NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD
ARIZONA

WASTE TREATMENT LAGOON

(No.)

CODE 359

DEFINITION

A waste treatment impoundment made by constructing an embankment and/or excavating a pit or dugout.

PURPOSE

To biologically treat waste, such as manure and wastewater, and thereby reduce pollution potential by serving as a treatment component of a waste management system.

CONDITIONS WHERE PRACTICE APPLIES

This practice may be applied as part of an agricultural waste treatment lagoon:

- Where the lagoon is a component of a planned agricultural waste management system.
- Where treatment is needed for organic wastes generated by agricultural production or processing.
- On any site where the lagoon can be constructed, operated and maintained without polluting air or water resources.
- To lagoons utilizing embankments with an effective height of 35 feet or less where damage resulting from failure would be limited to damage of farm buildings, agricultural land, or township and country roads.

CRITERIA

General Criteria for All Lagoons

Waste treatment lagoons shall be designed on an individual basis to meet site conditions and functional requirements. They shall be part of an approved and overall engineering plan for waste management, irrigation, drainage, channel improvement, or similar purposes.

Design and implementation of subsidiary components and/or structures shall meet all applicable Natural Resource Conservation Service (NRCS) standards. The criteria for the design of any components not specifically addressed in NRCS practice standards or specifications shall be consistent with sound engineering principles and/or manufacturer recommendations.

Laws and Regulations. All Federal, state, *Tribal*, and local laws, rules, and regulations governing the *planning, design and* construction and use of waste treatment lagoons must be followed. *Laws and regulations of particular concern include those involving water rights, land use, pollution control (i.e. biohazards, water quality, animal mortality, etc.), property easements, wetlands, preservation of cultural resources, and endangered species. State water quality standards for seepage loss shall be followed.*

The owner is responsible for securing necessary permits and water rights, complying with all laws and regulations, and meeting legal requirements applicable to the installation, operation, and maintenance of this practice and associated structures.

Cultural Resources and Wildlife Habitat. *Impact to cultural resources, wetlands and Federal and state protected species shall be evaluated and avoided or minimized to the extent practicable during planning, design and implementation of this conservation practice in accordance with established National policy, General Manual (GM) Title 420-Part 401; Title 450-Part 401, Title 190-Parts 410.22 and 410.26, National Planning Procedures Handbook (NPPH), National Cultural*

Resources Procedures Handbook (NCRPH), National Food Security Act Manual (NFSAM), and the National Environmental Compliance Handbook (NECH).

Location. To minimize the potential for contamination of streams, lagoons should be located outside of floodplains. However, if site restrictions require location within a floodplain, they shall be protected from inundation or damage from a 25-year flood event, or larger if required by laws, rules, and regulations. Lagoons shall be located so the potential impacts from breach of embankment, accidental release, and liner failure are minimized; and separation distances are such that prevailing winds and landscape elements such as building arrangement, landforms, and vegetation minimize odors and protect aesthetic values.

Lagoons should be located so they have as little drainage area as possible. If a lagoon has a drainage area, the volume of normal runoff during the treatment period and 25-year, 24-hour storm event runoff shall be included in the required volume of the lagoon.

New storage lagoons and expansion of existing storage lagoons, and land application of wastes should not occur within 100 feet of any watercourse. A horizontal setback of 100 feet shall be maintained between storage facilities and private drinking water supply wells. Public drinking water supplies will require a setback of 200 feet.

Soils and Foundation. The lagoon shall be located in soils with an acceptable permeability that meets all applicable regulations, or the lagoon shall be lined. Information and guidance on controlling seepage from waste impoundments can be found in the Agricultural Waste Management Field Handbook (AWMFH), Appendix 10D.

The lagoon shall have a bottom elevation that is a minimum of 2 feet above the seasonal high water table unless special design features are incorporated that address buoyant forces, lagoon seepage rates, and non-encroachment of the water table by contaminants. The water table may be lowered by use of perimeter drains to meet this requirement.

Unless otherwise specified by ADEQ regulations, soil compaction shall be no less than 90% Standard Proctor Density. If the facility is classified as a regulatory dam, the compaction requirement for an embankment increases to 95% Standard Proctor Density.

National Engineering Manual, Part 531, Geology, specifies geologic investigation requirements and soil transportation regulations.

Flexible Membranes. Flexible membrane liners shall meet or exceed the requirements of flexible membrane linings specified in *Arizona Conservation Practice Standard for* Pond Sealing or Lining, Flexible Membrane (code 521A).

Unless otherwise specified by ADEQ regulations, the permeability of waste storage ponds installed without a synthetic flexible membrane liner shall not exceed $1x10^{-7}$ centimeters per second.

Required Volume. The lagoon shall have the capability of storing the following volumes:

- Volume of accumulated sludge for the period between sludge removal events;
- Minimum treatment volume (anaerobic lagoons only);
- Volume of manure, wastewater, and other wastes accumulated during the treatment period;
- Depth of normal precipitation less evaporation on the surface area (at the required volume level) of the lagoon during the treatment period;
- Depth of the 25-year, 24-hour storm precipitation on the surface area (at the required volume level) of the lagoon.
- *If drainage area is routed into the lagoon, the volume of runoff from the drainage area and the lagoon from normal precipitation during the treatment period, in addition to the 25-year, 24-hour storm event, shall be included in the required volume of the lagoon.*

Treatment Period. The treatment period is the detention time between drawdown events. It shall be the greater of either 60 days; or the time required to provide the storage that allows environmentally safe utilization of waste considering the climate, crops, soil, and equipment requirements; or as required by local, state, and Federal regulations.

Waste Loading. Daily waste loading shall be based on the maximum daily loading considering all waste sources that will be treated by the lagoon. Reliable local information or laboratory test data should be used if available. If local information is not available Chapter 4 of the AWMFH *(NEH Part 651)* may be used for estimating waste loading.

Embankments. The minimum elevation of the top of the settled embankment shall be 1 foot above the lagoon's required volume. This height shall be increased by the amount needed to ensure that the top elevation will be maintained after settlement. This increase shall be not less than 5 percent. The minimum top widths are shown in Table 1. The combined side slopes of the settled embankment shall not be less than 5 horizontal to 1 vertical *(5H:1V)*, and neither slope shall be steeper than 2 horizontal to 1 vertical *(2H:1V)* unless provisions are made to provide stability.

Table 1 – Minimum Top Widths

Total Embankment Height (feet)	Top Width (feet)
15 or less	8
15 – 20	10
20 – 25	12
25 – 30	14
30 – 35	15

Unless otherwise specified by Arizona Department of Environmental Quality (ADEQ) regulations, all embankment waste storage facilities shall have a minimum 2 feet freeboard above the required design volume.

Excavations. Unless supported by a soil investigation, excavated side slopes shall be no steeper than 2 horizontal to 1 vertical *(2H:1V)*.

Inlet. Inlets shall be of any permanent type designed to resist corrosion, plugging, freeze damage, and ultraviolet ray deterioration, while incorporating erosion protection as necessary. Inlets shall be provided with a water-sealed trap and vent, or similar device if there is a potential, based on design configuration, for gases to enter buildings or other confined spaces.

Outlet. Outlets from the required volume shall be designed to resist corrosion and plugging. No outlet shall automatically discharge from the required volume of the lagoon.

Facility for Drawdown. Measures that facilitate safe drawdown of the liquid level in the lagoon shall be provided. Access areas and ramps used to withdraw waste shall have slopes that facilitate a safe operating environment. Docks, wells, pumping platforms, retaining walls, etc. shall permit drawdown without causing erosion or damage to liners.

Sludge Removal. Provision shall be made for periodic removal of accumulated sludge to preserve the treatment capacity of the lagoon.

Erosion Protection. Embankments and disturbed areas surrounding the lagoon shall be treated to control erosion. This includes the inside slopes of the lagoon as needed to protect the integrity of the liner.

Safety. Design shall include appropriate safety features to minimize the hazards of the lagoon. The lagoon shall be fenced around the perimeter and warning signs posted to prevent children and others from using it for other than its intended purpose.

Additional Criteria for Anaerobic Lagoons

Loading Rate. Anaerobic lagoons shall be designed to have a minimum treatment volume based on Volatile Solids (VS) loading per unit of volume. The maximum loading rate shall be as

indicated in AWMFH Figure 10-22 or according to state regulatory requirements, whichever is more stringent.

Operating Levels. The maximum operating level shall be the lagoon level that provides the required volume less the 25-year, 24-hour storm event precipitation on the surface of the lagoon. The maximum drawdown level shall be the lagoon level that provides volume for the required minimum treatment volume plus the volume of accumulated sludge between sludge removal events. Permanent markers shall be installed at these elevations. The proper operating range of the lagoon is above the maximum drawdown level and below the maximum operating level. These markers shall be referenced and described in the O&M plan.

Depth Requirements. The minimum depth at maximum drawdown shall be 6 feet. If subsurface conditions prevent practicable construction to accommodate the minimum depth at maximum drawdown, a lesser depth may be used, if the volume requirements are met.

Additional Criteria for Naturally Aerobic Lagoons

Loading Rate. Naturally aerobic lagoons shall be designed to have a minimum treatment surface area as determined on the basis of daily BOD_5 loading per unit of lagoon surface. The required minimum treatment surface area shall be the surface area at maximum drawdown. The maximum loading rate shall be as indicated by AWMFH Figure 10-25 or according to state regulatory requirements, whichever is more stringent.

Operating Levels. The maximum operating level shall be the lagoon level that provides the required volume less the 25-year, 24-hour storm event on the lagoon surface. The maximum drawdown level shall be the lagoon level that provides volume for the volume of manure, wastewater, and clean water accumulated during the treatment period plus the volume of accumulated sludge between sludge removal events. Permanent markers shall be installed at these elevations. The proper operating range of the lagoon is above the maximum drawdown level and below the maximum operating level. These markers shall be referenced and described in the O&M plan.

Depth Requirements. The minimum depth at maximum drawdown shall be 2 feet. The maximum liquid level shall be 5 feet.

Additional Criteria for Mechanically Aerated Lagoons

Loading Rate. Mechanically aerated waste treatment lagoons' treatment function shall be designed on the basis of daily BOD_5 loading and aeration equipment manufacturer's performance data for oxygen transfer and mixing. Aeration equipment shall provide a minimum of 1 pound of oxygen for each pound of daily BOD_5 loading.

Operating Levels. The maximum operating level shall be the lagoon level that provides the required lagoon volume less the 25-year, 24-hour storm event precipitation and shall not exceed the site and aeration equipment limitations. A permanent marker or recorder shall be installed at this elevation. The proper operating range of the lagoon is below this elevation and above the minimum treatment elevation established by the manufacturer of the aeration equipment. This marker shall be referenced and described in the O&M plan.

Investigations, Surveys and Design Criteria. *Waste management systems include practice components required for the complete management of waste. Documentation requirements will be as outlined below, in additional to the documentation requirements of the practice components used in the system.*

Make a preliminary site assessment, investigation or reconnaissance to determine the complexity of the problem, availability of land for utilizing the waste and water, and to select the type of waste management system component which will best meet the needs of the owner to

operate the waste management system. Volume of waste that will be produced per day shall be recorded in terms of biochemical oxygen demand (BOD_5), raw manure, volatile solids (V.S.), nutrients or water use. Additional information may include:

1. *Review of soil borings or geological site investigation, depending on existing site conditions or scope and complexity, to determine site feasibility, ground surface elevation of each hole or site, depth to ground water and seasonal high water table, description of each soil material (silty sand, lean clay, etc.), unified soil classification of each material (SM, CL, etc.), estimate of soil permeability of underlying materials (permeable, low permeability, etc.), and any soil limitations and/or whether the materials are oxidized or unoxidized.*
2. *Determine if the waste management system is to be designed for phosphorous or nitrogen (limiting nutrient). Where soil survey data is available, it may be used for preliminary planning.*
3. *Inventory of system- method of operation, number of livestock, waste disposal methods, type of equipment, future expansion plans, crop rotations on planned areas, component locations, structure requirements, quantities and costs.*
4. *Verify appropriate state or local laws for permitting and approval requirements and notify landowner of his/her responsibilities.*
5. *Verification or certification of used materials (if any).*

To adequately plan and layout this practice, a detailed topographic survey is required, that adequately details:

1. *Adequate topographic information/data at the proposed location of the waste storage facility in order to determine excavation and/or earthfill requirements. Obtain topographic data with the land disposal area to determine waste distribution system layout, pumping requirements and costs;*
2. *Topographic surveys of sufficient detail and extent to determine the drainage area around barns, high intensity areas (HIA), and pastures contributing runoff to the proposed facility. When possible, divert uncontaminated runoff, especially roof runoff.*
3. *Profiles along the centerline of proposed pipelines, ditches, diversions, etc.*
4. *Reference stakes, control elevations and locations of water levels, including impermeable or restrictive layers;*
5. *Location of underground or overhead utilities or markers;*
6. *A permanent benchmark(s) shall be set and described. Preferably, the elevations and coordinates should be based on a local (assumed) or coordinate system (State or grid) and clearly stated on the plan. Datum may be in the form of Northing and Easting coordinates, or Longitude and Latitude.*

Where applicable, USGS 7.5-minute topographic Quadrangles may be used, provided hydraulic analysis verifies minimum criteria are meet at all locations.

The design of a practice is the application of Field Office Technical Guide practice standards, NEH Part 651, AWMFH, using experience and judgment in the development of a solution to the problem or the objective. All computations and decisions made during the design of a practice are to be checked by another qualified individual and appropriate notations made. Design computations, calculations or analysis shall meet the following criteria:

1. *Complete soils investigation report as needed and construction recommendations. See NEH Part 651, Chapter 7, AWMFH;*
2. *Plot ground profiles at structure site(s) with the elevations of any drains and high intensity areas (HIA's) contributing waste, waste water and storm water runoff into the proposed facility;*
3. *Size the waste treatment lagoon using the appropriate engineering practice standard and the NEH Part 651, AWMFH;*
4. *Hydrologic determinations – documentation may include printouts from EFM2 or TR-55 programs or software/spreadsheets used for AWMS design;*

5. *Hydraulic calculations or analysis, as required to determine capacities, sizes and proportion of facilities such as pipelines, diversions, etc.;*
6. *Flood routing data from SITES or other approved software to evaluate pipe sizes for sediment basins;*
7. *Manure production/volume calculations (AWM, hand calculations or design spreadsheets for storage computation and documentation);*
8. *Structural design calculations;*
9. *Construction material estimates (material volume computations), includes estimates of earthwork, pipe, concrete, rock, vegetative components, geotextile and erosion control fabrics, or other appurtenances.*
10. *Subsidiary and applicable components shall be designed in accordance with applicable conservation practice standards (i.e., structures shall meet the requirements of Conservation Practice 587, Structure for Water Control, etc.).*

Installation and Basis of Acceptance. *For construction that does not meet State, OSHA, or Tribal criteria or requirements where deficient construction materials were used, NRCS may consider a waiver request for approval of construction after it has received a signed and sealed construction and/or material exemption from a licensed engineer. Required exemption shall be for installation of materials that do not meet minimum quality criteria as found in applicable Standards, Specifications, ASTM's, AWWA standards, etc.*

Contractors performing work under this practice shall abide by all Federal, State or Tribal laws or criteria, and must be licensed by the state board of technical registers where the work is being implemented.

CONSIDERATIONS

General

Lagoons should be located as close to the source of waste as possible.

Solid/liquid separation treatment should be considered between the waste source and the lagoon to reduce loading.

The configuration of the lagoon should be based on the method of sludge removal and method of sealing.

Due consideration should be given to economics, the overall waste management system plan, and safety and health factors.

Considerations for Minimizing the Potential for and Impacts of Sudden Breach of Embankment or Accidental Release from the Required Volume

Features, safeguards, and/or management measures to minimize the risk of embankment failure or accidental release, or to minimize or mitigate impact of this type of failure should be considered when any of the categories listed in Table 2 might be significantly affected.

The following should be considered either singly or in combination to minimize the potential of or the consequences of sudden breach of embankments when one or more of the potential impact categories listed in Table 2 may be significantly affected:

- An auxiliary (emergency) spillway
- Additional freeboard
- Storage volume for the wet year rather than normal year precipitation
- Reinforced embankment -- such as, additional top width, flattened and/or armored downstream side slopes
- Secondary containment
- Water level indicators or recorders

Table 2 – Potential Impact Categories from Breach of Embankment or Accidental Release

1. Surface water bodies – perennial streams, lakes, wetlands, and estuaries
2. Critical habitat for threatened and endangered species
3. Riparian areas
4. Farmstead, or other areas of habitation
5. Off-farm property

6. Historical and/or archaeological sites or structures that meet the eligibility criteria for listing in the National Register of Historical Places

The following should be considered to minimize the potential for accidental release from the required volume through gravity outlets when one or more of the potential impact categories listed in Table 2 may be significantly affected:

- Outlet gate locks or locked gate housing
- Secondary containment
- Alarm system
- Another means of emptying the required volume

Considerations for Minimizing the Potential of Lagoon Liner Seepage

Consideration should be given to providing an additional measure of safety from lagoon seepage when any of the potential impact categories listed in Table 3 may be affected.

Table 3 – Potential Impact Categories for Liner Seepage

1. Any underlying aquifer is at a shallow depth and not confined
2. The vadose zone is rock
3. The aquifer is a domestic water supply or ecologically vital water supply
4. The site is located in an area of carbonate rock (limestone or dolomite)

Should any of the potential impact categories listed in Table 3 be affected, consideration should be given to the following:

- A clay liner designed in accordance with procedures of AWMFH, Appendix 10D with a thickness and coefficient of permeability so that specific discharge is less than 1 x 10-6 cm/sec.
- A flexible membrane liner
- A geosynthetic clay liner (GCL) flexible membrane liner
- A concrete liner designed in accordance with slabs on grade criteria, Waste Storage Facility (313), for fabricated structures requiring water tightness.

Flexible membrane liners shall be used for all waste treatment lagoons in accordance with Conservation Practice Standard 521A unless the owner of the waste treatment lagoon independently obtains the services of a licensed professional engineer that will certify to the Arizona Department of Environmental Quality (ADEQ) that the alternative lining or process will satisfy the requirement that there will not be a hydrologic connection to surface water.

Considerations for Improving Air Quality

To reduce emissions of greenhouse gases, ammonia, volatile organic compounds, and odor:

- Reduce the recommended loading rate for anaerobic lagoons to one-half the values given in AWMFH Figure 10-22.
- Use additional practices such as Anaerobic Digester – Ambient Temperature (365), Anaerobic Digester – Controlled Temperature (366), Waste Facility Cover (367) and Composting Facilities (code 317) in the waste management system.
- Liquid/solid separation prior to discharge to lagoon will reduce volatile solids (VS) loading resulting in reduced gaseous emissions and odors. Composting of solids will further reduce emissions.
- Design lagoons to be naturally aerobic or to allow mechanical aeration.

Adjusting pH below 7 may reduce ammonia emissions from the lagoon but may increase odor when waste is surface applied (See Waste Utilization, code 633).

PLANS AND SPECIFICATIONS

Use Arizona standard drawings to the extent possible. These may be supplemented by additional drawings or specification notes on the drawings to provide full installation instructions.

Construction plans shall include all components needed for the safe operation of the proposed improvements such as railing, fencing, or warning signs as appropriate. The plans shall address operations near existing utilities, trench excavations and any other items related to

construction of the structure that may pose a safety risk to those involved.

Development of plans and specifications *for waste storage facilities will be guided by the National Engineering Handbook, Part 650, the Engineering Field Handbook, Chapter 5, and shall be in accordance with the National Engineering Manual, Parts 541 and 542, shall be prepared for specific field site,* shall be prepared in accordance with the criteria of this standard and shall describe the requirements for applying the practice to achieve its intended use. *Plans and specifications shall include such drawings, specifications, material requirements, quantities, construction requirements, equipment requirements, and other documents as are necessary to describe the work to be done. As a minimum, the plans and specifications shall provide the following:*

- *Project location map, including section, township and range, North arrow, cooperator/owner acknowledgement and certification signature blocks, engineering job class (cover sheet);*
- *References that the owner/cooperator are responsible for all permits, rights-of-way, easements and the contact, coordination and location determination of any existing utilities or clearances (buried utility disclaimer);*
- *If applicable, a map showing the location of the practice(s) or system in reference to a known or established benchmark or reference point with the location, description and elevation clearly shown. Topographical features and/or controls shall be shown, showing tie in with existing or other planned practices;*
- *Field surveys and notes, soil investigations or geologic soil boring locations and soil classifications, earthwork or material estimates/quantities (foundation or subgrade preparation and requirements);*
- *Overall system or plan view (i.e., complete waste system layout, waste distribution system, facility plan layout; structural alignment, sizes, stationing, elevations, reference points, cultural features, and other details of the facility; types of materials, thickness, anchorage requirements, lift thickness, covering; profiles showing intended grades, elevations, stationing, pipes and similar structures; cross sections, as needed, to show all pertinent details such as side slopes, berms, bottom widths, and elevation; layout of the containment structure, collection points, water transfer locations or pipelines, and topography of the site; special foundation or subgrade preparation requirements and details, including tolerances on smoothness of the finished grade; safety features, roof covers, ladders; quality control testing; vegetative, fence and signage requirements, if required; construction/installation criteria, State and Federal [OSHA] safety requirements, etc.), type, quality and quantity as necessary;*
- *Sufficient sectional, dimension or detail views of all system components and appurtenances (i.e., structural details, including dimensional plan views, sectional views to clearly show all necessary details for construction; reinforced concrete requires separate sectional or detail views; location, type, size of construction joints, expansion-contraction joints or special joints for fabricated structures; etc.) as required, for proper system functionality;*
- *Construction notes to clarify a component and furnish directions for installation by supplementing standard or general specifications as needed.*
- *Use Arizona Construction and Material Specifications for each item of work and material, as applicable and available. Additional specifications may need to be written to provide full material and installation instructions. Fill in blanks and add or delete items from the specifications to make them fit the job as needed.*

All designs completed by non-NRCS personal shall meet minimum State licensing board requirements and NRCS requirements and criteria as outlined in the General Manual, the National Engineering Manual (including Arizona Supplements), and the National Engineering Handbook.

ONCE ALL PARTIES HAVE ACCEPTED AND SIGNED THE PLANS AND SPECIFICATIONS, NO CHANGES SHALL BE MADE TO THE DRAWINGS OR SPECIFICATIONS WITHOUT PRIOR APPROVAL OF NRCS.

OPERATION AND MAINTENANCE

An operation and maintenance *(O&M)* plan, *specific to each site,* shall be developed *and reviewed with the landowner, cooperator or individual responsible for operation and maintenance and shall be commensurate with the size and complexity of the project. The plan shall be* consistent with the purposes of the practice, its intended life, safety requirements and the criteria for its design. *It shall document needed actions, including reference to periodic inspections and the prompt repair or replacement of damaged components, and should provide specific instructions for operating and maintaining facilities to ensure they function properly. This includes, but is not limited to:*

- The plan shall contain the operational requirements for emptying the storage facility. This shall include the requirement that waste shall be removed from the lagoon and utilized at locations, times, rates, and volume in accordance with the overall waste management system plan.
- In addition, the plan shall include a strategy for removal and disposition of waste with the least environmental damage during the normal storage period to the extent necessary to insure the lagoon's safe operation. This strategy shall also include the removal of *the contribution* of unusual storm events *that may cause the lagoon to fill to capacity prematurely with subsequent design inflow and usual precipitation prior to the end of the normal storage period.*
- Development of an emergency action plan should be considered for lagoons where there is a potential for significant impact from breach or accidental release. The plan shall include site-specific provisions for emergency actions that will minimize these impacts.
- *Maintain all pumps, agitators, piping, valves, and other electrical and mechanical equipment in good operation condition following the manufacturer's recommendations.*
- *Fences and/or warning signs shall be maintained to prevent unauthorized human or livestock entry.*
- *Appurtenances such as trash racks, outlet structures, and valves shall be kept free of trash, debris, foreign materials or blockage and replaced when needed to prevent clogging of outlet and overflow pipes*
- *Eradicate or otherwise remove all rodents or burrowing animals that have or may potentially damage any part of the delivery or application facilities. Immediately repair any damage caused by their activity.*
- *Determine and eliminate causes of settlement or cracks in earthen sections and repair damage.*
- *Make sure all structure drains are functional and soil is not being transported through the drainage system. The screens and/or rodent guards shall also be kept in place.*
- *Repair spalls, cracks, and weathered areas in concrete surfaces, and repair or replace rusted or damaged metal and paint.*
- *Maintain vigorous growth of desirable vegetative coverings. This may include re-seeding, fertilization, and controlled application of herbicides when necessary. Periodic mowing or grazing may be needed to control height.*
- *Apply insecticides for insect control as per manufacturer's recommendations and precautions.*
- *The practice should be inspected periodically and especially after storm events to determine whether it is functioning properly or if repairs are needed.*
- *Immediately repair any damage resulting from vandalism, vehicles, or livestock.*

REFERENCES

- *ASAE, 1984. D384 – Manure Production and Characteristics. ASAE. St. Joseph, MI.*
- *Midwest Plan Service. 1985. Livestock Waste Facilities Handbook. MWPS, Department of Agricultural and Bio-systems Engineering, Iowa State University, Ames, IA.*
- *Midwest Plan Service. 1985. Livestock Waste Management Systems. Department of Agricultural and Bio-systems Engineering, Iowa State University, Ames, IA.*
- *Quality Assurance and Quality Control for Waste Containment Facilities, EPA/1600/R-93/182, September 1993.*

- *NRCS, "Agricultural Waste Management Field Handbook", National Engineering Handbook, Part 651.*
- *National Engineering Handbook - Part 650, Engineering Field Handbook, Chapter 1 – Engineering Surveys; Chapter 3 –Hydraulics; Chapter 4 – Elementary Soils Engineering; Chapter 5 – Preparation of Engineering Plans; Chapter 6 – Structures; Chapter 10 – Agricultural Waste, and Chapter 17 – Construction & Construction Materials*
- *National Engineering Manual, Part 531 Geology 531.31, USDA, Natural Resources Conservation Service*
- *USDA-NRCS, TR-62 Engineering Layout, Notes, Staking and Calculations;*
- *General Manual, Title 420-Part 401, Title 450-Part 401, Title 190-Parts 410.22 and 410.26*
- *National Environmental Compliance Handbook*
- *National Planning Procedures Handbook*
- *USDA NRCS, Engineering Design Standards – Far West States*
- *National Cultural Resources Handbook*