LANDSCAPE PERFORMANCE SERIES
presented by the Landscape Architecture Foundation

North Carolina Botanical Garden Education Center

Methodology for Landscape Performance Benefits

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Overview of CSI: This investigation was conducted as part of the Landscape Architecture Foundation's 2015 *Case Study Investigation* (CSI) program. CSI matches faculty-student research teams with design practitioners to document the benefits of exemplary high-performing landscape projects. Teams develop methods to quantify environmental, economic and social benefits and produce Case Study Briefs for LAF's *Landscape Performance Series*.

The full case study can be found at: https://landscapeperformance.org/case-study-briefs/north-carolina-botanical-garden

Landscape Performance Benefits & Methodologies

Environmental Performance Benefits

- *Captures and treats approximately 6,247,000 gallons of stormwater runoff annually, including all rain events under 1.5 in, or 75% of all storms.*

Method:
All stormwater calculations were modeled using the US EPA National Stormwater Calculator using the following known values:

- Average annual rainfall in Chapel Hill, NC = 49.11”
- Impervious surface = 41,992 ft^2
- Porous pavement = 50,312 ft^2
    - Holding capacity of pavement system = 1.8” for 30 hours
- Eight (8) bioretention basins = 4,142 ft^2
- Eight (8) cisterns = 54,400 gallons

Data:
The Chapel Hill Land Use Management Ordinance, adopted January 2003, requires that “the stormwater runoff rate leaving the site post-development shall not exceed the stormwater run-off rate leaving the site pre-development for the local 1-year, 2-year and 25-year storms” (Neal, print). Therefore, the system is designed to manage a 25-year, or 1.5”, storm event. The new design required an addition of 41,992 ft^2 of impervious surfaces and other land changes that would increase peak rates of runoff. As a result the design uses 50,312 ft^2 of porous pavement parking, which has a 30-hour water holding capacity of 1.8” and eight (8) bioretention basins equaling 4,142 ft^2 to treat the runoff from the runoff from the new impervious areas. The system also contains 54,400 gallons of cistern holding capacity.

Land Cover Analysis:

- CAD file calculation (Figure 2): Impermeable area ~ 28%
- Base Map area proportion (Figure 3): Impermeable area ~ 40%
    - Average Impermeable Area = (28+40) / 2 = **34% = 110785.365 ft^2**

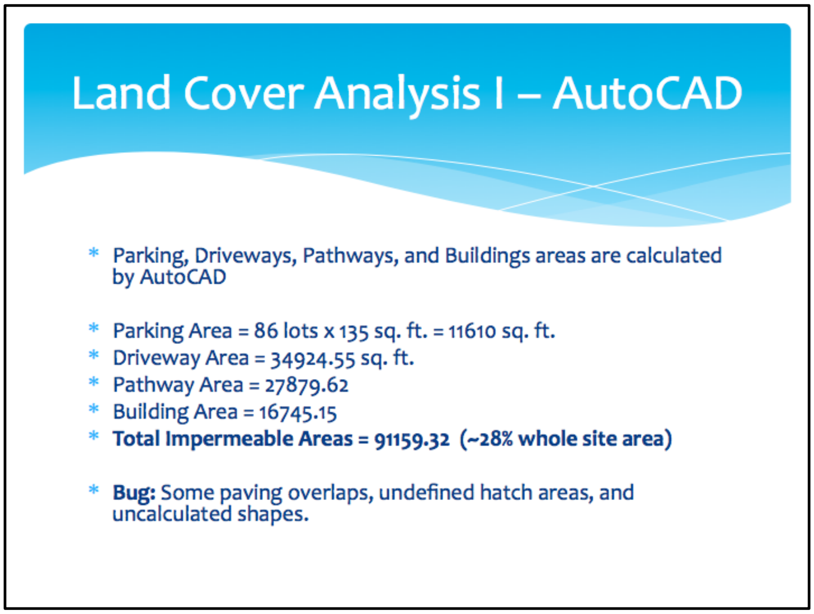

Figure 1: Land use analysis (I) of construction CAD base

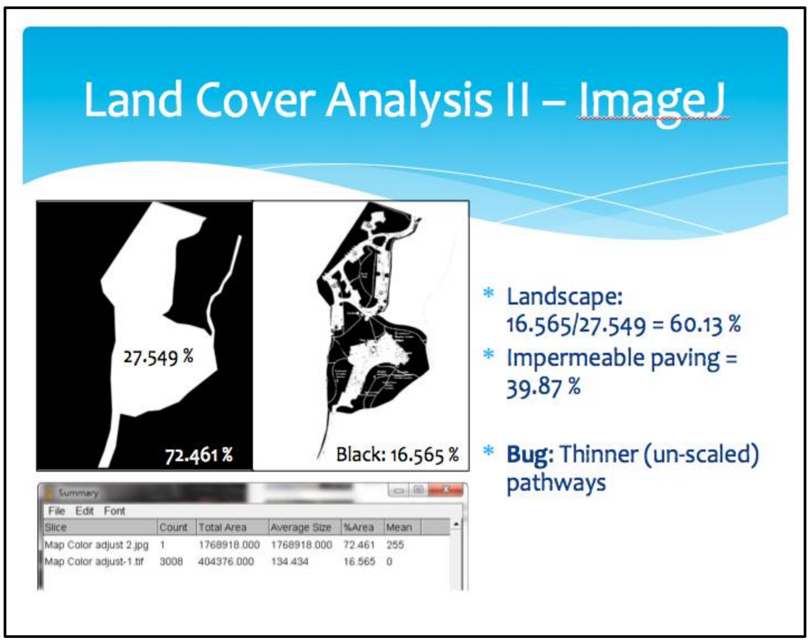

Figure 2: Land use analysis (II) of current graphic base map

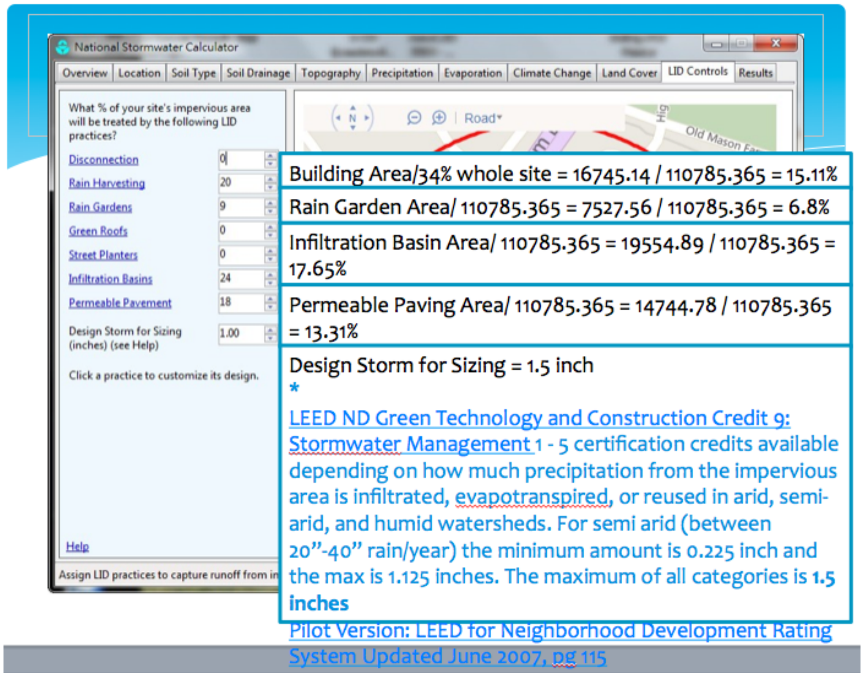

Figure 3: Defining and calculating the performance of various LID features in the US EPA National Stormwater Calculator

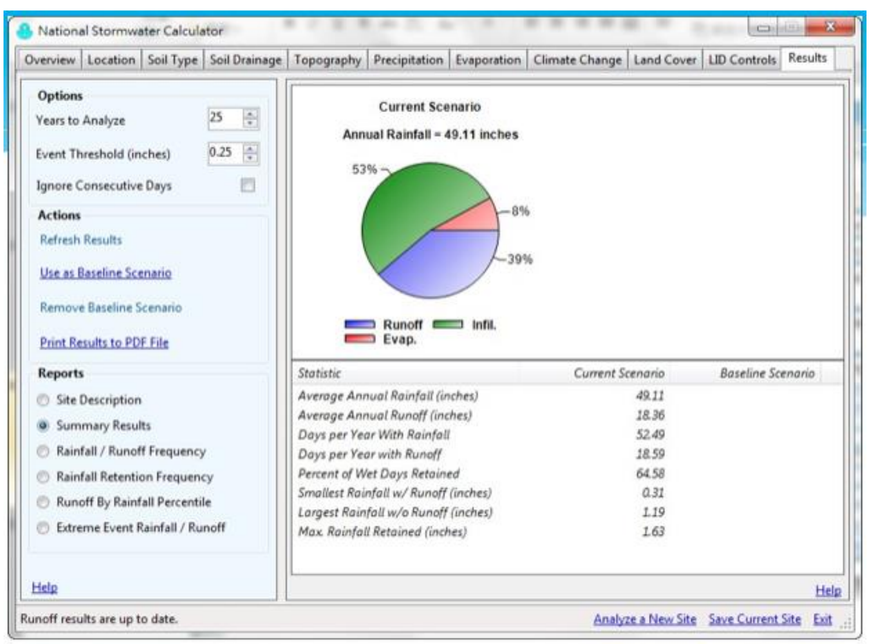

Figure 4: Post-development runoff model

Runoff Reduction Totals:

Average Annual Runoff = 49.11"

Development Average Annual Runoff = 18.36"

49.11" - 18.36" = 30.75"

Treatment Volume Conversion:
Total cistern capacity = 54,400 gal
Annual Average Runoff Difference: 30.75"
Runoff Volume = Runoff depth * drainage area
Reduction Volume = 30.75" * 325,891.31 sf. = 835,096.482 cubic ft., or ~ 6,246,955 gals.

Rain Event Frequency (Figure 5):
0" - 0.25" = 12%
0.25" - 0.5" = 16%
0.5" - 1.0" = 28%
1.1" - 1.5" = 19%
Total = 75%

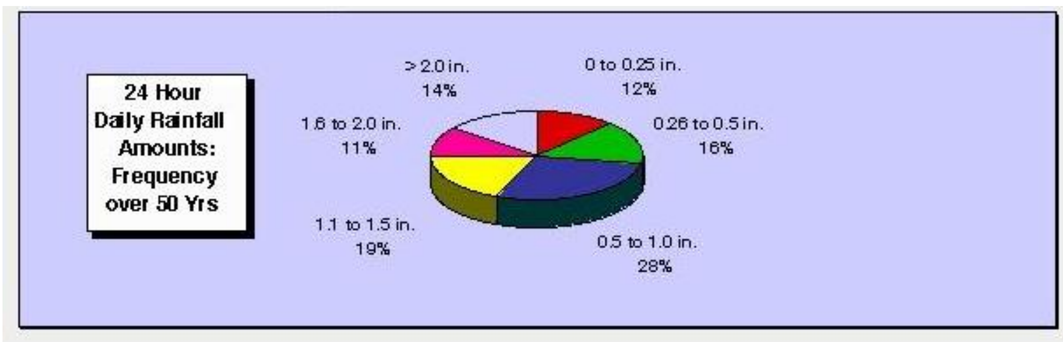

Figure 5: Rainfall frequency data for Chapel Hill, North Carolina

Limitations:
The land cover analyses used to determine cover types and runoff coefficients may deviate from actual site conditions. Areas in Analysis I contain slight paving overlaps, undefined hatch areas, and uncalculated shapes. Additionally, areas in Analysis II were delineated over an updated jpeg base map graphic, therefore specific dimensions of small, un-scaled pathways may include a slight margin of error due to thicknesses of lines, etc.

Actual storm event collection data was not available; therefore all calculations and resulting conclusions were made using the US EPA National Stormwater Calculator.

References:
Neal, Michael A. *North Carolina Botanical Garden Visitor Education Center: Chapel Hill, NC: Stormwater Management.* North Carolina: MANA. Print.

US EPA. 2015. National Stormwater Calculator, available online: http://www2.epa.gov/water-research/national-stormwater-calculator

- *Eliminates the use of potable water for irrigation.*

Method:
Obtained cistern and watering information from both the project landscape architect and the NCBG Director of Horticulture.

Data:
Since the installation of the cisterns, potable water has not been used for irrigation (per Ward, 2015).

Limitations:
The cisterns do not have monitoring devices and are buried within the garden, therefore there is no way to acquire specific data regarding the amount of water used, the associated draw-down time, and/or the total amount of water captured in the cistern.

References:
Correspondence with Jim Ward, Director of Horticulture, North Carolina Botanical Gardens, on June 1, 2015

- *Reduces summer parking lot surface temperature by 13.4° F using high-albedo pavers as compared to nearby asphalt*

Method:
The EPA recognizes the effects of urban heat and has made a number of suggestions for the mitigation of urban heat, one of which is the usage of high albedo paving materials. In order to illustrate the effectiveness of this design decision at NC Botanical Garden, surface temperatures of the site's high albedo paving were compared to nearby surface temperatures of low-albedo pavements. A solar pathfinder was used to ensure that the locations for temperature readings received the same amount of solar radiation.

Data:
Temperature data was gathered on June 30, 2015 between 7:30 and 7:45 am and again between 2:00 and 2:15pm. Based on weather data taken from a station on the site, the morning temperature was 65°F with 90% humidity and the afternoon temperature was 90.5°F and 55% humidity. There were scattered clouds throughout the day, however all readings were taken when no cloud cover was present.

Equation:

- Average low albedo temperature - Average high albedo temperature = Average Temperature difference
    - 106.63°- 93.2° = 13.43°

Limitations:
Obtaining temperature averages over a 24-hour period of time and through different types of weather would give a more accurate reading of the temperature differences between the two surfaces.

References:
US EPA. (2015). Available online: http://www.epa.gov/heatislands/mitigation/index.htm

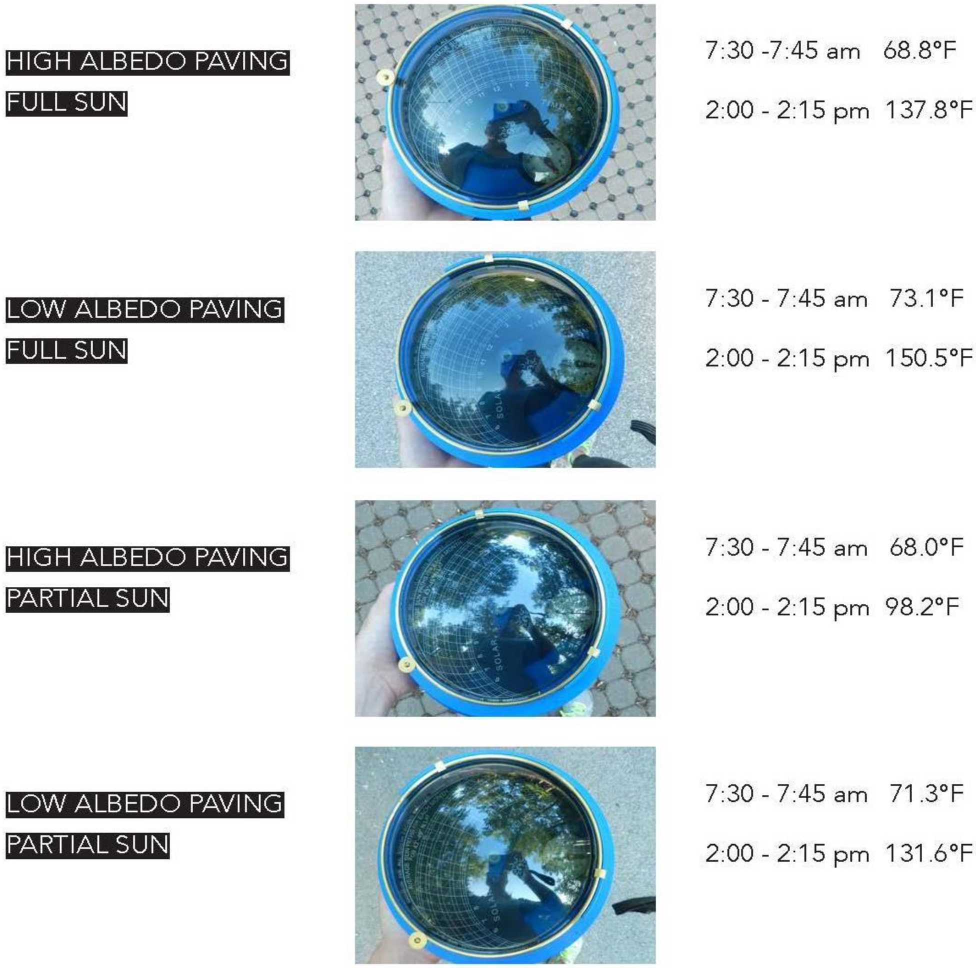

Figure 6: Temperature recordings at various paving conditions, with times, conditions, and results

- *Saved over 5.5 billion BTUs in embodied energy by using recycled concrete to construct site walls instead of cast-in-place concrete.*

Method:

Embodied energy is an important calculation for landscape architects to make as it can be used to compare the environmental impacts different materials and, in this case, the environmental impacts avoided by using recycled materials. As described by Meg Calkins, "embodied energy refers to the total energy consumed in raw material acquisition, manufacture, transport, use and disposal of building material/product" (p.337). The standard unit of calculation for embodied energy is the British Thermal Unit, or BTU. One (1) BTU is the amount of energy needed to raise the temperature of one (1) pound of water one (1) degree Fahrenheit.

The BTU data and standard baseline conversion equations were sourced from *Sustainable Landscape Construction* (Thompson and Sorvig, 2007). All calculations, including BTU equivalents and conversions, are provided below.

Data:

Project Data:

- Recycled, broken concrete retaining wall material = 58,094 CF (Swanson 2015)
    - Number verified by NCBG Contractor Pay Application (2007) = $21,517 for Broken Concrete Wall Materials:
        - $21,517.00 / 2,152 CY (see CF to CY conversion below) = $10.00/CY

BTU Conversion Data:

- Concrete = 96,100 BTU/CF

Materials by Volume	*CSI*	*AvgEst Btu/Cu Ft*
Concrete, ready CF	3.1	96,100
Concrete, ready CY	3.1	2,590,000
Lumber, hardwood	6.0	9,820
Lumber, softwood	6.0	8,555
Lumber, glue-lam beams	6.1	15,611
Lumber, plywood	6.1	14,883
Lumber: Roughsawn	6.1	495
Waterproofing, asphalt	7.1	8,639
Insulation, rigid polystyrene	7.2	15,300
Paint, exter oilbased	9.9	488,264
Paint, exter waterbased	9.9	489,032
Stains & Varnishes	9.9	503,668

Figure 7: BTU conversion table from Thompson and Sorvig, 2007

Calculations:

- Cubic Feet (CF) to Cubic Yard (CY) conversion:
    - 58,094*037037037 CY (or divide by 27) = **2,151.63 CY**
- CF to BTU conversion:
    - Concrete, ready CF = 96,100 BTU/CU FT (Thompson and Sorvig 2007)
        - 96,100*58,094 = **5,582,833,400 BTU**
- CY to BTU conversion:
    - Concrete, ready CY = 2,590,000 BTU/CU FT (Thompson and Sorvig 2007)
        - 2,590,000*2,151.63 = **5,572,721,700 BTU*****

Limitations:

The unit BTU cost values provided by Thompson and Sorvig resulted in a slight variation of calculated BTUs per a consistent volume (-10,111,700 BTUs = 1% deviation). The authors chose to report the lower calculated value (BTU per cubic yardage*** (CY)) so as to not overstate the performance benefits.

References:

Calkins, M. (2009). *Materials for sustainable sites: a complete guide to the evaluation, selection, and use of sustainable construction materials.* Hoboken, NJ: Wiley.

Correspondence with David Swanson, Landscape Architect, North Carolina Botanical Garden on May 22, 2015 and July 14, 2015.

North Carolina Botanical Garden, Contractor Application and Certification for Payment: Continuation Sheet (AIA Document G703), page 2, November 20, 2007.

Thompson, J. William, and Sorvig, Kim. (2007). Sustainable Landscape Construction: A Guide to Green Building Outdoors (2nd Edition). Washington, DC, USA: Island Press.

Wilcock, William. (2005). *Energy in natural processes and human consumption worksheet*. ENVIR215 Earth, Air, Water: The Human Context. University of Washington. Available online: http://www.ocean.washington.edu/courses/envir215/energynumbers.pdf

Social Performance Benefits

- *Attracts 6,300 participants annually with an average of 189 programs, classes, and events.*

Method:
Obtained total numbers of programs and program participants from project owner.

Data:

		Attendants	Programs
	2009 – 9 months	84	30
	2010- 12 months	1,369	129
	2011- 12 months	4,270	188
	2012- 12 months	12,142	276
	2013- 12 months	10,280	244
	2014 – 6 months	5,388	139
Totals	**5 years & 4 months or 64 months**	33,533	1,006

Figure 9: NCBG Program and participation records

Average Annual Programs = 189
- Average Annual Programs = (Total # Programs / Total # of Months) * 12
- 1,006/64 = 15.7
- 15.7 * 12 = 188.6

Average Annual Visitors = 6,287
- Average Annual Visitors = (Total # visitors/ Total # of Months) * 12
- 33,533/ 64 = 524
- 524 * 12 = 6,287.4

Limitations:
N/A

References:

Correspondence with Jim Ward, Director of Horticulture, North Carolina Botanical Gardens, on June 1, 2015.

- *Provides opportunities for 250 volunteers and generates 10,700 volunteer hours annually, with an estimated value of $250,000. Total volunteer hours increased by 35% after the Education Center's opening.*

Method:

Calculations were developed using the best available data provided by the project owner.

According to *Independent Sector*, a coalition of charities, foundations, corporations, and individuals that publishes research important to the nonprofit sector, monetizing the value of volunteer time is a generally accepted way of valuing volunteer time. As indexed from the U.S. Bureau of Labor Statistics data, the 2014 rate in the State of North Carolina was $21.47, based on an average of hourly earnings of all production and non-supervisory workers on private, non-farm payrolls, plus 12% (Independent Sector, 2015).

Data:

Volunteer hours:

Pre-install= 150 volunteers @ 7,000 hours (average = 46.67 hrs/person)
2011 = 235 volunteers @ 10,871 hours (average = 46.26 hrs/person)
2012 = no data
2013 = 235 volunteers, no data of hours
2014 = 280 volunteers @ 10,572 hours (average = 37.76 hrs/person)

Volunteers:

235+235+280 = 750/3 = 250 average annually recorded volunteers

Hours:

(10,871+10,572)/2 = 10,721.5 average annually recorded hours

- 3,721.5 / 10,721.5 = .3471 (35% increase)

Monetary valuation:

10,871+10,572 = 21,443 total recorded (2011+2014)

- 21,443*21.47 = **$460,381.21**

Limitations:

No data was available for 2012, and volunteer hour data was not provided for 2013.
The garden staff feels that the hours reported are undercounted by about 30%, so there is little risk of over-reporting.

References:

Correspondence with Jim Ward, Director of Horticulture, North Carolina Botanical Gardens, on June 1, 2015

Independent Sector. (2015). Available online: http://www.independentsector.org/volunteer_time

Cost Comparison:
The client and the design team agreed early in the process to pursue a Platinum Level LEED rating, resulting in the acceptance of additional upfront capital costs. For example, the project included a permeable parking lot to filter and store stormwater. The cost of using a permeable unit pavement system resulted in an approximate average cost increase of $323,994.00 over traditional paving materials, such as asphalt or concrete. At an average total system cost of $12.00/sf (Swanson 2015), the cost of installing the parking lot permeable unit paving system, including subsurface structural gravels concrete containment bands, was $460,000.00, whereas the cost of concrete ($3/sf (Swanson 2015), with an estimated total of $145,190.00) or asphalt ($3.32/sf (Maira 2015), with an estimated total of $126,821.00) were cheaper alternatives.

Calculations:
- (144,624 (concrete) + 126,821 (asphalt))/2 = 136,005.5
- 460,000 - 136,006 = 323,994
    - Concrete:
        - $3.80/sf *38,208 = $145,190.00
    - Asphalt:
        - 38,208/9(sy) = 4,245.33 x $11.50sy = $48,821 + $48,000 C.I.P. curb + $30,000 aggregate $3.30/sf = $126,821.
- Note: Asphalt and concrete pricing is not inclusive of striping. Striping was not required for the permeable unit paving system because different colored pavers were used to delineate parking stalls, drive aisles, etc.

References:
Correspondence with David Swanson, Swanson Associates, PA on July 10, 2015

Maira, Kevin. Project manager at Rustin Paving Company, Inc. Asphalt paving estimate provided forwarded by David Swanson, Swanson Associates, PA on July 10, 2015