HEAR TO LISTEN
ACOUSTICS ADELAIDE - SOUTH AUSTRALIA
6 - 9 NOVEMBER
2018

Strategic versus simplistic noise modelling of the Bay Area of California: comparing the impact on policy and the community

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ABSTRACT

Many levels of government have strategic planning schemes for the growth of cities and regional areas. Regarding transport noise, planning schemes often define zones to either restrict development, or to ensure new or upgraded developments are constructed in a manner that protects the inhabitants by limiting transportation noise intrusion.

The California Building Code defines external noise criteria, which are used to trigger the need for an acoustic assessment and potential building treatments to limit noise ingress. To assist the public in identifying which properties are impacted, local governments provide maps, developed using basic noise modelling, or simple set-back distances away from major transport routes. This approach ignores the value of terrain and topographical features in screening transport noise, potentially placing many properties incorrectly within impacted zones and adding unwarranted acoustic assessment costs.

Two road traffic noise models of the California Bay Area have been built. The first holds road sources only to replicate noise categories published by local authorities, while the second model adds buildings and terrain throughout the 21,000 km^2 (13,000 mi^2) area. A comparison between the two methods demonstrates an almost 50% reduction in the number of properties incorrectly zoned, when stratetic noise modelling is used. This removes the need for an acoustic assessment at these properties, thus lowering planning and/or construction costs within the region.

1 INTRODUCTION

Environmental noise exposure is linked with a range of health effects including ischaemic heart disease, sleep disturbance, cognitive impairment in children, annoyance, stress-related mental health risks and tinnitus.[1] In high income European countries, these risks combined account for a loss of 1-1.6 million disability adjusted life years.[1] While road traffic noise is the most pervasive noise-related issue, high aircraft noise levels are also linked with delayed reading ages, poor attention levels and high stress levels in children.[1]

Many developed countries and individual cities are now taking action to enhance their institutional and technical capabilities when it comes to monitoring, controlling and reducing noise exposure to their inhabitants.[2] Around the world, noise policies continue to be updated, as do building development and upgrade requirements for residential dwellings in high noise areas. To address transport noise, planning schemes often define zones to either restrict development, or to ensure new or upgraded developments are constructed in a manner that protects the inhabitants by limiting transportation noise intrusion.

To provide an understanding of the construction requirements for new or upgraded dwellings requiring noise abatement, transportation noise levels are often assessed by acoustic consultancies on an as needed basis. However, this method of noise assessment is costly and somewhat time consuming. Governments around the world are moving towards publishing noise levels maps, which categorise dwellings in defining a need to address transport noise intrusion, based on their predicted external noise levels.

In an endeavour to minimise perceived costs, noise maps published by government are often based on overly simplistic modelling (i.e. noise models that consider noise sources only without any other dataset), or setback distances from major roads, rail lines or other noise sources of interest. These maps lack detail as they ignore the value of terrain and topographical features (for example buildings and noise barriers) in screening transport noise, potentially placing many properties incorrectly within impacted zones and adding unwarranted acoustic assessment costs.

Strategic level noise modelling is another, less often used, method of creating noise maps for planning purposes. The exception is within the European Union where most major cities and transport corridors have been noise mapped using strategic modelling. Strategic modelling greatly improves the accuracy of noise maps when compared to simplistic models or setback distances. Strategic modelling can incorporate ground terrain, ground absorption, buildings and noise barriers – all of which greatly affect noise levels at dwellings.

The California Building Code[3] defines external noise criteria used to trigger the need for an acoustic assessment and potential building treatments to limit noise ingress. To assist the State in identifying which properties are impacted, some Californian local governments provide maps based on basic noise modelling, or simple set-back distances away from major transport routes.

2 THE CALIFORNIA CODE OF REGULATIONS, CALIFORNIA BUILDING CODE

The State of California has established noise insulation standards that apply to new multi-family residential units, hotels and motels that are subjected to relatively high levels of transportation-related noise. These requirements are collectively known as the California Noise Insulation Standards, California Code of Regulations, Title 24.[3] For any habitable room these standards have set an interior limit of a day-night average noise level (Ldn) of 45 dB. In regions where exterior noise levels are greater than Ldn 60 dB, an acoustical analysis is required to demonstrate how dwelling units have been designed to meet the standard.[3] Title 24 standards are typically enforced by local jurisdictions through the building permit application process.

To obtain a building permit, developers of all new residential developments or major remodels, are required to submit building plans and relevant documentation to the City (depending on their jurisdiction). As part of this documentation, cities require a noise study to prove that the interior sound level is less than 45 Ldn if the exterior sound level exceeds 60 Ldn.

Assuming measurements are done, a development with an external noise level below 60 Ldn will require no further action in terms of sound insulation – provided they meet State building codes. If above the limit, they will need a noise consultant to prove that their sound insulation measures are sufficient to achieve an internal noise limit of 45 Ldn. Once this analysis has been done and submitted with all the other documentation to the city planning department, the permit will be issued and construction can begin.

3 SIMPLISTIC NOISE MAPPING OR MODELLING USING SETBACK DISTANCES

To streamline the process of determining noise mitigation requirements for new building developments and upgrades to existing structures, many regions publish noise level categories using simplistic mapping. Throughout this paper, when we refer to the term 'simplistic mapping', we are referring to noise mapping generated through one of the following methods:

1. Setback distances mapping: the sound power level of each section of a road (or other source such as a rail line) is calculated within a GIS platform or a spreadsheet. Using a basic propagation algorithm, the distance from the noise source is calculated to achieve a noise level that is used to define a planning criterion. All sources are then offset and merged to create the nominated noise contours to define noise categories for planning.
2. Simplistic modelling: the locations of all subject noise sources are imported into a noise model including attribute data that is used to calculate the sound power levels. Using the propagation algorithms within the noise modelling package, noise contours are calculated over a flat terrain without any other topographical features. The noise contours again define noise categories for planning.

The difference between the two approaches is generally negligible. However simplistic modelling allows for the combination of noise levels from nearby/intersecting noise sources which extends the noise level footprint and subsequent noise category. All sensitive buildings and spaces within the nominated noise categories are defined as being impacted by the subject noise source and highlighted as potentially requiring additional construction measures to reduce noise intrusion.

While using simplistic mapping to determine construction requirements is not uncommon, it is not without some drawbacks. Firstly, any development within a noise planning category is typically required to have an acoustic assessment undertaken to demonstrate an internal compliance. In many instances, the actual ambient noise environment where noise attenuation is required is limited to the first row of dwellings fronting land-based noise sources, such as roads, industry or rail lines.

For dwellings where the subject noise source is screened behind a noise barrier and/or a row of dwellings, the noise levels are typically at a level that doesn't require treatments or an acoustic assessment. However, noise categories for planning calculated using simplistic methods won't capture this. For these dwellings, an acoustic assessment is still required and often the additional cost is seen as unwarranted.

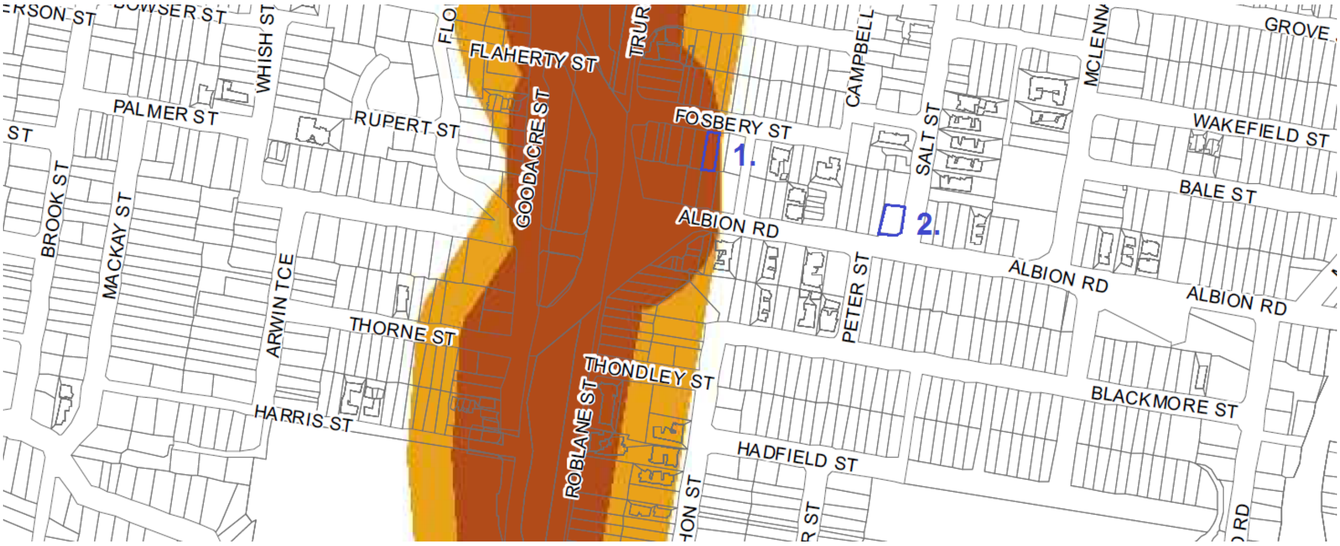
4 LIMITATIONS OF SIMPLISTIC NOISE MAPPING APPROACHES

4.1 Case study 1: Brisbane, Australia

In Australia, noise categories for local council roads are often produced using simplistic mapping. A 'flat-earth' model is used, that doesn't consider topography, existing buildings, or existing noise barriers – attributes that can significantly affect the extent of land adjacent to a designated road that is impacted by noise. The noise categories are essentially setback distances from the designated road network. This simplicity has resulted in adverse comment from the general public and construction industry.

The two highlighted properties (blue) in Figure 1 help demonstrate some of the frustration experienced by the community regarding the use of setback distances, as opposed to more detailed noise modelling. Figure 1 presents Queensland Development Code, Mandatory Part MP4.4[4] (QDC MP4.4) noise categories for the Brisbane City Council (BCC) designated road network in Windsor, and the neighbouring cadastral boundaries. These noise categories are used to define construction requirements to limit noise ingress to new or upgraded dwellings.

Within this study area, noise categories 3 (brown) and 2 (orange) are visible. There is no noise category 1 as compliance with the code is limited to within 250 m of the major road network.



Source (Brisbane City Council, 2018)

Figure 1: QDC MP4.4 noise categories in Brisbane's inner north[5]

Should a new development be proposed at site 1, BCC's simplistic noise mapping indicates this dwelling is in transport noise category 3 – requiring significant construction requirements including double glazing. However, on site, it's clear the property is separated from the major road by three dwellings and a natural break of the line of sight for noise from the main road (Lutwyche Road) to the dwellings via an embankment and retaining wall. As such, the actual noise levels at this property are likely to represent transport noise category 1 - requiring typical construction methods and materials only without the need for additional treatments to limit noise intrusion.

Figure 2 provides a view from the dwelling location to Lutwyche Rd.

Source (Google Maps, 2018)

Figure 2: Google Streeview from the street outside of Site 1

To avoid the substantial cost of upgrades to the building envelope that are needed to meet the requirements for transport noise category 3, a noise assessment is required by a suitably qualified engineer. These assessment reports can be viewed by home owners as significant and unnecessary costs. The alternative, which is to adopt the construction requirements for noise category 3, would be substantially more expensive.

Additionally (and frustratingly for the owner at site 1), if the development was one property east of site 1, there would be no need for any noise abatement or noise assessment at all, as the transport noise categories abruptly cease. This is because in this simplistic map all transport noise categories stop at a distance of 250 m from the designated road network.

At site 2, there are no transport noise categories for Albion Road despite it being a four-lane thoroughfare linking the major roads – Sandgate and Lutwyche Road. The exclusion of Albion Road may be due to a lower classification of the road, rather than a cut off for traffic movements or predicted noise levels.

The transport noise levels at properties fronting Albion Road (e.g. site 2) are likely to be significantly higher than at site 1, yet there is no obligation to provide noise abatement for these residents.

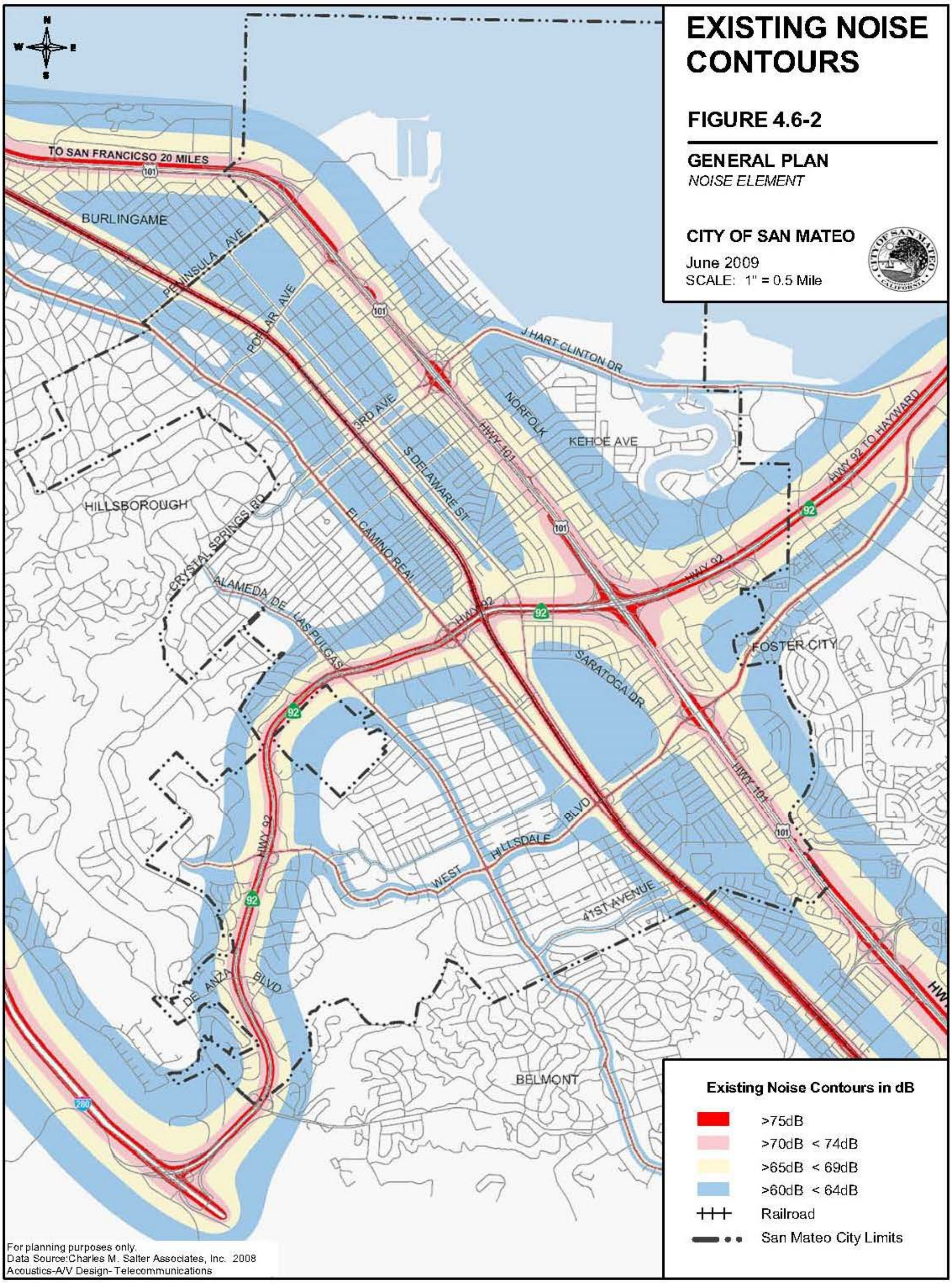
4.2 CASE STUDY 2: SAN MATEO, CALIFORNIA, USA

In a similar theme, noise contours are published by the City of San Mateo, reproduced in Figure 3.[6] Like the BCC noise categories, these contours do not consider terrain, buildings or existing noise barriers, however they are not limited by a 250 m cut-off distance. As a result, the predicted noise levels from the designated road network stretch further unimpeded.

Figure 4 focuses on the East San Mateo region of the noise map, near the J Arthur Younger Freeway. A background aerial image and buildings have been added for scale and reference.

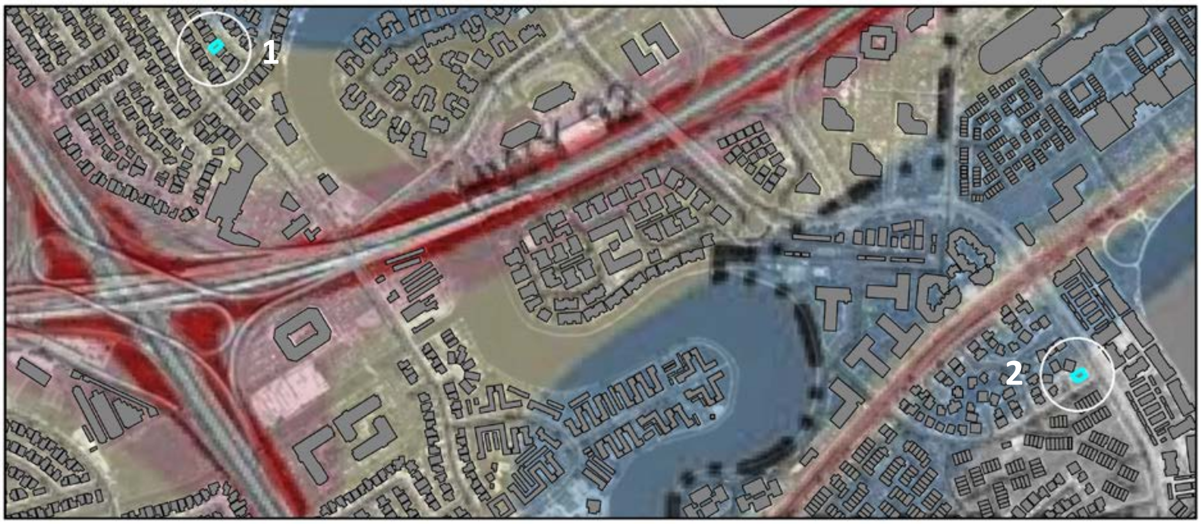
Two dwellings are highlighted in Figure 4. To the north west, a dwelling (1) fronts a local access road for residential access. This dwelling is approximately 370 m from the Bayshoe Freeway and 420 m from J Arthur Younger Freeway. Despite fronting a minor road, the noise map suggests this property has road traffic noise levels above 65 dBA due to its proximity to the two freeways.

For construction to commence, it is likely that a noise assessment would be required to demonstrate that construction assemblies are sufficient enough in terms of sound insulation to meet the 45 Ldn interior limit as per the California Building Code[3].



Source (City of San Mateo, 2018)

Figure 3: San Mateo Noise Contours[6]



Source (City of San Mateo, 2018)

Figure 4: San Mateo noise contours with buildings

To the south east of Figure 4, a dwelling (2) falls outside of the 60 dB published noise contour. However, according to the U.S. Department of Transport (DoT) Federal Highway Administration, Policy and Governmental Affairs, Office of Highway Policy Information; this dwelling fronts Edgewater Boulevard, a road with an AADT of 11,900 vehicles per day, which is likely to result in road traffic noise levels that exceed the 60 dBA screening criterion. The road traffic noise levels at this dwelling are likely to be higher than at the dwelling to the north west, however construction approval is unlikely to consider transport noise.

Both the Brisbane and San Mateo case studies suggest that, by applying a condition to minimise internal noise impacts to properties near a selected road network, the use of simplistic noise modelling can result in inconsistent and at times unfair construction requirements for new or upgraded buildings.

5 METHODS

In this study, we have built two noise models of the Bay Area of California to:

a) replicate the noise levels presented for San Mateo to demonstrate a benchmark; and

b) compare the number of buildings that may trigger the need for a noise assessment under the Californian Building Code.

5.1 Noise model 1: simplistic modelling using road sources only

Noise model 1 is a simplistic model that looks at the noise levels surrounding the road network without the consideration of buildings, terrain and barriers. Typically, with simplistic modelling or setback distance mapping, only major roads – not local roads – are considered when defining noise levels or categories for planning. For this study, traffic volumes were sourced from the DoT U.S. Traffic Volume dataset,[7] including freeways, highways, major and many feeder roads. All roads supplied were modelled (rather than just major roads), with a combined modelled road network length of 14,133 km, or 8,791 miles, stretching from Calpella in the north to San Lucus in the south and west to Stockton. Figure 5 maps the project extents of the road traffic noise models.

For the purposes of this study there are a number of clarifications and assumptions:

- Noise modelling was completed using SoundPLAN Version 8, with the CoRTN road traffic standard. It is acknowledged that TNM is the local standard, however as the primary purpose of the study was to demonstrate the difference in noise impacts primarily due to screening, the standard adopted was not considered an important difference.

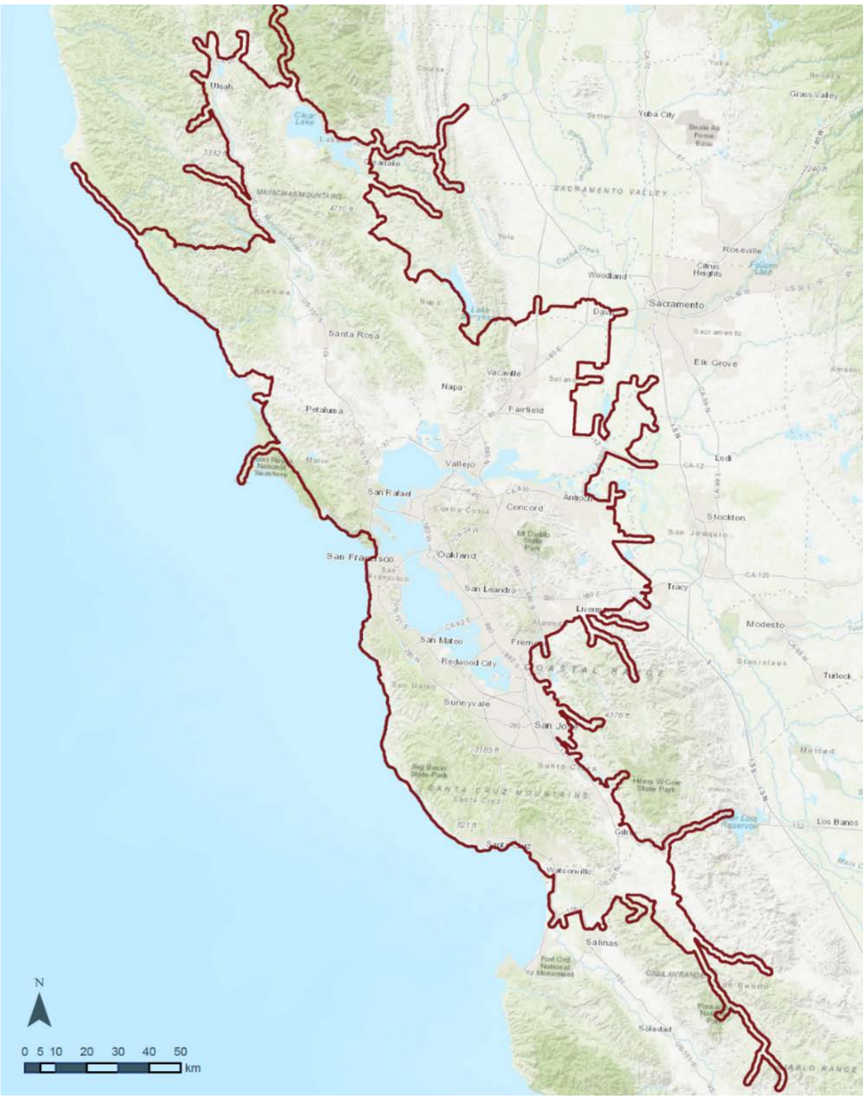
- The supplied traffic data did not include speeds and heavy vehicle percentages. A notional speed of 60 km/h and a heavy vehicle percentage of 10% was applied.
- Noise levels were calculated out to a distance of 1,000 m, with no reflections, at a 10 m grid resolution.

5.2 Noise model 2: strategic modelling

Using the road sources within noise model 1, terrain and buildings were added. Terrain was sourced by NASA's Shuttle Radar Topography Mission (SRTM), placing an elevation point roughly every 25 m. Ideally LiDAR would be used to better improve the accuracy of the terrain, however due to time and budget constraints, LiDAR was not considered for this study.

Building footprints were collated from numerous datasets. Many buildings had a defined height. Buildings that did not have a height value were allocated a height of 8 m, however buildings with a footprint below 12 m^2 were considered to be sheds/garages and allocated a height of 2 m.

In total, approximately 22.3 million buildings feature within the road traffic noise model. Besides the terrain and buildings, no additional features (e.g. noise barriers) were included due to time and budget constraints.

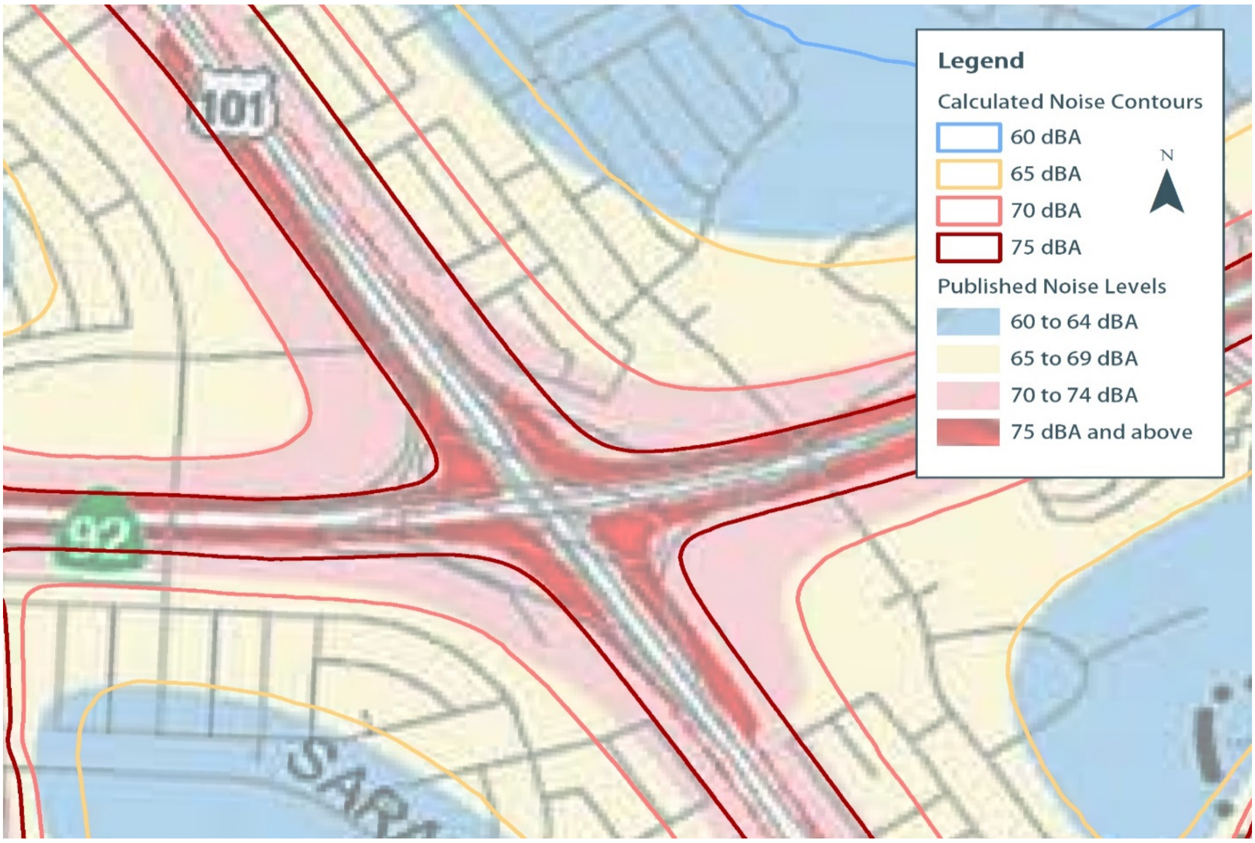


Source (Ambient, 2018)

Figure 5: The Bay Area of California modelling extents

6 RESULTS

Calculated noise levels from our simplistic noise model of San Mateo were first calibrated against the existing San Mateo noise map using the same road network. A comparison of the original and calculated noise levels is presented in Figure 6.



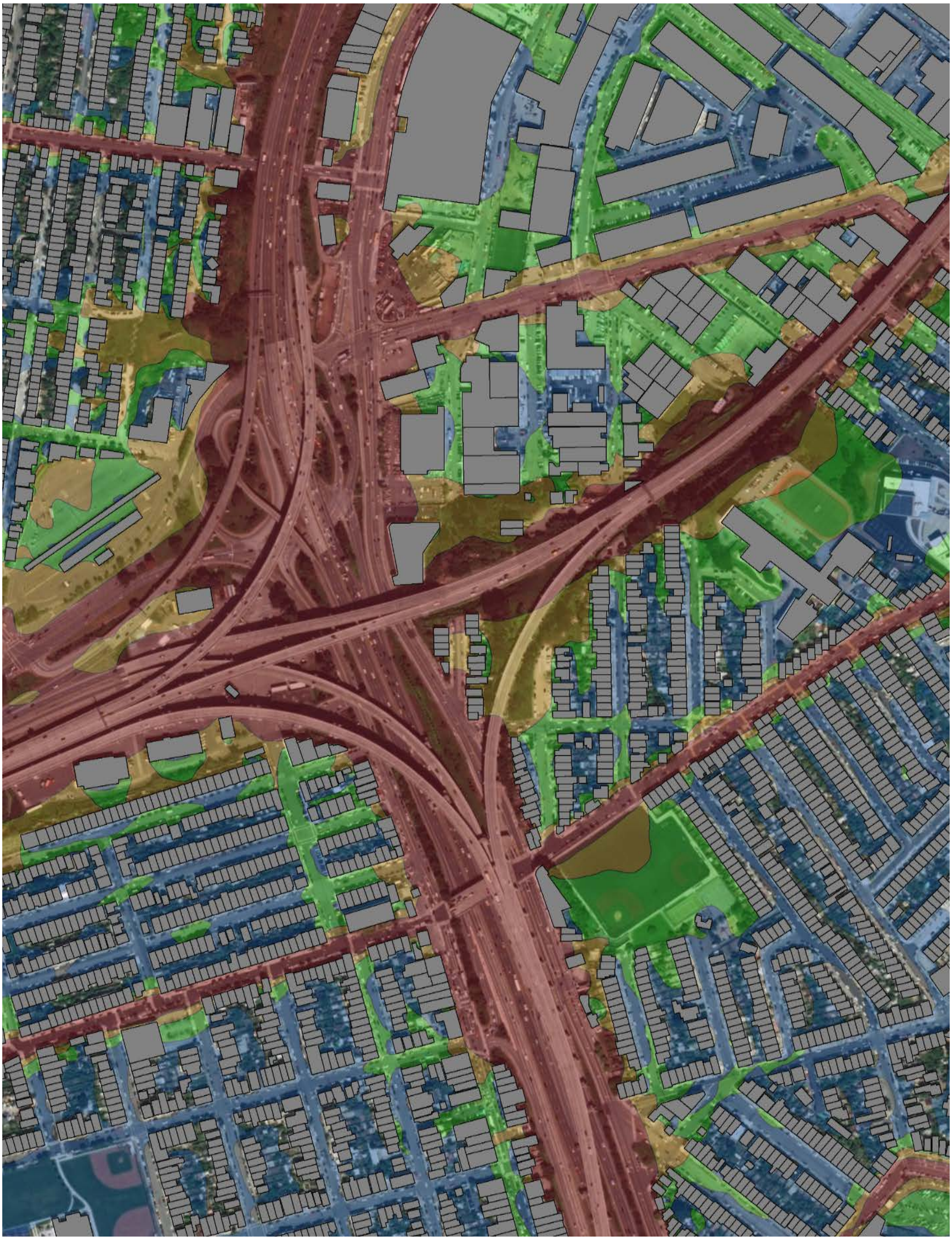
Source (City of San Mateo, Ambient, 2018)

Figure 6: San Mateo noise map – published and calculated noise levels

Once a level of confidence was established against the San Mateo noise levels, noise levels were calculated throughout both the simplistic and strategic models. Small extracts of the California Bay Area strategic noise map are presented in Figures 7-9.

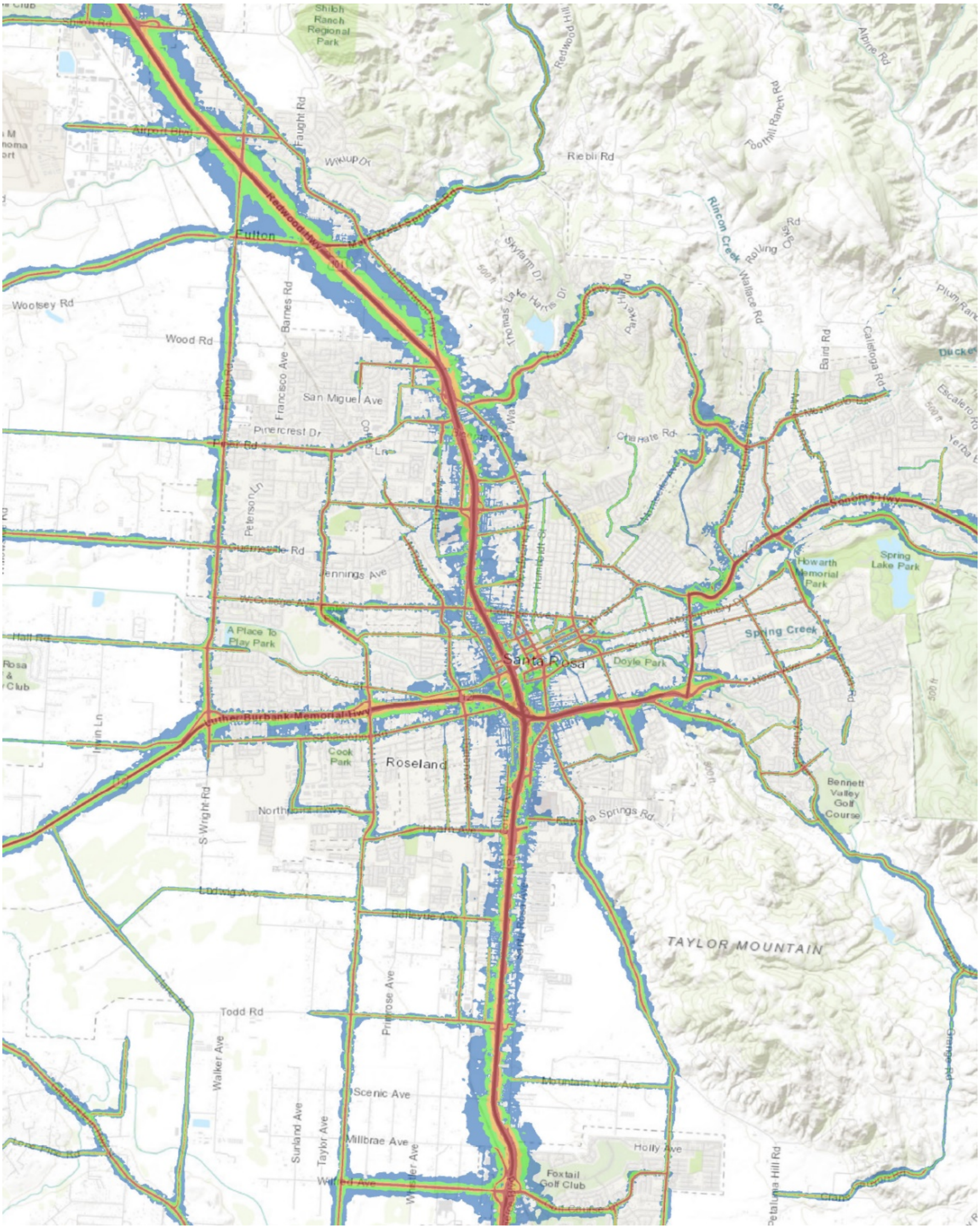
Source (Ambient, 2018)

Figure 7: San Jose noise map – suburb scale (suburbs via strategic modelling)



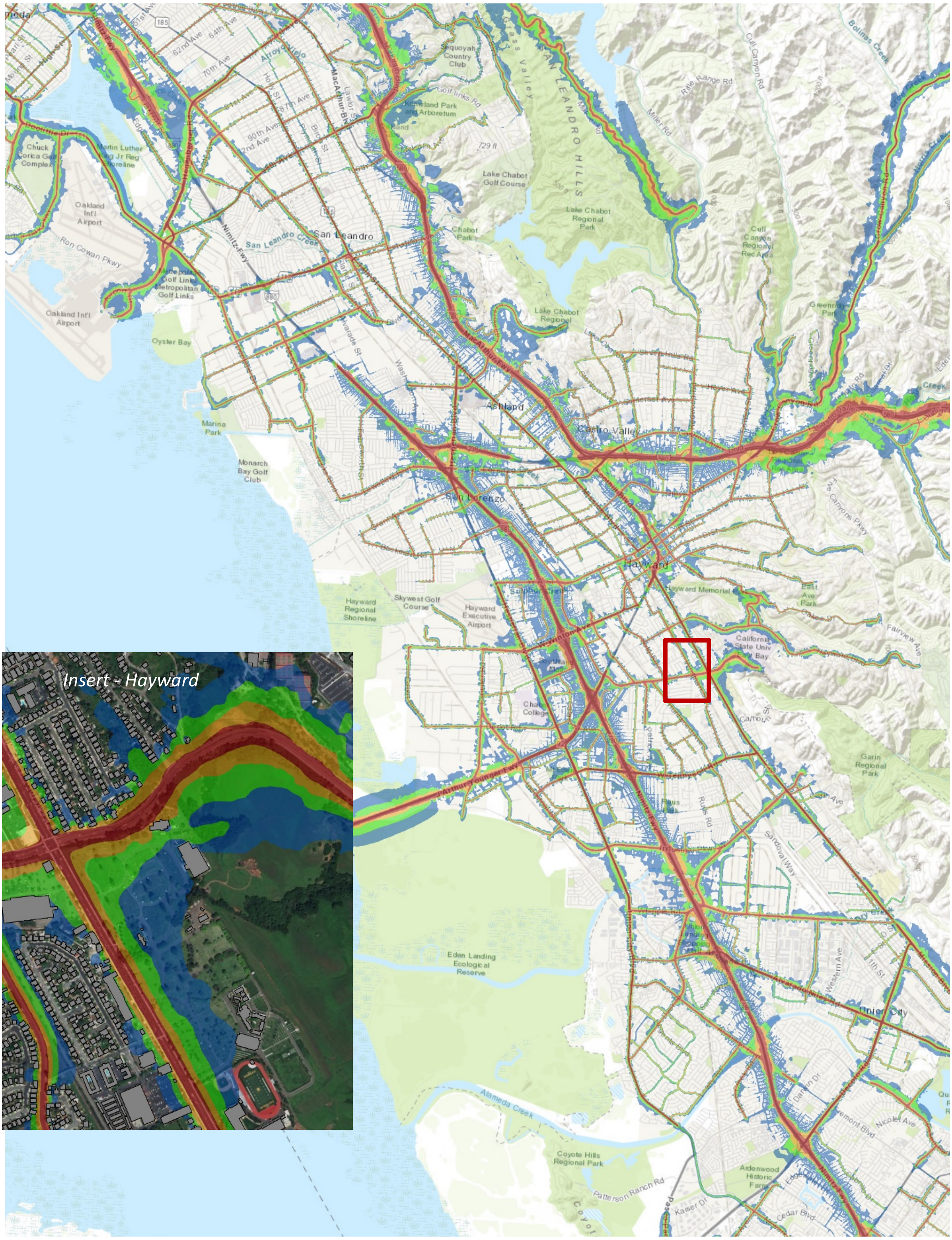
Source (Ambient, 2018)

Figure 8: San Francisco noise map – street scale (streets and buildings via strategic modelling)



Source (Ambient, 2018)

Figure 9: Santa Rosa noise map – city scale (towns and cities via strategic modelling)



Source (Ambient, 2018)

Figure 10: San Leandro to Fremont noise map – city scale (towns and cities via strategic modelling)

After modelling and developing our maps, we then counted the number of buildings that fell into the external noise categories:

- 60 to 64 dBA
- 65 to 69 dBA
- 70 to 74 dBA
- 75 dBA and above.

Table 1 presents the number of buildings within the simplistic and the strategic noise maps that fell into each category.

Table 1: Buildings within noise bands – simplistic versus strategic modelling

Range	Number of buildings		Percentage drop per interval
	Simplistic modelling	Strategic modelling	
60 to 64	548,926	236,759	56.9%
65 to 69	346,969	146,252	57.8%
70 to 74	190,666	128,631	32.5%
75 and above	75,137	69,865	7.0%

Our results showed that strategic noise modelling reduced the number of buildings requiring noise assessment across all noise categories. The lowest reduction was at the loudest noise interval, where only 7% of buildings benefited from adding additional data to the noise model. This was not surprising, as the 75 dBA noise contour in the simplistic model typically did not extend beyond the first row of dwellings. Hence there was not any opportunity within the strategic model for buildings to provide screening before the calculated noise levels dropped below 70 dBA. An example of the 75 dBA simplistic and strategic noise contours for the city of San Mateo is presented in Figure 11.

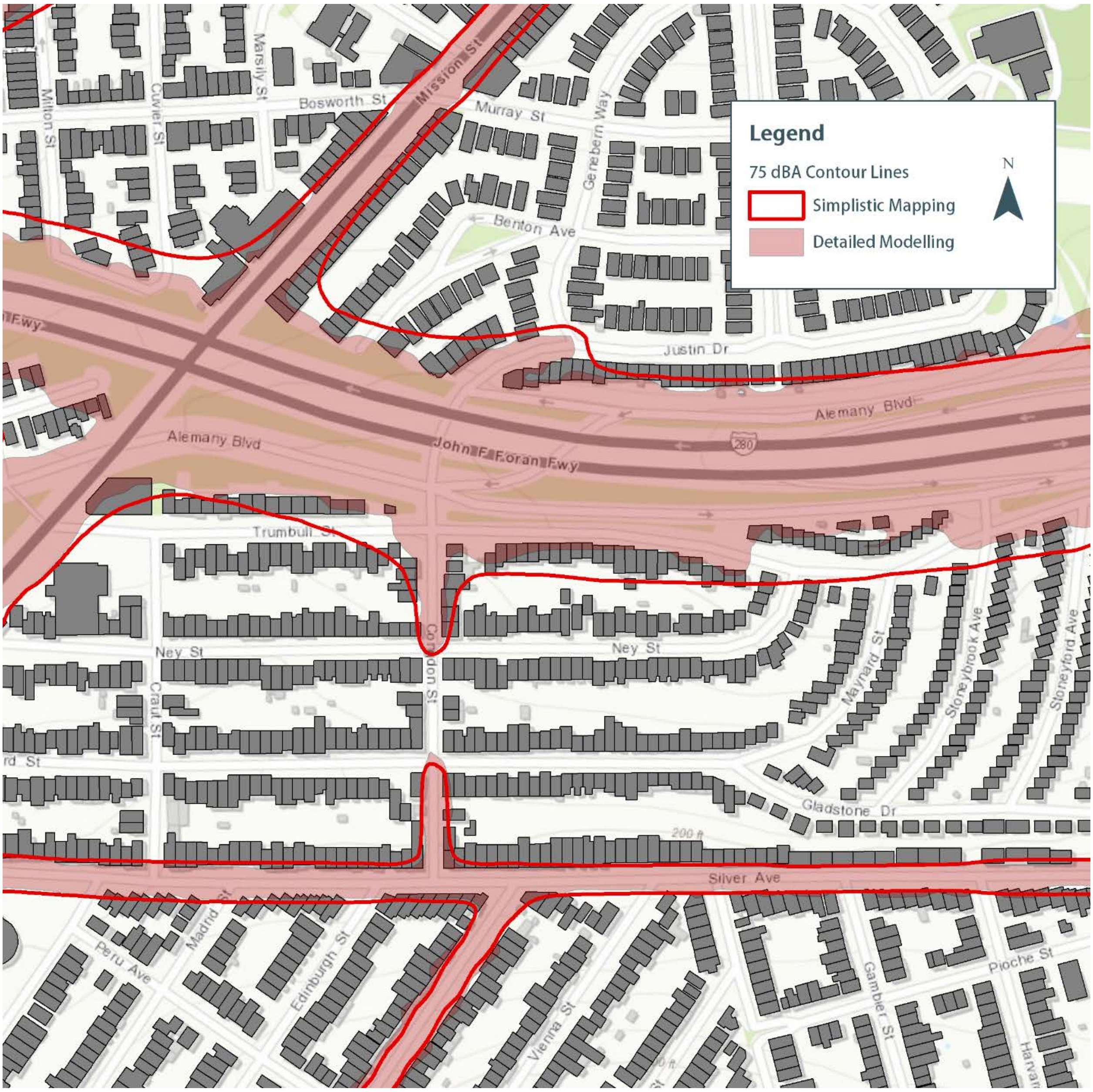
Noticeable reductions in the number of buildings requiring further noise assessment were noted in the lower noise categories, where a maximum reduction of 57.8% was noted for the 65 to 69 dBA band. The greatest reduction was expected to be within the 60 to 64 dBA noise range, as this noise category had the widest footprint and offered the greatest opportunity for reductions in noise levels due to screening. However, the number of dwellings within this noise band was increased with buildings that originally sat within the noise category(s) above that were lowered down a category(s) by the more detailed model.

The Californian Building Code identifies an external noise level of 60 dBA as a trigger for further assessment. Through the addition of basic terrain and buildings to our simple model, we were able to reduce the number of properties needing further noise assessment by half (49.9%).

7 DISCUSSION

It is not surprising that a reduction in the road traffic noise footprint – and hence the number of dwellings affected – was seen with the addition of buildings and terrain to the noise model. While buildings and terrain offer an obvious screening effect within the model, the reductions in overall noise level seen with this particular model are considered conservative.

Noise barriers offer another screening effect that has not been considered within this study. The addition of noise barriers to the noise model would again increase the level of noise attenuation and further lower the number of dwellings requiring noise assessment. Consideration of a more accurate terrain would also provide natural breaks in the line of sight from the road surface to nearby buildings when the road is within a cut or elevated against the receptor height.



Source (Ambient, 2018)

Figure 11: Strategic and simplistic 75 dBA noise contours

Two studies in Australia comparing simplistic modelling to a strategic level noise map – Brisbane and Redland City Council – noted reductions of 65% and 62%, respectively, in the number of dwellings requiring noise abatement measures or completion of a noise assessment prior to construction or upgrade. Both studies featured noise barriers and better terrain accuracy, when compared to the Bay Area California noise map considered in this study.

It is the author's opinion that the avoidance of strategic modelling for planning is directly related to cost and data availability. In discussions with various forms of government, there is a perception that noise modelling is a considerably expensive exercise. From experience, the expense of a noise map is directly comparable to the level of accuracy achieved. In many cases, most of the data for a strategic level noise map is now readily available, and a basic version can be completed at a relatively minimal cost. However as detail and accuracy increases, so too does the cost.

For a detailed road traffic noise model that is verified against noise measurements, approximately 90% of calculated noise levels typically fall within approximately ± 2 dBA of those measured. Two city noise maps the author has completed both returned a 90% confidence of ± 3.8 dBA for road traffic noise, when verified against almost 300 measurements for one city, and over 90 for another. The wider ranges can be related to differences in posted and actual traffic speeds, detail in terrain, building and noise barrier accuracy and the alignment of the source lines. A third city noise mapping completed noted an improved 90% confidence of ± 2.9 dBA across approximately 70 measurements, with the only difference being a highly detailed terrain.

If accuracy of a noise map is defined by a ± dBA range to provide a 90% confidence, it is the authors experience that for every 1 dBA reduction in the 90% confidence tolerance, the cost of producing a noise map doubles.

Further studies are warranted to investigate the cost/benefit ratio for governments who choose to develop noise categories for dwellings using strategic noise modelling; and the associated reduction in the number of noise assessments required for the approval of new developments or upgrades to existing dwellings in high traffic noise areas.

8 CONCLUSION

This study indicates that strategic noise modelling can reduce the number of properties requiring a detailed noise assessment, prior to construction or upgrade, by at least half. In this study, we built two road traffic noise models for the Bay Area of California. The first is a simplistic model that holds road sources only to replicate noise categories published by local authorities, while the second model adds buildings and terrain throughout the 21,000 km^2 (13,000 sq mile) area. A comparison between the two methods demonstrates that the inclusion of terrain and buildings alone reduces the number of properties identified for further acoustic assessment or construction requirements by 49.9%.

It is clear that the more datasets added to a noise model, the more accurate the model. Unfortunately, when local governments are paying for noise category information, cost becomes a major concern. Further studies are warranted to determine the cost/benefit ratio between the increased cost of more detailed maps, versus significant reductions in the number of building permit applications requiring a detailed noise assessment, and potentially even a reduced number of properties requiring noise abatement measures added to their construction costs.

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