SEDIMENT BUDGET TEMPLATE APPLIED TO ABERDEEN POOL

By

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PREFACE

The work reported here was performed under award NA06OAR4320264 06111039 to the Northern Gulf Institute (NGI) by the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean and Atmospheric Research, U.S. Department of Commerce. This report is a product of the NGI and the Civil and Environmental Engineering Department of Mississippi State University as part of the NGI project 07-MSU-05, “Modeling Mobile Bay Sediments and Pollutants with New Technologies.”

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David R. Shaw is Director, E. Glade Woods is Co-Director, and Michael Carron is Chief Scientific Officer of the Northern Gulf Institute. Dennis Truax was Head, Civil and Environmental Engineering Department, and Sarah Rajala was Dean, Bagley College of Engineering, during publication of this report.

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Northern Gulf Institute http://www.northerngulfinstitute.org/

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ABSTRACT

The purpose of this work is to create a sediment budget template (SBT) with Aberdeen Pool on the Tennessee-Tombigbee Waterway as the demonstration site. USGS data are used to define sediment concentrations and flows. The USGS data are the basis for the Power Curve Program which defines the sediment behavior in terms of a power function. The second program, Tier 1 Program, uses the power curve coefficients along with the bankfull discharge to define the sediment fluxes. Thirdly, the Tier 2 Program uses power curve coefficients with daily flows to calculate daily sediment flux which are integrated over each year to calculate the yearly fluxes. From the sediment fluxes, a mass balance equation is implemented to estimate total deposition. Lastly, the computer program SIAM is used to estimate deposition amount. Comparison among the three different methods provides a best estimate of the final depositional approximation.

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CHAPTER 1. INTRODUCTION

1.1 Background

Sediment budgets are important in defining the dynamic behavior of a river system. The primary purpose of a sediment budget is to characterize sediment behavior in the system as either depositional or erosional and the sediment fluxes at key locations. Understanding a river's sediment characteristics is important for comprehending problems associated with the watershed and maintaining the river for navigation. Since every system has different sources and sinks and has varying amounts of available data, most sediment budget models are only implemented once. Often sediment budgets are constructed for a single system using Excel or some other tabular method based on field data. Although these models are basic in form, they are unique for each study and are difficult to apply to a new system. This creates a problem when building a sediment budget for a large watershed.

Conceptually a sediment budget views a system as a box, through which the modeler's primary concern is the difference in sediment fluxes at the boundaries. The calculation involves a basic manipulation of the mass balance equation, where the inflow flux is subtracted from the outflow flux. The difference is the rate of change in volume represented by the total deposition or erosion and is controlled by the changes from the sources and sinks. After properly defining the sediment behavior through the fluxes, the sediment budget is complete.

1.2 Purpose

The purpose of this work is to generate and present tools that are easily used and understood in order to create an example sediment budget template, SBT, for the Mobile Bay Watershed. This thesis is not intended to produce a comprehensive sediment model, but rather an intermediate tool to connect more inclusive numerical models to theory. Reproducibility of work is imperative for ease of use and credibility. Therefore, the author's goal is to design multiple programs that allow other modelers to conveniently step through a tiered modeling approach to produce a sediment budget. In addition to new programs, pre-existing ones will also be implemented to help validate the final solution.

This report was prepared as part of the Northern Gulf Project, "Modeling Mobile Bay Sediments and Pollutants with New Technologies." One objective of that project is to provide understanding for the flow of sediment and how it is coupled with the transport of pollutants in Mobile Bay. The goal is to yield tools that basin officials can implement to improve decision-making and overall management (see Figure 1.1).

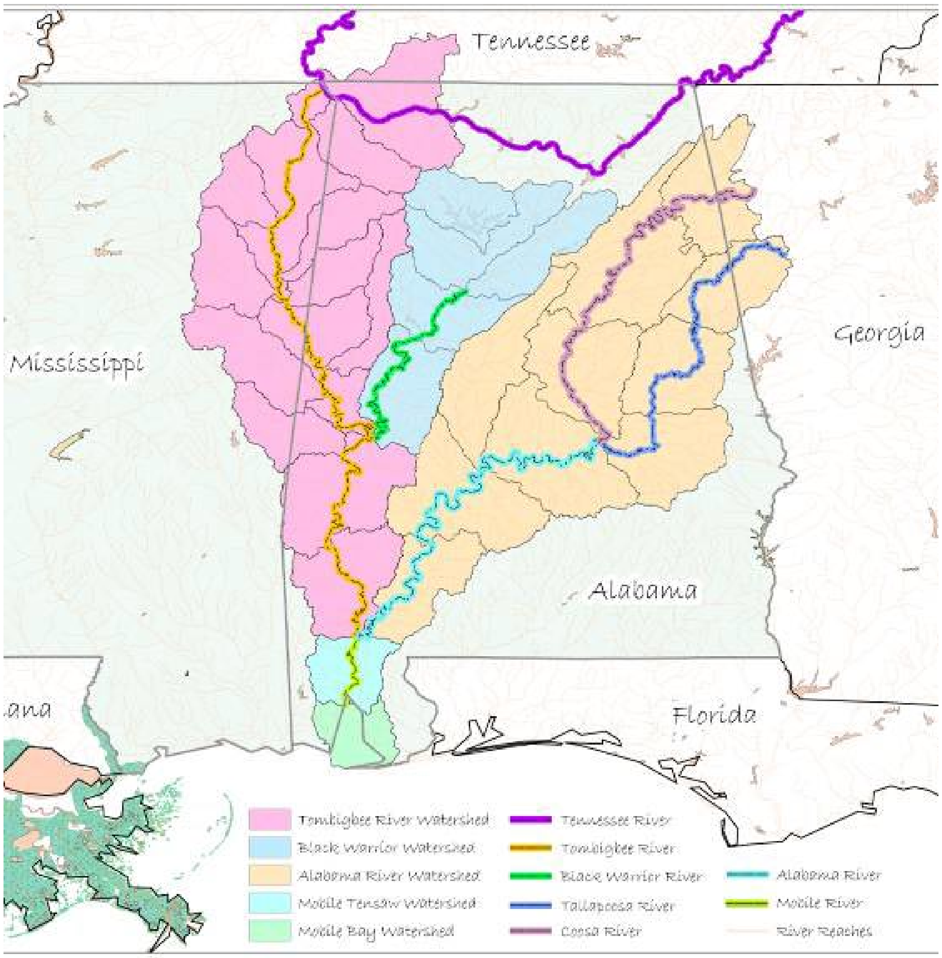


Figure 1.1 Map of Mobile Bay Watershed and sub-watersheds

In order to meet the above mentioned goals, certain tasks must be accomplished. First, both a sediment budget along with a water budget will be constructed. Then, pre-existing models can be implemented to run sediment, mercury, and DDT simulations. The fate of these issues will be observed closely so that managers can have an understanding of the factors that affect the transport of these hazards. Ultimately, the apex of this project is to join these models in such a fashion that a management model can be implemented for the watershed.

As part of the overall project, a sediment budget, which starts with a study of upstream conditions, must be estimated for Mobile Bay. Because understanding a system requires an in depth look at all of the contributing factors, the NGI study of sediment will examine all areas of the Mobile Watershed to define the incoming sediment fluxes.

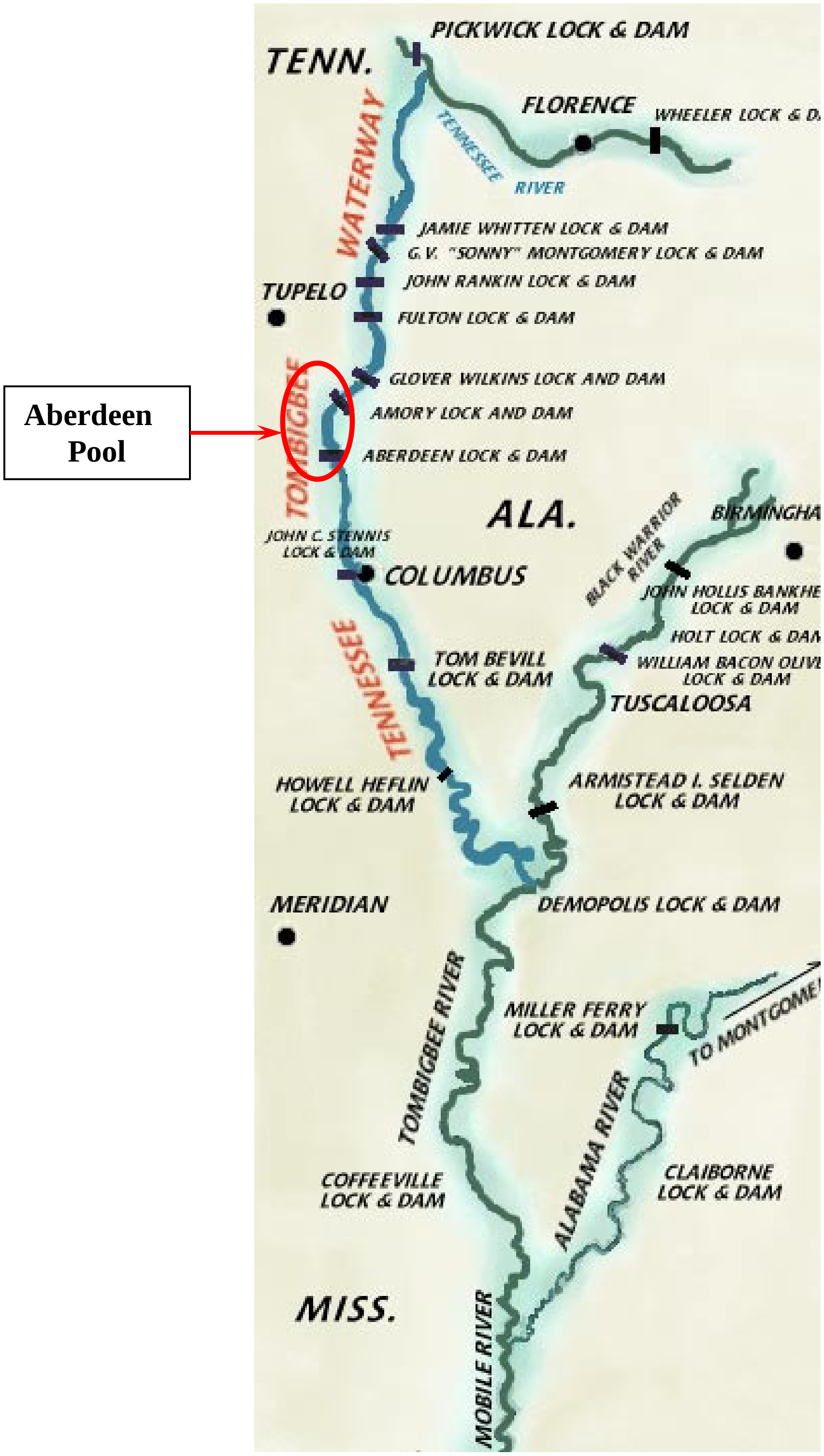
CHAPTER 2. STUDY SITE

Designing a model requires an appropriate study site. Since this is a template for a new model, the location dictates how the programs are arranged and the template is formed. The goal is to build the model in such a way that allows application to a variety of locations. Ideally, a study site should be relatively complex so there is little that is not considered in the model. The study site chosen is the Aberdeen Pool on the Tennessee-Tombigbee Waterway (TTW) (see Figure 2.1). Once the template is established and validated, it can be applied to other locations.

2.1 Tennessee-Tombigbee Waterway

Part of the upper end of the Mobile Bay Watershed includes the TTW. This inland waterway passes through the upper northeast corner of Mississippi and crosses into Alabama, there it merges with the Black Warrior River and then later with the Alabama River. When the Alabama River merges with the Tennessee-Tombigbee River, it forms the Mobile River, which discharges in the Mobile Bay (see Figure 1.1).

The TTW is a good starting point for the Mobile Bay sediment study for a variety of reasons. It is both a natural and man-made system that has been known to have several sediment issues associated with it. The TTW includes a network of locks and dams (see Figure 2.1). This allows the Waterway to be broken down into control volumes on a pool-by-pool basis. Additionally, the system is a complex maze of old meander loops, river runs, and incoming tributaries, which offers complexity in contributing areas and challenges in data collection. The TTW includes seven minimum flow structures (MFS) which transfer flow from the Waterway into tributaries that eventually feed back into the Waterway (see Figure 2.2). These MFS feed tributaries whose contributing areas were severed with the construction of the Waterway. Five MFS pass flow to the Tombigbee River, one passes flow to Matubby Creek which passes flow to Columbus Pool. Furthermore, the location of the TTW relative to MSU allows quick access to the Waterway so sampling can be conducted. By using the TTW watershed to establish a sediment budget template, modelers can apply that template to other systems in the Mobile Bay Watershed (see Figure 1.1).



Aberdeen Pool

Figure 2.1 Map of TTW Locks and Dams

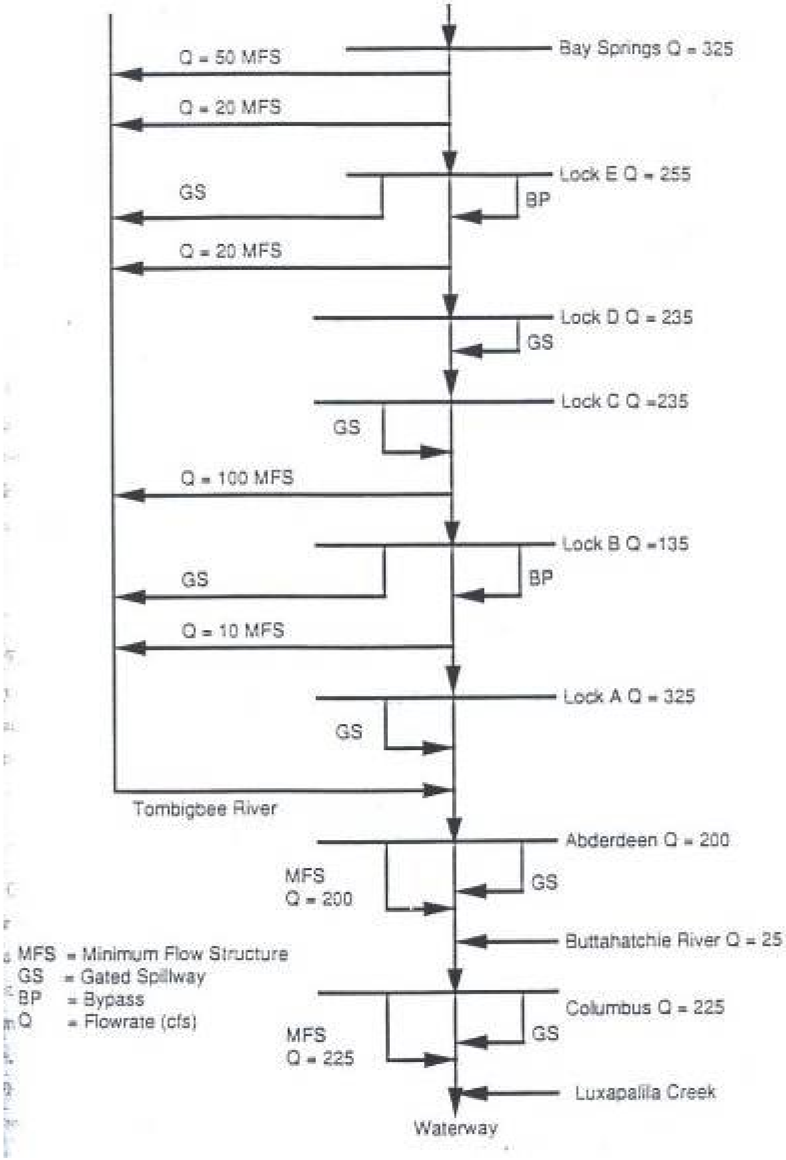


Figure 2.2 Minimum flows for TTW (Lunardini, 1990)

2.2 Constructed Sections

The primary mission of the Tennessee-Tombigbee Waterway (TTW) is navigation. Constructed by the U. S. Army Corps of Engineers, the waterway was completed in 1984. It consists of three sections: a 149 mile-long River Section, 46 mile-long Canal Section, and 39 mile-long Divide Cut. Under normal flow conditions, the 300 foot wide navigation channel is maintained at a depth of 9 to 10 feet. This flow depth is controlled by a series of ten locks and dams located within each of the three waterway sections. Along with the control structures, channel depth is also maintained by dredging.

The downstream end of the River section starts where the Black Warrior River meets the TTW at mile 217 and extends upstream to mile 366 near Amory, Mississippi. Generally, it follows the course of the Tombigbee River, with several meander loops that were cut off leaving 71 miles of loops still connected (McAnally et al 2004). Numerous tributaries flow into the River bringing large amounts of sediment into the system.

Starting at the upstream end of the River section, the Canal section stretches through a chain-of-pools that contains five lakes. A levee defines the Canal's western border, and its eastern side is defined by the natural topography. Whitten Lock and Dam and small tributaries on the eastern bank provide flow to the Canal section.

Upstream of the Canal lies the Divide Cut, which connects the TTW to the Tennessee River Basin. This section extends from Bay Springs Dam to Pickwick Lake. Incoming flows consist primarily of flows from Pickwick and local minor tributaries.

2.3 Aberdeen Lock and Dam

Aberdeen Lock and Dam is located on the TTW in the northeast corner of Mississippi in Monroe County (see Figure 2.1). It is approximately 23 miles upstream of Columbus Lock and Dam and is 14 miles downstream of Amory Lock and Dam. The Lock and Dam at Aberdeen is located at river mile 357.5. The structure consists of a lock with 27 feet of lift and a gated spillway. In the lock the upper sill elevation is 175 feet and the lower sill is 148 feet while the chamber floor is 143 feet above mean sea level. Aberdeen's Pool elevation is 190 feet and Columbus's Pool Elevation is approximately 163 feet above mean sea level (USACE, 1979).

Aberdeen Lake was selected as the initial study site for the model design for several reasons. First, it is relatively accessible from MSU. This allows frequent trips for sampling the confined disposal facilities (CDF) taking corings in the shallows, and collecting water samples for sediment concentration measurements. Furthermore, two other studies had been conducted that focused on the sediment in the pool or that which is coming in. The first is "Aberdeen Lock and Dam Design Memorandum No. 17" (USACE, 1979). This report was done prior to the construction of the waterway and describes the possible sediment characteristics of the Aberdeen Lake. Also the "Final Report, Tombigbee River (East Fork Study)" (USACE, 1986), reports the before and after TTW construction impacts on the Tombigbee East Fork. Both studies provide good insight on sediment issues and provide a means of validation. Lastly, since Aberdeen Pool is fairly complex, many system considerations must be accounted for in the model (see Figure A.1). This creates a fairly robust model that can be applied to many different systems with relative ease.

2.4 Contributing Areas

Several issues are associated with the watershed area that discharges into Aberdeen Lake. To avoid an improper evaluation of the sediment yield, all areas in the basin must be examined. The basin contains four stations that measure flow from contributing tributaries and one that measures the effluent. Of the five stations, three have suspended sediment data (see Table 2.1). One minimum flow structure (MFS) passes flow into Matubby Creek from Aberdeen Lake. Since flow to Matubby Creek was cut-off due to construction of the TTW, flow is maintained to the creek from the MFS at Aberdeen. The discharge at the MFS is a constant 200 cfs (see Figure 2.2).

Table 2.1 USGS Stations in Aberdeen Pool's watershed

USGS Stations				
Site number	Site Name	Sediment Data	Area, mi²	Period of Record
2433500	Tombigbee River at Bigbee, MS	Yes	1226	01/89 - 04/00
2433530	Burkett Creek at Amory, MS	No	6.6	12/63 - 09/67
2436500	Town Creek near Nettleton, MS	Yes	620	09/74 - 07/95
2437000	Tombigbee River near Amory, MS	Yes	1930	09/74 - 01/00
2437100	Tombigbee River at Aberdeen Lock and Dam, MS	No	2047	05/84 - 09/06

According to the Aberdeen Lock and Dam Design Memorandum No. 17 Sedimentation Program, the total contributing watershed is 2045 mi². However, the contributing area for the effluent flow according to USGS Station 2437100 is 2047 mi². The same value of 2047 mi² was reported in the East Fork Report. Because the East Fork value is a more recent report and it agrees with the USGS number, the USGS and East Fork value of 2047 mi² will be used.

Overlap of drainage areas associated with the USGS Stations (see Figure 2.3) and the sub-basin's areas cause the sum of the contributing areas for each station to exceed the total area of 2047 mi² by 1735 mi². This difference is caused by overlapping watersheds at three stations. One such difference is station 2433500 which is upstream of station 2437000. Station 2437000 has a contributing area of 1930 mi², but 1226 mi² of the 1930 mi² contributes to Station 2433500. Also the station that is located on Town Creek, Station 2436500, flows into Station 2437000. Note that not all of the 1930 mi² from Station 2437000 drains directly into Aberdeen. Some of the flow is intercepted by the upstream dams and/or discharged into the East Fork, Tombigbee River. According to the East Fork Report, 592 mi² is intercepted by the Canal Section from upstream dams. Since the total area is 2047 mi², 1455 mi² is not intercepted by upstream dams, and 127 mi² of the 1455 mi² is direct runoff not a part of the East Fork and Town Creek. This was determined by taking the difference between the total watershed area and the contributing area of Station 2437000. The direct runoff area, which is 127 mi², includes the area that is on the east side of the Aberdeen Lake and is drained by Weaver Creek, Halfway Creek, Tadpole Creek, and Moccasin Creek. See Table 2.2 for details of the contributing areas.

By summing the sub-basins, 127 mi^2, 592 mi^2, and 1328 mi^2 a total of 2047 mi^2 is obtained, and all sections of the total drainage basin are accounted for (see Table 2.2).

Table 2.2 Breakdown of contributing areas for Aberdeen Pool

Contributing Drainage Areas, miles^2						
Source	Area	Intercepted	Town Creek	Tombigbee River	Town & Tombigbee	Direct Runoff
USGS	2047	Included in Town & T.T.	620	1226	1920	127
Station ID	*2437100*		*2436500*	*2433530*	*2437000*	
Aberdeen Report (USACE, 1985)	2045	525	667	560	1227	293
East Fork Report (USACE, 1979)	2047	592			1455 *This includes direct runoff*	
Values Used	2047	592	667	661	1328	127

2.5 Sources and Sinks

Sediment sources, including upland areas, ditches, streams, creeks, and rivers, come into the control volume. Sediment movement is caused by the natural process of these flows, which transport a wide range of particle sizes through bed load and suspended load. Increased entrainment of the sediment into the flow is erosion. Julien (2002) refers to three different forms of land erosion as upland erosion, gully erosion, and bank failure. In addition to these, bed scour and vessel impacts also increase sediment loads. Bed scour will occur when the flow is increased causing an enhancement in the sediment capacity of the flow. “Depending on the size and degree of cohesion of the sediment grains and intensity of flow, the amount transported may be proportional to the speed squared, cubed, etc. So doubling of flow speed may increase sediment transport as much as eight-fold” (McAnally et al. 2004). Vessels also impact the sediment behavior on the TTW through the impacts of prop wash, flow around the vessel, bow and stern waves, and pressure fluctuations beneath the vessel (McAnally et al. 2004). All of these contributing factors play a role in the influent flow of the sediment flux.

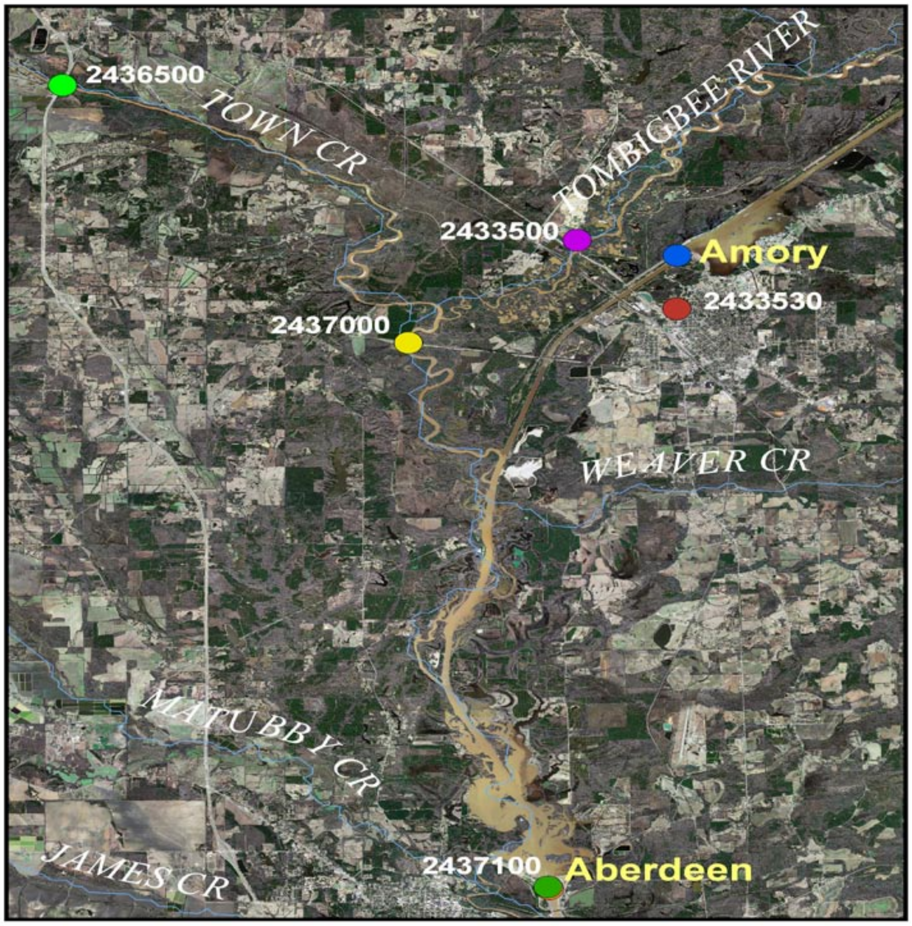


Figure 2.3 Aerial map of Aberdeen Pool and USGS Station locations

Aberdeen Pool has several contributing tributaries that supply the Pool with sediment (see Appendix A). Dominating the Pool's sediment behavior is the Tombigbee River, which merges with the waterway at mile 366. At this location, the greatest amount of dredging is done (Appendix A). Other sources include the following creeks located on the east shore: Weaver Creek, Halfway Creek, Tadpole Creek, Moccasin Creek, and Burkett Creek.

The East Fork Report postulates several causes of increased deposition due to the Tombigbee River flux. First, sediment loads from the Tombigbee River are not minimized by upstream dams. Unlike the rest of the TTW, this section has no dams to inhibit sediment flow. This allows transportation of normal sediment loads directly into the TTW. Second, a change in hydraulics allows flow velocity to decrease and deposition to occur where the two merge. Finally, flow has actually increased in the Tombigbee River due to the MFS. An increased flow would only cause further sediment transport, resulting in more deposition in the TTW.

Sinks remove sediment from a particular control volume or system. For Aberdeen Pool and most other pools on the TTW, a gated spillway, a MFS, a lock, and dredging remove sediment from the pool. Dredging volumes are relatively easy to quantify with dredging records. However, there are a number of problems with determining the amount of load that is transported through the structures. Because there is a certain amount of trap efficiency with the dam, not all of the total load approaching will pass the structure. However, there is no definitive, easily obtained answer as to the amount that will pass. Further complications arise in that the majority of sediment in question is the bed material load. A portion of the bed material load is comprised of bed load, which is the portion of the load that is the majority of unmeasurable load (USACE, 1989). It should also be understood that a single flood event can dominate a system by transporting more sediment during that one event, than the rest of the year. Therefore, underestimation of the peak flood event will greatly affect the projected amount of total sediment that is trapped.

The Aberdeen Lock and Dam Design Memorandum No. 17 Sedimentation Program estimated the trap efficiency of the structure in the first year of operation as 47 percent. After operating for 100 years it is estimated that it will be 43 percent.

The southwest shoreline of Aberdeen Pool slightly upstream of the dam is the location of a MFS that serves as a bypass to supply flow to Matubby Creek. It is considered an effluent for the system, and passes 200 cfs. The MFS provides environmental sustainability for the habitat in Matubby Creek. Relatively speaking, the MFS discharge is small compared to the gated spillway, but it does pass sediment and should be considered in the calculations as a sink.

Both the flow from the gated spillway and the lock chamber are captured by USGS Gaging Station 2437100[1]. Because this station is downstream of the lock and dam both effluent flows are considered a single flow. The gated spillway consists of 6 tainter gates that are 60 feet wide and 26 feet tall. These gates sit on a concrete weir at an elevation of 165 feet and an apron elevation of 139 feet. The lock is a single chamber that is 600 feet long and 110 feet wide. The lock lift is 27 feet, which provides a total dump volume of approximately 2 million feet^3. (USACE, 1979). The majority of the sediment will pass through the gated spillway and might include some bed load. However, this author believes that very little if any bed load will pass through the lock. Further investigation should be conducted to more precisely determine the amount of bed load passing through both the lock and the spillway.

2.6 Literature Review

Since a set of guidelines for constructing a sediment budget is being developed, validation of calculations is imperative. One of the reasons for choosing Aberdeen Pool as the study site is the availability of existing reports. Old reports for Aberdeen contain sediment fluxes and deposition amounts that are used to validate this model.

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[1] Personal communication: Michael S. Runner, Chief of Hydrologic Data Section, USGS.

2.6.1 Aberdeen Lock and Dam Design Memorandum No. 17

The “Aberdeen Lock and Dam Design Memorandum No. 17 Sedimentation Program” (USACE, 1979) is a study conducted pre-TTW. It consists of general design information for the Aberdeen Pool, as well as detailed information on the hydrology and sediment behavior.

Two periods of flow data are available at the Aberdeen Dam site for calculations in Design Memorandum 17. The first is a period of record from 1928 – 1958, and the second is from 1972 – 1977. For the combined sets, March has the highest monthly average flow of 7,580 cfs and August has the lowest flow of 608 cfs. The maximum daily discharge is 23,000 cfs occurring in March 1973. The minimum daily flow is 58 cfs, which occurred in September 1954.

Suspended sediment sampling was conducted from June 1971 – July 1979. Three sediment stations were placed upstream of the dam site. This provided the data necessary for estimating natural sediment loads. According to the report, suspended sediment loads varied greatly at the dam site during the year with an average annual sediment flux of 580,000 tons. Typically, the winter and spring months transport the most sediment, while the late summer and fall months transported the least. The maximum amount of load transported in one month was in March, which was 32 percent of the total annual load with an average of 190,000 tons. The lowest amount was in August that had 0.7 percent of the total suspended sediment load with an average of 3,830 tons.

Sediment load change is directly related to the rise and fall of flow during the corresponding month. “During the 6 month period from December through May, 89.8 percent of the yearly suspended load passes the Aberdeen dam site, transported by 81.8 percent of the average streamflow” (USACE, 1979). As should be expected, the higher flows produce larger sediment loads. However, it is noted that for a single event “sediment loads can decrease with time while streamflow slowly increases” (USACE, 1979). Though counter intuitive, the phenomenon is a direct result of settling velocities and runoff duration. While rainfall occurs, sediment is added to the system from upland processes due to runoff, but once rainfall stops, runoff slows and stops, which eliminates a significant source of sediment. By the time the peak flow reaches the downstream location of sampling, the particles settle out of the water column causing a lower reading of suspended sediment at a higher flow. This behavior causes the peak concentrations of suspended sediment to occur prior to the flow peak.

It was estimated that the first year trap efficiency is 47 percent, yielding 271,040 tons/yr of deposition. However, the Design Memorandum states that the reduced reservoir volume causes more sediment to pass through the system. After a hundred years of operation, the trap efficiency is 43 percent, or 247,972 tons/year of deposition. Furthermore, the report states that the shallows will gradually fill while the channel is maintained with dredging. The sediment fluxes are listed in Table 2.3.

Table 2.3 Comparison of sedimentation studies for headwaters of the TTW

Sediment Fluxes and Deposition from Reports, tons/yr					
Locations	Town Creek	Bigbee	Amory	Dam	Dep.
Station ID	2436500	2433500	2437000		
Design Memorandum	465,000	297,000	439,000	580,000	247,972
East Fork Report	949,000	547,000	1,631,000	n.a.	n.a.
Sedimentation Ranges:	n.a.	n.a.	n.a.	n.a.	624,362

2.6.2 Final Report Tombigbee River (East Fork) Study

The Final Report Tombigbee River (East Fork) Study (USACE, 1988) was done in 1988 after the opening of the TTW. Soon after the completion of the TTW, engineers realized that there were certain issues underestimated by the design. These issues primarily existed in the head waters of the Aberdeen Pool. The purpose of the report was to study the "natural hydraulic process at work in the reach and the impacts of federal and other projects on the East Fork flood plain" (USACE, 1988). As part of the scope and main issue, sedimentation is closely examined. In addition, a detailed study of hydraulic conditions is examined through construction of rating curves and other analysis processes.

As mentioned, sedimentation is one of the most pressing issues. The greatest effects of the hydraulic changes made on the Tombigbee are at the junctions of the East and West Forks of the Tombigbee River and at the Tombigbee River and the TTW. To estimate flux changes at the junctions "sediment rating curves plotting total suspended load versus total stream discharge were done with the least squares method" (USACE, 1988). The sediment fluxes calculated from the rating curves can be seen in Table 2.3, East Fork Report. All three values for the East Fork Report in Table 2.3 are bed material loads where the bed load was estimated at 20 percent of the suspended load. Also note that these values are double the value of their predecessors calculated in Design Memorandum 17. A deposition that is doubled may occur if incoming sediment fluxes in the Design Memorandum 17 are doubled. Therefore, sediment flux amounts from the East Fork Report relative to the Design Memorandum suggest that the total deposition in Aberdeen would be nearly 500,000 tons/yr.

2.6.3 Application of HEC-2 to Selected Reaches of the Tennessee-Tombigbee Waterway

A preexisting model for the Aberdeen Pool is the HEC-2 study. The HEC-2 report is thesis work conducted to analyze hydrodynamic behavior of low flows for the purpose of setting discharge limits on wastewater treatment plants (Lunardini, 1990). Though not directly related to sediment the model is a valuable source for historical cross sectional data. Dr. James Martin has previously converted the cross sections into HEC-

RAS Beta 4. The new version of HEC-RAS has a sediment model, SIAM, that is used for the final calculation of deposition (see Chapter 5).

2.6.4 Sedimentation Analysis for Aberdeen Lake

Design Memorandum 17 recommends semi-annual surveys of pre-established sedimentation ranges. These ranges are referenced to preset concrete monuments. The survey guidelines followed are in accordance with Engineering Manual EM 1110-2-4000. In the report, surveys were made almost annually with the first one occurring in 1985 and the most recent one in 1998 (USACE, 2000). The purpose of this work was to determine the amount of aggredation occurring within the Aberdeen Pool. This document was prepared by HDR Engineering, Inc in 1998.

Surveys of sediment ranges were done in 1998 to compare against historical ranges conducted annually since 1984 to compute changes in top widths and cross sectional areas. Data were collected from 54 ranges. Once the ranges were compiled, comparisons were made. Severe sedimentation issues were discovered in most of the ranges. However, a few ranges were classified as having scour conditions. It was also reported that the cause of aggradation was due to soil conditions and the relative "newness" of the TTW (USACE, 2000). Soils in the region consist of fine grain sizes that easily erode. Additionally, the TTW is a relatively new channel that has not reached a state of equilibrium. Without equilibrium, sedimentation will occur and continue to cause issues with navigation.

The report provides a valuable validation tool because a total deposition amount is estimated using the results of this work. By calculating the mean of the cross sections' change in area, an average annual change in area is estimated for the Pool. The average annual change in area is multiplied by the length of the Pool. This produces a total annual deposition amount. It is determined from this calculation that approximately 932,000 tons/year have deposited annually in the Aberdeen Pool, based on a specific gravity of 1.6 (see Section 3.3). After the yearly dredging, the total annual deposition in the pool is approximately 627,000 tons/year. This value is critical since it is assumed that it represents the true depositional volume and is referred to as the annual deposition. It is also relatively reliable since the annual average change in area is based on data collected from 1985 – 1998.

CHAPTER 3. SAMPLING IN ABERDEEN POOL

The Aberdeen Pool has three USGS gauging stations that measure incoming flow and suspended sediment concentrations into the pool. Station 2433500 is located on the Tombigbee River at Bigbee, Mississippi. Its period of record extends from January 5, 1989, to April 13, 2000. Samples were taken on a monthly basis with some gaps as large as six months with no data. The next location was Town Creek near Nettleton, Mississippi, Station 2436500. Its period of record extends from October 25, 1974, to July 26, 1995. Samples were taken on a monthly base with some gaps as large as three months. The final station is Tombigbee River near Amory, Mississippi, Station 2437000. Its period of record extends from October 25, 1974, to January 1, 2000. Station 2437000 has the most gaps in data with the largest being a fourteen year period of no record. Data gaps are detrimental to sediment flux analysis.

Sampling is a vital part of the Sediment Budget Template creation process for validation of both USGS data and calculations. The Civil and Environmental Engineering Department at MSU has the Research Vessel Kelly Gene Cook, a 20 foot pontoon boat which provides a stable platform to conduct sampling expeditions on the Pool, as well as reconnaissance work.

3.1 Corings:

Validating the estimated deposition depth was accomplished by collecting core samples. These core samples are taken in pool shallows and locations that provide stable bed strata for sampling (see Appendix A). Samples are collected using a clear cylindrical tube attached to a one way ball valve and extension pipe. The clear tube penetrates the bed and once the bed is penetrated the ball valve creates a vacuum, allowing the sample to be extracted. The diameter of the clear tube is 1.5 inches. If the bed material is cohesive enough then the sample will stay in the tube. However, the sample will not hold in the tube and will slide out if it is fluid mud or is non-cohesive sediment. This limits the locations where such sampling is done.

Once extracted from the bed, the core samples are visually inspected to evaluate the approximate amount of deposition that is occurring from year to year. Yearly deposition can sometimes be seen in corings with organic layers which are formed from leaves or other plant debris that deposits in the fall months. By measuring the distance between the rings, a total yearly deposition depth is estimated.

In the Aberdeen Pool, cores were collected from twelve different locations. Visual inspection was used to analyze each core. All locations seem to yield the same characteristics, but only two showed definitive layers. Each sample has a top brown layer of silt/sand mixture that is 0.25 inches to 2.5 inches thick and a lower gray layer of soft fine sediment that ranges from 0.5 feet to 3.0 feet thick.

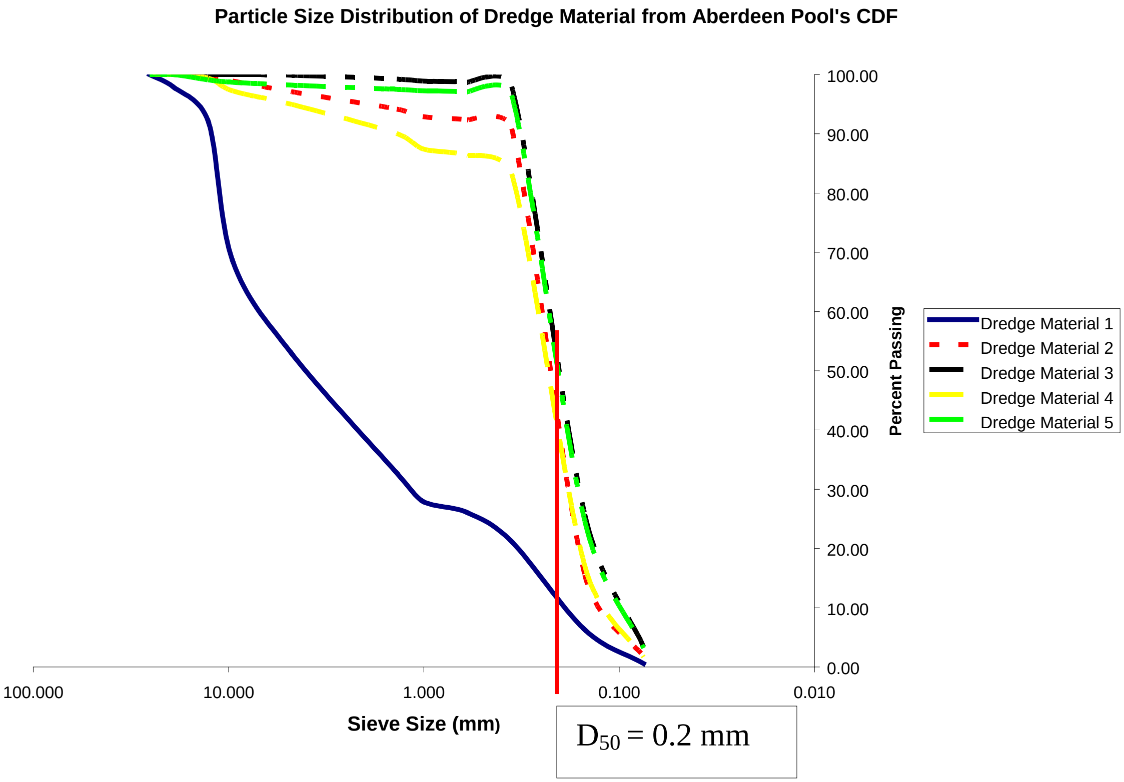
Only two samples showed organic layers and may indicate a depth of annual sediment deposition. In both cases, the sediment below the organic layer slipped and released the lower part of the sample out of the tube and back into the water. This may indicate that the attractive forces in the fine sediments were diminished with an organic layer between the two adjacent layers of fines. Therefore, the absence of organic rings does not negate their existence, but rather the sampling methods employed are incapable of capturing and holding the complete core. For one of the two samples, the majority of the organics is at the bottom of the sample, which may indicate that the sediment above the organic layer was deposited over the past year. Since the sampling was done at the end of the summer and before the fall, the sample may closely represent the past year's deposition depth. However, it is inadequate to represent the pool's annual deposition depth with only one core.

Since there are not enough core samples with organic layers to come to a definitive answer on annual deposition depth another means of estimated deposition is necessary. One alternative is to examine the depth of penetration. It is assumed that the sediment is under-lain by a hard natural soil, pre-construction surface. The total depth of deposition since the opening of the TTW may then be taken as the depth that the core sampler tube penetrated. This depth is 0.5 feet to 3 feet deep. Over 22 years of operation this penetration depth would indicate a deposition depth of 0.273 inches to 1.57 inches per year. The range of deposition depth provides a means for an estimate of total deposition volume. When the deposition depth is multiplied by the pools area of 4,121 acres the resulting deposition volume is 151,254 yds^3 per year – 869,851 yds^3 per year.

3.2 Sieve Analysis

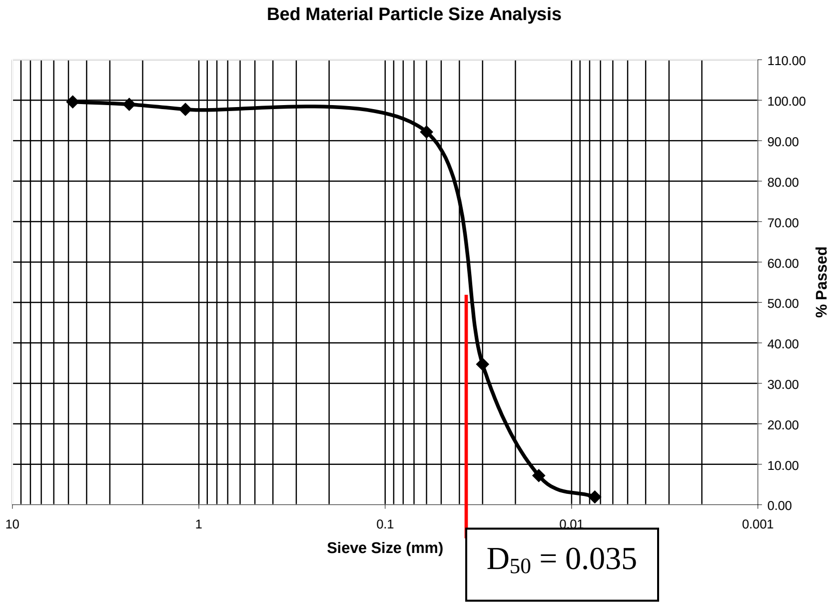
Prior to this thesis work, a sieve analysis was conducted by MSU for the U.S. Army Corp of Engineers. (See Appendix A) The analysis was conducted to determine possibly recycling the dredged material. Sieve analyses were done for different locations of confined disposal facilities (CDF) along the TTW. Two of the sieve analyses were conducted from material collected at Aberdeen's disposal facilities.

For the purpose of this work, both sieve analysis are used to evaluate the sediment that is dredged from Aberdeen. This evaluation is used in the final Tier 3 calculation. For further analysis and validation, five more sieve analysis were conducted from dredge material collected at one of Aberdeen's CDF (see Figure 3.1), and one was conducted from bed material collected at mile 366 (see Figure 3.2). Four of the five gradations in Figure 3.1 are similar to the two original gradations constructed before this report (see Table A.5). The final gradation (see Figure 3.2) is also similar to that of the original ones.


Particle Size Distribution of Dredge Material from Aberdeen Pool's CDF

D_{50} = 0.2 mm

Figure 3.1 Sieve analysis of dredge material from Aberdeen Pool


Bed Material Particle Size Analysis

D_{50} = 0.035

Figure 3.2 Sieve analysis of collected bed material from mile 366

It should be noted that the bed material was collected in October of 2007, which is after the yearly dredging. Results may be different if a sample is collected just before the commencement of dredging work. However, this difference may cause only minimal variation in the final depositional estimate.

3.3 Specific Gravity Measurements

Specific Gravity is an important value to quantify conversion between mass and volume. The U.S. Army Corp of Engineers conduct surveys before and after dredging to estimate the amount of material removed, which is reported in units of cubic yards. Since the concentrations are in mass per volume, sediment fluxes are typically reported in tons/yr. Therefore, in order to remove dredge material from total deposition, the dredge volume is converted to mass (see Equation 3.1).

$$M = V \times S.G. \times \gamma \tag{3.1}$$

Where:

γ = specific weight of water
V = volume of dredge material
S.G. = specific gravity (bulk)

For in-place sediment deposits, a value of 1.6 is recommended for the S.G. (ASCE, 1975). The recommended value is used in the example calculations of this work. However, proper validation is made to determine dependability of this value for the study site. S.G. is obtained from density and/or specific weight (see Equation 3.2).

$$S.G. = \frac{\gamma_s}{\gamma} = \frac{\rho_s}{\rho} \tag{3.2}$$

Where:

γ_s = specific weight of in place sediment
ρ_s = density of in place sediment, $\frac{\text{mass}}{\text{volume}}$
ρ = density of water

Multiple samples from the site are taken to measure mass and volume, which is used to calculate an average density. Difficulty arises when trying to collect a field measurement from which to measure volume.

An undisturbed sample is desired for density measurements so that a true representative sample of the in-place sediment is obtained (Das, 2002). Specifically, an undisturbed sample is imperative to measure the sample’s correct volume. Two methods were attempted to collect an undisturbed sample for estimating in-place density of deposited sediment. The first attempt used a Shelby Tube which was rigged for use under the water. The second used the coring device that was used to take bed samples in Section 3.1.

Attempt one was unsuccessful. The failed attempt is due to the large 2.8 inch diameter of the Shelby Tube. A Shelby Tube is desirable for collecting a density sample because the large diameter tube reduces the effects of sample distortion once extracted. However, when the tube was removed from the bed, the pressure head in the tube from the water above was greater than the attractive forces and the vacuum holding the sample in the tube, which caused the entire sample to be lost before extraction.

The next attempt implemented the previously used coring device to recover the samples. Because smaller diameter samples can produce more inaccuracies the coring device, which has a tube diameter of 1.5 inches, is less ideal for density samples than that of a Shelby Tube. However, since validation of the recommended specific gravity value is the purpose of this investigation, the smaller tube produced sufficient results.

Computations for density are done in the following approach. First, the volume of the sample is calculated from the height of the sample and the diameter of the tube. Next the sample is weighed and the mass of the sample is divided by the volume (see Table 3.1). The average specific gravity is 1.69 which is slightly higher than the recommended value of 1.6.

Table 3.1 S.G. calculated from sample densities

Sample Densities			
Soil, lbm	Soil, ρ, lbm/ft^3	Water, ρ, lbm/ft^3	S.G.
1.00	98.2	62.2	1.58
1.45	96.9	62.2	1.56
1.18	110.3	62.2	1.77
0.61	108.0	62.2	1.74
1.01	120.1	62.2	1.93
0.95	113.5	62.2	1.82
0.82	90.8	62.2	1.46

Each sample was taken at a difference distance below the water surface. It was discovered that a possible relationship between the S.G. and the depth below the water surface may exist. By careful selection of the measured S.G.s and their corresponding depth below water, Figure 3.3 was created. However, all the samples are graphed in Figure 3.4, and that graph does not indicate a smooth density profile like that of Figure 3.3.

Figure 3.3 indicates that an increase in water depth may cause a decrease in bed density. Because no samples could be taken below 10 feet, due to the inability of the coring device to collect and retain fluid mud sample, further exploration of a change in density with above water depth is impossible with this sampling method. Therefore, the mud densities at deeper depths is less than the density in the sampled shallows, which is a further indication that change in density is an inverse function of depth below the water surface.

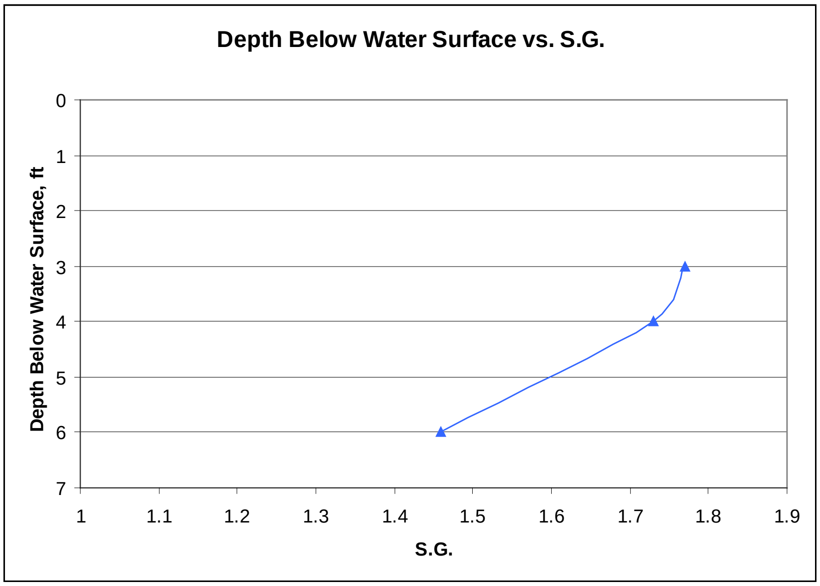


Figure 3.3 Depth below water surface vs. S.G.

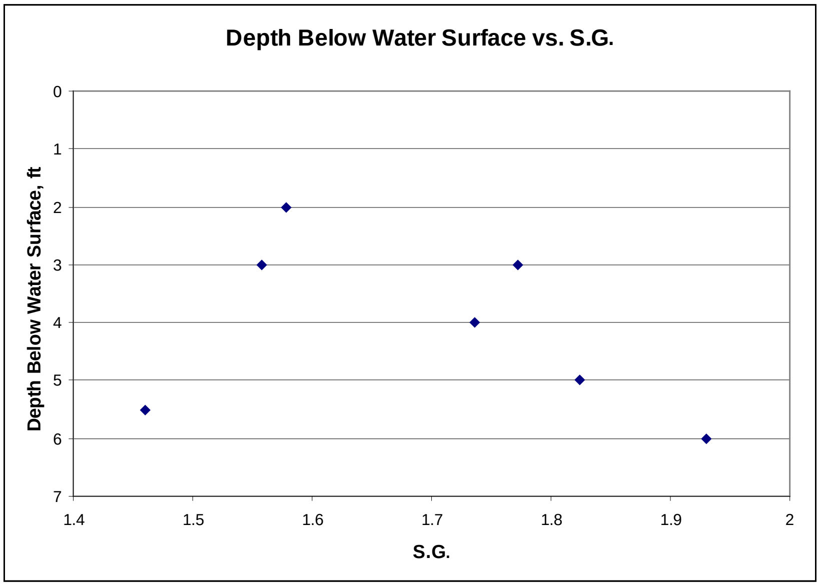


Figure 3.4 Distribution of all S.G. measurements

If the density of the bed is an inverse function of the above water depth, then the density in the main channel where dredging occurs is lower than the densities calculated from the samples. If the real density measures are lower than the average of 1.69 calculated from the sampling, the suggested value of 1.6 is an appropriate value.

3.4 Dredging

In the mass balance equation, the dredged material is the amount of sediment that is removed. For quantifying this amount, the US Army Corp of Engineers provided the dredged volumes that were removed per year since 1985 (see Table 3.2). These amounts are further subdivided into the CDF to which the material is pumped. Knowing the location of disposal allows for a rough estimate of the location of the sediment deposit. [2]Dredgers are required to provide 8000 feet of pipe, which is a limiting factor in the distance that they can dredge from the CDF.

Table 3.2: Dredging record for Aberdeen Pool

Aberdeen Pool	
Year	Material Dredged, yds/yr
1985	249,232
1986	54,641
1987	193,325
1988	189,842
1989	396,218
1990	45,763
1991	332,801
1992	18,777
1993	225,129
1994	223,273
1995	144,158
1996	242,883
1997	147,568
1998	178,339
1999	227,373
2000	196,763
2001	399,619
2002	368,178
2003	216,731
2004	387,186
2005	281,000
2006	270,600
Total	4,989,399
Average	226,791

According to the dredging records, an average of 226,791 yds/year, or 305,638 tons/yr based on a S.G. of 1.6, is removed from Aberdeen Pool. This is the amount that is used in the SBT calculations for Aberdeen Pool. Ideally, the amount dredged in a year

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[2] Pete Grace, USACE, personal communication, October 2007.

is the total amount of material that is deposited that year. However, this is only a fraction of the total incoming sediment deposition. Since the U.S. Congress only allocates a limited amount of money to use for dredge work, the Corp is forced to dredge only the highest priority locations.

CHAPTER 4. TIERED ANALYSIS

4.1 Tiered Analysis Method

The SBT implements a three tiered analysis (see Figure 4.1) approach. Tiered analysis allows a modeler to bracket an answer by refining the modeling process. It also helps eliminate human error, and results from each tier can be compared to reveal potential problems that may exist in one or more of the tiers.

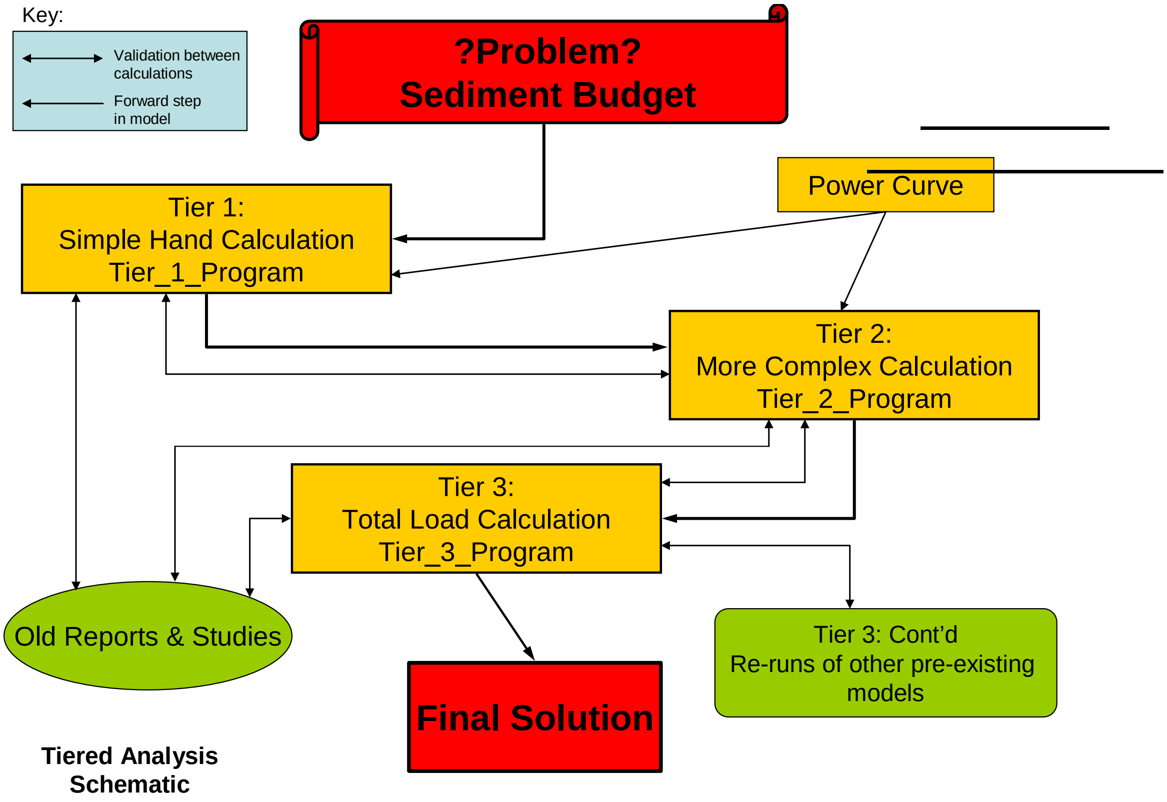

Figure 4.1 Schematic of Tiered Analysis for the SBT

Ideally, the values calculated during each progression of the tiered approach should steer the modeler to a better appropriate approximation of the true value. This means that the first calculation, or tier 1, should be a rough estimate of the final estimate. The next advancement is tier 2. A tier 2 calculation should be within the correct magnitude of the final approximation. Finally, tier 3 is the apex of the tiered analysis and is the final estimate. It should be within a reasonable amount of error of the true answer. Even though the exact answer is rarely obtained, tiered analysis provides the modeler with a relative amount of confidence in his final product.

When compared to other water resource fields, a justifiable range of error with sediment work is rather wide. Therefore, a reasonable value is at the discretion of the modeler. When possible, the implementation of pre-existing models should be used for comparison to further validate the SBT. These older models are considered validation tools for all three tiers. The TTW does have pre-existing sediment budgets that were used for comparison such as the Design Memorandums and the river study of the East Fork.

4.2 Tier 1

Tier 1 analysis implements basic principles to create a conceptual sediment budget. The sediment load is calculated using equation 3.1 from the USACE Engineering Manual 4000 (USACE, 1989). As seen below.

$$Q_s = 0.0027 \times Q \times C \times k \tag{4.1}$$

Where:

Q_s = sediment discharge, tons/day
0.0027 = converts cfs to tons/day/1000000 parts
Q = mean daily water discharge, cfs
C = mean daily sediment concentration, ppm
k = ppm to mg/l

For a concentration that is less than 16000 ppm, k = 1. (Note that for the purpose of this work, k will always be 1.) Q and C were determined by measurements obtained from USGS Gaging Stations. These data were downloaded from the USGS website and includes the annual flood flow and the suspended sediment concentrations. Concentrations and discharges were compiled from thirty-seven USGS Stations that sampled various locations in the watershed (see Table A.1). Equation 4.1 was used to solve Q_s using C and Q for each sample at all thirty-seven USGS Stations. Next, Q_s vs. Q was plotted on an XY log graph (see Figure C.1), and a power curve was fitted to the data. This resulted in the following equation:

$$Q_s = 0.073Q^{1.2588} \tag{4.2}$$

Solving for C:

$$0.0027 \times Q \times C = 0.073 \times Q^{1.2588} \tag{4.3}$$

$$C = \frac{0.073 \times Q^{1.2588}}{0.0027 \times Q} \tag{4.4}$$

For the Tier 1 calculation the Q term in Equation 4.1 is the bankfull discharge ($Q_{1.5}$). The $Q_{1.5}$ is calculated using the annual flood flow data along with the Log Pearson Type III method found in Bulletin 17-B (USDI, 1981), which is a statistical analysis for flood flow frequency. A return period of 1.5 years was chosen since it is considered the bankfull discharge (Julien, 2002). (See Bankfull Discharge section below) By using this value, it is assumed that the flow has a constant magnitude of $Q_{1.5}$ year round. Obviously, this is not true, but for the purpose of the first tier the value is sufficient to get an estimate of the sediment load.

For the locations in Aberdeen's Watershed that are not represented by gaging stations, an average $Q_{1.5}$ per area is calculated. The ungaged areas are subwatersheds where the flow is intercepted flow by upstream dams or the flow directly discharges into Aberdeen Pool. From the total area, 592 mi² is intercepted flow and 127 mi² is direct runoff. The average $Q_{1.5}$ per area is determined thus. It was decided to use a value based on the East Fork and Town Creek, Station 2437000. The 1.5 year discharge per area determined for Station 2437000 is divided by the contributing area of 1328 mi². This resulted in an average $Q_{1.5}$ of 22.106 cfs/mi². By multiplying this by the un-gauged area, the resulting total $Q_{1.5}$ flow was found to be approximately 16,000 cfs. From this flow value, the Qs was calculated for the ungaged area.

4.2.1 Tier 1 Tools

For the tier 1 analysis two VBA/Excel programs were written to calculate and graph the necessary products.

4.2.1.1 Power Curve Program

The first program, Power Curve Program, uses all of the available suspended sediment data in the Tennessee-Tombigbee River basin along with the discharges at those same locations (see Figure B.1). By use of Equation 4.1, Q_s is estimated. Then Q_s vs. Q is graphed, and a power curve is fit to that data. By characterizing the watershed's sediment data with a trend line, Q_s can be computed at any given discharge for the basin. The input sheet for Tier 1 is seen in Figure B.1.

4.2.1.2 Tier 1 Program

The next program is the Tier 1 Program. It uses the power curve coefficients along with the $Q_{1.5}$ to calculate Q_s. The program calculates the statistics of the annual flow data for the purpose of obtaining the log skew coefficient (see Figure B.2 & B.2). Once the log skew coefficient is established, Bulletin 17 B reference tables are used to acquire the Pearson Curve coefficient, k. The k value is then added to the program to calculate $Q_{1.5}$, the concentration, and Q_s. After Q_s is known, the mass balance equation (Equation 4.9) is used to estimate the total deposition in the pool.

4.2.2 Bankfull Discharge

Typically, bankfull discharge is defined by the physical bounds of the channel and the forming processes that are exhibited. It can range on an interval of a 1 to 5 year return period for any given year (Julien, 2002). Conceptually, bankfull discharge is the discharge that a channel can convey when the water surface is at the same elevation as the flood plane (Andrews 1980; Julien, 2002). Julien (2002) states that for natural channels that exhibit equilibrium, the return interval for bankfull is 1.5 years. Furthermore, bankfull can also indicate the flow that dominates the system's sediment characteristics. However, bankfull only dominates the sediment characteristics if the channel is in a state of equilibrium.

Therefore, it should be understood that the bankfull, which is one of three "channel forming discharge" estimators, might not be the best evaluation tool. A more appropriate evaluation for a system is the effective discharge (Doyle et al. 2007). This effective discharge is determined through the construction of a discharge effectiveness curve and is more appropriate for a sediment budget analysis (Doyle et al. 2007) but requires more data. Some studies have shown that the effective discharge and the bank full are approximately equal for a system in equilibrium (e.g., Wolman and Miller, 1960; Andrews, 1980; Emmett and Wolman, 2001). For the purpose of this study a bankfull discharge is sufficient since a tier 1 approximation is an estimate of the final evaluation. Further consideration of the bankfull discharge should be evaluated to indicate the relative state of equilibrium for Aberdeen Pool.

4.2.3 PeakFQWin

Since validation of all processes in this template is imperative for model accreditation, the $Q_{1.5}$ was checked against PeakFQWin. PeakFQWin is a program supported by USGS data that calculates flood flow frequencies for certain return intervals. It uses annual-maximum flood flow data and is based on the Pearson Type III Method.

Small differences do exist between the $Q_{1.5}$ calculated in Tier 1 Program and that which is calculated in PeakFQWin (see Table 4.1). The PeakFQ program uses a weighted log skew coefficient in its Log Pearson Type III method. It also removes any possible outliers whereas the Tier 1 program neither checks for outliers nor does it use a weighted log skew coefficient. The Tier 1 Program uses the standard log skew coefficient without a weighted average. Both of these items probably account for differences in the calculated $Q_{1.5}$ between the two programs.

Table 4.1 Comparison of $Q_{1.5}$ between PeakFQ & Tier 1 Program

Variations Between PeakFQ & Tier 1 Program						
Station ID	T1P, Q1.5	PeakFQ Q1.5	T1P, G	PeakFQ, G	T1P, num	PeakFQ, num
2437100	37580	38920	-0.309	-0.168	22	22
2437000	29369	20930	0.314	-0.22	71	53
2433530	371	n.a.	0.387	n.a.	4	0

T1P = Tier 1 Program
G = Log skew
num = number of peaks used in calculation

Each program is fairly close to the $Q_{1.5}$ at Station 2437100 with a 3 percent discrepancy. The difference in the two calculations is caused by PeakFQ using the weighted log skew coefficient. The most apparent difference is at Station 2437000 where there is approximately 28% difference between T1P and PeakFQ's $Q_{1.5}$. This is attributed to the number of peaks used in the calculation for both programs. Another apparent issue is Station 2433530; it has a short data record, and PeakFQ would not calculate the $Q_{1.5}$.

4.3 Tier 2

Tier 2 analysis is a refinement of the first tier, which the sediment budget was calculated using daily flow data. This provides a daily sediment load at each station. That daily load is integrated using the trapezoidal integration approximation, Equation 4.5, over an interval of one year for every complete year of data. Incomplete years were truncated.

$$\int_a^b f(x)dx \approx T_n = \frac{\Delta x}{2}[f(x_o) + 2f(x_1) + 2f(x_2) + \cdots + 2f(x_{n-1}) + f(x_n)] \tag{4.5}$$

Where:
f(x) = Qs
T_n = total yearly deposition
And:

$$\Delta x = \frac{(b-a)}{n} \tag{4.6}$$

Where:
a = lower limit
b = upper limit
n = number of intervals

The trapezoidal integration method provides a means to calculate the annual sediment load at each flow station. Once each station has a calculated annual sediment load, a sediment yield per area is estimated based on the average annual sediment load and the contributing areas of these flow stations. Two different sediment yields per area are used to calculate sediment loads for the intercepted flow areas and the non-intercepted flow areas, as discussed below.

Intercepted flow is flow that has been routed through upstream dams. In theory, intercepted flow should have lower sediment concentrations due to the reservoirs' retention time which allows sediment to settle. The removal of sediment due to upstream dams is best represented by the sediment loads calculated at the effluent end of the system, where sediment has had time to settle in the site pool before discharging to the next pool. For the intercepted flow areas the sediment load and contributing area for the outflow end, Station 02437100, is used to calculate the sediment yield per area, Equation 4.7.

A second sediment yield per area is calculated for non-intercepted flow areas that include those contributing areas that drain directly into to the system. It is assumed that ungaged areas that flow directly into the system will have similar sediment concentration to areas that are gaged and flow directly into the system but are not routed through a dam. The area that is not intercepted by dams but directly discharges into the system is called the remanding area. The remanding area along with the sediment load from that area is used to calculate the sediment yield per area (see Equation 4.8).

$$\text{Intercepted } Q_s = \frac{Q_s \text{ Out}}{\text{Total Area}} \times \text{Intercepted Flow Area} \tag{4.7}$$

$$\text{Non-intercepted } Q_s = \frac{\text{Sum } Q_s \text{ In}}{\text{Remanding Area}} \times \text{Non-intercepted Area} \tag{4.8}$$

Once each sediment yield per area is established the appropriate area is multiplied by the sediment yield to calculate both the intercepted load and non-intercepted load (Equation 4.7 and 4.8). When all of the contributing areas are accounted for, the mass balance equation is implemented to estimate the net deposition, Equation 4.9.

$$\sum Q_{sources} - \sum Q_{\sin ks} - \Delta V + P - R = \text{Residual} \tag{4.9}$$

Where:

Q_{source} = sources

$Q_{\sin ks}$ = sinks

ΔV = change in volume/year

P = amount of material placed/year

R = amount of material removed/year

Residual = represents degree of balance in cell/year

The sources' terms are the suspended loads that are calculated for each station and those areas not represented by stations where the suspended load is estimated using a sediment yield per area constant. The sink terms include both the minimum flow structure suspended load and the effluent suspended load. Change in volume is the net deposition or erosion occurring. Placed material volume is zero since no material is input in the system except through inflow. Removed material is the amount that has been dredged. For this work, the residual is assumed to be zero, so that the total deposition or erosion is the change in volume. Once all values are estimated, a proper sediment budget is developed.

4.3.1 Bed Load

Unlike the first tier calculation where no bed load (BL) is accounted for, Tier 2 considers bed load as a percentage of suspended load. In the Tombigbee (East Fork) Study, the BL was estimated to be 20 percent of the suspended load. For incoming flows, 20 percent is used. However, a lower value of 5 percent is assumed to calculate the effluent BL. The assumption is made since it is known that a dam will trap sediment (Julien 1998), so the outgoing BL load fraction is lower than the incoming BL fraction. Further evaluation is required to understand the true amount of BL passing over the structure. Figure B.7 shows that as the amount of BL passing the dam is decreasing then the amount of deposition is increasing in the pool. The Tier 2 Program is programmed so that these BL values can be changed. The values are subject to change once the tier 3 calculation is complete.

4.3.2 Tier 2 Tool:

For reuse and reliability, a third program is set up to run the Tier 2 calculations. It is similar to the Tier 1 Program because it is also designed to use the Power Curve Program to define the sediment behavior.

4.3.2.1 Power Curve Program

The Power Curve Program is implemented in the tier 2 calculation in the same manner as it was in the first calculation, but with different data. The sediment data used are directly associated with the contributing drainage area to the site being studied. Since only local gaging stations are used, this allows the model to define the sediment with local sediment parameters. Confining the sediment data to the study site yields a closer approximation to the final solution. Table 2.1 provides a list of USGS Stations in the Aberdeen Pool watershed.

4.3.2.2 Tier 2 Program

The Tier 2 Program (see Appendix B) uses the power curve coefficients from the Power Curve Program to define the sediment behavior and the daily flow data to calculate the sediment flux. Input includes one effluent station and up to nine influent stations. At each station, the user can specify a different set of power curve coefficients. Additionally, a specified minimum flow effluent is available for locations that have a MFS. Not all contributing watersheds are routed through a USGS Station. For those sub watersheds that are not routed through a USGS Station, they are the unaccounted or remanding areas and can be specified in the program by two different forms, as the intercepted flow area and the non-intercepted flow area. Once the required data are input the model is run. The final product consists of both suspended and bed load amounts per station, as well as the totals, and an overall depositional tonnage and depth.

CHAPTER 5. TIER 3, SIAM

5.1 SIAM

The following information in section 5.1 is a summary of Chapter 18 Sediment Impact Analysis Methods (SIAM) in the HEC-RAS Beta 4 Version User Manual.

"SIAM, Sediment Impact Assessment Model, is a sediment budget tool that compares annualized sediment reach transport capacities to supplies and indicates reaches of overall sediment surplus or deficit" (USCE 2006). SIAM is a subroutine that runs in HEC-RAS. It yields a bed material load deposition in tons/year by using the steady flow analysis in HEC-RAS along with five different user selected total load equations. The equations are Ackers-White, Engelund Hansen, Laursen (Copeland), Meyer-Peter and Muller, Toffaletti, and Yang. For defining equation parameters, the user can define the bed material gradation and incoming sediment sources. Then the flow duration and water temperature are specified. Finally, the system is broken up into sediment reaches.

Before SIAM is run, the user must run a steady-state flow analysis for the intended flow and geometric file. Ideally, multiple flow profiles are run in one flow data file in HEC-RAS to represent different flows that the reach may experience yearly. Flow profiles in HEC-RAS are automatically imported into SIAM. Then the flow duration for each profile is specified in number of days along with the water temperature. "Since SIAM predicts annual trends and is based on an annualized flow duration curve the populated flow profiles must be distributed over 365 days (USACE 2006). Therefore, total duration must equal 365 days. Theoretically, this represents different flows for the course of one year which are used to define the net sediment change.

A sediment reach is defined as a reach with similar sediment and hydraulic characteristics. It is composed of a group of cross sections where the flow parameters are averaged over those cross sections. Then the sediment parameters are entered for the reach, and the net deposition, erosion, or equilibrium is determined for that sediment reach. The net change is shown for each sediment reach in the output table.

Sediment parameter classifications define the bed material and the sediment sources. For the bed material the sediment is specified as percent finer in terms of the Φ scale (Fetter, 1994). The sediment sources are based on tons per year per particle diameter. Sediment sources are increased by a multiplication factor where one multiplication factor can represent a sediment yield per unit length of bank or a sediment yield per area. In addition to the sediment sources, a maximum wash load size is selected for each sediment reach. "SIAM does not apply the standard transport equations to compute a mass balance for wash load material. Instead, it automatically passes them through the system" (USACE 2006). Therefore, any particle equal to or smaller than the maximum wash load passes through the system.

SIAM computes sediment transport by one or more of six possible selections of total load equations. Depending on the system, careful consideration and multiple runs should be done before choosing an equation.

5.1.1 Cross Sections

Reliable cross sectional data, or a geometric file, is necessary for a proper evaluation of the hydraulic conditions in a given reach. With uncertainties in sediment analysis, it is recommended that, when possible, results from two or more cross section data files are compared. Two different sets of cross sectional data for Aberdeen Pool are used in this report. These two data sets provide a comparison between current conditions and historic conditions. By using more than one geometric file the user can check results and validate solutions. The geometric file from the HEC-2 study done in 1990 is used as the historic conditions. For current conditions, the Corps' office in Columbus provided a bathymetry study of the channel conducted in October 2005. A DEM, or digital elevation map, is used for the shallows that are not defined in the bathymetry study. The combination of the bathymetry study and the DEM yielded the current cross sections.

5.1.1.1 HEC-2 Study of Aberdeen

Applications of HEC-2 to Selected Reaches of the Tennessee-Tombigbee Waterway were done as part of the thesis work of Robert C. Launardini (Launardini, 1990). His work is the source of the historic cross sectional data. The cross sections were constructed by Launardini through field measurements and data from the U.S. Army Corps of Engineers. Field measurements were taken with a fathometer mounted on a research vessel. The locations of the cross sections were referenced by river mile markers. River mile markings are regularly placed over the length of the TTW, so it is assumed that Launardini cut cross sections at mile marker locations. These cross sections were taken from mile 312 to 449.7 on the TTW (Launardini, 1990). They are sub-divided into pools corresponding to the lock and dams on the TTW.

The original report (Launardini, 1990) has 16 cross sections that are in Aberdeen Pool and are referred to as HEC-2 in Table 5.1. The geometric file had 25 cross sections and will be referred to as the Historic data. It is assumed that the nine added cross sections were interpolated. In addition to the Historic a new set of cross sections, Current, have been created. Table 5.1 shows the three different cross sectional data where the individual cross sections are referenced by river miles.

Table 5.1 Comparison of different cross sectional information for Aberdeen Pool

Cross Section at River Mile		
Current	Historic	HEC-2
370.86	370.8	
370.58	370	370
369.76		368
369.17	369	367.9
368.36	368	366.4
367.39		366.3
366.43	366.5	
366.12	366.2	
	366.1	
	366	366
365.65	365.7	
	365.3	365.9
364.39	364.8	365.7
	364	364
363.69	363.7	
363.27	363.4	363.4
	363	
362.64	362.6	
	362.4	362.4
362.11	362	
361.58	361.6	361.6
	361.2	
	361	361
360.97		
360.37	360	
359.78		
359.23		
358.65	358.6	358.4
358.311	358.2	358.2
357.84	357.7	

5.1.1.2 Bathymetry Study from Corps

With most systems, especially one like Aberdeen, current bathymetry data is needed. Therefore, it is necessary to create a new set of cross sections. A digital bathymetry map was procured from the TTW Management Office in Columbus, MS. Survey work for the bathymetry map was done in October of 2005 by Cliff Johnston. The map has a 15 foot horizontal resolution and only includes the main channel. The bathymetry data were input into ARC GIS and cross sections were cut at key locations before and after river bends and incoming tributaries. There is a total of 22 cross sections that are in the Current data set.

Having only defined the main channel, the shallows are still in question. Because it is assumed that the majority of the flow passes through the deepest part of the TTW, which is usually the channel, channel bathymetry is the decisive piece in each cross section. The shallows must be defined since a portion of the flow will deposit sediment in it. The Historic sections lack refinement in the shallows and channel area. The Current section's shallows area are established with a digital elevation map, DEM. The DEM used has a 30 meter resolution. Cross sections for the DEM were cut in the same locations as the cross sections cut in the bathymetry data. For each corresponding cross section, the two separate cross sections are merged to form one continuous cross section. Any points in the channel that are DEM points are deleted and replaced with the points from the bathymetry study. The cross sections are merged by looking at a map of the pool and determining where the channel is relative to the cross section line. With a general idea of the location of the bathymetry data relative to the entire cross sectional data of the DEM file, the modeler can merge the two cross sections. Upon alignment, the station distance for the bathymetry cross sections is adjusted to correspond with the stationing of the DEM file cross sections. After the creation of the cross sections they are input into HEC-RAS to create the geometric file for the Current cross sectional data.

5.1.2 Steady State Flows

As previously stated, SIAM requires a steady state flow run in HEC-RAS prior to implementation of SIAM. In addition to the geometric data the steady state flow analysis requires incoming flows and boundary conditions. For the TTW, the pool elevations are held nearly constant at the dams; therefore the downstream boundary condition is a known water surface elevation (Lunardini, 1990). The incoming flows are specified at the different flow change locations and for the upstream boundary condition.

5.1.2.1 $Q_{1.5}$ Flow

As mentioned in the Tier 1 Section, the assumed channel forming discharge is the $Q_{1.5}$. In theory, the $Q_{1.5}$ is the dominant event that causes most of the channel changes in a natural system. For Tier 3, the $Q_{1.5}$ is one of two flows that are used to estimate sediment deposition. To validate the $Q_{1.5}$, it is necessary to conduct a comparative analysis between it and another flow.

5.1.2.2 Q^3 Flow

The second flow used for comparison is the Q^3, or the root mean cubed (RMC) of the flow (see Equation 5.1). Systems that are highly modified are not ideal locations to employ the bankfull discharge (Doyle, 2007). Therefore, a second flow should be analyzed to determine possible discrepancies in the $Q_{1.5}$. Since the TTW is not a natural channel, the channel forming discharge may have a lower flow volume. A lower flow channel forming discharge may be due to instabilities in the system. After an evaluation of daily flows, the magnitude for the Q^3 flow is lower than the $Q_{1.5}$.

Typically a shorter return interval produces a lower discharge indicating the viability of a lower flow such as the Q^3. This lower discharge may be a more appropriate estimate for the channel forming process. From the other two analyses, Tier 1 and Tier 2, it appears that an event lower than the $Q_{1.5}$ may dominate the sediment behavior of the pool. Other reports represent the fact (USACE, 1979; USACE, 1986) that Aberdeen is a point of high sediment deposition. The amount dredged every year remains relatively constant at some of the same locations, such as mile 366. Consistency in dredging records suggests that the Aberdeen Pool undergoes major bathymetric changes each year. If changes occur on a yearly bases then the channel forming discharge is lower than the $Q_{1.5}$ since the $Q_{1.5}$ occurs statistically once every year and a half.

To account for a channel forming flow lower than the $Q_{1.5}$ certain sediment capacities to flow ratios are considered. It is understood from Equation 5.1 that Q_s is some function of flow to some power (Andrews, 1980).

$$Q_s = f(Q_{RMX}) \tag{5.1}$$

Where:

$Q_{RMX} = \sqrt[x]{Q^x}$

Q = daily flow
x = 2….6

This new estimate for Q_s was established and compared to the average Q and the $Q_{1.5}$. The results of the flow comparison are shown in Table 5.2.

Table 5.2 Comparison of flows used in SIAM for Tier 3 Analysis

Comparison of $Q_{1.5}$ to Q_{RMX}					
Station	AVG Q	$Q_{1.5}$	X = 2	X = 3	X = 4
2437100	4,186	37,580	8,049	13,458	19,432
2433530	8	371	27	54	83
2437000	3,161	29,369	6,661	11,917	18,563
Intercepted Area	n.a.	13421	2874	4806	6940
Non-Intercepted Area	n.a.	2808	601	1006	1452

Three different values for Q_{RMX} are calculated. For the intercepted area and non-intercepted area, an estimate is used since there is no daily flow data to use to calculate Q_{RMX} from. The estimator is a percentage of the Q_{RMX} to $Q_{1.5}$ for station 2437100. The calculated percentages for each Q_{RMX} are multiplied by the $Q_{1.5}$ for both the intercepted area and non-intercepted area to produce its respective Q_{RMX}.

The second flow used in SIAM is the Q^3 flow which provides a means of comparison to the $Q_{1.5}$. It should be understood that the channel forming discharge is subject to change in a different system. Furthermore, the return interval for the channel forming discharge may also change in a given reach. For that reason, the modeler should explore other possible channel forming flows to evaluate the $Q_{1.5}$. The Q^3 was chosen since it was a lower flow. If depositions caused by the Q^3 are less than the deposition from the $Q_{1.5}$ then the $Q_{1.5}$ may be an over estimate for channel forming. If the two flows produce equal amounts of deposition then the $Q_{1.5}$ is an accurate representation of the channel forming discharge.

5.1.2.3 Assumptions Made for Constant Pool Elevation

The TTW pools are maintained at a nearly constant elevation for navigation purposes. For the Aberdeen Pool, this elevation is 190 feet. The water surface elevation is maintained by the opening and closing of gated spillways that regulate the tail water flow. The normal pool level is ideal for creating a HEC-RAS model since the downstream boundary conditions are already known. Knowing the downstream boundary conditions eliminates one more assumption and reduces the error associated with predicting a boundary condition.

There are challenges associated with attempting to model a nearly flat water surface. According to Dr. James Martin, an EFDC model was created for the Aliceville Pool and modelers struggled with modeling a flat pool elevation. The same problem appears with the HEC-RAS model for Aberdeen. If a three dimensional hydrodynamic model is unable to establish a nearly flat water surface, it is even more difficult to do this with a one dimensional model. At low flows, such as those in the HEC-2 study, a constant water surface elevation is easier to maintain. However, a sediment investigation models channel forming discharges that are significantly greater than minimum flows. In HEC-RAS, channel forming flow causes the water to back up (see Figure 5.1) as high as 10 feet with the $Q_{1.5}$ flow at Amory. Water back up is possible since the area has flooded but it is unlikely to occur at this magnitude. It is more probable to back up only on the order of a few feet and not 10 feet.

At high flows such as the $Q_{1.5}$ unreal and drastic measures are taken to achieve a semi-flat water surface. The modeler has two parameter at his disposal to adjust the model. These include Manning’s n and the expansion and contraction coefficients. First, the expansion and contraction coefficients were set to zero, but only dropped the water surface elevation slightly. Next, Manning’s n was set to 0.0001 for the entire cross section and had a greater impact on reducing water surface build up (see Figure 5.2). Finally, both the Manning’s n and the expansion and contraction coefficients were adjusted together, resulting in a more reasonable slope and slightly unstable water surface (see Figure 5.3, shown with Current cross sections). Reducing and eliminating these terms is unrealistic, and does not reflect the true physical characteristics of the system.

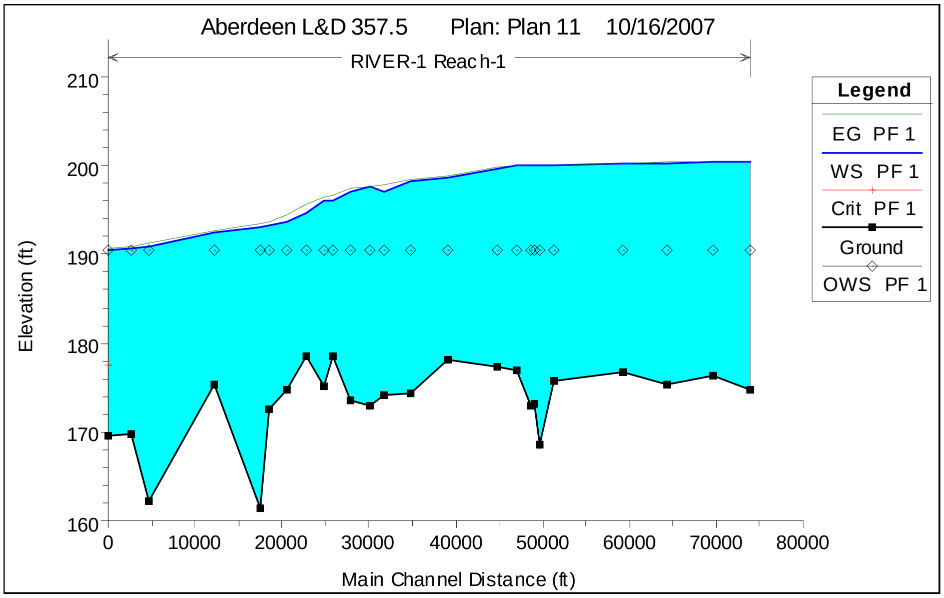

Figure 5.1 Water profile for Aberdeen with normal Manning's n = 0.03, 0.027 and expansion and contraction coefficients = 0

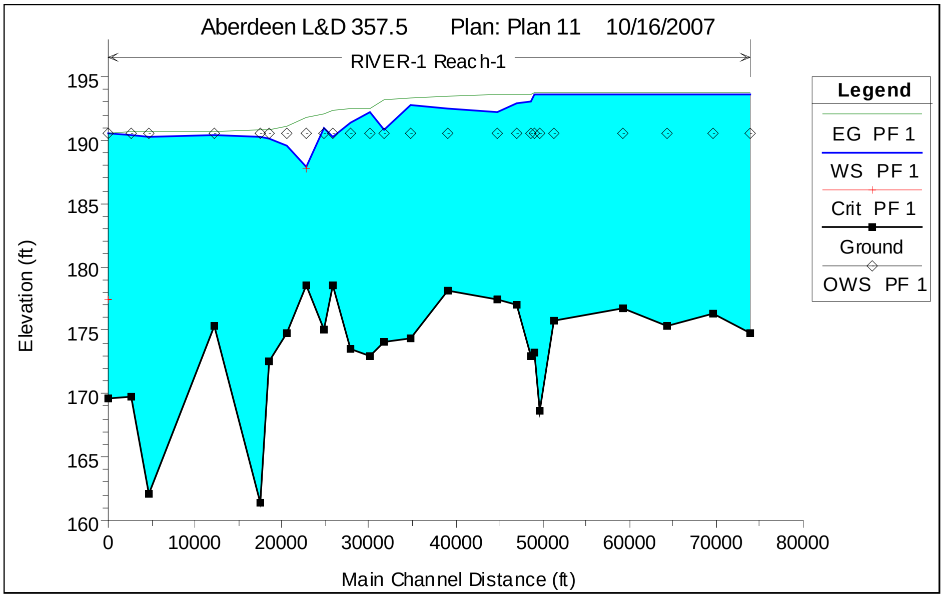

Figure 5.2 Water profile for Aberdeen with Manning's n = 0.0001 and the default expansion = 0.3 and contraction = 0.1 coefficients

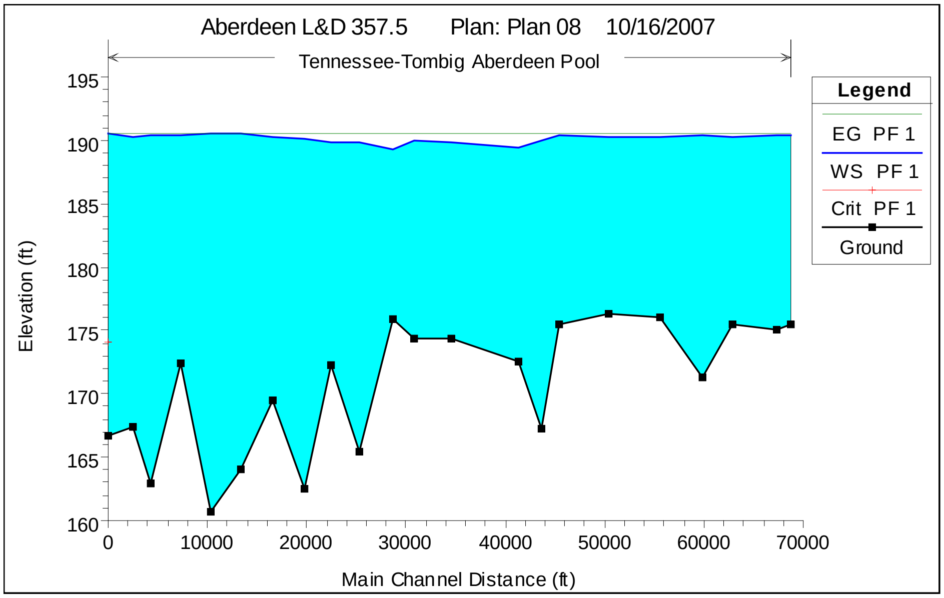

Figure 5.3 Water profile for Aberdeen with Manning's n = 0.0001 and the default expansion = 0 and contraction = 0 coefficients

Generally, decreasing Manning's n increases the flow velocity and causes an increase in sediment transport capacity resulting in model inaccuracies. By eliminating the expansion and contraction coefficients (minor losses) energy is conserved between cross sections (Sturm, 2001). Velocities are maintained through energy conservation which causes increased sediment capacity (Julien, 2002). Further studies need to be preformed to show the effects of depositions due to changes in Manning's n, expansion coefficients, and contraction coefficients.

5.2 Total Load Equations

From a preliminary analysis of the Historic cross sections, three of the six equations in SIAM have been chosen to serve as the transport equations for Aberdeen Pool. Though a good understanding of the equations and their uses is important, practical application of the equations is the basis of selecting the most appropriate equations. From the three test runs shown in Table 5.3, four equations seemed to produce the most consistent results. (Note: other runs where made but are not included in Table 5.3). Of the four, Engelund Hansen, Laursen (Copeland), and Meyer-Peter-Muller were chosen for Aberdeen Pool because of test runs and they have previously been shown to produce reasonable results on the TTW (McAnally et al 2004). Toffalet was excluded.

Table 5.3: Results from experimental test runs of SIAM to determine appropriate transport equations

			Deposition tons/yr	
Wash Load[1]	Sediment Sources	Equations	Canal	River
		Run1		
8 MS 0.5	Intercept & TN Tom	Ackers White	0	-1.27E+05
		Engelund Hanson	0	6.64E+04
		Laursen Copeland	0	6.64E+04
		MPM[2]	0	6.10E+04
		Toffaletti	0	6.64E+05
		Yang	-401	6.60E+04
		Run 2		
9 CS 1	Intercept & TN Tom	Ackers White	0	-1.40E+05
		Engelund Hanson	0	5.31E+04
		Laursen Copeland	0	5.31E+04
		MPM[2]	0	5.31E+04
		Toffaletti	0	5.31E+04
		Yang	-401	5.27E+04
		Run 3		
10 VCS 2	Intercept & TN Tom	Ackers White	0	-1.31E+05
		Engelund Hanson	0	3.98E+05
		Laursen Copeland	0	3.98E+05
		MPM[2]	0	3.98E+05
		Toffaletti	0	3.98E+05
		Yang	-401	3.95E+05

Notes:
Model is based on old cross sections
1. First column denotes maximum wash load size
2. Meyer-Peter-Muller

5.2.1 Engelund Hansen

"The Engelund-Hansen function is a total load predictor which gives adequate results for sandy rivers with substantial suspended load" (USACE, 2002). The data is based on flume studies (USACE, 2002). Engelund-Hansen, EH, is an ideal equation to use for the TTW since the majority of the sediment load is sand and silt (see Figure 6.10 and 6.11). The general equation is:

$$g_s = 0.05\gamma_s V^2 \sqrt{\frac{d_{50}}{g\left(\frac{\gamma_s}{\gamma}-1\right)}}\left[\frac{\tau_o}{(\gamma_s-\gamma)d_{50}}\right]^{3/2} \qquad (5.2)$$

Where:

g_s = Unit sediment transport
γ = Unit weight of water
γ_s = Unit wt of solid particles
V = Average channel velocity
τ_o = Bed shear stress
d_{50} = Particle size of which 50% of the bed is smaller

5.2.2 Laursen (Copeland)

The Laursen-Copeland, LC, is a modified Laursen equation. LC uses data for both sand and gravel and can calculated transport in a sand and gravel bed (USACE, 1990). At Aberdeen Pool there is some gravel in the bed shown from sieve analysis conducted from dredge material that was collected from the CDF (see Table C.5). The general equation is:

$$C = 0.01\gamma\sum P_i\left(\frac{d_i}{y}\right)^{7/6}\left[\frac{\tau_o'}{\tau_{ci}}-1\right] f\left(\frac{u_*'}{w_i}\right) \qquad (5.3)$$

Where:

C = concentration in weight per unit volume
P_i = fraction of grain size class in the bed
u_*' = grain shear velocity
w_i = fall velocity
i = the ith size particle
$f\left(\frac{u_*'}{w_i}\right)$ = function of the ratio of shear velocity to fall velocity, defined in Figure 14 of Laursen (1958)

The calculated hydraulic radius is used to calculate the grain shear stress:

$$\tau_o' = \left(\frac{\rho V^2}{58}\right)\left(\frac{D_{50}}{R_b'}\right)^{1/3} \qquad (5.4)$$

Where:

ρ = water density
D_{50} = particle size of which 50 percent of the bed is finer
R_b' = hydraulic radius of the bed attributed to grain roughness

5.2.3 Meyer-Peter Muller

The Meyer-Peter-Muller, MPM, function is based on experimental data and is used for coarse grain sediment (USACE, 2002). The equation is of the following form:

$$\left(\frac{k_r}{k_r'}\right)^{3/2} \gamma RS = 0.047(\gamma_s - \gamma)d_m + 0.25\left(\frac{\gamma}{g}\right)^{1/3}\left(\frac{\gamma_s - \gamma}{\gamma_s}\right)^{2/3} g_s^{\,2/3} \qquad (5.5)$$

Where:

g_s = Unit sediment transport rate in weight/time/unit width
k_r = A roughness coefficient
k_r' = A roughness coefficient based on grain size
g = Acceleration of gravity
d_m = Median particle diameter
R = hydraulic radius
S = Energy gradient

5.3 Limitations of SIAM

The SIAM program is a valuable tool in beta release, but improvement is needed and the user should be aware of program deficiencies. First, the program requires the user to identify the maximum allowable wash load size. Ideally, the program should calculate the wash load based on flow velocities in order to allow the wash load size to fluctuate between cross sections rather than sediment reaches. Fluctuation of wash load sizes would result in a closer approximation to deposition since wash load is a function of bed slope, water velocity, and flow. Furthermore, SIAM is only estimating deposition due to bed material load and not wash load (USACE, 2006). The program merely passes the wash load through the system and neglects any possible deposition that occurs due to changes in wash load as the slope changes. Finally, the user is required to specify the incoming source load. Determining the source load is the basis of a sediment budget. If the influent sediment load is known, the construction of a sediment budget is unnecessary. Thoughtful evaluation of this issue is required before SIAM is used as an analysis tool for net sediment change.

CHAPTER 6. EVALUATION OF RESULTS

6.1 Tier 1 Results

Aberdeen Pool has three gaging stations that provide the Tier 1 calculations with the necessary flood flow for estimating sediment fluxes. It is important to use stations that are close to the main channel since this gives an accurate representation of the incoming flow from tributaries before it enters the main channel. However, since availability of gaging stations is limited, using stations that are only close to the main channel may be impossible. In the case of Aberdeen Pool, the two stations 2437000 and 2433530 are influent stations, and Station 2437100 measures the effluent. These three stations provide the basis for the mass balance equation. For the sediment rating curve (see Appendix C) all available sediment stations in the TTW watershed were used.

Most of the runoff from Aberdeen's contributing watershed is routed through one of the two influent stations, but there is a portion that is unaccounted for. The unaccounted area is a non-point source and must be estimated in an average sediment load per unit area. Aberdeen's unaccounted area is approximately 719 mile^2. To estimate the sediment from the non-point source, an average $Q_{1.5}$ per area is specified as 22.11 cfs/mile^2, and it is based on the $Q_{1.5}$ estimated at the effluent. The constant is multiplied by the unaccounted area to yield a total $Q_{1.5}$ of 15,897 cfs. At this flow, the concentration is 330 mg/L and the sediment flux is estimated at 5,178,862 tons/year.

Station 2437000 has 71 years of flow data and measures the flow from the Tombigbee River. The $Q_{1.5}$ for the Tombigbee River is 29,369 cfs and at this flow the concentration is 387 mg/l. The resulting sediment flux is 11,214,782 tons/year. Flux at this location is expected to be higher than the non-point location since the flow is higher. A higher flow will produce greater sediment loads indicating thus far a reasonable evaluation since the load at the Tombigbee River is greater than the load from the non-point sources.

Station 2433530 routes 6.6 mile^2 of runoff and the $Q_{1.5}$ is 371 cfs. Relatively speaking, this is a small flow but it was not excluded from the calculation since it may provide useful insight. The concentration is estimated at 125 mg/L yielding a sediment flux of 45,767 tons/year. Flux at Station 2433530 is lower than the previous sediment fluxes since its contributing area is smaller than the unaccounted area and the area of Station 2437000.

The effluent end includes Station 2437000 and the minimum flow structures (MFS). Station 2437000 has a $Q_{1.5}$ of 37,580 cfs. The MFS has a constant flow of 200 cfs. Both discharges use the same concentration of 413 mg/L that is the calculated concentration at the dam. The sediment flux at Station 2437000 is 15,295,933 tons/year. The sediment flux for the MFS is 81,404 tons/year.

By applying the mass balance equation to the fluxes, the total net change or change in volume is 837,840 tons/year. The change in volume is the total deposition or erosion occurring. For the Aberdeen Pool, the change in volume is positive, which indicates a net deposition. Calculating deposition coincides with the known behavior of sediment in Aberdeen Pool.

The Tier 1 calculation provides a base for estimating the initial behavior of the system. Comparing the total deposition calculated in the Aberdeen Design Memorandum to that of the Tier 1 estimate shows that the Tier 1 calculation is triple the amount of the Design Memorandum estimate. Since the Tier 1 Program yields a result within one order of magnitude of the Design Memorandum, it is assumed that this is a good first approximation. However, the sediment fluxes calculated are extremely high for the system. For instance, at the Tombigbee River, the East Fork Report calculated a sediment flux of 1,360,000 tons/year, but the Tier 1 Program estimated a sediment flux of 11,214,782 tons/year. The two flux estimates have an order of magnitude difference. The divergence is explained by understanding that the $Q_{1.5}$ is used for every daily flow value during the year that may produce an abnormal flow causing a massive difference in sediment flux.

Furthermore, the effluent concentration is higher than any of the influent concentrations. The concentration at the effluent of a dam should be lower than that of the contributing tributaries unless some unusual event such as reservoir erosion near the dam is occuring. A higher concentration at the effluent suggests that the model is unable to define the true behavior of the discharge downstream of the dam. Typically, the flow behind most dams slows which reduces transport capacity causing deposition of suspended sediment (Julian, 1998). When the flow is discharged, its velocity increases and sediment capacity once again increases. Initially, the sediment capacity was higher than the sediment load causing the flow to collect sediment. The maximum load is usually not attained until some distance downstream from the dam. From the point of discharge to where the sediment load equals the capacity, the concentration will progressively increase. Therefore, in a typical dam tail-water system, at the effluent end the flow should not have concentrations greater than the tributaries.

Obviously the program cannot capture this discrepancy since it has a single definition for the sediment. It should be understood that this lack of refinement is a significant limitation in the Tier 1 Program and contributes to the collective error. However, the TTW is a run-of-the river system. The TTW design function is navigation and not flood control. With increased upstream flows, the lock operators simply pass the flow. By passing the flow the hydrograph is similar to that of a naturally occurring hydrograph and indicates that the dam might pass more sediment than one would initially expect. Since flow is simply being passed, the higher concentration might not be a bad representation of what is actually occurring. Passing flow prevents the flow velocity from dropping and keeps sediment suspended and moving.

6.2 Tier 2 Results

The Tier 2 analysis uses the same USGS flow gages that the Tier 1 analysis used. However, instead of evaluating a flood flow event used in Tier 1, Tier 2 uses daily flow events. Daily flows eliminate the need to use a return event and they provide a closer approximation to the natural flow conditions. Further variation between the first and second calculations arises with using USGS sediment stations that are in the contributing area of Aberdeen Pool for the Tier 2 sediment curves. Using only local stations allows for better understanding of the system and uses sediment characteristics that are common for that system.

The local stations' sediment data is implemented in such a way that seeks the true nature of the Pool's sediment characteristic through multiple sediment fluxes and depositions. Multiple sediment fluxes are ideal in that they produce a range of possible solutions. Having a range allows sediment deposition and fluxes to be defined for varying wet or dry years. Since years differ in the amount of rainfall and will also vary in the amount of deposition.

The Tier 2 calculation is a refinement of the first calculation in both flow data and sediment rating. For Tier 2 there are four main power curves constructed for Aberdeen Pool (see Equation 4.2). The last three of the four power curves evaluates a different individual sediment station in the contributing area. The first curve is a combination of all sediment data from the three sediment stations (see Table 6.1)

Table 6.1 USGS Sediment Stations and corresponding curve number

Curve	USGS Stations
1	2433500, 2436500, & 2437000
2	2437000
3	2433500
4	2436500

These four curves or main curves provide the basis for manipulating the available data. When possible each data set is broken down into individual years and is graphed on a separate chart with its own curve. The individual year curves are called minor curves. For Aberdeen there are 53 minor curves. A power curve is fit to each data set for both the major and minor curves. Tables 6.2 – 6.5 show the different power curve coefficients. (see Figures C.3 – C.7, for main curves graphs)

Table 6.2 Power curve coefficients for curve 1

Tier 2 Curve 1 Multiple Stations				
Curve ID	Year	A	B	R²
1	1974-2000	1.280E-02	1.5394	0.8557
1.1	1974-1975	1.650E-02	1.4143	0.8282
1.2	1981	2.210E-01	0.9937	0.7930
1.3	1982	3.190E-02	1.5006	0.9070
1.4	1983	1.061E-01	1.3665	0.9371
1.5	1984	3.220E-02	1.4851	0.9007
1.6	1985	4.770E-02	1.4943	0.9099
1.7	1986	1.340E-02	1.6028	0.8936
1.8	1987	1.050E-02	1.6696	0.8901
1.9	1988	1.270E-01	0.9969	0.7077
1.10	1989	8.800E-03	1.5452	0.8298
1.11	1990	3.500E-03	1.6997	0.8971
1.12	1991	2.920E-02	1.3904	0.7996
1.13	1992	2.290E-02	1.4438	0.6911
1.14	1993	1.200E-03	1.8137	0.9113
1.15	1994	4.400E-03	1.6697	0.7699
1.16	1995	1.500E-03	1.7949	0.9249
1.17	1996	5.000E-07	2.8127	0.7853
1.18	1997	6.200E-03	1.4875	0.9262
1.19	1998	4.000E-06	2.4130	0.9760
1.20	1999	1.400E-03	1.6150	0.9410
1.21	2000	2.000E-04	2.0603	0.9427

Table 6.3 Power curve coefficients for curve 2

Tier 2 Curve 2 Station 02437000				
Curve ID	Year	A	B	R²
2	1974 - 2000	1.200E-03	1.6954	0.8648
2.1	1974 - 1989	1.600E-03	1.6725	0.9785
2.2	1990	3.000E-05	2.1144	0.834
2.3	1991 - 1992	4.000E+19	-4.667	0.86663
2.4	1993	6.000E-07	2.6566	0.9493
2.5	1997	5.500E-03	1.481	0.8633
2.6	1998	2.000E-07	2.7373	0.9979
2.7	1999 - 2000	2.900E-02	1.2308	0.9624
2.8	1974-2000	6.000E-04	1.5903	0.9077

Table 6.4 Power curve coefficients for curve 3

Tier 2 Curve 3 Station 02433500

Curve ID	Year	A	B	R^2
3	1989 - 2000	2.900E-03	1.5759	0.9069
3.1	1989	6.000E-04	1.8226	0.891
3.2	1990	3.900E-03	1.5219	0.9623
3.3	1991	5.700E-03	1.4169	0.9974
3.4	1992	5.600E-03	1.5066	0.907
3.5	1993	4.500E-03	1.4929	0.8579
3.6	1994	2.000E-04	1.9548	0.9053
3.7	1995	1.200E-02	1.3127	0.9292
3.8	1996	5.000E-07	2.8127	0.7853
3.9	1997	4.400E-03	1.5529	0.9594
3.10	1998	1.000E-04	2.011	0.9899
3.11	1999	8.000E-04	1.6922	0.9625
3.12	2000	1.000E-04	2.112	0.9308
*3.13	1989 - 2000	3.600E-03	1.5401	0.9237

* Edited Data

Table 6.5 Power curve coefficients for curve 4

Tier 2 Curve 4 Station 02436500

Curve ID	Year	A	B	R^2
4	1974-1995	1.710E-02	1.5676	0.9134
4.1	1974-1981	1.254E-01	1.1331	0.8553
4.2	1982	3.190E-02	1.5006	0.9070
4.3	1983	1.061E-01	1.3665	0.9371
4.4	1984	3.220E-02	1.4851	0.9007
4.5	1985	4.470E-02	1.4943	0.9099
4.6	1986	1.340E-02	1.6028	0.8936
4.7	1987	1.050E-02	1.6696	0.8901
4.8	1988	1.270E-01	0.9969	0.7077
4.9	1989	1.110E-01	1.2919	0.8420
4.10	1990	7.400E-03	1.6822	0.9551
4.11	1991	2.160E-02	1.5127	0.8796
4.12	1992	8.100E-03	1.7193	0.8169
4.13	1993	1.900E-03	1.8315	0.9593
4.14	1994	8.500E-03	1.6591	0.8585
4.15	1995	5.200E-03	1.6957	0.9475

The power curves' coefficients are used to calculate sediment fluxes using daily flow measurements for each incoming and outgoing location and the total deposition in the Pool. The original values for each main curve are tabulated with both the deposition and fluxes in Table 6.6.

Table 6.6 Sediment fluxes and deposition of main power curves

	Comparison of Sediment Fluxes						
Curve	(-) MFS	(-) 2437100	(+) 2433530	(+) 2437000	(+) Intercepted Qs	(+) Non-Intercepted Qs	Dep. tons/yr
1	17,096	3,230,740	428	2,627,152	1,075,034	251,282	400,422
2	3,663	1,397,713	84	1,119,050	465,091	107,026	-15,762
3	4,700	1,044,311	115	846,057	347,496	80,922	-80,059
4	26,520	5,679,027	652	4,604,781	1,889,706	440,429	924,383

For a complete list of the other sediment fluxes and the deposition calculated from the minor curves coefficients, see Appendix C. Once each minor and main curve's coefficients are established, they are used to calculate the sediment flux and deposition for that individual year. Then the average for those years is calculated. These average values that are weighted by year are different than the original values which are calculated with the main curves. Though different from the original, the average values (see Table 6.7) still describe the same data set.

A third analysis of the data is done by truncating those years that have negative deposition values or extremely high depositional values. Dredging in the Aberdeen Pool has been done every year that the TTW has been open. The yearly need for dredging indicates that deposition is occurring in the channel rather than erosion. Since negative deposition indicates erosion, those years with negative values are removed. Defining an extremely high value resides on the judgment of the modeler. For Aberdeen an extremely high value is assumed to be one that is greater than 2 million tons per year. Therefore, the values greater than 2 million are eliminated. The new group of values that have had the extremely low depositions and high depositions removed are averaged to produce the edited average group (see Table 6.7).

As a final attempt to understand the sediment data, an average of the averages is calculated. The average of the averages is produced by averaging the original, the average, and the edited average (see Table 6.7). This final sediment deposition approximation results in a tighter range of values that are closer to the depositional values in the old reports. Table 6.7 shows results of the four different approaches.

Table 6.7 Comparison of Depositions

	Deposition, tons/year			
Curve	Original	Average	Edited Average	Avg of Avg
1	400,422	1,028,849	764,136	731,136
2	-15,762	424,954	609,539	339,577
3	-80,059	932,554	1,013,452	621,982
4	924,383	917,264	448,303	763,317

Table 6.7 does not represent four different sets of solutions. Rather, it represents four different views of the same data set. There is a 55.6 percent difference between the highest and lowest value in the average of the average. Likewise there is a 55.8 percent, 58.7 percent and 91.9 percent difference for the edited average, the average, and the original respectively. This percent difference possibly indicates that the average of the averages is the more appropriate view.

Fluxes for Aberdeen are chosen by examining those calculated from the minor curves. Selection is done by eliminating all the yearly average depositions that are greater than or less than the range of deposition in the average of the average. The range of acceptance is 339,577 tons/year – 763,317 tons/year. Fluxes that corresponded to depositions in this range are chosen. Table 6.8 shows the array of sediment fluxes that correspond to the best overall range of sediment depositions.

Table 6.8 Selected Sediment Fluxes for Aberdeen Pool

	Sediment Fluxes, tons/yr						
	(-)	(-)	(+)	(+)	(+)	(+)	
Curve	MFS	2437100	2433530	2437000	Intercepted Qs	Non-Intercepted Qs	Dep.
1	17,096	3,230,740	428	2,627,152	1,075,034	251,282	400,422
1.11	10,930	4,253,773	250	3,404,288	1,415,450	325,585	575,232
1.14	6,856	4,534,986	150	3,591,247	1,509,024	343,454	596,396
1.15	11,721	3,976,311	272	3,191,495	1,323,124	305,237	526,459
1.16	7,757	4,697,216	171	3,725,966	1,563,007	356,340	634,873
Avg. 2	2,909	3,980,314	78	3,093,439	1,324,456	295,841	424,954
4.4	32,255	4,803,663	838	3,928,103	1,598,427	375,734	761,546
4.11	25,044	4,207,894	638	3,431,135	1,400,184	328,189	621,570
Avg	14,321	4,210,612	353	3,374,103	1,401,089	322,708	567,681

The dominate sediment flux for Aberdeen Pool is supplied by the flow from the Tombigbee River (USACE, 1988). From the range of fluxes calculated for (see Table

6.8, station 2437000) the Tombigbee River, there is a 33 percent difference between the highest flux of 3,928,103 tons/yr and the lowest flux of 2,627,152 tons/yr. An average of the range of fluxes was calculated from the selected sediment flux. In addition to the fluxes, an average deposition was calculated from the deposition range. The average deposition is 567,681 tons/year. By combining the average deposition value along with the high and low values for the average of the average three possible numbers for the deposition are estimated.

The range of results constructed from the Tier 2 analysis is closer to the annual deposition amount calculated from the Sedimentation Analysis for Aberdeen Lake report than the Tier 1 calculation. Obviously, the use of daily flow and local sediment stations significantly impacts the refinement of the results. If the annual deposition amount was not within the range of deposition, a re-evaluation of the data analysis process may be required. Ideally Tier 2 results are significantly closer to the true value than those of the Tier 1.

Having a range of solutions gives the modeler an idea of depositions that occur during low, medium, and high flow years. The range is beneficial if a sediment budget is calculated on an annual basis rather than an average annual base. A range gives the modeler a validation tool when each year is examined. For a yearly based sediment budget a low flow year should have deposition closer towards the bottom of the range while a high flow year is closer to the top of the range. However, it is possible that both the low and high flow years produce a value beyond the range.

6.3 Tier 3 Results

SIAM is used for the final estimate for sediment deposition. For this analysis, eight different sieve classes are used to characterize both the sediment source and the bed material composition (see Table C.5). The classes were alternated between the source and the bed definitions along with the total load equations to calculate many different depositions. By alternating and comparing the sieves and total load equations, a second range of depositions is developed. Selection of the range for the final solution is based on the results from the previous two calculations as well as the annual deposition calculated in Section 3.4.

The sediment source is based on a sediment yield per area estimated from the average fluxes calculated in the Tier 2 analysis (see Table 6.8) broken down by location. For Aberdeen's contributing area, the sediment yield is 1872 tons/mile^2/yr (see Table 6.9).

Table 6.9 Average sediment yield per area based on incoming sediment fluxes from Tier 2 calculation

Sediment Yields based on Tier 2 Fluxes			
Location	Fluxes tons/yr	Area mile^2	Sediment Yield tons/mile^2/yr
2433530	353	7	54
2437000	3,374,103	1328	2541
Intercepted Qs	1,401,089	596	2351
Non-Intercepted Qs	322,708	127	2541

Average Sediment Yield = 1872 = Source

The sediment source is broken down according to grain size in tons/yr and is done by multiplying the average sediment yield by the amount retained on the sieve (see Table 6.10 and 6.11). Both cross sectional data sets used this sediment yield.

For further analysis, three different maximum wash load sizes are specified as 0.125 mm, 0.25 mm, and 0.5 mm. Multiple runs of SIAM seem to indicate the 0.25 mm grain size is best for Aberdeen Pool (see Tables C.6 – C.10, note: dredge volumes are not removed). Depositions calculated from this maximum wash load size closely coincide with the range of deposition in Tier 2.

Table 6.10 Amount of sediment yield as particle size for sieves from Aberdeen's Disposal Facilities (ABD) 9 & 12 and AVG 2 -5

	Average of ABD 9 & 12			Average of Materials 2-5		
Sieve Size (mm)	% Passing	% Amount Retained	Source Tons/year	% Passing	% Amount Retained	Source Tons/year
0.032	0.0	0.00	0	0.0	1.00	18.72
0.0625	0.0	1.75	32.76	1.0	10.38	194.22
0.125	1.8	19.75	369.72	11.4	50.50	945.36
0.25	21.5	54.25	1015.56	61.9	31.13	582.66
0.5	75.8	20.75	388.44	93.0	0.75	14.04
1	96.5	0.75	14.04	93.8	2.00	37.44
2	97.3	0.50	9.36	95.8	1.38	25.74
4	97.8	0.75	14.04	97.1	1.00	18.72
8	98.5	0.50	9.36	98.1	1.13	21.06
16	99.0	1.00	18.72	99.3	0.75	14.04
32	100.0			100.0		

Table 6.11 Amount of sediment yield as particle size for sieves average and bottom sample

Sieve Size	Bed Material, Average of all Sieves			Bottom Sample		
(mm)	% Passing	% Amount Retained	Source 1 Tons/year	% Passing	% Amount Retained	Source 1 Tons/year
0.004	0.0	0.0	0	0.0	0.0	0
0.008	0.0	0.0	0	2.0	5.00	93.6
0.016	0.0	0.0	0	7.0	30.00	561.6
0.032	0.0	0.57	10.69	37.0	56.00	1048.32
0.0625	0.6	7.00	131.04	93.0	2.50	46.8
0.125	7.6	36.00	673.92	95.5	0.50	9.36
0.25	43.6	34.71	649.85	96.0	0.50	9.36
0.5	78.3	6.79	127.02	96.5	0.50	9.36
1	85.1	2.93	54.82	97.0	1.50	28.08
2	88.0	2.43	45.46	98.5	0.50	9.36
4	90.4	2.71	50.81	99.0	1.00	18.72
8	93.1	5.57	104.29	100.0		
16	98.7	1.29	24.06	100.0		
32	100.0			100.0		

With all the different variations in SIAM, the group that is closet to the true deposition value, based on the judgment of this author, is the Current Cross Sections with a maximum wash load size of 0.25 mm (see Table 6.12). The values represented in Table 6.12 do not have dredge material removed from the deposition mount. After removal of dredge material, two deposition groups produced by source sieve Total and source sieve ABD 9 & 12 indicated deposition. Furthermore, in both groups, the two different channel forming flows indicate the same deposition amounts, which suggest the Q1.5 is an appropriate approximation to bank full discharge. The deposition amount used from source sieve Total is 832,000 tons/year, and with the removal of dredge material, the total deposition is 526,363 tons/year. For the group that uses source sieve ABD 9 & 12, the deposition is 930,000 tons/yr. After the removal of dredge material, the total deposition due to this source is 624,362 tons/yr and is only 2638 tons less than the annual deposition rate calculated from the Sediment Analysis for Aberdeen Lake report.

Table 6.12 Depositions for current cross section with different bed and source terms for different total load equations and flows

Deposition for different bed material and sieves						
CURRENT X-SECTIONS			Bed Material Sieve			
		Flow	ABD 9 & 12	AVG 2-5	Total	Bottom Sample
Source Sieve ABD 9 & 12						
Equations	EH	$Q_{1.5}$	930,000	930,000	930,000	930,000
		Q^3	930,000	930,000	930,000	930,000
	LC	$Q_{1.5}$	930,000	930,000	930,000	930,000
		Q^3	930,000	930,000	930,000	930,000
	MPM	$Q_{1.5}$	919,000	924,000	923,000	929,000
		Q^3	930,000	930,000	930,000	930,000
Source Sieve AVG 2-5						
Equations	EH	$Q_{1.5}$	268,600	268,600	268,600	268,600
		Q^3	268,600	268,600	268,600	268,600
	LC	$Q_{1.5}$	268,600	268,600	268,600	268,600
		Q^3	268,600	268,600	268,600	268,600
	MPM	$Q_{1.5}$	257,600	262,600	261,600	261,600
		Q^3	268,600	268,600	268,600	268,600
Source Sieve Total						
Equations	EH	$Q_{1.5}$	832,000	832,000	832,000	902,000
		Q^3	832,000	832,000	832,000	832,000
	LC	$Q_{1.5}$	832,000	832,000	832,000	902,000
		Q^3	832,000	832,000	832,000	832,000
	MPM	$Q_{1.5}$	822,000	827,000	826,000	2,765,000
		Q^3	832,000	832,000	832,000	832,000
Source Sieve Bottom						
Equations	EH	$Q_{1.5}$	134,100	134,100	134,100	134,100
		Q^3	172,900	172,900	172,900	172,900
	LC	$Q_{1.5}$	134,100	134,100	134,100	134,100
		Q^3	172,900	172,900	172,900	172,900
	MPM	$Q_{1.5}$	123,900	128,300	127,600	134,000
		Q^3	172,900	172,900	172,900	172,900

Max Wash Load = 7 FS 0.25

$Q_{1.5}$ = bankfull discharge see section 4.2.2 & 5.1.2.1

Q^3 = root mean cubed flow see section 5.1.2.2

Further analysis of all the calculated depositions shows a relationship between the amount of deposition and the specified maximum wash load. As seen in Figures 6.1 – 6.4, as the wash load size increases the deposition decreases. As stated previously, it appears that the best maximum wash load for Aberdeen is 0.25 mm, which is based solely on comparing depositions calculated to the annual average amount. However, if this wash load value is incorrectly assumed, the variation in deposition due to wash load may be an order of magnitude. All four figures are based on calculations made from the Current cross sections. Figure 6.1 is based on the source term estimated from sieve Total. Then Figure 6.2 is based on the source term estimated from sieve AVG 2 -5. Finally, Figure 6.3 is based on the source term defined from sieve ABD 9 & 12. As a comparison all three are shown in Figure 6.4. The curves on the comparison graph are based on a single total load equation with the different source definitions.

For Figures 6.1 – 6.3 only one curve is seen since all the curves are nearly the same. This similarity in curves indicates that the flows, though different, seem to deposit the same amount, further validating the use of the $Q_{1.5}$ as the bankfull discharge.

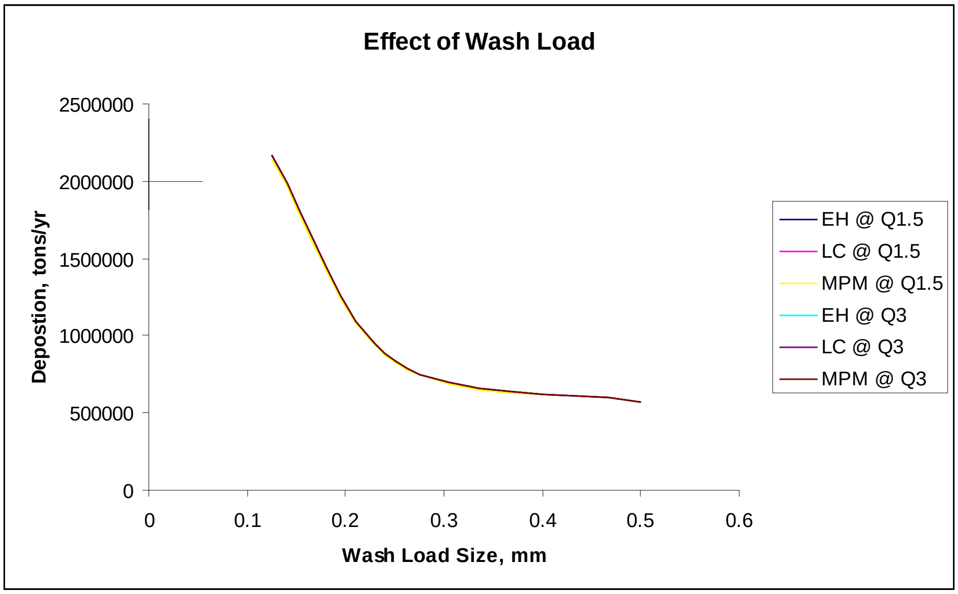

Figure 6.1 Effect of wash load based on Current cross sections and Total Average of all sieves for source term

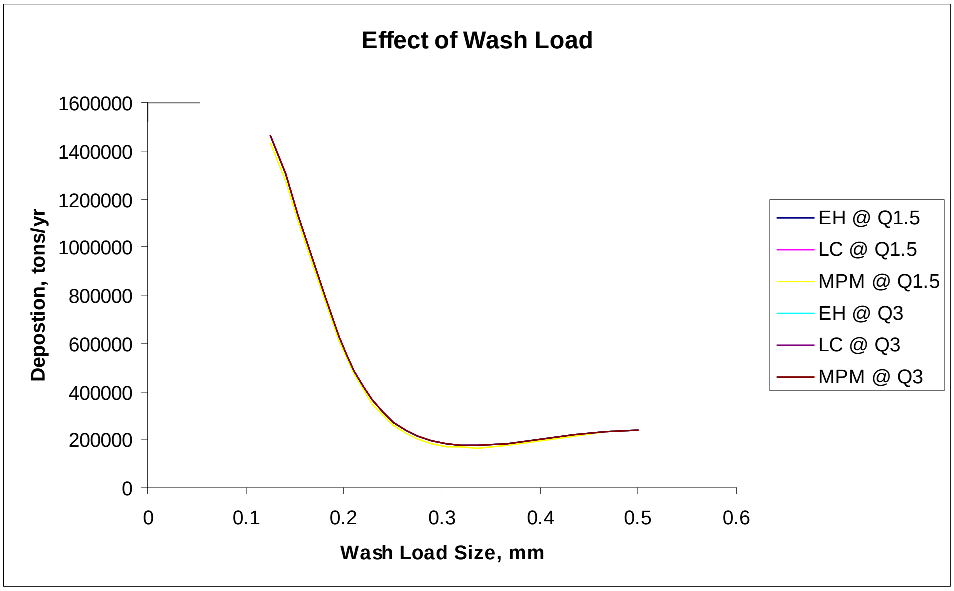

Figure 6.2 Effect of wash load based on current cross sections and average of sieves AVG 2 - 5 for source term

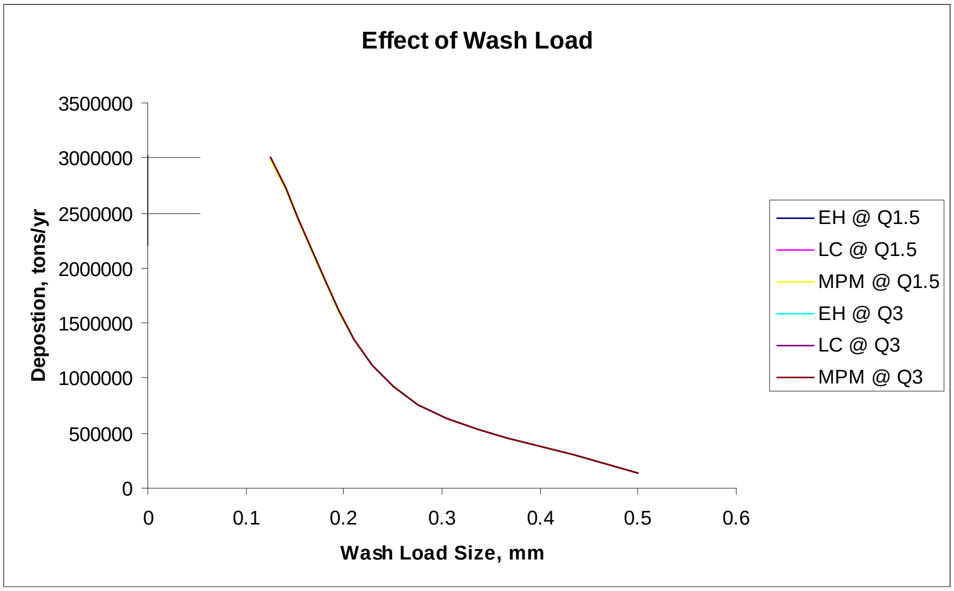

Figure 6.3 Effect of wash load based on current cross sections and sieves ABD 9 - 12 for source term

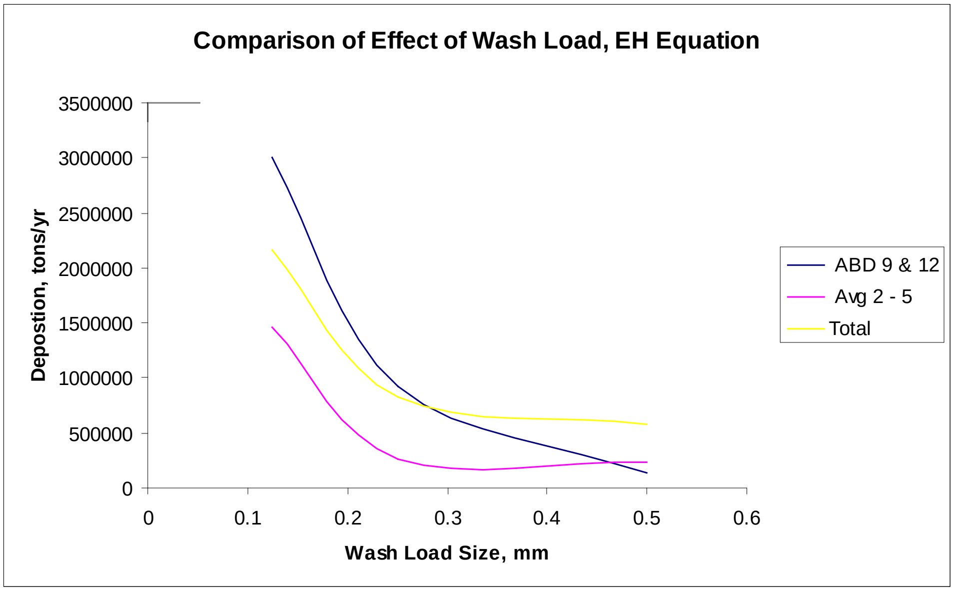

Figure 6.4 Comparison of three different source sieves on effective of wash load size to deposition based on Engelund-Hanson Equation

Tier 3 provides the basis for the final approximation of deposition in the Aberdeen Pool. However, further refinement of SIAM simulations is required to understand the behavioral differences in slight changes in the model. This program proved to be reliable and robust when applied in the appropriate manner with the correct inputs. However, specifying the incoming source load and the maximum wash load size relies too significantly on the modeler and the information at his disposal.

The only reason that the final solution in the Tier 3 is close to the best estimate of annual deposition is due to the first two calculations in the tiered process and old reports. Without both sources the modeler could easily predict the wrong values to input into SIAM. Therefore, it is imperative that multiple runs of different sieve combinations for both the source and bed terms and different total load equations are run in addition to the first two calculations. More than five hundred simulations were run on this example through SIAM using different total load equations and different sieves. Even with all the simulations and a general idea of the final solution, selection of the appropriate inputs is challenging.

6.4 Comparison of Deposition Estimates

As a final comparison Table 6.13 is constructed to show the differences between all the estimated deposition amounts. The Sedimentation Investigation of Aberdeen Lake report is the annual deposition amount listed by the Sediment Ranges and is used as the true amount of annual deposition.

Table 6.13 Comparison of deposition amounts from different calculations and reports

Comparison of Deposition Estimates, tons/yr	
Design Memorandum:	248,000*
Sedimentation Ranges:	627,000**
Tier 1:	838,000
Tier 2 Range:	340,000 - 763,000
Tier 2 Final:	568,000
Tier 3, SIAM:	624,000

* Annual amount of dredge material not removed
** Annual Deposition amount

As is seen in table 6.13, Tier 2 and Tier 3 approximations are relatively close to the annual deposition amount. The only unreasonable deposition amount is the Design Memorandum because after removal of dredge material, the net deposition is negative, which indicates erosion.

By evaluating the estimated solutions it is possible to select the most appropriate values for Aberdeen Pool. It is the authors opinion that the total annual deposition occurring is approximately 600,000 tons per year. For the influent sediment fluxes it is believed that the values are in the range of 4,000,000 to 4,500,000 tons per year. At the effluent end, the sediment flux falls between 3,000,000 to 4,800,000 tons per year. Aberdeen is a depositional system that is dominated by the Tombigbee River. The primary cause of the Aberdeen’s characteristics is system changes due to the TTW.

CHAPTER 7. RECOMMENDATIONS AND CONCLUSION

The objective of this work was to validate a SBT based on the Aberdeen Pool. With a properly established template, other systems will be easier to model. Further, this work provides a base to create and launch new programs and to improve the existing ones.

Application of the SBT requires the implementation of all three calculations (see Table 7.1). The SBT solutions are only understandable when viewed as a whole. Each solution estimated provides insight for further refinement and adjustment in the model, and without one Tier the others may lose meaning reducing model reliability. The SBT is a three legged stool, with each leg representing one Tier and requiring the use of all three legs for the stool to properly stand.

Table 7.1 Comparison of tiered calculations and required data

Comparison of Tiered Calculations		
Tier	Input Data (flows)	Analysis
1	USGS annual flood flow & daily sediment	Q1.5 → Qs→ Deposition
2	USGS daily flow & sediment	∫Qs daily → Qs→ Deposition
3	All the above & cross section & Q1.5 & Q^3	Tier 2 flux, sieve analysis, total load equations → Deposition

7.1 Recommendations

Limitations of the Tier 1 and Tier 2 programs include limited data. Most systems do not have enough flow and sediment data gauging stations.

A Tier 2 limitation is the estimation of amount of bed load that is exiting the system from the dam. For a follow up study, additional field work is recommended in order to define the amount exiting as both bed load and suspended load.

Tier 3, SIAM, does not calculate the incoming sediment fluxes. The creation of new model or use of an existing model that uses physical process to estimate sediment transport from the watershed to the system should be interfaced with SIAM to estimate the incoming sediment fluxes. The second program using total load equations could be implemented for systems that have limited cross sectional data. Additionally, the program could also calculate sediment fluxes that could then be used as a second source for sediment in SIAM, validating the source calculated with Tier 2 Fluxes.

Uncertainties in this SIAM application include the amount of cross sectional refinement that is required to produce an accurate sedimentation evaluation. Cross sectional refinement can be studied by increasing the number of cross sections and then comparing the solutions. Refinement may increase the model's ability to predict sediment deposition by representing the system more appropriately. Comparing the results from the historic and current cross sections shows that cross sectional refinement is helpful for the accuracy of predicting sediment depositions. However, the optimum cross sectional refinement in SIAM is unknown and should be explored.

Finally, the last SBT limitation with Tier 3 is where the modeler must specify a maximum wash load size. Since the final deposition amount relies heavily on the specification of the maximum wash load size, estimates for wash load should be examined.

Implementing these recommendations would further refine the SBT. These recommendations may best be implemented in other systems as required, since it may be necessary to write new programs for systems that have physical variations from the Aberdeen Pool. With the addition of new programs to the template, modelers are building a tool box of programs to choose from. Through continued development the SBT will be able to handle new systems without major reconstruction.

7.2 Template Conclusion

The SBT is a seemingly reliable process for defining a sediment budget. A further understanding of the analysis processes in the SBT requires implementation to other systems by using the same guidelines to build a sediment budget for another system. However, the Aberdeen Pool analysis does show the strengths and weakness of each Tier.

Tier 1 is the easiest and quickest way of obtaining an answer. The first program can be set up and run in the same day. As long as there are data available for the site, any location can be modeled. The data collected at Aberdeen came close to predicting the annual deposition amount. However, the sediment fluxes were extremely high and should not be used to calculate a sediment yield.

Tier 2 takes longer to run since it requires larger amounts of input data and multiple runs with different power functions. Total set up and run time is approximately one week. The second calculation provides a closer approximation to sediment deposition, and for Aberdeen its sediment fluxes were used in the Tier 3 calculation. If necessary, Tier 2 can act as the final solution, which would be useful under time constraints. The second calculation produced a deposition range that bracketed the final estimated annual deposition amount.

SIAM requires the longest set up and run time among the three programs. Set up includes a fairly extensive field survey requiring a sieve analysis, cross section surveys, and boundary conditions. A proper analysis requires bottom samples to be sieved. In addition it is recommended that corings are taken to define deposition depths and bed densities. The survey work can take as long as a month and model set up and runs may take as long as two weeks. Though required for a proper implementation of the SBT, application of Tier 3 may not be practical since it requires an extensive amount of field work. However, SIAM did produce the closet approximation to the estimated annual deposition amount. Therefore, it is recommended that SIAM is used in the SBT.

Some general observations were made after the analysis of all three calculations and the study of old reports for Aberdeen Pool. First, the majority of deposition is occurring at mile 366 where the Tombigbee River flows into the TTW. Secondly, since the TTW is a run of the river system it is assumed that wash load is passing through the system while deposition is primarily occurring due to bed material load. More analysis is required to understand the fate of sediment in the system. However, this work provides insight into the global sediment picture.

7.3 Sediment Budget Outlined Steps

1. Research watershed, tributaries, rivers, etc. for any existing reports that might have sediment data, flow, or other related needed data
2. Use USGS, GIS, topographic, and aerial maps to locate contributing USGS stations, and insure no overlap exists.
    A. Suspended sediment data from contributing or local stations.
    B. Obtain both annual flood and daily flow data from contributing stations.

Tier 1

3. Use the Power Curve Program to evaluate sediment data for all available sediment data in the watershed.
4. Determine the appropriate contributing watershed sub-area's values to use, and preferably use the stations that are closest to the water body of interest.
5. Use Tier 1 Program with power curve created in step 3 and annual flood data collected in step 2-B to create the conceptual sediment budget.

Tier 2

6. Re-evaluate sediment data. If possible use sediment data that are associated with the water body of interest; if not use any available sediment data that are close to water body of interest. Let the data demonstrate what patterns it conforms to.
7. Develop three different power curves based on the re-evaluation of sediment data from step 5.
8. Use Tier 2 Program with the three different power curves.
9. Include contributing areas of watershed that are not represented in the flow data from USGS Stations.

    A. Using known sediment yields from the sub-watersheds normalize these contributing areas to produce a sediment yield based on area.
    B. Use the sediment yield based on area to evaluate non-represented areas of the watershed to produce the contributing sediment yield.
10. Combine the values in the Tier 2 Program and the value found in step 9 to produce a new refined sediment budget.
11. Compare step 10 (Tier 2) to Tier 1 conceptual sediment budget.
12. Repeat steps 6 -11 if the two sediment yields do not correspond.

Tier 3

13. Collect needed data for Tier 3
    A. Cross-sectional data for HEC-RAS
    B. Sediment data for transport equations, SIAM
14. Run HEC-RAS model at steady state.
15. Run SIAM with current steady state hydraulics.
16. Compare results from all sediment budget evaluations.
17. Repeat any sediment evaluations if discrepancies arise.
18. Apply informed judgment to develop final estimates.

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APPENDIX A

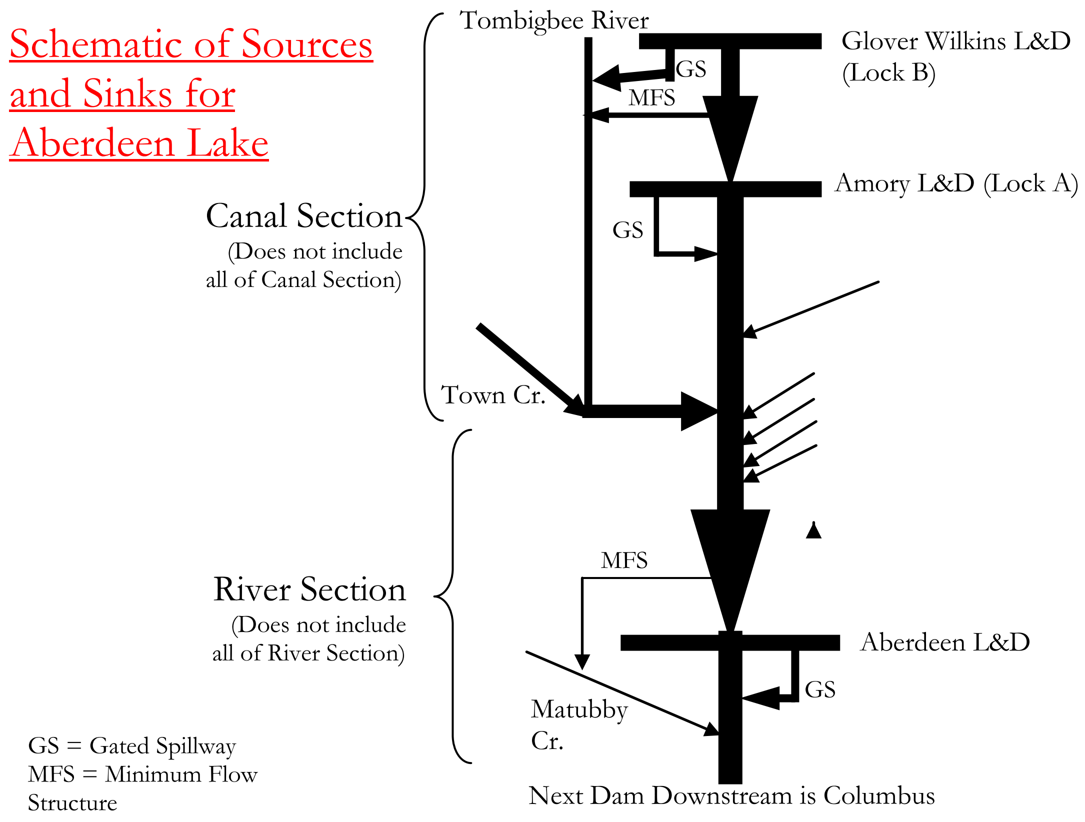


Figure A.1 Schematic of sources and sinks for Aberdeen Pool

Table A.1 USGS Stations with sediment data in the TTW watershed

Station ID	Name	LAT	LONG	AREA	Pool
2437000	TOMBIGBEE RIVER NR AMORY, MS	33.98555556	-88.55111111	1930	Aberdeen
2433500	TOMBIGBEE RIVER AT BIGBEE, MS	34.01138889	-88.51361111	1226	Aberdeen
2436500	TOWN CREEK NR NETTLETON, MS	34.05916667	-88.62805556	620	Aberdeen
2468500	CHICKASAW BOGUE NEAR LINDEN AL	32.3293083	-87.7908442	257	Below Demopolis
2469525	TOMBIGBEE RIVER NEAR NANAFALIA, AL.	32.13014697	-88.0411267	17,487	Below Demopolis
2469762	TOMBIGBEE R BL COFFEEVILLE L&D NEAR COFFEEVILLE	31.7571018	-88.1250095	18,417	Below Demopolis
2469800	SATILPA CREEK NEAR COFFEEVILLE AL	31.7443247	-88.0225066	164	Below Demopolis
2470040	TOMBIGBEE RIVER NEAR JACKSON, AL.	31.52155216	-87.9366672	19112	Below Demopolis
2470200	LITTLE BASSETT CREEK NEAR CHATOM AL	31.4573877	-88.1661189	NA	Below Demopolis
2438550	BUTTAHATCHEE RIVER AT HENSON SPRINGS AL	34.01871495	-88.0533659	NA	Columbus
2442500	LUXAPALLILA CREEK AT MILLPORT, AL	33.57511416	-88.0833605	247	Columbus
2442000	LUXAPALLILA CREEK NEAR FAYETTE AL	33.71955327	-87.8705763	130	Columbus
323642087541800	TOMBIGBEE R @ RATTLESNAKE BEND IN CUT NR DEMOPOLIS	32.6118012	-87.9050149	NA	Demopolis
323653087540800	TOMBIGBEE R @ RATTLESNAKE BEND IN OLD CHANNEL NR D	32.6148567	-87.902237	NA	Demopolis
323704087542400	TOMBIGBEE R @ RATTLESNAKE BEND AB CUT NR DEMOPOLIS	32.6179122	-87.9066816	NA	Demopolis
2430680	TWENTYMILE CREEK NR GUNTOWN, MS	34.45277778	-88.57722222	131	Fulton
2430500	TOMBIGBEE RIVER NR MARIETTA, MS	34.42666667	-88.42138889	308	Fulton
2431410	MANTACHIE CREEK BL DORSEY, MS	34.22805556	-88.45222222	66.94	Glover Wilkins
2431000	TOMBIGBEE RIVER NR FULTON, MS	34.265	-88.44527778	612	Glover Wilkins
2445000	LUBBUB CREEK NR CARROLLTON, AL	33.2501205	-88.083359	112	Howell Hefline
325645088100700	TOMBIGBEE R AT COOKS BEND IN CUT AT SED RANGE 4AL	32.94596114	-88.168638	NA	Howell Hefline

Table A.1 Continued from previous page

Station ID	Name	LAT	LONG	AREA	Pool
2449000	TOMBIGBEE RIVER AT GAINESVILLE, AL	32.8251306	-88.1566917	8632	Howell Hefline
2447008	TOMBIGBEE RIVER AT COOKS BEND AB CUT	32.95623864	-88.1625267	NA	Howell Hefline
2447010	TOMBIGBEE R.IN COOK'S BENDWAY NR. WARSAW,AL	32.96068314	-88.1872502	NA	Howell Hefline
2444500	TOMBIGBEE RIVER NEAR COCHRANE, AL.	33.08123655	-88.2378093	5940	Howell Hefline
2446500	SIPSEY RIVER NR ELROD, AL	33.25706249	-87.7764022	528	Howell Hefline
2447025	TOMBIGBEE R AT HEFLIN L&D NR GAINESVILLE ALA.	32.8481856	-88.1561363	7230	Howell Hefline (out)
3320300882122	TOMBIGBEE R. HAIRSTON BEND IN CUT NR.COLUMBUS,MS	33.34178774	-88.3561485	NA	Tom Bevill
332030088212200	TOMBIGBEE R. IN CUT AT HAIRSTON BEND BL COLUMBUS,M	33.34178774	-88.3561485	NA	Tom Bevill
332100088224500	TOMBIGBEE R. OLD CHANNEL AT HAIRSTON BEND BL COLUM	33.35012106	-88.3792049	NA	Tom Bevill
3321000882248	DTOMBIGBEE R. HAIRSTON BEND OLD CHANNEL NR COLUMBU	33.35012107	-88.3800382	NA	Tom Bevill
3321120882235	TOMBIGBEE R. HAIRSTON BEND AB. CUT NR. COLUMBUS,MS	33.3534543	-88.376427	NA	Tom Bevill
332112088223500	TOMBIGBEE R. AB.CUT AT HAIRSTON BEND BL.COLUMBUS,M	33.3534543	-88.376427	NA	Tom Bevill
332751088261000	TOMBIGBEE R. IN COLUMBUS CUT NR. COLUMBUS,MS	33.4642861	-88.4361518	NA	Tom Bevill
332929088273300	TOMBIGBEE RIVER ABOVE CUT NEAR COLUMBUS, MS.	33.49150805	-88.4592083	NA	Tom Bevill
2441498	TOMBIGBEE R.IN COLUMBUS BENDWAY AT COLUMBUS,MS	33.43512038	-88.4939314	NA	Tom Bevill
2444157	TOMBIGBEE RIVER AT STATE HWY86 NR PICKENSVILLE	33.22651178	-88.2914233	NA	Tom Bevill

Table A.2 Coring samples taken from Aberdeen Pool

Picture ID	Sample	North	East	Water Depth, ft	Sample Length, ft
	1	3745339	16359324	2.1	0.75
Sample #1	2	3745290	16359036	1.6	1.5
	3	3745912	16359001	2	1.5
	4	3747379	16358933	6	1
	5	3749847	16357665	4.5	1.5
	6	3750826	16357059	6	na
	7	3751696	16357489	3	1.3
	8	3752719	16357685	2.1	0.5
	9	3754427	16358375	4	0.5
Sample #2	10	3756027	16358241	2	1.5
	11	3757982	16358373	3.1	na
	12	3746443	16358788	7.9	1

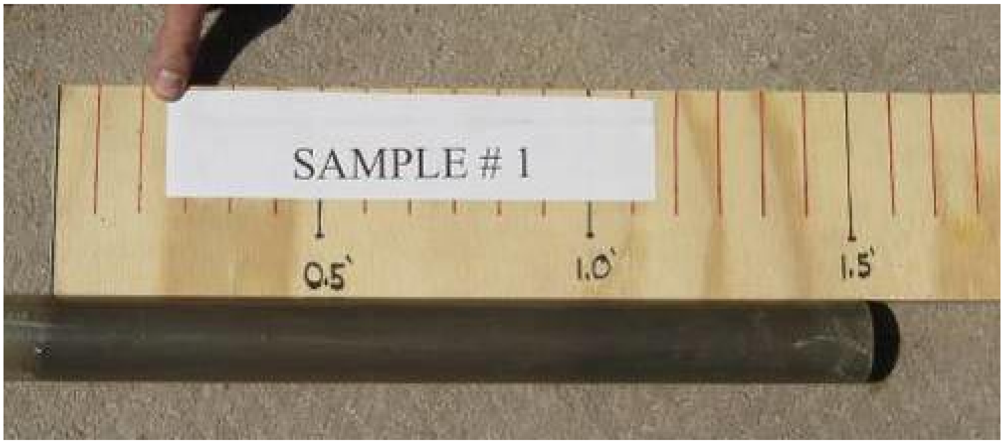


Figure A.2 Typical coring from Aberdeen Pool

Figure A.3 Coring examined for leaf layers

Figure A.4 Coring cut open

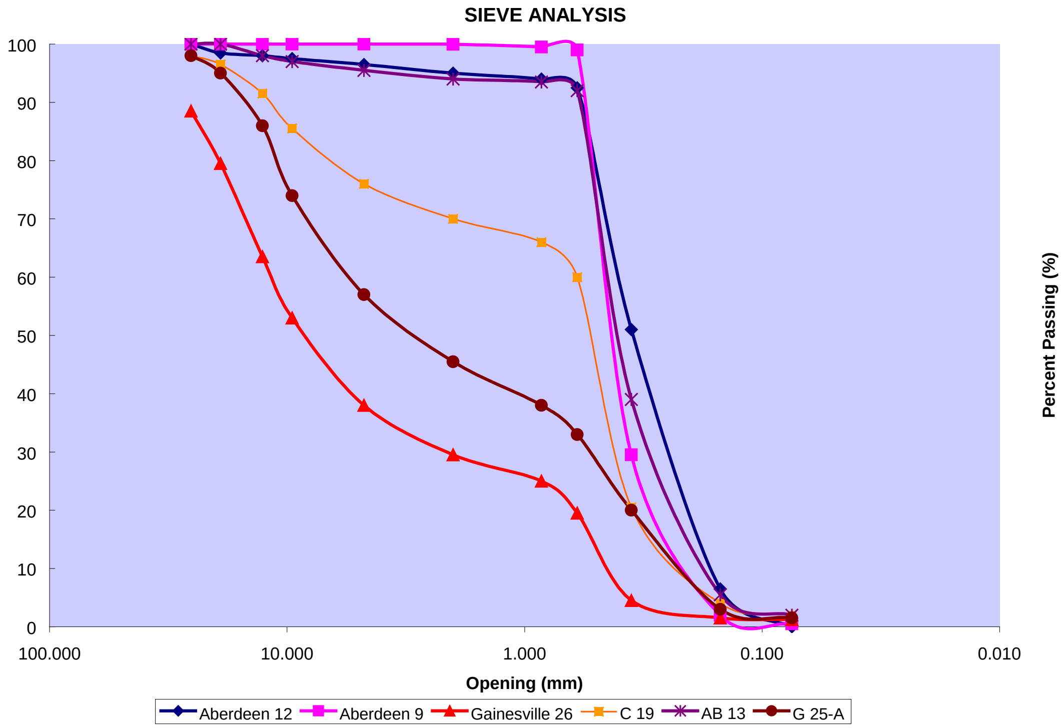


Figure A.5 Sieve analysis of disposal areas of TTW

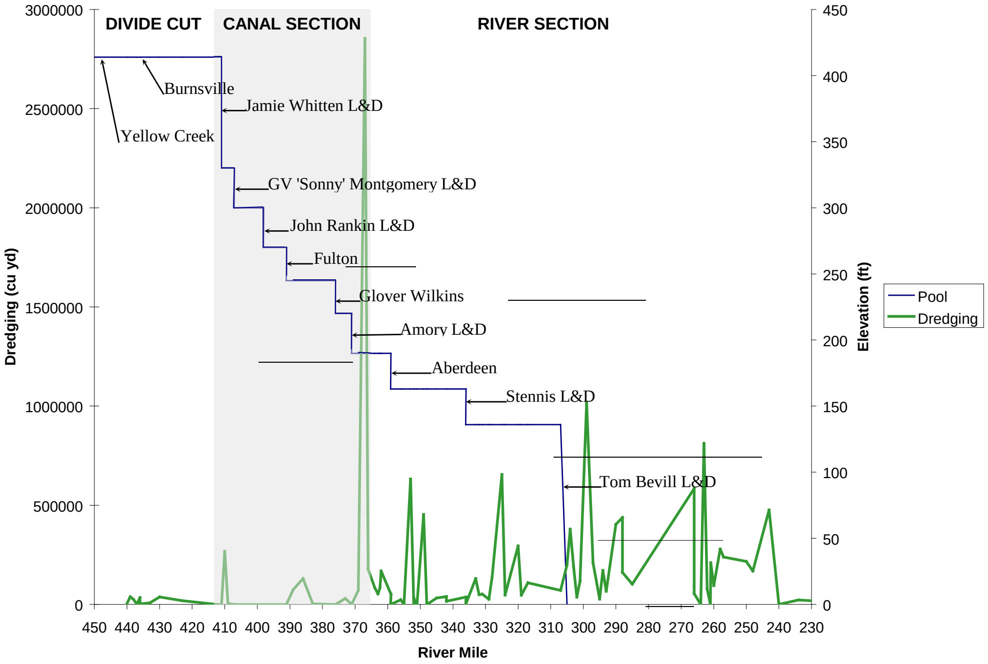


Figure A.6 TTW dredged amounts (McAnally et al. 2004)

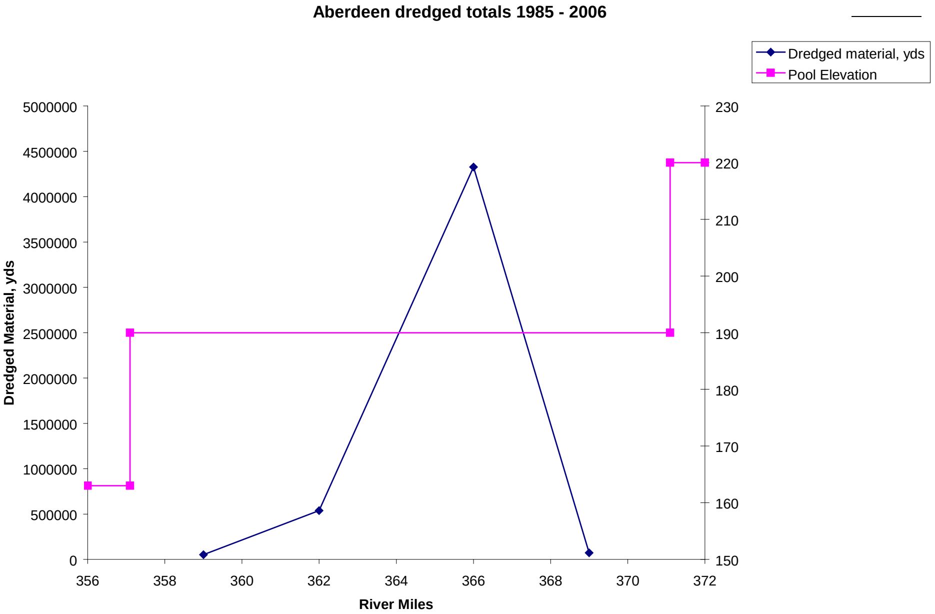
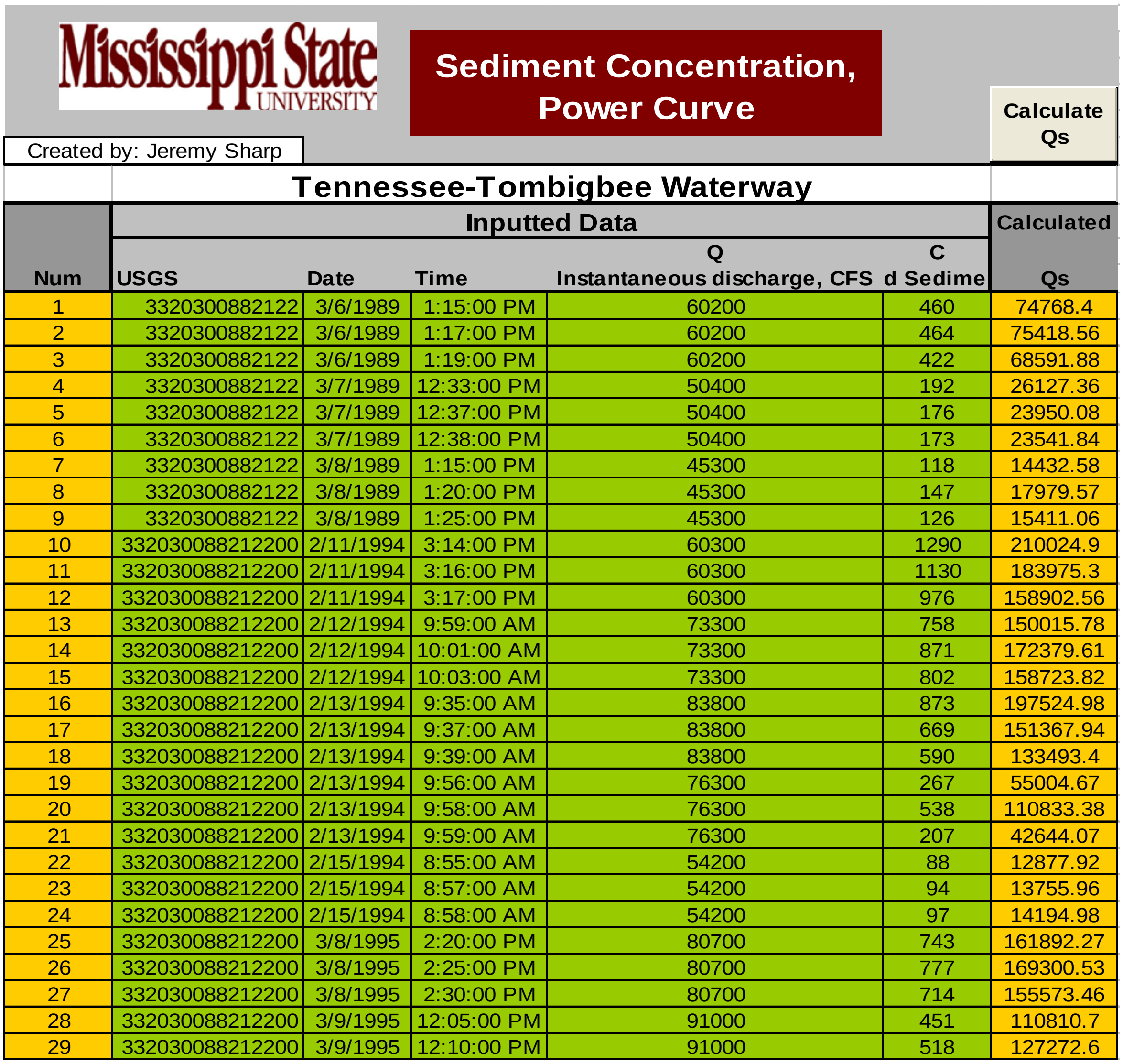


Figure A.7 Dredge volumes and locations for Aberdeen Pool

APPENDIX B



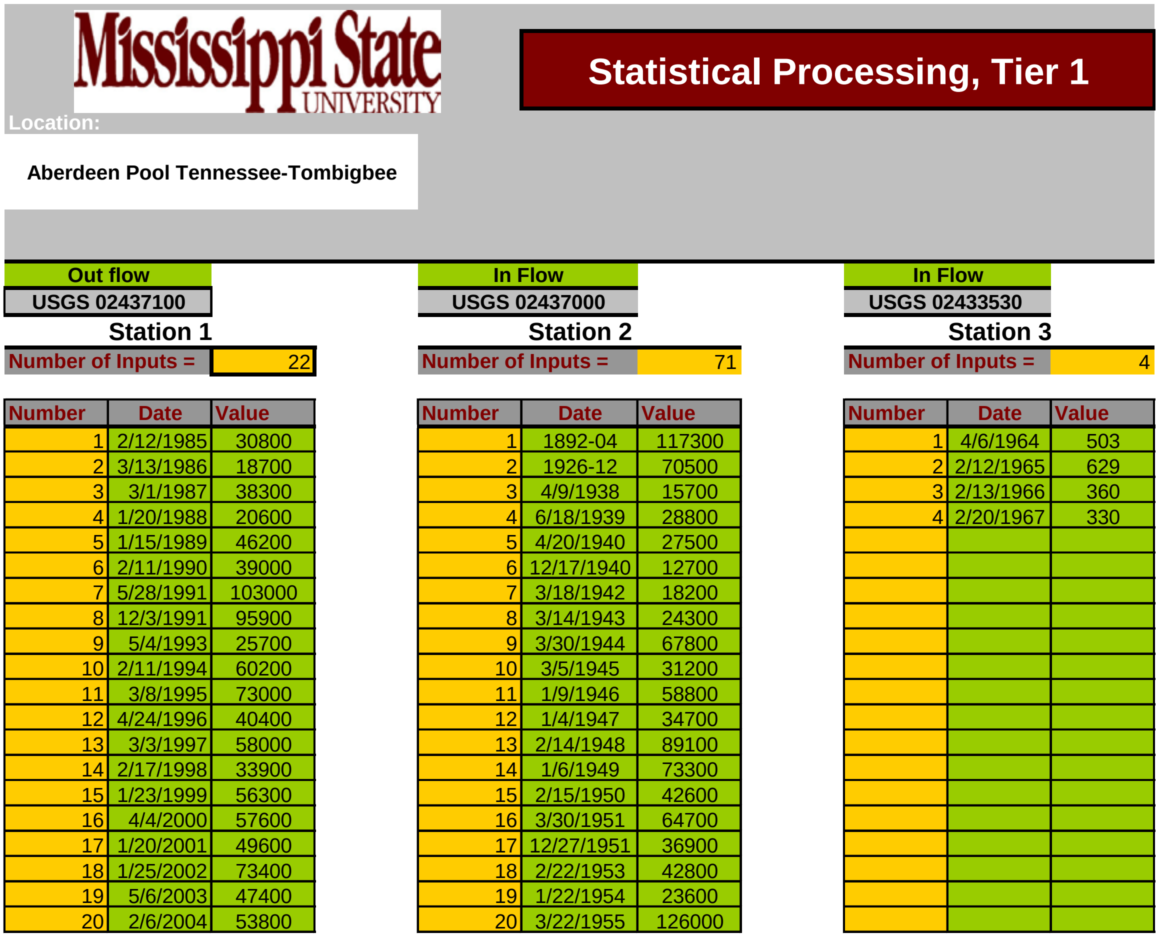
Sediment Concentration, Power Curve

Created by: Jeremy Sharp

Tennessee-Tombigbee Waterway

	Inputted Data					Calculated
Num	USGS	Date	Time	Q Instantaneous discharge, CFS	C d Sedime	Qs
1	3320300882122	3/6/1989	1:15:00 PM	60200	460	74768.4
2	3320300882122	3/6/1989	1:17:00 PM	60200	464	75418.56
3	3320300882122	3/6/1989	1:19:00 PM	60200	422	68591.88
4	3320300882122	3/7/1989	12:33:00 PM	50400	192	26127.36
5	3320300882122	3/7/1989	12:37:00 PM	50400	176	23950.08
6	3320300882122	3/7/1989	12:38:00 PM	50400	173	23541.84
7	3320300882122	3/8/1989	1:15:00 PM	45300	118	14432.58
8	3320300882122	3/8/1989	1:20:00 PM	45300	147	17979.57
9	3320300882122	3/8/1989	1:25:00 PM	45300	126	15411.06
10	332030088212200	2/11/1994	3:14:00 PM	60300	1290	210024.9
11	332030088212200	2/11/1994	3:16:00 PM	60300	1130	183975.3
12	332030088212200	2/11/1994	3:17:00 PM	60300	976	158902.56
13	332030088212200	2/12/1994	9:59:00 AM	73300	758	150015.78
14	332030088212200	2/12/1994	10:01:00 AM	73300	871	172379.61
15	332030088212200	2/12/1994	10:03:00 AM	73300	802	158723.82
16	332030088212200	2/13/1994	9:35:00 AM	83800	873	197524.98
17	332030088212200	2/13/1994	9:37:00 AM	83800	669	151367.94
18	332030088212200	2/13/1994	9:39:00 AM	83800	590	133493.4
19	332030088212200	2/13/1994	9:56:00 AM	76300	267	55004.67
20	332030088212200	2/13/1994	9:58:00 AM	76300	538	110833.38
21	332030088212200	2/13/1994	9:59:00 AM	76300	207	42644.07
22	332030088212200	2/15/1994	8:55:00 AM	54200	88	12877.92
23	332030088212200	2/15/1994	8:57:00 AM	54200	94	13755.96
24	332030088212200	2/15/1994	8:58:00 AM	54200	97	14194.98
25	332030088212200	3/8/1995	2:20:00 PM	80700	743	161892.27
26	332030088212200	3/8/1995	2:25:00 PM	80700	777	169300.53
27	332030088212200	3/8/1995	2:30:00 PM	80700	714	155573.46
28	332030088212200	3/9/1995	12:05:00 PM	91000	451	110810.7
29	332030088212200	3/9/1995	12:10:00 PM	91000	518	127272.6

Figure B.1 Power Curve Program input Sheet



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Statistical Processing, Tier 1

Location:

Aberdeen Pool Tennessee-Tombigbee

Out flow
USGS 02437100
Station 1
Number of Inputs = 22

Number	Date	Value
1	2/12/1985	30800
2	3/13/1986	18700
3	3/1/1987	38300
4	1/20/1988	20600
5	1/15/1989	46200
6	2/11/1990	39000
7	5/28/1991	103000
8	12/3/1991	95900
9	5/4/1993	25700
10	2/11/1994	60200
11	3/8/1995	73000
12	4/24/1996	40400
13	3/3/1997	58000
14	2/17/1998	33900
15	1/23/1999	56300
16	4/4/2000	57600
17	1/20/2001	49600
18	1/25/2002	73400
19	5/6/2003	47400
20	2/6/2004	53800

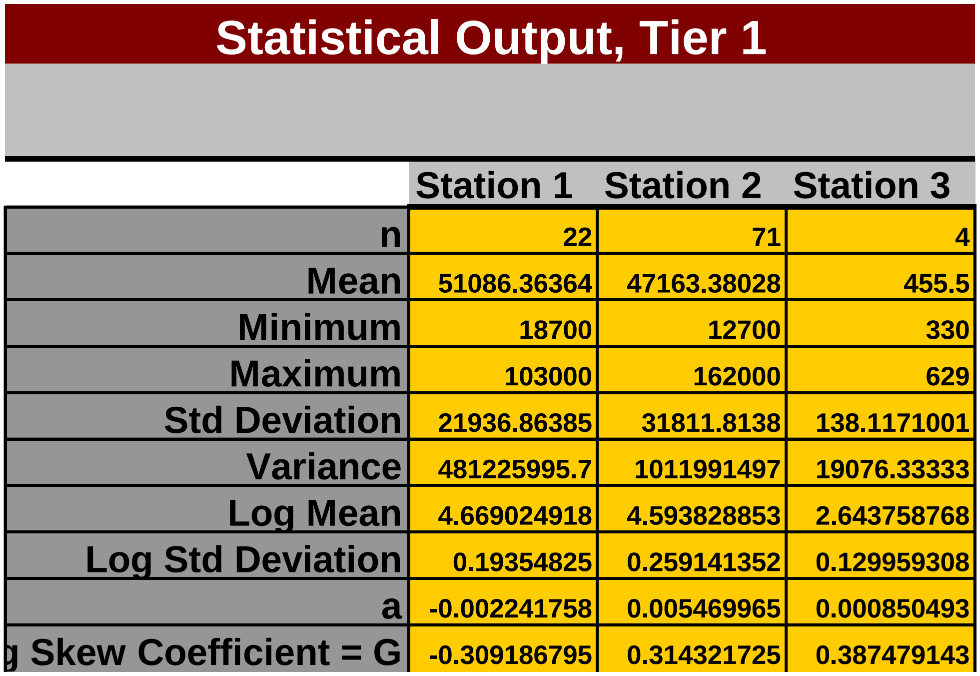
In Flow
USGS 02437000
Station 2
Number of Inputs = 71

Number	Date	Value
1	1892-04	117300
2	1926-12	70500
3	4/9/1938	15700
4	6/18/1939	28800
5	4/20/1940	27500
6	12/17/1940	12700
7	3/18/1942	18200
8	3/14/1943	24300
9	3/30/1944	67800
10	3/5/1945	31200
11	1/9/1946	58800
12	1/4/1947	34700
13	2/14/1948	89100
14	1/6/1949	73300
15	2/15/1950	42600
16	3/30/1951	64700
17	12/27/1951	36900
18	2/22/1953	42800
19	1/22/1954	23600
20	3/22/1955	126000

In Flow
USGS 02433530
Station 3
Number of Inputs = 4

Number	Date	Value
1	4/6/1964	503
2	2/12/1965	629
3	2/13/1966	360
4	2/20/1967	330

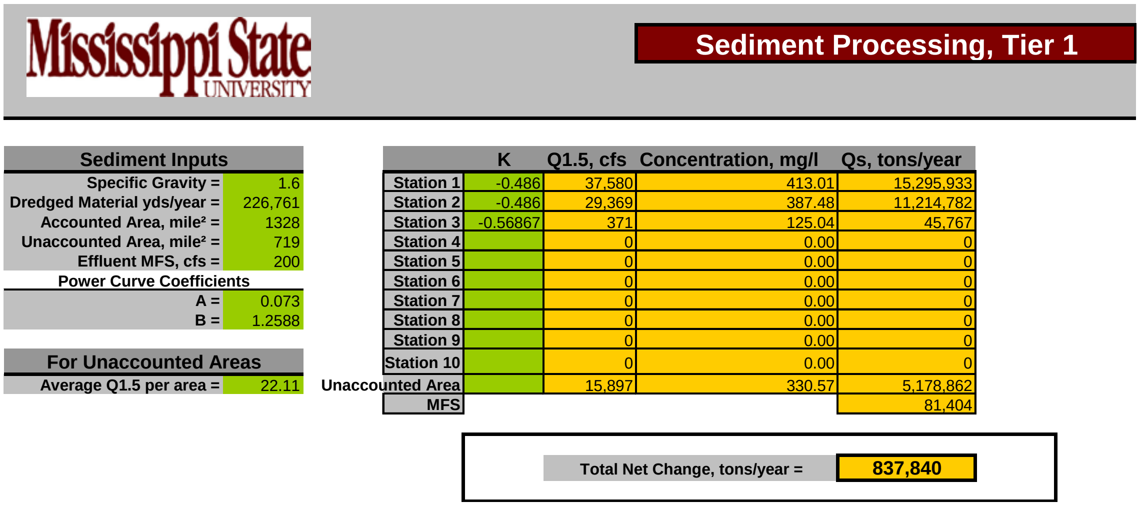
Figure B.2 Tier 1 Program, input of annual flood flow



Statistical Output, Tier 1

	Station 1	Station 2	Station 3
n	22	71	4
Mean	51086.36364	47163.38028	455.5
Minimum	18700	12700	330
Maximum	103000	162000	629
Std Deviation	21936.86385	31811.8138	138.1171001
Variance	481225995.7	1011991497	19076.33333
Log Mean	4.669024918	4.593828853	2.643758768
Log Std Deviation	0.19354825	0.259141352	0.129959308
a	-0.002241758	0.005469965	0.000850493
g Skew Coefficient = G	-0.309186795	0.314321725	0.387479143

Figure B.3 Tier 1 Program, statistical output of flow data



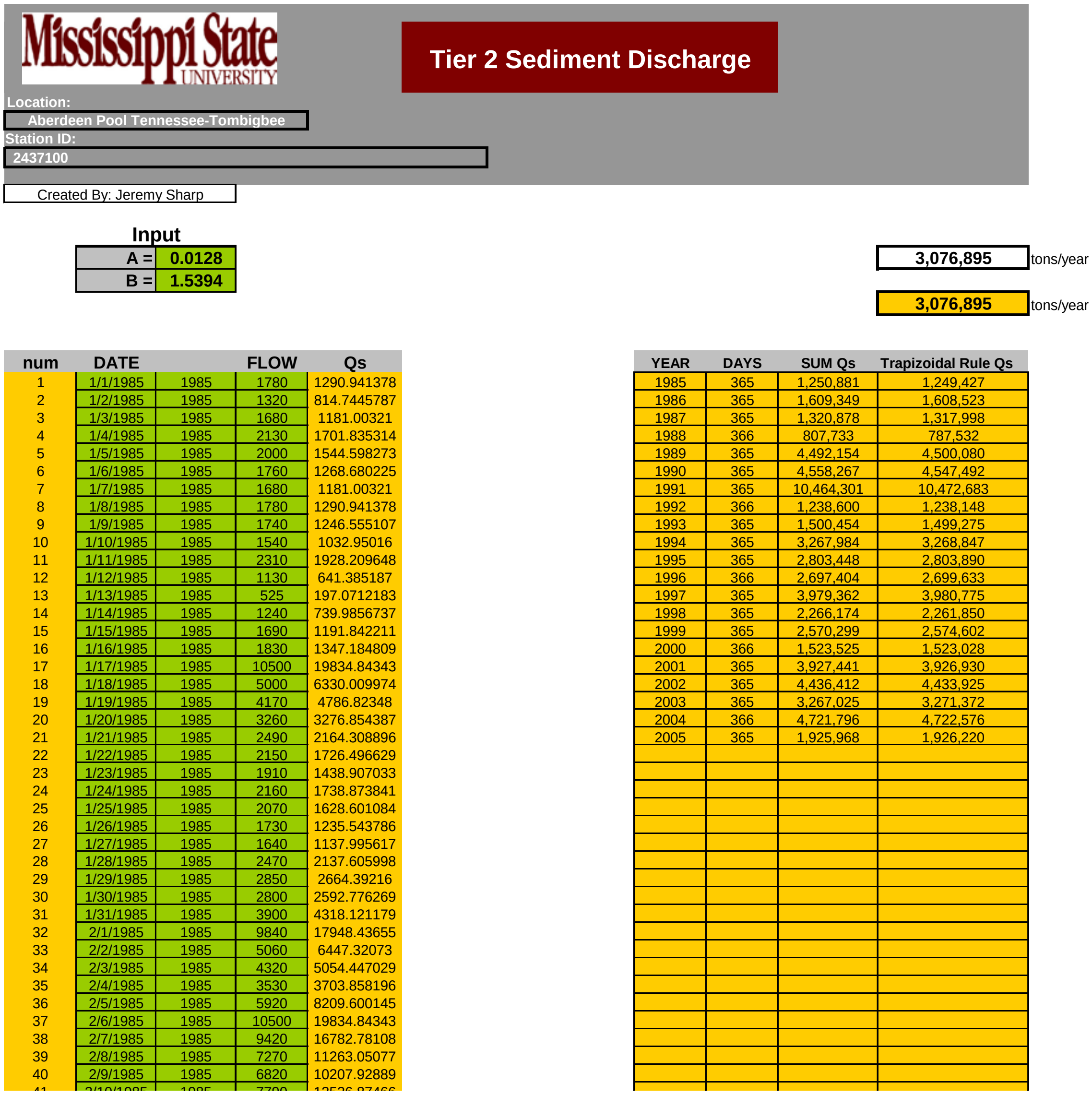
Sediment Processing, Tier 1

Sediment Inputs	
Specific Gravity =	1.6
Dredged Material yds/year =	226,761
Accounted Area, mile² =	1328
Unaccounted Area, mile² =	719
Effluent MFS, cfs =	200
Power Curve Coefficients	
A =	0.073
B =	1.2588
For Unaccounted Areas	
Average Q1.5 per area =	22.11

	K	Q1.5, cfs	Concentration, mg/l	Qs, tons/year
Station 1	-0.486	37,580	413.01	15,295,933
Station 2	-0.486	29,369	387.48	11,214,782
Station 3	-0.56867	371	125.04	45,767
Station 4		0	0.00	0
Station 5		0	0.00	0
Station 6		0	0.00	0
Station 7		0	0.00	0
Station 8		0	0.00	0
Station 9		0	0.00	0
Station 10		0	0.00	0
Unaccounted Area		15,897	330.57	5,178,862
MFS				81,404

Total Net Change, tons/year = 837,840

Figure B.4 Tier 1 Program sediment output



Tier 2 Sediment Discharge

Location:
Aberdeen Pool Tennessee-Tombigbee
Station ID:
2437100

Created By: Jeremy Sharp

Input

A =	**0.0128**
B =	**1.5394**

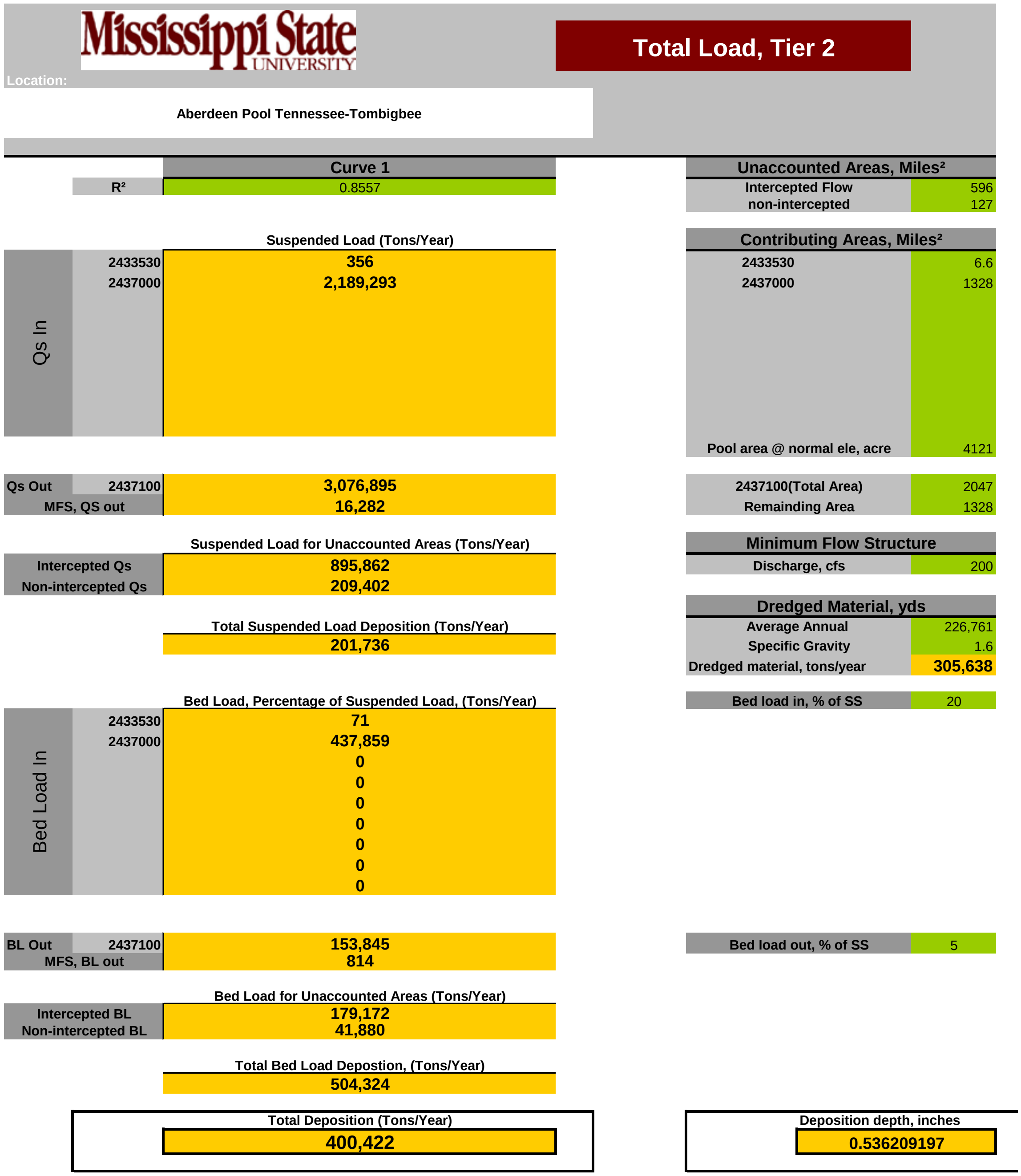
3,076,895 tons/year

3,076,895 tons/year

num	DATE		FLOW	Qs
1	1/1/1985	1985	1780	1290.941378
2	1/2/1985	1985	1320	814.7445787
3	1/3/1985	1985	1680	1181.00321
4	1/4/1985	1985	2130	1701.835314
5	1/5/1985	1985	2000	1544.598273
6	1/6/1985	1985	1760	1268.680225
7	1/7/1985	1985	1680	1181.00321
8	1/8/1985	1985	1780	1290.941378
9	1/9/1985	1985	1740	1246.555107
10	1/10/1985	1985	1540	1032.95016
11	1/11/1985	1985	2310	1928.209648
12	1/12/1985	1985	1130	641.385187
13	1/13/1985	1985	525	197.0712183
14	1/14/1985	1985	1240	739.9856737
15	1/15/1985	1985	1690	1191.842211
16	1/16/1985	1985	1830	1347.184809
17	1/17/1985	1985	10500	19834.84343
18	1/18/1985	1985	5000	6330.009974
19	1/19/1985	1985	4170	4786.82348
20	1/20/1985	1985	3260	3276.854387
21	1/21/1985	1985	2490	2164.308896
22	1/22/1985	1985	2150	1726.496629
23	1/23/1985	1985	1910	1438.907033
24	1/24/1985	1985	2160	1738.873841
25	1/25/1985	1985	2070	1628.601084
26	1/26/1985	1985	1730	1235.543786
27	1/27/1985	1985	1640	1137.995617
28	1/28/1985	1985	2470	2137.605998
29	1/29/1985	1985	2850	2664.39216
30	1/30/1985	1985	2800	2592.776269
31	1/31/1985	1985	3900	4318.121179
32	2/1/1985	1985	9840	17948.43655
33	2/2/1985	1985	5060	6447.32073
34	2/3/1985	1985	4320	5054.447029
35	2/4/1985	1985	3530	3703.858196
36	2/5/1985	1985	5920	8209.600145
37	2/6/1985	1985	10500	19834.84343
38	2/7/1985	1985	9420	16782.78108
39	2/8/1985	1985	7270	11263.05077
40	2/9/1985	1985	6820	10207.92889

YEAR	DAYS	SUM Qs	Trapizoidal Rule Qs
1985	365	1,250,881	1,249,427
1986	365	1,609,349	1,608,523
1987	365	1,320,878	1,317,998
1988	366	807,733	787,532
1989	365	4,492,154	4,500,080
1990	365	4,558,267	4,547,492
1991	365	10,464,301	10,472,683
1992	366	1,238,600	1,238,148
1993	365	1,500,454	1,499,275
1994	365	3,267,984	3,268,847
1995	365	2,803,448	2,803,890
1996	366	2,697,404	2,699,633
1997	365	3,979,362	3,980,775
1998	365	2,266,174	2,261,850
1999	365	2,570,299	2,574,602
2000	366	1,523,525	1,523,028
2001	365	3,927,441	3,926,930
2002	365	4,436,412	4,433,925
2003	365	3,267,025	3,271,372
2004	366	4,721,796	4,722,576
2005	365	1,925,968	1,926,220

Figure B.5 Tier 2, flow input sheet



Mississippi State University

Total Load, Tier 2

Location:

Aberdeen Pool Tennessee-Tombigbee

		Curve 1
	R²	0.8557

Suspended Load (Tons/Year)

Qs In	2433530	356
	2437000	2,189,293
Qs Out	2437100	3,076,895
MFS, QS out		16,282

Suspended Load for Unaccounted Areas (Tons/Year)

Intercepted Qs	895,862
Non-intercepted Qs	209,402

Total Suspended Load Deposition (Tons/Year)

201,736

Bed Load, Percentage of Suspended Load, (Tons/Year)

Bed Load In	2433530	71
	2437000	437,859
		0
		0
		0
		0
		0
		0
		0
BL Out	2437100	153,845
MFS, BL out		814

Bed Load for Unaccounted Areas (Tons/Year)

Intercepted BL	179,172
Non-intercepted BL	41,880

Total Bed Load Depostion, (Tons/Year)

504,324

Total Deposition (Tons/Year)

400,422

Unaccounted Areas, Miles²	
Intercepted Flow	596
non-intercepted	127

Contributing Areas, Miles²	
2433530	6.6
2437000	1328
Pool area @ normal ele, acre	4121
2437100(Total Area)	2047
Remainding Area	1328

Minimum Flow Structure	
Discharge, cfs	200

Dredged Material, yds	
Average Annual	226,761
Specific Gravity	1.6
Dredged material, tons/year	305,638

Bed load in, % of SS	20
Bed load out, % of SS	5

Deposition depth, inches

0.536209197

Figure B.6 Tier 2 Program output sheet for curve 1

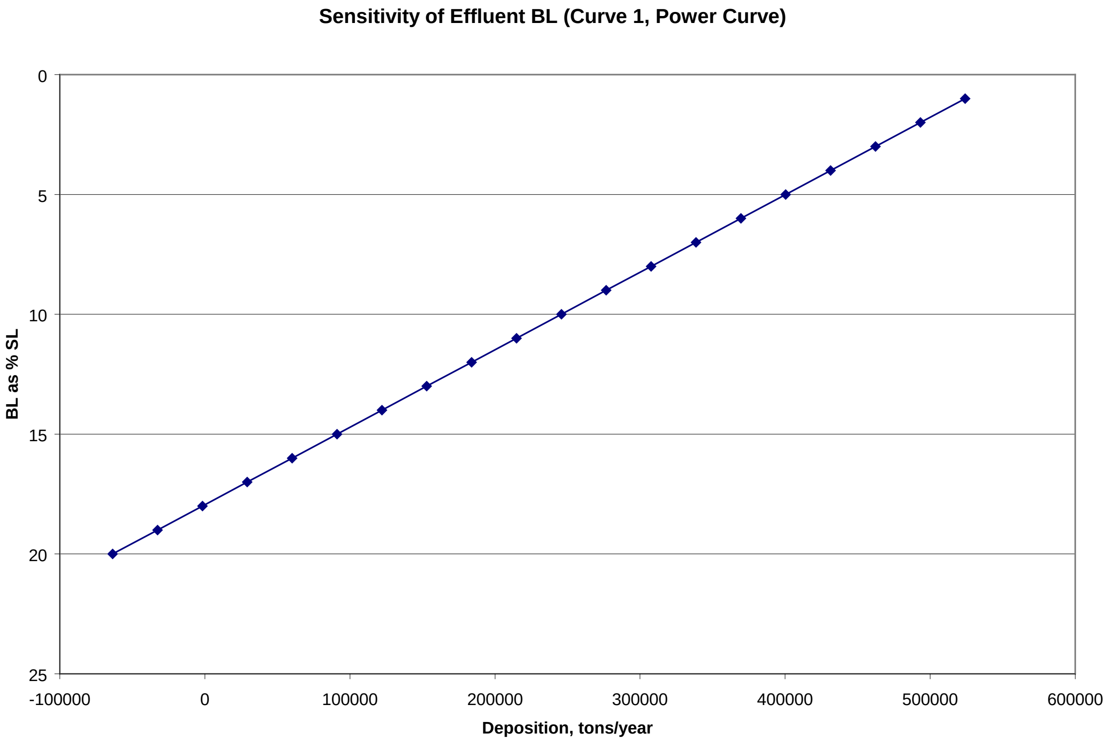


Figure B.7 Sensitivity of deposition to BL effluent

APPENDIX C

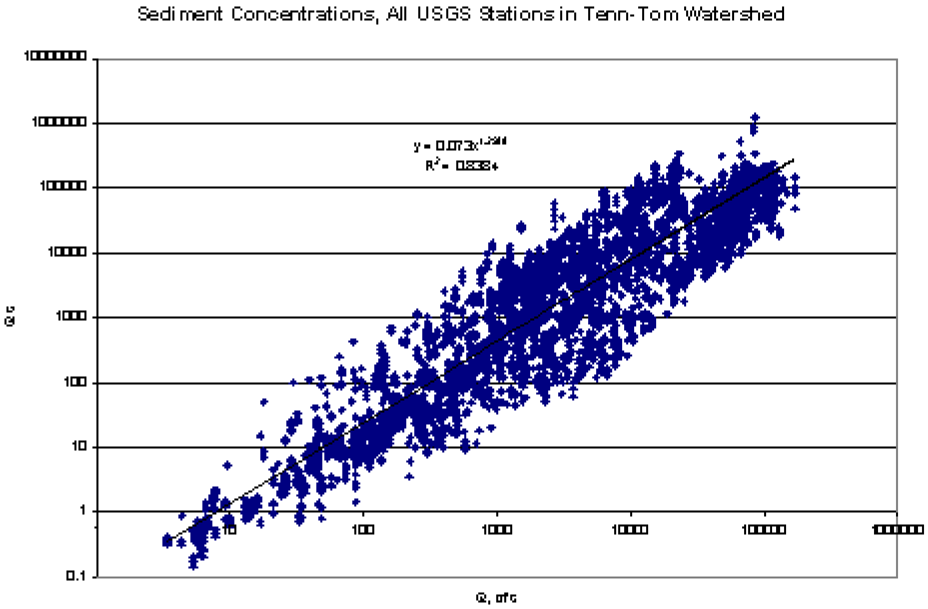


Figure C.1 Tier 1 graph of all USGS Stations Qs vs. Q

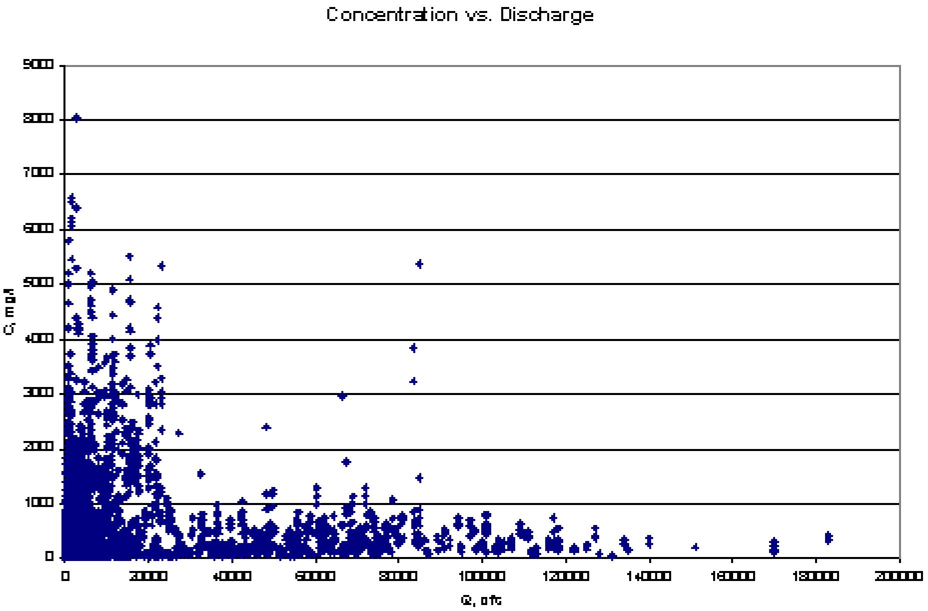


Figure C.2 Tier 1 graph of all USGS Stations C vs. Q

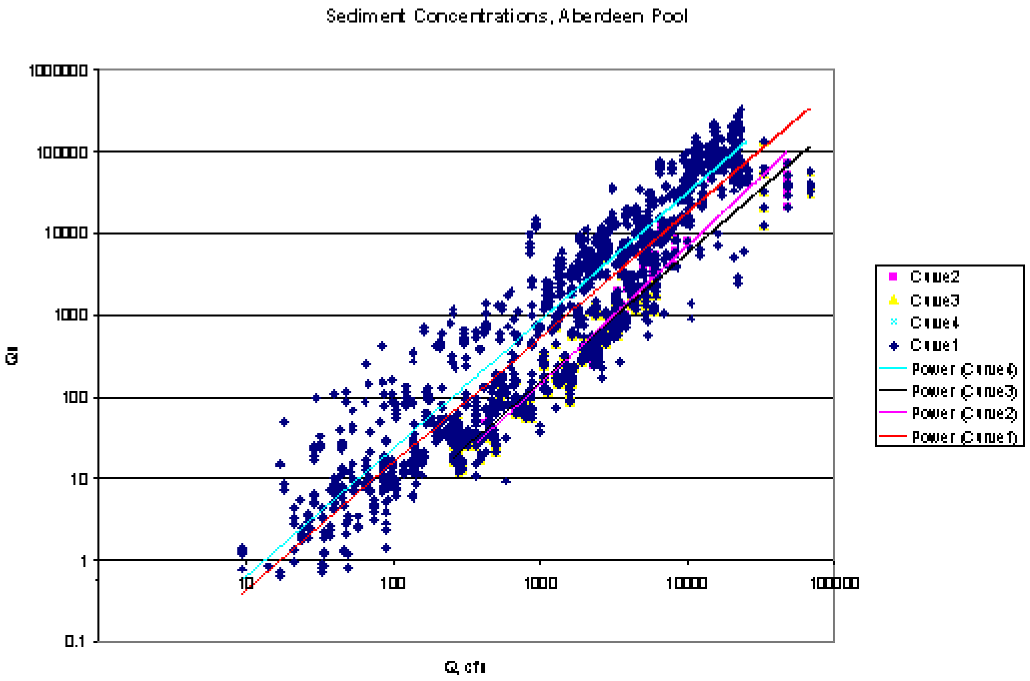


Figure C.3 Comparison of main curves

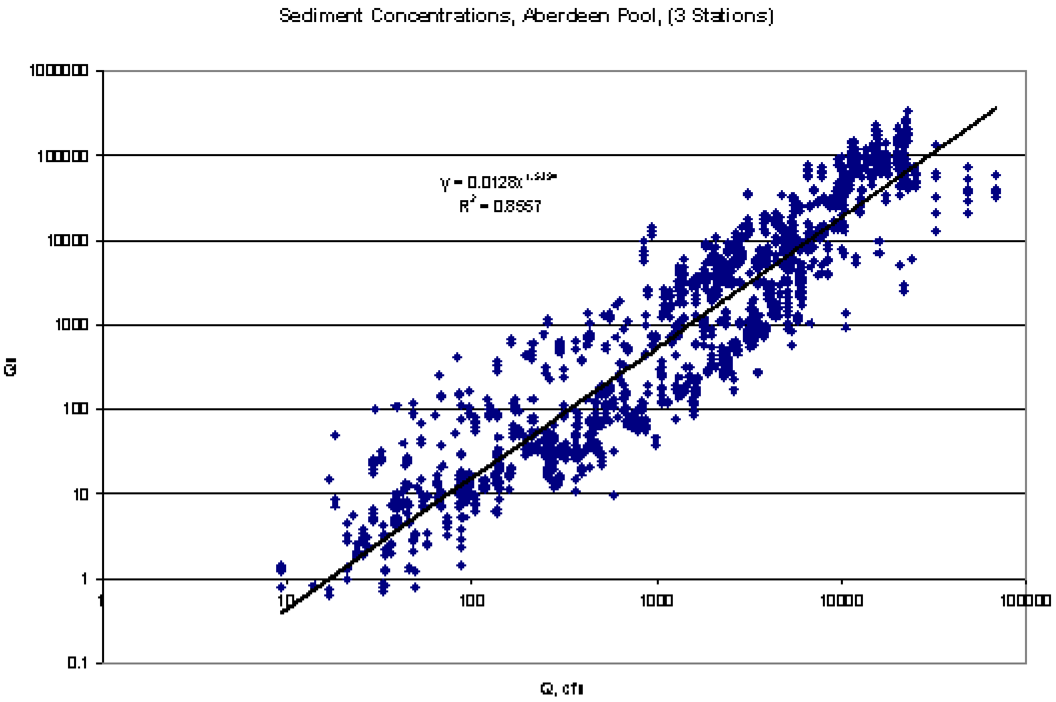


Figure C.4 Main curve 1

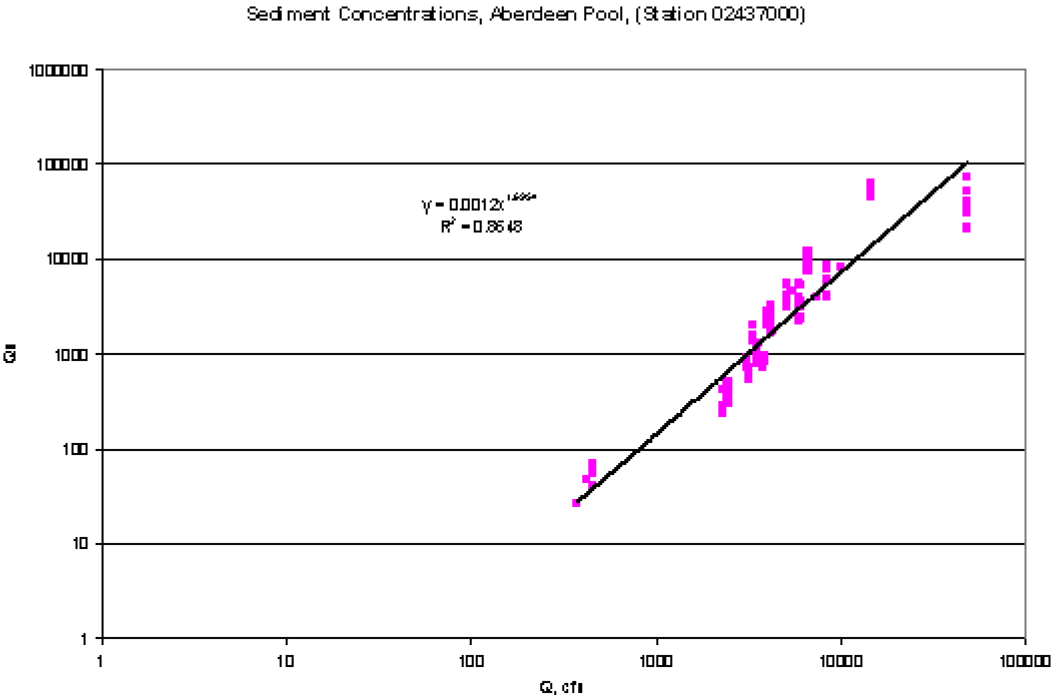


Figure C.5 Main curve 2

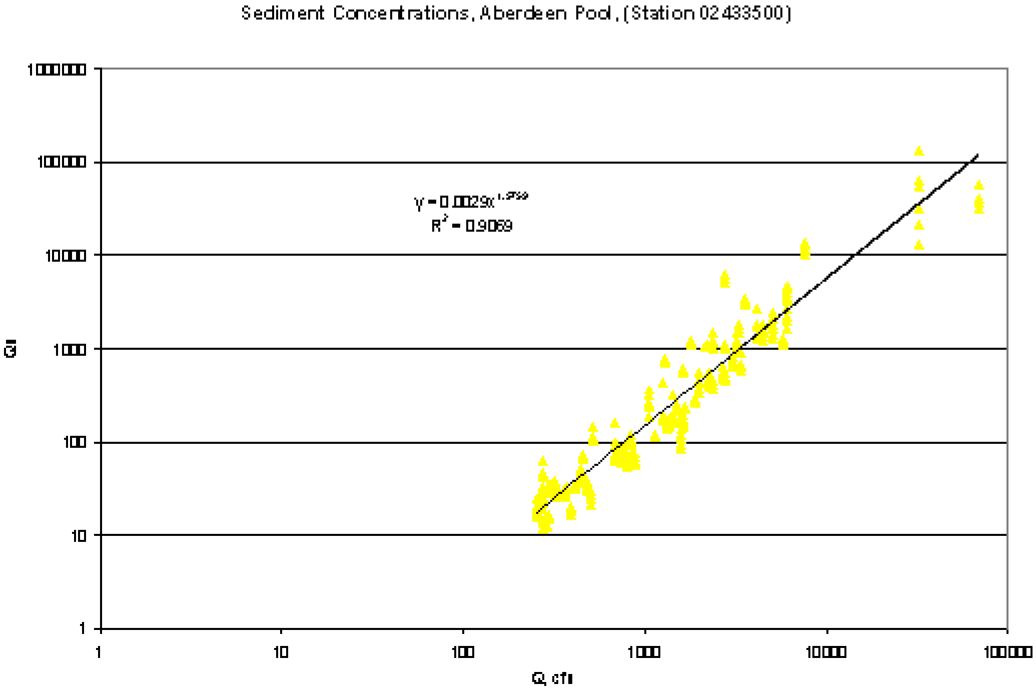


Figure C.6 Main curve 3

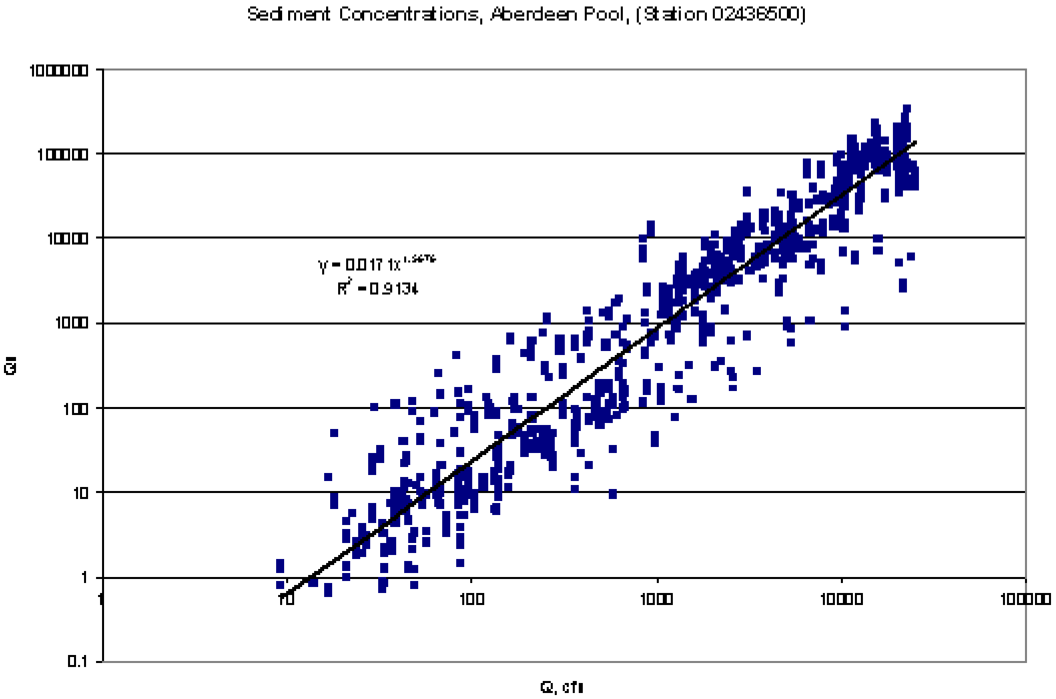


Figure C.7 Main curve 4

Table C.1 Annual sediment fluxes for main curve 1

	Sediment Fluxes For all Three Stations						
Curve	(-) MFS	(-) 2437100	(+) 2433530	(+) 2437000	(+) Intercepted Qs	(+) Non-Intercepted Qs	Dep.
1	17,096	3,230,740	428	2,627,152	1,075,034	251,282	400,422
1.1	11,358	1,246,514	312	1,026,854	414,780	98,230	-23,335
1.2	16,384	334,097	756	288,216	111,171	27,635	-228,340
1.3	34,690	5,527,712	891	4,512,944	1,839,356	431,669	916,821
1.4	56,696	5,080,545	1,621	4,206,310	1,690,560	402,415	858,028
1.5	32,255	4,803,663	838	3,928,103	1,598,427	375,734	761,546
1.6	50,168	7,777,204	1,294	6,353,611	2,587,878	607,736	1,417,509
1.7	25,043	6,276,266	603	5,070,993	2,088,438	485,010	1,038,098
1.8	27,956	9,479,572	650	7,608,636	3,154,344	727,695	1,678,160
1.9	9,576	197,616	439	170,412	65,757	16,339	-259,883
1.10	12,120	2,349,935	302	1,909,772	781,945	182,665	206,991
1.11	10,930	4,253,773	250	3,404,288	1,415,450	325,585	575,232
1.12	17,710	1,755,638	496	1,449,889	584,192	138,704	94,294
1.13	18,431	2,295,402	494	1,885,091	763,799	180,323	210,235
1.14	6,856	4,534,986	150	3,591,247	1,509,024	343,454	596,396
1.15	11,721	3,976,311	272	3,191,495	1,323,124	305,237	526,459
1.16	7,757	4,697,216	171	3,725,966	1,563,007	356,340	634,873
1.17	568	62,118,818	12	48,299,494	20,670,146	4,619,004	11,163,632
1.18	6,290	946,609	163	773,879	314,986	74,024	-95,486
1.19	547	7,125,746	11	5,468,423	2,371,105	522,960	930,568
1.20	2,791	738,954	67	596,319	245,888	57,034	-148,075
1.21	4,220	9,179,440	87	7,133,113	3,054,475	682,166	1,380,543
Avg.	17,326	6,723,944	468	5,328,282	2,237,404	509,602	1,028,849
							764,136

Table C.2 Annual sediment fluxes for main curve 2

	Sediment Fluxes Based on 02437000 Sediment Data						
	(-)	(-)	(+)	(+)	(+)	(+)	
Curve	MFS	2437100	2433530	2437000	Intercepted Qs	Non-Intercepted Qs	Dep.
2	3,663	1,397,713	84	1,119,050	465,091	107,026	-15,762
2.1	4,326	1,486,415	100	1,192,711	494,607	114,072	5,112
2.2	843	2,398,442	17	1,857,853	798,086	177,673	128,706
2.3	2.80E+11	6.49E+09	3.32E+23	4.89E+11	2,158,542,313	3.18E+22	3.64E+23
2.4	298	1.41E+07	6	1.08E+07	4,676,610	1,035,897	2,184,273
2.5	5,391	788,672	140	645,195	262,432	61,715	-130,219
2.6	152	1.11E+07	3	8,574,797	3,687,452	820,030	1,694,800
2.7	7,551	386,539	248	324,676	128,621	31,073	-215,108
2.8	1,049	248,687	25	201,183	82,751	19,242	-252,173
Avg.	2,909	3,980,314	78	3,093,439	1,324,456	295,841	424,954
							609,539

Table C.3 Annual Sediment fluxes for main curve 3

	Sediment Fluxes Based on 02433500 Sediment Data						
	(-)	(-)	(+)	(+)	(+)	(+)	
Curve	MFS	2437100	2433530	2437000	Intercepted Qs	Non-Intercepted Qs	Dep.
3.1	3,593	2,478,851	78	1,961,456	824,842	187,587	185,881
3.2	4,748	830,602	120	676,636	276,384	64,720	-123,127
3.3	3,978	441,462	109	363,569	146,897	34,779	-205,724
3.4	6,286	1,028,375	161	839,068	342,194	80,258	-78,619
3.5	4,698	723,840	121	591,429	240,859	56,571	-145,195
3.6	2,413	3,132,822	51	2,452,237	1,042,452	234,518	288,385
3.7	4,822	345,120	145	287,363	114,839	27,495	-225,738
3.8	568	62,118,818	12	48,299,494	20,670,146	4,619,004	11,163,632
3.9	6,313	1,266,347	157	1,028,341	421,379	98,358	-30,063
3.1	1,625	2,773,869	34	2,162,490	923,010	206,808	211,209
3.11	2,401	902,792	55	723,025	300,406	69,150	-118,195
3.12	2,775	7,799,977	57	6,042,727	2,595,456	577,887	1,107,737
3.13	4,826	914,847	121	743,876	304,417	71,150	-105,747
Avg.	3,773	6,519,825	94	5,090,132	2,169,483	486,791	917,264
							448,303

Table C.4 Annual sediment fluxes for main curve 4

	Sediment Fluxes Based on 02433500 Sediment Data						
	(-)	(-)	(+)	(+)	(+)	(+)	
Curve	MFS	2437100	2433530	2437000	Intercepted Qs	Non-Intercepted Qs	Dep.
4	26,520	5,679,027	652	4,604,781	1,889,706	440,429	924,383
4.1	19,457	675,478	724	573,448	224,766	54,910	-146,725
4.2	34,690	5,527,712	891	4,512,944	1,839,356	431,669	916,821
4.3	56,696	5,080,545	1,621	4,206,310	1,690,560	402,415	858,028
4.4	32,255	4,803,663	838	3,928,103	1,598,427	375,734	761,546
4.5	47,013	7,288,072	1,213	5,954,013	2,425,119	569,513	1,309,135
4.6	25,043	6,276,266	603	5,070,993	2,088,438	485,010	1,038,098
4.7	27,956	9,479,572	650	7,608,636	3,154,344	727,695	1,678,160
4.8	9,576	197,616	439	170,412	65,757	16,339	-259,883
4.9	39,949	2,623,831	1,228	2,189,553	873,084	209,510	303,958
4.1	21,062	7,565,277	486	6,064,716	2,517,359	580,031	1,270,616
4.11	25,044	4,207,894	638	3,431,135	1,400,184	328,189	621,570
4.12	28,063	11,953,217	637	9,548,244	3,977,454	913,184	2,152,601
4.13	11,928	8,582,049	259	6,785,488	2,855,692	648,938	1,390,763
4.14	21,406	6,919,587	500	5,559,612	2,302,505	531,728	1,147,713
4.15	15,898	6,074,750	365	4,863,484	2,021,384	465,142	954,088
Avg.	27,660	5,808,410	734	4,691,992	1,932,759	448,777	932,554
							1,013,452

Table C.5 Aberdeen Pool CDF sieve analysis

Sieves for Aberdeen Pool Dredge Material										
Sieve Size	% Passing		% Passing					AVG ABD 9 & 12	AVG 2 - 5	Total AVG
(mm)	ABD 9	ABD 12	1	2	3	4	5			
0.032	0	0	0	0	0	0	0	0.00	0.00	0.00
0.0625	0	0	0	1	2.5	0	0.5	0.00	1.00	0.57
0.125	1	2.5	4	6	15.5	9	15	1.75	11.38	7.57
0.25	13	30	14.5	58	68.5	54.5	66.5	21.50	61.88	43.57
0.5	71.5	80	24.5	92	97.5	86	96.5	75.75	93.00	78.29
1	99.5	93.5	27.5	93	98	87	97	96.50	93.75	85.07
2	100	94.5	38.5	95	99	91.5	97.5	97.25	95.75	88.00
4	100	95.5	49	96.5	100	94	98	97.75	97.13	90.43
8	100	97	62.5	98	100	96	98.5	98.50	98.13	93.14
16	100	98	96	99	100	99	99	99.00	99.25	98.71
32	100	100	100	100	100	100	100	100.00	100.00	100.00

Table C.6 Deposition in historic cross sections, 0.5 mm max wash load

Deposition for different bed material and sieves					
Historic X- Sections			Bed Material Sieve		
		Flow	ABD 9 & 12	AVG 2-5	Total
Source Sieve ABD 9 & 12					
Equations	EH	Q1.5	134,100	134,100	134,100
		Q^3	239,300	239,300	239,300
	LC	Q1.5	134,100	134,100	134,100
		Q^3	239,300	239,300	239,300
	MPM	Q1.5	125,400	133,800	132,200
		Q^3	239,300	239,300	239,300
Source Sieve AVG 2-5					
Equations	EH	Q1.5	239,300	239,300	239,300
		Q^3	2,773,000	2,773,000	239,300
	LC	Q1.5	239,300	239,300	239,300
		Q^3	2,773,000	2,773,000	239,300
	MPM	Q1.5	230,300	239,300	237,300
		Q^3	2,773,000	239,300	239,300
Source Sieve Total					
Equations	EH	Q1.5	2,773,000	2,773,000	237,300
		Q^3	2,773,000	2,773,000	2,773,000
	LC	Q1.5	2,773,000	2,773,000	237,300
		Q^3	2,773,000	2,773,000	2,773,000
	MPM	Q1.5	2,773,000	2,773,000	237,300
		Q^3	2,773,000	2,773,000	2,773,000

Max Wash Load = 8 FS 0.5

Table C.7 Deposition in historic cross sections, 0.25 mm max wash load

Deposition for different bed material and sieves					
Historic X- Sections			Bed Material Sieve		
		Flow	ABD 9 & 12	AVG 2-5	Total
Source Sieve ABD 9 & 12					
Equations	EH	Q1.5	861,000	930,000	930,000
		Q^3	239,300	239,300	239,300
	LC	Q1.5	930,000	930,000	930,000
		Q^3	239,300	239,300	239,300
	MPM	Q1.5	861,000	895,000	914,000
		Q^3	239,300	239,300	930,000
Source Sieve AVG 2-5					
Equations	EH	Q1.5	268,600	268,600	268,600
		Q^3	930,000	930,000	930,000
	LC	Q1.5	268,600	268,600	268,600
		Q^3	930,000	930,000	930,000
	MPM	Q1.5	199,600	233,600	252,600
		Q^3	930,000	930,000	930,000
Source Sieve Total					
Equations	EH	Q1.5	2,897,000	2,897,000	2,897,000
		Q^3	2,897,000	2,897,000	2,897,000
	LC	Q1.5	2,897,000	2,897,000	2,897,000
		Q^3	2,897,000	2,897,000	2,897,000
	MPM	Q1.5	2,897,000	2,897,000	2,897,000
		Q^3	2,897,000	2,897,000	2,897,000

Max Wash Load = 7 FS 0.25

Table C.8 Deposition in historic cross sections, 0.125 mm max wash load

Deposition for different bed material and sieves					
Historic X- Sections			Bed Material Sieve		
		Flow	ABD 9 & 12	AVG 2-5	Total
Source Sieve ABD 9 & 12					
Equations	EH	Q1.5	3,010,000	3,010,000	1,463,000
		Q^3	3,010,000	3,010,000	3,010,000
	LC	Q1.5	3,010,000	3,010,000	3,010,000
		Q^3	3,010,000	3,010,000	3,010,000
	MPM	Q1.5	2,910,000	2,900,000	2,970,000
		Q^3	3,010,000	3,010,000	3,010,000
Source Sieve AVG 2-5					
Equations	EH	Q1.5	1,463,000	1,463,000	1,463,000
		Q^3	1,463,000	1,463,000	1,463,000
	LC	Q1.5	1,463,000	1,463,000	1,463,000
		Q^3	1,463,000	1,463,000	1,463,000
	MPM	Q1.5	1,363,000	1,351,000	1,423,000
		Q^3	1,463,000	1,463,000	1,463,000
Source Sieve Total					
Equations	EH	Q1.5	3,278,000	3,278,000	3,278,000
		Q^3	2,165,000	2,165,000	2,165,000
	LC	Q1.5	3,278,000	3,278,000	3,278,000
		Q^3	2,165,000	2,165,000	2,165,000
	MPM	Q1.5	3,178,000	3,168,000	3,238,000
		Q^3	2,165,000	2,165,000	2,165,000

Max Wash Load = 6 VFS 0.125

Table C.9 Deposition in current cross sections, 0.5 mm max wash load

Deposition for different bed material and sieves					
CURRENT X-SECTIONS			Bed Material Sieve		
		Flow	ABD 9 & 12	AVG 2-5	Total
Source Sieve ABD 9 & 12					
Equations	EH	Q1.5	134,100	134,100	134,100
		Q^3	134,100	134,100	134,100
	LC	Q1.5	134,100	134,100	134,100
		Q^3	134,100	134,100	134,100
	MPM	Q1.5	134,100	134,100	134,100
		Q^3	134,100	134,100	239,300
Source Sieve AVG 2-5					
Equations	EH	Q1.5	239,300	239,300	239,300
		Q^3	239,300	239,300	239,300
	LC	Q1.5	239,300	239,300	239,300
		Q^3	239,300	239,300	239,300
	MPM	Q1.5	239,300	239,300	239,300
		Q^3	239,300	239,300	239,300
Source Sieve Total					
Equations	EH	Q1.5	572,000	572,000	572,000
		Q^3	572,000	572,000	572,000
	LC	Q1.5	572,000	572,000	572,000
		Q^3	572,000	572,000	572,000
	MPM	Q1.5	572,000	572,000	572,000
		Q^3	572,000	572,000	572,000

Max Wash Load = 8 FS 0.5

Table C.10 Deposition in current cross sections, 0.125 mm max wash load

Deposition for different bed material and sieves					
CURRENT X-SECTIONS			Bed Material Sieve		
		Flow	ABD 9 & 12	AVG 2-5	Total
Source Sieve ABD 9 & 12					
Equations	EH	Q1.5	3,010,000	3,010,000	3,010,000
		Q^3	3,010,000	3,010,000	3,010,000
	LC	Q1.5	3,010,000	3,010,000	3,010,000
		Q^3	3,010,000	3,010,000	3,010,000
	MPM	Q1.5	2,979,000	2,968,000	2,979,000
		Q^3	3,010,000	3,010,000	3,010,000
Source Sieve AVG 2-5					
Equations	EH	Q1.5	1,463,000	1,463,000	1,463,000
		Q^3	1,463,000	1,463,000	1,463,000
	LC	Q1.5	1,463,000	1,463,000	1,463,000
		Q^3	1,463,000	1,463,000	1,463,000
	MPM	Q1.5	1,442,000	1,420,000	1,431,000
		Q^3	1,463,000	1,463,000	1,463,000
Source Sieve Total					
Equations	EH	Q1.5	2,165,000	2,165,000	2,165,000
		Q^3	2,165,000	2,165,000	2,165,000
	LC	Q1.5	2,165,000	2,165,000	2,165,000
		Q^3	2,165,000	2,165,000	2,165,000
	MPM	Q1.5	2,135,000	2,124,000	2,134,000
		Q^3	2,165,000	2,165,000	2,165,000

Max Wash Load = 6 VFS 0.125