A Review of Sedimentation within Marion County Park and Lake, Kansas

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*Due to the COVID-19 pandemic we have limited our research to a comprehensive review of factors affecting reservoir sedimentation.

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Introduction

The greatest environmental concerns for the Great Plains are soil conservation and water quality (Bontrager, 2011). These concerns grow as the population does. There is a delicate balancing act between being able to provide water and space now and being able to provide them in the future. Sediment is slowly filling up water reservoirs and putting water quality at stake. It will get to a point soon, that some reservoirs will become unusable for their intended purpose. Thankfully, Marion County Park and Lake sedimentation is not an immediate threat. Yet it is important to understand sedimentation to better manage this recreational lake. In this paper, we will discuss our study site, the problems sedimentation causes, the factors that cause changes in sedimentation, dating techniques that can be used to determine changes in the rate of sedimentation, and characteristics of lake sediment to develop solutions for sedimentation.

History of Marion County Park and Lake

Construction of Marion County Park and Lake

According to the local history put together by Hett (2017), Marion County Park and Lake was designated as project SCS-27 and located 4 ½ miles south-east of Marion; work was started March 21, 1936, under supervision of Supt. E. C. McBurney. The project was to construct an earth type dam, 1200 feet in length and height of 44 feet, with a width at the base of 250 feet and width on top of 30 feet (Fig. 1). It required 200,000 cubic yards of earth fill, 70,000 cubic yards of rock rip-rap, and 6,500 square yards of rock to face the berm (Hett, 2017). The spillway is cut through solid limestone (Fig. 1). The maximum cut being 30 feet in height, 200 feet in width, and 900 feet in length necessitating the removal of approximately 100,000 cubic yards of rock (Hett, 2017).

The park area is 652 acres and the lake surface covers 160 acres after being filled (Fig. 3). The drainage area consists of 4,600 acres of pasture lands to the north and east (Hett, 2017). With the average rainfall for the locality it was anticipated the lake would be filled in 14 months, from July 1936 when the outlet valve was closed. In 1937, Marion County Lake was completed by the Civilian Conservation Corps for the purpose of recreation.

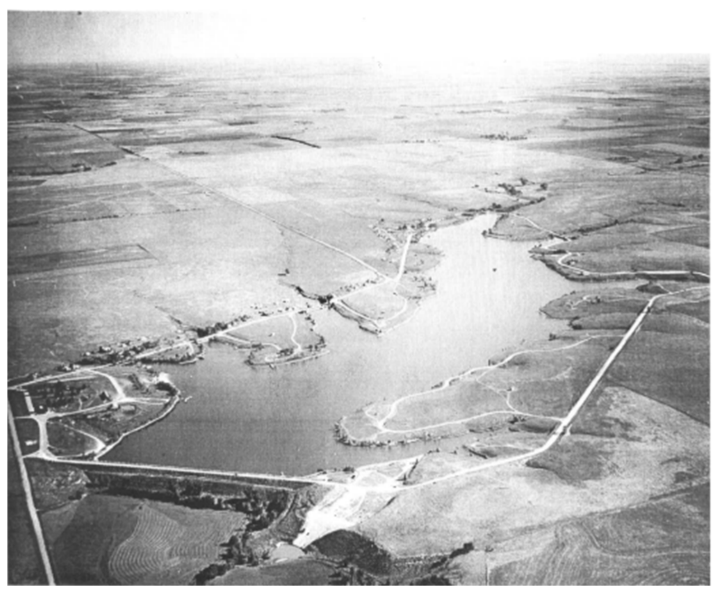


Figure 1: After completion of construction (Hett, 2017)

It is important to note that Marion County Park and Lake is a normally ponded reservoir, as stated by Meyerhoff (M. Meyerhoff, personal communication, January 23, 2020). Normally ponded reservoirs release water from the surface of the lake (Rahmani et al., 2018). A cross-section of a normally ponded reservoir that shows the outlet is provided in Figure 2 by the Shawnee County Conservation District (2018). This build makes it hard to properly manage the system due to the water only being released at the surface. Meyerhoff (M. Meyerhoff, personal communication, January 23, 2020) confirmed that there were frequent algal blooms in the lake during the summer. Kelley and Nater (2000) found that algal blooms could be used as an indicator of retention time. This form of outlet tends to have longer retention times and higher trapping efficiency (Rahmani et al., 2018). Due to this, algal blooms will be more prevalent and cause disturbances in the lake's recreational activities.

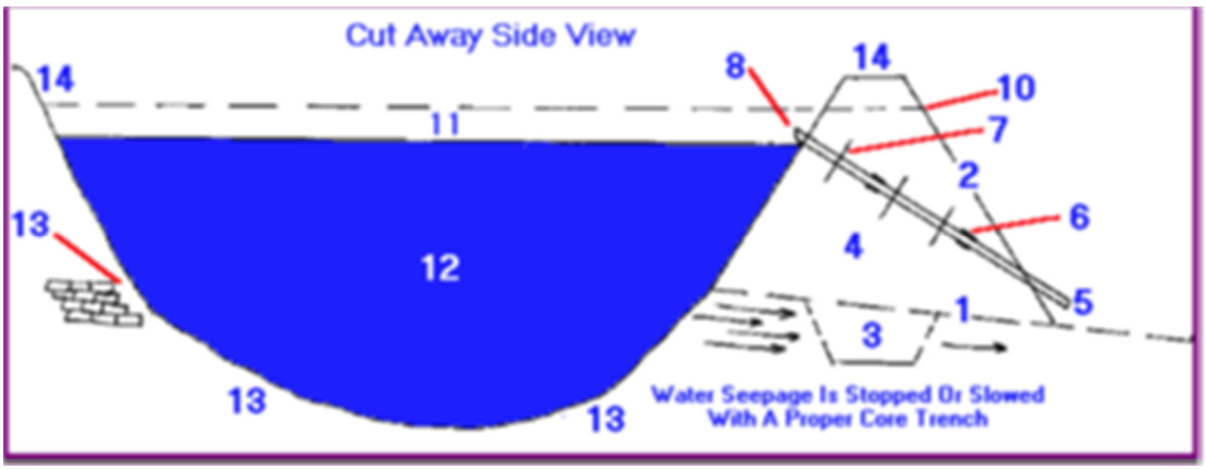


Figure 2: Normally ponded reservoir outlet structure (Shawnee County Conservation District, n.d.)

Construction of the Marion Reservoir

The Marion Reservoir was given authority to be built with the passing of the Flood Control Act of 1950. But construction wouldn't begin until March of 1964. In February of 1968 the project was placed in full flood control operation. At an estimated cost of $13,600,000, the project was designed and built under the supervision of the Tulsa District, Corps of Engineers (Madrona Publishers, 1977).

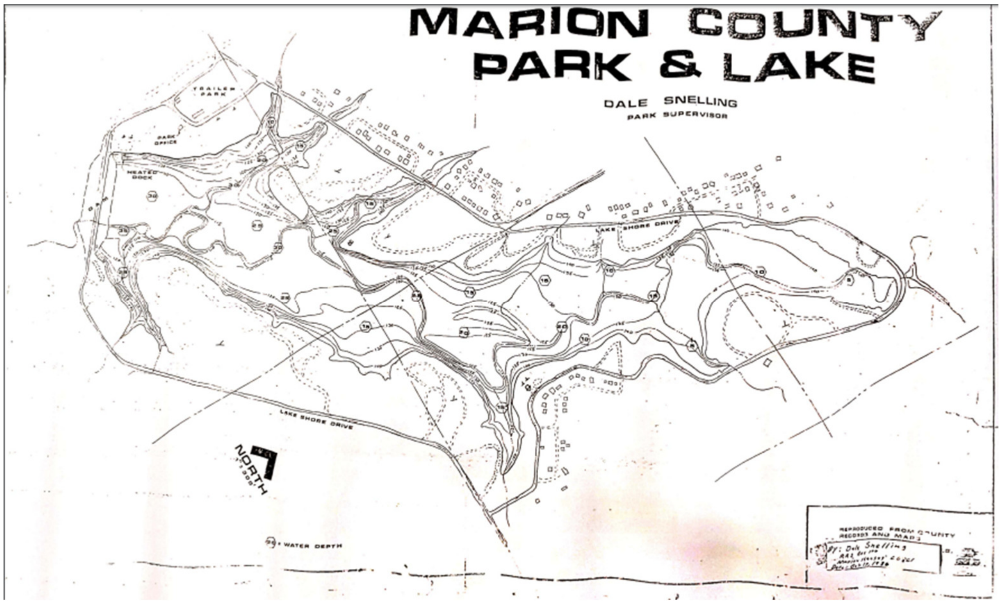


Figure 3: Map of water route in relation to the new boundaries of Marion Lake (Hett, 2017)

Research and surveys done at Marion County Park and Lake

On April 12th, 1977 the U.S Environmental Protection Agency (EPA) ran a survey to gain information on nutrient sources, concentrations, and impacts on selected freshwater lakes to formulate practices relating to point-source discharge reduction and nonpoint source pollution abatement in lake watersheds. It seemed that the EPA gathered that Marion County Park and Lake was phosphorus limited at the time that the sample was taken and that the only point that they could identify at the time for contributing to the phosphorus level was the municipal wastewater treatment facility at Canton (EPA, 1977).

Marion County Park and Lake was added to the National Register of Historic Places (NRHP) in 2002, with its historic significance listed as “Event” being its construction in the time period of 1925-1949 by the Civilian Conservation Corps (CCC). The Marion County Park and Lake’s historic functions were outdoor recreation and currently are used as both recreation and culture (Hett, 2017).

Many studies, papers, and projects have been done starting in 2018, going over a multitude of topics relating to Marion County Park and Lake. These studies range from climate change and changing land cover to pollinator habitat installation. These projects aim to give Marion County Park and Lake information that can be used to make a well informed park management plan that they can use to guide the park in the best way possible both financially and environmentally. One such study by Rahmani et al. (2018) found the deposition rates for the lake during a period of drought as seen in Figure 4. The study also determined that the trapping efficiency of Marion County Park and Lake was 100% (Rahmani et al., 2018). This indicates that all sediment flowing into the reservoir is being trapped within, contributing to our focus of sedimentation. One of the environmental issues to help guide Marion Parks and Recreation is, sedimentation and how it could affect the lake.

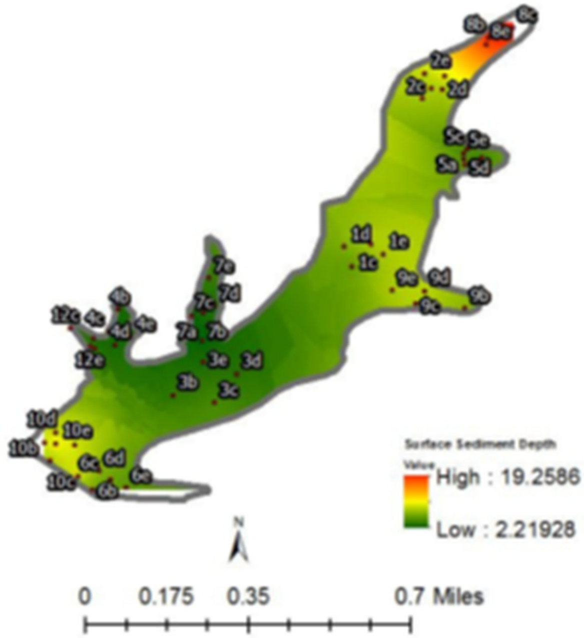


Figure 4: Sedimentation depth distribution for Marion County Park and Lake (in inches) (Rahmani et al., 2018)

Why sedimentation is a problem

As stated by Bontrager (2011), the greatest environmental concerns for the Great Plains are soil conservation and water quality. As the breadbasket of the United States, the Great Plains has the challenge of balancing the needs of the environment with the needs of people. One way the State of Kansas has changed the environment to support agriculture is by creating man-made lakes. Many of the lakes in Kansas and other parts of the Midwest were built to help with irrigation and water supply. While this is not the exact case for our lake, it will still experience the same issues. Man-made lakes struggle with the problem of sedimentation. The main difficulty that is faced with sedimentation are the impacts on storage capacity and thus the design life of the basins.

Effect on storage capacity

Most constructed dams have a sediment reserve storage capacity designed to capture sediment deposition over the lifetime of the project (Chin, 2013). However, due to changing conditions this storage capacity is filling faster than expected. Clark et al. (1985) found that 43% of 42 reservoirs in Iowa, Nebraska, and Missouri lost storage capacity due to sedimentation (Moriasi et al., 2018). The study done by Clark et al. (1985) in the surrounding Mid-west Region over 30 years ago saw that constructed dams were already losing capacity. The study accomplished by Moriasi et al. (2018) found that, "… the larger the reservoir size, the lesser the rate of water storage capacity loss." The Marion County Park and Lake is relatively small compared to the impoundments studied, so it will likely lose storage capacity at a faster rate. Their team also found that the reservoirs in their study had a storage capacity loss from 0.84% to 2.2% per year (Moriasi et al., 2018). This loss in storage capacity builds up year after year. The Kansas Water Office accomplished a study in 2019 that determined the sedimentation impact for the reservoirs of Kansas as seen in Figure 5 below. The Marion Reservoir is not the same as the Marion County Park and Lake, but the two may have similar sedimentation rates. According to the Kansas Water Office (2019), the Marion Reservoir saw a 6.4% decrease in total storage capacity, which is the second lowest in the state.

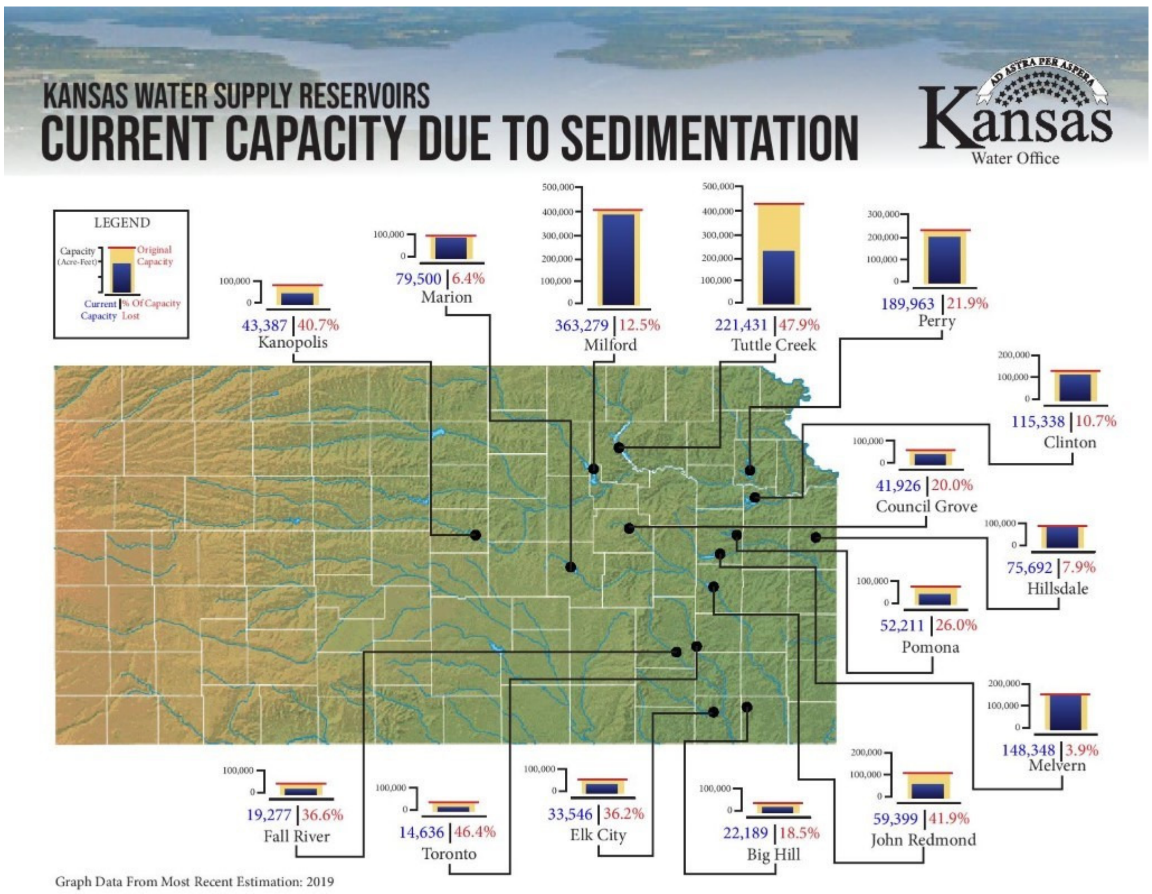


Figure 5: Current capacity of reservoirs in Kansas due to sedimentation (Kansas Water Office, 2019)

Design life of basins

The sediment storage capacity is directly determined by the design life of the basin. The fact of the matter is most reservoirs built in the United States are entering into the end of their expected design life (Patterson et al., 2019; Smith, 2011). Another issue that will be coming up is the fact that during the design of these basins, sedimentation rates were assumed to be constant over the expected lifetime (Patterson et al., 2019). However, this is no longer true due to warming climates, cyclic changes in precipitation, introduction of new regulations, and populations concentrating to urban environments (Patterson et al., 2019). These factors combined show the importance of dealing with sedimentation rather than waiting for it to become a bigger issue. If these basins continue to be used past their design life, greater care will have to be taken to ensure that the water quality and quantity are suitable for use.

The detrimental effects of sedimentation in basins can easily be seen when looking at how capacity is affected. Now, we must examine the causes of sedimentation to begin thinking of a solution.

External driving factors of sedimentation rates

Sedimentation rates change due to two main variables: water flow and watershed factors. At first, it appears that both cannot be changed since they are inherent to the system. However, as with most things, human interaction has altered these variables.

Water flow

Sedimentation occurs naturally where any body of water reduces speed. This can occur naturally at bends in the river and can be caused by an introduction of new flow. However, man-made structures affect the flow of water in a variety of ways. These structures can decrease the flow in two instances by (1) creating obstructions such as dams or (2) they can increase flow by creating impervious surfaces that cause water to drain rapidly.

For the first instance, Wen et al. (2019) found that after the construction of large-sized reservoirs, they could see an abrupt change in the suspended sediment load of the river and that sediment load reduction primarily occurs at dams throughout the world. Furthermore, Sullivan (2013) discovered that ponds are good at dissipating the energy of the stream, which causes the sediment to settle. The obstructions created by dams cause the water to pool, decreasing the velocity and dissipating the energy and thus the ability to carry sediment. This is demonstrated in Figure 6 below, an infographic provided by the Kansas Water Office (2019). Most of the sediment is deposited just after the stream or river reaches the still body and where the obstruction of the dam occurs. This verifies the data provided earlier by Rahmani et al. (2018). This concept provides an idea of where the issues of sedimentation will first occur.

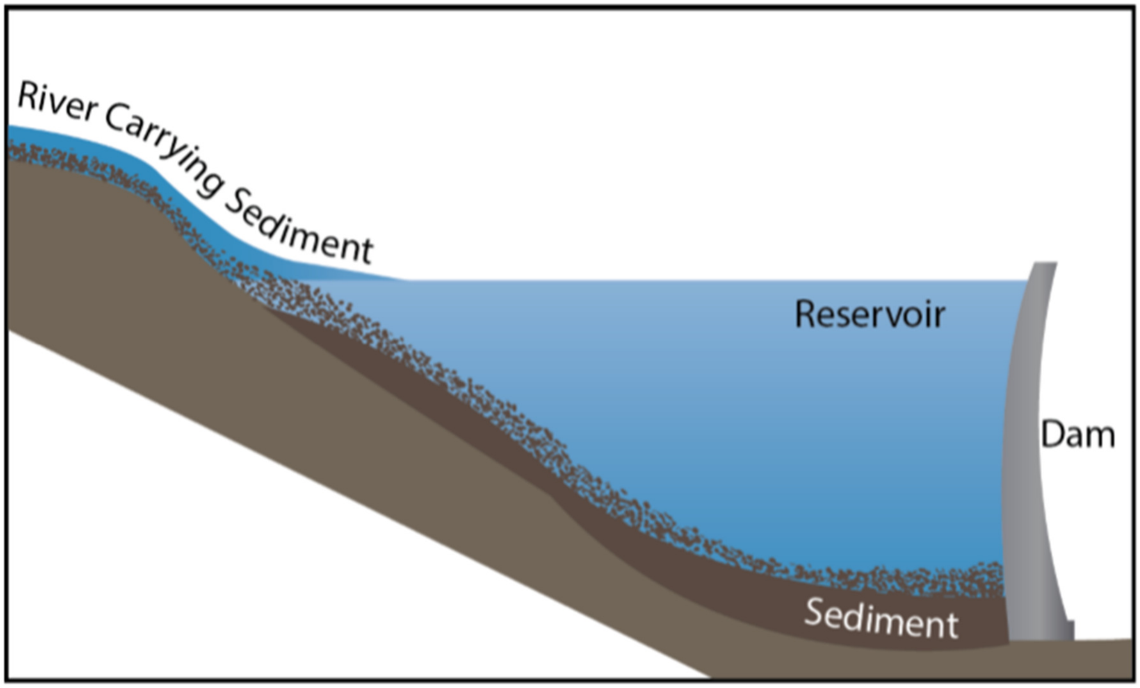


Figure 6: Depiction of sedimentation within a reservoir (Kansas Water Office, 2019)

For the second instance, it has been well documented that urban areas increase flow during storm events. This is primarily since water infiltration rates decrease significantly with the introduction and development of impervious surfaces (Balkenbusch et al., 2018). With vegetation removed and soil compaction from increased human activity, the infiltration of the area is reduced and overland flow increases, allowing erosion to occur more readily. Extreme rainfall events already increase the suspended solid load and sediment transportation according to Wen et al. (2019). These factors combine and create more erosion and thus sediment is transported into the basin. As Kansas has entered a wetter season since the 2018 data has been collected, there could be increased sedimentation within the Marion CountyPark and Lake. The way water flow is affected is crucial to understanding how changes in sedimentation occur. The other variable that determines the rate of sedimentation are the watershed factors.

Watershed factors

There are a variety of variables within watershed factors that contribute to sedimentation. Sedimentation rates are primarily influenced by drainage area, topography, soils, land use/land cover, climate factors, erosion, irrigation, and proximity to water bodies (Bontrager, 2011; Moriasi et al., 2018; Patterson et al., 2019). The factors that change the most are land use and climate.

Land use

Land use is the factor that is most directly impacted by human design. Research performed by Kelley and Nater (2000) found that the rate of sedimentation increased in watersheds that saw changes in land-use and destruction of native habitat. They also realized that these watershed basins that were altered to accommodate agriculture, urbanization, and industrialization saw increases in total sediment load (Kelley & Nater, 2000). Of these alterations, the Marion County Park and Lake watershed might be more influenced by agricultural factors, although highly proximal urbanization around the lakeshore has seen steady development since the recreation lake was established. Smith (2011) determined that the increased demand for food, animal feed, and biofuel has encouraged the agricultural market to increase production, leading to further land use and thus soil erosion. Agricultural land is becoming increasingly important in sustaining the country and must be effectively maintained to ensure use for future generations.

Agricultural practices are important factors in soil erosion. Kelley and Nater (2000) discovered that if there is any change in the type of soil available (like tilling) it will affect the rate of settling since the particle size may be different than before. This can affect the number of particles settling to the bottom of the reservoir, as smaller particles would take longer to settle and would likely be carried out of the reservoir and downstream. In the study conducted by Bontrager (2011), it was found that continuous wheat and rotation with sorghum had more erosion while no-till and pastureland had very little erosion. Grudzinski (2014) conducted a study to determine the trends between erosion and the type of grazer and intensity of grazing. The research found that there was a positive trend between discharge and the total suspended solids, total inorganic solids, and total volatile solids (Grudzinski, 2014). The amount of water flowing over the land increases the amount of sediment within the stream when the land is being used for grazing. Grudzinski (2014) also determined that the grazing leads to increased solids in streams. This would increase the amount of sedimentation seen in the reservoir. The best way to predict the amount of total volatile solids in a stream was by looking at the grazing treatment, followed by looking at the burn frequency and then the discharge of the stream (Grudzinski, 2014). For land that is grazed frequently or burned frequently, there will be more solids and sediments being deposited into the nearest body of water. All the ways land is used contributes to the availability of sediment within the watershed.

Land use is an important factor to examine when determining why sedimentation rates have changed. As stated previously, the watershed that drains into Marion County Park and Lake is primarily pastureland. Any change in agricultural practices will affect the types of sediment we see being deposited. Additionally, climate helps determine the amount of water available for sediment to be transported in.

Climate

Climate is the other major factor in determining the rate of sedimentation, as it determines how much water is available for sediment to be deposited into, and when there are periods of enhanced precipitation or periods of drought. Wen et al. (2019) determined that sediment load is more sensitive to the effects of climate change and human activities in arid/semi-arid environments. The given climate for our area is semi-arid as stated by Robinson and Dietz (2019). The Midwest is also known for the spells of drought that occur naturally. Common sense would dictate that drought would decrease the rate of sedimentation since there will be little run-off to transport sediment. However, drought will also lead to vegetation loss inhibiting infiltration and when it eventually does rain there may be increased erosion due to enhanced overland flow. Moriasi et al. (2018) determined that drought can negatively affect how sediment layers are formed in water bodies, as it can harden the top layer of soils. While this only affects reservoirs that completely dry out, it is an important factor to consider when attempting to determine the impact of sedimentation. Moriasi et al. (2018) stated that, "… intense storms increase the possibility of soil particles to detach and generate more surface runoff to transport detached particles." Kansas has intense storms; this increases the likelihood of increased sedimentation during these events. Climate is an important factor to consider when determining the impact of sedimentation on a reservoir.

Climate, land use, and waterflow are the important factors to observe to determine why there would be changes in the sedimentation rate of reservoirs. These variables are easily measured and determined but can be tricky to remedy. To analyze the rate of sedimentation within the lake, we must consider the various dating methods that can be utilized.

Dating methods for <100 year old lake sediments

Sediment dating can be used to determine sediment accumulation rates in lakes and reservoirs. Common methods used in these lacustrine systems include measuring optically stimulated luminescence (OSL) and radionuclide concentrations. However, there are some advantages and disadvantages for each of these methods to accurately date sediment samples, especially those more recently deposited. To determine the best method to use for assessing sedimentation rates in Marion County lake, we will compare the OSL, Lead-210 (^{210}Pb), Cesium-137 (^{137}Cs), and Carbon-14 (^{14}C) sediment dating techniques with a focus on their ability to reliably date samples deposited in the last one hundred years.

Optically stimulated luminescence

Luminescence dating is a geochronological technique that measures light signals (luminescence) given off by artificially stimulated, energy-storing minerals, such as quartz, found in sediments. These signals are indicative of the time period elapsed since a mineral was last exposed to sunlight. Radiation acquired energy is released when exposed to sunlight, and it is assumed that this event removes pre-existing signals that "resets" the time stamp.

However, a challenge is presented when using OSL dating, at least when used to date samples in the 260- to 10-year range (Duller, 2004). The relationship between a sample's radiation dose and luminescence signal intensity is not absolute nor linear. The issue has been resolved by generating a growth curve for a single aliquot for feldspar or quartz as a result of the development of single-aliquot regenerative-dose (SAR) methods for radiation dose determination (De). With this development, OSL dating has been made more reliable than previously in measuring Quaternary sediments, at least down to a few decades (Duller, 2004; Ballarini et al., 2003).

With the increased precision and reliability of OSL sediment dating, more recent research shows that this technique could potentially be used to analyze very young sediment activity in fluvial systems. Spencer et al. (2019) explored the plausibility of using OSL for this purpose. Three sites along the Amazon River were sampled using a corer, and the samples were analyzed. Two sites (Tapuama and Arapiuns) had high stream flow activity while the third (Cupari) was highly vegetated, slowing stream flow.

Stream flow activity is intuitively thought to heavily impact sediment accumulation in fluvial systems, meaning with high stream flow there will be more sediment removal and deposition resulting in younger sediments. Slower stream flows will have less sediment removal and deposition resulting in older sediments. Ages for samples from Tapuama and Arapiuns were approximated to be between 10 and 40 years, and those from Cupari to be between 300 and 600 years of age. This possible relationship between sediment activity and age increases the plausibility of using OSL dating as a tool for analyzing young fluvial sediments, and may equally be applied to young lake sediments.

Lead-210

Lead-210 (^{210}Pb) is a radionuclide used for the dating of materials including, but not limited to, sediments, otoliths, and ice cores. This method is used to identify age of material created or deposited within the last 120 years. ^{210}Pb is suggested to be the best radionuclide to date recently deposited (within the last 100 years) lake and reservoir sediment samples because of its rapid decay rate (short radioactive half-life) and quick transference from freshwater to sediment particles (Evans & Rigler 1980; Krishnaswamy, 1971). Other reasons ^{210}Pb is ideal for measuring in core samples include its geochemical ability to attach to sediment particles, its constant flux in fluvial systems, its defined input function into the environment, its large database from paleolimnological studies, and its atmospherically and non-atmospherically sourced particles can be differentiated (Appleby, 1997).

Some studies and papers question ^{210}Pb's reliability as a sediment dating technique. One study found ^{210}Pb to be unreliable when results showed inconsistent concentrations throughout the profile in the sediment core sample taken from an oxbow lake in Arkansas. There was also inconsistency found between ^{210}Pb and Cesium-137 (^{137}Cs; see more details on this technique in the following section) results. ^{137}Cs measurements aligned with fallout events, both global and local, but did not agree with ^{210}Pb dating, suggesting that ^{210}Pb concentrations were not reliable for dating sediments (Baskaran et al., 2014). However, another study showed consistency between ^{210}Pb and ^{137}Cs results. Both radionuclides were measured in recent and old samples of sediment (approximately 20 years difference). ^{210}Pb displayed smooth distribution throughout the profile (young and old samples), implying there was no sediment mixing and ^{210}Pb was merely buried. Meanwhile, ^{137}Cs showed spikes in concentration in the profile aligning with fallout events, in old and new samples. Combined, both ^{210}Pb and ^{137}Cs were able to determine accurate sedimentation rates and validate the reliability of the other radionuclide dating method (Benoit & Rozan, 2001).

Cesium-137

By looking at the distribution of radionuclide Cesium-137 (^{137}Cs) in lake sediment cores, scientists can date sediment samples through correspondence of peak concentrations with fallout events that result in substance input. For example, most sediment cores should have an increase in ^{137}Cs activity corresponding with the nuclear weapons testing in 1963, a global fallout event, as a common marker (Miller & Heit, 1986). Local fallout events will likely appear in the sediment profiles as well, so knowledge of local historical events is imperative. Figure 7 illustrates what ^{137}Cs levels look like over time based on sediment profiles of samples taken from reservoirs in Texas, Alabama, South Dakota, and Missouri. The bars represent yearly fallout, while the lines show cumulative fallout.

The data produced from this technique allows for the determination of sedimentation rates occurring in lakes and reservoirs. ^{137}Cs molecules are strongly absorbed into the soil upon contact with limited removal via natural chemical processes. With high concentrations primarily in the upper 5 cm of sediment sample profiles (area which is mostly likely to be eroded and contribute to sediment load) and slow diffusion rates through the soil, ^{137}Cs can be used to trace erosion and sedimentation (Ritchie et al., 1973).

^{137}Cs enter watersheds via runoff, erosion, atmospheric deposition (direct input), or transport from upstream. ^{137}Cs entering the system through the latter two methods are usually lost from the lake either by outflow or deposition into lakebed sediment, ultimately becoming a part of the sediment record. A majority of the time, researchers only have information such as lake area, volume and water residence time, watershed area, rainfall data, and basic chemistry of the water to plug into models (Appleby, 1997). This makes sedimentation rate estimates difficult to calculate as more detailed information is needed such as pollutant residence time in the water column and watershed/lake transport rates. Additionally, high quality samples will produce more accurate sedimentation estimates. This means that sediments that have not experienced excessive movement or disturbance through various processes or phenomena, can provide at least adequate information to date sediment in correspondence with historical events of substance flux.

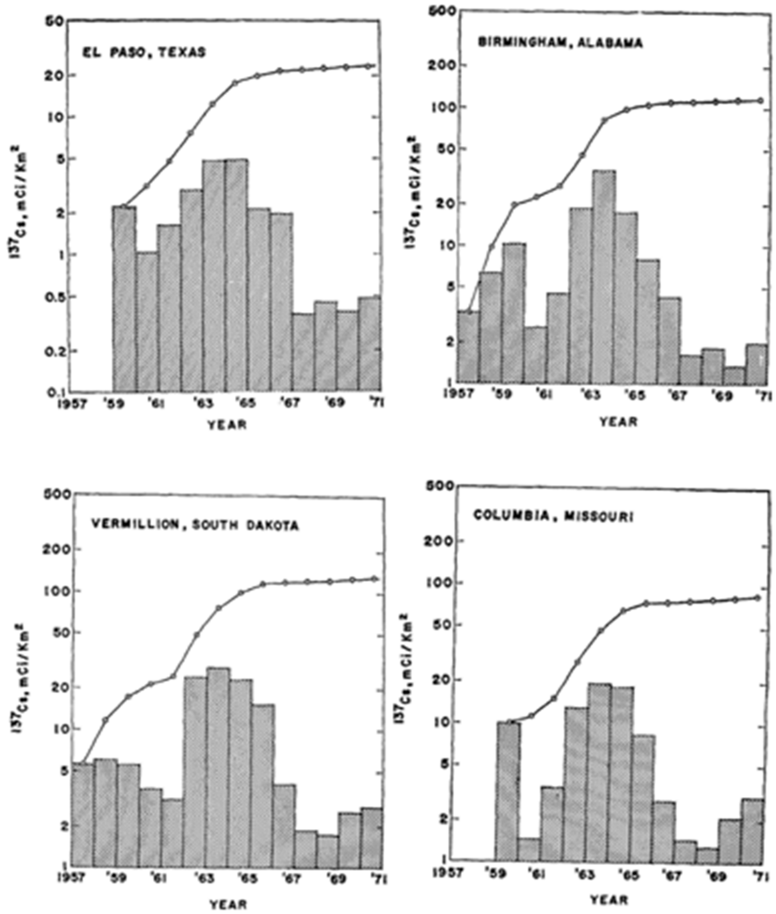


Figure 7: Fallout deposition patterns of 137Cs (Ritchie et al., 1973)

Despite all of the conditional circumstances needed to produce reliable measurements, ^{137}Cs has some characteristics that make it an ideal method for validation of other techniques and models. These include its solubility, defined input functions into the environment, large database from paleolimnological sediment studies, and that its atmospherically and non-atmospherically sourced particles can be differentiated.

Carbon-14

Carbon-14 (^{14}C) is a radioactive isotope that is continuously produced in the atmosphere. It is then oxidized to produce CO_2 and spread throughout the atmosphere before being deposited into carbon reservoirs of the biosphere such as oceans, land, immediately surrounding atmosphere, living organisms, etc. In lake sediments, dating can be influenced by reservoir effects, causing samples to seem older than they are. This happens because radiocarbon in lakes come from depleted sources, like dissolved inorganic carbon in groundwater and carbonates from limestone. Additionally, mixing of older material into sediments complicates ^{14}C dating even further (Hua, 2009). These factors affect the reliability of the method and call for research to determine its validity.

In one study, a core was collected from Sky Lake, Mississippi and analyzed for ^{14}C in the organic components of the sample. Davidson et al. (2004) found that twigs from local plants that represented 1-2 years of growth were more reliable than other components (such as fine organic debris or woody fragments from tree trunks) for bomb-pulse radiocarbon dating, a variation of ^{14}C dating which measures the significant decrease of ^{14}C concentrations in organismic material mimicking the atmospheric decline after the period of nuclear weapons testing in the mid-1900s. Based on this evidence, Davidson and team used twigs from two other cores from the same lake to date. The results were consistent with nearby tree rings. Data was compared to a bomb curve. Any variations deviating from the curve were attributed to minor bioturbation or inputs of reworked material. Another method tested by McGeehin et al. (2004) that may be used in ^{14}C dating is examining the deposit. Humin, insoluble remnants of soil organic matter, was extracted from two cores collected from Grenada Lake, Mississippi and then oxidized to CO_2 by stepped-combustion. Bomb ^{14}C values were higher in the lower temperature (400 degrees C) combustion than the high temperature (900 degrees C) combustion. The study's researchers thought that the low temperature combustion could lower the contribution of reworked carbon in clay minerals. These values were still lower than that of the atmosphere, suggesting that the reservoir effect affected the direct analysis of sediments (Hua, 2009; McGeehin et al., 2004).

It is recommended that short-lived macrofossils of local plants (like small twigs and grass stems) be used for lake sediment dating. Direct dating is problematic because of the reservoir effect and helpful alternatives would be ^{137}Cs, ^{210}Pb, and ^{241}Am to confirm ^{14}C dating. Analyzing a series of ^{14}C from a sequence in peat profiles has been successful (Hua, 2009).

Comparison outcome

Of the lake and reservoir sediment dating methods discussed, the literature supports the reliability of OSL and Lead-210 dating methods. Both methods provide the ability to accurately date recently deposited sediments (within the last 100 years) collected from lakes and reservoirs and relate the results back to sedimentation rates of those sites. Cesium-137 can be highly accurate, but only marks significant fallout events. Therefore, limiting its ability to date sediments by a single year or decade, especially since the last event. Carbon-14 is primarily used for and most reliable with dating much older sediments than the most recent 100-year timescale. Regardless, many studies highly recommend using a combination of these techniques to validate whichever method is chosen for dating. Besides sediment age, additional analysis of lake sediment characteristics are needed for a thorough understanding of sedimentation in Marion County Lake.

Characteristics of lake sediments

Characteristics of lake sediments start from soil material that is broken down, eroded, and then transported through streams and rivers into lake beds like Marion County Lake. Hillel (2003) describes soil erosion as "the detachment, transport, and sedimentation of particles from the soil surface by water or wind". Through erosion the characteristics of the lake sediments can then help us find the source of where the sedimentation first occurred.

Sources of sediments

Characteristics of lake sediments are important to understand because they can determine the source of where the sediment is coming from. Lake sediments come from many places, such as bank erosion within the reservoir, erosion along the rivers, and streams that empty into reservoirs. Sediments can be carried numerous miles from their initial location depending on the size of the watershed. Jaracek (2011) depicted a watershed that drains into Kanopolis lake near Ellsworth, KS and is shown in Figure 8 and showcases just how far sediments can travel. The Kanopolis lake watershed stretches all the way into eastern Colorado, this lake is much larger than the Marion County Park and Lake, and would likely have more types of sediment at the bottom of this lake. However, because soil characteristics vary over small areas, we can still characterize the sediments at the bottom of Marion County Lake

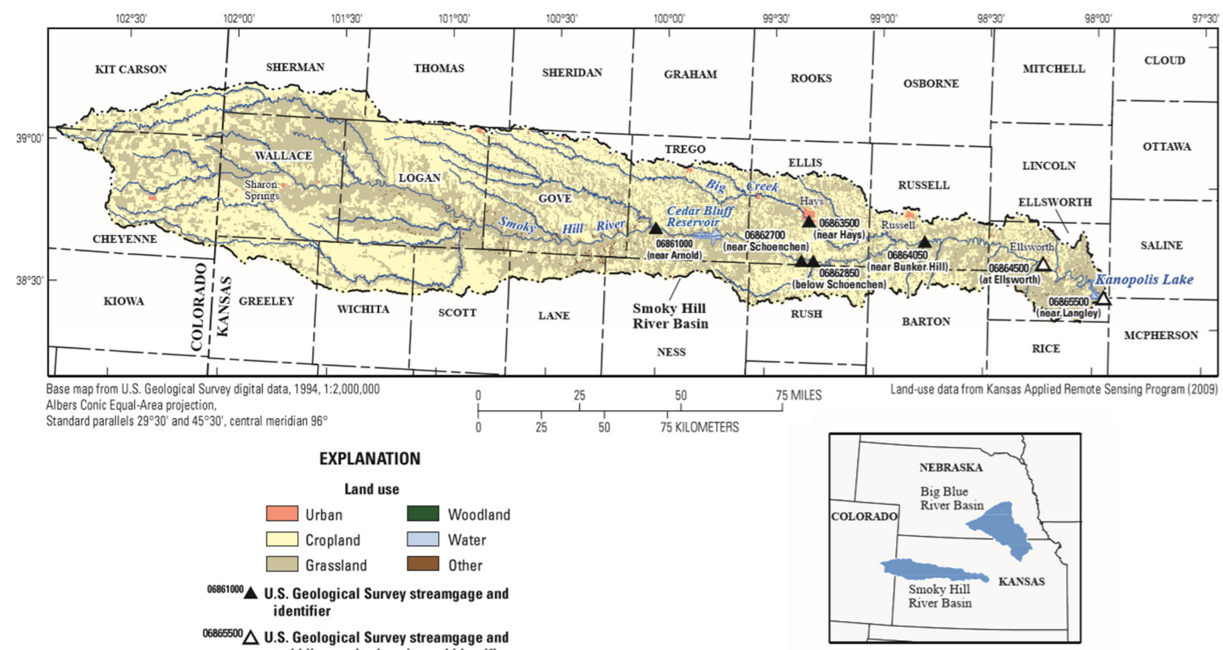


Figure 8: Watershed of Kanopolis Lake (Jaracek, 2011)

based on the particle size and texture (sand, silt, clay), land use (agriculture, urban development), mineralogy, and age of soils using various dating methods. Not specified, but just as important, is soil structure such as that of blocky, columnar, platy, etc. "According to Panagos" et al. (2014) soil structures are an important factor for soil erosion. Studies should examine sediment cores at Marion County lake and extract sediment and soil samples in areas like banks and stream bottoms, and even places like fields that may be along a stream of interest.

Texture and soil type

Soil texture and soil type of lake sediments can be a huge indicator on narrowing down where lake bottom sediments come from along the watershed. Kansas consists mostly of silty textured soils such as silt, loam, and silty clay loams as seen in the 2020 NLDAS soil texture types illustration produced by NASA (Fig. 9; NLDAS Soils Datasets and Illustration). To help understand soil texture, the USDA soil texture triangle, shown in Figure 10, can be used (Soil Survey Staff). The triangle can help determine what texture is present based on how much sand, silt, and clay is in the soil. The USDA Web Soil Survey of the Marion County Park and Lake area, shown in Figure 11, details how many different soil types and textures can be found in one small area (Soil Survey Staff, 2019). The details of the soil type and texture for each area for Figure 11 is located in Appendix A. This can help determine which soil types erode faster due to water/wind erosion, find areas of rill and sheet erosion in nearby fields that could be contributors, and establish the stream banks which are likely the largest sediment contributors. When soil texture is added to the picture, different particle sizes (sand, silt, clay) all erode differently and at different rates, changing the sediment availability. According to Moldnhuner and Long (1964), a rain model was done in a lab with these five different textures of soil: silty clay, silty clay loam, sand, silt, and loam. During this experiment they found that the intensity of the rainfall and raindrop impact both matter to determine how much soil is eroded and that everything except for the sand had similar amounts of soil loss.

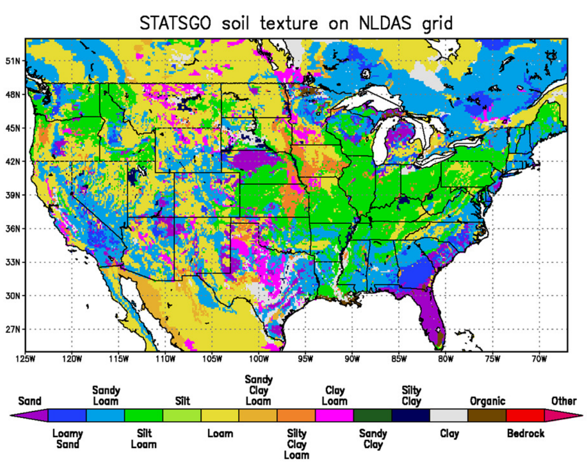
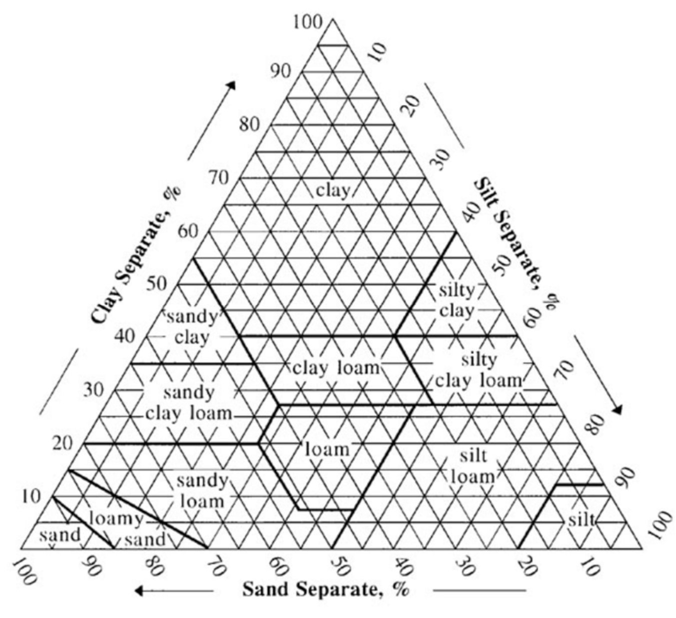


Figure 9: 2020 STATSGO soil texture on NLDAS grid (NLDAS Soils Datasets and Illustration 2020)

Figure 10: USDA soil texture triangle (Schoeneberger et al., 2012)



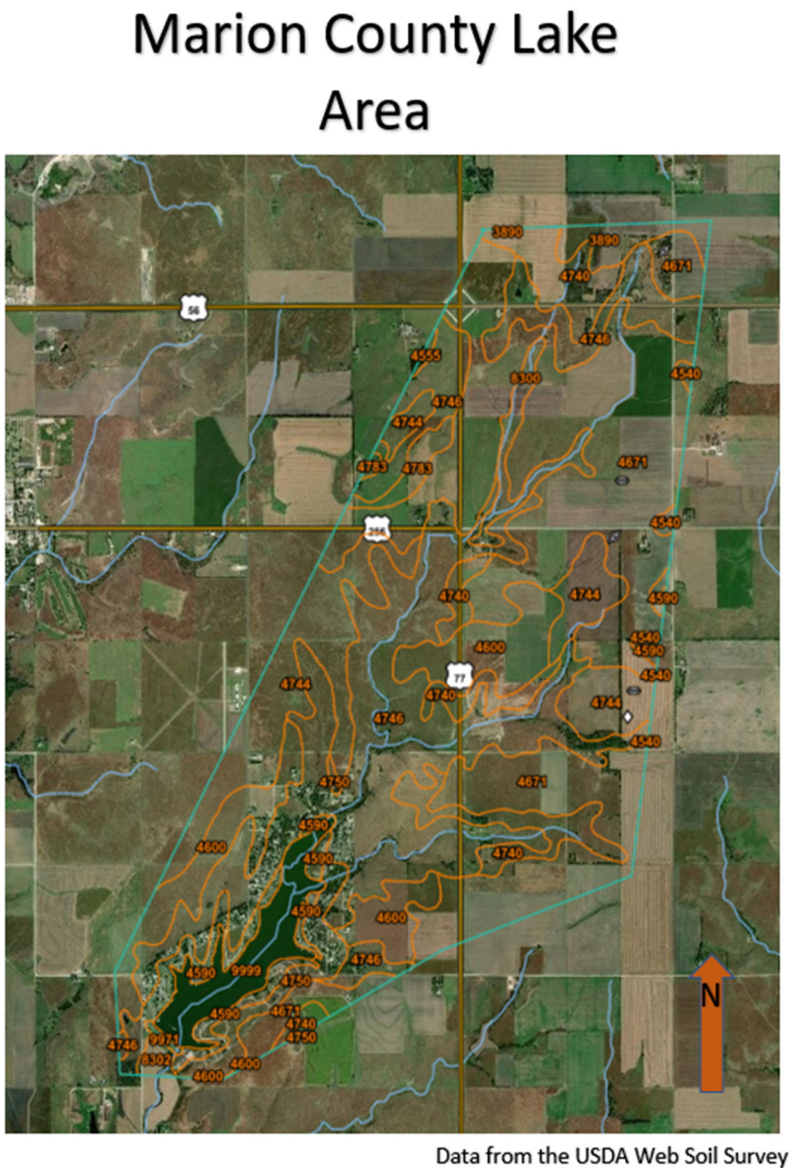


Figure 11: 2020 Web Soil Survey of Marion County Park and Lake (Soil Survey Staff, 2019)

Soil structure

The field book for describing and sampling soils (Schoeneberger et al., 2012) defines soil structure as, “the naturally occuring arrangement of soil particles into aggregates that results from pedogenic processes”. Soil structure is important for erosion problems because it determines water drainage and infiltration after a rainfall event. As an example, Figure 12 depicts the soil structures used by the National Resource Conservation Service (NRCS) (Schoeneberger et al., 2012). This includes the soils with a platy structure will have more water runoff, as well as more ponding than a soil with a granular or columnar structure. This is because the soils that have a granular structure will allow water to infiltrate and fill pore spaces.

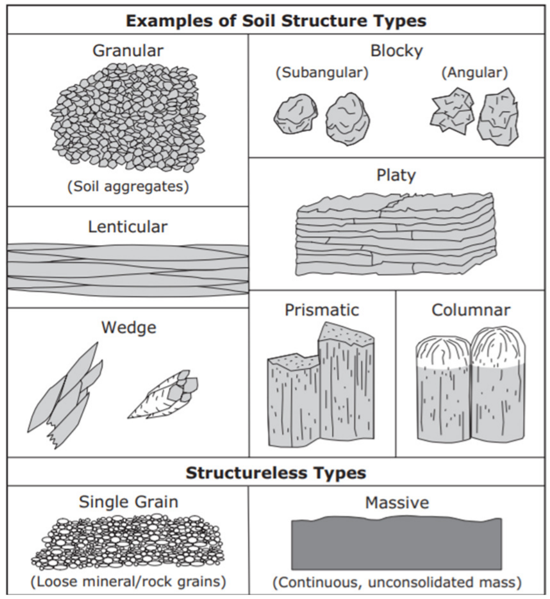


Figure 12: Soil structure types (Schoeneberger et al., 2012)

Discussion

Solutions for sedimentation

There are two main solutions for sedimentation, dredging and best management practices (BMPs). Both are man-made ways to help decrease sedimentation within a watershed without changing how the land is viewed. The most visible but least recommended is dredging.

Dredging

According to Manap & Voulvoulis (2014), dredging removes sediment from the beds of water bodies. The type of dredging of interest would be maintenance dredging, which deepens the area for continued use (Manap & Voulvoulis, 2014). It is sometimes seen as the cheaper option (Smith, 2011). In fact, the Kansas Water Office is currently working towards performing a water injection dredge (WID) of Tuttle Creek Lake (Kansas Water Office, 2019). This form of dredging is still being developed. As of September 26, 2018, the project has collected sediment cores, surface sediment samples, water quality samples, and velocity current transects to begin implementing this technology (Kansas Water Office, 2019). However, while it can be cheaper in certain cases, dredging can also be more harmful to the environment. Fischer (2009) found that dredging is an invasive process that directly and indirectly impacts the ability of the ecosystem to operate. Dredging alters the habitat by increasing turbidity and causing pits to form (Fischer, 2009). This would not be beneficial to Marion County Park and Lake’s recreation. While dredging is the most direct solution, it can have harmful consequences and must be considered from every angle before implementation. A less invasive option is the implementation of best management practices (BMPs).

Best Management Practices (BMPs)

It is suggested to investigate ways to reduce erosion if sedimentation begins to affect reservoir use (Smith, 2011). The BMPs are the ways to help reduce erosion within a watershed. It can range from what type of crops are planted to how the land is shaped. The study done by Bontrager (2011) determined that the BMPs used to reduce sedimentation are reduced-tillage crop rotations and terrace construction. No-till farming practices can help reduce erosion from fields with the plant matter from previous harvests, working as a mulch to protect soils from erosions such as wind and water (Huggins and Reganold, 2008). Farming with tilling can lead to more erosion of soils because it leaves the soils bare making runoff of sediment which also carries things like pesticides and fertilizers into streams and eventually into lakes like Marion County Lake which could have a negative impact on water quality, storage capacity of the lake, wildlife and other environmental concerns (Huggins and Reganold, 2008). It was determined that terraces help limit erosion by modifying the speed and direction of runoff to help disperse flow in a precipitation event (Bontrager, 2011).

However, for these BMPs to be effective, they must be placed in the optimum location. Smith (2011) found that to reduce sedimentation, the project should target cropland that are closer to the water bodies, that have a steeper slope, that experience more erosion, and that are more likely to have larger flow during a precipitation event. By targeting these sections of land, available sediment can be reduced. The use of these practices can help treat the issue of sedimentation at the source.

Despite addressing the problem at its source, BMPs tend to be a bit difficult to implement and enforce. The study done by Smith (2011) found that cost-effective conservation is good for the budget but can be hard to approach politically and socially, mostly because it will not pay individuals for practices they already implement. Citizens must no longer rely on state and federal regulation to provide the backbone of law and money to keep our water resources useful. If they wish to ensure further use of their water resources, they must be willing to implement these methods themselves. Acknowledging this, further research should be done to understand this problem and the specific watershed.

Recommendations for further study

Further research on this topic should focus on sediment dating and characteristics. The most reliable methods for dating, OSL and Lead-210, should be used to determine sedimentation rates, however, literature suggests using multiple techniques to validate accuracy. Additional analysis of other lake sediment characteristics should also be conducted to help understand the cause of sedimentation, where the original source of the sedimentation was by comparing the characteristics found in the lake sediment vs possible sites, and determine any underlying factors affecting dating results.

Conclusion

In conclusion, work was started on March 21, 1936, by the Civilian Conservation Corps under supervision of Supt. E. C. McBurney. The park area is 652 acres and the lake surface covers 160 acres. In 1937, Marion County Park and Lake was completed. The focus on sedimentation is necessary because of the potential impact on storage capacity for reservoirs that are already beginning to reach the end of their design life. Sedimentation rates change due to two main variables: water flow and watershed factors. The obstructions created by dams cause the water to deposit sediments. The watershed characteristics determine the amount of soil available to erode via the land use and climate. Sediment dating is one key technique in determining the rates at which sediment accumulates in these systems, and how those rates may change over time. Utilizing the OSL dating and Lead-210 methods would help reveal the magnitude of the issue of sedimentation and help provide a basis by which to build a lake management plan. Knowing the sediment characteristics will help determine the erosion seen and find the sources of sediment upstream from the lake. Once the sources upstream are found, practices can be implemented to help slow the sedimentation rate. With this knowledge the resources within Marion County Park and Lake can be more effectively managed.

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Appendix A: Web Soil Survey Unit Symbols

Map Unit Symbol	Map Unit Name
3890	Ladysmith silty clay loam, 0 to 1 percent slopes
4540	Clime silty clay loam, 1 to 3 percent slopes
4555	Clime silty clay loam, 3 to 7 percent slopes
4590	Clime-sogn complex, 3 to 20 percent slopes
4600	Dwight silt loam, 0 to 1 percent slopes
4671	Irwin silty clay loam, 1 to 3 percent slopes
4740	Labette silty clay loam, 1 to 3 percent slopes
4744	Labette-Dwight complex, o to 3 percent slopes
4746	Labette-Sogn silty clay loam 0 to 8 percent slopes
4750	Sogn silty clay loam, 0 to 10 percent slopes
4783	Tully silty clay loam, 3 to 7 percent slopes
8300	Verdigris silt loam, channelled, 0 to 2 percent slopes, frequently flooded
8302	Verdigris silt loam, 0 to 1 percent slopes, occasionally flooded
9971	Arents earthen dam
9999	Water