Dairy Teaching and Research Center
Feasibility Study

For

Michigan State University

Dairy Farm Address:
4075 N. College Rd
Lansing, MI 48910

November 9, 2022

Prepared by:

CWA
Curry-Wille & Associates
Consulting Engineers, P.C.
Ames, Iowa
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[---Engineer's Seal Provided On Hard Copies---]

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Part 1.  **Project Background and Program Justifications**

**Introduction**

Michigan State University (MSU) is a major agricultural U.S. land grant university located in East Lansing, Michigan and provides important dairy teaching, research, and outreach activities to the one of the state’s most important agricultural industries. Michigan’s instate commercial dairies are very important to not only the state but also the country by ranking 6th in the U.S. for total milk produced in 2020. MSU’s College of Agriculture and Natural Resources, College of Veterinary Medicine, MSU AgBioResearch, and MSU Extension has made the university a world leader in dairy teaching, research, and production expertise. The Michigan dairy industry is also strong within the state and:

- ranks No. 1 in farm receipts among state agricultural commodities,
- generates $24 billion annually,
- supports 111,000+ jobs,
- accounts for nearly 5% of the state’s GDP,
- has grown by 109% in milk output over the last 20 years

Over the years, consumers have developed increasing expectations for dairy farms to provide a very high level of environmental sustainability, health and safety of dairy products, and animal welfare for the cattle throughout their life stages. In order to continue to meet those expectations, MSU needs modern state of the art facilities that will further enhance outreach, teaching and research programs benefiting students, stakeholders and ultimately the state of Michigan.

**Scope of Study**

The scope of this study was to provide professional services and conduct a feasibility study to guide the pre-design planning for a new Dairy Teaching and Research Center situated on South Campus. Areas of focus included the existing dairy enterprise, specifically the need for increasing herd capacity for research, teaching, and outreach activities and updating old, outdated facilities built in the 1960’s. The information collected and presented in this study was established in close collaboration with representatives from MSU’s College of Agriculture and Natural Resources, College of Veterinary Medicine, Institutional Space Planning and Management, and Infrastructure Planning and Facilities.

The design team conducted numerous meetings and workshops with key university stakeholders, such as university and college administrative leadership, department chairs, farm management, and faculty representatives. The design team also performed existing facility evaluations and toured a private commercial dairy with stakeholders to discuss various features and serve as a benchmark facility for additional discussions.

**Project Background**

The Michigan State University Dairy Cattle Teaching and Research Center is situated on South Campus, near College and Forest Roads, with approximately 40 acres of existing facilities and infrastructure used to house and support the dairy enterprise proper. The dairy herd is maintained for teaching, research, and outreach activities. The facility is utilized by both the College of Veterinary Medicine and College of Agriculture and Natural Resources for hands on teaching and student coursework in dairy related disciplines. Research is conducted in the areas of nutrition, mammary and reproductive physiology, animal breeding and selection, animal health, and dairy management. The facility also hosts tours for elementary students and extension programs in dairy management. In addition to the facility on south campus, Michigan State University’s Kellogg Biological Station (KBS) operates a pasture dairy center in Hickory Corners, approximately 64 miles from south campus. The KBS facility currently raises and develops heifers for the herd on south campus.
General Dairy Facility Activities
Current uses of the Dairy Cattle Teaching and Research Center are to facilitate research, teaching, and outreach activities that: 1.) demonstrate novel approaches to improve dairy sustainability, 2.) address impacts of climate change on commercial milk production, and 3.) to train students/professionals/stakeholders in the dairy industry. Specific research, teaching, and outreach activities are discussed below:

Research Focused Activities
Research activities focus on nutrition, health & immunity, mammary & reproductive physiology, animal breeding & selection, and dairy management. As an example, a high percentage of the current research performed at this facility is nutrient based and performed on transition cows.

The first few weeks of the start of lactation is commonly called the “transition period” and is considered one of the most challenging and important periods of a dairy cow’s production cycle. This transition period accounts for roughly half of all mature cow diseases on a dairy farm and sets the stage for future lactation and reproductive success. As a result, there is a huge amount of interest in conducting research on nutritional, pharmaceutical, and management strategies to improve cow health and productivity during this short transitional time.

Teaching Focused Activities
The dairy farm provides hands on teaching and learning experiences for students in both Animal Science and Veterinary Medicine programs. This is becoming an important learning activity as more students have an urban background. Veterinary Medicine classes focus more on cow health while Animal Science focuses more on management and dairy production. Teaching activities occur in the livestock areas as well as in a classroom setting. Additionally, the dairy employs students each semester to help care for the animals and provide opportunities to learn about general stockmanship, calf feeding & care, cow care & milking, equipment utilization, and facility upkeep.

Outreach Focused Activities
Outreach activities generally consist of facility tours and extension programs in dairy management. Both self-guided tours and guided tours are set up for the public and K-12 students. Tours consist of walking through the various dairy facilities to learn about cow housing, the milking process, milk storage, cow health, and observing the feed center to learn about different types of feed ingredients used in dairy cow rations. Goals of the tours are to teach participants about dairy production and general production agriculture. Outreach programs typically utilize classroom environments as a place for presentations, seminars, and general informational discussions.

Existing Facility Evaluations
Visual evaluations were conducted of the existing facilities located at the Dairy Cattle Teaching and Research Center (located on South Campus at 4075 N College Road, Lansing, MI 48910) and the Kellogg Biological Station (10461 N. 40th St., Hickory Corners, MI 49060). The purpose of the evaluations was to observe the condition and features of the facilities to determine their ability to meet the teaching, research, and outreach activities identified by MSU’s faculty and stakeholders.

Existing Facilities Review (South Campus Dairy Farm)
General Overview of Facilities
The MSU Dairy Cattle Teaching and Research Center was initially constructed in the 1960’s and is comprised of multiple structures consisting of animal housing, milking and support, feed mixing and storage, and spaces for teaching and administration. Many of the existing dairy facilities were built in the 1960’s and represent typical construction and management practices used at that time. These 1960’s structures include most of the
animal housing areas, administration, and parlor areas. Over the years additional structures were added to the site to improve research capacity and efficiency. Some of these newer structures include a hay barn, composting building, anaerobic digestor, feed center, and freestall barn.

Teaching, Administration, Worker Support Areas
This area consisted of office space, classroom, bathrooms, storage, and other support areas constructed in the 1960’s. Overall these spaces were in poor condition and showing their age. Many of the spaces were minimally remodeled and repurposed over the years. Floors, walls, and hardware were extremely worn and in many places missing or broken. Floor settlement and cracking issues were observed within some of these spaces along with lack of fire separation walls and fire protection that meets current building codes. With the spaces being very old and in poor condition, they appeared inadequate to facilitate modern dairy research, teaching, and outreach activities. Limited storage spaces created cluttered rooms with reduced circulation. Quantity of bathrooms and changing areas were inadequate for the number of workers and ADA requirements. A preliminary asbestos review was performed by MSU and asbestos containing material was noted in multiple areas. These general admin and worker support spaces do not appear to have any useful repurpose values.

Livestock Housing Area (34 Cow Barn, 80 Cow Barn)
These two livestock areas were separate barns connected with a covered alley and used to house lactating cows. These spaces including the covered connecting alleys were part of the initial facilities constructed in the 1960’s. Livestock housing consisted of tie stalls with a barn cleaner for manure removal which increases labor and is not representative of freestall housing in current production facilities. The ceilings were painted plywood and were in poor condition due to the humidity and water from wash down activities. The ventilation system appeared inadequate across both barns and more than likely would not meet current animal care guidelines. Cows were all hand fed with feed tubs, requiring a larger labor force. Feed alleys were small making it difficult for even small, wheeled feed carts with scales to maneuver.

Milking Parlor and Milk House
The milking parlor and milk house support areas were initially constructed in the 1960’s and have seen multiple remodels over the years. The milking parlor was a double 7 with a recessed worker pit. The cow holding area appeared small with tight turns for cows to enter the cow deck to be milked. The parlor storage area and mechanical rooms were small and difficult to move around due to the lack of storage space. Two milk tanks were being used to store milk, one directly in front of the other which greatly reduced personnel circulation capability. The parlor’s current configuration does not allow for adequate visitor viewing space and does not meet ADA accessibility (visitors must physically be in the parlor area and stand in a manure covered cattle alley to view milking activities). Due to the age and limited circulation space, this area does not appear to have any useful repurpose value.

Livestock Housing Area (North & South Slatted Barn)
This barn housed dry cows and utilized freestalls with headlocks along the feed lane. The manure system was originally design as a pit system with slats above. Due to difficulties pumping manure out of the pit and transporting to another location, the slats were covered up with rubber mats and manure is manually scraped out of the building. It was noted some of the slats were deteriorating and recently failed. Overall the barn was in poor condition almost to the point of not being safe for current use and does not have any useful value.

Livestock Housing Area (64 Cow Barn)
This tie stall barn was built in the 1980’s. Manure collection consisted of a barn cleaner for manure removal. Manure was conveyed outside into a wagon and manually hauled to either the digestor or composting. Researchers indicated poor ventilation in the barn as well as difficulty cleaning the walls and ceiling due to painted plywood. Overall the barn was in poor condition and does not have any useful value.
Livestock Housing Area (South Freestall Barn)
This barn contained freestall housing used for lactating cows. A small manure pit was originally located on one end of the barn, however the pit is no longer in use with manure being scraped daily and hauled instead of storing here. Geometric structural issues were observed with the installation of knee braces on the trusses, potentially creating unbalanced loading conditions. However the trusses have stood the test of time and did not appear to have shifted from their initial construction. This building does have limited potential for reuse particularly as a quarantine barn or flex dry cow housing.

Hay barn and Calf barn
This structure is a clear span, three-sided barn with open side wall to the east. The west wall has a couple larger sliding doors for access along with adjustable ventilation swing outs. The barn is currently used to house calves in group pens, hay storage, and miscellaneous equipment storage. Two bays located on the northern end of the barn were being used to store smaller bulk commodities and included an area to load bulk and micro ingredients into a TMR wagon. Overall the barn appeared functional and in reasonable condition to be repurposed.

Metabolism Barn
The metabolism barn was built within the last 20 years or so and was designed for special research projects involving nutritional, environmental, and physiological variables affecting dairy cows. This space appeared to be remodeled and modified over the years to suit various research studies performed at the time. Overall, the facility appeared in good condition and could be reused for small special research trials. A small repair/shop was located on the northern portion of the building that could be reused. It was also noted that this building was immediately adjacent to the main electrical transformer and distribution center for the whole dairy (additional discussion can be found in the electrical section).

Feed Center and Storage
Feed center and storage area consisted of a newer hoop building and concrete bunkers for silage storage. The original feed center including multiple upright silos were recently destroyed in 2021 due to a fire. The concrete bunkers were starting to show a little age and were a little small in size but appeared to be functional for the short-term dairy’s feed needs.

South Campus Anerobic Digestor
The digestor was built in 2013 and consists of concrete reception tanks, above ground complete mix digestion tank, and a separate above ground steel digestate storage tank. The digestor’s main focus is to process south farms dairy manure however the digestor also receives food waste from MSU’s dining halls. It was noted by researchers familiar with the management and operation of the digestor, that the current digestor only has enough capacity to receive just the manure generated from a proposed herd size of 700 head. If the digestor plans to continue receiving food waste, then additional upgrades to the digestor would be needed to handle the increase in waste material and to efficiently utilize the proposed increase in gas production.

Existing Facilities Review (Kellogg Biological Station)
Kellogg Biological Station – Pasture Dairy Center
The Kellogg Biological Station’s Pasture Dairy Center (KBS) is home to an automatic milking robot facility with a pasture based lactating cow herd. Additional livestock housing and support barns were located onsite and housed developing heifers prior to entering the lactating herd. The KBS heifer barn was reviewed as part of this study since South Campus heifers are taken here for development and brought back to the South Campus Dairy Farm to be placed into the dairy herd for milk production.

The current heifer housing facility at KBS consists of freestall housing with headlocks located along the feed alley. The barn was originally designed and operated as a flush system for manure removal. Floor slope appeared excessive at approximately 6% (current design standards target 3% slope for flush barns). The current
farm manager indicated hoof and leg issues were common for developing heifers due to the steep flooring. At some point in the distant past, the flushing system was abandoned and is now manually scraped with a skid loader.

Currently the KBS site does not have enough indoor space to house all South Campus heifers and KBS heifers indoors at the same time. This lack of livestock housing will become more problematic at KBS with the increase in herd size at South Campus.

**Ability of Existing Facilities to Meet Research, Teaching, and Outreach Activities**

The condition and capabilities of the current Dairy Cattle Teaching & Research Center do not meet the teaching, research, and outreach needs identified by the stakeholders. In general, the 60-year-old facilities are worn out and do not represent modern dairy facilities, thereby hindering the teaching, research, and outreach capabilities. Issues and concerns also exist with these buildings not meeting current building standards for life safety, ADA, milk sanitation, etc. Example facility and infrastructure shortcomings are listed below:

*Dairy Industry has moved away from tie stalls and now uses freestalls*

Modern commercial dairy operations utilize freestalls instead of tie stalls for cattle housing. Freestalls allow cows more freedom to move around the facility and is perceived to improve animal wellbeing. Less labor is also required to move freestall cows to the parlor for milking compared to tie stalls (do not need to manually release and rehook each cow). In the 1960’s when this facility was constructed, tie stalls were still being used for research purposes. However new technology over the past 30 years or so has allowed researchers greater flexibility in utilizing freestall housing while still being able to collect individual cow data.

*Backlog of research trials due to small herd*

The current 220 head lactating cow herd is not large enough to facilitate the teaching and research needs of MSU’s Dairy Science and Vet Med faculty. MSU’s dairy researchers are experiencing a 2+ year backlog of projects that are already funded but unable to start due to waiting for other university cows to come off research studies. Many potentially valuable studies are not even proposed by faculty because of the excessive delays in project execution. Likewise, when a large proportion of cows in the herd are on research projects (generally around 60% of the current herd), there are very few cows left that are available for teaching purposes. A larger herd would not only increase the number of active research studies occurring at a time but would also improve the integrity of studies by enabling a separate herd that could be used primarily for teaching purposes allowing students valuable hands-on training without disrupting research trials or data.

*Ventilation and manure cleaning issues in existing facility*

The cross-ventilation system is outdated compared to commercial production standards and of poor design not allowing enough air changes for cow comfort and health which can result in cow heat stress. The dairy industry has generally gone away from cross ventilation barns due to difficulties with maintaining air velocity across the newer wider barns. The majority of commercial operations are moving towards natural or tunnel ventilation systems.

*Poor condition and inadequate space of animal and support spaces*

Overall, the 60-year-old facilities were worn out making it difficult to meet MSU’s teaching, research, and outreach needs. Old, worn-out facilities make it difficult to attract and retain new students, faculty, and staff. The inadequacy of the facilities forces instructors and researchers to adapt research trials and teaching activities to the capabilities of the current facilities. Over the years the number of students has increased, and teaching program needs have expanded beyond the capacity of the existing facilities.
Technology Shortcomings
Technology in modern dairy facilities have changed tremendously since the 1960’s when the current dairy structures were built. Modern production and research dairies employ a wide range of technology including imaging, movement sensors, rumen sensors, feed/water intake measurements, and automation technologies for milking, cooling, feeding, manure collection, and bedding. As a result of labor shortages, many dairies are installing robotic milking units to free up available labor for other farm activities. The existing facilities lack the capabilities and infrastructure to utilize these modern technologies to improve data collection, efficiency, and minimize labor.

Manure Handling System – high maintenance and high labor
The manure handling system, specifically the barn cleaners, are high maintenance systems that also require a lot of labor to physically haul manure around the site. Each building has its own barn cleaner that empties into a wagon that must be hauled to either the composting facility or directly to the digester. Some barns also have manure tanks that periodically need to be pumped and hauled to alternate locations. After discussions with many individuals in the agricultural industry, it seems there is difficulty finding and retaining employees willing to perform agricultural type of work and is expected to only get worse in the future. Therefore, the industry is starting to move towards less workers and more automation. A new updated manure system is one area where a huge amount of labor could be saved by moving all manure to a centralized collection and processing building.

Solid Organic Bedding Issues with Bacteria
MSU’s current bedding system utilizes organic material which has been proven to have higher bacterial counts compared to sand. Sand is considered the “gold standard” in the dairy industry for cow comfort and health and is typically found in modern commercial dairies. Sand is an inorganic material that doesn’t promote pathogen growth and is generally economical and improves cleanliness of cows. It also has advantages for leg and hoof health. Sand bedded systems require specialized manure handling equipment and would not work with the existing facilities or the present manure handling system.

Labor Shortage Concerns- want to minimize labor workforce.
Current facilities require a lot of labor for day-to-day operation. Examples include hand feeding cows with manually moved feed carts, hand moving bedding into stalls, hand scrapping manure, and manure is manually hauled to the digester.

Programmatic Needs for New Dairy
General Needs
In order to fulfill MSU’s dairy teaching, research, and outreach missions for the state and country, MSU generally needs the following: 1) a modern dairy facility with equipment and infrastructure that aligns with today’s dairy standards, 2) increased herd size to better facilitate teaching and research activities, 3) safe modern hands-on teaching facilities for student learning, 4) a facility that minimizes labor needs and promotes efficiency, 5) meets current animal care and building code standards, 6) and a welcoming environment for hosting dairy outreach activities. Additional needs specific to research, teaching, and outreach are discussed below:

Research Needs
Herd Size
Research in the fields of dairy science and veterinary medicine has evolved over the years requiring more cows per treatment to be accepted for peer reviewed publications. For example, research studies 20 years ago required approximately 7-8 early-lactation cows per treatment to be accepted for publication. Now, with the understanding of huge cow-to-cow variance during the transition phase of the production cycle, at least twice as many cows are required for a study to be considered acceptable for most publication reviewers. This directly
impacts the number of animals needed for research trials. The limited cow capacity of the existing dairy and the need for larger research studies involving more cows dramatically slows the rate at which studies can be completed as multiple smaller trials are needed over a longer period of time. As a result, MSU’s dairy faculty have a 2 plus year backlog on already funded research projects. Many potentially valuable studies are not even proposed due to the excessive delays in project execution. Likewise, when a large proportion of the existing herd is on research projects, few cows are available for teaching and outreach activities. Therefore, a separate group of lactating cows are needed to fulfill the teaching programs while not disrupting cows on studies. The combined needs for efficient research through-put and teaching needs would indicate a need for a new herd capacity of around 700 mature cows as well as the corresponding 500 developing heifers.

Modern Facilities
Researchers need modern research facilities that mimic commercial dairies but allow flexibility for various research trials and data collection. Some of the main areas of research focus on nutrition, mammary and reproductive physiology, animal breeding and selection, and dairy management. Therefore, a new facility will need specialized areas designed for breeding & artificial insemination, research feed tubs & waterers to monitor individual cow intakes, and safe facilities for sample collection consisting of self-locking headlocks, stocks, rails, and surgery suites. Looking into the future regarding research associated with climate change and greenhouse gases, researchers also expressed interest in being able to measure gases exhaled from cows, gases released from barns, gases generated during manure handling and storage, and gas fluxes from row crops. The driving factor for gas measurements stems from climate change research with emissions from dairy farms being identified as a contributor to greenhouse gases. Transdisciplinary research between animal science, engineering, plant science, ecology, economics is needed to better understand how these nutrients and gases move through the food system, through crops, and effects on the environment and atmosphere. New facilities also need to be designed to promote the health and wellbeing of not only the animals but also the caretakers. New facilities need to be equipped with laboratories and equipment for rapid diagnosis allowing research not only for animal care best practices but also for rapid detection and treatment strategies. Researchers also mentioned biomonitoring infrastructure as a key component for new facilities giving the ability to monitor animal activity, temperature, estrus behavior, feeding and rumination behavior, and location. This type of data allows for new research in animal behavior and physiology allowing dairy producers to make management decisions to optimize animal welfare, nutrition, management, and ultimately increase milk production and food safety.

Teaching Needs
Herd Size
A larger cow herd is needed to be able to provide enough animals for teaching students while other cows are on research studies. With the current herd size, limited teaching activities can occur during larger studies that require more cows. There is also a biosecurity risk and potential variables added when cows are dually used for both purposes. Therefore, a larger herd size is needed with normally separate cows that can be used primarily for teaching activities and would not disrupt research activities.

Facilities
The dairy industry continuously needs a skilled workforce of herd managers, nutritionists, and veterinarians available to operate and care for dairy livestock not only within the state of Michigan, but also across the United States. MSU’s coursework in Dairy Science and Vet Med puts MSU in a position to teach and train students needed to fulfill the next generation of skilled professionals required for the state’s dairy industry.

MSU needs safe and welcoming environments for human-livestock interactions. When the current dairy facilities were constructed in the 1960’s, many of the students taking dairy related courses or performing research had grown up around cattle and had at least a limited degree of comfort around them. Over the years more and more students have entered the dairy program with little to no prior exposure to livestock. This can create potentially unsafe situations when students interact with large 1,600 lb animals especially in outdated
facilities not designed with safe livestock handling facilities and equipment. Such negative unsafe situations could also hinder the program’s ability to attract and retain students and may deter some from considering the dairy industry as a viable career. Therefore, MSU needs facilities with dedicated space to allow undergraduate students, DVM students, and graduate research students to learn modern, safe, and humane animal handling. Students expressing interest in dairy management need opportunities and experience for safe hands-on training in milking cows, feeding calves, and providing basic care for sick animals. To address the safety aspect, new dairy facilities need more modern self-locking headlocks, stocks, rails, surgery suites, and multiple modern accessible classrooms and supporting facilities. With new facilities, students trained will be better prepared and equipped to step onto modern farms and contribute to the important dairy industry for the state of Michigan.

**Outreach Needs**

*Herd Size*

Herd size and availability for outreach needs are similar to the teaching herd needs. Mainly there is a need for more animals available for outreach and demonstrations that will not negatively affect active research trials. The cows used for outreach and teaching can be the same animals.

*Facilities*

Outreach facilities need a safe and welcoming environment for tour participants to learn about modern dairy production. A small visitors center area is needed to allow larger tour groups of students and adults to congregate and view dairy related displays and other educational content while waiting for tours. A safe and biosecure viewing space to see the inner workings of the parlor and milking process is also needed for not only learning aspects but also to expose potential future students to the dairy industry and associated careers.

**Part 2. New Dairy Facility Programming Elements**

**Herd Size and Justification**

MSU has numerous research teams interested in performing research during a cows first few weeks of lactation (commonly called the “transition period”). This period is the most challenging of a cow’s production cycle accounting for roughly half of all mature animal diseases on a dairy farm. This important time period sets the stage for lactation and reproductive success. As a result, there is a huge amount of interest in conducting research on nutritional, pharmaceutical, and management strategies to improve animal health and productivity during this narrow window of time. Furthermore, these challenges are most apparent in multiparous cows – those that have just given birth to a 2nd, 3rd, or 4th calf (etc.).

MSU has approximately 5+ research groups focused on transitional cows for the reasons stated above. If each of these groups were to carry out 2 studies per year with 40 cows per study, that would add up to 400 transition cows needed annually. Most of these studies would exclude cows that just had their first calf, for the reasons above. Those cows typically make up about 30% of the herd. Furthermore, roughly 5% of transition cows have health problems and must be excluded from research. This means 65% - of a herd is available for transitional studies in a given 13-month window (the average calving interval).

\[
\frac{400 \text{ cows}}{.65} = 615 \text{ cows}
\]

\[
615 \times \frac{13}{12} \text{ (not on a 12-month calving interval)} = 666 \text{ mature cows needed for transition cow research demand}
\]

Additional considerations regarding herd size includes economies of scale. Harvested milk is sold at commodity prices and this revenue accounts for most of the funds available to pay for feed, labor, and maintenance at a dairy. Constructing a new dairy facility for only 250 cows (similar to current herd size) would be difficult to cash flow and could create immediate and future funding difficulties. Therefore a 600 to 700-cow
unit, although still small by industry standards for a new dairy, will substantially improve cash flow capabilities and allow research and teaching goals to be met.

Prior to this study, an initial herd size request was for 700 head, however after discussions with researchers on research needs, cow grouping, and housing arrangements, it was determined a slightly smaller mature cow herd could be utilized while still maintaining research, teaching, and outreach goals. Therefore, a mature cow herd (lactating + dry) of 614 cows was deemed acceptable by stakeholders. The following table presents herd numbers for each animal housing area, operating capacity, and stall capacity. Note: stall capacity is higher than operating capacity as not every stall will be filled with a cow. For example, cows will be taken out of the conventional freestall barns and placed into tie stalls for specific research studies.

### Dairy Animal Allocation Table

<table>
<thead>
<tr>
<th></th>
<th>Default Operating Capacity</th>
<th>Stall/Housing Capacity</th>
<th>Research Feed</th>
<th>Penning Configuration</th>
<th>Housing Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Lactating Cow Capacity</td>
<td>504</td>
<td>564</td>
<td>n/a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional Freestall-Small Group</td>
<td>96</td>
<td>96</td>
<td>8 pens @ 12 hd/pen</td>
<td>Free stalls</td>
<td></td>
</tr>
<tr>
<td>Conventional Freestall-Large Group</td>
<td>192</td>
<td>192</td>
<td>2 pens @ 96 hd/pen</td>
<td>Free stalls</td>
<td></td>
</tr>
<tr>
<td>Robotic Milking Barn</td>
<td>120</td>
<td>120</td>
<td>2 pens @ 60 hd/pen</td>
<td>Free stalls</td>
<td></td>
</tr>
<tr>
<td>Feed Intake Research Area</td>
<td>96</td>
<td>96</td>
<td>8 pens @ 12 hd/pen</td>
<td>Freestalls</td>
<td></td>
</tr>
<tr>
<td>Tie Stalls</td>
<td>-</td>
<td>60</td>
<td></td>
<td>Tie stalls</td>
<td></td>
</tr>
<tr>
<td>Special Needs ¹</td>
<td>11</td>
<td>12</td>
<td></td>
<td>Maternity/Special needs bldg. Bedded Pack</td>
<td></td>
</tr>
<tr>
<td>Maternity ²</td>
<td>-</td>
<td>4</td>
<td>4 stalls @ 12'x14'</td>
<td>Maternity/Special needs bldg. (Bedded pack)</td>
<td></td>
</tr>
<tr>
<td>Maternity ²</td>
<td>-</td>
<td>6</td>
<td>2 pens @ 3 hd/pen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Odds and Ends&quot; / Quarantine Pen ²</td>
<td>20+</td>
<td>20+</td>
<td>2 pens</td>
<td>Utilize Existing Heifer Barn</td>
<td></td>
</tr>
<tr>
<td>Dry Cows ²</td>
<td>110</td>
<td>112</td>
<td>2 pens @ 36 hd/pen</td>
<td>Freestalls</td>
<td></td>
</tr>
</tbody>
</table>

### Dairy Animal Allocation Table

| Replacement Stock            | 78                        | 87                      | individual   | All calves kept for 2 mo |
| Calves (0 to 2 months)       | 27                        | 30                      | 4 pens @ 8hd/pen | Only heifer replacement calves |
| Calves (2 to thru 4 months)  | 258                       | 289                     |              | Hauler Housing offsite (at KBS) |

1 – Based on 35% cull rate. All males and unneeded heifers sold by 2 mo

2 – Information provided to design team by Users.

3 – Based on 2% of total lactating cows

4 – Number of head in each unit whenever no studies are occurring

### Space Planning Needs

The space needs presented in this study reflect multiple meetings and discussions with MSU stakeholders to learn what area was needed for research, teaching, and outreach activities. These needs were documented, summarized, and analyzed taking advantage of areas where dual uses of spaces could be utilized to reduce total square footage. The major building / areas including sub areas are shown in the table below:
Site

The site of the new dairy facility should be located on South Campus due to close physical proximity to main campus buildings for research and teaching use as well as serving as a visitor and outreach center for the public. The new dairy will utilize existing building infrastructure such as the anaerobic digester and composting facility to treat and store manure from the expanded operation. Additional infrastructure to reutilize includes the hay storage barn, feed processing areas, metabolism/shop area, and south heifer barn.

Urban Development

The South Campus area generally consists of a mix of agricultural land and livestock production facilities surrounded by urban development. The western side of the South Campus area has seen the most urban
development recently and is located approximately 2,700 ft from the current dairy. It is anticipated development will continue on the western side of South Campus into the near future. As with any agricultural facility surrounded by an urban environment, odors and manure concerns with a new dairy should be investigated and minimized when possible. Typical odor mitigation techniques include landscape filters, controlled digestion, impermeable covers on manure storage structures, composting, and liquid manure injection/incorporation into the soil.

**Potential New Dairy Locations**

Three potential locations for the new dairy were conceptually investigated 1) north of the existing dairy, 2) west of the existing dairy, and 3) south of the existing dairy (see Appendix A, page 29, for map of potential locations). All three locations are close to the existing dairy to capitalize on existing infrastructure utilization such as the anaerobic digestor, hay & machine storage barn, composting facility, feed processing area, metabolism/shop, and south heifer barn. After considerable discussions with stakeholders and preliminary reviews of each location, it was determined south of the existing dairy was the best option to proceed forward with a conceptual layout. Deciding criteria consisted of site grading, drainage, vehicular safety, public visual perspectives, and the ability to utilize existing infrastructure.

**Road Access**

Road access to the proposed facility is provided off College Road on the east side of the dairy for visitors and farm workers. Farm equipment and deliveries will utilize the less traveled drive of Bennett Road in order to prevent large heavy machinery from driving down the busy College Road which is a main north south corridor. Farm tractor traffic, especially during feeding, will occur multiple times throughout the day, therefore easy driveway access from the feed center to the new cattle barns should be a high priority from an efficiency standpoint as well as safety.

**Buildings and Configurations**

The agricultural structures to consist of multiple buildings connected by covered walkways and will provide housing and milking facilities for a maximum lactating cow herd of 504 lactating dairy cows (120 hd robotic milking + 384 hd conventional milking freestalls). The site will include a conventional milking parlor, robotic milking units, milking support areas, cattle holding area, lactating cow housing, dry cow housing, special needs & maternity, calf barn, and cattle working areas. The facilities will also feature an automated manure scraping system, feeding by tractor wagon & feed carts, and individual cow intake research tubs (96 total). The following facilities were identified as critical components of the new dairy facility:

*Conventional Freestall – Large Group*

Conventional freestall -large group area to include housing for a maximum of 192 cows separated into 2 pens of 96 hd/pen. Drover lanes will be provided along the outer walls of the area to facilitate cow movement. Feed to be delivered via tractor and feed wagon. Manure will either be scraped with an automatic scraper, removed with front end loader/skid steer, or removed by hand with shovel and/or wash water. The automated scraping system will be located in the cattle alleys and will convey manure to a flush flume system. Cross overs, drover lanes, and other areas will either be manually scraped with front end loader/ skid steer or by hand. The manure system will have the ability to handle sand bedding.

*Conventional Freestall – Small Group*

Conventional freestall – small group area will consist of similar facilities as the large group freestall except for cow group size. Groupings of 12 head per pen across 8 pens (96 head total) will allow researchers to perform studies on smaller groups of cows. It is anticipated this area would be close in proximity to the large group.
Feed Intake Research Area
Area to consist of 96 load cell monitored feed mangers for individual feed intake monitoring. Pen grouping to be 8 pens with 12 head per pen for a total of 96 head. Drover lanes will be provided along outer walls to facilitate cow movement to and from the parlor. Feed to be delivered via tractor and feed wagon. Manure will either be scraped with an automatic scraper, removed with front end loader/skid steer, or removed by hand with shovel and/or wash water. The automated scraping system will be located in the cattle alleys and will convey manure to a flush flume system. Cross overs, drover lanes, and other areas will either be manually scraped with front end loader/ skid steer or by hand. The manure system will have the ability to handle sand bedding.

Robotic Milking Barn
The robotic milking freestall area will include freestall housing for a maximum of 120 lactating cows and space for 2 automated robotic milking units. Additional space will be provided for milking support, drovers lanes, and cow catching/working areas. Milk will be pumped from each robotic unit to a central milk tank shared with the conventional milking parlor. Feed to be delivered via tractor and feed wagon. Manure will either be scraped with an automatic scraper, removed with front end loader/skid steer, or removed by hand with shovel and/or wash water. The automated scraping system will be located in the cattle alleys and will convey manure to a flush flume system. Cross overs, drover lanes, and other areas will either be manually scraped with front end loader/ skid steer or by hand. The manure system will have the ability to handle sand bedding.

Tie Stall Area
Space will be provided for sixty tie stalls allowing researchers capacity for closer intensive research studies. Feed lanes will be provided along the outside walls and allow access for feed research carts or motorized research feed delivery. Each tie stall to include individual water intake meters. Cable trays will be provided above the cows for instrumentation. The manure collection system will be compatible for total collection when necessary. Vacuum lines will be provided when protocols dictate in-stall milking

Dry Cows
Dry cows to be housed in sand bedded freestalls (112 hd capacity) with drover alleys located on each side of the barn for cow movement. A central feed lane will be located down the middle of the building to allow for feed to be delivered via tractor and feed wagon. An automated manure scraping system will be used to move manure to a flush flume system. Manure located in cross overs, drover lanes, and other areas will either be manually scraped with front end loader/ skid steer or by hand. Cow groupings to consist of 2 pens containing 20 head each and 2 pens containing 36 head each.

Maternity
The maternity area is designed to utilize just in time calving management style. Therefore 4 bedded pack box stalls are provided for calving cows. Two additional flex pens (2 pens at 3 hd/pen) are provided for close up monitoring of cows prior to calving. A drive through central feed alley is located down the middle of the area for feeding. Additional observation area and work around is provided within the maternity space to facilitate teaching and research needs.

Calf Barn
Calf housing will provide housing space for 112 head of calves separated by age group. Calves 0 to 2 months will be housed in individual calf pens (80 pens total) and calves 2 to 4 months will be housed in group pens of 8 hd per pen (4 pens total). The facility will feature the ability to prepare and feed milk and solid feed matter. The manure system will be manual scraping by hand or with front end loader. Calves would be utilized as replacement stock to the herd and housed in a separate building from the lactating herd.
**Treatment and Vet Med**

Treatment (a.k.a. special needs) and Vet Med will consist of 2 bedded pack pens (up to 6 head each), 2 standing surgery rooms, surgery prep/recovery, lab area, office & storage room, and associated livestock sorting and gating. Manure will be removed by hand or front-end loader. A drive through feed lane is provided on one end of the building to facilitate feed delivery with a tractor and TMR wagon. Drover lanes are located along the outside walls of the building for cow movement.

**Milking Parlor and Support**

A fully equipped and controlled double 12 parallel (24 stalls total) milking center with energy recovery & efficiency, raised cow decks, rapid exit area, holding pen, milk room, and equipment/utility room. Milk will be pumped from the parlor to a central milk house/tank shared with the robotic milking units. Holding pen will include crowd gate with double exit lane.

**Administration, Visitors Center, Worker Support**

The administration, visitors center, and worker support spaces will be housed within one building but separated into different biosecurity levels and occupancy classification code levels. The visitors center and classroom area (both considered education occupancy code) will be the least biosecure and will have a separate entrance into the building. The worker support areas consisting of locker rooms, laundry, lab, walk in freezer, and pharmacy (all business occupancy code), will be the most biosecure and will have its own building entrance. Biosecurity for the administration areas consisting of offices, breakrooms, records, and conference room will be somewhere in between the visitors and worker areas allowing for cross over between the spaces if needed. The visitors center to have access to a glassed viewing area of the milking parlor activities. All remaining spaces will be considered agricultural occupancy.

**Sand / Manure Separation Area**

The sand separation building is anticipated to contain two mechanical sand separators, concrete reception pits, multiple pumps, and sand storage. A flush flume system is anticipated to convey sand laden manure from each of the livestock buildings to the separation building. After sand separation, the manure will be pumped to the existing anaerobic digestor located on the Northwest side of the existing dairy.

**Feed Storage and Processing**

These facilities would provide storage of silage, hay, and other feedstuffs needed to meet the feed needs for the expanded herd. MSU anticipates only having enough land available to meet the expanded herd’s silage and forage needs. Therefore, additional grain and other feed stock would need to be sourced throughout the year from local farmers as needed to supplement MSU produced forage for the expanded dairy. The silage storage to consist of covered above ground bunkers with concrete walls. The storage systems will be modern facilities to minimize losses as well as allow research on optimal methods of preserving forage quality, handling silage leachate/runoff and reducing potential environmental concerns. High moisture corn will be stored in bags along with some special research silage. Bulk commodity storage and concentrate storage will be re-arranged for the increase in feed needs.

New feed bunkers will be constructed in the location of the old dairy structures to be demolished (see Building Demolition Plan on page 30). One years’ worth of silage storage is needed as all silage needed to support the expanded herd will be harvested in early fall from fields located on South Campus. Larger dive over bunkers will be provided with space for special silage bag storage for smaller research rations. The existing feed processing areas will be repurposed and reconfigured to improve efficiency. These areas include:

- North end of existing hay barn
  - Relocate ingredient hopper bins to hoop building
  - Install concrete blocks to create additional covered storage bunkers for bulk commodities
  - Repurpose portions for additional bedding storage
• Hoop Building-
  o Install ingredient bin augers emptying into building.
  o Reconfigure block bulk commodity bunkers to allow all ingredient loading of TMR wagon inside structure.
• Remaining portions of hay barn-
  o To be used for hay storage

**Maintenance Shop**
A new maintenance shop is needed to perform routine maintenance and repairs on equipment. The existing shop attached to the metabolism building is too small to fit the current feeding tractor and TMR wagon thus requiring maintenance activities to be performed outside in the elements. Therefore, new heated shop space is needed with adequate capacity to pull in a tractor and feed wagon and still have room for safe worker circulation, access to tools, welder, and torch as needed.

**Heifer Development**
Three options exist for developing heifers: 1) continue taking heifers to KBS, 2) send heifers offsite to a private heifer development contractor, or 3) construct additional heifer housing at South Campus Dairy. Due to the limited land available on South Campus for manure application and feed source, the feasibility of housing heifers at that location is not very practical. Therefore options 1 and 2 are appear more practical from a nutrient and feed standpoint. If heifers are taken to KBS, then additional housing and support infrastructure would be needed to accommodate the increase in herd size. A heifer facility consisting of freestall housing for 289 head (5 to 23 months of age) is estimated to cost $4.1 million. Depending on the final site location, additional infrastructure might need to be improved for water and manure capacity. A new heifer facility at KBS would only be used to house the South Campus heifers (KBS heifers would continue to use existing facilities).

**Basis of Design**

**Building Construction Type**
Building structures should be representative of typical modern dairy facilities. Buildings are anticipated to be pre-engineered steel or wood post frame building designed for loads as identified by current federal, state and local codes. Eave height will be evaluated during the design phase for each building to facilitate ventilation or accommodate special ceiling heights. Main frame locations to have intermediate posts set in such a manner to not interfere with building layout and function. Roofs and sidewalls where applicable to be enclosed with 26 GA metal panels with openings framed for curtains, fans, and louvers. In livestock areas, sidewalls to be curtain sided allowing for summer ventilation. All building primary and secondary framing to be designed for animal environments to eliminate or minimize corrosion and moisture build up.

**Ventilation System**
The livestock areas to be naturally ventilated with curtain sidewalls. Stir fans with water drip cooling should be located throughout the barn to assist with air movement over the cows during warm calm days.

**Feeding System**
Majority of the cows will be fed utilizing a tractor and TMR feed wagon. Certain areas may require more precise means of feed delivery with the ability to measure feed intake. These areas will utilize either a motorized feed delivery unit or a moveable manual feeding cart. Localized hand feeding of sick cows and young calves will be required in respective areas.

**Research Specific Feeding System**
One specialized research area will contain load cell monitored feed mangers for individual cow feed intake monitoring. This feeding system will have the ability to measure real time feed intake on an individual cow basis. Feed will be delivered either via tractor & TMR wagon or motorized research feed delivery unit.
Cow Grouping
Cow grouping was established to allow maximum flexibility for reach trials. Large and small freestall grouping options are available in various buildings ranging from groupings of 12 cows per group up to 48 cows per group. Additional research can be provided on an individual cow basis located in the tie stall barn. The cow housing areas should be designed to allow flexible gating options allowing researchers larger grouping sizes when no research trials are active. The number of pens and cows per pen were set up to take advantage of even numbers generally divisible by 2, 4, 8, 12, and 24. This important flexibility does result in additional building space per cow because of the increase in housing crossovers.

Manure Handling
The manure system will consist of collection, transport, separation, digestion, and storage of dairy manure for utilization as crop fertilizer and soil amendments. The majority of the manure will be sand laden and will require sand manure separation utilizing mechanical methods. The inclusion of the existing anaerobic digester allows the site to continue producing renewable energy from the manure stream. Additionally manure solids and liquids will be separated with liquids being stored in an existing tank and solids going to the existing composting facility on site. The majority of the manure will be collected automatically with some collection occurring manually and mechanically.

Vehicular Access:
The conceptual site plan provides vehicular access to the site for farm traffic, feed deliveries, farm workers, and public visitors. From a safety and biosecurity standpoint, farm traffic should be separated from visitor traffic where possible. Visitor traffic will be limited to the parking lot in front of the visitor’s center/admin building on the east side of the site. Road access to this parking lot will come from College Road. Workers will also utilize either the same parking lot as the visitors or could have a separate lot in the same vicinity of the public lot. Regardless of parking location, workers will have a separate building entrance to allow more control over biosecurity. Farm traffic such as tractors, feed wagons, manure haulers will utilize a combination of existing private site drives such as Bennett Road and new drives constructed around the new dairy buildings to the south. It is anticipated the Composting facility will also continue to use Bennett Road for their truck and trailer access. Feed deliveries will either use Bennett Road or the existing road entrance on the north of the site.

ADA
All new facilities will be accessible for persons with disabilities in non-animal areas. Due to the unpredictable nature of animals and inherent risks of injury within animal areas, various spaces will not be considered accessible. Generally the following areas will not be designed for accessibility:

- Milking parlor
- Holding pen and cow lanes to and from
- Special treatment pen area for cows
- All cow housing pens/stalls and trafficked areas (exception is the feed lane to be accessible)
- Calf area except the center lane and feed mixing in the calf barn
- Animal rooms and feed mixing areas
- Feed center
- Silage storage
- Manure separation, treatment, and storage

Information Technology Systems
A new facility needs to have the capabilities and wiring infrastructure to be able to handle dozens of continuous data streams and archive capabilities to receive and store data in a manner that makes them readily accessible to students and faculty. The digital infrastructure needs to be matched with flexible animal housing design to allow for controlled research studies evaluating how applied management decisions impact animal behavior and other measures of well-being.
Manure and Land Application

While reviewing the existing herd and associated manure production and land application needs, it was noted limited land was available on South Campus to apply all manure currently generated from the existing dairy and therefore required manure to be sold and transported to offsite locations resulting in a costly endeavor. The amount of manure needing land applied offsite will only increase with a larger herd size. For these reasons mentioned above, the new dairy facility needs to minimize manure and wastewater generation where feasible and look into new technologies for nutrient recovery in waste streams allowing for more efficient and cost-effective transportation of manure off South Campus.

Manure Flow

Manure from the new dairy will generally be separated into liquid sand laden manure and dry bedded manure. Dry bedded manure generally will come from the maternity area, calves, and 2-4 month old heifers while the liquid sand laden manure will generally come from the lactating and dry cow areas. All dry bedded manure will go directly to the onsite composting facility utilizing existing composting and disposal methods.

Sand laden manure will be collected from the lactating and dry cow areas with the use of a mechanical scraper and moved to a flush flume system. From there manure will travel to a sand separation building where the sand will be removed from the manure and reused as bedding for the cows. The remaining manure will be pumped to the existing anaerobic digester where the digestion process will occur producing methane gas to be used to generate electricity. The digestate is then pumped to a solids separator with the solids going to composting and the liquid portion pumped into an existing above ground steel storage structure until it is land applied or sold.

Manure Quantity

Total annual manure production from a mature dairy cow herd of 614 cows yields 25,741 tons of manure annually (see table below). Portions of this manure will go directly to composting, portions to the digester, and portions (specifically the older heifers) be produced at offsite locations pending final heifer siting.

MSU Dairy - Total Manure Production (Outputs) 1

<table>
<thead>
<tr>
<th>Type</th>
<th>Total head</th>
<th>Daily Manure Production (as excreted)</th>
<th>Sand Bedding</th>
<th>Organic Bedding</th>
<th>Totals (Manure+Sand+Organic)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>lbs per animal</td>
<td>Daily Production</td>
<td>Annual Production</td>
<td>lbs per animal</td>
</tr>
<tr>
<td>Lactating</td>
<td>504</td>
<td>160.0 lbs</td>
<td>80,640</td>
<td>29,433,600</td>
<td>54.0 lbs</td>
</tr>
<tr>
<td>Dry Cow / Transition</td>
<td>110</td>
<td>88.0 lbs</td>
<td>9,680</td>
<td>3,533,200</td>
<td>54.0 lbs</td>
</tr>
<tr>
<td>Calves (0-2 months)</td>
<td>78</td>
<td>12.0 lbs</td>
<td>936</td>
<td>341,640</td>
<td>-</td>
</tr>
<tr>
<td>Heifers (2-4 months)</td>
<td>27</td>
<td>20.0 lbs</td>
<td>540</td>
<td>197,100</td>
<td>2.0 lbs</td>
</tr>
<tr>
<td>Heifers (5-23 months)</td>
<td>260</td>
<td>59.0 lbs</td>
<td>15,340</td>
<td>5,599,100</td>
<td>2.0 lbs</td>
</tr>
<tr>
<td><strong>Subtotal:</strong></td>
<td><strong>782</strong></td>
<td><strong>19,552 tons</strong></td>
<td><strong>6,051 tons</strong></td>
<td><strong>138 tons</strong></td>
<td>19,552 tons</td>
</tr>
</tbody>
</table>

Notes:
1 – Based on a 614 mature cow herd
2 – Based on 35% cull rate. All males and unneeded heifers sold by 2 mo

The existing dairy sends approximately 11,000 tons per year [2.6 million gallons] of manure to the digester. The new dairy is estimated to send approximately 17,000 tons of manure resulting in an increase of 56% (assumes manure from lactating and dry cows and 90% of sand bedding is recoverable). The exact volume of digestate leaving the digester system from the expanded dairy is difficult to estimate due to numerous variables such as a different manure system, food waste concentrations, and manure consistency could vary significantly from the

Prepared by: Curry-Wille & Associates Consulting Engineers P.C.
present manure system (e.g., scraped organic bedding vs sand laden manure in flush flume). All variables considered the best guess volume of digestate associated with the dairy manure portion will increase by 600,000 gallons. The existing digestate storage capacity onsite is 2.4 million gallons, therefore a second storage tank would be needed to handle the increase in digestate estimated at $600,000. Depending on anticipated land application windows, additional storage capacity beyond 600,000 gallons may be desired.

**Manure Nutrients and Utilization**

*Nutrients Generated*

The total manure nutrient production from the proposed expanded dairy herd is shown in the table below. As previously discussed in the manure flow discussion, solid manure nutrients collected from the calves and young heifer areas would go directly to the composting facility for processing and disposal (approximately 4,070 lbs N, 351 lbs P). The nutrients associated with the 5-23 month old heifers would be disposed of offsite pending final decision on where heifer development will occur. This leaves 211,060 lbs N & 34,556 lbs P being sent to the anaerobic digestor.

**MSU Dairy - Total Manure Nutrient Production**

<table>
<thead>
<tr>
<th>Type</th>
<th>Total head</th>
<th>Daily Manure Production (as excreted lbs per animal)</th>
<th>Annual Nutrient Production ³</th>
<th>Annual Nutrient Production ³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Daily Production</td>
<td>Annual Production</td>
<td>Total N</td>
</tr>
<tr>
<td>Dairy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lactating</td>
<td>504</td>
<td>160.0 lbs</td>
<td>80,640</td>
<td>29,433,600</td>
</tr>
<tr>
<td>Dry Cow / Transition</td>
<td>110</td>
<td>88.0 lbs</td>
<td>9,680</td>
<td>3,533,200</td>
</tr>
<tr>
<td>Calves (0-2 months)</td>
<td>78</td>
<td>12.0 lbs</td>
<td>936</td>
<td>341,640</td>
</tr>
<tr>
<td>Heifers (2-4 months)</td>
<td>27</td>
<td>20.0 lbs</td>
<td>540</td>
<td>197,100</td>
</tr>
<tr>
<td>Heifers (5-23 months)</td>
<td>260</td>
<td>59.0 lbs</td>
<td>15,340</td>
<td>5,599,100</td>
</tr>
<tr>
<td>Subtotal:</td>
<td></td>
<td>107,136</td>
<td>39,104,640</td>
<td>293,144</td>
</tr>
</tbody>
</table>

19,552 tons 293,144 lbs 44,113 lbs 93,783 lbs
146.6 tons 22.1 tons 46.9 tons

Notes:

1 – Based on a 614 mature cow herd
2 – Based on 35% cull rate. All males and unneeded heifers sold by 2 mo.
3 – No losses taken into consideration. Includes nutrients from manure + bedding

The digestion process was assumed to remove little to no total nitrogen and phosphorus amounts. Therefore the nutrients entering the digestor were passed through. After the digestion process, remaining solids are removed through solid separation with the solids portion going to composting and liquid portions going to storage. Based on current operating conditions, the digestate consisted of 15% recoverable solids and 85% liquids. A brief literature review indicated the recoverable solids portion contains 6% of the N and 8% of the P. All variables and assumptions considered, the best guess of nutrients in the liquid portion requiring land application is 198,434 lbs N and 31,832 lbs P. See table below for nutrient summary.
Land Application

All manure & liquid digestate will be land applied at agronomic rates and according to a nutrient management plan. Priority will be given for land application on fields located on South Campus. Remaining manure & liquid digestate would be sold to off-site enterprises. Currently more manure is produced on all the south campus livestock farms than land is available for application at agronomic rates. The availability of land for manure application varies from year to year depending on cropping system and active short and long-term research studies. Therefore, the increase in dairy manure needs to be incorporated into the larger South Campus nutrient management plan that takes into consideration all manure produced from each livestock operation. The recommended practice for liquid manure application is to inject manure within the top 4-6 inches of the soil surface as this significantly reduces odors and allows the soil to better utilize the nutrients for growing crops.

Feed and Silage Needs

Feed and Silage needs were calculated based on current feed usage information provided by MSU. Current usage information was normalized on a mature cow basis and extrapolated to a lactating + dry cow herd size of 614 head. All wet feeds such as silage is to come from university owned fields on south campus. All dry feeds will come from site locations on an as needed basis. See table below for projected feed needs.

### Projected Feed & Silage Needs

<table>
<thead>
<tr>
<th>Feed Group</th>
<th>Current Feed Usage Per Year</th>
<th>Projected Feed Needs For New Dairy</th>
<th>Projected Feed Storage Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feed Used/Year Tons As-Fed</td>
<td>Feed per hd Tons/HD</td>
<td>Anticipated Mature Herd Size</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alfalfa Haylage</td>
<td>1350</td>
<td>4.58</td>
<td>614 hd</td>
</tr>
<tr>
<td>Corn Silage</td>
<td>3200</td>
<td>10.85</td>
<td>614 hd</td>
</tr>
<tr>
<td>Straw</td>
<td>24</td>
<td>0.08</td>
<td>614 hd</td>
</tr>
<tr>
<td>Alfalfa Dry Hay</td>
<td>50</td>
<td>0.17</td>
<td>614 hd</td>
</tr>
<tr>
<td>Grass Hay</td>
<td>40</td>
<td>0.14</td>
<td>614 hd</td>
</tr>
<tr>
<td>Dry Ground Corn</td>
<td>438</td>
<td>1.48</td>
<td>614 hd</td>
</tr>
<tr>
<td>High Moisture Corn</td>
<td>96</td>
<td>0.33</td>
<td>614 hd</td>
</tr>
<tr>
<td>Soybean Meal</td>
<td>288</td>
<td>0.98</td>
<td>614 hd</td>
</tr>
<tr>
<td>Other Proteins</td>
<td>237</td>
<td>0.80</td>
<td>614 hd</td>
</tr>
<tr>
<td>Fat Products</td>
<td>19.2</td>
<td>0.07</td>
<td>614 hd</td>
</tr>
<tr>
<td>Soyhull Pellets</td>
<td>163</td>
<td>0.55</td>
<td>614 hd</td>
</tr>
<tr>
<td>Mineral</td>
<td>104</td>
<td>0.35</td>
<td>614 hd</td>
</tr>
<tr>
<td>Cottonseed</td>
<td>300</td>
<td>1.02</td>
<td>614 hd</td>
</tr>
</tbody>
</table>

**Sub Total**: 44,554

**Notes:**
1- Normalized on as As-Fed mature cow basis (259 lactating+36 dry)
2-Mature Cows = Lactating + dry cows

### Nutrient Split Between Liquid and Solid Fractions

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>N (lbs)</th>
<th>P (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure to Digestor</td>
<td>17,000 tons</td>
<td>211,100 lbs</td>
<td>34,600 lbs</td>
</tr>
<tr>
<td>To Liquid storage</td>
<td>3.2 million gals</td>
<td>198,434 lbs</td>
<td>31,832 lbs</td>
</tr>
<tr>
<td>To Composting</td>
<td>2,400 tons</td>
<td>12,666 lbs</td>
<td>2,768 lbs</td>
</tr>
</tbody>
</table>

**Notes:**
1- Assumes digestate solid separation removes 6% N & 8% P.
2- Source: Nutrient From Digestor Effluent, March 5, 2019
3- Current liquid storage capacity is 2.4 million gallons thus requiring an additional 600,000 gal storage depending on management and application windows.
**Alternative Energy Options**

The Dairy is well positioned for opportunities to utilize a variety of energy options. Examples include utilizing energy produced from the onsite anaerobic digestor to provide supplemental power for the expanded dairy operation. Solar panels were also discussed as an option for clean energy and would complement other MSU solar projects constructed on campus. As with any alternative energy sources, care must be taken to minimize any potential negative effects it might have on cow health and research studies. Other clean and energy efficient options include natural ventilation systems for cow housing areas, energy recovery systems associated with milk cooling, gray water re-use, and sand bedding recovery.

**CAFO Permitting Discussion**

Michigan’s Department of Environment, Great Lakes, and Energy department (EGLE) oversees the permitting process for Concentrated Animal Feeding Operations (CAFO) within the state. Medium dairy CAFO’s are defined as operations with 200 to 699 head of mature dairy cattle. Large CAFO’s are defined as operations with 700 head or more of mature dairy cattle. Large CAFO’s are required to apply for an NPDES permit and follow a specific design process and requirements. The goal of the CAFO program is to reduce the discharge of pollutants to surface waters of the state from livestock operations.

Other livestock operations within close geographic proximity of one another that share similar management could affect CAFO classifications on a case-by-case basis (currently none of the livestock facilities located on south campus are considered a large CAFO). The new dairy is proposed to include 614 head of mature dairy cattle. This puts the new dairy into a medium CAFO classification and therefore should not require an NPDES permit for the dairy itself. MSU is also an exempt teaching/government facility and therefore is not necessarily required to follow CAFO design criteria, however MSU stake holders expressed desire to follow CAFO design criteria where possible. The exact details of the CAFO permitting requirements will be evaluated in future design phases.

**General Utility and MEP Facility Needs**

**Wastewater**

*Domestic Sanitary Wastewater*

All domestic sanitary wastewater generated from sinks, bathrooms, clothes washers, and floor drains located within human occupied areas will all continue to go to the city’s sanitary system for treatment. Sanitary sewer lines run along College Road. Tie in location and details to be determined in design phase.

*Parlor Clean In Place (CIP) Milk System Wash water*

Due to the limited land availability for the land application of wastes at South Campus, the best option for CIP wash water is to continue sending to the city for treatment and disposal assuming the city has capacity and willing to accept the waste. Currently the CIP wash water from the existing parlor all gets diverted to the city for treatment and recommend continuing to do so. Washing is anticipated to occur 3 times daily and estimated around 1,500 gallons to 2,000 gallons per day.

*Miscellaneous Wash Water*

All wash water containing manure particulates will be collected and routed to the digestor for treatment. These areas generally include the parlor’s holding pen, cow deck, standing procedure rooms, hospital area, and wash down of cattle travel lanes. Options may exist to divert non manure laden wash water to the city for treatment and disposal to reduce operating costs assuming the city is willing to accept such waste.
Stormwater Runoff

Stormwater Management
Clean stormwater will be kept separate from agricultural wastewater and will be designed according to state stormwater conveyance requirements. Stormwater piping with surface inlets will be located throughout the new dairy structures and will convey clean runoff northward around the east side of the existing dairy. An infiltration area coupled with a detention structure is anticipated in the area east of the existing dairy buildings.

Agricultural Stormwater Runoff and Feed Leachate Collection
Leachate and agricultural runoff from the feed center area will be collected and stored onsite until land application on cropland can occur. Depending on final site layout, the leachate collection system could utilize the existing settling basin and pumping system. A lined earthen storage basin is anticipated for this wastewater storage structure however alternative structures could be utilized pending land availability.

Electrical

Electrical System
Main electrical lines extend along the northern and southern side of the existing dairy site. Both of these lines go to the anaerobic digestor complex, specifically to the generator. An electrical line branches off near the digestor and extends to a transformer and switchgear located just outside and to the west of the metabolism/shop structure. Existing power lines are also located along college road to the east of the facility.

Electrical Main Transformer and Switchgear Relocation
The main electrical distribution point for the existing dairy facilities was recently remodeled and is located just west of the existing metabolism/shop building. Options were brainstormed for leaving the electrical main transformer and switch gear as is or relocating to another spot onsite. Reasons for leaving as is include cost savings associated with no relocation. Reasons for relocating include improved feed processing & delivery efficiency with reduced worker and tractor travel times by allowing the feed bunkers to be placed closer to the feed center. Relocating the electrical main and demolishing the metabolism/shop building would reduce the feed travel distance by 200 feet each time the TMR wagon is loaded with silage material (100 ft each way). Multiple TMR wagon trips to the silage bunkers during each feeding time would occur coupled with two feeding times per day at 365 days a year, results in a significant reduction in labor and maintenance cost over the course of a year. Therefore, it is our professional recommendation to relocate the electrical main in order to improve feeding efficiency and reduce TMR wagon travel distance. If the electrical main is not relocated, then a new line would extend from the current transformer location and extend to the south to service the new structures.

Backup Generator
Backup generator power will be required for portions of this facility. At a minimum it will provide emergency power to all parlor milking equipment, lighting & ventilation required for safety and operation of critical animal areas, critical lab equipment, and freezers. Generator to be located outside in a weatherproof enclosure. Power source to be 480/277 volt, 3 phase, 4 wire diesel driven standby-rated engine generator.

Project Phasing
Phasing strategies were reviewed and could be separated into 3 major phases. The major phases identified below generally follow the construction sequence of Phase 1- site development and building new dairy facilities to the south of the existing farm; Phase 2- demolish existing buildings identified in the demo plan and construct new silage and feed storage structures within the demo’ed areas. Phase 3 construction is reserved for remaining items not constructed in previous phases, upgrades to existing feed mixing center, digestor upgrades, and new heifer development facility (location to be determined, could be KBS or South Campus). Generally the phasing
needs to occur in order however some items are independent may occur earlier or later in the construction process.

**Phase 1**

Minimum Construction Requirements:
1. New (South) Site development including roads, utilities and storm water
2. New manure collection system and sand removal building
3. Parlor and holding area
4. Administration (needed to support parlor & worker activities)
5. Treatment/Sorting/Vet Med area
6. Covered Connecting Walkway

Potential Livestock Buildings to Support Minimum Requirements: (selectable)
7. Conventional freestall
8. Small group housing
9. Feed Research Tub Area
10. Robotic milking
11. Tie stall housing

Optional Buildings that could be constructed now (or later): If constructed later, these spaces would continue to operate at the existing facility
12. Dry cows and maternity
13. Calf housing

**Phase 2**

Construct Remaining Buildings left out of Phase 1

Existing Facility Demolition / New Construction: (phases could be mixed and matched)
1. Demolition structures north of existing parlor
2. Construct new silage storage north of the existing parlor
3. Demolition structures south of existing parlor
4. Construct new silage storge south of existing parlor
5. Redo leachate collection and storage
6. New shop, machine storage and maintenance area

**Phase 3**

7. Expand heifer housing at KBS
8. Upgrade digester if needed
9. Redo and add concentrate storage to the hoop building
10. Redo existing concentrate loadout into bulk commodity storage
Part 3. **Opinion of Probable Construction Cost**

**Assumptions**
- Assumes normal level of finishes and standard dairy construction practices
- Estimate reflects current construction costs as of October 2022
- No MSU project administrative costs were included
- Assumed all onsite roads to be asphalt. While we would recommend the heavily trafficked areas be concrete, there is some flexibility to rock some portions of the drives to save money.
- Cost Alternates: On page 1 we listed two cost alternates:
  - 1) If all roads were surfaced with rock instead of asphalt then you could save $504,084.
  - 2) Collecting only contaminated runoff from the new feed bunkers instead of the entire feed center would save roughly $162,181.
- Estimate does not include any costs for:
  - New heifer housing facility (estimated at $4.1 million)
  - Anaerobic digestor upgrades
  - Redoing feed mixing center (specifically the hoop building and north bay of the hay barn)

**Project Contingency**
- Contingency set at 10%
- Includes minor scope changes that could occur during design phase
- Includes unforeseen changes in construction market

**Opinion of Probable Construction Cost**
Opinion of probable construction cost for the outlined facilities presented in this study is approximately $38.4 million dollars. See Appendix C– Opinion of Probable Construction Cost on page 42 for construction cost separated by building.
Part 4. **APPENDIX**

Appendix A. – Site Plans

a. Dairy Cattle Teaching and Research Center Location (South Campus)
b. Existing Site Plan
c. Potential New Dairy Locations at Existing Dairy Farm
d. Building Demolition Plan

NOTES:
1. EXISTING STRUCTURES IN RED
2. EXISTING STRUCTURES TO BE DEMOLED IN GREEN

DEMOLITION PLAN
e. New Conceptual Site Plan (South Location)
Appendix B. – Building Block Diagrams

a. Administration/Visitors Center/Worker Support

![Building Block Diagram]

ADMINISTRATION, VISITOR’S CENTER, WORKER SUPPORT AREA PLAN VIEW

NOTES:
1) TOTAL AREA = 9,000 ft²

SCALE: 1/16" = 1' - 0"
b. Conventional Freestall – Large Group
c. Conventional Freestall – Small Group

![Diagram of Conventional Freestall - Small Group]

**NOTES:**
1) **TOTAL AREA** = 22,176 sq ft
2) **CAPACITY** = 96 COWS

**SCALE:** 1/32" = 1'-0"
d. Robotic Freestall Barn

[Diagram of Robotic Freestall Barn]
e. Feed Research Tub Area
f. Dry Cow Housing
g. Maternity Area
h. Calf Barn
i. Tie Stall Area
j. Treatment / Vet Med Area
### Appendix C. – Opinion of Probable Construction Cost

**SUMMARY OF COST ESTIMATE prepared by STECKER-HARMSEN, INC.**

**PROJECT:** MICHIGAN STATE DAIRY COMPLEX  
**OWNER:** MICHIGAN STATE UNIVERSITY  
**ENGINEER:** CURRY-WILLE & ASSOCIATES  
**LOCATION:** EAST LANSING, MI  
**DATE:** NOVEMBER 7, 2022  
**STATUS:** FEASIBILITY STUDY

#### PHASE 1

<table>
<thead>
<tr>
<th>Description of Work</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) NEW SITE DEVELOPMENT - ROADS &amp; UTILITIES</td>
<td>2,678,223</td>
</tr>
<tr>
<td>2) NEW MANURE COLLECTION SYSTEM &amp; SAND REMOVAL BLDG</td>
<td>2,202,930</td>
</tr>
<tr>
<td>3) PARLOR &amp; HOLDING AREA</td>
<td>2,433,707</td>
</tr>
<tr>
<td>4) ADMINISTRATION</td>
<td>1,929,037</td>
</tr>
<tr>
<td>5) TREATMENT/SORTING/VET MED AREA</td>
<td>1,712,282</td>
</tr>
<tr>
<td>6) CONVENTIONAL FREESTALL - LARGE GROUP</td>
<td>4,154,168</td>
</tr>
<tr>
<td>7) CONVENTIONAL FREESTALL - SMALL GROUP</td>
<td>2,792,753</td>
</tr>
<tr>
<td>8) FEED RESEARCH TUB AREA</td>
<td>4,412,025</td>
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<tr>
<td>9) ROBOTIC MILKING</td>
<td>4,634,753</td>
</tr>
<tr>
<td>10) TIE STALL HOUSING</td>
<td>1,621,006</td>
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<tr>
<td>11) DRY COWS &amp; MATERNITY</td>
<td>3,666,556</td>
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<tr>
<td>12) CALVES</td>
<td>1,475,031</td>
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<tr>
<td>13) CONNECTING ALLEYS (COVERED)</td>
<td>1,493,627</td>
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</tbody>
</table>

#### PHASE 2

<table>
<thead>
<tr>
<th>Description of Work</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) DEMOLISH EXTG STRUCTURES</td>
<td>899,346</td>
</tr>
<tr>
<td>2) CONSTRUCT NEW SILAGE STORAGE</td>
<td>1,439,893</td>
</tr>
<tr>
<td>3) REDO LEACHATE COLLECTION &amp; STORAGE</td>
<td>282,835</td>
</tr>
<tr>
<td>4) MAINTENANCE SHOP BUILDING</td>
<td>422,348</td>
</tr>
</tbody>
</table>

**COST ESTIMATE TOTAL**  
$38,450,635

**ALTERNATES**

1) PROVIDE GRAVEL SURFACING IN LIEU OF ASPHALT PAVING - DEDUCT  
($504,084)

2) COLLECT ONLY BUNKER AREA RUN-OFF IN LIEU OF ENTIRE FEED CENTER - DEDUCT  
($162,181)