White River Sediment Abatement Project

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Background

The West Fork White River (HUC Id. 1101000104) contains part of the White River and many tributaries that drain into the Beaver Reservoir. The West Fork of the White river is listed on the Arkansas Department of Environmental Quality (ADEQ) 303(d) list for excessive silt and turbidity. Much of the extra sediment in this river is due to erosion from upstream headwaters. Possible causes include increasing population in the Northwest Arkansas and the introduction of more pervious areas through high amounts of urban construction. This hydrologic unit is listed in Arkansas' Unified Watershed Assessment as the number one priority for restoration. Beaver Reservoir is on a high priority list because the health of these waters is imperative to the quality of the water in Beaver Lake, the primary drinking source to over 300,000 residents of Northwest Arkansas.

Problem Statement

The primary site for development of a sedimentation abatement system is an existing basin in the floodplain of the West Fork of the White River on Dead Horse Mountain Rd. Reducing sediment is crucial to maintaining quality of water downstream and wildlife habitat. This sedimentation abatement is needed to collect and reduce the excess silt and suspended solids before they move further downstream to cause damage by reducing dissolved oxygen and increase water turbidity. The basin would be designed and developed to capture sediment from water during relatively low-flow, high-frequency storm events. In addition they system could be designed as a constructed wetland with multiple ecosystem services. A sediment abatement solution could address a serious problem with a crucial water source to the region.

Design Objectives

Our goal is to design a currently existing pond to serve as a sediment catchment with the following objectives:

- Reduce erosion in the West Fork of the White River
- Capture excess sediment
- Improve/restore ecosystem services in the area
    - Wildlife habitat
    - Water quality
    - Mitigate droughts/floods
    - Maintain biodiversity

Design Constraints

The following are our design constraints:

- Pond must be at a low enough elevation that water can flow from the river into the pond.
- The drainage area above the pond must not displace too much water from the river with its runoff during storm events, or:
- It must be feasible to divert runoff from the drainage area around the pond
- The volume of the pond must be large enough to capture water from a 1.5 year storm event.

Analysis and Design

To determine the design specifications of the sedimentation abatement system an extensive site analysis was performed. The analysis included collecting data that would allow us to determine the hydrologic properties of the basin; current basin volume, maximum basin volume, and flow volume for the river for low-flow high-frequency storm events.

Methods

Initial Site Visit

In an initial site visit and assessment our project team was accompanied by Beaver Watershed Alliance's executive director Jason Kindall and the City of Fayetteville's Water and Wastewater Operations Manager William Winn. With them present they were able to give the team some insight on the history and dynamics of the site.

Site Survey & Data Analysis

A topographic survey of the pond bank and crucial features around the pond was conducted using a total station and a Carlson Explorer data collector. In addition, a bathymetric survey of the area below the pond was conducted. A benchmark on the bridge was tied into in order to correct the elevations of the surveyed data to known elevations.

The data was uploaded into ArcGIS, and since we were unable to locate coordinates for features located in the field, we geo-referenced our data set to points from a high resolution aerial photo that was adjusted to NAD1983 UTM Zone 15 coordinates.

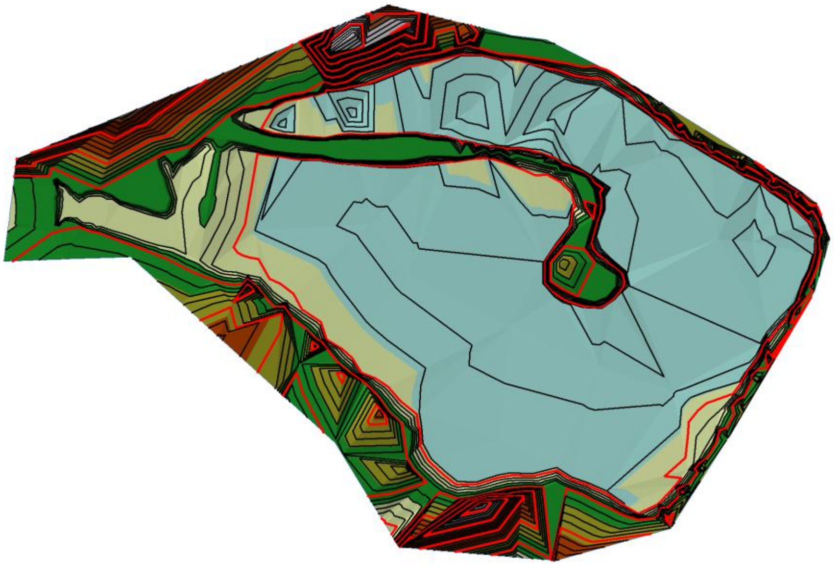


Figure 1

Once the points were adjusted, we used the TIN Management tool in ArcGIS to generate a TIN of the pond (Figure 1). A Triangulated Irregular Network (TIN) is a vector-based data structure used in GIS systems to represent land topography. It uses irregular points or nodes (our surveyed data points) as vertices of a network of tessellated triangles, calculated using Delaunay triangulation.

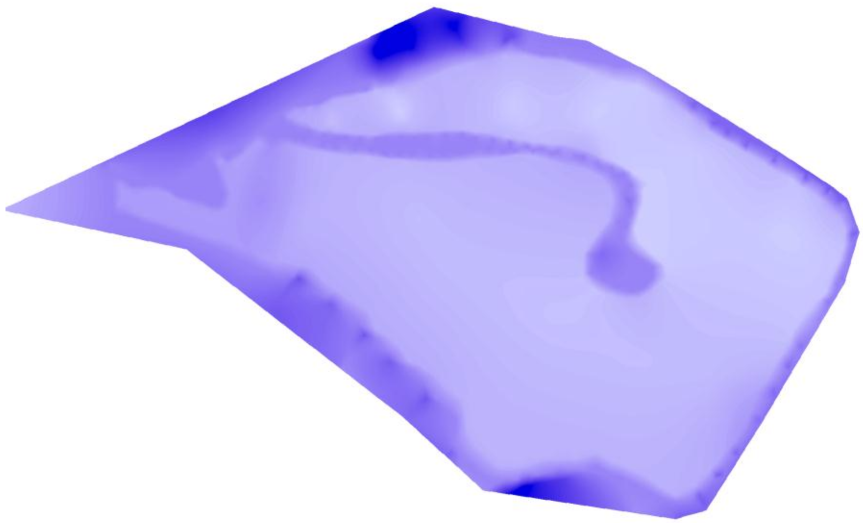
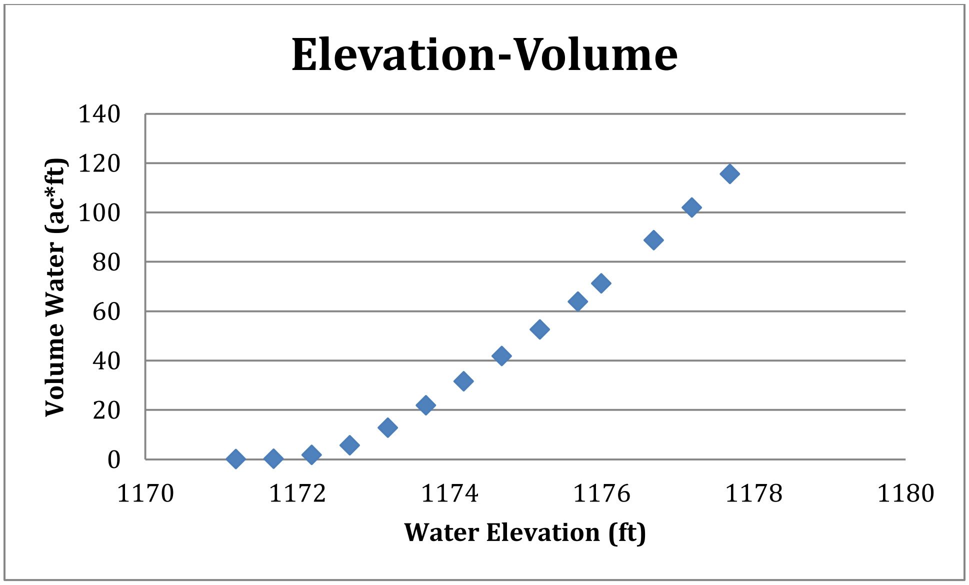


Figure 2

The generated TIN was converted to a rasterized Digital Elevation Model (DEM), from which water elevation (stage) and volume data could be calculated using ArcGIS Surface Volume tool (Figure 2).

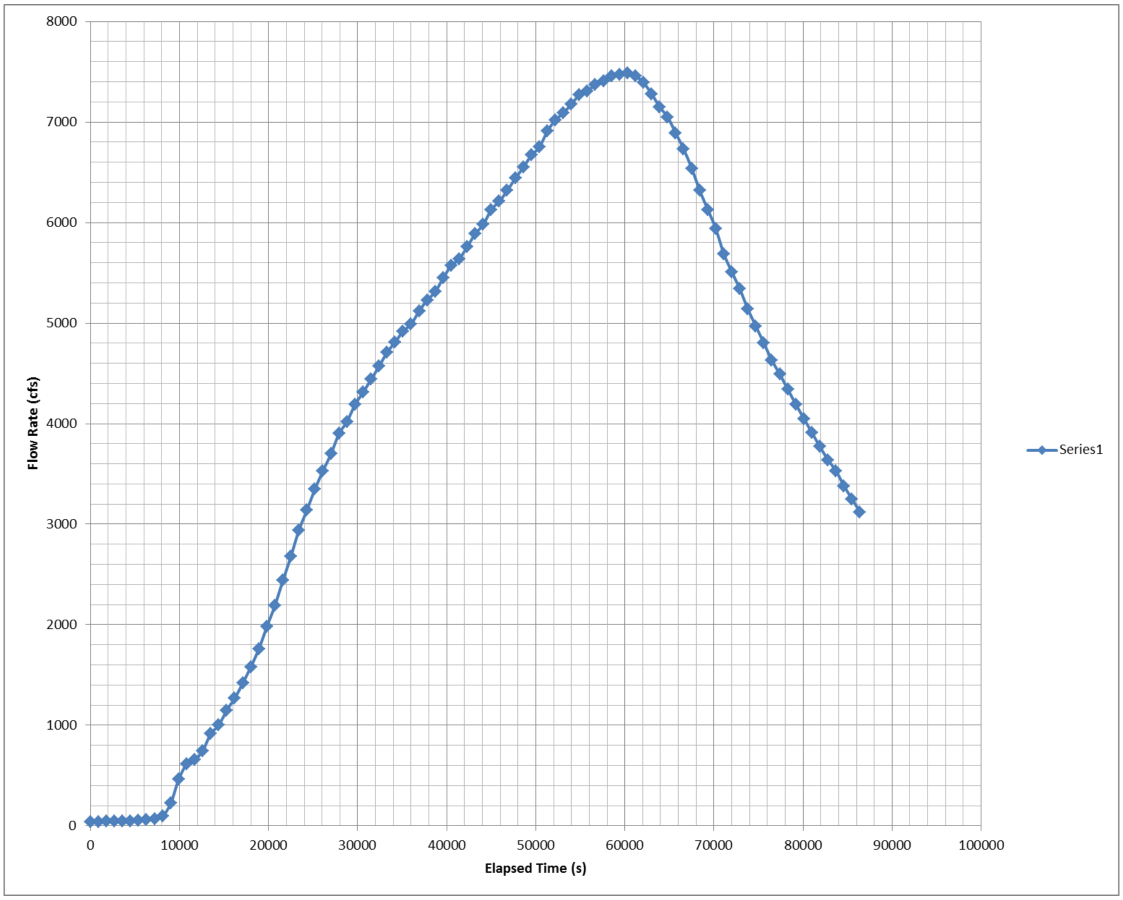


It was calculated that the pond can hold 72.12 acre*ft at an elevation of 1176 ft, the elevation of the lowest point on the pond dam.

Elevation	Volume			
ft	ft^3	acre*ft	gal*10^6	m^3
1171.19	0.001	2.432E-08	7.924E-09	3.00E-05
1171.69	8213.399	0.19	0.06	232.58
1172.19	75317.841	1.73	0.56	2132.76
1172.69	246566.995	5.66	1.84	6981.99
1173.19	556509.017	12.78	4.16	15758.55
1173.69	952056.326	21.86	7.12	26959.19
1174.19	1372434.482	31.51	10.27	38862.95
1174.69	1816806.286	41.71	13.59	51446.14
1175.19	2289112.341	52.55	17.12	64820.34
1175.69	2781005.894	63.84	20.80	78749.19
1176.00	3098190.030	71.12	23.18	87730.83
1176.69	3860671.605	88.63	28.88	109321.87
1177.19	4437139.081	101.86	33.19	125645.58
1177.69	5028906.051	115.45	37.62	142402.53

Determining Volume of 1.5 Year Storm Event: West Fork, White River

To determine flow volume for the West Fork White River data was extracted from USGS's online database. The USGS gage station number 07048550 West Fork White River east of Fayetteville, AR was determined to be the closest station located roughly two miles downstream of our project site. Peak discharge values were collected from this gage station's data and analyzed to find peak discharge for a 1.5 year return interval. We used normal cumulative distribution and lognormal cumulative distribution to determine peak discharge rates for this time interval. The calculated values were 9394 cfs and 6380 cfs respectively. We then looked for a documented flood event that displayed data closest to the 1.5 year return interval calculations. This storm event was graphed over a 24 hour time interval and we used the area under this curve to find the total event volume.



The area under this curve produced a volume of 8283 acre-feet.

Determining Volume of 1.5 Year Storm Event: Catchment Area Above Pond

To determine the runoff volume of water for a 1.5 year return event for the catchment area above the pond, ArcGIS was employed. We delineated the catchment and used ArcGIS analysis tools to determine attributes of the watershed necessary to calculate peak flow during a 1.5 year storm event. Namely: catchment slope, length, elevation change, and area.

From this data, we used the Soil Conservation Society's TR55 methods to determine peak flow and runoff volumes from that catchment. The following are assumptions and parameters used:

- We assumed moderate antecedent moisture conditions
- Using GIS data we determine the soil type to be Enders. Enders soil is Hydrologic Soil Group C.
- Using GIS data, we determined the following land use/land cover and correlated that to the listed CN values from SCS land uses

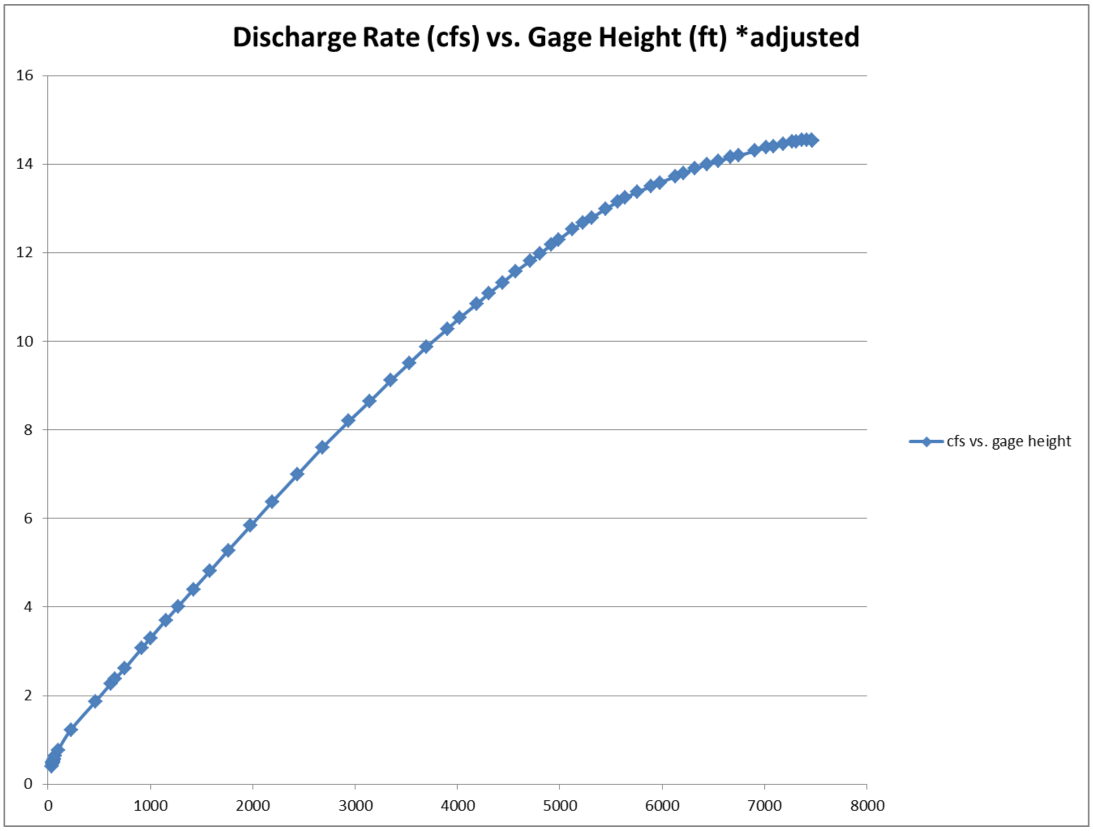
LULC Category Name	Area (ft^2)	CN
Urban: Intensity 1	1521279.55	91
Urban: Intensity 3	690695.89	94
Barren Land	52457.92	86
Water: Perennial	629494.98	-
Herbaceous/Woody/Transitional	883041.58	70
Forest Unclassified (L1 Value Only) **(For All Forest Areas 2004 & 2006)**	2517979.94	73
Warm Season Grasses	515836.17	79
Cool Season Grasses (Combined Pasture Versions = 210)	734410.82	79

- Using a weighted average, the Curve Number for the watershed was determined to be 80.
- The area of our catchment was determined to be 7,492,320 ft^2 (172 ac).
- The length of the longest channel was determined to be 7,083.4 ft, with an elevation change of 344.3 feet.
- We found the accumulated precipitation form this storm event to be 1.69 inches.
- There were no swamplands or ponds.

Based on these assumptions, we calculated the peak flow for a 1.5 year storm event to be 52.2 cfs. Using SCS methods, we determined time to peak flow to be 0.83 hours and the time to return to base flow to be 2.21 hours. With this data, a runoff hydrograph was constructed, from which we determined the runoff volume for such an event to be 207809.70 ft^3 or 4.77 acre-feet.

Determining water elevation at discharge rates

In order to find the water elevation at our site for particular discharge rates, first we used our survey data of the ripple at the site to determine an elevation. We took an average of the survey elevations across the riffle for an elevation to use in our calculations. We determined this elevation to be 1167 ft. Then we checked the river gage data two miles downstream on the day we surveyed the riffle. The average height on this day was 2.72ft. We subtracted this value from the gage height values during our 1.5 year storm data to estimate a water elevation at our site during this storm event. We graphed these adjusted gage height values against the USGS data for discharge.



This data allows us to estimate the water elevation at our site for any amount of discharge up to 7470 cfs, the peak discharge for this event. The following table gives resulting water elevation from the actual storm event, adjusted for our site two miles upstream of the USGS gage at values for the peak discharge of the storm event and our lognormal cumulative distribution value for a 1.5 year event.

Flow Rates (cfs)	Gage Height (ft)	Total Water Elevation	Bank Elevation
7490	17.2	1181.57	1178.00
6320	16.6	1180.97	

Further work will need to be done to better estimate total water elevation. To our knowledge, a 1.5 year event should not crest the river banks as our data indicates.