DAIRY GOAT RESEARCH FACILITY:

Revealing Process &

Provoking Interactions

by

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A thesis
presented to the University Of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Architecture

Waterloo, Ontario, Canada 2021

AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

ABSTRACT

The dairy goat industry in Ontario is in need of benchmarking data on the raising and caring for goats resulting in better welfare and production. The power of collective data cannot be overstated to benefit and advance the industry as seen in Ontario's dairy, swine and poultry industries. The goal of this thesis is to create a framework for the design behind a research facility dedicated to dairy goats with the animals as the main priority. As a dairy goat farmer and an architecture graduate student, I believe my experiences and knowledge in agriculture and architecture have given me the tools to understand the particularities of goats and how their environment may affect them. The research studies on goat behaviour and welfare analyzed in this thesis, encompass a range of aspects from understanding social needs, and evaluating adaptable behaviour, to assessing the performance characteristics of materials and housing components. Drawing from Dr. Temple Grandin's research and methods when designing for animals, starts with collecting data, both facts and statistics that come from behavioural studies along with personal observations, then categorizing the data. The studies and observations on goat behaviour are then used to re-design elements that are essential to dairy goat farming and thus forming the program for a dairy goat research facility. The emerging designs for the Dairy Goat Research Facility embody an integration of goat behaviour research, farm culture and industrialization, and sustainability.

ACKNOWLEDGMENTS

I would like to thank my supervisor Val Rynnimeri for his guidance and unwavering support. To my committee member Jane, who encouraged me in the early days of TRD1 to push the envelope and have fun designing for goats. Thank you for your insightfulness and enthusiasm. Thank you to John McMinn for his encouragement and thoughtful comments throughout the development of the thesis and the final review. Sarah Gunawan, thank you for your attendance during my final review. Your fresh perspectives and critical feedback both challenged and enriched my understanding of my design work.

To Rick Haldenby I would like to extend my sincerest thanks for your unwavering support throuhout my time studying at Waterloo. From the incredible experience in Rome to the enduring confidence in me that helped me complete this thesis.

To my best friends Claire and Maddi. Without you I never would have survived undergrad. I cannot express enough gratitude for the support, laughter and love you both bring to my life, even from afar, that helped me push to the end of this thesis. Your friendship continues to inspire me.

To my husband, Bruce. I am continuously grateful for your unconditional love and support. Your work ethic and passion was an inspirational force behind this thesis. A huge thank you to my family, especially my Mom and Dad, for your unwavering support, love and understanding throughout all my years at Waterloo. I would not be where I am today without your constant encouragement and uplifting determination.

DEDICATION

And of course...to all of the goats I have and continue to cherish under my care.

TABLE OF CONTENTS

List of Figures

PART ONE: INTRODUCTION

PART TWO: GOAT BEHAVIOUR

PART THREE: APPROACHES

PART FOUR: PROGRAM

PART FIVE: DESIGN

CONCLUSION

APPENDICES: APPENDIX A

APPENDIX B

APPENDIX C

"If we're interested in animals, then we need to study animals for
their own sake, and on their own terms, to the extent that it's possible.
What are they doing?
What are they feeling?
What are they thinking?
What are they saying?"

Temple Grandin,
Animals in Translation, 2005

part one

INTRODUCTION

Ontario's dairy goat industry is a growing agricultural sector that seeks to move in a direction that allows it to emphasize animal welfare and a more integrated community. On the other hand, livestock research centres are nowadays an industrial facility with a lot of demands regarding both technological processes and indoor environments. The strong contrasts between food production as a cultural function and food production as an industrial product, resonates with the current design of livestock research facilities. Our needs and day to day activities have been perceived as separate from the cultivation and production of food causing the processes and systems of food to become invisible. These two poles do not exclude each other, but they can mutually complement and create integrated solutions where the technical and social demands inform the architecture during the design process. Food production from livestock can be understood and challenged in a number of ways, from an almost scientific approach with research and new technology orientated to maximize efficiency, to a merely tactile and poetic attitude in the perception of rolling grass hills with animals grazing. The unique behaviour of goats allows for imagination and greater interaction within built environments.

The goal of this Masters Thesis is to strengthen the design process of our food system for livestock handling, as a manifestation of a set of social and environmental conditions within an agriculture setting while integrating cultural functions. Using precedents, goat behaviour research, and design explorations, this work seeks to challenge the notion of separation between producer and consumer within the food network, with architecture as the medium for communicating transformed ideas about our relationships with food production, to the building inhabitants, and to the public at large.

The thesis demonstrates through the development of key elements of the herd management, research and public areas of a potential research facility, that these elements can act as a catalyst for community, sustainability, and research. The architecture of the facility aims to be clear and honest in its expression prioritizing function and welfare over aesthetics, providing carefully designed agricultural experiences for the visitors, employees, and animals, while the production itself is efficient and functionally organized. As well, the local land must be respected but refined with an innovative approach to benefit the comfort and efficiency of the building by pushing the ground plane to be more than just a flat surface.

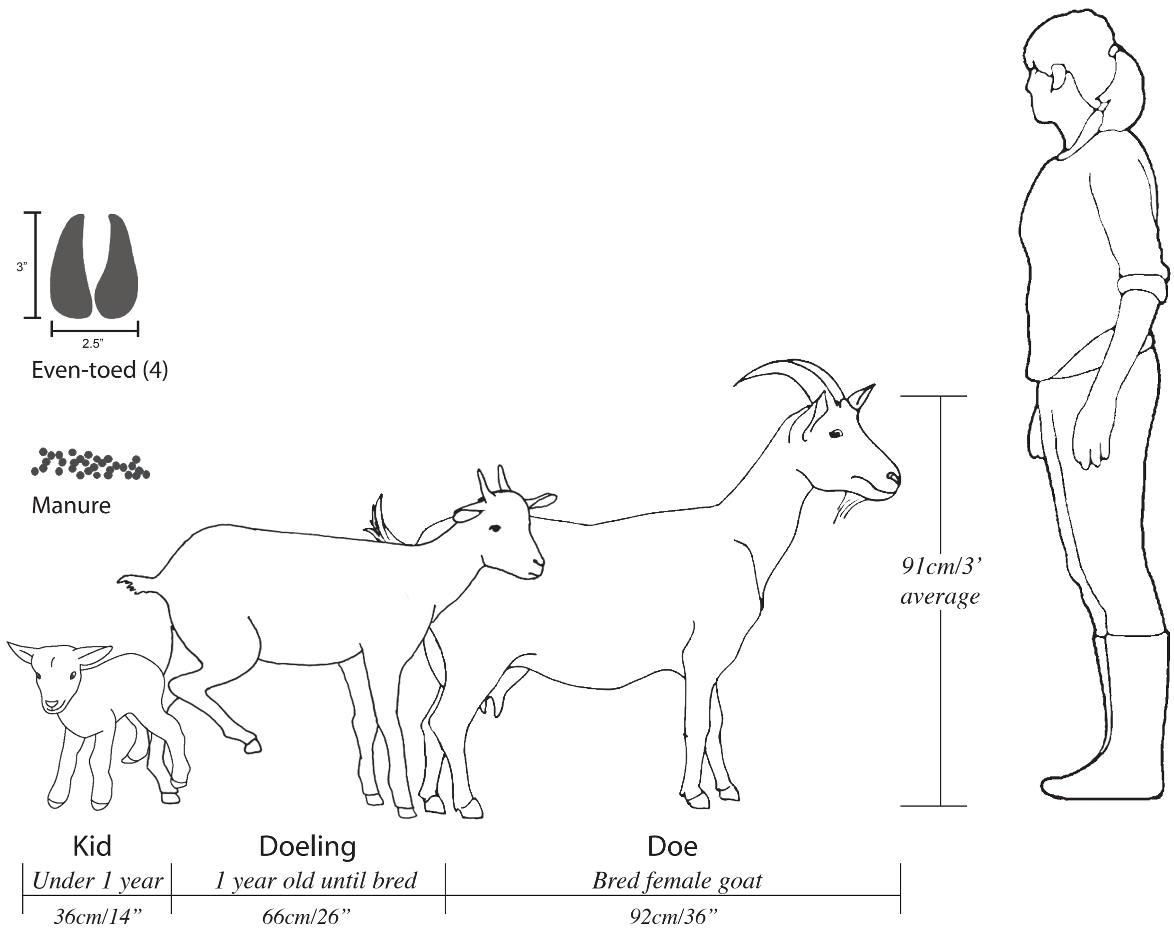

Figure 1.1 *Goats are horned mammals belonging to the Capra genus. They are one of the oldest animal species domesticated by man. A typical goat weighs between 44-130lbs (19-140kg) and has a lifespan of roughly 15-18 years. A goat’s average size through it’s common life stages in farming practices is shown above along with their manure type.*

A steady demand for goat milk, cheese and other dairy goat products have stimulated the further professionalization of the dairy goat industry in Ontario. There are approximately two-hundred and sixty commercial dairy goat farms in Ontario, according to the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). Yet, there is no research facility for the goat farming community. In 2009, a government feasibility study was undertaken in response to requests from Ontario goat producers for a 'Dairy Goat Research Centre of Excellence'. The need and demand for a goat research facility has been an ongoing issue in Ontario as the demands for dairy goat products rise. In 2010, Ontario dairy goat farmers produced thirty million litres of goat milk and five years later, in 2015, forty-three million litres of goat milk was produced.[1]

The feasibility study and research of the importance and need for a dairy goat research facility has been done many times over. But we cannot continue to just take the already established design of a dairy cow facility, shrink it to fit goats and expect it to function efficiently, as seen in many dairy goat farms in Ontario operating today. This is an opportunity to design a facility that is able to respond to and reflect the particular behaviour and energy of goats. As seen in Figure 1.1, the size and the two-toe hoof shape of a goat makes them sure-footed and agile leading to the aptitude for climbing and jumping.

The agricultural industry, like other sectors of the economy, relies on market growth for continued prosperity. No longer is it enough to simply produce. The industry must also seek to diversify production and processing activities with an eye to the market. Price and taste have long been the most important decision factors for the majority of consumers when choosing food. However, there are some notable factors driving consumer preferences that can influence new product development and product acceptance: shifting demographics, convenience, environmental stewardship, and desire for more information about food. Shifting demographics, precipitated by aging baby boomers, the growing purchasing power of millennials, and increased ethnic diversity, are contributing to changing food preferences.[2]

These factors are influencing trends toward food products with enhanced nutrition, ethical food choices (such as animal welfare and fair trade), environmentally sustainable diets, as well as new taste profiles. Opportunities abound for the creation of new markets, establishment of partnerships and exploration of crowd-source funding investments.

1 Canada, Agriculture and Agri-Food. 2019. "Goat Milk Production by Province." Dairyinfo.gc.ca. August 12, 2019. https://dairyinfo.gc.ca/eng/dairy-statistics-and-market-information/farm-statistics/milk-production-at-the-farm/goat-milk-production-by-province/?id=1502473181675.

2 "State of the Ontario Goat Industry." n.d. Www.omafra.gov.on.ca. Accessed November 7, 2018. http://www.omafra.gov.on.ca/english/livestock/goat/facts/14-019.htm.

Figure 1.2 *Goats in typical indoor housing with straw bedding and trough feeders for grain. Milking parlour visible in background.*

Figure 1.3 *The most common perception of a typical wild goat in mountainous landscapes.*

Relevance

Achieving high production in goat agricultural practices involves specialized management, usually in enclosed barns with large group sizes, and homogeneous bedding and feed. This is incompatible with how goats navigate their natural habitats by employing complex foraging and social skills within small intricate groups based on steep, rocky, and often nutritionally challenging terrain. These conflicting environments are demonstrated in Figures 1.2 and 1.3 where our impression of a goat's habitat is starkly different from typical farm housing. In the habitat, goats are climbing steep and rocky terrain, bounded by no fences or concrete walls, and able to forage anything and everything in sight. In the housing, there is nothing meant for them to climb, and feed is accessed in the same place day in and day out.

As a goat's welfare is based on a balance between physical health, positive experiences, and opportunities for natural adaptations, decreasing the mismatch between the behaviour they can express in current husbandry systems and the behaviour and traits they developed to survive in their natural habitat, would be important to achieving this harmony. Yet, commercial dairy goats often live in barren environments, unable to form stable social relationships, and on the opposite side of the spectrum, pet goats may experience a solitary and confined life.

Given the size of commercial dairy systems around the world (e.g., Netherlands, 596 farms, mean 427 goats/farm; New Zealand, 72 farms, mean 650 goats/farm - Prosser and Stafford, 2017; Ontario, Canada, 206 farms, mean 407 goats/farm, hundreds of thousands, if not millions, of goats could benefit from such improvements.[3]

3 Zobel, Gosia, and Christian Nawroth. 2020. "Current State of Knowledge on the Cognitive Capacities of Goats and Its Potential to Inform Species-Specific Enrichment." Small Ruminant Research 192 (November): 106208. https://doi.org/10.1016/j.smallrumres.2020.106208.

Background

In 2014, Hewitt's Dairy, Ontario's oldest family-owned and operated dairy, was sold to Gay Lea Foods, the second largest dairy cooperative in Canada. Michael Barrett, president and CEO of Gay Lea, said at the time that the dairy cooperative believes there is a growing market for goat products and saw Hewitt's as one of the leaders in the segment. For farmers, this verified the increase in goat milk demand in North America.[4] In Kingston, Ontario, a $225-million infant formula factory by China's Feihe International, will create an even greater demand for dairy goats to meet their global economic needs. The infant formula factory in Kingston will begin by using excess skim milk quota to produce its product and within five to seven years later, it will incorporate goat milk. During that time, Ontario will need to establish the goat milk production to meet the factory's demand. Surrounding rural areas are excited as the plant is expected to require seventy-five million litres of goat milk, creating a huge economic opportunity.[5]

Training and education will need to be a priority for not only Canada, but also the Province of Ontario, to take advantage of the Feihe opportunity and many more to come. The steadily growing goat milk market in Ontario is apparent and will need more training and research to help propel the existing markets and those to come. A steady increase in the construction of new livestock research in Ontario responds to the demand and growth of Ontario's agricultural industries. So why not goats?

Ontario livestock research facilities are one category in a range of research stations and infrastructure operated by OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs), ARIO (Agriculture Research Institute of Ontario), and the University of Guelph/OAC (Ontario Agriculture College). Research stations provide extension roles and teaching demonstrations, and conduct research on new practices for recipient farms and students. OMAFRA and U of G partnership research projects have access to thirteen animal research stations and seven crop research stations, with many of the newer stations open for public tours.[6] The research stations separate the multitude of livestock in Ontario including - poultry, swine, dairy, equine, aquatic, and ruminant, as each have different biological makeups that need a facility designed to meet those differences.[7] The design of each station must provide flexibility for meeting multi-disciplinary needs through the collection of data and samples. Innovative facilities benefit research, education, training needs, and the priorities of the Ontario and Canadian livestock sectors ensuring a strong and vibrant future for the agri-food industry.

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4 The Hamilton Spectator. 2014. "Hewitt's Dairy Sold to Gay Lea Foods," October 16, 2014, sec. Business. https://www.thespec.com/business/2014/10/16/hewitt-s-dairy-sold-to-gay-lea-foods.html

5 "Feihe International Baby Formula Plant, Kingston, Ontario - Food Processing Technology." n.d. Www.foodprocessing-Technology.com. Accessed October 30, 2018. https://www.foodprocessing-technology.com/projects/feihe-international-baby-formula-plant-kingston-ontario/.

6 "Research Stations | Ontario Agricultural College." n.d. Www.uoguelph.ca. Accessed April 30, 2021. https://www.uoguelph.ca/oac/research/research-stations.

7 Weichbrod, Robert H, Gail A Thompson, and John N Norton. 2018. Management of Animal Care and Use Programs in Research, Education, and Testing. Boca Raton, Fl: Crc Press.

Any livestock research facility must also enable the maintenance of research animals free of unwanted and unacceptable diseases, and chemical and biological contaminants, while fostering a steady-state existence in which they are subjected to minimal stress and environmental fluctuations. In the 1960s, livestock behaviour was researched as just behaviour, an approach known as behaviourism. The approach minimzed the personality in aminals and handlers and was devoid of emotion and feelings, relying heavily on the subject's conditioning. Dr. Temple Grandin, a prolific animal scientist based in Colorado, challenged this way of looking at animals through her own struggles with autism. She recognized her own behaviour was not only coming from her environment. She argued that animal instincts, which are hardwired behaviour patterns an animal is born with, operate no matter the environment and are heavily based on prey versus perdator instincts. Her research on cattle behaviour revolutionized the animal's experience in feedlots and slaughterhouses by connecting the animal's instinctual behaviour with changes to something in the environment, thus lessening stressful situations for both the animal and the handler.[8]

Dairy cow farming has been established in Ontario and North America for more than a hundred years.[9] The dev elopment of infrastructure designed and built for cows is now very well known that the Livestock Research Centre of Excellence in the town of Elora in southwestern Ontario, near Guelph, was quick in its progression from a need to update an existing dairy cow facility to a newly built infrastructure opening in 2015.[10] Everything is standard within the research centre and dairy cow facilities as a result of the industries long history. Naturally, this leads to a notion that a dairy goat facility can be designed simply by reducing the size of a cow facility - the livestock are both producing milk and require similar feed such as grain and grass. Note Figures 1.4 and 1.5, chosen specifically to demonstrate the similarities in farm housing for two distinct animals. This thesis takes the view that a goat facility has its own nature connected to specific goat behaviour and that by adopting Dr. Grandin's approach and exploration of cow behaviour and the development of her designs, an argument can be formulated and proved with conclusive evidence that a dairy goat research facility should and can be designed around specific behavioural traits of goats.

Since food production of any kind is based first on traditional farming principles and then the adoption and adptation of ongoing new experience, know-how, and advancements in research, an architect's deep understanding of this complex procedure as part of a building and site design process is essential for an appropriate solution for all actors within the goat dairy industry. The fundamental examination in this thesis is how architecture and built form can create an impact on the welfare of animals using Dr. Grandin's research and designs as an example. Although the interests of this thesis may lie with goats, a different livestock and at a different stage of their lives, Dr. Grandin's designs are essential examples of the negotation between a built form and an inhabitant's natural behaviour to create a successful process.

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8 Grandin, Temple, and Catherine Johnson. 2006. Animals in Translation : Using the Mysteries of Autism to Decode Animal Behavior. Orlando, Fla.: Harcourt.

9 Clarke, E H, and Colin L Brethour. 1966. A History of the Toronto Milk Producers' Association, 1900-1966. Toronto, Ontario: Toronto Milk Producers' Association.

10 bsnarchitects.com. n.d. "Dairy Research Centre." Baird Sampson Neuert Architects. Accessed May 1, 2021. https://www.bsnarchitects.com/dairyresearchcentre.

Figure 1.4 *Common zero-graze dairy goat barn where goats are house indoors all year round and are fed grass clippings and nutrional supplements from a central feed alley. Note the goats who have obvisouly escaped their pens and are loose in the feed alley (a constant frustration for dairy goat farmers).*

Figure 1.5 *Common dairy cow barn in Ontario with a central feed alley accessible by head gates. Width of feed alley determined to allow large equipment for feed distribution.*

Context

Architecture affects how humans perceive spaces and how we think about them (memorable, common, special). Research studies by animal scientists in Europe and New Zealand have been conducted to better understand a goats behaviour within their own built environment. These studies demonstrate a goat's reaction to certain materials, layouts, and feeding methods within goat housing and underlie the studies of the physical design of such places in this thesis design work. These design case studies are used to validate my own experience working with goats for the past seven years as part of a family business. In this thesis work, an argument is also laid out beyond that of creating favourable farm spaces for goats, for why research facilities should be more transparent and provide an opportunity to enlighten the public on every day farming practices and areas of research priorities that stem from consumers wants and needs. In the second half of the thesis, an overview of livestock research facilities looks at how they house the animals, integrate the public, and demonstrate the production in an inviting way through their design and construction. Furthermore, a set standard of building performances such as access of daylight, natural ventilation, and temperature control is established. These building standards along with lessons-learned from existing livestock research facilities, and goat research, are brought together in a final design section laying out the integrated design framework for a dairy goat research facility in Ontario.

Thesis Scope and Limitations

This thesis focuses on the more detailed design of goat spaces, with the intention to create a usable framework by which future design and consideration of a dairy goat research should follow with goat behaviour at the forefront of design configurations. The creation of such key components is the main goal of this thesis, therefore, an actual building site was not integrated into the final thesis design work. Site options were explored in early stages of the thesis work and site plans can be found in Appendix A along with specific site considerations for pasture rotation and site access by both public and large equipment. As part of the study of a potential site and development of a site plan, a collection of case studies on wineries was prepared to provide examples of design dedicated to forming an experience that connects the consumer to the product: wine. These case studies can be found in Appendix B.

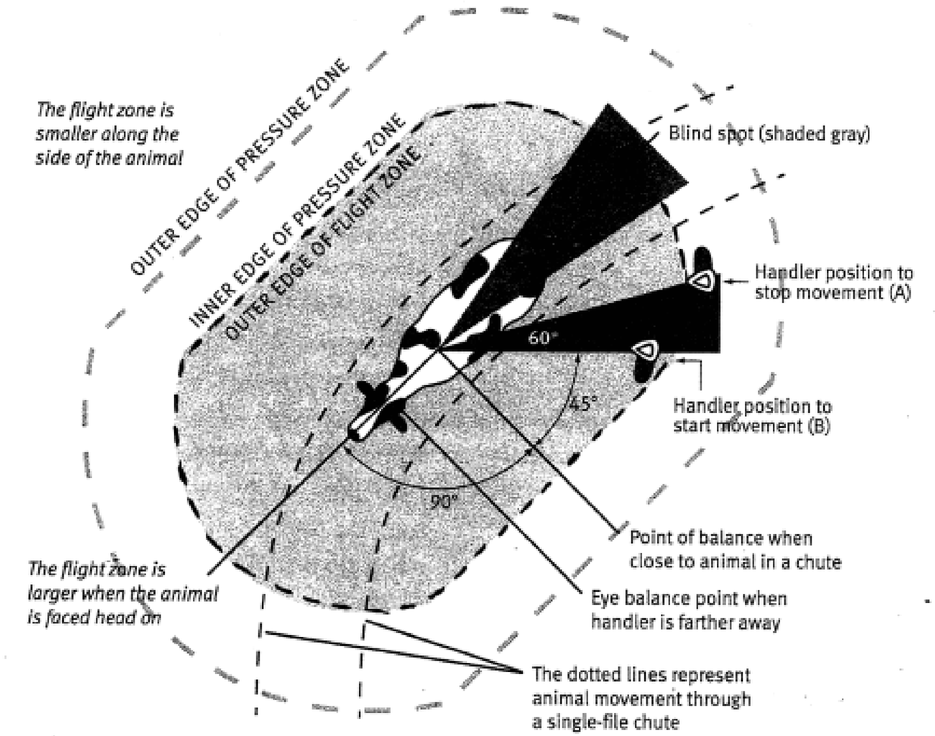

Figure 1.6 *A cow's flight zone and point of balance. The curved dashed lines represent a chute and how the cow perceives its surroundings. This is diagram is especially useful for training handlers to move cows through chutes. The animal will move forward when the handler moves into a position behind the point of balance at the shoulder.*

Figure 1.7 *By looking at facility environments through the eyes of a cow, Dr. Grandin was able to identify small environmental changes that could effect a cow's instinctual behaviour. When a cattle moves as a herd they move in a circle to maintain their line of vision as demonstrated in the photo on the left. When cows move indoors, shadows and bright objects may startle them and keep them from moving forward, compelling handlers to use force.*

Livestock Research

When Temple Grandin started her graduate degree in animal science from Arizona State University in 1975, behaviourism was the focal point of animal studies. Much of the research dealt with rewarding good behaviour and punishing bad behaviour. If the animal passed the tightly constrained test a reward such as a treat was given, but if the animal failed the test or cheated, a punishment was laid. Grandin claimed this to be an artificial way of tracking animal behaviour as their behaviour in labs could never truly replicate their behaviour in a natural environment. She then decided to study visual illusions in animals. She herself identifies as a visual thinker as she thinks in pictures and not words. Her focus on the visual environment changed the point of view of the researcher from a lab to walking through the environment from the animal's point of view. By doing this Dr. Grandin began to notice how shadows, as seen in Figure 1.7, dangling chains, and bright colours would startle the cattle and keep them from moving forward through a chute or onto a transport truck.[11]

Livestock behaviour contributes to much of the interactions between handlers and animals within the farm's varying confinement areas. Behaviour is one of the most important early indicators of the welfare of an individual and its adaptation to its environment and reflects the immediate response to the interaction between the animal and its environment. Reducing stress during handling will improve productivity and prevent physiological changes that could confound research results or lower productivity. Handling stresses lower conception rates and reduces both immune and digesting function.[12] Handlers who understand livestock behavior can reduce stress. Grandin discovered this when tackling slaughterhouse through her visual study of the facilities design and found a correlation between animal behaviour and efficiency. She's discovered and investigated many behavioural particularities of cows that added up to a big difference in how cows are treated and handled such as their flight zone and prey behaviour. Figure 1.6 is a diagram indicating a cow's flight zone. With this handlers can approach a cow in a way that encourages movement without having to touch or make noise, reducing stress. Her discoveries led to the design of two inventions used in most feedlots today: the cattle dip vat system and the curved loading chutes.

A cow's natural instinct is to walk in a circle and never in a straight line, as demonstrated in Figure 1.7 where the cows circle an intruder rather than face head-on. One main reason is their vision: cattle have peripheral vision and poor depth perception in from of them. The curved chutes allows the cow to believe they are turning back to where they came from, thus exiting the chutes. Shadows caused by open chutes would startle the cattle and cause them to panic and cease moving forward efficiently. Cows also see in colour and are easily startled by bright colours and even shiny objects. Having the chutes clear of any objects allows the cows to move ahead without pause.[13]

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11 Grandin, Temple, and Catherine Johnson. 2006. Animals in Translation : Using the Mysteries of Autism to Decode Animal Behavior. Orlando, Fla.: Harcourt.

12 Grandin, Temple, J.E. Oldfield, and L.J. Boyd. 1998. "Review: Reducing Handling Stress Improves Both Productivity and Welfare." The Professional Animal Scientist 14 (1): 1–10. https://doi.org/10.15232/s1080-7446(15)31783-6.

13 Grandin, Temple, ed. 2019. Livestock Handling and Transport. 5th ed. CABI.

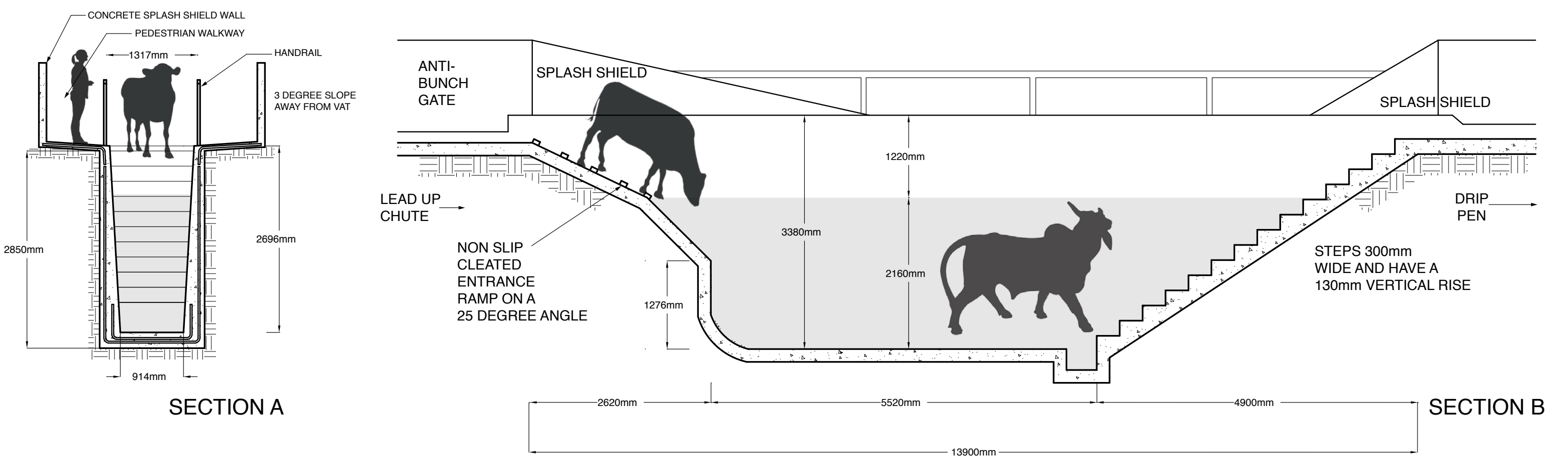


Figure 1.8 *The cattle dip vat system designed by Dr. Grandin who observed existing systems on feedlots and identified the major problems with the design that caused drownings of cattle and excessive handler intervention.*

The Cattle Dip Vat System

Throughout the world, cattle dip vats (plunge dips) are used to kill external parasites. To be effective, the animal must be completely submerged. The 25 degree angle of the ramp orients the animal's center of gravity towards the water, and there is a steep drop off at the end of the ramp that is hidden under the water. The non-slip surface of the ramp encourages the animal to continue walking forward. When the entering animal steps off the end of the 25 degree ramp, it falls in and becomes fully submerged. The cattle continue to move forward and up the steps. The design eliminates the need for handlers forcing the animals head under with poles and the chance of the animal drowning as the vat is only wide enough for one animal to enter at a time. The vat also reduces splashing because the adjustable splash shield prevents wild leaping. Reducing splashing also reduces the risks of chemicals getting on handlers.[14]

14 "Explanation of Dip Vat Entrance Design." n.d. Www.grandin.com. https://www.grandin.com/design/blueprint/enter.dipvat.html.

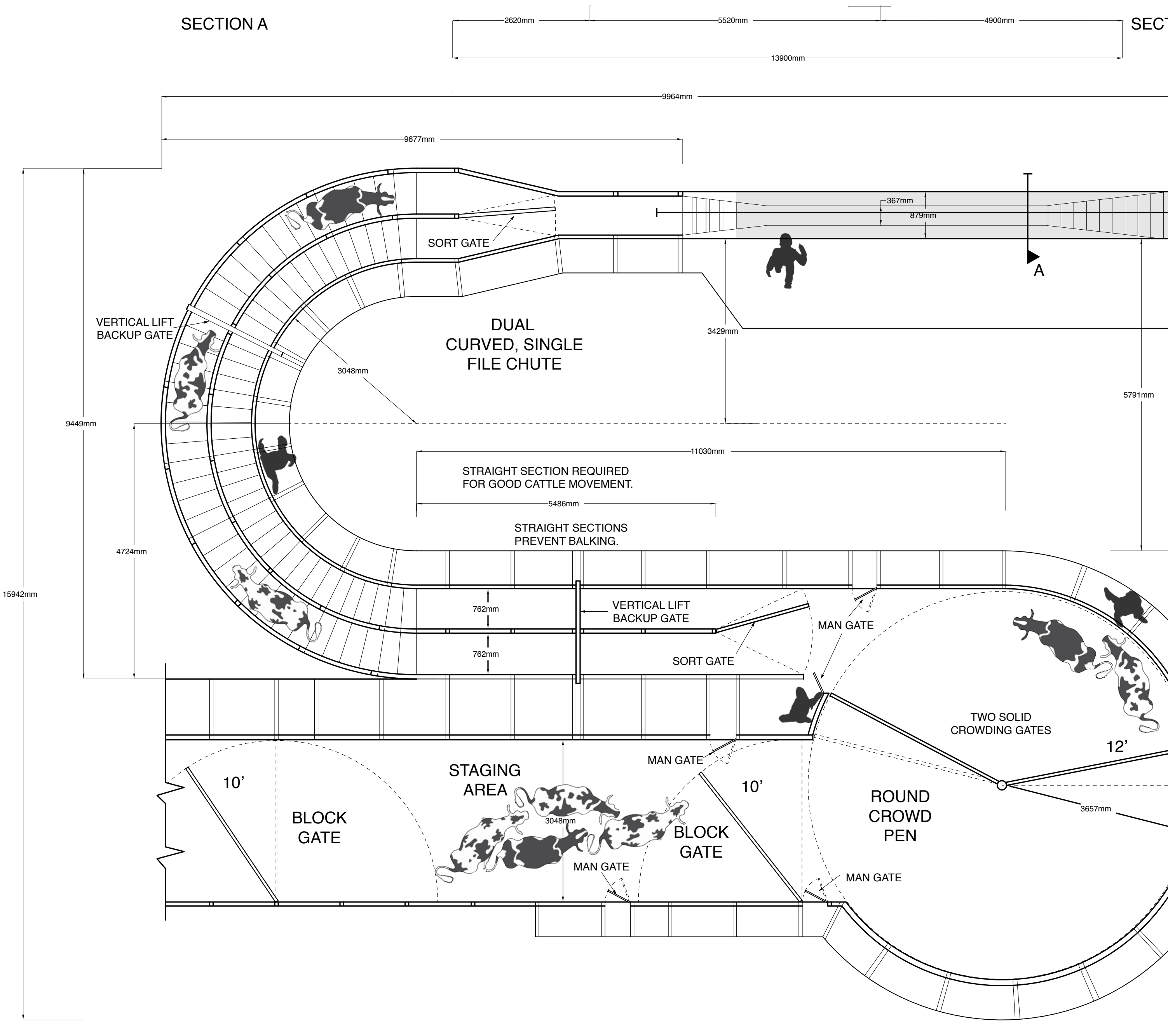
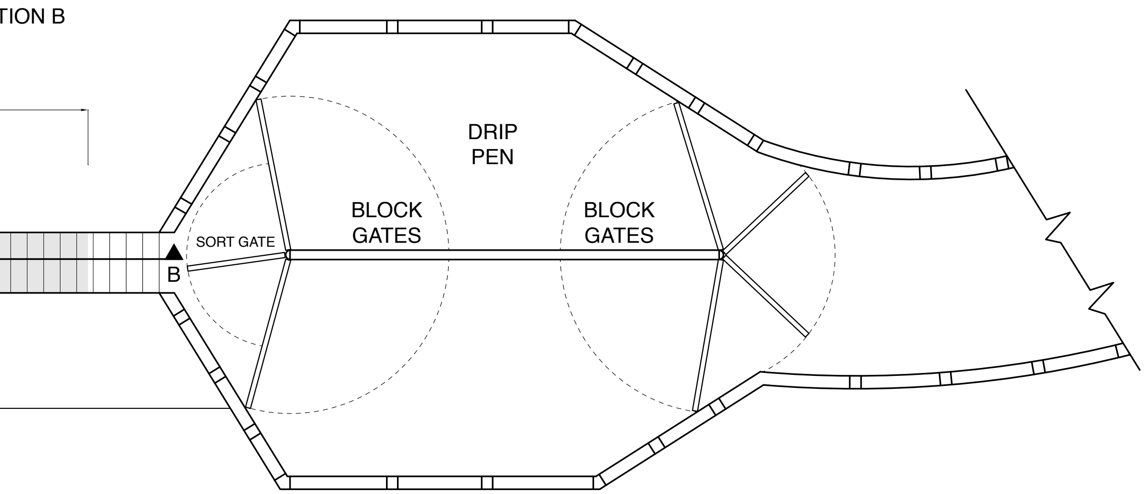
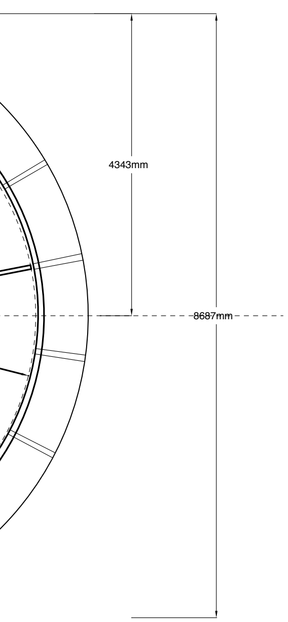


Figure 1.9 *The round pens and chutes capitalize on a cow's peripheral vision. As the cow follows the curve of the pens and chutes, it's able to see its surroundings while framed by a solid wall, feeling secure knowing the full span of its surroundings. Note the handlers walk on the outside of the solid walls that make up the pens and the chutes, and walk in the oppostie direction of the cow. Handlers who are experienced with livestock and understand an animal's flight zone, will find ways to encourage an animal to move without physical intervention or making noise that can stress an animal and make it less likely to cooperate.*





Curved Loading Chutes

The round crowd/forcing pen mimics a cattle's natural instinct to walk in a circle while keeping the operator separate from the cattle and still in full control of movement. By studying a cows line of sight and strength of vision, handlers are able to approach and stand near a cow in a way that forces the cow to move in a certain direction. Walking opposite a cow in a curved chute invites them to move ahead.[15]

Furthermore, the efficiency of Dr. Grandin's designs, which stem from her ability to understand cow behaviour, began a shift of interest into scientic research on domestic animal feelings and emotions beyond just biological and genetic research. The results have spurred efficient designs of cattle facilities we see as typical today that prioriotize the behaviour and experience of the animal. Grandin understood our comfortability in our environment depends on our feelings and emotions and shifted that thinking to include animals as well.[16] The behavioural and emotional research on goats is just starting, and much more prominent in Europe and expanding in New Zealand.

15 Grandin, Temple. 1989. "Behavioral Principles of Livestock Handling." The Professional Animal Scientist 5 (2): 1–11. https://doi.org/10.15232/s1080-7446(15)32304-4.
16 Grandin, Temple, and Catherine Johnson. 2006. Animals in Translation : Using the Mysteries of Autism to Decode Animal Behavior. Orlando, Fla.: Harcourt.

In New Zealand, AgResearch, an organization dedicated to delivering new knowledge and technology to support agriculture, acknowledges the link between farming practices and meeting consumer wants with the best practices in animal welfare and environmental stewardship. New research exploring the moods and personalities of farm animals is approached as an opportunity to better understand and enhance their welfare. The research by Dr. Gosia Zobel and Dr. Jim Webster, looks at how animals respond in new and different situations. It is the latest work by AgResearch's Animal Welfare Team who are dedicated to helping expand the knowledge of livestock behaviour, at a time of growing consumer demand for strong welfare standards. Much of Dr. Zobel's research looks at a goat's behaviour in more natural environments than what they are used to on a typical farm. The study allows the goats to behave in an environment devoid of restrictions to see what behaviour arises. The goal is to explore ways in which those behaviours can be incorporated in a built environment.

In Ontario, researchers and scientists from the University of Guelph are only recently shifting their research focus to goats with an emphasis on improved management standards. Research priorities for the Ontario goat sector over the past three years have been focused on optimizing kid health, lameness, end of life management, and disease control measures.[17] A most recent on-farm study was conducted by Dr. Cathy Bauman, an assistant professor in the Health Science department at the University of Guelph, which looked at kid goat management on dairy goat farms. Around 60 farmers in Ontario were contacted at random, requesting participation in a study that aimed to find the overall mortality rate among dairy goat farmers and reasons why mortality rates were so high. My farm was not asked to take part in the study. Farmers who agreed to participate, were asked to document every kid death and provide the carcass to the University for an autopsy. Farm tours by Dr. Bauman and her team, were also conducted to see the operations up close. The conclusions to the report not only gave health deficiencies in the documented kid mortalities, but environmental reasons for sickness and death amongst kids such as ventilation, pen density, and bedding. The study took three years to complete.

On-farm research studies are the common practice in Ontario with a lack of a dedicated research facility. The current benefits to on-farm research is the investigation of varying practices and standards amongst dairy goat farms and the ability to identify the merits and problems with each. Many farmers such as myself will tour other barns and ask other farmers questions relating to how they manage their herd and deal with challenges we all seem to face when raising and milking goats. Since protocols in place for dairy goats are not as strict and standardized as dairy cow, each farmer has interpreted guidelines differently and found ways to manage goat behaviour that works best for their set-up and available labour. As these on-farm studies and studies from other countries continue to provide evidence that will form a list of best practices, these best practices such as pen size, ventilation and daylight requirements, feed equipment and bedding type, should be demonstrated through built protoypes similar to how Temple Grandin came to design her dip vat and chute systems that are now implemented in 1/3 of all feedlots in North America.

17 Livestock Research Innovation Corporation. 2020. Review of Goat Research Priorities. Edited by Livestock Research Innovation Corporation. Livestock Research. Livestock Research Innovation Corporation. https://www.livestockresearch.ca/uploads/sectors/files/Goat-2019-Research-Priorities-FINAL.pdf.

A study that was conducted in August 2016 at the Ruakura Research Centre in Hamilton, New Zealand, offered feed at variable heights to determine how feed intake and feeding behavior would vary. The goats preferred to eat from a high feeder, about 1.5m off the ground.[18] Normally, goats eat their daily ration at floor level in a feed alley, but the study concluded they ate more when it was elevated. Another study from 2009 conducted at the Agroscope Reckenholz-Tanikon Research Station in Switzherland, tested whether the goat pens with elevated platforms was effective in reducing interruptions in feeding and resting behaviour in small groups of goats. The goats displayed various behaviours choosing to climb the platforms, play on them, and to sleep on and under the platforms. This ability to perform various behaviours resulted in positive feeding and resting.[19] Both behaviours can be derived from a goat's origins in complex natural environments that have equipped them with a sophisticated behavioural repertoire grounded in a series of cognitive capacities. The rocky and often steep terrain that goats inhabit allows for predator avoidance and access to shelter, so it is not surprising that domesticated goats also seek out elevation and hiding spaces. Using these examples, one can argue that to promote good welfare, goats require at least some opportunity to utilize these cognitive capacities. A study by Dr. Zobel and Christian Nawhorth finalized in July of 2020, highlighted the benefits of providing an enriched housing environment, particularly the development of increased behavioural flexibility and its positive associations. Considering these, it's apparent that fostering a goat's ability to express natural behaviour and make use of their cognitive capacities is grounded in rethinking how these animals are commonly housed and promoting a discussion of options for goat-specific enrichment for commercial goat housing systems.

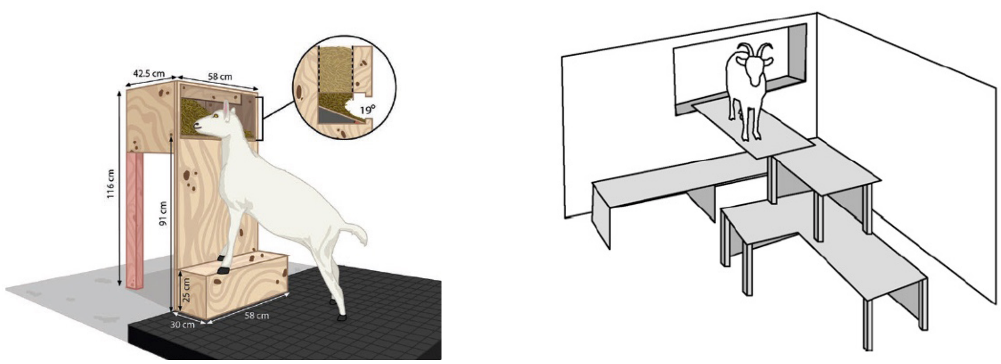


Figure 1.10 *The elevated feeder (left) and elevated platforms (right) are two images from research studies implementing environmental conditions to promote a goat's natural behaviour and seeing positive welfare outcomes.*

18 Neave, H, et al. "225 Raising the Bar: Feed Intake and Competitive Behavior of Dairy Goats When Offered Different Feed Bunk Heights." Journal of Animal Science, vol. 96, no. suppl_3, Dec. 2018, pp. 7–8, 10.1093/jas/sky404.017.

19 Aschwanden, Janine, et al. "Loose Housing of Small Goat Groups: Influence of Visual Cover and Elevated Levels on Feeding, Resting and Agonistic Behaviour." Applied Animal Behaviour Science, vol. 119, no. 3-4, July 2009, pp. 171–179, 10.1016/j.applanim.2009.04.005. Accessed 11 Aug. 2021.

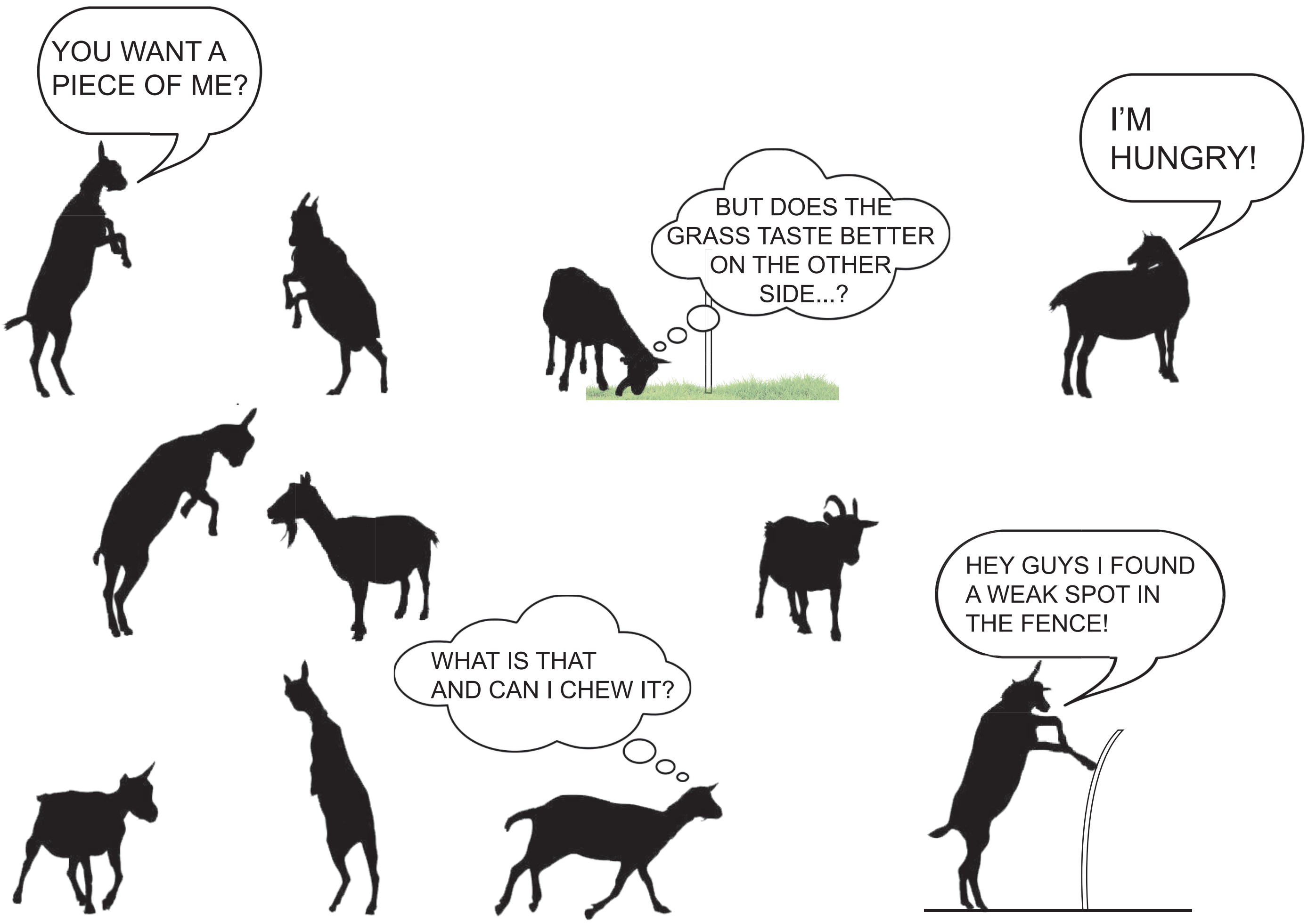


Figure 2.1 *What I think my goats are thinking/telling me when they perform what is perceived as "bad behaviour" such as escaping pens, chewing everything and anything, and constantly making noise. Much of this bad behaviour stems from lack of stimulants in their housing so they seek some elsewhere while trying to make the most of their environment.*

part two

GOAT BEHAVIOUR

Public interest regarding food sources, and social movements to reconsider animal-human relationships, is stimulating farming industries to improve animal welfare in production systems. Indoor housing of ruminants has received scrutiny because of perceived intensiveness and lack of naturalness. Animal welfare has traditionally focused on health benefits (e.g., bedding management and reducing disease) and reducing negative experiences (e.g., painful husbandry practices). Recent attention to animals extends expectations to provide increased care and opportunities for positive experiences and natural behaviors.[20] Although not all natural behaviors necessarily contribute to improved welfare, we present evidence in this thesis for why many are important for better agricultural outcomes, and for how they can be promoted in commercial systems. Worldwide, commercial dairy goats are frequently housed in large open barns with space to move and soft bedding for lying; however, this environment is not sufficient to promote the range of natural behaviors of goats, which in turn suggests that commercial housing could be improved. The basis for this thinking is from the range of behaviors expressed by wild goats. Collectively, goat species have evolved cognitive and behavioral strategies to cope with harsh and changing environments, as well as variable and limited vegetation. The rocky and often steep terrain that goats naturally inhabit allows for predator avoidance and access to shelter, so it is not surprising that domesticated goats also seek out elevation and hiding spaces; indeed, their hoof structure is designed for the movement and grip in such rugged environments. The browsing techniques and flexibility in diet selection of wild, feral and extensively managed goats, appears to be equally important to housed goats, highlighting the need for more complexity in how and what goats are fed. Goats naturally live in small, dynamic groups, governed by complex social structures. Commercial housing systems should consider the benefits of more natural-sized social groups as an exmaple of sensitivty to such social behaviour. This thesis suggests that cognitive stimulation is a potential welfare improvement for goats in commercial settings and sequentially cut down on animal and handler stress. For each behaviour category, design suggestions are made for housing, milking parlour, and circulation improvements that could be readily adopted into current systems without compromising production efficiency needed for economic viability.

Using existing studies on goat behaviour and my own seven years of experience farming with goats, the behaviour that affects ther adaption to space will be separated into four categories: spatial behaviour, stress behaviour, social behaviour, and consumption behaviour.

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20 King, Mike, et al. “Interactive Data-Gathering Posters as a Research Tool: A Case Study Assessing Public Opinion on Incorporation of Natural Behavior into Management Systems.” Animals, vol. 10, no. 6, 3 June 2020, p. 971, 10.3390/ani10060971. Accessed 18 Aug. 2020.

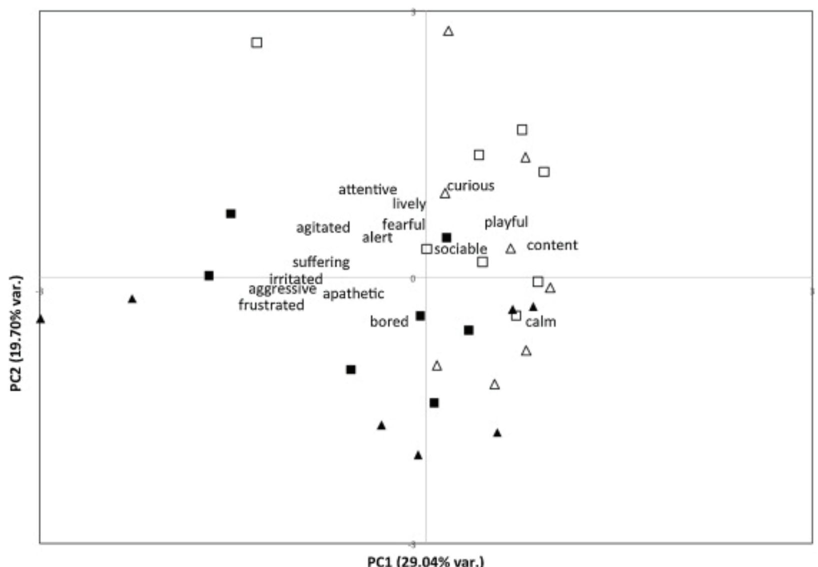

Figure 2.2 *A fixed-list of descriptors was specifically developed for dairy goats when conducting a study on Qualitiative Behaviour Assessment (QBA). QBA can be a reliable welfare indicator, used by observers with different backgrounds.*

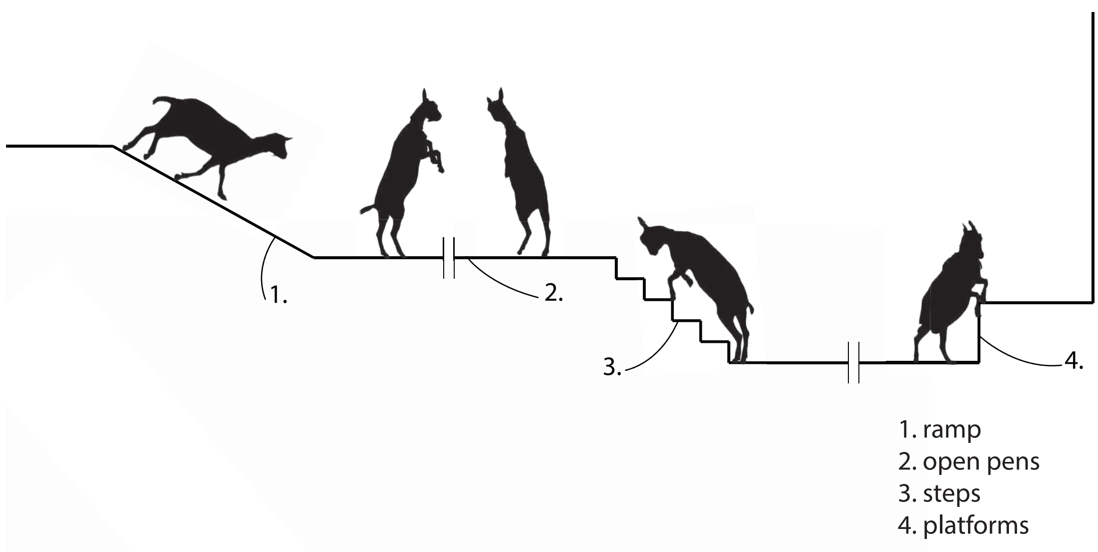

Figure 2.3 *Opportunities for goats to hide, climb, interact with objects that promote behavioural variability, and segregate to other areas with preferred pen mates are ways to wield their spatial navigation capabilities. To do so, barns should be designed with additional spatial and structural complexity.*

Spatial Behaviour

Spatial navigation is immensely important for animals. Having the capability to remember and locate preferred feeding locations, as well as remembering where other group members or safe hiding and resting areas can be found, is a highly adaptive trait for natural selection that drives survival in the wild. While navigating in the physical world can appear complex, goats display many adaptations that help them cope with these challenges and remember solutions over an extended period. Current husbandry practices with standardised and inflexible feeding regimes and locations offer limited options to make use of these highly evolved spatial skills.[21] I would argue from personal experience and observation, that this is a reason why goats are accomplished escape artists. Where cows see fences and gates as a limitation, goats see them as a dare. Where cows are content to see a four-wire fence, or a single strand electric fence in front of them, such enclosures will fail in keeping the average goat from tasting freedom. These behaviours boil down to a lack of stimulation within their pens compelling them to explore beyond their fenced-in area. Place something new outside their pen and be prepared for the security of fences to be thoroughly tested. While goats are definitely concerned about anything that seems threatening, they are curious enough that they can quickly get over their concern once they've established that there is no threat. Commercially housed goats, as well as those kept as pets, would therefore benefit from having more complex environments that challenge and allow goats to utilize their spatial navigation capabilities. This will in turn reduce the amount of goats escaping from pens and causing destruction to the environment around them as they are occupied with remembering and revisiting different food patches and exploring spatial features.

Commercial dairy goat management systems are aimed at providing health and production benefits including consistent access and quality of feed, shelter from the elements and predators, and reduced exposure to parasites and infectious diseases. These beneficial factors, combined with genetic improvements, aim at improving milk production. However, the design goals of these systems have been to automate feeding, cleaning, and milking, with less focus on the needs of individual goats. Shifting housing design to include behaviour of the herd social group and a focus on the individual animal will allow for commercially housed goats to achieve a wider behavioral repertoire closer to that of goats in natural systems.

21 Zobel, Gosia, Heather W Neave, and Jim Webster. 2018. "Understanding Natural Behavior to Improve Dairy Goat (Capra Hircus) Management Systems." Translational Animal Science 3 (1): 212–24. https://doi.org/10.1093/tas/txy145.

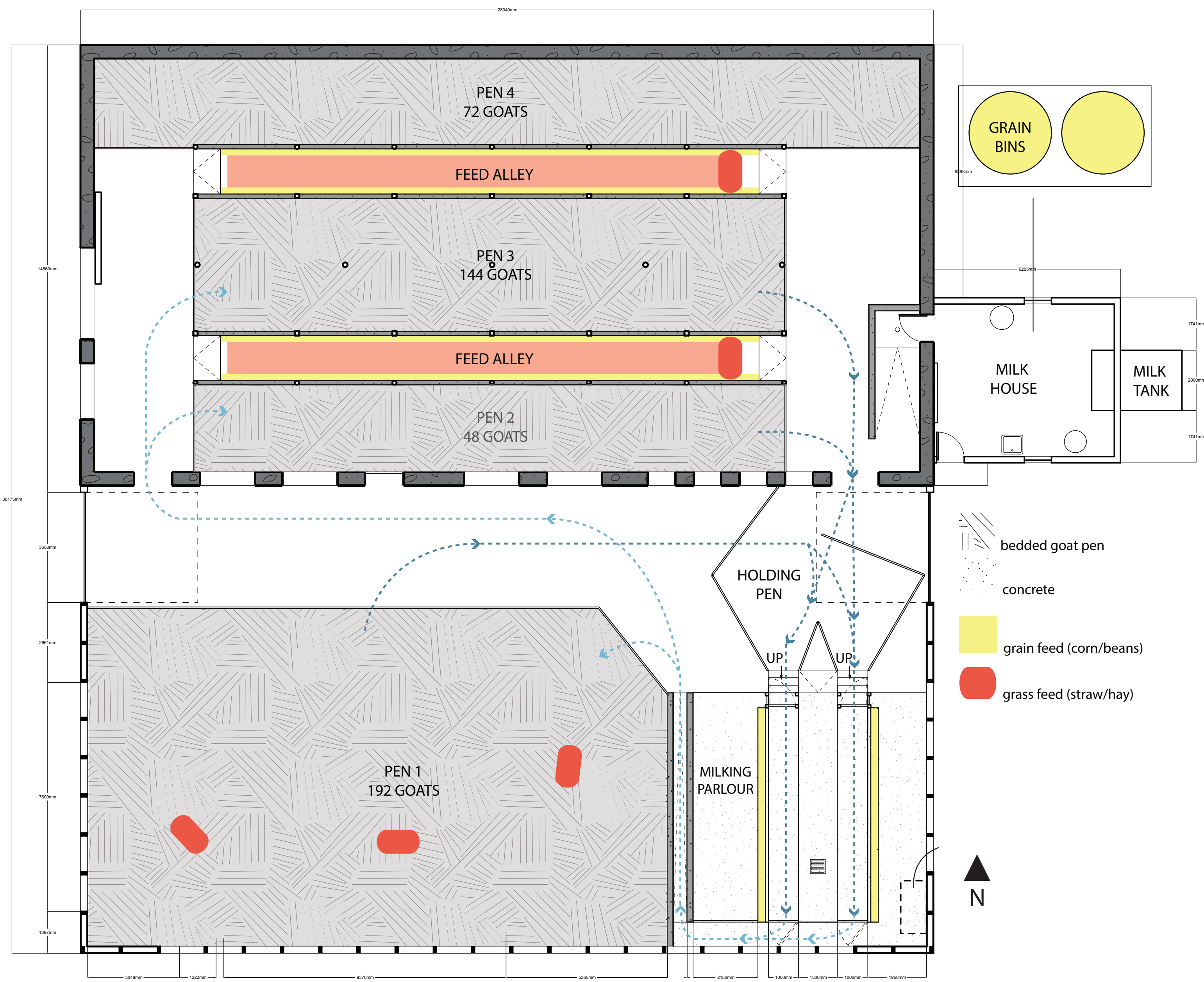

Figure 2.4 *The main level floor plan of my family's dairy goat barn. The dark grey walled area to the north is a 150-year old bank barn. The addition on the south was built specifically for the goats while the bank barn was cleared out and given new poured concrete feed alleys. This plan shows the location and size of the pens, location of feeders and alleys, as well as the milking parlour indicating circulation between the pens and parlour.*

In looking at my own goat dairy barn, I can identify typical farming practices that are passed on from cow barns to current goat husbandry. First, as one sees in the floor plan of Figure 2.4, everything except the parlour is on one level. Cows are heavy animals with skinny legs. These animals can't easily see the ground right at their feet and the design of their hips and knees makes it hard to shift their weight backwards to stop them from tripping and falling when faced with changes in level.[22] When a cow falls, there is a huge risk of the animal injuring itself or injuring a handler who is close by, and due to the cows extreme weight, an injury can be life threatening for both. This is why many cow facilities are always a continuous level so the cows are always walking on a flat surface. Noticing a goat's ability to jump, climb, and play compared to the weight and size of a cow, opens the case for any new goat facility to think outside the box and establish an architecture of varying heights that allows the goats to climb: as long as the higher areas are away from fences to keep them from jumping over their barriers and invading other parts of the facility. It is certainly a concern for farmers when goats escape especially when certain goats are together either based on their age, stage of breeding, or amount of milk they produce. And a goat now roaming free outside of their pen can be driven by their curiosity to meander through feeding areas, soiling and wasting the feed, and even chew or knock over equipment.

Secondly, feeding in my goat barn is accessible by hay feeders and feed alleys. The feed alleys provide a clean area for grain that is either eye level, or at their feet, and accessed through gates with spacing allowing the goats to pass their heads through. Feed is always available in the same spot and grasses are fed as free choice meaning there is always some available. Goats are restricted to their pens and kept indoors. Groups in pens are sized based on parlour capabilities. Currently, many farmers tend to keep goats in large groups, similar to cows, rather than smaller groups in multiple pens.[23]

Their origins in complex natural environments have equipped goats with a sophisticated behavioural repertoire grounded in a series of cognitive capacities. The research of how goats navigate spatial, social and feeding contexts, is conducted by observing the way goats recognize and remember patterns, places and individuals.[24] Using these examples, and the goal of promoting good welfare, goats require at least some opportunity to utilize these cognitive capacities. When looking at quintessential goat facilty space of both farmed and potentially lab goats, fostering a goat's ability to express natural behaviour and make use of their cognitive capacities is grounded in rethinking how these animals are commonly housed. As the thesis demonstrates in the following design interations, these quintessential spaces can be amplified in providing an enriched housing environment, particularly the development of increased behavioural flexibility and its positive associations.

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22 Grandin, Temple, ed. 2019. Livestock Handling and Transport. 5th ed. CABI.

23 Guthrie, Alice. n.d. "Par-Chier Farms Downsized in a Big Way." Progressive Dairy: Canada. Accessed May 7, 2021. https://www.progressivedairycanada.com/topics/people/par-chier-farms-downsized-in-a-big-way.

24 Zobel, Gosia, and Christian Nawroth. 2020. "Current State of Knowledge on the Cognitive Capacities of Goats and Its Potential to Inform Species-Specific Enrichment." Small Ruminant Research 192 (November): 106208. https://doi.org/10.1016/j.smallrumres.2020.106208.

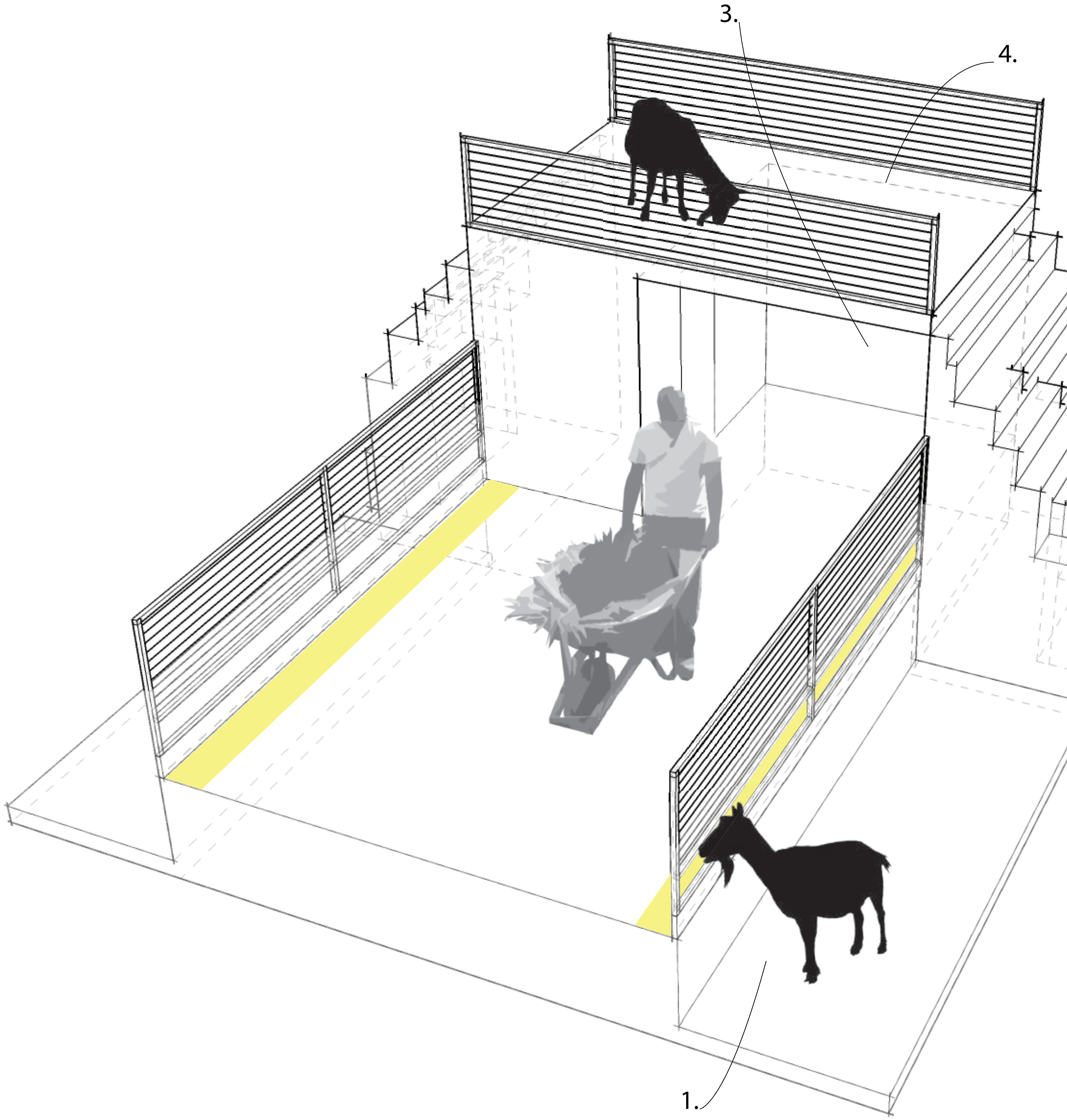

Figure 2.5 *Providing circulation that allows the goats t*
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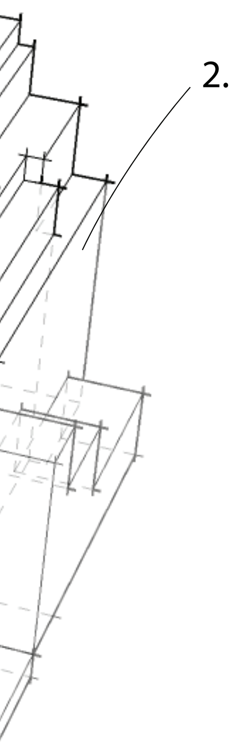
neath for circulation of h



Leveling Up

As seen in the previous barn floor plan, circulation between pens and the parlour overlaps with areas where handlers access and equipment is operated. By providing the ability for goats to climb and move above (4) certain areas, it allows for natural behaviour and separates the goats from high traffic areas which can reduce stress for both the animal and the handlers. This design allows goats to climb (2) and cross above a feed alley (3) minimizing contamination of feed with manure. Note the deeper pens (1) provide the height for feeding as seen to promote higher consumption of feed in the 2016 Ruakura Research Centre elevated feed study. Allowing the goats to move freely between pens also allows them to choose the area they feel most comfortable.

to climb and move from one area to another serving as en areas. Raised circulation can free up space under- andlers and equipment.

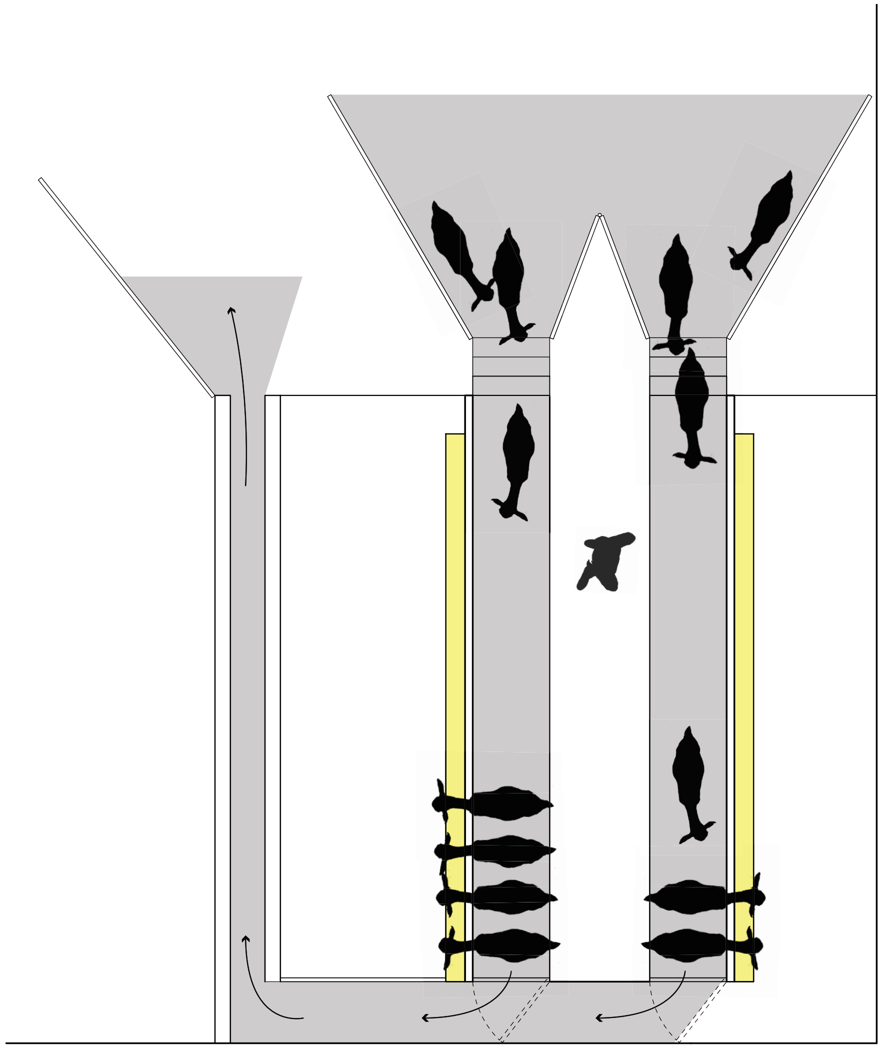


Figure 2.6 *This is the current configuration of my family's milking parlour. Goats climb four steps and lower their head in the next available head gate to eat grain while being milked. Once everyone is milked on one side of the parlour, the group is released back to the pen.*

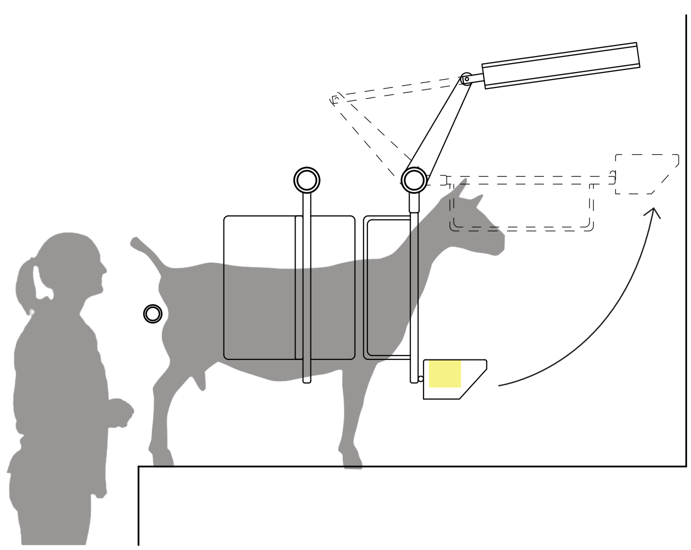


Figure 2.7 *A rapid exit parlour lifts the feed trough and barrier along the entire group of goats allowing them to easily move forward and return to their pen for food and water.*

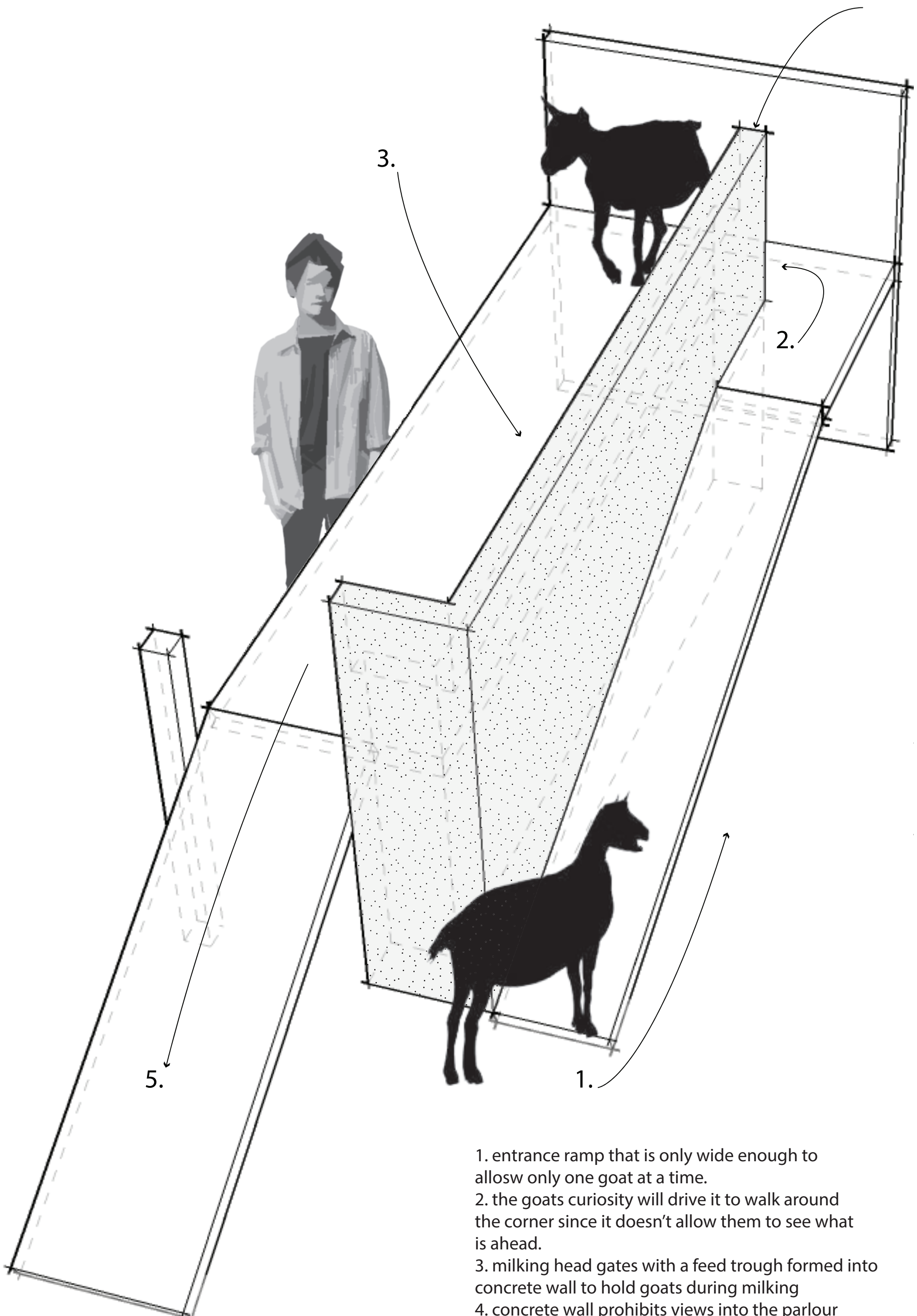
Stress Behaviour

What is unique to goats is their flight mode when startled, a behaviour which makes goats difficult to herd. This is due to a goat's wild instinct as prey but unlike sheep and cows who crowd when they feel threatened as they find strength in numbers; goats will crowd but then scatter. Consequently, moving goats in smaller groups allows for easier control. Therefore, their pens and holding areas should be smaller in floor area to allow a tighter space for handlers to move goats. This aligns well with the literature on wild goat behaviour which demonstrates that goats choose smaller group sizes when able to do so.[25] When goats are able to maintain a small and consistent grouping, the group is more likely to move as one unlike large groups with constant changes in members that will move with the 'everyone for themselves' mentality. When goats do herd they look for corners and will bunch together. This can cause harm to the goats against the gate or wall who may get pinned. Ideally, and similar to Grandin's designs, eliminating corners by using round gates encourages the goats to continue moving forward rather than crowding in a corner.

In Figure 2.6, the typical layout of a milking parlour, is an area of high stress due to confinement and being herded. Small improvements such as blocking views into the parlour, can minimize the circulation and bunching of goats. Many farmers have begun to cover gates that lead their goats to the parlour. Not allowing the goats to see others being milked in the parlour, and only the goats leaving the area, convinces the goat that if they enter the parlour they are immediately going back to where they came from.

The design of the parlour then should limit views into the milking area and utilize curves, similar to Dr. Grandin's designs, to promote movement without the goats gathering in a corner. Rapid exit head gates, in Figure 2.7, which lift up and over the goats, are efficient in their ability to release all goats at once, taking advantage of a goat's natural instinct to flee. Therefore, the milking time and stress is lessened as goats only need to turn to face the grain bin in front which is then raised and they can leave straight from the parlour and back to their pen.

25 Zobel, Gosia, and Christian Nawroth. 2020. "Current State of Knowledge on the Cognitive Capacities of Goats and Its Potential to Inform Species-Specifi c Enrichment." Small Ruminant Research 192 (November): 106208. https://doi.org/10.1016/j.smallrumres.2020.106208.



1. entrance ramp that is only wide enough to allosw only one goat at a time.
2. the goats curiosity will drive it to walk around the corner since it doesn't allow them to see what is ahead.
3. milking head gates with a feed trough formed into concrete wall to hold goats during milking
4. concrete wall prohibits views into the parlour and is durable against goats continously "walking" against it.
5. exit ramp places the goats right back in their pen in a single file after being release from head gates

Figure 2.8 *Typical 6-10 goat milking parlour with minimal view into milking area.*

A Typical Milking Parlour

Milking parlours allow a person to milk an animal from a suitable height by either requiring the animals to ascend an incline or the handler to descend into a pit. The milking process of goats can be broken down into sub-tasks: collecting goats, routing goats into holding area, routing goats into the parlour, inspection and cleaning of teats, attachment of milking equipment to teats, the extraction of milk, removal of milking equipment, routing goats out of the parlour. Typical goat operations milk twice a day, seven days a week, with an average of twelve hours between both milkings. Automatic milking systems (AMS), also known as robotic milking, provides milking of dairy cows without human labour. The AMS have revolutionized dairy farming by providing cows the choice as to when they are milked along with automated detection of udder health issues, and individualized feeding.[26] No such system exists for goats currently but would benefit the industry greatly by granting goats social choice and enhancing spatial navigation. Current designs of milking parlours can be expanded to limit stress on goats and handlers, and cut down on time spent milking.

26 Hansen, Björn Gunnar, and Egil Petter Stræte. 2020. "Dairy Farmers' Job Satisfaction and the Influence of Automatic Milking Systems." NJAS - Wageningen Journal of Life Sciences 92 (December): 100328. https://doi.org/10.1016/j.njas.2020.100328.

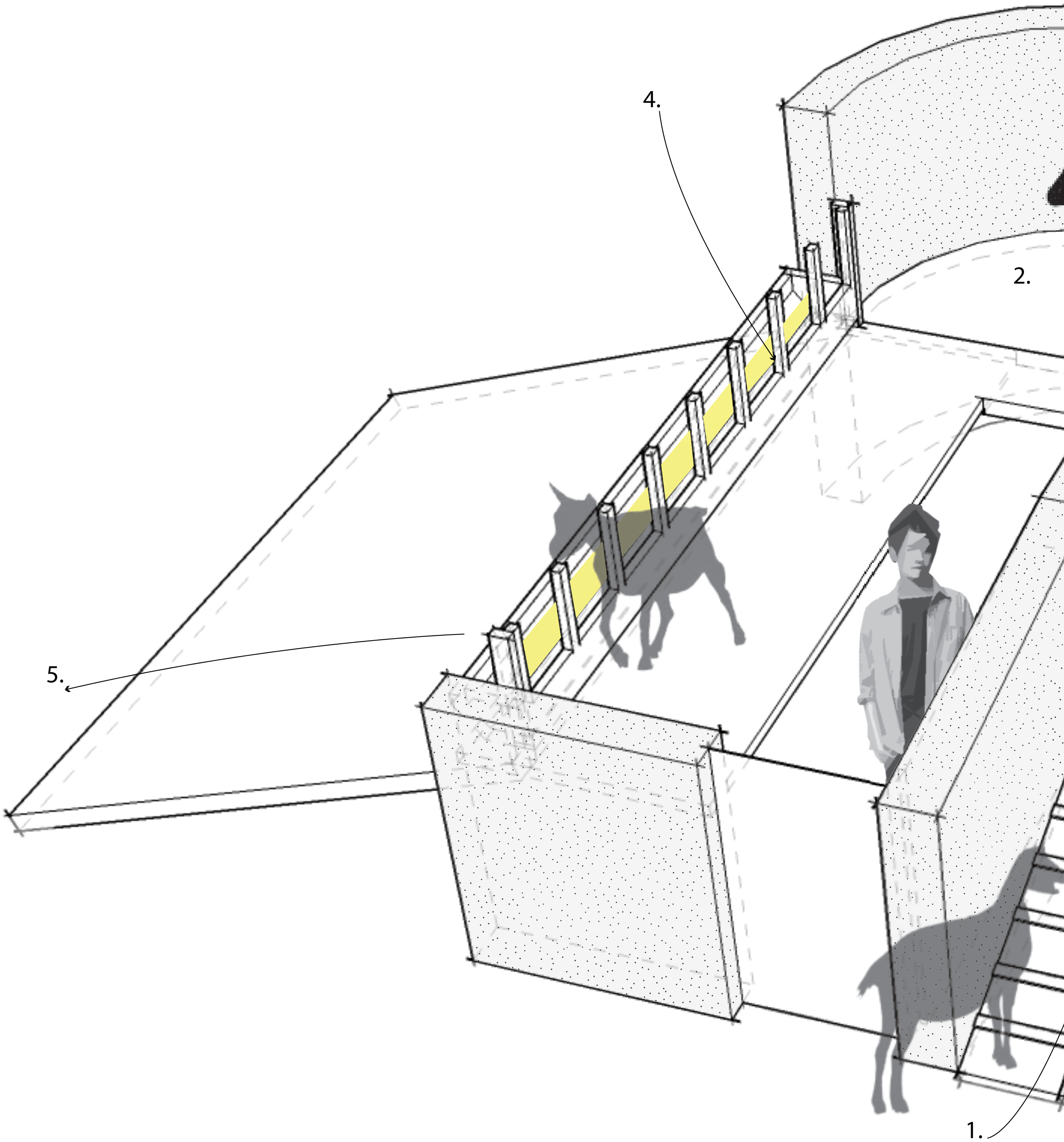
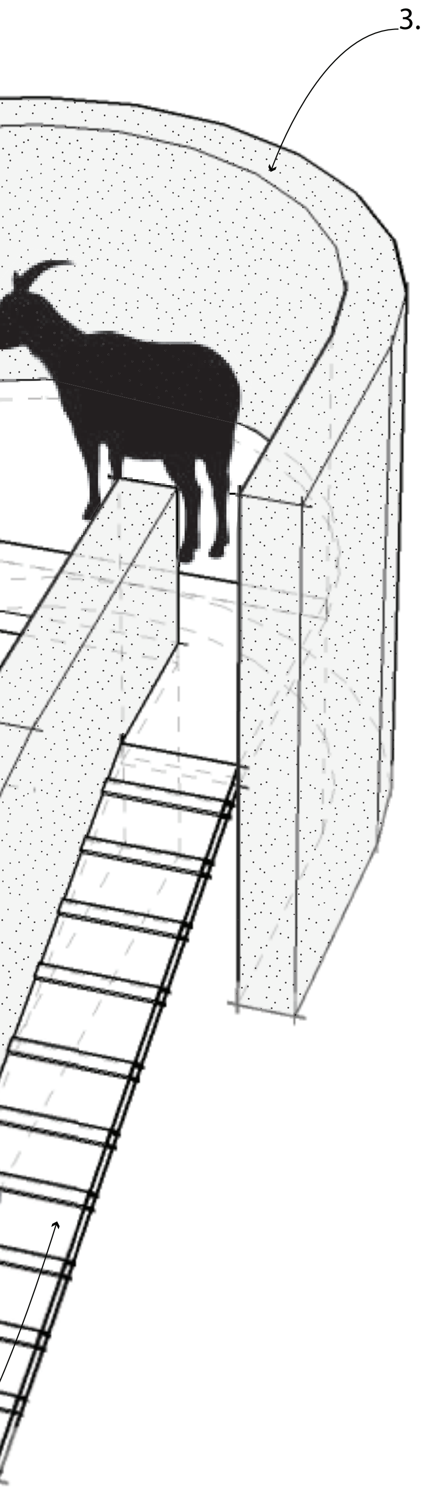


Figure 2.9 *Milking parlour for 10 goats wi*



th a rounded end and rapid exit headgates.

A Milking Parlour for Goats

In this new design, a typical milking parlour is expdanded to reflect a goat's behaviour. A ramp with cleats (1) allows for better traction for goats entering the parlour and the width of the ramp only allows for one goat at a time, limiting bunching and goats turning around. The round curve (3) lets the goats think they are returning to the holding area and by removing the corner they follow the curve (2). The walls leading up to the curve are solid, limiting the views into the parlour which most often contains blinking lights, lots of noises, and other goats which are not moving. These views can startle a goat causing them to stop moving and attempt to flee. Finally, a rapid exit gating system (4) allows the goats to eat grain during the milking and release the goats quickly onto a large ramp where they can return to their pens (5). The goat parlour is currently designed to milk ten goats at a time.

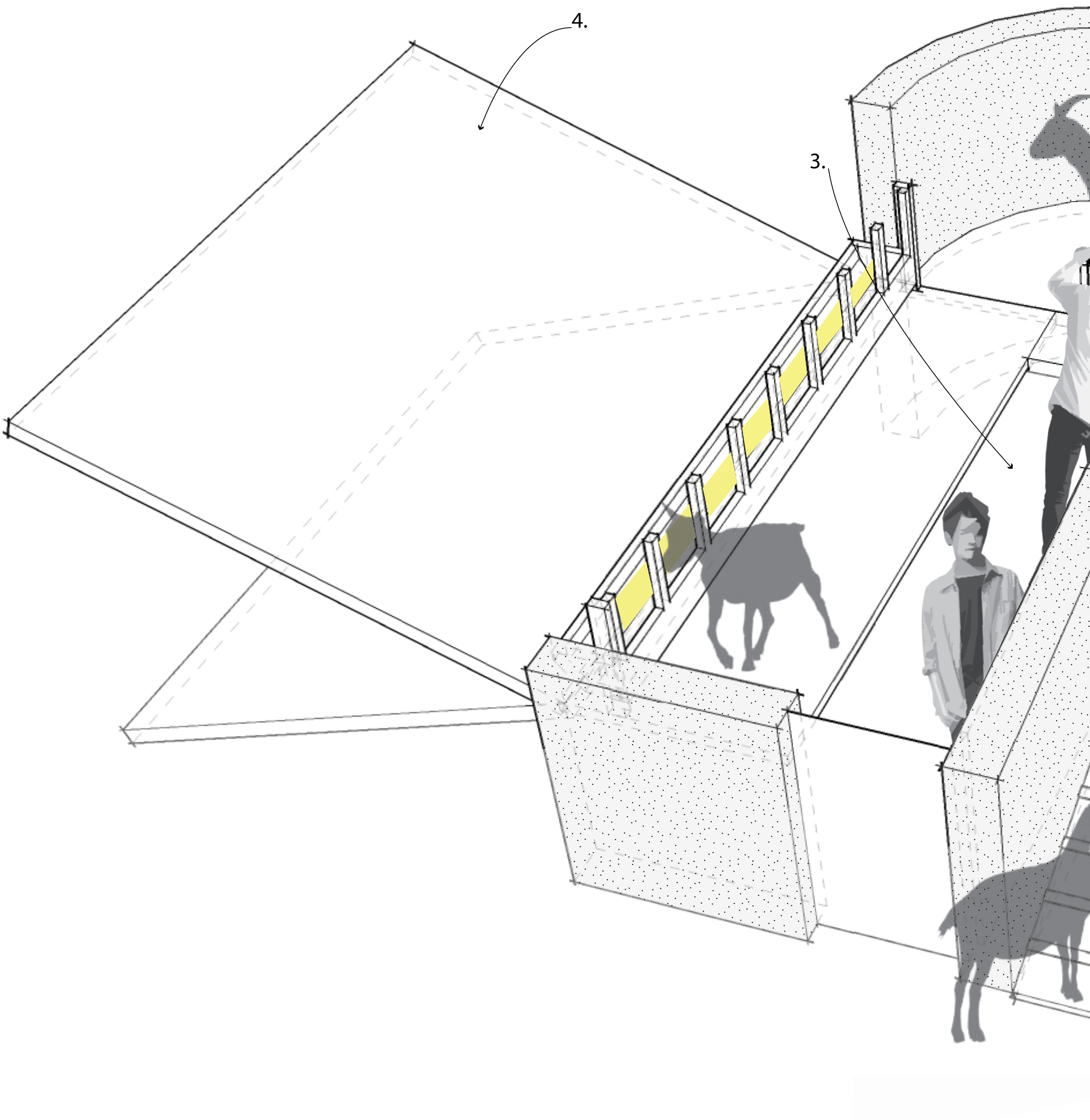
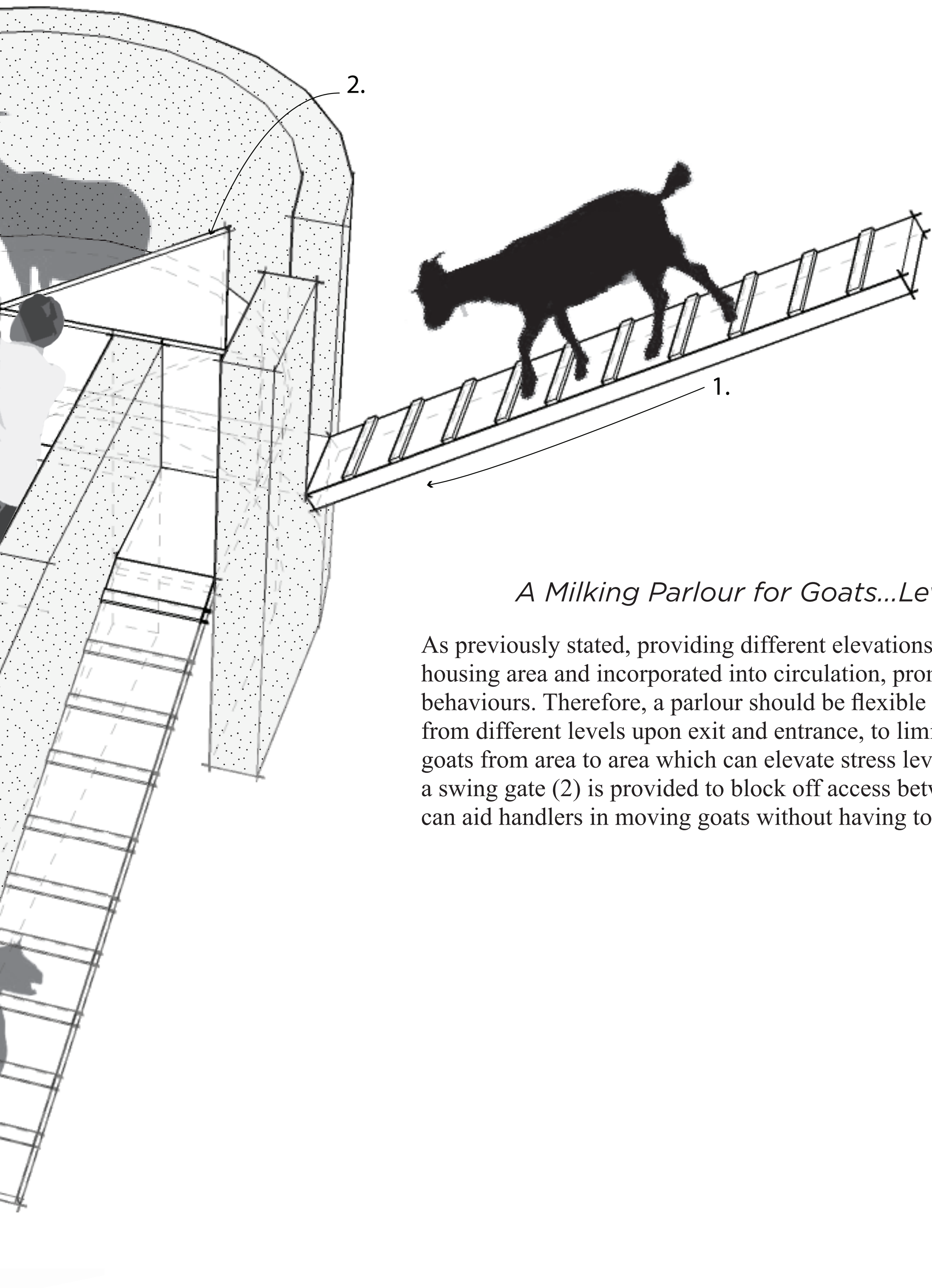


Figure 2.10 *Milking parlour with access from pen*



A Milking Parlour for Goats...Leveled Up

As previously stated, providing different elevations (1+4) within a housing area and incorporated into circulation, promotes many natural behaviours. Therefore, a parlour should be flexible in receiving goats from different levels upon exit and entrance, to limit the movement of goats from area to area which can elevate stress levels. In this design, a swing gate (2) is provided to block off access between entrances and can aid handlers in moving goats without having to leave the pit (3).

s on multiple levels and exiting to differing levels.

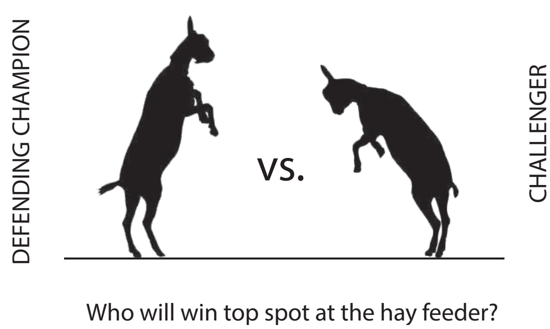


Figure 2.11 *To establish pack leaders and hierarchies amongst groups, one common "dual" is butting. Pregnant goats will especially try and win social duals to give their kids a higher status amongst the group after birth. Some perks of being high within the hierarchy of a group is first choice access to feed.*

Social Behaviour

Social behaviour is best defined as the interactions between two or more individuals in a group that modify the activity of the group and that cover the function of species-specific communication such as signals. Such collective behaviour serves many purposes, including group cohesion and ecological integration, and provides a number of advantages, such as better protection from predators, more efficient foraging, easier potential access to sexual partners, and more successful defence of newborns. However, living in a group can have costs, particularly, competition for food or access to other resources, which can lower the fitness of individuals.[27] Goats alter their behaviour based on social and foraging context. Goats that were in company of two or more other goats increased their feed intake compared to when only one other goat was present.[28] Furthermore, a study showed that when feed availability was low, individuals avoided dominant group members, while high feed availability diminished this segregation.[29] This suggests that goats have the capacity to closely monitor their social group and establish complex dominance hierarchies.

The physical structure of a group includes its size and some of the characteristics of individuals, such as their age, sex, and parentage. Group structure is established and maintained by the agonistic (aggressive) and affiliative (positive) social interactions among individuals. Aggressive postures in goats can include side-on locking of horns, butting the flank of another feeding goat, and ear biting. When a conflict between goats escalates, the typical aggressive behaviour involves one goat standing up on its hind legs, lowering its head, and striking it against its opponent's head. In an environmental enrichment program in Norwegian dairy goats, it was reported that provision of additional walls in the resting area to increase the distance between individuals and to keep potential opponents out of visual contact, did not appear to reduce aggression.[30]

Goats are capable of distinguishing between individuals using cues of different sensory modalities. Groups formed either by production level, age or parentage, create bonds and form a social hierarchy. Constantly moving goats between pens and introducting new groups has been shown to have long lasting negative consequences, including increased aggression, for the introduced goat. Studies suggest that it is due to the absence of a familiar individual, thus making individual recognition an important component in the daily life of goats.[31] Further research in this area is instrumental for improving our understanding of the complexity behind goats being able to recognize individuals, how they use this capability to form social bonds, and ultimately how different group sizes impact on their welfare.

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27 Miranda-de la Lama, G. C., and S. Mattiello. 2010. "The Importance of Social Behaviour for Goat Welfare in Livestock Farming." Small Ruminant Research 90 (1): 1–10. https://doi.org/10.1016/j.smallrumres.2010.01.006.

28 Van, Do Thi Thanh, et al. "Effect of Group Size on Feed Intake, Aggressive Behaviour and Growth Rate in Goat Kids and Lambs." Small Ruminant Research, vol. 72, no. 2-3, Oct. 2007, pp. 187–196, 10.1016/j.smallrumres.2006.10.010. Accessed 12 Aug. 2021.

29 Zobel, Gosia, and Christian Nawroth. 2020. "Current State of Knowledge on the Cognitive Capacities of Goats and Its Potential to Inform Species-Specifi c Enrichment." Small Ruminant Research 192 (November): 106208. https://doi.org/10.1016/j.smallrumres.2020.106208.

30 Aschwanden, Janine, et al. "Loose Housing of Small Goat Groups: Influence of Visual Cover and Elevated Levels on Feeding, Resting and Agonistic Behaviour." Applied Animal Behaviour Science, vol. 119, no. 3-4, July 2009, pp. 171–179, 10.1016/j.applanim.2009.04.005. Accessed 11 Aug. 2021.

31 Górecki, Marcin T., et al. "Dominance Hierarchy, Milking Order, and Neighbour Preference in Domestic Goats." Small Ruminant Research, vol. 191, no. 191, Oct. 2020, p. 106166, 10.1016/j.smallrumres.2020.106166. Accessed 12 Aug. 2021.

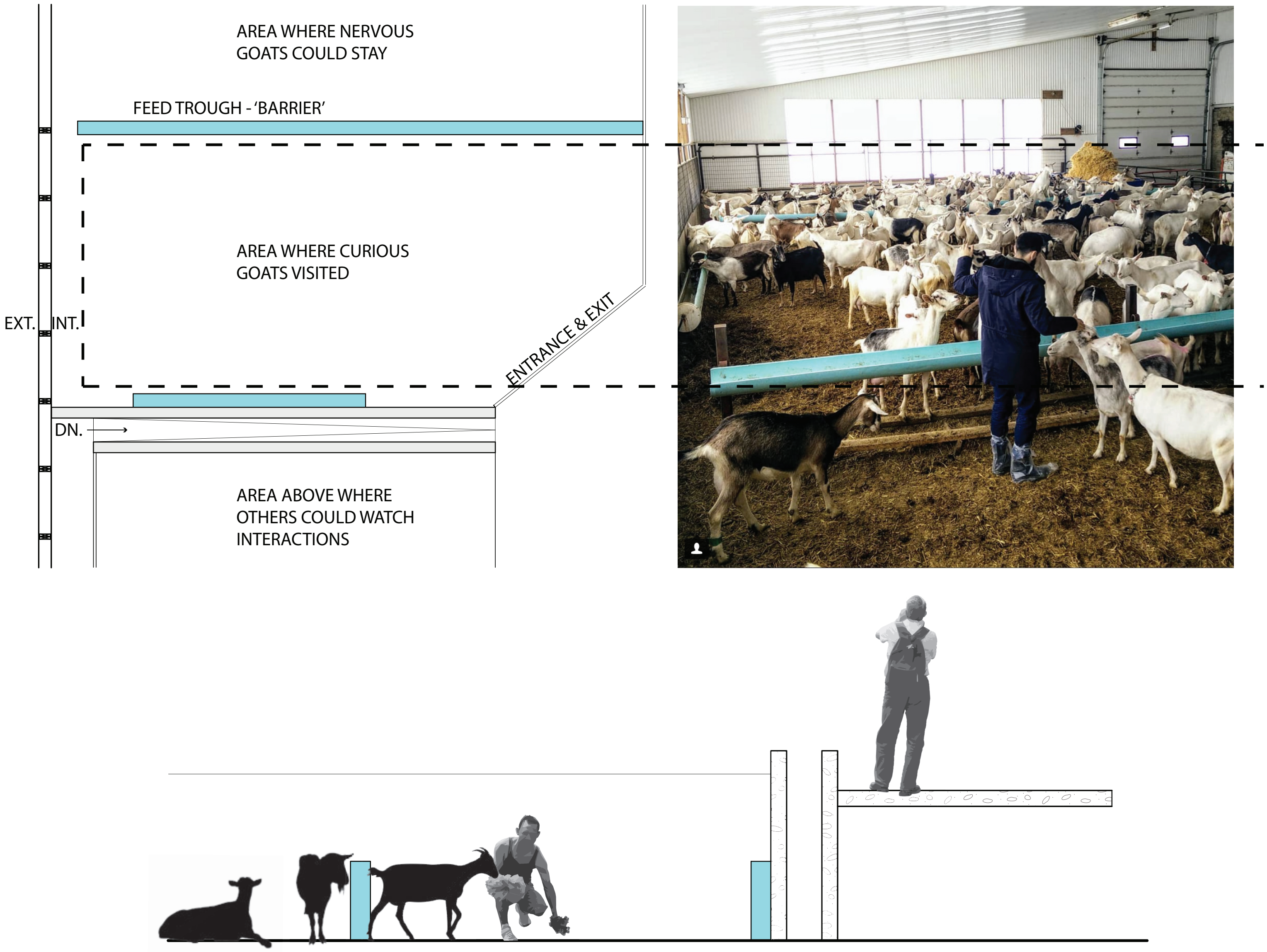

Figure 2.12 *After documenting the interaction between students and goats within my own barn, I took note of the layout of the spaces in which the interaction occured. Goats quick to visit passed all barriers and came directly to the students. Goats more cautious felt comfortable observing from behind the troughs for added security. Students who did not wish to enter the pen were able to watch the other students interact with the goats from a higher vantage point.*

Human-Goat Interaction

Another important layer to the social behaviour of goats is their interaction with people. A recent review on the cognitive capacities of goats by Christian Nawroth, a post-doctoral researcher at the Leibniz-Institute for Farm Animal Biology, highlighted that goats are quick to look at people for help whether its accessing food, scratching a hard to reach spot or solving a task for a study.[32] Gentling is a form of positive physical attention that serves to calm the animal and increases the affinity for a healthy animal–human bond. Research on various livestock species has shown that gentled animals have shorter avoidance distances reducing the fear towards handlers especially in stressful situations. The importance of early contact with humans and gentling treatments on the establishment of the human–animal can thus improve this relationship and result in tamer animals, which exhibit less fear and, therefore, are easier to handle.[33]

Their ability to bond with people is not unlike other livestock, but their size and lack of aggression makes them ideal for interaction. I myself have brought kid goats to the school of architecture, where I study, as a "stress relief" moment for students during exam weeks. Creating spaces where goats and humans can interact beyond their pens should be crucial for a research facility for training and promotion. As groups of goats are made up of strong and docile personalities, I always see the same goats who will approach strangers more easily and quicker than others. When I observed a group of visiting architecture students walking through my family's barn to visit the goats, the bolder goats came right up to the students while the more shy goats maintained their distance. Similarily, I've seen people of all ages who are not comfortable getting to close to the goats and prefer to see them from afar. Allowing different views and vantage points for both the visitors and goats sustains the ability to observe surroundings from a preferred area of comfortability.

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32 Nawroth, Christian. 2017. "Invited Review: Socio-Cognitive Capacities of Goats and Their Impact on Human–Animal Interactions." Small Ruminant Research 150 (May): 70–75. https://doi.org/10.1016/j.smallrumres.2017.03.005.

33 Zobel, Gosia, and Christian Nawroth. 2020. "Current State of Knowledge on the Cognitive Capacities of Goats and Its Potential to Inform Species-Specifi c Enrichment." Small Ruminant Research 192 (November): 106208. https://doi.org/10.1016/j.smallrumres.2020.106208.

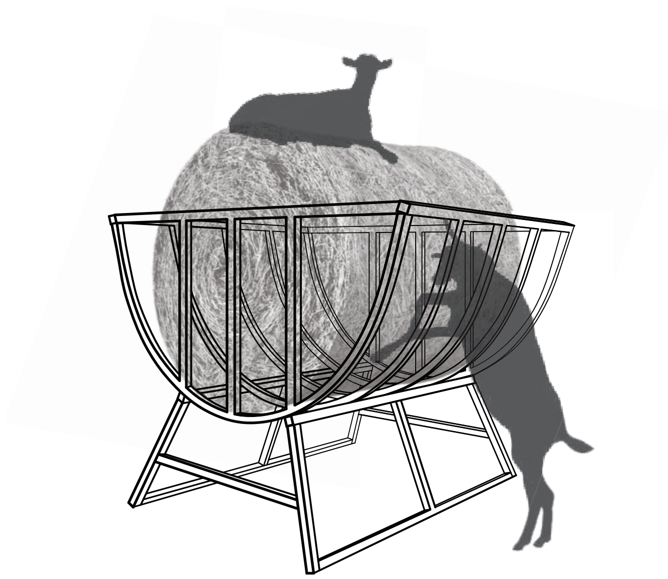

Figure 2.13 *When faced with little stimulants and areas to climb in housing, goats tend to find others ways to keep themselves occupied and asserting dominance, such as hay feeders.*

Consumption Behaviour

The portrayal of goats as garbage eaters is a misconception: they don't eat garbage, they chew it. Goats have two times the number of taste buds as humans and are surprisingly picky eaters. They also tend to spend more time eating each day than other ruminants, often eating for as long as 11 hours.[34] This can dictate two large factors within a goat research facility: materiality and layout of feeding area. As mentioned, goats will chew everything, especially soft pliant materials like wood and plastic. No exposed structure should be wood, or the goat will begin to test the structural integrity of the facility. In saying this, the easiest way to reduce damage to the facility from goat mouths is to pull back their pens from any walls. Although this may seem like a waste of space, a farmer's ability to walk completely around the pen, allows a better view of their goats and easier access to the herd in case of emergency.

The other factor is the layout of the feeding area. With goats being picky eaters, they will refuse food that is wet and contaminated with feces. This means the feeding area must be as clean and controlled as possible. Many goat farmers establish feed alleys between their open pens. The feed alleys are normally raised to a height that the goat will either need to step up on a ledge to eat or only their heads can lean over the wall to get at grain and hay. This stops the goats from being able to excrete on the feed or place their feet within the feeding area thus reducing contamination. Any goat raising facility oriented to research in particular, will have to take into consideration the importance of flexibility, especially with studying different feed programs. This would require pens having particular feeding areas that are controlled and segregated from being contaminated by others, especially if an organic feeding system would be tested within the facility.

34 Dar, Yousuf, Kamal Sarma, Shalini Suri, Jonali Devi, Sumeet Kour, and Javaid Akhter Bhat. 2016. "Histomorphological Development of Lingual Taste Buds in Goat (Capra Hircus)." Applied Biological Research 18 (1): 80. https://doi.org/10.5958/0974-4517.2016.00013.6.

Figure 2.14 *Goats graze on an argan tree in southwestern Morocco.*

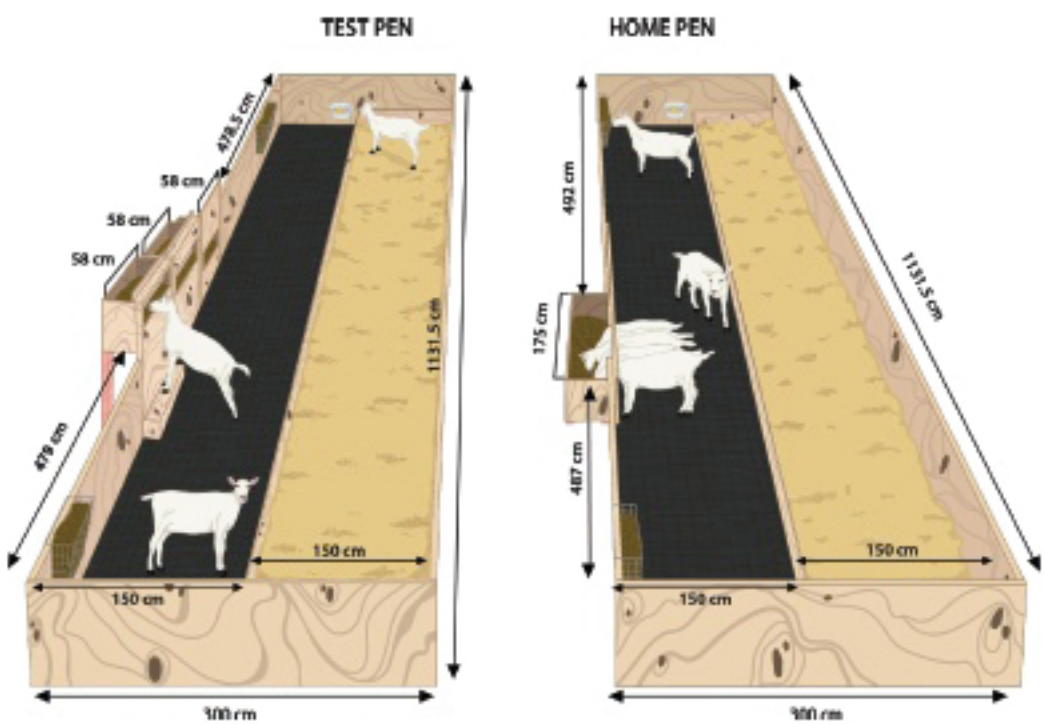

Figure 2.15 *Layout of the feed elevation test pens. The home pen contained a single feeder 175 cm in length; each day the height of this feeder was varied (floor level, head level, and elevated level) to familiarize the goats with the 3 feeding positions. The test pen contained 3 smaller feeders, one of each feeder height.*

Goats in commercial systems are typically fed consistent diets, including total mixed rations, preserved feeds such as hay and silages top dressed with pelleted concentrates or grains, high energy 'complete ration pellets' supplemented with straw and fresh cut grass.[35] Regardless of type, these diets are homogenous and are delivered routinely across the day. Goats have little foraging choice when fed this way yet are classified as both browsers and grazers. They are highly efficient at digesting poor quality roughage and adjust to a variety of vegetation types depending on conditions and location. Due to their diet flexibility in changing conditions, they are often labeled "mixed-feeding opportunists". A study done by the AgResearch team in New Zealand, examined how providing goats a choice between different feeding heights can affect feeding and social behavior. Goats were least likely to visit the floor-level feeder and were most likely to competitively displace one another at the highest feeder, suggesting that the animals were motived to feed from higher locations.[36] The natural feeding behavior of goats, such as foraging by climbing trees as seen in Figure 2.14, is markedly different in complexity, duration, and posture compared to the energy-rich, uniform diet fed at ground level that is common in indoor commercial systems. Goats have a narrow mouth, a mobile upper lip, and shorter jaws (relative to many other ruminant species) that allow them to be highly selective while foraging and chew faster. Thus, feeding at increased feeding heights may promote natural selective foraging behavior, resulting in increased intake per unit of time.[37]

A goat's individual flexible foraging conditions promotes small- to medium-sized social groups. These adaptations contain a cognitive component. When housing goats, whether on smallholdings or large commercial systems, environmental variability should be balanced for the level of stimulation best suited for goats' capacities. For example, housing in large groups may be over stimulating, while offering monotonous feeding regimes may promote boredom or frustration; both types of states compromise welfare. Benefits could include the expression of more natural behaviours and increased behavioural flexibility; the latter will help individuals to better cope with common management stressors, such as sudden environmental changes (i.e. goats mixing after quaratine into the milking herd) or handling practices (i.e. hoof trimming, milking, participation in breed shows).[38]

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35 Lunn, Dennis. "Feeding and Management of Dairy Goats." Shur-Gain, a Member of Maple Leaf Foods Inc., Feb. 2011.
36 Neave, Heather W., Marina A.G. von Keyserlingk, Daniel M. Weary, and Gosia Zobel. 2018. "Feed Intake and Behavior of Dairy Goats When Offered an Elevated Feed Bunk." Journal of Dairy Science 101 (4): 3303–10. https://doi.org/10.3168/jds.2017-13934.
37 Zobel, Gosia, Heather W Neave, and Jim Webster. 2018. "Understanding Natural Behavior to Improve Dairy Goat (Capra Hircus) Management Systems." Translational Animal Science 3 (1): 212–24. https://doi.org/10.1093/tas/txy145.
38 Miranda-de la Lama, G. C., and S. Mattiello. 2010. "The Importance of Social Behaviour for Goat Welfare in Livestock Farming." Small Ruminant Research 90 (1): 1–10. https://doi.org/10.1016/j.smallrumres.2010.01.006.

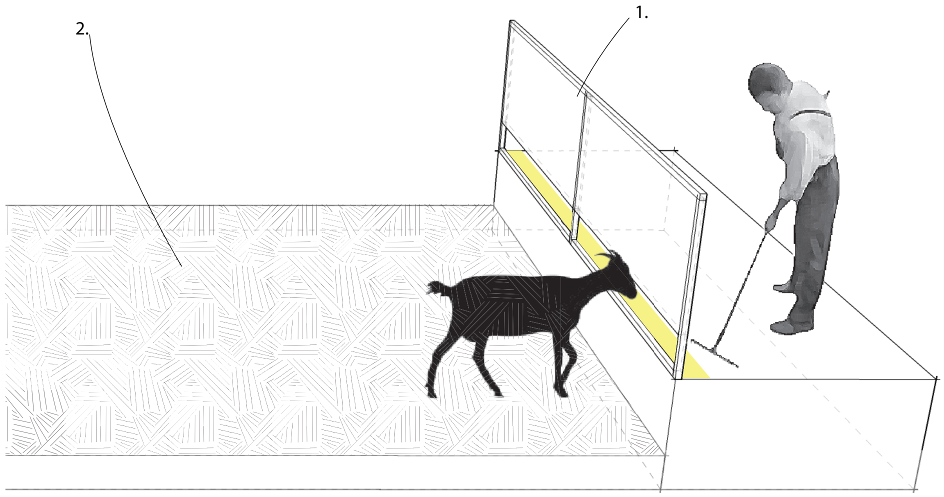


Figure 2.16 *Example of a typical pen with a single feed alley and a bedded area to sleep and rest.*

Figure 2.17 *Commercial dairy goat farm, in Ontario, promoting eye-level feeding by elevating the feed. Note the feed alley width allows for large equipment to deposit feed on both sides.*

A Typical Goat Pen

A typical goat pen uses a single feed alley to provide access to feed. The alley is only accessible by the goat's head which only allows feeding and reduces contamination compared to if the troughs were inside the pen for goats to jump and climb onto. A bedded area to sleep and rest on one level and bedded with a soft, dry material such as hay or straw. Figure 2.15 shows an Ontario dairy goat farm with the single feed alley large enough for equipment to feed both sides of the alley since it feeds two opposing pens. The pens are quite crowded indicating large group sizes. These typical pens lack infrastructure where goats can climb, rest underneath, or express their cognitive abilities to create patterns in feed locations. The natural environment for goats is often harsh, yet their ability to thrive in areas of high elevation, and steep, mountainous terrain where many other species cannot, demonstrates their flexibility and adaptability. Although it is not sensible to provide harsh environments in a production context, the key point is that goats have adapted unique abilities to cope with these complex and variable environments. Elevated areas, hard dry surfaces, and hiding spaces are environmental features that are part of the natural behavioral repertoire of wild and feral goats, and this must be allowed for within a commercial setting when the aim is to improve welfare.

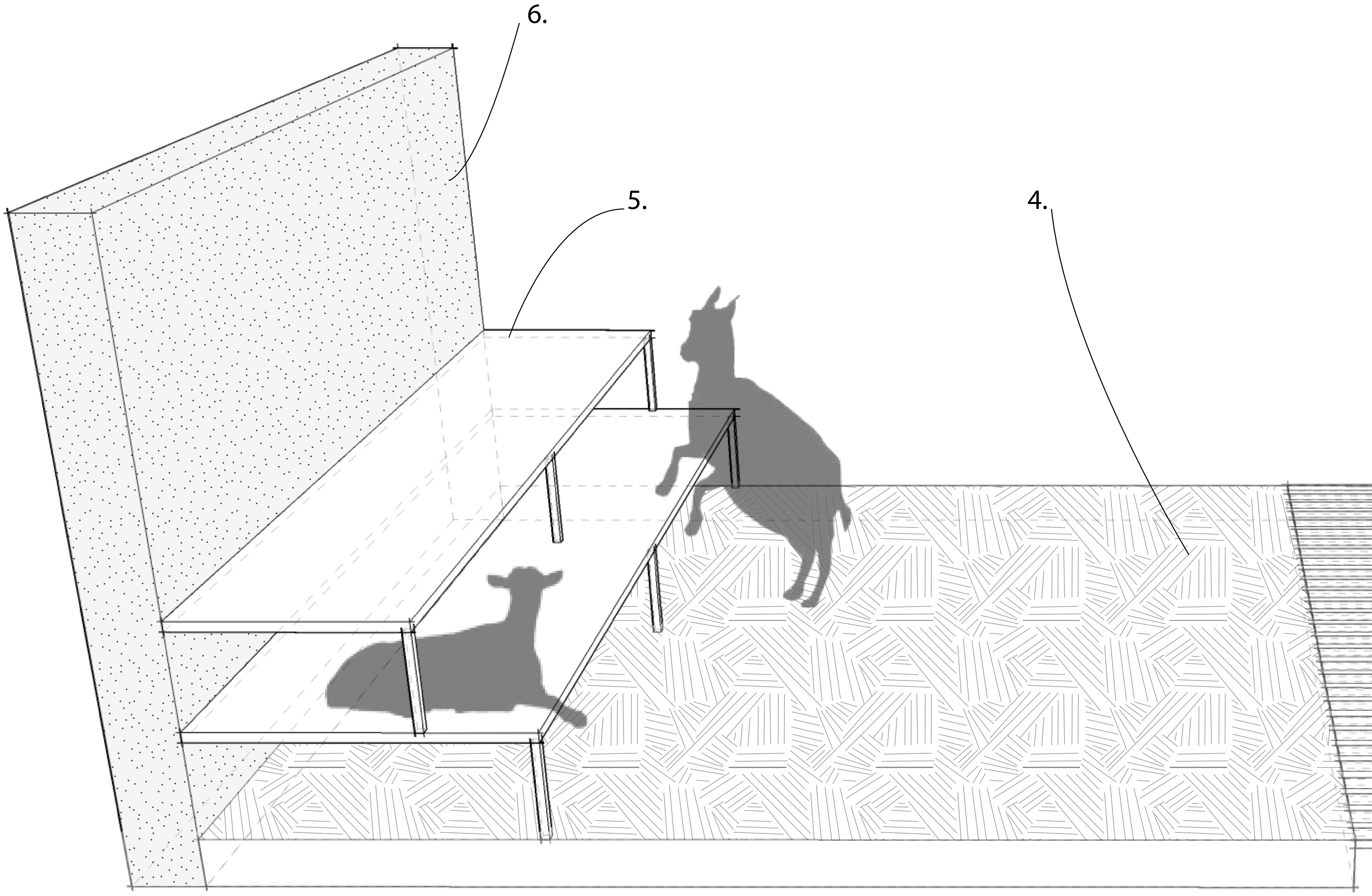
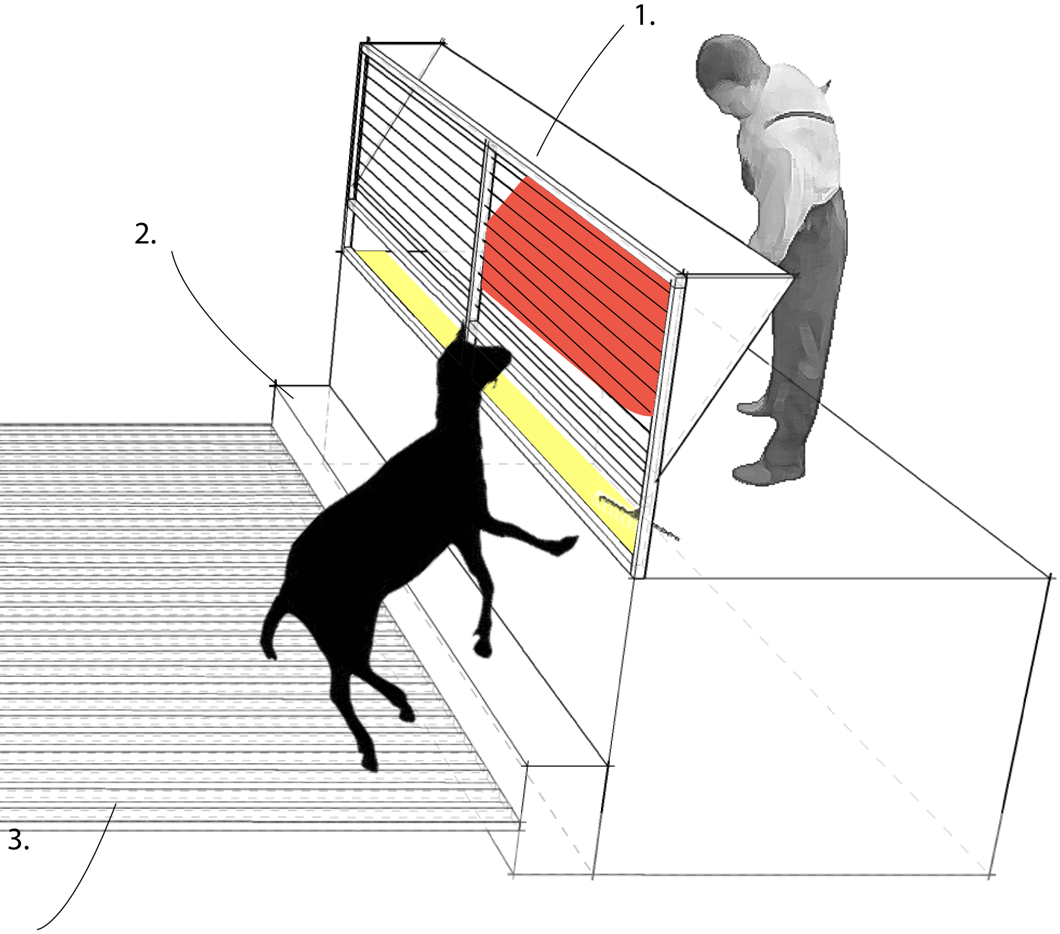


Figure 2.18 *To push the pen even further, multiple pla*
provides more sheltered space for goats seeking solitud
ture and bacteria that cultivates in packed bedding. O
types while allowing for highe



An Improved Goat Pen

The feed alley is raised to elevate feed more better consumption of both grain and grasses (1). A step (2) is provided for better reach to the elevated feed mimicking reaching to a higher branch when foraging. A study conducted in 2017 in New Zealand, found that dairy goats prefer to use different flooring types.[39] The slatted flooring (3) is located in a zone where feed and water is more likely to spread within the pen, eliminating floods and feed from soiling the bedded area. The bedded area (4) where less moisture is important, is pulled away from the water and feed areas. Varying elevated platforms (5) offer more area for goats to rest and climb without taking up considerable floor area in the pen. Concrete walls (6) offer durability where goats are placed against a wall.

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39 Sutherland, Mhairi A., et al. "Dairy Goats Prefer to Use Different Flooring Types to Perform Different Behaviours." Applied Animal Behaviour Science, vol. 197, no. 197, Dec. 2017, pp. 24–31, 10.1016/j.applanim.2017.09.004.

tforms creates a more challenging climbing area and de. Combining multiple flooring types can lessen mois- ne feed alley is possible to maintain separation of feed r elevation of consuming feed.

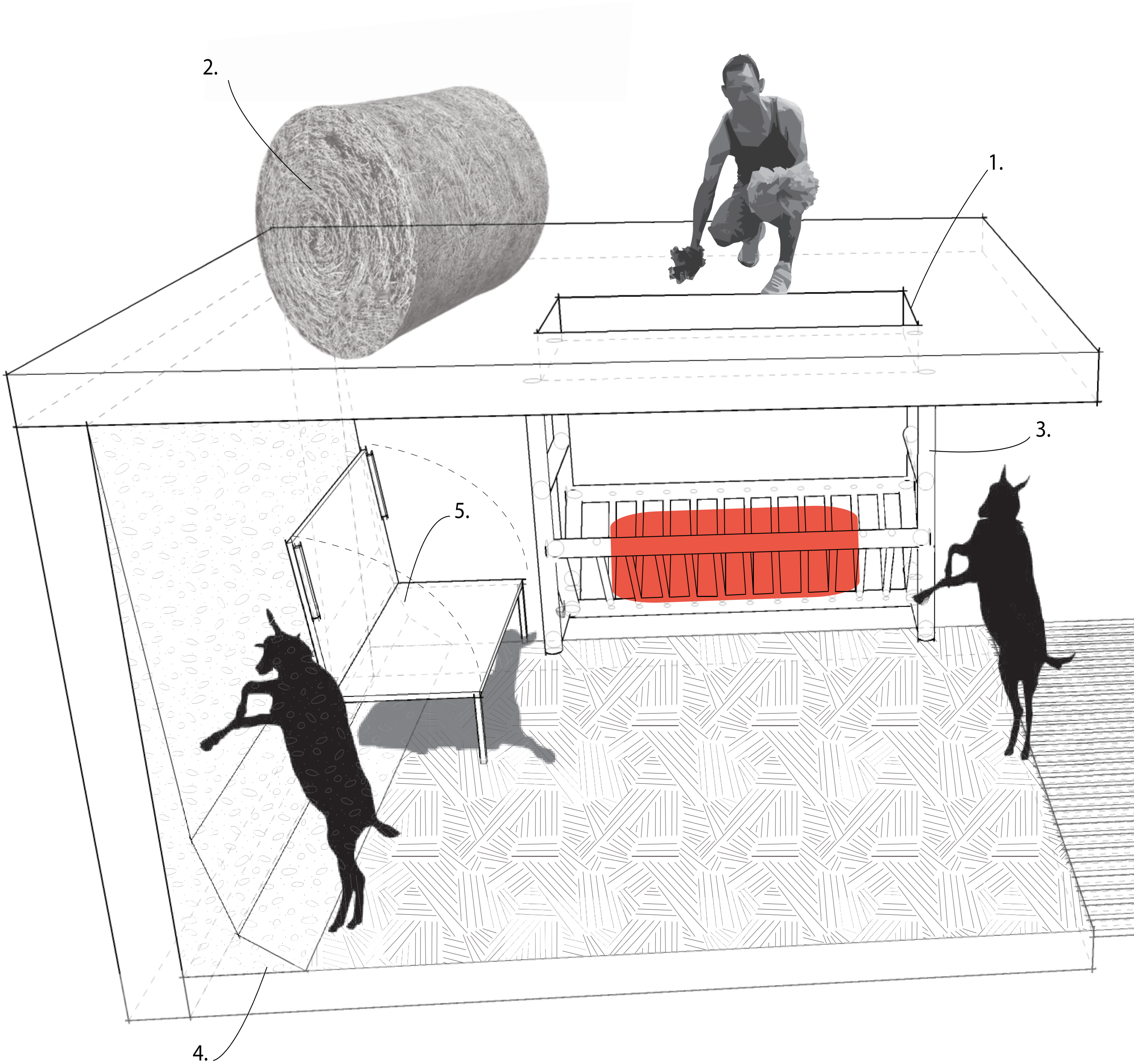
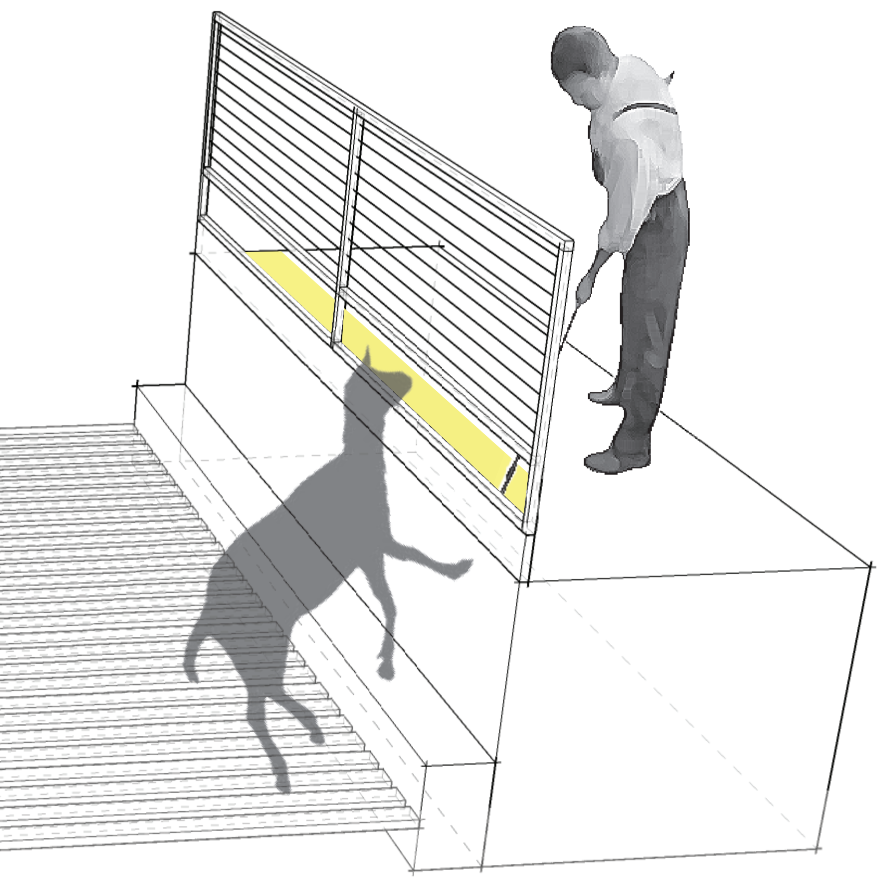


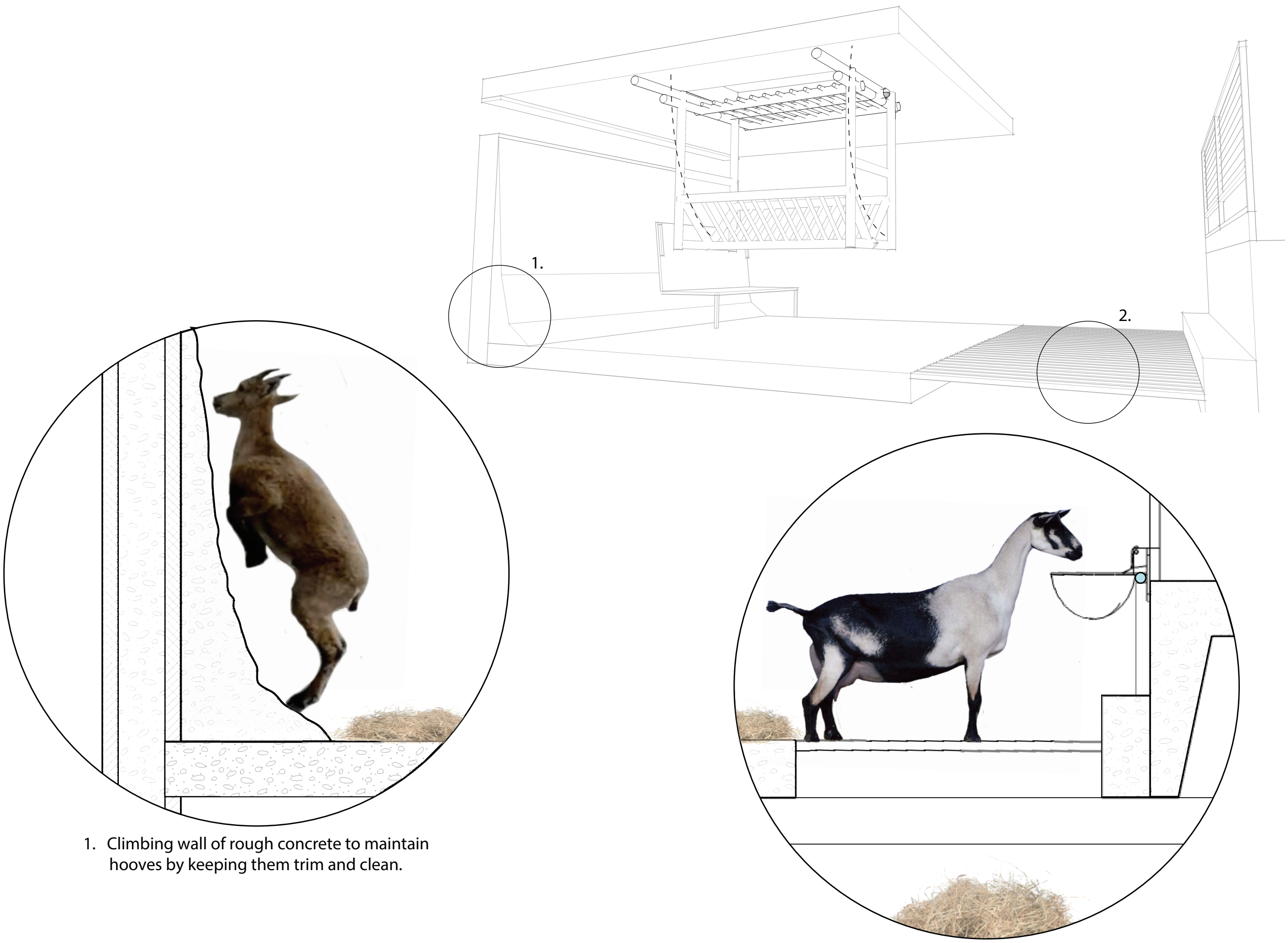
Figure 2.19 *An enriched housing environment within*
vioural flexibility and its positive associations such as f
and climbing, differing flooring and r



An Even Better Goat Pen

A hanging hay feeder (3) is raised above the pen allowing for forage style feeding and provides bedding from loose hay falling into the pen. This maintains the feed alley for grain only. The bale storage (2) above the pens eliminates the need to drive large equipment through the facility to deposit a bale, rather handlers can deposit hay easily into the feeders through a trap door (1). Along the back of the pen, a slanted rough concrete wall (4) gives goats a surface for climbing that can clean and maintain hoof lenghts. The platforms (5) can be tucked away for easy access to area below when cleaning out pens.

a pen, particularly with elements that increase beha-
feed at higher intake heights, platforms for segregating
rough surfaces for hoof maintenance.



1. Climbing wall of rough concrete to maintain hooves by keeping them trim and clean.

2. Slatted floors in areas of higher manure, foot traffic, and water sources, minimizes moisture and bacteria retained in bedding.

Figure 2.20 *Specific design elements that help with foot health that can be integrated into pens.*

Hoof Health

The preference of goats for drier, rocky areas appears to have a hoof health benefit. The feral goat has evolved flexible, cloven hooves to facilitate movement on rough, steep rocky terrain; however, this has resulted in the hooves growing continuously to counteract constant wear. This hoof anatomy also results in a unique ability to climb trees. Indeed, goats' hooves have the ability to withstand a variety of challenging conditions, including traveling significant distances, and even extensively managed domestic goats can walk several kilometers per day when foraging.[40] One study in particular found that milking does that traveled upward of three kilometres in a twenty-four hour period had convex, solid yet spongy hoof soles and toes that were similar in length to a recently trimmed hoof, despite the hooves not being trimmed for at least five months. In contrast, when goats are kept in environments devoid of climbing opportunities or hard surfaces, hoof overgrowth is a constant management issue.[41] Footrot and lameness has been high on the priority list for goat welfare research in Ontario for the past two years. The spongier hooves of goats soak in moisture, espcially from packed bedding. A lack of hard and rough surfaces within a goat's pen does not give their hooves a chance to shed dirt and dry-out. By providing rough surfaces at an incline that challenge a goats will to climb, the hooves are being maintained by the act of brushing the hooves against the rough surface.

Additionally, areas of high standing traffic is where goats tend to release bowel movements, therefore by providing flooring that allows said manure to drain away, it lessens the amount of moisture preserved in a pen.[42] Along the feed alley, where goats will stand to eat and drink, slatted floors, which have been utilized in cow barns for decades, allows manure to fall between the slats, minimizing the moisture and bacteria that can remain in a packed bedding, and leaves a goat's foot before traveling to other parts of the pen or facility, and tracking the bacteria around. This helps to maintain a dry and clean area along the climbing wall, where goats will feel more comfortable to sleep.

40 Zobel, Gosia, Heather W Neave, and Jim Webster. 2018. "Understanding Natural Behavior to Improve Dairy Goat (Capra Hircus) Management Systems." Translational Animal Science 3 (1): 212–24. https://doi.org/10.1093/tas/txy145.

41 Askins G. D. , and E. E.Turner. 1972. A behavioral study of Angora goats on West Texas range. J. Range Manag. 25:82–87.

42 Sutherland, Mhairi A., et al. "Dairy Goats Prefer to Use Different Flooring Types to Perform Different Behaviours." Applied Animal Behaviour Science, vol. 197, no. 197, Dec. 2017, pp. 24–31, 10.1016/j.applanim.2017.09.004.

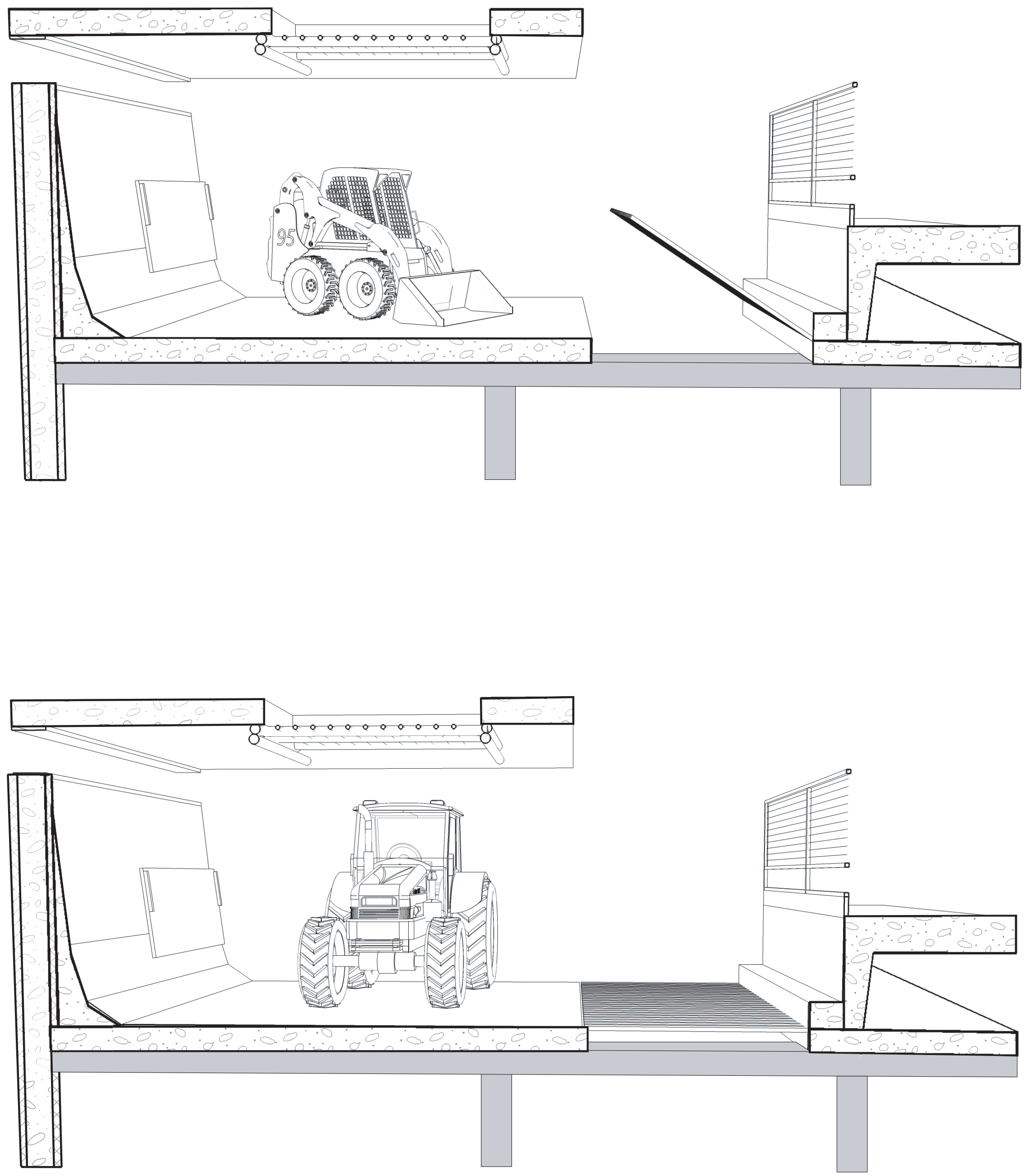


Figure 2.21 *With the suspended hay feeder able to fold-in, large equipment can easily access the pens for quick and efficient cleaning of the pens. Platforms should be able to fold up to keep out of the way. With potential storage of manure below the pen, I've designed the slatted floors to lift and open an area where equipment can dump manure.*

Flexibility

Goat housing should be easy to maintain and manage where operations and procedures can be standardized, be ergonomically sound, and provide for a working environment and amenities that promote handler welfare as well. The facility design should account for physical durability, reliability, and maintainability, while retaining the flexibility to adapt to unpredictable needs. As seen in Figure 2.21, equipment needs to easily access all corners of a pen for cleaning. The slatted floors could be opened to allow manure cleaned into a pit below the pens for collection. Size of pens in tems of width and height should also consider size of standard equipment used to clean and potentially repair pen infrastructure. The hay feeders fold-up, giving enough head space for equipment and handlers when accessing the pens. To account for changes in pen sizes and provide environmetal complexity, the feeders can also move along a track, as seen in Figure 2.22, to provide flexibility in the goats' behaviours as well.

To achieve the flexibility in changing pen sizes, mobile gates with mounting brackets at intervals to form modular pens, runs and enclosures, to allow for their positioning in the most efficient manner possible within the space available. In Figure 2.23, the spacing of mounting brackets should consider the smallest pen size to house small groups for specific studies or to create a pen for the ability to introduce a new animal to an existing group in stages. Goats should never be housed alone, so in need of separation due to illness or treatment, a lone goat should be able to see and hear other goats.[43] The ability to house more than one animal, while allowing for the isolation of a specific individual, will allow for greater flexibility in a group housing system.

To support the collection of data and using equipment where or near where the animals are housed, greater pressure is exerted on the facility to support and enable the use of various research devices and forms of equipment. As science continues to progress, the frontier is almost limitless and somewhat unpredictable as to what may be needed to accommodate the types, functions, purposes, numbers, and sizes of these constantly evolving and improving items. Creating general spaces that are designed and outfitted for flexibility and for ease of renovation allow for research needs to be met. Within this context, storage space devoted to research equipment that is used with regular periodicity should be allocated by design or enabled through flexibility from design.[44] To design a successful research facility a development of programming with future growth in mind by encouraging flexibility in layout and design whenever possible to consider future research needs.

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43 Miranda-de la Lama, G. C., and S. Mattiello. 2010. "The Importance of Social Behaviour for Goat Welfare in Livestock Farming." Small Ruminant Research 90 (1): 1–10. https://doi.org/10.1016/j.smallrumres.2010.01.006.

44 Weichbrod, Robert H, Gail A Thompson, and John N Norton. 2018. Management of Animal Care and Use Programs in Research, Education, and Testing. Boca Raton, Fl: Crc Press.

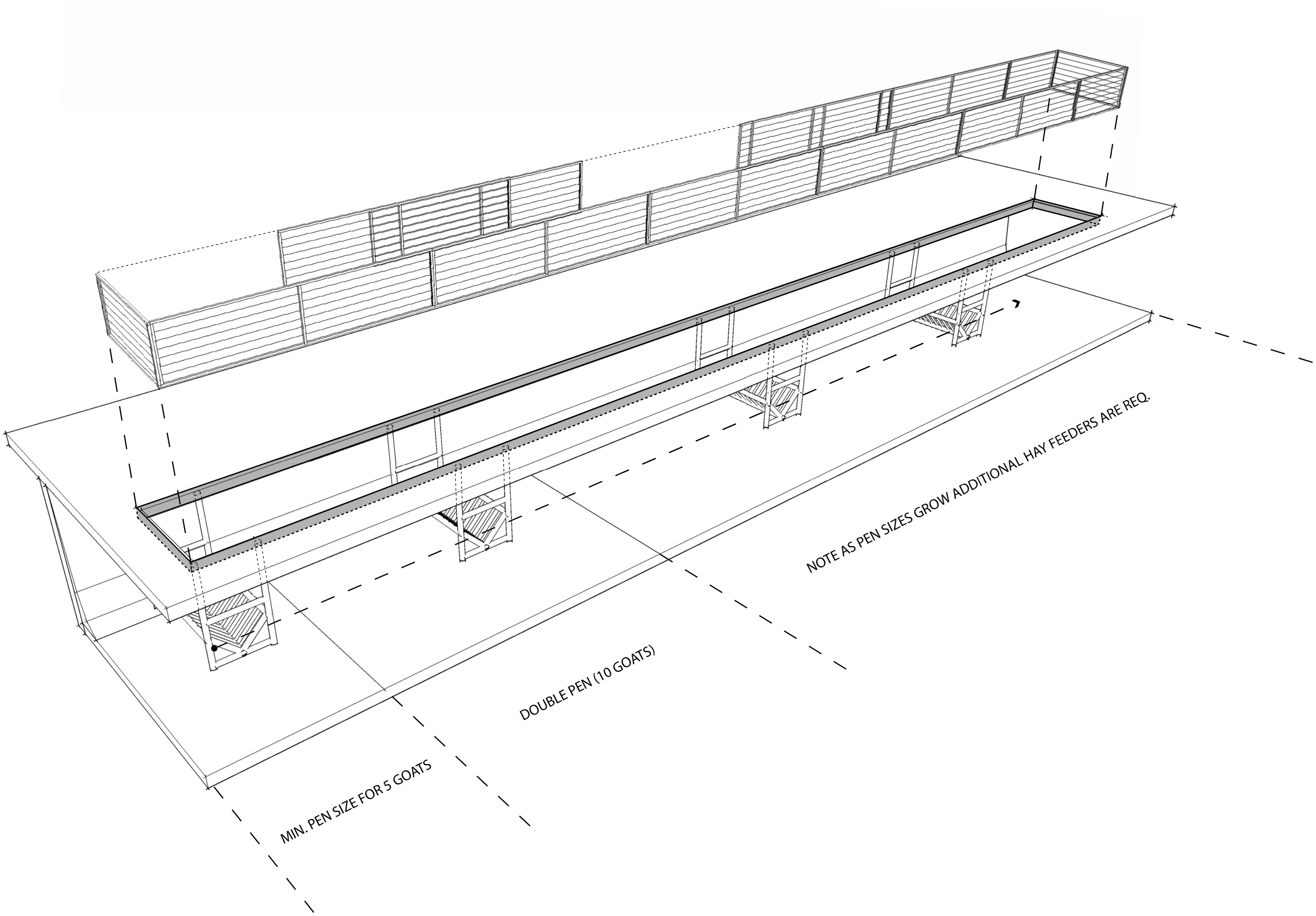

Figure 2.22 *By using a track system for the suspended bale feeders, flexibility is achieved to ensure any pen size can access the required amount of grass feed. The feeders can also move locations and during different times, mimicking a heterogeneous environment where some food patches emerge while others decline.*

Flexible Pens

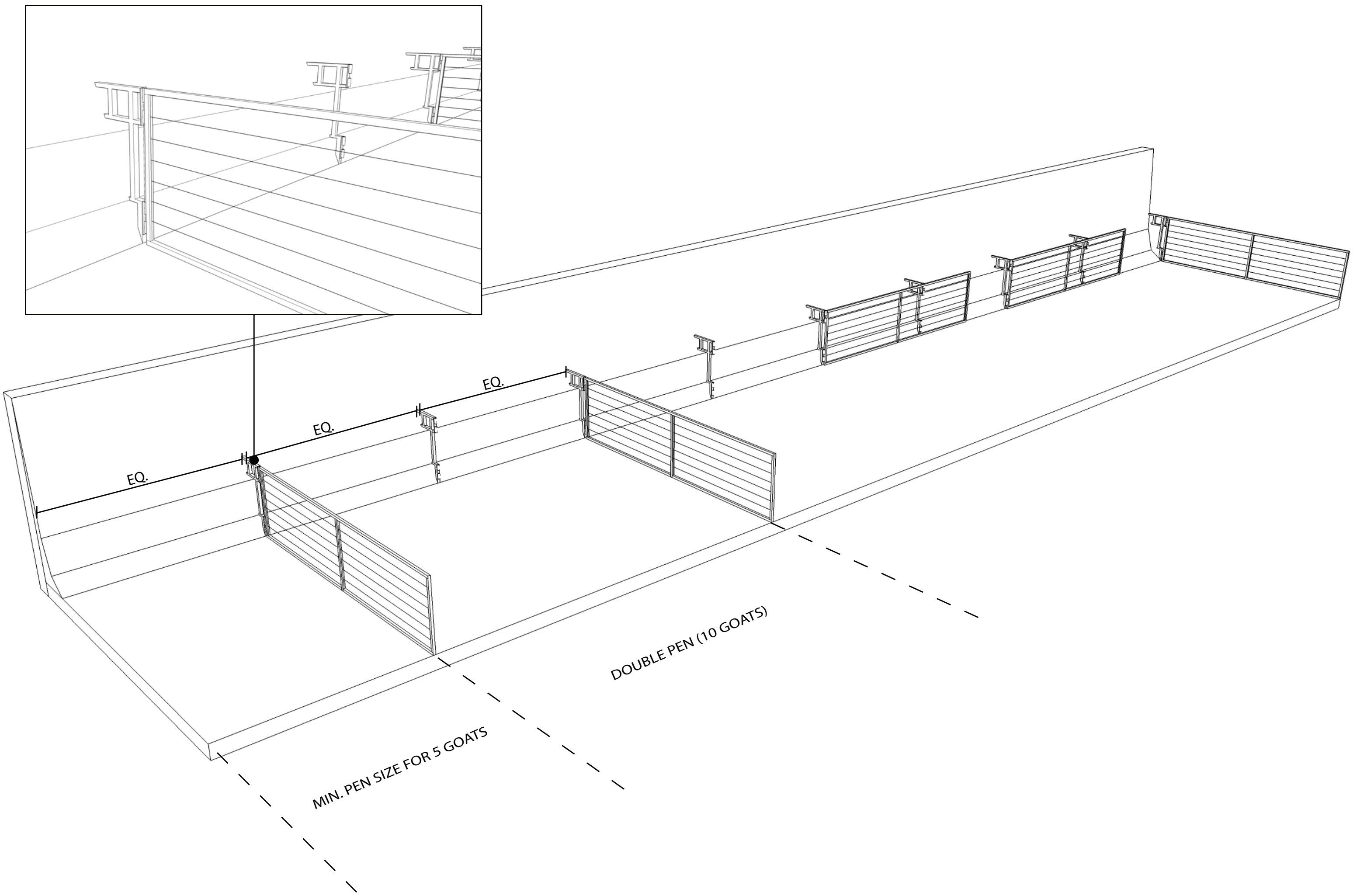

Figure 2.23 *Flexible pen and enclosures can be made using mobile gates and mounting brackets spaced apart based on ideal pen sizes for certain group configurations. The gates can also be placed along the walls to create an open pen for large equipment when clean-out is required.*

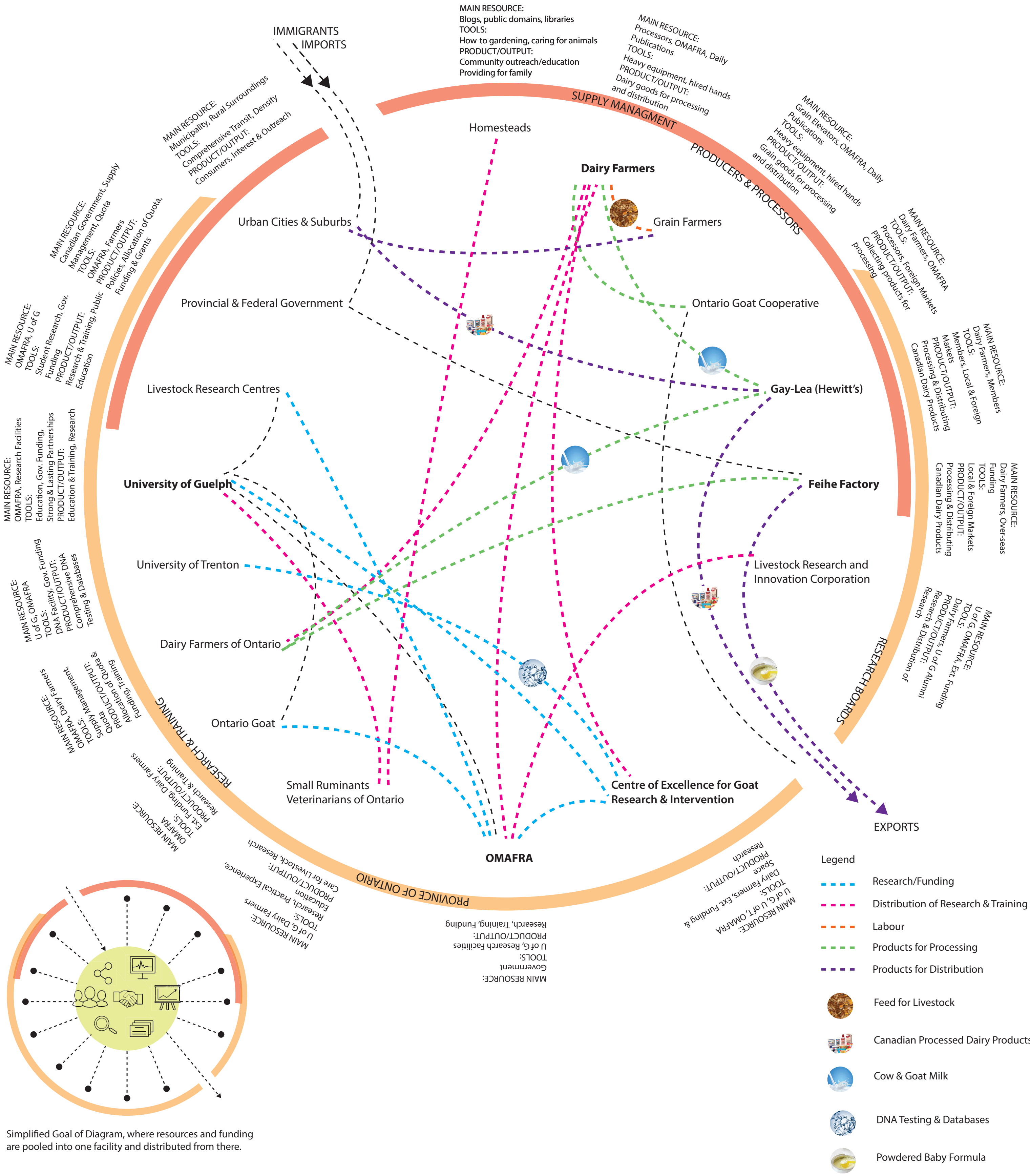

Figure 2.24 *The key stakeholders within the dairy goat industry are bounded the regulations and restrictions by Canada's supply management system and the government of Ontario. The smaller and more organized diagram to the right, showcases the goal of the thesis: to create an architectural structure that allows resources and funding to be pooled into on facility and distributed from there.*

Human Behaviour - Transparency in Farming Practices

Engaging the public rather than trying to educate the public could be the best path to ensure continued trust in animal agriculture. Less connection to farms means that few people have a concept of how animal agriculture works, leading to challenges with their interpretation of farming practices. The Ontario goat industry was shaken up when a dairy goat farm in Caledon was reported on an aminal activists' website with claims of animal abuse along with first account stories and photos.[45] Different attention-getting tactics by animal activists groups have caused tension and mental challenges for farmers. Recent laws restricting access to farms could cause futher tension between farmers and consumers as many see transparency directly linked to accountability. A great risk to animal agriculture is the public finding out about practices through unreliable sources and these practices being construed. Many of the claims of the animal abuse scandal on the Caledon farm, were the demonstration of a goats natural behaviour within a typical unstimulating barn. It was clear the activists were not aware of goat's behaviour and misinterpreted as a lack of care by the farmer.

A University of British Columbia (UBC) study on public perceptions of dairy cattle care found participants actually lost confidence in production methods after seeing a working dairy and being accurately informed of its various practices.[46] Marina Von Keyserlingk, a professor in animal welfare at UBC, said those involved in animal agriculture cannot afford to be rigid in their stance on how they do things, and accept that they can't do certain things anymore because consumers don't approve. She suggests negotiations between activists, farmers, and vets to maintain productive communication and provide more accountability on all fronts.[47] As of April 2019, Ontario Goat announced an update is to be made to Canada's Code of Practice for the Care and Handling of Goats. The Goat Code of Practice was open to the public between December 18, 2020 and closed on Febraury 22, 2021, in hopes that public comments could be futher explored and incorporated within the Code.[48]

Cosntructing a research facility to act as a catalyst for communication and collaboration between stakeholders such as farmers, consumers, researchers, vets, feed companies, and manufacturers, allows for any innovations and developments within the dairy goat industry practices and policies, to come from multiple perceptions and require integrity from all parties.

45 Last Chance for Animals. 2020. Review of Breaking: LCA's Investigation Exposes Animal Suffering at Escarpment's Edge Dairy Farm! Edited by Last Chance for Animals. Investigations (blog). January 2, 2020. https://www.lcanimal.org/index.php/component/content/article/7-investigations/282-escarpments-edge-dairy.

46 UBC Dairy Education and Research Centre. 2016. Review of Public Expectations of a Dairy Farm. Edited by Clarissa Cardoso. UBC Dairy Education and Research Centre. https://lfs-dairycentre.sites.olt.ubc.ca/files/2017/01/UBC-Dairy-Centre-Research-Report_Expectations-of-a-dairy-farm-Vol16-2rev-1.pdf.

47 Glen, Barb. 2021. Review of Education Campaigns about Agriculture Have Drawbacks: Professor. Edited by Farmtario. Farmtario, January 22, 2021. https://farmtario.com/news/education-campaigns-about-agriculture-have-drawbacks-professor/.

48 Postmedia News. 2021. Review of Draft Goat Code of Practice Now Open for Public Comment. Edited by Ontario Farmer. Ontario Farmer, January 13, 2021. https://www.ontariofarmer.com/livestock/draft-goat-code-of-practice-now-open-for-public-comment.

part three

APPROACHES

Precedents

Agriculture research facilities play a central role in the environmental characteristics of everyday farming practices. Over the past few decades, they have accompanied the development of the agricultural activities of various industries from livestock to crops, by ameliorating animal genetics, crop yields, and by transforming agricultural processes and products in a functional and efficient way.[49] Aimed at producing optimal environmental conditions for plants and animals, while at the same time protecting the hygiene and health of workers involved in the daily operations of the care of living organisms at different stages of their development, the research facilities constitutes a unique and unrepeatable technological model. Indeed, the originality of what happens inside the research facilities corresponds to what happens outside. The birth, growth and development of living vegetal or animal organisms contained inside these buildings raise architectural and technical issues that are completely different to those of other industries. The role that the facilities have historically played is strictly connected with the surrounding environment, due to the need of the farmer to live in close contact with agricultural land and animal husbandry.[50]

The construction of new livestock research facilities in Ontario not only responds to growing research and product demands but also the increase in public interests into the agri-food industry. As the demand for dairy goat products rises, the rise of research stems from producer needs to meet market demands. With ever-changing trends in food and agriculture, it's important to allow public to interact with ongoing research to educate. Although older research facilities find it harder to manage public tours due to biosecurity retrofits to an outdated facility, the new facilities have managed to include public interaction as paths for public tours and research spaces for students within the design of the facilities. For example, the Elora dairy research centre and the Rayner dairy research centre in Saskatoon, Saskatchewan, allow for public tours but in two distinctively different ways. The Elora centre provides tours of up to a hundred persons and allows the tour to walk through the livestock areas where the laneways are twice as wide as an average barn to accommodate for traffic where employees will be working. Elora also has a separate entrance or the public away from employees and the loading areas.

The role of the architect is questioned within these precedents as professional architects are rarely involved in the process of designing and the construction of farm buildings, whether dairy or of a different kind. Typically agriculture engineers and contractors are the ones involved in the consulting, design, and construction of farm buildings. With farm buildings, especially dairy cow, being structured around strict policies and standardized housing and feeding systems, and architect's design input is seldom required as aesthetics are not a priority. Therefore, I analyzed four research facilities on the following criteria: innovation, aesthetics, animal husbandy and public interactions.

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49 Hessler, Jack R, and Noel D M Lehner. 2009. Planning and Designing Research Animal Facilities. Amsterdam ; Boston: Elsevier/Academicpress.

50 Picuno, Pietro. 2012. "Vernacular Farm Buildings in Landscape Planning: A Typological Analysis." Journal of Agricultural Engineering 43 (3): 20. https://doi.org/10.4081/jae.2012.150.

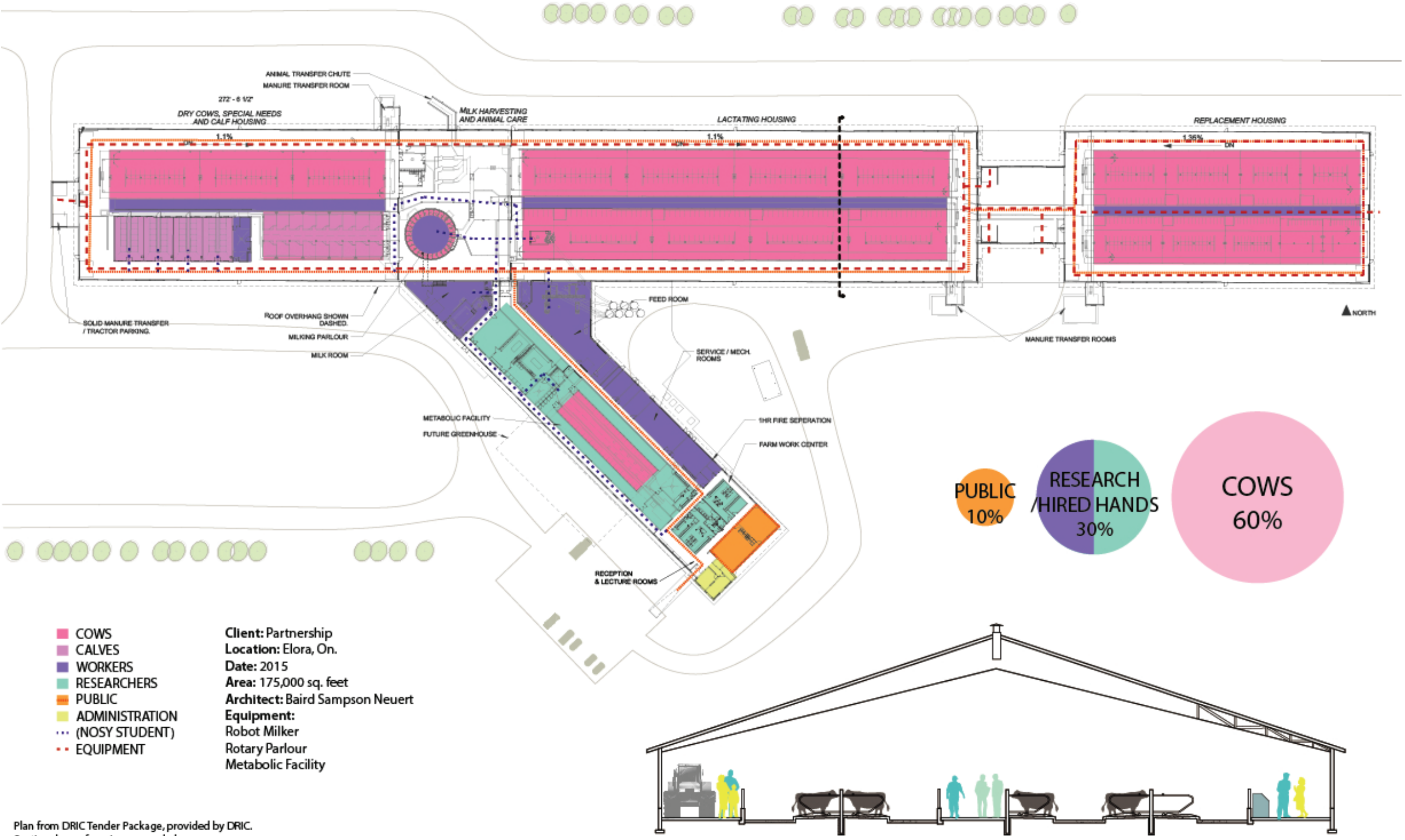

Figure 3.1 *Elora Research Station floor area breakdown*

Figure 3.2 *Elora Research Station exterior & interior views*

Dairy Research and Innovation Centre

This 16,250m^2 facility is a partnership between the ARIO, OMAFRA, the University of Guelph and the Ontario dairy industry. Housing 750 animals, the facility incorporates specialized equipment for automated precision feeding, robotic milking, and organics composting. Spaces include an isolated housing compartment to measure methane production, surgical facilities, as well as research and lab spaces that include a lab for milk testing. Further, the design has provided multipurpose spaces intended for teaching and industry conferencing events.

The areas of research conducted within the facility are joint to support the dairy industry and consumer interests. Dairy industry research includes animal health and welfare, genetics and genomics, animal and human nutrition, management and technology, and product development. Consumer research includes creation of a patented feed that helps cows produce DHA-laden milk (DHA is an omega 3 nutrient that supports brain, heart and eye health[51]), and a testing procedure and management tool to identify animals with high immune response rates that can be passed down to offspring, limiting the dependency on antibiotics.[52]

The facility was designed by Baird Sampson Neuert (BSN) in partnership with engineering consultants Lemay & Choiniere Inc., who specialize in farm building construction and environmental legislation compliance.[53] It is evident that BSN's true design focus was on the main entrance (Figure 3.2 left) accessed by public and the administrative functions such as the reception area with offices and lectures rooms. Figure 3.1 shows a breakdown of the floor plan in terms of program dedicated to either the public, research and staff, and finally the cows. The facility as a whole resembles typical dairy barns with scissor or raised tie trusses for ample ceiling height and space with widespread columns. The right image of Figure 3.2 shows the wide expanse of space created with a scissor truss roof system giving height throughout the barn for large equipment. The modified 'T' shape and layout of the building accommodates the critical functional relationships of the facility while retaining optimal orientation for energy conserving systems. The primary barn (the long pink area of Figure 3.1) is positioned to take advantage of the prevailing summer winds and is designed to optimize passive ventilation and free cooling. The research wing is angled to face south (the mainly green and purple area of Figure 3.1), enabling future solar-harvesting hot water or photovoltaic systems.[54] Therefore, BSN was able to manipulate somewhat the typical shed like building of the dairy barn to better accommodate the site and implement more sustainable typologies.

The partnership between BSN and Lemay & Choiniere continues with the Beef Research Facility (completed in 2019) and the Swine Research Facility (construction slated for 2021).

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51 Huang, Guoxin, Yangdong Zhang, Qingbiao Xu, Nan Zheng, Shengguo Zhao, Kaizhen Liu, Xueyin Qu, Jing Yu, and Jiaqi Wang. 2020. "DHA Content in Milk and Biohydrogenation Pathway in Rumen: A Review." PeerJ 8 (December): e10230. https://doi.org/10.7717/peerj.10230.

52 "Elora Research Station – Dairy Facility | Ontario Agri-Food Innovation Alliance." 2015. Uoguelph.ca. 2015. https://www.uoguelph.ca/alliance/research-facilities/elora-dairy.

53 "University of Guelph." n.d. Consultants Lemay & Choinière Inc. Accessed May 8, 2021. http://www.lemaychoiniere.com/en/projet/university-of-guelph/.

54 bsnarchitects.com. n.d. "Dairy Research Centre." Baird Sampson Neuert Architects. https://www.bsnarchitects.com/dairyresearchcentre.

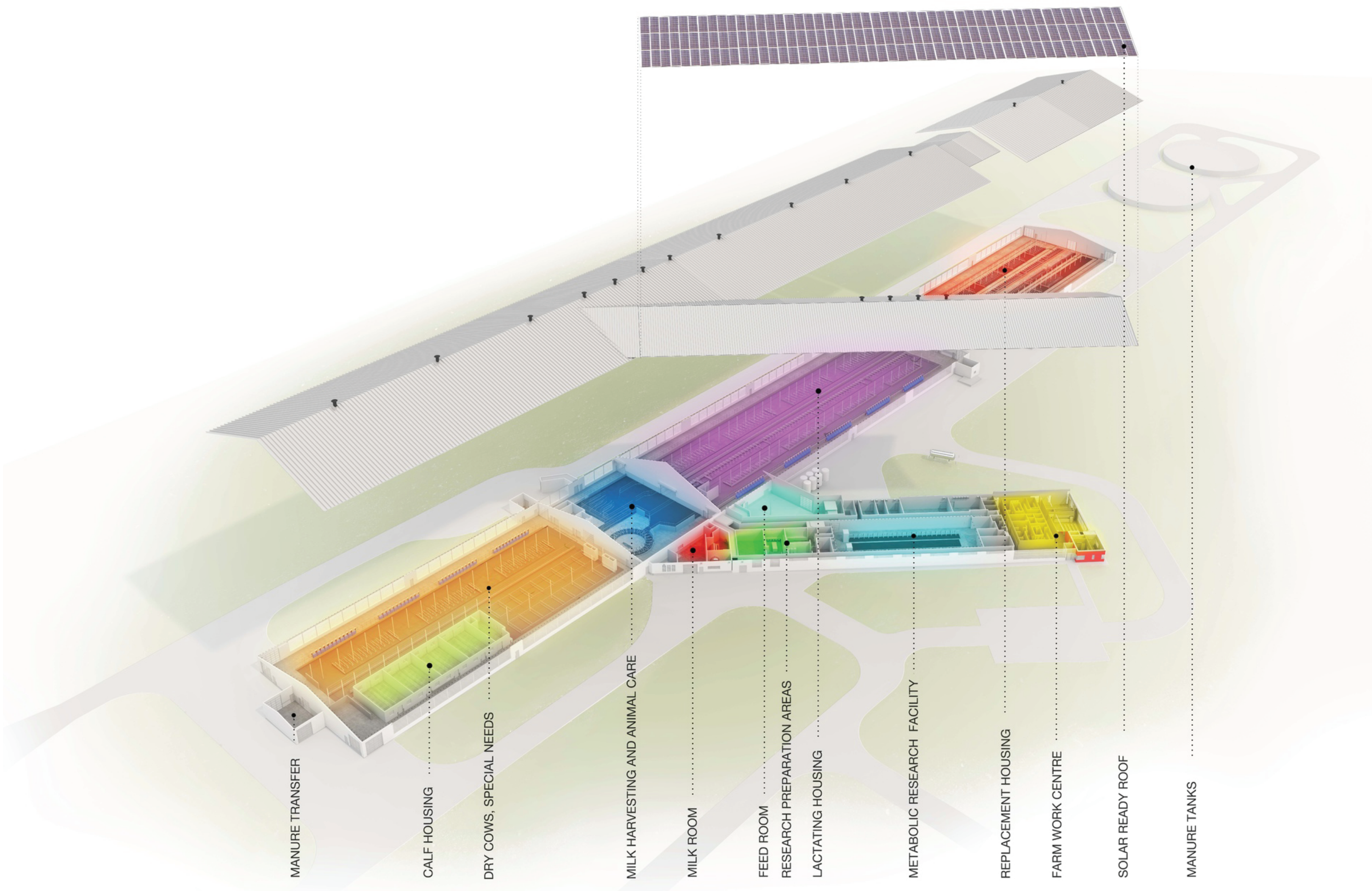

Figure 3.3 *Axonometric of the Elora facility showing the main programs within the modified 'T' layout of the building.*

The modified ‘T’ shape of the building not only accommodates the optimal orientation but also creates separate functional areas: lab and research, housing, milking, feed and waste management, and administrative. The later is at the farthest part of the small extension of the building for public access directly from the main parking lot. This main entrance is highlighted by a bright red steel cladding that wraps around the corner and is highly visible from the parking lot. The recently completed beef research centre also uses bright red cladding seeming to create a design element to denote the UofG research stations. Placing the main facility entrance for staff and public on one side of the building keeps the large equipment to the north side of the building for deliveries such as feed. The pick-up of milk happens at the node where the two forms of the building meet.[55] The various milking apparatuses are in the centre of the primary barn with pens on either side for easy circulation of cows. The circulation between the milking parlour and the pens is an area of great importance for circulation of animals coming and leaving their pens. As previosuly stated, the parlour can be a place of high stress for animals, therefore creating an efficient circulation can keep the animals moving without too much intervention from handlers.

The advantage of separating the main research facility programs from the administrative programs such as offices and training rooms, is creating a clean and safe entry with a main reception. Visitors would receive gear such as plastic boot coverings and any other requirements for biosecurity. Staff can access change rooms and washrooms to change before entering lab areas and again before leaving. I would argue that some visuals to various facility functions such as the parlour or the pens from reception area gives the vistors immediate access to what they are truly coming to see. Also, specific demonstrations for dairy goat industry training that would require the animal such as artificial insemination (AI), body conditioning scores, hoof trimming, assisted delivery of kids, and any other training, would beneift from being near goat pens.

55 bsnarchitects.com. n.d. “Dairy Research Centre.” Baird Sampson Neuert Architects. https://www.bsnarchitects.com/dairyresearchcentre.

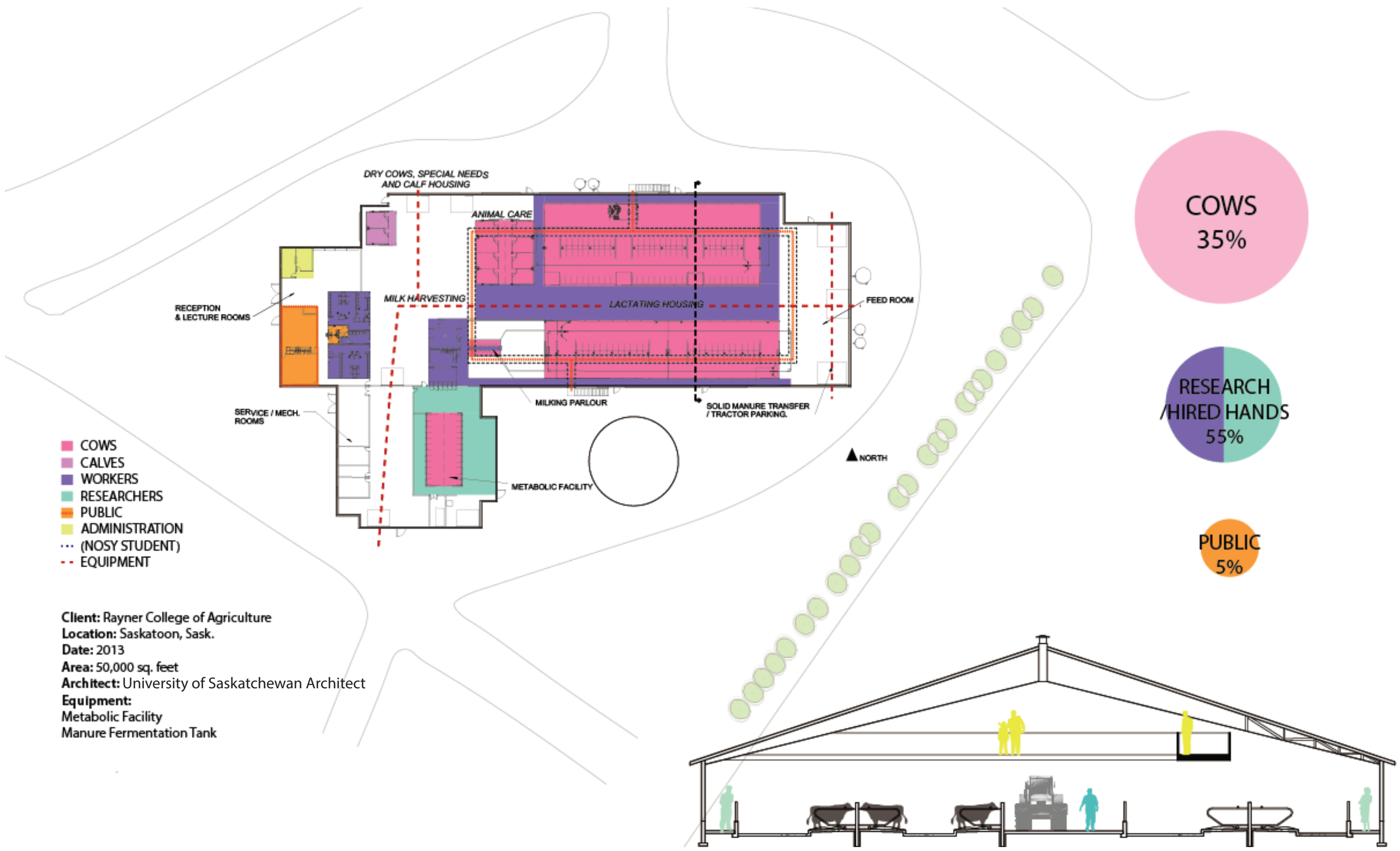

Figure 3.4 *Rayner Dairy Research Facility floor area breakdown.*

Figure 3.5 *Rayner Site Plan & Interior View*

Rayner Dairy Research & Training Facility

The Rayner Dairy Research and Teaching Facility, located on the University of Saskatchewan campus and opened in 2013, accommodates approximately 100 lactating cows with both robotic, parlor and tiestall milking capabilities, animal handling and teaching areas, and research and staff space. Research performed in the 4,650m^2 facility includes dairy nutrition and feed development, animal fertility and health, animal management, technology development, application of information technologies, and development of green technologies for improved sustainability.

The Rayner centre has a raised open catwalk that travels over the facility to allow public viewing of the research without disrupting the flow of work below. The raised walkway, as seen in the right image of Figure 3.5, provides a bird's-eye view of the herd, milking parlour and a computer-based milk robot.[56] Located in the Rayner Dairy Research and Teaching Facility, the Feeding the World Interpretive Center educates the public about agriculture. The interpretive centre uses dairy production as a way for visitors to explore the agricultural story of Saskatchewan and its role in global food production.[57]

The University of Saskatchewan Architect, Colin Tennent, was more focused on the research programs and abilities within the building rather than the overall look of the building, demonstrated in a video of him walking by the facility under construction and talking about the site and the research to be conducted within the building. His focus was solely how the design of the facility could amplify the research capabilities by it's interior configuration.[58] There isn't anything remarkable about the exterior of the building and unlike the Elora dairy facility, the Rayner facility lacks any architectural feature that would announce the main entrance. The left image of Figure 3.5 shows the front facade of the research facility with its consistent metal cladding and repeating windows. There are multiple doors along the front facade but no overhang or other design features to highlight one over the other. I would argue that this lack of apparent front entrance makes the building unwelcoming and gives the impression that the research facility is not accessible for tours and public outreach.

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56 "Rayner Dairy Research and Teaching Facility - College of Agriculture and Bioresources - University of Saskatchewan." n.d. Agbio.usask.ca. Accessed May 14, 2021. https://agbio.usask.ca/research/centres-and-facilities/rayner-dairy-research-and-teaching-facility.php#About.

57 "Feeding the World Interpretive Centre - College of Agriculture and Bioresources - University of Saskatchewan." n.d. Agbio.usask.ca. Accessed May 14, 2021. https://agbio.usask.ca/community-outreach/feeding-the-world-interpretive-centre.php.

58 "U of S Architect Colin Tennent Talks about the New Rayner Dairy Research and Teaching Facility." n.d. Www.youtube.com. Accessed May 14, 2021. https://www.youtube.com/watch?v=RHJQCvXubs8&t=104s.

Figure 3.6 *View from raised walkway in the Rayner facility. The view can reinforce the perception that the cows are for research only. But offering a raised view does give a different perspective to watch the animal's behaviour.*

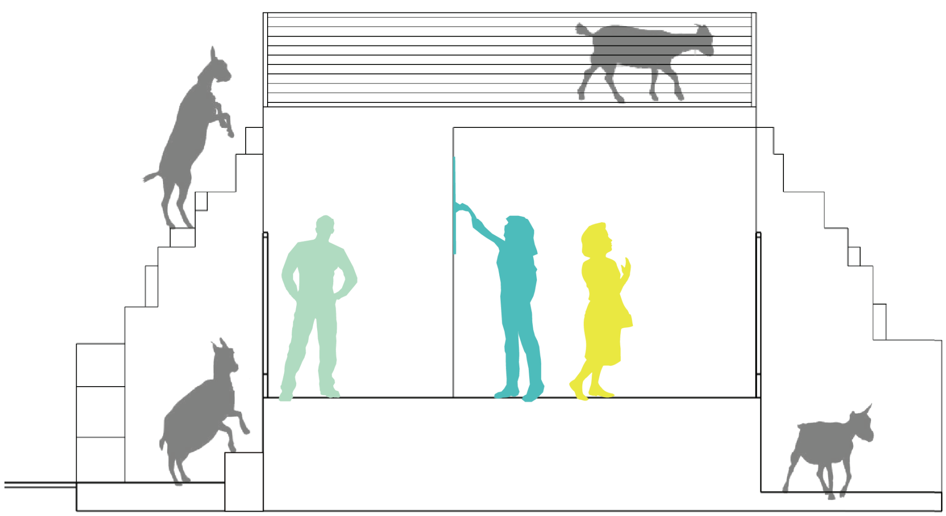

Figure 3.7 *Having moments within a research facility that allows the goats to climb and be above the handlers, researchers, and public demonstrate the natural behaviour of goats and can give the facility an atmosphere of wellbeing for the goats rather than pure lab work.*

A raised walkway allows for the ground space to be used solely for research without having to accommodate for public tours where allowing public to walk through can be risky and pose a threat to a person or an animal. Figure 3.6 shows the view granted to the public of the cows and research programs below. Whereas, the ability for people to walk through certain areas gives them a firsthand look and exploration of certain research and even the animal care and maintenance. A combination of walkways and public interaction at grade can be implemented to decrease risk in higher traffic or quarantine areas and still maintain transparency. I argue only visualizing cows from above gives the impression of looking down at lab animals such as rats or mice being studied. Goats are climbers, therefore, the opportunity to have them walk above people demonstrates natural behaviour in a more clinical environment. Many tourist attractions with goats have ramps and bridges, and even roofs accessed by goats for unique and exciting views.

The design of a layout that permits visitors walking around pens with ideal separation from equipment can mitigate risk and allow interaction between the public and the goats. By allowing the goats to circulate above visitors and handlers, not only is it providing behavioural variability for the goats, but demonstrating the behaviour visually to visitors and researchers as seen in Figure 3.7. This provides accountability between the indusry and consumers as well as assurances that animals are able to perform important natural behaviours. Being able to see an animal from all perspectives may give the best account of its wellbeing.

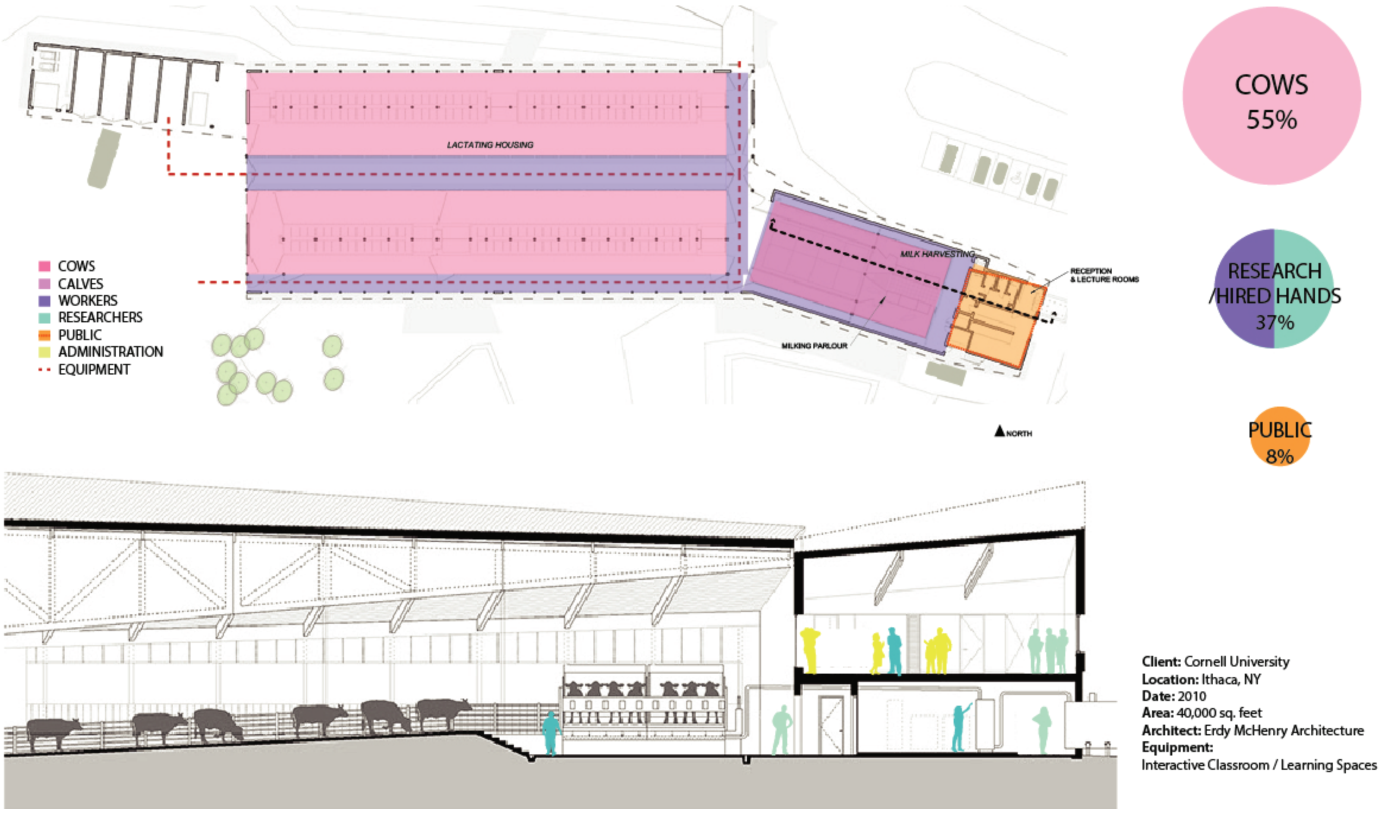

Figure 3.8 *Cornell Teaching Dairy Barn floor area breakdown*

Figure 3.9 *Exterior rendering and view of the Cornell facility*

Cornell Teaching Dairy Barn

When creating a new dairy barn for the College of Veterinary Medicine, Cornell University requested a facility that would operate in the same manner as a traditional New York State dairy barn while serving as an environment to instruct students on the functional, organizational and operational aspects of running a dairy facility.

Early in the design process, Erdy McHenry Architecture led the design team in working with the University to establish the project goals which became instrumental in shaping the final award winning design: optimize cow comfort, increase herd flow efficiency, allow natural ventilation of freestyle barn, reduce energy consumption, and provide interactive classrooms and learning spaces. The 3,700m^2 barn is on track to win LEED Silver. The interior is broken into two main spaces: the freestall barn, where the cows can roam, eat, and sleep, and the milking parlor, which students observe from a second-story classroom. The freestall barn, with 486 stalls, has capability to house cows in both large and small groups for the conduct of replicated pen studies. To optimize cow comfort, the Freestall Barn was oriented to allow for maximum cross ventilation based on prevailing wind patterns. The milking area was incorporated at the end of the facility to maximize herd management while the classroom was placed on the second floor overlooking the milking parlor providing a firsthand view of the operations without compromising functionality.[59] Figure 3.8 shows this second floor classroom which sits above the milk house, where the cooler tanks are kept to store milk until the milk truck comes to pick it up. The milk house is more of a mechanical room containing pumps, water tanks, and washing stations for the regular washing of the milking equipment. The milk house must be kept clean and benefits from less traffic going in and out.

Similar to Elora, the elongated rectangular barn shape is skewed in places giving the research facility a much more interesting form and maximizing sun and wind exposure. Much attention has been given to the overall asthetics of the barn more so than the two previous precidents. Envisioned as the face of the College of Veterinary Medicine, the dairy barn was to exemplify the University's commitment to quality architectural design and sustainability.[60] This is achieved with ribbed transparent cladding that creates a bright interior during the day, and becomes a beacon of light at night, demonstrated in the the image on the right of Figure 3.9. This creates a modern take on traditional barn design. The clerestory windows and large overhead doors at either end create a dramatic effect of opening the building to catch prevailing winds. The exposed laminated plywood trusses create an inviting interior. Many barn trusses are sealed to create a cleaner environment where birds cannot perch and dust cannot collect. The laminated trusses prevent birds and are easy to keep clean.[61]

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59 2021. Architectmagazine.com. 2021. https://www.architectmagazine.com/project-gallery/cornell-university-teaching-dairy-barn.
60 "TEACHING DAIRY BARN." n.d. Em-Arc.com. Accessed May 8, 2021. http://em-arc.com/teaching-dairy-barn.html.
61 "The Dairy Barn, Redesigned." 2013. Modern Farmer. September 30, 2013. https://modernfarmer.com/2013/09/dairy-redesigned-cornells-barn-innovation-makes-cows-humans-happy/.

Figure 3.10 *View into parlour from classroom at the Teaching Barn.*

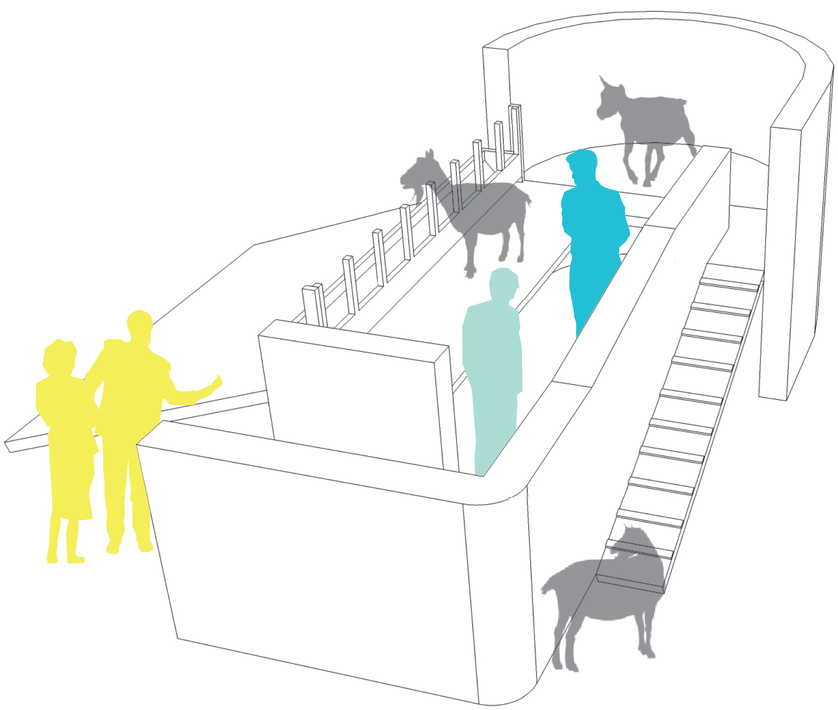

Figure 3.11 *Allowing for close-up views of milking processes while keeping strangers hidden during entrance to the parlour can reduce stress for both the goats and the handlers.*

Figure 3.9 shows the view from the second story classroom over the parlour to view animal behaviour when entering and exiting the parlour and the overall efficiency. When thinking about milking demonstrations, a view in-line with the goats being milked is another critical view for teaching demonstrations, research, and for public viewing. The difficulty lies in how goats react when new objects/people are within their regular environment. My family and I notice it when we milk with visitors in the barn, our goats are skiddish and don't want to enter the parlour. Blocking views in the parlour are a great way to establish for efficiency of goats entering the parlour for milking. If new people are out of sight until the goats are already within the parlour gates, then they are less likely to cause trouble. Parlours are always a change in level between the animal and the handler so the handler is working at eye level with the animal's udders for milking. A pit parlour is where the handler moves down a level into a parlour, standard with cows, though a slight ramp may be used to elevate the cows further. Goat parlours can be both pit or have the goats climb up a ramp or set of stairs. Some rotary parlours both for cows and goats have access through an underground tunnel that allows the handlers to access the interior of the round machinery for both milking if the parlour is an internal rotary and for maintenance of equipment. Figure 3.10 is the design of a parlour area which incorporates access for researchers and visitors viewing and learning from the milking process up close that does not disrupt the flow of the procedure.

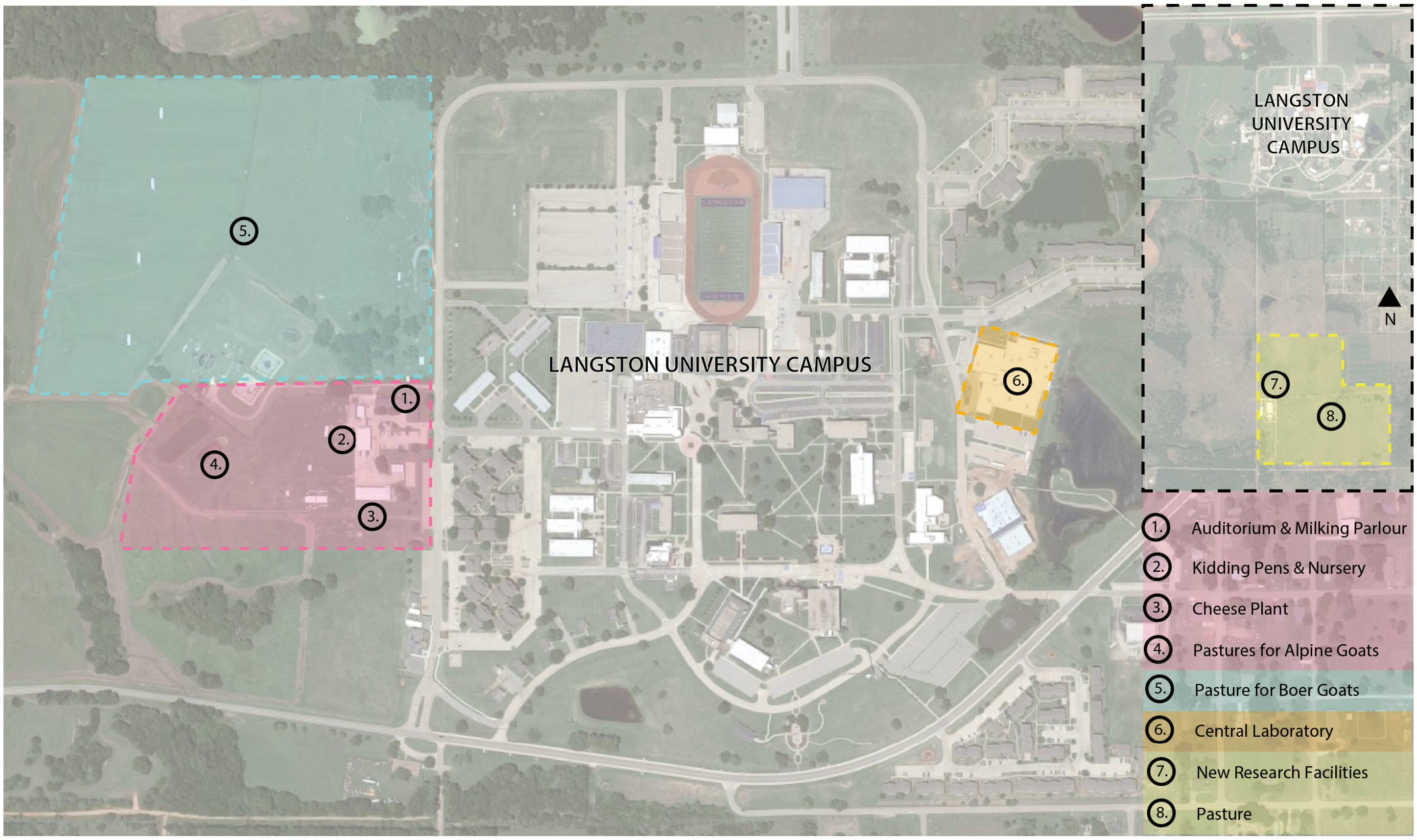

Figure 3.12 *Sketch of the layout of the main research buildings where events for the annual field days take place and the milking does are housed. Key map shows the multiple locations around Langston campus used by the research farm.*


Figure 3.13 *Left image is the arena on a field day. The arena was an existing building on campus converted to provide space for lectures and training (1985). The right photo is the animal testing room located in the most recent build for the institute completed in 2016. The need for physical improvements in contemporary animal research facilities as well as the necessary personnel safety and comfort propelled the build.*

Langston University Goat Research Facility

Located on the Langston University Campus in Langston, Oklahoma, the E (Kika) de la Garza American Institute for Goat Research is a farm operation with research and training to develop and transfer enhanced goat production system technoliogies with impacts at local, state, regional, national, and international levels. To deliver new research that is relevant and usable by researchers and producers, the research facility provides through hands-on workshops, annual field days, and web-based interactive information.[62]

Approximately 320 fenced acres of land serve as home to 1,500 goats. The goats produce milk, meat, cheese, yogurt, ice cream, cashmere, and mohair. The land is used both for pasture grazing and harvested forage production. Figure 3.12 displays the farm which is spread out around the perimeter of Langston's campus divided into four components: west of campus is the alpine dairy herd, north of campus among pastures are the spanish, boer and angora goats used for meat and hair, east is the central laboratory with classrooms, and south are brand new research buildings with housing and laboratories.

The research facility's ability to provide extension programs that benefit not only local producers and researchers, but also national researchers and farmers of larger operations, and interional producers in Africa and India, comes from not only a dedication to being a leader in goat production technologies, but human capacity building as well. With the workshops and field day providing regular access by the public, the human perception and experience within and around the facility is significant and seen as part of the facilities ability to provide efficient best practices to producers. A small auditorium was built as part of the initial research buildings to provide a gathering space where lectures and demonstrations can be conducted. The auditorium, pictured in Figure 3.13, is connected to research pens and the milking parlour where tours and viewing spots are offered to provide a quick transition from lecture to hands-on.[63]

62 E (Kika) de la Garza American Institute for Goat Research. "Exploring New Frontiers." Langston University, Jan. 2017.
63 E (Kika) de la Garza American Institute for Goat Research. "Expanding Boundaries." Langston University, June 2012.

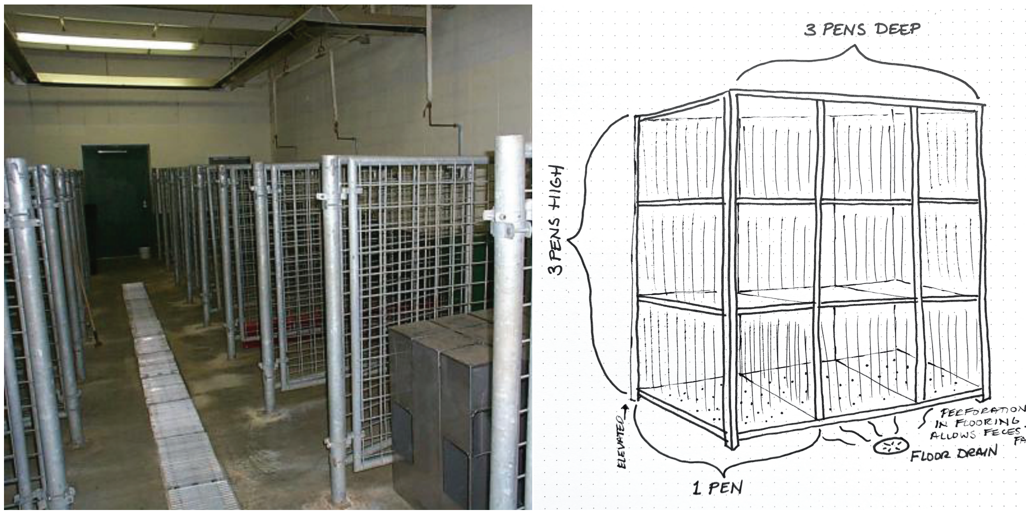

Figure 3.14 *On the left is a photo of the maternity pens for pregnant does before and after giving birth. The kids are then moved to the adjoining room. On the right is a sketch of the current pen system being used in the nursery.*

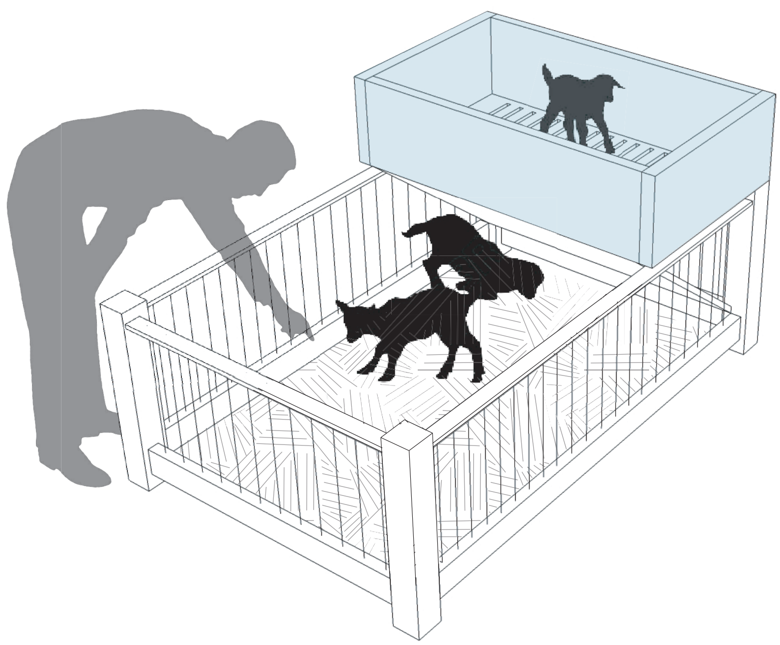

Figure 3.15 *A proposed kid pen design that allows for multiple stories of housing for different ages, that creates easy acccess by handlers to feed and manage kids while promoting good air flow and prolonging dry bedding. All important factors for raising goat kids.*

I attended the annual "Goat and Hair Sheep Field Day" in 2018. Events for the field day took part over two days and included workshops on everyting from making goat cheese, nutrition requirements when feeding dairy goats, parasite mitigation when pasture grazing, and even how to train goats to pull wagons. The annual event garners over 300 participants. I was surprised to find many of the producers in attendance that were predominantly regional (myself and the other producer who is from Arthur, Ontario, were the first ever field day participants from Canada), had between 5 and 20 goats. The farm practices and overall scale were drastically different than in Ontario with the goats being one of many farm endeavors providing an income rather than the main farm operation. Although the scale of my farming operation is much larger than the typical attendee to the field days, I found the workshops just as valuable and informative.

While walking through the buildings on a tour, the researchers woud ask my opinion on the state of the penning and buildings the goats were housed in. As the facility was established in 1984 with only two goats, the buildings are compact brick structures with room enough for the previously hopeful growth of the program but are in need of updates to materials and the penning systems as the scale of research has exceeded original expectations. The nursery for example, where the kids are raised on powdered milk replacer, has stacked pens that resemble multiple level cages where the kids are housed. Figure3.15 shows the typical metal frame penning used for both the kidding pens and nursery pens. The right image is a sketch I drew of the stacked penning system in the nursery. The bottom pens are raised on perforated platforms that allow manure to fall through and easily washed away with water for quick cleaning. The researchers expressed their unhappiness with the system and hope to update the nursery. Their unhappiness comes from the overall perception of the pens that are "cage like" and wanting to lead by example with new penning that benefits the goat kids and the handlers.

Raising goat kids is a difficult area of management on a dairy goat farm. In many commercial dairy farms, the kid is separated from the doe soon after birth or within the first two days after birth, in order to set aside milk for commercial purposes and disease management as some diseases are passed from doe to infant through feeding milk.[64] Cathy Bauman, a researcher with the University of Guelph, is currently conducting a three-year study on kid mortalities and management practices among 60 goat farms in Ontario. Typically, goat farms either have a very high or very low mortality rate with little reason or explanation of why.[65] Since these studies are still ongoing, little research exists to propel a convincing nursery design. My own design iterations of kid pens, such as Figure 3.16, and general comments on environmental needs are included in Appendix C in response to Langston's researchers seeking a new pen design for their research facilitiy and my own need for better kid goat pens at the farm.

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64 Miranda-de la Lama, G. C., and S. Mattiello. 2010. "The Importance of Social Behaviour for Goat Welfare in Livestock Farming." Small Ruminant Research 90 (1): 1–10. https://doi.org/10.1016/j.smallrumres.2010.01.006.

65 Pearce, Sydney. 2019. "What's Happening to These Kids? Three-Year Study Aims to Unravel Why Goat Kid Mortalities Happen | Ontario Agri-Food Innovation Alliance." Www.uoguelph.ca. University of Guelph. November 26, 2019. https://www.uoguelph.ca/alliance/news/2019/11/whats-happening-these-kids-three-year-study-aims-unravel-why-goat-kid-mortalities.

Figure 3.16 *A look at a rock climbing wall shared by goats and visitors by bringing together the natural habitat of a goat and blending it with typical bouldering courses to have both goats and humans enjoy the same activity side by side.*

Opportunities for Public Interaction

Extension programs are known as non-formal education and learning activities to link farmers and consumers through initiatives such as Farm to Table, township agriculture fairs, the Royal Winter Fair and others, with entertainment, education, and food as ways to close the gap between urban and rural. Physical activity promotion is a new extension focus and one trend that has seen a huge interest is goat yoga, a popular event that combines traditional yoga practices and small goats. This shows the opportunities in involving farm efforts to influence physical activity, and goats can offer a multitude of activities. A goat's size, energy, and general curiosity makes them a welcoming animal that easily interacts with people. Exposing goat yoga participants to the goat industry may generate interest in goat products (meat, milk, and cashmere wool) and functions. Additionally, goat yoga could increase interest in raising goats in urban areas, as goats are often allowed where larger livestock are not.[66]

When considering other appropriate enrichments, we must promote their relevance to goats; climbing is certainly one relevant behaviour, as identified in the aforementioned research. Indoor and outdoor rock climbing and bouldering are enjoyed by Canadians and provide physical activity and cognitive challenges. Figure 3.17 presents an opportunity to have both humans and goats engage in similar activities - rock climbing. By creating a space where children and adults along with goats can climb demonstrates the goats impressive climbing skills and further demonstrates the ability to foster the activity in a commercial environment. By showcasing the goats in a fun and more interactive environment, a research facility creates a persona of allowing the animals to engage in their environment and not just viewed as a lab animal constantly tested and monitored.

66 Balis, Laura. (2019). Ideas at Work Goat Yoga: Preliminary Implications for Health, Agriculture, and 4-H. Journal of Extension. 57

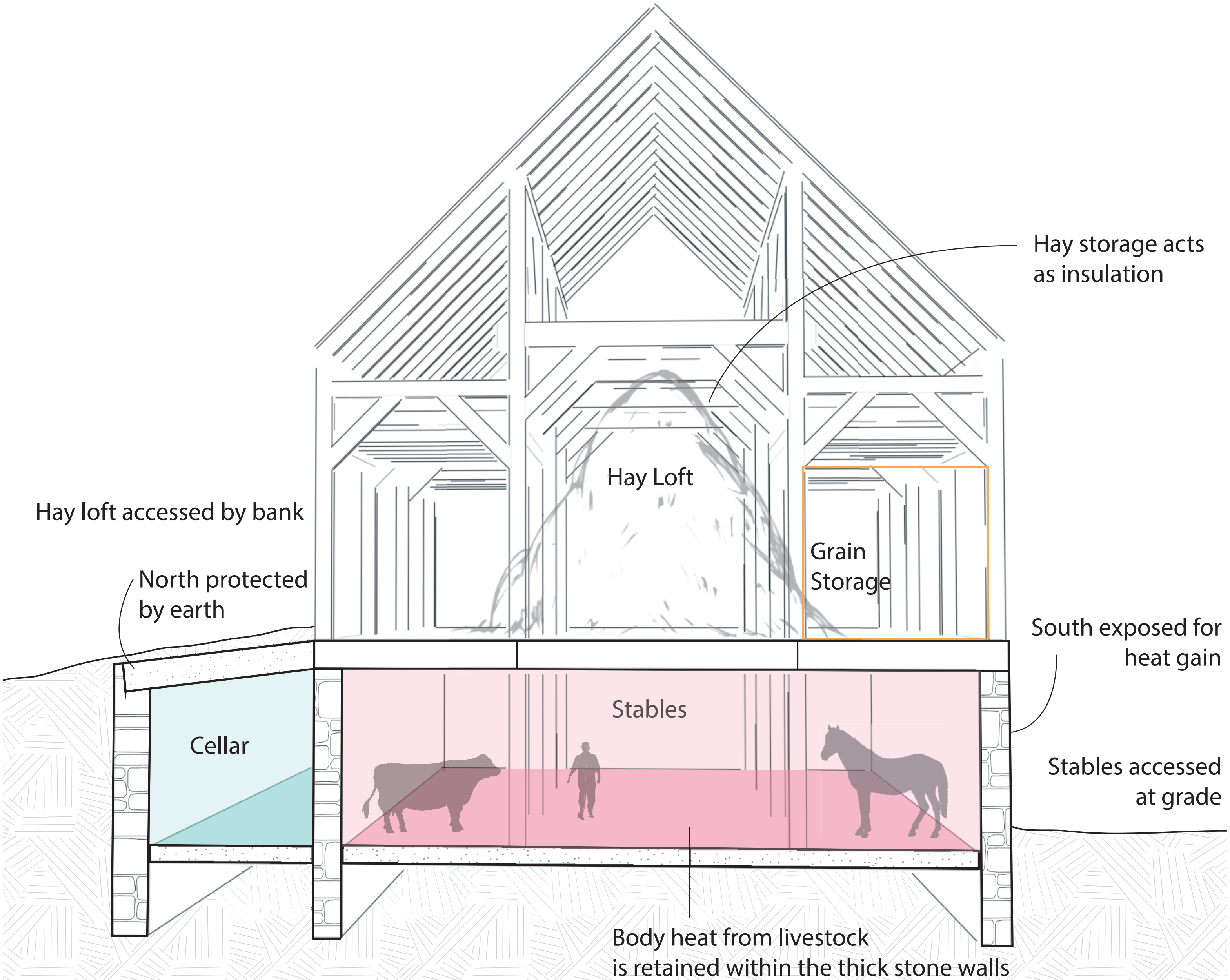

Figure 3.17 *Section through bank barn showing the strategies implemented when construction took place before mechanical and electrical interventions were added to provide ventilation and lighting. The multiple storeys allowed for a division of livestock and feed storage while maintaining easy access through trapdoors in the floor. Windows along the east and the west of the barn allowed for cross-ventilation.*

Vernacular Farm Building Typologies

An important precedent that should not be overlooked is the vernacular farm building typology of Ontario, where the goat research facility is sited. Original bank barns built in Ontario were named so because a bank on the north end of the barn (either manmade or existing) sheltered the stone walls while the south walls were exposed for heat and solar gain. The bank was also used in some cases for cellars. The second floor of the barn, built out of timber, was used for storage of hay, straw and grain which also acted as insulation in the winter. Openings on the east and west walls aimed to provide cross-ventilation while in conjunction with the south openings, brought in some daylight. The gambrel roof construction was later adopted to provide more loft space for storage.

Bank barns are an intriguing example of original technical and scientific design before mechanical and electrical interventions. Their design is conceived to host livestock, plants and farmers in intensive conditions unaffected by the external climate. On the other hand, constructions built by farmers marked their territory, influencing and steering the spontaneous development of the surrounding land. Many existing bank barns in Ontario still remain as examples of vernacular farm buildings that continue to express the culture, traditions and ways of life of generations of rural populations.[67]

The role that the farm buildings have historically played is strictly connected with the surrounding environment, due to the need of the farmer to live in close contact with agricultural land and animal husbandry. The fundamental improvements of clearing, drainage, and tillage reshaped landscapes for better yield and encouraged efficiency in the constructing and maintaining of farm buildings. This led to the spread in rural areas of many examples of buildings that served for farming, storage and processing of agricultural products constituting, at the same time, housing for the farmer and his family. Therefore, the interventions made by farmers have often strongly influenced the agricultural environment and the visual perception of the rural landscape. Craftmanship and construction became the field of the farming community which rarely engaged with an architect, as many farmers did not see the value or need for specialized services. Much credit for the development of farm buildings, especially technological advances, is owed to the services of agricultural colleges, manufacturers, trade associations, and research facilities.[68]

As identified in the preceding research facilities, architects have joined the team of decision makers in their design and construction. As the scale of research facilities grows in size, function, and exposure, architects become vital decision makers in navigating zoning and building code requirements, public and training spaces, and aesthetics.

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67 Schuyler, David., Ensminger, Robert F., Muller, Edward K.., Conniff, Gregory. The Pennsylvania barn : its origin, evolution, and distribution in North America. United Kingdom: Johns Hopkins University Press, 2003.
68 Carter, Deane G.., Foster, William Arthur. Farm Buildings. United Kingdom: J. Wiley & Sons, 1941.

Figure 3.18 *Textile facade of the barn in Lignières demonstrating the exterior and interior atmosphere elevated by a screened facade incorporated into the wood framing that provides light, natural ventilation and exceptional views.*

Building Performance

The needs of animals touch on four dimensions of physical environments; light, ventilation, temperature and humidity. These days, farm buildings rely more on mechanical elements to control the interior climate which implies a high energy consumption and therefore a decrease in profits. The main goals of many farmers today is to design/build a farm building that promotes animal health and production while limiting its energy consumption which in turn means less maintenance costs. To offer spaces adapted and conducive to production, it is important to know the comfort zone of goats in each of these dimensions.

The brightness inside livestock buildings is a very important concept for milk production and comfort of animals. As much the amount of light as the duration must be controlled according to the stage of production of the goat. Some farmers will manipulate lighting in their barns to promote out of season breeding according to their breeding cycle.[69] The orientation of the building and the type and size of openings allowing the provision of natural light are the key elements to minimize the use of artificial devices that consume electricity. Strategic placement of openings within the building, based on its orientation and where the animals are placed is one way of promoting higher light levels in barns. The facade can also be adapted to interior needs by adding architectural features to promote winter sun while limiting summer heat gain; e.i. the overhangs of roofs, canopies and rolling shades. These interventions can allow bring light inwards during colder months while limiting solar gains that can cause the building to overheat in warmer months. They also offer protection against natural elements, such as precipitation, to animals that are outdoors adjacent to the facade.

Some architects have already looked into the question of natural lighting for the construction of farm buildings. A cow barn in Lignières, Switzerland by Localarchitecture, offers a textile membrane on the south-east façade to allow for considerable light input to inside the building. The exterior membrane is simply attached to the barn's vertical structure with nails. As a country associated with the open air, with magnificent landscapes and placid cows, Switzerland has understandably chosen to focus on notions of authenticity, quality and respect for nature in its agricultural production strategy. It also provides a very interesting visual signature that is not common to this type of agricultural use. Instead it has undertaken a major effort to define and consolidate characteristics that may give its agriculture products a competitive advantage with the upgraded building typology.[70]

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69 Simões, João. (2015). Recent advances on synchronization of ovulation in goats, out of season, for a more sustainable production. Asian Pacific Journal of Reproduction.

70 "Cow Barn in Lignières // LOCALARCHITECTURE - Architizer Journal." Architizer, 13 Dec. 2013, architizer.com/blog/inspiration/industry/cow-barn-in-lignieres/. Accessed 12 May 2020.

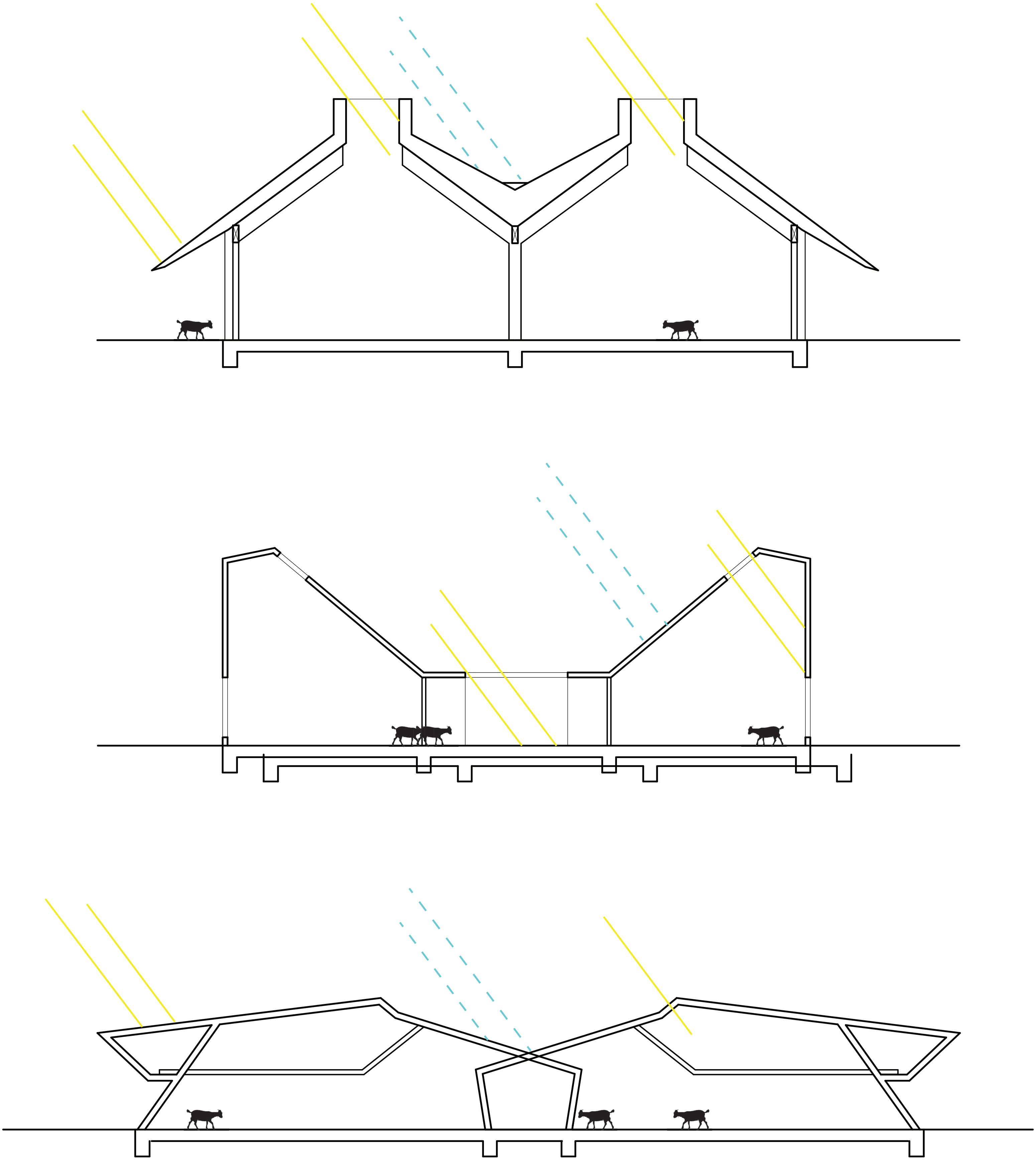


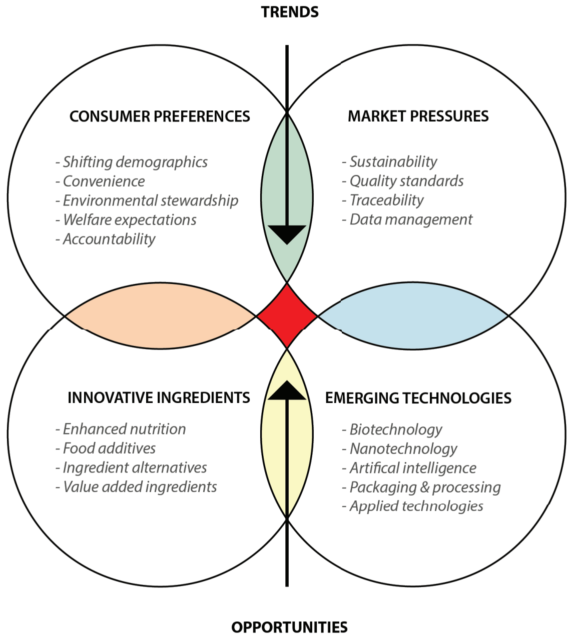
Figure 3.19 *Exploration of different roof configurations to better provide natural ventilations strategies, daylighting and water collection.by*

Ventilation, ambient temperature and air humidity are the three elements that form the thermal atmosphere of a space. This atmosphere can influence an animals behaviour. A temperature too hot or too cold, too fast air speed or too much humidity can have major impacts on a herds health such as changes in appetite, higher aggression, and body energy being burned at a faster or slower rate. [71]A relative humidity of 70 to 80% would be the recommended level within farm buildings. When the temperature inside decreases, it is preferable that the ambient air is drier to avoid thermal losses between moist air and animals. To achieve this, an adequate and effective ventilation must allow a renewal of the air enough to remove the excess moisture and evacuate the gases produced by the digestion of cows. There are two main categories of natural ventilation systems that make it possible: transverse ventilation (wind effect) and thermal ventilation (chimney effect), which can operate with little or no mechanical elements.[72]

Thermal ventilation consists of introducing cold air from outside which warms up when in contact with the animals absorbing moisture and then comes out through an opening at a opening in the top of the building. For this system to be effective, the difference in temperature and humidity between the inside and the outside must be regulated. In addition, a certain difference in height between the point of entry and exit of the air is also necessary. Cross ventilation uses prevailing winds to temper the building and is effective even though the temperature difference between inside and outside is low, but obviously depends on wind direction and speed. The comfort zone for dairy goats is between 12 and 21^{o} C. Milk production and feed intake are generally not affected with lower temperatures but temperatures over 27^{o}C will result in reduced feed intake and milk production.[73]

Figure 84 presents different opportunities for the shape of a goat farm building's roof. In addition to capturing and distributing light and ventilation by chimney effect, the roof can also be used in the recovery of rainwater. This simple intervention allows for the storage and use of water throughout the building from animal intake to cleaning systems and used in plumbing fixtures.

71 Salama, Ahmed A.K., et al. "Metabolic and Behavior Responses of Lactating Goats under Heat Stress." Small Ruminant Research, Aug. 2021, p. 106496, 10.1016/j.smallrumres.2021.106496. Accessed 8 Aug. 2021.
72 Lunn, Dennis. "Feeding and Management of Dairy Goats." Shur-Gain, a Member of Maple Leaf Foods Inc., Feb. 2011.
73 Zobel, Gosia & Leslie, K. & Weary, Daniel & Keyserlingk, Marina. (2014). Producer concern and prevalence of subclinical intramammary infections between lactations on 10 dairy goat farms in Ontario, Canada.



RESEARCH MANDATES

- Need for benchmarking data on the industry. The power of
- Collective data cannot be overstated to benefit and advance the industry.
- The research areas identified will provide the most significant benefit to the animals and the industry.
- All researchoutcomes need to reference economic viability.
- Strong knowledge translation and transfer plans to ensure research results are communicated to and adopted by the industry as soon as possible.
- Clear need for 360-degree research/analysis

RESEARCH AREAS

HEALTH

1. Chronic wasting diseases (CAE, CL)
2. Goat kid health and mortality
3. Milk quality and udder health
4. Animal health products
5. Respiratory disease
6. Infectious abortion
7. Parasites

NUTRITION

1. Primary nutrition
2. Gut health
3. Nutritional and feed related diseases
4. Feed additives and binders

PRODUCTION

1. Genetics
2. Overall management practices
3. Lactation data

WELFARE

1. Pain management
2. Lameness and hoof-care
3. Housing and handling equipment and natural behaviour
4. Euthanasia
5. Consumer research
6. Nonstun killing for halal food

INSIGHTS

Health:

- Requires diligent monitoring of goats and kids in housing
- Lab testing of milk for quality
- Lab testing of bodily fluids for parasites and infections
- Collection of on-farm data through selecting certain numbers of farms to participate in studies

Nutrition:

- Requires diligent monitoring of goats and kids in housing
- Tracking milk production
- Monitoring of body condition scores
- Lab testing of bodily fluids for gut health and digestion functions

Production:

- Genetics laboratories
- Tracking milk production
- Collection of on-farm data through selecting certain numbers of farms to participate in studies
- Monitoring of body condition scores
- Lab testing of bodily fluids for gut health and digestion functions

Welfare:

- Requires diligent monitoring of goats and kids in housing
- Tracking milk production
- Monitoring of body condition scores
- Tracking of goat behaviour (ie. agonistic and affiliative)

Figure 4.1 *Research priorities depend greatly on demand from consumer wants while the availablity of technologies can advance certain studies. The above list of research priorities was constructed in 2019 with representatives from the goat industry at a roundtable discussion to update and prioritize industry research needs.*

part four

PROGRAM

With an understanding of goat behaviour and the redesign of some key herd management components, a program guide sets the square footage, space, and operational requirements within the context of needs for 250-500 goats. The guide separates the program into five elements—each a different aspect a research facilities' mission and needs. Diagrams of each element show the program areas, configurations, and adjacencies. The goals and objectives have been reflected in required spatial allocations between nonprogram and program components, including administrative, mechanical, animal housing, and animal care support. Space functions and quantities, the functional adjacencies, and staffing projections are also layered into the diagrams.

The program for the herd management started from the program of a working dairy goat farm. It was expanded from there based on the program of the Langston institute to include isolation pens for closed research trials, and a handling area where chutes are set-up for easy containent of goats for routine care and sample extraction. The lab types amongst the program for the research functions was also created looking at Langston as well as the Elora dairy facility. Specific research areas such as genetics and disease control require closed labs. A surgical room for autopsies and potential c-sections was added to continue research on kid mortality and further research into disease treatment and prevention.

Following this process, the comfort of moving through the facility for the occupants, both human and goat, should be a priority. Additionally, conditions allowing flexibility are critical and should be integrated into the programs for the herd management and research. As research focuses change and funding is allocated based on needs, a research facility must be flexible in accomodating changing research areas as well as number of goats part of a specfic research program and equipment required. Figure 4.1 pulls the Ontario dairy goat industry research priorities as determined by the LRIC (Livestock Research Innovation Centre), an organization dedicated to assisting all livestock industries with research priority setting by developing annual cross-sector priority documents. These research priorities are at the forefront of the program determined for the research components of the facility.

Code constraints for the facility will be addressing conditions under 'Assembly' and 'Industrial'. as specified in the OBC (Ontario Building Code) due to the human occupancy in critical areas and the storage of feed and chemicals as needed.

PROGRAM
HERD MANAGEMENT

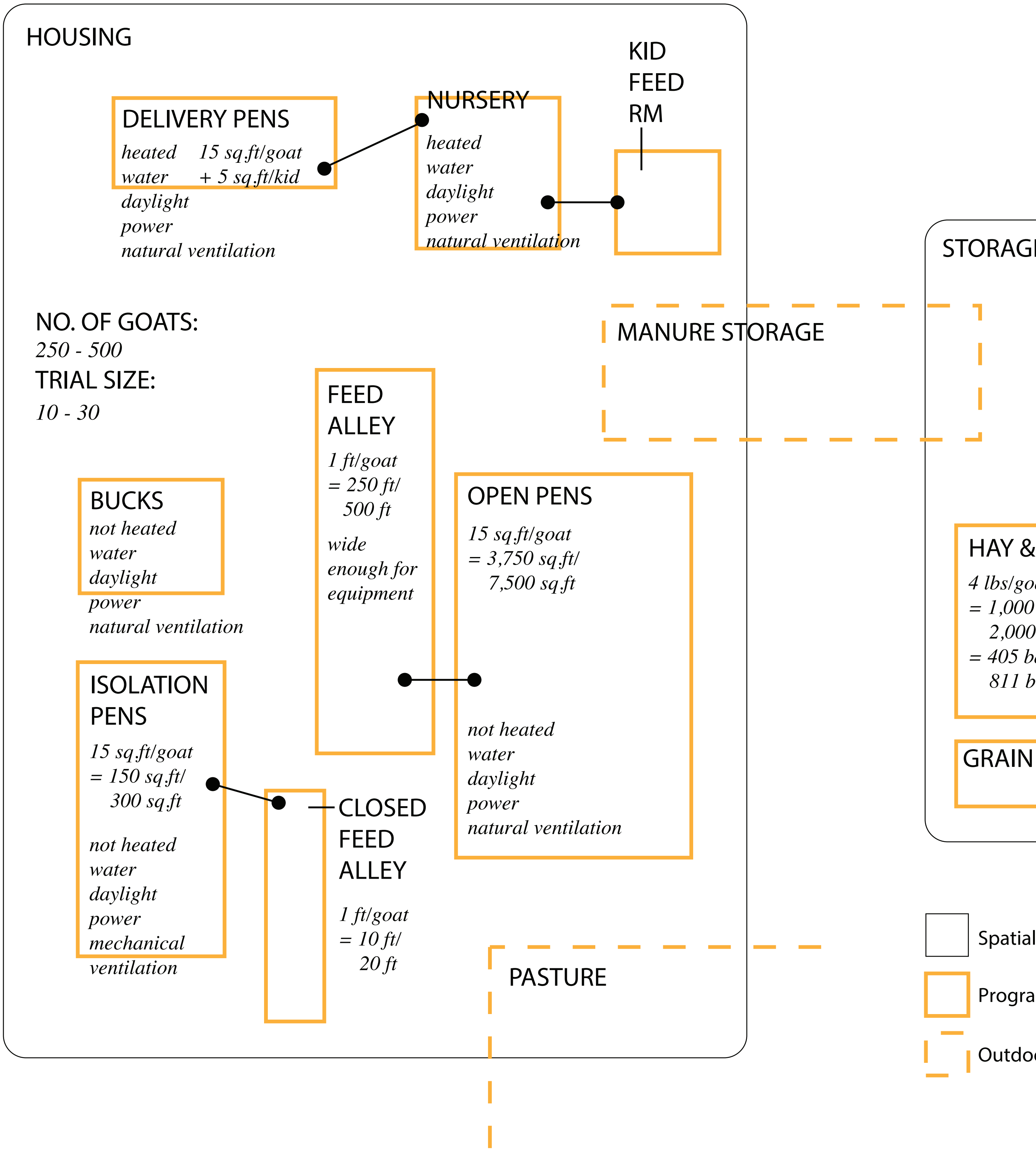
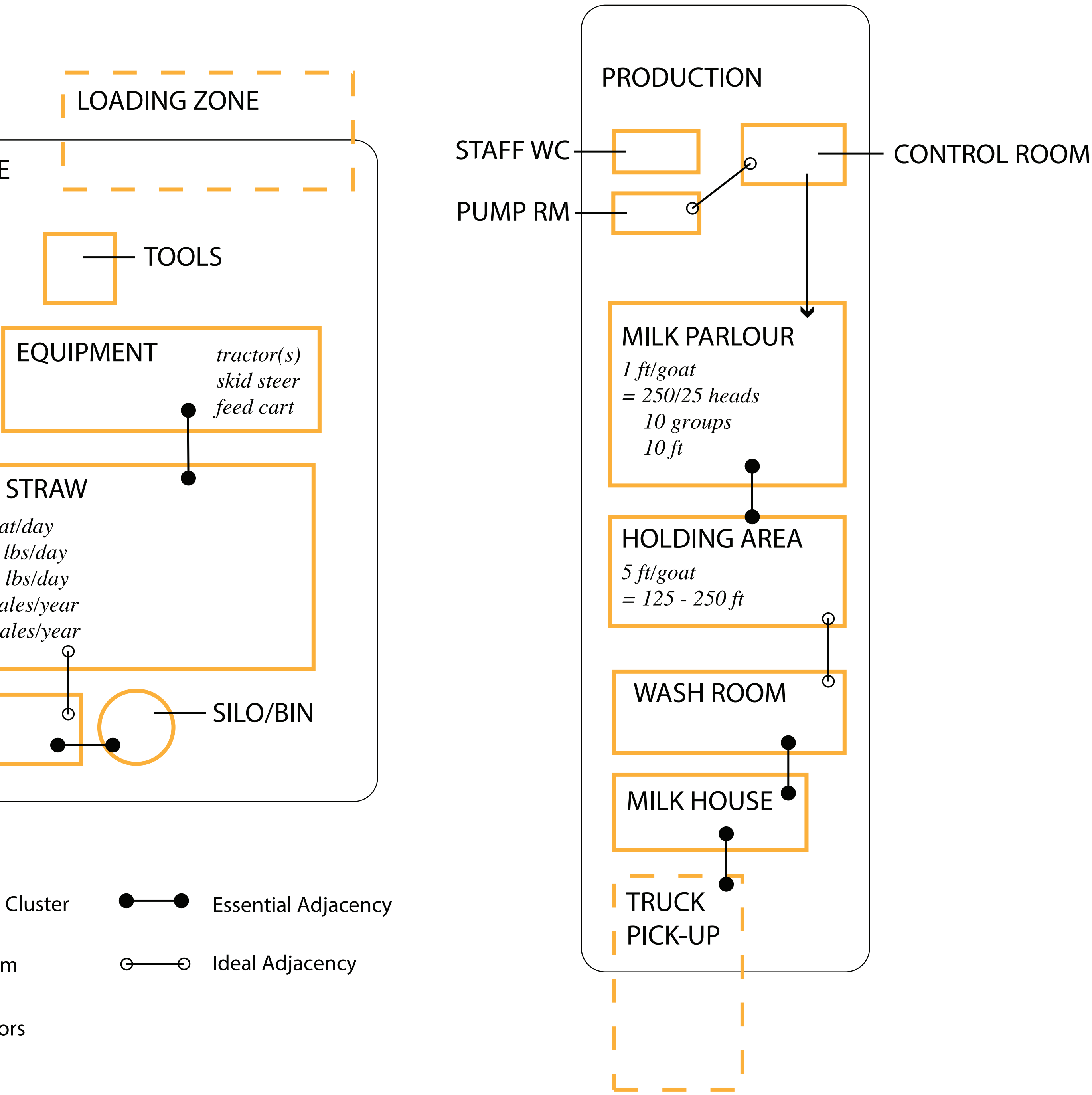


Figure 4.2 *Diagram demonstrating required program*
included for determination of size based on OMAF



and their connections for herd management. Formulas
RA regulations as well as lists of required services.

HERD MANAGEMENT

w/ circulation

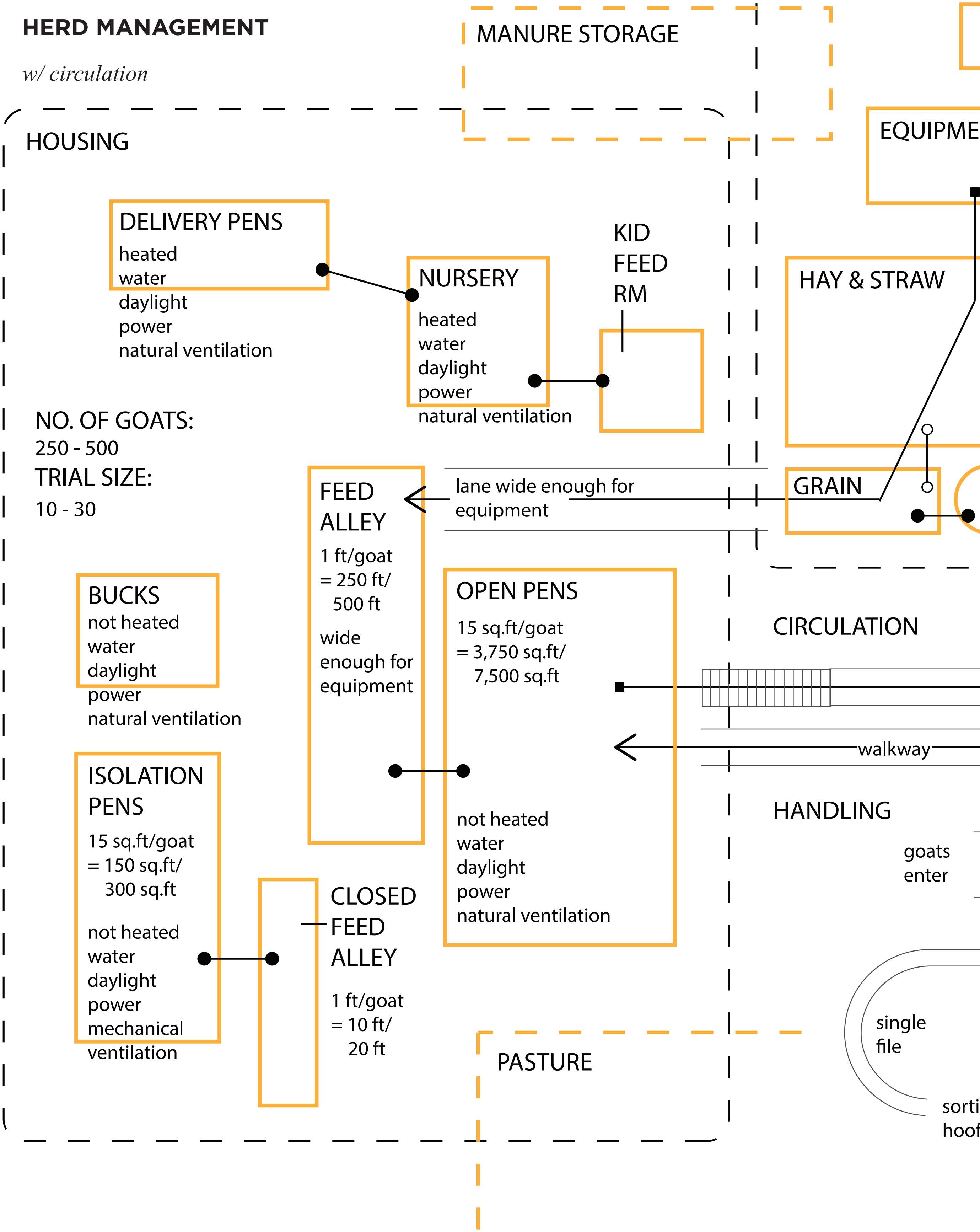
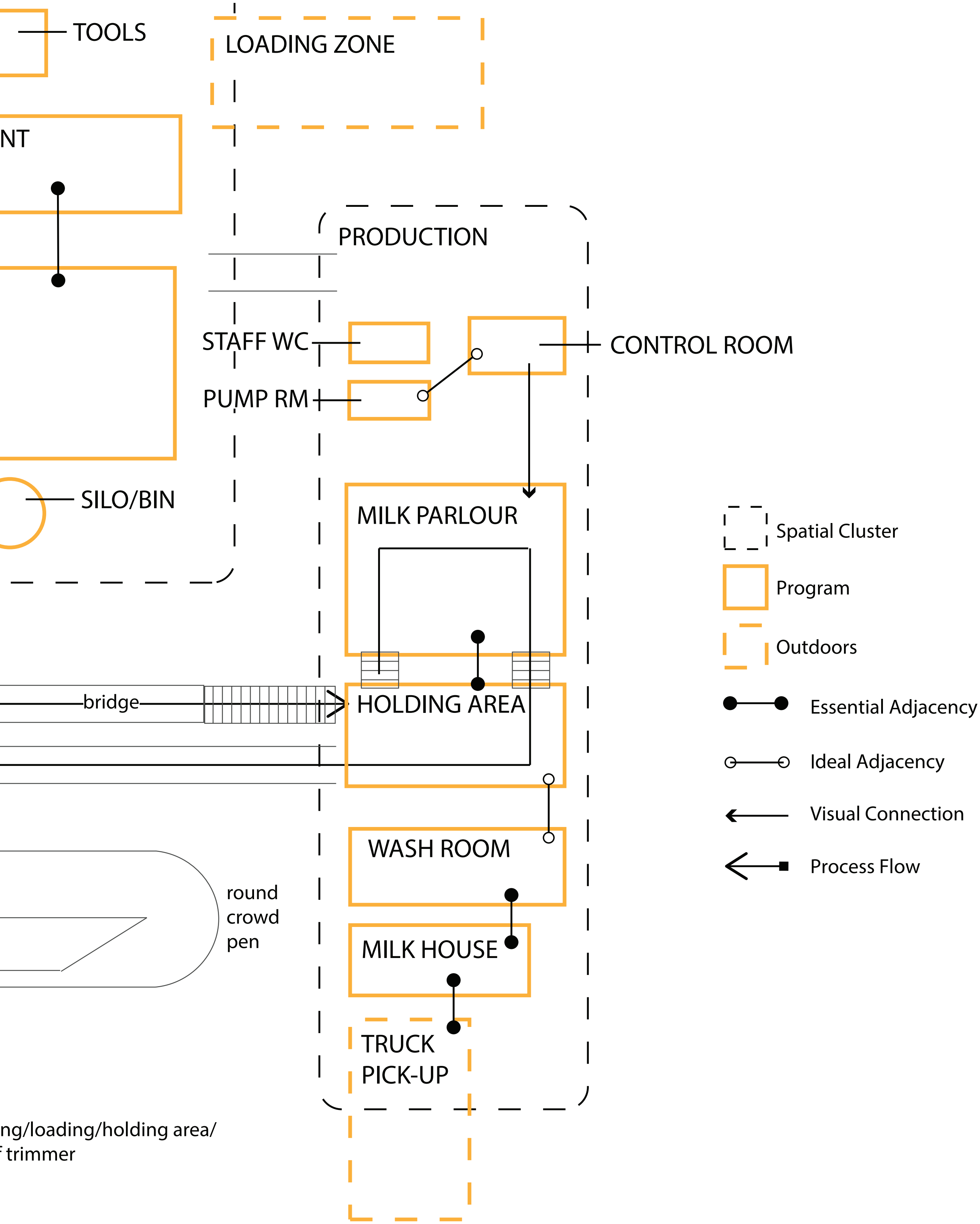


Figure 4.3 *Diagram is further organized with circulat adjacencies for maximum efficiency*



tion added to establish a spatial layout that maintains
v for both goat and feed circulation.

PROGRAM
RESEARCH & STAFF

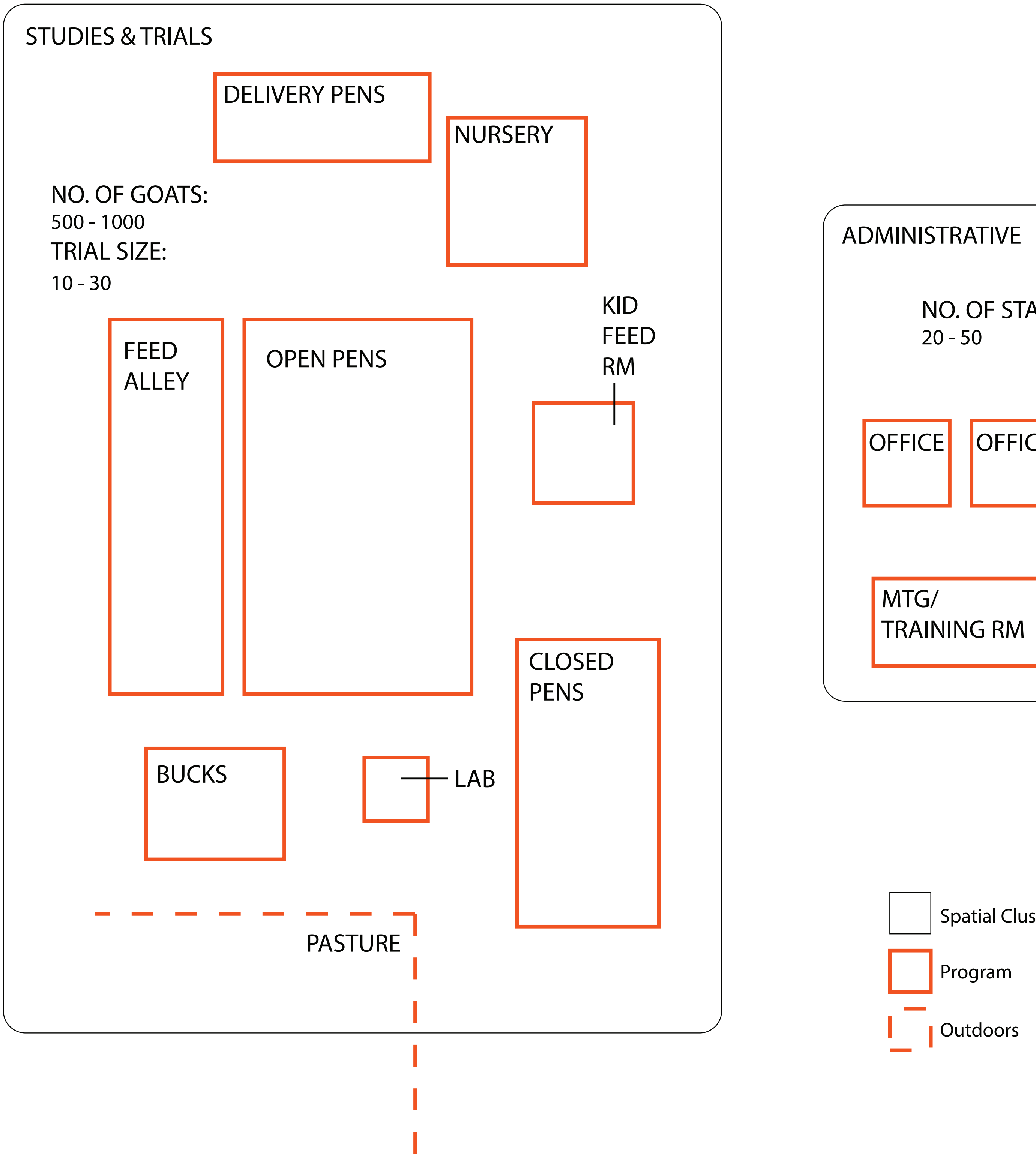
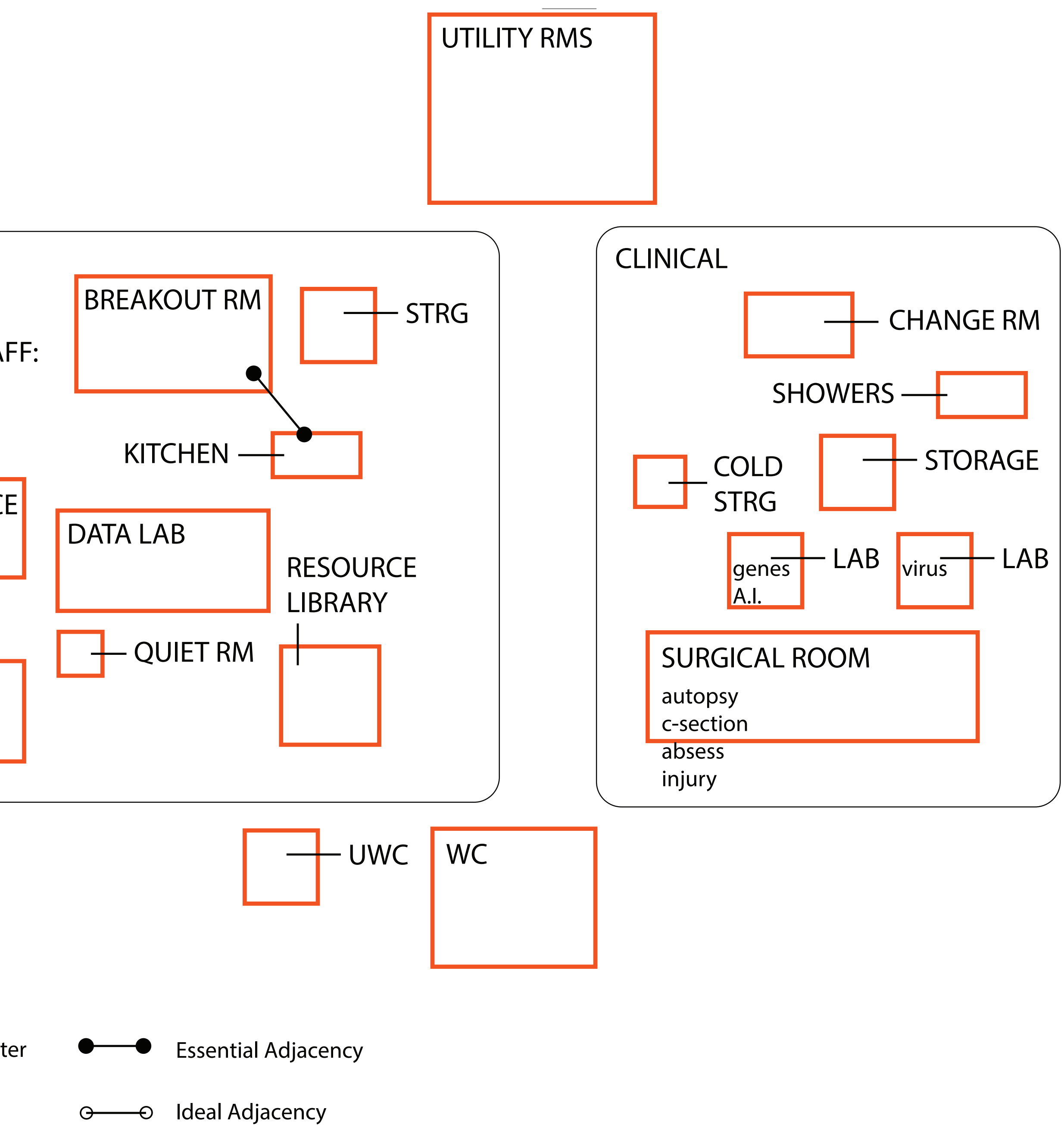


Figure 4.4 *Diagram demonstrating program and their*
mulas based on OB



*connections required for the research programs. For-
C occupancy loads.*

PROGRAM
RESEARCH & STAFF
w/ circulation

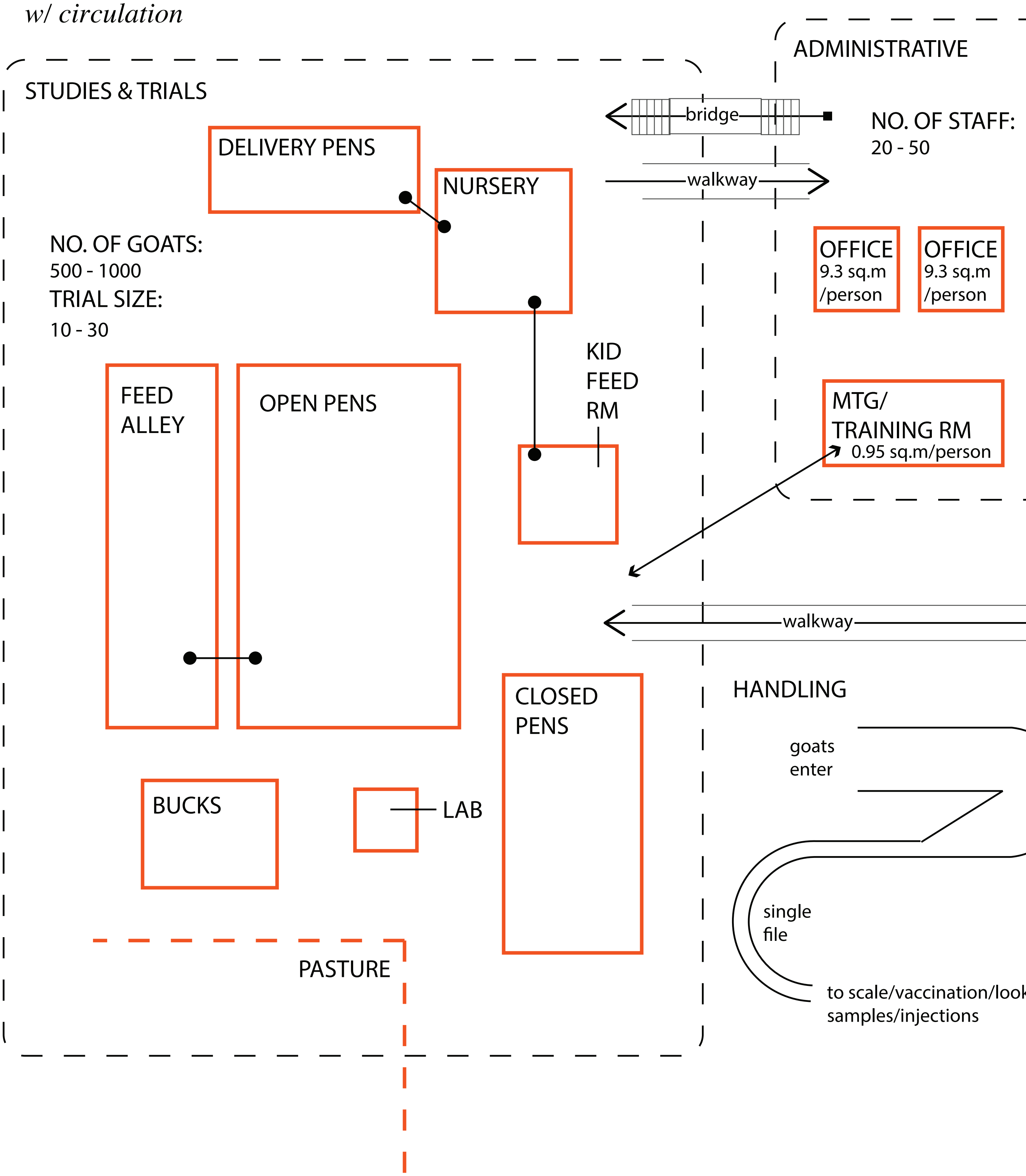
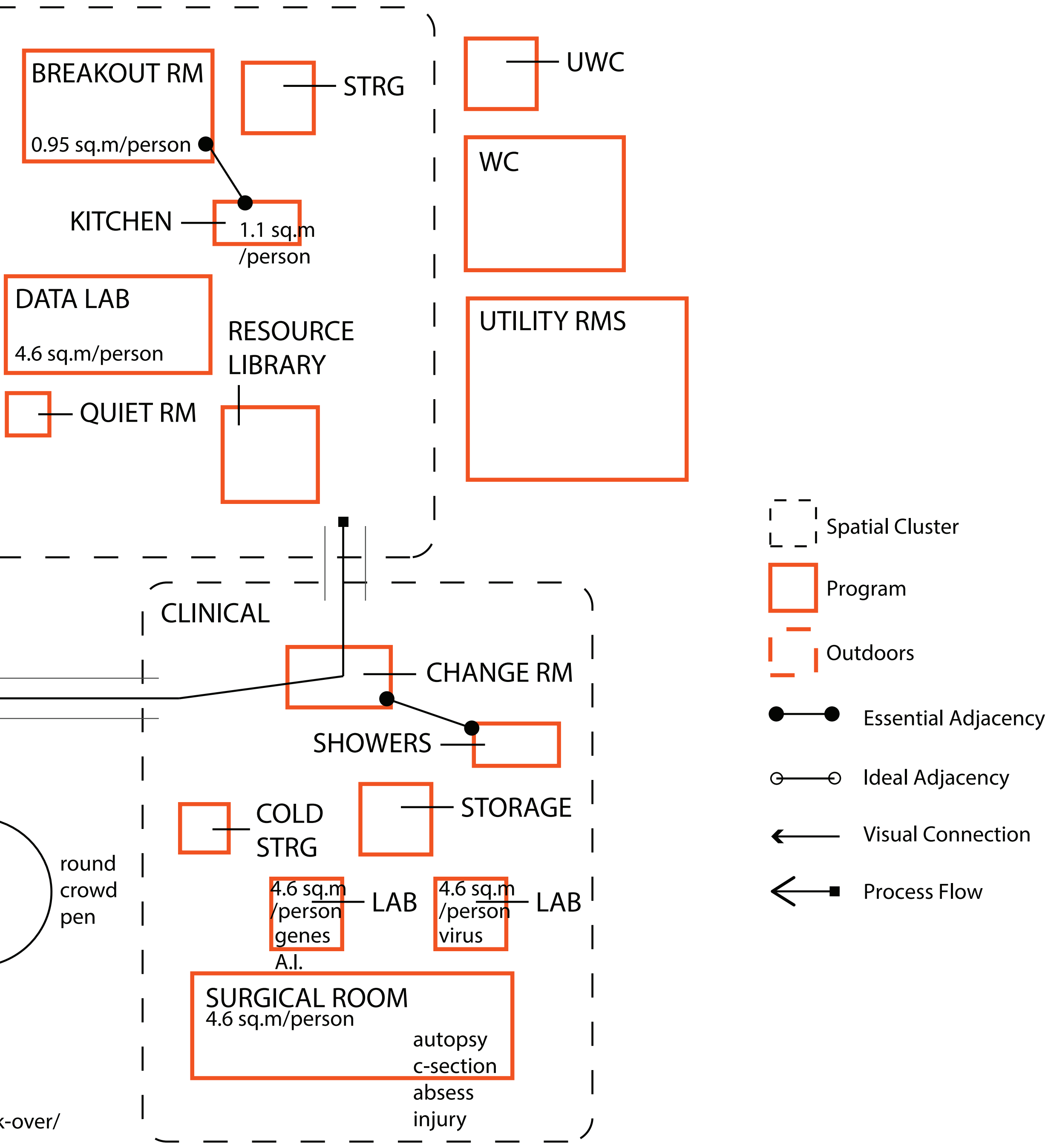


Figure 4.5 *Diagram for research program is further o*
layout that maintains adjacencies between lab and



organized with circulation added to establish a spatial housing and critical views for behavioural analysis.

PROGRAM
PUBLIC INTERACTION
w/ circulation

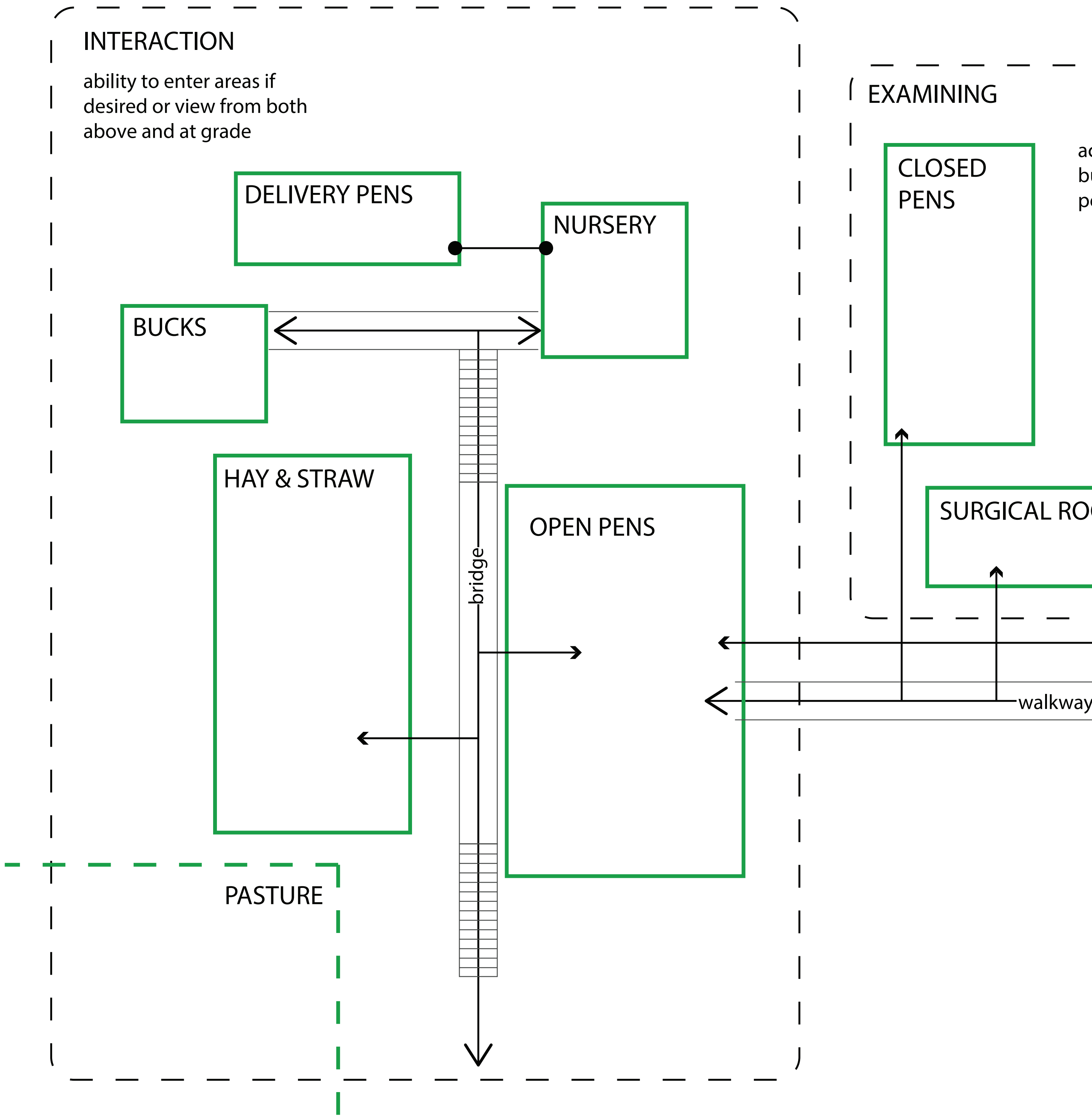
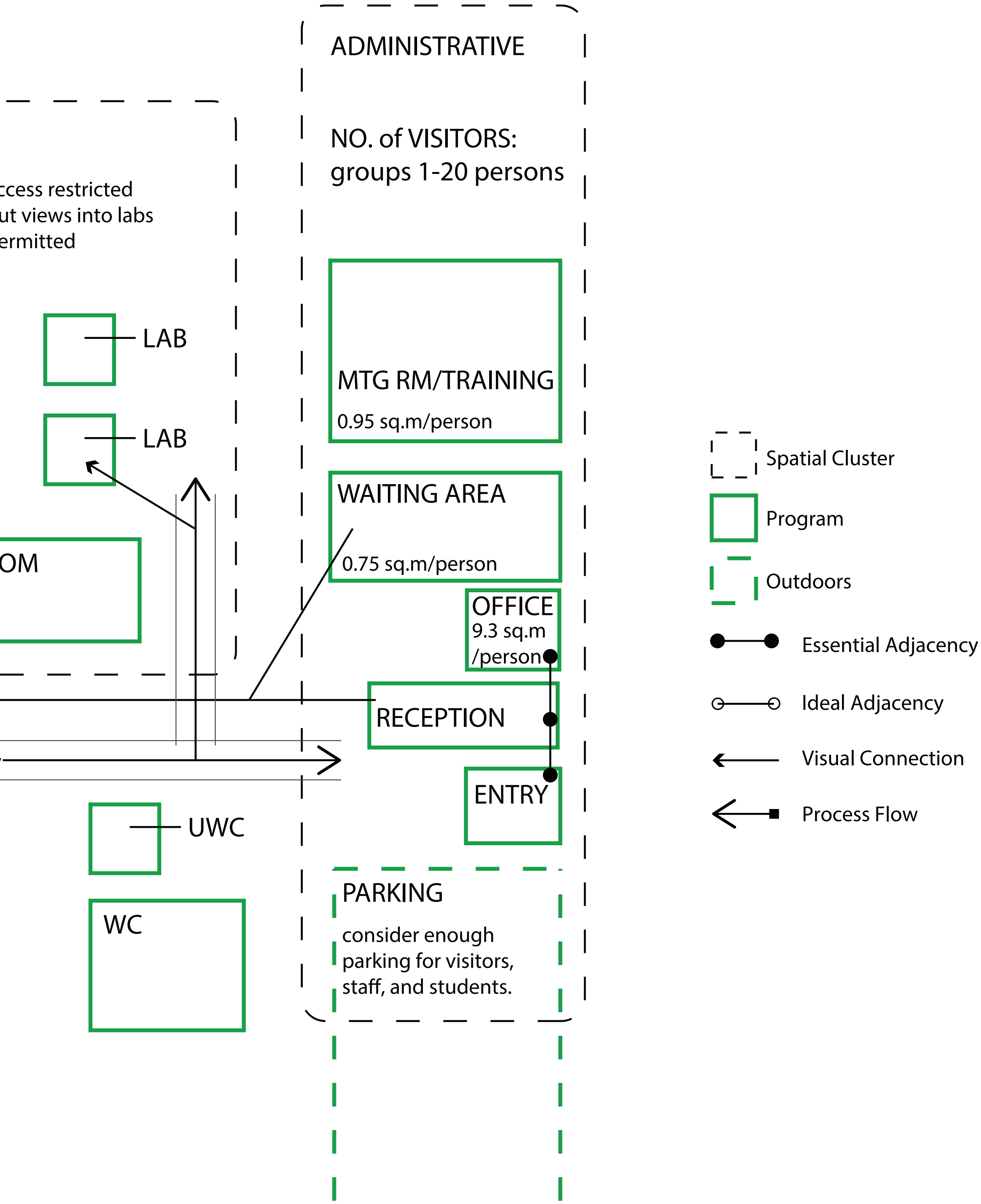


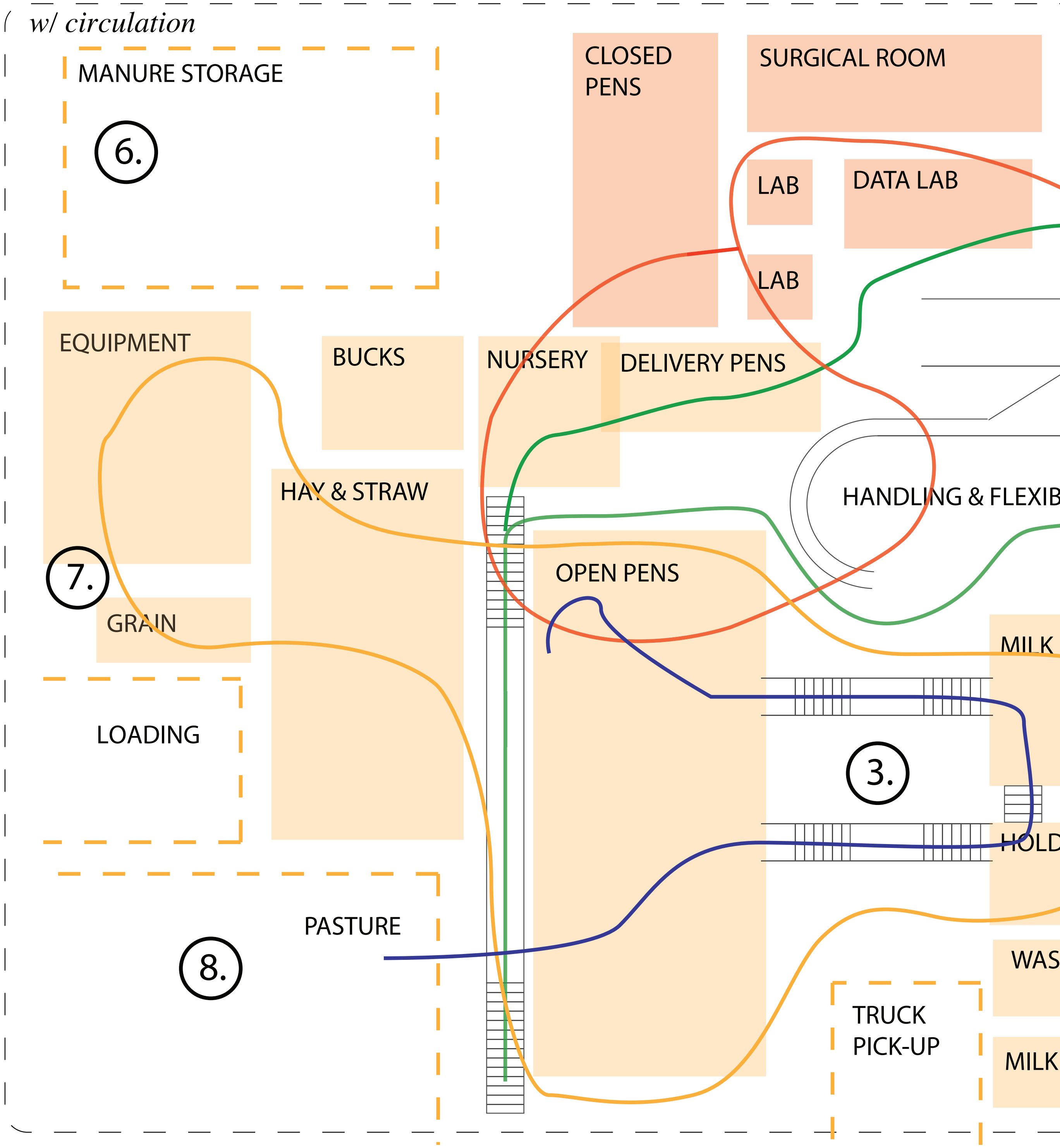
Figure 4.6 *Diagram for the public interaction demonst*
supporting circulation that



rates the various program accessed by the public while allows for different views.

PROGRAM AMALGAMATION

w/ circulation

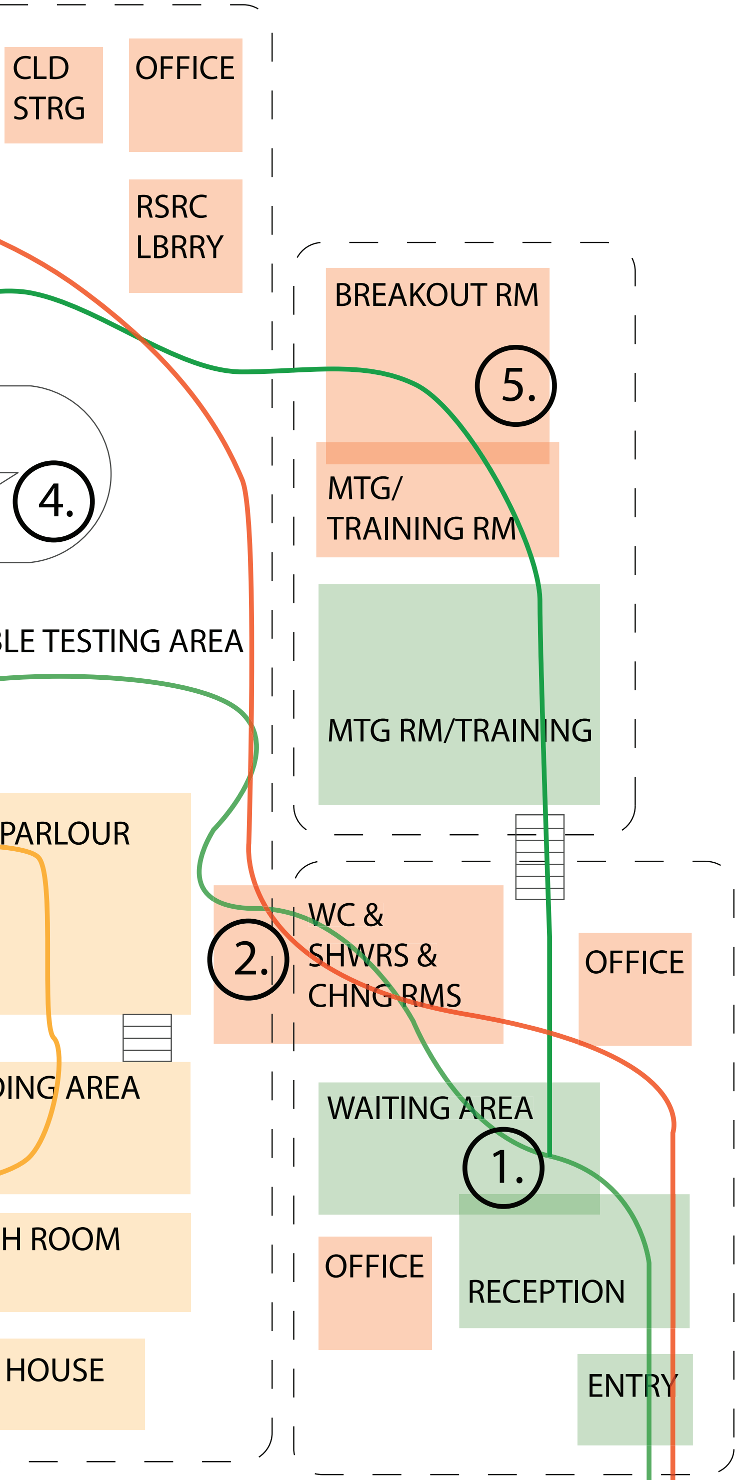


1. Reception and waiting area are important spaces to feel welcoming and provide visitors with all the pertinent information needed for their tour, training, or questions. Views into goat area provide immediate connection to the animals.

2. All visitors, staff and reseachers should be entering/exiting the research and housing areas after using washroom facilities. Showers an change rooms provided for staff and researchers, and any visitors.

3. Areas of high tra
especially stressf
be maintained fo
without distracti
strangers.

Figure 4.7 *When amalgamating program from all key c
to layer in when moving program to suit adjacencies.
from a farming point-of-view, while others try to provid
and maintain transpa*



5. Having meeting and training rooms on a second floor allows for views into key areas for demonstrations but can also feel removed from the distractions of the facility when distractions are not wanted.

6. Keping manure storage away from the entrance can be key for reducing smell, insects, and leaching. Proper manure handling during the seasons need to be adhered to. For proper manure handling, see Appendix A. Manure also expes a lot of heat and could be utilized to provide some heat during the winter months when storage is necessary.

Spatial Cluster

Program

Outdoors

Public Circulation

Staff & Handlers Circulation

Research Circulation

Goat Circulation

7. Programs where large equipment is used for circulation and where loading and unloading of large goods, should be separated from access and circulation of visitors for safety reasons.

ffic for goats, ul areas, should r goats to move on or fear of

4. A large flexible open area can provide space for testing different handling and/or milking equipment without infiltrating other key areas. This area can also be viewed from above training rooms therefore demonstrations can be done for viewing.

8. Having any outdoor pastures visible from the road allows for immediate views of the animals and demonstrates that the facility is not only driven by research but animal welfare as well with the animals outside enjoying the space and fresh air.

omponents, the merging of circulation is also critical Some strategies behind space locations are practical de views that demonstrate the goal of animal welfare rency throughout.

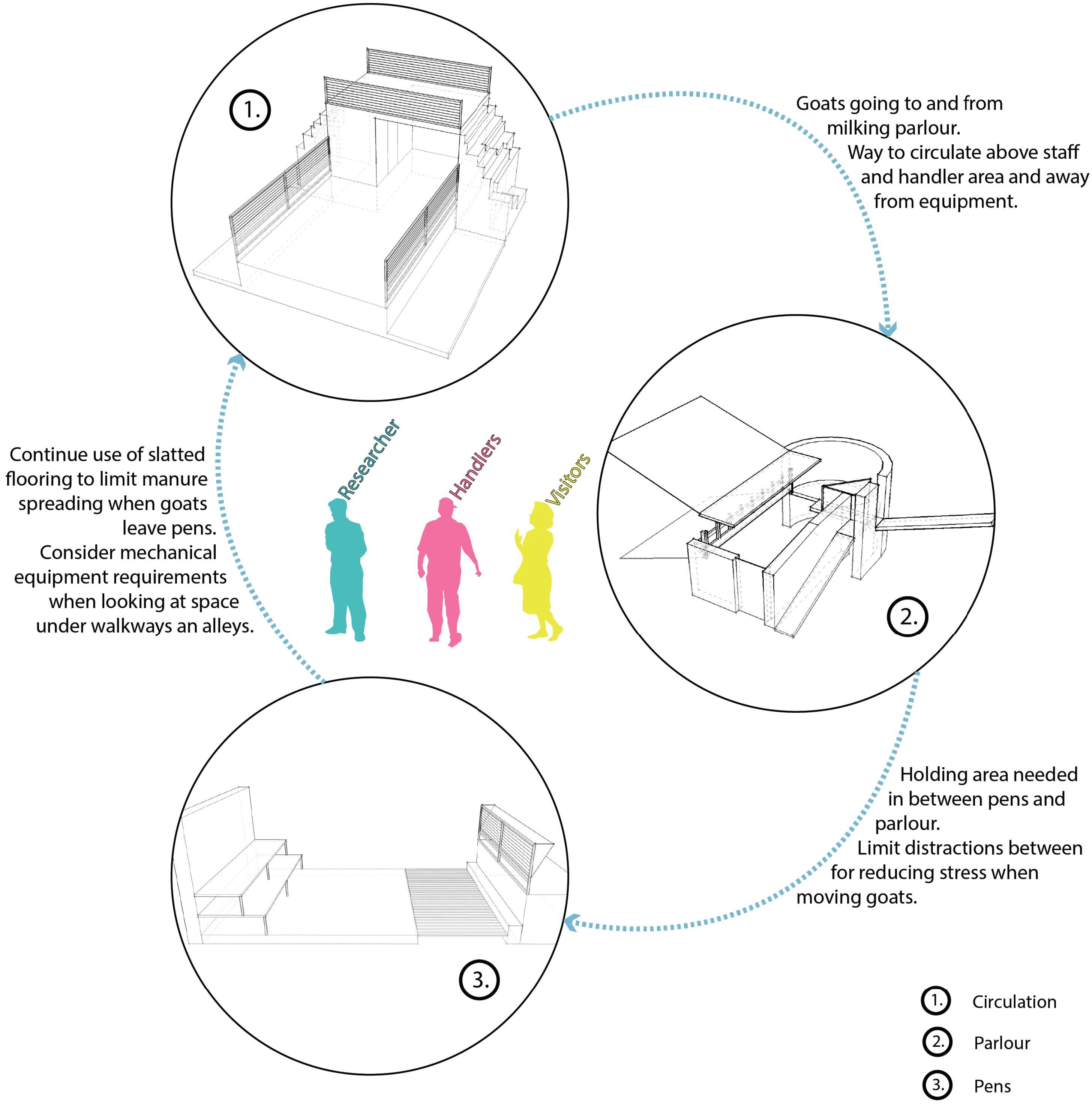


Figure 5.1 *The key operation components redesigned in Part Two, must come together and consider the required circulation and efficiency for all users.*

part five

DESIGN

An overall design proposal to guide the conception of a dairy goat research facility begins by combining the key areas of a goat dairy operation that were previously redesigned using conclusions drawn from research and spatial outcomes that enable goats to utilize their cognitive and social behaviours. Using the program diagrams, the key pieces must come together and fit within the greater circulation of goats, handlers, researchers, and visitors, as everyone moves through these spaces. The key components redesigned in Part Two - Goat Behaviour, as seen Figure 5.1, now come together and demonstrate their spatial relations. All elements discussed in the previous sections including vernacular farm architecture, missing pieces from precedent facilities, and potential interactions and key views, will also be part of the coming together of the key elements. The goal of this design proposal is to create a process where the pieces coming together further pushes the requirements and goals of the facility: animal welfare, transparency to consumers, and flexible research space.

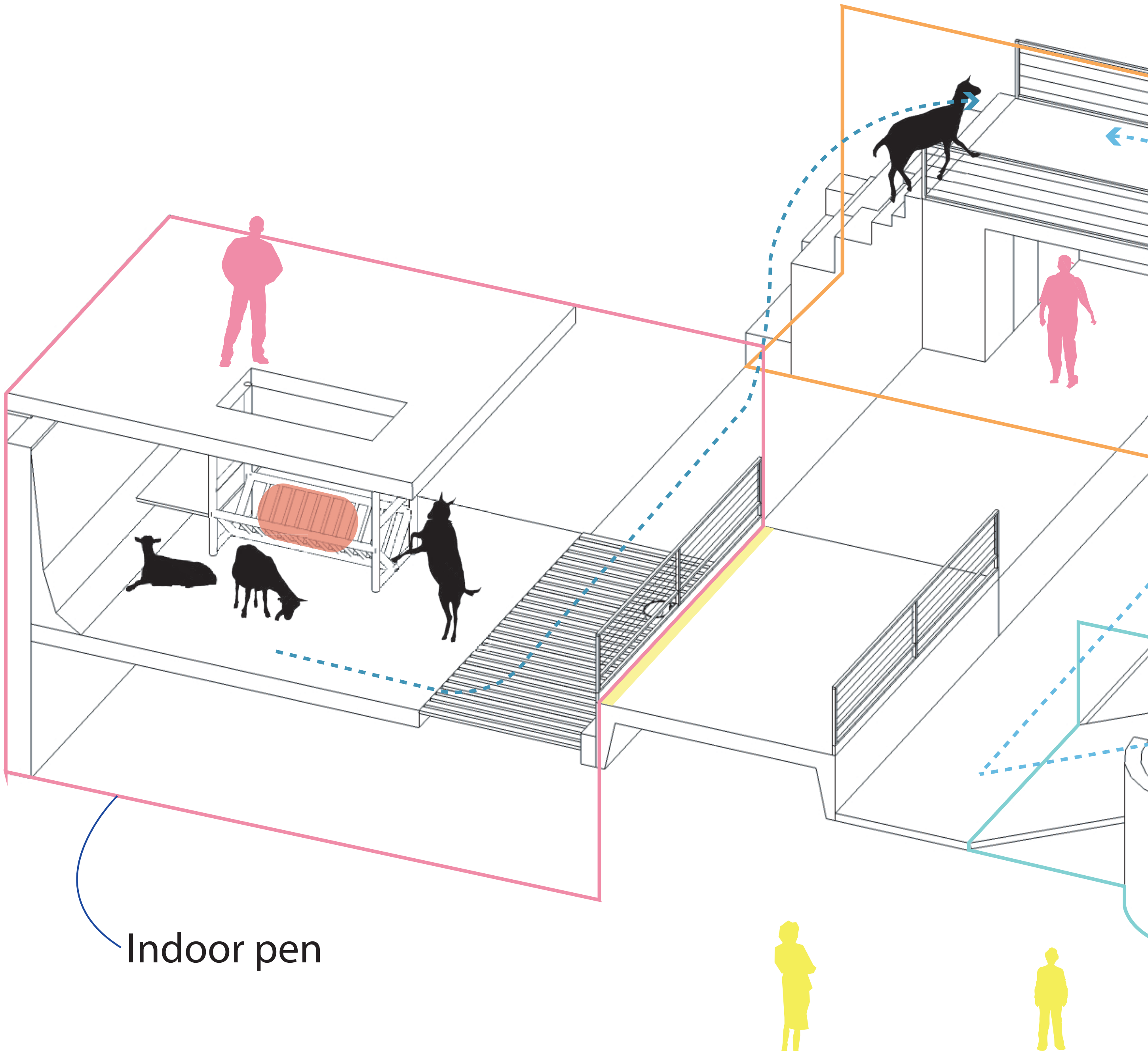
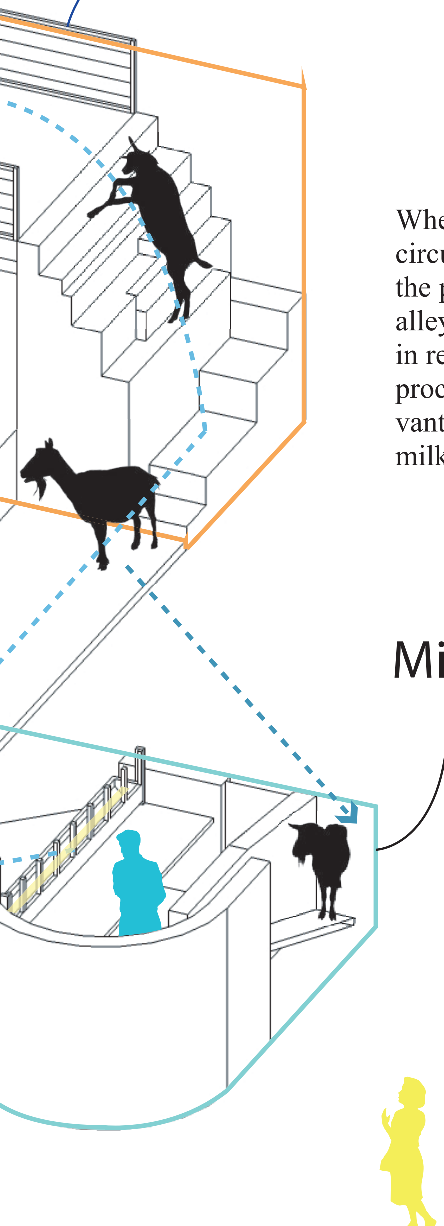


Figure 5.2 *The three components coming together c*
offered to researcher



Coming Together

When placing the three components together, the placement is determined by the circulation of goats between the three. The goats walk across the slated floors in the pen, cleaning off their feet of bedding, use the bridge to walk across the feed alley, and entering the milking parlour. The journey back would be the same but in reverse. Handlers would need to open and close the required gates. The whole process of bringing goats to and from the milking parlour, is visible from multiple vantage points including the feed alley to ensure all goats have left the pen and the milking parlour to ensure all goats enter the parlour.

onsidering easy circulation for goats, and the views rs, staff, and visitors.

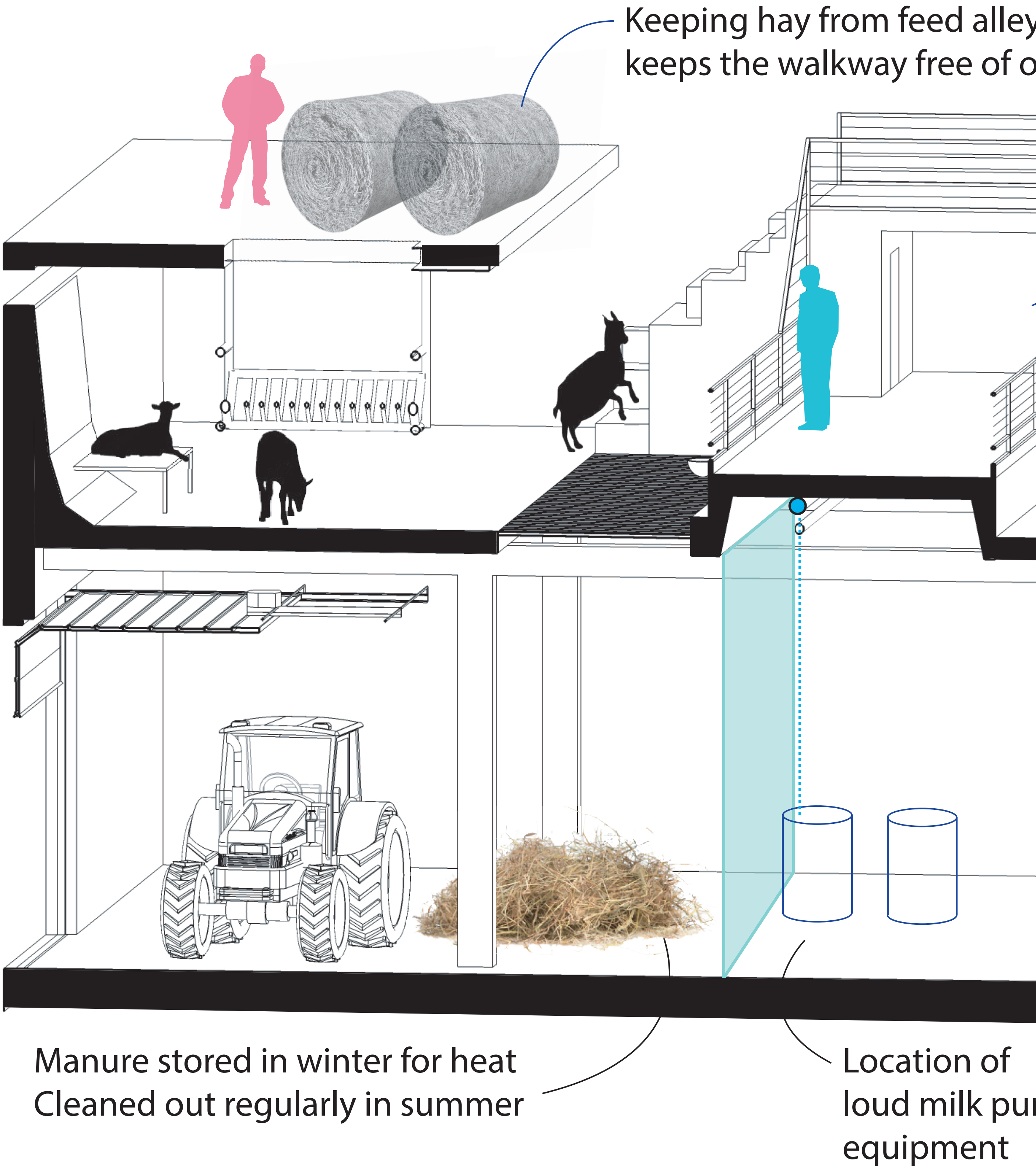
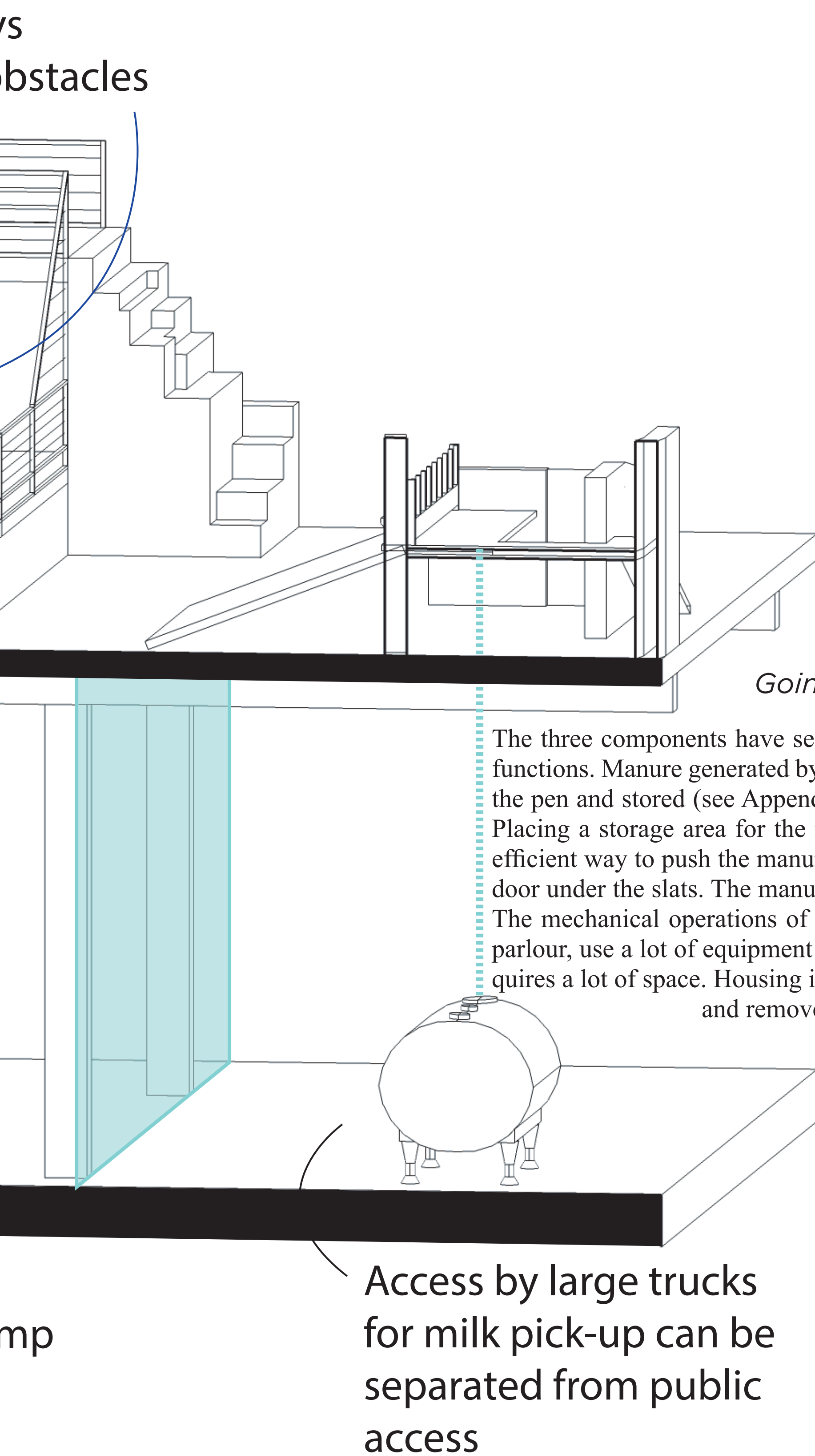


Figure 5.3 *The addition of important program for the*
must provide further efficiency



Going Below

The three components have secondary programs that support their functions. Manure generated by the goats needs to be removed from the pen and stored (see Appendix A for manure storage strategies). Placing a storage area for the manure underneath pen makes it an efficient way to push the manure out of the pens and through a trap door under the slats. The manure is then stored underneath the pen. The mechanical operations of the facility, particularly the milking parlour, use a lot of equipment that is noisy when operating and requires a lot of space. Housing it below can diffuse sound pollution and removes it from taking valuable floor area.

services as part of the key components. Their location
and have sustainable factors.

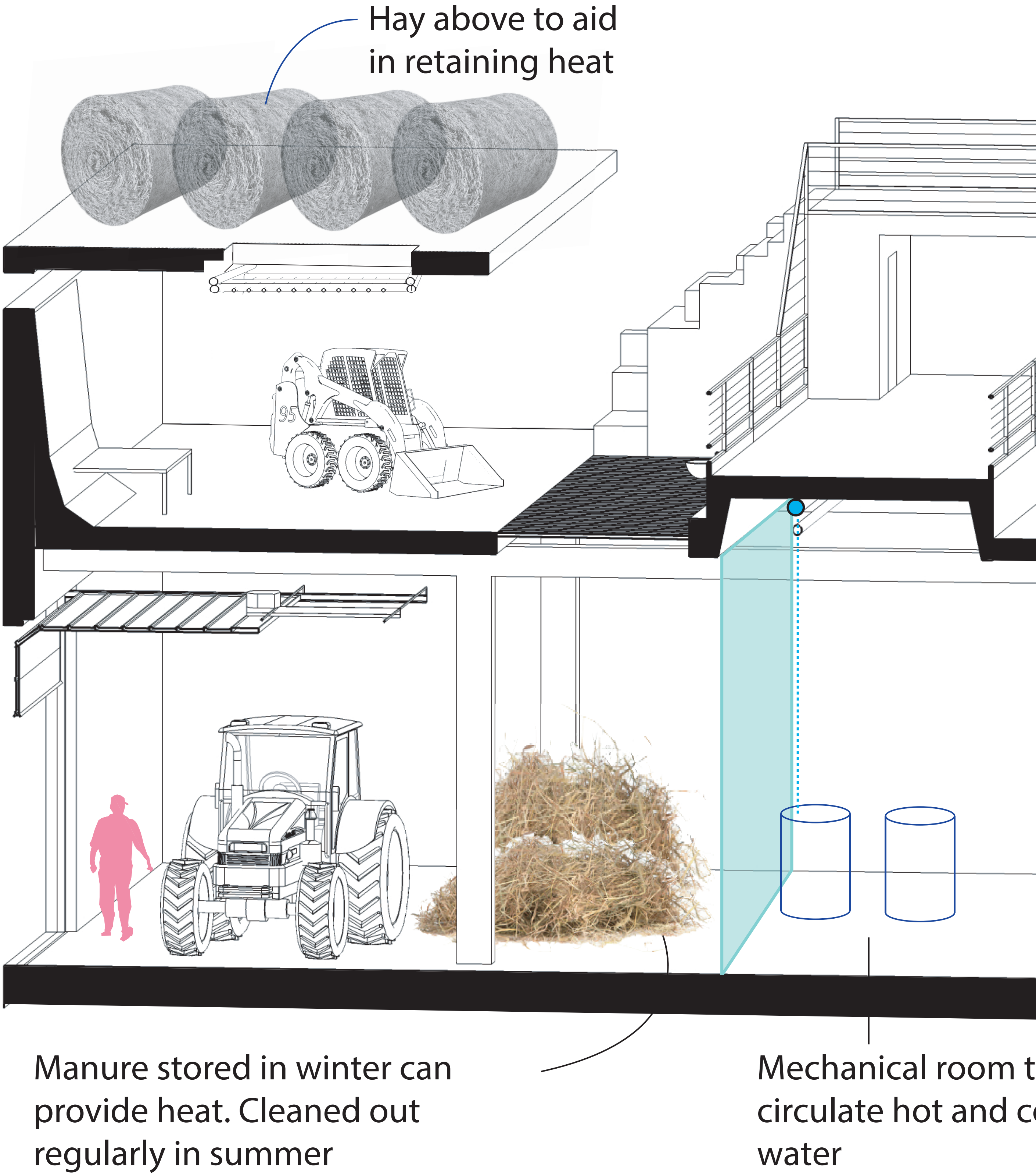
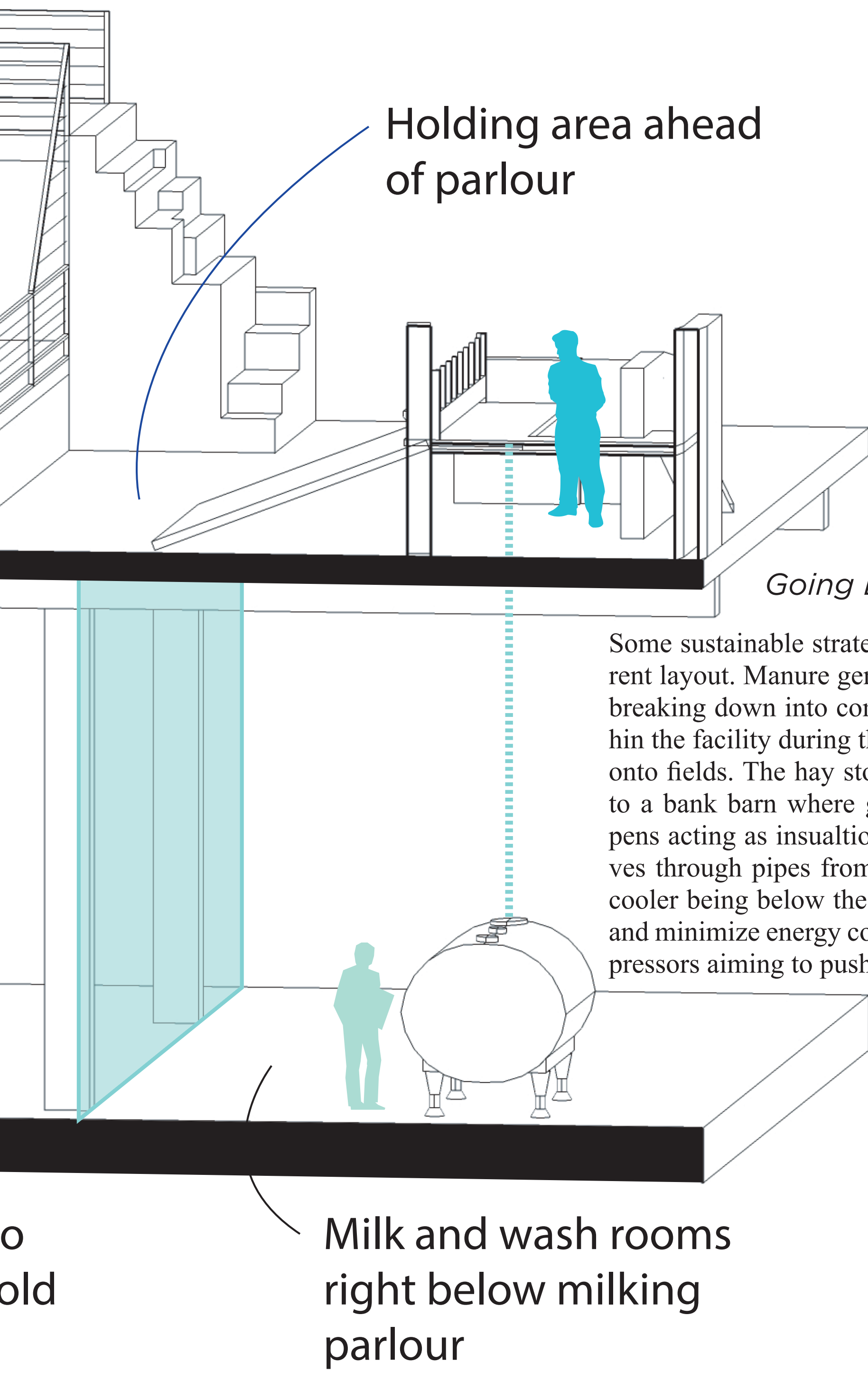


Figure 5.4 *Creating an atmosphere that is safe for al*
large eq

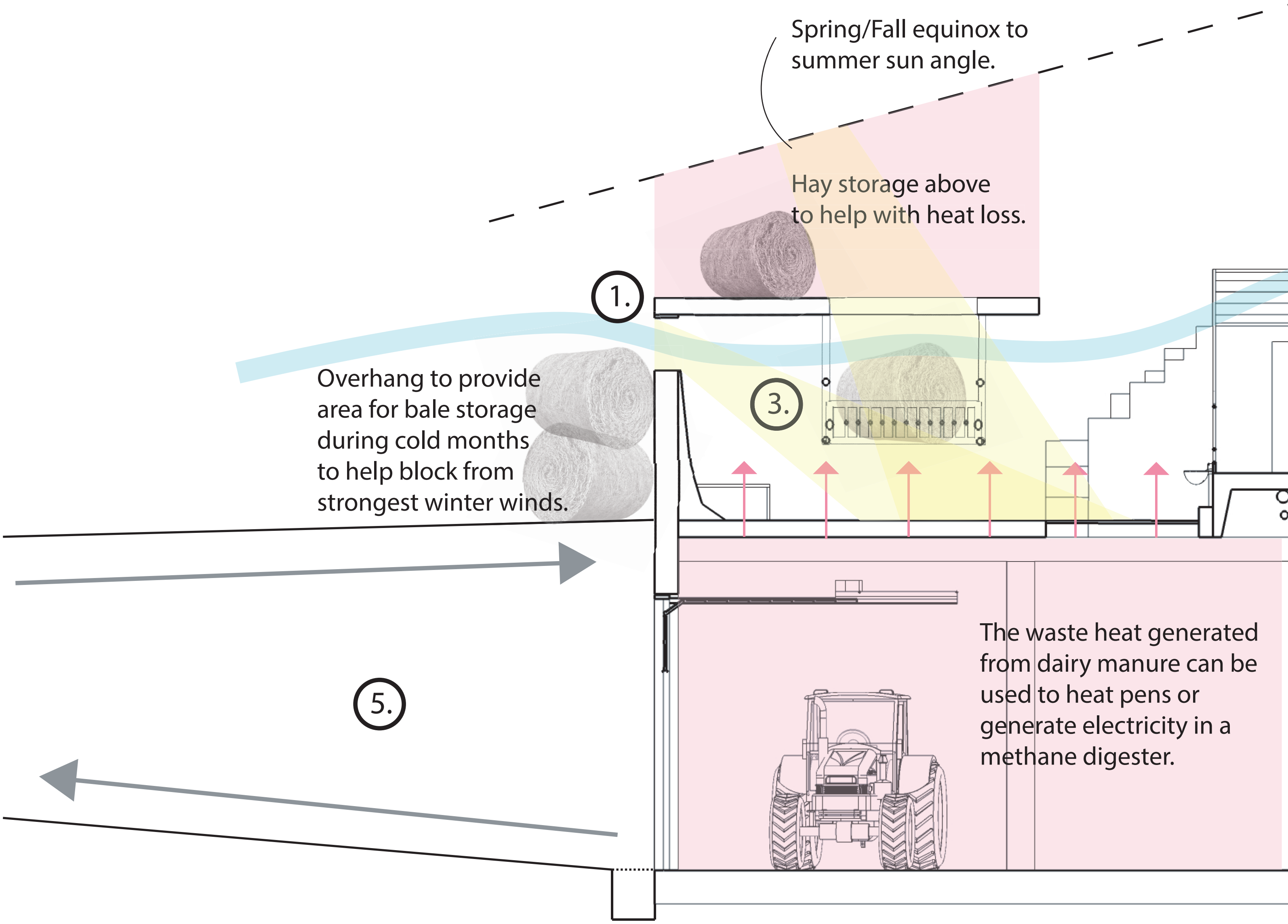


Going Below Continued

Some sustainable strategies can be implemented in the current layout. Manure generates a lot of heat, especially when breaking down into compost. The heat can be retained within the facility during the winter when manure is not spread onto fields. The hay storage above the pens, acts similarily to a bank barn where grain and hay was stored above the pens acting as insualtion to retain body heat. The milk moves through pipes from the parlour to the cooler. With the cooler being below the parlour, the milk can be gravity fed and minimize energy consumption from pumps and air compressors aiming to push the milk through.

l occupants must consider noise, smell, and traffic of
uipment.

SUSTAINABLE STRATEGIES

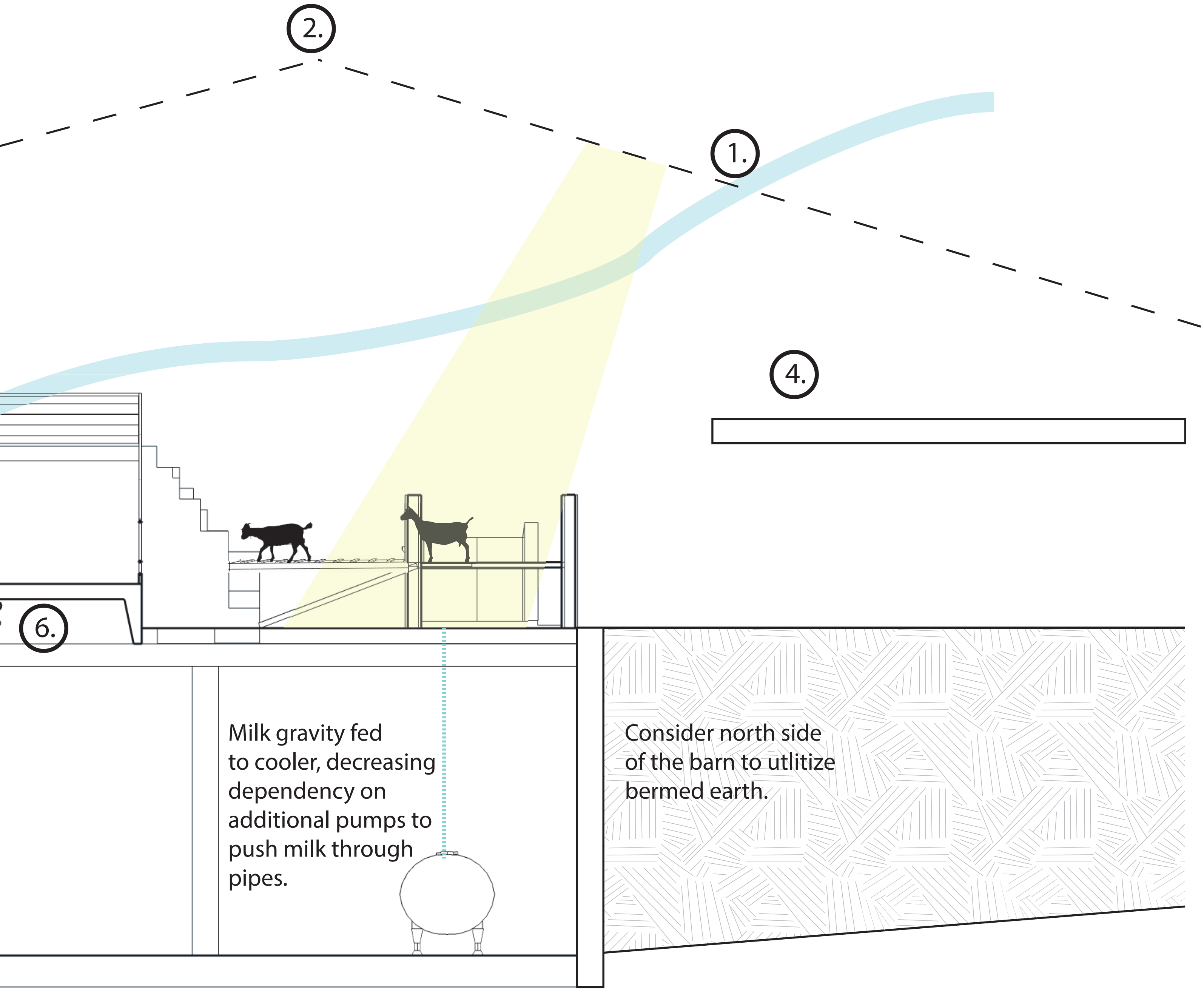


1. Openings that promote cross-ventilation promote air movement across key areas such as penning and the milking parlour. Operable openings and vents within the roof structure can aid in air movement.

2. Since farm buildings have become greater in size, they offer a large roof area where ample amounts of water and solar energy could be harvested.

3. Opening in hay loft above pen placed to provide shaded area when summer sun penetrates from above. Depth of overhangs along south of building should allow winter sun to penetrate pen area for natural daylight.

Figure 5.5 *In section, many sustainable and econom architecture, and common sustainable best prac*



4. Views from training rooms offer demonstrations from a safe distance if demonstration involves high stress for animals, or requires minimal contamination from exterior sources.

5. Separating equipment used for feeding and manure, decreases chance of contamination, and allows for better traffic flow around the building during warm months where manure is constantly moved form the building.

6. Protecting services such as water pipes and conduit from goats that chew, and in insulated areas can minimize maintenance requirements and keep a facility going where power failures and/or frozen water bowls can setback daily processes and research studies.

ical approaches are demonstrated. Vernacular farm tices can easily be joined within farm buildings.

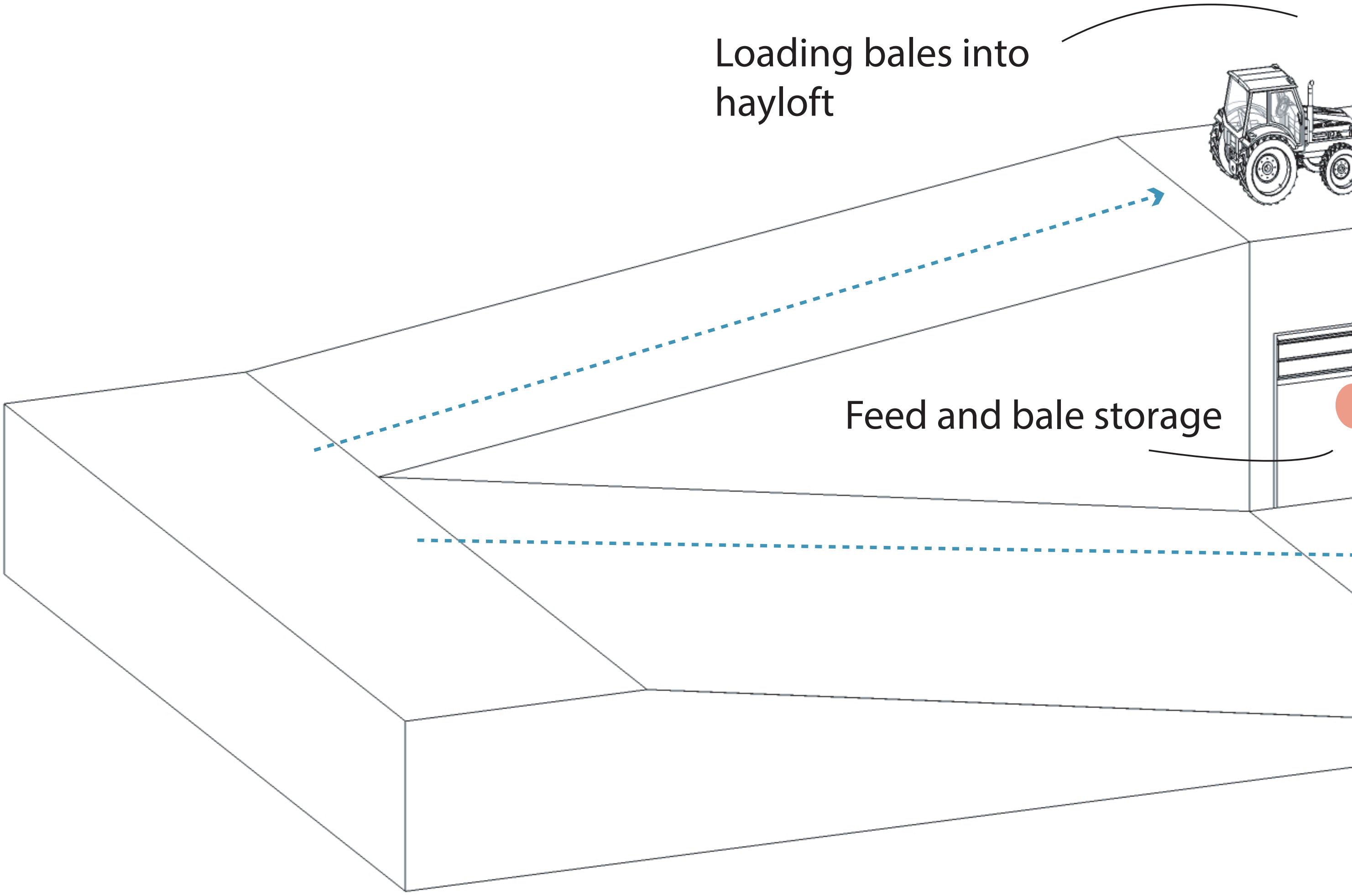
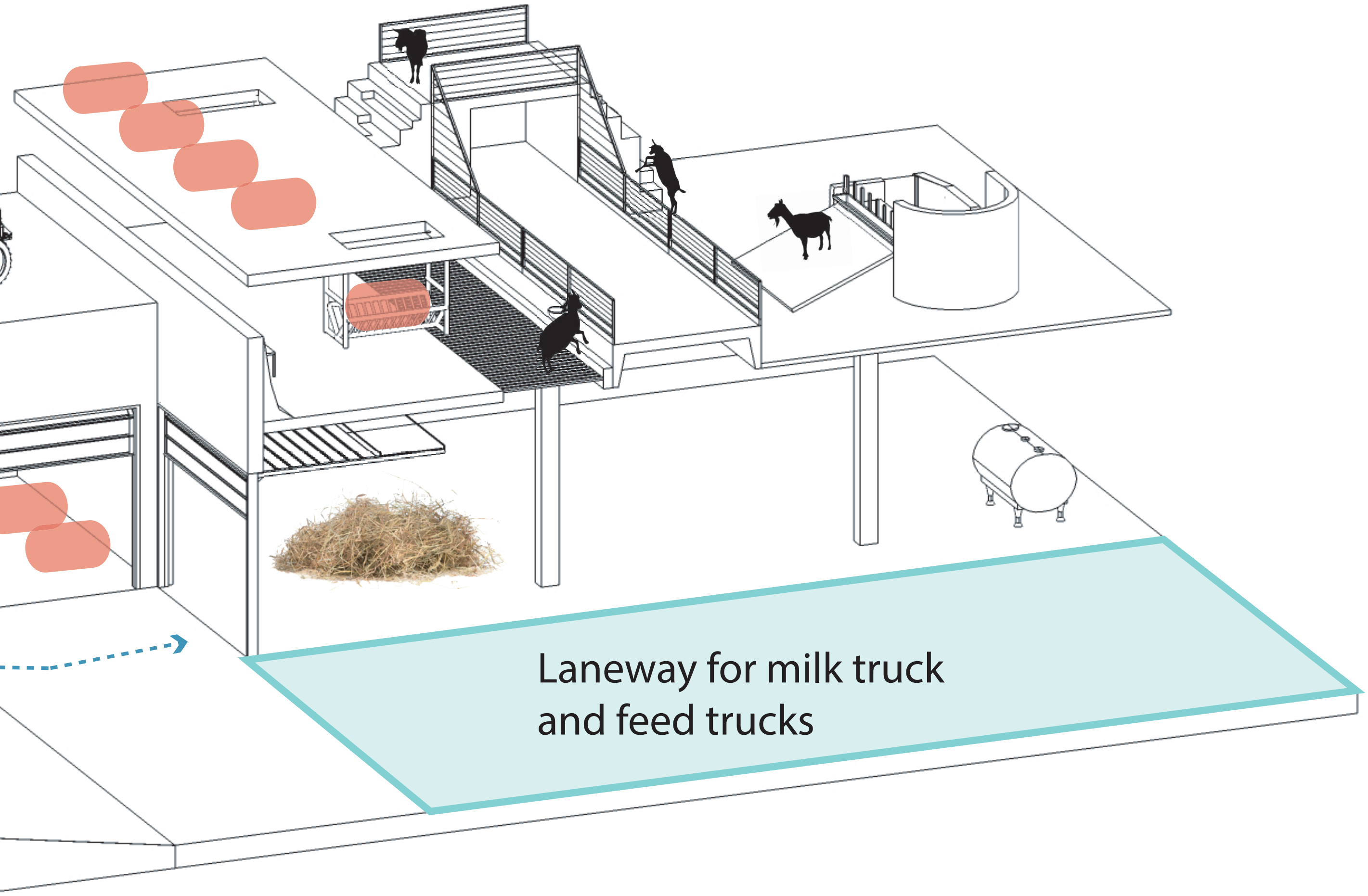


Figure 5.6 *Site circulation is vital to continue the ong*
distribution of equipment around the building wher



Looking Outwards

To access the hay storage and manure storage, equipment such as large tractors would require ramps. The ramp to allow equipment to access the hay storage can be incorporated into the overall structure of the facility, providing additional storage underneath for equipment and feed. The ramp to access the storage below can also be utilized by the milk truck to access the milk house and pick-up milk. The lane used by large equipment is then separated from the main route for visitors and staff coming to the facility.

going operations of the facility and create an efficient
e vistors and goats are also sharing exterior space.

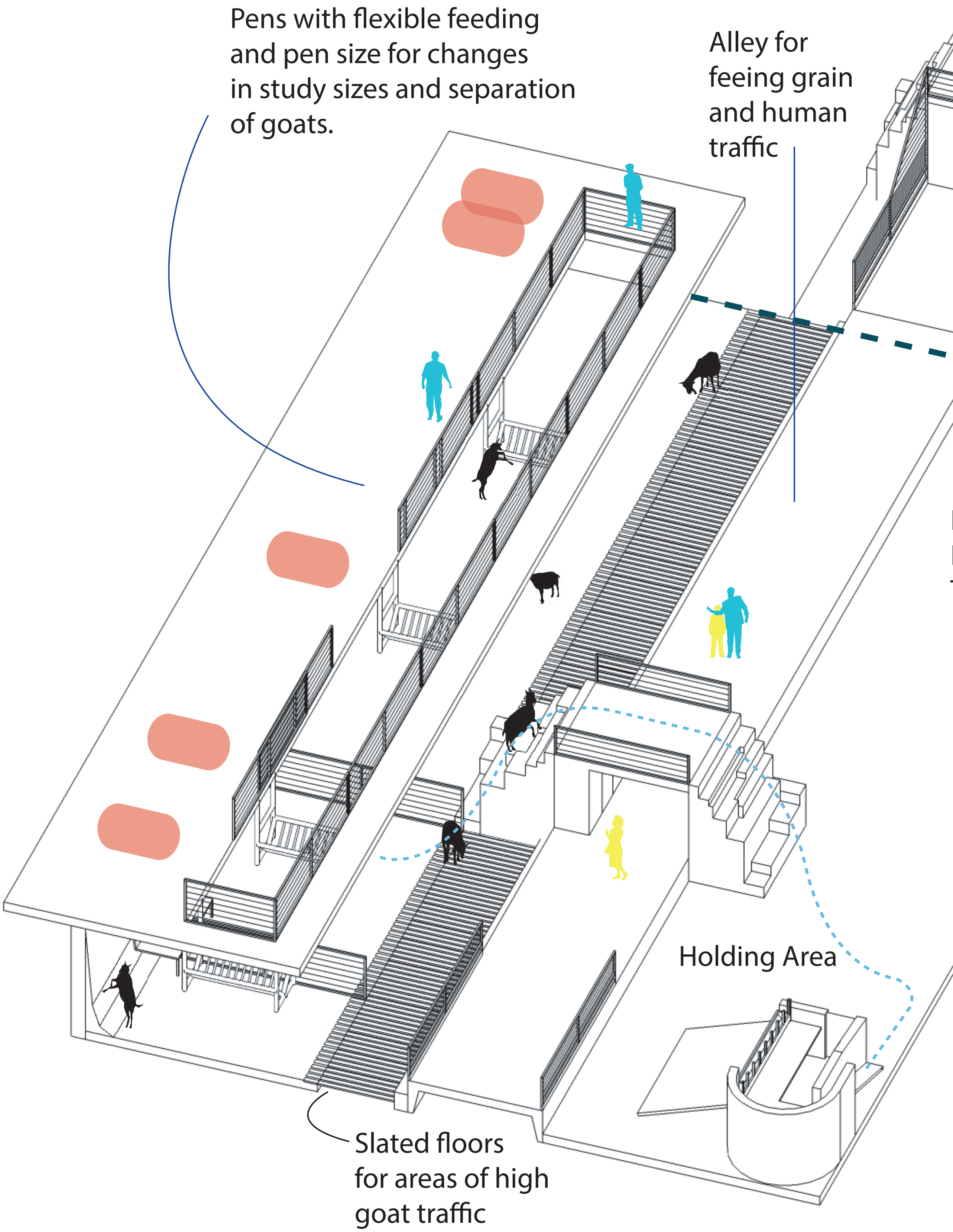
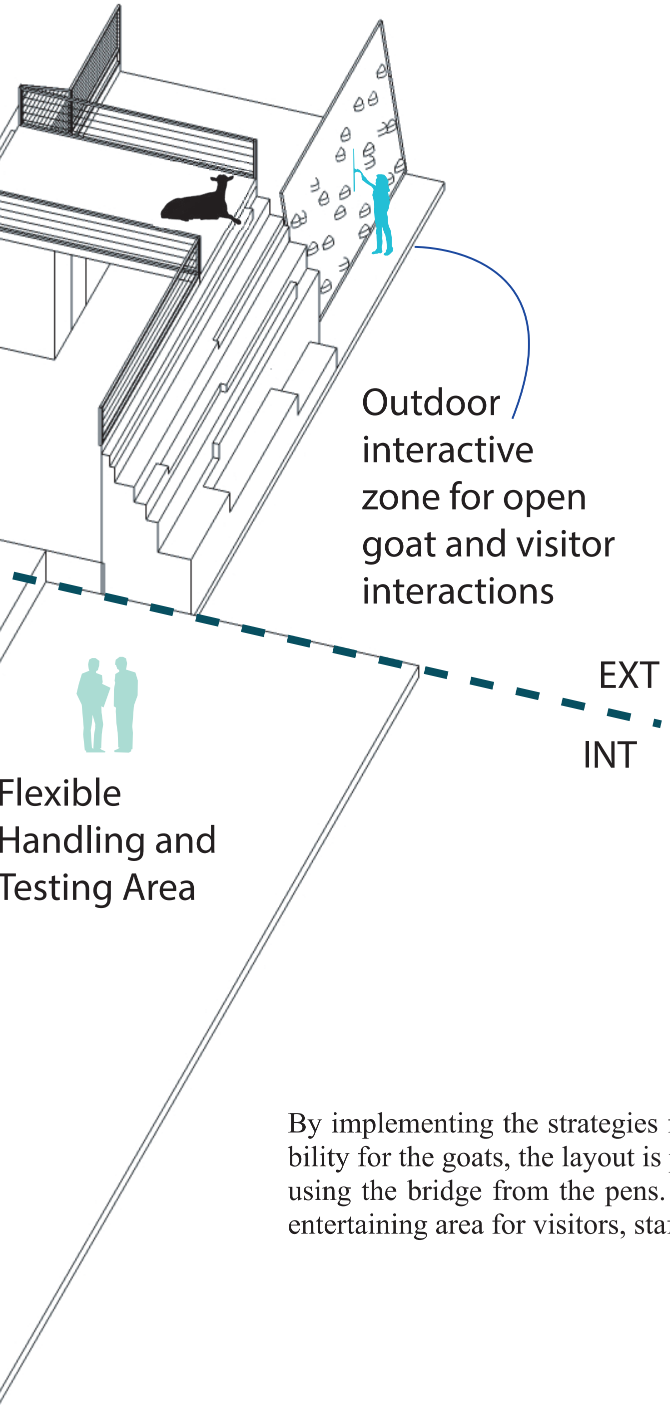


Figure 5.7 *Integrating flexible pen strategies such as*
set of pens with access to a feed alley and views from
designs by integrating spaces design



Flexibility

By implementing the strategies for providing flexible pens for both research and adaptability for the goats, the layout is pushed to reveal areas for handling and testing accessible using the bridge from the pens. An outdoor interactive area is also added to provide an entertaining area for visitors, staff, and the goats.

hay feed systems on tracks and mobile gates creates a
the hayloft and alleys. Consideration for exterior pen
ed specifically for public interaction.

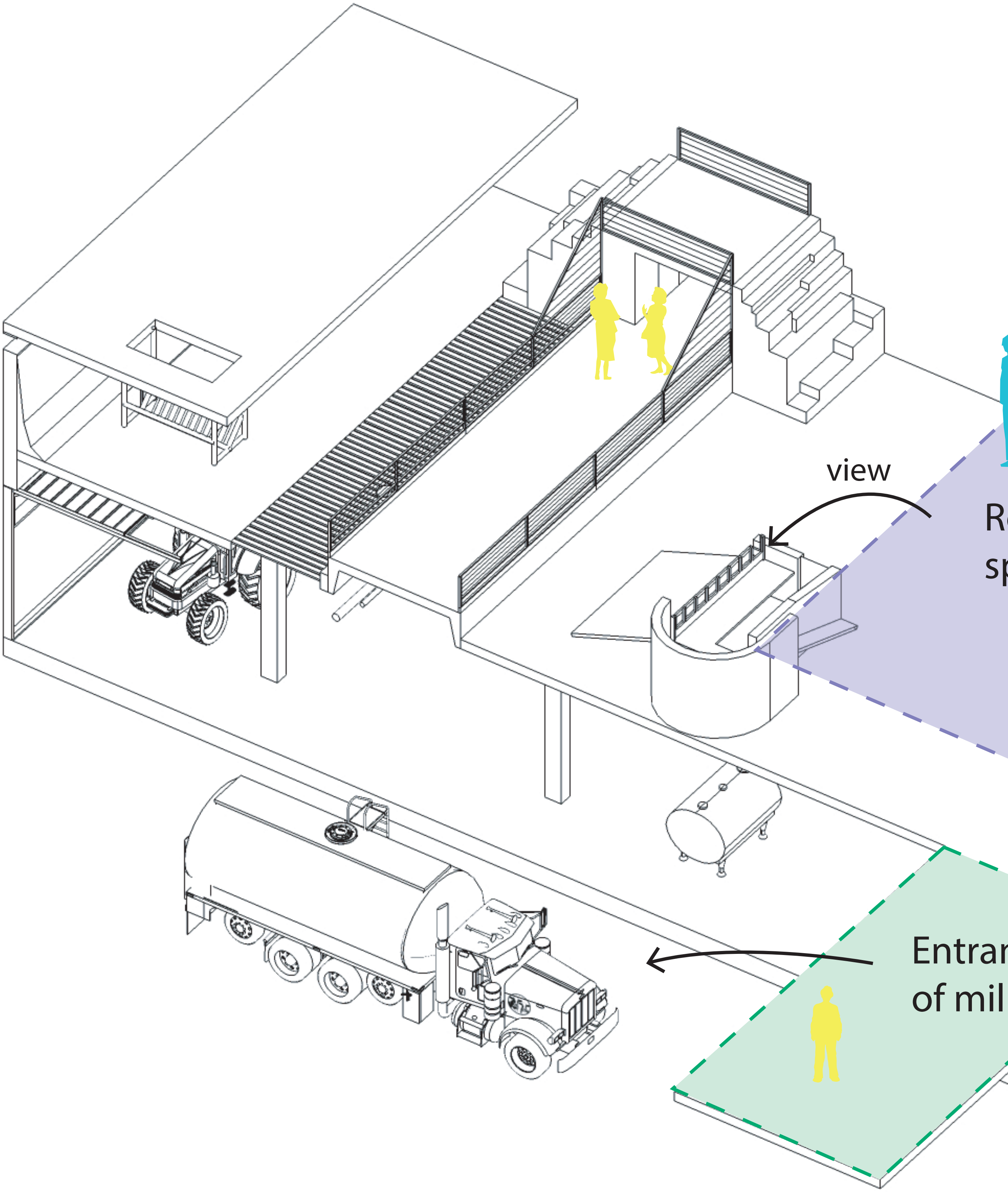
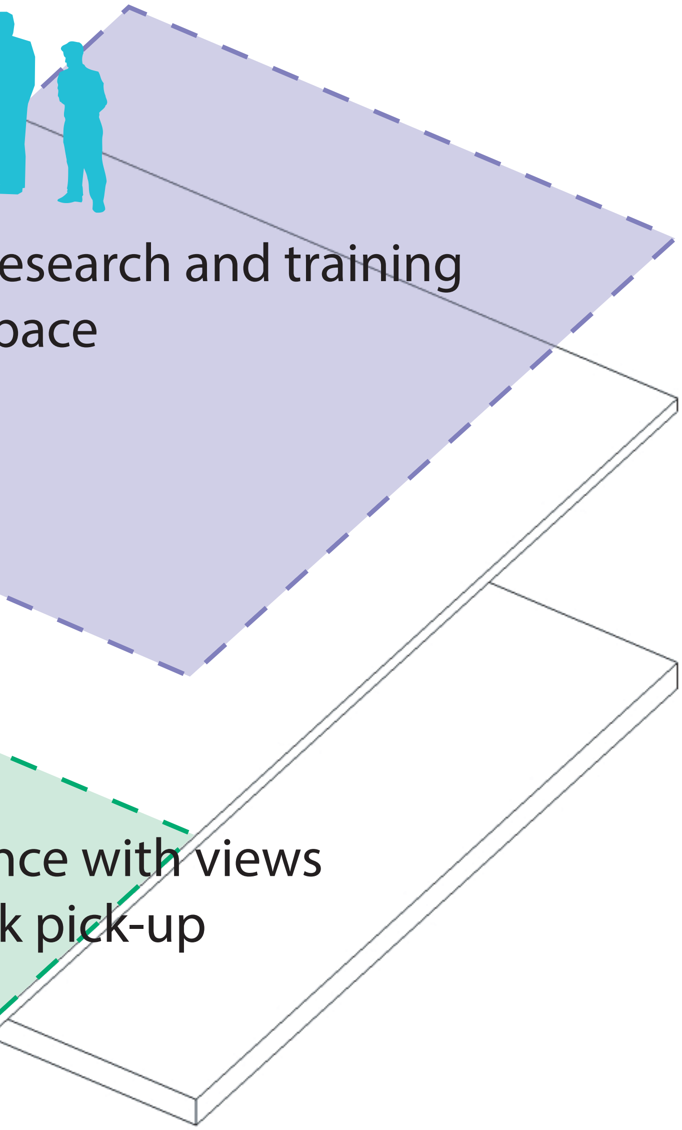


Figure 5.8 *Views in and around the facility can offer i*
tions to visitors. By having the milk truck pick-up belo
the facility is also



Views

Views of the functions and processes of the facility are available from higher vantage points. The circulation of large equipment such as the milk and feed trucks can be viewed as people walk towards the building to access. This allows the view of the operation of picking-up milk similar to many dairy farms and a look at the various equipment used while maintaining a safe distance. Meeting and training areas can be poised above the parlour and research spaces to provide views of studies, process, and even training demonstrations that involve goats, wtihout having multiple people standing in the way.

*mportant research insights and demonstrate the func-
w a walkway into the building, visitors can clearly see
a working dairy.*

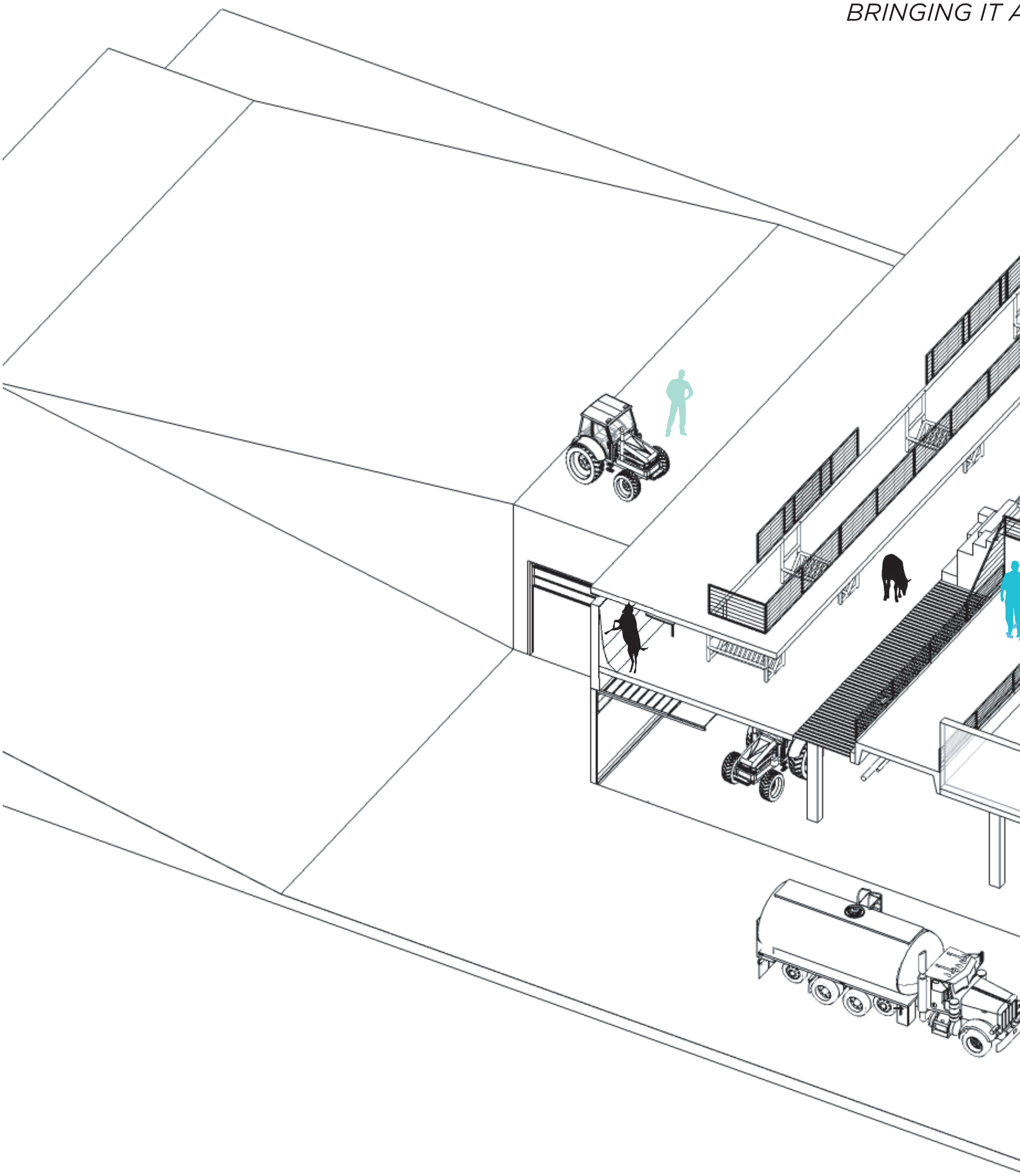
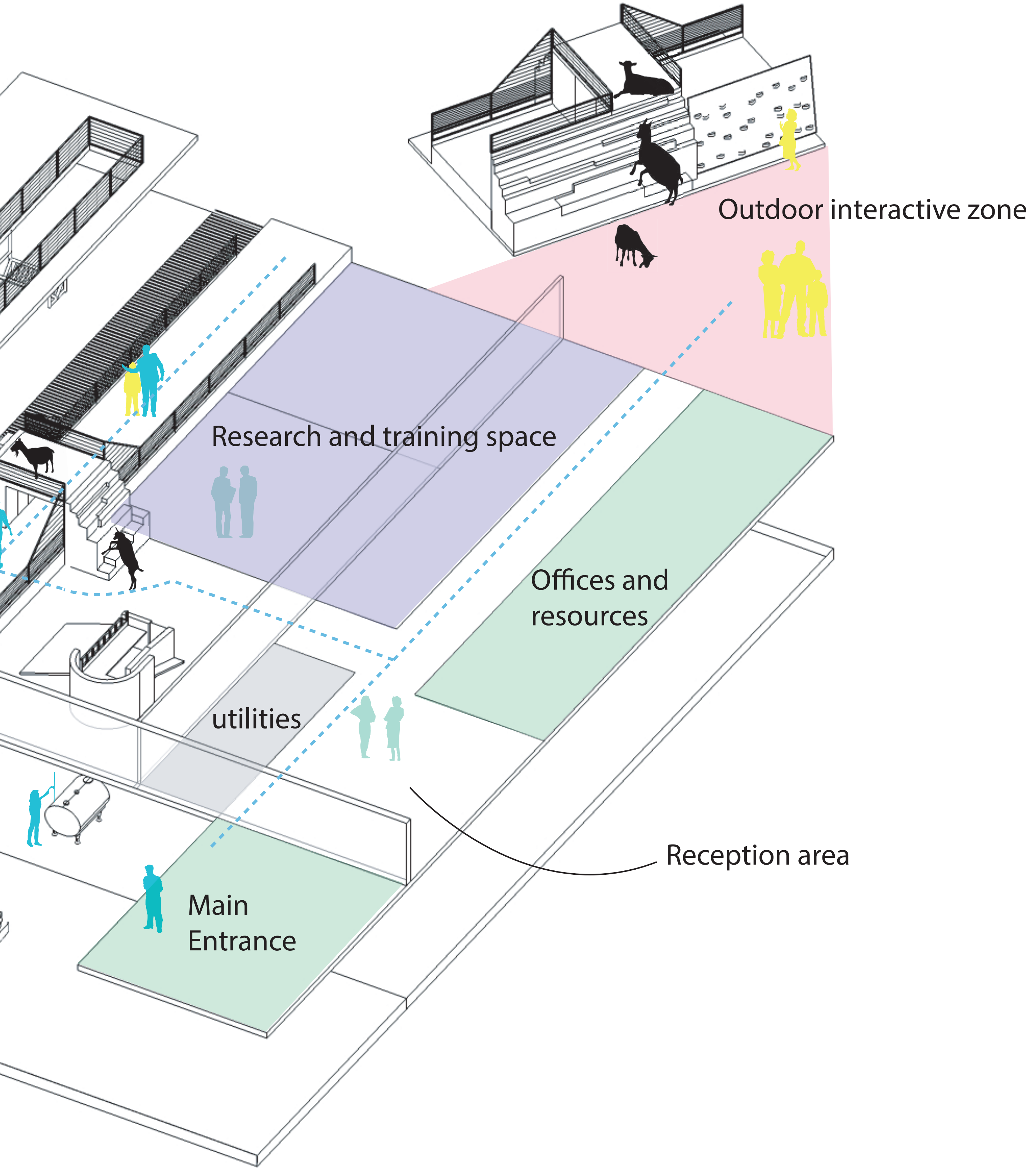


Figure 5.9 *This axo begins to piece together the recep*
to research facilities. Maintaining important views a
when placing administrative and lab progr



tion and administrative areas that are also important nd considering key circulation paths are also critical ams alongside her management operations.

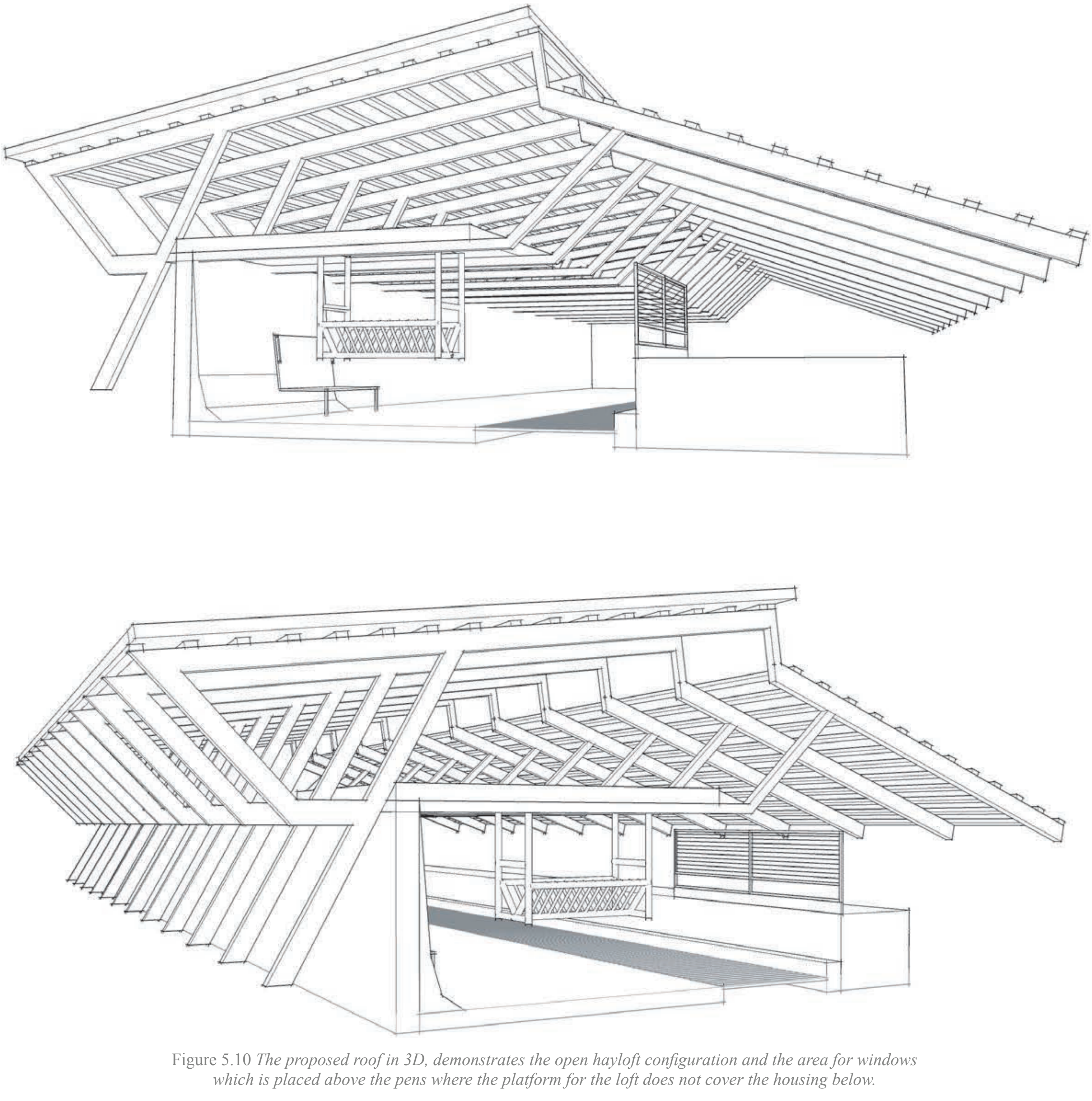


Figure 5.10 *The proposed roof in 3D, demonstrates the open hayloft configuration and the area for windows which is placed above the pens where the platform for the loft does not cover the housing below.*

Putting a Lid on It

The roof of the facility should not only provide shelter from weather, but allow for ventilation, daylight, and water collection. The scale of many farm buildings including research facilities, requires a significant amount of roof area. By pushing the form of the roof, the overall form of the research facility can begin to step away from generic farm building typologies and create a more interesting and multi-purpose space. The significant building height on many barns, particulary cow barns, provide lots of ventilation but can also be perceived as wasted space. By including spaces underneath the roof, the roof not only provides the necessary light and air, but can also provide program such as the hay storage and provide the space for the bridge where goats pass over the feed alley.

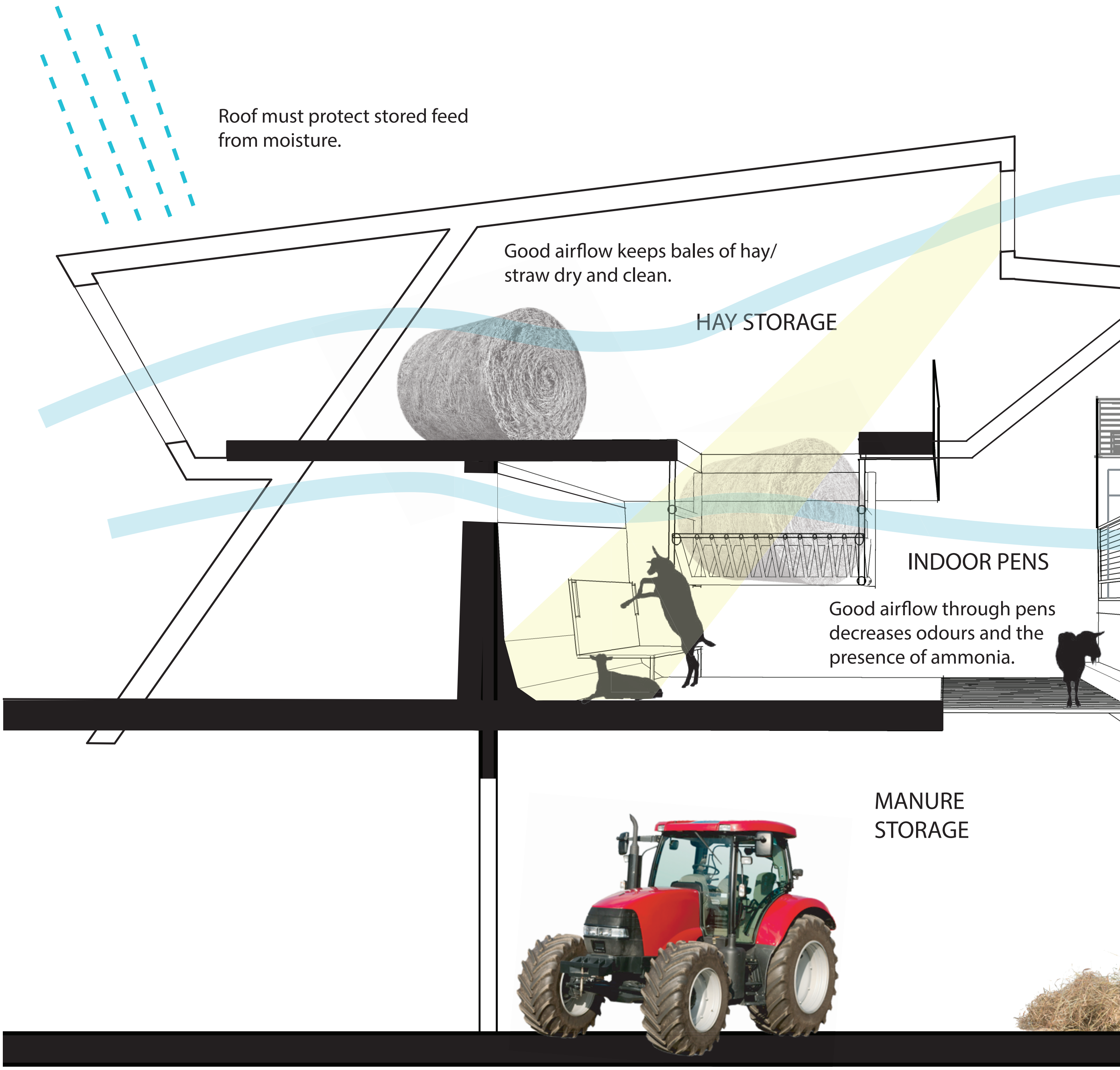
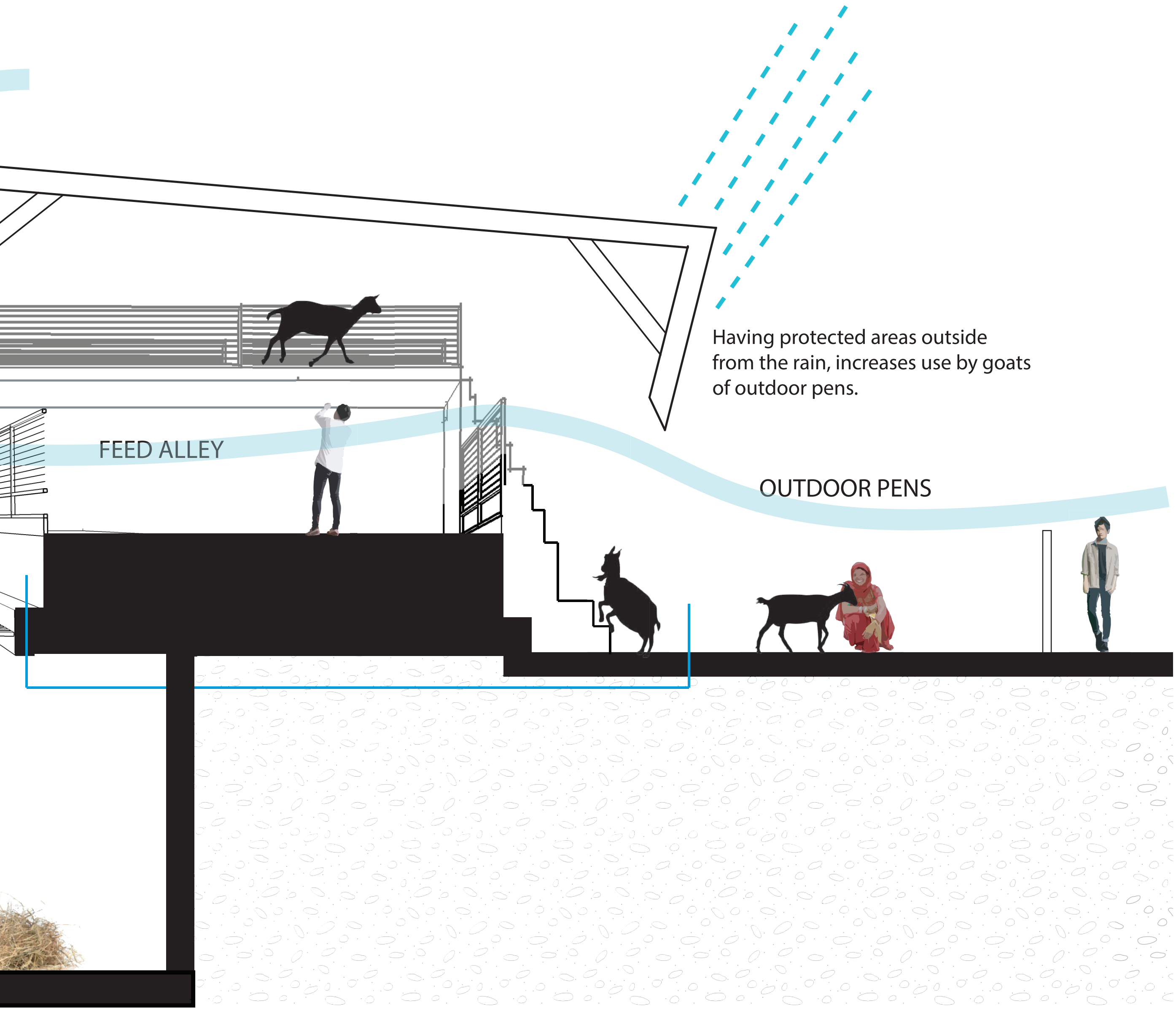


Figure 5.11 *With the dynamic levels of the proposed respond to the program in such a way to provide acc benefit the occupants and atmosphere of the overall b the hayloft with covered storage below for additional b alleys. Sawtooth type confirgurations allows for*



research facility design, the roof would also need to ess, ventilation, daylight, and height requirements to uilding. This proposed roof scheme provides access to ales. The hayloft is maintained as open to the pens and operable windows for daylight and ventilation.

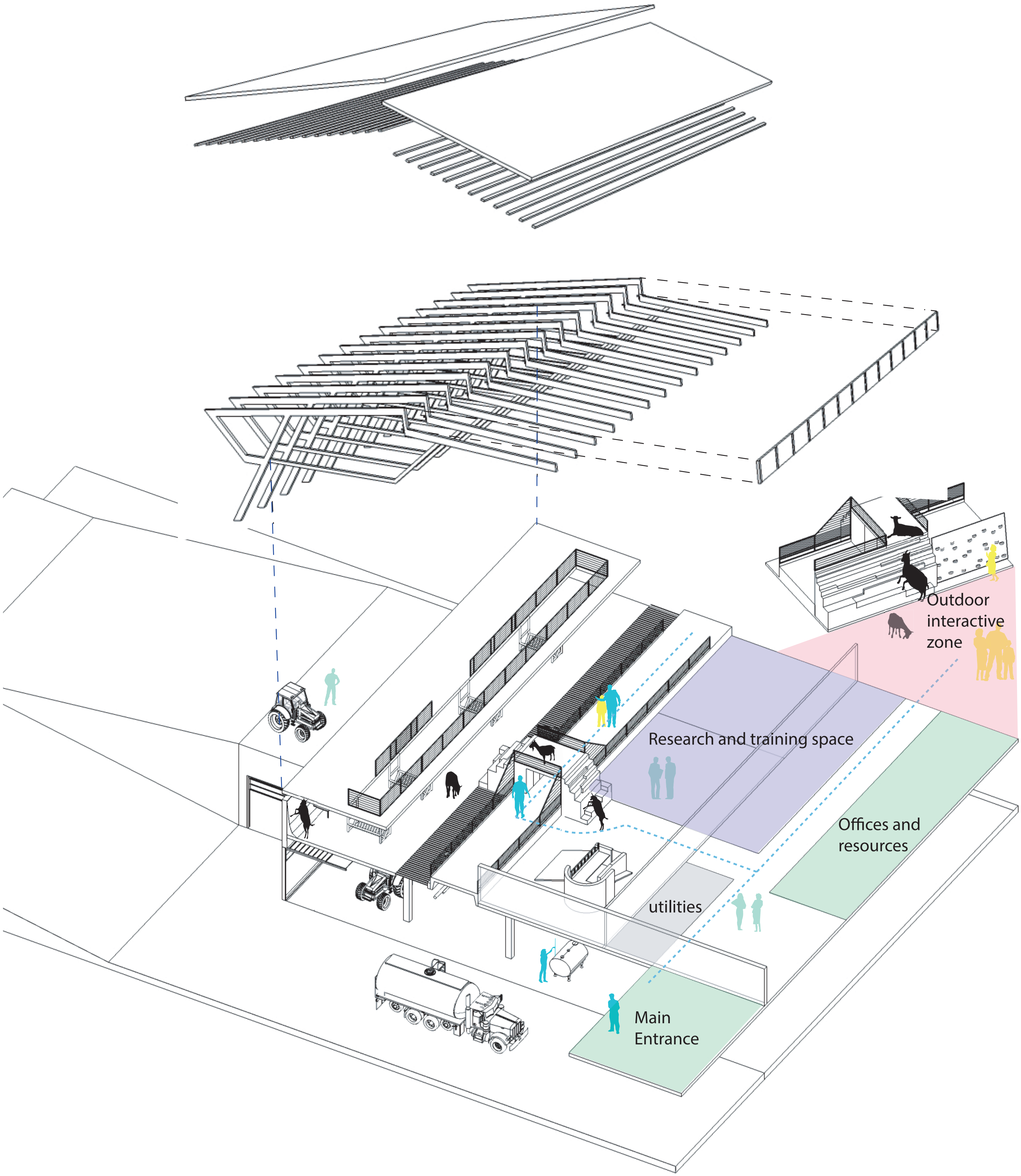


Figure 5.12 *The proposed design methodology for the dairy goat research facility demonstrating the joining of the key dairy operations components, public and research spaces, and site configurations.*

A Facility for Goats

The amalgamation of functions of the herd management, research and public areas of this potential research facility, have come together to provide spaces that embrace the peculiar behaviours of goats. By embracing these behaviours, the architecture of the facility becomes a home for the animals that promotes welfare and can be enjoyed by those who will work and visit the animals. Research facilities should be accessible to everyone, be a leader in the industry for best practices, and look to collaborative opportunities with farmers and consumers. All of these opportunities co-exist and mutually complement each other, creating an efficient and safe building for all, as demonstrated by Figure 5.13. What started out as typical farm spaces redesigned for goats, has now become a facility that resembles nothing of a cow research facility, but begins to demonstrate the architectural features that arise when goat behaviour is implemented in the design process.

Figure 6.1 *Goats have a reputation for being stubborn and misbehaved; but if you understand their behaviour, they can be far easier to work with.*

part six

CONCLUSION

Animal care in research, teaching, and testing facilities has undergone a remarkable transformation in the past two decades, and there is a heightened emphasis on the psychological status of animals living in these institutions. Today, providing for the psychological well-being of research animals is an integral part of animal care programs and its promotion within facilities. This change occurred as the scientific community realized that animals have many behavioral needs, which, if not met, can adversely affect their behavior, physical health, and research utility. Programs to address the well-being of livestock animals by providing them with more complex and interesting environments are becoming more common but need to be accelerated within Ontario's dairy goat industry. Environmental enrichment enhances the well-being of animals by providing them with species-specific opportunities for exercise and manipulating objects, and cognitive challenges As the industry is still in its premier years of establishment, creating building environment and housing policies that focus on goat welfare must include penning and feeding systems that encourage goat behaviour. As seen throughout this thesis, much research exists to demonstrate the benefts in encouraging said behaviour rather than suppresing it.

Livestock research facilities are an important icon within our society. They represent a cooperative and moral relationship between research, agriculture production, and consumers. Public consultation can make policy more responsive to the practical contexts it is applied within, revealing where policy may be misguided or could lead to unintended consequences. Public views are, for these reasons, influential for the development of animal welfare policy and should be taken into consideration by animal use industries. Expert opinion is also important for informing animal welfare policy and animal management practices. The Dairy Goat Research Facility must bring all of these groups together. The design thesis is not only a production unit, but a way to provide best practices to farmers and demonstrate said practices to consumers. Unfortunately, farming practices are often represented falsely within our society. The historical small hobby farms appeal to society more than their contemporary counterparts due to the barren architecture. This contemporary farm architecture is often designed around equipment such as large tractors utilized to feed, therefore, wide feed alleys flanked by pens. The Dairy Goat Research Facility uses the site, land, and most importantly, goat behaviour, to design the agricultural operations and architecture. It does this in order to convey a form which represents the important ideals society and the farmer value on a farm.

Figure 6.2 *Author with favourite goat, Charlotte, on family farm.*

With the scale of livestock research facilities growing exponentially, many architects are now leaving their imprint on agricultural architecture. The process of design demonstrated in this thesis, encourages architects to look to the animals more and push the boundaries of what housing can be designed for any livestock. The design of the Dairy Goat Research Facility represents an integration of goat behaviour, farm culture, farm technology, and sustainability issues. The research available demonstrating a goats cognitive and social behaviours can be utilized to design appropriate space for a healthy and stress free environment for both the goats and their handlers. By treating the goat more as a client and critical user of the space, their ability to better adapt and harmonize with their environment affects the overall efficiency and research outcomes within the facility.

Truly, a livestock research facility is a representation of what is possible within its corresponding industry. The Elora Dairy Facility demonstrates superior technology, Cornell Teaching Barn focuses on a healthy environment for the cows, while the Langston Goat Research Facility (E Kika) continues to be the leader for enhancing information exchange. As Ontario's dairy goat industry continues to grow and establish itself amongst the dairy cow and swine industries, creating a distinct and appropriate building and planning approchaes that highlight the unique behaviour and capabilities of goats. Through this, dairy goat barns can begin provide better welfare. Simple changes to these environments such as inclusion of opportunities to climb, hide, develop smaller social groups, and interact with different surfaces and heights for both resting and feeding could promote a better quality of life without compromising the production efficiency of modern dairy goat systems. Given the size of commercial dairy systems in Ontario, Canada, and the world, as well as the number of backyard goats, hundreds of thousands, if not millions, of goats could benefit from such improvements.

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APPENDICES

APPENDIX A

Site

The University of Guelph had retained BSN Architects to develop a comprehensive Land Use Master Plan for the Elora and Ponsonby Agricultural Research Stations. The Plan needed to consolidate and expand nearly 1000 hectares of agricultural research land and develop sites for $150M of new facilities and infrastructure improvements for existing stations.74

Mission 2050 (M2050) is an endeavour to replace the animal research facilities currently operated under contract by the University of Guelph for the ARIO and OMAFRA with new facilities. The project envisions a complex in Elora, Ontario, that has the flexibility to answer many current and future challenges and opportunities that face a majority of the livestock industries in Ontario and elsewhere.75

Elora, Ontario, located in Wellington County which surrounds and interacts with Guelph—a city of more than 120,000 people—and is adjacent to other economic centres such as Kitchener-Waterloo, Orangeville and the western Greater Toronto Hamilton Area (GTHA), areas of agricultural activity and innovation. Only 1.5 hours from the U.S. border with access to 135 million people within a day's drive, Wellington County is part of the broad, rapidly-expanding economic region known as the Greater Golden Horseshoe (GGH). The total population of the GGH is 8.8 million—over one-quarter of Canada's total population. Along with manufacturing, agriculture is a foundation of the Wellington economy, accounting for more than 5,800 jobs—an increase of 43% over the past five years. With 2,511 farms, Wellington has the highest number of farms in Southwestern Ontario.76

Dairying, livestock raising and mixed farming are the main farm enterprises. Dairying prevails in the areas close to large centres of population. Beef and hog raising are important in Erin Township and in the region near Fergus and Elora, and mixed farming is most common in the northern townships. The main emphasis is placed on livestock raising as confirmed by the census figures showing-119,000 cattle, 13,500 sheep, 94,000 pigs and 1,200,000 chickens.77

74 Planning for Agricultural Research. 12 Sept. 2017, www.bsnarchitects.com/news/planning-for-agricultural-research. Accessed 17 Aug. 2020.

75 Editor 5pm. "Mission 2050 - Research and Industry Infrastructure in 2050." Www.thepigsite.com, 27 Jan. 2009, www.thepigsite.com/articles/mission-2050-research-and-industry-infrastructure-in-2050. Accessed 17 Aug. 2020.

76 "Wellington County Agriculture: Room to Grow." Sept. 2015, https://edac.ca/wp-content/uploads/2015/08/Wellington8.pdf

77 Hoffman, D. W., et al. "Soil Survey of Wellington County Ontario." 1963.

Figure 7.3 *Top map showing Elora in relation to Guelph. Bottom map showing all UofG research stations in Elora and potential Goat Dairy Research Centre site.*

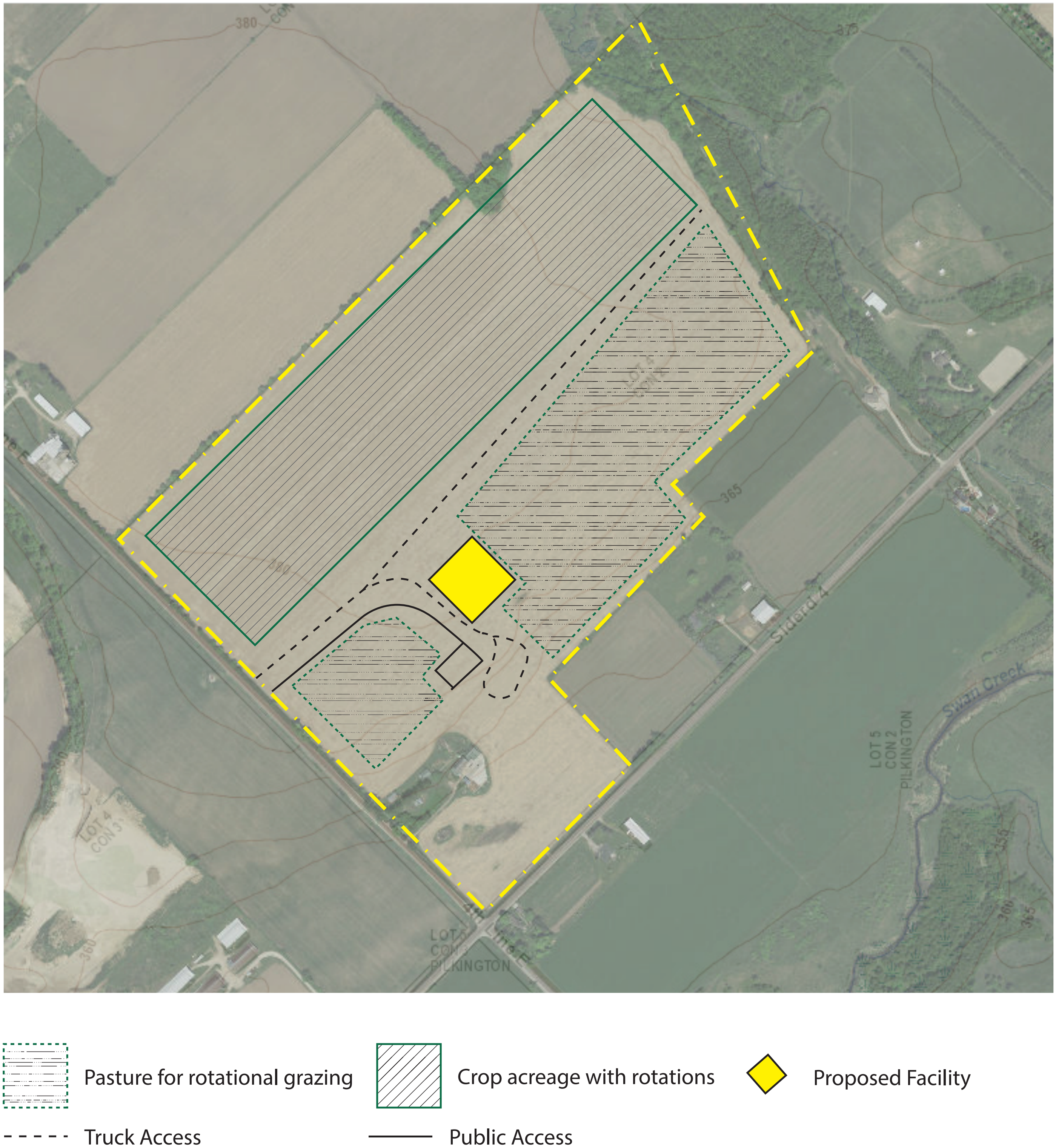

Figure 7.4 *Proposed site in Elora, 1:1000.*

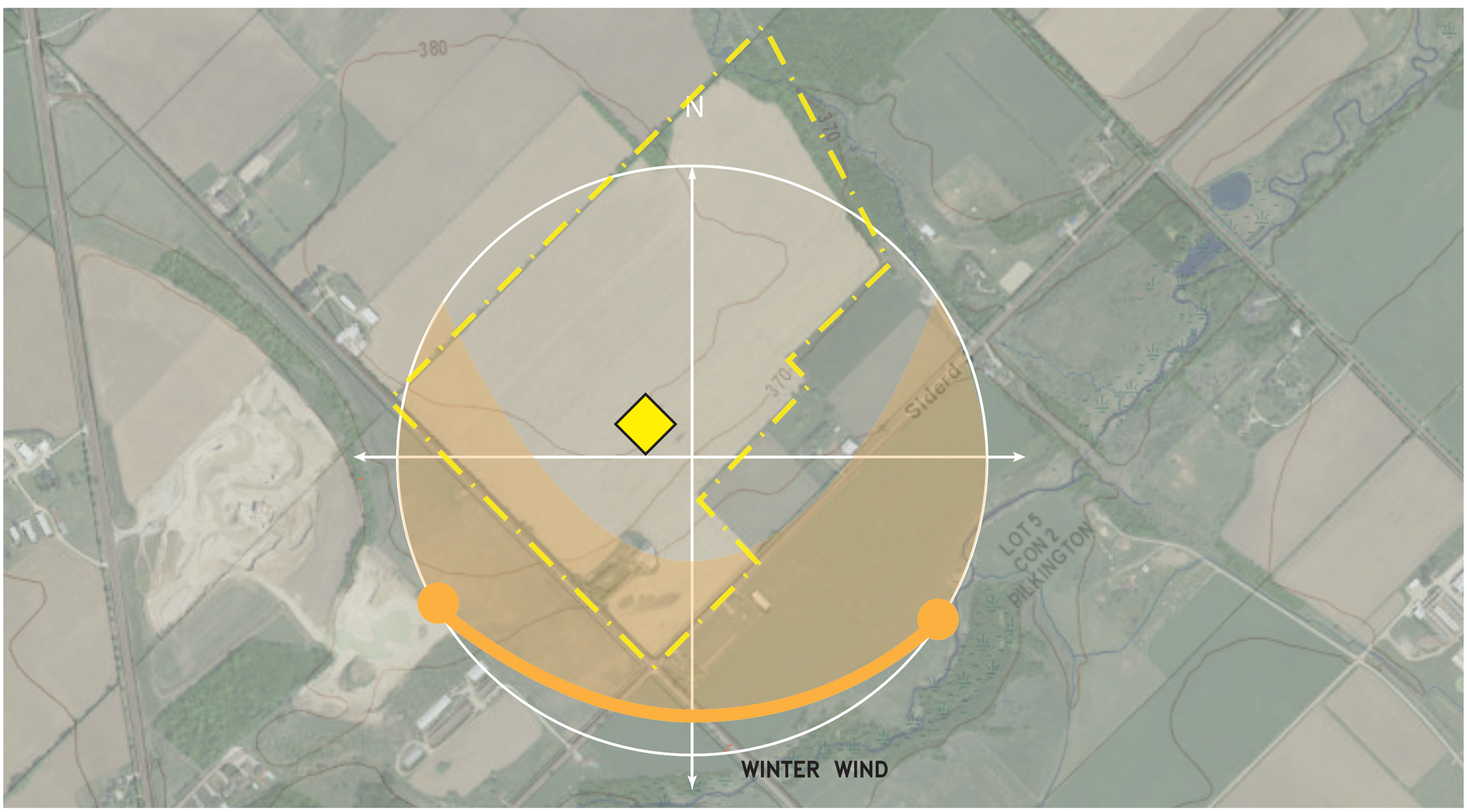

Figure 7.5 *Sun study of site.*

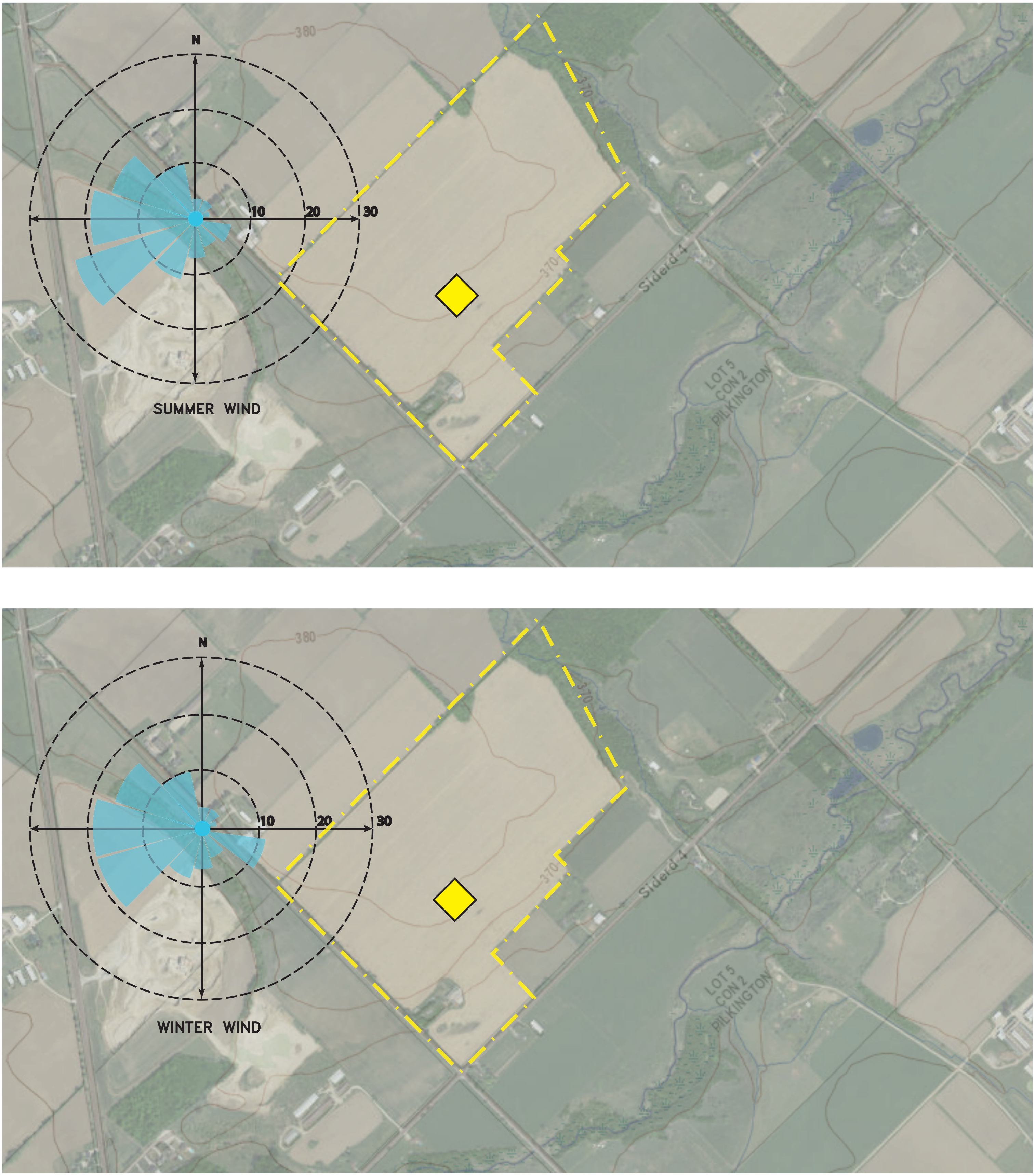

Figure 7.6 *Wind study of site.*

Crop Acreage and Rotation

The climate and the soils of Wellington County are suitable for the growing of a wide variety of crops. General farm crops such as oats, barley, mixed grain, silage corn, hay, and pasture, and cash crops such as winter wheat, turnips, and potatoes are widely grown.[78] Most of the farm land is used for growing hay, mixed grains and oats. Large acreages of these crops are necessary to provide feed for the large numbers of livestock in the county. Silage corn is also an important livestock feed and a considerable acreage is devoted to this crop.

Micro-organisms in soil need a diversity of nutrients. Plant roots can provide beneficial nutrients when rotated. Every plant draws certain nutrients from the soil to grow and can differ in their levels from one plant to another. If the same crop is planted over and over again, it will continue to deplete the soil of its needed nutrients, and crop yields with drop every year. Rotating crops allows the soil to give and take from different plants. In most of Ontario, a standard crop rotation is corn – soybeans – wheat (wheat is typically planted in the fall after corn/beans has been harvested and will survive in winter). Some crops need to be cultivated and re-planted every year whereas hay, for example, can grow for years without being replanted.[79]

Goats have a higher dry matter intake (DMI) compared to dairy cows. Average DMI is 5% of body weight compared to 3% in dairy cows. A high producing doe will consume up to 7% of its body weight. This results in a faster rumen turnover rate and shorter retention time of ingested feed.Most producers feed grassy hay with medium to high protein level (10%-20%). Some producers feed corn silage, haylage or baleage, which are fermented forages. Lactating goats' diet is supplemented with pellets (feed made up of rolled corn, beans, with minerals and vitamins with a protein level range of 12%-18%) or mixed grain (oats, corn, beans) with free choice minerals. Grain amounts for feeding is based on a goat's milk production and recommended by feed companies.[80]

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78 "Field Crops." Www.omafra.gov.on.ca, www.omafra.gov.on.ca/english/stats/crops/.

79 Brown, Christine. "Considering Crop Rotation in Nutrient Balancing." Www.omafra.gov.on.ca, 25 Oct. 2017, www.omafra.gov.on.ca/english/crops/field/news/croptalk/2017/ct-1117a6.htm. Accessed 13 Aug. 2021.

80 Lunn, Dennis. "Feeding and Management of Dairy Goats." Shur-Gain, a Member of Maple Leaf Foods Inc., Feb. 2011.

Control Grazing

The basic principle of control grazing is to allow goats to graze for a limited time, leaving a leafy stubble, and then to move them to another pasture, paddock or sub-paddock. Smaller paddocks are more uniformly grazed and surplus paddocks can be harvested for hay. The pasture forage plants, with some leaves still attached, can then use the energy from the sun through photosynthesis to grow back without using up all of their root reserves. Even brush will need a recovery time if it is being used as forage for goats. Without this rest period, the goats can kill the brush through continuous browsing.[81]

Under control grazing, legumes and native grasses may reappear in the pasture, and producers often report that the pasture plant community becomes more diverse. Control grazing can be used to improve the pasture, extend the grazing season and enable the producer to provide a higher quality forage at a lower cost with fewer purchased inputs. Control grazing can also be useful in reducing internal parasite problems if producers are careful to move the goats to a new pasture before the forage plants are grazed too short–less than 4 inches. Pasture size at a minimum must provide 30 to 50 square feet per goat.[82]

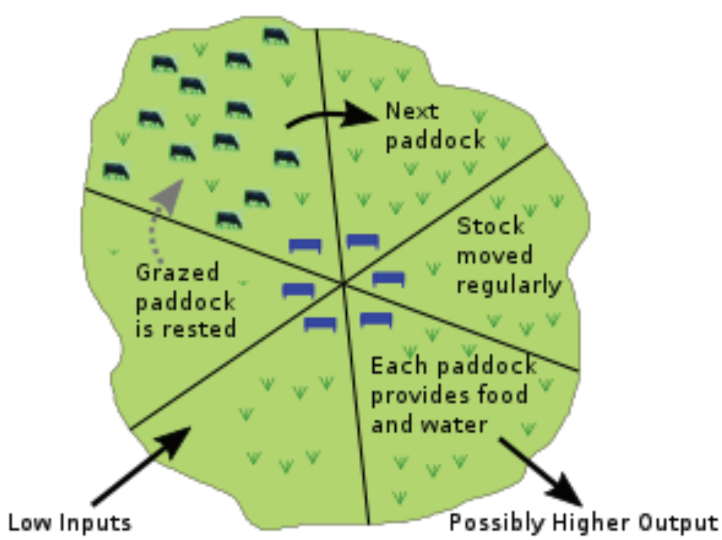


Figure 7.7 *Diagram showing the basic system of rotational grazing.*

81 "Goat Pasture Management – Goats." Goats.extension.org, 14 Aug. 2019, goats.extension.org/goat-pasture-management/#Control_Grazing_and_Strip_Grazing. Accessed 13 Nov. 2019.

82 "Dairy Goat Farm Production Requirements." Www.omafra.gov.on.ca, www.omafra.gov.on.ca/english/food/inspection/dairy/page-1.htm. Accessed 13 Nov. 2019.

Figure 7.8 *Goat manure.*

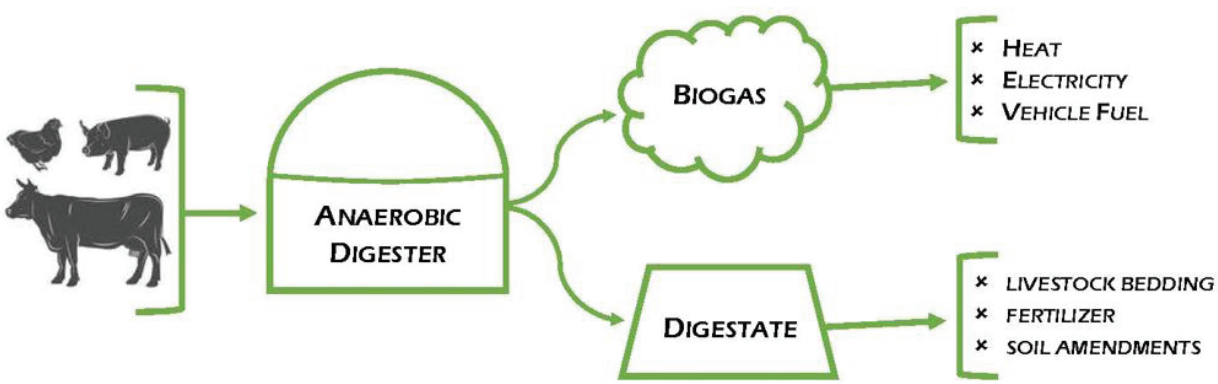


Figure 7.9 *Options for breaking down livestock manure for use.*

Manure Storage and Use

Barn manure is the solids that accumulates in farm housing, on both indoor and outdoor farms. Most goat farmers use straw, wood chips and/or shavings as bedding material. As dung and urine build up over time, more bedding material is added to keep the goats in clean, dry conditions. The amount of barn manure that an indoor farm produces is large. Measurements of barn and kid barn manure indicate that on average an indoor milking doe produces over a tonne of wet barn manure per year and a kid raised mostly indoors for two months produces about 35 kg. Therefore, an indoor farm with 500 milking does and 125 kids would accumulate about 537 tonnes of wet barn manure per year (625 m^3).

Barn manure is a source of the major plant nutrients and trace minerals needed for pasture or crop production. There are good levels of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S), the elements most commonly applied in fertilisers. The organic matter in barn manure is also important for improving soil structure and soil biology. This improves soil water holding capacity, aeration and drainage, and makes soil less prone to compaction and erosion. Manure can be stored outdoors or under a structure. When manure is stored outdoors there is some nutrient loss to air and leeching. Some farmers will cover their manure with tarps to mitigate the loss of nutrients.

Composting barn manure is a process that uses aerobic organisms to break down the raw materials to create a product that has a finer, more uniform texture and stable forms of nutrients. The biological activity produces a lot of heat, which helps to speed up the process. A heaped storage of barn manure is not composting. For real composting to take place the material must be well aerated. For a heap of barn manure this would involve mechanical mixing and turning. An unturned heap of manure is anaerobic, and biological activity inside is slow. Spreading the composted barn manure on crop fields improves the soil structure and limits the use of fertilisers during crop growth. A storage area will be needed for the volume of manure removed from the barn on a monthly or annual basis as Ontario's climate does not allow for manure to be spread all throughout the year. Optimal time to spread manure means the ground is not frozen, there is minimal moisture to cause manure runoff, and the soil has time to be properly turned to limit any manure being harvested into the hay.[83]

83"A Guide to Managing Barn Manure on Dairy Goat Farms." Dairy Goat Co-operative (N.Z.) Ltd (DGC), July 2010.

Figure 7.10 *Winery Case Study: Image 1: Mont Ras Jorge, Vidal Spain Image 2: Dominus Estate, Napa Valley Image 3: Dornier Winery, South Africa*

APPENDIX B

Winery Case Studies

An exploration of the design of wineries demonstrated the built form of a product historically rooted to society that represents a symbol of tradition, connection, craft and high spirits. Therefore, there is an expectation in the consumer's mind that there will be compatible imagery between their view of the brand of the wine, what it means to them, and the experience that they have at the winery itself. The focus is that wine is about the sounds, flavours, and colours. So, if you are working very hard to create great enjoyment with the sense of taste in the wine, why would you not give equal consideration to ensuring that the visual enjoyment of the winery is at the same standard? Thus, both the wine and building design are equally important for a winery's success.

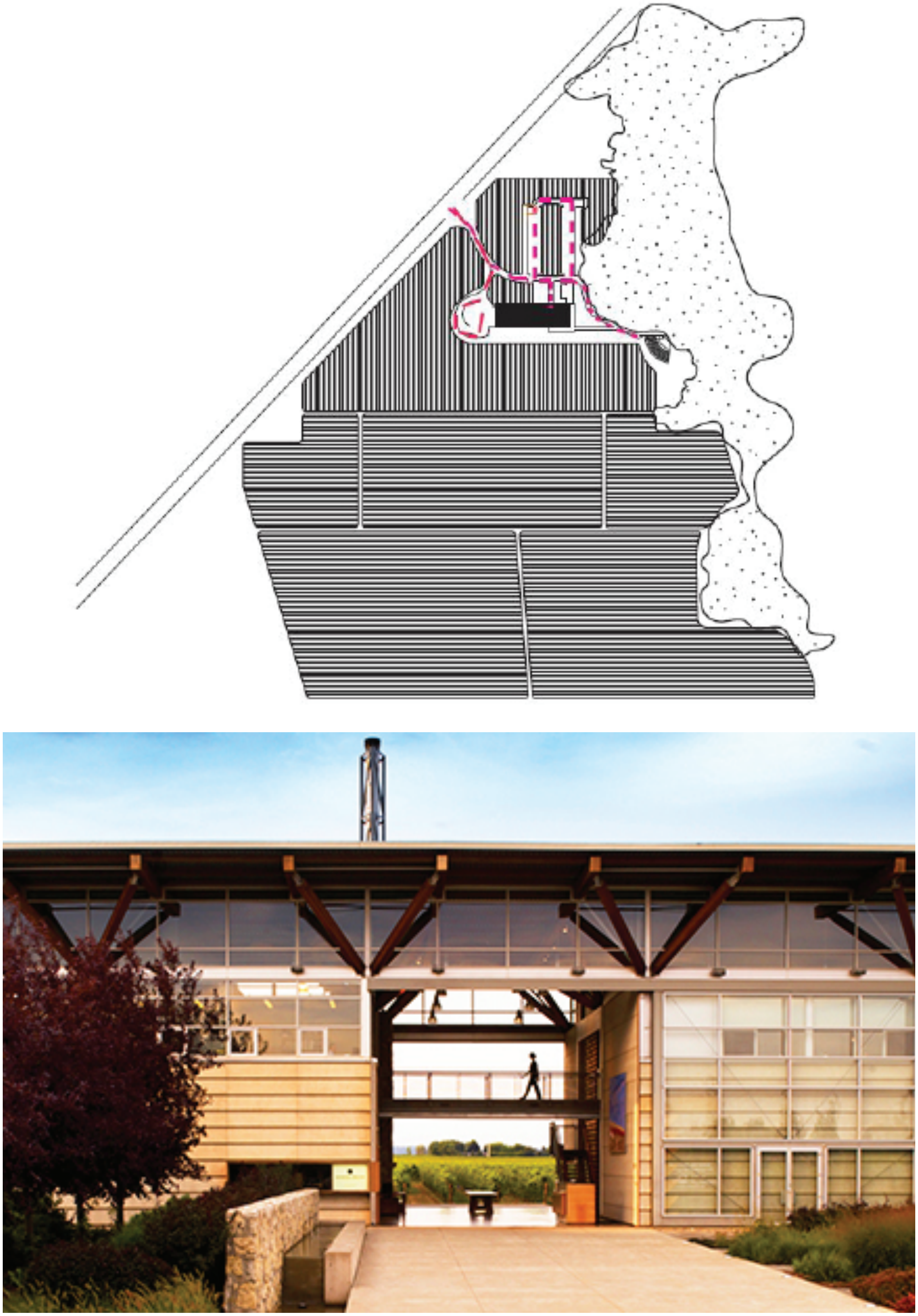


Figure 7.11 *Jackson Triggs Winery site plan and entrance. Dotted pink line in the site plan depicts visitor circulation while the red line depicts loading.*

Connection to the Fields

The Jackson Trigg's Winery in Niagara Falls, Ontario, and the Dominus Estate in Napa Valley, have the same architectural feature where a visitor can see firsthand the rows of grapes through a break in the building as they approach. These wineries are designed to encourage understanding of process through links between production and consumption with both the vineyards and winemaking facilities visually linked to tasting areas, restaurants and wine shops.

The two-storey, 4,000m^2 winery is comprised of two main programmed components divided by a 'Great Hall', that are unified under one floating roof plane. The large, double height Great Hall acts as a link and buffer; it both divides and bridges the public and production areas. The full height oversize sliding doors that open the hall and entrance court to the vineyards in mild weather. This large open room provides immediate sensory connections to the vineyards: visually it is unobstructed by glazing reflections, breezes blow through the space, and the sounds and smells of the grape growing process filter through.[84]

84 "Jackson-Triggs Niagara Estate Winery." KPMB, www.kpmb.com/project/jackson-triggs-niagara-estate-winery/. Accessed 27 July 2021.

Figure 7.12 *Dominus Estate Winery, site plan with similar configuration to Jackson Triggs and the front entrance which also provides views to the vineyards.*

Similarly to the Jackson Triggs winery, the Dominus Estate Winery uses a central atrium to continue views across the vinyards to the moutain range beyond. The 4,650m^2 structure's outer shell is constructed using gabions. The organization of of the size of local basalt rocks allows for light to penetrate or not depending on programmatic requirements. This gives the building a more natural facade as it sits surrounded by vineyards with the mountain range behind it. Also, with the gabion system, the architects eliminated the need for mechanical systems by using the natural temperatures of cool nights in California. This intuitive construction allows those who encounter the building to recognize the process of construction as transparent as the production of the wine inside the building.[85]

85 Fairs, Marcus. "Dominus Winery by Herzog & de Meuron." Dezeen, 9 Sept. 2007, www.dezeen.com/2007/09/09/dominus-winery-by-herzog-de-meuron/. Accessed 26 Jan. 2019.

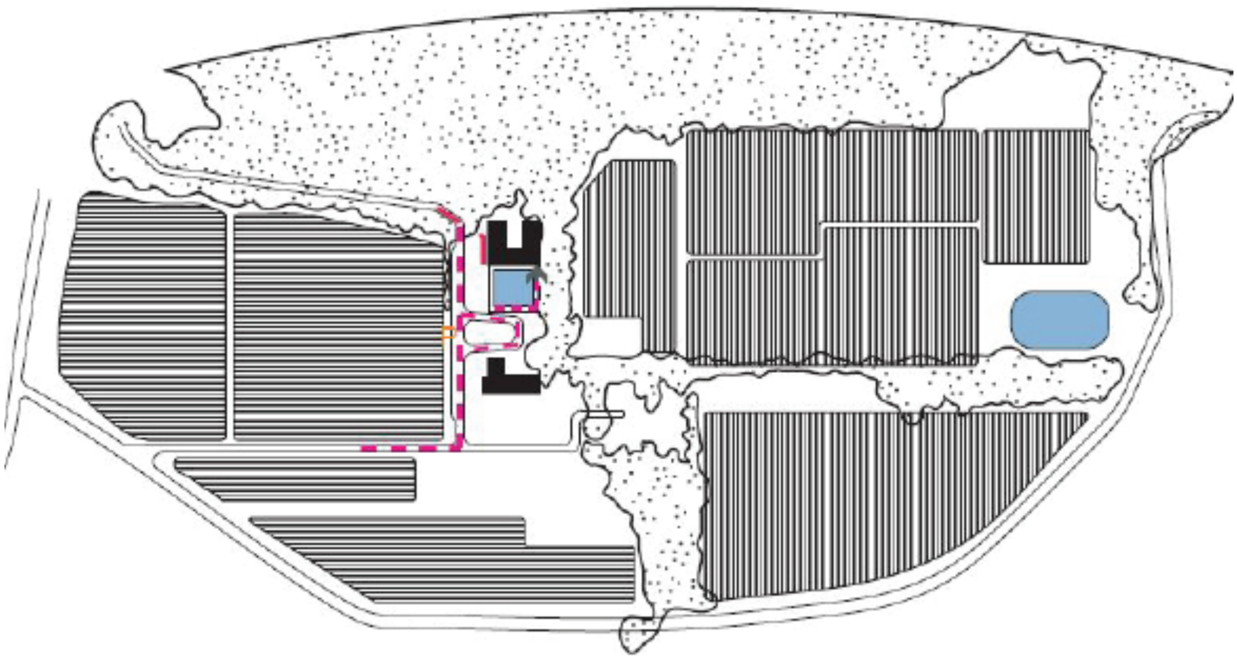


Figure 7.13 *Dornier Winery South Africa site plan and front facade that reflects in the pool of water.*

Connection to Water

The Dornier Winery in South Africa and the Tawse Winery in Niagara both highlight water by placing a pond near the entrance to the building that becomes part of the walk from the parking to the main entrance. Rather than tucking the pond behind the building or near the edge of the fields, the body of water becomes highlighted as part of the production of the wine. In the case of the Dornier Winery, the water along the front of the building creates a reflection of the building and the moutains beyond.

Water is a crucial part of any agricultural practice and many farms or processing plants use a pond for irrigation purposes, providing drinking water to livestock, water for fire emergencies, and general maintenance purposes.[86]

86 Russell, Mia. “Fine Wines and Architecture Make for the Dornier Distinction.” The South African, 4 Dec. 2020, www.thesouthafrican.com/food/drinks/wine/dornier-wine-estate-stellenbosch. Accessed 27 Jan. 2019.

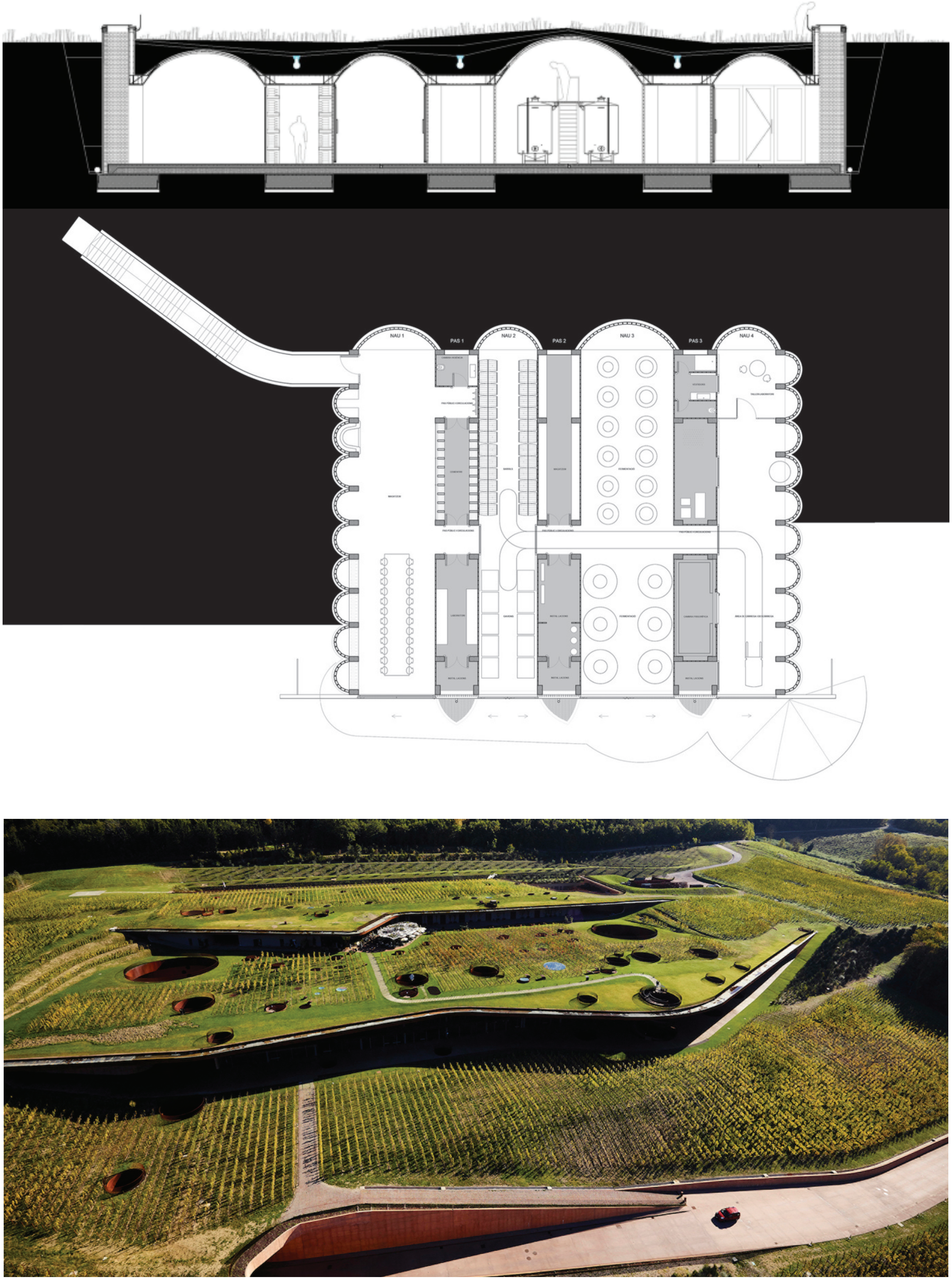


Figure 7.14 *Mont Ras, Spain, floor plan and section above, aerial view of the Antori Winery below.*

Connection to the Earth

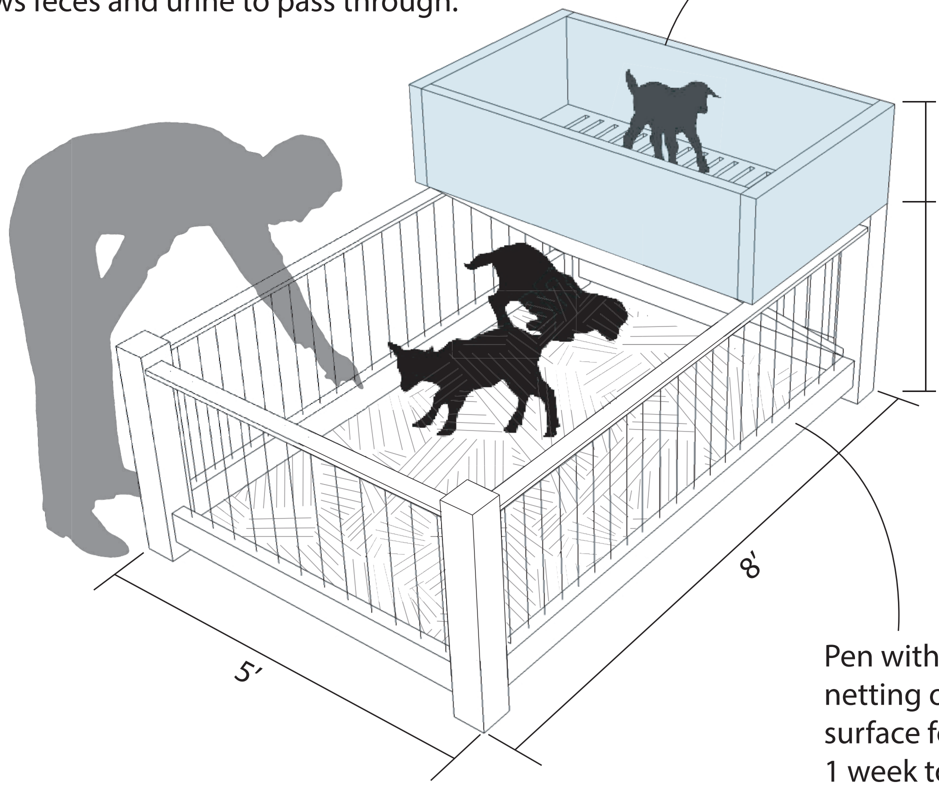
The architects for Mont Ras winery, Jorge Vidal and Víctor Rahola, buried most of the building underground the use the soil's humidity to maintain ideal temperature for the wine and to continue the land for producing on top of the building. The building being enveloped by the earth is part of the architect's wanting to demonstrate the production of wine where the production starts from the earth.[87]

The Antori Winery, located in Chianti, Italy was completed in 2012 is an immense architectural feat, designed by Archea Associati. It is a building that is simultaneously industrial (a winery is after all, a factory with warehousing), a visitor destination complete with a museum and restaurant, an an office housing 120 people. The public face and administration area are at the front, factory functions are set higher at the back, and a sequence of wine vaults dug into the slope links the two. According to the architectural firm, the wine facility is designed to merge as completely with the landscape as possible, only seen as two horizontal slashes in the earth.[88]

87 Schuster, Lara Marisa. "Hyperbolic Vaults: Winery in Mont-Ras." Detail-Online.com, 1 Aug. 2018, www.detail-online.com/article/hyperbolic-vaults-winery-in-mont-ras-32593/. Accessed 27 Jan. 2019.

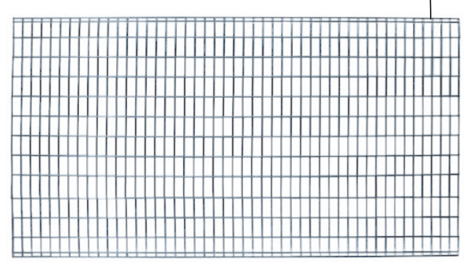
88 Frearson, Amy. "Antinori Winery by Archea Associati." Dezeen, 4 May 2013, www.dezeen.com/2013/05/04/antinori-winery-by-archea-associati/. Accessed 28 Jan. 2019.

A mesh container provides airflow through and the perforated bottom allows feces and urine to pass through.



Two kids is the most common litter size for dairy breeds in Ontario. Kids of the same litter should be kept together for the first 48 hours which limits the number of kids in the raised containers to no more than 4 kids.

Based on the lower pen's dimensions, kids can be housed in groups of 10 kids of similar age and weight to facilitate management. Groups should be as homogeneous as possible to avoid competition at feeding, and move groups based on weight as often as possible to keep the homogeneity.



The openings in the wire mesh must be small enough to not allow kids to pass head or legs through and cause injuries. Minimum 8 guage steel.

Figure 7.15 *Proposed design of kid pen that houses newborns and week old kids.*

Goat Kid Pen Design

Current recommendations and scientific knowledge on dairy goat kid rearing practices for Ontario dairy farms is very limited. Dairy goat kid rearing is the foundation of future herd productivity, yet little is known on best management practices to maximize kid performance. I myself understand first hand the frustration with the lack of tested and proven best practices in raising kid goats. In Ontario, kid mortality on dairy goat farms has been estimated to be 20% from birth to weaning.[89] With the mortality rate of kid goats being much higher than the average dairy calf mortality, OMAFRA has funded multiple research studies that deal with how to manage kid mortality from best management during the first 48 hours, performing autopsies on deadstock to determine cause of death (both studies coordinated by Cathy Bauman) and a recent study looking at the nutritional value of colostrum used by farmers to raise kids.[90]

While raising calves is universal across dairy farms in Ontario, there are so many different ways that goat kids are raised in Ontario farms and is determined by the priorities of the farmer: if the goal is to eradicate diseases such as CAE, which are passed down to infant through mother's milk, removing the kid from it's mother and raising in a nursery with other kids is one way; another is leaving the kid with it's mother for the first few hours so the kid will drink the natural colostrum offered by the mother, and only separate once the kid is independent and showing weight gain.[91] Both come with challenges, especially transfering the kid from mom's milk to a powdered replacer, and then from the replacer to being weaned off as I have experienced myself. Both are stressful times and their environment must minimize stress.

Due to a kid's rather liquid diet, their feces during the first few weeks can be of a more watery consistency and they may urinate more frequently. To limit the growth and spread of parasites such as coccidiosis which causes diarrhea, good husbandry practices are the best known preventative measures. Regular removal of manure and wasted feed, elevating feed and water bowls to limit fecal matter contamination, reducing risk of leaking water bowls, sufficient sunlight enters the space, and adequate ventilation to flow through the pens to minimize humidity and prevent odours and gases such as ammonia.[92] Ontario farms especially, have to be cognizant of the colder temperatures in the winter. Providing heat in the winter is crucial, especially during the first 48 hours.

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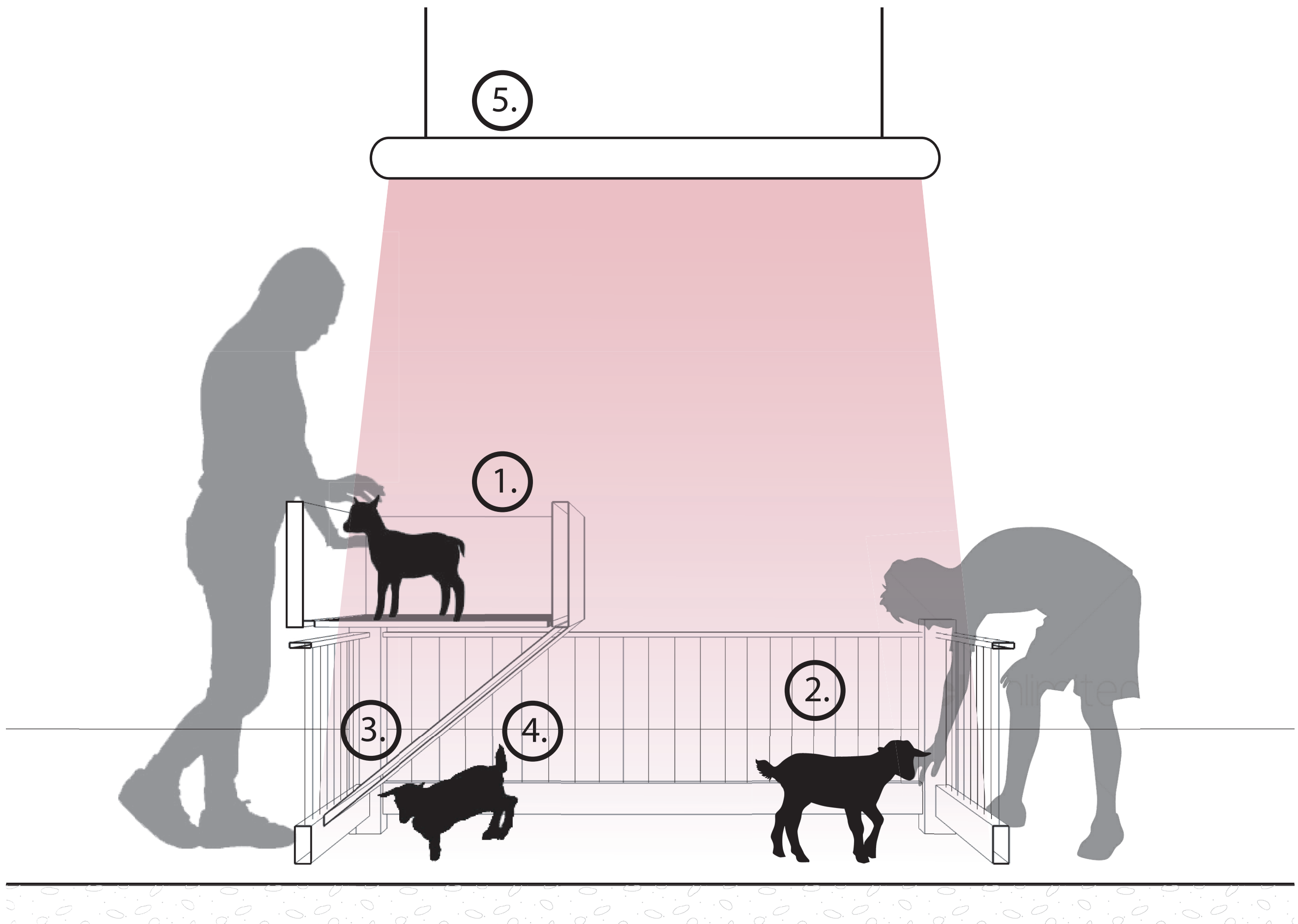
89 Rätsep, Emily Ann. Kid Mortality on Ontario Goat Farms. Sept. 2020, atrium.lib.uoguelph.ca/xmlui/handle/10214/21199. Accessed 15 Dec. 2020.

90 Kim, Julia, et al. "Investigating Dairy Goat Kid Mortality and Associated Risk Factors." University of Guelph, 19 Mar. 2019.

91 Bélanger-Naud, S., and E. Vasseur. "Graduate Student Literature Review: Current Recommendations and Scientific Knowledge on Dairy Goat Kid Rearing Practices in Intensive Production Systems in Canada, the United States, and France." Journal of Dairy Science, vol. 104, no. 6, June 2021, pp. 7323–7333, 10.3168/jds.2020-18859. Accessed 27 January 2019.

92 Luginbuhl, JM, and Kevin Anderson. "Coccidiosis, the Most Common Cause of Diarrhea in Young Goats." Animal Science Facts, 29 Sept. 2015. NC State Extension, content.ces.ncsu.edu/coccidiosis-the-most-common-cause-of-diarrhea-in-young-goats. Accessed 27 Jan. 2021.



1. Kids within 48 hours are most critical to watch for early ailments. Raising them makes it easier to access and view them, they can be closer to heat sources and having a perforated box eliminates liquid manure as it happens.

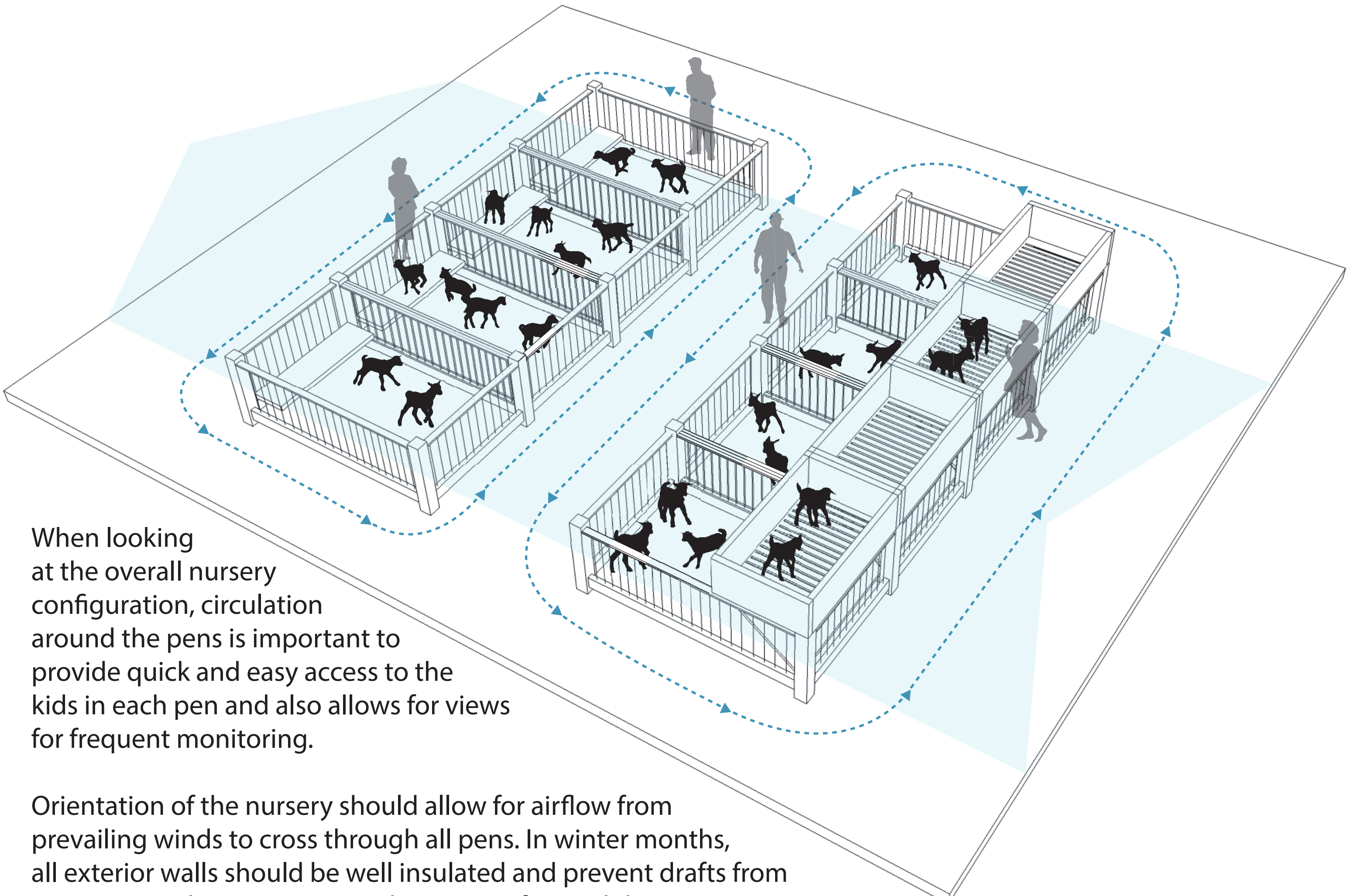
2. Keeping the walls of the pens around 3′ tall allow easy access to grab kids and clean out feed and water systems within the pen. Keeping a 3″ gap around the bottom perimeter of the pen allows air to pass along the bedding pack to minimize humidity and parasite growth.

3. A smooth and solid tray underneath the kid tubs collects manure and keeps it out of the pen below. The tray can be removed and easily cleaned.

4. Goat kids can lay together in a large heap especially when cold. Unfortunately, some kids can be suffocated if at the bottom of the pile. Creating an area where a platform sits above forces the kids to crawl into the warm area and limits their ability to lay on top of another.

5. Radiant heaters placed above pens can provide additional heat during cold winter months and can aid in maintaing a dry environment.

Figure 7.16 *Strategies behind the proposed kid pen design.*



When looking
at the overall nursery
configuration, circulation
around the pens is important to
provide quick and easy access to the
kids in each pen and also allows for views
for frequent monitoring.

Orientation of the nursery should allow for airflow from
prevailing winds to cross through all pens. In winter months,
all exterior walls should be well insulated and prevent drafts from
entering. It is best to separate the nursery from adult goat pens to minimize
the spread of disease.

Figure 7.17 *A look at how the pens would be laid out in a nursery setting.*