Sludge Survey Methods for Anaerobic Lagoons

The sludge that accumulates in anaerobic lagoons consists of organic and nonorganic material produced when anaerobic organisms digest animal waste and other substances. Lagoon design includes consideration of sludge accumulation, and lagoon management should include periodic measurement of the sludge layer's depth. When its accumulation becomes excessive, sludge must be removed.

The Natural Resources Conservation Service (NRCS) has a practice standard for lagoon management in North Carolina (Code 359) that requires an annual sludge survey after five years of lagoon operation, and the North Carolina Division of Water Quality (DWQ) often requires annual sludge surveys when it issues lagoon permits. This publication for lagoon managers and operators describes how to carry out a sludge survey and discusses sludge depth measurement, volume determination, and nutrient sampling. It draws upon and supplements the information in another publication on sludge management in anaerobic lagoons: *Sludge Management and Closure Procedures for Anaerobic Lagoons* (AG-604).

A sludge survey begins in a swine lagoon with two people in a flat-bottomed boat. The man holds a Sludge Gun, a Sludge Judge rests beside him, and a sonar device floats beside the boat.

REQUIREMENTS FOR SLUDGE SURVEYS

The NRCS Conservation Practice Standard for Waste Treatment Lagoons (Code 359) in North Carolina requires proper operation and maintenance of lagoons. Specifically, the standard states, "After five years, the sludge accumulation in the treatment lagoon shall be measured annually, or as needed, to define and document the rate of sludge accumulation in the lagoon and as directed by DWQ. If sludge accumulation in the treatment volume exceeds 50% of the planned treatment volume, the sludge should be either removed or the lagoon managed in accordance with an approved Sludge Management/Operation Plan as approved by DWQ."

Many permits for animal facilities issued by DWQ require a survey of sludge accumulation in lagoons within one year of receiving the individual permit or Certificate of Coverage (COC) and every year thereafter. The survey frequency may be reduced if it can be demonstrated to the satisfaction of DWQ that the rate of sludge accumulation does not warrant an annual survey. The survey shall include, but not be limited to, a sketch showing the depth of sludge in various locations within each lagoon. If the sludge accumulation is such that it reduces the lagoon's minimum treatment volume to less than 50 percent of the treatment volume for which the lagoon was designed, a plan must be submitted to the DWQ Central Office within 90 days of the determination. The plan must document the sludge-removal methods and waste-utilization procedures to be used.

SLUDGE CHARACTERISTICS

Two distinctly different zones occur within an anaerobic lagoon. First is the sludge accumulation zone at the bottom of the lagoon (Figure 1). The sludge is composed of settled manure solids, nonorganic constituents of manure, active and dead microbial cells, and other

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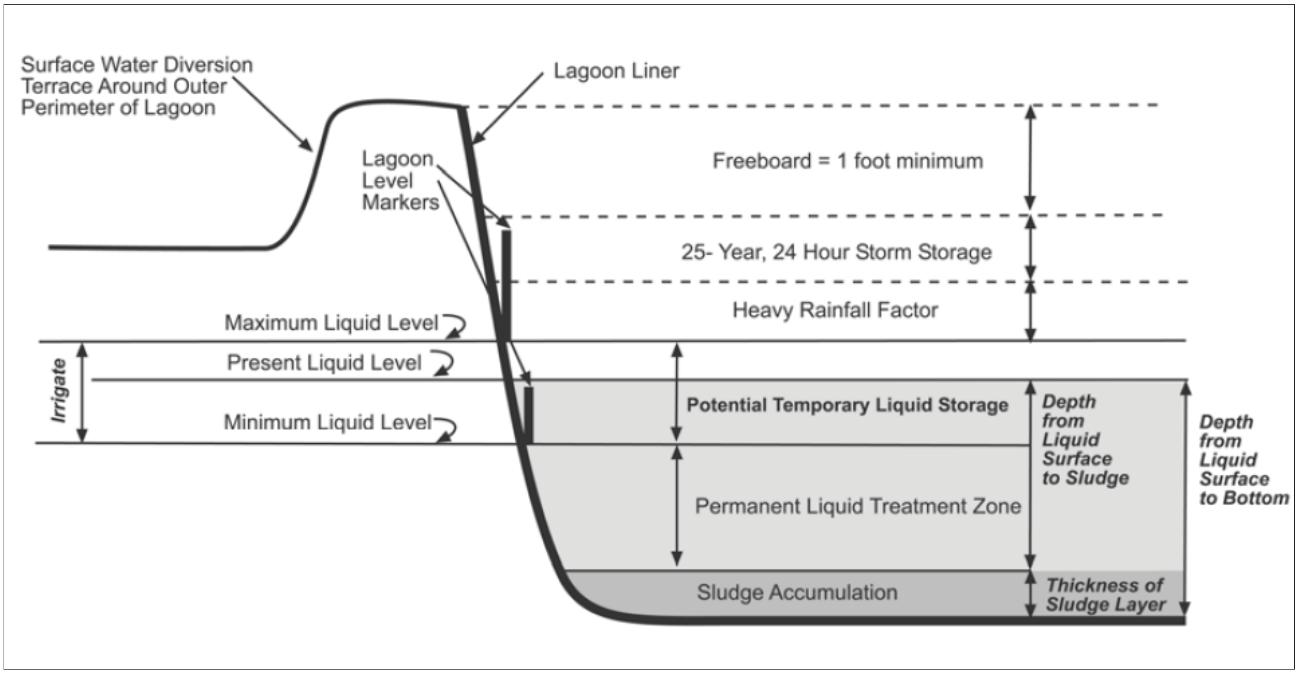

Figure 1. An anaerobic waste treatment lagoon (drawing is not to scale). (Adapted from AG-604)

materials (such as debris and sand) that entered the manure collection system and settled to the bottom. Sludge is black, moderately viscous, typically about 10 percent solids and 90 percent liquid, and high in nutrients, bacteria, and organic matter. Biological anaerobic degradation activity occurs in the sludge, as can be evidenced by the biogas that periodically floats sludge to the liquid surface. Sludge can be removed by pumps designed for 10 to 15 percent solids applications. Refer to *Sludge Management and Closure Procedures for Anaerobic Lagoons* (AG-604) for sludge-removal options.

The second distinct zone in the lagoon is the liquid layer above the sludge (Figure 1). This liquid, typically called lagoon supernatant or effluent, is low in solids (generally 0.3 to 0.6 percent solids), moderately rich in nutrients, and easily pumped with irrigation pumps. If the liquid and sludge are mixed, the solids content probably will be between 2 percent and 8 percent solids, depending on the proportion of sludge.

CONDUCTING A SLUDGE SURVEY—AN OVERVIEW

A sludge survey involves two steps: locating the top of the sludge layer and measuring its thickness at several locations in a lagoon. Both are discussed below in "Steps in the Sludge Survey" and "Measuring Sludge Layer Thickness." Using the measurements and Appendix 1, determine the thickness of the sludge layer and the thickness of the Permanent Liquid Treatment Zone (distance from the Minimum Liquid Level [Figure 1] to the top of the sludge layer). Appendix 2 is a Sludge Survey Data Sheet for recording measurements at each point of the survey grid. The volume of sludge and the fraction of the original liquid treatment zone that is filled with sludge can be estimated using Appendix 3. Appendix 4 is a conversion table that converts inches to tenths of a foot. If you anticipate that sludge removal might soon be required, take samples of the sludge or "cores" of the liquid column and sludge at the same time as the survey and send them for nutrient analyses.

Unless "remote" methods are developed, the sludge survey and sampling must be conducted from a boat on the lagoon. Special care should be taken when going onto a lagoon in a boat. For safety reasons, at least three people should be present: two in the boat and one on the lagoon bank. The extra person(s) on shore may be needed as a rescuer(s), should anything go awry. The extra person on the boat assists with getting in and out of the boat and anchoring the boat at the measurement locations. Also, it is more efficient if one person in the boat uses the measuring instruments and the other records the data. Flat-bottom or johnboats are preferred over canoes or V-bottom boats, as they are more stable. All persons working within the inner slopes of the lagoon, and especially those in the boat, should wear appropriate flotation devices.

The sludge layer is generally a "mobile" fluid, but it may form peaks and valleys within the lagoon. Small (usually older) lagoons seem to have more variation in sludge layer thickness. For this reason, at least 8 depth measurements should be taken for a lagoon of less than 1.33 acres in area, and at least 6 measurements per acre should be taken for lagoons that are equal to or greater than 1.33 acres, up to a maximum of 24 for the whole lagoon. The locations for measurements should be determined by a uniform grid, if possible. Avoid measuring over the slope of the lagoon embankments. For example, if a lagoon is 12 feet deep and the side slope is 3:1 (horizontal to vertical), then the slope extends for 36 feet into the lagoon. In this case, the measurements should be taken more than 36 feet from the inside top of the lagoon embankment. All measurements from the various locations on the grid should be averaged to produce an average sludge layer thickness and to calculate the volume of sludge.

STEPS IN THE SLUDGE SURVEY

1. Gather the necessary people and equipment: boat, life jackets, paddles, anchor, map or sketch of lagoon, clipboard and pencils, sludge detection device (such as an infrared sensor or a disk-on-rope with interval markings [See "Measuring Sludge Layer Thickness"]) to determine the top of the sludge layer, and a solid rod or pole with interval markings to determine the depth to the lagoon bottom. A 12-foot johnboat with a trolling motor is recommended. There should be two people in the boat and one on the bank.
2. Determine the number of points at which to take measurements. Measure sludge at a minimum of 6 points per acre on a uniform grid, using 24 points maximum, or measure a minimum of 8 points if the lagoon is smaller than 1.33 acres. If you are unsure of the lagoon area, multiply the length times the width at the inside top of the bank and divide by 43,560 to get acres (1 acre = 43,560 sq ft). Multiply the number of acres by 6, and round to the nearest number that gives a uniform grid, with a minimum of 8 points for lagoons of less than 1.33 acres. Once the number of measurement points has been determined, set up a uniform grid on the lagoon sketch to show the location of those points. For a 1-acre lagoon twice as long as it is wide, 8 locations of about 60 feet by 50 feet would be marked on the grid (Figure 2). This sketch must be attached to the "Sludge Survey Data Sheet."
3. Use survey flags or landmarks (such as the inlet pipe, power pole, and confinement house) on the lagoon bank to mark lines corresponding to the grid developed in step 2.
4. Prepare data sheets and forms to record information (use the "Lagoon Sludge Survey Form" [Appendix 1] and "Sludge Survey Data Sheet" [Appendix 2] for recording information).
5. Launch the boat and move to the first sample point. Measure the depth from the surface of the liquid to the top of the sludge. Record this depth. Insert a pole

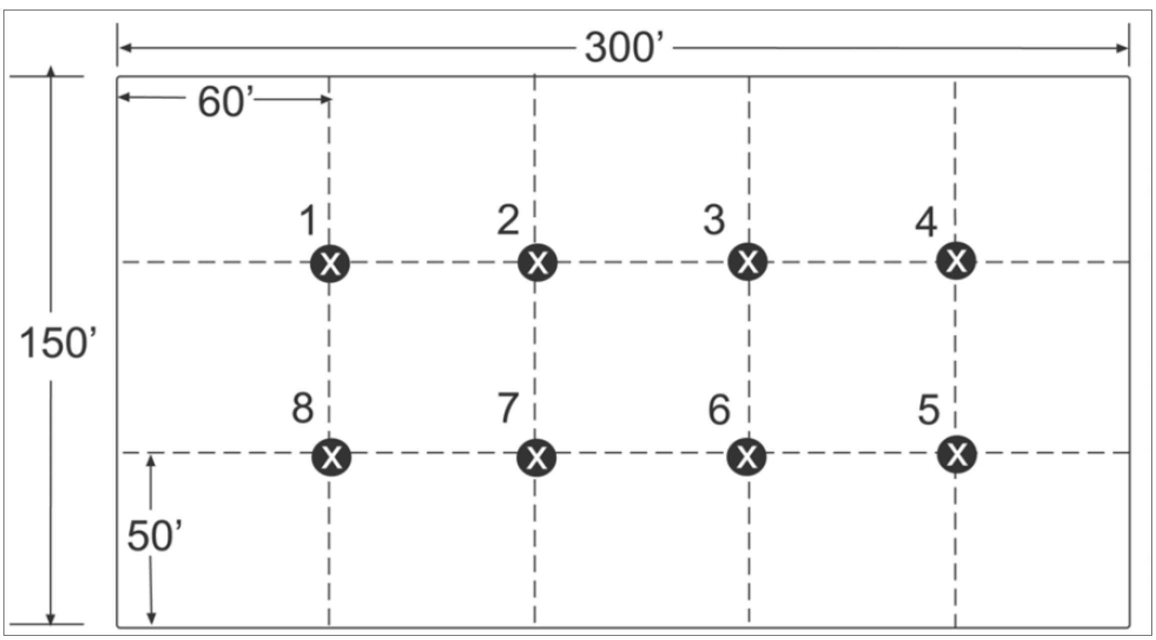

Figure 2. Layout for a lagoon 150 feet × 300 feet (1.03 acres), showing 8 locations to take sludge measurements (4 × 2 grid).

vertically at the same location until the lagoon bottom (soil contact) is felt. Record this depth. The sludge thickness is the difference between the two readings. If measurements are taken in feet and inches, convert to feet and tenths of a foot using the conversion table in Appendix 4.

6. Proceed to all other sample points, and record measurements as in item 5.
7. To determine the average sludge layer thickness in the lagoon, add all sludge layer thickness determinations and divide by the number of readings taken. This average sludge layer thickness will be used in the "Sludge Volume Worksheet" (Appendix 3) to determine how much sludge is in the lagoon. If the lagoon has an irregular shape, estimate the sludge volume by first estimating the total surface area in square feet and taking the square root to obtain the dimensions for a square lagoon. Then use the procedures in Appendix 3. If help is needed in determining the total surface area for an irregular shape, contact the local NRCS office.
8. For each survey, the Present Liquid Level should be referenced to a permanent elevation or benchmark, and the Maximum Liquid Level should be noted from the lagoon gauge. By knowing or measuring the difference in elevation between the Maximum Liquid Level and the Minimum Liquid Level on the lagoon gauges, the difference between the Minimum Liquid Level and the top of the sludge layer can be calculated. This is considered the existing Permanent Liquid Treatment Zone. This should be calculated and recorded on the "Lagoon Sludge Survey Form," Appendix 1. If the existing Permanent Liquid Treatment Zone is less than the existing sludge layer thickness, the volumes of the Treatment Zone and the Sludge layer must be calculated in Appendix 3.

MEASURING SLUDGE LAYER THICKNESS

Basic approach

Measure the depth from the liquid surface to the top of the sludge layer, and then measure the depth from the liquid surface to the lagoon bottom (soil contact); calculate the difference to obtain the thickness of the sludge layer.

Depth to top of the sludge

Various methods can be used to measure the depth from the liquid surface to the top of the sludge layer. Although some writers recommend a capped pipe or a pipe with a disk or a tee attached to the bottom to detect the sludge layer by "feel" (resistance from the sludge), these "feel" methods are likely to yield variable and inaccurate results. Although sludge is more viscous than the lagoon liquid, it is still difficult to feel when the sludge is first encountered. Therefore, "feel" methods are not recommended. Alternative methods that have proven to be more accurate include commercially available infrared sensors, a disk-on-rope device, a clear plastic pipe (such as the Sludge Judge) for obtaining a liquid column, or an electronic sonar depth finder.

Infrared sensors—Depth from the liquid surface to the top of the sludge layer can be measured reliably in most lagoons with infrared detectors, such as the Markland Engineering Sludge Gun or Raven Sludge Interface Detector. The infrared detectors indicate when the sludge layer is reached by emitting an audible sound. The sensitivity of the detectors can be adjusted, but in lagoons that have a high solids content, the detectors might sound as soon as the sensor is put into the liquid. If this occurs, another method may be needed to detect the top of the sludge layer. Infrared detectors cost between $750 and $1,000. ***Sources:*** **Sludge Gun (Sludge Blanket Level Detector) Model 10** from Markland Specialty Engineering Ltd. of Toronto, Canada, has a price, including shipment, of $875; it includes a 10-meter cable marked in feet. Markland recommends Model 10 HP ($995) for lagoons. Phone (416) 244-4980, e-mail: markland@sludgecontrols.com, or online at www.sludgecontrols.com. **Raven Sludge Interface Detector** made by Raven Environmental Products can be ordered from USA BlueBook (item MC-41441). Phone 1-800-548-1234. Price with a 20-foot line is about $750. The device has lights that illuminate and also makes an audible sound when the sludge layer is detected. Online at www.ravenep.com, or phone 1-800-545-6953,

Disk-on-rope—A much less expensive but somewhat more time-consuming method for detecting the top of the sludge layer is with a disk or plate that sinks through the liquid and settles on the sludge. When used carefully, this method generally agrees within 1 inch with the infrared detectors. A PVC disk ¼-inch thick and about 8 to 12 inches in diameter or of square shape (specific gravity = 1.4) has shown results consistent with the infrared detectors. The size (area) of the disk should make little difference because the pressure exerted on the sludge is constant per unit area. Disks of Lexan (specific gravity = 1.2) give similar results. Materials that are heavier than PVC could exert more pressure and penetrate the sludge.

The wire, rope, or string by which the infrared detectors or disks are lowered into the lagoon should be marked in inches or tenths of feet for easy reading. This line should not be elastic because stretching will cause variations in readings. The disk should be lowered slowly to keep it from swaying off vertical line. Holes drilled in the disk to allow liquid to pass through may reduce swaying. The rope or string can be attached to the disk at the center or at 2 to 4 symmetrically placed locations to keep the disk more stable. The depth to the sludge layer should be measured with the disk before using a pole to measure depth to the lagoon bottom because the pole may disturb the sludge layer.

Sludge Judge or clear plastic pipe—These methods are also considered slightly less accurate for determining the top of the sludge layer. A Sludge Judge or similar clear plastic pipe with a valve at the bottom, if used carefully, can agree within 1 to 3 inches with the infrared and disk methods. Typically, however, the sludge does not flow freely into the pipe, and the reading indicates slightly less depth to the sludge than is actually present. Observe the liquid level inside the pipe as the Sludge Judge is slowly lowered into the lagoon. When the sludge layer is reached, the liquid level inside the pipe will drop slightly below the liquid level outside the pipe. Then, the Sludge Judge can be removed and the depth of the liquid column to the sludge can be recorded. (There will be at least 1 to 2 inches of sludge at the bottom end of the pipe to ensure that the sludge layer has been reached). The Sludge Judge costs $80 to $140 and can be ordered in either a ¾-inch or 1¼-inch outside diameter. ***Sources:*** **Sludge Judge** information can be found online at www.pollardwater.com. Pollard Water offers three models with prices of about $80 to $115 for a 15-foot length in three 5-foot sections; phone 1-800-437-1146. Wildlife Supply Co. at www.wildco.com also offers three types with prices of about $90 to $140 for a 15-foot length; phone 1-800-799-8301.

You can make an apparatus by attaching a ball valve with handle (operated by a rope) at the bottom of a clear plastic pipe. The pipe can be constructed of sections that can be disassembled for transport. The pipe can be as large as 2 inches in diameter, but it will be heavy to handle when collecting liquid and sludge. Experience shows that penetrating the sludge layer with an open pipe does not yield accurate thickness estimates of the sludge layer, probably because of sludge compression or clogging of the pipe. Either the Sludge Judge or a pipe you modify can be used to obtain a sludge sample for nutrient analysis.

Electronic sonar depth finder— The depth finders used by boaters and fishermen can also be used to determine the distance from a lagoon's liquid surface to its sludge layer. Only individuals who have experience with electronic sonar equipment set-up and operation should use this method. In addition, the operation of any equipment should be verified under lagoon conditions before actually being used on a boat in a lagoon.

Lagoon managers have built and used different versions of remotely controlled boats in conjunction with a fish finder. By utilizing global positioning system (GPS) technology in conjunction with the fish finder, both the location and depth to the top of the sludge layer can be recorded electronically. The recorded data can then be used to develop contour maps of the sludge or simply to calculate the average depth to sludge.

Fish finders and depth finders, which utilize sonar (sound, navigation and ranging) technology, transmit a high frequency signal from an antenna (called a transducer) and measure the time that it takes the signal to be reflected back to the transducer. The receiver then calculates the distance based on the time delay between the transmitted and reflected signals and the speed at which the signal travels in water (approximately 4,800 feet per second).

An experienced operator can obtain good results with a properly selected sonar unit. The results obtained from a sonar unit should be compared to results from another recommended method until the operator is confident of the results. A suitable unit will cost between $120 and $200. If additional features, such as GPS and a memory card, are desired, the cost may be considerably more. Here are some important considerations for selecting a sonar unit:

- Transmitter power – Higher power increases the likelihood that a signal will be reflected back to the transducer in lagoons with high solids content.
- Transducer – Narrow cone angles concentrate the signal into a smaller area and are preferable.
- Receiver – Manually adjustable controls, such as sensitivity, are important to reduce false readings, especially in lagoons with high solids content.
- Display – A graphic (picture) display with high resolution and good contrast is less likely than a digital display to produce false readings.

Also consider these factors when measuring with a sonar unit:

1. The relative location of the transducer to the surface of lagoon liquid should be recorded and the liquid level in the lagoon referenced to a fixed elevation (such as the start/stop pumping marker).
2. For the initial survey, a permanent grid should be determined and the lagoon bottom elevation should be measured with a pole or other method and recorded for each point on the grid.

3. If the sonar unit is be used on a large boat with an operator rather than a remotely controlled boat, the transducer is best mounted on a float independent of the boat so that it remains at a constant relative location to the liquid surface (i.e. it doesn't move up and down with a rocking boat). The distance from the transducer to the liquid surface should be recorded and added to the depth measurement if necessary.
4. Adjust the sensitivity to the lowest possible setting and turn off the fish identification feature, if the unit is so equipped, to reduce the interference from suspended solids.
5. Record the depth to the top of the sludge at each reference point.

Depth to the bottom of the lagoon

After the depth to the sludge layer has been measured, determine the depth from the liquid surface to the lagoon bottom at the same location. Use a ½-inch to 1-inch diameter pole marked off in inches or tenths of feet. It can be made of wood, aluminum, or PVC with end cap. Push the pole through the sludge until the bottom (soil) is reached. The pole should be held vertically and not be pushed into the soil; it should only make contact. The marked readings should begin at zero at the end inserted into the lagoon, so that the distance from the lagoon bottom to the liquid surface can be read directly. Poles may be constructed of sections that can be joined together, such as 4-foot lengths of PVC with joints, but the sections should always be assembled so that the depth indicators are accurate.

TAKING A SLUDGE SAMPLE

Samples of sludge or "cores" of the lagoon liquid and the sludge may be extracted for laboratory analysis of nutrient content either at the time of the lagoon survey or when a lagoon manager determines that sludge should be removed. Samples should be taken from several locations, then mixed into one composite sample.

How the sample is collected depends on how the sludge will be removed. If the lagoon will be agitated to mix lagoon liquid and sludge during sludge removal, a "core" of the mixed liquid and sludge should be taken. A Sludge Judge with a clear plastic tube and "float valve" at the bottom is a useful device for this task. Also, a 1½-inch diameter PVC pipe with a ball valve at the bottom and a handle operated by a rope can be used to take a core. However, the large-diameter pipe is difficult to manage because the pipe must be longer than the lagoon depth (liquid surface to lagoon soil bottom) and typically will be more than 10 feet long and heavy. Constructing a pipe of 4- to 5-foot sections will make the device easier to transport between lagoons and to store.

To obtain a liquid-and-sludge sample, open the valve and slowly insert the pipe vertically into the lagoon until it reaches the bottom. Then pull the rope to close the valve. Pull the pipe up out of the lagoon. This will capture a core

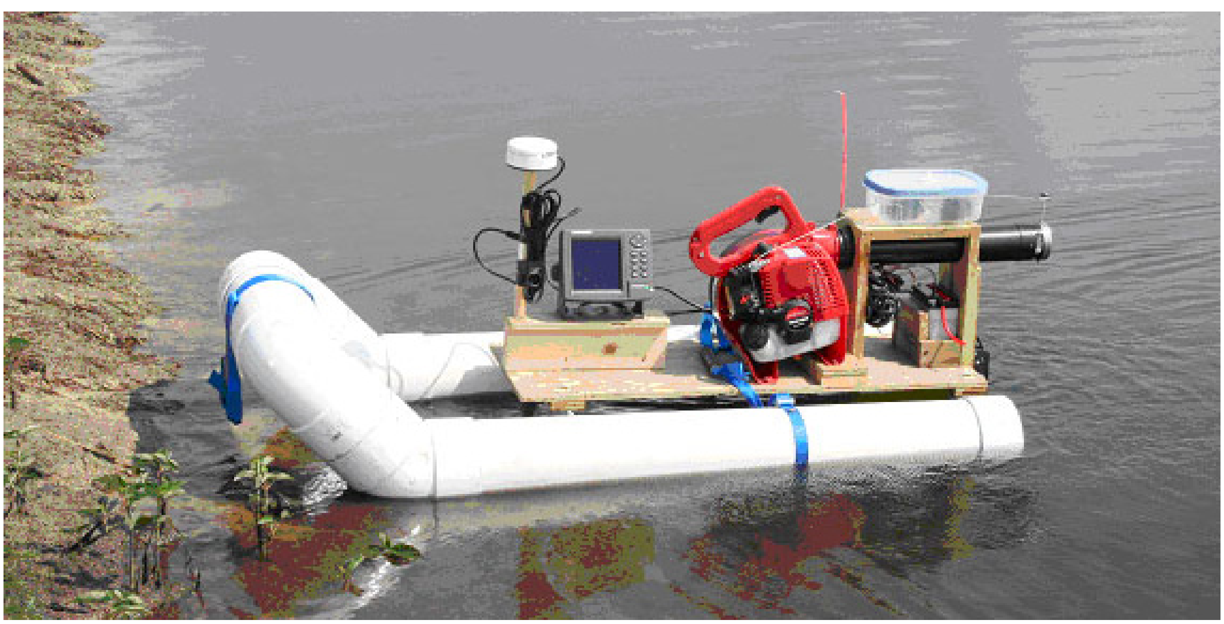

Figure 3. Remotely controlled sludge survey boat designed and built by Dan Bailey (Extension Agricultural Agent, Sampson County) utilizing a fish finder, GPS, and a gas-powered leaf blower for propulsion.

or profile of lagoon effluent and sludge. Empty the contents of the pipe into a clean 5-gallon bucket by opening the ball valve.

Place several samples in the bucket and mix thoroughly before removing a sub-sample for analysis. A wide-mouthed plastic bottle is a good container for shipping samples to the laboratory.

If the lagoon liquid is going to be drawn down and primarily only sludge pumped out, then only the sludge portion of the core of liquid and sludge should be released into the bucket and sampled. Another method of obtaining a sludge sample is with a "grab sampler," such as the Ekman Bottom Grab Sampler. ***Sources:*** The Ekman Bottom Grab Sampler is available from various sources, such as Wildlife Supply Co., online at www.wildco.com; phone 1-800-799-8301. Cost of a standard stainless steel sampler kit is $485.

If you are unsure of how the sludge will be removed, take a sample of sludge only and a sample of the sludge-and-liquid entire core, label them separately, and have both analyzed.

RESOURCES

For more information on preparing sludge samples for analysis, consult these publications:

Sheffield, R. E., J. C. Barker, and K. A. Shaffer. 2000. *Sludge Management and Closure Procedures for Anaerobic Lagoons* (AG-604). Raleigh: N.C. Cooperative Extension, N.C. State University. Online: http://www.bae.ncsu.edu/programs/extension/manure/ag604.pdf

Crouse, D. 2003. Tools for the Plan. In *Certification Training Manual for Operators of Animal Waste Management Systems*. Raleigh: Department of Soil Science, N.C. State University. Online: http://www.soil.ncsu.edu/certification/Manual/a/chapter4A.htm

Zublena, J. P. and C. R. Campbell. 1997. *Soil Facts: Waste Analysis* (AG-439-33). Raleigh: N.C. Cooperative Extension, N.C. State University. Online: http://www.soil.ncsu.edu/publications/Soilfacts/AG-439-33/

APPENDIX 1. LAGOON SLUDGE SURVEY FORM — REVISED AUGUST 2008

A. Farm Permit or DWQ Identification Number________________________________

B. Lagoon Identification ____

C. Person(s) Taking Measurements ____

D. Date of Measurements ____

E. Methods/Devices Used for Measurement of:

a. Distance from the lagoon liquid surface to the top of the sludge layer: _____________________________

b. Distance from the lagoon liquid surface to the bottom (soil) of the lagoon: _________________________

c. Thickness of the sludge layer if making a direct measurement with "core sampler":___________________

F. Lagoon Surface Area (using dimensions at inside top of bank): _____________(acres)

(Draw a sketch of the lagoon on a separate sheet, list dimensions, and calculate surface area. The lagoon may have been built differently than designed, so measurements should be made.)

G. Estimate number of sampling points:

a. Less than 1.33 acres: Use 8 points.

b. If more than 1.33 acres, ______ acres × 6 = _______, with maximum of 24.

(Using sketch and dimensions, develop a uniform grid that has the same number of intersections as the estimated number of sampling points needed. Number the intersection points on the lagoon grid so that data recorded at each can be easily matched.)

H. Conduct sludge survey and record data on "Sludge Survey Data Sheet" (Appendix 2). Also, at the location of the pump intake, take measurement of distance from liquid surface to top of sludge layer and record it on the Data Sheet (last row); this must be at least 2.5 ft when irrigating.

I. At the time of the sludge survey, also measure the distance from the Maximum Liquid Level to the Present Liquid Level (measure at the lagoon gauge pole): ________

J. Determine the distance from the top of bank to the Maximum Liquid Level: ___________

(Use lagoon management plan or other lagoon records.)

K. Determine the distance from the Maximum Liquid Level to the Minimum Liquid Level: ________

(Use lagoon management plan or other lagoon records.)

L. Calculate the distance from the present liquid surface level to the Minimum Liquid Level: ________

(Item K minus Item I, assuming the present liquid level is below the Maximum Liquid Level.)

M. Record from the Sludge Survey Data Sheet the distance from the present liquid surface level to the lagoon bottom (average for all the measurement points): _________

N. Record from the Sludge Survey Data Sheet the distance from the present liquid surface level to the top of the sludge layer (average for all the measurement points): _________

O. Record from the Sludge Survey Data Sheet the average thickness of the sludge layer: _________

P. Calculate the thickness of the existing Liquid Treatment Zone (Item N minus Item L): _________

Q. If Item O is greater than Item P, proceed to the Worksheet for Sludge Volume and Treatment Volume. If Item O is equal to or less than Item P, you do not have to determine volumes.

Completed by: ______________________________ ______________________________ Date:_____________

Print Name — Signature

APPENDIX 2. SLUDGE SURVEY DATA SHEET* REVISED AUGUST 2008

Lagoon Identification: ____

Completed by: ______________________ ______________________ Date:__________
Print Name Signature

(A) Grid Point No.	(B) Distance from liquid surface to top of sludge		(C) Distance from liquid surface to lagoon bottom (soil)		(C) minus (B) Thickness of sludge layer	
	ft & in.	ft (tenths)	ft & in.	Ft (tenths)	ft & in.	ft (tenths)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
Number of points with readings			X		X	
Average of points						
At pump intake			X	X	X	X

*All Grid Points and corresponding sludge layer thicknesses must be shown on a sketch attached to this Sludge Survey Data Sheet. See Appendix 4 for conversion from inches to tenths of a foot.

APPENDIX 3. WORKSHEET FOR SLUDGE VOLUME AND TREATMENT VOLUME   REVISED AUGUST 2008

The average thickness of the sludge layer and the thickness of the existing liquid (sludge-free) treatment zone are determined from information on the Lagoon Sludge Survey Form (Items O and P, respectively). In this example, the average sludge layer thickness is 2.5 feet and the existing liquid treatment zone is 3.5 feet. If the lagoon has a designed sludge storage volume, see notes at end of the worksheet. The dimensions of the lagoon as measured and the side slope are needed for calculations of sludge volume and of total treatment volume. If the lagoon is a standard geometric shape, the sludge volume and treatment volume in the lagoon can be estimated by using standard equations. For approximate volumes of rectangular lagoons with constant side slope, calculate length and width at the midpoint of the layer, and multiply by layer thickness to calculate layer volume, as shown in the example. For irregular shapes, convert the total surface area to a square or rectangular shape. For exact volumes for lagoons with constant side slope, the "Prismoidal Equations" may be used.

	Example	Your lagoon
1. Average Sludge Layer Thickness (T)	2.5 ft	
2. Depth of lagoon from top of bank to bottom soil surface (D)	11 ft	
3. Slope = horizontal/vertical side slope (S)	3	
4. Length at top inside bank (L)	457 ft	
5. Width at top inside bank (W)	229 ft	
6. Length at midpoint of sludge layer: Lm = L – 2 S (D- (T/2))	398.5 ft	
7. Width at midpoint of sludge layer: Wm = W – 2 S (D – (T/2))	170.5 ft	
8. Volume of sludge (Vs): Vs = Lm Wm T	169,860 ft^3	
9. Volume in gallons (Vsg): Vsg = V * 7.5 gal/ft3	1,273,950 gal	
10. Thickness of existing liquid treatment zone (Y)	3.5 ft	
11. Thickness of total treatment zone (Z): Z = T + Y	6.0 ft	
12. Length at midpoint of total treatment zone: Lz = L – 2(S) (D – (Z/2)	409 ft	
13. Width at midpoint of total treatment zone: Wz = W – 2(S) (D – (Z/2)	181 ft	
14. Volume of total treatment zone (Vz): Vz = Lz Wz Z	444,174 ft^3	
15. Ratio (R) of sludge layer volume to total treatment volume: R = Vs/Vz If the ratio exceeds 0.50, than a sludge Plan of Action may be required. Check with DWQ for information on filing the Plan of Action.	0.38	

Note: If the lagoon has a designed sludge storage volume (DSSV), subtract that volume from both the volume of sludge (Vs) (Item 8) and from the volume of total treatment zone (Vz) (Item 14), and take the ratio:

R = (Vs – DSSV) / (Vz – DSSV)

Example: If DSSV = 85,000 ft^3, then R = (169,860 – 85,000) / (444,174 – 85,000)
R = 84,860 / 359,174 = 0.24

APPENDIX 4. CONVERSION TABLE FROM INCHES TO TENTHS OF A FOOT

Inches	Tenths of a foot	Inches	Tenths of a foot
1	0.1	7	0.6
2	0.2	8	0.7
3	0.2	9	0.7
4	0.3	10	0.8
5	0.4	11	0.9
6	0.5		

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