

SEDIMENT CORE SAMPLING AND ANALYSIS OF KAW LAKE

¹Dejene Alemayehu, ²Jason McAlister and ²William Fox

¹Department of Kaw Nation Environmental, USA

²Blackland Research Center, Texas A and M, USA

Received 2014-07-21; Revised 2014-08-25; Accepted 2014-09-06

ABSTRACT

The Kaw Nation and Black land Research Center in July 2012 conducted a sediment core sampling from Kaw Lake. Kaw Lake is a reservoir constructed in 1976 by the Army Corps of Engineers for the purpose of water supply and recreation. It is located 11 miles east of Ponca City, Kay County, Oklahoma. This reservoir covers approximately 17,040 acres (69 km²) and is also known to be the seventh largest lake in Oklahoma by surface area. This lake holds 428,600 acre feet (528,700, 00 m³) of water which is said to be the ninth largest lake in Oklahoma. The lake is fed by the Arkansas River that flows from Colorado, through Kansas and into Kaw Lake. The Arkansas River flows through Kaw Lake shared by several small creeks and empties into the Mississippi River. The purpose of the study was to determine the rate of sediment accumulation and examine the level of nutrient and heavy metals accumulation or deposition at the bottom of the lake. Four core samples from different parts of the lake at different depth were sampled for analysis. Each core sample was sectioned into 20 cm, dried and ground into homogenous powder. Samples from each section were tested for organic carbon content and heavy metals. Organic carbon content was verified by burning through a muffle furnace, while the remaining core samples were digested into a solution and ran through an Atomic Absorption Spectrophotometer (AAS) to evaluate the concentration of heavy metals. Particle size analyses were also determined. Results were organized by depth, concentration, particle size distribution and bulk density. Data showed phosphorous and some heavy metals concentrations at core 3 and 4 were higher than core 1 and 2. Phosphorous concentration at four sediment core sites ranged from 350 mg kg⁻¹ to 550 mg kg⁻¹. Whereas Aluminum concentration was 40,000 mg kg⁻¹ to 70,000 mg kg⁻¹, Barium 280 mg kg⁻¹ to 420 mg kg⁻¹, manganese 600 mg kg⁻¹ to 710 mg kg⁻¹, iron 30,000 mg kg⁻¹ to 48,000 mg kg⁻¹ are few to be cited. Bulk density, a measure of soil mass per unit of volume of soil in a water increased with water depth as the water content decreased.

Keywords: Sediment Coring, Sediment Core and Analysis, Lake Sediment Sampling, Vibracoring

1. INTRODUCTION

Kaw Lake is located 11 miles east of Ponca City, Kaw County, Oklahoma. Kaw Lake was constructed by the Army Corps of Engineers (ACDE) in 1976 for the purpose of water supply, electricity and recreational facility. The Lake is fed by the Arkansas River that flows from Colorado, through Kansas into Kaw Lake, Oklahoma. The Arkansas River flows through Kaw

Lake and empties into Mississippi River. The Arkansas River before it enters into Kaw Lake, several small creeks join the River. Kaw Lake is one of the lakes categorized under hydrological unit code of 11060001.

Kaw Nation Environmental Department monitors the lake once in a month for water quality parameter such as nutrient, sediment, trace heavy metal, pesticides and bacteria. The water quality data is uploaded on U.S. Environmental protection Water

Corresponding Author: Dejene Alemayehu, Department of Kaw Nation Environmental, USA

Quality Exchange (WQX) database through the Kaw Nation Node. Runoff from the park, agricultural farms, wetlands, oil and natural gases fields, mining, rangelands, septic systems, have the potential to enter into the lake as non-point source pollution loaded with sediment. In shallow lake systems, sediments can influence the physical and chemical environment of a water column by deposition, resuspension and transportation (Jin, 2002; Rydin *et al.*, 2000). Expansion of agricultural areas, clearing of forest, road construction and urbanization around the Kaw Lake can be considered a major contributor to the increased phosphorous presence in the lake, which may in turn promote seasonal algal blooms (Rydin *et al.*, 2000).

This research consists of four core samples from different parts of the lake at different depths for analysis. Each core sample has been sectioned into 20 cm, dried and grounded into homogenous powder. Samples from each section are tested for organic carbon content and heavy metals. Organic carbon content gets verified by burning through a muffle furnace, while the remaining core samples are digested into a solution and ran through an Atomic Absorption Spectroscopy (AAS). This helps to evaluate the concentration of heavy metals and determine particle size analysis results by organized depth, concentration, particle size distribution and bulk density.

2. MATERIALS AND METHODS

Sediment samples were collected from beneath an aqueous layer in July 2012 using a Vibrocoring system consisting of a tube (pipe) sampler, to a depth of 24 inches to 20 feet. The sediment core sample was taken on a pontoon boat (Fig. 1). The boat was equipped with a 10 feet tall tripod and an electric winch for vibracoring operations. The deck of the boat has a 2×3 foot area to facilitate coring of the sediment sample. The sediment cores were conducted at four sites.

Vibrocoring is a technique used for collecting samples of unconsolidated saturated sediments. A core tube is attached to a source of mechanical vibration (the power head) and lowered into the sediment. The vibration provides energy for rearranging the particles within the sediment in a way that the core tube penetrate under the static weight of the vibrocoring apparatus. The main benefit of coring is potentially less sample disturbance. The sediment cores were collected using a small boat equipped with vibrocore sampler to a maximum depth of twenty feet below the sediment surface or a point of refusal. The core

sampler equipped with a plastic liner was driven and sediment samples were extracted from each designated sample location.

The sediment collection procedure was as follows:

- The pipe corer or the vibrocore was lowered to 20 feet depth of the lake bottom using an electric winch
- Sufficient length of the winch capable was spooled out to allow the free fall of the tube corer to penetrate deep into the bottom of the lake One the tube corer is firmly and vertically stabilized
- Then the corer was retrieved using an electric winch
- Water overlying the core is siphoned off to minimize disturbance of the upper core layers
- Core length was measured, labeled with date, time and depth
- Latitude and longitude of each sampling point was recorded. The sediment core was transported to Oklahoma State University for profile description, particle size analysis and chemical analysis for heavy metals
- The core segment is sliced off and sub sectioned at 20 cm with a diameter of 2.5 cm and placed into labeled Petri dishes
- Each core was 2 m in depth or length

All sediment cores were collected from 24 inches to 20 feet depth of the lake. Sample locations and approximate water depths are shown in **Table 1**:

- Parts of core samples were placed in a drying oven overnight at a temperature of 80°C. After the core sections dried they were weighed and pulverized into a homogenous powder and placed into a plastic zip lock bag
- About one gram of the homogenized sediment sample was put into the aluminum pans. The sample was placed into a muffle furnace and fired overnight to burn off the organic carbon
- Each sample was weighted on an electronic balance. After burning in the muffle furnace as a post furnace weight. The post furnace weight is subtracted from pre-furnace weight. The loss of weight was attributed to loss of organic carbon

2.1. Textural Analyses

Sediment core samples were analyzed for water content, bulk density and particle size (gravel, sand, silt and clay content):

- Water content was determined
- By weighing 20-30 g of wet sediment

Drying the sediment at 65°C and then re-weighed the dried sediment. The loss of moisture is the % water in the soil Equation 1:

$$\% \text{ water} = \frac{W_w}{W_t} \times 100 \quad (1)$$

Where:

W_w = The weight of the water

W_t = The weight of wet sediment

Bulk density (P_b) was calculated from water content utilizing Equation 2 by assuming an average grain density (P_s) of 2.72 g/cm³ and saturation of voids with water of density $P_w = 1.0$ g/cm³. This method was adopted from the work of (Bennett and Lambert, 1971; Richard *et al.*, 2000):

$$P_b = \frac{W_t}{W_d / 2.72 + W_w} \quad (2)$$

Where:

W_t = The weight of wet sediment

W_w = The weight of water

W_d = The weight of dry sediment

P_b = Bulk density

2.2. Particle Size Analysis

Sand, Silt and clay contents were examined using particle size analysis detailed in (Kerhin *et al.*, 1988; Richard *et al.*, 2000). Particle size analysis requires clearing of the sample in solution of 10% hydrochloric acid and 6 or 15% hydrogen peroxide with subsequent rinsing with deionized water. This process removes soluble salt, carbonates and organic matter that could interfere with individual grains (Richard *et al.*, 2000). Then samples were then treated with a 0.26% solution of the dispersant sodium hexametaphosphate ($\text{Na}_3\text{PO}_3)_6$) to ensure that individual grains do not interfere with analysis.

2.3. Process of Separation of Sand Silt and Clay Particles

The separation of sand, silt and clay particles was accomplished by wet sieving method through a 4phi mesh sieve (62.5 µm, Standard sieve #230):

- The sand fraction was dried and weighed
- The finer particles, silt and clay were suspended in 1000 mL cylinder in a 0.26% in a sodium hexametaphosphate
- The suspension was agitated and at specified time, those after 20 mL pipette withdrawals were made (Carver, 1971; Folk, 1988; Richard *et al.*, 2000) the rationale for the process was that the larger particles settle faster than the smaller ones
- By calculating the settling velocities time for withdrawal can be determined at which all particles of a specified size will have settled part the point of withdrawal
- Sampling times were calculated to permit the determination of the amount of silt (4phi to 8phi (62.5µm to 4.0 µm)) and clay sized finer than 8 phi (4 µm) particles in suspension
- Withdrawn sample were dried at 65°C and weighed from those data the percentages by dry weight of sand, silt and clay were calculated for each sample and classified according to (Shepard, 1954) nomenclature (Fig. 2) and perjury (1988) classification and (Richard *et al.*, 2000).

2.4. Chemical Analysis

Cored sediment samples were analyzed for 12 elements: Cadmium (Cd), Chromium (Cr), Copper (Cu), iron (Fe), lead (Pb), Manganese (Mn), Nickel (Ni), Phosphorous (P), Barium (Ba), Beryllium (Be), Aluminum (Al) and mercury (Hg).

According to Richard *et al.* (2000), these elements are non-volatile, less likely to be lost in the analytical procedures and gives good estimate. Studies have shown that these elements can be used as environmental indicators (Hennessey *et al.*, 1990; Simex and Helz, 1981; Richard *et al.*, 2000). Concentrations of the above elements were determined using a microwave digestion technique followed by analysis of digestive on an Inductively Coupled Argon Plasma spectrophotometer (ICAP), (Richard *et al.*, 2000).

Table 1. Sediment core sample location

Core #	Latitude	Longitude	Water depth (cm)	Local description
1	36° 47' 36" N	96° 54' 34" W	254	Coon creek
2	36° 46' 39" N	96° 51' 31" W	140	Washunga 1
3	36° 47' 36" N	96° 50' 4" W	142	Washunga 2
4	36° 45' 29" N	96° 49' 58" W	105	Sarge



Fig. 1. Sediment coring on a pontune boat at Kaw Lake

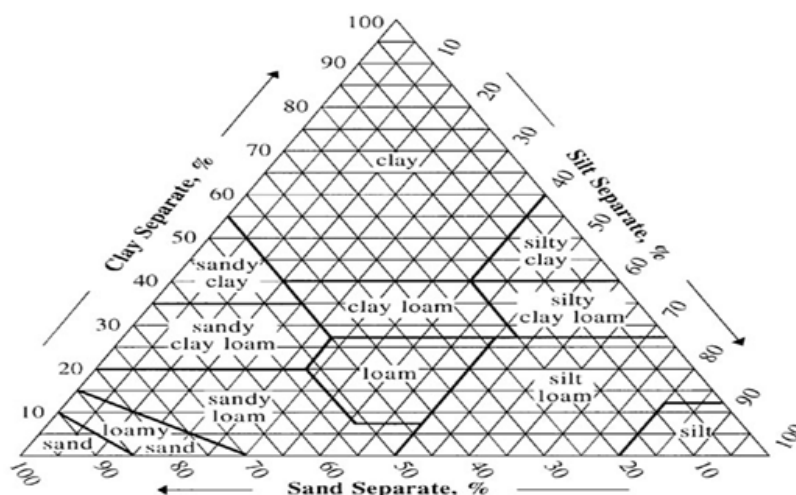


Fig. 2. Soil texture triangle of the USDA system

3. RESULTS AND DISCUSSION

According to **Table 2** above, the color of the sediment changed with depth from 10YR5/2 to 10YR4/1 and this could be due to decrease in percent of water content. The soil texture also changed from silt loam to silt clay loam showing translocation of clay particles from the surface to the bottom of the lake.

At the bottom of the lake, at a depth of 140 m cm, as in **Table 3**, the soil texture changed from silt clay to silt

loam indicating reaching harder surface materials with very hard consistency and higher bulk density.

As percent of water content decreases with depth, the bulk density increased (**Table 4 and 5**) after reaching 60 cm. higher bulk density means more pore space and more deposition of sediment.

In core 1 sediment sample, except at the surface there was no much change with the bulk density. But in core 2 sediment sample the bulk density increased with depth after reaching a depth of 120 cm below the surface.

In both core 3 and 4 sediment samples, the bulk densities showed an increasing trend with depth from 0.5 to 2 g/cm³ showing more deposition of sediment with less percent of water content.

Core sediment samples were collected from various sites within Kaw Lake. Laboratory sediment analysis at Accurate and Oklahoma State University showed high concentration of nutrients mainly phosphorous and heavy metals.

Phosphorous is a nutrient essential for plant growth. Excessive presence of phosphorous where nitrogen is not a limiting factor, may contribute for eutrophication (nutrient enrichment) of a lake (Hem and Usdi, 1991). The phosphorous may be associated with sediment loads that are transported to Kaw Lake as a runoff from agricultural fields treated with fertilizer, wetlands, sewage disposals and rangelands. The concentration of phosphorous in the sediment core sample ranged from 365-548 mg L⁻¹.

In lakes, coarser materials like sand and gravel settle first at the bottom of the river as it enters a lake system and velocity is reduced. On the other hand, silt and clay, source of phosphorous may stay in suspension. Fine grained sediments, mainly silt and clay is responsible for a significant proportion of the annual transport of metals and phosphorous (Bennett and Cabbage, 1992) and move farther within the lake (Fig. 3 and 4).

The presence of heavy metals in lake sediments can provide evidence of past anthropogenic influence on lake systems (Brent and Zackary, 2004). Chemical treatments, industrial pollution around Wichita, fertilizer and pesticides application in the agricultural fields have varying effects on the overall quality of lake system by deposition, re-suspension and transportation of sediment (Jin, 2002; Rydin *et al.*, 2000). The Kaw Lake sediment core had aluminum concentration 22,700-69,900 mg kg⁻¹, Barium, 186 mg kg⁻¹-430 mg kg⁻¹, manganese, 289 mg kg⁻¹-720 mg kg⁻¹, iron, 18,300 mg kg⁻¹-47,700 mg kg⁻¹, zinc, 60.3 mg kg⁻¹-140 mg kg⁻¹ and chromium, 8.08 mg kg⁻¹-45 mg kg⁻¹ as shown in Fig. 5 and 6.

Anoxic condition may occur near the deepest part close to the dam (Fig. 7) and may even release more phosphorous that may affect the water quality of the Lake (Morris, 1998). Sedimentation survey and core sampling results indicate Kaw Lake has accumulated 46,873 acre-feet of sediment since impoundment began in 1976. Assuming a constant sediment accumulation rate, Kaw Lake loses approximately 1064 acre feet of capacity per year. A mean sediment thickness of 2.3 feet was observed with the heaviest deposition primarily in the Arkansas River confluence area of Kaw Lake (McAlister and Fox, 2012) represented at core 01 (Fig. 7).

Table 2. Kaw Lake core 1 (initial core length 254cm) described by: Bill Jones and Scott fine

Sample ID¶	Horizon	Depth* (cm)	Color (moist)	Structure**	Texture***	Consistence (dry)§	Boundary§§	Effervesce§§§	Bulk density (g/cm ³)	Special features
1A	C1	21	10YR 5/2 (10YR 3/1)	M	SiL	HA	-	ST	0.93	
1B	C2	41	10YR 5/2 (10YR 4/2)	M	SiL	MH	-	ST	1.06	
1C	C3	62	10YR 4/1 (10YR 3/1)	M	SiCL	R	-	VS	0.61	
1D	C4	83	10YR 5/1 (10YR 3/1)	M	SiL	R	-	VS	0.60	Note: All samples were saturated with water. For cores 3 and 4, the upper part contained sediment suspended in a water column and not classified as soil, actual lake bottom sediments, sub-aqueous soil, started at 33 and 18 cm below the top of the core for 3 and 4, respectively. Please note the corresponding "apparent" bulk densities for segments 3AB and 4AB (suspended sediment) after drying.
1E	C4	105	10YR 5/1 (10YR 3/1)	M	SiCL	R	-	VS	0.63	
1F	C5	125	10YR 4/1 (10YR 3/1)	M	SiL	R	-	VS	0.63	
1G	C6	146	10YR 5/2 (10YR 3/1)	M	SiCL	R	-	VS	0.57	
1H	C6	167	10YR 4/1 (10YR 3/1)	M	SiCL	R	-	VS	0.59	
1I	C6	188	10YR 4/1 (10YR 3/1)	M	SiCL	R	-	VS	0.66	
1J	C6	209	10YR 4/1 (10YR 3/1)	M	SiCL	R	-	VS	0.61	
1K	C6	230	10YR 4/1 (10YR 3/1)	M	SiCL	R	-	VS	0.62	
1L	C6	250	10YR 4/1 (10YR 3/1)	M	SiCL	R	-	VS	0.65	

¶Number is core identification and following letter is sub-sample identification; *Depth from the sediment surface (not overall metal core); **M = structureless massive; ***SiL = Silt Loam, SiCL = Silty Clay Loam; §MH = moderately hard, HA = Hard, R = rigid; §§§ST = strong, VS = Very Slightly

Table 3. Kaw Lake core 2 (initial core length 140 cm) described by: Bill Jones and Scott fine

Sample ID¶	Horizon	Depth* (cm)	Color (moist)	Structure**	Texture***	Consistence (dry)§	Boundedary§§	Effer-vesce§§§	Bulk density (g/cm ³)	Special features
2A	C1	19	10YR 4/1 (10YR 3/1)	M	SiL	R	-	ST	0.33	
2B	C2	39	10YR 3/1 (10YR 2/1)	M	SiL	R	-	ST	0.42	
2C	C3	60	10YR 3/1 (10YR 2/1)	M	SiC	R	-	VS	0.44	
2D	C3	80	10YR 3/1 (10YR 2/1)	M	SiC	R	-	VS	0.42	Note: All samples were saturated with water. For cores 3 and 4, the upper part contained sediment suspended in a water column classified as soil, actual lake and not bottom sediments, sub-aqueous soil, started at 33 and 18 cm below the top of the core for 3 and 4, respectively. Please note the corresponding "apparent" bulk densities for segments 3AB and 4AB (suspended sediment) after drying.
2E	C4	100	10YR 3/1 (10YR 2/1)	M	SiL	R	-	VS	0.48	
2F	C5	120	10YR 3/1 (10YR 2/1)	M	SiCL	R	-	NE	0.54	
2G	C6	140	10YR 4/2 (10YR 2/1)	M	SiL	VH	-	NE	1.26	

¶Number is core identification and following letter is sub-sample identification; *Depth from the sediment surface (not overall metal core); **M = structureless massive; ***SiL = Silt Loam, SiCL = Silty Clay Loam, SiC = Silty Clay; §R = Rigid; §§§ST = strong, VS = Very Slightly, NE = Non-Effervescent

Table 4. Kaw Lake core 3 (initial core length 142 cm) described by: Bill Jones and Scott fine

Sample ID¶	Horizon	Depth* (cm)	Color (moist)	Structure**	Texture***	Consistence (dry)§	Boundedary§§	Effer-vesce§§§	Bulk density (g/cm ³)	Special features
3AB	C1	7	10YR 3/2 (10YR 2/2)	M	SiCL	R	-	VS	0.35	
3C	C2	27	10YR 3/1 (10YR 2/1)	M	SiCL	R	-	VS	0.39	
3D	C2	47	10YR 3/1 (10YR 2/1)	M	SiCL	R	-	VS	0.44	
3E	C3	67	10YR 3/1 (10YR 2/1)	M	SiL	R	-	VS	0.44	
3F	C4	87	10YR 4/1 (10YR 2/1)	M	SiL	R	-	VS	0.58	
3G	C5	109	10YR 4/2 (10YR 2/1)	M	SiL	R	-	NE	1.35	Few coarse roots/organic debris Note: All samples were saturated with water. For cores 3 and 4, the upper part contained sediment suspended in a water column and not classified as soil, actual lake bottom sediments, sub-aqueous soil, started at 33 and 18 cm below the top of the core for 3 and 4, respectively. Please note the corresponding "apparent" bulk densities for segments 3AB and 4AB (suspended sediment) after drying.

¶Number is core identification and following letter is sub-sample identification; *Depth from the sediment surface (not overall metal core); **M = structureless massive; ***SiL = Silt Loam, SiCL = Silty Clay Loam; §R = Rigid; §§§VS = Very Slightly, NE = Non-Effervescent

Table 5. Kaw Lake core 4 (initial core length 105 cm) described by: Bill Jones and Scott fine

Sample ID¶	Horizon	Depth* (cm)	Color (moist)	Structure**	Texture***	Consistence (dry)§	Bound-ary§§	Effer-vesce§§§	Bulk density (g/cm³)	Special features
4AB	C1	23	10YR 3/1 (10YR 2/1)	M	SiL	R	-	VS	0.43	
4C	C1	43	10YR 3/1 (10YR 2/1)	M	SiL	R	-	SL	0.49	
4Da	C2	55	10YR 3/1 (10YR 2/2)	M	SiL	HA	A	VS	0.90	
4Db	2C3	63	10YR 6/3 (10YR 5/3)	M	LS	SH	-	NE	1.72	Few quartz gravels
4E	2C4	86	10YR 6/6 (10YR 4/6)	M	GrS	MH	-	NE	2.06	Many (>15%) quartz gravels Note: All samples were saturated with water. For cores 3 and 4, the upper part contained sediment suspended in a water column and not classified as soil, actual lake bottom sediments, sub-aqueous soil, started at 33 and 18 cm below the top of the core for 3 and 4, respectively. Please note the corresponding “apparent” bulk densities for segments 3AB and 4AB (suspended sediment) after drying.

¶Number is core identification and following letter is sub-sample identification; *Depth from the sediment surface (not overall metal core); **M = structureless massive; ***SiL = Silt Loam, LS = Loamy Sand, GrS = Gravelly Sand; §SH = Slightly Hard, HA = Hard, R = Rigid; §§A = abrupt; §§§SL = Slightly, VS = Very Slightly, NE = Non-Effervescent

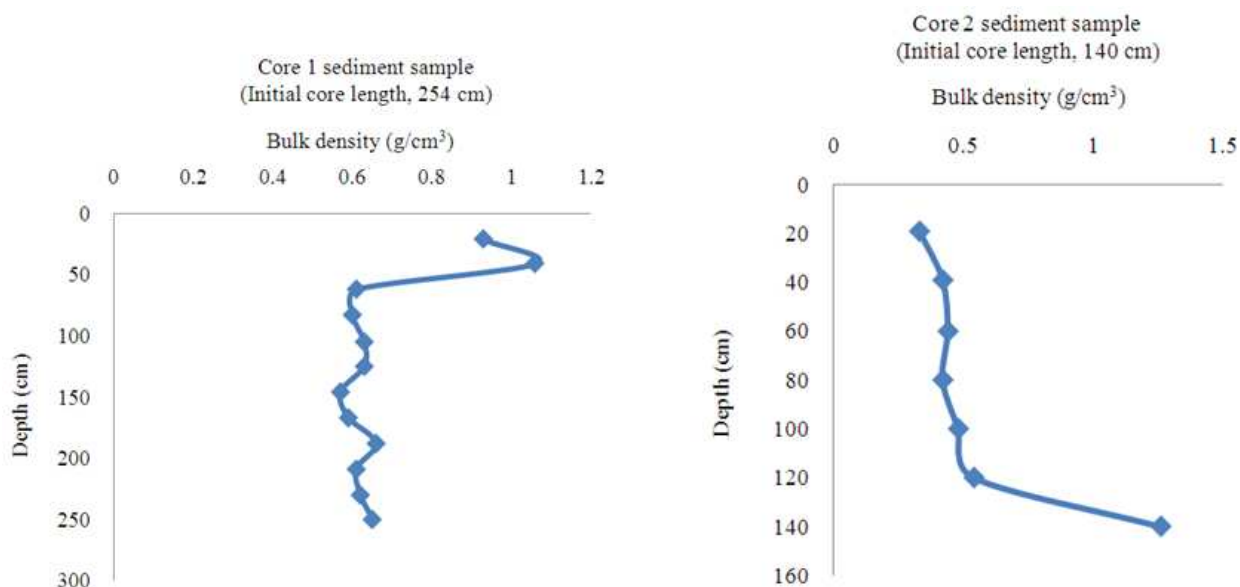


Fig. 3. Bulk density of core 1 and 2 sediment samples

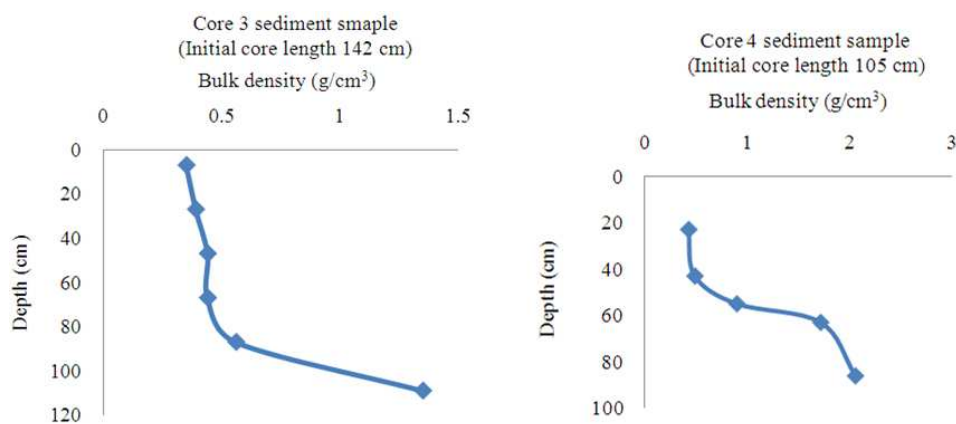


Fig. 4. Bulk density of core 3 and 4 sediment samples at a depth greater than 105 cm

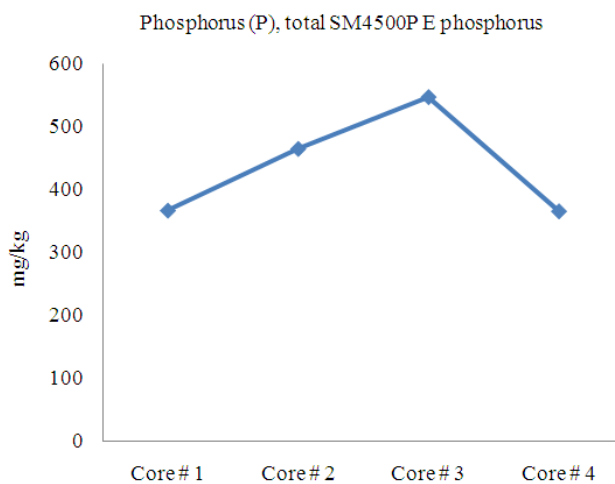
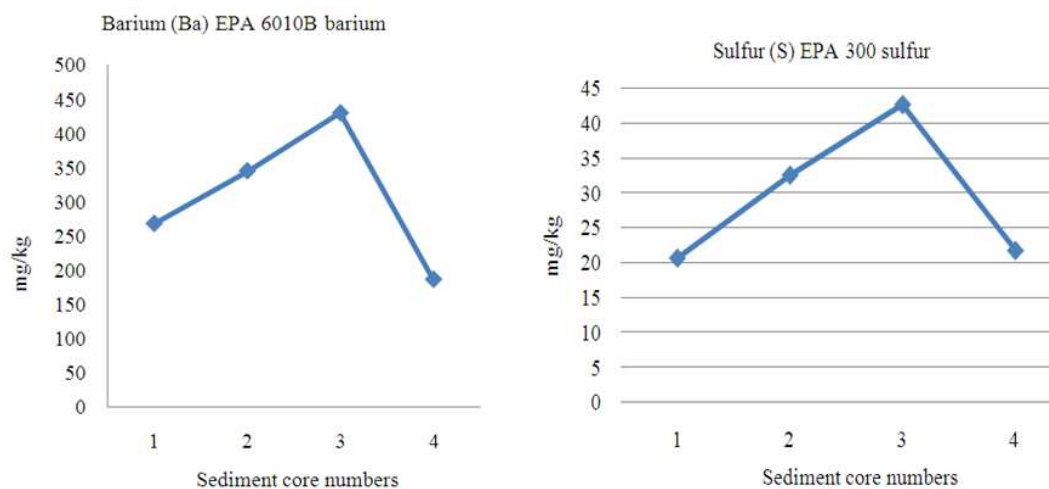


Fig. 5. Concentration of phosphorous at various sediment core sampling sites, bottom of Kaw Lake



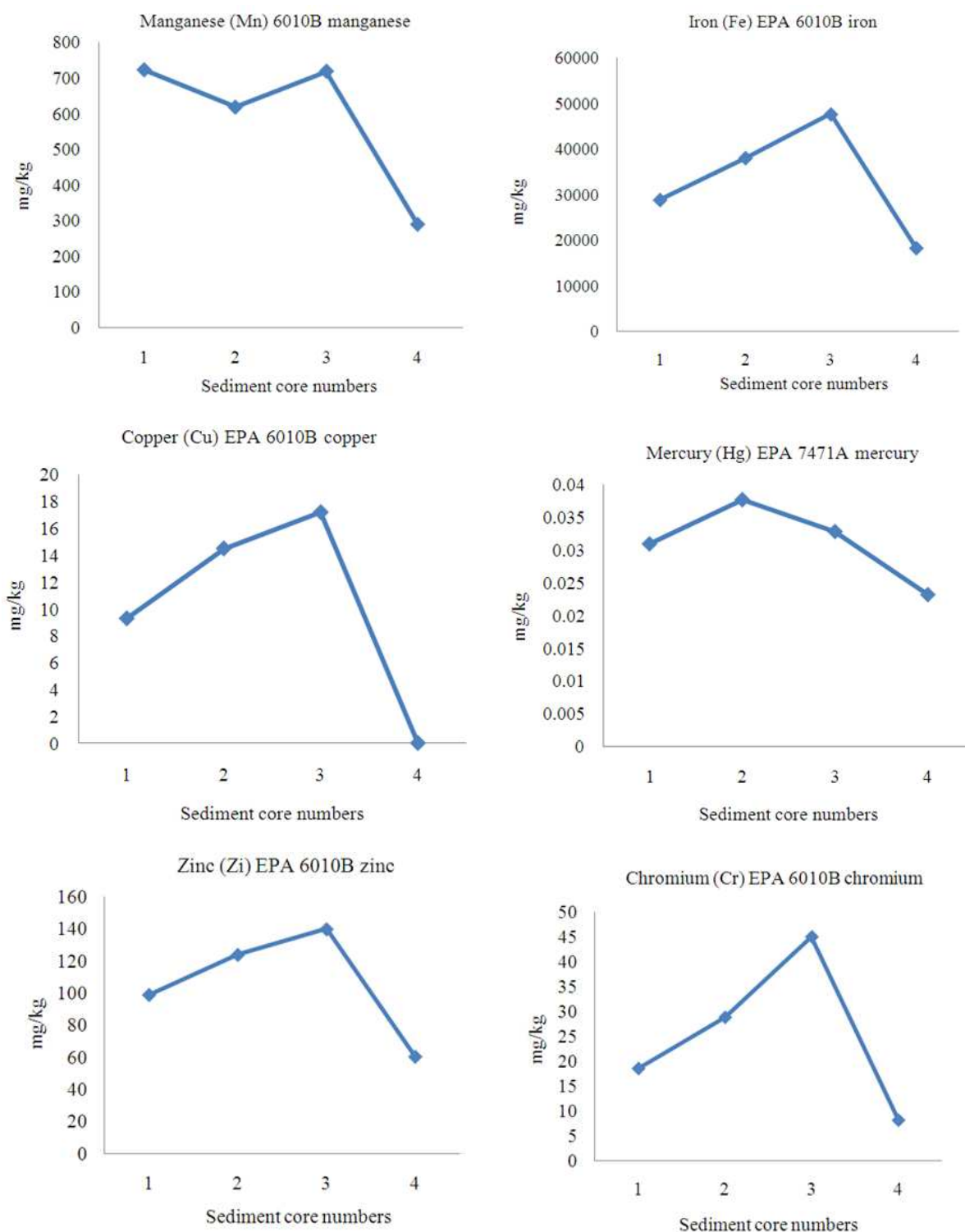


Fig. 6. Concentration of trace metals at various sediment core sampling sites at the bottom of Kaw Lake

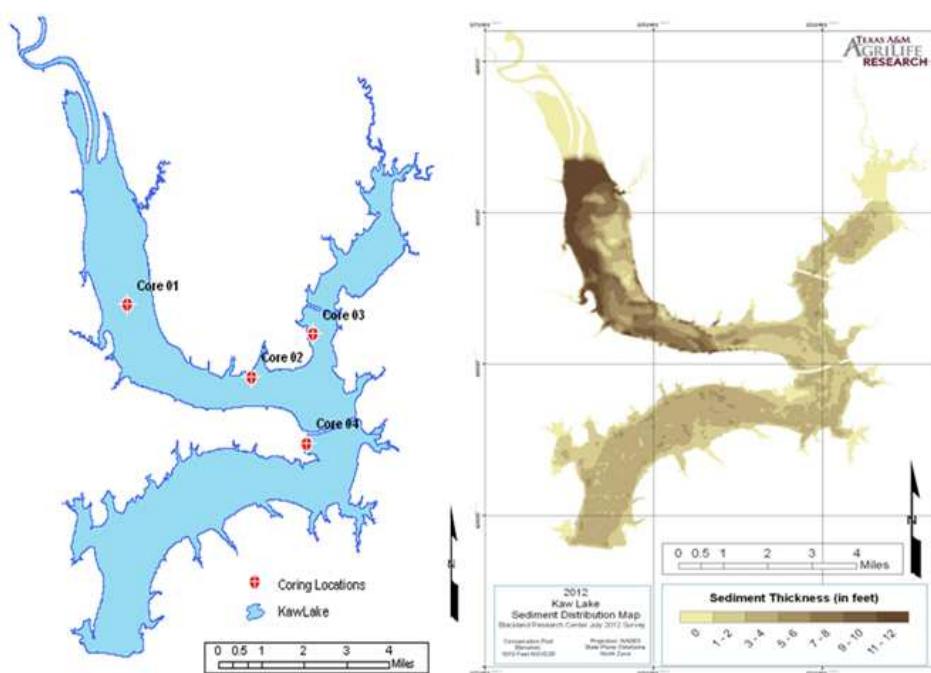


Fig. 7. Kaw Lake suspended sediment distribution and thickness

4. CONCLUSION

From the sediment core analyses, the concentration of phosphorous in the lake was higher than the state standards due to run off fertilizer coming from agricultural fields within the watershed into the lake. Phosphorous could be adsorbed to fine sediment such as silt and clay particles and stay in the lake as a Total Suspended (TSS) material. Repeated laboratory analysis of phosphorous in Kaw Lake showed high concentration of phosphorous greater than 0.3 mg L^{-1} . Heavy metal concentrations within sediment cores and variability within the reservoir could be locational characteristics as it is close to a boat ramp (all activities associated with its usage) and the local hydrology as it relates to suspension, deposition and overall fluvial mechanism. The hydrology may be (1) dominated broadly by Beaver Creek contribution, (2) that contribution is buffered/restricted by the artificial weir created by E. Ferguson Rd. bisection of the lake and (3) possibly influenced by a lateral eddying effect forward (downstream if you will) of that flow restriction. Residence time of water (and its associated quality) may play an important role in the adsorption of metals to sediments within the reservoir. Waters/sediments moving from the Arkansas confluence continually move toward the outlet/dam (in theory). This

would suggest in the main body of the reservoir, there is deposition, but there may also be a “scrubbing” effect; whereas, again, the Beaver Creek arm and core 3 location may again be relegated to a backwater eddy unless Beaver Creek drainage is active.

5. ACKNOWLEDGMENT

Financial support for this study was provided by U.S. Environmental Protection Agency, Region 6, Dallas, Texas.

6. REFERENCES

- Bennett, J. and J. Cabbage, 1992. Copper in Sediments from Steilacoom Lake, Pierce County, Washington. Washington State Department of Ecology, pp: 5.
- Bennett, R.H. and D.V. Lambert, 1971. Rapid and reliable technique for determining unit weight and porosity of deep-sea sediments. *Marine Geol.*, 11: 201-207. DOI: 10.1016/0025-3227(71)90007-7
- Brent, L. and B.H. Zackary, 2004. Sediment core sampling in spanaway lake: A timeline for heavy metal presence in a shallow urbanized lake.
- Carver, R.E., 1971. *Procedures in Sedimentary Petrology*. 1st Edn., John Wiley and Sons Canada, New York, pp: 653.

- Folk, R.L., 1988. Petrology of Sedimentary Rocks. 1st Edn., Hemphill's, Austin, pp: 169.
- Hennessey, E.L., R.H. Cuthbertson and J.M. Hill, 1990. Sedimentary environment, in assessment of the environmental impacts of the hart and miller islands contaminant facility. Proceedings of the 8th Annual Intercept Report, Aug. 1988-1989, Annapolis, MD, Tidewater Admin., pp: 20-94.
- Hem, J.D. and H.D. Usdi, 1991. Study and Interpretation of the Chemical Characteristics of Natural Water: United States Geological Survey Water-Supply Paper 2254. 3rd Edn., Scientific Publishers, ISBN-10: 817233012X, pp: 264.
- Jin, K., 2002. A 3-D sediment transport model in a shallow lake: The role of sediment resuspension. *J. Environ. Quality*, 31: 103-125.
- Kerhin, R.T., J.P. Halka, D.V. Wells, E.L. Hennessey and P.J. Blakeslee *et al.*, 1988. The surficial sediments of chesapeake bay. Maryland, Physicalchar density and sediment budget. Maryland Geological Survey Report of Investigation.
- McAlister, J. and W. Fox. 2012. Kaw lake volumetric and sedimentary survey, blackland research and extension center. Unpublished report.
- Morris, G.L., 1998. Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs and Watersheds for Sustainable Use. 1st Edn., McGraw Hill Professional, New York, ISBN-10: 007043302X, pp: 848.
- Richard, A.O., T.K. Randall, W. Darlene and C. Jeff, 2000. Bathymetric survey and sedimentation analysis of loch raven and prèt boy reservoirs. Department of Natural Resources, Maryland Geological Survey coastal and Estuarine Geology.
- Rydin, E., B. Huser and E.B. Welch, 2000. Amount of phosphorus inactivated by alum treatments in Washington lakes. *Limnol. Oceanography*, 45: 226-230. DOI: 10.4319/lo.2000.45.1.0226
- Shepard, F.P., 1954. Nomenclature based on sand-silt-clay ratios. *J. Sedimentary Petrol.*, 24: 151-158. DOI: 10.1306/D4269774-2B26-11D7-8648000102C1865D
- Simex, S.A. and G.R. Helz, 1981. Regional geochemistry of trace elements in Chesapeake bay sediments. *Environ. Geol.*, 3: 315-323. DOI: 10.1007/BF02473521