Final report

Continuous Assurance Regulatory Tech Grant

Project code: V.MFS.2300

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Executive summary

Supply chain participants aim to produce, process, and distribute products in ways that satisfy compliance requirements and enables traceability for biosecurity and food safety responses. Participant business processes are designed to ensure compliance with regulators, customers, and the participant businesses seeking assurances that such compliance requirements are being met. Generating a combined, coherent set of compliance outcomes is technically challenging, time consuming, and costly in human effort providing barriers to improving operational efficiencies or performing traceability analysis.

A new approach, Continuous Assurance, showcases an alternate approach to confirming compliance outcomes by specifying a common set of events across all plants and a common and consistent approach to defining and evaluating compliance, which significantly standardises compliance reporting across the entire industry, offering plant operators significantly improved capabilities for continuous compliance monitoring and reporting, process monitoring and improvement, and traceability analysis, and regulators a common method for consistently, continually, and cheaply evaluating and monitoring plant compliance industry-wide.

In conjunction with delivery partner Eratos and utilising CSIROs DAMOCLES™ technology, this project has developed a functioning prototype of the Continuous Assurance application for use in red meat supply chains. The initial Continuous Assurance prototype has been designed to ‘light up’ the existing compliance system, utilising data streams that presently exist and which are typically digitised. This approach has enabled the utility and potential of Continuous Assurance to be demonstrated across red meat processing plant staff and with state and federal regulators. Feedback from red meat processing plant staff and regulators confirmed the potential and likely benefits to all potential users of the Continuous Assurance application. Plant staff and regulators were able to articulate the value proposition from their own perspective and provided strong encouragement for the ongoing development of Continuous Assurance prototype including proposed additional phases. Additional phases of Continuous Assurance would focus on expanding the application via shifts in digitalisation and sensorisation of red meat supply chains as well as the incorporation of machine learning and artificial intelligence approaches to further enable system learning. The modular nature of Continuous Assurance permits users to incorporate the application into their processes immediately and bring new components online as they make investments in digitisation of the red meat supply chain.

Background

Provide a brief overview of the purpose of this research, including:

- *the main question being addressed and why*
- *the main target audience/demographic and why*
- *what the results of the research will be used for.*

Objectives

Outline the aims/objectives of the project and whether or not they were achieved (3-4 sentences; dot points acceptable).

Methodology

Briefly outline the methodology that was used (2-4 sentences; dot points acceptable).

Results/key findings

Outline the primary results/key findings of the project. If there were no results, provide details of possible reasons that the work undertaken was not successful (2-3 sentences).

Benefits to industry

Outline the benefits to industry of the project results (2-3 sentences).

Future research and recommendations

Based on the results of the project, provide any industry/stakeholder recommendations for future research or development (2-3 sentences).

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1. Background

Australian agrifood businesses operate in an ever-evolving regulatory environment driven by market demands, increasing global competition, and changing consumer needs. The National Agricultural Traceability Strategy 2023 to 2033 and its associated Implementation Plan (https://www.agriculture.gov.au/biosecurity-trade/market-access-trade/national-traceability#toc_0) seeks to improve tracking and tracing capabilities, reduce regulatory burden, and promote efficient market access. Supply chain participants aim to produce, process, and distribute products in ways that satisfy compliance requirements and enables traceability for biosecurity and food safety responses. Red meat processing plants collect large volumes of data which underpin compliance and traceability requirements; however, these data sets are routinely disparate and often siloed, providing limited additional insights and efficiencies. Consequently, compliance is routinely demonstrated at a ‘point-in-time’, not in a continuous nature and similarly, traceability investigations are maladroit and time consuming. The establishment of data-led systems that enable continuous assurance of compliance and traceability requirements creates opportunities for supply chain participants, such as processing plants, to improve tracking and tracing capabilities and reduce the burden associated with achieving regulatory compliance.

The Continuous Assurance project aims to transition Australian agrifood businesses towards a data-driven ecosystem, akin to continuous auditing, where critical events are continuously captured and evaluated against regulatory compliance pathways relevant for the business. In turn, the reporting of compliance evaluations provides incentive for continuous internal improvement for the business and streamlines regulatory procedures via permissioned sharing of data streams or the outcomes of analysis. Continuous Assurance provides an opportunity to seamlessly capture, visualise and report on compliance activities in a ‘measure once, report many’ sense. Permissioned access to outcome reports could satisfy multiple audit streams without duplication and repetition. Furthermore, the ability to evaluate compliance in real-time or at least at frequencies exceeding existing audit schedules should reduce the costs of demonstrating compliance whilst simultaneously providing greater confidence in the products entering markets.

2. Objectives

This project aims to investigate how the red meat processing industry might transition to continuous assurance of compliance, by developing a data-driven approach that can be applied across the entire industry and demonstrating the benefits and applicability of such through a prototype application. This will establish credibility for Continuous Assurance and will facilitate the development of strategies for continuous internal and external auditing.

The objectives of the project are:

1. Establish Continuous Assurance framework – map regulatory compliance pathways in red meat processing plants.
2. Prioritise compliance pathways – conduct a priority assessment of identified compliance pathways and associated data streams.
3. Develop and deploy a Continuous Assurance prototype application – build a continuous assurance prototype for demonstration to project partners and DAFF.
4. Progress development of Safe Food Production Queensland's digital processing plant risk assessment tool using permissioned access to the Continuous Assurance prototype – trended analytics from the Continuous Assurance prototype are available for use in SFQ's risk assessment tool.
5. Develop business plan and operating model for Continuous Assurance – a business plan is prepared to support the operation of the continuous assurance application.
6. Demonstration the utility of the Continuous Assurance prototype to DAFF – compliance reporting and proactive food safety management components demonstrate potential increased efficiency of export processes for DAFF.
7. Final report – a summary report of the outcomes from objectives 1-6.

3. Methodology

Establishing the Continuous Assurance framework

Within the red meat industry, compliance requirements include both regulatory requirements, such as food safety, workplace health and safety, animal welfare, and traceability, as well as those that drive business outcomes, such as efficiency, customer demands, and market access, as shown at the top of Figure 1**Error! Reference source not found.**.

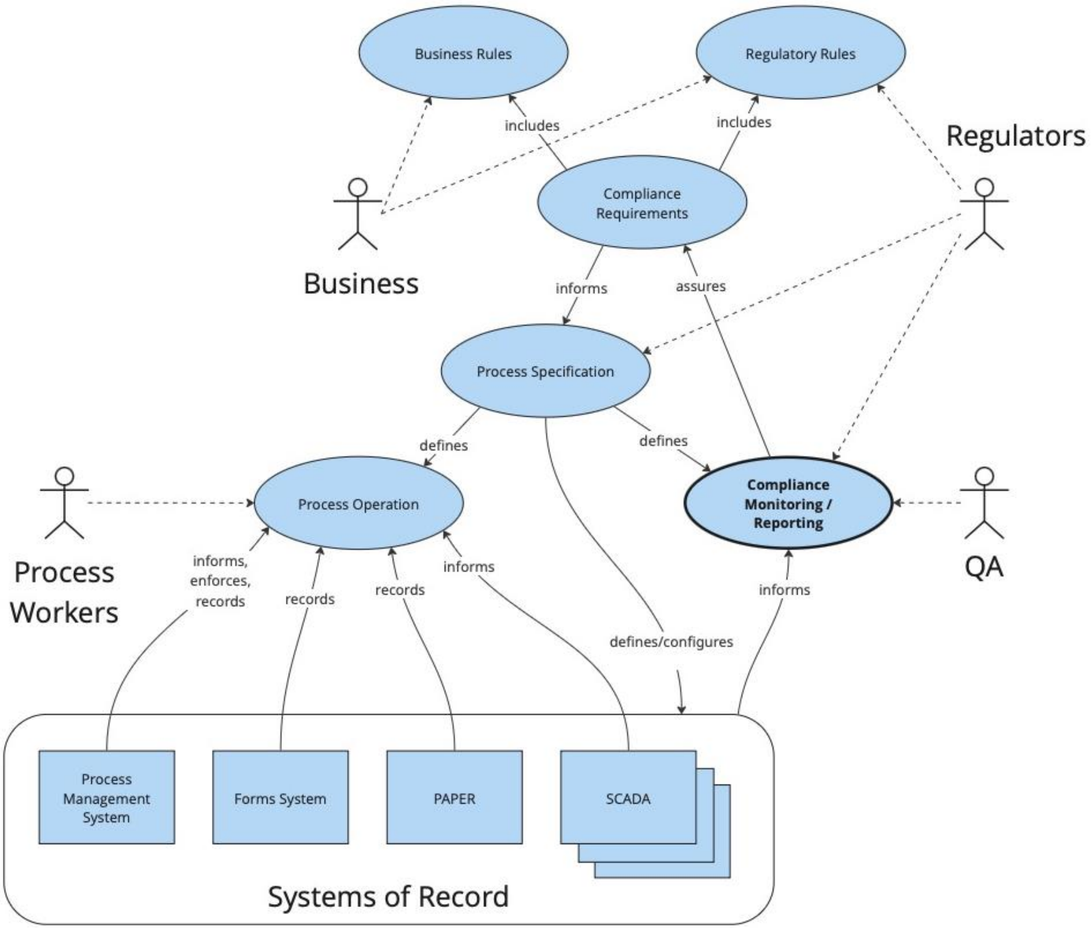


Figure 1. Relationships between compliance requirements, process specification, and systems of record

Processors work with regulators and customers to specify operational processes that, if correctly followed, should ensure all compliance requirements are met. Some operational processes are monitored closely to ensure that actual operations are continuously compliant, the CCP (critical control point) in Figure 2**Error! Reference source not found.** being one such example, but most processes (and their specifications) are evaluated at discrete points in time through audits and reviews. Any post hoc evaluation of compliance requires evaluation of process operations, which in turn requires access to records of how each was conducted.

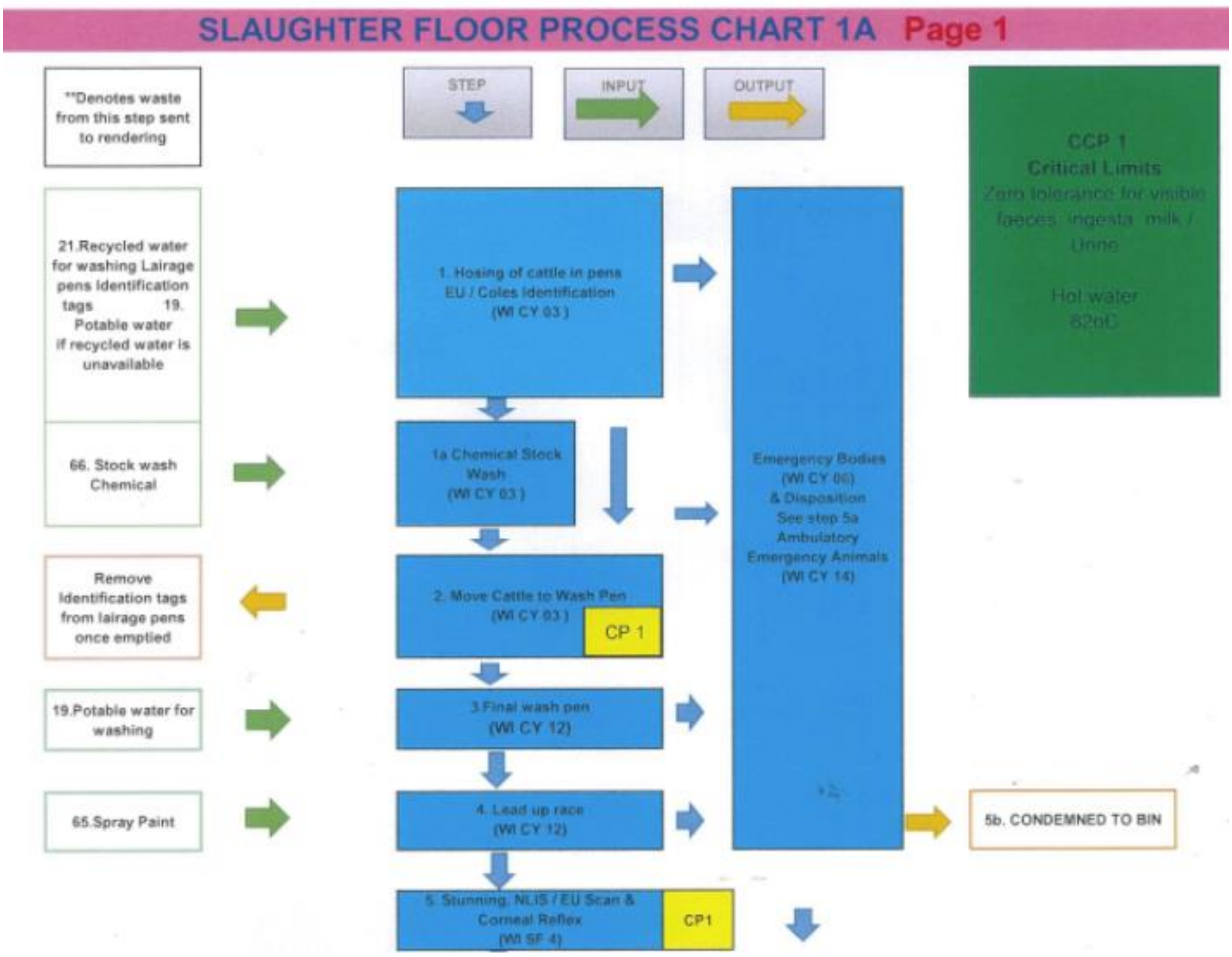


Figure 2. An example process flow chart used to inform the mapping of the red meat supply chain

Red meat processing plants generate and collect large volumes of such data during day-to-day operation, which is stored in various Systems of Record, including paper, as shown schematically in the bottom of Figure 1. Obtaining a combined, coherent record of plant operations from these disparate systems of record is technically challenging, time consuming, and costly in human effort, especially where the data is not easily accessible. This not only makes audits costly and painful; it also significantly limits the ability for plants to perform more comprehensive continuous assurance of compliance; not to mention improving operational efficiencies or performing traceability analyses in a timely manner. Although all red meat processing plants operate in similar ways, there are significant differences between the operators in process detail and in the nature of the Systems of Record. Using traditional approaches to extracting compliance evaluation records results in significant duplicated effort across the industry.

Continuous Assurance develops an alternate approach which specifies a common set of data to be extracted across all plants and a common and consistent approach to defining and evaluating compliance, which significantly standardises compliance reporting across the entire industry, offering plant operators significantly improved capabilities for continuous compliance monitoring and reporting, process monitoring and improvement, and traceability analysis, and regulators a common method for consistently, continually, and cheaply evaluating and monitoring plant compliance industry-wide.

This approach is based on the recognition that evaluation of compliance relies on knowledge of specific “events” that occur within the operational processes of all red meat processing plants. For example, in considering a compliance requirement like “cattle transportation time must be less than 36 hours”, we need to know when the cattle transport began and when it finished; in the system we developed, these correspond to the “consignment-departed” and “consignment-received” events. Any processor seeking to comply to such a requirement must be able to extract data from their Systems of Record that correspond to these events.

Red meat production is not a single continuous process. It’s a series of interconnected modules, each of which has multiple interconnected processes, with each adding value and specialisation across breeding, production, transport, slaughter, processing, distribution, and sale of red meat animals and their products. To determine the boundary modules for the initial phase of Continuous Assurance development, the red meat supply was mapped from primary production through to manufacturing, wholesale and retail sale. Modules were assessed for tasks completed, data points, data generation and collection methods, digitisation points, systems, hazards, compliance requirements and controls, regulatory bodies, and pain points. Supply chain mapping was informed either through interviews with project partner staff representing all modules of red meat production or using process flow charts as shown in Figure 2.

An example of the supply chain mapping outputs is shown in Figure 3. The mapping identified a concentration of data generation, critical control points, and compliance assessments that occur within the modules of livestock transport through to the end of boning, resulting in the following modules to be considered within the application: consignments, lairage, slaughter, chilling, and boning.

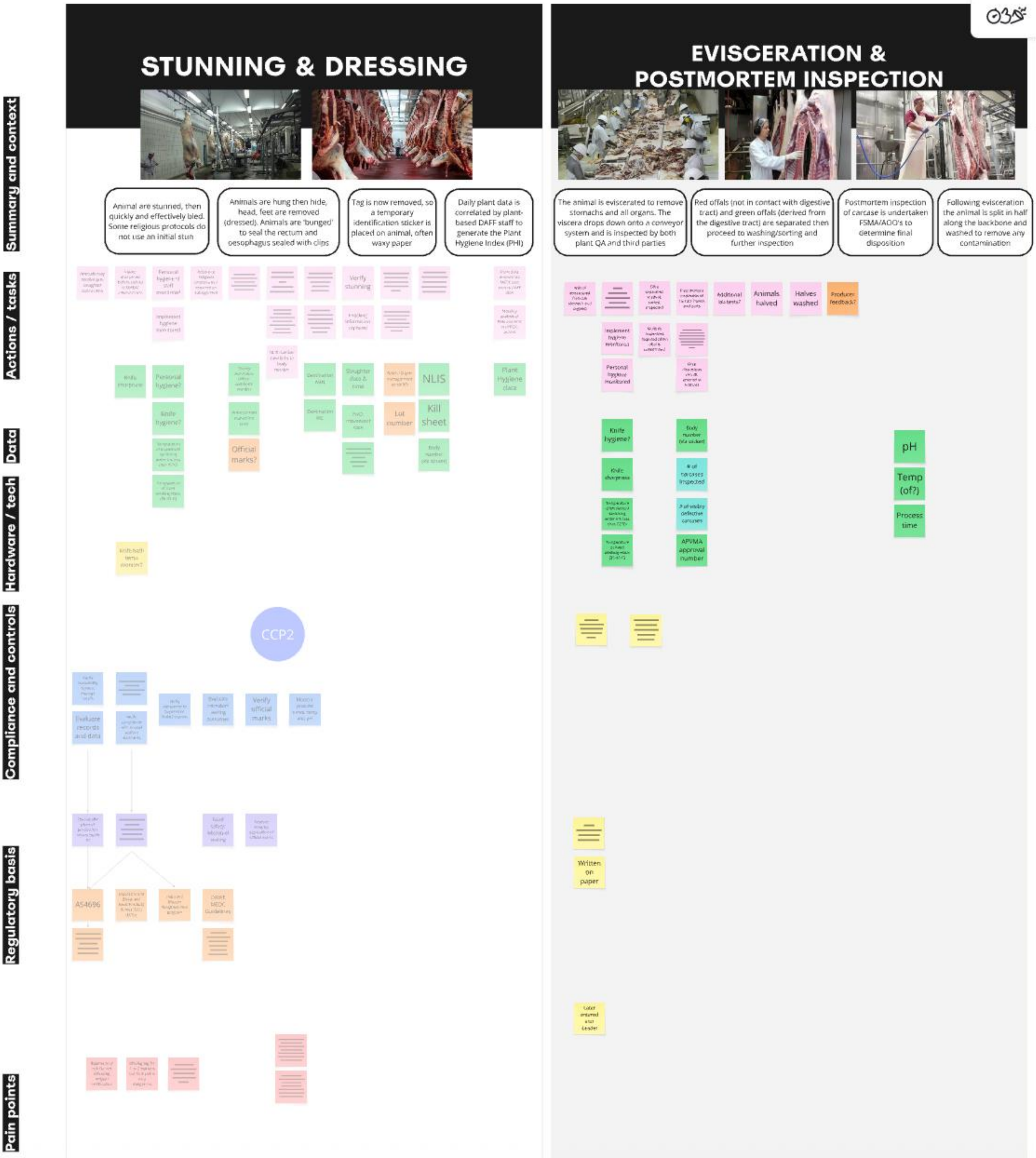


Figure 3. A summary of the stunning and dressing, and evisceration and postmortem inspection modules resulting from supply chain mapping

3.1 Prioritise compliance pathways

Discussions with project partners as well as Australian Meat Processor Corporation (AMPC) and the Department of Agriculture, Fisheries and Forestry (DAFF) Meat Exports Standards Branch during the supply chain mapping process helped to identify pain points that could be addressed through the development of the Continuous Assurance application. A significant number of these centre on tracking times and temperatures, and sometimes a combination thereof, as shown in Figure 4.

Figure 4. Data identification for time and temperature base compliance across transport, lairage and slaughter.

In addition to these we identified one other regulatory compliance requirement around Refrigeration Index (RI), which is derived from carcase-side temperature, and one business compliance requirement around carcase-side weight gain in chillers due to spray chilling. We also identified, in discussions with meat processors themselves, two other compliance-related uses cases that represent significant industry pain points, namely:

1. Proactive risk management of products entering markets that classify Shiga-Toxigenic Escherichia coli (STEC) as adulterants (e.g. North America).
2. Achieving market driven shelf-life requirements.

3.2 Translating compliance requirements to compliance rules, compliance indicators, and events

Compliance requirements can be couched as rules, with each rule specifying one, or perhaps more, “compliance indicator” subjects plus a predicate. For the previously mentioned requirement that “cattle transportation time must be less than 36 hours”, the compliance indicator (i.e. subject) is the cattle transportation time. We recognised that since failing to meet a compliance rule is an undesirable outcome, it would be highly beneficial to plant operators to obtain warnings of potential compliance requirement failures before they occurred. To this end, many of the compliance rules we identified have associated “warning” rules based on predicted compliance indicators.

For every compliance indicator identified by an actual or predicted rule, we identified what events would be required to calculate it. For the previously mentioned cattle transportation compliance indicator, this requires events relating to consignment departure and arrival. Predicted compliance indicators rely on business (process) events and derived – often predicted – values that are calculated therefrom. For example, to generate a warning about a possible cattle transportation time failure, we need a prediction of how long the cattle might take to arrive at the plant; this in turn needs knowledge of when they left (the consignment-departed business event) and a predicted journey time.

In addition to business and derived events, we also need measurements of temperatures and environmental conditions for some compliance rules. We think of these sometimes as business events (e.g. generated by a temperature logger attached to a chilling carcase side) and in others as events from external systems. Such “sensor” measurement events typically represent a “time series” and may be more-or-less ongoing or may be initiated and stopped by certain other business or derived events.

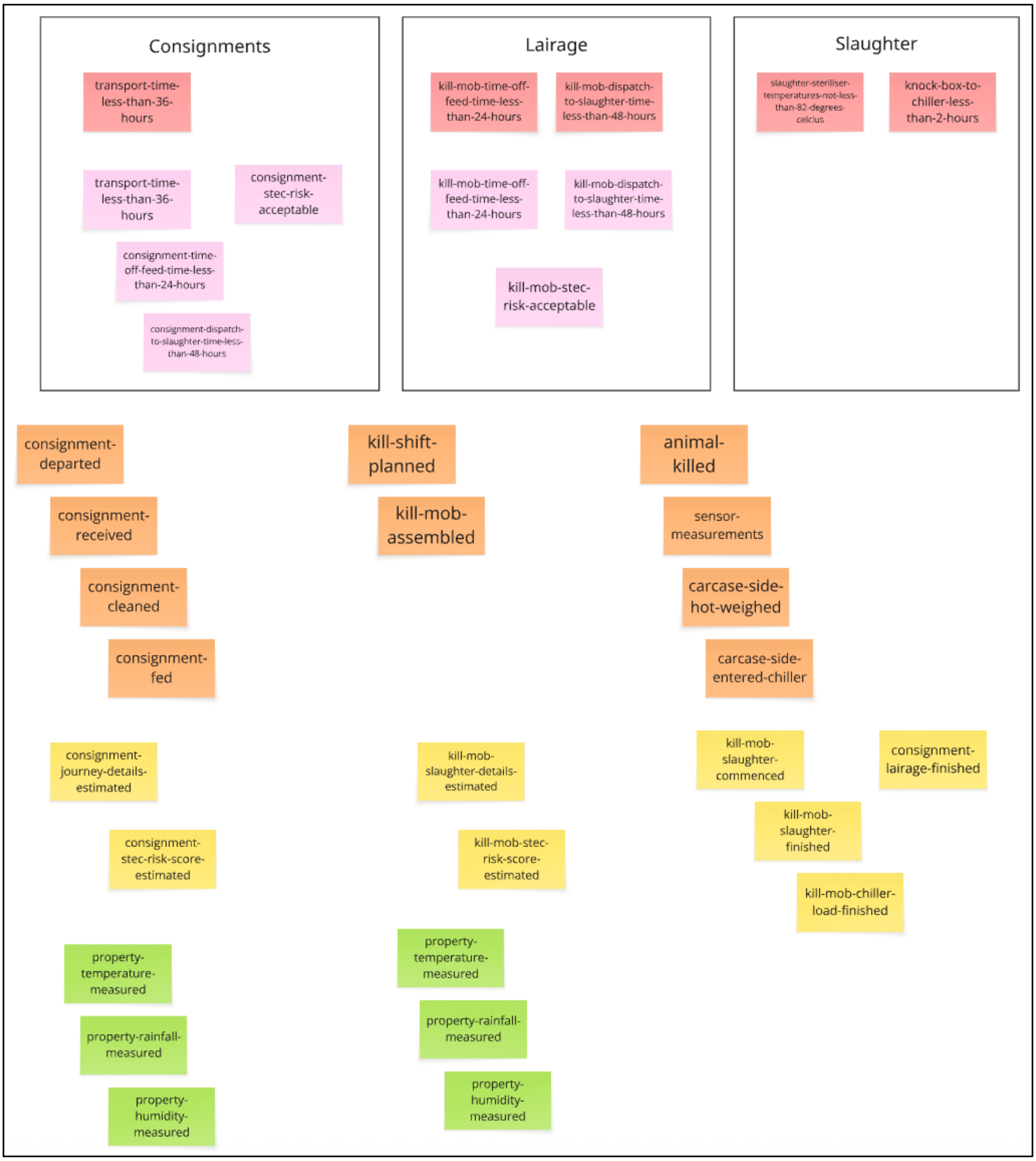


Figure 5. Compliance rules, business process events, derived events, and external events for consignments, lairage, and slaughter modules

Figure 5 and Figure 6 show the compliance rules (actual in dark pink and predicted in light pink) and supporting business (orange), derived (yellow), and external system (green) events identified for the Continuous Assurance application. The rules have been partitioned into modules, which is an important categorisation for the design of the system's user interface. In addition to events required to support the calculation of compliance indicators, the system has a number of other business and derived events that are used to calculate traceability information.

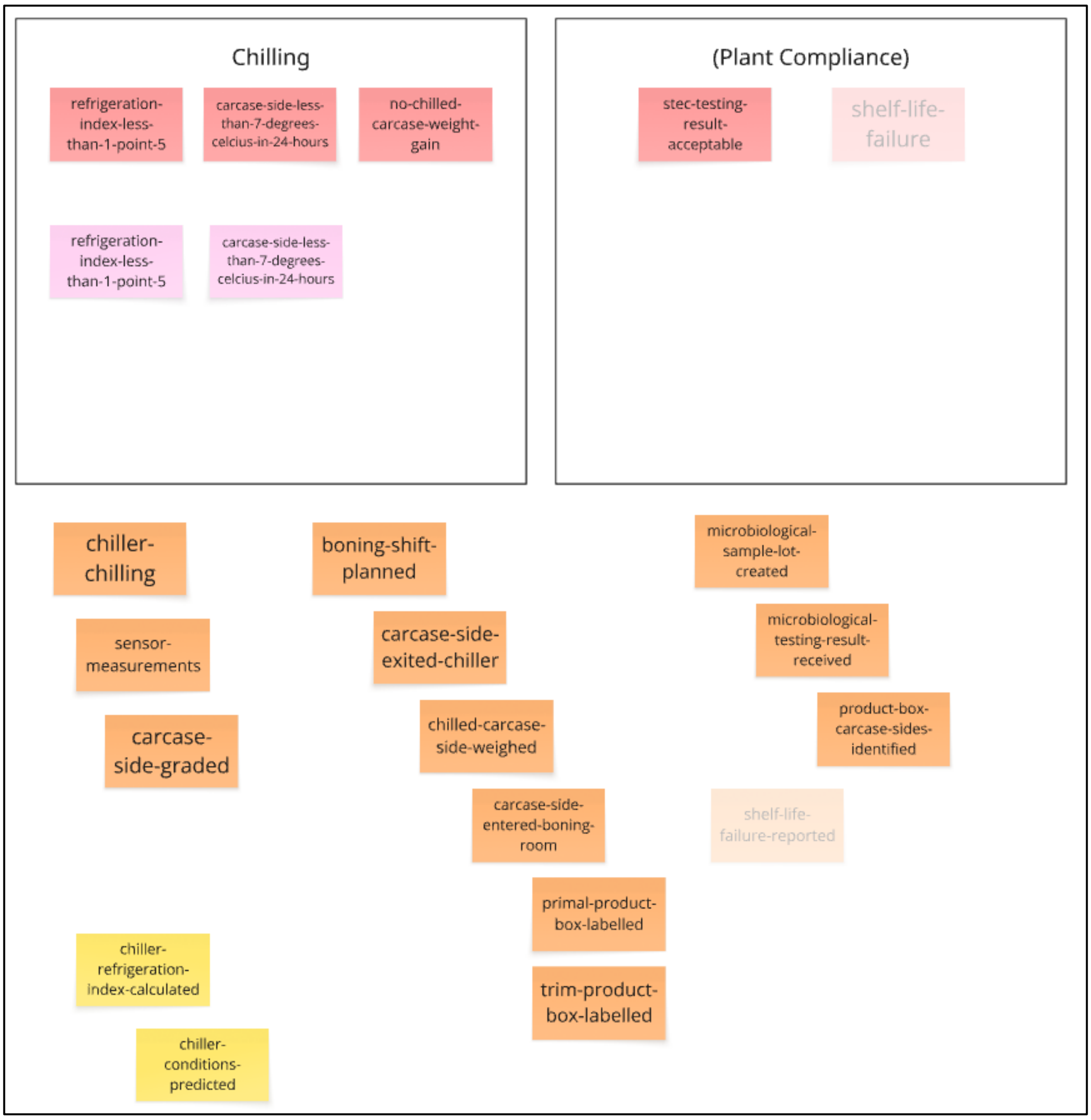


Figure 6. Compliance rules, business process events, derived events, and external events for the chilling module and for STEC and shelf-life compliance rules

The compliance-related uses cases around STEC are captured as very simple compliance rules which simply state that an STEC positive testing result should not occur. Whilst the event occurs post-processing, its capture is important for reporting and traceability. The shelf-life failure use case is similar with events reported by customers sometimes many weeks after the products were produced.

3.3 Traceability requirements

In many situations the relationship between a compliance failure and its cause is easily identified but for shelf-life and STEC failures, it is most likely that a combination of factors come together to create a failure. Nevertheless, quality assurance staff must undertake a traceability analysis to identify, for a given end-point failure, what aspects of the production process may have contributed. To perform this, knowledge of the relationships between process resources (consignments, kill mobs, carcase sides, chillers, boning runs, product boxes, and microbiological test lots) is needed. Some of the events needed to calculate other compliance indicators contain such information but we have included the additional business events needed to identify all possible relations, including: kill-shift-planned, kill-mob-assembled, boning-run-planned, and product-box-carcase-side-identified. The relationships between the resources, derivable from the events, can be used for both trace-back (e.g. identifying all consignments contributing cattle meat to a STEC-positive microbiological testing lot) and trace-forward (e.g. identifying all boxes of product potentially containing meat from carcase sides).

3.4 Continuous Assurance application design and implementation

3.4.1 High level design

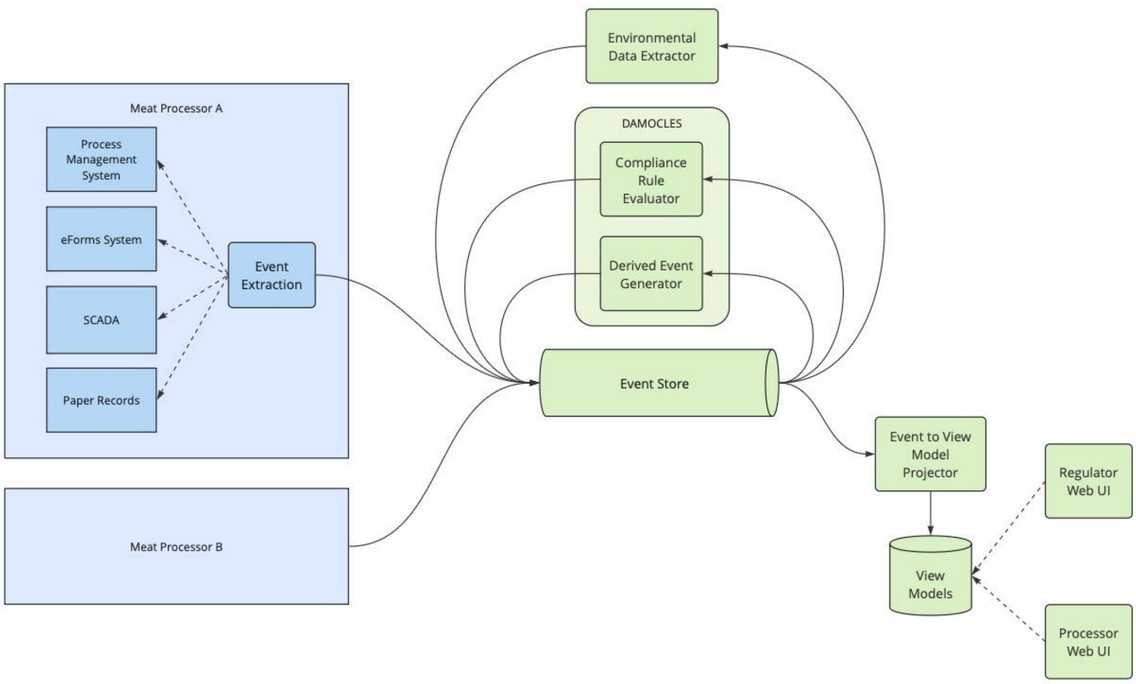


Figure 7. Continuous Assurance application conceptual design

The Continuous Assurance application prototype has been designed to demonstrate the feasibility and desirability of our event-driven approach to continuous assurance. Taking business events from meat processors, the system evaluates compliance on a continuous basis, highlighting to users, both regulators and meat processors, compliance issues that occur during a meat processing plant's operation, both historically and in real-time.

A high-level conceptual diagram of the application is shown in Figure 7. Meat processors extract business events from their Systems of Record and send them to the application. The business rules are stored in receipt order in an event store, which is monitored by other processing elements that generate further events which, in turn, are also added to the event store and subject to further processing.

Environmental data events are added to the system by the Environment Data Extractor process, which is triggered by certain events to either fetch a historical record, or obtain data on an ongoing basis until some other event causes that to cease. The DAMOCLES™ system, discussed in more detail in Section **Error! Reference source not found.**, is responsible for generating both derived events and compliance-rule-update events, which it does using event records and human-readable, machine-executable rules, maintaining any necessary state required to perform its calculations without having to read data again from the event store. The Event to View Model Projector process is responsible for producing an aggregated view of event data that focuses on elements that are better suited for "view" in a user interface than raw event data.

A major benefit of the event-based approach to monitoring and reporting on compliance issues on a continual basis is that is offers a very light-touch, and possibly incremental, approach to integration with meat processors. To produce business events, meat processors need to extract such from their Systems of Record. This is similar to the process of extracting data for reporting, monitoring, and auditing, but should be much simpler as the discrete nature of the events means less combination of data from different systems. The system is designed to support the asynchronous generation and processing of events, which allows the event extraction processes to be decoupled within a meat processor's infrastructure. Such decoupling is not only more robust, it offers the opportunity for a staged approach to integration, with meat processors starting with producing a set of core events and expanding those out over time. Finally, the benefits realised from real-time monitoring of compliance issues depends on the timeliness of business event generation. We envisage that early integration work will focus on a schedule-driven generation of a "batch" of events, rather than a more real-time "stream". Given that the system supports such an operation, meat processors will be able to evaluate where they will see the most benefit for improving the timeliness of event generation, from a compliance monitoring point of view.

3.4.2 User interface design

The application's user interface was designed to support compliance failure reporting and trend analysis, real-time monitoring of compliance issues, and traceability analysis within a compliance failure context. It was developed in consultation with, and validated by, project partners, using screen mock-ups designed in Figma. All screens developed for the prototype are included as supplementary material to this report. A description of the main user interface screens and their use is provided in Appendix 1.

3.4.3 System architecture

CSIRO engaged Eratos to assist with the design and implementation of the Continuous Assurance application and together we utilised a series of workshops to determine the high-level architecture and user experience requirements. Solution architecture refinement and technology stack selection were progressed with a focus on key principles of technical suitability, Eratos capability and capacity alignment, portability, and community size and support available. A simplified view of component architecture is shown in Figure 8 with technology stack selection decisions and alternatives considered shown in **Error! Reference source not found.**.

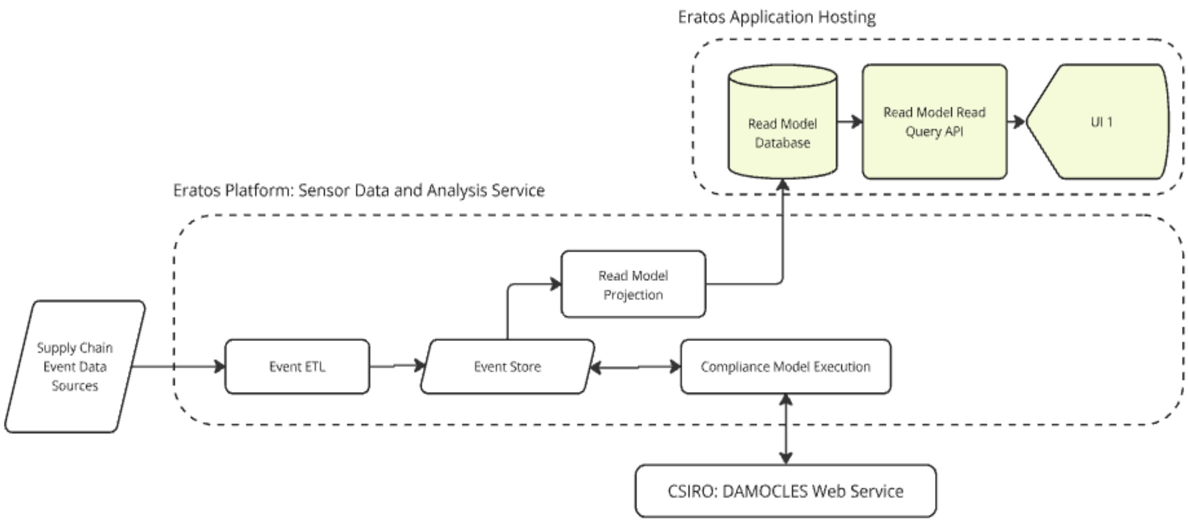


Figure 8. Simplified view of the component architecture

3.4.4 Read models and user interfaces

The read model for the Continuous Assurance solution was designed to support the web user interface described in section **Error! Reference source not found.**. This read model is formally described using an entity relationship diagram, as simplified version of which appears in Figure **9**. The event-based architecture allows this database design to be optimised specifically to support the visualisations and interactions required to implement the dashboard UI.

Table 1 Technology stack selection decisions and alternatives

Item	Decision	Other options considered
Read Model Database Paradigm	• Traditional RDMS	• Labelled Property Graph
Dashboard UI frameworks, technologies	• TypeScript • Next.js (uses React) • Shadcn/ui UI component library • Tailwindcss CSS styling • SWR data fetching	• OutSystems ODC • Laveral
Read Model Middleware API	• Python • Django • Django REST Framework • Knox token authentication	• OutSystems ODC • Laveral • FastAPI
CI/CD and deployment architecture	• GitHub Actions • AWS ECR • AWS AppRunner • AWS RDS	• Heruko • AWS ECS/Fargate
Data ingestion tools	• Python	
Platform workflows for event projection and general processing	• Python	

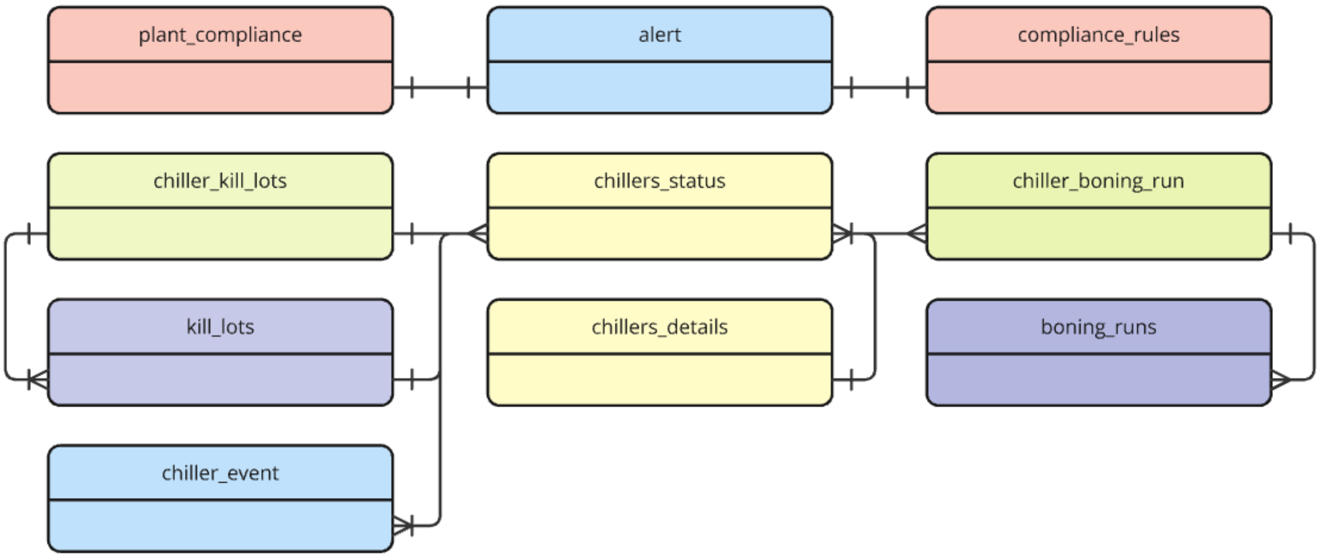


Figure 9. Simplified view of the entity relationship diagram developed for the dashboard application

3.4.5 Read model read query API

The Read Model Read Query API provides a mechanism to deliver data to the user interface and for external usage if the underlying read model is suitable. This API is read-only by design in the event-based architecture. The API is designed to follow conventional REST principles and is self-describing using OpenAPI specification with an embedded interactive API-docs page (Swagger UI). Access to the API is authenticated using JWT tokens generated by the Auth0 service.

This solution is flexible to allow easy integration of additional clients if the implemented data model is suitable, noting that the middleware information model is exclusively designed to support the UI. In the event-based architecture, the core event store is considered the source of truth and additional read models can be developed to support diverse use cases.

3.4.6 User interface

The User Interface is built as a Single Page Application (SPA) with a high level of modularity. The key components used across multiple views are defined independently which allows for easier maintenance and changes as the application evolves. Application authentication is integrated with the Read Model Query API described above, so user credentials defined in the API will be used to access the UI via a conventional login screen.

3.4.7 User interface application deployment architecture

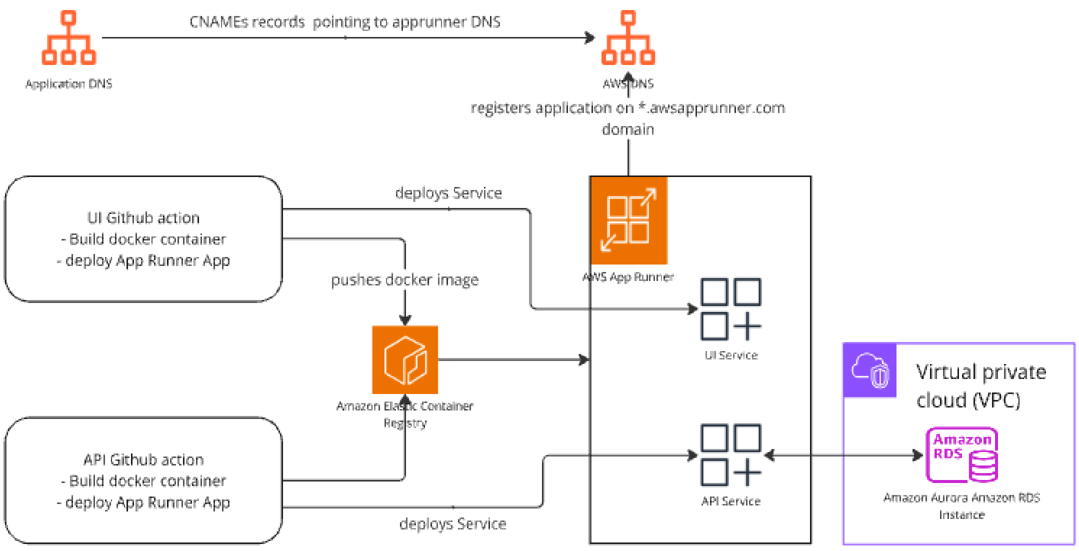


Figure 10. Deployment architecture for user interface

The deployment diagram (Figure 10) summarises the key components involved in the deployment of the Dashboard Application. AppRunner provides a simplified abstraction over container hosting in AWS, providing a robust service for deployment, autoscaling, security and load balancing without the need to design a bespoke solution. Using AppRunner allowed the project to maintain a simple deployment method without the need to introduce advanced Infrastructure as Code at an early stage of operations.

3.4.8 Event handling and processing loop

The event processing, enrichment and projection is hosted within an Eratos Workflow. The workflow processes events provided from an external source. Aside from the direct ingestion of processor events, the workflow also integrates data from two additional sources, the DAMOCLES™ model and BoM environmental data.

The DAMOCLES™ model is hosted externally on CSIRO operated infrastructure; it is available to the Workflow operator via a HTTPS endpoint described by an API specification. Weather station data is sourced from BoM data already hosted in the Eratos platform on behalf of CSIRO Energy for the Data Clearing House (DCH) project.

The Eratos Workflow system is a batch processing system which can be configured to execute on a one-minute interval schedule to continuously process events. The workflow keeps track of state such as the current system time, the message IDs for the DAMOCLES™ integration, and the timestamps of the most recently projected event. Upon each execution of a workflow job the actions shown in Figure 11 occur.

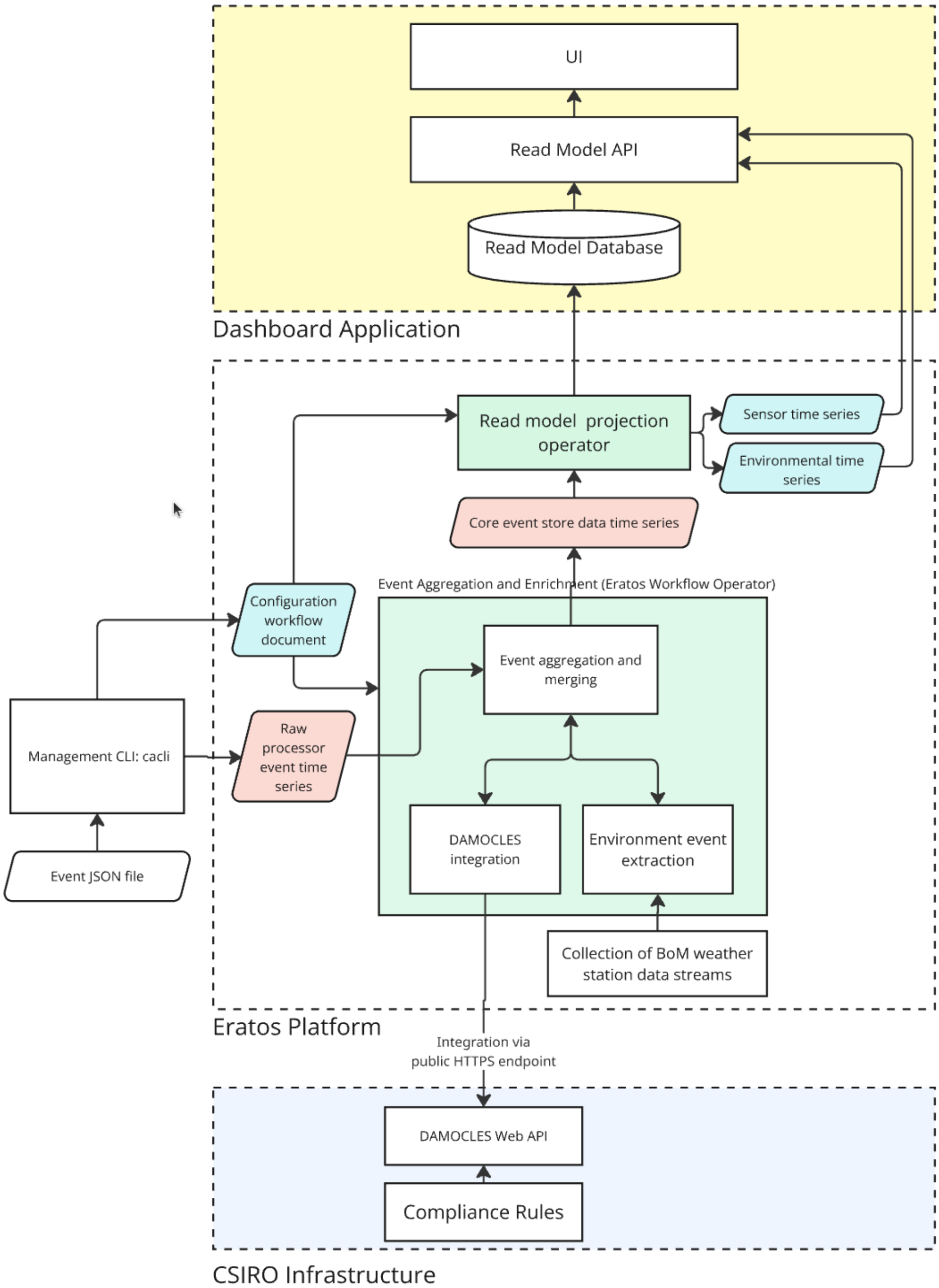


Figure 11. Data flow diagram showing event ingestion, processing and projection

Event Enrichment and Merging:

1. New raw events are loaded from the raw processor event stream.
2. Environmental event extraction is executed to source new environmental data from all current property identifiers.
3. All events are sent to DAMOCLES™ for handling. Returned events are also sent back to DAMOCLES™, looping until no new output events are generated by DAMOCLES™.
4. The core event stream is updated.

Event Projection:

1. New events from the core event stream are loaded.
2. New events are projected into the read model database and auxiliary sensor and environmental data streams.

3.4.9 DAMOCLES™

DAMOCLES™ (Data-Aware Management of Operational Compliance in Live Enterprise Systems) is a domain-agnostic process management platform, developed in the Trustworthy Processes Team at CSIRO. A high-level schematic diagram of DAMOCLES™ capabilities is shown in Figure 12.

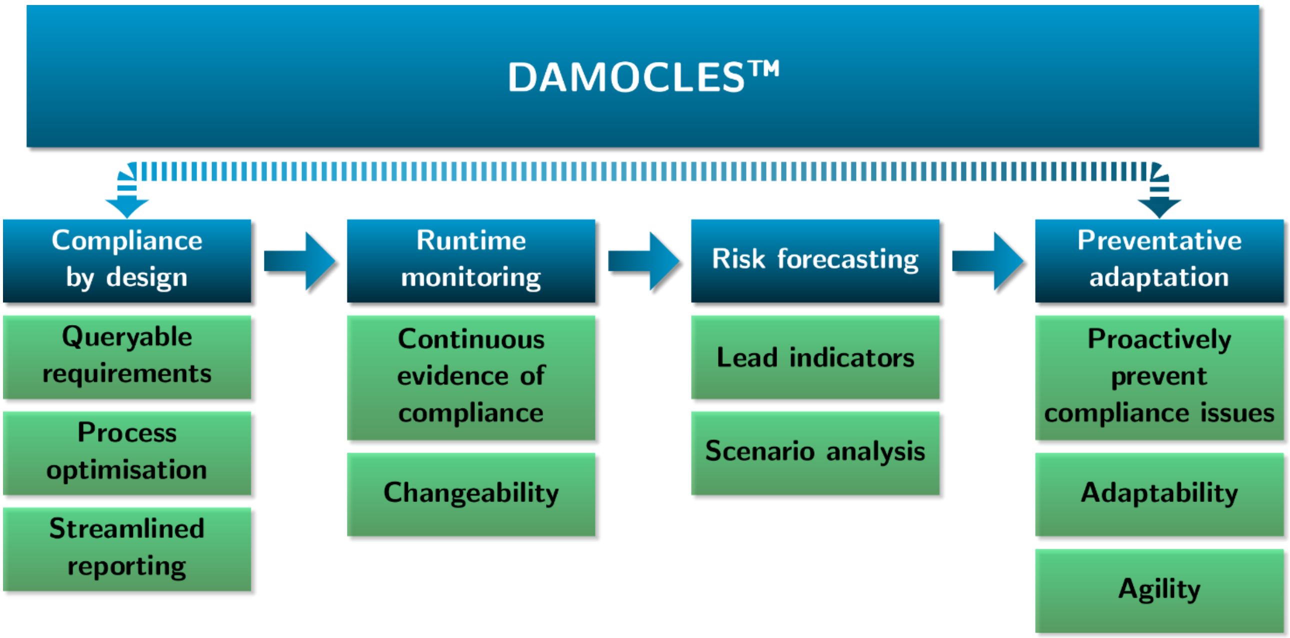


Figure 12. Outline of DAMOCLES modules

DAMOCLES™ allows users to create an explicit digital representation of regulatory requirements, standards, guidelines, and business rules. The requirements are modelled such that they are both human understandable and machine interpretable. As a result, DAMOCLES™ integrates process information, operational data and operational requirements, to ensure correctness of processes and compliance with regulations, standards, guidelines and business rules.

DAMOCLES™ implements efficient algorithms to monitor and verify processes against requirements through their lifecycle from design to deployment.

The API prototype developed in this project relies primarily on the runtime monitoring and risk forecasting modules (Figure 12) of DAMOCLES™. The runtime monitoring module allows real-time determination of whether an execution aligns with the expected behaviour and subsequently to identify and report when that is not the case. This ensures continuous and objective evidence of compliance during execution, while supporting changeability of running processes.

When unexpected behaviours occur during the execution of a business process, the risk forecasting module of DAMOCLES™ can be used to forecast the continuation of the execution resulting from the unexpected behaviours, allowing pre-emptive identification of possible scenarios where continuation of the process can lead to compliance risks.

3.4.10 DAMOCLES™ integration

DAMOCLES™ is hosted on AWS EC2 and interacted through the specified API endpoints. Input events are posted to the API by Eratos, processed by DAMOCLES™, and corresponding output events are retrieved from the API by Eratos.

The processing step firstly updates the internal memory based on the given event. The internal memory is an aggregated form of any data that will be needed to evaluate rules for future events. This memory is regularly saved to disk to recover from any system or communication failures, and data is deleted from memory when it is no longer needed based on the stage of the process. The processing step secondly re-evaluates any applicable rules and generates output events based on the evaluation outcome.

There are 3 categories of output events which DAMOCLES™ generates:

- Derived events
- Compliance warnings
- Compliance rules

Each unique type of output event is a rule that prescribes the logic, calculations and predictions that DAMOCLES™ must perform to generate the correct output. The rules are written in a text file and defined using the DAMOCLES™ rules language. In this rule format, conditions are written in human-readable text, where each rule has three conditions: trigger, requirement and deadline. Additionally, rules are associated with a domain, which represents a specific group as it proceeds through a phase of the process, such as consignment, kill-mob and chiller-id. DAMOCLES™ processes an event by identifying which active domain instances it applies to, while data associated to domain instances that are no longer active is removed from memory.

```
name: kill-mob-chiller-load-finished
type: achievement
expressions:
  "kill-mob-head-count": # total head count at assembly
    expression: LAST(total(kill-mob/consignment-mobs{mob/head}), event/type == 'kill-mob-assembled')
  "side-entered-count": # total sides entered chiller
    expression: COUNTIF(event/type == 'carcase-side-entered-chiller')
trigger: side-entered-count==1
requirement: side-entered-count == 2*kill-mob-head-count
deadline: false
domain: [kill-mob/date, kill-mob/shift, kill-mob/number]
retriggerable: false # only one interval of kill mob entering chiller
```

Figure 13. Derived event example

The rule definitions make use of pre-defined DAMOCLES™ functions. For example, for the derived event generated when chiller load has finished, defined in Figure 13, we use COUNTIF to track the total carcase sides that have entered the chiller. These predefined functions aggregate the data efficiently while keeping rules human-readable. The refrigeration-index compliance rule is defined in Figure 14, which also makes use of such functions to define a complex growth formula.

```
name: refrigeration-index-does-not-exceed-1-point-5-actual
type: maintenance
expressions:
  "Tave": # at new temp measurement, take average between previous and current temp value
    expression: MOVING_AVE(2, measurement/value, event/type=='sensor-measurement' & subject/typ=='chiller')
  "sqrt-r": # sqrt of rate, as defined by literature
    expression: 0.04647975690755*(Tave-4.14)*(1-e^(0.2636* (Tave-49.55)))
  "rate": # growth rate in 1/hours. sets to 0 if above value is negative
    expression: (sqrt-r>0)?(sqrt-r^2):0.0
  "value": # apply growth at every temp measurement to give the bacteria value relative to the starting state
    expression: GROWTH(rate, event/type=='sensor-measurement' & subject/type=='chiller')
  "logVal": # log of bacteria value, to give generations
    expression: log10(value)
  "refrigeration-index": # RI only uses above value if greater than 0
    expression: (logVal>0.0)?(logVal):0.0
trigger: event/type=='chiller-chilling'
requirement: refrigeration-index < 1.5
deadline: event/type=='carcase-side-exited-chiller'
domain: [chiller/id]
retriggerable: false
persistent: true # we constantly monitor for possible RI values, even if the obligation instance has been violated
```

Figure 14. Compliance rule example

In addition to the predefined functions, custom-built functions have been implemented in Java to handle more complex predictions. This includes calculating the STEC risk scores and forecasting the chiller temperature. For the chiller temperature forecast, the current time-series temperature data is fit to an exponential and forecast until the future time where the temperature drops below T_{min} or the chiller has been in use for 24 hours. For the STEC risk calculation, a formula has been defined based on known risk factors. Each factor is associated with Normal (0), Medium (1) and High (2) risk scores based on thresholds defined in Table 2. The overall STEC risk score takes the weighted sum of the individual scores, and returns High if the score is ≥12, Medium if ≥6 and Low otherwise.

Table 2. STEC risk formula, thresholds and weights for each factor

Risk score	Rainfall	Temperature	Mud score	Transport time	Lairage rainfall	Lairage temperature	Time in Lairage
2 High	>20mm	>30 ^{o}C	>3	>36h	>20mm	>30 ^{o}C	>24h
1 Medium	>13mm	>25 ^{o}C	>1.5	>24h	>13mm	>25 ^{o}C	>12h
0 Normal	Else	Else	Else	Else	Else	Else	Else
Notes	Daily average of past 3 days on farm.	Daily average of past 3 days on farm		Uses actual if present, otherwise uses estimated	Daily average across time spent in lairage	Daily average across time spent in lairage	Used to scale the effect of lairage weather
Weight	4	2	3	1	1*lairage time risk	0.5*lairage time risk	

4 Results

Safe Food Production Queensland digital plant risk assessment tool

Safe Food Production Queensland is the statutory body responsible for regulating food safety in Queensland's food production and processing sectors, specifically for meat, eggs, dairy, seafood, and horticulture (seed sprouts). Their role includes accrediting food safety programs, ensuring compliance with national standards, identifying and mitigating food safety risks, and fostering consumer confidence in Queensland's food supply through a risk-based and collaborative regulatory approach. To support this, Safe Food Production Queensland have been developing tools that utilise data and risk assessment to identify areas of best resource utilisation for ongoing continuous improvement of food production and processing. They have existing programs with poultry and red meat processing plants that supply data sets (typically via excel but some through an API) that report on a plant’s performance against key criteria/CCPs. In poultry these relate to feed withdrawal, free available chlorine, water temperatures, product temperatures, and the detection of foodborne pathogens Salmonella and Campylobacter. In red meat processing plants, the focus is on verification points associated with abattoir livestock receival and holding, ante-mortem inspection, post-mortem inspection, chilling and storage, and boning and packaging, as shown in Figure 15.

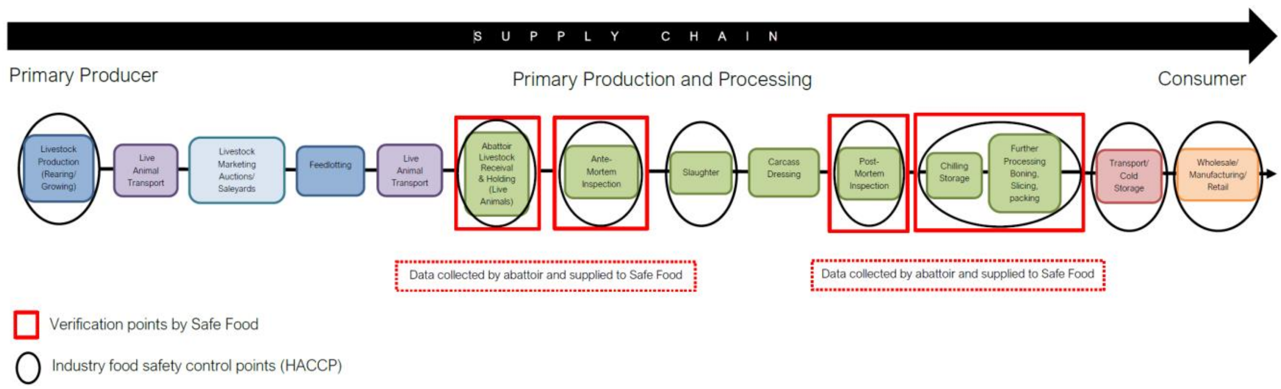


Figure 15. Red meat supply chain and verification points of focus for Safe Food Production Queensland

The Continuous Assurance prototype has been demonstrated to Safe Food Production Queensland with an emphasis on the compliance trend reporting capability of the application. Safe Food Production Queensland acknowledged that Continuous Assurance expands the risk assessment potential of their tool, providing data and trended outcomes across all activities from livestock departing farms or feedlots through to boning and packaging. Whilst Continuous Assurance would undoubtedly aid their risk assessment models, they noted that issue resolution is a key focus for regulators and although Continuous Assurance can be used to demonstrate temporal reductions in non-compliance events, the interventions applied to mitigate or prevent the event from re-occurring are not captured in the current Continuous Assurance prototype. Inclusion of these details in a future phase of Continuous Assurance as part of the regulator UI would be welcome. As the interventions applied to mitigate risk would likely constitute a defined set of events, the event read model approach used in the development of Continuous Assurance would be easily adapted to incorporate this requirement.

5 Conclusion

In order to generate a business plan and operating model for the Continuous Assurance application, a product value proposition was first defined. A value proposition is essential to both a business plan and operating model because it defines the unique value delivered to customers and serves as the strategic foundation for all business decisions. This was then used to inform product commercialisation options (operating models; Table 3) and a product roadmap (business plan; Figure 16).

5.1 Continuous Assurance Value Proposition

Enliven red meat processing plants to monitor compliance from farm feedlot through to boxed product and inform decision-making to drive business outcomes.

Revenue model:

Preliminary product assessment suggests a Software as a Service model is the most suitable pathway for the Continuous Assurance application to enter the market and to support ongoing support and development.

Service offering:

Manual onboarding – transformation and federation of disparate data streams

Software application – for process insights and monitoring compliance

Support – response and support times to an agreed service level

5.2 Product commercialisation options (Operating Model)

Table 3. Possible commercialisation pathways for Continuous Assurance

CSIRO designated pathway	Description	Resource required for SaaS model	Barrier to entry
License for royalties and/or equity	Continuous Assurance could be picked up by an existing organisation for further development or commercialisation, in exchange for royalties on revenue or a share in the company.	Existing entity or enterprise with established offering in the product space. No ongoing CSIRO resource except establishment and maintenance of agreement.	Low
Proto-business (spin-in)	A special team is developed within CSIRO to be dedicated to it full time and operate it like a business.	Substantial ongoing CSIRO resource with elevated risk from competing internal demands, resource requirements and operating models.	High
CSIRO spin-out	A separate legal entity is established with the intention of it being the commercialisation vehicle for the product.	Substantial CSIRO resource to establish deal and entity, e.g. legal representation, capital raising support, commercialisation and business plan, IP arrangements. No ongoing CSIRO resource except possible board seat if deal terms require.	Med-High

5.3 Continuous Assurance Product Roadmap (Business Plan)

	NOW (August 2025) TRIAL "ALPHA" VERSION	NEXT EXTENDED "BETA" VERSION	LATER OPERATIONAL PRODUCT
THEME	• Demonstrate food safety compliance across the scope of red meat processing, from farm feedlot through to product in a box • Test, learn, refine with trial audience	• Stable, more functional version of the tool • Extend the trial audience to broader base • Demonstrate integration	• Expansion across supply chains • A viable product with commercialisation potential
SCOPE	• Manual onboarding; human-assisted data transformation and connection, federation • Set of controlled events to inform event model • Basic functionality; singular organisation login, database provided behind the scenes where events are saved • Intended for red meat food safety, with a modularised format to enable future development • Simple compliance visualisation dashboard to enable sharing with state and federal regulators • Foundations of food safety risk management which can inform future science	• Defined event vocabulary and scalable processes of data mapping (still requiring our system architecture capability) • Near real time ingestion of data • Food safety compliance visualisation, at varying granularities and frequencies relevant to internal and external party requirements • Identify actionable insights for enhanced compliance management • Role-based access and sign-on system	• Simplified and efficient user-driven onboarding • Real time ingestion of data (where available) • Options for integrating quantitative analysis • Proactive food safety risk management system • Customisation of features and content for various user types • Enterprise connected single sign-on
SUCCESS METRICS	• Tool is actively tested by trial partners to evaluate utility for managing compliance • Trial audience contribute feedback and input to future product direction and scope • Consensus across project partners on functionality and utility • Early scoping of long-term maintenance and hosting options, evaluation of technical suitability • Limitations for data transformation and supply are documented	• Expansion of usage across red meat processors • Expansion of usage across third parties (e.g. regulators) • Defined event vocabulary • Increase profit through decreases in food safety compliance failures • Reduction in cost to meet compliance • Clarity around long term maintenance / hosting • Digitisation of data sources that support compliance	• Commodity expansion (i.e. to horticulture) • Vertical and horizontal expansion across supply chains • Standard operating model for red meat • Interest in development of wider application and credentialling focus across domestic and international stakeholders, including industry • Sustainable business model • Digital uplift / transformation of industry to drive sensor-supported and automated data streams
REVENUE	• Partner in-kind contributions and grant funds	• Further investment in TRL progression • Extension projects with partners	• Customer revenue, e.g. subscription model

5.4 Utility of the Continuous Assurance application for DAFF

The Department of Agriculture, Fisheries and Foresty (DAFF) play a crucial role in the export of red meat products by regulating the process under the Export Control Act 2020, licensing exporters and providing export certification that meets international import requirements. DAFF ensures compliance with these requirements through a scientifically based inspection system, veterinary oversight, and audits of export-registered establishments. The utility of the Continuous Assurance to DAFFs activities was explored through two mechanisms which firstly included demonstration and discussion of the Continuous Assurance application and its role in proactive food safety management with members of the Agricultural Trade and Regulation Group. Secondly, the Continuous Assurance concept has been used in several meetings and conferences that have focused on the digitalisation of national food control systems.

Demonstration and discussions with members of DAFF including those from the Meat Exports Team confirmed strong support for the use of the Continuous Assurance approach in red meat supply chains. The incorporation of predictive tools for regulated foodborne disease-causing microorganisms such as Shiga-toxigenic *Escherichia coli* is consistent with an intent to promote proactive food safety management systems. Similarly, they saw potential for Continuous

Assurance to complement the Product Hygiene Indicators and the National Carcase Microbiology Monitoring Programs. Feedback regarding the ability to access trended compliance failures mirrored that of Safe Food Production Queensland. That is, whilst it's useful to observe changes in trends across compliance, the emphasis of regulators will be on the interventions or mitigating factors to achieve the change. This suggestion was again noted and will be a design element built into future phases of Continuous Assurance.

The role of Continuous Assurance in complementing the inspection services and veterinary oversight required by establishments registered for export with DAFF has been an ongoing discussion throughout the development of Continuous Assurance. It is anticipated that the integration of Continuous Assurance into red meat processing plants would allow pivots in the scope of activities currently undertaken by On-Plant Veterinarians or Australian Government Authorised Officers with a shift towards focusing on verifying outcomes and away from routine inspection. Further consideration of the role of Continuous Assurance within the Australian Export Meat Inspection System is therefore warranted.

Broader discussions regarding the digitalisation of national food control systems and the role for 'big data' in assuring the quality and safety of domestic and export red meat supply chains have utilised Continuous Assurance as an exemplar activity. The Continuous Assurance concept has been shared by invitation at meetings and with committees including the Codex Committee on Food Import and Export Inspection and Certification Systems (CCFICS27), the Export Meat Industry Advisory Committee (EMIAC), United Nations Industrial Development Organization - Vienna Food Safety Forum 25, and World Food Safety Day hosted by the Exports & Veterinary Services Division. A common them emerging from these discussions and throughout the development of Continuous Assurance is the potential for food systems to learn. The ability for food systems such as red meat supply chains to be in compliance yet achieve an unsatisfactory outcome such as a pathogen detection or shelf-life failure is common. The potential for 'big data' scenarios, such as what Continuous Assurance enables, allows for the application of artificial intelligence and machine learning capabilities to identify opportunities for improvement.

6 Future research and recommendations

Supply chain participants aim to produce, process, and distribute products in ways that satisfy compliance requirements and enables traceability for biosecurity and food safety responses. Participant business processes are designed to ensure compliance with regulators, customers, and the participant businesses seeking assurances that such compliance requirements are being met. Consequently, large volumes of data are generated daily and stored in various systems of record. Generating a combined, coherent set of compliance outcomes is technically challenging, time consuming, and costly in human effort providing barriers to improving operational efficiencies or performing traceability analysis.

A new approach, Continuous Assurance, focuses on recording the 'events' that occur within each activity offering a new approach to combining and analysing data from disparate systems of record. The Continuous Assurance application provides for two layers of monitoring modes and an investigation mode. The first layer of monitoring modes – 'process overview' allows users to view all activities occurring at a point in time, giving them capacity to understand the performance of the system without specifically selecting a consignment, kill mob or boning run. Alternatively, the second layer of monitoring modes – 'farm to chilling' and 'chilling to boning' provide a historical perspective of the performance of a particular consignment, kill mob or boning run. The investigation mode provides processing plants and regulators with a daily, weekly, or monthly report of compliance failures for each module of the process enabling a continuous perspective of a plant's compliance.

The initial Continuous Assurance prototype has been designed to 'light up' the existing compliance system, utilising data streams that presently exist and which are typically digitised. This approach has enabled the utility and potential of Continuous Assurance to be demonstrated across red meat processing plant staff and with state and federal regulators. Subsequent phases of Continuous Assurance would focus on expanding the application via shifts in digitalisation and sensorisation of red meat supply chains as well as the incorporation of machine learning and artificial intelligence approaches to further enable system learning. The modular nature of Continuous Assurance permits users to incorporate the application into their processes immediately and bring new components online as they make investments in digitisation of the red meat supply chain.

The outcome of this project is the successful development and demonstration of the Continuous Assurance application. The following recommendations represent a series of next steps towards commercialisation of Continuous Assurance.

- Further develop the regulator user interface to incorporate and enable the capture of risk intervention events, pre- and post-mortem inspection results into the investigation mode to provide On-Plant Veterinarians or Australian Government Authorised Officers opportunities to shift towards focusing on verifying outcomes and away from routine inspection.

- Develop and implement the packaging module into the Continuous Assurance prototype.
- In conjunction with data system manufacturers, conduct a feasibility assessment for conducting a three-stage (extraction, transformation, and loading) data integration process from existing systems of record to Continuous Assurance's event store.
- Further define animal welfare, producer, and quality modules for the Continuous Assurance application.
- Test and refine the Shiga-toxigenic Escherichia coli predictive model and consider opportunities for the capture of additional data streams that are currently not digitised (e.g. animal mud scores and historical performance of producer).
- Apply AI/ML methodologies to events contributing to compliance failures and identify mitigation opportunities.

7 Appendix

User interface

The main entry screen for the system, see Figure A 1, allows the user to select one of two kinds of modes: monitoring or investigation. The Plant Compliance Trends, see Figure A 2, is the single investigation mode that was developed for the prototype. This screen is the primary screen that regulators would use to monitor plant compliance failures and to analyse failure trends. The table shown at the bottom of Figure A 2 would allow meat processor, though not regulatory, users to investigate the details of a specific failure in its context; this is discussed in more detail below. The monitoring modes support a more “real-time” view of compliance, enabling processors to focus on compliance issues occurring within each module of plant operations. There are three monitoring modes, each with a slightly different focus on compliance issues.

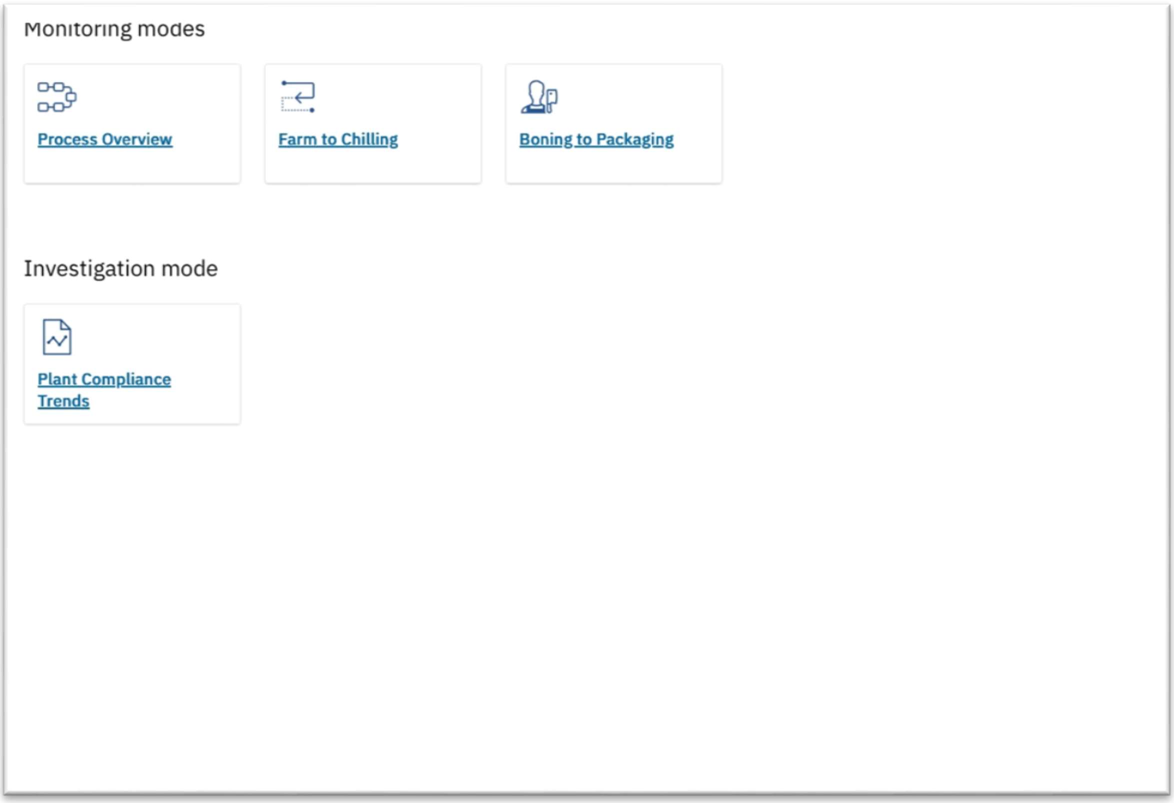
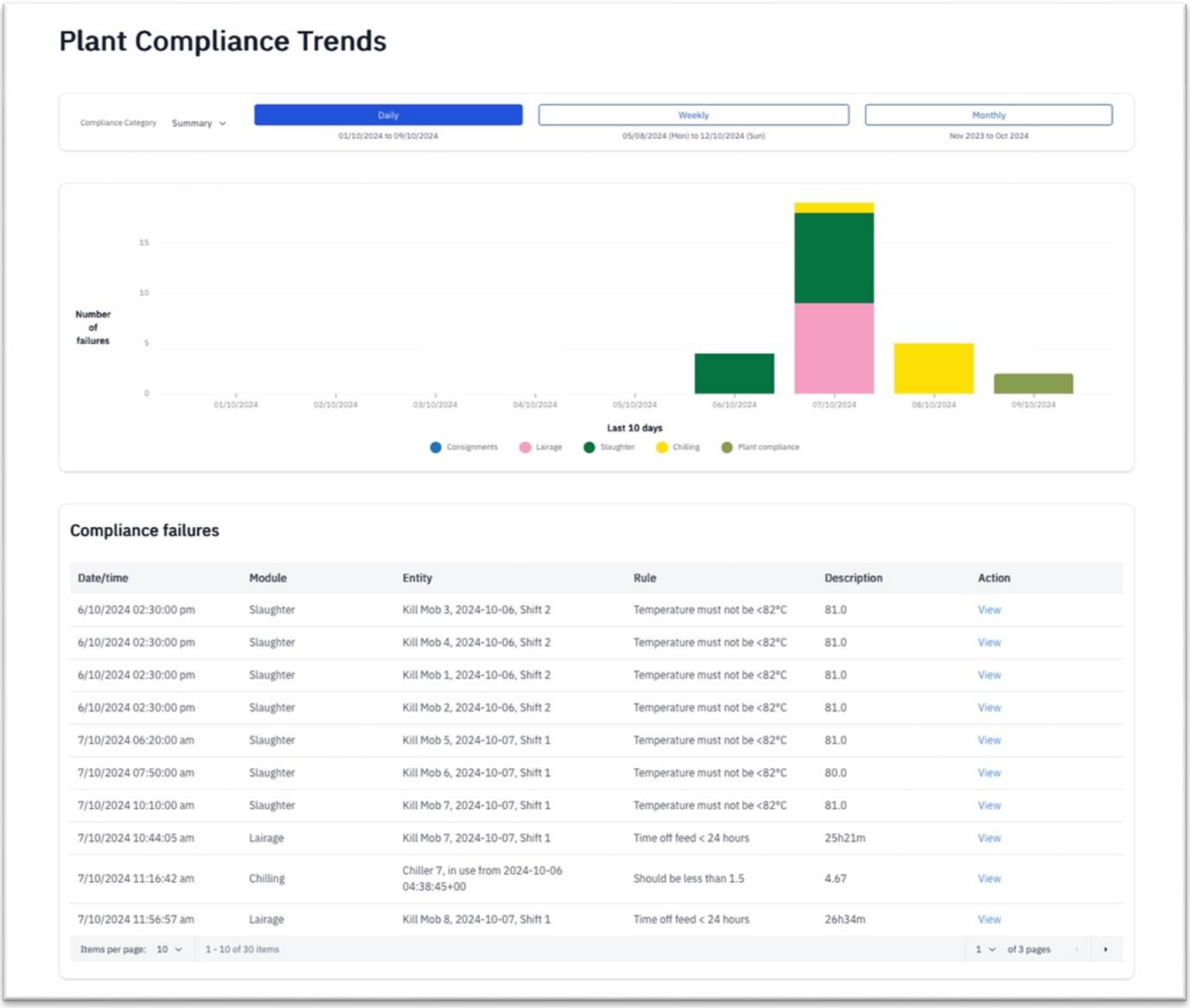


Figure A 1. Main entry screen



Date/time	Module	Entity	Rule	Description	Action
6/10/2024 02:30:00 pm	Slaughter	Kill Mob 3, 2024-10-06, Shift 2	Temperature must not be <82°C	81.0	View
6/10/2024 02:30:00 pm	Slaughter	Kill Mob 4, 2024-10-06, Shift 2	Temperature must not be <82°C	81.0	View
6/10/2024 02:30:00 pm	Slaughter	Kill Mob 1, 2024-10-06, Shift 2	Temperature must not be <82°C	81.0	View
6/10/2024 02:30:00 pm	Slaughter	Kill Mob 2, 2024-10-06, Shift 2	Temperature must not be <82°C	81.0	View
7/10/2024 06:20:00 am	Slaughter	Kill Mob 5, 2024-10-07, Shift 1	Temperature must not be <82°C	81.0	View
7/10/2024 07:50:00 am	Slaughter	Kill Mob 6, 2024-10-07, Shift 1	Temperature must not be <82°C	80.0	View
7/10/2024 10:10:00 am	Slaughter	Kill Mob 7, 2024-10-07, Shift 1	Temperature must not be <82°C	81.0	View
7/10/2024 10:44:05 am	Lairage	Kill Mob 7, 2024-10-07, Shift 1	Time off feed < 24 hours	25h21m	View
7/10/2024 11:16:42 am	Chilling	Chiller 7, in use from 2024-10-06 04:38:45+00	Should be less than 1.5	4.67	View
7/10/2024 11:56:57 am	Lairage	Kill Mob 8, 2024-10-07, Shift 1	Time off feed < 24 hours	26h34m	View

Figure A 2. Plant Compliance Trends

A common pattern for presenting information to users in the monitoring modes is to break it up by module, as shown in Figure A 3. Each module focuses on a specific resource type that corresponds to the primary resource being processed within that module. The Consignments module deals, naturally, with consignments. The Lairage and Slaughter modules both deal with kill mobs, and the Chilling module with chillers. It is worth noting that we considered also showing consignments within Lairage but the module’s design became significantly more complex, with little added benefit from a compliance issue display point of view. Which resources are actually shown in each module depends on the current “focus” for each module. The compliance issue counts displayed for each module are simply the total of all compliance issues associated with the resources currently in focus for that module.

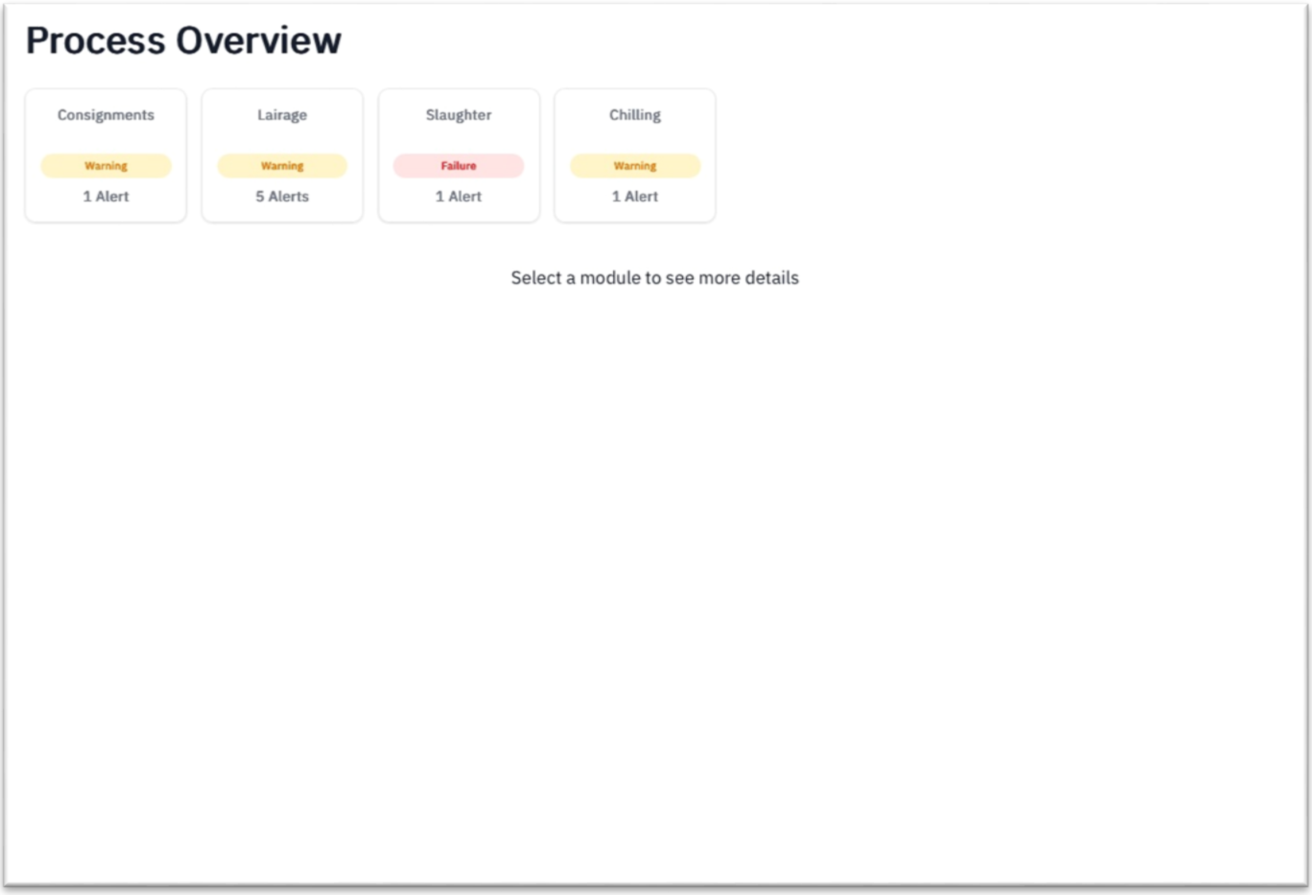


Figure A 3. Process Overview

When looking at the Process Overview, see Figure A 3, the focus of each module is determined by what resources are currently being "processed" within that module. Specifically, the Consignments module shows all consignments that have left a Farm/Feedlot but have not yet been entirely slaughtered, see Figure A 4, Lairage shows all kill mobs that have been assembled but not yet entirely slaughtered, see Figure A 5, Slaughter shows all kill mobs that have begun to be slaughtered but whose carcase sides have not all been stored in chillers, see Figure A 6, and the Chillers module, see Figure A 7, shows all chillers in active use (loading, chilling, unloading), as well as those ready for use. The pattern across each of these module views is the same, each is opened by clicking the corresponding module at the top of the screen and then the status of each associated resource is shown below. Clicking on the hyperlink in the Alerts column of any one of these resources will open up some detail for that resource, as discussed in more detail below.

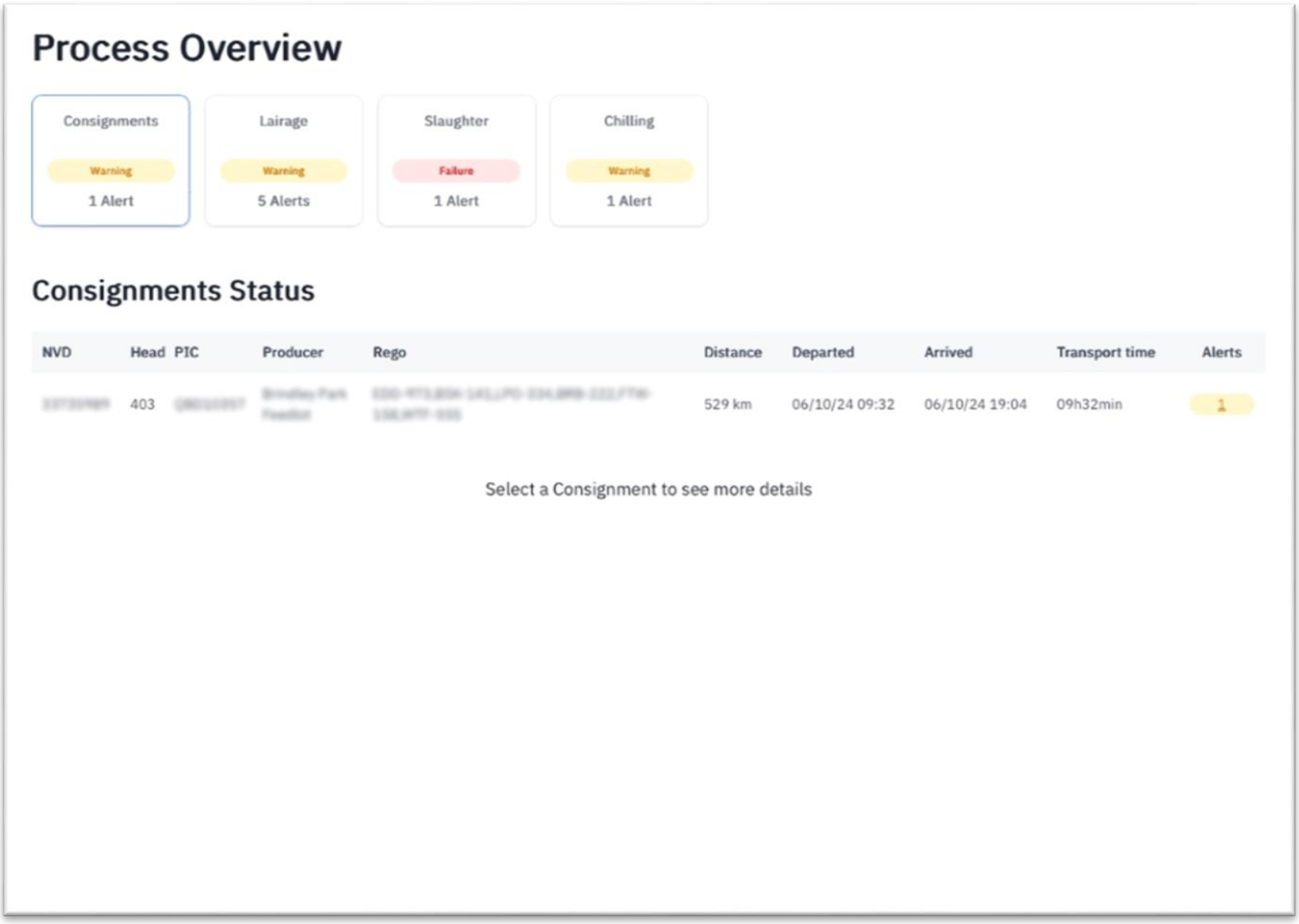
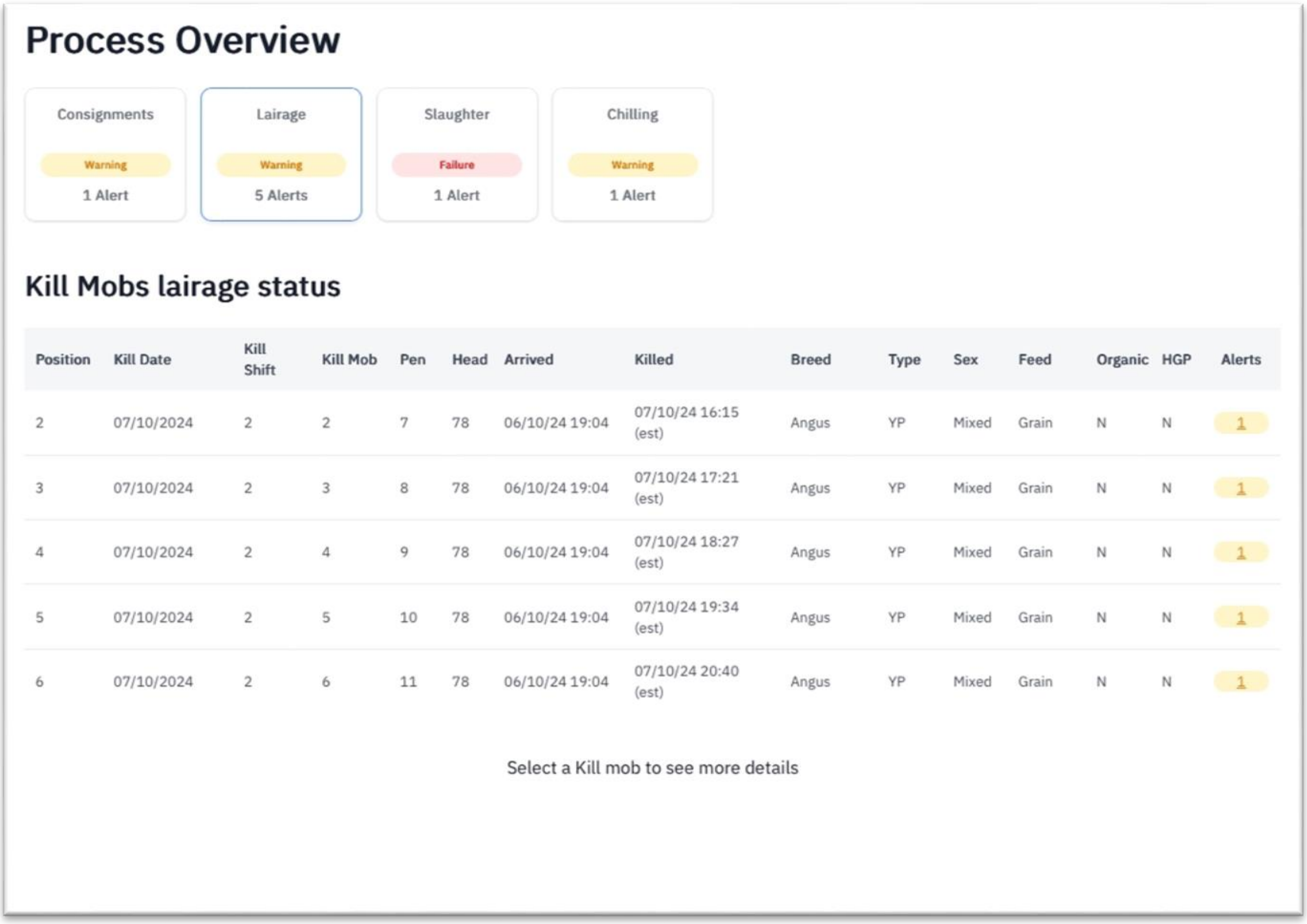
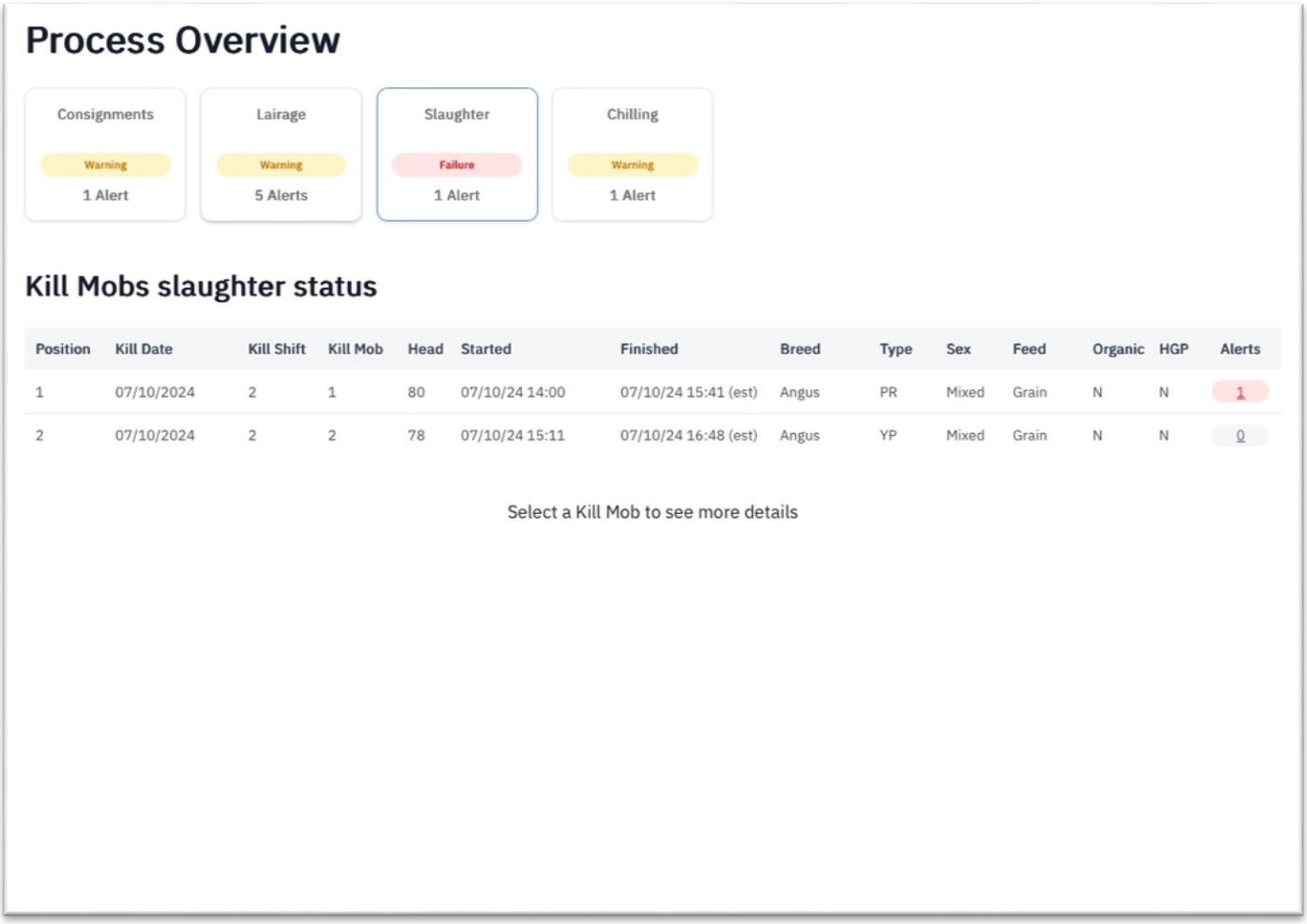


Figure A 4. Consignments module for Process Overview



Position	Kill Date	Kill Shift	Kill Mob	Pen	Head	Arrived	Killed	Breed	Type	Sex	Feed	Organic	HGP	Alerts
2	07/10/2024	2	2	7	78	06/10/24 19:04	07/10/24 16:15 (est)	Angus	YP	Mixed	Grain	N	N	1
3	07/10/2024	2	3	8	78	06/10/24 19:04	07/10/24 17:21 (est)	Angus	YP	Mixed	Grain	N	N	1
4	07/10/2024	2	4	9	78	06/10/24 19:04	07/10/24 18:27 (est)	Angus	YP	Mixed	Grain	N	N	1
5	07/10/2024	2	5	10	78	06/10/24 19:04	07/10/24 19:34 (est)	Angus	YP	Mixed	Grain	N	N	1
6	07/10/2024	2	6	11	78	06/10/24 19:04	07/10/24 20:40 (est)	Angus	YP	Mixed	Grain	N	N	1

Figure A 5. Lairage module for Process Overview



Position	Kill Date	Kill Shift	Kill Mob	Head	Started	Finished	Breed	Type	Sex	Feed	Organic	HGP	Alerts
1	07/10/2024	2	1	80	07/10/24 14:00	07/10/24 15:41 (est)	Angus	PR	Mixed	Grain	N	N	1
2	07/10/2024	2	2	78	07/10/24 15:11	07/10/24 16:48 (est)	Angus	YP	Mixed	Grain	N	N	0

Figure A 6. Slaughter module for Process Overview

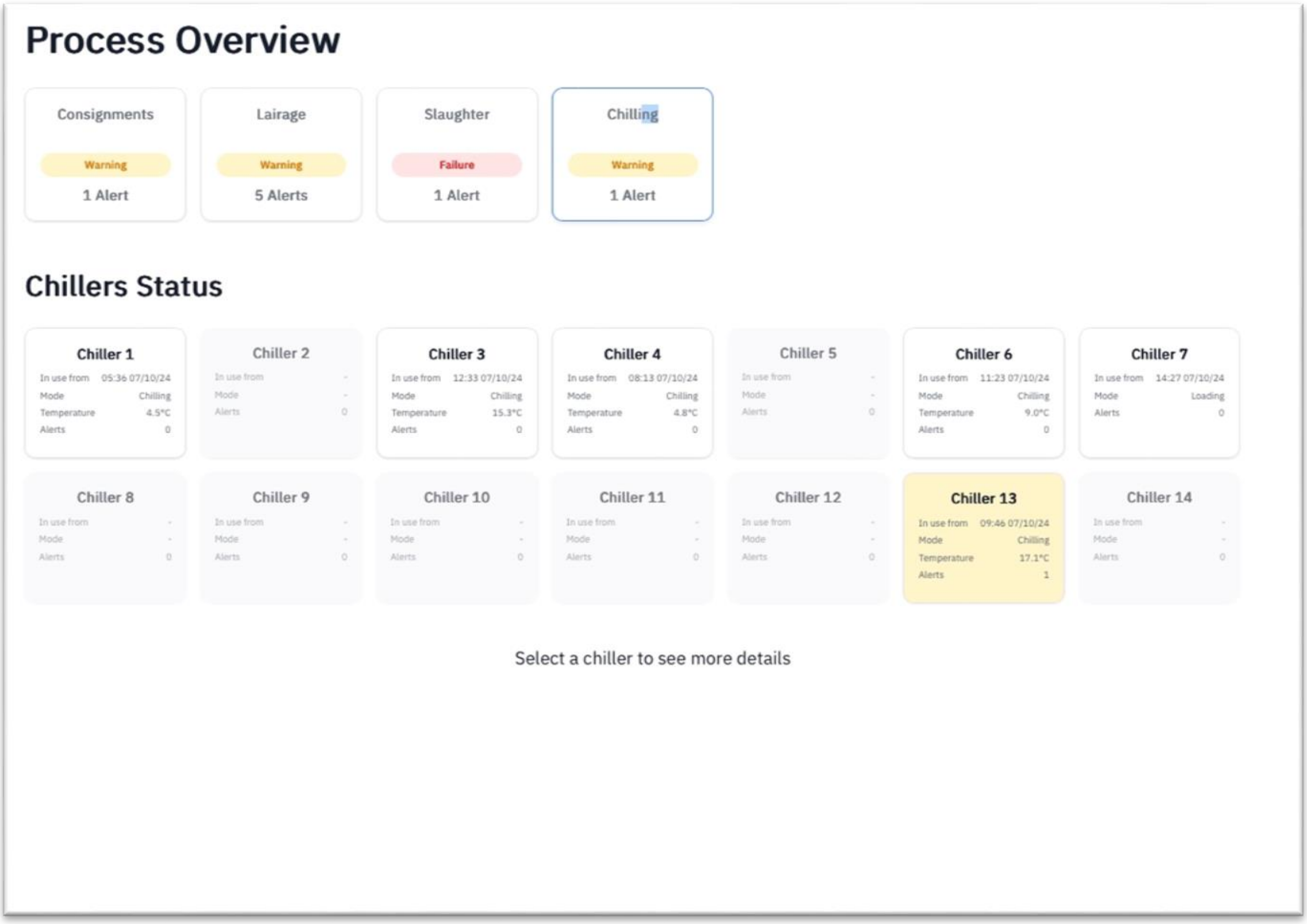


Figure A 7. Chilling module for Process Overview

Whenever the user interface displays a list of resources, the resource can be examined in detail by clicking on the “alerts” link. The detail information for each resources follows a common pattern: the resource’s core information, which other resources are associated with it using traceability information, a set of compliance rules relevant to the resource type in the currently viewed module, along with their compliance indicator values, and a section for other compliance indicators which allows the user to see how certain compliance indicator values vary over time. A 8 to A **11** shows the details for consignments, kill mobs, and chillers across the Consignments, Lairage, Slaughter, and Chilling modules.

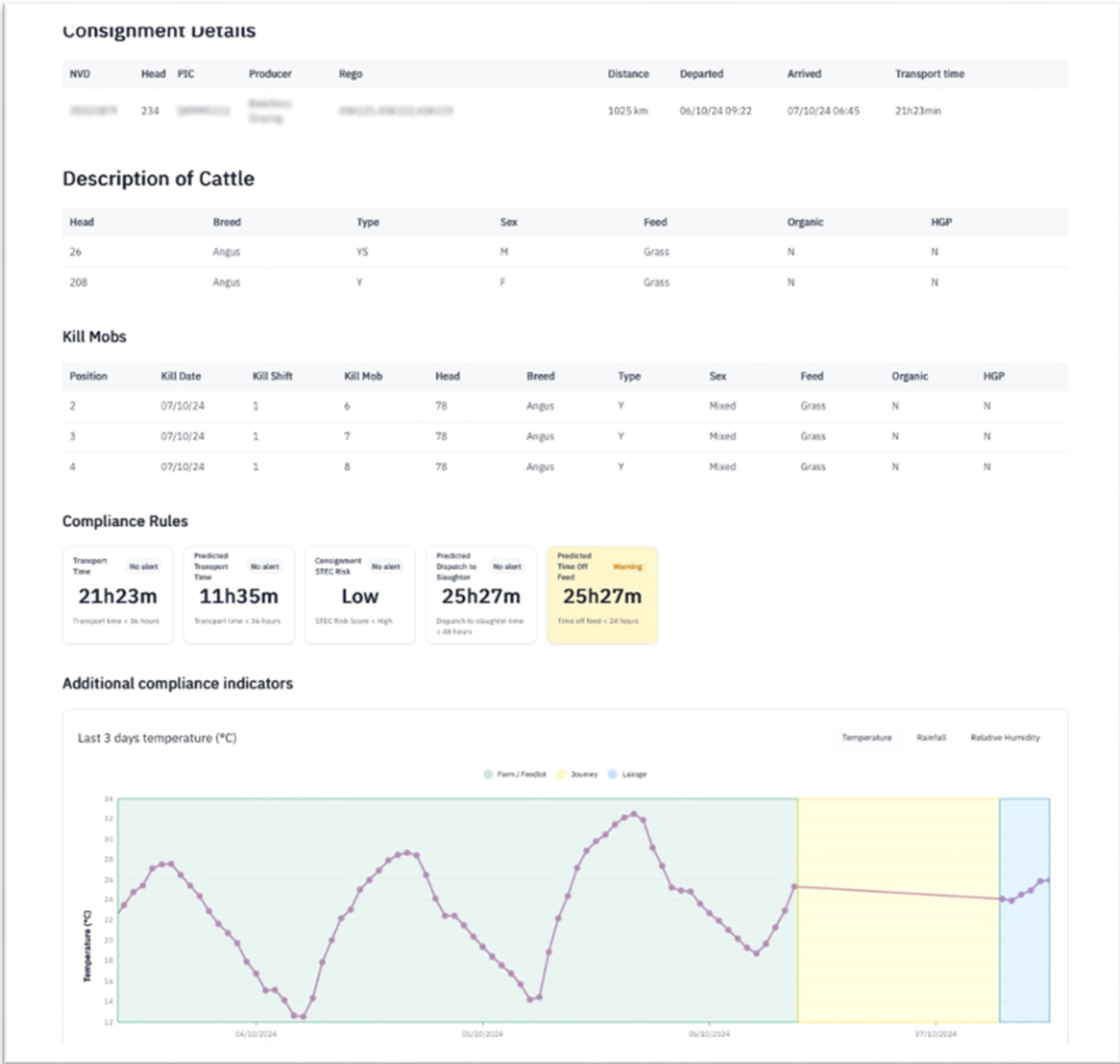


Figure A 8. Consignment details

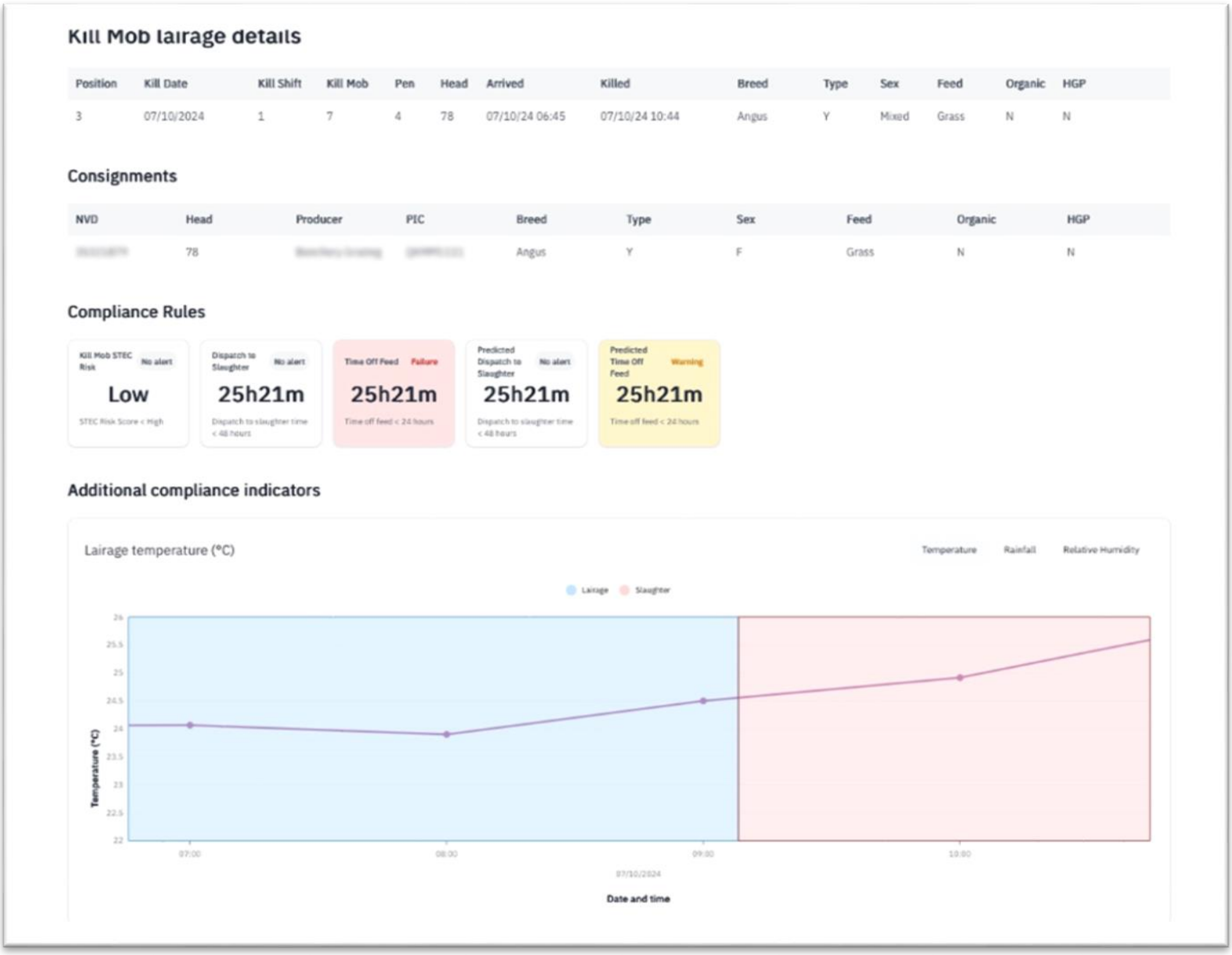


Figure A 9. Kill mob details (Lairage module)

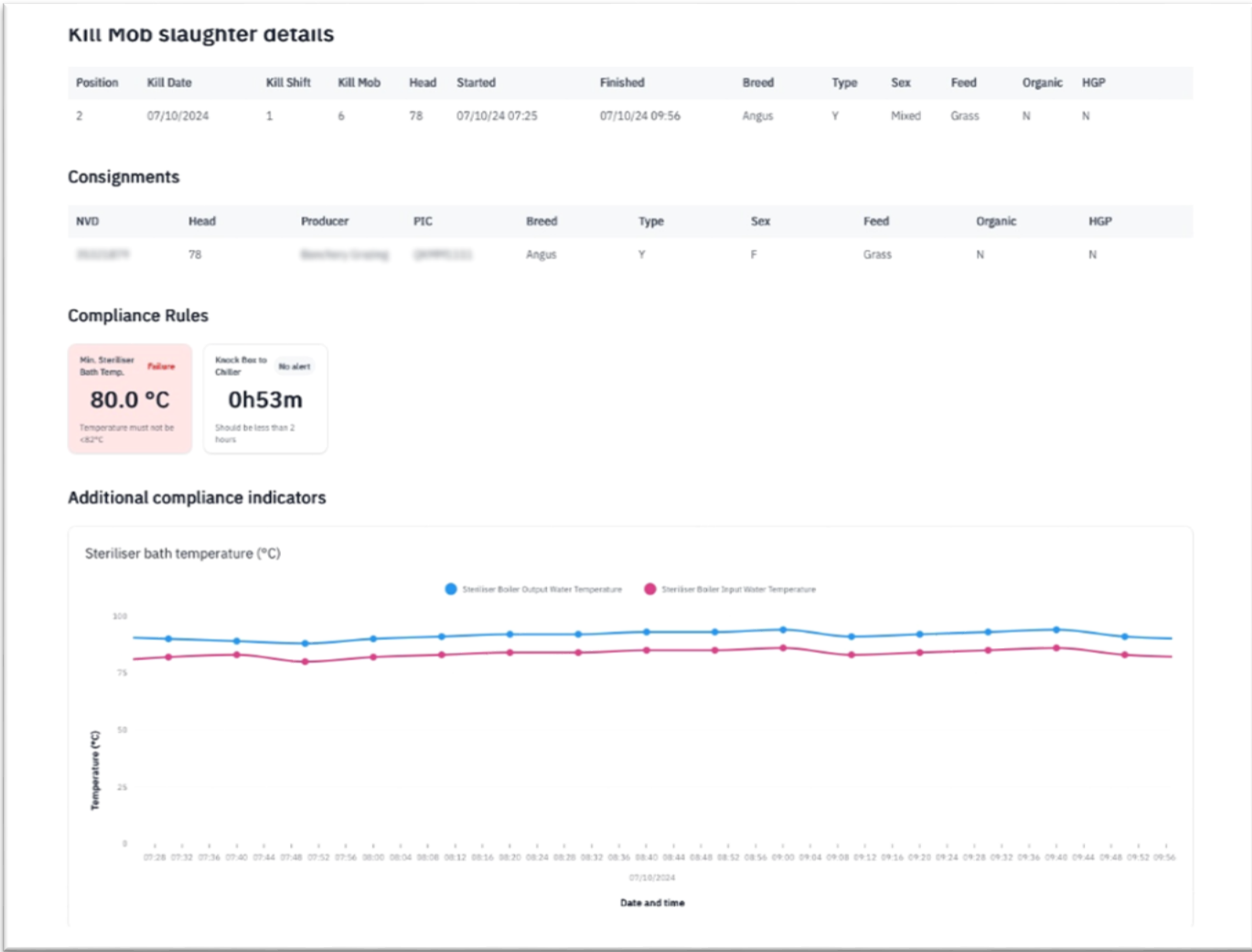


Figure A 10. Kill mob details (Slaughter module)

Chiller Details

Chiller number	In use from	Mode
13	09:46 07/10/24	Chilling

Kill Mobs

Position	Kill Date	Kill Shift	Kill Mob	# Sides	Breed	Type	Sex	Feed	Organic	HGP
2	07/10/24	1	6	4	Angus	Y	Mixed	Grass	N	N
3	07/10/24	1	7	128	Angus	Y	Mixed	Grass	N	N

Boning Runs

Position	Date	Shift	Run #	# Sides	Grade	Breed	Type	Sex	Feed	Organic	HGP

No results.

Compliance Rules

Carcase temp.	Refrigeration Index	Predicted carcase temp.	Max. Predicted RI
No alert	No alert	No alert	Warning
17.1 °C	0.9	4.4 °C	1.7
Below 7°C on unloading or within 24h	Should be less than 1.5	Below 7°C on unloading or within 24h	Should be less than 1.5

Additional compliance indicators

Figure A 11. Chiller details

The Farm to Chilling view, see Figure A 12, focuses on sets of kill mobs that are to be killed within a single operational “shift” according to a so-called “kill sheet”; the first kill sheet shown on this screen has been expanded, whereas the second is collapsed. On this screen we see each kill mob and next to it a per-module count of compliance issues. There are two ways to examine compliance issues from this screen: clicking on the one of the modules at the top, or clicking on one of the hyperlinks within the kill mobs table; the first sets the current “focus” to the set of kill mobs in the kill sheet, and the second sets it to a single, specific kill mob.

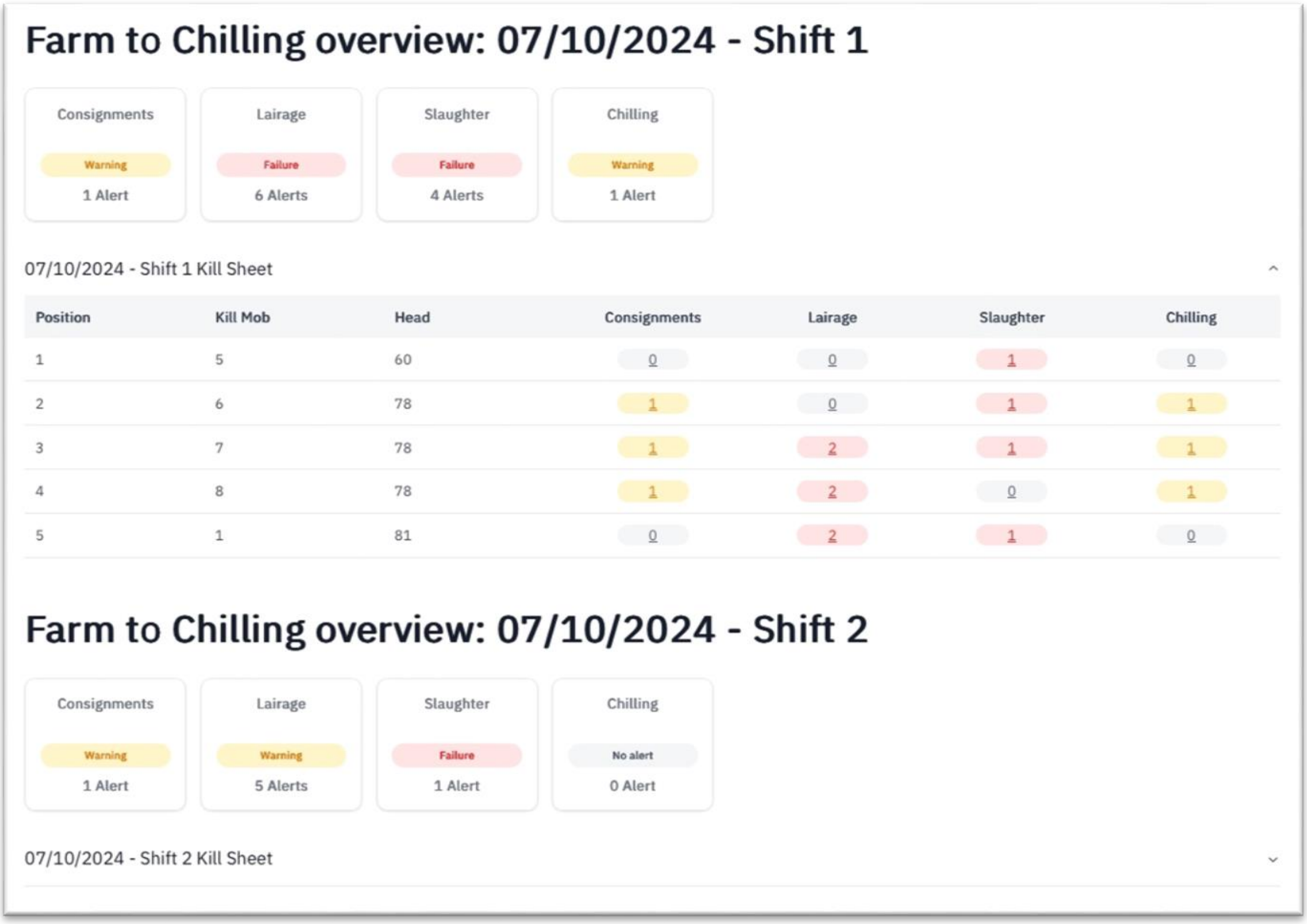


Figure A 12. Farm to Chilling

Figure A 13, Figure A 14, Figure A 15, and Figure A 16 show each of the modules at a kill sheet focus. At the top is the list of items being focused, i.e. the kill sheet, and underneath that is a list of module-specific resources. In the case of the Lairage (Figure A 14) and Slaughter (Figure A 15) modules, the list of module resources is the same as the kill sheet, because the kill sheet is a collection of kill mobs. For the Consignments module (Figure A 13), the list of module resources, i.e. consignments, corresponds to all consignments that contributed cattle to all of the kill mobs in the focus set. This is an example of using the traceability information in the system. Likewise, the Chilling module (Figure A 16), shows the Chillers that contain carcase sides from any of the kill mobs in the focus set. If the user had instead clicked on one of the kill mob specific module links in the expanded kill sheet on Figure A 12, they will see similar screens with a single Kill Mob as focus, and the matching resources on each module are determined in the same way as for the kill sheet, i.e. Consignments shows all consignments that contributed cattle to the kill mob, Lairage and Slaughter show the kill mob itself, and Chilling shows any chillers that contain carcase sides from the kill mob. This is shown in A 17 to A **20**.

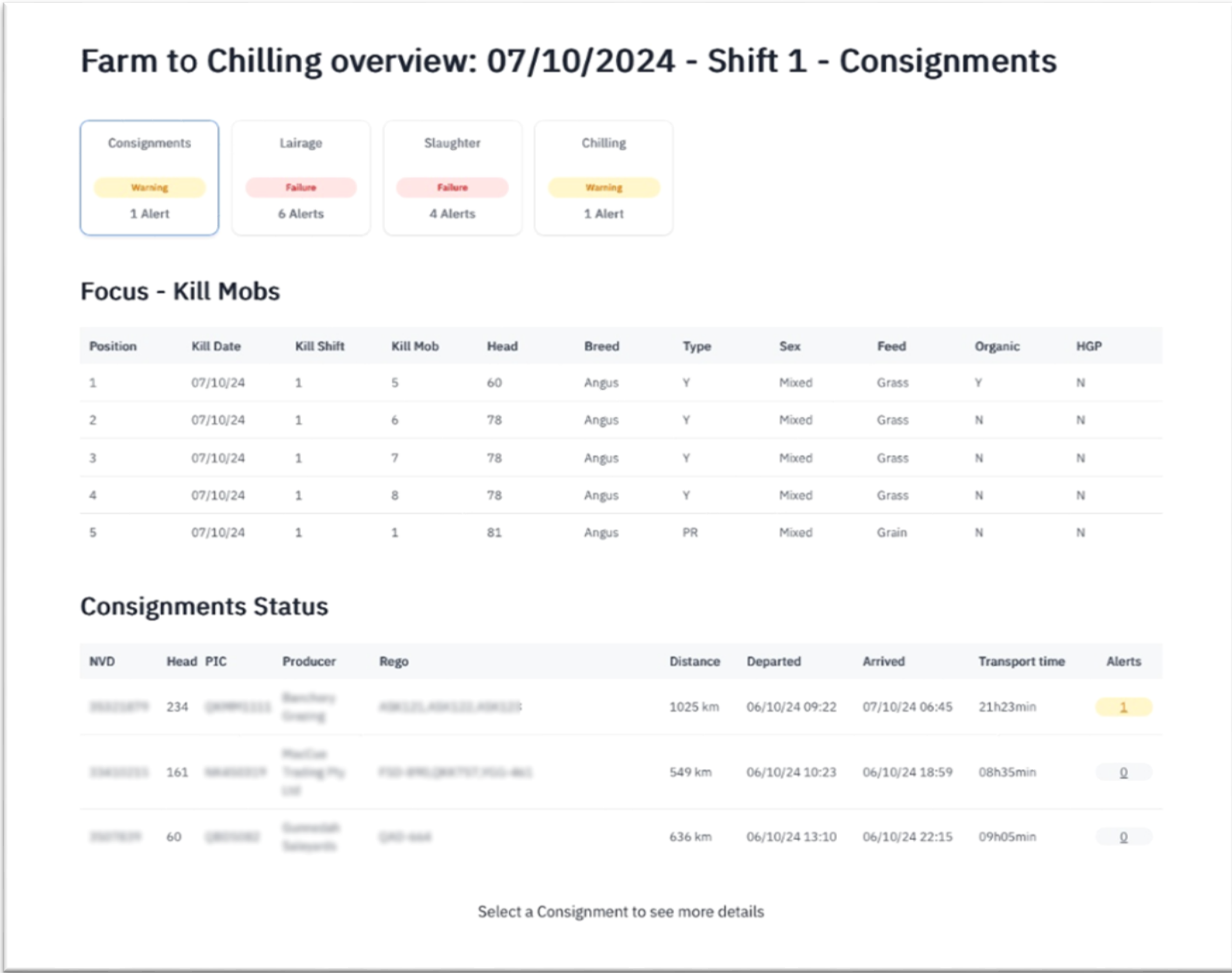
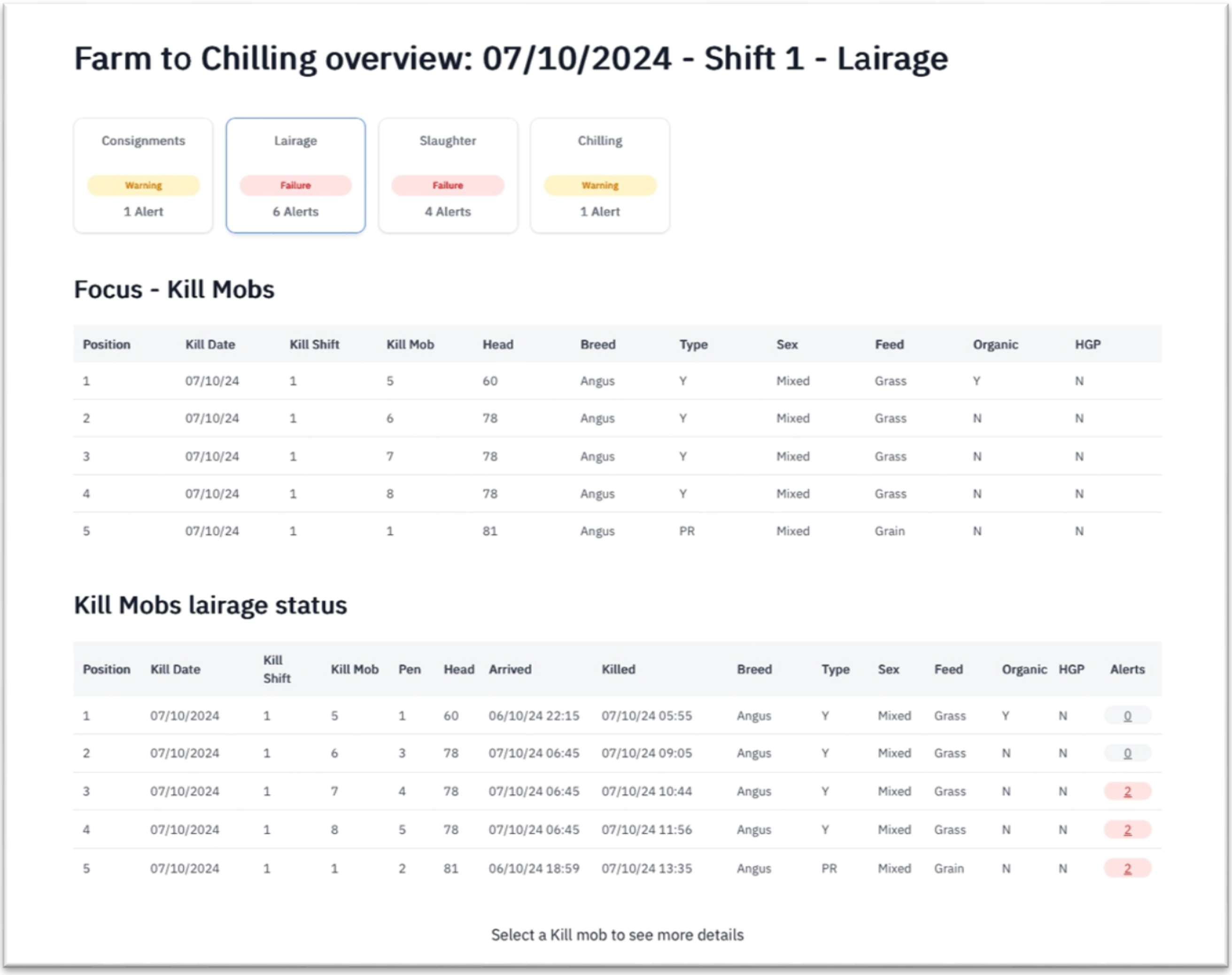


Figure A **13**. Farm to Chilling - Consignments module for kill sheet focus



Farm to Chilling overview: 07/10/2024 - Shift 1 - Lairage

Consignments	Lairage	Slaughter	Chilling
Warning	Failure	Failure	Warning
1 Alert	6 Alerts	4 Alerts	1 Alert

Focus - Kill Mobs

Position	Kill Date	Kill Shift	Kill Mob	Head	Breed	Type	Sex	Feed	Organic	HGP
1	07/10/24	1	5	60	Angus	Y	Mixed	Grass	Y	N
2	07/10/24	1	6	78	Angus	Y	Mixed	Grass	N	N
3	07/10/24	1	7	78	Angus	Y	Mixed	Grass	N	N
4	07/10/24	1	8	78	Angus	Y	Mixed	Grass	N	N
5	07/10/24	1	1	81	Angus	PR	Mixed	Grain	N	N

Kill Mobs lairage status

Position	Kill Date	Kill Shift	Kill Mob	Pen	Head	Arrived	Killed	Breed	Type	Sex	Feed	Organic	HGP	Alerts
1	07/10/2024	1	5	1	60	06/10/24 22:15	07/10/24 05:55	Angus	Y	Mixed	Grass	Y	N	0
2	07/10/2024	1	6	3	78	07/10/24 06:45	07/10/24 09:05	Angus	Y	Mixed	Grass	N	N	0
3	07/10/2024	1	7	4	78	07/10/24 06:45	07/10/24 10:44	Angus	Y	Mixed	Grass	N	N	2
4	07/10/2024	1	8	5	78	07/10/24 06:45	07/10/24 11:56	Angus	Y	Mixed	Grass	N	N	2
5	07/10/2024	1	1	2	81	06/10/24 18:59	07/10/24 13:35	Angus	PR	Mixed	Grain	N	N	2

Select a Kill mob to see more details

Figure A **14**. Farm to Chilling - Lairage module for kill sheet focus

Farm to Chilling overview: 07/10/2024 - Shift 1 - Slaughter

Consignments	Lairage	Slaughter	Chilling
Warning	Failure	Failure	Warning
1 Alert	6 Alerts	4 Alerts	1 Alert

Focus - Kill Mobs

Position	Kill Date	Kill Shift	Kill Mob	Head	Breed	Type	Sex	Feed	Organic	HGP
1	07/10/24	1	5	60	Angus	Y	Mixed	Grass	Y	N
2	07/10/24	1	6	78	Angus	Y	Mixed	Grass	N	N
3	07/10/24	1	7	78	Angus	Y	Mixed	Grass	N	N
4	07/10/24	1	8	78	Angus	Y	Mixed	Grass	N	N
5	07/10/24	1	1	81	Angus	PR	Mixed	Grain	N	N

Kill Mobs slaughter status

Position	Kill Date	Kill Shift	Kill Mob	Head	Started	Finished	Breed	Type	Sex	Feed	Organic	HGP	Alerts
1	07/10/2024	1	5	60	07/10/24 05:00	07/10/24 06:38	Angus	Y	Mixed	Grass	Y	N	1
2	07/10/2024	1	6	78	07/10/24 07:25	07/10/24 09:56	Angus	Y	Mixed	Grass	N	N	1
3	07/10/2024	1	7	78	07/10/24 09:08	07/10/24 11:12	Angus	Y	Mixed	Grass	N	N	1
4	07/10/2024	1	8	78	07/10/24 10:46	07/10/24 12:27	Angus	Y	Mixed	Grass	N	N	0
5	07/10/2024	1	1	81	07/10/24 11:59	07/10/24 14:02	Angus	PR	Mixed	Grain	N	N	1

Select a Kill Mob to see more details

Figure A 15. Farm to Chilling - Slaughter module for kill sheet focus

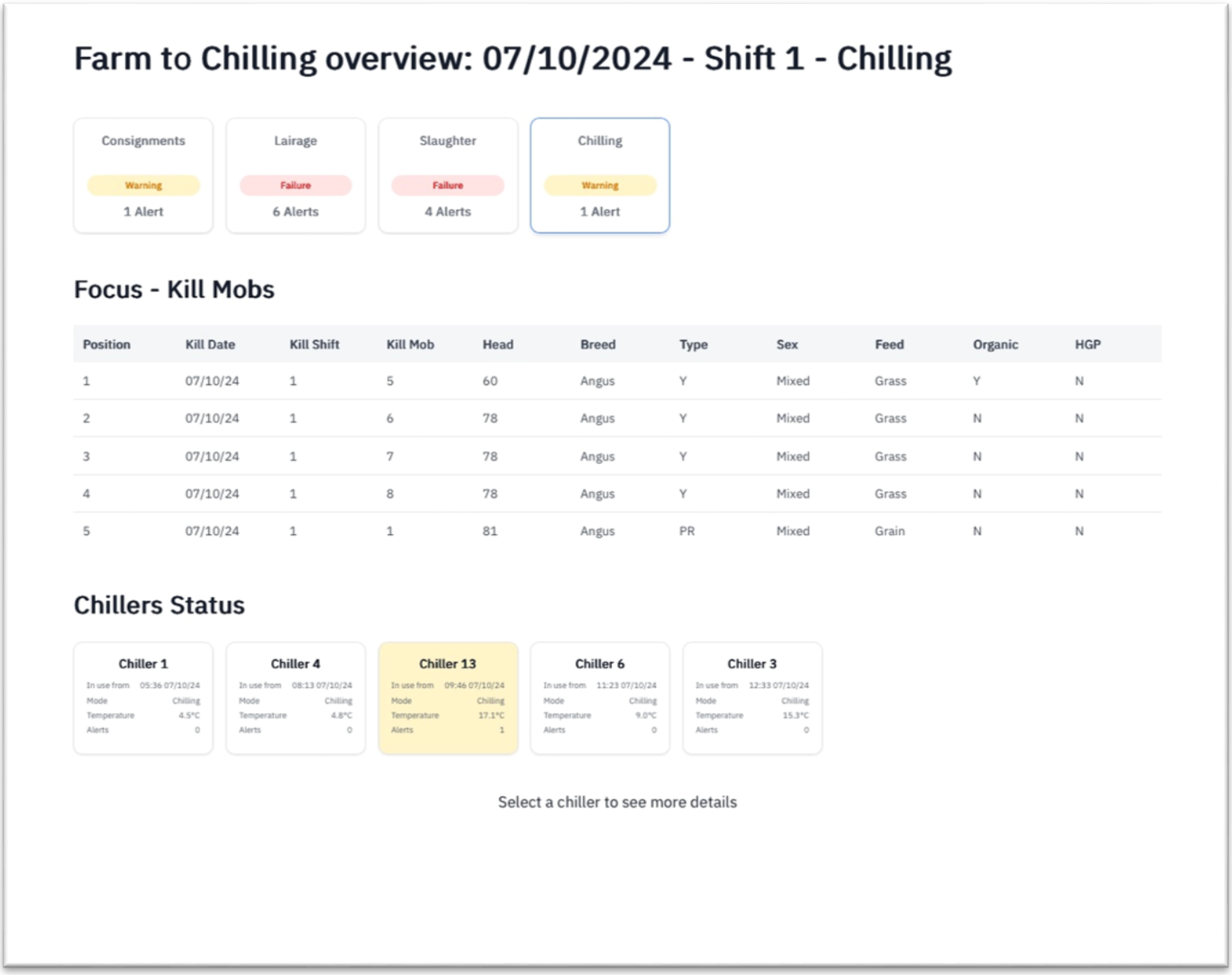


Figure A 16. Farm to Chilling - Chilling module for kill sheet focus

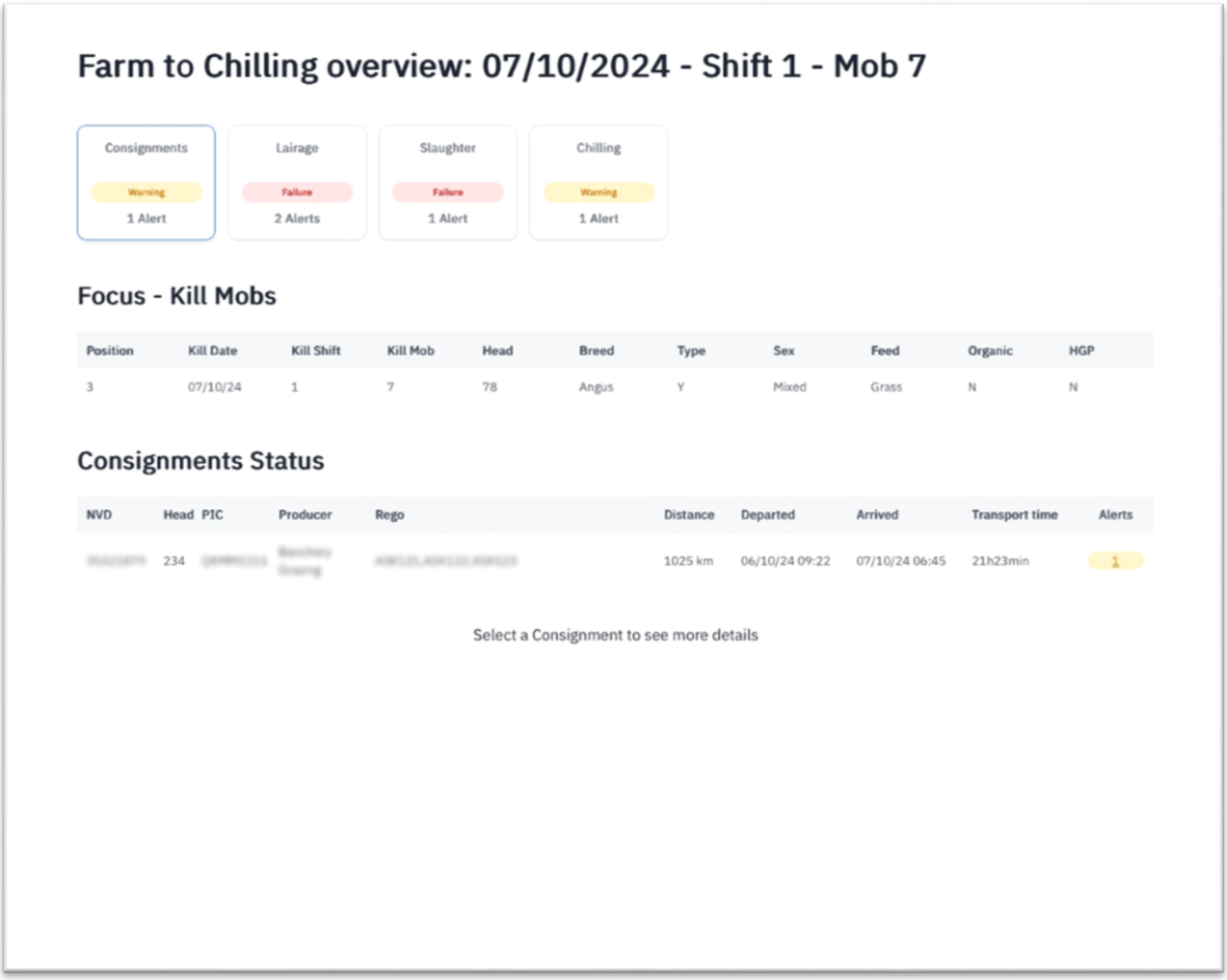


Figure A 17. Farm to Chilling - Consignments module for kill mob focus

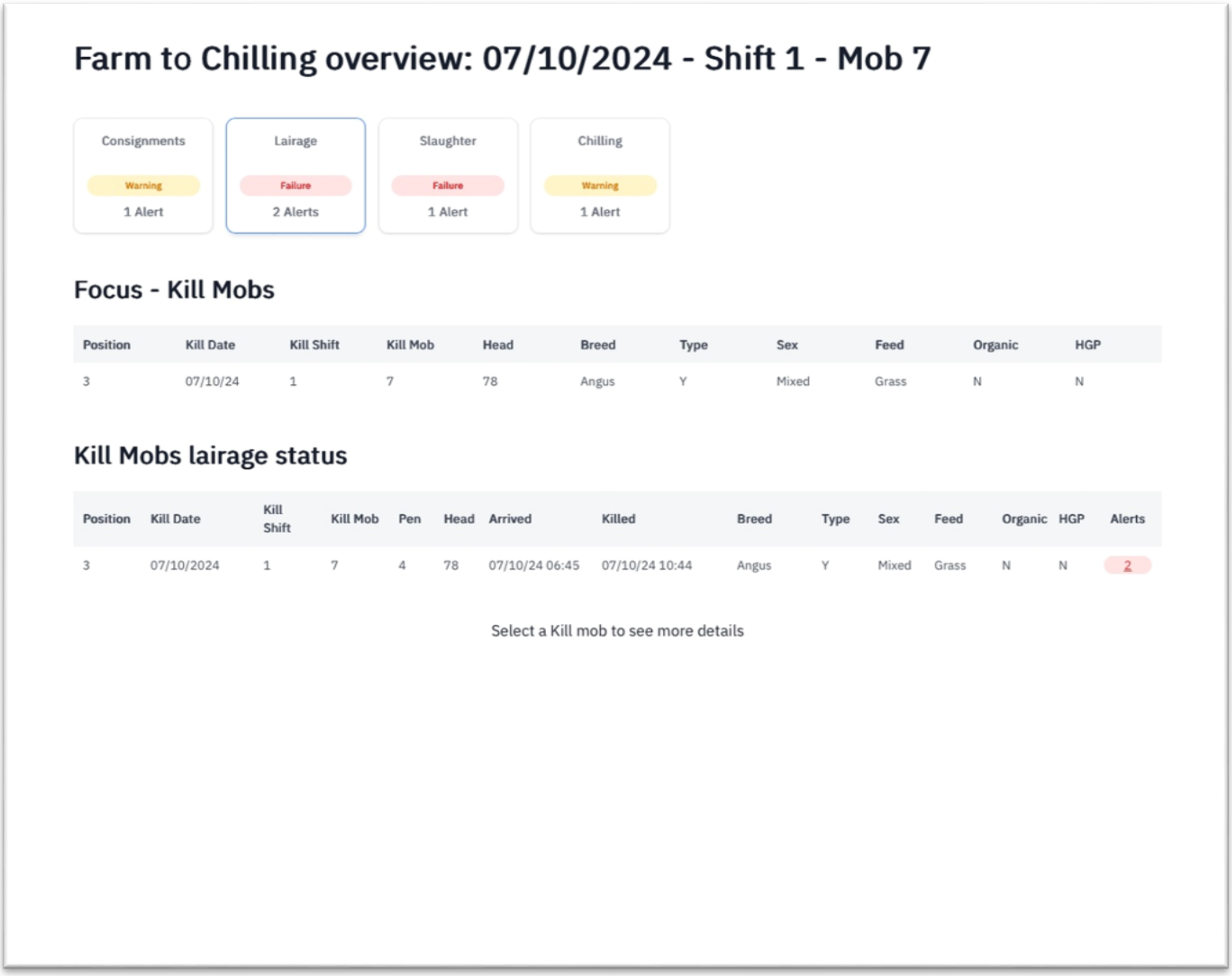


Figure A 18. Farm to Chilling - Lairage module for kill mob focus

Figure A 19. Farm to Chilling - Slaughter module for kill mob focus

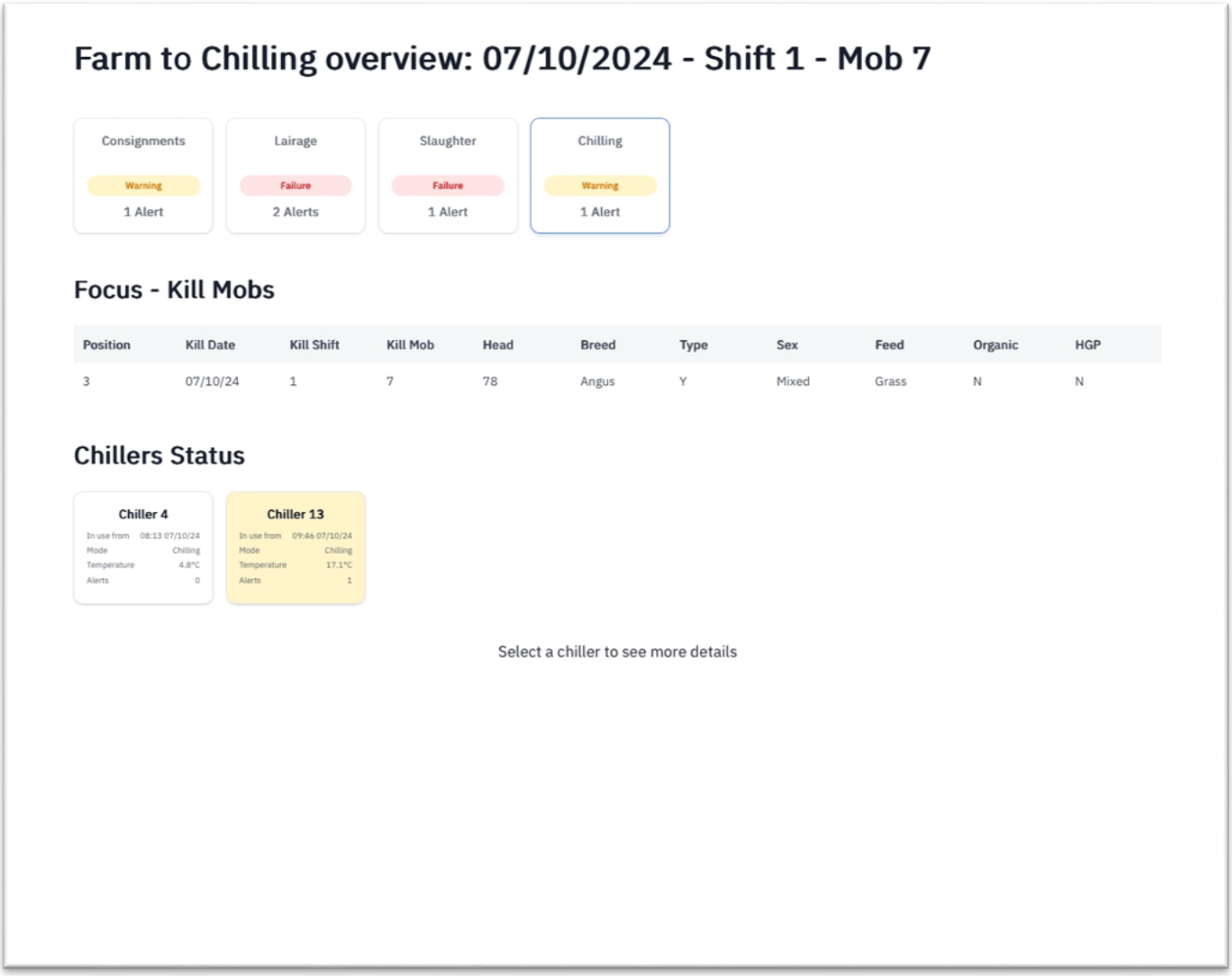


Figure A 20. Farm to Chilling - Chilling module for kill mob focus

The focus of the Boning to Packaging view is, a “boning sheet”, which is a set of boning runs, typically organised around an operational shift. The operation of this screen is the same as for Farm to Chilling but the resources shown when looking at any one of the modules, with either a boning sheet focus, or a single boning run focus, is determined as follows; the chillers shown in Chilling module are those that contain carcase sides from the focused boning run(s); the Lairage and Slaughter modules show the kill mobs which contributed carcase sides to the focused boning run(s); the Consignments module shows the consignments which supplied cattle to the kill mobs which contributed carcase sides to the focused boning run(s). Again, this relies on traceability information that connects boning runs to carcase sides to chillers or kill mobs and kill mobs back to consignments. From A 21 to A **29** show the same kind of screens for Boning to Packaging as was described for Farm to Chilling.

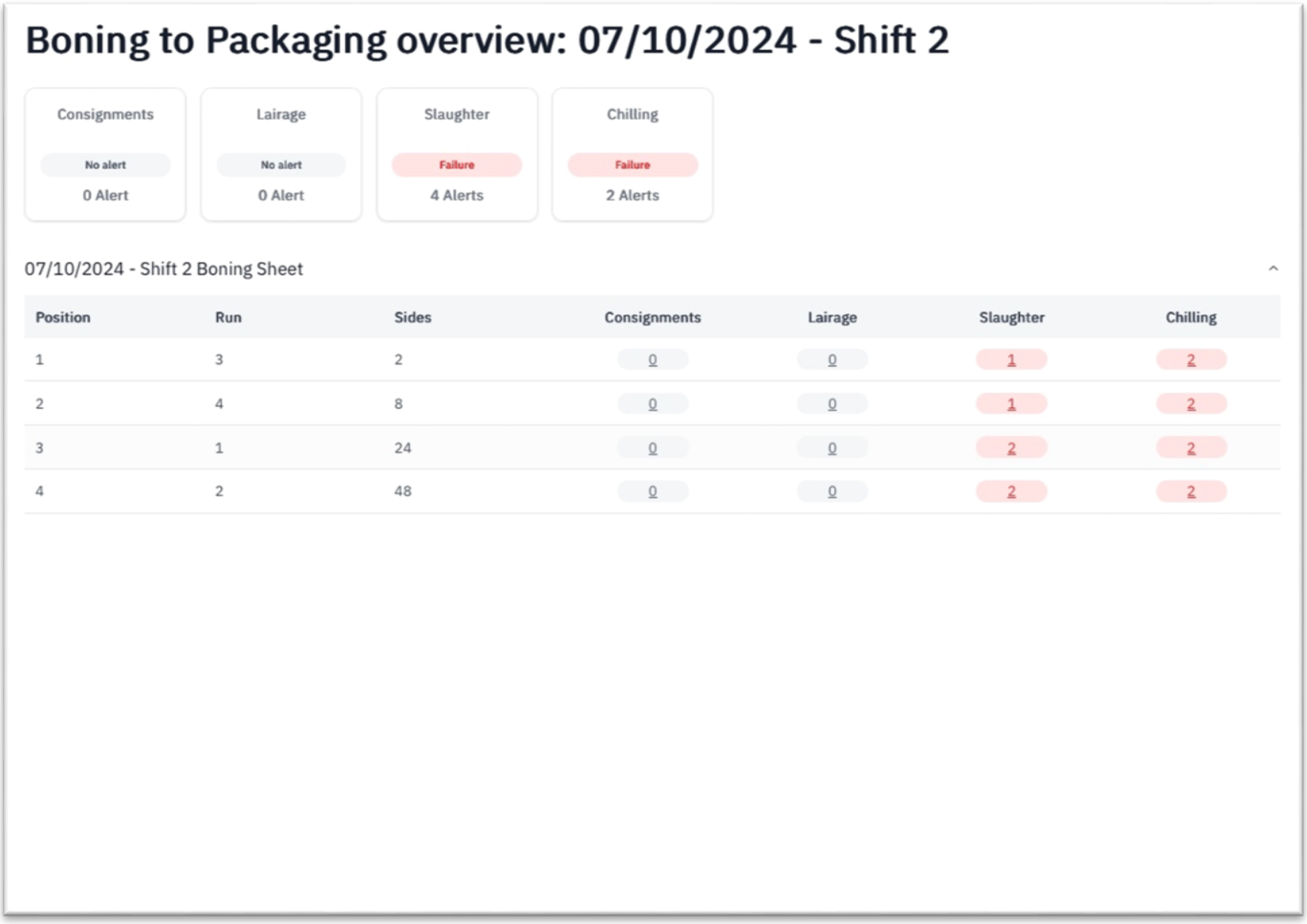
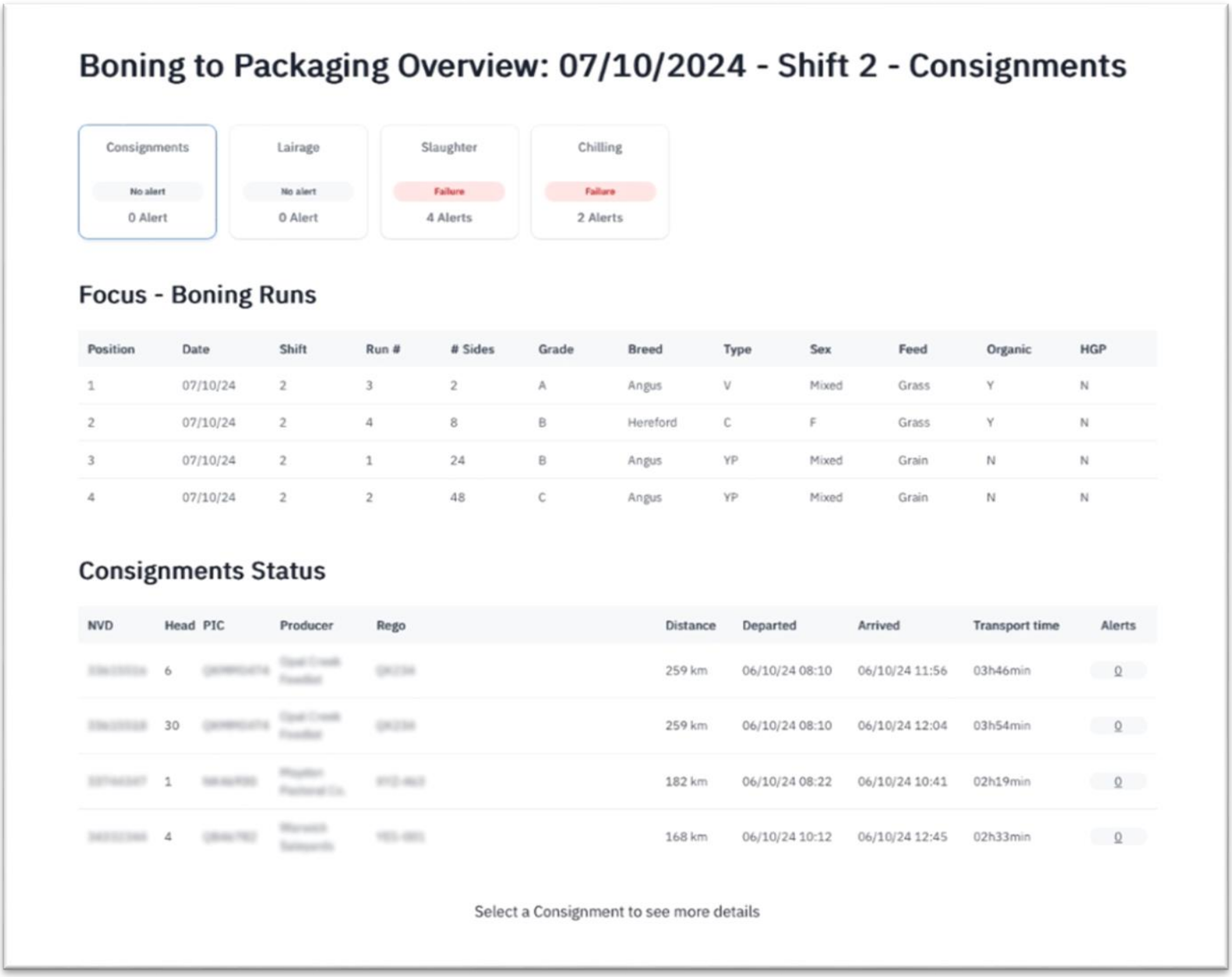


Figure A 21. Boning to Packaging



Boning to Packaging Overview: 07/10/2024 - Shift 2 - Consignments

Consignments	Lairage	Slaughter	Chilling
No alert	No alert	Failure	Failure
0 Alert	0 Alert	4 Alerts	2 Alerts

Focus - Boning Runs

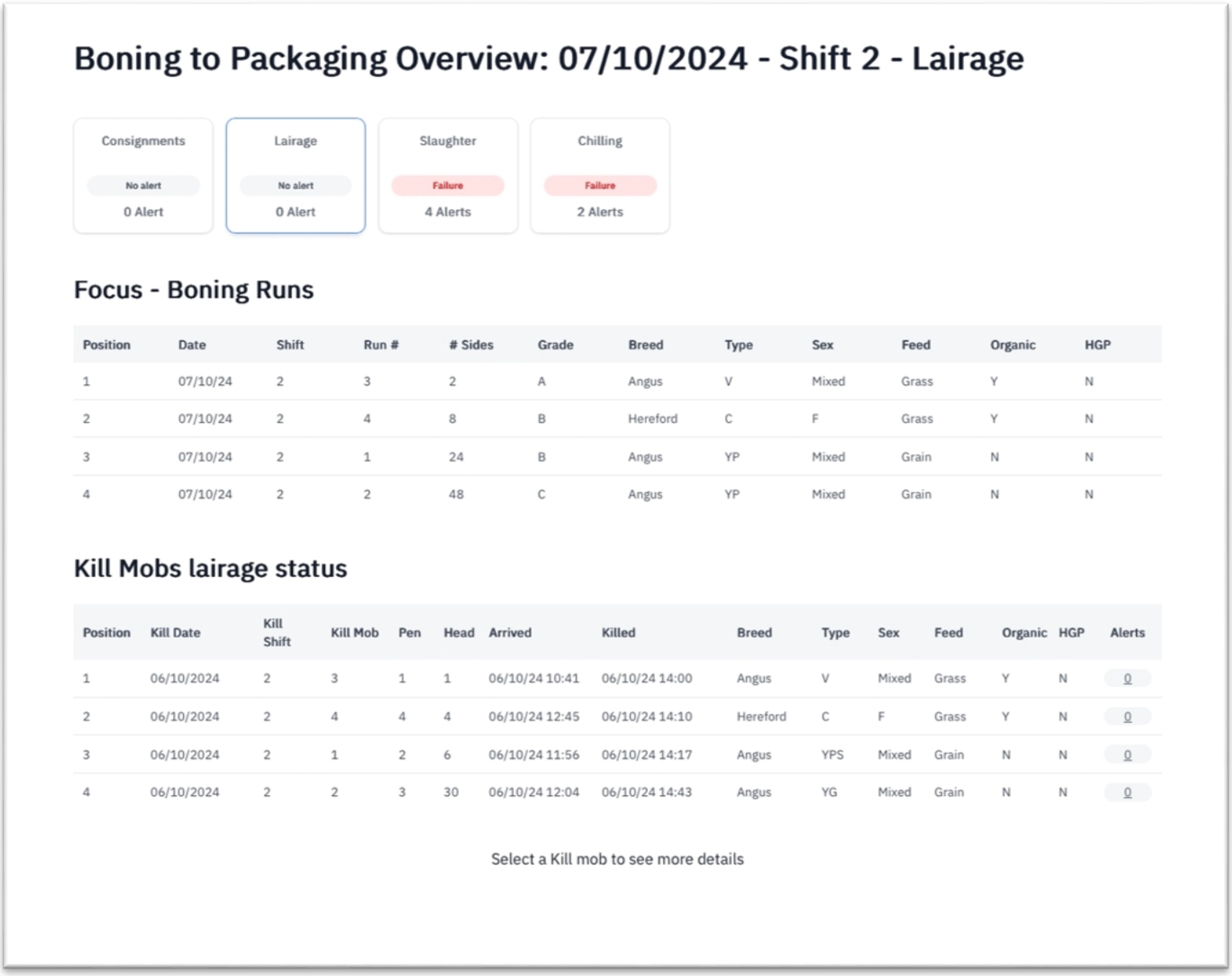
Position	Date	Shift	Run #	# Sides	Grade	Breed	Type	Sex	Feed	Organic	HGP
1	07/10/24	2	3	2	A	Angus	V	Mixed	Grass	Y	N
2	07/10/24	2	4	8	B	Hereford	C	F	Grass	Y	N
3	07/10/24	2	1	24	B	Angus	YP	Mixed	Grain	N	N
4	07/10/24	2	2	48	C	Angus	YP	Mixed	Grain	N	N

Consignments Status

NVD	Head	PIC	Producer	Rego	Distance	Departed	Arrived	Transport time	Alerts
[illegible]	6	[illegible]	[illegible]	[illegible]	259 km	06/10/24 08:10	06/10/24 11:56	03h46min	0
[illegible]	30	[illegible]	[illegible]	[illegible]	259 km	06/10/24 08:10	06/10/24 12:04	03h54min	0
[illegible]	1	[illegible]	[illegible]	[illegible]	182 km	06/10/24 08:22	06/10/24 10:41	02h19min	0
[illegible]	4	[illegible]	[illegible]	[illegible]	168 km	06/10/24 10:12	06/10/24 12:45	02h33min	0

Select a Consignment to see more details

Figure A 22. Boning to Packaging - Consignments module for boning sheet focus



Boning to Packaging Overview: 07/10/2024 - Shift 2 - Lairage

Consignments	Lairage	Slaughter	Chilling
No alert	No alert	Failure	Failure
0 Alert	0 Alert	4 Alerts	2 Alerts

Focus - Boning Runs

Position	Date	Shift	Run #	# Sides	Grade	Breed	Type	Sex	Feed	Organic	HGP
1	07/10/24	2	3	2	A	Angus	V	Mixed	Grass	Y	N
2	07/10/24	2	4	8	B	Hereford	C	F	Grass	Y	N
3	07/10/24	2	1	24	B	Angus	YP	Mixed	Grain	N	N
4	07/10/24	2	2	48	C	Angus	YP	Mixed	Grain	N	N

Kill Mobs lairage status

Position	Kill Date	Kill Shift	Kill Mob	Pen	Head	Arrived	Killed	Breed	Type	Sex	Feed	Organic	HGP	Alerts
1	06/10/2024	2	3	1	1	06/10/24 10:41	06/10/24 14:00	Angus	V	Mixed	Grass	Y	N	0
2	06/10/2024	2	4	4	4	06/10/24 12:45	06/10/24 14:10	Hereford	C	F	Grass	Y	N	0
3	06/10/2024	2	1	2	6	06/10/24 11:56	06/10/24 14:17	Angus	YPS	Mixed	Grain	N	N	0
4	06/10/2024	2	2	3	30	06/10/24 12:04	06/10/24 14:43	Angus	YG	Mixed	Grain	N	N	0

Select a Kill mob to see more details

Figure A 23. Boning to Packaging - Lairage module for boning sheet focus

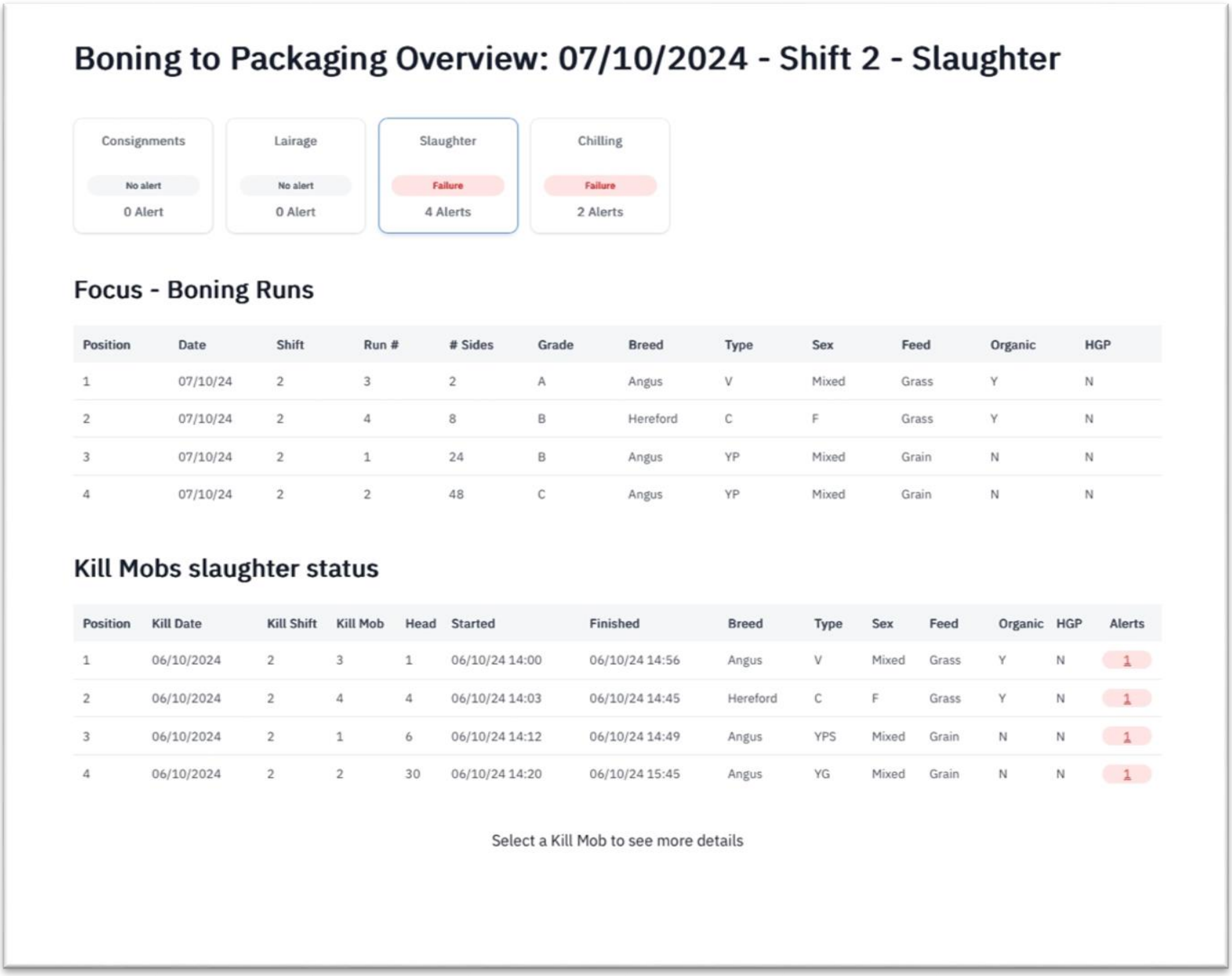


Figure A 24. Boning to Packaging - Slaughter module for boning sheet focus

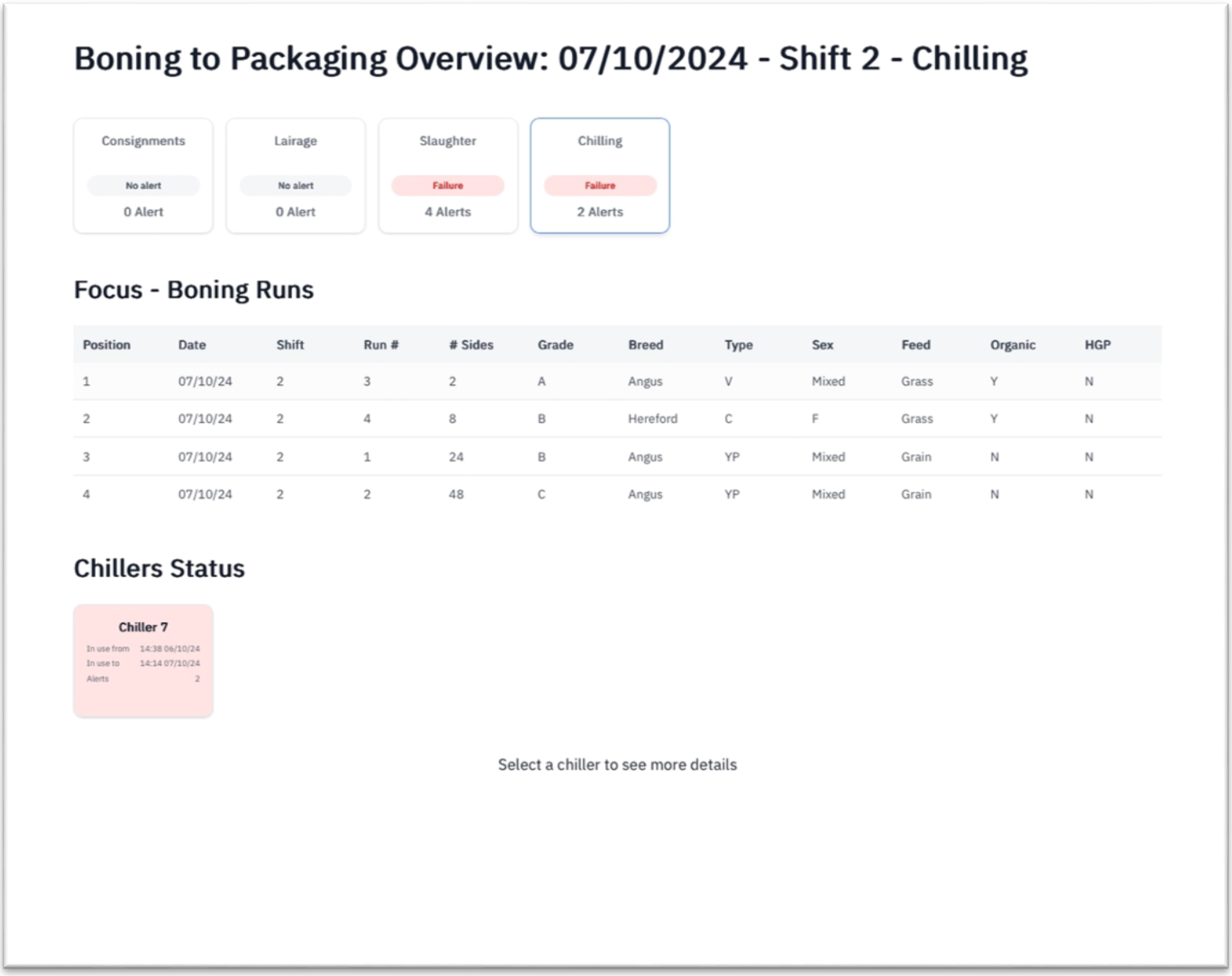


Figure A 25. Boning to Packaging - Chilling module for boning sheet focus

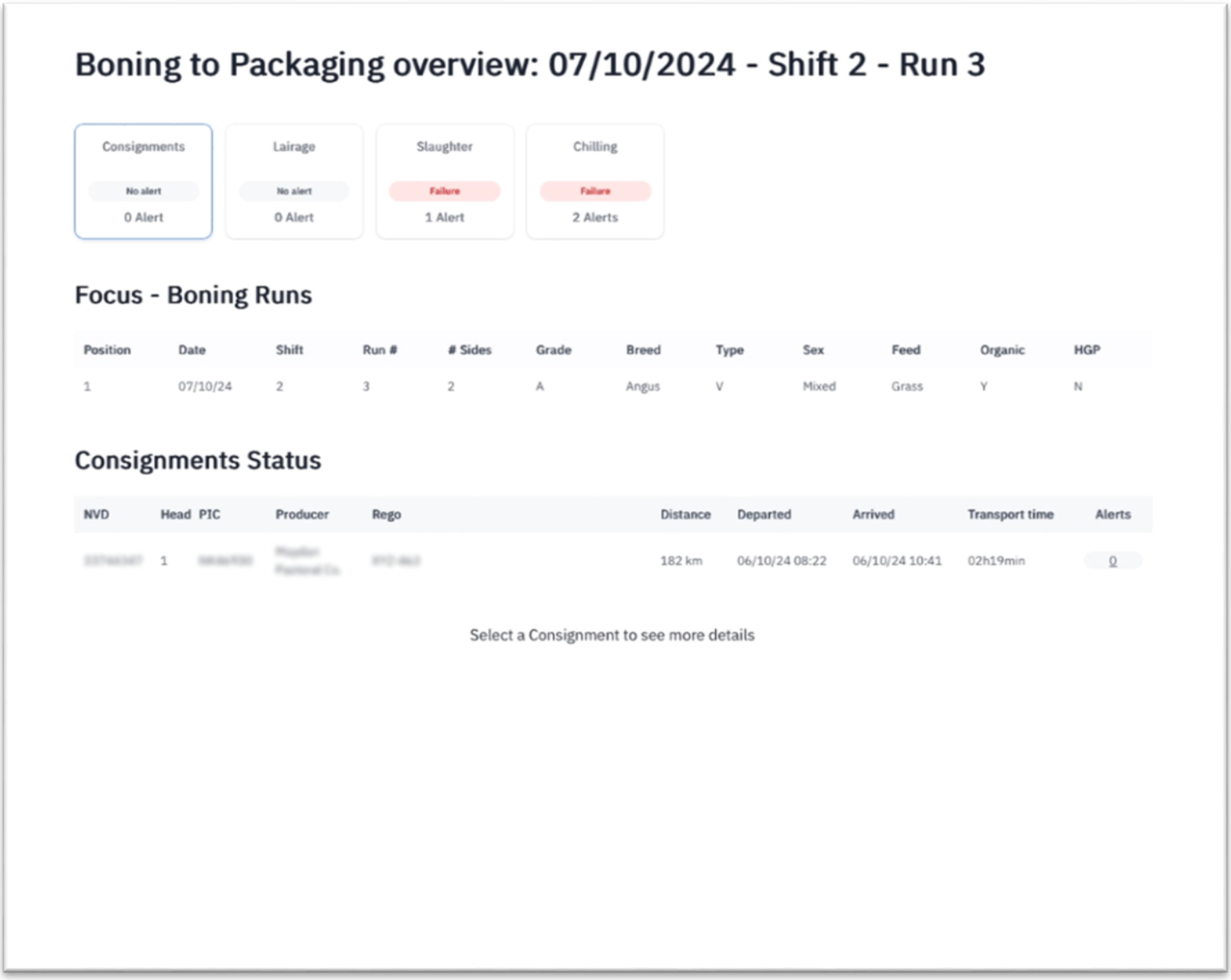


Figure A 26. Boning to Packaging - Consignments module for boning run focus

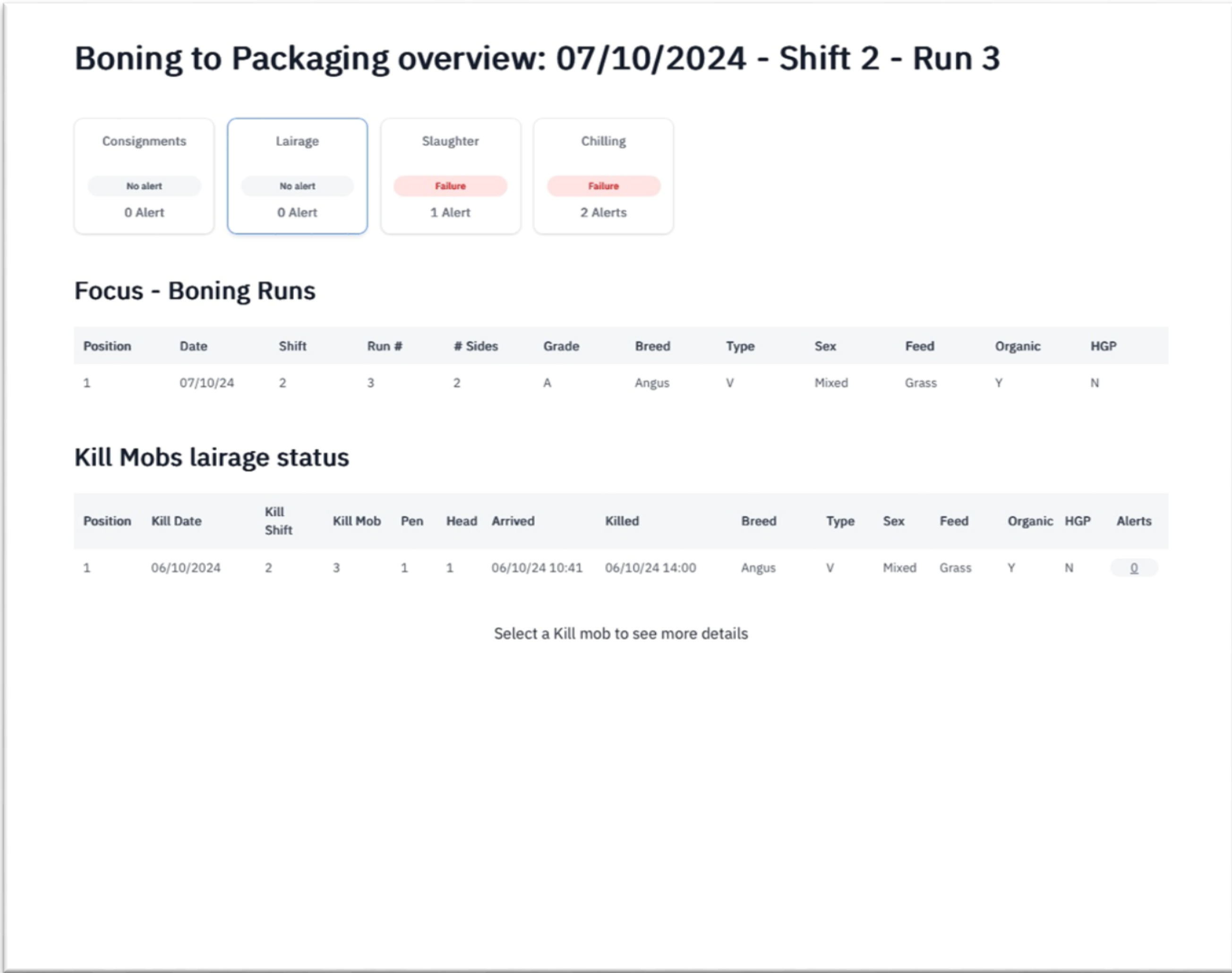


Figure A 27. Boning to Packaging - Lairage module for boning run focus

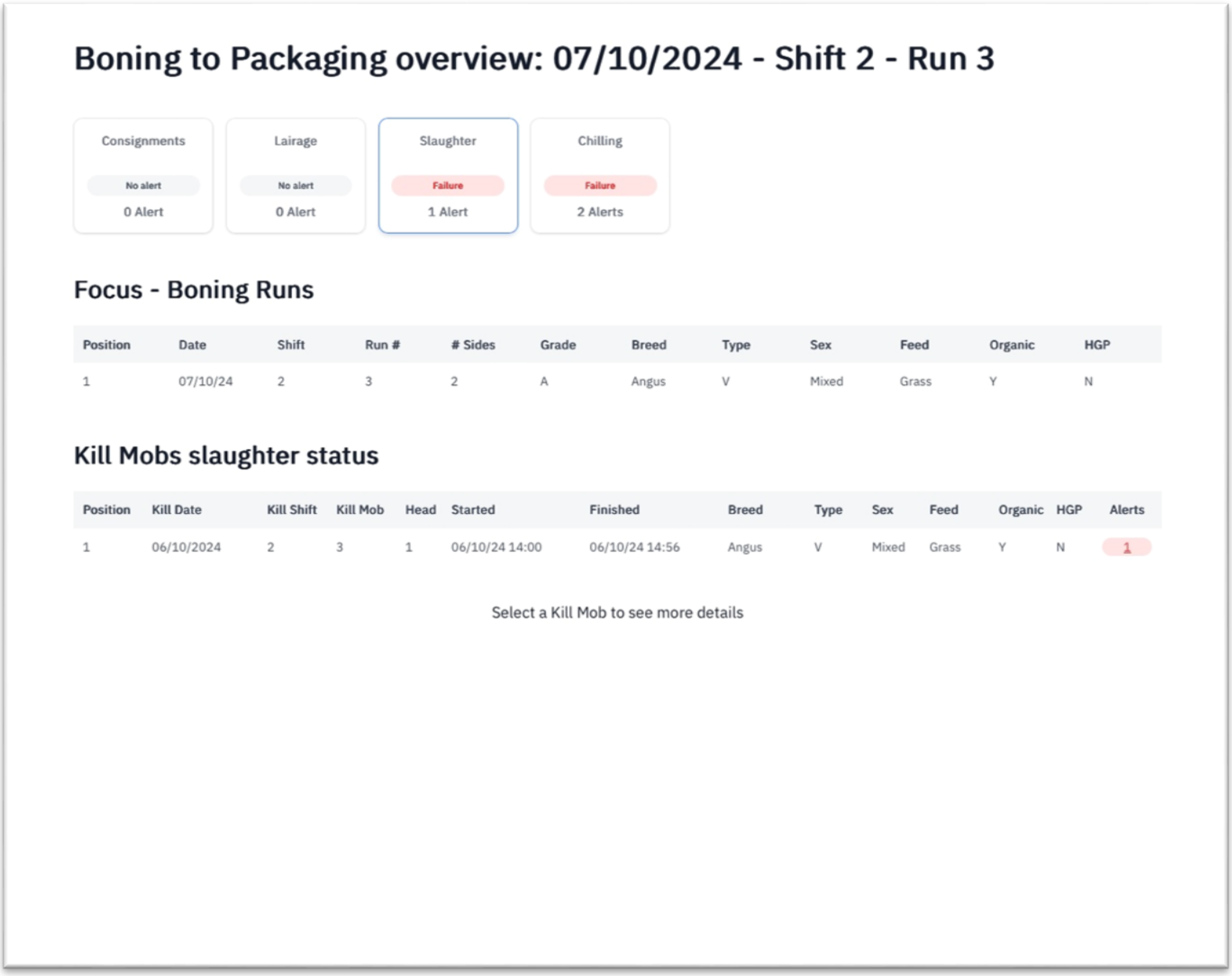


Figure A 28. Boning to Packaging - Slaughter module for boning run focus

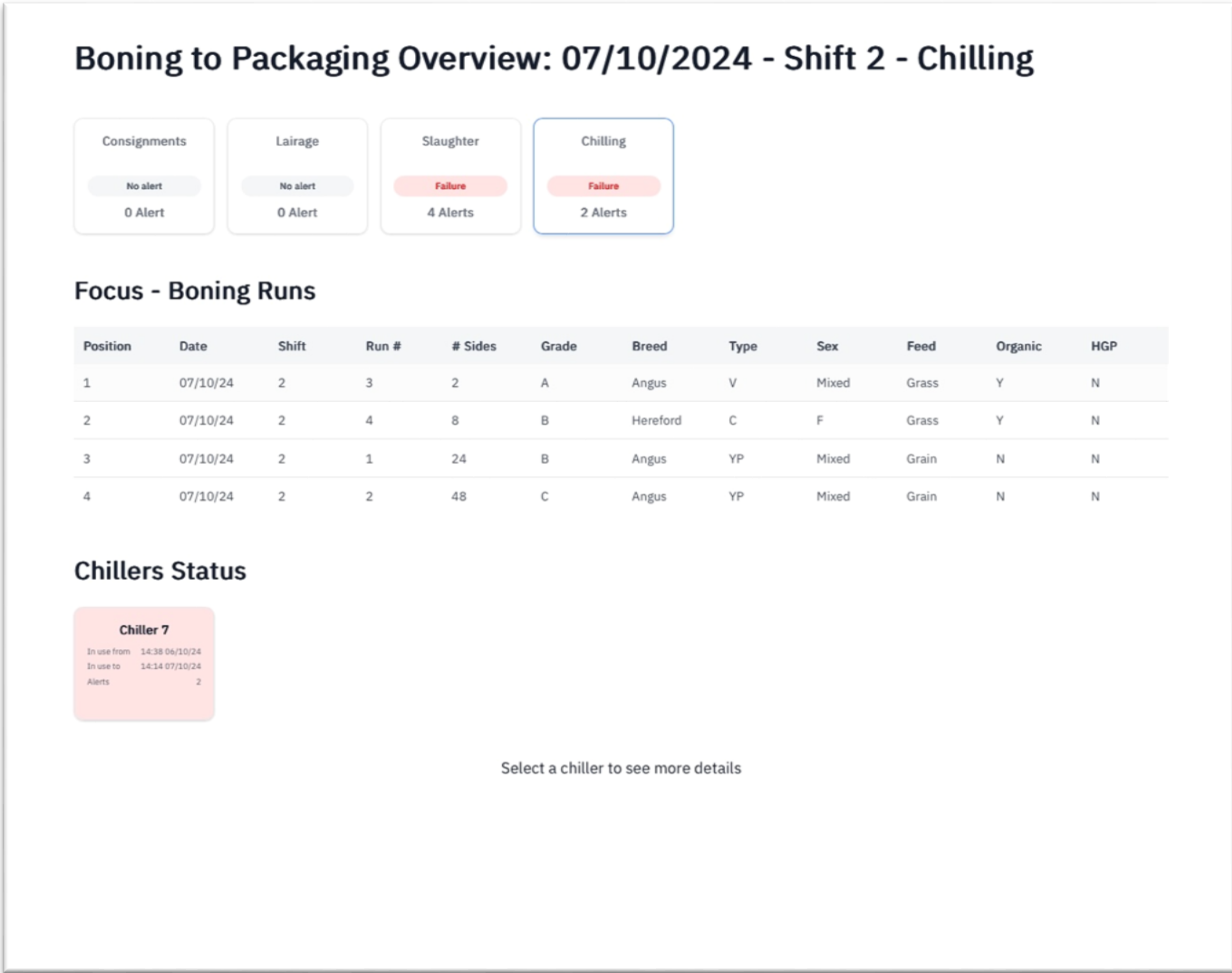


Figure A 29. Boning to Packaging - Chilling module for boning run focus

We briefly mentioned that in the Plant Compliance Trends investigative mode, that a particular compliance failure can be selected for view. The corresponding screen, shown in Figure A 30, has the same layout and operation as the monitoring modes but the focus in this particular case is the resource that the compliance failure is associated with and the forward and backward traceability “graphs” that includes this entity. The particular failure shown in Figure A 31 has a complicated traceability graph that includes elements that are not visible in any module on the user interface in the prototype, though would be shown with the addition of Boning, Packaging, and Testing modules. An STEC failure is associated with a microbiological testing lot that comprises a number of boxes of trim product, typically several hundred. The associated boxes of trim can be traced back to a set of carcase sides based information about carcase to boning room entry times. Once the carcase sides have been determined then boning runs and kill mobs can be identified, and, from kill mobs, consignments. A 32 to A **34** show the module views with this particular failure as a focus.

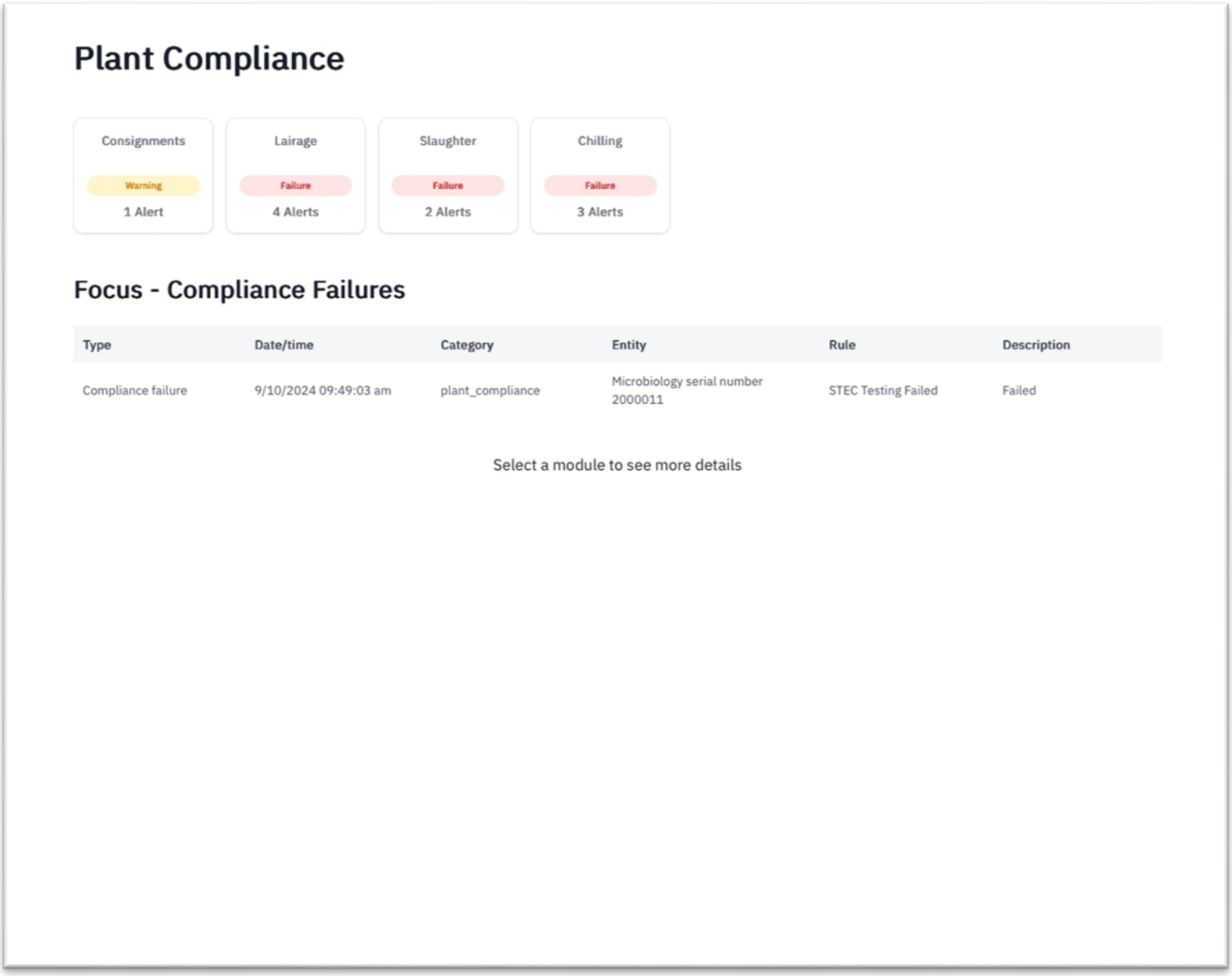


Figure A 30. Investigative mode compliance failure focus

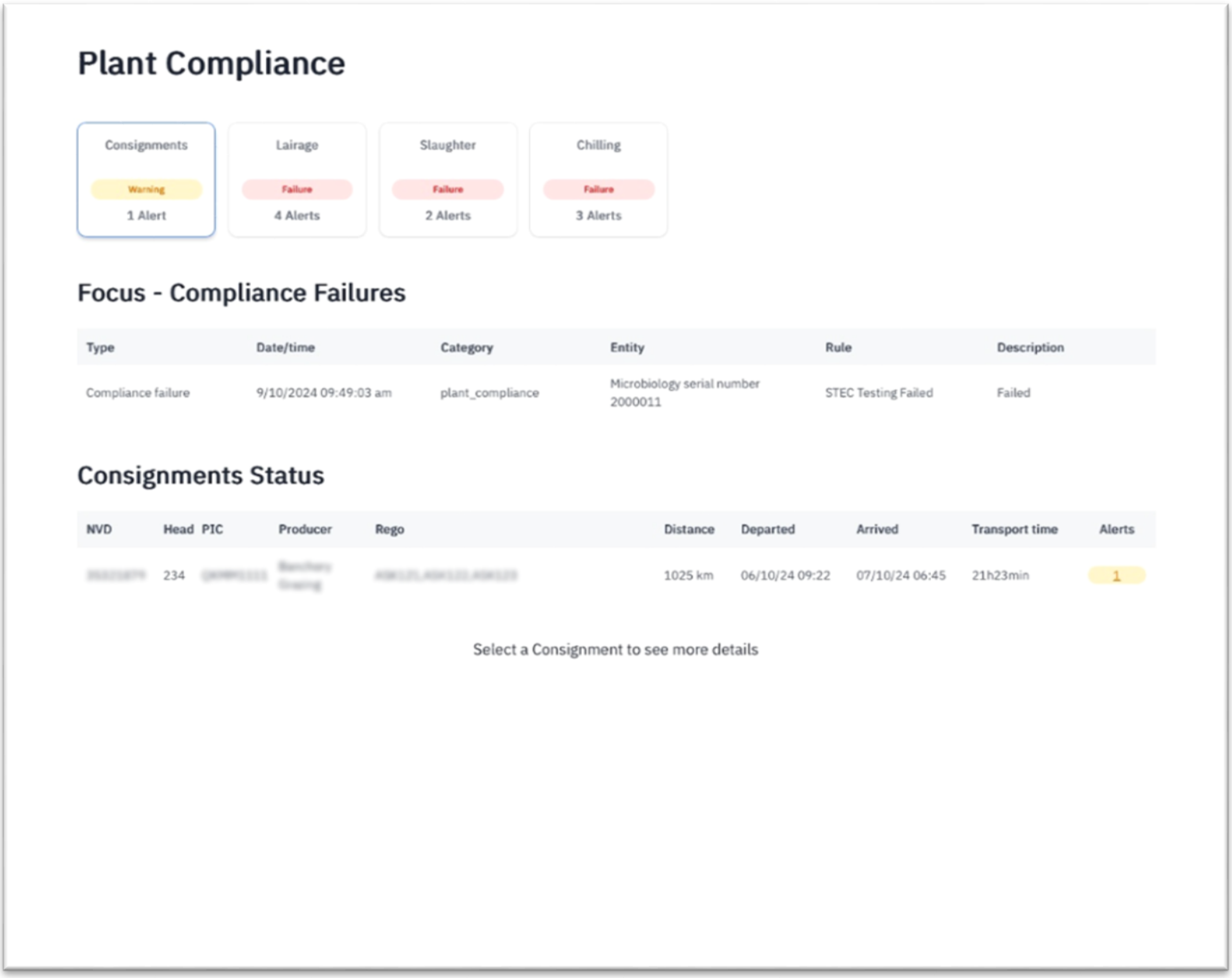


Figure A 31. Investigative mode Consignments view for an STEC compliance failure focus

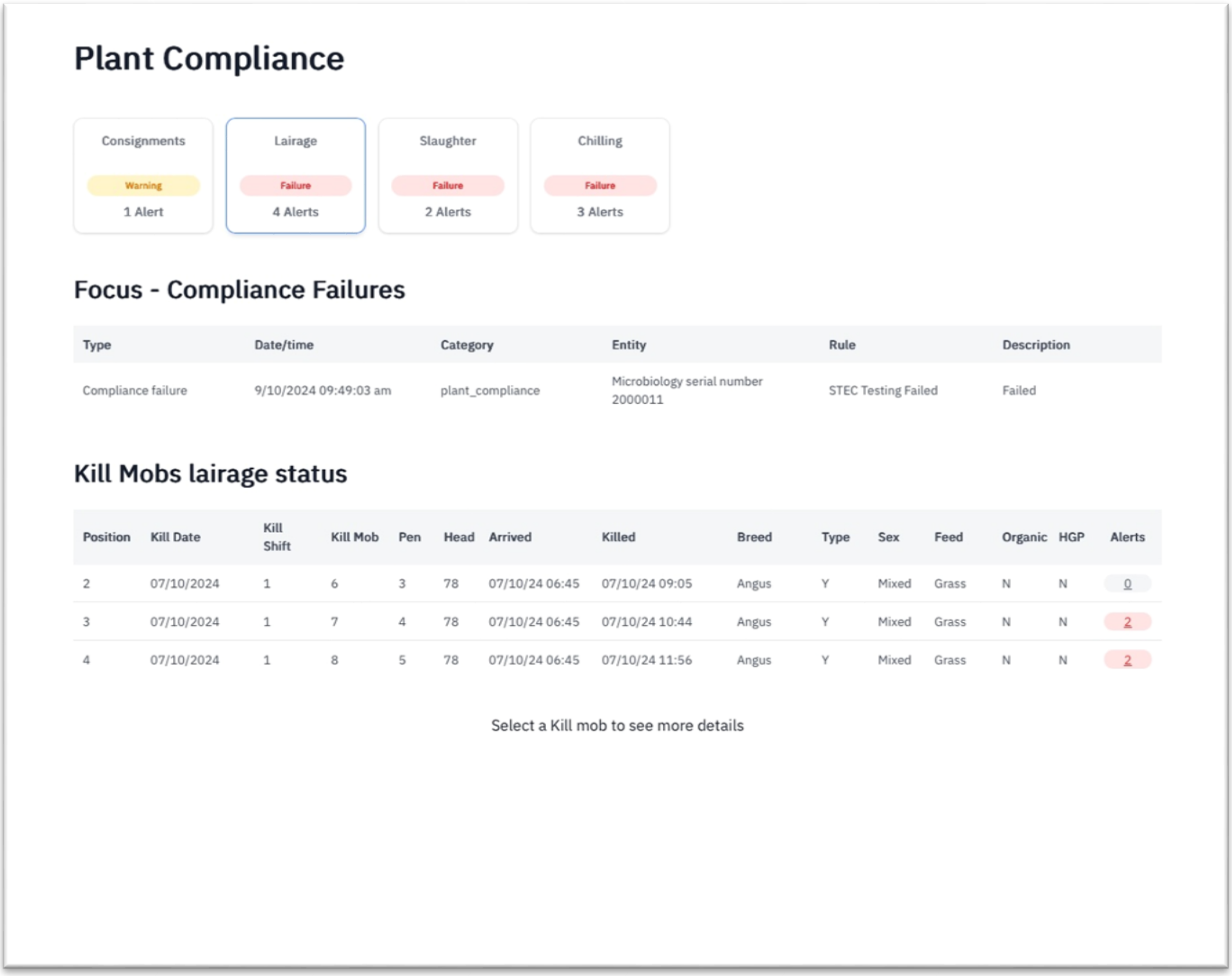
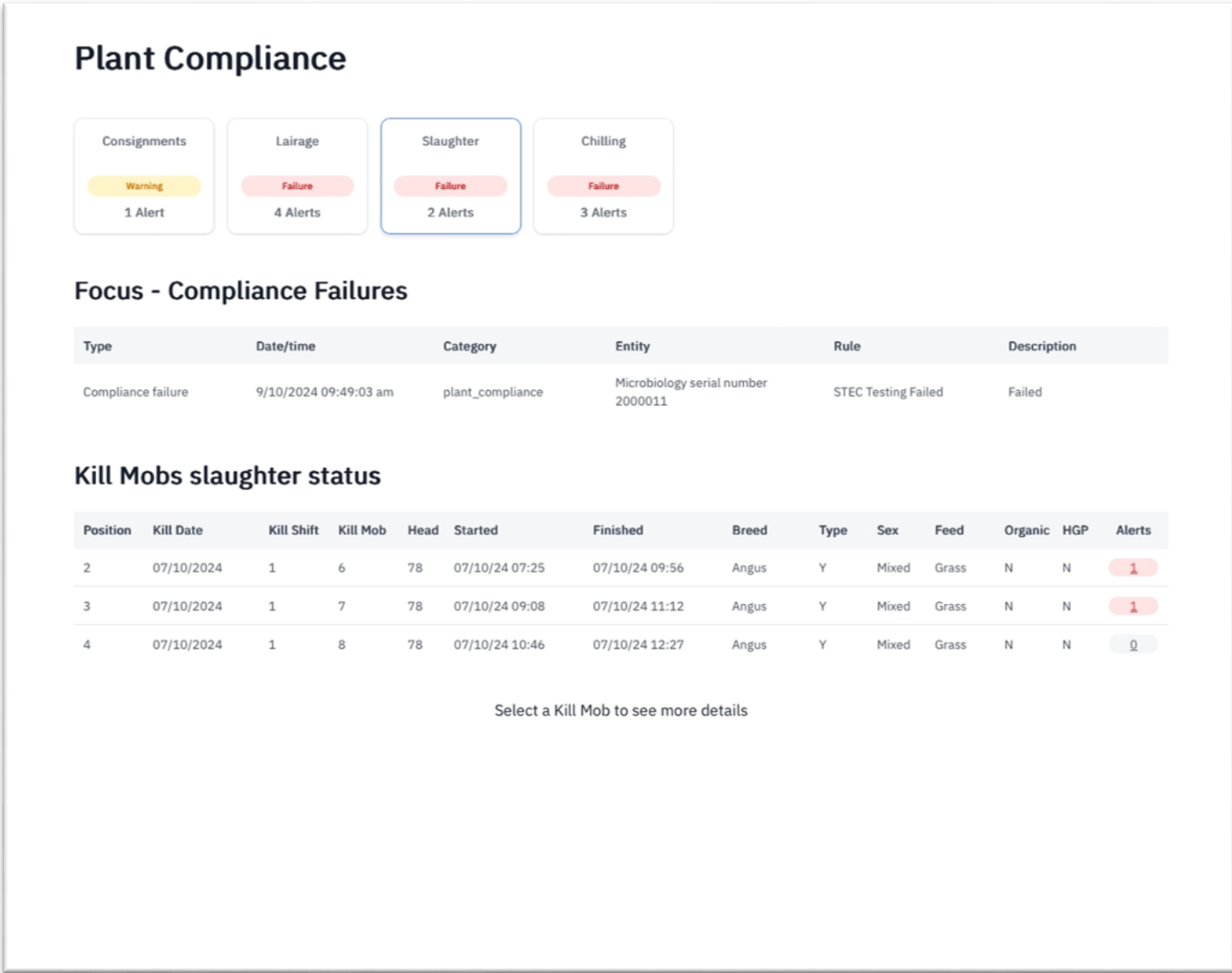


Figure A 32. Investigative mode Lairage view for an STEC compliance failure focus



Type	Date/time	Category	Entity	Rule	Description
Compliance failure	9/10/2024 09:49:03 am	plant_compliance	Microbiology serial number 2000011	STEC Testing Failed	Failed

Kill Mobs slaughter status

Position	Kill Date	Kill Shift	Kill Mob	Head	Started	Finished	Breed	Type	Sex	Feed	Organic	HGP	Alerts
2	07/10/2024	1	6	78	07/10/24 07:25	07/10/24 09:56	Angus	Y	Mixed	Grass	N	N	1
3	07/10/2024	1	7	78	07/10/24 09:08	07/10/24 11:12	Angus	Y	Mixed	Grass	N	N	1
4	07/10/2024	1	8	78	07/10/24 10:46	07/10/24 12:27	Angus	Y	Mixed	Grass	N	N	0

Figure A 33. Investigative mode Slaughter view for an STEC compliance failure focus

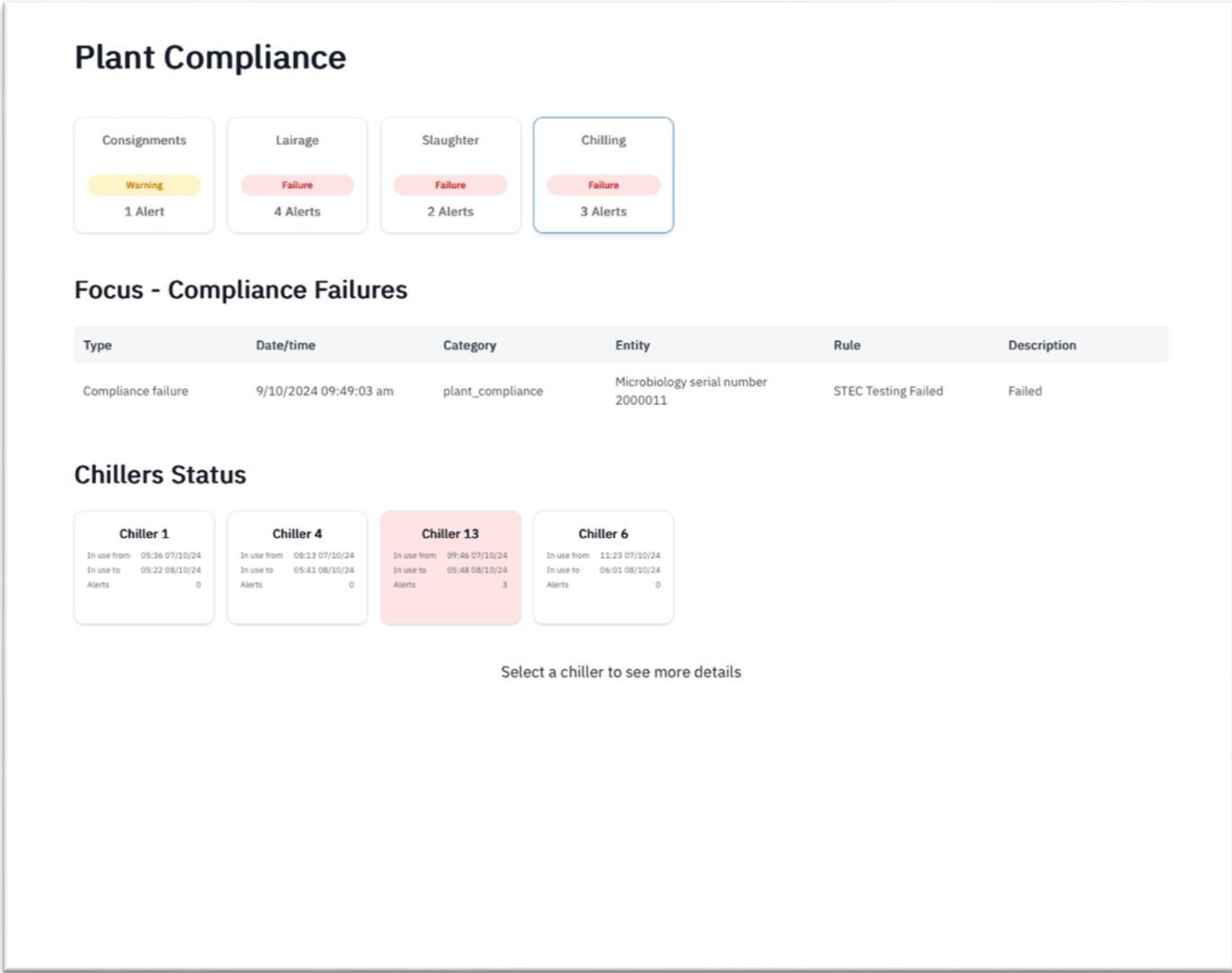


Figure A 34. Investigative mode Chilling view for an STEC compliance failure focus