Frontier Project – Rancho Cucamonga, CA
Methodology for Landscape Performance Benefits
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Environmental

Infiltrates or reuses all rainwater falling on the site for up to a 5-year storm event, preventing an estimated 48,878 gallons from entering the local municipal stormwater system for each 5-year event.

Table 1: 5-year Small Area Unit Hydrograph Results (Source: RFB Consulting)

		5-year event				
Condition	A **= Drainage Area (ac)** [1]	T_c **= Time of Concentration (min)**	Q **= Peak Discharge (cfs)**	**Volume per** T_c **(ac-ft)**	**Volume (gal.)**
Pre-Development	0.79	7.81	1.36	0.0146	4758
Developed (w/o BMP mitigation)	0.86	6.28	1.9	0.1561	50,868
Developed with BMPs	0.86	7.95	1.21	0.15	48,878

[1] *Derived from construction document takeoffs.* Site Paving Plan, Concrete Stairs, & Roof Deck: *6029-BSCN.dwg.* 2008. EPT Design.

The peak discharge for pre-development, for expected development without BMPs, and for expected with BMPs was calculated by the stormwater consultant alongside the design team. The equation used to calculate peak discharge is $Q = C*i*A$, where Q is peak discharge, C is the runoff coefficient of the land cover material, i is the average intensity of rainfall on the site per the time of concentration (T_c), and A is the drainage area (San Bernardino Hydrology Manual, 1986).

The pre-development condition produced a calculated 4,758 gallons of runoff during a 5-year storm event. With the BMPs implemented (thus increasing the time of concentration and decreasing the amount of runoff), the site was anticipated to produce 48,878 gallons of runoff. The site however collects 100% of the runoff by means of the BMPs, which store runoff in the cistern or infiltrate it into the ground. Ultimately all water is infiltrated to recharge groundwater.

Reduces irrigation water needs by over 75% as compared to a conventional Southern California landscape through the use of water-wise native plants and an efficient drip irrigation system.

Calculations were done for three scenarios: typical irrigation water use for a traditional Southern California landscape, as-designed irrigation water use for the site, and actual irrigation water use for the site. The performance benefit only compares irrigation water use of a traditional landscape with the site's actual irrigation water use. The as-designed irrigation water use calculations are included here to serve as a point of reference only.

The format for calculating water usage for irrigation (as seen in Tables 2-1 and 2-2) was derived from the LEED Calculator 2.2 for the Water Efficient Landscaping credit (WE Credit 1).

Table 2-1: Conventional Southern California Landscape Irrigation Usage (Source: Adapted from LEED 2.2 Water Efficiency Calculator)

Landscape Type	Evapo-transpiration Rate (July)[1] ET_0	Area[2] [SF]	Species Factor (k_s)	Density Factor (k_d)	Microclimate Factor (k_{mc})	K_L (k_s*k_d*k_{mc})	Landscape-specific Evapotranspiration Rate ET_L (ET_o*k_L)	Irrigation Type & Efficiency IE		Total Water Applied (July) [gal] A*(ET_L / IE)*0.6233
Turfgrass	8.12	11,463	0.8	1.0	1.2	0.960	7.795	Sprinkler	0.625	89,113.328
Shrubs, High		3,679	0.7	1.1	1.3	1.001	8.128	Sprinkler	0.625	29,822.016
Trees, Average		4,452	0.5	1.0	1.0	0.500	4.060	Sprinkler	0.625	18,025.146
Total		**8,131**						**Net Gallons of Water Applied** [gal]		**136,960**

Table 2-2: As-Designed Irrigation Usage (Source: Adapted from LEED 2.2 Water Efficiency Calculator)

Landscape Type	Evapo-transpiration Rate (July)[1] ET_0	Area[2] [SF]	Species Factor (k_s)	Density Factor (k_d)	Microclimate Factor (k_{mc})	Landscape Coefficient K_L (k_s*k_d*k_{mc})	Landscape-specific Evapotranspiration Rate ET_L (ET_o*k_L)	Irrigation Type & Efficiency IE [IE]		Total Water Applied (July) [gal] A*(ET_L / IE)*0.6233
Shrubs, Low	8.12	11,463	0.2	1.0	0.5	0.100	0.812	Drip	0.900	6,446.277
Shrubs, Average		3,679	0.5	1.0	1.0	0.500	4.060	Drip	0.900	10,344.522
Trees, Low		1,142	0.2	0.5	0.5	0.050	0.406	Drip	0.900	321.105
Trees, Average		3,310	0.5	1.0	1.0	0.500	4.060	Drip	0.900	9,306.415
Total		**19,594**						**Net Gallons of Water Applied** [gal]		**26,418**

[1] *See Table 2-4 for origin of data*
[2] *Area derived from construction document takeoffs.* EPT Design. 2008 . "Site Paving Plan, Concrete Stairs, & Roof Deck." *6029-BSCN.dwg.*
[3] *See Table 2-5 for origin of data*

Table 2-3: Actual Irrigation Usage (Source: EPT Design)

FRONTIER PROJECT - MONTHLY WATER USAGE CALCULATIONS							
Valve	Station	Irrigation method	Daily Run-time (minutes)	Station GPMs (Gallons per minute)	Gallons/day	Gallons (6) days/week	Gallons/month
B1	1	Drip emitters	30	15	450	2700	10800
B2	2	12" Drip Line	7	5	35	210	840
B3	3	Drip emitters	0	11	0	0	0
B4	4	Drip emitters	15	12	180	1080	4320
B5	5	Drip tubing	5	8	40	240	960
B6	6	Drip - shrub/grnd cover	15	11	165	990	3960
B7	7	Drip emitters	10	29	290	1740	6960
B9	8	Drip emitters	7	16	112	672	2688
A1	9	Tree root bubblers	0	22	0	0	0
A2	10	Tree root bubblers	10	14	140	840	3360
B9	11	Drip - shrub/grnd cover	0	13	0	0	0
			TOTALS	156	1412	8472	**33,888**

Note: Table 2-3 was produced by EPT Design by measuring each irrigation controller's output of water in gallons per minute and the daily run time. Each controller's total gallons per month of irrigation water were then calculated and then added together to get the net gallons of water applied for the entire landscape.

Table: 2-4: Monthly Average ETo Report (Source: California Irrigation Management Information System)

Number	Name	Region
192	Lake Arrowhead	San Bernardino

Stn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
192	1.77	2.60	4.58	5.95	7.04	7.63	8.12	7.36	5.43	4.05	2.36	1.75	58.64

Note: Monthly Average ETo. Station 192-Lake Arrowhead, Since March 2004. Department of Water Resources. Office of Water Use Efficiency. http://wwwcimis.water.ca.gov/cimis/frontMonthlyEToReport.do

Table 2-5: Landscape Factors (Source: USGBC-LEED. "LEED-NC Version 2.2 Reference Guide: Water Efficiency". Pg 120)

Vegetation Type	Species Factor (k_s)			Density Factor (k_d)			Microclimate Factor (k_{mc})		
	low	average	high	low	average	high	low	average	high
Trees	0.2	0.5	0.9	0.5	1.0	1.3	0.5	1.0	1.4
Shrubs	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.3
Groundcovers	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.2
Mixed: trees, shrubs, groundcovers	0.2	0.5	0.9	0.6	1.1	1.3	0.5	1.0	1.4
Turfgrass	0.6	0.7	0.8	0.6	1.0	1.0	0.8	1.0	1.2

The **average evapotranspiration (ETo) rate for July** is specific to the San Bernardino region and the Monthly Average ETo Report (Table 2-4) comes from the Lake Arrowhead station, 25mi from the Frontier Project.

The **Areas** for each planting type were derived from construction document takeoffs. In order to arrive at an estimated area for each planting type for the baseline case, it was assumed that all low-watering-needs shrubs (the majority of the site) would typically have been planted with a high-watering-need turfgrass. The average-watering-needs shrubs would have typically been high-watering-needs ornamental shrubs. And the variation in low to average-watering-needs trees would have typically been planted with all average-watering needs trees.

The values used in Tables 2-1 and 2-2 for **Species Factor (k_s)**, **Density Factor (k_d)**, and **Microclimate Factor (k_{mc})** were referenced from the LEED Water Efficiency Manual.

The following six definitions are borrowed from the LEED Water Efficiency Manual, pgs 119-120:

> The **Species Factor (k_s)** accounts for variation of water needs by different plant species. The species factor can be divided into three categories (high, average and low) depending on the plant species considered… This factor is somewhat subjective but landscape professionals should have a general idea of the water needs of particular plant species. Landscapes can be maintained in acceptable condition at about 50% of the reference evapotranspiration (ETo) value and thus, the average value of k_s is 0.5. (Note: If a species does not require irrigation once it is established, then the effective $k_s = 0$ and the resulting $K_L = 0$).
>
> The **Density Factor (k_d)** accounts for the number of plants and the total leaf area of a landscape. Sparsely planted areas will have lower evapotranspiration rates than densely planted areas. An average k_d is applied to areas where ground shading from trees is in the range of 60% to 100%. This is also equivalent to shrubs and ground cover shading 90% to 100% of the landscape area. Low k_d values are found where ground shading from trees is less than 60% or shrub and groundcover is less than 90%. For instance, a 25% ground shading from trees results in a k_d value of 0.5. In mixed landscape plantings where trees cover understory groundcover and shrubs, evapotranspiration increases. This represents the highest level of landscape density and the k_d value should be between 1.0 and 1.3.

The **Microclimate Factor (k_{mc})** accounts for environmental conditions specific to the landscape, including temperature, wind and humidity… The average k_{mc} is 1.0 and this refers to conditions where the landscape evapotranspiration rate is unaffected by buildings, pavements, reflective surfaces and slopes. Higher k_{mc} conditions occur where evaporative potential is increased due to landscapes surrounded by heat-absorbing and reflective surfaces or are exposed to particularly windy conditions… Low microclimate areas include shaded areas and areas protected from wind.

The **Landscape Coefficient (K_L)** indicates the volume of water lost via evapotranspiration and is a product of the species factor, the density factor, and the microclimate factor. $K_L = k_s*k_d*k_{mc}$

The **Landscape-Specific Evapotranspiration Rate (ET_L)** for each landscape area is thus the product of the Regional Evapotranspiration Rate by the Landscape Coefficient. $ET_L = ET_O*K_L$

The **Irrigation Efficiency (EI)** is based on the type of irrigation system used. The number indicates the relative amount of water emitted from the sprinkler that actually reaches the roots of the plant.

The **Total Water Applied for July** in gallons is then calculated per landscape type by multiplying the Area by the quotient of the Landscape Specific Evapotranspiration Rate and the Irrigation Efficiency and converting the product from square feet to gallons. $TWA = A*(ET_L / IE)*0.6233$ The sum from each landscape type was added together to get the **Net Gallons of Water Applied** for the entire landscape.

Avoids the production of 865 lbs of CO2 annually by eliminating the need for fertilizer, pesticides, and mowing through the use of low-maintenance, climactically adapted native and naturalized plantings.

Table 4: CO_2 Emissions from Landscape Maintenance

Maintenance Activity	CO_2 emission equivalent[1] (lbs/1000Sq.ft/yr)	A = Softscape Area (Sq.ft)[2]	CO_2 emmision equivalent (lbs/yr)
Fertilizer Application	29	19593.75	568.22
Mowing (w/o green roof)	15	18485.15	277.28
Pesticide Application	0.999	19593.75	19.57
Total			865.07

[1] Jones, Pierce. Nd. "Land Development, Landscaping and Greenhouse Gas Emissions." University of Florida. Program for Resource Efficient Communities. http://buildgreen.ufl.edu/ppt/Handout_Landscaping_Carbon_Footprint.pdf

[2] *Derived from construction document takeoffs.* EPT Design. 2008. "Site Paving Plan, Concrete Stairs, & Roof Deck." *6029-BSCN.dwg.*

The three highest-polluting landscape maintenance activities were used as the baseline case for a typical California landscape of equal size. This assumes that a typical landscape would endure all three activities while the Frontier Project's low-maintenance, non-turfgrass, native landscape does not require these maintenance activities. This assumption is supported by the discussion the research team had with the head of the on-site maintenance team.

The CO_2 emission equivalent numbers were derived from the "Land Development, Landscaping and Greenhouse Gas Emissions" research from the University of Florida which can be accessed online at: http://buildgreen.ufl.edu/ppt/Handout_Landscaping_Carbon_Footprint.pdf.

The CO_2 emission equivalent for the entire landscape was then calculated by multiplying the CO_2 emission equivalent numbers by the total area of softscape, all of which is assumed to endure each maintenance activity.

Reduces absorption of solar radiation through the use of high-albedo roofing material and a greenroof, which have solar reflectance index (SRI) values 23 and 7 times higher than that of a conventional blacktop roof.

The Solar Roof Index number is derived from the emissivity rating and reflectance factor of a material. The SRI for the greenroof is 7 times that of a blacktop roof (28/4=7). The SRI for the Terazzo finish roof is 23 times that of a blacktop roof (94/4=23.5). The SRI average for the implemented roof is 21.5 times that of a blacktop roof of equal size (86/4=21.5).

Table 5: Solar Reflectance Index Comparison

Condition	Material	A = Area (Sq.ft) [1]	% of Total Area	Emissivity Rating	Reflectance Factor	SRI [2]	SRI avg
Roof	Greenroof	1110	12.65	0.90 [3]	0.30 [3]	28	86
	Terazzo finish	7664	87.45	0.90 [4]	0.76 [4]	94	
Baseline	Blacktop	8774	100.00	0.86 [5]	0.06 [5]	4	4

[1] *Derived from construction document takeoffs.* EPT Design. 2008. "Site Paving Plan, Concrete Stairs, & Roof Deck." *6029-BSCN.dwg.*
[2] *SRI Calculations done through the following worksheet.* Cool Roof Rating Council (CRRC). 2009. "Solar Reflectance Index (SRI) Calculation Worksheet."
http://www.energy.ca.gov/title24/2008standards/sri_calculator/SRI_Calculator_Worksheet.pdf
[3] Wark, Chris. 2011. "Cooler than Cool Roofs: how Heat Doesn't Move Through a Green Roof." Greenroofs.com. http://www.greenroofs.com/content/energy_editor007.htm
[4] Hill, Holly. 2008. *LEED SS Credit 7.2: Heat Island Effect: Roof*.
[5] Sarnafil Inc., adapted by International Code Council Inc. 2007. "Emissive & Reflective Properties of Common Products." pg 2. http://www.coolroofs.org/documents/ICCtoCRRC-HeatWavePowerPoint_3of3_.pdf

Social

Provides sustainable landscape design education to approximately 5,000 visitors annually through on-site demonstrations, facility tours, special events, workshops, and conferences.

Table 6: Total Visitors to the Frontier Project

	Days	# of event attendees [1]	# of stop-in visitors [2]
2010	365	5488	572
2011	365	5580	
2012 (Jan-June 20)	*201*	*521*	
Daily Average	931	12.45	0.61
Average # of total visitors per year:			4768

[1] Frontier Project. 2010, 2011, 2012. Frontier Project Event Calendar. Provided by Shelley Cirrito – Public Affairs Representative at the Frontier Project.

[2] Frontier Project. 2009-2012. Frontier Project Visitor's Log. Provided by Shelley Cirrito – Public Affairs Representative at the Frontier Project.

Calculations used attendance data compiled from January 1, 2010 through June 20, 2012 (date of site visit). The log of stop-in visitors as well as a composite list of events hosted by the Frontier Project and the number of event attendees for each are kept at the Frontier Project and were provided by Shelley Cirrito. Stop-in visitors were only counted if they sign the Visitor's Log.

Calculating the average number of visitors per day based on the total number of days that the Frontier Project has been open provided an average estimate of visitors per year.

Improves overall workplace satisfaction, with 87% of Frontier Project employees reporting an improved mood, 67% feeling more able to cope with work-related stress, and 53% feeling more relaxed, after viewing, walking through, and spending time in the Frontier Project's landscape.

To assess if the Frontier Project's landscape increases overall workplace satisfaction, we took a census of all (5) Frontier Project employees. Using Survey Monkey (which keeps all answers anonymous) our IRB approved Likert-type scale survey was issued to all employees via email. We received a 100% survey response rate.

Table 7: Census of Frontier Project Employees' Overall Workplace Satisfaction

Questions Asked: Note: the wording of the original survey questions has been simplified for the sake of this chart.	**Sense of Tranquility**	**Overall Mood**	**Ability to cope with work-related stress**
Walking through the Frontier Project's landscape (on my way to and from work) improves my:	40%	80%	60%
Spending time in the Frontier Project's landscape (during breaks and/or lunch) improves my:	20%	80%	60%
Viewing the Frontier Project's landscape (from my office window) improves my:	100%	100%	80%
TOTAL AVERAGE	**53.33%**	**86.66%**	**66.66%**

Notes:

N=5 Respondents
Questions were measured on a Likert-type scale of 1-5 (strongly disagree, disagree, neutral, agree, strongly agree)
Answers were coded in a binary manner (in agreement or not in agreement) with neutral responses being null.
Figures shown in the table are the percent of respondents in agreement with questions asked.

Economic

The Frontier Project is estimated to cost $58 per year to irrigate, whereas irrigating a similarly-sized conventional Southern California landscape would cost $234 per year. This represents an annual savings of $176.

Calculations were done for three scenarios: a traditional Southern California landscape, a projection of the as-designed irrigation water usage costs, and the actual irrigation water usage costs. The cost comparison only highlights traditional landscape costs with the actual irrigation water usage costs, and the as-designed calculations are only meant to compare both to the design intent of the landscape.

Table 8-1: Conventional Landscape Irrigation Costs

Landscape Type	Total Water Applied (July) [1] [gal]	Cost of Water [4] [$/gal]	Cost of Irrigation (July)	Annual Cost of Irrigation (8 months)
Shrubs, High	29,822.016	2.139E-04	$6.38	$51.03
Trees, Average	18,025.146	2.139E-04	$3.86	$30.84
Turfgrass	89,113.328	2.139E-04	$19.06	$152.49
Net Gallons of Water Applied [gal]	**136,960**	**Total Cost**	**$29.30**	**$234.37**

Table 8-2: As-Designed Irrigation Costs

Landscape Type	Total Water Applied (July) [2] [gal]	Cost of Water [4] [$/1000gal]	Cost of Irrigation (July)	Annual Cost of Irrigation (8 months)
Shrubs, Low	6,446.277	0.21390	$1.38	$11.03
Shrubs, Average	10,344.522	0.21390	$2.21	$17.70
Trees, Low	321.105	0.21390	$0.07	$0.55
Trees, Average	9,306.415	0.21390	$1.99	$15.93
Total	**26,418**	**Total Cost**	**$5.65**	**$45.21**

Table 8-3: Estimated Costs Based on Actual Irrigation Usage

Total Water Applied (July) [3] [gal]	Cost of Water [4] [$/gal]	Cost of Irrigation (July)	Annual Cost of Irrigation (8 months)
33,888	**2.139E-04**	**$7.25**	**$57.99**

[1] *see table 2-1 for calculations*
[2] *see table 2-2 for calculations*
[3] *See table 2-3 for calculations*
[4] Cucamonga Valley Water District. 2008. "Water Rates". http://www.cvwdwater.com/index.aspx?page=53

Calculations for the **Total Water Applied** were done in Performance Benefit 2, Tables 2-1, 2-2, and 2-3.

The **Cost of Water** for the Cucamonga Valley Water district was determined. Note that this is just a cost per gallon and does not include the Bi-Monthly Service Charge or the Commodity Rate. The **Cost of Irrigation for the Month of July** (July was used to calculate the total water applied in performance benefit 2) was then calculated by multiplying the Total Water Applied by the Cost of Water per gallon.

The **Annual Cost of Irrigation** was estimated by multiplying the cost of irrigation for one month (in this case July) by 8 months, which is the estimated watering season for California. This cost estimate is most likely higher than the actual cost being that July is usually the most irrigated month. However, because the same month is used for each of the scenarios the resulting costs are proportional regardless of a slight inflation.