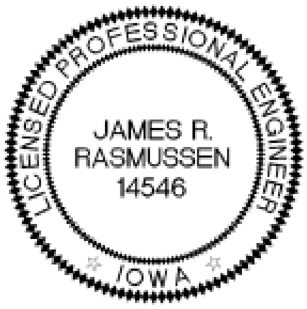

I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Iowa.

______________________________ Date:___________

JAMES R. RASMUSSEN, P.E.

License No. **14546**

My renewal date is **December 31**, **2011**

Pages or sheets covered by this seal:

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Appendix

1.0 EXECUTIVE SUMMARY

1.1 General

The Ames Water Pollution Control Facility (WPCF) began operations in 1989. Sludge from the treatment processes is treated in two primary anaerobic digesters. The digested sludge (i.e., biosolids or residuals) is then transferred to a secondary digester and temporarily stored. Biosolids is routinely transferred from the secondary digester to a sludge storage lagoon for holding until final disposal. Since 1990, the City has land applied the biosolids to approximately 300 acres of City-owned agricultural land. The land application process is completed by WPCF staff. The process of pumping the biosolids from the lagoon, loading the Terragators, and land applying the biosolids requires extensive effort and expense. Much of the land application equipment is at the end of its useful life.

The primary purpose of this Biosolids Storage, Handling and Disposal Study is to evaluate alternatives and recommend a biosolids plan for the next 20 years for the City of Ames. The study includes a forecast of biosolids production rates due to growth and future nutrient removal. The study also includes an investigation of the current anaerobic digester mixing system and makes a recommendation for replacement of this system.

1.2 Biosolids Production and Impact of Nutrient Removal

This study examined the past 18 years of biosolids land application history, and especially the past five years of solids processing and disposal, to help determine the future design conditions. The City of Ames has a Comprehensive Plan that predicts the 2030 population to be 11.2 percent greater than the current population.

More significantly, the Ames WPCF will eventually receive a discharge permit with more stringent nutrient removal requirements. Due to the probable permit limits and the liquid treatment process changes needed to achieve those limits, a greater than 30 percent increase in biosolids production is anticipated.

1.3 Biosolids Storage, Handling and Disposal Evaluation

Chapter 7 identifies and evaluates alternatives for biosolids storage, handling and disposal. Five alternatives for biosolids storage, handling and disposal were shortlisted in Workshop II for the project. This section presents each alternative and describes the capital cost elements and the operations and maintenance differences. In addition, a non-economic evaluation was prepared for each alternative considered. The five alternatives considered for biosolids storage, handling and disposal are:

Alternative 1 – Continue Present Operations
Replace existing biosolids handling and land application equipment and operate as in the past. Replace land application equipment, rehabilitate storage lagoon and replace the biosolids pumping equipment. WPCF conduct land application at current rates on permitted land. In the future, add biosolids storage capacity.

Alternative 2 – Contracted Removal and Land Application
Repair existing biosolids storage lagoon, store liquid sludge, remove lagoon pumping equipment, Contractor to remove and land apply biosolids on Ames permitted land at current rates. In the future; add thickening biosolids up to 8 percent solids and contractor to land apply.

Alternative 3 – Contracted Land Application
Repair existing biosolids storage lagoon, construct an additional storage tank for the remaining storage needs, Contractor to land apply biosolids at current rates to Ames permitted land. In the future; add thickening facilities to thicken biosolids to 8 percent solids.

Alternative 4 – Dewatering, Contracted Land Application
Discontinue biosolids storage lagoon operation, dewater biosolids from secondary digester, store on-site in cake storage structure, Contractor to land apply dewatered cake at current rates. In the future; continue dewatering for future conditions. Expand cake storage structure for additional biosolids.

Alternative 5 – Thickening, Contracted Land Application
Abandon biosolids storage lagoon, thicken sludge up to an 8 percent solids sludge and store in storage tanks with mixing and loadout facilities, Contractor to land apply on existing permitted land. In the future; provide an additional storage tank for additional biosolids production.

1.4 Recommended Alternative

Alternative 3 is recommended for the City of Ames to implement. This alternative includes 365-day storage capacity for biosolids, enhancing operational flexibility. The capital cost to implement this alternative is $1,387,000. In the future when biosolids production significantly increases due to nutrient removal, an additional capital cost of $1,015,000 will be needed to expand the biosolids handling infrastructure. The majority of land application of biosolids will be done by a biosolids specialty contractor, but WPCF staff will retain the capability to land apply biosolids in spring or summer.

1.5 Anaerobic Digester Mixing Evaluation

Chapter 8 evaluates mixing alternatives for the primary anaerobic digesters. The existing system has reached the end of its useful life and requires higher-than-normal maintenance effort from operations staff. A single internal draft tube mixing system with an integral heat exchanger is the recommended approach for each primary digester. This alternative has the lowest capital cost and lowest present worth cost. The capital cost for these recommended improvements is $350,000.

1.6 Implementation

The implementation of these recommended improvements should be added to the Capital Improvements Plan for the City of Ames. The City should proceed immediately with the selection of a biosolids specialty contractor for the land application of biosolids. The capital improvements for the biosolids storage, handling and disposal improvements should be implemented as soon as funding is available. Mixer replacement at the anaerobic digesters should be implemented as an equipment replacement project.

Item	Budget	Target Date
Proposal for Selecting Biosolids Contractor		June 2010
Biosolids Contractor Under Contract		August 2010
Biosolids Storage, Handling and Disposal Recommendations		
Salvage Terragators	-$25,000	July 2011
Purchase Four-wheel Drive Tractor and Wagon with Biosolids Application Eq	$270,000	July 2011
Design 1.6 MG Biosolids Storage Tank and Loadout Facilities	$100,000	September 2010
Construct 1.6 MG Biosolids Storage Tank and Loadout Facilities	$1,059,000	June 2012
Rehab Biosolids Storage Lagoon	$58,000	November 2012
Anaerobic Digester Mixing Replacement		
Design Mixing Replacement	$35,000	Jan 2012
Implementation of Mixer Replacement	$350,000	July 2012/July 2013

2.0 PURPOSE

The City of Ames has followed its original plan for biosolids storage, handling and disposal since the Water Pollution Control Facility (WPCF) opened in 1989. Much of the equipment and infrastructure used for storage and handling of stabilized sludge is nearing the end of its useful life. The primary purpose of this study is to examine the biosolids produced at the plant today and begin planning for the future method of storage, handling and disposal.

A second focus of this study is to evaluate the existing anaerobic digestion process with respect to replacement of the digester mixing system. An effective mixing system has the benefits of enhancing the digestion process and improving methane gas production for use in the engine generators. This study reviews digester mixing technologies and makes a recommendation for replacement of the existing mixing system.

A list of the scope elements of this study is as follows:

- Review current biosolids handling, storage and disposal operations
- Review regulatory impacts due to nutrient removal
- Evaluate biosolids processing, storage, and handling alternatives
- Evaluate digester mixing replacement alternatives
- Present recommendations and a timeline for improvements

In the kickoff meeting for the study, HR Green and the City worked together to develop goals for the project. These goals were used as a basis for alternatives, evaluations and recommendations. These goals are:

Biosolids Storage and Handling and Disposal

1) Capital cost – Recommendations must be implemented within current rates and phased to reflect costs for future nutrient removal impacts
2) Life-cycle costs – Capital and O&M costs for a 20-year planning period will be used for evaluations
3) Innovation vs.Reliable Technology – New technologies will be considered but more focus will be given to reliable technologies with flexible operations
4) Best use of staff and existing infrastructure – Alternatives will incorporate assets of existing infrastructure and focus on best use of staff for operations and maintenance
5) Environmentally Sustainable – Continue to beneficially re-use biosolids while protecting the environment and public health

Digester Mixing Replacement

1) Capital and O&M Costs - Review alternatives with life cycle costs in mind. Preferred payback should be 5-7 years
2) Select alternatives with operations and maintenance of equipment in mind
3) Alternatives should reflect future conditions related to solids production, gas production, energy use, etc

3.0 BACKGROUND

3.1 General

The Ames Water Pollution Control Facility (WPCF) began operations in 1989. The plant discharges treated effluent to the South Skunk River under the terms of a National Pollutant Discharge Elimination System (NPDES) permit which expired several years ago.

Sludge from the treatment processes is treated in two primary anaerobic digesters. The digested sludge (i.e., biosolids or residuals) is then transferred to a secondary digester and temporarily stored. Biosolids are routinely transferred from the secondary digester to a sludge storage lagoon for holding until final disposal.

Since 1990 the City has applied biosolids to approximately 300 acres of City-owned agricultural land. Additional privately-owned land is available for application as needed. Two City-owned AgChem 2505 Terragators have been used for land application. The biosolids are used as a soil conditioner and fertilizer, reducing the cost for fertilizers for crop production.

Liquid biosolids are loaded into the Terragators from the biosolids storage lagoon by means of a dredge system. Generally, the biosolids are applied to farmland after the harvest in the fall. In some years the City is able to land apply before planting in the spring.

Both Terragators are approaching the end of their useful life and will need to be replaced in the near future. Similarly, the aging dredge equipment has difficulty removing the solids from the lagoon. This operation is an inordinate consumer of staff time and productivity. In addition, likely changes in nutrient removal requirements are on the horizon in a future discharge permit. The additional requirement to remove nutrients will have a significant impact on the biosolids production and the potential disposal options.

Another issue at the Ames WPCF is the mixing in the primary anaerobic digesters. The mixing equipment is thought to be nearing the end of its life. Additionally, a more efficient mixing system could boost methane gas production from the anaerobic digestion process.

3.2 Biosolids Storage, Handling and Disposal

A site plan for the Ames WPCF is presented in Figure 3-1.

Insert Figure 3-1 Ames WPCF Site Plan

The solids treatment process at the Ames WPCF is as follows:

1. Primary sludge is pumped continuously from the primary clarifiers to the primary digesters,
2. Primary digesters stabilize biosolids and transfer to secondary digester,
3. Secondary digester transfers biosolids to earthen biosolids storage lagoon,
4. Dredge and pump system removes sludge from lagoon to land application equipment, and
5. Finally the biosolids are land applied by the plant staff to City-owned farm fields surrounding the plant.

The City shares the proceeds from the harvested crops with the farmers who lease the ground.

Figure 3-2 shows the City-owned and privately-owned biosolids application fields. The City owns approximately 340 acres of farm land used for biosolids land application. The City has an additional 156 acres of fields that can be used for biosolids land application close to the plant that are not owned by the City. The City has effectively used this land for land application of biosolids produced at the Ames WPCF since the plant opened in 1989.

The City-owned farmland for land application close to the wastewater treatment plant is a great asset. As shown in Figure 3-2, the farm fields are all relatively close to the plant. In addition, the fields are very flat with low potential for runoff.

3.3 Anaerobic Digestion Facilities

Two anaerobic primary digesters provide stabilization to meet the requirements for a Class B biosolids material. A single floating cover secondary digester is used to store the stabilized biosolids and the digester gas generated in the primary digesters. The digester gas stored in the secondary digester is used to fuel engine generators to produce electricity to be used at the plant. The use of digester gas reduces power usage at the WPCF by about 20-25%.

3.4 Growth

The City recently completed a Comprehensive Plan which forecasts a population of 59,600 for Ames by 2030, an 11.2 percent increase from the 2010 population of 53,600. This study assumes that an increase in population will generate a proportional increase in wastewater produced. Growth for the 20-year planning period (2030) is assumed to be 11.2 percent.

Insert Figure 3-2 Ames Biosolids Application Map

4.0 CURRENT OPERATION, CONDITION AND LIMITATIONS

4.1 Biosolids Storage, Handling and Disposal

A Workshop to discuss the current conditions and biosolids storage, handling and disposal options was held early in this study. Several technical memoranda were prepared in advance of the workshop to identify technical solutions and foster discussion. These technical memoranda are included in Appendix A.

4.1.1 Current Operations

The existing biosolids storage lagoon has a capacity of approximately 3.1 million gallons (MG). The lagoon is an earthen basin with a 100 mil thickness HDPE liner installed in 1989. Biosolids are transferred to the lagoon from the secondary digester. For most of its history the biosolids storage lagoon in combination with the secondary digester has provided all the needed storage. Recently, as biosolids quantities have increased, the Ames WPCF has relied on spring land application or summer land application on hay ground to reduce the biosolids inventory.

Figure 4-1 Existing Biosolids Storage Lagoon and Dredge

A dredge platform with pump, also originally installed in 1989, is moored in the lagoon. This dredge is used to mix the lagoon contents and pump sludge into land application equipment. There is limited mixing in the lagoon, which results in a labor intensive removal of settled biosolids. The lower layers of stored biosolids tend to be very thick; up to approximately 8 percent solids. This necessitates water addition or thinner sludge from the secondary digester to dilute the sludge enough to allow pumping for land application. The upper layers of thinner liquid sludge, or supernatant, can be decanted back to the head of the plant. Four decant pipes are situated to withdraw liquid material from different elevations as needed. A valve pit structure is located east of the existing lagoon. The decanted material is conveyed by gravity back to the Headworks Facility. The solids content of the decanted flow ranges from 1 to 2 percent. The lagoons have been cleaned periodically through contract with a specialty biosolids contractor.

Figure 4-2 Existing Terragators

Figure 4-3 Sludge Loadout

The biosolids storage lagoon does not have enough storage capacity to store 365 days of biosolids produced at the WPCF (at reasonable solids concentrations). The 3.1 MG lagoon capacity is managed by thickening solids and land applying biosolids during various times of the year. Additional storage is available in the Secondary Digester. As sludge quantities increase due to growth and/or nutrient removal, the lagoon storage will become even more undersized. Managing biosolids inventories and storage volumes through decanting and other means will be more difficult.

The City of Ames WPCF currently removes the biosolids from the storage lagoon and land applies their biosolids with their current staff. The City staff annually log more than 750 hours of labor in the pumping, loading, hauling, and land application of residuals. Generally, the land application process occurs in the fall after the crops have been removed. Currently, final land application using the Terragators requires approximately 8 weeks of labor using both vehicles. Typically, the Ames WPCF applies all the biosolids between October 1st and the end of November.

In Iowa, most municipalities apply biosolids at a rate of 2 tons/acre or less. Biosolids may be applied at a higher rate, up to an agronomic rate based on soil sampling. Ames generally applies biosolids at a rate higher than 2 tons/acre primarily to reduce the number of trips to a field. Soil testing is done on these land application sites. Biosolids are generally applied to only a portion of the permitted land application sites each year. After two years of land application, the field is allowed to “rest” for a year with no biosolids application. Table 4-1 below shows the reported land application of biosolids quantities for the City of Ames since the WPCF opened in 1989. Table 4-2 shows the past four years of City biosolids land application. Note that in 2005 and 2006 the volume of sludge does not match because a Contractor was hired to land apply biosolids for the digester cleaning and lagoon cleaning events. The complete biosolids land application records for the City’s application for the past several years are included in Appendix B of this report.

Table 4-1 – Reported Land Application of Biosolids

Year	Dry Tons Applied	Comments
1990	0	Startup of new plant
1991	404	
1992		No Data
1993	467	
1994	1057	
1995	665	
1996	388	
1997	299	
1998	410	
1999	287	
2000	304	
2001	260	
2002	418	
2003	684	
2004	854	
2005	1098	Digester Cleaning
2006	1007	Sludge Lagoon & EQ Basin Cleaning
2007	746	
2008	793	

Table 4-2 – 2005-2008 Biosolids Land Application Quantities

Year	**Total Volume**	**Total Acres Used**	**Average Application Rate**	**Weighted Average Total Solids Concentration**	**Dry Ton Average Application Rate**
	(gallons)	(acres)	(gallons/acre)	(%)	(tons/acre)
2005	3,932,000	244.1	16,180	4.70	3.16
2006	2,716,000	217.3	8,968	4.35	1.84
2007	4,748,000	307.5	15,728	3.76	2.42
2008	4,352,000	260.4	16,514	4.37	3.04

4.1.2 Condition Assessment

The current biosolids storage, handling and disposal equipment and infrastructure were inspected and plant staff members were interviewed. The equipment has served its intended use for the past 20+ years and in many cases needs replacement. The Ames WPCF staff has done an outstanding job keeping the equipment operational but the attention needed to keep the equipment in reliable working condition has begun to increase significantly.

Figure 4-4 Existing Sludge Lagoon Liner

The biosolids storage lagoon is generally in good condition except for some flaws in the liner above the liquid level. There is no evidence that the liner below the lagoon liquid surface has been damaged or is in poor condition. When the lagoon was cleaned in 2006, the cleaning contractor was careful not to damage the liner and there were no visible leaks under the liquid surface. Above the liquid surface, some seams are separating and a few holes have appeared. Other areas appear to show a shift in the underlying soil along the sloped sides. These areas need to be repaired as soon as possible to prevent further damage.

The original liner is a 100 mil HDPE liner. This thickness is significantly more than what is currently required for a biosolids storage lagoon (30 mils). This additional thickness has contributed to the liner's long life. However, the liner needs to be replaced soon to protect the integrity of the biosolids storage lagoon.

The dredge platform with pump is nearing the end of its useful life and needs replacement. The dredge originally was designed to be moved around the lagoon bottom to pull solids off all areas of the lagoon. For the last several years the Ames plant staff has used the dredge in a stationary position. The staff has moved the biosolids in the lagoon to the dredge. The pump has provided good service but has needed increasing maintenance in the last few years, and should also be replaced.

Figure 4-5 Terragator Storage

Two City-owned AgChem 2505 Terragators were purchased as part of the original construction contract in 1989. They have operated with regular maintenance for the past 20 years. The Terragators are stored in the drive-through area of the Raw Water Building. This area shares an environment with other areas of the plant where raw wastewater and grit are exposed and open to the environment. This moist wastewater atmosphere is very corrosive to metals. The Terragators' exposure to this environment has caused corrosion, especially affecting their electrical system components.

Mechanically, one of the Terragator rear end was overhauled last year and a similar overhaul is expected on the other. Plant staff indicate that they expect to invest $20,000 in the repair of the Terragators (rear end on other terragator and knife rebuild on both) soon to keep them operational. A life cycle cost comparison of the Terragators verses other land application equipment is included in Section 7.3.

4.1.3 Limitations of Current System

There are a number of limitations with the existing biosolids storage, handling and disposal system that need to be resolved at the existing Ames WPCF to meet the needs for the next 20 years. Some of the limitations are a result of the age and condition of the infrastructure and some are a result of changing biosolids conditions and quantities.

4.1.3.1 Lagoon Storage

The existing 3.1 MG biosolids storage lagoon already does not provide 365 days of biosolids. At 2008 biosolids production rates the sludge lagoon provides approximately 230 days storage. This problem is compounded by anticipated population growth (11.2%) and the additional biosolids produced when nutrient removal is implemented (31.5% increase).

The insufficiency of storage capacity becomes yet more acute when Ames has a wet fall season, or when winter weather starts early.

Land application by a biosolids contractor may require less storage simply due to the fact that they can remove and land apply biosolids at a much faster rate. The daily application rate for a biosolids contractor can be as much as 1.0 MG/day.

4.1.3.2 Land Application Sites Outside of the Floodplain

Almost all of the City-owned land application fields lie within the flood zone of the South Skunk River (Figure 4-6 shows the FEMA Flood Map of the area). Therefore, land application of biosolids on these City-owned sites will not be feasible in some years, and storage will be required to hold additional biosolids until land application or other disposal method can continue.

Another limitation with the flood zone is the access to the Ames WPCF. A bridge on the Story County gravel road to the plant lies within the flood zone. The bridge has load restrictions and is narrow. This bridge will restrict hauling of biosolids to other sites east of the WPCF.

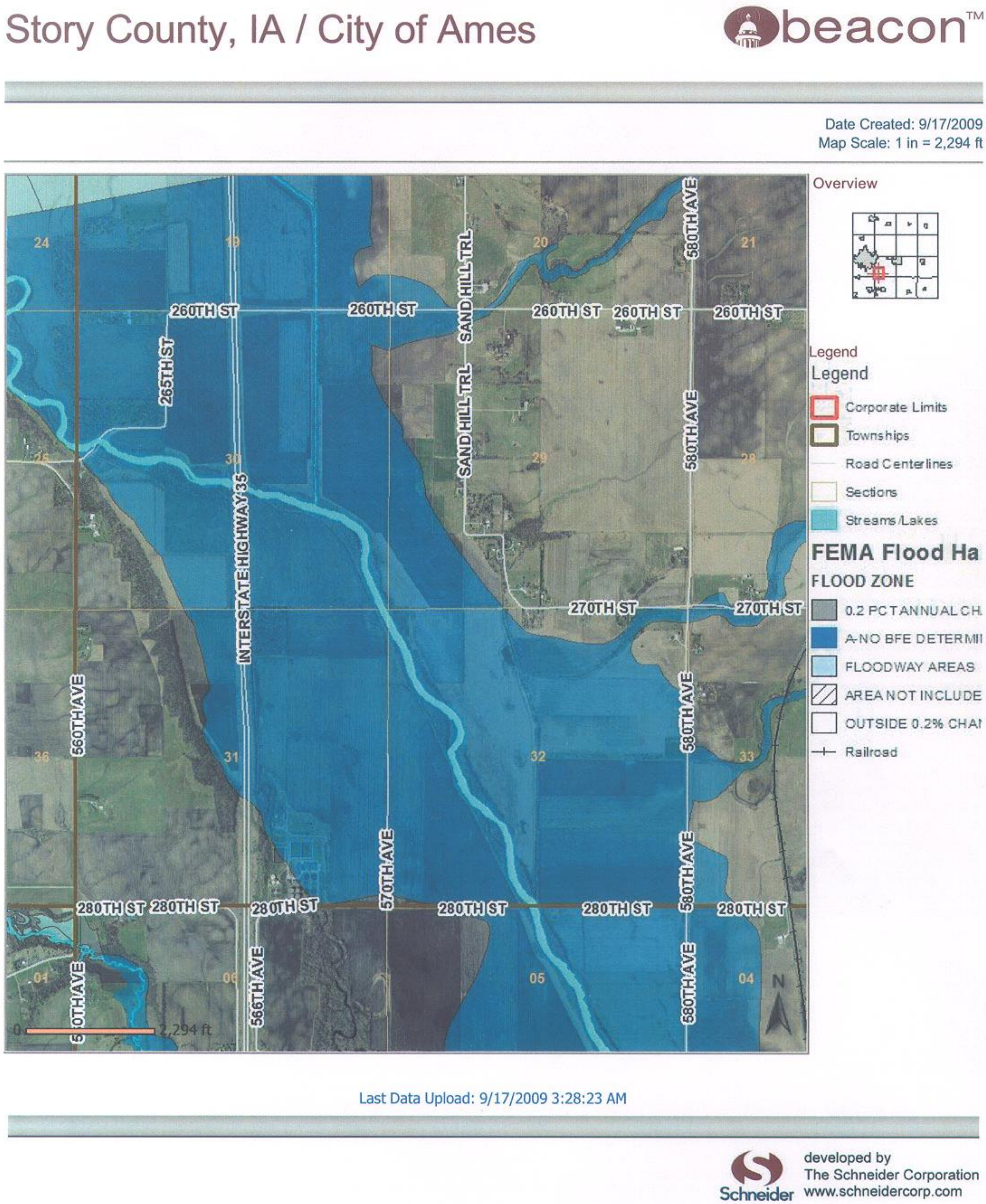

Figure 4-6 – FEMA Flood Map

4.1.3.2 Condition of Terragators (and other Equipment)

An obvious limitation on the future of City-run land application is the condition of the equipment. The Terragators are at the end of their useful life. They have some large pending maintenance costs. The replacement cost for one Terragator of comparable size is $550K. Leasing of Terragators for land application by the City is not feasible.

The existing biosolids lagoon dredge and pump system is at the end of its useful life and needs to be replaced. If replaced, this system should be replaced with a system designed to travel along the bottom of the lagoon so that less effort is needed to move the biosolids to the dredge.

4.1.3.3 Effort for City Staff

The number of City staff hours spent to pump, load and land apply biosolids is significant. Based on the time charges the effort is at least 750 manhours each fall for biosolids land application. Additional time is spent in the spring for land applying biosolids from the secondary digester. Generally, these hours are worked by maintenance staff during the eight-week land application season in the fall.

4.1.3.4 Phosphorus Loading of Soils

Another potential limitation pertains to nutrient loading of the soils. When phosphorus removal effluent requirements are implemented, the phosphorus removed will be present in the biosolids, thus affecting the soils where biosolids are applied. In 2004 a paper entitled "Using The Iowa Phosphorus Index to Assess Risk of Off-Site P Movement in Biosolids Management" was presented by Dr. Michael L. Thompson of Iowa State University. The paper presented an analysis of the P-Index for several biosolids land application sites in Iowa, including one of the Ames land application farms. The results for the Ames land application site indicated low risk of P movement into adjacent water courses. With additional phosphorus in the biosolids the results would likely be similar due to the relatively flat sites.

Thus the risk of additional phosphorus in the biosolids is more related to crop resistance to high phosphorus loads. High phosphorus levels can have a toxic effect on crops. Therefore, it is very likely that additional land will be needed for land application of biosolids in the future.

4.2 **Anaerobic Digestion**

A Workshop to discuss the current anaerobic digester operation, mixing, heating, gas utilization and impacts to solids production was held early in this study. Several Technical Memoranda were prepared in advance of the workshop to help identify alternatives and develop discussions. These technical memoranda are included in Appendix C.

4.2.1 Existing Condition

4.2.1.1 Digestion Facilities

The Ames WPCF utilizes two primary digesters and one secondary digester. The anaerobic digestion process also includes several ancillary processes such as sludge heating, mixing, covers, and gas collecting and handling.

The primary digesters are fed with five 4-inch air-operated diaphragm pumps. These pumps pull sludge directly from the primary clarifiers and feed the digesters continuously. Stroke length and frequency of strokes determine the pumping rate. The secondary digester is gravity fed as sludge is displaced from the primary digester as it fills. Specific characteristics of the digesters are provided in Table 4-3.

Table 4-3 – Existing Digester Facilities

	Primary Digester(s)	Secondary Digester
Quantity	2	1
Cover type	Fixed, Steel	Floating Gasholder
Diameter, ft	65	80
Sidewater Depth, ft	29	24.6
Active Storage Volume, Each Gal (w/o Cone)	720,000	925,000
Gas Volume Storage, cf	N/A	36,000

4.2.1.2 Sludge Heating

Sludge is heated by a heat exchanger wrapped around the draft tube inside each of the primary digesters. There are two heating loops. The primary heating loop circulates heated water from three dual-fuel engine generators. The primary loop heat is transferred to the secondary loop by means of a parallel plate heat exchanger. The secondary loop is then circulated as needed through the draft tube heat exchangers to maintain a set point temperature in the digesters (typically 95 degrees-F). The internal sludge heat exchanger can transfer 1,000,000 btu/hr.

4.2.1.3 Mixing

Mixing occurs in the primary digesters only. Mixing is provided by compressed gas directed through a center-mounted draft tube to impart a rolling pattern. Mixing through the draft tube also accomplishes the sludge heating described previously.

Digester gas is compressed using a 20 Hp positive displacement blower located on the cover of each primary digester. The system is designed to mix the contents of the digester in 27 minutes.

4.2.1.4 Gas Collection and Handling

Gas generated in the primary digester is collected and transferred to the secondary digester for holding. The gas is held in the gas holding cover until it is used. Gas is used in the engine generators to produce electricity. Currently, only one generator will run at any given time. A control issue is presently being resolved to allow simultaneous running of multiple generators. One generator will use all digester gas produced during most times of the year. There are times during the winter when digester gas production is not adequate to supply the needed heat, at which time supplemental natural gas is used. Customary operation in summer is to use digester gas and waste excess heat to external radiators. These generators, when run in parallel, will be able to use additional digester gas produced in the digesters. Other uses for the excess heat could also be investigated. Operating pressure of the digester gas is approximately 15 inches water column.

4.2.2 Historic Data

Historical plant solids data were analyzed to determine operational performance of the existing digester system at the Ames WPCF. The study period was from year 2003 to present with special scrutiny applied to the last two years to establish the “current” condition. See the figures in Appendix D for a graphical presentation of these data. Each figure is discussed below.

Figure D-1. Primary Sludge Pumped. Primary sludge has increased steadily over the study period. The average sludge pumped during the “current” condition is 26,175 gallons per day.

Figure D-2. Primary Sludge % Total Solids and % Volatile Solids. The percent total solids (TS) to the digesters from the primary clarifiers was within typical operating limits. Operation in the upper tier of the operating range is recommended to reduce water to the digester, thus increasing the solids retention time (SRT) for optimum volatile solids reduction (VSR). The observed percent VS to the digester was also very high, indicating a potential for increased gas production. The 2008 flood impact is evident in the data; the wash-in of inert material was apparent as an increase in % TS and corresponding reduction in % VS.

Figure D-3. Primary Sludge Total and Volatile Solids Pumped. The total and volatile solids to the digester were calculated from the flow and percent solids. The total and volatile solids have increased steadily during the study period. The total solids appear to have increased at a faster rate than the volatile solids, but this information is skewed by the large amount of inert material that entered the plant during the 2008 floods.

Figure D-4. Volatile Solids Reduced in the Digester and Gas Production. The volatile solids reduction in the digester was estimated based on limited data. Also, gas production was graphed on the secondary axis. This shows a true correlation as would be expected.

Figure D-5. Ratio of Gas Produced versus VS Reduced. The information shown in Figure D-4 was used to calculate a ratio of gas produced versus volatile solids reduced. The ratio ranges from 10-40 cf/lb VSR, with some outliers. The average for the range of data was approximately 20 cf/lb. This is higher than typically encountered with municipal sludge, which generally produces approximately 15 cf/lb VSR. The greater gas production observed at Ames may result from periodic grease loads that are pumped directly to the digester.

Figure D-6. Digester SRT. The volume pumped to the digester was used to calculate a solids retention time (SRT). The SRT at Ames is long, with minimum SRT well above 20 days, indicating that excess capacity exists in the digesters. (Minimum SRT typically used for design is 15 days.)

Figure D-7. Digester Gas Produced versus Used in Generators. Generator run hours were examined in conjunction with typical gas usage to estimate gas used in generators. The figure shows gas usage correlates well with gas production. However, there are many dates where gas used exceeds gas produced. Possible explanations include inaccurate gas meter readings, inaccurate gas use readings based on assumed generator average hourly gas use and unmeasured use of stored gas from the secondary digester.

Table 4-4 – Current Digester Solids Loading and Performance

	Current	Max Month
Flow, gpd	26,175	47,682
TS, %	4.20	4.20
Solids, TS	9,175	16,732
Solids, VS	6,693	11,426
VS Load, lb/cf/day	0.035	0.059
VS/TS, %	73%	68%
HRT, day	55	30
VSR, %	63	59
Gas, cf/d *	84,700	133,830
Dig Sludge, lbs	4,908	10,013
Biodegradable Biosolids Fraction	0.66	0.62
* Gas production assumes 20 cf / lb VSR, based on recent data		

4.2.3 Operation and Maintenance Challenges

The compressed digester gas mixing equipment has required extensive maintenance and has questionable mixing effectiveness. WPCF staff has indicated that this equipment is at the end of its useful life and needs replacement.

In addition to the mixing inefficiencies noted above, Ames WPCF staff reports that screenings in the sludge cause operational problems. The existing Headworks mechanical screen deposits influent screenings into a grinder, where they are macerated and returned to the flow. Once in the digester, the macerated screenings tend to rebind into a rag-type material. This affects both the transfer and final disposal of biosolids. The impact of these rags on mixing alternatives is considered in the evaluation of digester mixing alternatives.

5.0 NUTRIENT REMOVAL IMPACTS ON BIOSOLIDS

5.1 Background

The City of Ames currently discharges treated wastewater effluent to the South Skunk River under the terms of an NPDES permit which expired several years ago. The Iowa Department of Natural Resources (IDNR) did not issue a new permit at the time of expiration, due to the unsettled nature of stream classification regulations at that time. A new permit will be issued eventually, and the new permit is anticipated to include strict ammonia and bacteria limits. At some point, future permits are anticipated to include nutrient removal at the Ames WPCF. These permits could include both total nitrogen (TN) and total phosphorus (TP). Past permits for the Ames WPCF have not included such requirements. The addition of nutrient removal processes to the treatment regime at the Ames WPCF will affect the production of biosolids, and thus impact the practices of biosolids storage, handling and land application.

5.2 Emerging Nutrient Limits

IDNR has indicated that nutrient limits are on the horizon, but timing of Environmental Protection Agency (EPA) approval is unknown. IDNR has estimated larger facilities could see nutrient limits in the next permit cycle (within 5 years) and smaller facilities in subsequent cycles (> 5 years). Many reviews, public hearings, appeals and much debate will occur prior to the establishment of final limits. Consequently, the limits are presently unknown but could range from 0.3 to 1.5 mg/l for phosphorus and 3 to 8 mg/l for total nitrogen. This report conservatively assumes a set of limits at the lower end of these likely ranges for estimation of biosolids quantities.

5.3 Assumptions

The timeframe for implementing improvements related to increased sludge quantities for nutrient limits is assumed to be approximately 10 years in the future. For the purposes of estimating sludge quantities, the anticipated effluent quality of the plant is as follows:

- BOD <10 mg/L
- TSS <10 mg/L
- NH3 <1 mg/L
- TN <3 mg/L
- TP <0.5 mg/L

5.4 Nutrient Removal Techniques

Reduction of phosphorus can be accomplished in many ways including: source reduction, biological removal and chemical precipitation/enhanced sedimentation. Reduction of nitrogen is completed through denitrification of nitrified wastewaters. Additional discussion on the nutrient removal techniques can be found the in “Evaluation of Nutrient Removal Alternatives and Solids Production” technical memorandum. This technical memorandum is included in Appendix E.

5.4.1 Phosphorus Removal

Chemical phosphorus removal is flexible and reliable. It has the secondary benefit of binding hydrogen sulfide, thus reducing odors generated from the treatment process. The primary disadvantage of chemical phosphorus removal is the dependence on a corrosive chemical (ferric chloride). In addition to its corrosive characteristics, ferric chloride also may interfere with the ultraviolet (UV) transmittance of wastewater, thus inhibiting UV disinfection. This fact must be considered when designing UV disinfection systems for facilities using iron salts for phosphorus removal.

Biological phosphorus removal is difficult to achieve with a fixed-film secondary treatment process. Anaerobic conditions need to exist in the absence of nitrates for biological phosphorus uptake to occur. Eliminating nitrates is achieved by providing denitrification ahead of an anaerobic zone. Currently, the Ames WPCF uses a fixed-film secondary process without denitrification or anaerobic zones.

5.4.2 Nitrogen Removal

Effluent filters for nitrogen removal would provide great benefits in addition to removal of TN. These benefits include particulate removal of both BOD and TSS, resulting in lower effluent values for those constituents. Methanol was evaluated for the TN-removal carbon source feed, but other sources may be used if readily available. Pilot testing of this TN removal process should be completed to determine sizing, chemical need, chemical type, etc.

5.5 Future Nutrient Impacts

Solids resulting from chemical phosphorus removal when phosphate and hydroxide precipitates are formed by adding metal salts (ferric chloride, etc.) to the primary influent wastewater. Solids result from nitrogen removal in the form of biological solids produced during the growth and decay of denitrifying bacteria. The denitrifying bacteria are present in the filter media and remove the nitrogen (in the form of nitrate in liquid) from the wastewater effluent.

In addition to changes in the *quantity* of solids produced, there will also be changes in the solids *composition* as a result of nutrient removal. The most obvious compositional change is the elemental nutrient content of the sludge. The elemental phosphorus and nitrogen in the sludge should increase by approximately 200 lbs per day and 154 lbs per day, respectively. Estimation of these changes can be further refined by pilot testing.

Current biological solids production (from the secondary processes) will reduce if chemical phosphorus removal is used, due to reduction of BOD to the secondary processes. Particulate BOD removal in the primary clarifiers will increase. This will result in the primary effluent having reduced BOD for secondary removal. The biological growth will be reduced in the trickling filters and solids contact processes. The resulting impact will be similar solids to the digester from BOD removal; however, the readily biodegradable material will increase causing an increase in VSS reduction in the digester. This should also lead to increased gas production assuming all other conditions remain the same.

6.0 PRESENT AND FUTURE BIOSOLIDS PRODUCTION

6.1 Existing Solids Loading Conditions

The existing digester feed information from January 2003 to April 2009 was evaluated to determine historical digester hydraulic and solids loading, solids concentrations, solids destruction and gas production. A summary of the current and maximum month data was provided earlier in Table 4-4. This table identifies data from February 2008 thru February 2009 as “current” data.

6.1.1 Historical Data

The existing flow and loadings are summarized below as defined in the IDNR Wastewater Standards Manual. The information is from plant sampling and testing records for a five-year period from 2003 through 2008.

6.1.1.1 Flow

a) Average Dry Weather Flow = ~4.8 mgd
b) Average Wet Weather Flow = 14.6 mgd (June 2008), 11.3 mgd (May 2007)
c) Max Wet Weather Flow = 26.7 mgd
d) PHWW = No Data

6.1.1.2 BOD Loading

a) Average = 7,433 ppd (2/1/08-end 2008)
b) Max month = 9,203 ppd
c) Max day = 14,973 ppd
d) Peak = No Data

6.1.1.3 TSS Loading

a) Average = 10,126 ppd
b) Max Month = 14,430 ppd
c) Max Day = 51,116ppd
d) Peak = No Data

6.1.1.4 Total Kjeldalh Nitrogen (TKN) Loading

a) Average = 1,708 ppd
Concentration: ~36 mg/L average (range 15-48 mg/L)
b) Max Month = No Data
c) Max Day = ~3,954 ppd
d) Peak = No Data

6.1.1.5 Ammonia (NH_3-N) Loading

a) Average = 1,096 ppd
b) Max Month = 1,449 ppd
c) Max Day = 1,805 ppd
d) Peak = No Data

6.1.1.6 Phosphorus (P) Loading

a) Average = 262 ppd
   Concentration: ~5.5 mg/L average (range 1.4-9.3 mg/l)
b) Max Month = No Data
c) Max Day = ~572 ppd
d) Peak = No Data

6.1.1.7 Land Application Quantities (Included in section 4 of this report)

6.2 Future Biosolids Production

Future biosolids quantities are a combination of the current solids loading, increases from projected growth during the planning period, and increases from nutrient removal processes. Additional discussion on the nutrient removal impacts to biosolids production can be found in the "Evaluation of Nutrient Removal Alternatives and Solids Production" technical memorandum in Appendix E.

Growth. Increased solids loadings from population growth during the planning period was based on the City's planning report that estimated 11.2 percent population growth in the service area between 2010 and 2030. The additional solids loading due to population growth was assumed to be a linear increase and was estimated by multiplying the current loadings by the 11.2 percent projected growth.

Phosphorus removal. Assuming 10 parts of ferric chloride are added for every part of P above the assumed effluent P limit (refer to section 5.3) the solids increase due to chemical phosphorus removal is estimated to be 18 percent or 1,660 lbs/day greater than current solids loadings.

Nitrogen Removal. Approximately 1.1 pounds of biological solids are produced per pound of nitrate (nitrogen). Solids increase due to nitrogen removal is estimated to be 13.5 percent or 1,238 lbs/day greater than current solids loadings.

Total solids increase, if phosphorus and nitrogen removal are needed, is estimated to be 31.5 percent or 2,900 lbs/day greater than current solids loadings. The elemental phosphorus (P) and nitrogen (N) in the sludge should increase by approximately 200 lbs per day and 154 lbs per day, respectively. Including the projected growth, the total solids loading would increase 43 percent, or 3,926 lbs per day. Future average solids loading to the digesters is shown in Table 6-1.

Table 6-1 – Future Average Solids Loading and Characteristics

	Digester Feed		VSS/TSS
	Total Solids Lbs/day	Volatile Solids Lbs/day	
Current	9,175	6,693	72.9%
Growth	1,028	750	72.9%
TN-Removal	1,238	930	75%
TP-Removal	1,660	-0-	0%
Total	13,101	8,373	63.9%
Change from Current	+43%	+25.1%	

The impact of nutrient removal on current loadings was evaluated using a digestion model developed from historical data. The existing digester process was input into an Excel model of the Ames WPCF digestion process and calibrated to existing conditions. The model is used to predict gas production, the percent volatile solids reduction (VSR, %), and resulting digested solids quantity. The nutrient removal impacts are added to the current values.

Table 6-2 summarizes the estimated impact of nutrient removal to total solids production and digester performance using the digester performance model.

The total solids percentage to the digester is expected to increase due to chemical phosphorus removal causing enhanced settling in the primary clarifiers. The estimated increase in percent (%) total solids (TS) due to enhanced settling is 0.2%.

Phosphorus removal will also increase the readily biodegradable fraction of volatile solids (VS) to the digester in the future. The model results in Table 6-2 account for this anticipated increase. Total volatile solids to the digester are expected to remain similar to current levels.

Table 6-2 – Impacts of Nutrient Removal on Solids Production and Digester Performance

	Current w/growth	Max Month w/growth	C+P	MM+P	C+N	MM+N	C+N+P	MM+N+P
Flow, gpd	28,996	52,821	32,328	55,229	32,662	56,655	35,701	58,603
TS, %	4.20	4.20	4.40	4.40	4.20	4.20	4.40	4.40
Solids, TS	10,203	18,607	11,863	20,267	11,441	19,845	13,101	21,505
Solids, VS	7,443	12,653	7,443	12,653	8,373	13,583	8,373	13,583
VS Load, lb/cf/day	0.039	0.066	0.039	0.066	0.043	0.071	0.043	0.071
VS/TS, %	73%	68%	64%	62%	73%	68%	64%	64%
HRT, day	50	27	45	29	44	25	40	27
VSR, %	63	59	64	60	63	59	64	60
Gas, cf/d *	70,000	111,000	70,000	113,000	79,000	123,000	80,000	124,000
Dig Sludge, lbs/day	5,508	11,092	7,182	12746	6,204	12,319	7,764	13,268
Biodegradable Biosolids Fraction	0.66	0.62	0.67	0.63	0.66	0.62	0.67	0.63

C = Current with projected growth
MM = Max Month with projected growth
P = Phosphorus removal
N = Nitrogen removal
* Gas production assumes 15 cf / lb VSR, based on recent data

7.0 BIOSOLIDS STORAGE, HANDLING AND DISPOSAL EVALUATION

7.1 General Alternative Analysis

7.1.1 Background

Five alternatives for biosolids storage, handling and disposal were shortlisted in Workshop II for the project. This section presents each alternative and describes the capital cost elements and the operations and maintenance differences. In addition, a non-economic evaluation has been prepared for each alternative considered.

The capital costs developed for each alternative are based on budget costs for equipment and infrastructure needed to implement the improvements at the Ames WPCF. The capital costs are intended to compare alternatives but are not intended to include all the elements associated with an improvements project. The operations and maintenance costs were developed for each alternative for comparison. These O&M costs were intended to estimate the cost associated with labor, chemicals, power, and other operating costs. The non-economic evaluation scores each alternative on the basis of other important but non-monetary factors.

7.1.2 Assumptions

Development of capital and O&M costs for each alternative assumes the following:

1) 365 days of biosolids will be stored for each alternative (except 1 and 2)
2) Current condition is to store biosolids at an average percent solids of 4.37%
3) Rotary drum thickening will be assumed where thickening is evaluated
4) Aquastore glass lined, open-top tanks will be used for storage tank options
5) Belt filter presses will be assumed for dewatering technologies
6) Labor costs are $28/hr
7) Electricity costs are $.08/KW-hr
8) Polymer costs are based on similar polymer usage at comparable facilities (12 pounds per dry ton (lb/dt) for thickening and 16-20 lb/dt for dewatering)
9) O&M costs increase by 4 percent per year
10) Contractor biosolids land application costs for liquid biosolids up to 8% solids is $.03/gal
11) Contractor biosolids land application costs for dewatered biosolids is $17/wet ton

7.1.3 Ames WPCF Biosolids Quantities

Table 7-1 shows the projected biosolids quantities from the anaerobic digestion process at the Ames WPCF as developed in Section 6 of this report. The biosolids production in gallons is included for multiple assumed percent solids alternatives for four different flow conditions. The flow conditions are:

1) Current – Current biosolids production at 4,958 lb/day
2) Growth – Biosolids production for 2030 based on 11.2 percent population growth in service area (from planning report)
3) Current w/ nutrient removal – Biosolids production based on current rates with additional biosolids produced as a result of nutrient removal
4) Growth w/ nutrient removal – Biosolids produced from 2030 population with additional biosolids produced as a result of nutrient removal

Table 7-1 – Ames WPCF Biosolids Production at Various % Solids (in gal x 1000)

	4% Solids	4.37% Solids	4.5% Solids	6% Solids	8% Solids	20% Solids
Current (2008)	5,425	4,958	4,822	3,616	2,712	1,085
w/Growth (2030)	6,032	5,521	5,362	4,021	3,016	1,206
Current w/Nutrients	7,920	7,249	7,040	5,280	3,960	1,584
Growth w/Nutrients	8,807	8,061	7,828	5,871	4,403	1,761

7.1.4 Description of Alternatives

Several alternatives for biosolids storage, handling and disposal were discussed in Workshop II for further evaluation in this section. Each alternative is a viable solution for the City of Ames and practiced at numerous wastewater treatment facilities in the Midwest. The “future” condition discussed with each alternative is for the increased production of biosolids due to more stringent effluent requirements to further remove nutrients. As indicated in Table 7-1, when further nutrient removal is required a significant increase in biosolids (up to 31.5 percent increase) will be realized. The shortlisted alternatives for further evaluation are:

Alternative 1 – Continue Present Operations
Replace existing biosolids handling and land application equipment and operate as in the past. Repair storage lagoon and replace the biosolids pumping equipment. WPCF staff conducts land application at current rates on permitted land. In the future: add biosolids storage capacity.

Alternative 2 – Contracted Removal and Land Application
Repair existing biosolids storage lagoon and remove lagoon pumping equipment. Contractor to remove and apply biosolids on Ames permitted land at current rates. In the future: add thickening facilities to thicken biosolids to 8 percent solids.

Alternative 3 – Contracted Land Application
Repair existing biosolids storage lagoon and construct an additional storage tank for the remaining storage needs. Contractor to land apply biosolids at current rates to Ames permitted land. In the future: add thickening facilities to thicken biosolids to 8 percent solids.

Alternative 4 – Dewatering, Contracted Land Application
Abandon biosolids storage lagoon. Dewater biosolids from secondary digester; store on-site in cake storage structure, Contractor to land apply dewatered cake at current rates. In the future: continue dewatering for future conditions, and expand cake storage structure for additional biosolids.

Alternative 5 – Thickening, Contracted Land Application
Abandon biosolids storage lagoon. Thicken sludge to 8 percent solids and store in tanks with mixing and loadout facilities. Contractor to land apply on existing permitted land. In the future: provide an additional storage tank.

7.1.5 Economic Summary

The economic summary analysis included capital, O&M, present worth, and equivalent annual cost (EAC) for each alternative as shown in Table 7-17. The capital costs shown are for capital expenditures during the design period as outlined in the alternatives discussions below. Future capital expenditure costs were inflated by 4 percent annually from current (2009) costs. O&M costs shown are for recurring annual costs during the design period as outlined in the alternatives discussion below. O&M costs were inflated by 4 percent annually.

Present worth costs were calculated to compare total costs (capital plus O&M) of alternatives in current (2009) dollars. 10-year and 20-year present worth values were calculated to compare present worth costs before and after nutrient removal, respectively. Both present worth values were calculated using a 7 percent rate of return.

The EAC is the annual cost for each alternative over the 20-year design period. The EAC was calculated using a 7 percent rate of return.

7.1.6 Non-Economic Summary

A non-economic summary was prepared for each alternative. The non-economic summary is intended to give consideration to other elements of each alternative other than cost. The non-economic considerations focus on how the alternative matches the project goals and fits at the Ames WPCF with current staff and management.

7.1.7 Recommendations

The recommendations for each alternative are presented at the end of each of the alternative evaluations. The recommendations are based mainly on economic considerations with some additional attention to the non-economic evaluations. The economic evaluation for the first 10 year period was given the most weight in any economic evaluation. The 20 year economic projections account for the additional biosolids produced after nutrient removal is implemented. There is considerable uncertainty when nutrient removal will be required. For this study, a very conservative approach for additional biosolids produced due to nutrient removal was used.

7.2 Land Application Alternative Comparison

One of the most critical questions for this study is whether the City should continue to land apply biosolids on City-owned farm ground adjacent to the plant, or select a contractor for land application of biosolids. One of the alternatives evaluated later in this chapter includes City land application and the other four include land application by a biosolids contractor. The specific considerations between these two options are discussed more fully in this section.

Several biosolids land application contractors have established businesses in central Iowa. Most have several methods of land disposal available to them. Some have land application options available that are designed to reduce compaction on farmland. These contractors would be able to meet the objectives of the City of Ames.

7.2.1 City Land Application

City to land apply primarily in the fall using City staff and equipment. Costs include capital cost for equipment and O&M costs for labor, power and maintenance of equipment.

7.2.1.1 Summary of Capital Costs

a) Purchase of land application equipment – two tractors, two 6,750 gal wagons, with incorporation equipment
b) Purchase of new lagoon dredge and pumping system
c) At 10 yrs – purchase another tractor and 6,750 gal wagon with incorporation equipment - additional capital $ 270K
d) Total Capital - $400k tractors, $140K for land application equipment, $195K for dredge and pumping equipment = $735K
e) Total Capital at 10 yrs – additional $270K

7.2.1.2 Summary of O & M Costs

a) Labor – 750 manhours @$28/hr
b) Power – pumping
c) Maintenance of equipment
d) Depreciation of mobile equipment - $50k/yr
e) O&M Cost - $21K/ yr for labor, $2K for power, $5K for maintenance and $50K for depreciation = $78K/yr
f) At 10 yrs – Additional labor – 350 manhours and $25K depreciation for additional O&M of $35K/yr

7.2.1.3 Advantages of City Land Application

a) Control – City has control of the operation
b) Coordination with farmers will be good

7.2.1.4 Disadvantages of City Land Application

a) Time consumption (labor and calendar)
b) Large capital investment for equipment used infrequently
c) Maintenance at plant falls behind during land application

7.2.1.5 Present Worth - City Land Application

PW_{10} – $1,607,000
PW_{20} - $2,337,000

7.2.2 Contractor Land Application

City to contract with Biosolids Contractor to land apply spring and fall. Contractor will take care of all pumping, dredging, mixing, hauling, and land application. Costs include annual contract cost as O&M only.

7.2.2.1 Summary of O & M Costs

a) Current solids production at current percent solids is 4.96 mg @ $.03/gal = $150K/yr
b) Credit for staff hours to keep up with maintenance is 750 manhours credit – ($21K/yr credit)
c) Total O&M - $129/yr
d) Future (10 yrs) - $240K/yr for contract land application and an additional credit of ($ 10K/yr) for labor not spent. Total O&M (10 yrs) - $209/yr

7.2.2.2 Advantages of Contractor Land Application

a) City needs less storage – Contractor can land apply quicker and make better use of window of time available
b) Several biosolids contractors are available in the Ames area
c) City can dictate terms of contract
d) Takes less time (labor and calendar); more flexible for weather and for farmers
e) Potential to use Contractor permitted land if needed
f) Can dictate land application method with less compaction

7.2.2.3 Disadvantages of Contractor Land Application

a) Risk of Contractor not performing (loss of control)

7.2.2.4 Present Worth – Biosolids Contractor Land Application

PW_{10} – $1,107,000
PW_{20} - $2,456,000

7.2.3 Recommendation

There are three key issues relating to the recommendation for land application by City or by specialty contractor.

First, the City uses a tremendous amount of labor during the land application season. Plant maintenance is limited to the most critical needs during this time because three maintenance staff work land application. As the plant is getting older, the regular maintenance of equipment to support treatment processes is becoming more essential.

Second, the current practice of land application only in the fall has led the City to provide biosolids storage for 365 days of production. If the time required for land application can be significantly reduced, then the potential exists for spring land application of biosolids to reduce the amount of storage needed. There are years when it is too wet to land apply in the spring. For this reason, it may be wise to plant more City-owned fields to hay so that land application can occur in late spring/early summer. The reduced storage by land applying a significant amount of biosolids in the spring (or early summer) can significantly reduce the costs of storage without much risk. Moreover, greater nutrient uptake by vegetation would occur, enhancing environmental protection.

Finally, the City's current land application equipment is at the end of its useful life and needs significant investment. The economic analysis reflects the replacement costs for the land application equipment. The 10 year present worth analysis shows the contractor land application option carries significantly less cost than City land application.

This study recommends that the City contract for the land application of biosolids. A multi-year contract for biosolids land application should be implemented.

7.3 Comparison of Terragators vs. Tractors

7.3.1 Description of Alternative

Two possibilities were evaluated for land application of biosolids by City staff; use of the existing Terragators or purchase of tractors with pull-behind wagons and incorporation equipment. In order to be a viable option, the existing Terragators need rehabilitation due to age and corrosion. A discussion of these options with a life-cycle analysis is below. After the major repairs needed for the Terragators, it is anticipated that yearly general maintenance would be the same for both options, therefore yearly O&M costs are not factored into the analysis.

7.3.2 Assumptions for Continued Use of Existing Terragators

The existing Ag-Chem Terragators were purchased in 1989 and have been in regular service for the past 20 years. The low side of the rear end was recently overhauled on Terragator #1. Rebuilding the rear axle of unit #2 and the replacement of the knives and backsprings on both units is needed soon. The City has also received a quotation for additional repairs needed on both units for a complete overhaul. These repairs include engine, transmission and radiator replacement or reconditioning as well as brake work and steering cylinder replacement. Electrical work due to the corrosion in the storage area will be needed in the near future as well. It is anticipated that completion of these repairs would allow for another five years of use for the Terragators.

7.3.2.1 Summary of Capital Costs and Timeframe

a) Rebuilding the rear axle of Terragator #2 and the knives for both is anticipated to cost $20,000 immediately
b) Overhaul both Terragators = $165,000 in year 1(includes 25% contingency)
c) The electrical systems of both Terragators will also need an estimated $30,000 of repairs by year 2
d) Current purchase price for a single Terragator with required accessories is $550,000. Two new units are anticipated to be needed in year six.

7.3.2.2 Advantages and Disadvantages of Terragators

a) Plant staff are used to working with them.
b) Reliability of repairs is unknown.
c) Terragators can only be used for land application, not as versatile as other equipment

7.3.2.3 Present Worth – Continued use of Terragators

PW10 = $1,136,200
PW20 = $1,136,200

7.3.3 Assumptions for Tractors and Wagons with Incorporation Equipment

The use of 4-wheel drive tractors with a wagon and incorporation equipment are another alternative for land application by the City. Generally, it is recommended that the tractors be oversized when hauling fully-loaded wagons on uneven terrain. However, the City-owned land has flat slopes with short hauling distances, so larger tractors would not be necessary.

7.3.3.1 Summary of Capital Costs and Timeframe

a) Purchase of two tractors with two wagons and two sets of incorporation equipment will be needed immediately if Terragator repairs are not completed. Cost = $540,000.
b) A third wagon and incorporation equipment is anticipated in 10 years to meet additional capacity demands. Cost = $70,000

7.3.3.2 Advantages and Disadvantages of Tractors

a) Tractors can be used for other tasks at the plant if needed.
b) Storage improvements needed to prevent similar corrosion problems.

7.3.3.3 Present Worth – Tractors and Wagons with Incorporation Equipment

PW10 = $592,700
PW20 = $592,700

7.3.4 Recommendations

The present worth comparison shows that while the immediate purchase of tractors with wagons and incorporation equipment costs more than repairing the Terragators, the longer term comparison shows it to be more economical. It is possible that the purchase of new Terragators could occur in separate years rather than assuming two units needed at the six-year point. Regardless, the immediate repairs needed for the Terragators would not likely allow for a 10-year equipment life and replacement will be needed within that timeframe.

Under either scenario, a vehicle storage area in the north building or improvements to the ventilation in the existing storage area will be needed. Continued use of the existing storage area will result in corrosion to the equipment, similar to what has occurred with the existing Terragators.

Due to the lower present worth and greater versatility of tractors, this equipment will be assumed for alternatives involving City land application.

7.4 Alternative 1 – Store Liquid Sludge in Lagoon, Land Application by City, Add Storage Tanks in Future

7.4.1 Description of Alternative

Replace the existing equipment and operate as in the past. Replace land application equipment, rehab storage lagoon with pumping equipment, City to land apply biosolids at current rates on permitted land. Store biosolids in liquid up to 4.37% solids now through decanting and with growth either 1) add storage volume for liquid sludge (See tank option in Alternative 3), or 2) get by with less days in storage, or 3) have contractor land apply 500,000 gal in Spring (selected for evaluation). In the future (when the nutrient removal requirements are implemented) add two additional storage tanks with mixing and loadout facilities. A site plan for this alternative is included at the end of this section.

7.4.2 Assumptions

1) Biosolids storage for this alternative will be less than 365 days of biosolids produced
2) Land application by contractor of 500,000 gal in Spring (for growth @ year 1-5 and 1.0 MG year 5-10)
3) Replace lagoon liner
4) Store liquid sludge with decanting up to 4.37% solids
5) In future (year 10) include two sludge storage tanks
6) Replace fixed pump with new pump on lagoon dredge (or PTO driven pump)
7) Labor for land application will be generally the same as the past
8) Power costs $.08/KW hr
9) Land application with 4 wheel drive tractor and wagons
10) 10 year – add storage tanks with mixing and loadout and another set of land application equipment

7.4.3 Summary of Capital Cost Items

1) Replace sludge lagoon liner
2) Replace sludge pumping equipment in lagoon
3) New land application equipment
4) 10 yr – 2 storage tanks w/ mixing and loadout
5) 10 yr – additional land application equipment

7.4.3.1 Repair existing sludge lagoon

a) Remove sludge
b) Replace lagoon liner

7.4.3.2 Replace sludge pumping equipment

a) New lagoon dredge and pumping equipment

7.4.3.3 Replace land application equipment

a) Two new 6,750 gallon pull-behind wagons with incorporation equipment to be pulled behind a 4-wheel drive tractor for incorporation into the soil.
b) Two new 4-wheel drive tractors
c) At 10 yrs – Purchase 3rd wagon and incorporation equipment and lease third tractor for additional biosolids land application

Table 7-2 – Alternative 1 - Opinion of Probable Construction Cost

Item Description	Quantity	Unit	Unit Cost	Total Cost
Repair existing sludge lagoon				
Clean and dewater lagoon		Lump Sum	8000	$8,000
Replace lagoon liner	50000	sq ft	1.00	$50,000
			subtotal	$58,000
Sludge Pumping Equipment				
Dredge (or PTO pump)		Lump Sum	140000	$140,000
Pumps and piping	2	Each	20000	$40,000
Electrical & Controls		Lump Sum	15000	$15,000
			subtotal	$195,000
Land Application Equipment				
Pull behind Wagon, 6,750 gal	2	Each	50000	$100,000
Incorporation equip.	2	Each	20000	$40,000
4 wheel dr tractor	2	Each	200000	$400,000
			subtotal	$540,000
	Subtotal - Alternative 1 Capital Cost			$793,000

Year 10 Capital costs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Additional Storage w/ mixing				
Storage tanks, 2 @ 1.6 MG w/ concrete foundation	2	Each	721000	$1,442,000
Recirculation Mixing/loadout		Lump Sum	150000	$150,000
Building	600	sq ft	180.00	$108,000
			subtotal	$1,700,000
Land Application Equipment				
6,750 gal wagon	1	Each	50000	$50,000
incorporation eq		Lump Sum	20000	$20,000
			subtotal	$70,000
	Subtotal - Additional 10 year Capital Cost			$1,770,000

7.4.4 Summary of Operations and Maintenance Costs

1) Labor – $28/hr @ 750 hrs/yr for pumping and land application
2) Power – for pumping
3) Maintenance on tractors and equipment
4) Depreciation for mobile equipment - $50K/yr
5) At 10 yrs – tractor rental - $50/hr, additional labor 350 manhours, and additional depreciation
6) Contractor land application @ $.03/gal starting year 1 thru 5 (500,000 gal) and year 5 thru 10 (1.0 MG)

Table 7-3 – Alternative 1 - Annual Operations & Maintenance Costs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Sludge Pumping				
Labor - Covered in land app.				
Power - 100 hp @ 200 hrs/yr	25000	KW	0.08	$2,000
Land Application				
Labor - 750 manhours	750	hrs	28	$21,000
Fuel		Lump Sum	2000	$2,000
Equip Maintenance		Lump Sum	5000	$5,000
Land Application by Contractor (year 1-5)	500,000	gal	0.03	$15,000
Depreciation for equipment		Lump Sum	50000	$50,000
	Subtotal - Alt 1 Annual O&M (current)			$95,000
Additional O&M				
Land Application by Contractor (year 5-10)	500,000	gal	0.03	$15,000
Year 10 - Additional storage				
Power				$2,000
Year 10 - Additional Land Application				
Lease				$16,000
Labor				$12,000
Equip Maint				$1,000
Fuel				$1,000
Depreciation for equipment		Lump Sum	5000	$5,000
	Subtotal - Annual O&M (future)			$52,000

7.4.5 Present Worth Analysis

PW_{10} – $3,000,000
PW_{20} - $3,755,000

Table 7-4 – Alternative 1 - Non-Economic Evaluation Worksheet

Evaluation Factor	Description	Score
Fits with current operations	Closest to existing operation	++
Ease of operations	Spend lots of manhours to pump and land apply	- -
Fits with current site	Future will need additional space	+
Use of Existing Infrastructure	Continue to use secondary digester and lagoon	++
Flexible		-
Reliance on contractors	None	++
Compatible with farmers		0
Proprietary		++
subtotal		6
Notes:		
Total		
Key: ++ Very Favorable = 2, + Favorable = 1, 0 Neutral = 0, - Less Favorable = -1, -- Unfavorable = -2		

Insert Alternative 1 Plan Sheet

7.4.6 Recommendation

This alternative is not recommended for several reasons.

First, as the previous evaluation shows, it is less expensive for a biosolids contractor to remove and land apply biosolids. This is primarily due to the amount of staff time required for the handling and land application process.

This alternative also has less flexibility due to the reduced biosolids storage and the requirement that biosolids be land applied at other times of the year in addition to fall. It consumes the most WPCF staff time for biosolids handling and land application and requires the most capital investment for biosolids storage infrastructure in the future. The present worth at 10 years is not the lowest nor does it reflect the lack of flexibility compared to the other alternatives.

Many of the negatives of this alternative are discussed in the City vs. contractor land application evaluation presented in Section 7.2 of this report. The non-economic evaluation indicates this option is positive because of familiarity but weak due to investment of staff time and flexibility.

7.5 Alternative 2 – Store Liquid Sludge in Lagoon, Land Application by Contractor, Future Thickening

7.5.1 Description of Alternative

Repair existing sludge lagoon, store liquid sludge, remove lagoon pumping equipment, contractor to land apply at current rates on existing permitted land. In the future (when the nutrient removal requirements are implemented) thicken sludge up to 8 percent to work with existing storage volume. A site plan for this alternative is included at the end of this section.

7.5.2 Assumptions

1) Biosolids storage for this alternative will be less than 365 days of storage
2) Land application by contractor of 500,000 gal in Spring (for year 1 thru 5 and 1.0 MG for year 5 thru 10)
3) Replace existing lagoon liner with new liner.
4) Store liquid sludge with decanting up to 4.37 percent solids
5) Remove lagoon pumping equipment (City will no longer pump sludge from lagoon).
6) Land application by contractor at $.03/gal
7) Power costs $.08/KW hr
8) 10 year – Thickening facilities – includes; rotary drum thickeners (RDTs), polymer system, RDT feed pumps, thickened sludge pumps and building.
9) Manhours currently used for land application will be credited to O&M costs for this alternative

7.5.3 Summary of Capital Cost Items

1) Repair existing sludge lagoon and replace lagoon liner
2) Purchase land application equipment (6,750 gal tank wagon, pump and incorporation equipment) for contingency
3) 10 yrs - Thickening facility

7.5.3.1 Repair existing sludge lagoon

a) Remove sludge
b) Replace sludge lagoon liner with new

7.5.3.2 Replace land application equipment

a) One new 6,750 gallon pull-behind wagon with incorporation equipment to be pulled behind a 4-wheel drive tractor for incorporation into the soil.
b) One lagoon pump to be used to pump lagoon as needed by City
c) Tractor to be leased locally as needed

7.5.3.3 Thickening Facility (year 10)

a) Two rotary drum thickeners
b) RDT feed pumps
c) Thickened sludge pumps
d) Polymer system
e) Building

Table 7-5 – Alternative 2 - Opinion of Probable Construction Cost

Item Description	Quantity	Unit	Unit Cost	Total Cost
Repair existing sludge lagoon				
Clean and dewater lagoon		Lump Sum	8000	$8,000
Replace lagoon liner	50,000	sq ft	1.00	$50,000
			subtotal	$58,000
Land Application Equipment				
Purchase of PTO driven pump		Lump Sum	25000	$25,000
Pull behind wagon, 6,750 gal	1	Each	50000	$50,000
Incorporation equip.		Lump Sum	20000	$20,000
			subtotal	$95,000
	Subtotal - Alternative 2 Capital Cost			**$153,000**

Year 10 Capital costs - Add thickening facilities

Item Description	Quantity	Unit	Unit Cost	Total Cost
Thickening Facility				
Rotary drum thickeners	2	Each	150000	$300,000
RDT feed pumps	2	Each	20000	$40,000
Thickened sludge pumps	2	Each	30000	$60,000
Polymer system		Lump Sum	50000	$50,000
Thickening Building	2000	sq ft	180	$360,000
Process piping		Lump Sum	25000	$25,000
Mechanical		Lump Sum	30000	$30,000
Electrical & Controls		Lump Sum	150000	$150,000
			subtotal	$1,015,000
	Subtotal - Capital Cost - 10 years			**$1,015,000**

7.5.4 Summary of Operations and Maintenance Costs

1) Land application - $.03/gal (up to 8% thickened sludge)
2) 10 years – Additional labor, polymer, power, and land application costs

Table 7-6 – Alternative 2 - Annual Operations & Maintenance Costs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Land Application by Contractor				
Removal and land app	5,000,000	gal	0.03	$150,000
Depreciation		Lump sum	5000	$5,000
Manhours credit	750	hours	28	-$21,000
	Subtotal - Alt 2 Annual O&M (current)			$134,000

Item Description	Quantity	Unit	Unit Cost	Total Cost
Additional O&M				
Year 5 - Land Application by Contractor	500,000	gal	0.03	$15,000
Year 10 - Thickening				
Power				$1,000
Chemicals - Polymer				$10,000
Labor				$12,000
Land Application				$30,000
Manhours credit	360	hours	28	-$10,000
	Subtotal - Alt 2 Annual O&M (10 years)			$58,000

7.5.5 Present Worth

PW_{10} = $2,126,000
PW_{20} = $3,172,000

Table 7-7 – Alternative 2 - Non-Economic Evaluation Worksheet

Evaluation Factor	Description	Score
Fits with current operations	Very similar	++
Ease of operations	Easy operation. Thicken in future	+
Fits with current site		+
Use of Existing Infrastructure	Continue to use existing secondary digester and lagoon	++
Flexible		0
Reliance on contractors	Several able to do land application	-
Compatible with farmers		++
Proprietary		++
subtotal		9
Notes:		
Total		
Key: ++ Very Favorable = 2, + Favorable = 1, 0 Neutral = 0, - Less Favorable = -1, -- Unfavorable = -2		

Insert Alternative 2 Plan Sheet

7.5.6 Recommendation

This alternative has the least expensive present worth of all the options and is one of the highest scoring non-economic options. However there are several limitations with this alternative.

This alternative is not as flexible due to the reduced storage. The existing 3.1 million gallon sludge lagoon has enough storage at current biosolids production rates for approximately 230 days of storage. This will provide adequate time for land application of biosolids in fall and spring assuming the weather is suitable. A contingency plan will be needed during those years when land application is difficult due to wet land. That contingency might be met by having the City obtain additional land outside the flood plain. The additional land needed would be around 150 acres. This contingency could be met by having the biosolids contractor haul to other sites but this might be complicated due to the need to cross the county road bridge.

Another limitation of this alternative is the inability to remove biosolids from the lagoon if the City wants to land apply biosolids. A lagoon pump has been included; neverless, removal of biosolids from the lagoon would be difficult.

This option could be implemented on a trial basis to see how land application by contractor works in practice. It is anticipated that in normal years the biosolids land application will be completed in less than a week in the spring and fall. The City will have land application equipment that can be used as a contingency or as a regular practice on summer hay ground or as staff time permits.

In summary, this alternative is not recommended for the Ames WPCF. Its lack of flexibility is of primary concern.

7.6 Alternative 3 – Store Liquid Sludge in Lagoon and Storage Tank, Land Application by Contractor, Thicken Sludge in Future

7.6.1 Description of Alternative

Repair existing sludge lagoon, store liquid sludge, add a storage tank to supplement storage, remove lagoon pumping equipment, contractor to land apply at current rates on existing permitted land. In the future (when the nutrient removal requirements are implemented) thicken sludge up to 8% to work with existing storage volume. A site plan for this alternative is included at the end of this section.

7.6.2 Assumptions

1) Examine current condition with storage of 100% of biosolids produced (365 days)
2) Replace existing lagoon liner with new liner.
3) Store liquid sludge with decanting up to 4.37% solids
4) Aquastore open top storage tank with recirculation mixing
5) Future thickening equipment in expansion of mixing facility
6) Remove lagoon pumping equipment (City will no longer pump sludge from lagoon).
7) Land application by contractor at $.03/gal
8) Power costs $.08/KW hr
9) 10 year – Thickening Facilities – includes; rotary drum thickeners, polymer system, RDT feed pumps, thickened sludge pumps and building
10) Manhours currently used for land application will be credited to O&M costs for this alternative

7.6.3 Summary of Capital Cost Items

1) Repair existing sludge and replace lagoon liner
2) Add new 1.6 MG sludge storage tank
3) Sludge mixing and loadout building
4) Purchase land application equipment (Tractor with 6,750 gal tank wagon and incorporation equipment) for contingency
5) 10 year – Add thickening facilities

7.6.3.1 Repair existing sludge lagoon

a) Remove sludge
b) Replace sludge lagoon liner with new

7.6.3.2 New sludge storage tank

a) Open top storage tank with concrete foundation (1.6 MG and 120 ft diam.)

7.6.3.3 Replace land application equipment

a) One new 6,750 gallon pull-behind wagon with incorporation equipment to be pulled behind a 4-wheel drive tractor for incorporation into the soil.
b) Tractor to be purchased for contingency use.

7.6.3.4 Sludge mixing building

a) Recirculation mixing in 600 sq. ft. building with site area available for expansion for future thickening equipment.

Table 7-8 – Alternative 3 - Opinion of Probable Construction Cost

Item Description	Quantity	Unit	Unit Cost	Total Cost
Repair existing sludge lagoon				
Clean and dewater lagoon		Lump Sum	8000	$8,000
Replace lagoon liner	50,000	sq ft	1.00	$50,000
			subtotal	$58,000
Sludge Storage Tank				
Tank w/concrete foundation	1	Each	721000	$721,000
Mixing system building	600	sq ft	180	$108,000
Mixing/loadout system		Lump Sum	150000	$150,000
Piping		Lump Sum	20000	$20,000
Electrical & Controls		Lump Sum	60000	$60,000
			subtotal	$1,059,000
Land Application Equipment				
Tractor (4-wheel drive)	1	Each	200000	$200,000
Pull behind wagon, 6,750 gal	1	Each	50000	$50,000
Incorporation equip.		Lump Sum	20000	$20,000
			subtotal	$70,000
	Subtotal - Alternative 3 Capital Cost			**$1,387,000**

Additional Capital Costs (at 10 yrs) - Add thickening facilities to thicken to 8% solids

Item Description	Quantity	Unit	Unit Cost	Total Cost
Thickening Facility				
Rotary drum thickeners	2	Each	150000	$300,000
RDT feed pumps	2	Each	20000	$40,000
Thickened sludge pumps	2	Each	30000	$60,000
Polymer system		Lump Sum	50000	$50,000
Thickening Building	2000	sq ft	180	$360,000
Process piping		Lump Sum	25000	$25,000
Mechanical		Lump Sum	30000	$30,000
Electrical & Controls		Lump Sum	150000	$150,000
			subtotal	$1,015,000
	Subtotal - Capital Cost - 10 years			**$1,015,000**

7.6.4 Summary of Operations and Maintenance Costs

1) Power – for pumping, mixing
2) Contractor land application @ $.03/gal (up to 8% thickened sludge)
3) 10 yrs – Additional labor, power, polymer, and land application

Table 7-9 – Alternative 3 - Annual Operations & Maintenance Costs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Land Application by Contractor				
Removal and land app	5,000,000	gal	0.03	$150,000
Depreciation		Lump sum	5000	$5,000
Manhours credit	750	hours	28	-$21,000
	Subtotal - Alt 3 Annual O&M (current)			$134,000

Additional O&M at 10 yrs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Year 10 - Thickening				
Power				$2,000
Chemicals - Polymer				$10,000
Labor				$12,000
Land Application				$30,000
Manhours credit	360	hours	28	-$10,000
	Subtotal - Alt 3 Annual O&M (10 years)			$44,000

7.6.5 Present Worth Analysis

PW_{10} – $3,306,000
PW_{20} - $4,450,000

Table 7-10 – Alternative 3 - Non-Economic Evaluation Worksheet

Evaluation Factor	Description	Score
Fits with current operations	Additional storage tank	+
Ease of operations	Easy operation, thickening in future	+
Fits with current site		+
Use of Existing Infrastructure	Continue to use existing secondary digester and lagoon, no pumping	++
Flexible		++
Reliance on contractors		0
Compatible with farmers		++
Proprietary		++
subtotal		11
Notes:		
Total		
Key: ++ Very Favorable = 2, + Favorable = 1, 0 Neutral = 0, - Less Favorable = -1, -- Unfavorable = -2		

Insert Alternative 3 Plan Sheet

7.6.6 Recommendation

This alternative is the recommended alternative for the City of Ames. It provides a great amount of flexibility with biosolids storage, handling and land application both now and in the future.

The storage tank included with this alternative increases the available storage from 230 days to 365 days at current production. This additional storage will address the occasional wet fall seasons when biosolids land application is impossible. With this additional storage it is not likely that additional farmland for land application is necessary.

The provision of the sludge loadout facilities will allow the City to land apply some of the biosolids in spring or on hay crop during early summer as they have staff available. This operation can be done without the labor intensive pumping from the lagoon.

7.7 Alternative 4 - Dewater Sludge and Store in Concrete Storage Tanks, Land Application by Contractor

7.7.1 Description of Alternative

Abandon existing sludge holding lagoon, dewater digested sludge from Secondary Digester, store dewatered cake sludge in above-ground concrete storage tank and land application by contract hauler. A site plan for this alternative is included at the end of this section.

7.7.2 Assumptions

1) Examine current condition, current with growth and current with growth + nutrient removal. Store 100% of biosolids produced (365 days)
2) Rotary press or belt filter press for dewatering, dewater sludge from secondary digester to 24% solids
3) Cast-in-place concrete open top structure for sludge storage built into hillside
4) Capital cost for Contractor land application includes a City purchase of a manure spreader
5) Dewater up to 2 days per week at current and up to 4 days per week at max future condition
6) Storage area adjacent to dewatering area. Belt conveyor used to handle cake.
7) One operator assigned to dewatering for this operation
8) Land application by contractor at $17/wt
9) Power costs $.08/KW hr
10) Manhours currently used for land application will be credited to O&M costs for this alternative

7.7.3 Summary of Capital Cost Items

1) Abandon existing sludge lagoon
2) Dewatering facility
3) Dewatered sludge storage adjacent to dewatering building
4) Manure spreader
5) 10 yrs – Additional storage (expansion) required

7.7.3.1 Abandon existing sludge lagoon

a) Remove sludge
b) Remove liner, piping, dredge, pumping equipment
c) Backfill

7.7.3.2 Dewatering Facility

a) Two (2) 2-meter belt filter presses or a 6-channel rotary press
b) Belt filter press feed pumps – progressing cavity
c) Belt conveyor to storage area
d) Polymer system
e) Dewatering Building, 2,500 sq ft
f) Mechanical and Electrical costs (as % of construction)

7.7.3.3 Dewatered Sludge Storage

a) Cast-in-place concrete tank divided into 2 cells with aluminum stop logs for loading. Future third cell when nutrient removal requirements are implemented.

7.7.3.4 Manure Spreader

a) Tractor will be leased locally

Table 7-11 – Alternative 4 - Opinion of Probable Construction Cost

Item Description	Quantity	Unit	Unit Cost	Total Cost
Abandon existing sludge lagoon				
Demolition & disposal		Lump Sum	15000	$15,000
			subtotal	$15,000
Dewatering Facility				
Belt Filter Presses	2	Each	385000	$770,000
BFP feed pumps	2	Each	20000	$40,000
Sludge Cake Conveyors	2	Each	50000	$100,000
Polymer system		Lump Sum	50000	$50,000
Dewatering Building	2500	sq ft	180	$450,000
Process piping		Lump Sum	20000	$20,000
Mechanical		Lump Sum	30000	$30,000
Electrical & Controls		Lump Sum	150000	$150,000
			subtotal	$1,610,000
CIP Concrete Sludge Cake Storage Cells				
Structural fill		Lump Sum	15000	$15,000
Sidewalls	600	CY	700	$420,000
Slab & footings	840	CY	400	$336,000
Stop Logs		Lump Sum	30000	$30,000
Electrical & Controls		Lump Sum	15000	$15,000
			subtotal	$801,000
Manure Spreader		Lump Sum	50000	$50,000
			subtotal	$50,000
	Subtotal - Alternative 4 Capital Cost			$2,476,000

10 year Capital costs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Expansion of dewatered cake storage facility		Lump Sum	300000	$300,000
	Subtotal - Alt 4 Capital Cost - 10 yrs			$300,000

7.7.4 Summary of Operations and Maintenance Costs

1) Labor – 1 additional operator
2) Chemicals – polymer
3) Power – for pumping, dewatering, handling and building
4) Land application - $17/wet ton (24% dewatered cake)
5) 10 years – Additional labor, power, polymer, and land application

Table 7-12 – Alternative 4 - Annual Operations & Maintenance Costs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Dewatering Process				
Labor - 4 hrs/day at 2 days/week	420	hrs	28	$12,000
Power - 30 hp at 16 hrs/ wk	18613	KWH	0.08	$1,500
Polymer	15385	lb	2	$31,000
Sludge Cake Handling				
Labor - No additional labor				
Land Application				
Contractor - $17/wet ton	3772	wet ton	17	$64,124
Manhours credit	750	hours	28	-$21,000
	Subtotal - Alt 4 Annual O&M (current)			$87,624

Additional O&M - year 10

Item Description	Quantity	Unit	Unit Cost	Total Cost
Dewatering				
Labor				$6,000
Power				$700
Polymer				$15,000
Land Application	1600	wet ton	17	$27,200
Manhours credit	360	hours	28	-$10,000
	Subtotal - Alt 4 Annual O&M (10 yrs)			$38,900

7.7.5 Present Worth Analysis

PW_{10} – $3,454,000
PW_{20} - $4,271,000

Table 7-13 – Alternative 4 - Non-Economic Evaluation Worksheet

Evaluation Factor	Description	Score
Fits with current operations	Most different from current operation	- -
Ease of operations	Additional dewatering process	-
Fits with current site		+
Use of Existing Infrastructure	Continue to use existing secondary digester	+
Flexible		++
Reliance on contractors	Cake application	0
Compatible with farmers		+
Proprietary		++
subtotal		4
Notes:		
Total		
Key: ++ Very Favorable = 2, + Favorable = 1, 0 Neutral = 0, - Less Favorable = -1, -- Unfavorable = -2		

Insert Alternative 4 Plan Sheet

7.7.6 Recommendation

This alternative is not recommended for the City of Ames due to its high initial capital cost.

This alternative relies on further processing of biosolids into a dewatered cake. Because the current land application sites are so close to the Ames WPCF, the usual advantage of a drier cake is not realized. If the haul distance to the farm fields were greater, the reduced hauling costs could sway this alternative for further consideration.

The non-economic evaluation scored this alternative the lowest primarily because it is the most different from the City's current practice.

The amount of cake storage included in this alternative could be reduced to provide an amount closer to 200 days. This would reduce the initial capital cost and present worth by approximately $200K - $300K.

7.8 Alternative 5 – Thicken Sludge and Store in Storage Tanks, Land Application by Contractor

7.8.1 Description of Alternative

Abandon existing sludge holding lagoon, thicken digested sludge from Secondary Digester, store thickened sludge in aboveground storage tanks, land application by contract hauler. A site plan for this alternative is included at the end of this section.

7.8.2 Assumptions

1) Examine current condition, current with growth and current with growth + nutrient removal. Store 100% of biosolids produced (365 days)
2) Rotary drum thickener for thickening, thicken sludge from secondary digester to 7% solids
3) Aquastore open top tanks for sludge storage with recirculation mixing and loadout located on existing lagoon storage site
4) Capital cost for Contractor land application includes a City purchased 6,750 gal tanker and incorporation equipment (rent tractor)
5) Thicken 2 days per week at current and up to 4 days per week at max future condition
6) No additional operator until nutrient removal starts (10 yrs), then one full time operator for this operation
7) Land application by contractor at $.03/gal
8) Power costs $.08/KW hr
9) Manhours currently used for land application will be credited to O&M costs for this alternative

7.8.3 Summary of Capital Cost Items (for comparison)

1) Abandon existing sludge lagoon
2) Thickening facility
3) Thickened sludge storage tanks with pumped recirculation mixing and loadout
4) 6,750 gal pull behind wagon w/ incorporation equipment
5) 10 year – Additional storage tank

7.8.3.1 Abandon existing sludge lagoon

a) Remove sludge
b) Remove liner, piping, dredge, pumping equipment
c) Backfill

7.8.3.2 Thickening Facility

a) Two (2) rotary drum thickeners at 200 gpm each
b) RDT feed pumps (2) - centrifugal
c) Thickened sludge pumps (2) – progressive cavity
d) Polymer system
e) Thickening Building, 2,000 sq ft
f) Mechanical and Electrical costs (as % of construction)

7.8.3.3 Thickened Sludge Storage Tanks

a) Aquastore glass lined open top tanks with concrete foundation – Two (120 ft diam) tanks at approx 1.6 MG to handle current operation and for growth until nutrient removal. Will need a third tank (same size) when nutrient removal requirements are implemented.
b) Pump recirculation mixing system with loadout. One set of pumps to serve two mixing systems (each tank) with a loadout station. Mixing pumps in a small building.

Table 7-14 – Alternative 5 - Opinion of Probable Construction Cost

Item Description	Quantity	Unit	Unit Cost	Total Cost
Abandon existing sludge lagoon				
Demolition & disposal		Lump Sum	15000	$15,000
Backfill	10000	cu yd	3.00	$30,000
			subtotal	$45,000
Thickening Facility				
Rotary drum thickeners	2	Each	150000	$300,000
RDT feed pumps	2	Each	20000	$40,000
Thickened sludge pumps	2	Each	30000	$60,000
Polymer system		Lump Sum	50000	$50,000
Thickening Building	2000	sq ft	180	$360,000
Process piping		Lump Sum	25000	$25,000
Mechanical		Lump Sum	30000	$30,000
Electrical & Controls		Lump Sum	150000	$150,000
			subtotal	$1,015,000
Thickened Sludge Storage Tanks				
Tank w/ concrete foundation	2	Each	721000	$1,442,000
Mixing system building	600	sq ft	180	$108,000
Mixing/loadout system		Lump Sum	150000	$150,000
Piping		Lump Sum	30000	$30,000
Electrical & Controls		Lump Sum	80000	$80,000
			subtotal	$1,810,000
Pull behind wagon, 6750 gal		Lump Sum	50000	$50,000
Incorporation equip.		Lump Sum	20000	$20,000
			subtotal	$70,000
	Subtotal - Alternative 5 Capital Cost			$2,940,000

Year 10 Capital costs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Thickened Sludge Storage Tanks				
Tank w/ concrete foundation	1	Each	721000	$721,000
	Subtotal - Alt 5 Capital Cost - 10 year			$721,000

7.8.4 Summary of Operations and Maintenance Costs – (for comparison)

1) Labor – current – within current staffing
2) Chemicals – polymer
3) Power – for pumping, thickening, mixing and building
4) Land application - $.03/gal (7% thickened sludge)
5) 10 years – Additional labor, power, polymer, and land application

Table 7-15 – Alternative 5 - Annual Operations & Maintenance Costs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Thickening Process				
Power - 20 hp at 16 hrs/ wk		Lump sum		$1,000
Polymer		Lump sum		$12,000
Sludge Mixing				
Labor - No additional labor				
Power - 100 hp @ 336 hrs/yr	25055	KWH	0.08	$2,000
Land Application				
Contractor - $.03/gal	2.7	MG	30000	$81,000
Manhours credit	750	hours	28	-$21,000
	Subtotal - Alt 5 Annual O&M (current)			$75,000

Yr 10 Additional O&M costs

Item Description	Quantity	Unit	Unit Cost	Total Cost
Labor				$12,000
Power				$500
Polymer				$6,000
Land application	1.7	MG	30000	$51,000
Manhours credit	360	hours	28	-$10,000
	Subtotal - Alt 5 Annual O&M (10 year)			$59,500

7.8.5 Present Worth Analysis

PW_{10} – $4,126,000
PW_{20} - $4,995,000

Table 7-16 – Alternative 5 - Non-Economic Evaluation Worksheet

Evaluation Factor	Description	Score
Fits with current operations		0
Ease of operations	Easy operation, trade off in manpower	0
Fits with current site	Construction sequence will be challenging	+
Use of Existing Infrastructure	Continue to use existing secondary digester	0
Flexible		++
Reliance on contractors	Several able to do land application	0
Compatible with farmers		+
Proprietary		++
subtotal		6
Notes:		
Total		
Key: ++ Very Favorable = 2, + Favorable = 1, 0 Neutral = 0, - Less Favorable = -1, -- Unfavorable = -2		

Insert Alternative 5 Plan Sheet

7.8.6 Recommendation

This alternative is not recommended for the City of Ames due to its high initial capital cost.

This alternative relies on further processing of biosolids into a thickened sludge. Similar to Alternative 4, the advantage of a more thickened biosolids is not realized because of the relatively short haul distances to the farm fields.

The non-economic evaluation scored this alternative in the middle of the alternatives. It was positive from a flexibility standpoint and did not receive any negative non-economic scores.

7.9 Recommended Alternative

A summary of the economic and non-economic evaluations is included here for all the alternatives.

Table 7-17 – Land Application Alternatives Economic Analysis Summary

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Capital Cost (yr 0)*	$793,000	$153,000	$1,387,000	$2,476,000	$2,940,000
Capital Cost (yr 10)*	$1,770,000	$1,015,000	$1,015,000	$300,000	$721,000
Annual O&M Cost (yr 0-5)*	$95,000	$134,000	$134,000	$87,624	$75,000
Annual O&M Cost (yr 6-10)*	$110,000	$149,000	$134,000	$87,624	$75,000
Annual O&M Cost (yr 11-20)*	$117,000	$162,000	$178,000	$126,524	$134,500
10 Year Total Present Worth (PW10)*	$3,000,000	$2,126,000	$3,306,000	$3,454,000	$4,126,000
20 Year Total Present Worth (PW20)*	$3,755,000	$3,172,000	$4,450,000	$4,271,000	$4,995,000
Equivalent Annual Cost	($354,000)	($299,000)	($419,000)	($403,000)	($471,000)
PW10 Rank	2	1	3	4	5
PW20 Rank	2	1	4	3	5

* 2009 dollars

Table 7-18 – Summary - All Alternatives Non-Economic Evaluation Worksheet

Evaluation Factor	Alternative 1 Score	Alternative 2 Score	Alternative 3 Score	Alternative 4 Score	Alternative 5 Score
Fits with current operations	++	++	+	- -	0
Ease of operations	- -	+	+	-	0
Fits with current site	+	+	+	+	+
Use of Existing Infrastructure	++	++	++	+	0
Flexible	-	0	++	++	++
Reliance on contractors	++	-	0	0	0
Compatible with farmers	0	++	++	+	+
Proprietary	++	++	++	++	++
subtotal	6	9	11	4	6
Notes:					
Total					
Key: ++ Very Favorable = 2, + Favorable = 1, 0 Neutral = 0, - Less Favorable = -1, -- Unfavorable = -2					

As presented in Sections 7.4 through 7.8 the recommended alternative for Ames WPCF is Alternative 3. Alternative 3 includes the construction of a 1.6 MG biosolids storage tank with mixing and loadout system, rehabilitation of the existing sludge storage lagoon and land application by biosolids contractor. In the future as the biosolids production increases as a result of nutrient removal, a biosolids thickening facility will be constructed.

Alternative 3 is a flexible alternative with many non-economic advantages. It best fits the goals established by the study team as identified in Section 2 of this report.

The implementation of Alternative 3 allows the City of Ames to start land application of biosolids through a biosolids contractor with little initial capital investment. The storage tank can be constructed as funding is secured at a later date. After a few years of land application by contractor, the City can reevaluate the contractor process if desired.

8.0 ANAEROBIC DIGESTER MIXING EVALUATION

8.1 General Alternatives Analysis

8.1.1 Mixing System Objectives:

The current digester capacity is adequate for the population growth projections in the Land Use Policy Plan and the likely additional demand from future nutrient requirements. The digester performance is within the normal range. However, the digester is the most corrosive environment in a plant, and a 20-year lifespan for a mixing system is common. Plant staff has reported the replacement of lobes on the current gas compressors approximately every two years. Additionally, the current draft tubes need to be recoated.

The objectives of the digester mixing system are to improve operational performance by:

1) Reducing thermal stratification
2) Minimizing scum accumulation
3) Creating uniform physical, chemical, and biological conditions throughout the digester
4) Dispersing toxic chemicals that may enter the digester
5) Maximizing the effective volume of the digester
6) Promoting separation of product gases
7) Keeping inorganic matter in suspension
8) Circulating the substrate to encourage contact between the sludge feed and the active biomass

8.1.2 Basis of Design

The basis of design for mixing is to turn over the digester contents in 20-30 minutes at a power requirement of 0.2-1.5 hp/1,000 cubic feet. Thus, the minimum horsepower for Ames for a mechanical mixer is approximately 25 Hp or the equivalent for gas systems. These guidelines were used to review and compare selected mixing system replacement alternatives.

Information on each of the technologies considered including equipment sketches and vendor information is included in Appendix G of this report.

8.2 Alternative 1 – Confined Gas Mixing System

8.2.1 Description of Alternative

The Cannon Mixing System, manufactured by Infilco Degremont, uses a confined gas mixing system. Gas produced in the digestion process is compressed and recirculated through the primary digester. This is accomplished with several “stack” pipes that are at least 18 inches in diameter, located within the digester. Pipes are typically suspended 24 to 30 inches above the digester floor, and 2 to 6 feet below the surface of the digester. Air compressors supply compressed digester gas to a bubble generator that creates a large bubble of digester gas within the stack pipes. The bubble rises from the base of the stack pipes to the top and acts as a piston, driving the liquid out the top of the stack. This process repeats, creating a liquid flow stream within the digester. Air bubbles released at the top of the digester generate turbulence and prevent scum blanket build-up.

Similar systems are available from other manufacturers including the Siemens Perth gas mixing system, for example.

8.2.2 Assumptions

1) Six, floor mounted, 24-inch mixers, four duty and two redundant
2) Two air compressor assemblies, one per digester (10 HP)
3) Two wall mounted control panels
4) Two gas flow balancing systems consisting of one gas flow meter, one pressure gauge, one balancing valve, and isolation valves for each mixer.
5) Freight and seven days of startup service in one trip
6) Four O&M Manuals
7) A 25 percent allowance for installation
8) A 25 percent contingency

8.2.3 Advantages and Disadvantages

One advantage of confined gas mixing systems is that little equipment is contained within the digester; therefore, when maintenance is required, the digester does not have to be drained. The location of the equipment requires that the cover be able to structurally support the equipment. This may result in costs to modify the cover. Since the cover of the Ames digester currently supports gas mixing equipment, it is assumed that such modifications would be minimal.

A disadvantage of confined gas mixing systems is that the process requires space on top of the digester cover for the air compressor and gas handling equipment. The space would have to be classified as a Class 1, Division 1 explosion-proof area. Another disadvantage is the high capital cost of the mixing equipment. If not properly designed and operated, gas mixing systems can also cause the formation of a scum layer at the top of the digester due to the gas bubbles attaching to solids. Foaming can occur in any digester, but is of special concern with gas mixing systems.

8.3 **Alternative 2 – External/Internal Draft Tube Mixing System**

8.3.1 Description of Alternative

An external draft tube mixer, such as the Eimco EIMIX External Draft Tube Mixer, is another option for digester mixing at the Ames WPCF. The tube is located outside the digester with one end connected to the bottom of the digester and the other end connected to the top of the digester. A propeller located in the draft tube pulls sludge from the top of the digester and recirculates it into the bottom. The inlet and outlet ports are angled to promote good circulation of digester contents. The propellers are designed to shed debris and stringy material to prevent accumulation on the propeller.

A copy of a brochure from Eimco further describing the External Draft Tube (EDT) mixing system is included in Appendix G. The external draft tube mixer would not require any changes to the digester cover.

An internal draft tube mixer is also available with the drive mounted on the roof of the digester and the lower draft tube located within the digester. This requires the mixer to be accessed from the roof. It is similar to the existing system except that mechanical mixing is provided in lieu of gas bubble mixing. The mixer manufacturer also provides a mounting port and entrance tube so the mixer may be removed from the digester without the loss of digester gas.

For the Ames WPCF, Eimco proposes one 25-HP draft tube mixer for each digester. Other internal draft tube manufacturers include Envirodyne, Olympic Technologies Inc, (OTI) and Wes-Tech. Mixing can also occur in the reverse direction. This may be necessary to assist in shedding solids from the propeller. A variable frequency drive (VFD) controller is recommended for the draft tube mixers. The VFD provides operational flexibility in the event of digester foaming or lower sludge level conditions. It also can be turned down to reduce energy consumption once the digester contents are in motion. The draft tube can be equipped with an external heat exchanger jacket to maintain temperature within the digester. A 1,000,000 Btu/hr heat exchanger jacket would be appropriate for each digester at the Ames WPCF. Hot water recirculation would be used with the heat exchanger jacket, similar to the current situation.

8.3.2 Assumptions

1) Internal draft tube (two; one per digester)
2) 25 HP explosion proof motor (two; one per digester) with VFD
3) Draft tube heat exchanger
4) Controls
5) Freight and startup service
6) A 25 percent allowance for installation
7) A 25 percent contingency

8.3.3 Advantages and Disadvantages

The internal draft tube mixer has several advantages over the external draft tube mixer for retrofit applications. The internal draft tube mixer is less expensive to purchase and install. The external system requires modifications for installation including concrete cutting, excavation, and foundation exposure. Therefore, only the internal draft tube mixer will be compared with the other mixing systems.

Another advantage of the internal draft tube mixer is that the main components are located outside the digesters. Consequently, the digester would not have to be taken out of service and drained for maintenance purposes. In addition, the system does not require gas handling. The draft tube can be operated with equal efficiency in both the forward and reverse directions. This helps prevent the formation of a scum layer on the top by drawing the contents down through the draft tube. If solids settling becomes a concern, the draft tube can be operated in an upward direction, pulling solids up and distributing them. Redundancy can be provided if desired by installing multiple mixers on a single tank. In this arrangement, if one mixer were out of service, the other mixers would continue to provide some mixing and heat. Purchasing additional mixers for each digester would increase the capital cost for this option. Given that redundancy for digester mixing systems is not critical, one draft tube per digester is recommended.

Disadvantages of the system are that the components are exposed to the outdoor environment, and as a result, maintenance to these items may have to be completed during extreme summer or winter conditions. The weight of each mixer will need to be addressed during design for retrofitting existing covers. With the proposed design, redundancy is provided by using the existing sludge pumps and not a redundant draft tube mixer.

Another disadvantage is that installations with significant amounts of rags and debris may find that these will accumulate on the propeller, even with the "ragless" design. Operational procedures do exist to counteract this problem, such as a regular automated schedule of reversing to shed the debris. Regular monitoring of drive amperage can provide early indication of a problem.

8.4 Alternative 3 – Linear Motion Mixer

8.4.1 Description of Alternative

The linear motion (LM) mixer is a relatively new technology. The LM mixer consists of a flat disk suspended by a vertical shaft in the liquid. The disk is moved vertically by a cover-mounted cam drive assembly. The drive is rated explosion-proof for use in a Class 1, Division 1 classified area. The mixing action can be varied by changing the stroke length and frequency. The linear motion creates both oscillating velocities and pressure waves to provide high-efficiency mixing. The mixer's efficient design results in the use of a relatively small motor to mix a large volume of material.

A VFD controller is recommended for LM mixers. The VFD provides operational flexibility and can be turned down to reduce energy consumption once the digester contents are in motion. Variable sludge levels in the digesters do not impact the LM mixer. The linear motion mixing action imparts less turbulence to the liquid than rotary style mixers.

The LM mixer is a patented technology by Enersave Fluid Mixers located in Ontario, Canada. They are licensed exclusively through Eimco Water Technologies in the United States. The equipment has gone through independent tracer testing to demonstrate uniform mixing results. The company can also perform a computational fluid dynamic (CFD) analysis for each installation. The Eimco product information and installation list are provided in Appendix G. There are several Canadian installations and one multiple-unit installation in Arizona. A paper on the Arizona LM mixer installation was presented at the 2008 WEFTEC conference.

Eimco recommends a single 10-HP LM mixer for each digester at Ames. The weight of the mixer assembly would require additional support and cover modifications to allow a retrofit installation. The disk diameter is 84-inches and would require a 102-inch diameter port in the center of the cover to remove it in one piece. An alternative is to have the disk fabricated in a split-ring design which would possibly allow it to be removed through the existing center opening but would then require additional assembly and disassembly whenever it needed to be removed.

8.4.2 Assumptions

1) One SS Hydro-disk and SS lower shaft (per digester)
2) One 10 HP motors (per digester) and Cam-drive system
3) VFD (two, one per digester)
4) Seal tube and mounting port
5) Control Panel (one per motor)
6) Freight and startup service
7) Two spiral-type heat exchangers
8) Two heat exchanger sludge pumps and associated piping
9) A 15 percent allowance for installation
10) 30' x 20' digester building addition
11) A 25 percent contingency

8.4.3 Advantages and Disadvantages

Advantages of the LM mixer include the low power consumption and less maintenance than other more complicated systems. One disadvantage of this new technology is that the installation list is small. It is not anticipated that rags would be an operational problem with the disk, but there may not be enough installations to make this determination. The large disk diameter is a disadvantage with a retrofit installation and would either require a new cover or extensive modifications to the existing cover, neither of which is necessary with the other mixing options. With the proposed design, redundancy is provided by using the existing sludge pumps instead of a redundant LM mixer.

Finally, since there would no longer be a draft tube used for heat exchange, the use of the LM mixer would require a new system to heat the digesters. This would require pumps and heat exchangers located inside a new building or an addition to the existing building. The current building layout does not have adequate space for this equipment. A 30' x 20' addition to digester building equipment area is anticipated for the pumps and heat exchangers. In a water-to-sludge heat exchanger, plugging of the openings on the sludge side of the heat exchanger may be a concern because of the volume of screenings and rags. Spiral-type heat exchangers (one per digester) are recommended for the digester heating system due to the larger sludge side openings to reduce plugging potential. The use of a pumped heat exchange would provide a degree of mixing and redundancy in the event that the LM mixer was down for maintenance.

8.5 Alternative 4 – Pumped Recirculation Mixing System

8.5.1 Description of Alternative

Pumped recirculation systems use a pump to pull biosolids out of the digester at one location and inject them back into the digester at another location. This continuous process creates a current within the digester and mixes the sludge. The sludge pulled out of the digester can be heated before being injected into the digester to provide digester heating. A separate heat exchanger would be needed.

A pumped mixing system can be provided by Liquid Dynamics "Jet-Mix" or Vaughn "Rota-mix" as well as other manufacturers. Jet-Mix was evaluated for this study but Rotamix is similar. The system uses a suction pipe at the bottom center of the tank that conveys sludge to a self-priming, chopper-type, horizontal centrifugal pump that discharges the sludge to two nozzle assemblies, creating a mixing pattern. Each of these manufacturers provides nozzles created for this type of application including either hardened steel or thick glass lined components. The size of the existing 10-inch sludge draw-off piping will need to be addressed during design for being adequate to serve as the pumped suction line.

8.5.2 Assumptions

1) Three Rotatable Nozzle Assemblies (per digester)
2) Three 40 HP motors and chopper pumps, two duty and 1 redundant
3) Control Panel (one per motor)
4) Freight and startup service
5) Two spiral-type heat exchangers
6) A 25 percent allowance for installation
7) 30' x 20' digester building addition
8) A 25 percent contingency

8.5.3 Advantages and Disadvantages

The pumped recirculation system requires no mechanical components within the digester; therefore, the digester does not have to be taken out of service and drained for maintenance purposes. Another advantage is that any rags that accumulate will be macerated in the pump and will not collect within the digester.

A disadvantage of the system is the higher operational cost of large pumps. The chopper pump and nozzles are less efficient than other mixing systems. Another disadvantage is that, similar to the linear motion mixers, a new digester heating system would be needed, since there would no longer be a draft tube for heat exchange. Spiral-type heat exchangers (one per digester) are recommended for the digester heating system. This system could be designed so that the chopper pump both circulates the flow through the nozzles and through a heat exchanger before discharging into the tank. The use of the chopper pumps and spiral-type heat exchangers would reduce heat exchanger plugging. A 30' x 20' addition to digester building equipment area would also be needed for the chopper pumps and heat exchangers as there currently is no space for additional equipment.

8.6 Alternative Analysis

Economic Summary

Table 8-1 below shows an economic comparison of the alternatives. Present worth was calculated from the capital cost and electrical costs for 20 years at a return of 7%. Electrical cost was calculated assuming continuous operation for all systems, and a cost of $0.08/KWhr. Electricity use is based on the rated horsepower (HP) of the equipment. Other considerations which have not been included at this time are improvements to the screenings facilities to reduce maintenance on mixing equipment and any engineering, legal, or administrative costs.

Table 8-1 – Mixing Alternatives Capital and Operational Costs

	Confined Gas Mixing	Internal Draft Tube	Linear Motion (LM) Mixing	Recirculation Mixing
Capital Cost	$900,000	$350,000	$370,150	$645,000
Heat Exchanger Equipment Capital Cost	NA	NA	$78,000	$78,000
Heat Exchanger Sludge Pump and Piping Capital Cost	NA	NA	$40,000	NA
Building Addition Capital Cost	NA	NA	$100,000	$100,000
Total Capital Cost	$900,000	$350,000	$498,150	$862,733
Electricity Cost	$9,933	$24,833	$9,933	$39,733
20-Yr Present Worth	$1,231,063	$681,063	$720,575	$1,352,701

8.6.1 Non-economic Summary

Some mixing systems are more suitable than others for retrofitting into an existing digester, depending on constraints of particular facilities. Two key constraints at Ames will limit the applicability of some types of mixing equipment. One is the lack of building space for additional equipment. The other is that the heat exchanger is incorporated into the mixing equipment installed in the digester. If a separate heat exchanger is needed for the mixing system, it would need to have a separate sludge recirculation loop, pumps, piping, and heat exchanger. The internal draft tubes and the confined gas mixing systems would not require any additional building space. The internal/external draft tubes would not require additional heating equipment. Table 8-2 shows the non-economic factors.

Table 8-2 – Mixing Alternatives Non-economic Factors

	Confined Gas Mixing	Internal Draft Tube	Linear Motion (LM) Mixing	Recirculation Mixing
Retrofit to cover	N	Y	Y	N
Retrofit to heating system	N	N	Y	N
Adjustable Operation	Y	Y	Y	Y
Proven Technology	Y	Y	N	Y
Ease of Maintenance/Operator Safety	N	N	N	Y

8.7 Recommended Alternative

The existing system has reached the end of its useful life and requires higher-than-normal maintenance effort from operations staff. There are many newer technology mixing systems that can be retrofitted into this application. However, there are unique circumstances with this installation that favor one type of system.

A single internal draft tube mixing system is recommended with an integral heat exchanger similar to the existing heat exchanger arrangement. This alternative has the lowest capital cost and lowest present worth. Internal draft tube mixers are a proven technology, with many installations throughout the country (including Iowa) and well-documented long-term performance results. The single internal draft tube mixer per digester has one distinct advantage over the other alternatives; it is a very similar arrangement to the existing gas mixing system and can be easily retrofitted into the existing primary digesters. This mixing system will rely on the continued use of the existing heating water system. Redundancy is provided by digester pumps which could be used to mix the system and the flexible use of two primary digesters in the event one digester mixing system is off-line. The Linear Motion Mixer is the second lowest present worth cost, but was not chosen due to the minimal number of installations and lack of long-term performance results.

To reduce system downtime the improvements could be implemented at the same time as cleaning and interior repainting of the digesters.

An additional recommendation for the Ames WPCF would be to consider replacing the existing coarse screening and comminutor with fine screens. Fine screening will more effectively prevent stringy material and rags from entering the digesters.

9.0 IMPLEMENTATION

The implementation of these recommended improvements should be added to the Capital Improvements Plan for the City of Ames.

Generally, the City should proceed immediately with the selection process of a biosolids specialty contractor for the land application of biosolids. A scope of services should be developed to secure a biosolids specialty contractor for this work. The scope should include qualifications of the firms, similar experience with references, a statement of availability (during land application season), project team, project approach, and cost basis information. The City then can look at each of the firms and make an evaluated selection for land application. At that point, the City can finalize the contract with the selected contractor.

The capital improvements for the biosolids storage, handling and disposal improvements should be implemented as soon as funding is available. The clock is ticking on the condition and availability of the existing biosolids infrastructure without significant repair or replacement costs. The City may elect to replace the biosolids process equipment and infrastructure piecemeal. The priority for this work may depend on the comfort and experience of the transition to land application by a biosolids contractor.

Mixer replacement at the anaerobic digesters should be implemented as an equipment replacement project. The existing mixing system is at the end of its life and continued maintenance will be even more frequent with the existing mixing system. This replacement project should be planned in conjunction with digester cleaning. The replacement of influent screens with a fine screen design will have a positive impact on the digesters, as well. Although screening is not part of this study, an investigation to replace the influent screening should be implemented soon.

A proposed timeline for implementation of these recommended improvements is as follows:

Item	Budget	Target Date
Proposal for Selecting Biosolids Contractor		June 2010
Biosolids Contractor Under Contract		August 2010
Biosolids Storage, Handling and Disposal Recommendations		
Salvage Terragators	-$25,000	July 2011
Purchase Four-wheel Drive Tractor and Wagon with Biosolids Application Eq	$270,000	July 2011
Design 1.6 MG Biosolids Storage Tank and Loadout Facilities	$100,000	September 2010
Construct 1.6 MG Biosolids Storage Tank and Loadout Facilities	$1,059,000	June 2012
Rehab Biosolids Storage Lagoon	$58,000	November 2012
Anaerobic Digester Mixing Replacement		
Design Mixing Replacement	$35,000	Jan 2012
Implementation of Mixer Replacement	$350,000	July 2012/July 2013