Bioretention Cell Construction

Conference Paper · January 2008

DOI: 10.13031/2013.24923

Rebecca A. Chavez
Oklahoma State University - Stillwater

Glenn O. Brown
Oklahoma State University - Stillwater

2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

An ASABE Meeting Presentation

Paper Number: 084439

Bioretention Cell Construction

R.A. Chavez, Research Engineer

Oklahoma State University, 111 Agricultural Hall, Stillwater, OK 74078

G.O. Brown, Professor, P.E., Ph.D.

Oklahoma State University, 111 Agricultural Hall, Stillwater, OK 74078

D.E. Storm, Professor, Ph.D.

Oklahoma State University, 111 Agricultural Hall, Stillwater, OK 74078

Written for presentation at the
2008 ASABE Annual International Meeting
Sponsored by ASABE
Rhode Island Convention Center
Providence, Rhode Island
June 29 – July 2, 2008

Abstract. *Eight bioretention cells were installed in Grove, Oklahoma in Summer 2007 as part of a technology demonstration and evaluation project. Cell design focused on phosphorus and nitrate attenuation by utilizing fly ash as an additive to the filter medium and incorporating a biozone or anaerobic zone, respectively. Sites included two commercial properties, four public or municipal properties, and two residential properties. Construction was professionally contracted as an official state project with a formal Plans, Specifications, and Estimates (PS&E) package. Two additional cells were constructed by Oklahoma State University in Spring 2008 at the Oklahoma State University Botanical Gardens. This paper discusses construction details and implementation including costs, problems and successes encountered during the construction process, as well as a comparison of contracted and in-house cell construction.*

Keywords. Bioretention, low-impact development, stormwater runoff, phosphorus attenuation

Introduction

Ten bioretention cells have been constructed as part of an ongoing study. Eight are located in in Grove, and two are located in Stillwater, as shown in Figure 1. Previous findings related to bioretention cell design and construction specifications have been presented by Chavez, et al, in 2006 and 2007, respectively. This paper presents the newest findings of an ongoing project, specifically pertaining to the construction process, including costs and lessons learned.

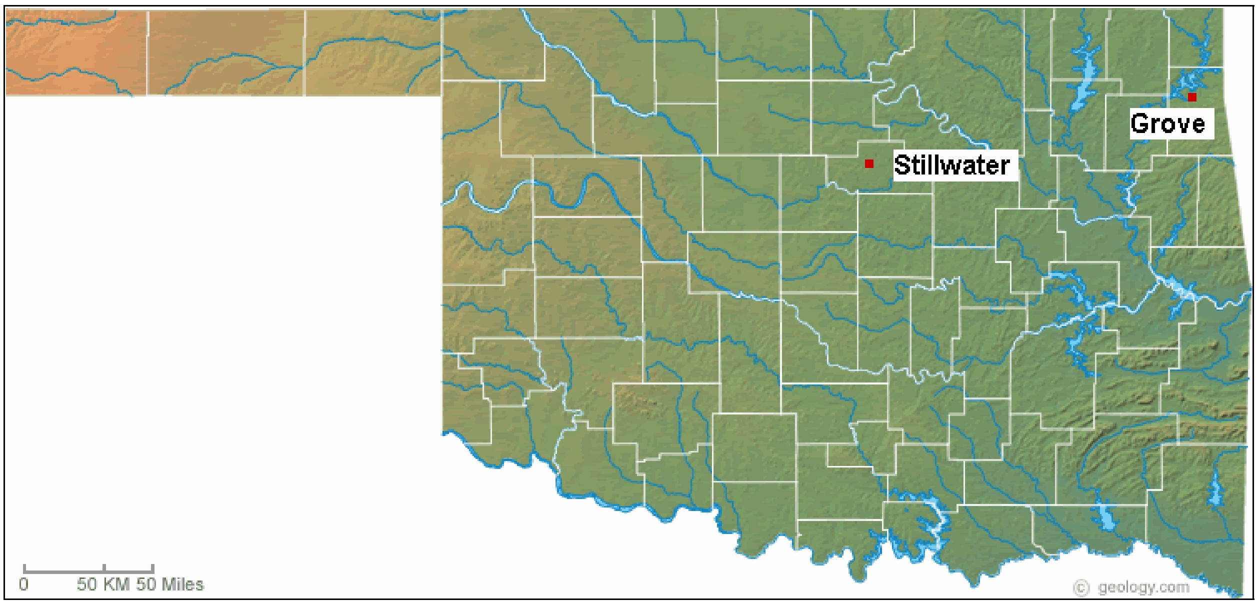

Figure 1. Map of Oklahoma depicting project locations.

Construction Costs

Two sites have been added to the project and will be part of an environmental research and education program in partnership with the Oklahoma State University Botanical Gardens in Stillwater, Oklahoma. Cell A and Cell B will receive runoff from a short stretch of roadway serving as an entrance into the botanical gardens and a nearby parking lot, respectively. Both the roadway and parking lot will be constructed in Fall 2008.

Land use, property types, and drainage areas are listed in Table 1. Of the sites listed, two are commercial properties, two are residential, and six are public. Land use includes both paved and turf or grass runoff surfaces. Additionally, there is one site where the paved surface and the grass surface are approximately equal, and one where the runoff is intercepted primarily from a roof surface. Drainage areas vary from 0.11 acre to 1.90 acres, with all but one being less than one acre.

Table 1. List of sites designated for bioretention cell installation in Grove and Stillwater, including property type, land usage, and drainage area.

Site	**Property Type**	**Land Use**	**Drainage Area (Acres)**
Elm Creek Plaza	Commercial	Paved	0.62
Lendonwood Gardens	Public	Turf	0.54
Grove High School	Public	Paved	0.65
Grand Lake Association	Public	Paved/Turf	1.90
Cherokee Queen Riverboats	Commercial	Paved	0.45
Early Childhood Development Center	Public	Paved (Roof only)	0.11
Spicer Residence	Residential	Turf	0.39
Clark Residence	Residential	Turf	0.18
OSU Botanical Gardens, Cell A, Stillwater	Public	Paved	0.32
OSU Botanical Gardens, Cell B, Stillwater	Public	Paved	0.90

The sites listed in Table 2 were constructed by a contractor selected through a formal state bidding process. All eight sites are located in Grove, Oklahoma. Cost was bid by on a volume basis and includes mulch but not vegetation. Cell cost ranged from $7,368 to $29,172. Final costs for all cells, with the exception of the Spicer residence were the same as the bid cost. Increased quantities of sod and soil quantities due to changes in design were responsible for the $1500 difference between bid cost and final cost for this cell.

Table 3 lists the two bioretention cells constructed at the Oklahoma State University Botanical Gardens in Stillwater, Oklahoma. These cells were constructed primarily “in house.” Excavation was professionally contracted, though not through a bidding process as were the cells listed in Table 2. Final costs for both Cell A and Cell B were $4753 and $11,479, respectively. This was more than the estimated costs due to increased soil stabilization costs (hydromulching in place of sod), an increase in scope for excavation to include the trenching for the drainage outlets, and increased costs for sand, hauling and labor.

Table 2. Bioretention cell area, volume and cost as bid and constructed by a contractor in Grove, Oklahoma.

Location	Area (m^2)	Volume (m^3)	Bid Cost	Final Cost
Elm Creek Plaza	63	128	12,496	12,496
Lendonwood Gardens	23	19	8,847	8,847
Grove High School	149	161	17,071	17,071
Grand Lake Association	172	435	29,173	29,173
Cherokee Queen Riverboats	116	108	13,796	13,796
Early Childhood Development Center	48	70	10,715	10,715
Spicer Residence	101	93	11,771	13,271
Clark Residence	30	27	7,368	7,368

Table 3. Bioretention cell area, volume and cost as constructed by Oklahoma State University .

Location	Area (m^2)	Volume (m^3)	Estimated Cost	Final Cost
Cell A	28	66	3000	4,753
Cell B	160	208	7000	11,479

A linear regression equation was fit to cell cost as a function of volume for both contractor and in-house constructed cells in Figure 2. There is a difference of approximately $6000 between contractor and in-house construction costs. However, the price difference may decrease as bioretention technology becomes more common in the region and contractors learn more about what cell construction entails. Competition may also contribute to a decrease in contractor constructed projects.

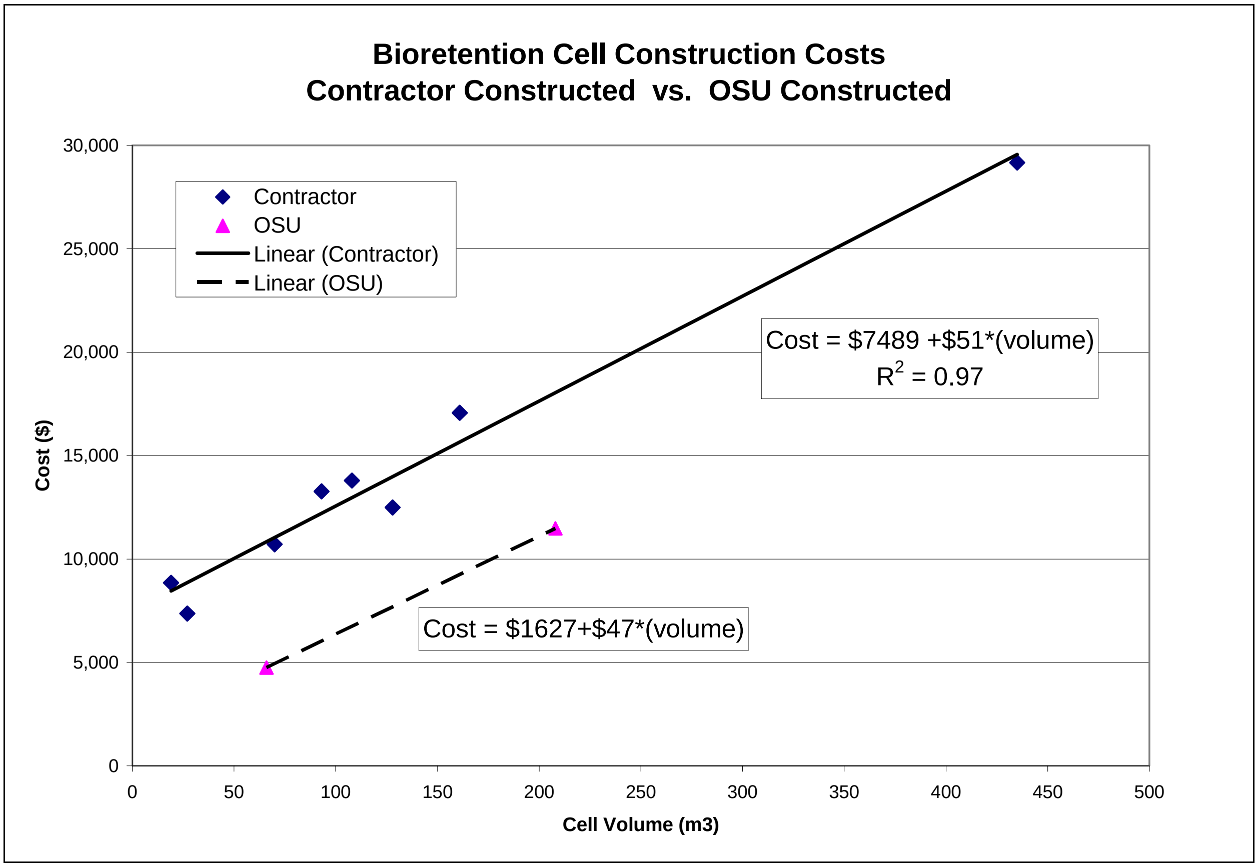

Figure 2. Comparison of Bioretention Cell costs; contractor versus OSU constructed cells.

Planting Costs

Planting was not part of the construction contract as bid through the state. Eight of the cells have been planted and are listed in Table 4. Material costs ranged from $526 to $3025, depending on cell area and plant selection. Quantities were based on 65% surface coverage.

Mulch was included in the construction costs. However, three cells required additional mulch at the time of planting due to losses from cell failure, inadequate mulch size, and submersion from extreme lake water elevations. Three of the cells were planted as volunteer opportunities. The rest were contracted out. Labor costs, as listed in Table 4, were based upon total man-hours required per cell. Plant materials and labor for the two cells in Stillwater will be provided by the OSU Botanical Gardens as part of the above mentioned environmental research and education program.

Table 4. List of Bioretention Cells plant material, mulch, and labor costs in Grove, Oklahoma.

Location	Area (m^2)	Plant Cost	Mulch Cost	Labor Cost	Total Cost
Elm Creek Plaza	63	796	144	750	1690
Lendonwood Gardens[a,b]	23	546	-	-	546
Grove High School[a]	149	1280	-	750	2030
Grand Lake Association	172	3025	456	1000	4481
Cherokee Queen [a] Riverboats	116	870	-	500	1370
Early Childhood [a] Development Center	48	449	-	400	849
Spicer Residence[b]	101	1094	150	-	1244
Clark Residence[a,b]	30	526	-	-	526

a – Mulch was included in the cost of construction and no extra was needed at the time of planting
b – Bioretention cell was planted by volunteers

Lessons Learned

With any project, some things go better than expected and others can be improved upon. Experience is a good teacher, and the lessons learned during practical applications can be invaluable. Overall, the design process translated well to the construction of the bioretention cells for this project. However, there is always room for improvement. Key lessons learned from the field are presented in this section.

Mixing fly ash in the field presented a challenge and was approached using two methods. The first involved mixing loads of media with heavy equipment before placement in the cell. A load of sand was deposited near the cell site; the appropriate amount of fly ash was then mixed into the sand by repeatedly filling the bucket of a backhoe and pouring it back over the pile containing the sand and fly ash, until an even blend was achieved. The second method entailed using a roto-tiller to mix media in lifts inside the cell. A 6 inch lift of sand was placed into the cell. The appropriate amount of fly ash was then evenly distributed on top and tilled into the sand. Samples are being analyzed to determine which method achieved a more consistent mix of sand and fly ash.

Another area of interest was to observe the differences in capabilities and costs when comparing construction by a contractor versus construction in-house. On average, the contractor was able to complete a cell within four days, with three people, a backhoe and a bobcat. The cells constructed by OSU averaged six days, using five people, two tractors, a dingo, and a roto-tiller. Most of the additional time required for the in-house construction was during the backfilling process. The contractor was able to use heavy equipment with a greater capacity for moving soil than the process employed the in-house team, which relied more on man-power and smaller, more readily available equipment. It costs approximately $6000 more to have a contractor build a cell. However, it takes half the time and considerably less man power and equipment. Differences in cost and labor are attributed to the issues surrounding man versus machine and in-house versus contractor labor.

There were two cell failures. The first was at Elm Creek Plaza, where the cell is receives runoff from a parking lot and abuts a stream to the back. Berm failure occurred due to excess water from a neighboring property during a 50 year storm and poor placement of the overflow weir. The cell was repaired and reinforced, and the overflow was moved to a different location to alleviate the possibility of a repeated failure. One positive outcome is that immediate benefits with regard to erosion have been observed at this site. The second failure was at the Spicer residence. The cell is located near the lakefront, above the GRDA takeline and the U.S. Army Corps of Engineer's regulation line. Excessive rains after a long period of drought have caused the lake to rise to unusually high elevations. The shore effects at the high lake elevations caused erosion of the cell berm. Repairs are scheduled to commence once the water recedes. High water levels around the lake area also delayed construction and even submerged at least one cell

Conclusion

In conclusion, high water levels and flooding are increasing in frequency, highlighting the importance of stormwater best management practices, specifically low-impact development. Making the technology more accessible, by providing design and construction guidance, in conjunction with cost analysis, will maximize the benefits through widespread use and awareness.

References –

Chavez, R.A., G.O. Brown, and D.E. Storm. 2006. Bioretention Cell Design for Full Scale Project in Grove, Oklahoma. ASABE Paper No. 062305. St. Joseph, Mich: ASABE.

Chavez, R.A., G.O. Brown, and D.E. Storm. 2007. Bioretention Cell Design and Construction Specifications. ASABE Paper No. 072268. St. Joseph, Mich: ASABE.