degree of saturation and layout requirements.

1.4.3 Stage 3 – Strategic Recommendations

- Formulation of strategic solutions to cater for additional traffic and minimise potential traffic impacts on the existing road network.

1.5 Scope of Report

This report summarises the findings, conclusions and recommendations with respect to the traffic impacts of the potential developments on the surrounding road network.

2.Existing Conditions

2.1 Road Network

2.1.1 Major Approach Roads

The major access route to the study area is provided by the by-pass route along Terminus Street and Cecil Avenue which connects to Old Northern Road and Showground Road. The direct access to and from the area will be via Cecil Avenue; Orange Street and Crane Road would also be used. The road network has the following key features:

- The route along Terminus Street and the section of Cecil Avenue, between Terminus Street and Old Northern Road, has a four-lane divided carriageway with turning lanes at all signalised intersections along this route.
- Cecil Avenue, east of Terminus Street, has a 10.0m wide carriageway, with parking permitted on both sides of the road.
- East of Terminus Street, Crane Road has a 10.0m wide carriageway.
- Orange Grove has a narrower 9.0m carriageway.
- Traffic to and from Cecil Avenue, east of Terminus Street is restricted by a median along the by-pass route to left turning in and out only.
- Traffic to and from the south may use Roger Avenue and Francis Street to access Old Northern Road. Francis Street has a 10m carriageway with parking permitted on both sides. Roger Avenue has a narrower carriageway, between 6 and 7 m in width. Francis Street is controlled by a Stop Sign. A pedestrian refuge assists pedestrians crossing Francis Street.
- Traffic signals control the intersection of the Cecil Avenue with Old Northern Road, and the intersections of Terminus Street with the access to Council's car park and with Crane Street.
- A one lane circulating roundabout is provided at the intersection of Cecil Avenue with Orange Grove.

2.2 Operation of Existing Road System

2.2.1 Traffic Counts

The existing traffic volumes in the study area were obtained from counts carried out between December 2016 and August 2017 at the following intersections (existing intersection control in brackets):

- Old Northern Road with Castle Street and Crane Road (traffic signals);
- Old Northern Road with Cecil Avenue (traffic signals);
- Terminus Street with Crane Road (traffic signals);
- Orange Grove with Francis Street (roundabout);
- Orange Grove with Cecil Avenue (roundabout);

- Cecil Avenue with Terminus Street (unsignalised);
- Francis Street with Roger Avenue (unsignalised);
- Old Northern Road with Brisbane Road (unsignalised);
- Old Northern Road with Church Street (unsignalised);
- Old Northern Road with Francis Street (unsignalised); and
- Orange Grove with Crane Street (unsignalised).

These counts were carried out during the weekday morning (7:00 to 9:00 am) and afternoon (between 4:00 and 6:00 pm) peak periods. Over the entire study area, the collective peak hours were found to occur between 8:00 and 9:00 am during the morning period, and from 4:30 to 5:30 pm during the afternoon period.

These counts were supplemented by earlier counts at the following signalised intersections:

- Old Northern Road with McMullen Avenue (Gennaoui, 2010);
- Old Northern Road with Showground Road (Brown, 2014); and
- Terminus Street with Car Park Access (Gennaoui, 2012).

The peak hour volumes at these intersections are presented in **Figure 2** and **Figure 3** for both the morning and afternoon peak hours respectively.

2.2.2 Operation of Major Approach Roads

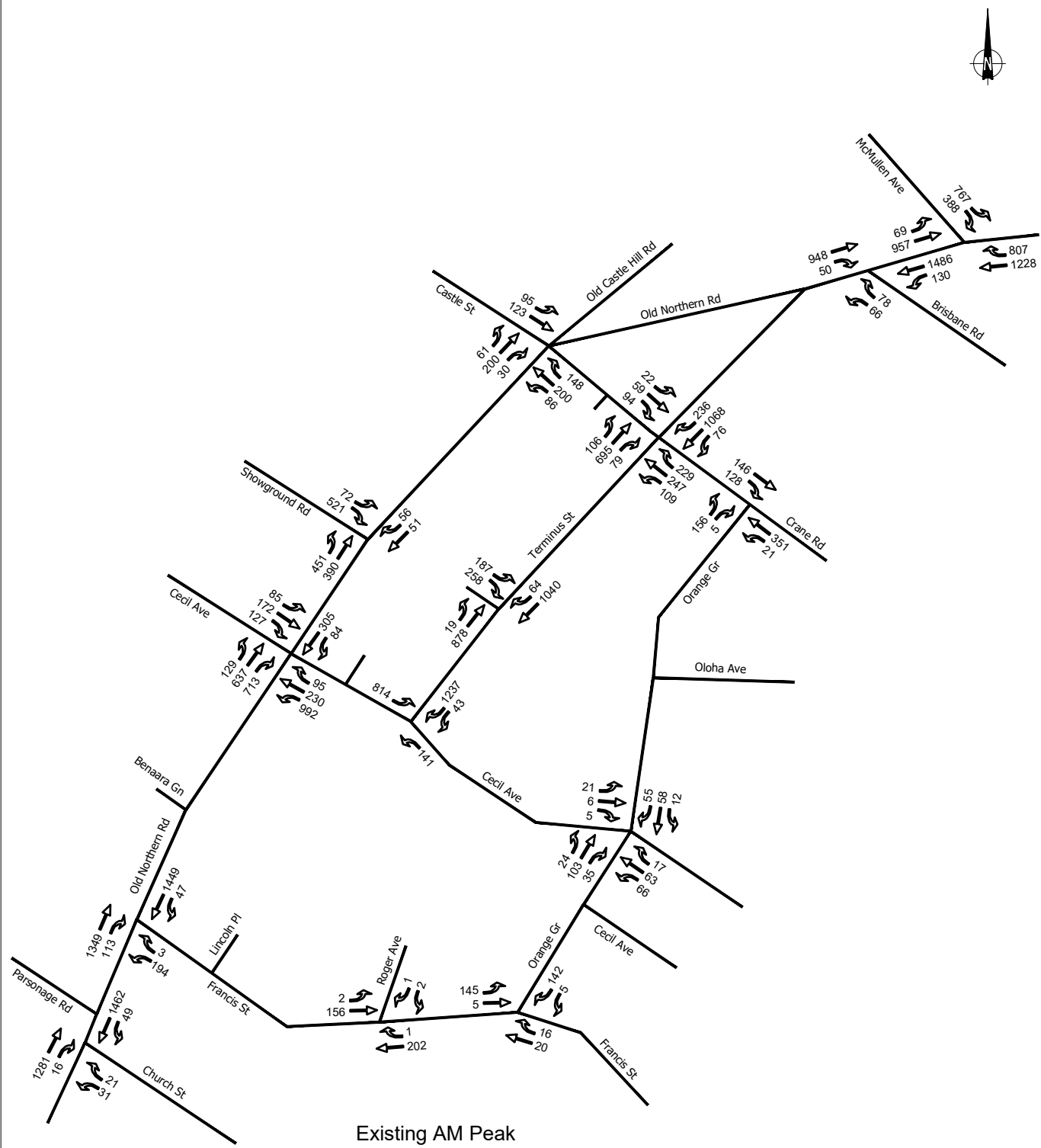
The concepts of carriageway capacity and Level of Service (LoS) are discussed in **Appendix A** together with criteria for their assessment.

The absence of major traffic movements entering/crossing from major developments along Terminus Street, Old Northern Road, south of Cecil Avenue and east of Terminus Street, and Crane Street between Terminus Street and Old Northern Road, means that the service one-way hourly volumes for uninterrupted traffic included in Table A2 of **Appendix A** could be used; all other streets were assessed based on the service one-way hourly volumes for interrupted traffic included in Table A1 of **Appendix A**.

2.2.3 Existing Operation of Major Approach Roads

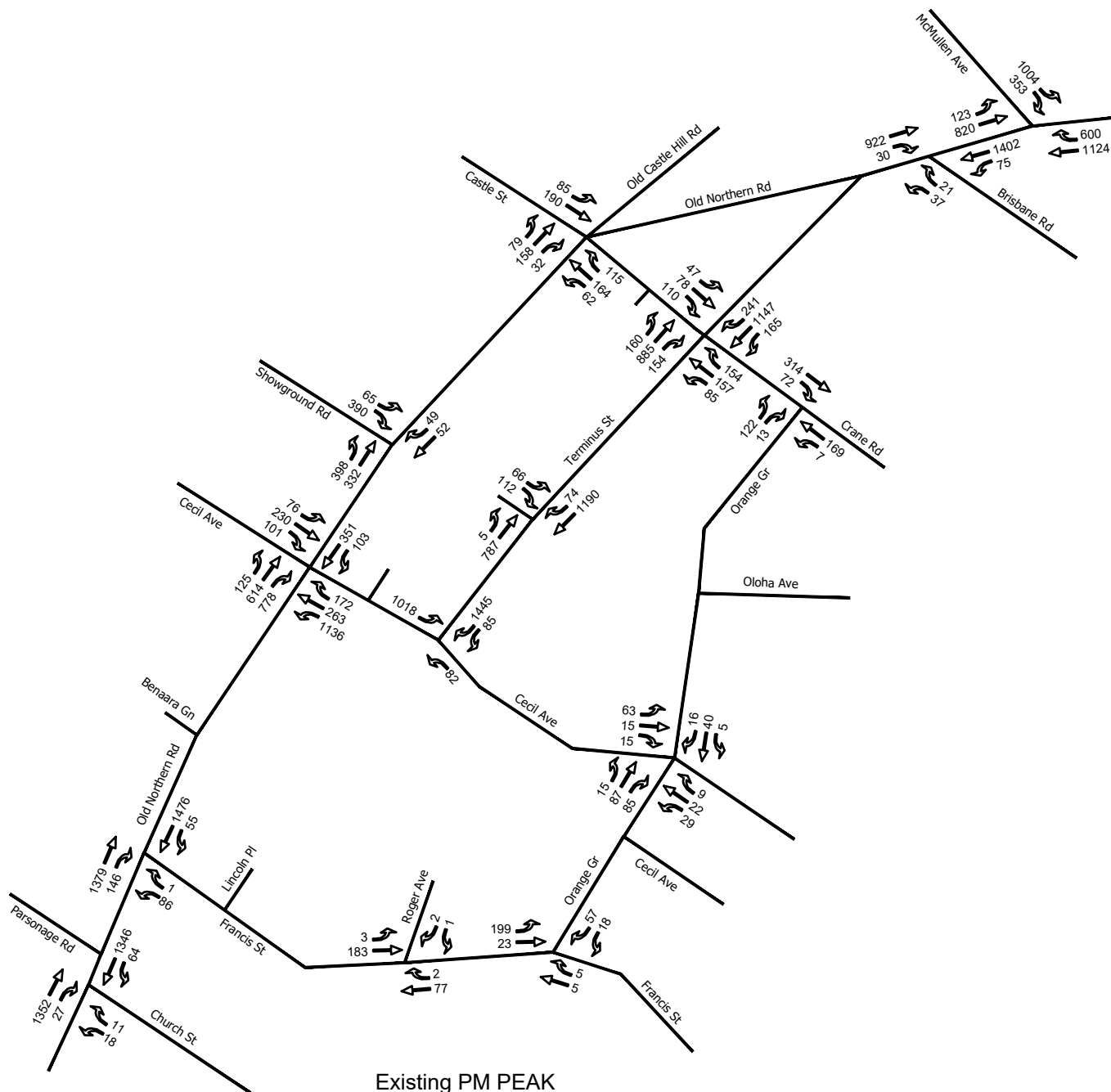
The existing traffic volumes along Terminus Street, Cecil Avenue, Old Northern Road and Crane Road are summarised below in **Table 1**, together with their appropriate level of service. Existing volumes along a number of other streets are also included.

Thursday, 28 September 2017 20mm



Existing AM Peak
7:30 - 8:30am

Thursday, 28 September 2010 20mm



Existing PM PEAK
4:00 - 5:00pm

Castle Hill South - Traffic Study

Existing PM Peak Hour Traffic Volumes



3

SCALE: NTS

LOCATION	LANES	AM PEAK			PM PEAK		
		East/North	South/West	LoS	East/North	South/West	LoS
Interrupted Flow Conditions - (Table A1 of Appendix A)							
Brisbane Road							
South of Old Northern	4U	144	180	A	58	105	A
Castle Street							
West of Old Northern	2U/1U	218	261	A	275	243	A
Crane Road							
East of Terminus	1U/2U	214	585	A	397	396	A
East of Orange Grove	4UP	151	372	A	327	176	A
Cecil Avenue							
East of Orange Grove	4UP	53	147	A	105	60	A
East of Terminus	4UP	43	141	A	95	82	A
West of Old Northern	4U	384	359	A	407	388	A
Church Street							
East of Old Northern	2U	65	52	A	91	29	A
Francis Street							
East of Old Northern	4UP	160	197	A	201	87	A
East of Roger Avenue	4UP	158	203	A	184	79	A
Old Northern Road							
North of Cecil Avenue	4U	817	389	A	862	454	A
South of Castle Street	2U	291	86	A	269	62	A
Orange Grove							
South of Crane Street	4UP	161	149	A	135	79	A
North of Cecil Ave	4UP	144	128	A	162	64	A
South of Cecil Ave	4UP	162	129	A	187	84	A
Roger Avenue							
North of Francis Street	2U	1	3	A	5	3	A
Uninterrupted Flow Conditions - Table A2 of Appendix A							
Cecil Avenue							
East of Old Northern	4DC	969	1,317	A	1,111	1,571	A
Crane Road							
West of Terminus	4UC	175	589	A	235	558	A
Old Northern Road							
South of Francis Street	4UC	1462	1,643	B	1,525	1,562	B

LOCATION	LANES	AM PEAK			PM PEAK		
		East/North	South/West	LoS	East/North	South/West	LoS
South of Cecil Avenue	4UC	1479	1,424	A	1,517	1,588	B
West of Brisbane	4DC	998	1552	A	952	1439	A
Terminus Street							
North of Cecil Avenue	4DC	814	1,237	A	1,018	1,540	A
South of Crane Street	4DC	880	1,271	A	1,199	1,342	A
North of Crane Street	4DC	946	1,380	A	1,086	1,553	A

Table 1: Existing Carriageway Level of Service

4DC 4 lanes divided carriageway with clearway (Uninterrupted flow conditions of Appendix A)
 4UC 4 lanes undivided carriageway with clearway
 4U 4 lanes undivided carriageway with some parking
 2U 2 lanes undivided carriageway

Currently Old Northern Road operates at a good level of service “B” or better. All other roads operate at a very good Level of Service “A”.

2.2.4 Operation of Existing Critical Intersection

The concepts of intersection capacity and level of service, as defined in the Guidelines published by the RTA (Road and Traffic Authority Guidelines of New South Wales, now Roads and Maritime Services (RMS) (2002), are discussed in **Appendix B** together with criteria for their assessment. The assessment of the level of service of traffic signals is based on the evaluation of the average delay (seconds per vehicle) of vehicles on all approaches. The assessment of the level of service of roundabouts and signed controlled intersections is based on the average delay (seconds per vehicle) of the critical movement.

An analysis of the operation of all critical intersections within the study area was carried out using the SIDRA computer modelling program. The results of this analysis are summarised in Table 2.

All signalised intersections currently operate at a satisfactory level of service “C” or better during both the morning and the afternoon peak hours.

The roundabouts controlling the intersection of Orange Grove with both Cecil Avenue and Francis Street operate at a very good level of service “A” during the morning and afternoon peak periods.

The right turning movements from Old Northern Road into Francis Street experience very high delays whilst waiting for a gap in the large volume of southbound traffic along Old Northern Road, resulting in a very poor level of service “F”. The banning of the right turning movement onto Francis Street from Old Northern Road is not possible, as it is the only direct access to a very large residential area east of Old Northern Road.

The right turning movement from Francis Street onto Old Northern Road is very difficult due to the considerable volume of southbound traffic. The installation of traffic signals would resolve this existing problem and should seriously be considered by Council.

INTERSECTION	AM		PM	
	Delay sec/v	LoS	Delay sec/v	Los
Traffic Signals				
Old Northern Road with Castle Street / Crane Road	23.7	B	23.5	B
Old Northern Road with Cecil Avenue	29.3	C	39.6	C
Old Northern Road with McMullan Avenue	22.2	B	24.7	B
Old Northern Road with Showground Road	20.8	B	17.9	B
Terminus Street with Crane Street	42.3	C/D	37.1	C
Terminus Street with Access to Car Park	15.3	B	13.2	A
Roundabout				
Orange Grove with Cecil Avenue	8.9	A	9.10	A
Orange Grove with Francis Street	8.2	A	7.7	A
T-Junctions				
Cecil Avenue with Terminus Street	11.6	A	12.5	A
Francis Street with Roger Avenue	6.2	A	5.6	A
Old Northern Road with Brisbane Road	>70	F	>70	F
Old Northern Road with Church Street	>70	F	>70	F
Orange Grove with Crane Road	9.0	A	8.4	A
Old Northern Road with Francis Street	>70	F	>70	F

Table 2: Existing Operation of Intersections

The right turning movement from Church Street onto Old Northern Road is also very difficult, resulting in a very poor level of service “F”. On-site observations suggest that there are a number of courtesy gaps that become available, especially due to the presence of the Old Northern Road / Kerrs Road signalised intersection approximately 70m to the south. This is not reflected within the SIDRA model, however it remains evident that there are still very large delays for right turning vehicles from Church Street onto Old Northern Road.

The right turning movement from Brisbane Road onto Old Northern Road is also very difficult, resulting in a very poor level of service “F”. Nevertheless, a small number of vehicles make this movement taking advantage of the gaps in traffic generated by the signals at McMullen Avenue, and the ‘Keep Clear’ designation in the eastbound direction of Old Northern Road.

The remaining intersections operate at a very good level of service “A”.

3. Traffic Impact Assessment

3.1 Potential Development in Castle Hill South

Council's Planning Section have provided the potential floor area for each major property within the study area. The study area has been divided into 13 zones by TDG for the purposes of traffic distribution, as shown in **Figure 4**.

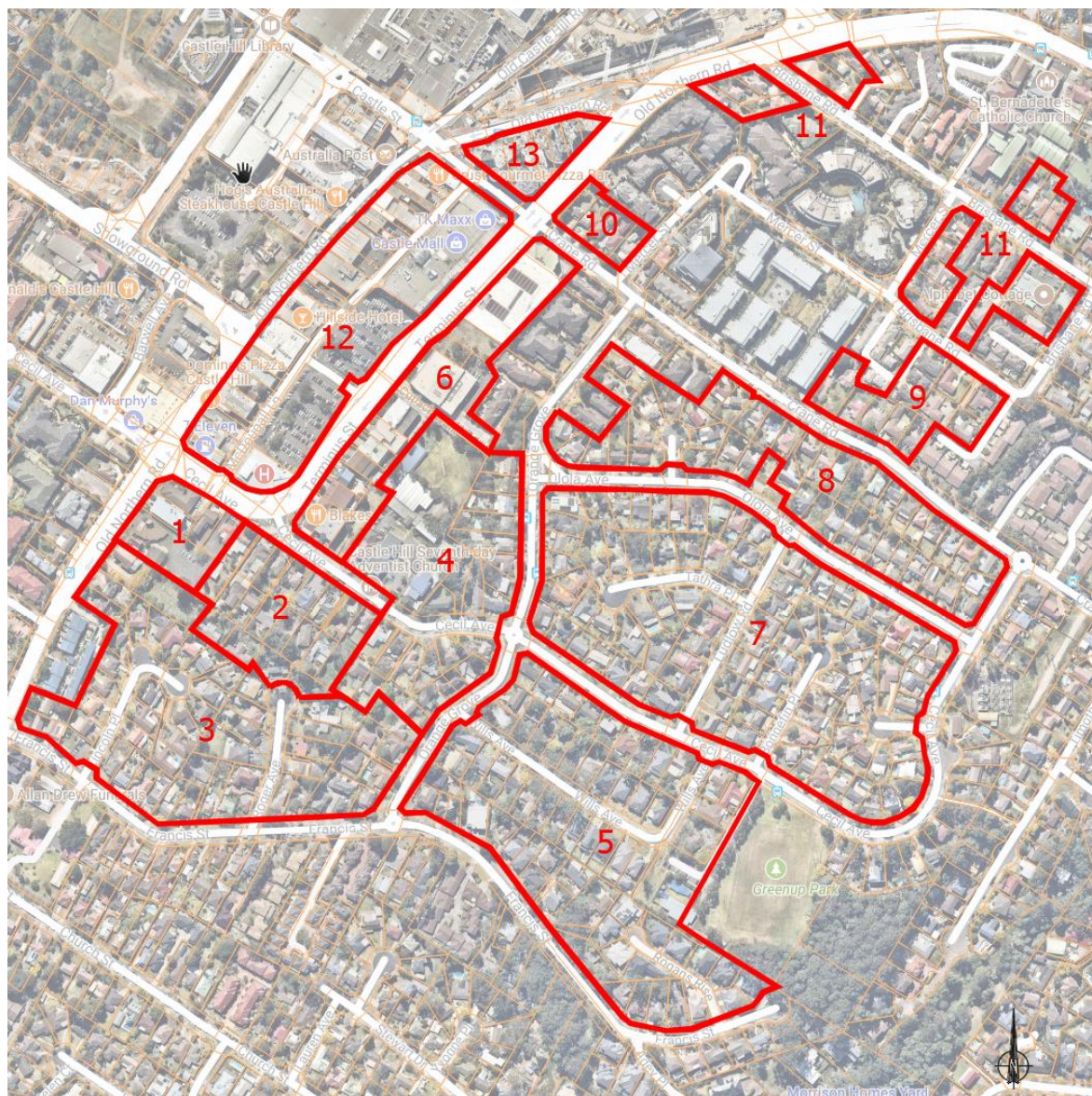


Figure 4: Designated Development Zones

Potential growth for retail, office and residential land uses are detailed in **Appendix C** and summarised in **Table 3**. The largest proportion of developments in the study area is high density residential buildings, comprising approximately 3,400 apartments.

Approximately 37,240 m² GFA of offices could be provided within the study area, mostly in Zones 2, 6 and 12, either side of Terminus Street. Approximately 21,850 m² GFA of retail is also anticipated.

Zone No	Block No	Retail m ² GFA	Office m ² GFA	Additional Dwellings
1	1	0	3,706	109
2	2 **	810	8,000	442
3	3 & 5	0	0	379
4	4 & 9	0	0	414
5	7 & 8	0	0	220
6	6	15,536	15,536	0
7	10 & 11	0	0	377
8	12, 13 & 14	0	0	382
9	15	0	0	84
10	16	0	0	74
11	17, 18,19, 20 & 21	0	0	152
12	22 *	5,500	10,000	351
13	Crane Rd Target Site			378
		21,846	37,241	3,363

Table 3: Potential Development in Castle Hill South

*source: Gennaoui, 2012

**source: Gennaoui, 2017

3.2 Peak Hourly Trip Generation and Distribution

3.2.1 Trip Generation of Proposed Developments

The trip generations of the potential development within the study area were estimated as follows:

- **Residential:** The RMS Technical Directive 04a (2013) indicates that the average trip generation rates for high density residential buildings near railway stations is an average of 0.19 trips/unit, based on a range of 0.07 to 0.32 trips/unit (from eight high density buildings) during the morning peak hour. During the afternoon peak hour, the average trip generation rate is 0.15 vehicle trips/unit, based on a range of 0.06 to 0.41 trips/unit.

The 85% rates of 0.28 trips/unit and 0.18 trips/unit have been adopted to estimate the trip generation during the morning and afternoon peak hours of the proposed high density residential buildings, respectively.

- **Office:** The latest trip generation rates published by the RMS (TD) for office developments are 1.6 and 1.2 trips per 100 m² GFA for the morning and afternoon peak hours respectively. These rates were used to estimate the trip generation of the office component of the potential development.
- **Retail:** The trip generation rates determined in the Norwest Business Park Master Plan Study (Gennaoui, 2003) for retail developments of 9.0 trips per 100 m² GFA for the afternoon peak hour were used to estimate the trip generation of this land use. A trip generation rate equivalent to 50 percent (4.5 trips per 100m² GFA) of the afternoon peak was adopted for the morning peak hour.

The study area is expected to generate about 2,520 and 3,020 vehicle trips during the morning and afternoon peak hours respectively, as noted in **Table 4** below:

Zone No	AM PEAK				PM PEAK			
	Residential	Retail	Office	Total	Residential	Retail	Office	Total
	Two Way	Two Way	Two Way	Two Way	Two Way	Two Way	Two Way	Two Way
1	31	0	59	90	20	0	44	64
2	124	36	128	288	80	73	96	248
3	106	0	0	106	68	0	0	68
4	116	0	0	116	75	0	0	75
5	62	0	0	62	40	0	0	40
6	0	699	249	948	0	1398	186	1585
7	105	0	0	105	68	0	0	68
8	107	0	0	107	69	0	0	69
9	23	0	0	23	15	0	0	15
10	21	0	0	21	13	0	0	13
11	43	0	0	43	27	0	0	27
12	98	248	160	506	63	495	120	678
13	106	0	0	106	68	0	0	68
Total	942	983	596	2,520	605	1,966	477	3,018

Table 4: Estimated Trip Generation of Potential Developments in Castle Hill South

3.2.2 Trip Distribution and Assignment

The route distribution for approaching and departing traffic, included in **Table 5** was adopted to assign the traffic generated by the potential developments within the study area to the road network.

ORIGIN	ROUTE	PERCENTAGES			
		AM Peak		PM Peak	
		Arriving	Departing	Arriving	Departing
East	Old Northern Road / Brisbane Road	35.0%	35.0%	35.0%	35.0%
West	Cecil Avenue / Old Northern Road	15.0%	15.0%	15.0%	15.0%
	Showground Road / Old Northern Road	15.0%	15.0%	15.0%	15.0%
	Castle Street / Old Northern Road	10.0%	5.0%	10.0%	5.0%
North	Old Castle Hill Road / Castle Street	0.0%	5.0%	0.0%	5.0%
South	Old Northern Road / Francis Street	25.0%	25.0%	25.0%	25.0%
Total		100.0%	100.0%	100.0%	100.0%

Table 5: Peak Trip Distribution for Castle Hill South Potential Developments

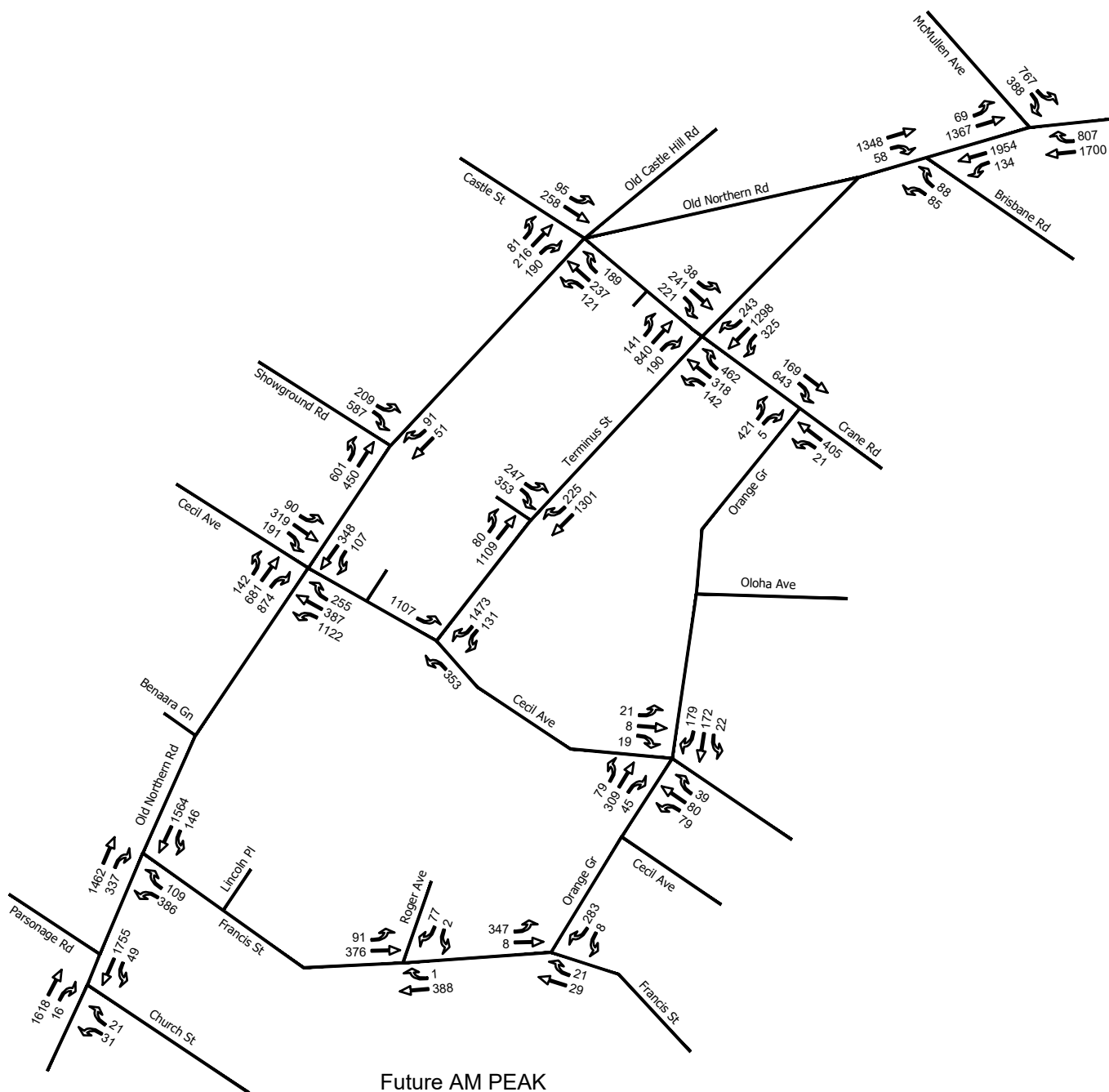
The distribution in Table 5Error! Reference source not found. was then applied to the trips generated by each zone of the study area to derive the origin and distribution of trips presented in **Table 6** and detailed in **Appendix D**.

ORIGIN	ROUTE	PERCENTAGES			
		AM Peak		PM Peak	
		Arriving	Departing	Arriving	Departing
East	ONR east Brisbane	472	410	502	554
West	Cecil west of ONR	202	176	215	237
	Showground west ONR	202	176	215	237
	Castle west ONR	135	59	144	79
North	Old Castle Hill	0	59	0	79
South	ONR / Francis	337	293	359	396
Total		1,349	1,171	1,436	1,583

Table 6: Directional Peak Trip Distribution for Castle Hill South Potential Developments

The trips were then assigned to the overall road network. The resultant volumes at all relevant intersections within the Study Area are presented in **Figure 5** and **Figure 6** for the morning and afternoon peak hour respectively.

Thursday, 28 September 2010 20mm



Future AM PEAK
7:30 - 8:30am

Castle Hill South - Traffic Study

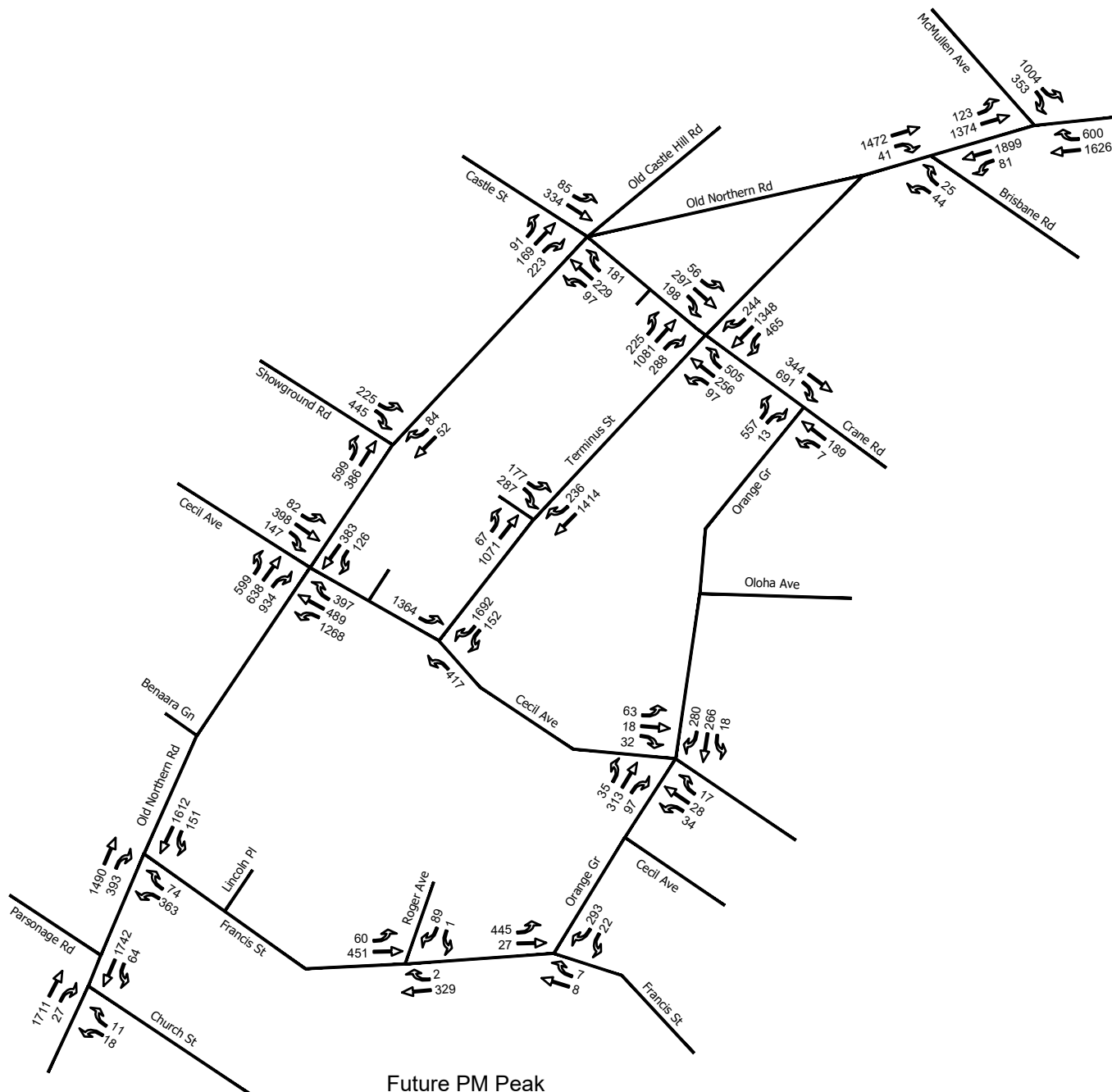
Future AM Peak Hour Traffic Volumes



5

SCALE: NTS

Thursday, 28 September 2010 20mm



Castle Hill South - Traffic Study

Future PM Peak Hour Traffic Volumes



6

SCALE: NTS

3.3 Traffic Impact of Proposed Development

3.3.1 Impact on Major Approach Roads

The carriageway traffic volumes along all approach roads and most roads within the study area at full development are summarised in **Table 7**, together with their appropriate level of service.

LOCATION	LANES	AM PEAK			PM PEAK		
		East/North	South/West	LoS	East/North	South/West	LoS
Interrupted Flow Conditions							
Brisbane Road							
South of Old Northern	4U	173	192	A	69	122	A
Castle Street							
West of Old Northern	2U/1U	373	318	A	419	320	A
Crane Road							
East of Terminus Street	1U/2U	756	922	F	1050	858	F
East of Orange Grove	4UP	174	426	A	357	196	A
Cecil Avenue							
East of Orange Grove	4UP	75	198	A	133	79	A
East of Terminus Street	4UP	131	353	A	152	417	A
West of Old Northern	4U	600	529	A	627	619	A
Church Street							
East of Old Northern	2U	65	52	A	91	29	A
Francis Street							
East of Old Northern	4UP	483	495	A	544	437	A
East of Roger Avenue	4UP	378	389	A	452	331	A
Old Northern Road							
North of Cecil Avenue	4UC	1026	455	A	1117	509	B
South of Castle Street	2U	487	121	A	483	97	A
Orange Grove							
South of Crane Street	4UP	426	664	C	570	698	C
North of Cecil Avenue	4UP	372	376	A	396	567	B
South of Cecil Avenue	4UP	433	270	A	445	332	A
Roger Avenue							
North of Francis Street	2U	92	79	A	62	90	A

LOCATION	LANES	AM PEAK			PM PEAK		
		East/North	South/West	LoS	East/North	South/West	LoS
Uninterrupted Flow Conditions							
Cecil Avenue							
East of Old Northern Road	4DC	1300	1,764	B	1,458	2,154	D
Crane Road							
West of Terminus Street	4UC	500	702	A	551	725	A
Old Northern Road							
South of Francis Street	4UC	1799	1,950	C	1,883	1,975	C
South of Cecil Avenue	4UC	1697	1,661	B	1,702	1,798	C
West of Brisbane Street	4DC	1406	2039	C	1513	1943	C
Terminus Street							
North of Cecil Avenue	4DC	1107	1,473	A	1,364	1,844	B
South of Crane Street	4DC	1171	1,661	B	1,594	1,643	B
North of Crane Street	4DC	1340	1,866	C	1,642	2,057	C

Table 7: Carriageway Level of Service at Ultimate Development

4DC	4 lanes divided carriageway with clearway
4UC	4 lanes undivided carriageway with clearway
4UP	4 lanes undivided carriageway with parking
2U	2 lanes undivided carriageway

At full potential development, the majority of approach roads within the study area would operate at a good level of service “C” or better except the following:

- Crane Road between Terminus Street and Orange Grove which would operate a poor level of service “F” during the morning and afternoon peaks; this could be addressed by prohibiting on-street parking during both the morning and afternoon peak periods and the widening of Crane Road to provide four traffic lanes.
- The section of Cecil Avenue between Old Northern Road and Terminus Street which would operate a poor but acceptable level of service “D” during the afternoon peak.

3.3.2 Impact on Critical Intersections

An analysis of the operation of all relevant intersections likely to be affected by the potential developments in Castle Hill South was carried out using the SIDRA intersection modelling program. The results of this analysis are summarised in **Table 8**.

INTERSECTION	AM		PM	
	Delay sec/v	LoS	Delay sec/v	Los
Traffic Signals				
Old Northern Road with Castle Street / Crane Road	33.0	C	34.9	C
Old Northern Road with Cecil Avenue	>70	F	>70	F
Old Northern Road with McMullen Avenue	26.3	B	22.3	B
Old Northern Road with McMullen Avenue / Brisbane Road	77.8	F	44.4	D
Old Northern Road with Showground Road	19.7	B	16.9	B
Terminus Street with Crane Road	>70	F	>70	F
Terminus Street with access to Car Park	19.9	B	17.8	B
Old Northern Road with Francis Street	21.7	B	25.3	B
Roundabout				
Orange Grove with Cecil Avenue	10.5	A	11.7	A
Orange Grove with Francis Street	9.0	A	9.0	A
T-Junctions				
Cecil Avenue with Terminus Street	16.2	B	23.6	B
Francis Street with Roger Avenue	9.4	A	9.6	A
Old Northern Road with Brisbane Road	>70	F	>70	F
Old Northern Road with Church Street	>70	F	>70	F
Orange Grove with Crane Road	22.7	B	28.0	B/C
Old Northern Road with Francis Street	>70	F	>70	F

Table 8: Future Operation of Intersections

This assessment of the impact of the potential growth in Castle Hill South has highlighted the following issues:

- The intersection of Old Northern Road with Cecil Avenue would operate at a very poor level of service “F” during the morning peak and the afternoon peak hours. Additional capacity would be required;
- The traffic signals at the intersection of Terminus Street with Crane Road would operate at a very poor level of service “F” during the morning peak and the afternoon peak hours. Additional capacity would be required;
- The right turning movement from Brisbane Street to Old Northern Road would increase the conflicts with through traffic resulting in an unsafe situation. To resolve this problem, serious consideration ought to be given to the realignment of Brisbane Street with McMullen Avenue as suggested in a previous report (Gennaoui, 2010);
- The intersection of Orange Grove with Crane Road may require the provision of a roundabout due to the large volume of vehicles turning right onto Orange Grove from Crane Road;

- The provision of traffic signals incorporating an exclusive right turn bay at the intersection of Old Northern Road with Francis Street would operate at satisfactory level of service "B". However, the length of the right turning bay would be past Parsonage Street, which may in turn be restricted to left turning in and out only movements.

The roundabouts controlling the intersections of Orange Grove with Cecil Avenue and with Francis Street would continue to operate at a very good level of service "A" during the morning and afternoon peak periods.

4. Summary and Recommendations

4.1 Summary

Approximately 52,800 m² GFA of offices could be provided within the Study Area mostly in Zones 2, 6 and 12 either side of Terminus Street. Approximately 21,850 m² GFA of retail is also anticipated.

The Castle Hill South study area is expected to generate about 2,770 and 3,200 vehicle trips during the morning and afternoon peak hours respectively.

At full potential developments, the majority of roads within the study area would operate at a good level of service “C” or better except the following:

- Crane Road between Terminus Street and Orange Grove, which would operate at a poor level of service “F” during the morning and afternoon peaks; this could be addressed by the widening of Crane Road to provide four traffic lanes;
- The section of Cecil Avenue between Old Northern Road and Terminus Street which would operate at a poor but acceptable level of service “D” during the afternoon peak.

This assessment has highlighted the following issues:

- The intersections of Old Northern Road with Cecil Avenue and the intersection of Terminus Street with Crane Road would operate at very poor levels of service “F” during the morning peak and the afternoon peak hours. Additional capacity would be required;
- The right turning movement from Brisbane Street to Old Northern Road will be exacerbated resulting in an unsafe situation. To resolve this problem, serious consideration ought to be given to the realignment of Brisbane Street with McMullen Avenue as suggested in a previous report (Gennaoui, 2010);
- The intersection of Orange Grove with Crane Road may require the provision of a roundabout;
- The provision of traffic signals at the intersection of Old Northern Road with Francis Street would necessitate an exclusive right turn bay which would extend beyond Parsonage Road.

4.2 Recommendations

In order to address the traffic issues identified above, the following improvements are recommended for serious consideration:

- Widening of Crane Road between Terminus Street and Orange Grove to achieve a four lane carriageway;
- Provision of additional capacity at the intersections of Old Northern Road with Cecil Avenue and the intersection of Terminus Street with Crane Road; if not possible, then consideration to reduce the potential trip generation by reducing the retail floor area being the land use with highest trip generation rates;

- Installation of traffic signals at the junction of Old Northern Road with Francis Street together with restriction of traffic movement in Parsonage Road to left turn in and out only at Old Northern Road;
- Provision of a roundabout at the intersection of Crane Road with Orange Grove;
- Serious consideration should be given to the realignment of Brisbane Street with McMullen Avenue.

5. References

Brown (2014). *"Review of Residential Development in Castle Hill North Precinct. Traffic & Accessibility Study Report."* The Hills Shire Council. May.

Gennaoui Consulting (2010). *"Capacity of Proposed Intersection of Old Northern Road with McMullen Ave & Brisbane Rd."* The Hills Shire Council. October.

Gennaoui Consulting (2012). *"Terminus Street Car Park Traffic Impact Study."* The Hills Shire. May

TDG (2017). *"Mixed Residential Development at Cecil Avenue, Castle Hill."* Merc Property Pty Ltd. June.

Appendix A

Concept of Carriageway Capacity and Level of Service

The capacity of major streets within an urban area can be based on an assessment of their operating Level of Service.

Level of service is defined by Austroads as a "qualitative measure of the effects of a number of features, which include speed and travel time, traffic interruptions, freedom to manoeuvre, safety, driving comfort and convenience, and operating costs. Levels of service are designated from A to F from best (free flow conditions) to worst (forced flow with stop start operation, long queues and delays) as follows:

***LEVELS OF SERVICE**

- A - Free flow (almost no delays)
- B - Stable flow (slight delays)
- C - Stable flow (acceptable delays)
- D - Approaching unstable flow (tolerable delays)
- E - Unstable flow (congestion; intolerable delays), and
- F - Forced flow (jammed)

A service volume, as defined by Austroads, is the maximum number of vehicles that can pass over a given section of roadway in one direction during one hour while operating conditions are maintained at a specified level of service. It is suggested that ideally arterial and sub-arterial roads should not exceed service volumes at level of service C. At this level, whilst most drivers are restricted in their freedom to manoeuvre, operating speeds are still reasonable and acceptable delays experienced. However, in urban situations, arterial and sub-arterial roads operating at Level of Service D are still considered adequate. Traffic Volumes along urban roads with interrupted and uninterrupted flow conditions are included in **Table A1** and **A2** respectively.

	DESCRIPTION	LEVEL OF SERVICE					
		A	B	C	D	E	F
2U	2 Lane Undivided	540	630	720	810	900	F
4UP	4 Lane Undivided with Two Parking Lanes	540	630	720	810	900	F
4U	4 Lane Undivided with Some Parking	900	1050	1200	1350	1500	O
4UC	4 Lane Undivided with Clearways	1080	1260	1440	1620	1800	R
4D	4 Lane Divided with Clearways	1140	1330	1520	1710	1900	C
6U	6 Lane Undivided	1440	1680	1920	2160	2400	E
6D	6 Lane Divided with Clearway	1740	2030	2320	2610	2900	D

Table A1: Level of Service Interrupted Flow Conditions along Urban Roads (One Way Hourly Volumes)

	DESCRIPTION	LEVEL OF SERVICE					
		A	B	C	D	E	F
2U	2 Lane Undivided	760	880	1000	1130	1260	F
4U	4 Lane Undivided with Some Parking	1260	1470	1680	1890	2100	O
4UC	4 Lane Undivided with Clearways	1510	1760	2010	2270	2520	R
4DC	4 Lane Divided with Clearways	1600	1860	2130	2400	2660	C
4DCL	6 Lane Undivided with Clearways	2250	2620	3000	3380	3740	E
6DC	6 Lane Divided with Clearway	2440	2840	3250	3660	4060	D

* 40% higher than base volumes in Table F1

Table A2: Level of Service Uninterrupted Flow Conditions along Urban Roads (One Way Hourly Volumes)

Appendix B

Guidelines for Evaluation of Intersection Operation

The RTA has included in the "Guide to Traffic Generating Developments" (Dec 1993, Issue 2) a section on the assessment of intersections. The assessment of the level of service of an intersection is based on the evaluation of the following Measures of Effectiveness:

- (a) Average delay (seconds/veh) (all forms of control)
- (b) Delay to critical movement (seconds/veh) (all forms of control)
- (c) Degree of saturation (traffic signals and roundabouts)
- (d) Cycle length (traffic signals)

INTANAL was used to calculate the relevant intersection parameters. INTANAL is a software which allows comparisons between different forms of intersection control and different forms of intersection configurations to be readily evaluated. That is at each intersection the priority control, roundabout and signal control options will be examined to determine the most efficient form of control.

The best indicator of the level of service at an intersection is the average delay experienced by vehicles at that intersection. For traffic signals, the average delay over all movements should be taken. For roundabouts and priority control intersections (with Stop and Give Way signs or operating under the T-junction rule) the critical movement for level of service assessment should be that with the highest average delay.

With traffic signals, delays per approach tend to be equalised, subject to any over-riding requirements of signal co-ordination as well as to variations within individual movements. With roundabouts and priority - control intersections, the critical criterion for assessment is the movement with the highest delay per vehicle. With this type of control the volume balance might be such that some movements suffer high levels of delay while other movements have minimal delay. An overall average delay for the intersection of 25 seconds might not be satisfactory if the average delay on one movement is 60 seconds.

The average delay for level of service E should be no more than 70 seconds. The accepted maximum practical cycle length for traffic signals under saturated conditions is 120 - 140 seconds. Under these conditions 120 seconds is near maximum for two and three phase intersections and 140 seconds near maximum for more complex phase designs. Drivers and pedestrians expect cycle lengths of these magnitudes and their inherent delays in peak hours. A cycle length of 140 seconds for an intersection which is almost saturated has an average vehicle delay of about 70 seconds, although this can vary. If the average vehicle delay is more than 70 seconds, the intersection is assumed to be at Level of Service F.

Table B1 sets out average delays for different levels of service. There is no consistent correlation between definitions of levels of service for road links as defined elsewhere in this section, and the ranges set out in Table G1. In assigning a level of service, the average delay to the motoring public needs to be considered, keeping in mind the location of the intersection. For example, drivers in inner-urban areas of Sydney have a higher tolerance of delay than drivers in country areas. Table B1 provides a recommended baseline for assessment.

Level of Service	Average Delay per Vehicle (seconds/veh)	Traffic Signals, Roundabout	Give Way and Stop Signs
A	less than 14	Good operation	Good operation
B	15 to 28	Good with acceptable delays and spare capacity	Acceptable delays and spare capacity
C	29 - 42	Satisfactory	Satisfactory, but accident study required
D	43 to 56	Operating near capacity	Near capacity and accident study required
E	57 to 70	At capacity; at signals, incidents will cause excessive delays Roundabouts require other control mode	At capacity, required other control mode

Table B1: Level of Service Criteria for Intersections

The figures in Table B1 are intended as a guide only. Any particular assessment should take into account site-specific factors including maximum queue lengths (and their effect on lane blocking), the influence of nearby intersections and the sensitivity of the location to delays. In many situations, a comparison of the current and future average delay provides a better appreciation of the impact of a proposal, and not simply the change in the level of service.

The intersection degree of saturation (DS) can also be used to measure the performance of isolated intersections. At intersections controlled by traffic signals, both queue length and delays increase rapidly as DS approaches 1.0. An upper limit of 0.9 is appropriate. When DS exceeds 0.8 - 0.85, overflow queues start to become a problem. Satisfactory intersection operation is generally achieved with a DS of about 0.7 - 0.8. (Note that these figures are based on isolated signalised intersections with cycle lengths of 120 seconds. In co-ordinated signal systems DS might be actively maximised at key intersections). Although in some situations additional traffic does not alter the level of service, particularly where the level of service is E or F, additional capacity may still be required. This is particularly appropriate for service level F, where small increases in flow can cause disproportionately greater increases in delay. In this situation, it is advisable to consider means of control to maintain the existing level of absolute delay. Suggested criteria for the evaluation of the capacity of signalised intersections based on the Degree of Saturation are summarised in Table B2.

Level Of Service	Optimum Cycle Length (Seconds) (Co)	Volume/Saturation Y	Intersection Degree Of Saturation X
A/B - Very good operation	< 90	< 0.70	< 0.80
C - Satisfactory	90-120	0.70-0.80	0.80-0.85
D - Poor but manageable	120-140	0.80-0.85	0.85-0.90
E/F - Bad, extra capacity required	>140	>0.85	> 0.90

Table B2: Criteria for Evaluating Capacity Of Signalised Intersections*

* Source: Roads & Traffic Authority (2002)

Appendix C

Potential Floor Areas for Castle Hill South

Castle Hill (Dwelling Potential) - Excluding Growth on Castle Towers)					
			*Assume 10,000 m ² existing		
		GFA			Dwellings
Zone No.	Block No.	Retail	Office		Additional
1	1		3,705.5		109
2	2	810.0	8,000.0		442
3	3	0.0	0.0		113
4	4		0.0		81
3	5		0.0		266
6	6	15,535.5	15,535.5		0
5	7		0.0		59
5	8		0.0		161
4	9		0.0		333
7	10		0.0		286
7	11		0.0		91
8	12		0.0		109
8	13		0.0		108
8	14		0.0		164
9	15		0.0		84
10	16		0.0		74
11	17		0.0		54
11	18		0.0		9
11	19		0.0		15
11	20		0.0		6
11	21		0.0		67
	Sub-Total	16,346	27,241		2,633
12	22	5,500.0	10,000.0		351
	Sub-Total				351
13	Street Trag	Approved DA			378
	Pennant Street Tar	Approved DA			0
	Sub-Total				378
TOTAL		21,845.5	37,241.0		3,363

Appendix D

Origin-Destination of Potential Trips

ORIGIN DESTINATION OF TRIPS

APPROACH ROUTES		AM PEAK																											
		Zone 1		Zone 2		Zone 3		Zone 4		Zone 5		Zone 6		Zone 7		Zone 8		Zone 9		Zone 10		Zone 11		Zone 12		Zone 13		TOTAL	
		Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep

Old Northern Road

S of Francis	25%	14	8	40	32	8	19	9	20	5	11	155	82	8	18	8	19	2	4	2	4	3	7	76	50	8	19	329	274
	35%	20	12	56	44	11	26	12	28	6	15	216	115	11	26	11	26	2	6	2	5	4	10	107	70	11	26	461	384
Cecil Avenue		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W of Old Northern Rd	15%	8	5	24	19	5	11	5	12	3	6	93	49	5	11	5	11	1	2	1	2	2	4	46	30	5	11	198	165
Showground Road		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West of Old Northern Rd	15%	8	5	24	19	5	11	5	12	3	6	93	49	5	11	5	11	1	2	1	2	2	4	46	30	5	11	198	165
Crane Street		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W of Old Northern Rd	10%	6	2	16	6	3	4	3	4	2	2	62	16	3	4	3	4	1	1	1	1	1	1	31	10	3	4	132	55
Old Castle Hill Road																													
n of Crane St	0%	0	2	0	6	0	4	0	4	0	2	0	16	0	4	0	4	0	1	0	1	0	1	0	10	0	4	0	55
Total		100%	57	161	127	32	74	35	81	19	43	618	329	32	74	32	75	7	16	6	15	13	30	306	200	32	74	1317	1097

ORIGIN DESTINATION OF TRIPS

PM PEAK																			
APPROACH ROUTES		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	TOTAL				
	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Arr	Dep	Dep
Old Northern Road																			
S of Francis	25%	5	11	26	36	10	7	10	7	2	2	3	77	92	10	7	349	389	
e of Brisbane St	35%	7	15	36	51	14	10	14	9	3	2	4	108	129	14	10	488	544	
Cecil Avenue		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
W of Old Northern Rd	15%	3	7	16	22	6	4	6	4	1	1	2	46	55	6	4	209	233	
Showground Road		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
West of Old Northern Rd	15%	3	7	16	22	6	4	6	4	1	1	2	46	55	6	4	209	233	
Crane Street		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
W of Old Northern Rd	10%	2	4	10	15	4	3	4	3	2	1	2	31	37	4	3	139	156	
Old Castle Hill Road		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
n of Crane St	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total	100%	21	43	103	145	41	27	41	27	9	6	16	309	369	41	27	1395	1555	