Technical Safeguarding Assessment of Air Navigation Equipment

Ryans Road Industrial Development, Christchurch

18 November 2025

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Document Information

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V1.0	Version issue 1.0	18 November 2025	Initial issue

Executive Summary

Cyrrus Limited has been engaged by Carter Group Limited to undertake a technical safeguarding assessment of the potential impacts that the proposed Ryans Road Industrial Development may have on air navigation equipment located at Christchurch aerodrome.

The objective of the assessment is to evaluate and ensure that the proposed Ryans Road Industrial Development will not adversely affect the safe operation of air navigation equipment supporting operations at Christchurch aerodrome and supporting Airways New Zealand's nationwide service.

The proposed development infringes, or is in close proximity to, the protection surfaces for the following air navigation facilities:

- Instrument Landing System (ILS) Localiser Runway 02;
- ILS Localiser Runway 20;
- ILS Glidepath Runway 02;
- ILS Distance Measuring Equipment (DME) Runway 02;
- Doppler VHF Omni-directional Range (DVOR)/DME; and
- Primary Surveillance Radar (PSR)/Secondary Surveillance Radar (SSR).

Given the above, the methodology adopted in this assessment applies a staged, model-based analysis to identify and quantify potential impacts from the development on navigation and radar systems, and where appropriate, indicate mitigations to ensure compliance with international standards and to support continued aviation safety.

The methodology for assessing the development's impact is summarised as follows:

- ILS analysis and safeguarding follows a staged process: first, a worst-case computer simulation is conducted, modelling the development as highly reflective surfaces to assess maximum potential impact on ILS signal parameters; if results are acceptable, no further action is needed. If not, the model is refined to better represent actual building characteristics, and if necessary, mitigation options such as adjusting building heights, orientations, or materials are explored, with the goal of ensuring the ongoing safe operation of the ILS while allowing controlled development.

- DME analysis involves assessing the potential effects of large structures on DME signals, focusing on two main risks; reflections that can cause multipath interference and incorrect distance measurements, and line-of-sight (LoS) shadowing that can block DME transmissions. The analysis uses ray optics and 3D modelling to determine the direction and magnitude of signal reflections, as well as Geographic Information System tools to evaluate LoS coverage, ensuring that any impacts are understood and if required can be mitigated—such as through equipment features like Short Distance Echo Suppression (SDES).

- DVOR analysis involves using computer simulation tools to model the effects of large metallic structures on DVOR radio signals, focusing on two main risks; reflections, which can cause bearing and range errors, and shadowing, which may reduce signal strength and coverage in certain sectors. The analysis includes simulating the illuminated faces of the development, calculating potential bearing errors, and using 3D radio propagation modelling to assess the

extent of signal shadowing, ensuring that any impacts are identified and evaluated against international standards.

- For radar analysis, this assessment evaluates the potential effects of large structures on both PSR and SSR by considering three main risks; beam forming (how nearby structures might affect the formation of the radar beam), shadowing (physical obstructions causing radar shadows and potential loss of detection in certain airspace volumes), and reflections (which can increase ground clutter, generate false targets, or corrupt data). The analysis assesses the proximity and height of proposed buildings relative to radar antennas, models the likely paths of reflected signals, and considers mitigation strategies such as configuring radar beams or using internal reflector files to minimize adverse effects.

The main findings of the assessment are summarised below:

ILS Localiser Runway 02

Worst-case modelling indicates that the proposed development will have a very minor[1] and acceptable impact on Localiser 02 performance. The actual effects are expected to be less than those predicted by the worst-case model.

ILS Localiser Runway 20

Worst-case modelling indicates that the proposed development will have a negligible[1] and acceptable impact on Localiser 20 performance. The actual effects are expected to be less than those predicted by the worst-case model.

ILS Glidepath Runway 02

Initial worst-case modelling indicated that the proposed development would have a noticeable[1] impact on Glidepath 02 performance. However, by rotating the 20m high buildings within sites 121 and 122 counterclockwise by 2°, the simulated Glidepath disturbance is reduced so that the development has only a minor[1] and acceptable impact on Glidepath 02 performance. The actual effects are expected to be less than those predicted by the worst-case model, and it is noted that the development has been modified to rotate the buildings on sites 121 and 122 counterclockwise by 2° in response to the modelling results.

ILS DME Runway 02

Reflections of DME 02 signals from the closest proposed 10m high building (on Lot 123) will cross the runway 02 extended centreline which may cause a temporary loss of range information for aircraft making approaches. This should be mitigated by the aircraft interrogator's 'velocity memory' mode and in any case, aircraft will likely fly above rather than through the area of potential multipath interference.

[1] See paragraph 6.2.5 for definitions of 'negligible', 'very minor', 'minor' and 'noticeable' impacts for the purposes of ILS modelling.

Airways New Zealand has confirmed that the DME 02 ground transponder is configured with Short Distance Echo Suppression (SDES) enabled, so no effects are anticipated from building reflections.

Potential Line of Sight (LoS) shadowing of DME signals will be confined to areas south of the Airport and will not occur within the required area of operational coverage.

DVOR/DME

Worst-case modelling of the proposed development indicates some disturbance to the DVOR azimuth angle between radials 088 and 163 and between radials 243 and 003; however, the magnitude of the disturbance will be well within the international standard tolerance (i.e. acceptable), and the proposed development will have no impact on aircraft flying VOR approach procedures.

DME reflections from the proposed development may result in multipath interference at ranges up to 1.78 Nautical Miles (NM) from the facility; however, upward reflections will be at shallow angles of elevation, and they will have no impact on aircraft flying runway approaches.

Although Airways New Zealand has advised that SDES is not currently enabled on the DME ground transponder, configuring the DME with SDES will, if required, provide immunity from building reflections.

Potential LoS shadowing of DVOR/DME signals will be confined to areas east of the Airport. This will have no impact on aircraft flying VOR/DME approach procedures to runways 02 and 20 and so therefore will have no effect on airport operations.

Radar

The proposed development will have no impact on correct PSR/SSR beam formation and therefore should not adversely affect the PSR/SSR's ability to meet Eurocontrol minimum Air Traffic Management surveillance system performance requirements (ESASSP v1.3).

The maximum elevation of the proposed development is below the PSR/SSR antennas so shadowing and obscuration of radar signals will not affect airborne targets.

Reflected radar energy from vertical building surfaces will be directed towards the ground where it will be scattered and absorbed and so will have no effect on surveillance system performance.

Reflections of radar energy from horizontal building roofs can potentially result in PSR target fading or SSR data corruption. Any reflections from roofs made of flat surfaces within the proposed development would be at shallow angles and, at a range of 20NM from the radar site, will only illuminate or be detected by aircraft at or below altitudes of circa 1,000 feet. Discontinuities on building roof areas will scatter the radar reflections, reducing the likelihood of adverse effects.

The 3D pencil beams of the Indra PSR can be configured to avoid radar illumination of the proposed development and the SSR builds up its own internal reflector file so that it will ignore reflections from known receptors. Therefore, these reflections are assessed as being acceptable.

Full details of the assessment and findings are presented within the body of this report.

Conclusion

In conclusion, this technical safeguarding assessment modelling:

1. Confirms that the effects on air navigation equipment from development of the Ryans Road land are manageable to an acceptable standard.

2. Has modelled a worse-case scenario. The actual effects are expected to be less than those predicted by the worst-case model.

3. Confirms that effects on air navigation equipment from development of the Ryans Road land will be of an acceptable standard, provided that:

    a. Development occurs in accordance with the modelled parameters of the development as detailed in paragraph 2.2.1 of the report; or

    b. Development is of no greater height or width than the modelled parameters of the development as detailed in paragraph 2.2.1 of this report; or

    c. Alternative development is re-modelled and assessed to confirm it has acceptable effects on air navigation equipment.

Abbreviations

AGL	Above Ground Level
AMSL	Above Mean Sea Level
ANE	Air Navigation Equipment
ATM	Air Traffic Management
BBP	Beam Bend Potential
BRA	Building Restricted Area
DME	Distance Measuring Equipment
DOC	Designated Operational Coverage
DVOR	Doppler VHF Omni-directional Range
ESASSP	Eurocontrol Specification for ATM Surveillance System Performance
GIS	Geographic Information System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
ILS Point A	A point on the extended runway centreline in the approach direction 4 Nautical Miles from threshold.
ILS Point B	A point on the extended runway centreline in the approach direction 3,500 feet from threshold.
ILS Point C	A point through which the ILS glidepath passes at 100 feet above the horizontal plane of the threshold.
ILS Point D	A point 12 feet above the runway centreline and 3,000 feet from the threshold in the direction of the localiser.
ILS Point E	A point 12 feet above the runway centreline and 2,000 feet from the stop end of the runway in the direction of the threshold.
ILS Zone 2	Between ILS Point A and ILS Point B.
ILS Zone 3	Between ILS Point B and Threshold.
ILS Zone 4	Between Threshold and ILS Point D.
ILS Zone 5	Between ILS Point D and ILS Point E
LoS	Line of Sight
NM	Nautical Miles
OUNPPM	Ohio University Navaid Performance Prediction Model
PSR	Primary Surveillance Radar
RCS	Radar Cross Section
RF	Radio Frequency
RSS	Root Sum Squared

SDES	Short Distance Echo Suppression
SSR	Secondary Surveillance Radar
VHF	Very High Frequency

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1. Introduction

1.1. Background

1.1.1. A new development, Ryans Road Industrial Development, is proposed at a site to the south of Christchurch aerodrome. The site boundary is approximately 180m south of the main 02/20 runway at its closest point.

1.1.2. Carter Group Limited, the Client, has engaged Cyrrus Limited to undertake a technical safeguarding assessment of the potential impacts the development may have on Air Navigation Equipment (ANE) located at the aerodrome.

1.2. General

1.2.1. Prior to the construction of new developments on or near an airport, it is important to consider the potential resultant effect on the performance of the ANE.

1.2.2. For example, the Instrument Landing System (ILS) provides both lateral and vertical guidance by means of radio signals to enable aircraft to approach and land without visual reference to the ground in times of poor visibility. By using this system, approach and landing may be carried out either automatically or by suitable instrument guidance to the pilot. To ensure the safety and integrity of such systems, it is necessary to provide a high level of safeguarding of the system performance.

1.2.3. Site modelling of ILS performance allows the potential impact of a new development to be assessed. This may support the development as proposed, or otherwise recommend changes which would make the development acceptable in terms of navigation aid performance and, hence, user safety.

1.3. Rationale

1.3.1. The methodology for the evaluation is detailed in the following paragraphs. Each study is unique, but the steps taken are similar.

1.3.2. The first stage is to evaluate the proposed development. This includes building details, position, and the local environment.

1.3.3. A detailed examination of flight inspection data follows, with due regard to equipment type and configuration. This gives an overview of the existing system performance and is also used later to validate the computer model.

1.3.4. A survey may be carried out to determine the building positions and to record the local topography. The visibility of the development from the ANE under investigation is assessed; terrain or existing buildings may mask part or all of the proposed development. This is a data gathering exercise for computer modelling later.

1.3.5. The development is assessed using a software modelling tool, Ohio University Navaid Performance Prediction Model (OUNPPM), to simulate the possible effects of the development on the airport's ILS and Doppler VHF Omni-directional Range (DVOR) facilities.

At this stage, a 'worst-case' scenario model is set up, i.e. reflecting objects are modelled to provide maximum reflection and hence potential disruption to the navigational aid performance.

1.3.6. The Beam Bend Potential (BBP) is evaluated from this worst-case model. If the subsequent degradation is substantial, iteration to a more representative model is taken, and significantly more data is entered. If the BBP is within acceptable limits, then this will be reported to Airways New Zealand as the air navigation service provider for New Zealand.

1.3.7. Often, the modelling tool can be used to mitigate the effects of new developments, by using a 'what if' scenario to vary building, siting and equipment parameters which may optimise the performance of the radio navigation aid in the presence of the development.

2. Evaluation Tools and Data

2.1. Software

2.1.1. The following software packages were used while undertaking the assessments:

- OUNPPM v1989a.2023;
- Global Mapper v26.1; and
- ZWCAD 2022 SP2.2 Professional Edition.

2.2. Data provided by the Client

2.2.1. The parameters of the proposed development upon which this assessment is based are detailed in the following documents supplied by the Client:

- 2024_052_Carter Group_104 Ryans Road Building Height Map_E 1.dwg;
- 1252 Scheme Plan WGS84 251006 Out.dwg; and
- 2024_051 Carter Group 104 Ryans Road - Building Heights D (noting version 'D' superseded the version 'C' document originally supplied and initially modelled, in order to adopt the recommended rotation of buildings on sites 121 and 122 counterclockwise by 2° in response to the initial modelling results).

2.3. Other data

2.3.1. Other data sources used for the assessment are listed below:

- CH ILS 02 GP CAT 3 - 07 APR 2025 – Watermarked.pdf – ILS Glidepath 02 Flight Inspection data;
- CH ILS 02 LOC CAT 3 - 07 APR 2025 – Watermarked.pdf – ILS Localiser 02 Flight Inspection data;
- CH ILS 20 LOC CAT 3 - 07 APR 2025 – Watermarked.pdf – ILS Localiser 20 Flight Inspection data;
- CH VOR & DME - 04 SEP 2025 – Watermarked.pdf – VOR/DME Flight Inspection data; and
- NZCH_AD2.pdf – Christchurch Airport details in the New Zealand Aeronautical Information Publication.

3. Development

3.1. Location

3.1.1. The location of the proposed development site is shown in Figure 1.

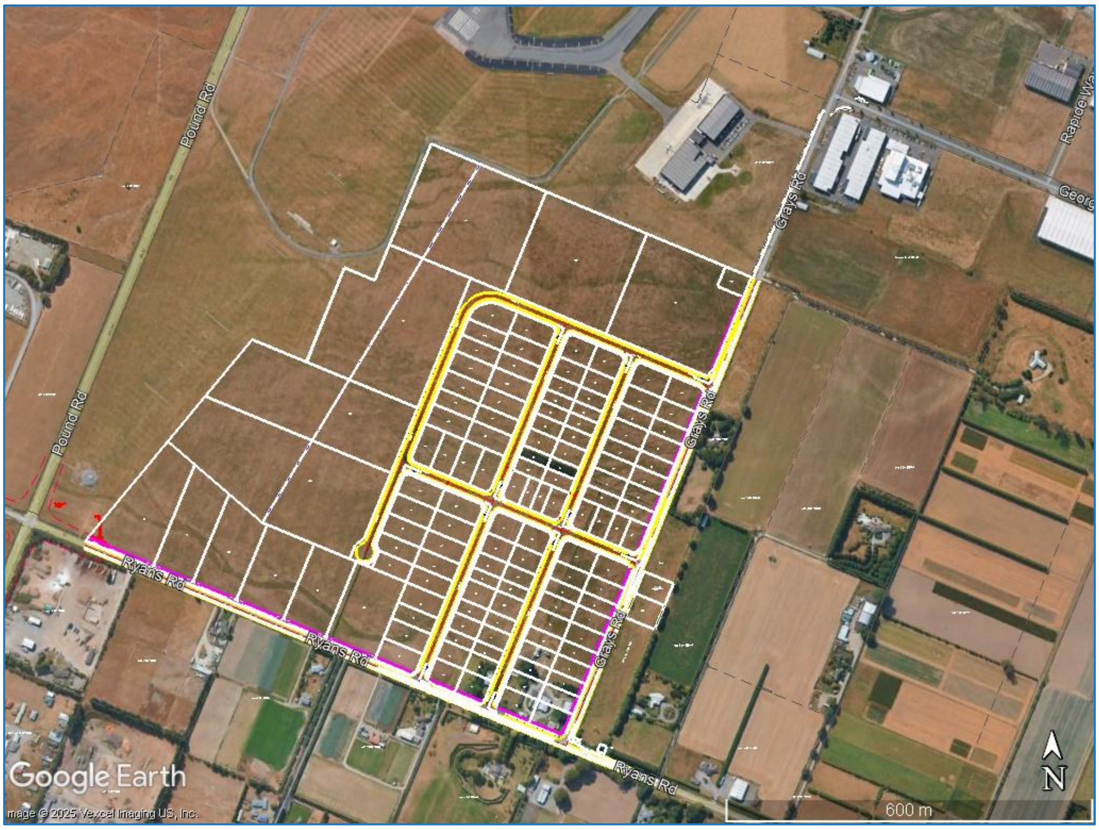

Figure 1: Development site location

3.1.2. The building layout and height scheme used for the assessment is depicted in Figure 2.

Figure 2: Building layout and height scheme

3.2. ANE under consideration at Christchurch aerodrome

3.2.1. The ANE under consideration at Christchurch aerodrome consists of ILS Localiser, Glidepath and Distance Measuring Equipment (DME) facilities serving runways 02 and 20, a combined DVOR/DME facility and a co-located Primary Surveillance Radar (PSR) and Secondary Surveillance Radar (SSR) system.

3.2.2. The ILS Localiser provides lateral guidance to approaching aircraft and the ILS Glidepath provides vertical guidance. The ILS Localiser and Glidepath facilities installed at Christchurch currently provide a Category I service but are being maintained to Category III standards and between them are therefore capable of guiding aircraft to the thresholds of runways 02 and 20 at Christchurch aerodrome without the pilot having a visual reference.

3.2.3. The DME provides the pilot of an aircraft with direct and continuous visual indication of the distance between the DME antenna and the aircraft.

3.2.4. The DVOR provides suitably equipped aircraft with their magnetic azimuth relative to the DVOR.

3.2.5. The PSR transmits short pulses of high energy radio signals and detects the radio signals when they are reflected back from aircraft targets. The time interval between transmission and reception determines the aircraft's range and the azimuth of the radar antenna at the time gives bearing information. The aircraft returns are plotted on Air Traffic Control radar display equipment, enabling controllers to see the aircraft positions.

3.2.6. The SSR transmits a coded interrogation pulse train which is detected by aircraft transponders. The transponders reply to the interrogation with a pulse train encoded with aircraft identification, flight level and other discretionary information.

3.2.7. The development relative to the ANE at Christchurch aerodrome is shown in Figure 3.

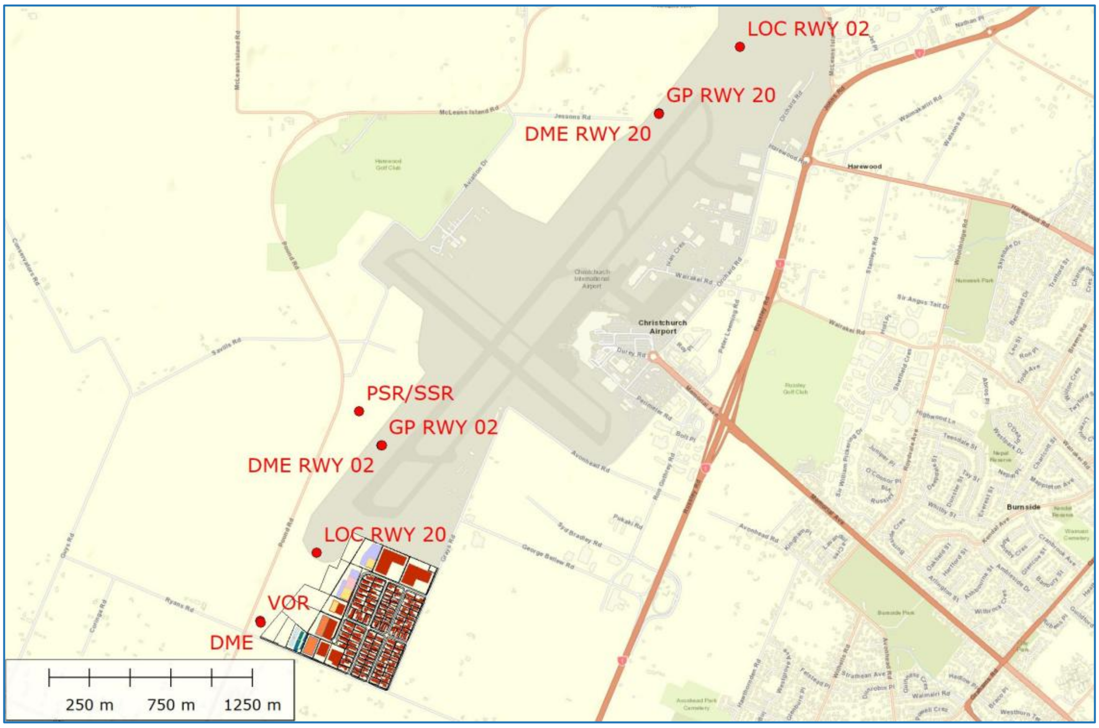

Figure 3: Development relative to ANE

3.3. Safeguarding of ANE

3.3.1. In order to protect ANE signals, safeguarded areas are established around the facility sites. The purpose of the safeguarded area is to identify obstacles with the potential for causing unacceptable interference to the signals. Structures that infringe the safeguarded area must undergo technical assessments to determine the degree of potential interference, if any, and whether the interference will be acceptable.

3.3.2. The International Civil Aviation Organization (ICAO) has defined minimum safeguarded areas for ANE in the document ICAO EUR DOC 015[2]. The document defines Building Restricted Area (BRA) shapes for both directional and omni-directional facilities.

3.3.3. Figure 4 shows an example of the BRA shape for directional facilities such as ILS Localisers and Glidepaths, as depicted in ICAO EUR 015 Figures 3.1, 3.2, 3.3 and 3.4. Note that the shapes are applicable from ground terrain upwards.

[2] ICAO EUR DOC 015 European Guidance Material on Managing Building Restricted Areas, Third Edition, November 2015

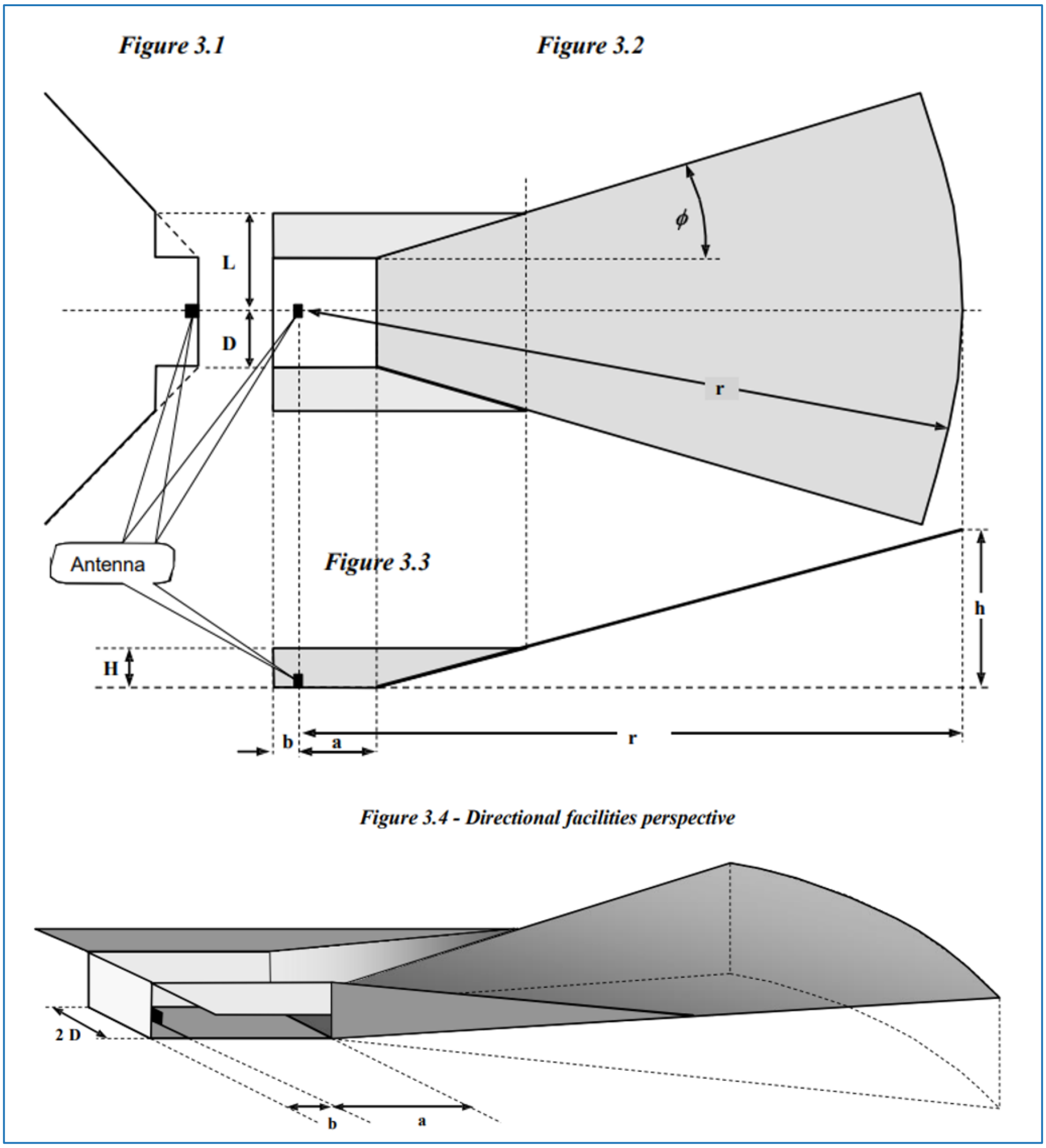

Figure 4: ICAO EUR DOC 015 Figures 3.1-3.4 – BRA shape for directional facilities

3.3.4. The dimensions to be applied for the various directional facilities are shown in Figure 5.

Type of navigation facilities	*A (m)*	*b (m)*	*h(m)*	*r (m)*	*D (m)*	*H (m)*	*L (m)*	*ϕ (°)*
ILS LLZ (medium aperture single frequency)	Distance to threshold	500	70	a+6000	500	10	2300	30
ILS LLZ (medium aperture dual frequency)	Distance to threshold	500	70	a+6000	500	20	1500	20
ILS GP M–Type (dual frequency)	800	50	70	6000	250	5	325	10
MLS AZ	Distance to threshold	20	70	a+6000	600	20	1500	40
MLS EL	300	20	70	6000	200	20	1500	40
DME (directional antennas)	Distance to threshold	20	70	a+6000	600	20	1500	40

Figure 5: EUR DOC 015 Table 2 – Harmonised guidance figures for directional facilities

3.3.5. The safeguarded areas for Localiser 02 (magenta) and Localiser 20 (red) are illustrated in Figure 6.

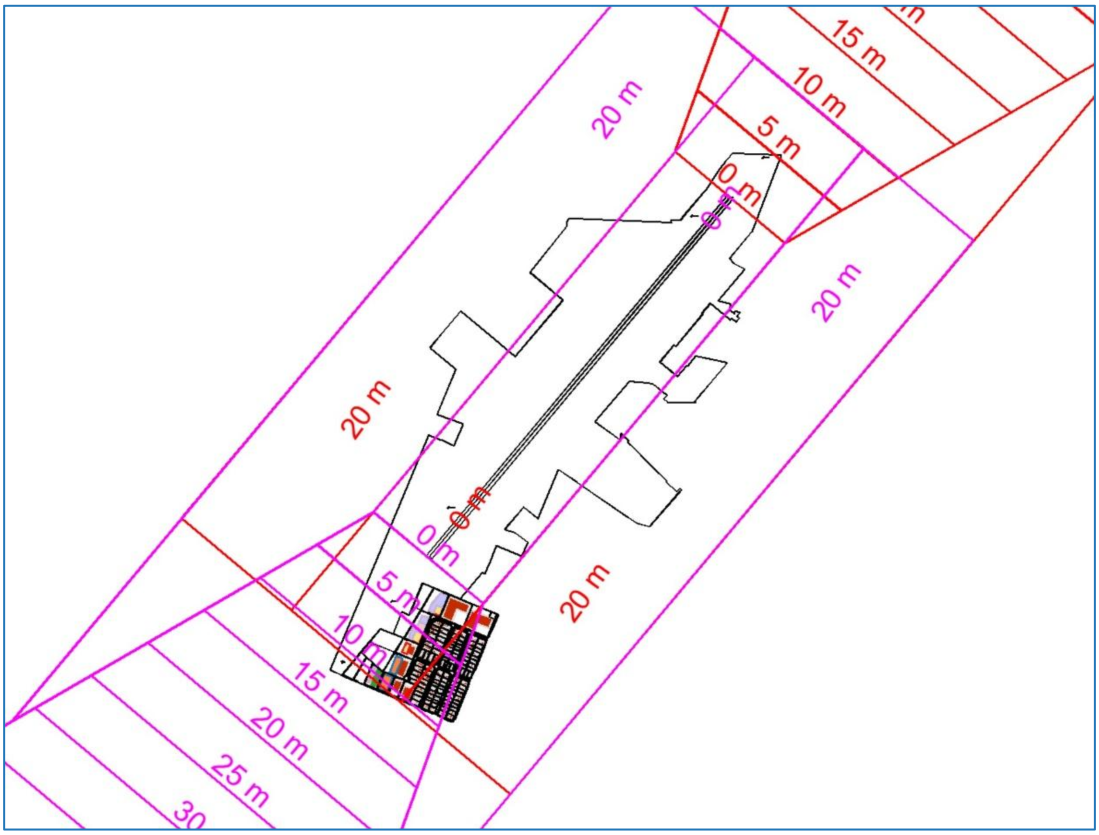

Figure 6: Localiser 02/20 safeguarded areas

3.3.6. Buildings at the proposed development site will infringe both safeguarded areas, therefore they must be modelled to determine potential impacts on Localisers 02 and 20.

3.3.7. The safeguarded areas for Glidepath 02 (magenta) and Glidepath 20 (red) are illustrated in Figure 7 and a zoomed view of the Glidepath 02 safeguarded area is shown in Figure 8.

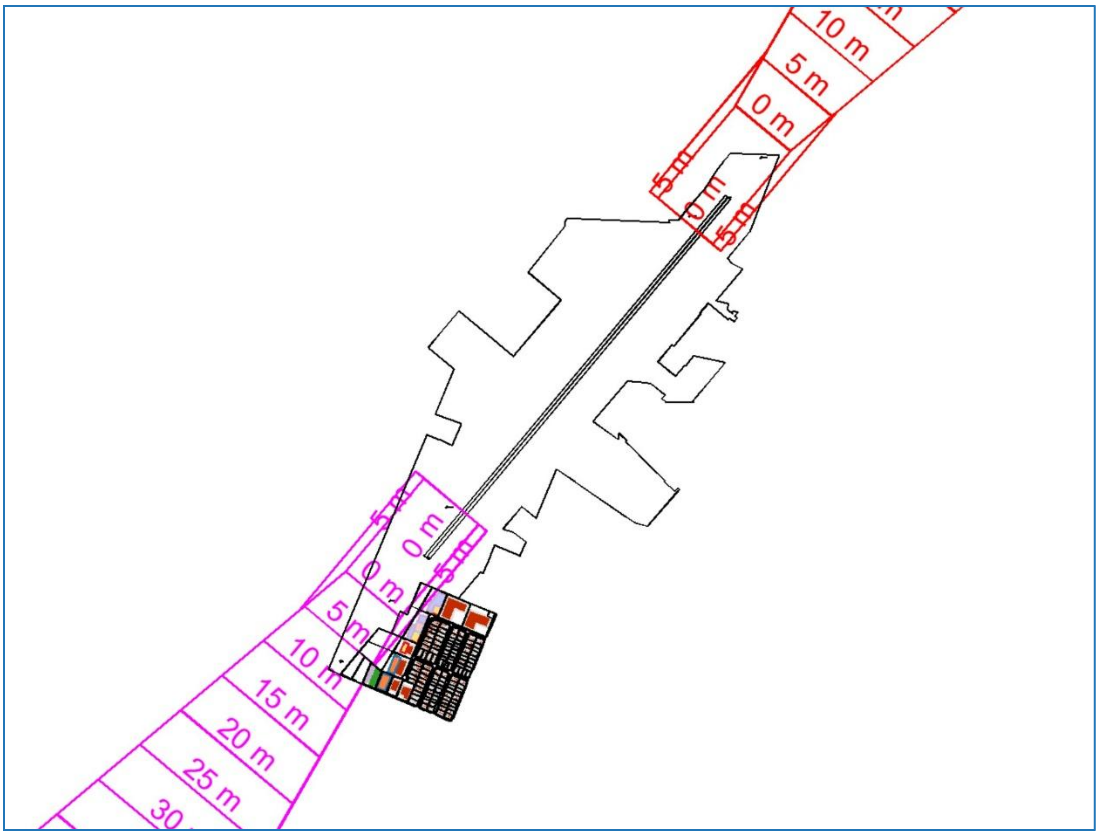

Figure 7: Glidepath 02/20 safeguarded areas

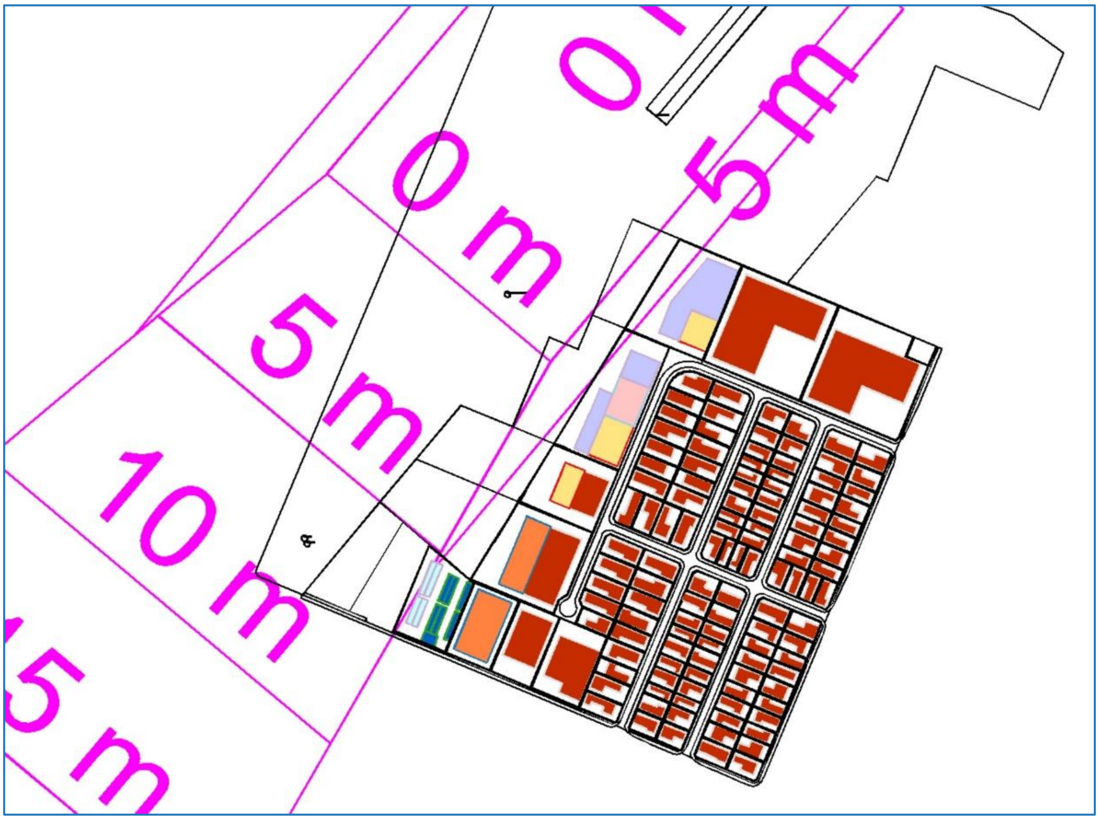

Figure 8: Glidepath 02 safeguarded areas – zoomed

3.3.8. The proposed development site does not infringe the Glidepath 20 safeguarded area. A technical assessment of this facility is therefore not required.

3.3.9. Figure 8 shows that the site is within the Glidepath 02 safeguarded area; however, none of the buildings in the layout under assessment will infringe the safeguarded surfaces. Given the scale of the development and its proximity to the Glidepath 02 safeguarded area, it is considered prudent to model the buildings' potential impact on this facility.

3.3.10. Figure 9 shows an example of the BRA shape for an omni-directional facility, as depicted in ICAO EUR DOC 015 Figures 2.1 and 2.2.

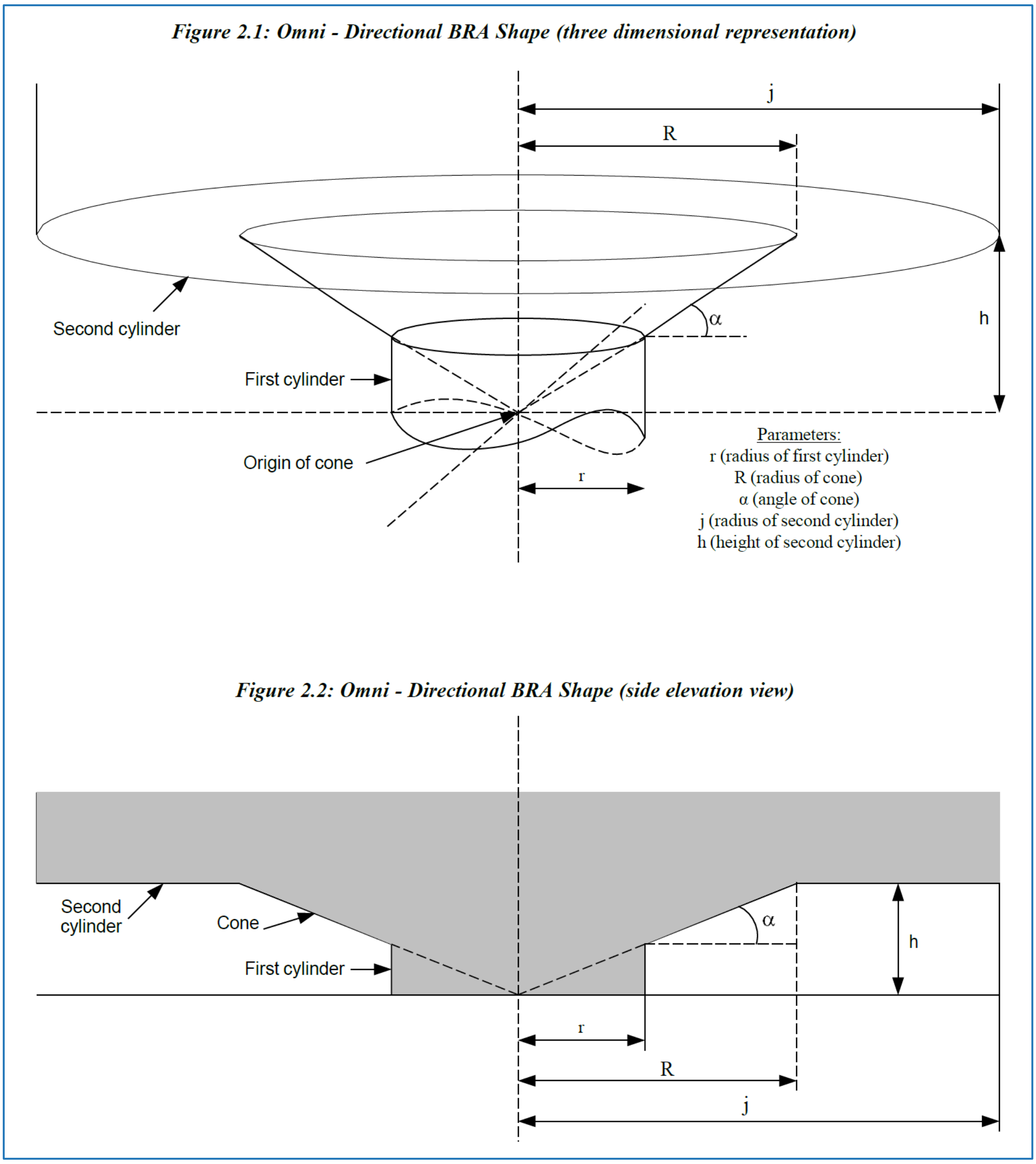

Figure 9: ICAO EUR DOC 015 Figures 2.1 and 2.2 – BRA shape for omni-directional facilities

3.3.11. Applicable dimensions to be applied for DVOR and DME omni-directional facilities are reproduced from EUR DOC 015 in Figure 10.

Type of navigation facilities	*Radius (r – Cylinder) (m)*	*Alpha (α – cone) (°)*	*Radius (R- Cone) (m)*	*Radius (j – Cylinder) (m) Wind turbine(s) only*	*Height of cylinder j (h -height) (m) Wind turbine(s) only*	*Origin of cone and axis of cylinders*
DME N	300	1.0	3000	N/A	N/A	Base of antenna at ground level
CVOR	600	1.0	3000	15000	52	Centre of antenna system at ground level
DVOR	600	1.0	3000	10000	52	Centre of antenna system at ground level

Figure 10: EUR DOC 015 Table 1 – Harmonised guidance figures for omni-directional facilities

3.3.12. ILS DME 02 and ILS DME 20 have omni-directional antennas. The safeguarded areas for DME 02 (magenta) and DME 20 (red) are illustrated in Figure 11. Heights shown are relative to ground levels at the base of the antennas (DME 02: 35m Above Mean Sea Level (AMSL), DME 20: 29m AMSL).

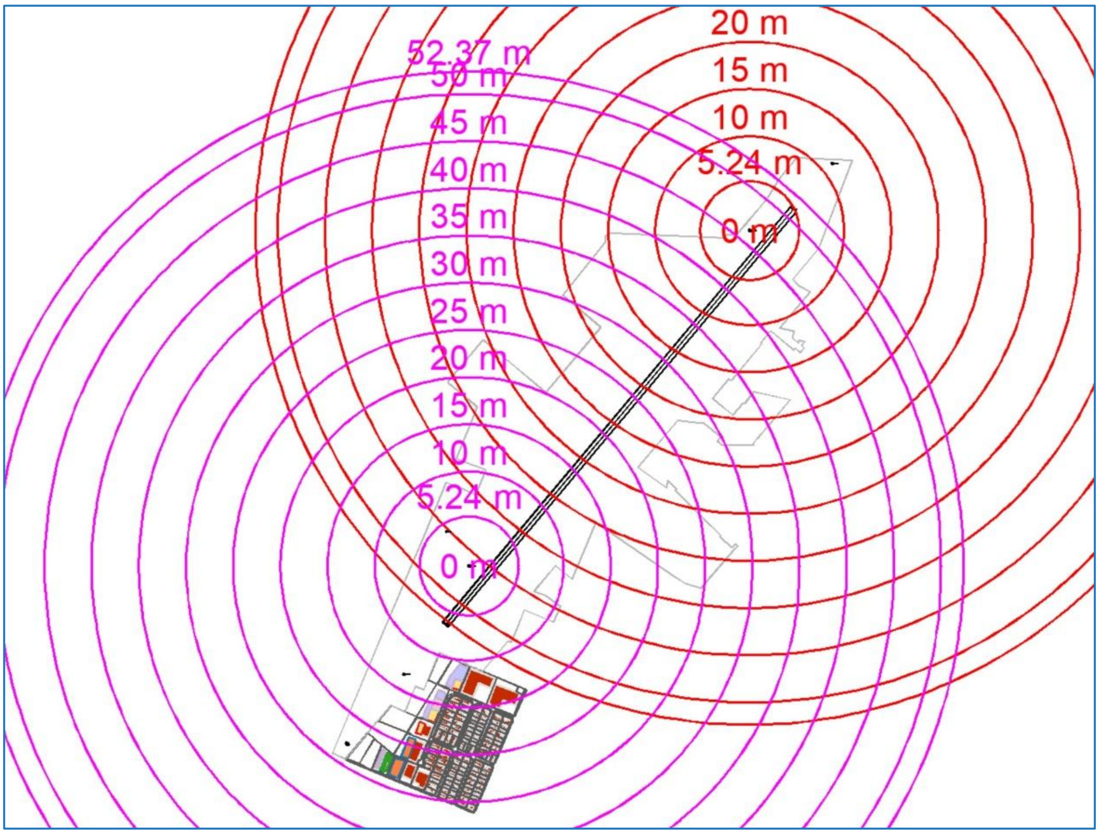

Figure 11: DME 02/20 safeguarded areas

3.3.13. The proposed development site is clear of the DME 20 safeguarded area, so a technical assessment of this facility is not required.

3.3.14. Buildings at the site will infringe the DME 02 safeguarded surface, therefore a technical assessment of this facility is required.

3.3.15. The safeguarded area for the DVOR/DME facility is shown in Figure 12. Heights shown are relative to the ground level at the base of the DVOR antenna, 39m AMSL.

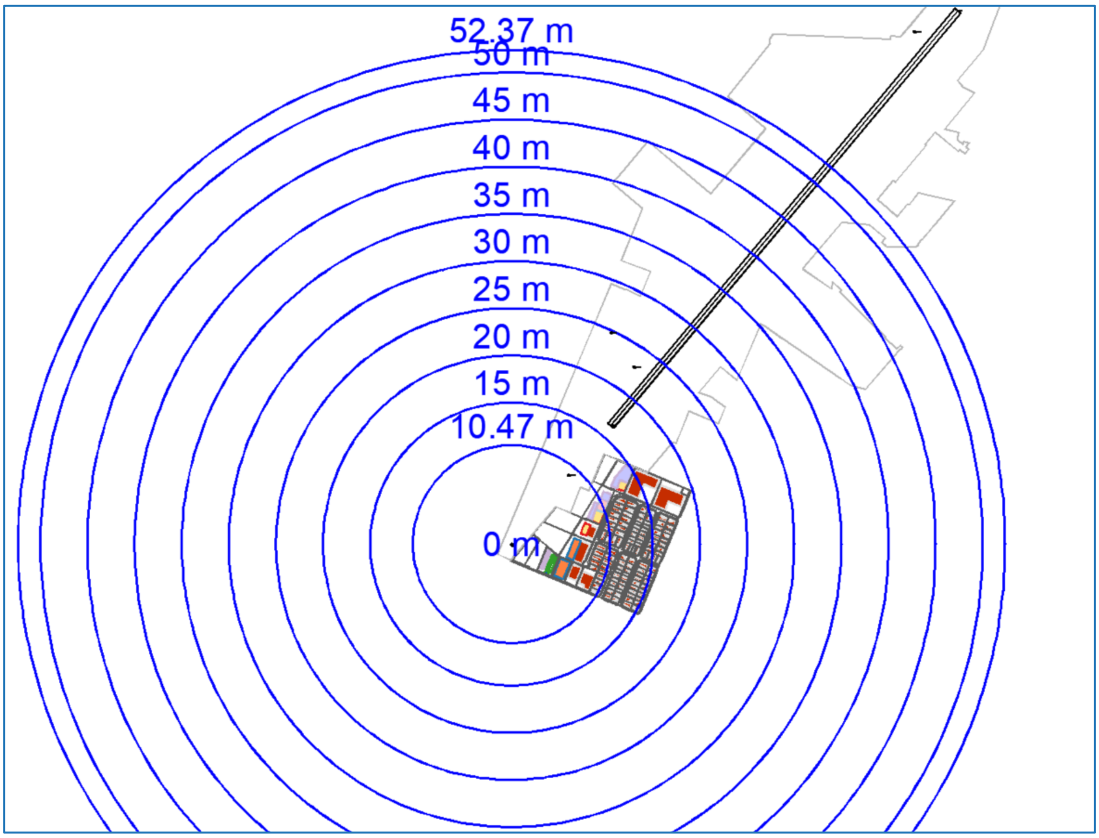

Figure 12: DVOR/DME safeguarded area

3.3.16. Buildings at the proposed development site will infringe the DVOR/DME safeguarded area, therefore a technical assessment of this facility is required.

3.3.17. The safeguarded area for the PSR/SSR facility is shown in Figure 13. Heights shown are relative to the ground level at the base of the PSR/SSR antennas, 36m AMSL.

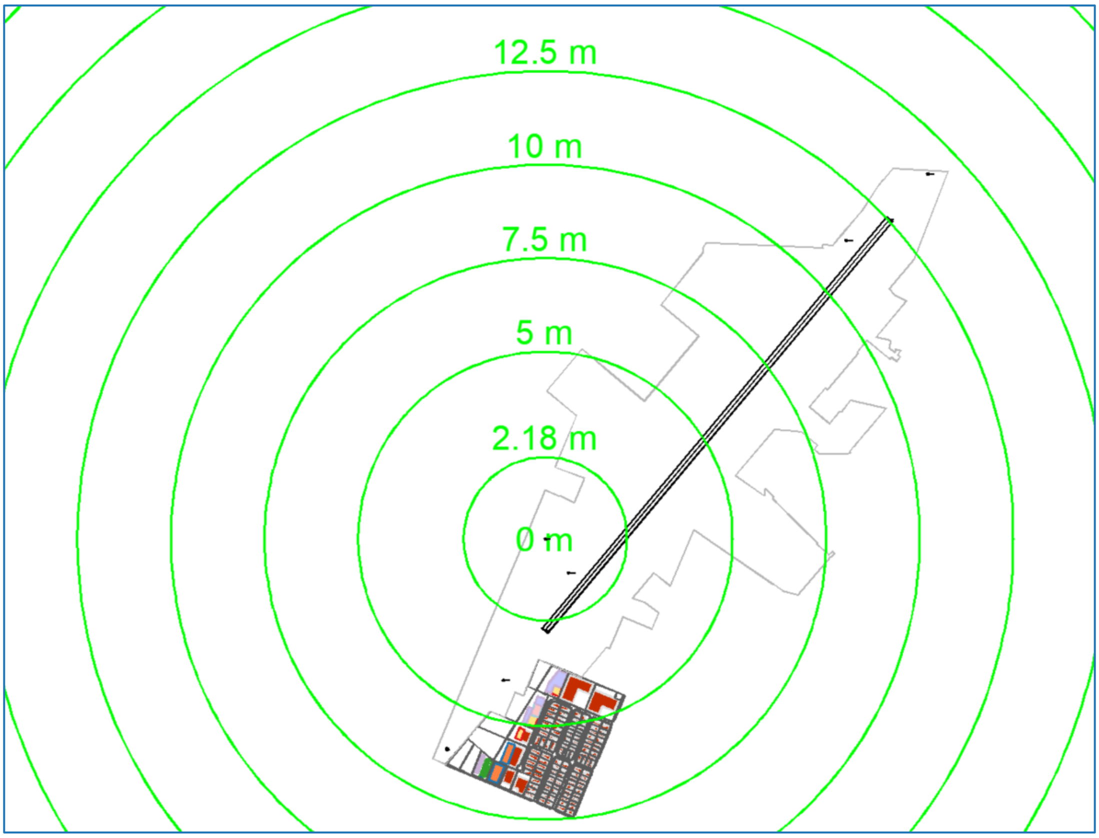

Figure 13: PSR/SSR safeguarded area

3.3.18. Buildings at the proposed development site will infringe the PSR/SSR safeguarded area, therefore a technical assessment of this facility is required.

3.3.19. In summary, technical assessment of the proposed development is required for the following facilities:

- ILS Localiser 02;
- ILS Localiser 20;
- ILS Glidepath 02;
- ILS DME 02;
- DVOR/DME; and
- PSR/SSR.

4. ANE Specifications

4.1. ILS Localiser Runway 02

- Equipment Type – Indra Normarc 7014B3 20 element dual frequency;
- Localiser Frequency – 109.9MHz;
- Localiser Position – S43 28 21.09, E172 33 04.10;
- Localiser Antenna Height – 3m Above Ground Level (AGL);
- Facility Performance Category III tolerances applied;
- The equipment is assumed to be of standard configuration of feeder distribution and signal ratios.

4.2. ILS Localiser Runway 20

- Equipment Type – Indra Normarc 7014B3 20 element dual frequency;
- Localiser Frequency – 110.3MHz;
- Localiser Position – S43 30 01.45, E172 31 08.11;
- Localiser Antenna Height – 3m AGL;
- Facility Performance Category III tolerances applied;
- The equipment is assumed to be of standard configuration of feeder distribution and signal ratios.

4.3. ILS Glidepath Runway 02

- Equipment Type – Indra Normarc 7034B3 M Array;
- Glidepath Frequency – 333.8MHz;
- Glidepath Position – S43 29 40.13, E172 31 25.90;
- Glidepath Antenna Height – 14m AGL;
- Facility Performance Category III tolerances applied;
- The equipment is assumed to be of standard configuration of feeder distribution and signal ratios.

4.4. ILS DME Runway 02

- Equipment Type – Indra LDB 102;
- DME Frequency – 997MHz CH36X;
- DME Position – S43 29 40.04, E172 31 26.02;
- DME Antenna Height – 7m AGL.

4.5. DVOR/DME

- Equipment Type – DVOR Indra VRB-53D, DME Indra/Interscan LDB102;
- DVOR Frequency – 115.3MHz;
- DME Frequency – 1187MHz CH100X;
- DVOR Position – S43 30 14.77, E172 30 52.74;
- DME Position – S43 30 15.12, E172 30 52.89;
- Magnetic Variation – 24.53°E

- DVOR Antenna Height – 4.7m AGL;
- DME Antenna Height – 7.5m AGL.

4.6. PSR/SSR

- Equipment Type – Indra PSR3D/MSSR;
- PSR Frequency – 1290.50MHz, 1274.96MHz, 1277.96MHz;
- SSR Frequency – 1030MHz;
- PSR/SSR Position – S43 29 33.25, E172 31 19.80;
- PSR Antenna Centre Height – 23.4m AGL;
- SSR Antenna Centre Height – 25.5m AGL.

5. ILS Technical Safeguarding Process

5.1. Steps

5.1.1. The primary objective of ILS Safeguarding is to ensure the on-going safe operation of the ILS. The secondary objective is to allow development in a controlled manner whilst ensuring that the primary objective continues to be met.

5.1.2. If a development falls within the safeguarded area of an ILS, the technical assessment process for a proposed development in the presence of that specific ILS can normally be considered in three stages:

- Worst-case model;
- Refined model;
- Explore mitigation options.

5.1.3. Whilst the process is illustrated in Figure 14, overleaf, a brief explanation of the staged process which is normally applied to ILS safeguarding is as follows:

- A worst-case computer simulation is made outlining the development as a series of perfectly reflecting smooth metal sheets. If the results of the worst-case model show acceptable degradation to the ILS signal parameters, then no further investigation is required, and the development is accepted. If the effects are unacceptable, then the safeguarding process moves on to stage 2;
- The worst-case computer simulation is now refined to more accurately represent the proposed development. This includes using actual proposed building dimensions, orientations and better representation of the construction materials proposed. If the results show acceptable degradation to the ILS signal parameters, then no further investigation is required, and the development is accepted. If the effects are unacceptable, then the safeguarding process moves on to stage 3;
- The third stage is to identify possible mitigations in the design of the proposed development. These may include reducing building heights, changing the orientation of buildings, change of building materials, change of building layout, modifications to building shapes or the addition of screening or shadowing structures. If the results show acceptable degradation to the ILS signal parameters, then no further investigation is required, and the development is accepted.
- It is possible to optimise the ILS signal to some extent by electrical and/or mechanical modifications to the ILS equipment and antennas. The degree of optimisation available depends on the configuration of the system; it should be noted that optimisation is not always possible. Generally, ILS can only be optimised to deal with one specific problem and cannot be adapted for multiple developments. If, after optimisation, the results show acceptable degradation to the ILS signal parameters, then no further investigation is required, and the development is accepted.
- A more radical step may be to consider upgrading the ILS equipment to a configuration that is unaffected by the proposed development, or even relocation of the equipment.
- If all other mitigation measures fail to safeguard the ILS performance, then downgrading of the ILS facility performance category may be considered as the only option for the development to proceed. Although such a decision would not to be taken lightly, Airways New Zealand as the air navigation service provider may, for example, in

consultation with the users (airlines), Airport operator and the regulator (Civil Aviation Authority of New Zealand), and possibly also the Ministry of Transport be authorised to sacrifice ILS performance for the sake of building a new terminal following a cost benefit analysis.

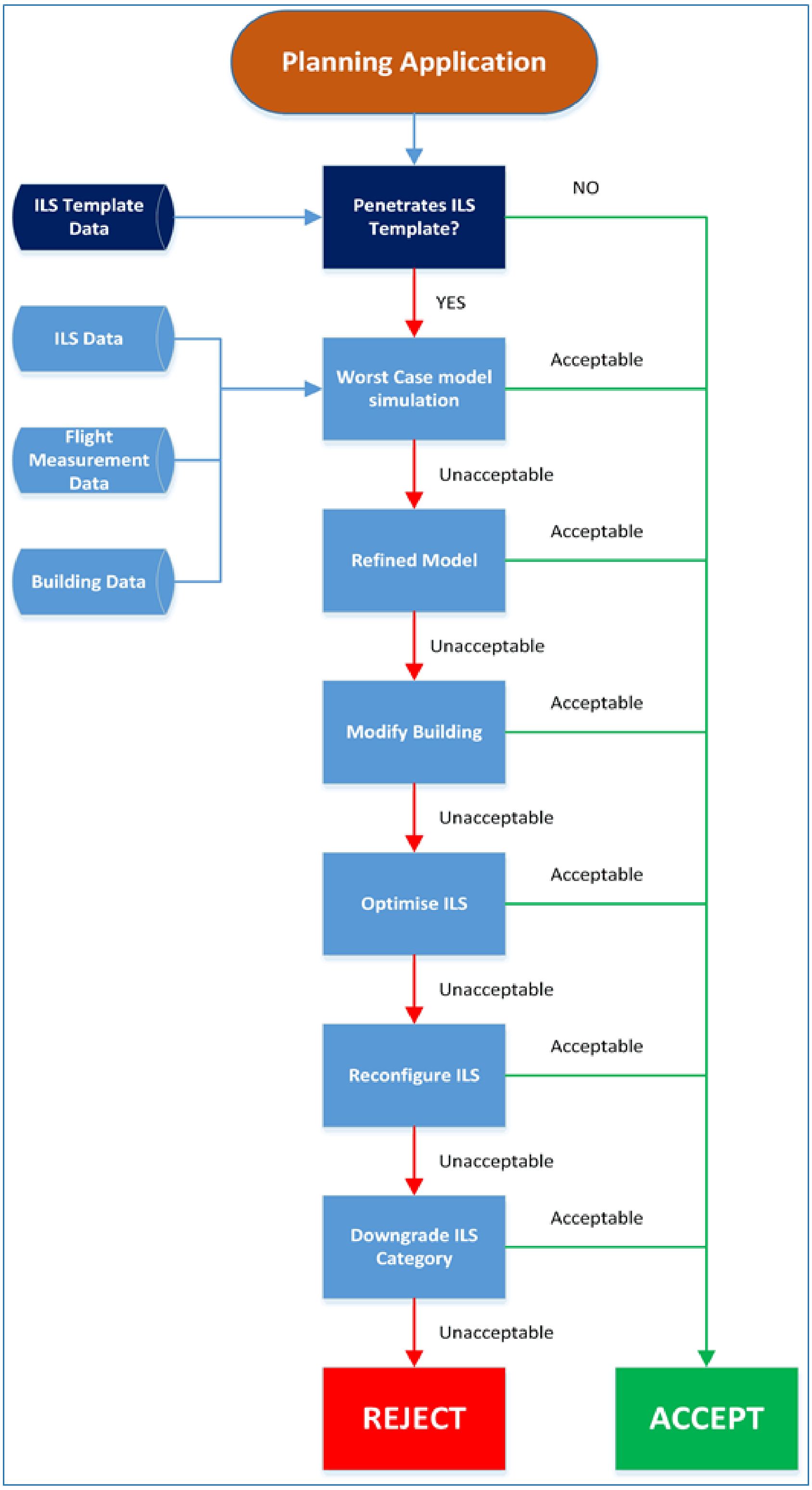

Figure 14: Nominal ILS technical assessment process

6. ILS Localiser and Glidepath Analysis

6.1. Behaviour characteristics of the modelling tools

6.1.1. ILS signals will be reflected and diffracted by any objects that are illuminated by the Radio Frequency (RF) radiation from the ILS antennas. If the antenna is considered as a light bulb, light will be reflected from objects that the light falls on. Similarly, if an object is not illuminated by the ILS, it will not reflect the RF energy which causes distortions to the ILS pattern. Therefore, when modelling a development, only those faces illuminated by the ILS are considered.

6.1.2. The beam guidance structure of the ILS will be the vector sum of the directly radiated signal and signals that are reflected from other objects illuminated by the ILS antennas. In the case of Christchurch Airport, signals will be reflected from the ground, the existing buildings, plus moving vehicles. It is not possible to accurately simulate all of these variables and therefore necessary to consider the effects of the development in isolation. The additional disturbance predicted may then be compared with the existing disturbance determined by flight measurement.

6.1.3. The modelling software, OUNPPM, considers the height and width of an obstacle, its distance from the Localiser or Glidepath and offset from the Localiser or Glidepath centreline, its angle in relation to the runway centreline and tilt relative to the vertical.

6.2. ILS Localiser and Glidepath tolerances

6.2.1. Ideally, the ILS Localiser or Glidepath beam would be a straight line. Reflections from terrain and objects illuminated by the Localiser or Glidepath signal will distort the beam, introducing disturbances. The limits of these disturbances are defined in Annex 10[3] by ICAO.

6.2.2. The Christchurch ILS facilities are promulgated as Category I but are maintained to operate within Category III tolerances, therefore the more demanding Category III tolerances will be used for the assessment.

6.2.3. The Localiser Category III tolerance for course bends is ±30µA from the edge of Designated Operational Coverage (DOC) to ILS Point A (4 Nautical Miles (NM) from the runway threshold), reducing linearly to ±5µA at ILS Point B (3,500 feet from the runway threshold), then remaining at ±5µA to the ILS reference datum. From ILS reference datum to ILS Point D (3,000 feet from the threshold in the direction of the Localiser) the tolerance remains at ±5µA, then increases linearly to ±10µA at ILS Point E (2,000 feet from the stop end of the runway in the direction of the threshold).

6.2.4. The Glidepath Category III tolerance for course bends is ±30µA from the edge of DOC to ILS Point A, reducing linearly to ±20µA at ILS Point B, then remaining at ±20µA to the ILS reference datum.

[3] ICAO Annex 10 Aeronautical Telecommunications Volume 1 Radio Navigation Aids, Eighth Edition, July 2023

6.2.5. For the purposes of the ILS modelling detailed in this section the following definitions of impact have been used:

- Negligible: The predicted ILS disturbance will not change the existing disturbance.
- Very minor: The predicted ILS disturbance will increase the existing disturbance by less than ±0.5µA.
- Minor: The predicted ILS disturbance will increase the existing disturbance by between ±0.5µA and ±1.0µA.
- Noticeable: The predicted ILS disturbance will increase the existing disturbance by more than ±1.0µA.

6.2.6. All of the above impacts can be considered to be acceptable provided the overall ILS disturbance remains within the defined Category III tolerances for course bends; however, disturbances of magnitude ±4µA or more may have an adverse effect on the flyability of an ILS and are therefore undesirable.

6.3. ILS Localiser Runway 02 modelling

6.3.1. OUNPPM configuration

6.3.1.1. The configuration of the modelling software used for the assessment is shown in Figure 15.

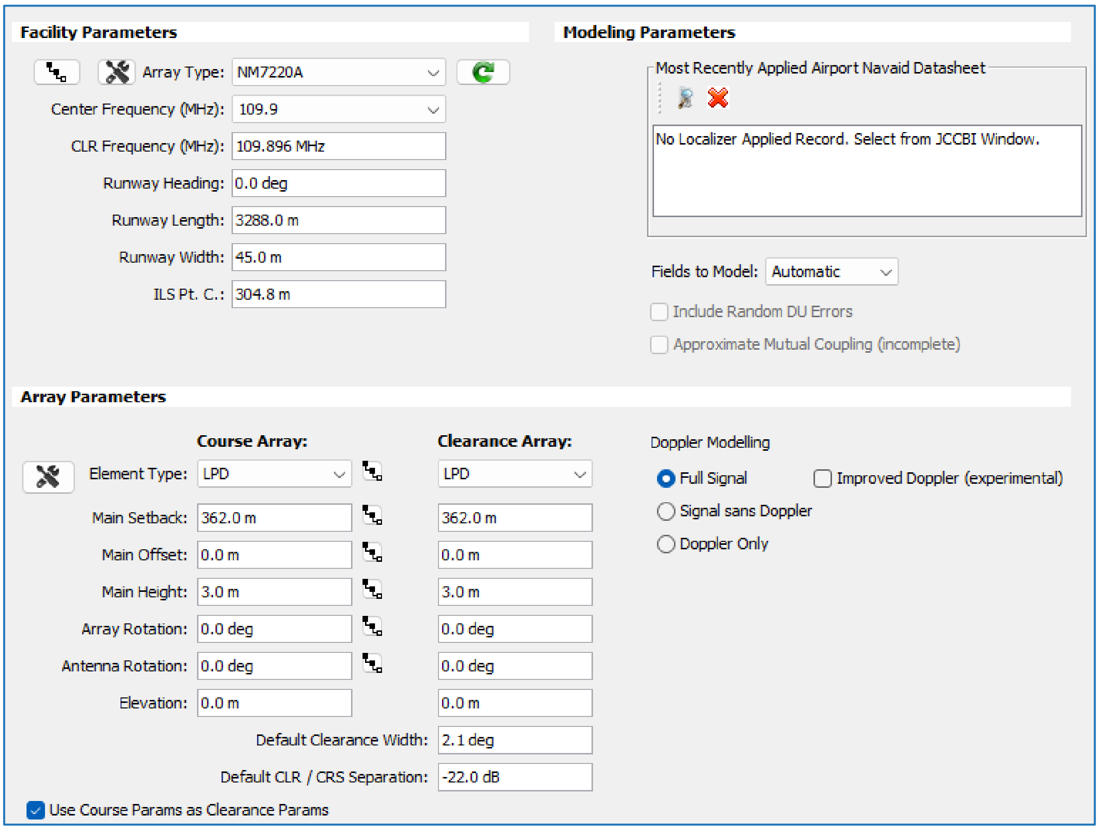

Figure 15: Localiser Runway 02 modelling configuration

6.3.1.2. The default antenna height is adjusted to 3m to align with the actual height of the installed facility.

6.3.1.3. Initial modelling is undertaken with no reflecting objects introduced into the model. This establishes a baseline, the results of which are shown in Figure 16 and Figure 17.

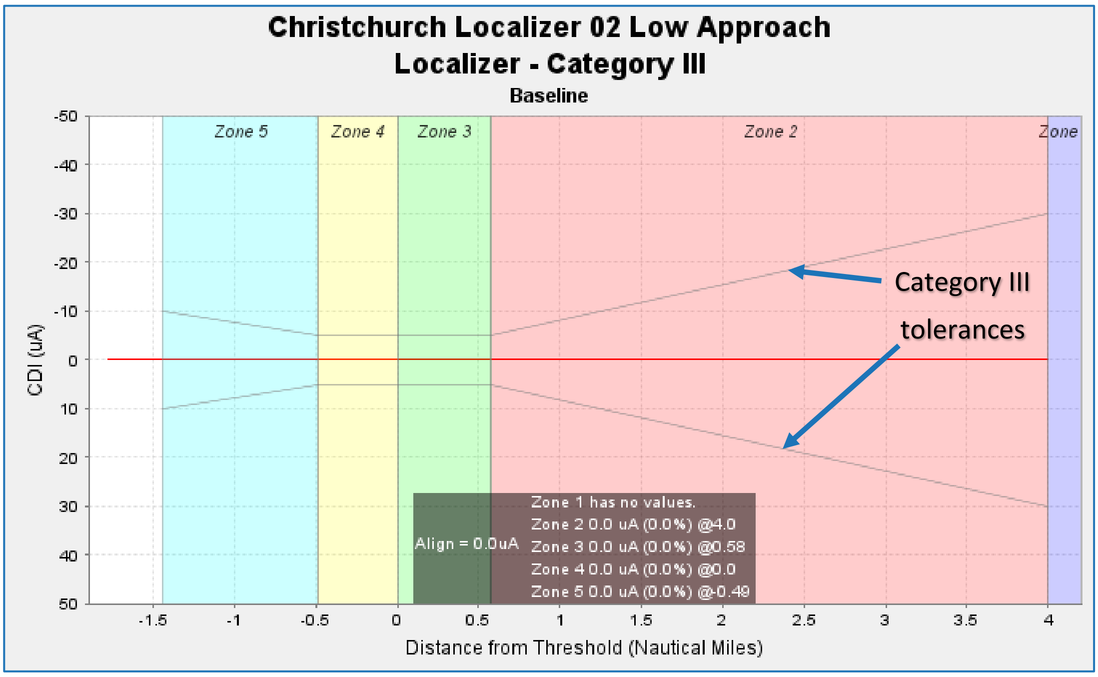

Figure 16: Localiser Runway 02 approach course structure baseline – no scatter objects

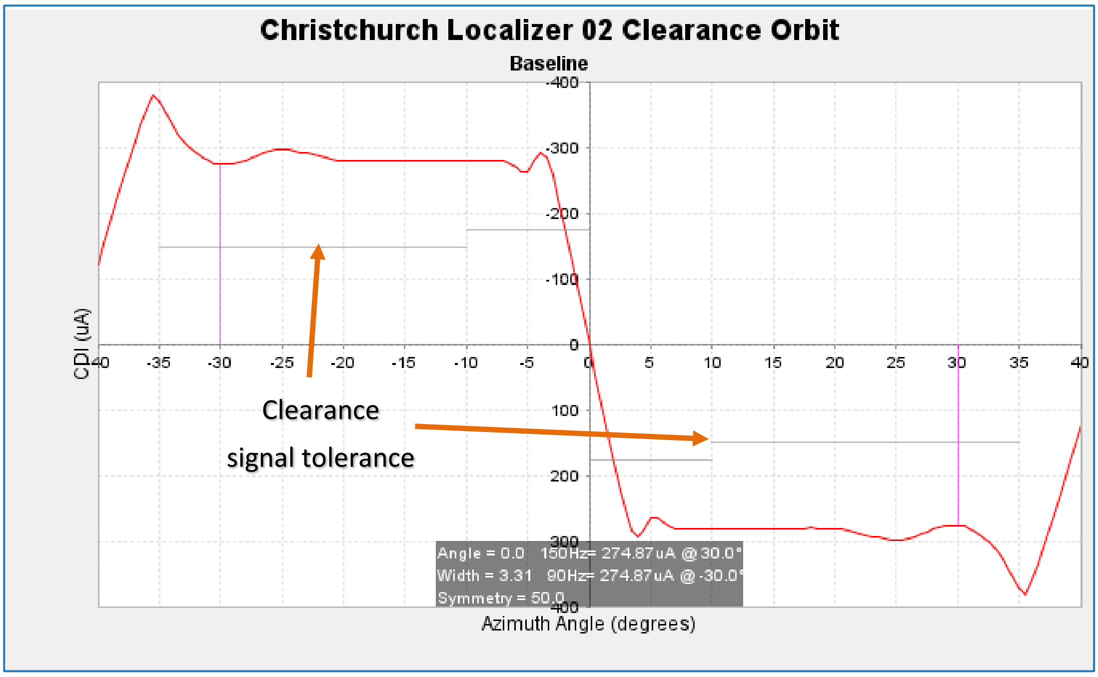

Figure 17: Localiser Runway 02 orbit baseline – no scatter objects

6.3.2. Simulation analysis

6.3.2.1. The model is configured with scatter objects which are representative of the buildings that are in view of the Localiser. Only the areas which will be illuminated by the Localiser need to be considered for the simulation.

6.3.2.2. The buildings illuminated by Localiser 02 are depicted in Figure 18.

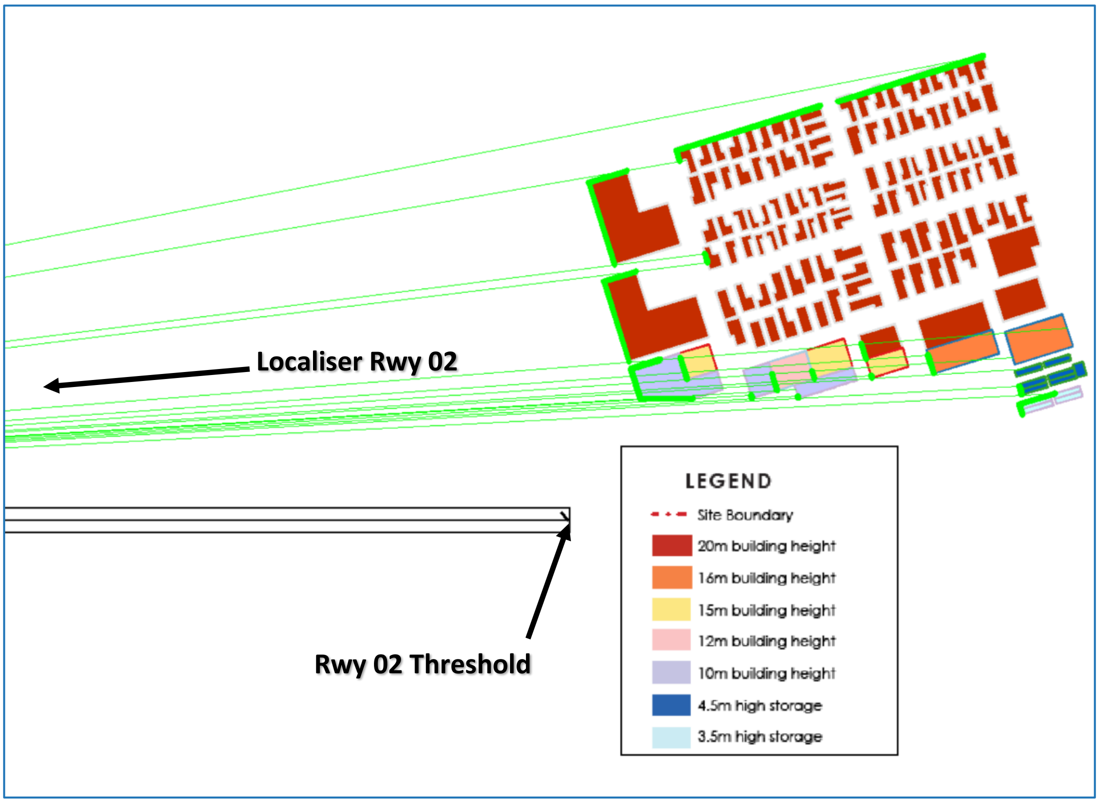

Figure 18: Buildings illuminated by Localiser 02

6.3.2.3. A plan view of the scatter objects used in the model scenario is shown in Figure 19.

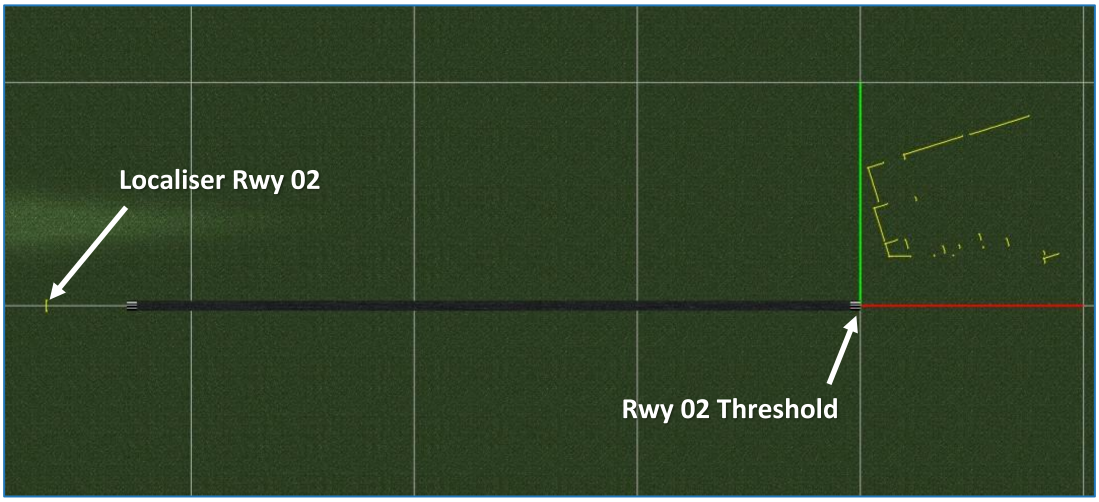

Figure 19: Plan view of Localiser 02 scatter objects

6.3.2.4. A 3D view of the scatter objects is shown in Figure 20.

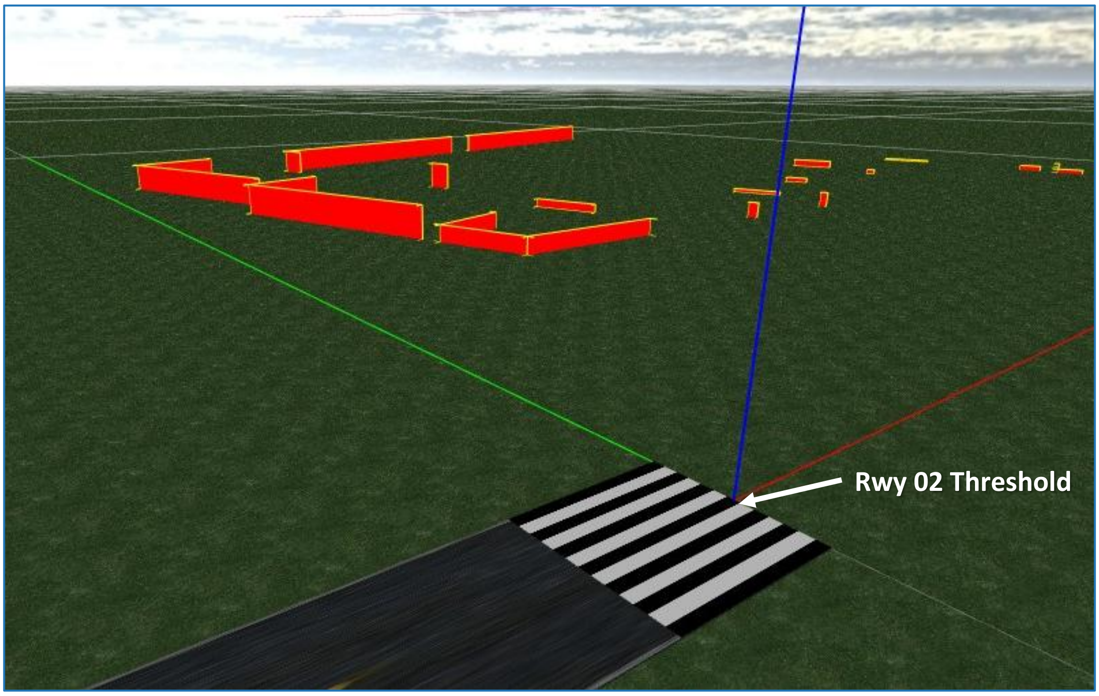

Figure 20: 3D view of Localiser 02 scatter objects

6.3.2.5. The buildings are represented as a series of vertical rectangular plates. Each scatter object is worst-case modelled as having a steel surface for maximum reflectivity.

6.3.2.6. The results of the simulation of the proposed development are shown in Figure 21 and Figure 22.

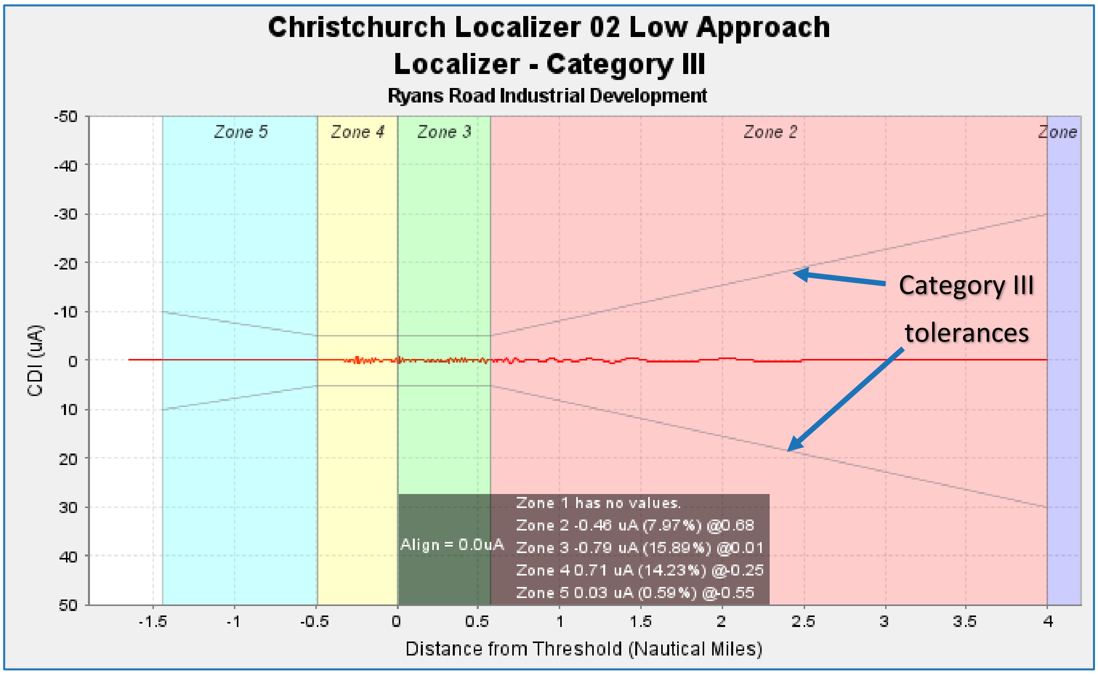

Figure 21: Localiser Runway 02 approach course structure – building scatter objects

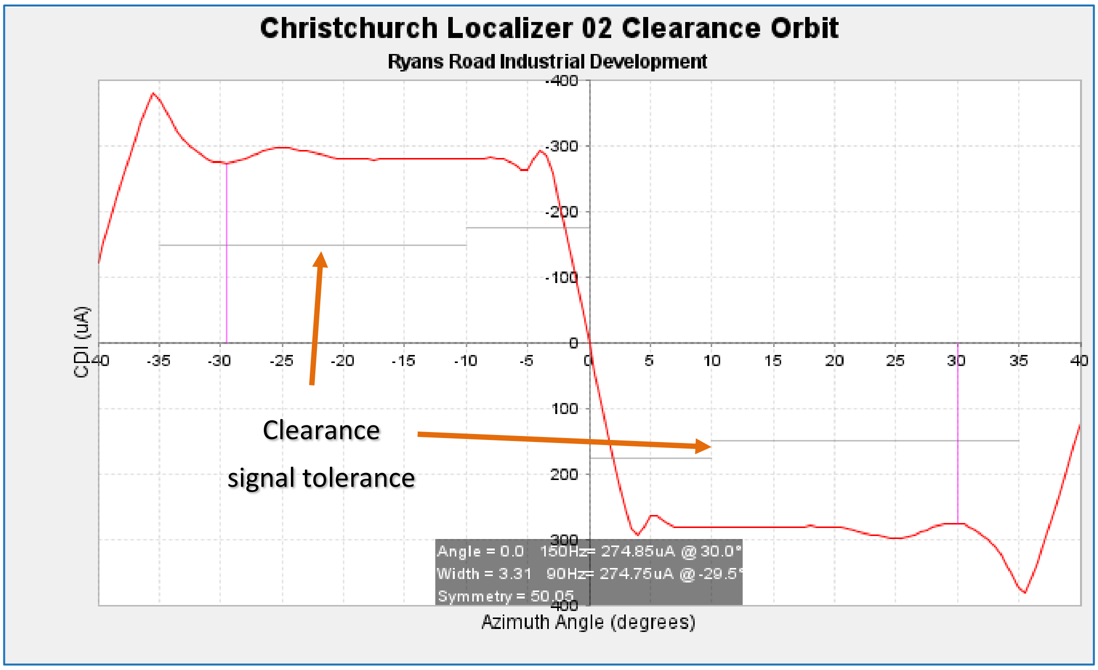

Figure 22: Localiser Runway 02 orbit – building scatter objects

6.3.2.7. Figure 21 shows that the maximum simulated course disturbance in ILS Zone 2 (ILS Point A to ILS Point B) is -0.46µA, in Zone 3 (ILS Point B to Threshold) is -0.79µA, in Zone 4 (Threshold to ILS Point D) is -0.71µA and in Zone 5 (ILS Point D to ILS Point E) is 0.03µA.

6.3.2.8. Examination of the existing disturbance, as measured by flight inspection, indicates typical errors of ±1.4µA in Zone 2, ±1.4µA in Zone 3, ±0.6µA in Zone 4, and ±0.8µA in Zone 5.

6.3.2.9. To find the potential impact of the simulated disturbance, the existing measured disturbance is combined with the predicted simulated disturbance using Root Sum Squared (RSS) vector addition to give overall results of ±1.5µA in Zone 2, ±1.6µA in Zone 3, ±0.9µA in Zone 4, and ±0.8µA in Zone 5.

6.3.2.10. This shows that the additional simulated disturbance has a very minor impact on the existing disturbance in Zones 2, 3 and 4, with a maximum increase in error of ±0.3µA in Zone 4. The increase in error will be imperceptible to pilots flying ILS approaches to runway 02.

6.3.2.11. Comparing the orbit simulation of Figure 17 with Figure 22 shows virtually no impact on the Localiser clearance signal.

6.3.2.12. The results of the worst-case modelling indicate that the proposed development will have a very minor impact on Localiser 02 performance. The actual effects are expected to be less than those predicted by the worst-case model.

6.4. ILS Localiser Runway 20 modelling

6.4.1. OUNPPM configuration

6.4.1.1. The configuration of the modelling software used for the assessment is shown in Figure 23.

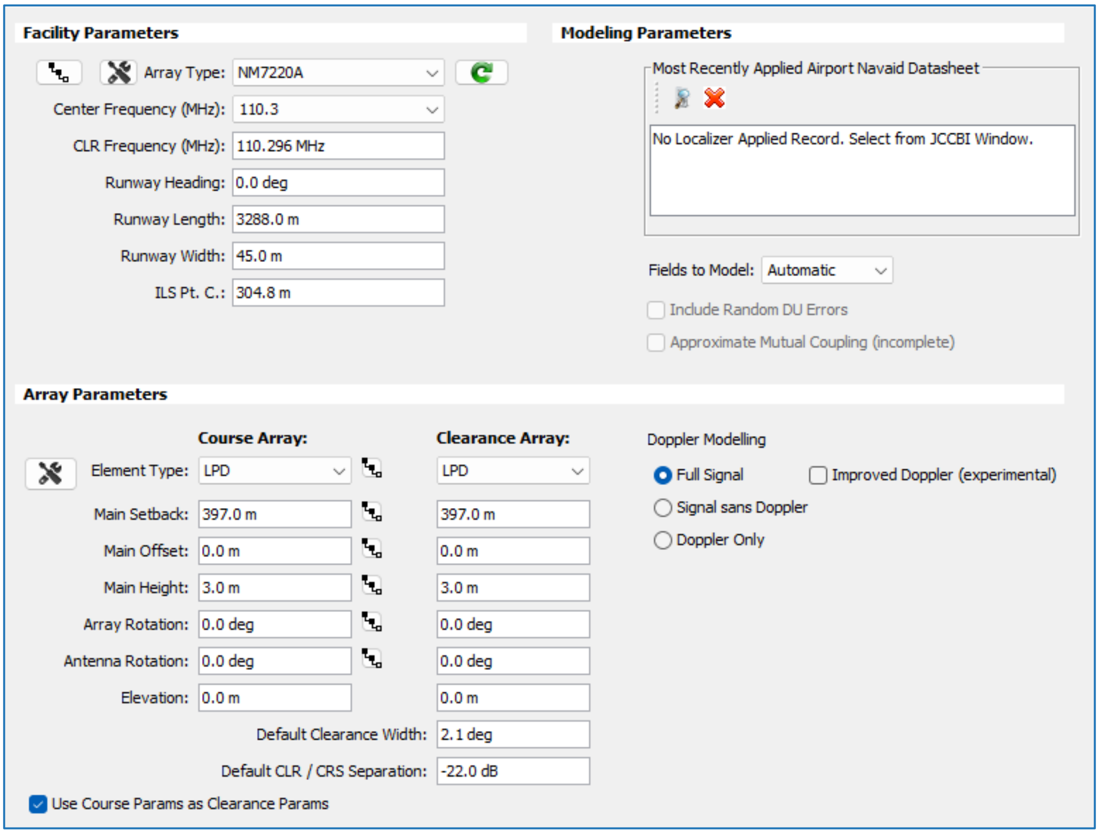

Figure 23: Localiser Runway 20 modelling configuration

6.4.1.2. The default antenna height is adjusted to 3m to align with the actual height of the installed facility.

6.4.1.3. Initial modelling is undertaken with no reflecting objects introduced into the model. This establishes a baseline, the results of which are shown in Figure 24 and Figure 25.

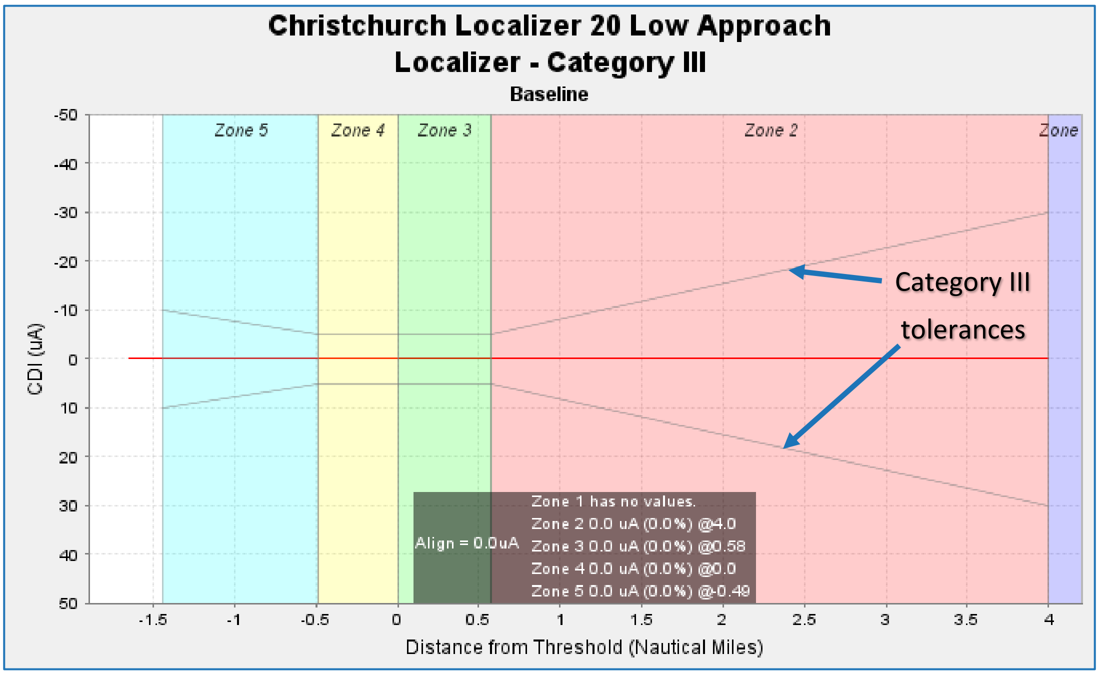

Figure 24: Localiser Runway 20 approach course structure baseline – no scatter objects

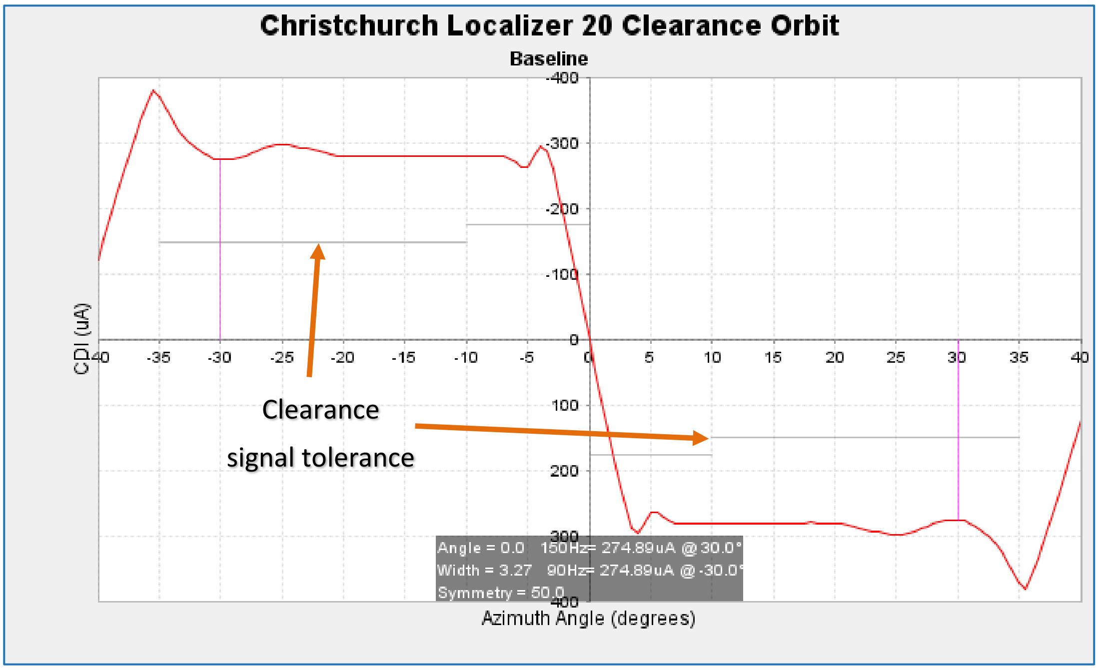

Figure 25: Localiser Runway 20 orbit baseline – no scatter objects

6.4.2. Simulation analysis

6.4.2.1. The model is configured with scatter objects which are representative of the buildings that are in view of the Localiser. Only the areas which will be illuminated by the Localiser need to be considered for the simulation.

6.4.2.2. The buildings illuminated by Localiser 20 are depicted in Figure 26.

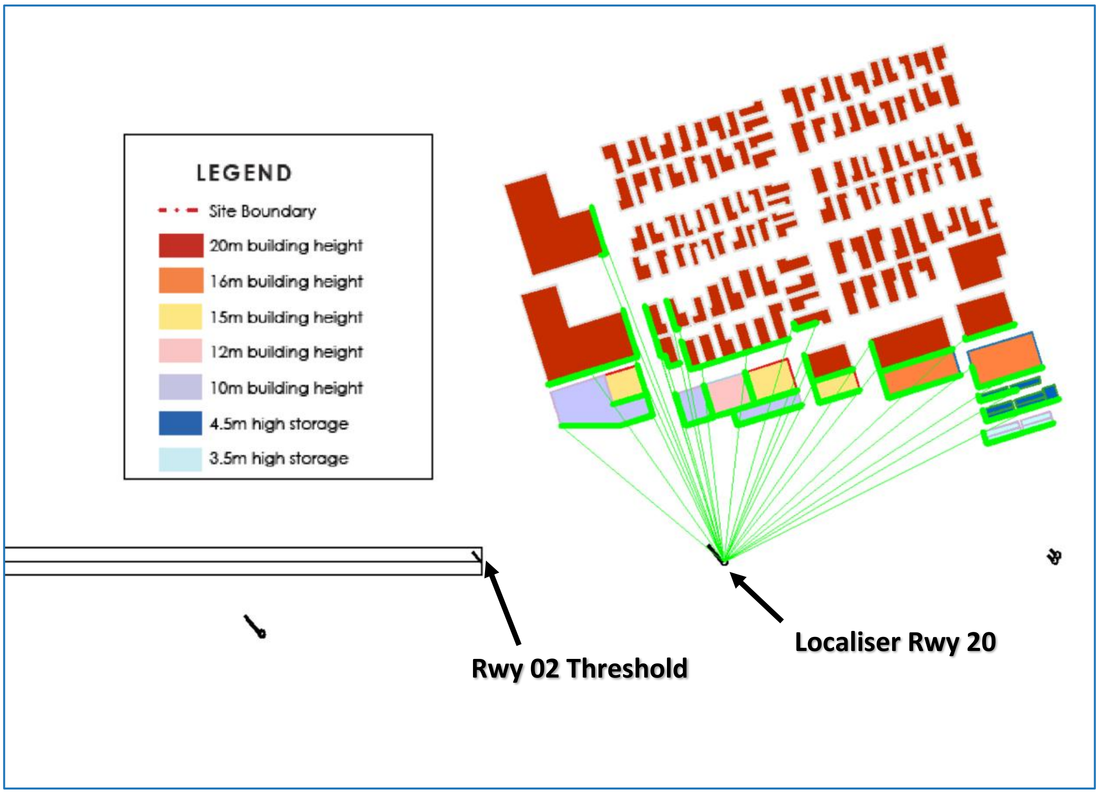

Figure 26: Buildings illuminated by Localiser 20

6.4.2.3. A plan view of the scatter objects used in the model scenario is shown in Figure 27.

Figure 27: Plan view of Localiser 20 scatter objects

6.4.2.4. A 3D view of Localiser 20 and the scatter objects is shown in Figure 28.

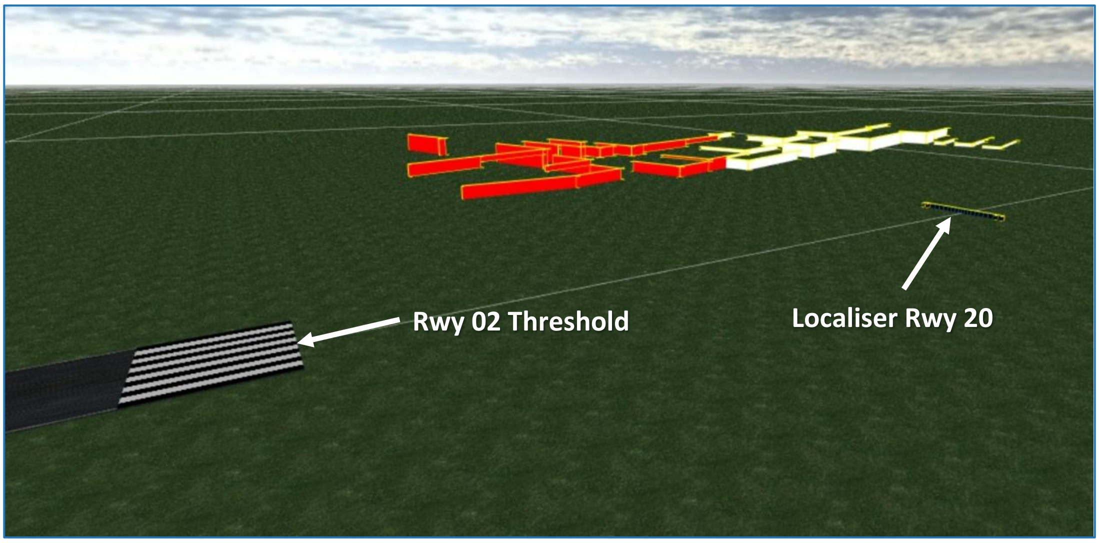

Figure 28: 3D view of Localiser 20 scatter objects

6.4.2.5. The buildings are represented as a series of vertical rectangular plates. Each scatter object is worst-case modelled as having a steel surface for maximum reflectivity.

6.4.2.6. The results of the simulation of the proposed development are shown in Figure 29 and Figure 30.

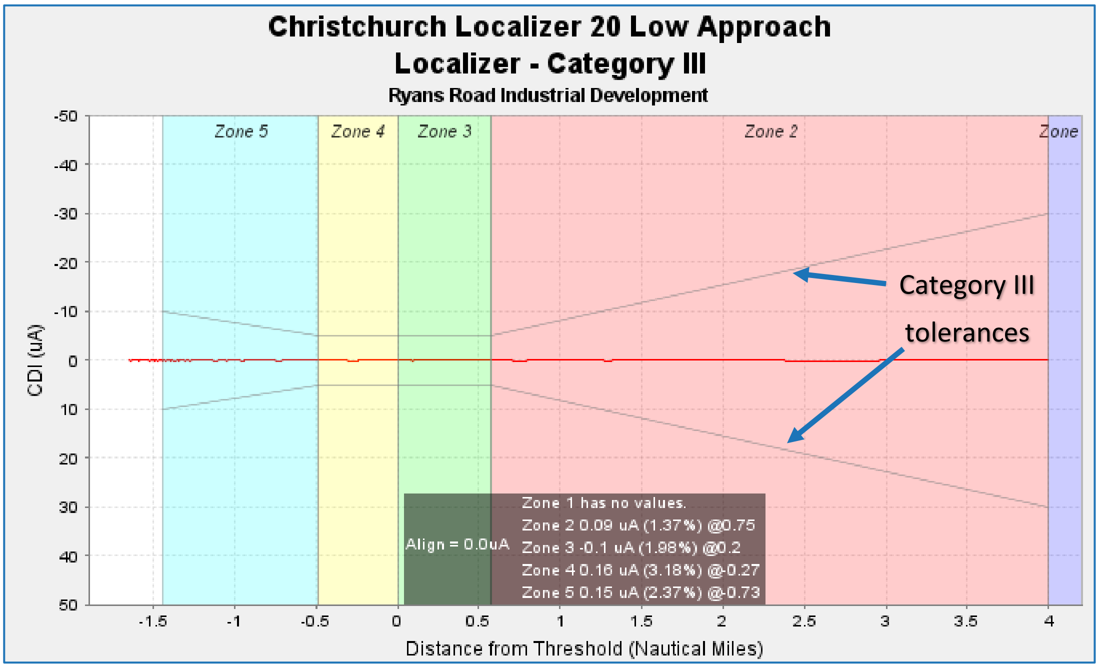

Figure 29: Localiser Runway 20 approach course structure – building scatter objects

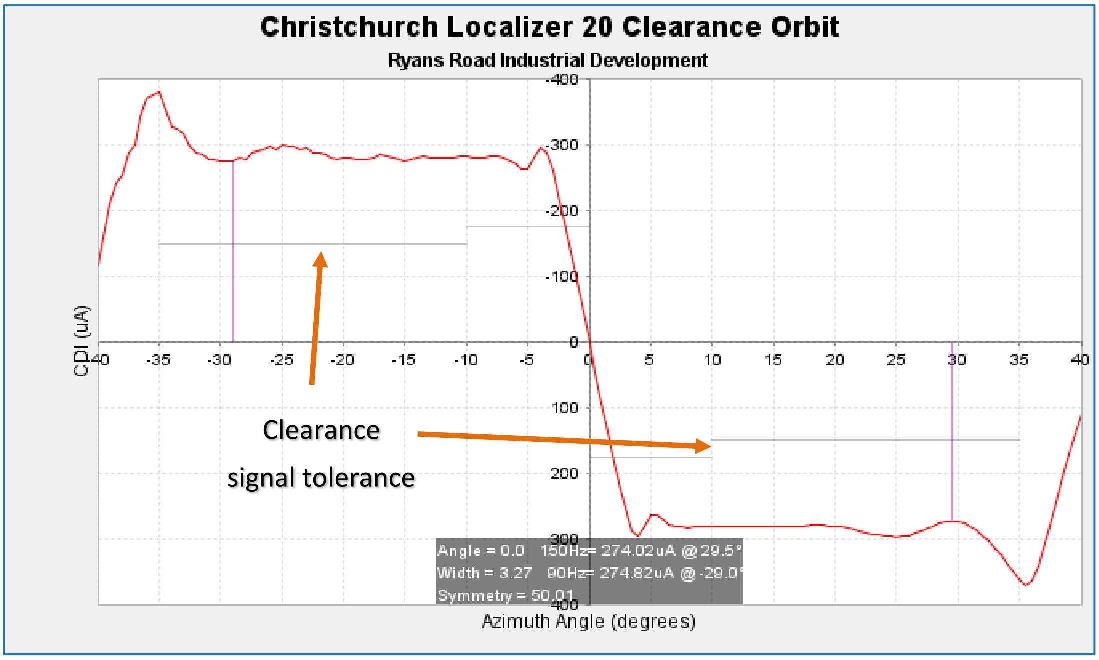

Figure 30: Localiser Runway 20 orbit – building scatter objects

6.4.2.7. Figure 29 shows that the maximum simulated course disturbance in ILS Zone 2 is 0.09µA, in Zone 3 is -0.10µA, in Zone 4 is 0.16µA and in Zone 5 is 0.15µA.

6.4.2.8. Examination of the existing disturbance, as measured by flight inspection, indicates typical errors of ±0.8µA in Zone 2, ±1.3µA in Zone 3, ±0.8µA in Zone 4, and ±0.4µA in Zone 5.

6.4.2.9. To find the potential impact of the simulated disturbance, the existing measured disturbance is combined with the predicted simulated disturbance using RSS vector addition to give overall results of ±0.8µA in Zone 2, ±1.3µA in Zone 3, ±0.8µA in Zone 4, and ±0.4µA in Zone 5.

6.4.2.10. This shows that the additional simulated disturbance will have a negligible impact on the existing Localiser disturbance.

6.4.2.11. Comparing the orbit simulation of Figure 25 with Figure 30 shows some marginal disturbance to the Localiser clearance signal to the left of the extended runway centreline. The disturbance will not be noticed by users of the facility.

6.4.2.12. The results of the worst-case modelling indicate that the proposed development will have a negligible impact on Localiser 20 performance. The actual effects are expected to be less than those predicted by the worst-case model.

6.5. ILS Glidepath Runway 02 modelling

6.5.1. OUNPPM configuration

6.5.1.1. The configuration of the modelling software used for the assessment is shown in Figure 31.

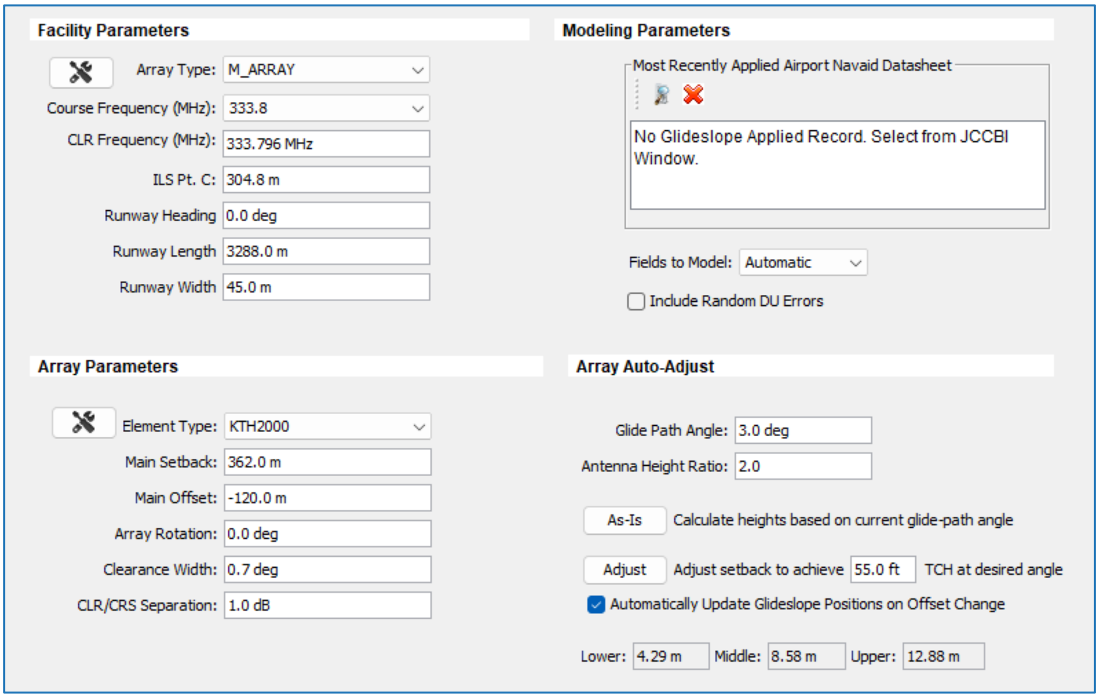

Figure 31: Glidepath Runway 02 modelling configuration

6.5.1.2. The OUNPPM software assumes a perfectly flat terrain, so the appropriate default antenna heights for a flat beam forming area have been used for the simulations.

6.5.1.3. Initial modelling is undertaken with no reflecting objects introduced into the model. This establishes a baseline, the result of which is shown in Figure 32.

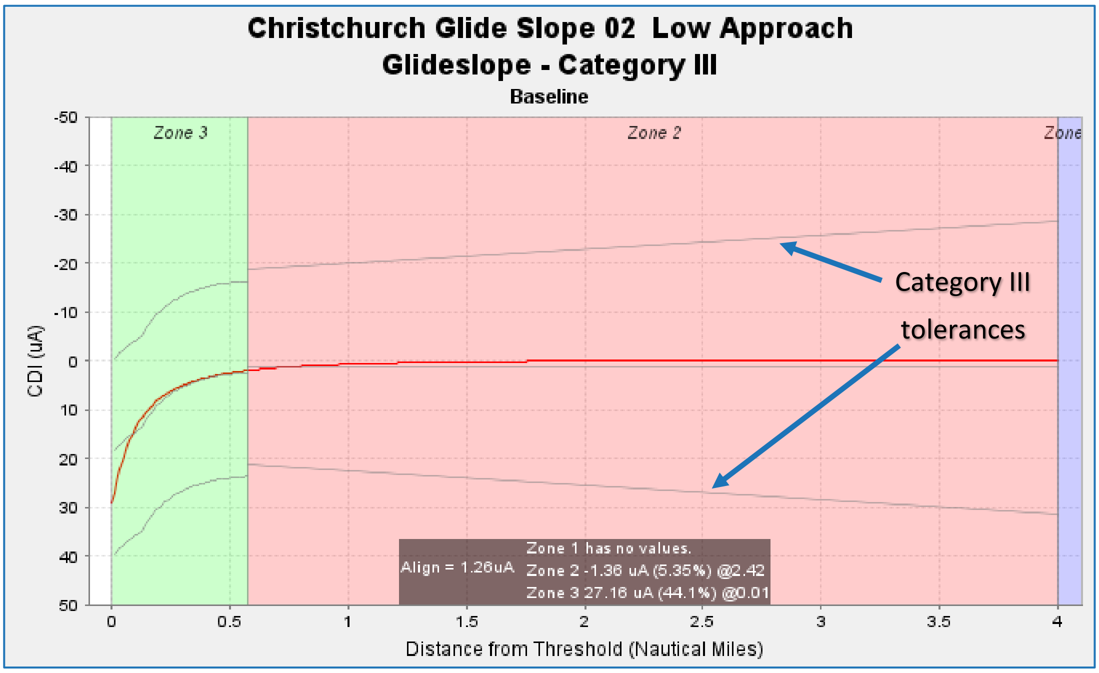

Figure 32: Glidepath Runway 02 approach course structure baseline – no scatter objects

6.5.2. Simulation analysis

6.5.2.1. The model is configured with scatter objects which are representative of the buildings that are in view of the Glidepath. Only the areas which will be illuminated by the Glidepath need to be considered for the simulation.

6.5.2.2. The buildings illuminated by Glidepath 02 are depicted in Figure 33.

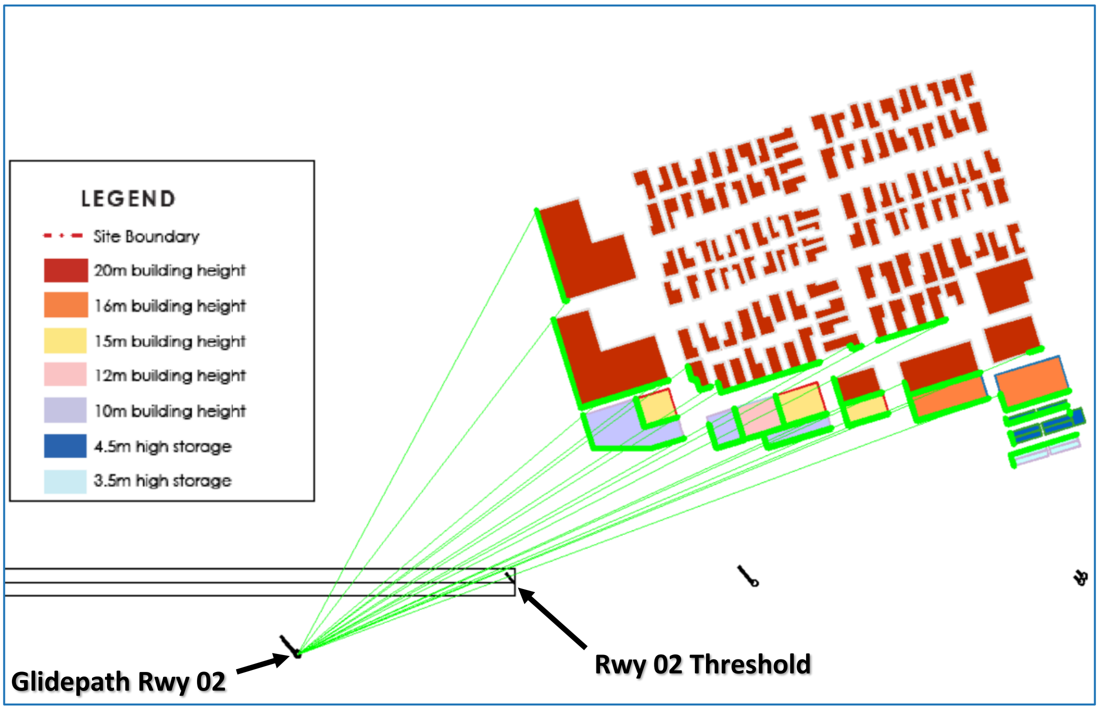

Figure 33: Buildings illuminated by Glidepath 02

6.5.2.3. A plan view of the scatter objects used in the model scenario is shown in Figure 34.

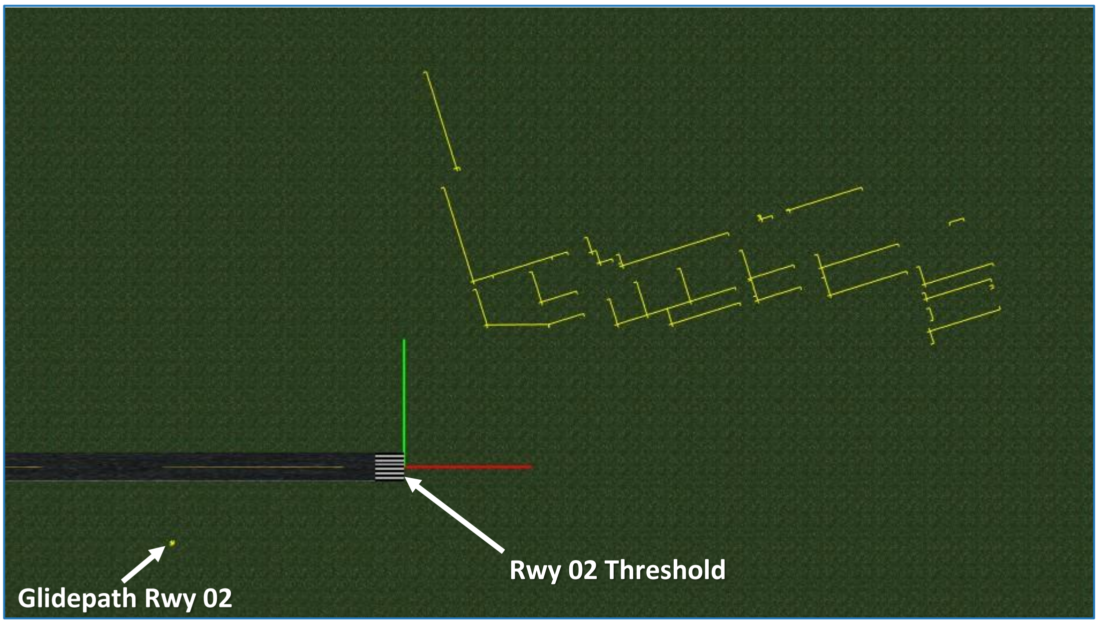

Figure 34: Plan view of Glidepath 02 scatter objects

6.5.2.4. A 3D view of Glidepath 02 and the scatter objects is shown in Figure 35.

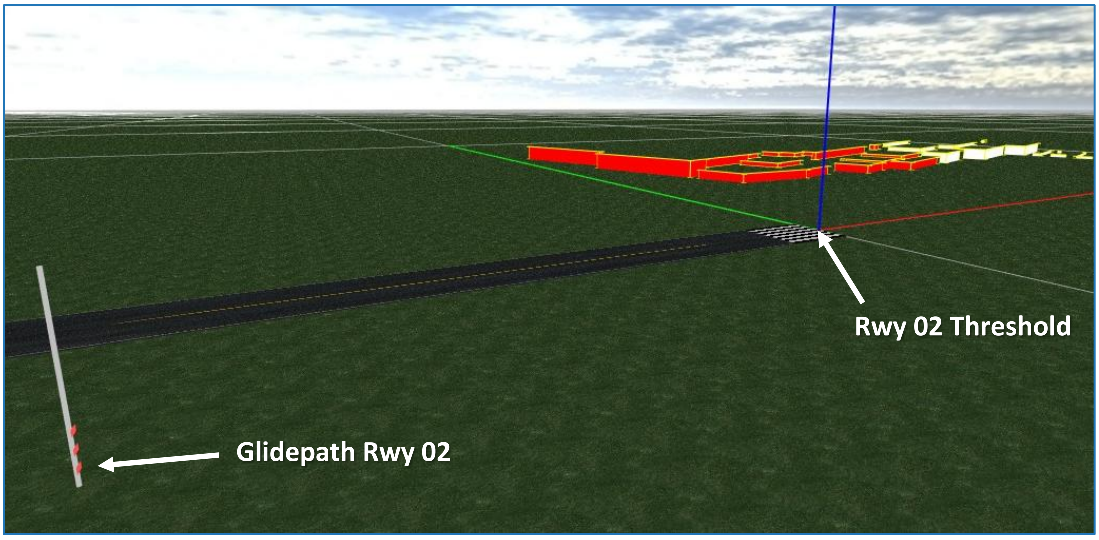

Figure 35: 3D view of Glidepath 02 scatter objects

6.5.2.5. The buildings are represented as a series of vertical rectangular plates. Each scatter object is worst-case modelled as having a steel surface for maximum reflectivity.

6.5.2.6. The result of the simulation of the proposed development is shown in Figure 36.

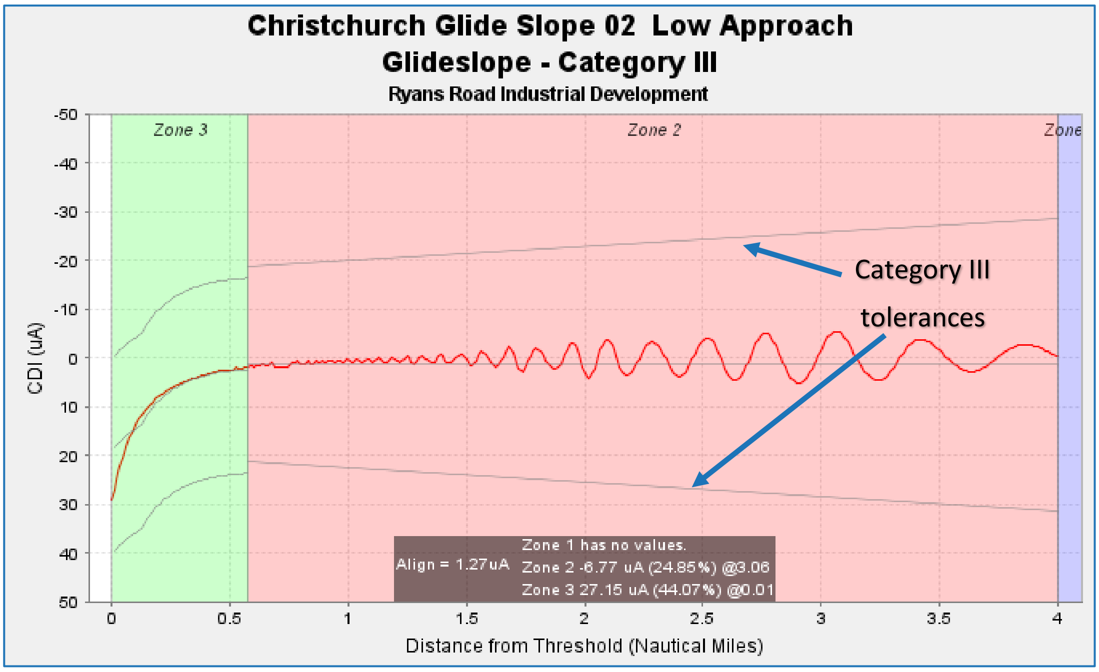

Figure 36: Glidepath Runway 02 approach course structure – building scatter objects

6.5.2.7. Figure 36 shows some impact on the Glidepath approach course structure. The maximum simulated course disturbance in ILS Zone 2 is ±5.4µA and in ILS Zone 3 is ±0.2µA.

6.5.2.8. Examination of the existing disturbance, as measured by flight inspection, indicates maximum errors of ±1.6µA in Zone 2 and ±2.8µA in Zone 3.

6.5.2.9. To find the potential impact of the simulated disturbance, the existing measured disturbance is combined with the predicted simulated disturbance using RSS vector addition to give overall results of ±5.6µA in Zone 2 and ±2.8µA in Zone 3.

6.5.2.10. The magnitude of the predicted disturbance is considered significant and will have a noticeable impact on the existing Glidepath disturbance.

6.5.2.11. The results of the worst-case modelling indicate that the proposed development will have a noticeable impact on Glidepath 02 performance. The actual effects are expected to be less than those predicted by the worst-case model. While the range of the disturbance remains within Category III glidepath course bend tolerances, the disturbance is such that the aircraft would not fly a steady glide angle and so the guidance may not be flyable in practice.

6.5.2.12. To mitigate the impact on Glidepath 02 changes to the design of the proposed development can be made.

6.5.2.13. The first mitigation option under consideration is to reduce building heights. The 20m high buildings within sites 121 and 122 (as labelled in Figure 2) are likely to be a major source of multipath reflections, so the model can be reconfigured with their heights reduced to 10m. Note that this exposes more buildings beyond these sites to illumination by the Glidepath, as shown in Figure 37.

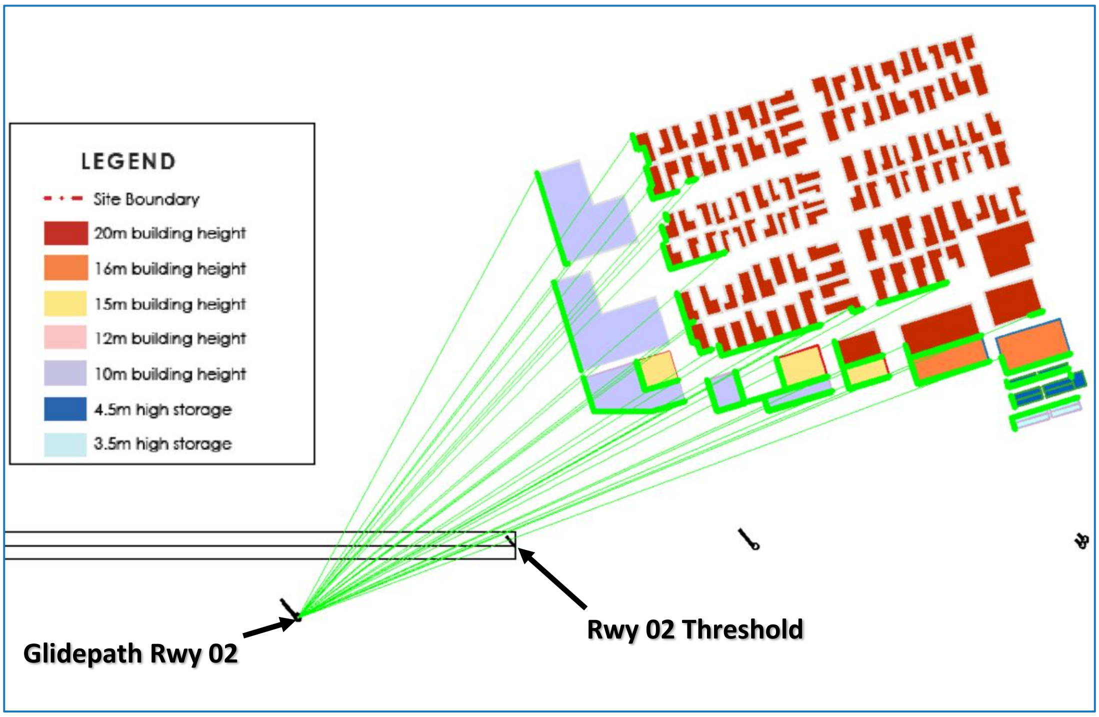

Figure 37: Buildings illuminated by Glidepath 02 – building heights reduced

6.5.2.14. The result of the simulation of the proposed development with building heights reduced is shown in Figure 38.

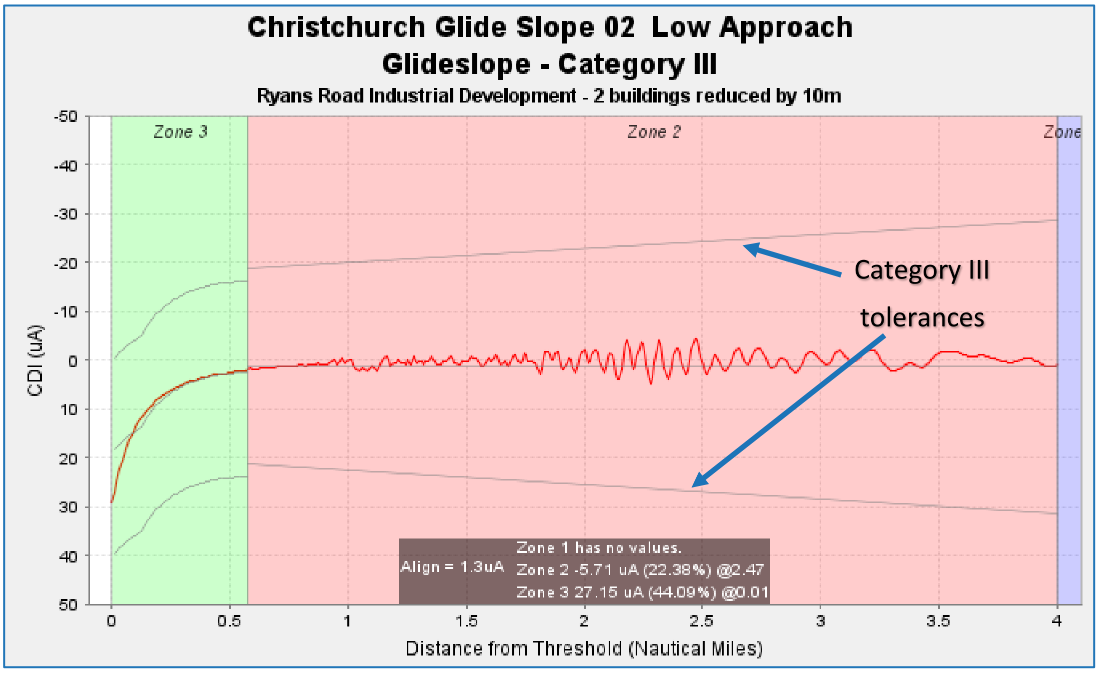

Figure 38: Glidepath Runway 02 approach course structure – building heights reduced

6.5.2.15. Figure 38 shows some impact on the Glidepath approach course structure. The maximum simulated course disturbance in ILS Zone 2 is ±4.4µA and in ILS Zone 3 is ±0.1µA.

6.5.2.16. Reducing the heights of the buildings within sites 121 and 122 has marginally improved the Glidepath course structure, but the magnitude of disturbance is still considered significant so further mitigations must be explored.

6.5.2.17. The closest buildings to Glidepath 02 are likely to have the greatest impact, so the buildings at sites 121, 122 and 123 are removed from the model, as shown in Figure 39.

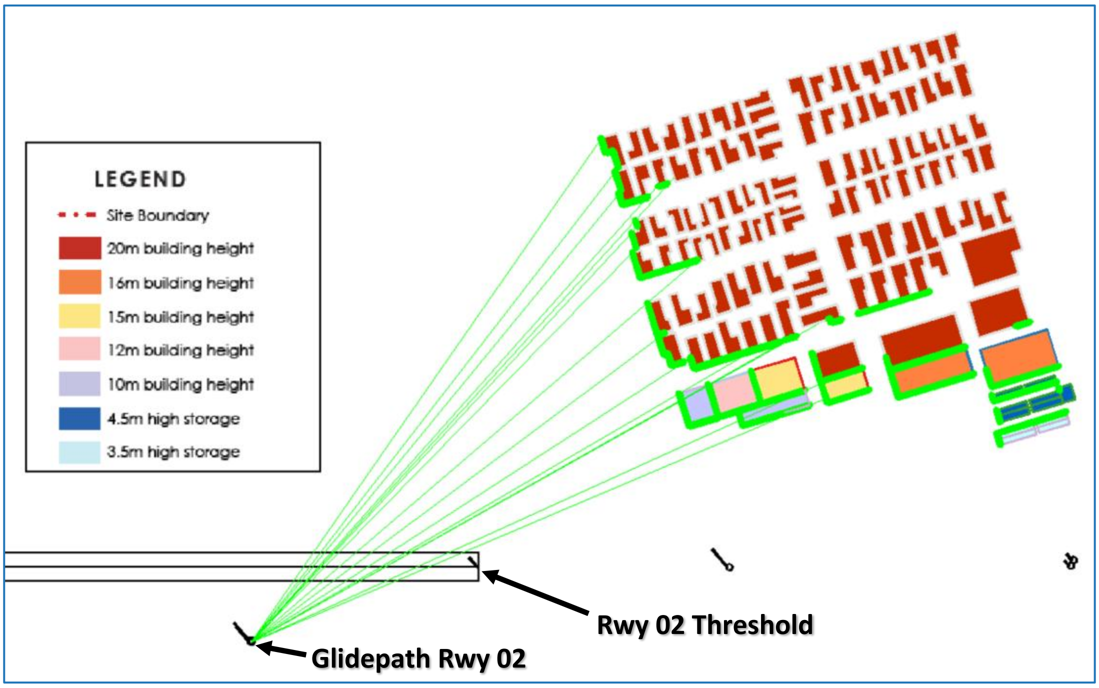

Figure 39: Buildings illuminated by Glidepath 02 – buildings removed

6.5.2.18. The result of the simulation of the proposed development with buildings removed is shown in Figure 40.

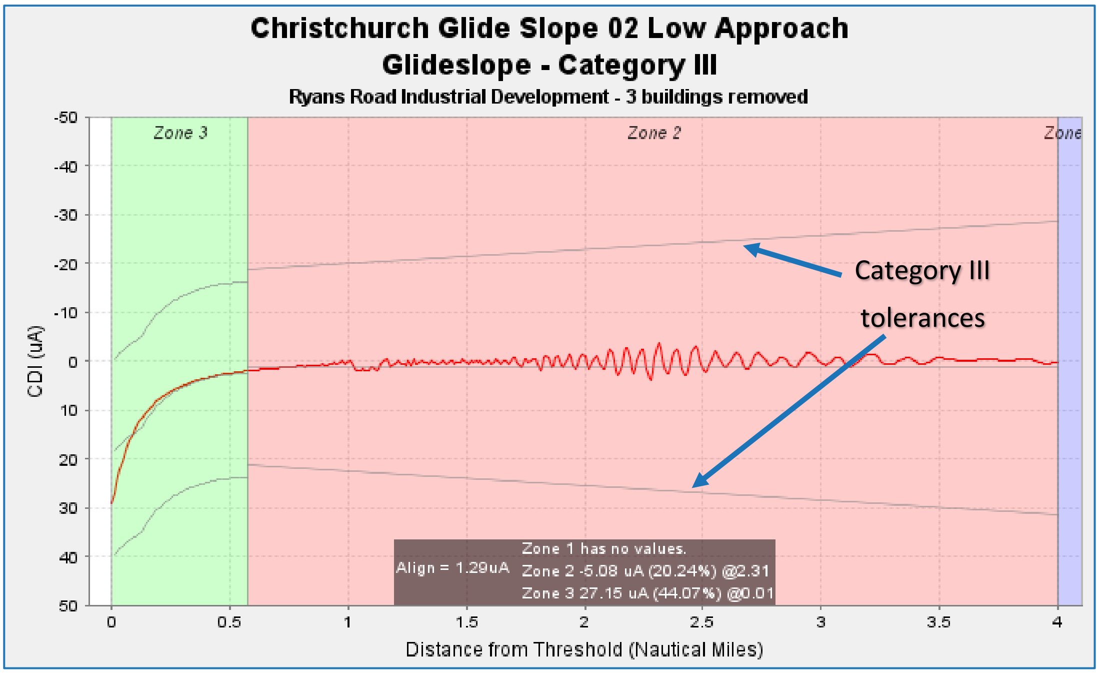

Figure 40: Glidepath Runway 02 approach course structure – buildings removed

6.5.2.19. Figure 40 shows some impact on the Glidepath approach course structure. The maximum simulated course disturbance in ILS Zone 2 is ±3.8µA and in ILS Zone 3 is ±0.1µA.

6.5.2.20. Removing the buildings within sites 121, 122 and 123 has again marginally improved the Glidepath course structure but the magnitude of disturbance is still considered significant.

6.5.2.21. Reducing the heights of the closest buildings to Glidepath 02 or removing them altogether has marginally improved the Glidepath structure, but there is still significant disturbance because more of the buildings beyond are now exposed to illumination by Glidepath signals, generating further multipath interference. A further mitigation option is to change the orientation of buildings.

6.5.2.22. In Figure 41 the 20m high buildings in sites 121 and 122 have been rotated counterclockwise by 2°.

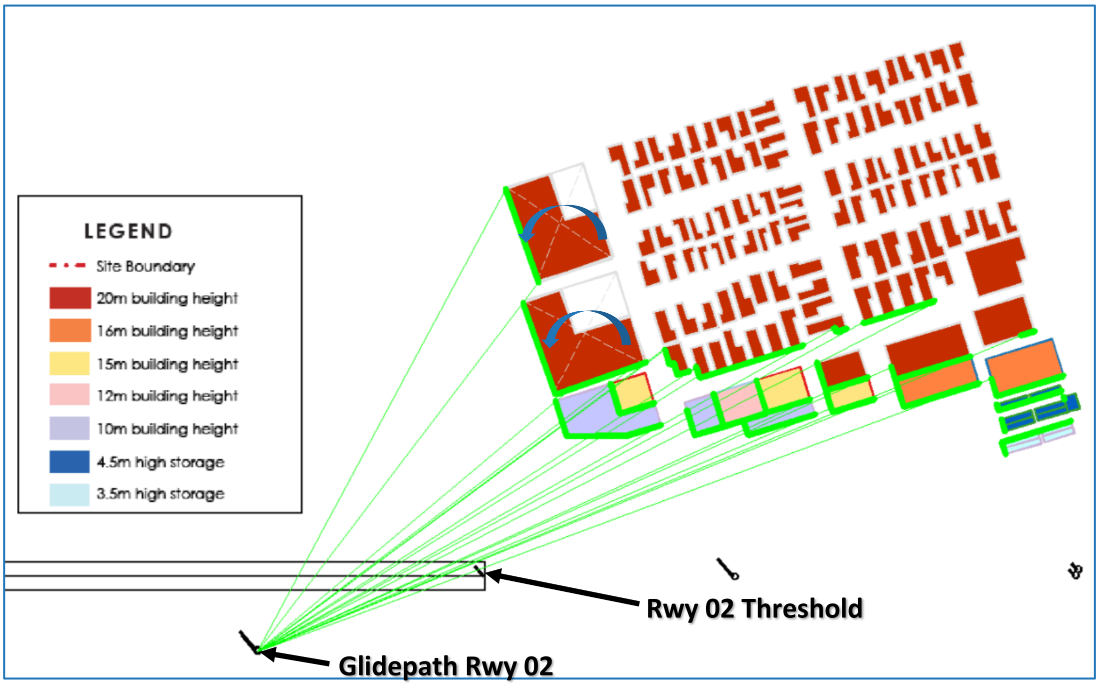

Figure 41: : Buildings illuminated by Glidepath 02 – buildings rotated

6.5.2.23. The result of the simulation of the proposed development with two buildings rotated counterclockwise by 2° is shown in Figure 42.

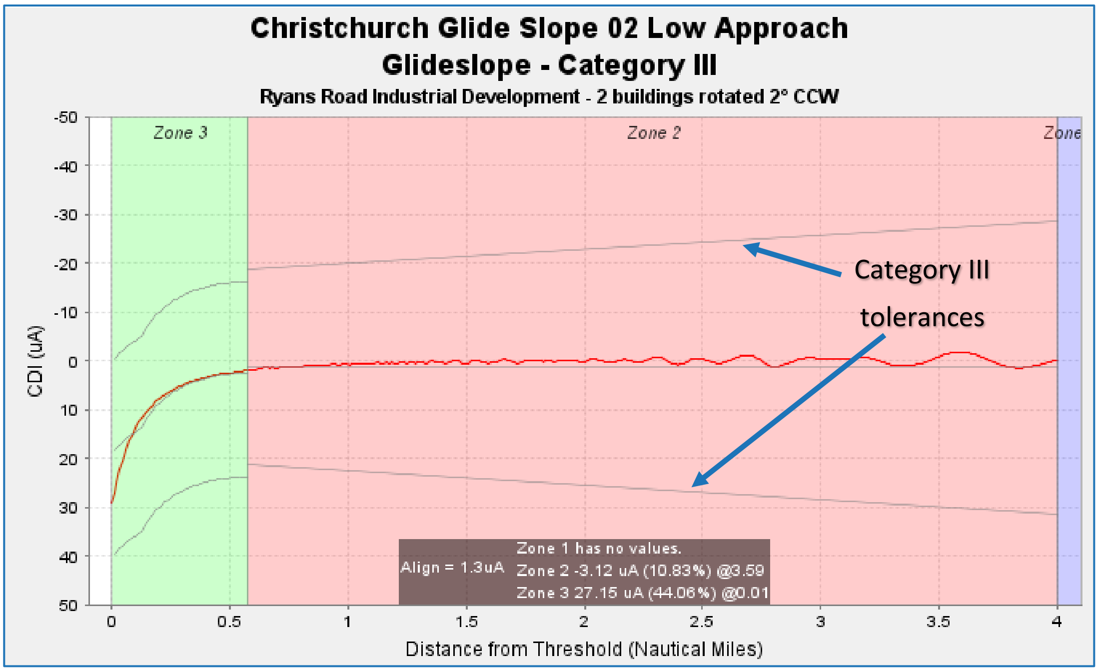

Figure 42: Glidepath Runway 02 approach course structure – buildings rotated

6.5.2.24. Figure 42 shows some impact on the Glidepath approach course structure. The maximum simulated course disturbance in ILS Zone 2 is ±1.6µA and in ILS Zone 3 is ±0.1µA.

6.5.2.25. As previously noted, the existing disturbance, as measured by flight inspection, indicates maximum errors of ±1.6µA in Zone 2 and ±2.8µA in Zone 3.

6.5.2.26. To find the potential impact of the simulated disturbance, the existing measured disturbance is combined with the predicted simulated disturbance using RSS vector addition to give overall results of ±2.3µA in Zone 2 and ±2.8µA in Zone 3.

6.5.2.27. This shows that the additional simulated disturbance has a minor impact on the existing disturbance in Zone 2, with an increase in error of ±0.7µA. The increase in error will be imperceptible to pilots flying ILS approaches to runway 02.

6.5.2.28. The results of the worst-case modelling with two buildings rotated counterclockwise by 2° indicate that the proposed development will have a minor impact on Glidepath 02 performance. The actual effects are expected to be less than those predicted by the worst-case model. Accounting for these findings, the Client has modified their development proposal, so as to rotate the buildings on sites 121 and 122 counterclockwise by 2° - as now shown in the drawing '2024_051 Carter Group 104 Ryans Road - Building Heights D'.

7. ILS DME Analysis

7.1. Effects of structures on DME

7.1.1. Large structures can have two potential effects on DME:

- DME signals can be reflected from large objects, causing multipath interference and measured distances to be incorrect;
- They can block the line of sight of DME transmissions, creating a shadow area behind the structure preventing reception of the DME signal.

7.1.2. The aircraft DME interrogator transmits a pair of pulses. These are received by the transponder on the ground, which retransmits the pulses after a specified time delay. The aircraft measures the time delay between transmission and reception of the pulse pairs, which corresponds to the range.

7.1.3. If the DME pulse pairs are reflected from a building or object, the DME will receive 2 pulse pairs separated by a time proportional to the path difference between the direct and reflected signals. The reflected signals will always be delayed compared to the direct signal.

7.1.4. A DME pulse has a nominal duration of 3.5µs. If the pulse width is greater than 4µs, the interrogator and transponder will reject the pulse. This occurs when the path length difference is small, typically between 150m and 1,000m. This results in the aircraft not receiving range information. The aircraft interrogator will revert to a 'velocity memory' mode for a period of 10s – 20s before ceasing to provide the pilot with range information.

7.2. ILS DME Runway 02 reflections

7.2.1. To analyse the potential effects of the proposed development on the DME 02, it is necessary to establish the direction of the DME signal reflections, and also the likely area affected. The direction of DME reflections from a vertical plane surface can be established from a CAD drawing using the theory of ray optics.

7.2.2. The most significant sources of DME reflections will be from the west-facing elevations of the proposed buildings as reflections will be towards the runway 02 extended centreline and could impact aircraft as they approach to land. The areas of potential DME reflections, and hence multipath interference, will be confined to the green hatched areas in Figure 43.

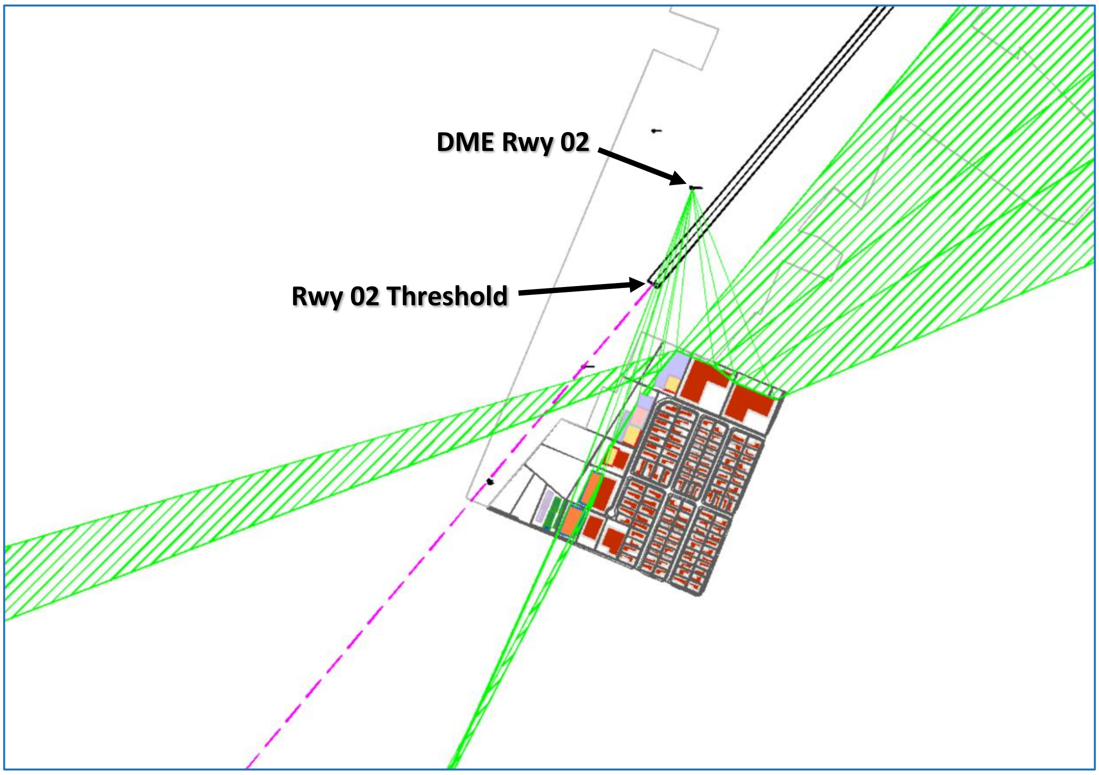

Figure 43: DME 02 reflections from proposed development

7.2.3. In Figure 43 it can be seen that DME reflections from the building at site 123 will cross the extended runway centreline. At 10m high, the building is marginally taller than the DME 02 antenna elevation (7m AGL), hence reflections could be directed upwards towards aircraft making approaches to runway 02.

7.2.4. Further analysis of the reflections can be carried out to determine their magnitude and hence the range at which they may cause undesirable effects.

7.2.5. The range for possible effects can be estimated by calculation:

- The closest point of the reflecting surfaces is **598m** from the DME.
- Assuming a 150W transmitter, then the effective radiated power of the DME is in the region of **+51.8dBm** (ILS/DME).
- The free space path loss to the reflecting surface is **-88.0dB**.
- Thus, the effective signal power at the reflecting surface is **-36.2dBm**.

7.2.6. The amount of DME signal re-radiated is a function of the Radar Cross Section (RCS) gain.

7.2.7. The reflecting surface cannot be considered in its entirety for the RCS calculation as it is representing a plane structure. For a flat plane perpendicular to the direction of radiation, the reflective area cannot exceed the aperture of the largest antenna. The aircraft antenna aperture is about 5cm. The ground DME antenna is typically circa 2m x 0.2m in physical aperture. Hence, for the purposes of this evaluation, a 2m section of the reflecting surface is being considered.

7.2.8. In reality, the signal may be reflected from several smaller parts of various buildings. The signal received at the aircraft would be the vector sum of all of these smaller components, the value of which is likely to be much less than the idealised calculation carried out here.

7.2.9. The RCS for a 2m x 0.2m plate, perpendicular to the source, is 22.3m^2 at the DME frequency. *Note: The forward reflection would be less than the perpendicular reflection calculation carried out here to represent worst-case.*

- The effective gain for 22.3m^2 RCS is **+34.9dB** at the DME frequency.
- The equivalent signal power re-radiated from the building is:
  - Equivalent Signal Power Re-radiated = -36.2dBm + 34.9dB = **-1.3dBm**.
- The DME receiver at the aircraft requires a signal >-90dBm. The minimum path loss to drop the reflected signal below the detection threshold is therefore:
  - Minimum Path Loss Drop = -90dBm – (-1.3dBm) = **-88.7dB**.
- Distance until desired path loss drop is **652m** or **0.35NM**.

7.2.10. The range for possible multipath effects will reduce for DME reflections from parts of the development that are further away from the DME 02 antenna. If the above calculation process is repeated for other parts of the proposed development, then the extents of the areas for potential DME multipath can be reduced to represent the ranges of the desired path loss drops, as shown by the green hatching in Figure 44.

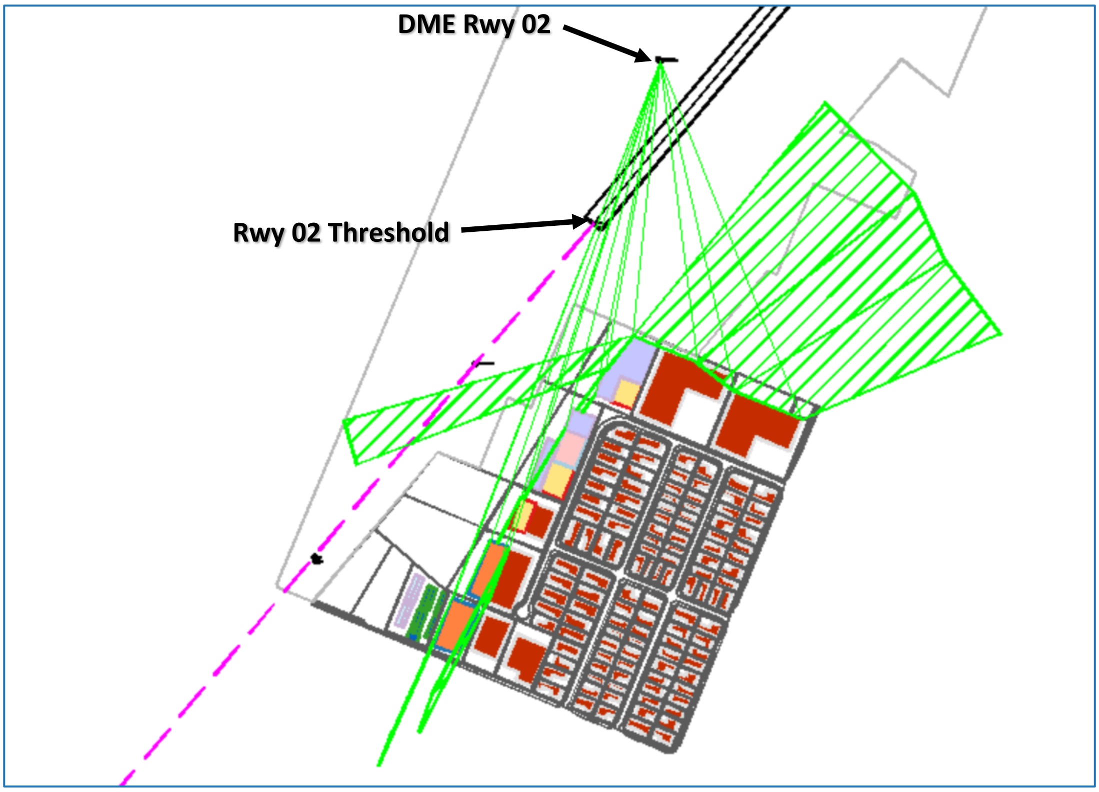

Figure 44: Maximum range of potential DME 02 multipath effects

7.2.11. In Figure 44 it can be seen that the reflection area from the site 123 building still crosses the extended runway centreline. The reflection area covers 163m along the centreline. If an approach speed of 100 knots is assumed, then it would take an aircraft approximately 3 seconds to pass through the area. If a reflected signal causes a brief loss of range information an aircraft DME interrogator will continue to output range data in 'velocity memory' mode. In any case, upward reflections from the 10m high building will be at shallow angles and aircraft are more likely to be flying above rather than through the area of potential multipath interference. Signals reflected from the 10m high building will be at no more than 13m above the ground as they cross the centreline, whereas aircraft descending on a 3° approach will be at heights of between 40 and 50m in the same area. In summary, DME reflections will not have any impact on approaching aircraft.

7.2.12. The ground DME transponder has an inbuilt immunity to local signal reflections by a mechanism called Short Distance Echo Suppression (SDES), which rejects reflected pulses within 12µs of a valid pulse decode to help filter out reflections from nearby obstacles. Airways New Zealand has confirmed that DME 02 is configured with SDES enabled, so no effects are anticipated as a result of the development.

7.3. ILS DME Runway 02 shadowing

7.3.1. Assessment of the relative locations of DME 02 and the proposed development indicates that any potential shadowing of DME 02 will be confined to areas south of the Airport.

7.3.2. DME 02, as an associated aid with the ILS, is required to have the same coverage as Localiser 02. 3D radio propagation modelling can be used to ascertain the development's impact on coverage.

7.3.3. The outlines of the proposed buildings are imported into Geographic Information System (GIS) software (Global Mapper) and heights applied to create a 3D model of the development. Terrain is created using 1m LiDAR data from Land Information New Zealand, supplemented by Shuttle Radar Topography Mission worldwide elevation data.

7.3.4. The 3D model is shown in Figure 45.

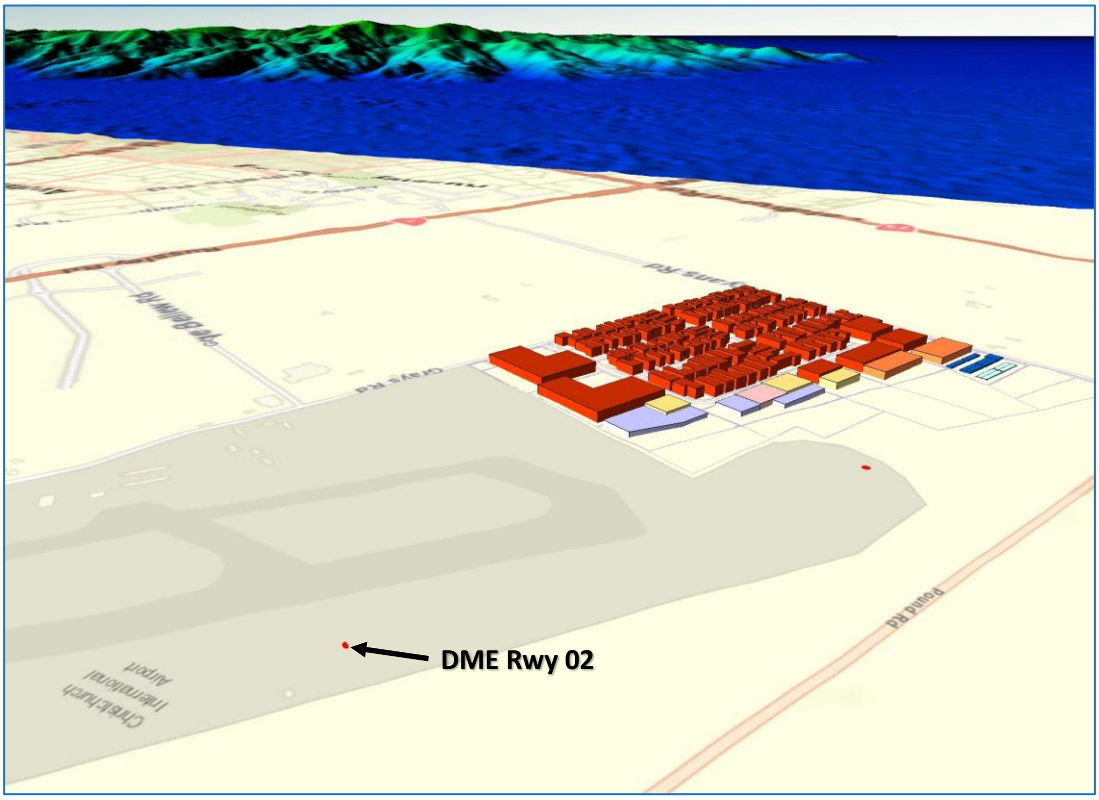

Figure 45: Proposed development 3D model

7.3.5. Line of Sight (LoS) coverage, in a sector encompassing the development, at 1,000 feet above aerodrome level to a range of 25NM from DME 02 is shown in Figure 46. The solid red outline indicates the required area of operational coverage for Localiser 02.

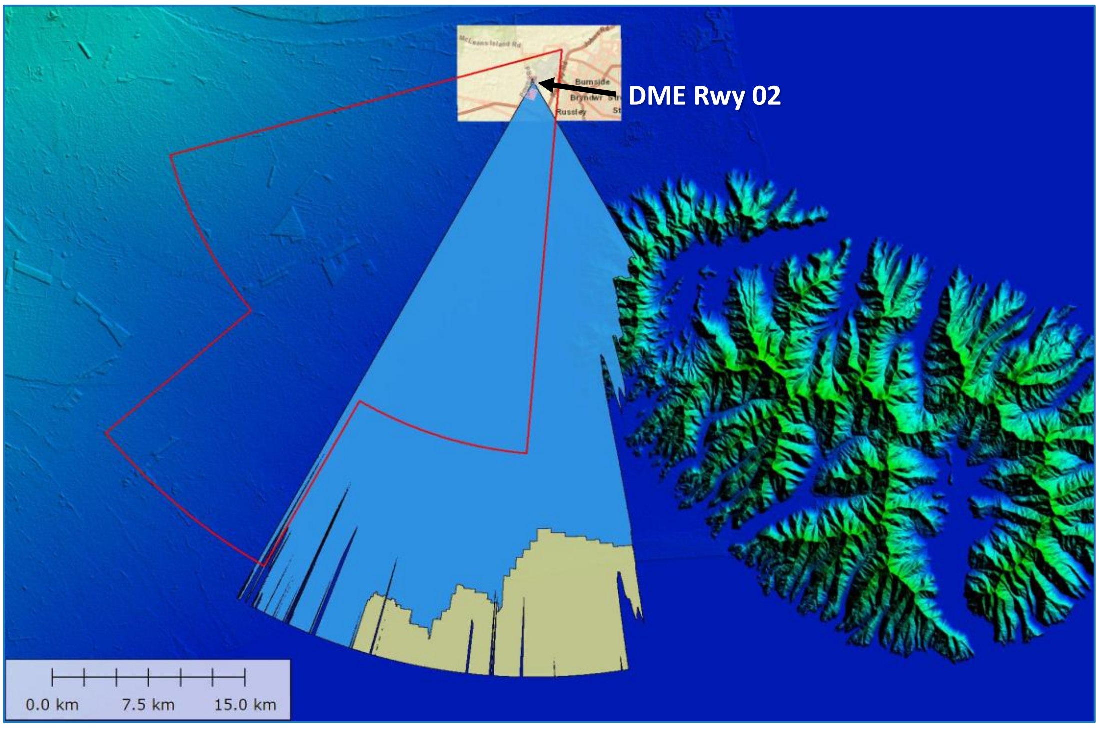

Figure 46: DME 02 LoS coverage at 1,000 feet above aerodrome level

7.3.6. In Figure 46 the yellow shading shows where LoS coverage to an aircraft at 1,000 feet above the aerodrome may be impacted by the proposed development. No shadowing of the DME 02 signal will occur within the required area of operational coverage.

7.3.7. LoS shadowing does not mean that no signal will be received. The DME signal will refract around the development (Huygens-Fresnel Principle) and 'fill in' the shadowed area. However, a reduction in signal strength could be experienced in the area identified. As it lies outside the required operational coverage area this will have no impact on DME 02 users.

8. DVOR/DME Analysis

8.1. General

8.1.1. The DVOR provides suitably equipped aircraft with their azimuth relative to the DVOR antenna. The DME provides suitably equipped aircraft with their distance to the facility. The combination of DVOR and DME enables the aircraft to establish its position in range and azimuth from the facility.

8.1.2. Large metallic structures close to a DVOR/DME have two effects on the radio signal:

- **Reflections –** reflections from the surfaces of the structure may cause bearing and range errors;
- **Shadowing –** the structure may cause shadowing, resulting in reduced signal level and poor coverage in the sector obscured.

8.1.3. The effect of reflections is modelled using computer simulation of the system performance and the effect of shadowing is shown by 3D radio propagation modelling.

8.2. DVOR reflections

8.2.1. The impact of reflections from the proposed development on DVOR performance can be modelled using the OUNPPM software simulation tool.

8.2.1.1. The configuration of the modelling software used for the assessment is shown in Figure 47.

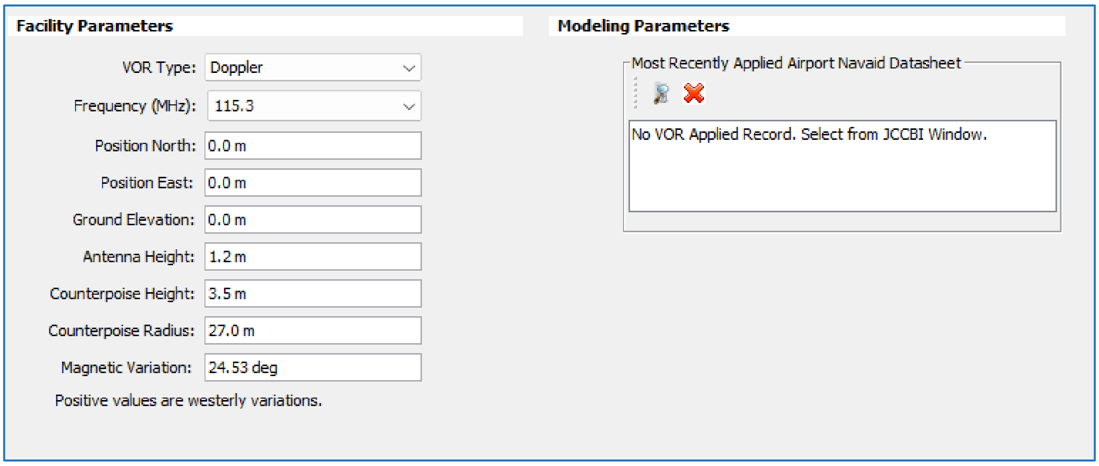

Figure 47: DVOR modelling configuration

8.2.2. Only those faces of the development that are illuminated by the DVOR signal will cause reflections and re-radiation of the navigation facility signals.

8.2.3. For the initial worst-case DVOR modelling, it is assumed that the DVOR has full visibility of the development. In Figure 48, the illuminated faces of the development that are modelled in the simulation software are highlighted in green.

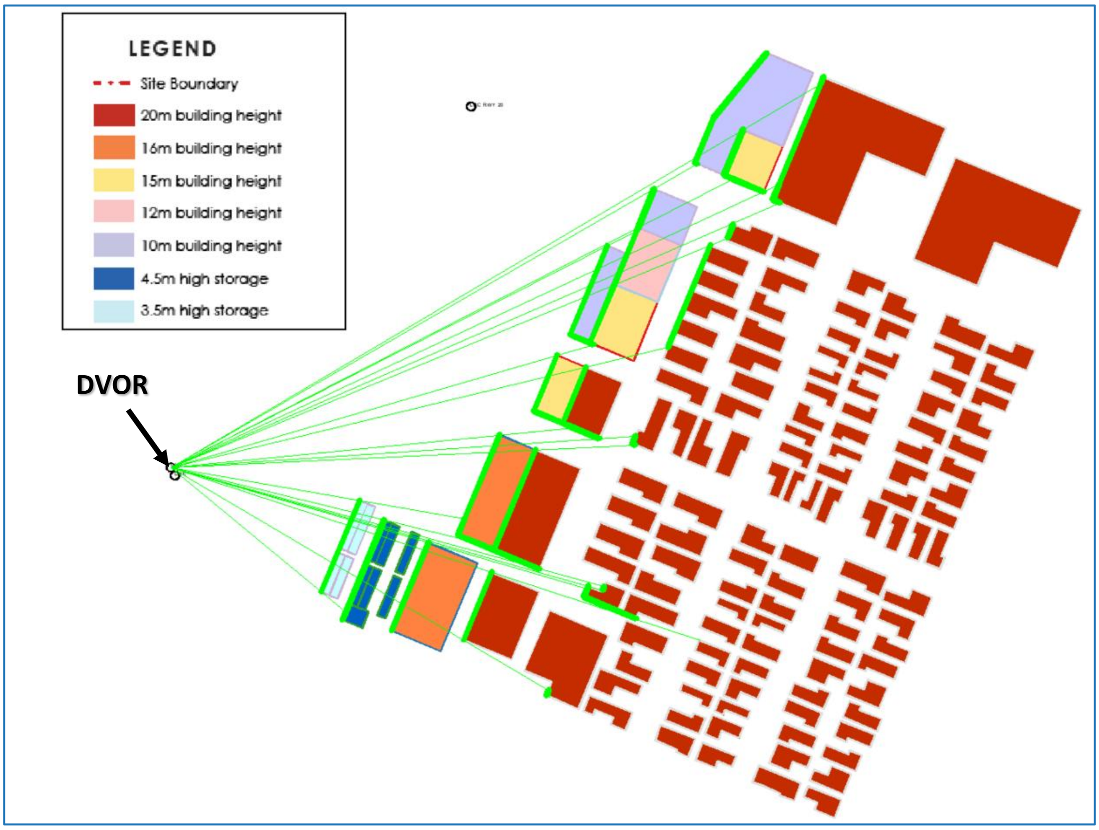

Figure 48: Proposed development illuminated by DVOR

8.2.4. A plan view of the scatter objects used in the model scenario is shown in Figure 49.

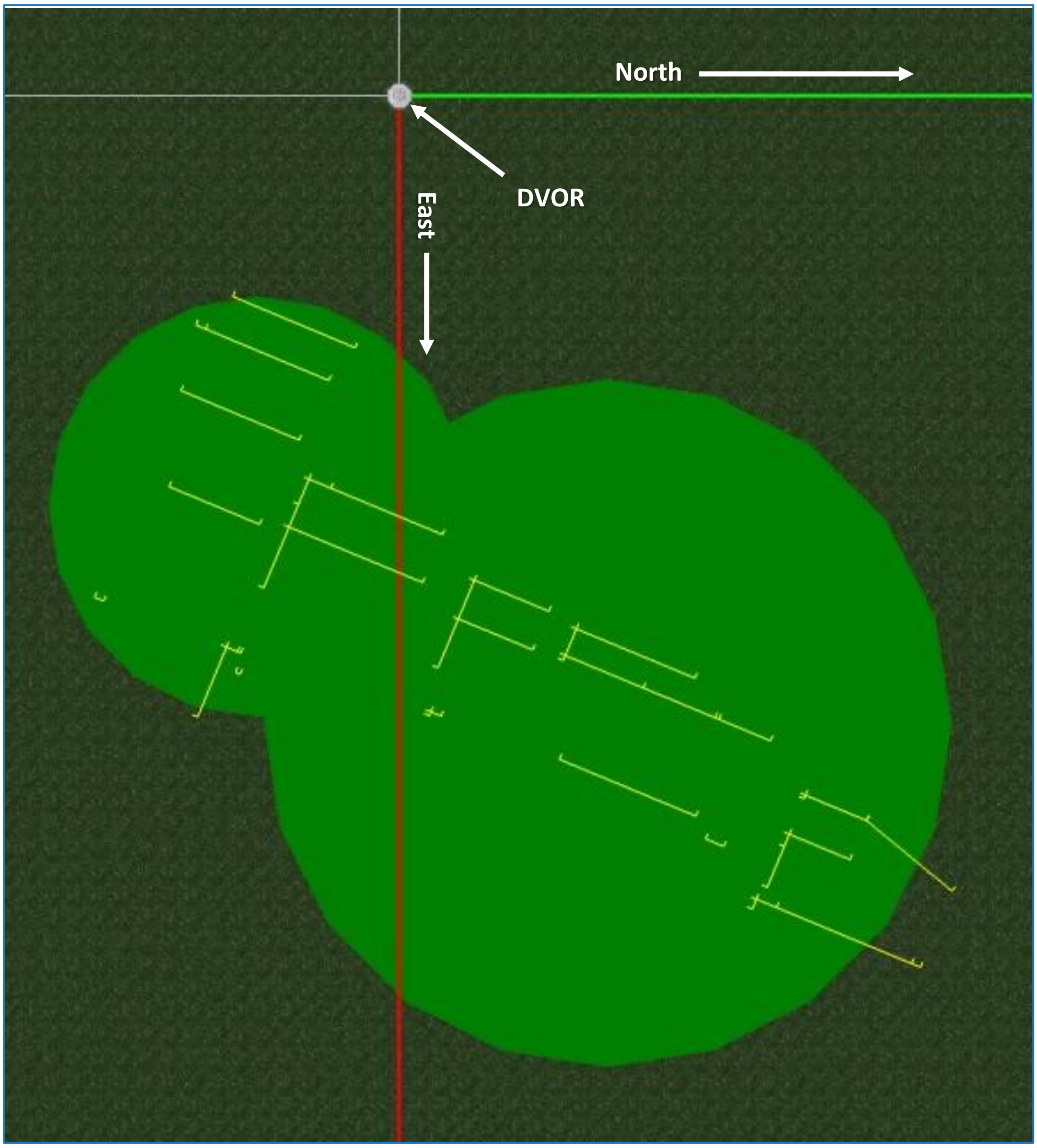

Figure 49: Plan view of DVOR scatter objects

8.2.5. A 3D view of the DVOR and the scatter objects is shown in Figure 50.

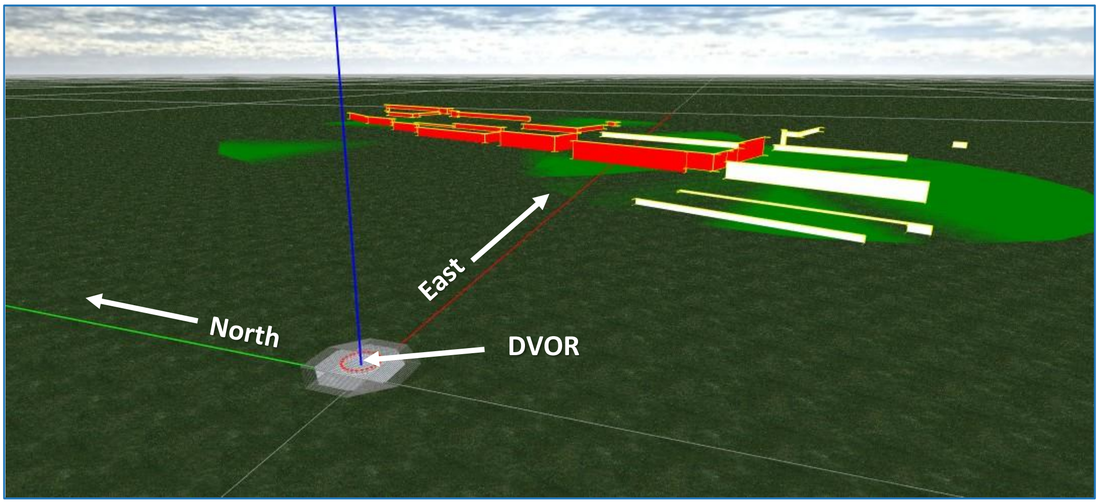

Figure 50: 3D view of DVOR scatter objects

8.2.6. The software calculates potential DVOR bearing errors introduced by the development. The effect on a simulated orbital flight at 6NM from the DVOR at an altitude of 4,000 feet, as flown for the DVOR flight inspection, is shown in Figure 51.

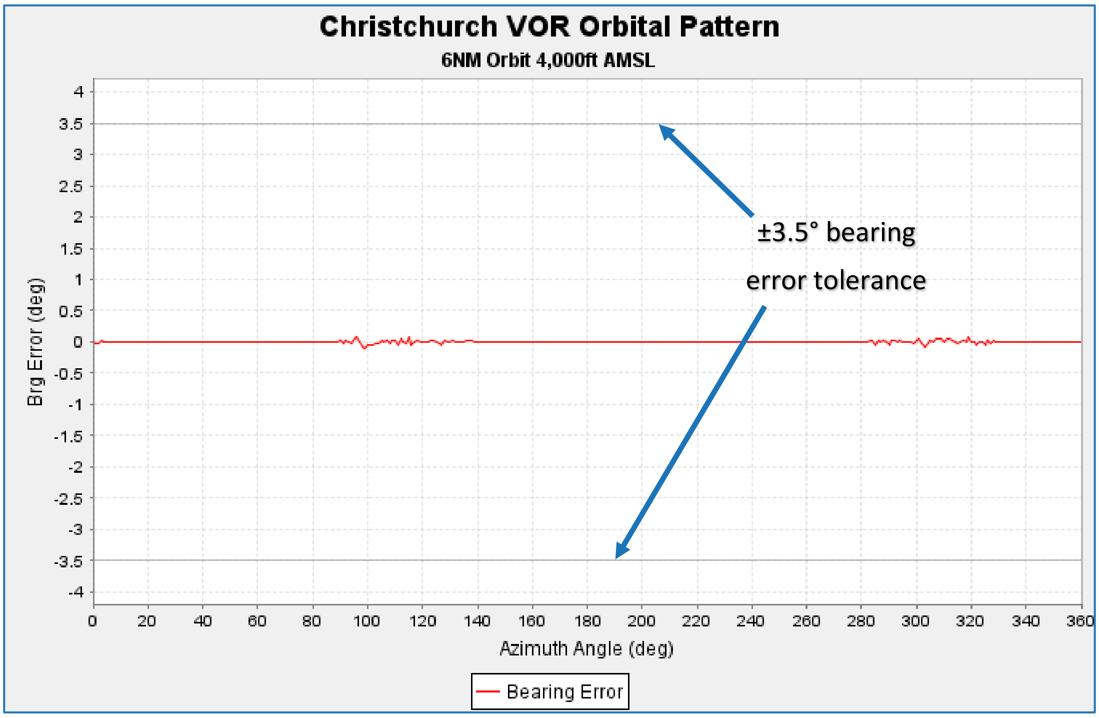

Figure 51: Effect of development on DVOR 6NM/4,000 feet AMSL orbital pattern

8.2.7. Predicted disturbance to the DVOR azimuth angle occurs chiefly in two sectors, between radials 088 and 149, and between radials 280 and 330. Maximum bearing errors in these sectors occur at radial 099 (-0.09^{o}) and at radial 303 (-0.08^{o}). The maximum induced bearing error is approximately 3% of the bearing error tolerance of ±3.5° and unlikely to be detectable by users of the facility.

8.2.8. Examination of the existing disturbance, as measured by flight inspection, indicates maximum errors of ±0.5° and ±0.1° respectively in the two impacted sectors. Combining the existing and predicted errors using RSS vector addition gives overall results of ±0.5° and ±0.1° and thus shows no impact on the existing DVOR disturbance.

8.2.9. The DVOR supports approach procedures at Christchurch Airport where inbound legs are flown from ranges of up to 14.3NM from the facility at an altitude of 2,000 feet. To encompass this range and altitude a second simulated lower angle orbit flight at 15NM from the DVOR at an altitude of 2,000 feet is shown in Figure 52.

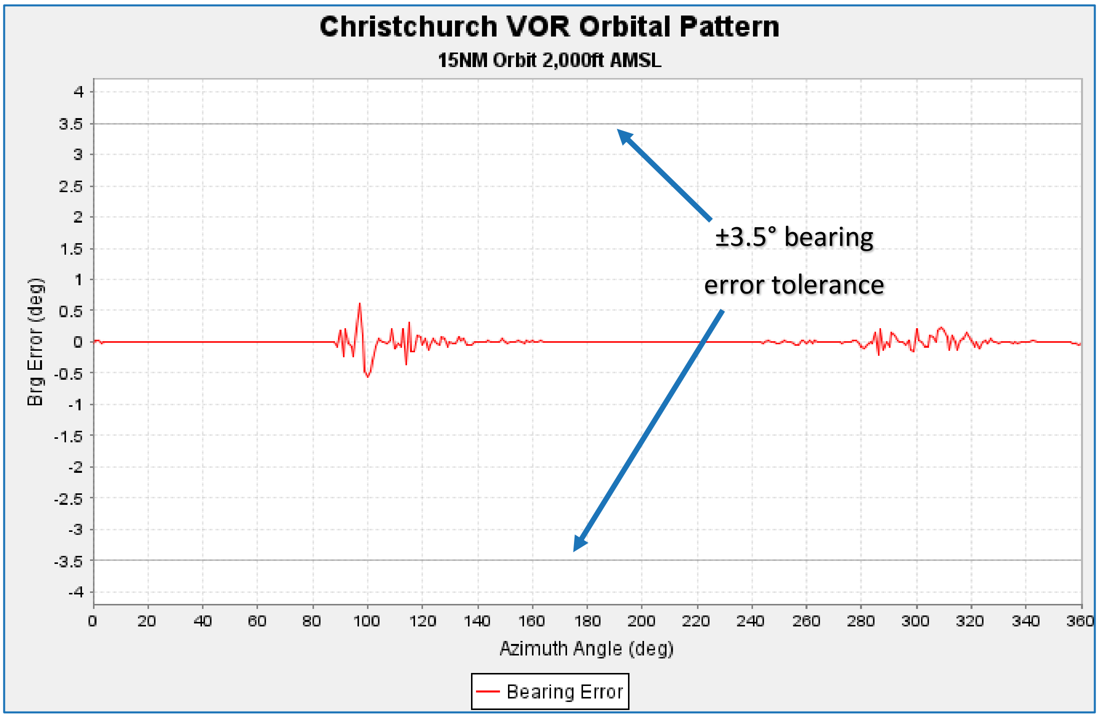

Figure 52: Effect of development on DVOR 15NM/2,000 feet AMSL orbital pattern

8.2.10. Again, predicted disturbance to the DVOR azimuth angle occurs chiefly in two areas, between radials 088 and 163, and between radials 243 and 003. Maximum bearing errors in these sectors occur at radial 097 (+0.63^{o}) and at radial 309 (+0.23^{o}). The maximum induced bearing error is well within the international standard tolerance, being approximately 18% of the bearing error tolerance of ±3.5°.

8.2.11. Further investigation can be carried out by simulating flights along the inbound radials, 196 and 016, used for the VOR approach procedures to runways 02 and 20 at Christchurch Airport.

8.2.12. Figure 53 shows that the proposed development will have no effect on a simulated flight along radial 196 descending from 2,000 feet altitude between ranges of 11.5NM and 0.1NM from the DVOR, as used for the VOR approach to runway 02.

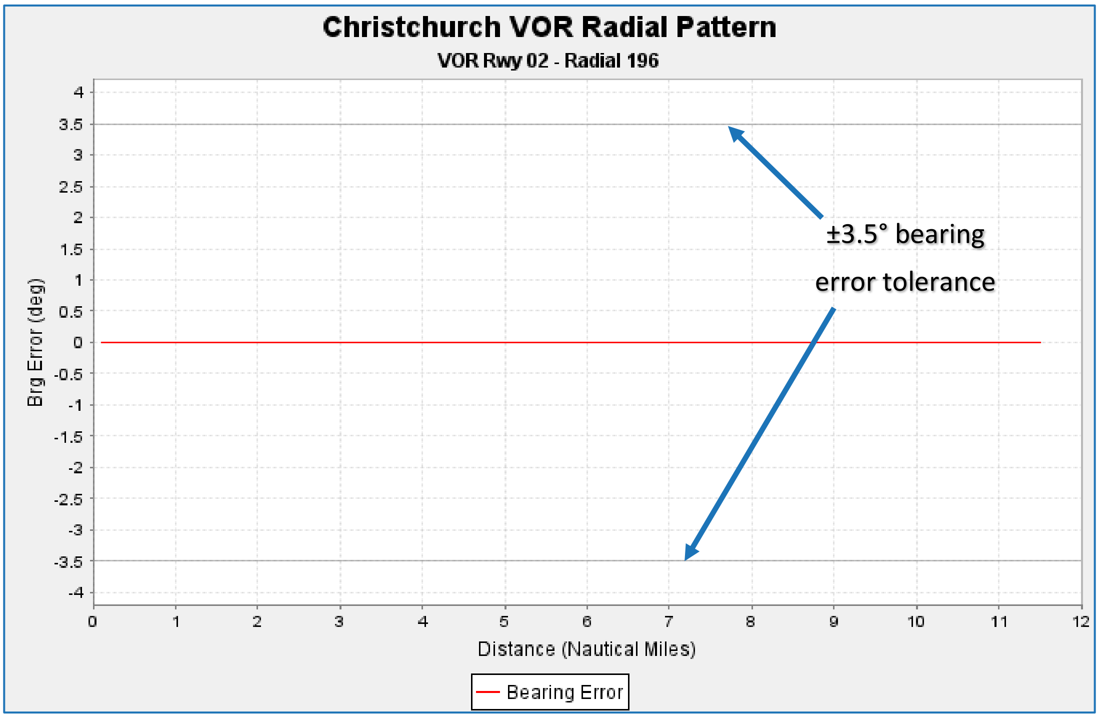

Figure 53: VOR Approach Runway 02 (Radial 196)

8.2.13. Figure 54 shows that the proposed development will have no effect on a simulated flight along radial 016 descending from 2,000 feet altitude between ranges of 14.3NM and 0.1NM from the DVOR, as used for the VOR approach to runway 20.

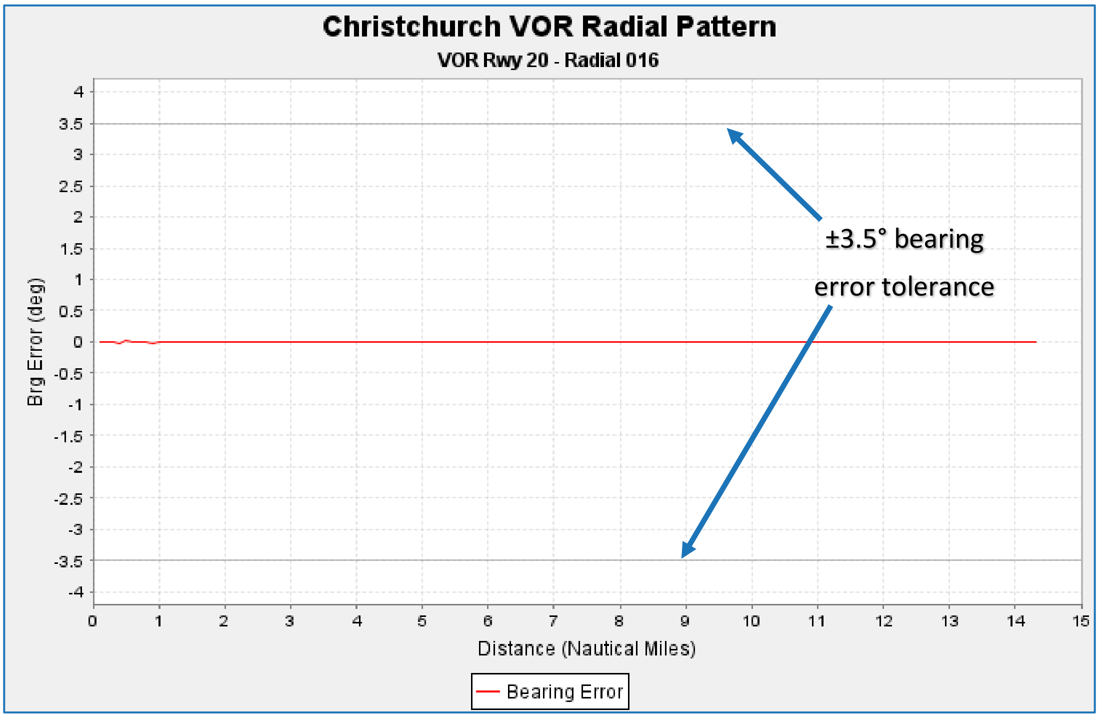

Figure 54: VOR Approach Runway 20 (Radial 016)

8.2.14. The maximum bend tolerance for the DVOR is ±3.5°. The predicted disturbance during the simulated flight inspection orbit is negligible and is still well within standard tolerance during the lower angle orbit at greater range. The proposed development will have no impact on the DVOR approach procedures.

8.3. DME reflections

8.3.1. The proposed development presents large flat reflecting surfaces to signals from the DME associated with the DVOR. Multipath interference from DME reflections can result in false ranges or loss of range information to the aircraft.

8.3.2. The faces of the development can be considered to be a mirror of the DME signal. The areas where potential multipath may be experienced are determined by ray optics.

8.3.3. The areas of potential DME multipath due to the proposed development are indicated by the green hatching in Figure 55.

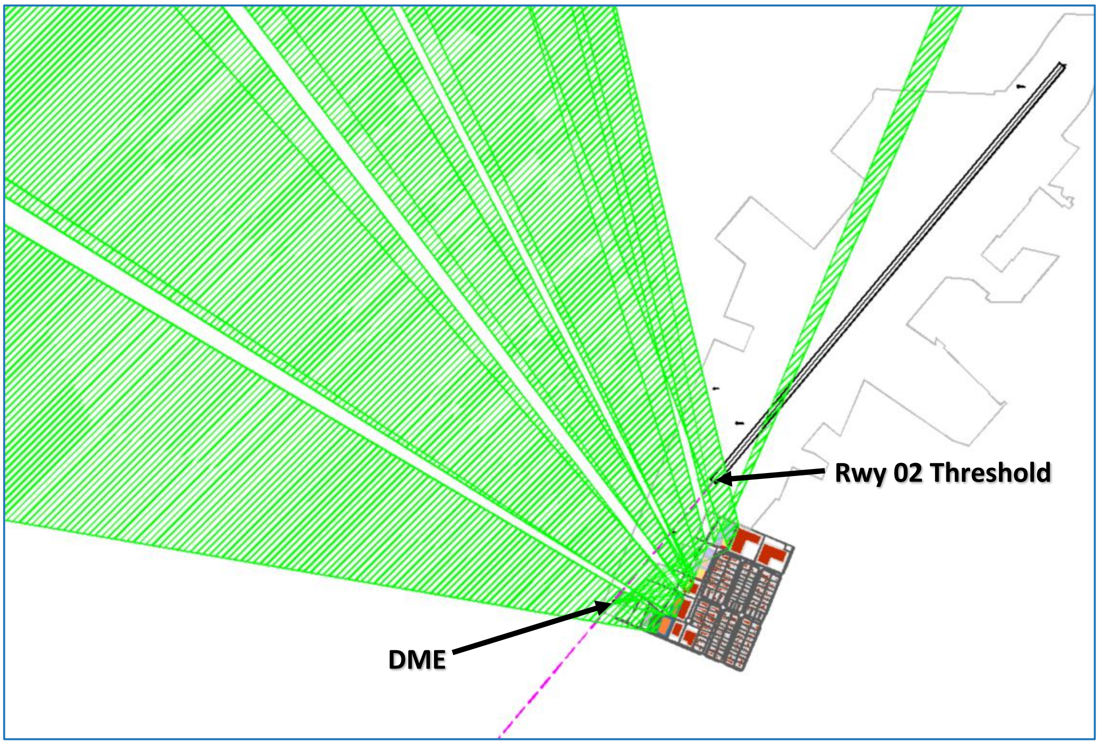

Figure 55: Areas of potential DME multipath interference

8.3.4. West-facing elevations of the proposed buildings will reflect DME signals across the extended runway 02 centreline and could impact aircraft as they approach to land. The main area of impact is in the final 0.5NM before the runway 02 threshold.

8.3.5. Further analysis of the vertical reflections can be carried out to determine their magnitude and hence the range at which they may cause undesirable effects.

8.3.6. The range for possible effects can be estimated by calculation:

- The closest point of the development is 304m from the DME.
- The DME has an effective radiated power of 1,000W or **+60dBm**.
- The free space path loss to the reflecting surface is **-83.6dB**.

- Thus, the effective signal power at the reflecting surface is **-23.6dBm**.

8.3.7. The amount of DME signal re-radiated is a function of the RCS gain.

8.3.8. The reflecting surface cannot be considered in its entirety for the RCS calculation as it is representing a plane structure. For a flat plane perpendicular to the direction of radiation, the reflective area cannot exceed the aperture of the largest antenna. The aircraft antenna aperture is about 5cm. The ground DME antenna is circa 2m x 0.2m in physical aperture. Hence, for the purposes of this evaluation, a 2m section of the reflecting surface is being considered.

8.3.9. In reality, the signal may be reflected from several smaller parts of the development. The signal received at an aircraft would be the vector sum of all these smaller components, the value of which is likely to be much less than the idealised calculation carried out here.

8.3.10. The RCS for a 2m x 0.2m plate, perpendicular to the source is 31.5m^2 at the DME frequency.

- The effective gain for 31.5m^2 RCS is **+37.9dB** at the DME frequency.
- The equivalent signal power re-radiated from the hangar is:
    - Equivalent Signal Power Re-radiated = -23.6dBm + 37.9dB = **+14.3dBm**
- The DME receiver at the aircraft requires a signal >-90dBm. The minimum path loss to drop the reflected signal below the detection threshold is therefore:
    - Minimum Path Loss Drop = -90dBm – 14.3dBm) = **-104.3dBm**
- Distance until desired path loss drop is **3,300m** or **1.78NM.**

8.3.11. The range for possible multipath effects will be reduced for DME reflections from parts of the development that are further away from the DME antenna. If the above calculations are repeated for other parts of the proposed development, then the extents of the areas for potential DME multipath can be reduced to represent the ranges of the desired path loss drops, as shown by the green hatching in Figure 56.

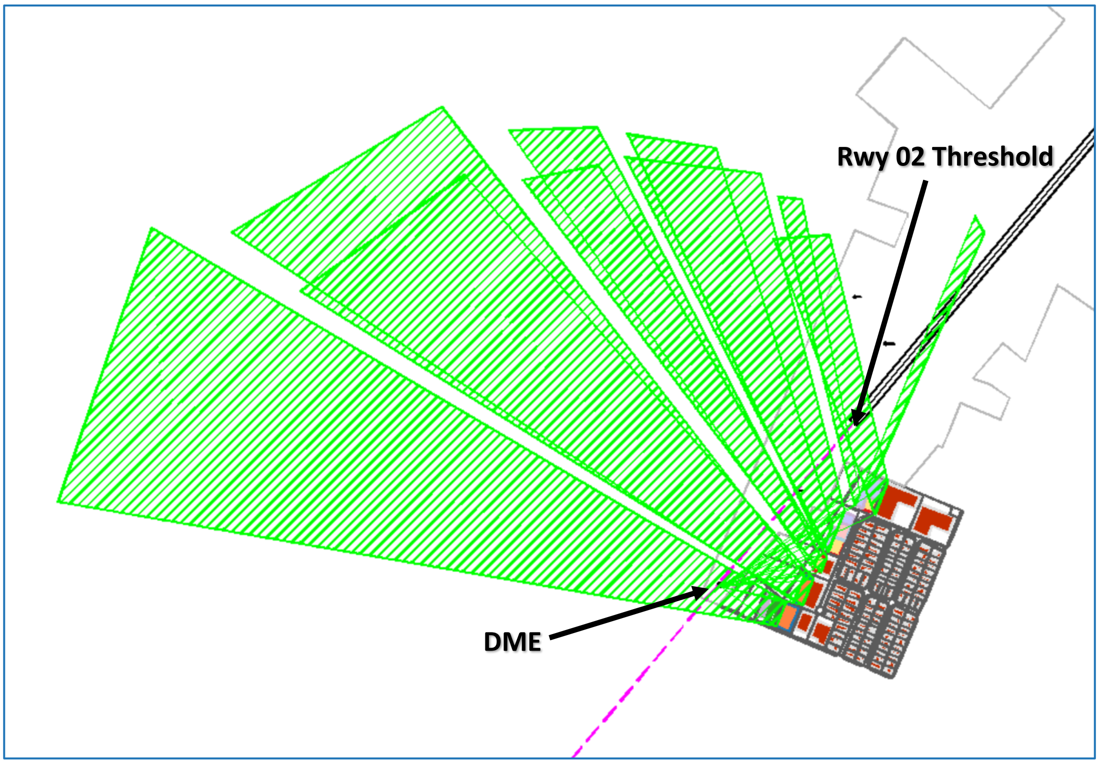

Figure 56: Maximum range of potential DME multipath effects

8.3.12. It can be seen in Figure 56 that reflections from the proposed development still cross the extended runway centreline. In theory an aircraft flying at 100 knots could lose DME range information for up to 18 seconds in the final 0.5NM of the approach; but, in a similar way to ILS DME 02, 'velocity memory' mode would compensate for this. Upward reflections from the proposed buildings will be at shallow angles, so aircraft are more likely to be flying above rather than through the areas of potential multipath interference, and in any case pilots flying the VOR/DME Runway 02 approach procedure will not be relying on DME range information between the DVOR/DME site and runway 02 threshold once they have flown through the DVOR/DME overhead. In summary, DME reflections will not have any impact on approaching aircraft.

8.3.13. Ground DME transponders can use SDES to help filter out reflections from nearby obstacles. Although Airways New Zealand has advised that SDES is not currently enabled on the DME equipment, configuring the DME with SDES will, if required, provide immunity from reflections emanating from the development.

8.4. DVOR/DME shadowing

8.4.1. The proposed development will form an obstruction to DVOR/DME signals which could reduce signal strength and lead to a potential loss of range and bearing information in the shadowed area.

8.4.2. The relative locations of the DVOR/DME and the proposed development indicates that any potential shadowing will be confined to areas to the east of Christchurch Airport.

8.4.3. Using Global Mapper GIS software, LoS coverage in a sector encompassing the development can be determined. The range and altitude modelled for the lower angle DVOR orbit flight are used, i.e. 15NM at an altitude of 2,000 feet. The coverage result is shown in Figure 57.

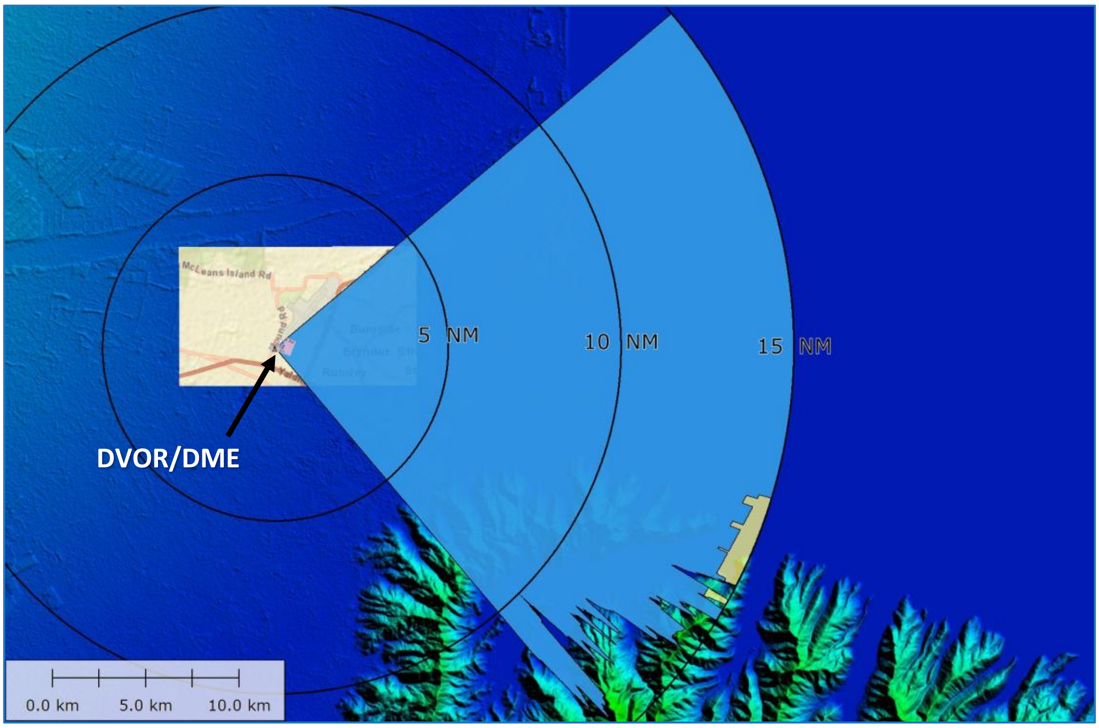

Figure 57: DVOR/DME LoS coverage at 2,000 feet AMSL

8.4.4. In Figure 57 the yellow shading shows where LoS coverage to an aircraft at an altitude of 2,000 feet may be impacted by the proposed development. Aircraft flying the VOR/DME approach procedures to runways 02 and 20 at Christchurch Airport will not be within the yellow areas.

8.4.5. LoS shadowing does not mean that no signals will be received. The DVOR/DME signals will refract or 'bend' around the development and 'fill in' the shadowed area. However, a reduction in signal strength could be experienced in the area identified.

9. Radar Analysis

9.1. General

9.1.1. PSR operates by transmitting short pulses of high energy RF radiation. Some of this energy is reflected back to the PSR antenna by aircraft targets. The time interval between transmission and reception determines the range of the aircraft target.

9.1.2. The azimuth of the radar antenna at the time gives bearing information, allowing the aircraft position relative to the radar to be determined.

9.1.3. The transmitted radar pulse also illuminates everything on the ground in the local area. Reflections from unwanted ground reflections creates 'clutter', which can compromise the ability of the radar to correctly detect wanted aircraft targets.

9.1.4. Large structures can have three unwanted effects on PSR:

- **Beam Forming** – Structures close to the radar antenna can affect the forming of the radar beam as the beam is not fully formed until circa 500m from the radar antenna**;**
- **Shadowing** – This is where the building forms a physical obstruction causing a radar shadow behind the structure. This may result in the loss of radar detection of wanted targets in a particular volume of airspace;
- **Reflections** – Radar energy may be reflected from the faces of the building which may result in the detection of false targets. Radar energy reflected from the flat roof of a structure can cause fading of targets over a particular azimuth sector. Reflections also add additional clutter, which may serve to desensitise the radar, resulting in reduced ability to detect wanted targets.

9.1.5. SSR only detects cooperative aircraft targets which carry an SSR transponder. The radar transmits a coded interrogation pulse train. The aircraft transponder replies to the coded interrogation with a pulse train encoded with the aircraft identification, flight level, and other discretionary information.

9.1.6. As with PSR, large structures can have three unwanted effects on SSR:

- **Beam Forming** – Structures close to the radar antenna can affect the forming of the radar beam leading to track jitter, reduced sensitivity and reduced azimuth accuracy;
- **Shadowing** – This is where the building forms a physical obstruction causing a radar shadow behind the structure. This may result in the loss of radar detection of wanted targets in a particular volume of airspace;
- **Reflections** – Radar energy may be reflected from the surfaces of structures which can result in the detection of false targets or corruption of data.

9.2. Beam forming

9.2.1. The closest building within the proposed development is 809m from the PSR/SSR site, as shown in Figure 58.

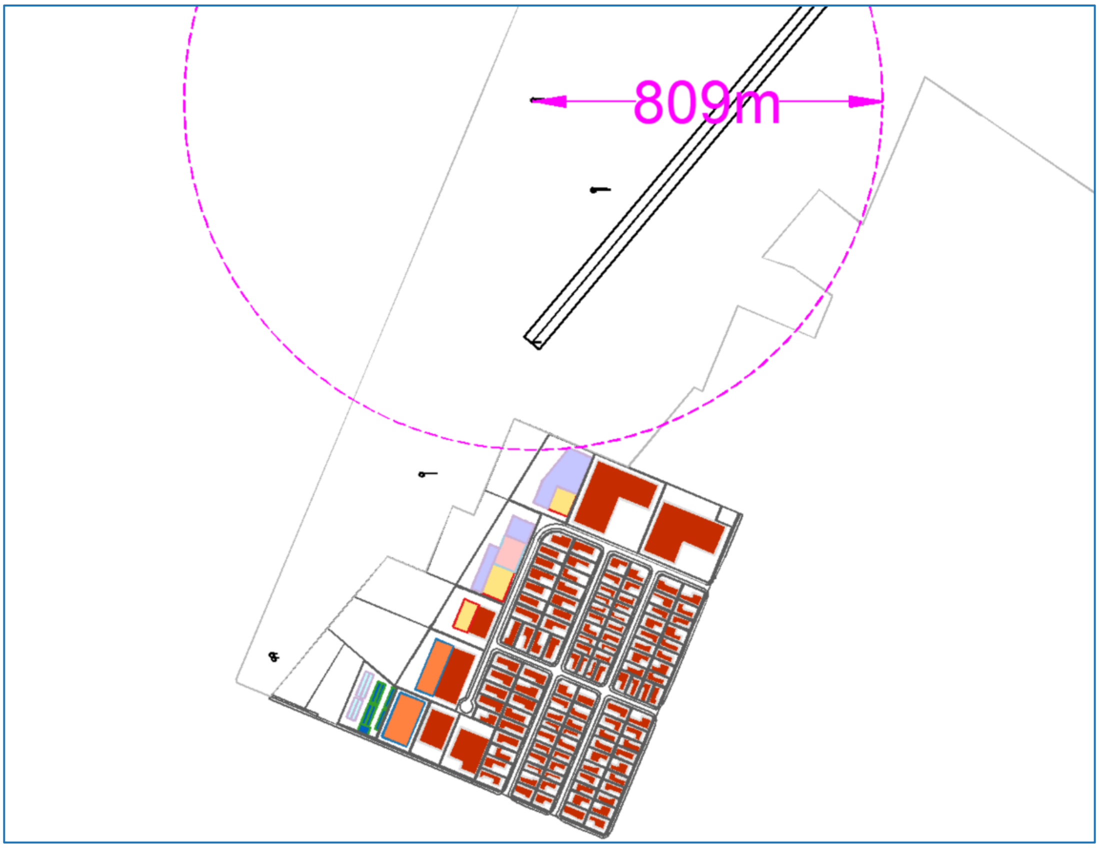

Figure 58: Development range from PSR/SSR

9.2.2. A radar beam can be considered to be fully formed at the distance where its gain becomes equal to its value at infinity. Most literature agrees that the beam is formed by more than 99% at a range of $2D^2/\lambda$ from the radar, where D is the largest dimension of the reflector and λ is the wavelength.

9.2.3. The Indra PSR antenna is 5.5m wide, which means a beam forming range of 260m, while the SSR antenna is 8.5m wide, giving a beam forming range of 497m. At a minimum distance of 809m from the radar site the proposed development will have no impact on correct PSR/SSR beam formation.

9.2.4. Given that the proposed development is significantly beyond the radar beam forming ranges, the development should not adversely affect the radars' ability to meet minimum Air Traffic Management (ATM) surveillance system performance requirements as defined by Eurocontrol[4].

9.3. Shadowing

9.3.1. The maximum elevation of the proposed development buildings is approximately 3m below the PSR antenna electrical centre, therefore shadowing and obscuration due to the buildings will only affect airborne targets below the maximum roof heights and so will not be an issue.

[4] EUROCONTROL Specification for ATM Surveillance System Performance (ESASSP), Edition 1.3, March 2024

9.4. Reflections

9.4.1. Reflections from buildings increase PSR ground clutter and may also result in the generation of false aircraft targets.

9.4.2. The mechanism for creating a false aircraft target, when radar energy is reflected from a vertical building face, is shown in Figure 59.

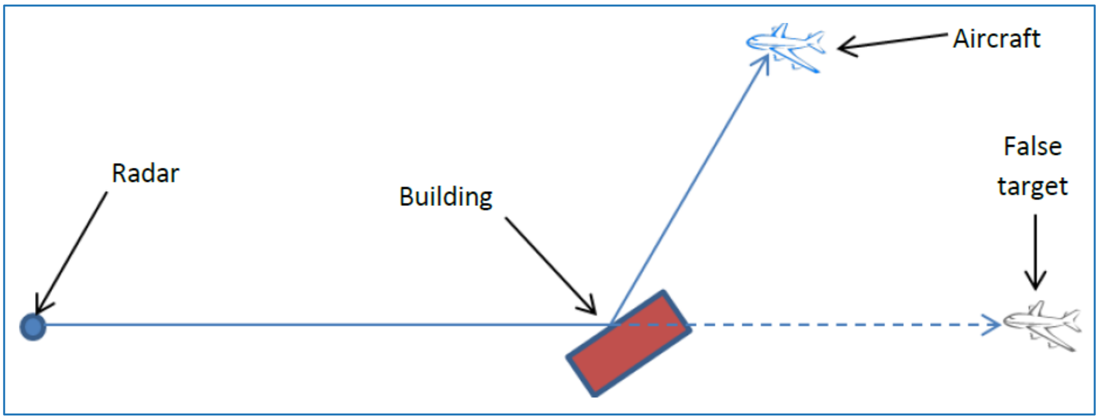

Figure 59: Generation of a false aircraft plot

9.4.3. False targets are caused by the radar signal being reflected to an actual target and, in the case of PSR, the radar detecting the reflected return signal from the aircraft via the building face. With SSR, the radar receives the aircraft transponder reply via reflection from the building face. In both instances the false target will appear on the bearing of the reflector from the radar, i.e. the real target is duplicated on the bearing of the building.

9.4.4. Where the reflecting surface is horizontal or tilted perpendicular to the radar, for example a building roof, this can lead to a reflection which interferes with the direct radar signal, as shown in Figure 60.

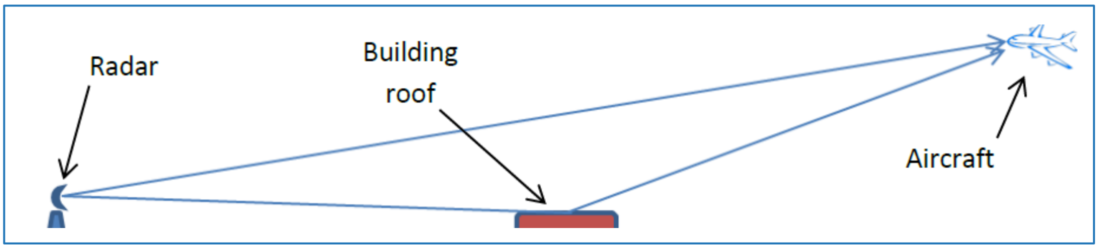

Figure 60: Reflection causing interference

9.4.5. The received radar signal is the sum of these two signals. Depending on the relative phases of the signals, this can either reinforce the signal or cancel the signal causing the PSR target to fade from the display or corruption/loss of the SSR signal data. For close-in targets, this can result in the radar seeing two targets on the same bearing closely separated in range. Any sideways slope to the roof results in a change in azimuth between the main and reflected signal, which can lead to azimuth errors in the reported positions of aircraft. This effect is equally applicable to PSR and SSR.

9.4.6. As the maximum building elevations are below the PSR/SSR antennas, reflected radar energy from vertical surfaces will be directed towards the ground where it will be scattered and absorbed.

9.4.7. Reflections from building roofs will be directed upwards towards the south and may illuminate or be detected by airborne traffic, possibly resulting in PSR target fading or SSR data corruption.

9.4.8. Reflections from the roofs of proposed buildings that are 15m high or less will be blocked by the taller buildings, while upward reflections from the roofs of 16m and 20m high buildings will be at shallow elevation angles. For example, if the building roofs are assumed to be horizontal then upward reflections from the closest 16m and 20m high buildings will be at a maximum angular elevation of 0.45°. At a range of 20NM from the radar, such reflections will only illuminate or be detected by aircraft at or below altitudes of circa 1,000 feet.

9.4.9. Any discontinuities on the building roof areas will serve to scatter the radar reflections, significantly reducing the likelihood of any adverse effects.

9.4.10. In the unlikely event that radar reflections and clutter from the development are found to be an issue, the 3D pencil beams of the Indra PSR can be configured to avoid radar illumination of the development. The SSR should be more immune to the effects of reflections as it builds up its own internal reflector file so that it will ignore any reflections from identified receptors.

10. Summary

10.1. ILS Localiser Runway 02

10.1.1. Worst-case modelling indicates that the proposed development will have a very minor and acceptable impact on Localiser 02 performance. The actual effects are expected to be less than those predicted by the worst-case model.

10.2. ILS Localiser Runway 20

10.2.1. Worst-case modelling indicates that the proposed development will have a negligible and acceptable impact on Localiser 20 performance. The actual effects are expected to be less than those predicted by the worst-case model.

10.3. ILS Glidepath Runway 02

10.3.1. Initial worst-case modelling indicated that the proposed development would have a noticeable impact on Glidepath 02 performance. By rotating the 20m high buildings within sites 121 and 122 counterclockwise by 2°, as is now proposed, the simulated Glidepath disturbance is reduced so that the development has only a minor and acceptable impact on Glidepath 02 performance. The actual effects are expected to be less than those predicted by the worst-case model.

10.4. ILS DME Runway 02

10.4.1. Reflections of DME 02 signals from the closest proposed 10m high building will cross the runway 02 extended centreline which may cause a temporary loss of range information for aircraft making approaches. This should be mitigated by the aircraft interrogator's 'velocity memory' mode and in any case, aircraft will likely fly above rather than through the area of potential multipath interference.

10.4.2. Airways New Zealand has confirmed that the DME 02 ground transponder is configured with SDES enabled, so no effects are anticipated from building reflections.

10.4.3. Potential LoS shadowing of DME signals will be confined to areas south of the Airport and will not occur within the required area of operational coverage.

10.5. DVOR/DME

10.5.1. Worst-case modelling of the proposed development indicates some disturbance to the DVOR azimuth angle between radials 088 and 163 and between radials 243 and 003; however, the magnitude of the disturbance will be acceptable, being well within the international standard tolerance, and the proposed development will have no impact on aircraft flying VOR approach procedures.

10.5.2. DME reflections from the proposed development may result in multipath interference at ranges up to 1.78NM from the facility; however, upward reflections will be at shallow angles of elevation, and they will have no impact on aircraft flying runway approaches.

10.5.3. Although Airways New Zealand has advised that SDES is not currently enabled on the DME ground transponder, configuring the DME with SDES will, if required, provide immunity from building reflections.

10.5.4. Potential LoS shadowing of DVOR/DME signals will be confined to areas east of the Airport. This will have no impact on aircraft flying VOR/DME approach procedures to runways 02 and 20 and so therefore will have no effect on airport operations.

10.6. Radar

10.6.1. The proposed development will have no impact on correct PSR/SSR beam formation and therefore should not adversely affect the PSR/SSR's ability to meet Eurocontrol minimum ATM surveillance system performance requirements (ESASSP v1.3).

10.6.2. The maximum elevation of the proposed development is below the PSR/SSR antennas so shadowing and obscuration of radar signals will not affect airborne targets.

10.6.3. Reflected radar energy from vertical building surfaces will be directed towards the ground where it will be scattered and absorbed and so will have no effect on surveillance system performance.

10.6.4. Reflections of radar energy from horizontal building roofs can potentially result in PSR target fading or SSR data corruption. Any reflections from roofs within the proposed development will be at shallow angles and, at a range of 20NM from the radar site, will only illuminate or be detected by aircraft at or below altitudes of circa 1,000 feet. Discontinuities on building roof areas will scatter the radar reflections, reducing the likelihood of adverse effects.

10.6.5. The 3D pencil beams of the Indra PSR can be configured to avoid radar illumination of the proposed development and the SSR builds up its own internal reflector file so that it will ignore reflections from known receptors. Any impacts are therefore acceptable.

10.7. Conclusion

10.7.1. The objective of this assessment is to evaluate and ensure that the proposed Ryans Road Industrial Development will not adversely affect the safe operation of ANE located at Christchurch aerodrome.

10.7.2. The methodology adopted in this assessment has applied a staged, model-based analysis to identify, quantify, and mitigate potential impacts from the development on navigation and radar systems, ensuring compliance with international standards and maintaining aviation safety.

10.7.3. Based on our assessment, we conclude that the proposed Ryans Road Industrial Development, as detailed in the documents described in paragraph 2.2.1 of this report, will not adversely affect the safe operation of the ANE.

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