A Case Study of Specialist Acoustic Advice for a Large Multi-Stage Industrial Development on a Rural Greenfield Site

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ABSTRACT
Our approach to specifying industrial noise control and the assessment of environmental noise emissions from milk processing facilities has been developed over recent years while working on a large number of sites around New Zealand. This paper uses the Fonterra Darfield site, situated in Canterbury, New Zealand, as a case study to outline our current approach for rural greenfield projects. Our involvement has included all stages of the project from early feasibility assessments, the consenting, design and commissioning of two stages of development, through to advising on future expansion plans. Our advice for the Darfield site addressed issues including environmental noise effects, setting contract specifications and protecting against potential reverse sensitivity effects. We have used three-dimensional computer noise models to inform our advice throughout the various stages of the project. This paper also discusses some of the key benefits and outcomes of this approach for both the client and project team.

1. INTRODUCTION
The Fonterra Darfield dairy factory is a 680 hectare rural greenfield development which currently has the largest milk dryer in the world. This paper uses our work on this site as a case study to demonstrate our current approach to implementing industrial noise control throughout the various stages of the project, and assessing noise emissions from major milk processing facilities. There were a number of key milestones and desired outcomes for the Darfield development which relied on specialist acoustical input, including:

- Obtaining planning permission to operate the site under appropriate environmental noise provisions;
- Developing a master plan for the site;
- Providing robust construction/supply contracts; and of course
- Long-term compliance with all noise limits even after additional stages of development.

These outcomes are not specific to dairy processing sites, but apply generally to large-scale industrial facilities. The aim of this paper is to give an overview of how a range of common technical skills and concepts can be applied by a consulting acoustician throughout the various stages of a large-scale industrial project to achieve the outcomes above.

2. BACKGROUND INFORMATION

2.1 Fonterra Dairy Co-Operative Ltd
Formed in 2001 from the merger of other dairy co-operatives, Fonterra represented around 95% of all dairy farmers in New Zealand at formation (Fonterra n.d.). At its creation, Fonterra inherited around 30 production sites across New Zealand. Our work with Fonterra has predominantly revolved around resolving historical noise issues at existing dairy processing sites to address noise complaints and/or allow expansion projects to proceed.
At the time Fonterra was formed, the New Zealand Government passed The Dairy Industry Restructuring Act 2001 (DIRA) (New Zealand Government 2016). Created to avoid the potential for monopolistic abuse, DIRA includes a legislative requirement for Fonterra to accept all milk from farmers who wished to supply the Co-operative. Recent high world market milk prices have encouraged many farmers to convert from arable farming to dairy production. To meet the increased production, Fonterra has had to build additional milk processing capacity.

2.2 The Fonterra Darfield Site
Work began on the Fonterra Darfield development in 2010, which was Fonterra's first greenfield development since 2001. The site is situated in the South Island of New Zealand, in inland rural Canterbury. As shown in Figure 1, the site is approximately 45 minutes' drive from Christchurch and around 5km from the nearby town of Darfield. Prior to establishing the Fonterra dairy factory, the 680 hectare site included a large farm with established irrigation, surrounded by primarily arable land operated by around a dozen households.

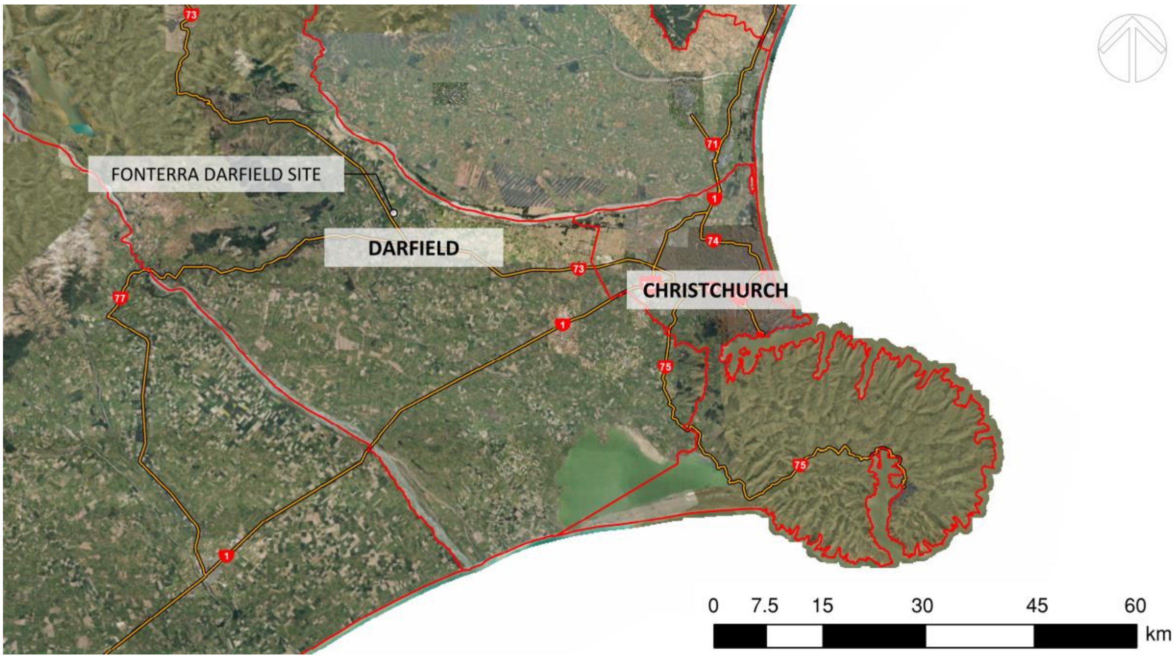

Figure 1 – Fonterra Darfield location (Environment Canterbury n.d.)

The main production elements of the site are the two whole milk powder (WMP) dryers serviced by two coal-fired boilers and other ancillary services. Darfield dryer 2 (DD2) is around 50 metres tall, and is the world's largest WMP dryer. Figure 2 shows the site early on during the construction of the Darfield dryer 1 (DD1) building, which is around 40 metres tall. DD2 construction activity is occurring in the foreground.

Figure 2 – Fonterra Darfield dryer 2 under construction with dryer 1 in background (image courtesy Fonterra)

Milk is transported from farms to the site by a fleet of 37 tankers, and an on-site rail spur is used to transport outgoing product and incoming materials. More than 230 staff work at the site and, at peak capacity, 7.2 million litres of milk can be processed each day with 220,000 tonnes of WMP produced annually. Of the 680 hectare site, the factory covers more than 10 hectares, including a 54,000 square metre drystore used for product storage (Fonterra n.d.).

2.3 Legislative Planning Framework

The primary legislation in New Zealand with respect to the environment and amenity is the Resource Management Act 1991 (RMA) (New Zealand Government 2016). Under the RMA, each Local Territorial Authority (LTA) has a District Plan which sets the objectives, policies and performance standards for different areas (zones) of the District. It is important to note that performance standards are not prescribed by the RMA but, with few exceptions, are set by each LTA. With respect to noise, District Plan rules typically include the following:

- Noise measurement and assessment methods and standards; and
- Noise performance standards including noise limits, parameters used and assessment locations.

The Fonterra Darfield site lies within the Selwyn District (the District), governed by the Selwyn District Council and the Selwyn District Plan (Local Government NZ 2010).

2.4 Resource Consents

All activities have a default status under a District Plan. The status of the activity depends on the level of noise generated, as well as factors such as the site zoning, and the nature, scale and intensity of the activity. 'Permitted' activities are those activities which meet all the relevant District Plan standards. These activities do not require a resource consent. Any activity which does not meet all the relevant performance standards may only operate if the LTA grants a Resource Consent.

Resource Consents will often include conditions of consent that specify the noise limits that apply to the activity. The wording of these conditions is critical as the consent conditions defines the noise performance standards (and assessment methods) for the activity.

3. KEY TOOLS

The following sections outline the main tools we have used to advise Fonterra on noise-related issues around the Darfield site.

3.1 Simple Noise Model

A simple noise model was developed based primarily on measurements of the recently completed expansion of Fonterra's factory in Edendale, Southland referred to as the ED4 project. Established in 1881, Edendale is the oldest manufacturing site in New Zealand, and Fonterra's largest production site, covering more than 20 hectares (Fonterra n.d.). Key advantages of using the ED4 project and the Edendale site in general as a basis for the simple model included:

- All the key activities at the Darfield facility were part of the ED4 project, namely a whole milk power (WMP) dryer building, boiler and rail spur.
- As the most recent development of its type, the project represented current industry practice. Most interestingly, there had been no specific acoustical input into the design. Therefore, ED4 was considered by the entire project team as a 'standard' development, without any potential benefits that might arise from input from an acoustics specialist.
- The project was useful as a costing benchmark against which various constructions and noise control treatment options could be compared. The critical noise sources and challenges, strategies and costs associated with installing noise control treatment could be directly determined.

Our review of measurements at Edendale indicated that noise emissions from dairy factories are dominated by a small number of noise sources. These noise sources are usually challenging or costly to control, typically due to significant low-frequency sound, high velocity air discharges, large sources (e.g. dryer building ventilation intakes) or a requirement to be located outside.

3.2 Detailed Noise Model

While simple noise models are generally suitable for predicting noise levels from an industrial site, detailed computer noise models have a range of benefits including:

- Ability to identify and prioritise cost-effective noise control opportunities for an existing site in greater detail that simple models;
- Accurate assessment of how future expansions may affect total site noise emissions;

- Inform the development of noise budgets for contract purposes and compliance with relevant environmental noise standards; and
- More effective communication with project team, site operators and general public through the use of model outputs such as noise contour maps.

Preparing a detailed noise model requires the acoustics specialist to collect data for every noise source on the site. For existing sites, we collect data through detailed on-site noise surveys. This requires multiple days of surveys for large sites. For greenfield sites or projects which are still in the design phase, it is necessary to review proposed equipment selections, contract specifications, building designs and landscaping plans. Activities are modelled based on manufacturer's noise data, first-principle sound power derivations and measurements of existing equipment and facilities around New Zealand. A more detailed outline of the benefits of a detailed noise model and a standard approach to developing detailed models for large industrial sites is provided by Staples (2016).

The model of the Fonterra Darfield site is essentially an 'as-built' model derived from site measurements conducted once each development stage was completed. To collect the data, close-up measurements of equipment were conducted during the daytime and calibration measurements at more distant positions were conducted during the night-time. The cost of this labour intensive approach is off-set overall as the model is used to analyse noise emissions from the site in detail and ensures that only the noise sources which pose a critical risk to the site (either the long-term development or overall compliance with the noise limits) are treated, while at the same time reducing non-compliance and project costs for future stages of development.

3.3 Noise Bucket Concept

It is often difficult for people outside the acoustical profession to understand how noise from a site interacts with the environment, especially when factors such as the logarithmic nature of the decibel unit and noise source spectra of different noise sources is considered. When working with a diverse project team on a major project, we have found benefit in a simple method of explaining noise that gives the wider team a framework to understand our approach, and facilitate discussion about the implications of their design approach on the noise emissions. For the Fonterra Darfield development, we used the concept of a 'Noise Bucket. Figure 3 illustrates the general concept graphically.

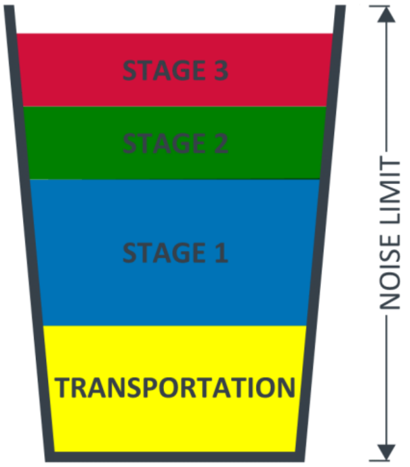

Figure 3: A simple representation of the 'Noise Bucket' concept

While the concept is technically limited in many ways, it assists in to communicating to the team key ideas relating to noise assessment, noise control, site design and site master planning including the following:

- Noise limits: The size of the bucket is primarily related to the site noise limit. Overflowing the bucket means the site exceeds the noise limits and therefore doesn't comply.
- Making space in the bucket: If there is space in the bucket, either more noise is able to be generated by an activity (reducing cost of noise mitigation), or more sources can be added to the bucket (increasing the scope for development on a single site).

- Distance can be considered as ‘free’ noise mitigation: Other than the actual noise level of a source, the main factor influencing the amount filled up by any source is the distance from any receivers. Therefore, for a given activity, a larger setback from noise sensitive receivers makes more space in the bucket.
- Relative contribution of sources: While the contribution from some sources can be reduced to a small ‘drop’ by implementing noise control, there is a minimum amount of space that some activities will always take up (e.g. material handling, trucks and rail activity). Therefore there is a practical minimum setback required for any large dairy factor development. In addition, by reducing the contribution from these activities (by increasing setback distances or specific site designs) more space is available for other activities.
- Noise budgets: Once the size of the bucket is set, and the contribution from ‘uncontrollable’ sources (e.g. transport) is taken into account, each stage of development, activity or noise source must not take up more space in the bucket than allocated, or the bucket will overflow. In the simple scenario of a multi-stage development with identical stages, the most cost-effective approach is usually to implement the same level of treatment for every stage. Therefore, while the bucket will be relatively ‘empty’ in the early stages of development, this does not mean contractual noise levels can be increased. Conversely, while the bucket may look ‘empty’ early on, there may in fact be risks to future stages.

4. SITE FEASIBILITY AND MASTER PLANNING

The aim of the site feasibility investigation and master planning is to:

- Reduced construction cost for both existing and future development by advising on factory location during feasibility investigation; and
- Provide a planning framework that has clear and simple assessment/compliance requirements with minimal ongoing compliance costs, and permits the future development of the site to occur at the desired scale and intensity.

4.1 Initial Site Feasibility Investigation

Many factors need to be accounted for when assessing the feasibility of a site for any major industrial development. For greenfield developments in particular, many of the decisions made at the earliest stages of a project have a major effect on site noise emissions. The Noise Bucket concept was critical for communicating with the project team during this early phase of the Fonterra Darfield site development. Together with our simple noise model, we were able to rapidly assess various options and provide high-level conceptual guidance to the team. Our key contributions during the early stages of the Darfield project included:

- Identifying transportation and material handling as the most significant single noise sources. Dairy factory noise control design had previously focused almost exclusively on mechanical plant noise.
- Demonstrating that that, as a result of changes in industry design and construction practice, the main process air discharge stacks and ventilation air intakes of a Whole Milk Powder plant (traditionally one of the largest and noisiest sources on a dairy factory) was not a significant contributor to the overall noise emissions for this style of plant. These items are frequently problematic at other older sites.
- Advising on the placement of the factory within the site. In particular, we identified significant restrictions or additional costs to long-term development plans at the two locations initially proposed (red markers in Figure 4). In conjunction with Fonterra’s environmental and capital projects teams, the current location (visible in Figure 2 and Figure 4) was selected. Placing the factory in this location increased the distance to the nearest dwellings by approximately 500 metres, reducing the amount of noise control required on the mechanical plant, and ensuring noise from transportation and material handling would be sufficiently reduced by distance to facility all planned stages of the site development.

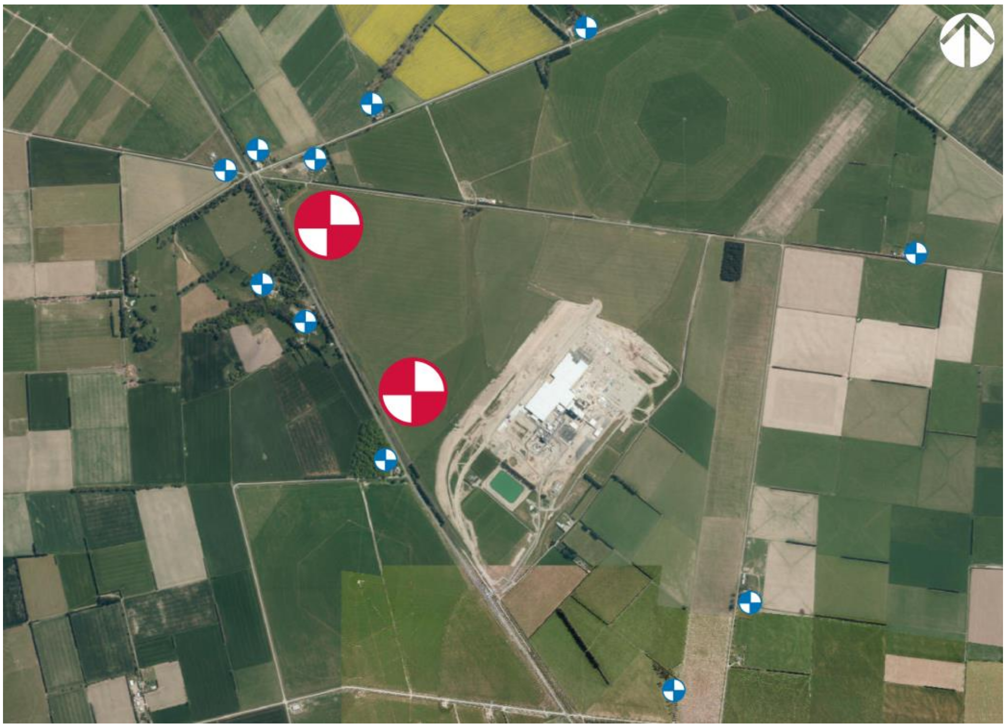

Figure 4 –Darfield site with Stage 2 under construction and alternative locations marked in red and dwellings in blue.

4.2 The Future of the Darfield Site

For a number of reasons, changes to land zoning and the potential reverse sensitivity effects has recently become a significant element in our involvement with Fonterra on many sites around New Zealand. This is discussed in detail by Hay (2016), but a key aspect relevant to the Fonterra Darfield site is the increasing use of a Noise Control Boundary (NCB) and associated rules to control noise effects for a site.

A recent Plan Change has allowed specific areas to be created within the Selwyn District where dairy processing facilities can establish without needing a resource consent (PC43, Selwyn District Council 2016). With respect to noise, the key tool is the creation of an 'Outline Development Plan' (ODP) for a specific site that includes an NCB.

The accompanying set of rules provides reverse sensitivity controls which put the onus on any noise sensitive activities establishing within the NCB to ensure internal noise levels are acceptable. With respect to controlling noise emissions from the site the rules are, in summary:

- Noise limits of 55 dB L_{Aeq} (daytime) and 45 dB L_{Aeq} (night-time) apply at the NCB; and
- Noise from rail movements (but not unloading/loading activities) into, within and out of the site is not included in any assessment of compliance on the basis that the effects of the rail activity are assessed separately.

Fonterra's intention is to create an NCB for the Fonterra Darfield site. To support this process, our detailed noise model of the existing site is a baseline model from which we can develop a range of future expansion scenarios. Noise contours predicted by the model then inform the shape of the potential NCB for the Darfield site. The key to the process is giving Fonterra confidence they can comply with in the long-term, and providing Council and the wider public with assurance of the realistic maximum extent of potential noise effects in the future.

5. PLANNING APPLICATIONS AND NOISE MONITORING FOR CURRENT OPERATIONS

Resource Consents have been required to-date for all existing activities on the Darfield site. The two most significant consent applications are the 2010 application for the Stage 1 initial development (Planit Associates 2010) and the 2012 application for the Stage 2 expansion (Planit Associates 2012).

Critically for our involvement, both Stage 1 and Stage 2 developments were 'discretionary' activities. As a discretionary activity, Selwyn District Council (SDC) was able to take into account any potential effects arising from the proposed activity when choosing whether or not to grant consent. In addition, SDC could impose conditions on the consent if considered appropriate.

5.1 Predicting Noise Levels

A simple noise model based on the Fonterra Edendale site was used to predict noise levels from the Stage 1 development during consenting, as design work on the project had not progressed to a point where sufficient information was available to prepare a detailed noise model. As a higher degree of detail was available for the Stage 2 consent application and a detailed model had been developed during the design phase of Stage 1 (see Section 6), a detailed noise model was used to predict noise levels with the Stage 2 development. Key outcomes and points of interest include:

- Noise levels predicted using the two models only differed by around 2 dB at the surrounding properties, even though there were only 14 noise sources in the simple model (12 'fixed plant' sources, tankers and rail activity) and around 200 in the detailed model. This confirmed our experience at Edendale that noise emissions from dairy factories are often dominated by a relatively small number of noise sources.
- Overall noise levels of 36 dB L_{Aeq} or less were predicted at all nearby properties, well below the night-time noise limit of 45 dB L_{Aeq}. The low noise levels were expected as the Stage 1 and 2 development have been designed to allow for the future development of the site.

5.2 Noise Monitoring

5.2.1 Darfield Site Monitoring Approach

At the Fonterra Darfield site, noise monitoring is required on a regular basis at key control locations around the site. The key control locations were established following the initial noise survey in December 2012 on the following basis:

- The locations are generally around the perimeter of the operational site, not at notional boundaries as noise emissions from the plant are relatively low and generally cannot be reliably measured at notional boundary positions.
- The positions take into account future expansions of the site, as well as accessibility, the ability to reliably find the same location every year, potential safety issues associated with monitoring at the positions during the night-time, as well as ensuring noise from as areas of the site was assessed.
- Perhaps most critically, noise levels at the surrounding properties can be determined based on measurements at the key control locations.

5.2.2 Noise Monitoring Outcomes

As a result of monitoring we have been able to identify and resolve potential issues such as missed attenuation or excessive noise shortly after commissioning, and confirm that any additional noise mitigation has been successful during the next year's survey. In our experience, new large-scale industrial facilities typically have a small number of issues that need to be resolved post-completion. The streamlined consent conditions reduce the time and cost of ongoing monitoring as measurements are only strictly required at the key monitoring positions (control locations), while also ensuring trends in site noise levels are tracked. Key outcomes from our noise surveys include:

- Verifying noise levels predicted during consent. At the completion of Stage 1 (December 2012), the noise levels at the surrounding dwellings were within 2dB of the predicted levels. At the completion of Stage 2 (December 2013) noise levels were within 1dB and noise levels specifically from activity on the rail siding are within 2dB of the predicted values at the worst-affected position.
- Identifying potential risks and opportunities for improvement: One year following the completion of Stage 2 (October 2014), we identified the presence of an unknown noise source that caused a significant increase in boundary noise levels. As a result, Fonterra commenced an investigation to establish the cause of the noise. We have identified opportunities for improving overall noise emissions, including replacing tonal reversing alarms from container handling equipment with broadband alarms; and
- Confirming compliance: Under the worst-case scenario, our monitoring shows that overall noise levels at the surrounding properties are between 7 and 18dB below the night-time noise limit.

6. FACTORY DESIGN & COMMISSIONING

The work undertaken for planning and feasibility phases of a project is essentially a theoretical exercise. The monitoring phase of work on the other hand is only concerned with what is occurring at a particular moment in time. The connection between these two aspects is the design and construction of the site. Involvement in the design phase of the Darfield Stage 1 and Stage 2 developments broadly covered the following areas:

- Assisting Fonterra and their project managers in setting appropriate contract specifications to control noise emissions;
- Assisting individual contractors with their design to ensure the contract specifications were achieved;
- Commissioning the site;
- Conducting noise monitoring during critical night-time construction activities; and
- Providing advice on specific noise control treatment.

We relied heavily on our detailed design model to assist us during the design stages. Initially, our model was based on Stage 1 specifications and preliminary plant selections provided to us by the design engineers. For some activities, such as the boiler house, it was necessary to develop constructions, noise control treatment and penetration details based on measurements of similar developments and first-principle calculations derived from equipment specifications. When the design for Stage 2 commenced, we were able to use our theoretical model of the Stage 2 development from the consent process, which was updated based on commissioning measurements from the Stage 1 development. Being able to base the Stage 2 design on a calibrated as-built model of the Stage 1 development provided a high degree of detail and confidence. Some of the key advantages of using a detailed noise model during the design phase included:

- Quickly assessing alternative designs;
- Considering each area in the context of the overall noise emissions from the entire site, and the location of the various noise sensitive receivers and compliance locations;
- Ensuring that screening and reflections off the various large buildings on site were taken into account; and
- Assessing noise levels from any group of sources at any position to develop item-by-item noise budgets and specifications for designers and engineers.

Commissioning of both Stage 1 and Stage 2 was significantly easier having used a detailed model during the design phase. In particular, we were able to identify any noise sources not included in the original budget/design and sources which were significantly louder than allowed for in the design. In addition, we could take into account whether any one non-compliance or noisy source had an impact on the overall noise emissions from a given area of contractual responsibility in the context of the overall noise emissions from the site.

7. FINAL REMARKS

Being able to communicate and integrate specialist acoustic advice into the design of a site is critical for large-scale, complex industrial developments. As demonstrated in this paper, tools such as the Noise Bucket concept and both simple and detailed noise models allow a consulting acoustician to engage with the project team to achieve the desired outcomes for the project. Using this approach we expect that for many projects, costs can be minimised, the long term development of a site can be secured, and public concerns can be addressed in a robust and reliable manner.

We consider the Fonterra Darfield site to be an example of how good design principles and practices, combined with a collaborative multi-disciplinary project team providing both high level conceptual advice and detailed specifications and recommendations can result in a successful large-scale greenfield industrial development.

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