Landscape Architecture Foundation

# Capitol Valley Ranch



## Landscape Peformance Benefits

- Reduces atmospheric carbon by more than 8.7 tons annually through 137 trees planted on the property, approximately the same amount of CO2 released by burning 884 gallons of gasoline.
- Saves over 1,000,000 gallons of irrigation water and 400 lb of fertilizer annually by limiting lawn area to 5,440 sf, 7% of the total planted area on the entire 35-acre site.
- Generates an estimated 1,820 kilowatt hours of electricity monthly, saving $150 dollars in monthly energy costs through 8 solar panels installed in the landscape.
- Produces an estimated 141 lb of organic vegetables each year, which have an approximate value of $400.
- Provides pleasant outdoor spaces with 77% of outdoor recreational areas in the human comfort zone in the morning, 42% in the afternoon, and 48% in the evening during the summer. Landscape design techniques such as building orientation, thermal massing, and tree placement were used to modify the microclimates of the outdoor spaces.
- Maintains the area's pastoral setting by reducing visibility of the house from the nearby ranch road by nearly 100%.

**Designer**
Design Workshop, Inc.

**Land Use**
Agriculture
Residential

**Project Type**
Single-family residence

**Location**
Undisclosed
Pitkin County, Colorado

**Size**
1 acre within 35-acre working ranch

**Budget**
Undisclosed

**Completion Date**
2006

### Overview

Capitol Valley Ranch, a one-acre home site situated on a larger working cattle ranch, is nestled into a rural high-altitude Colorado landscape. The design for the property required an integration of functions. A working ranch with horses, stables, and a barn coexists with a residence, thereby retaining traditional practices that preserve regional culture and open space values. The intimate and social spaces conducive to outdoor living and entertaining assimilate with the architecture and echo the site's naturalistic setting at 8,000 ft above sea level. In order to preserve the agricultural heritage of the valley, the design limited site disturbance, adhered to historical stormwater drainage patterns and ditch locations, and utilized native vegetation. Through careful site planning, the home makes use of passive solar energy to heat the swimming pool with solar panels. Bioclimatic design strategies, such as the use of vegetation to mitigate wind and sun exposure, produce comfortable outdoor spaces for three-season use.

### Sustainable Features

- This one-acre home site contains a small vegetable garden, perennial plantings, outdoor living room, extensive patio spaces, and a system of irrigation ditches and pond, all surrounded by ranch pastures.
- Over 8,000 sf of usable outdoor space is created with flagstone hardscape in sheltered areas around the home, including a 1,400-sf sun terrace, a 3,500-sf outdoor living room, a 2,500-sf pool deck and a 600-sf guest wing patio.
- Over 70,000 sf of native vegetation was planted on the property, including over 30 perennial species such as blue lupine, redosier dogwood, and western wheatgrass, and trees such as aspen, long-leaf cottonwood, and Colorado spruce.
- The autocourt, constructed of 18-in deep, crushed gravel, is permeable, allowing for groundwater infiltration. The decision to use this material resulted in considerable construction cost savings.

- Two-foot-high stone walls provide visual limits to the outdoor living spaces immediate to the residence, buffer the surrounding agricultural lands and, provide visual screening of the neighboring property from the autocourt.
- A 120-sf edible garden protected by occlusive fencing enables the homeowners to grow fresh vegetables, such as spinach, lettuce, potatoes and onions.
- Eight photovoltaic cells oriented east-southeast catch the early morning light and midday sun to heat the outdoor pool and assist with the home's hot water needs.
- Over 600 ft of agricultural irrigation ditches on the site were created and planted with species similar to those historically found on the property. These irrigation ditches provide non-potable water to all plantings on-site.
- A three-railed fence designed to match the pastoral setting allows wildlife movement while containing domestic horses on the property.

**Challenge**

The multitude of requirements of the home and its surrounding landscape called for innovative and considered design. The site is a high-altitude, working cattle ranch located in a valley where elk and many other species of wildlife live and migrate. The designers were faced with integrating a residential landscape with a traditional vegetable garden into an active ranch that required barns, stables, agricultural equipment, and other facilities. To create a comfortable mountain retreat with an abundance of usable outdoor space, high winds and temperature extremes needed to be tempered. Altitude and temperature severely limited the planting palette and growing season, while the request for a heated outdoor pool and spa required using sustainable energy.

**Solution**

A number of techniques separate differing uses and create microclimates around the home that meet the needs of the client and the demands of the site. A series of stone walls divide the open, native land from the more formal, cultivated perennial gardens and outdoor living spaces near the home. Occlusive fencing protects the vegetable gardens from the native wildlife that live in and migrate through the valley. Designers considered sun and shadow relationships on all sides of the house in the creation of comfortable outdoor environments. Native tree species planted at intervals provide shade during the hottest times of a summer day. The flagstones of the indoor/outdoor terraces act as thermal mass and radiate warmth in the evening. Frequent winds were addressed by expanding architectural forms to enclose courtyards without obstructing the striking views of the nearby Elk Mountain Range. The eight photovoltaic cells, part of the closed-loop solar water heating system, were located and oriented to catch the most possible energy during the client's peak use hours in the early morning.

**Cost Comparison**

- By installing solar panels in the landscape, the homeowners saved nearly $60,000 in current Pitkin County Renewable Energy Mitigation Program (REMP) fees. Purchase, installation and maintenance of the units totaled approximately $24,000.

**Lessons Learned**

- The solar panels in the landscape, which were installed primarily to heat the swimming pool, are oriented east-southeast rather than south. The landscape architect predicted that the panels would better catch early morning light at this angle and thus more successfully meet the needs of the client, an early morning swimmer. A resident survey reveals satisfaction with the panels' orientation and performance, proving that the choice to deviate from the traditional due-south orientation of solar panels was successful.
- The vegetable garden on the north side of the residence has seen adaptation and change throughout the years as the homeowners discover which types of vegetables are most successful at high altitude and with an average of only three frost-free months each growing season. While the original idea was to grow a wide variety of edible vegetables, after several disappointments the garden proved to be most rewarding when planted with hardier species such as spinach, onions, and potatoes.
- The client made key decisions regarding hardscaping materials based on aesthetic properties rather than durability or local availability. The stone has proven susceptible to extreme temperatures and precipitation found in the local climate and shows premature signs of wear. A more durable, local stone might have been less subject to weathering and produced fewer emissions in the transportation of the material to the site.

**Project Team**

Master Plan & Landscape Plan: Design Workshop, Inc.
Architect: CCY Architects, Ltd.
General Contractor: New Age Homes

Landscape Contractor: Landscape Workshop

**Role of the Landscape Architect**

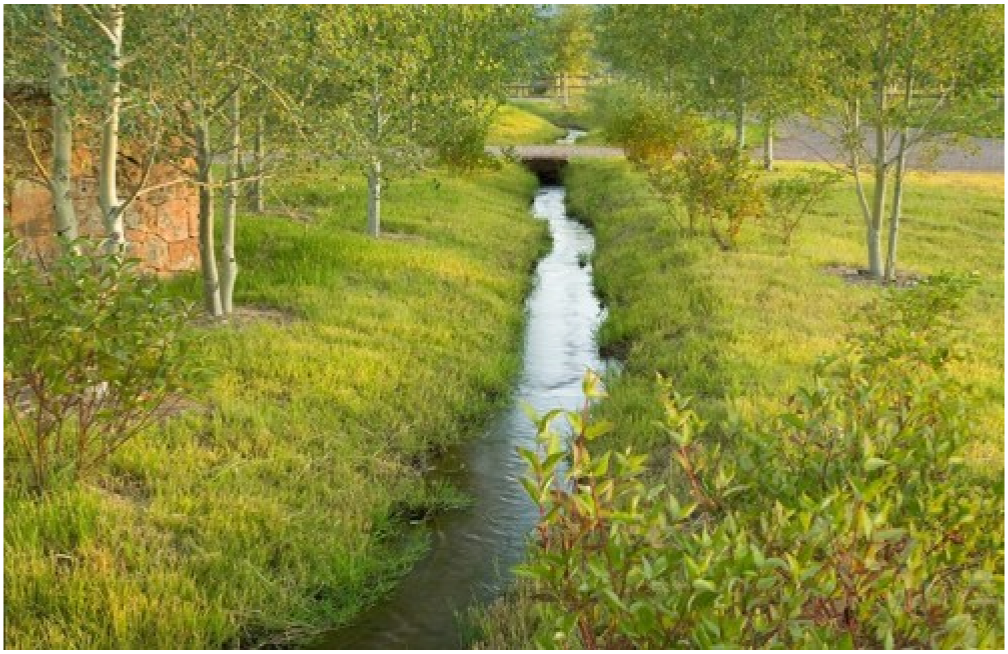
The landscape architect addressed all aspects of exterior design of the home and collaborated with the architect to locate the building and achieve a seamless, bioclimatic design both indoors and out.

Case Study Prepared By:
Research Fellow: Bo Yang, PhD, Assistant Professor, Utah State University
Research Assistant: Pamela Blackmore, BLA, Utah State University
Research Assistant: Chris Binder, MLA Candidate, Utah State University
Firm Liaisons: Allyson Mendenhall, Suzanne Jackson, and Richard Shaw, Design Workshop
October 2013

**References & Resources**

ASLA Colorado, Honor Award for Residential Design, Land Stewardship Designation, 2010
Garden Legacy: The Residential Landscapes of Design Workshop, 2010

## Additional Images



# LANDSCAPE PERFORMANCE SERIES

## Capitol Valley Ranch
## Methodology for Landscape Performance Benefits

**Case Study Prepared By**:

**Research Fellow**: Bo Yang, PhD, Assistant Professor, Utah State University
**Research Assistant**: Pamela Blackmore, BLA, Utah State University
**Research Assistant**: Chris Binder, MLA Candidate, Utah State University
**Firm Liaisons**: Allyson Mendenhall, Suzanne Jackson, and Richard Shaw, Design Workshop
*October 2013*

- ***Reduces atmospheric carbon by more than 8.7 tons annually through 137 trees planted on the property, approximately the same amount of $CO_2$ released by burning 884 gallons of gasoline.***

The research team counted all trees on site and measured their DBH (at 4.5 ft from ground). The research team then entered these measurements into the tree value calculator (http://www.treebenefits.com/calculator/).

The calculation tool estimated the amount of atmospheric carbon reduction from these trees. This total is 17,473 lb 17,473 lb / 2,000 lb/ton = 8.7365 tons.

The amount of carbon dioxide released by burning a gallon of gasoline was found here: http://www.epa.gov/cleanenergy/energy-resources/refs.html.

It is 0.00892 metric tons / gallon of gasoline.

0.00892 metric tons = 19.67 lb CO2 / gallon of gas. This is confirmed by the 19.64 lb $CO_2$ / gallon of gas reported here: http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=11.

8.7 tons = 17,400 lb 17,400 / 19.67 = 884.60 gallons of gasoline.

*Limitation*

1) Some of the aspen trees have multiple trunks. There is no feature in the calculator to accommodate this so each trunk was treated as an individual tree.

- ***Saves over an estimated 1,000,000 gallons of irrigation water and 400 lb of fertilizer annually by limiting lawn area to 5,440 sf, 7% of the total planted area on the entire 35-acre site.***

The total area of native plantings was assessed from AutoCAD planting plans. Areas of lawn were assessed in the same way.

Total Area of Irrigated Lawn: 5,440 sf

Total Area of Native Plantings: 72,147 sf

(High Altitude Pasture Mix: 63,153 sf + Crested Wheat: 7,672 sf + Wildflower Sod: 1,322 sf = 72,147 sf)

Total Area: 77,587 sf

(72,147 sf + 5,440 sf = 77,587 sf)

Maintenance records were not available for this property. However, records for a similar property nearby in Pitkin County were available. That property uses 2 pounds of fertilizer per 1,000 square feet of lawn to be applied 3 times per year.

2 lb / 1,000 sf X 3 times per year = 6 lb / 1,000 sf per year

6 lb X 5.44 = 32.64 lb of fertilizer per year are needed on the existing lawn.

6 lb X 77.587 = 465.522 lb of fertilizer per year would be needed if all planted area was lawn.

32.64 / 465.22 = 0.07016 or about 7% of the amount of fertilizer is needed compared to a traditional lawn. This is a reduced consumption of 93%.

Saves 465.522 – 32.64 = 432.882 lb of fertilizer saved per year.

Maintenance records were not available for this property. However, records for a similar property nearby in Pitkin County were available. That property irrigates lawn with 1 inch of water per week during the 24 weeks of the maintenance (snow-free) season.

1 in of water per week X 24 weeks = 24 in of water per year = 2 ft per year

2 ft X 5,440 sf = 10,880 cu ft of water per year current condition

2 ft X 77,587 sf = 155,174 cu ft of water per year if entire area was irrigated lawn

10,880 / 155,174 = 0.0701 or about 7% of the amount of water is needed compared to a traditional lawn. This is a reduced consumption of 93%.

1 cu ft = 7.48 gallons

10,880 cu ft X 7.48 = 81,382.4 gallons

155,174 cu ft X 7.48 = 1,160,701.52 gallons

1,160,701.52 gallons – 81,382.4 gallons = 1,079,319.12 gallons of water saved per year.

*Limitation*

1) The irrigation regime used for these calculations follow the maintenance schedule of a nearby property that, while comparable, may not reflect the exact maintenance needs of this property.
2) The maintenance records used for the calculations come from a nearby property that, while comparable, may not reflect the exact maintenance needs of this property.
3) The fertilizer type is not specified in the records, so the exact contents (especially nitrogen content) is unknown.

• ***Generates an estimated 1,820 kilowatt hours of electricity monthly, saving $150 dollars in monthly energy costs through 8 solar panels installed in the landscape.  This output is more than enough energy to heat an outdoor pool, and the excess goes toward assisting the home water heating system.***

The number of solar panels and their sizes were derived through on site observation.  There are eight solar panels, each covering 27 sf. The panel model is Gobi 3366 manufactured by Heliodyne, Inc.

The kilowatt hours of energy produced was found by checking the Solar Rating and Certification Corporation Certified Performance Data for the model (http://www.altestore.com/mmsolar/others/GobiPerformance.pdf).

Logically, the output of a solar panel depends on the weather and climate of a given area.  In order to arrive at a reasonable average, the kWh output for 'Mildly Cloudy Day' was used instead of 'Clear Day' or 'Cloudy Day' (the other two alternatives).  As the application of the panels is to heat a pool in a cool climate, Category B (Ti [inlet fluid temperature] – Ta [ambient temperature] = 9 degrees F) was chosen in preference of the other options (pool heating in warm climate, water heating in warm or cool climate, industrial process water heating).  Thus, the kWh per Gobi 3366 per day is 7.62.  With 8 units, this means a total of 8 x 7.62 kWh per day = 60.69 kWh per day on average.  60.69 kWh per day x 30 days per month = 1820.7 kWh per month.

The average price of electricity in Colorado per kilowatt hour was found to be 8.36 cents (source: http://www.instituteforenergyresearch.org/state-regs/pdf/Colorado.pdf).

1820.7 kWh per month x 8.36 cents per kWh = 15221.052 cents per month = $152.21 per month

A survey of the client provided the information that the energy produced is more than enough to heat the pool and that the excess assists the home water heating system, but exact records for the amount of energy used were not available.

*Limitations*

1) The production capacity of the solar panels may have changed over time from the expected capacity at installation.
2) The price of electricity will fluctuate with the market and may vary significantly for this homeowner from the average paid in Colorado.

• ***Produces an estimated 141 lb of organic vegetables, which have an approximate value of $400.***

First, researchers determined the area of the garden by consulting the AutoCAD plans for the site and using the 'area' command.  The area is 120 sf.

Next, a resident provided information on the different types of produce being grown through a survey.  The four most successful plants grown (spinach, lettuce, onions, and potatoes) were used in the calculations. The amount of each type of produce that can be expected from the garden plot (30 sf per type of vegetable) was calculated using the vegetable garden value calculator found at http://www.plangarden.com/app/vegetable_value/. The total for each type of vegetable is as follows: spinach-15 lb, lettuce-27 lb, onions-69 lb, potatoes-30 lb.

Finally, the monetary value of the produce was calculated by checking prices of organic produce at the local Whole Foods Market, one of the grocery stores where the resident surveyed indicated that produce would be purchased if it were not grown at home.  Those prices are as follows:

Spinach $2.99/bunch (~1 lb), Lettuce $2.99/bunch (~1 lb), Onions $1.99/lb, Potatoes $1.99/lb.

Thus, the total value of the spinach is $44.85, the lettuce is $80.73, the onions are $137.31, and the potatoes are $53.73.  Total value is $395.77.

*Limitations*

1) This calculation is based on average harvests for a given type of vegetable.  The harvests on this property may be higher or lower due to many factors including elevation, growing season, and temperature.
2) The cost of produce at the local organic food market may change throughout the season.  We were only able to survey the prices at one time, and do not have access to the average, maximum, or minimum prices during the year.

- ***Provides pleasant outdoor spaces with 77% of outdoor recreational areas in the human comfort zone in the morning, 42% in the afternoon, and 48% in the evening during the summer. Landscape design techniques such as building orientation, thermal massing, and tree placement were used to modify the microclimates of the outdoor spaces.***

The landscape architect's design was directly based on the goal of creating comfortable outdoor spaces.  This was achieved through a consideration of the natural environment present on the site and the relative placement of different elements in the landscape such as the home, patio, plantings, and hardscape.  In addition, the materials used also affect the creation of comfortable microclimates. The flagstone of the hardscape, for example, acts as a thermal mass that collects heat when exposed to direct sun and then radiates it out when in the shade.   Sheltered courtyards are created on both the north and south sides of the house for use during different seasons and times of the day. For example, the north side is used during hot days and the south side is good for winter and evenings or mornings. There is a fireplace on each side (front and back) of the residence which also allows people to be comfortable outside on cooler days and evenings. These factors can be quantified through in-situ measurements compared against an established metric that defines the conditions conducive to human comfort.

Using the Human Comfort Zone developed by Victor Olgyay (1973), temperature, relative humidity, and wind velocity were measured on site three times (morning at 9:15 am, afternoon at 12:30 pm, and evening at 5:00 pm) on June 18, 2013 at sixty six points throughout the landscape. The measurement device used was a Kestrel 4000 Pocket Weather Tracker. Wind speed accuracy: ±3%. Temperature: ±1°C. Relative humidity accuracy: ±3%. (http://www.forestry-suppliers.com/product_pages/View_Catalog_Page.asp?mi=71381&title=Kestrel%AE+4000+Pocket+Weather%99+Tracker%99%3CBR%3ETakes+weather+monitoring+to+a+new+level%21)

Temperature was recorded once it stabilized; relative humidity was taken at that same time. Wind velocity represents the maximum reached while the temperature was stabilizing.  Measurements were taken facing northeast, with the Kestrel device approximately eighteen in away from the body and not in the shadow of the operator.

Sampling points are seen below in Figure 1.

**Figure 1.** Sampling locations of bioclimatic study on June 18, 2013

Data gathered on site for each point is seen in Figure 2.

| | | Evening | | | | Afternoon | | | | Morning | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Point | time | Rh | Temp | comfort? | time | Rh | Temp | comfort? | time | Rh | Temp | comfort? |
| Agricultural Irrigation Ditch | 1 | 5:06 | 19.5 | 84.9 | hot & dry | 12:35 | 20.0 | 81.9 | hot | 9:16 | 40.5 | 66.2 | cold |
| Agricultural Irrigation Ditch | 2 | 5:07 | 18.9 | 82.6 | hot & dry | 12:36 | 23.8 | 79.1 | comfort | 9:21 | 43.2 | 65.9 | cold |
| Agricultural Irrigation Ditch | 3 | 5:08 | 22.2 | 79.2 | comfort | 12:37 | 25.8 | 78.2 | comfort | 9:21 | 43.1 | 68.0 | comfort |
| Agricultural Irrigation Ditch | 4 | 5:09 | 21.5 | 79.9 | comfort | 12:38 | 24.6 | 77.1 | comfort | 9:22 | 41.1 | 70.6 | comfort |
| Agricultural Irrigation Ditch | 5 | 5:12 | 21.0 | 80.5 | hot | 12:39 | 24.1 | 76.9 | comfort | 9:23 | 37.0 | 72.0 | comfort |
| Agricultural Irrigation Ditch | 6 | 5:14 | 23.8 | 82.6 | hot | 12:40 | 22.9 | 78.6 | comfort | 9:25 | 39.5 | 69.4 | comfort |
| Agricultural Irrigation Ditch | 7 | 5:15 | 24.1 | 81.4 | hot | 12:41 | 19.6 | 79.5 | dry | 9:26 | 42.1 | 73.5 | comfort |
| Agricultural Irrigation Ditch | 8 | 5:16 | 23.5 | 77.7 | comfort | 12:42 | 20.6 | 81.0 | hot | 9:27 | 39.2 | 78.9 | comfort |
| Agricultural Irrigation Ditch | 9 | 5:17 | 23.7 | 78.6 | comfort | 12:43 | 19.6 | 75.2 | dry | 9:28 | 32.3 | 72.0 | comfort |
| South Lawn | 10 | 5:19 | 18.6 | 83.3 | hot & dry | 12:43 | 21.4 | 75.3 | comfort | 9:29 | 41.1 | 73.6 | comfort |
| Sun Terrace | 11 | 5:21 | 22.7 | 78.9 | comfort | 12:44 | 19.9 | 75.6 | dry | 9:29 | 37.2 | 72.6 | comfort |
| Sun Terrace | 12 | 5:21 | 23.7 | 79.2 | comfort | 12:45 | 18.5 | 78.4 | dry | 9:30 | 40.7 | 78.0 | comfort |
| Sun Terrace | 13 | 5:23 | 22.2 | 80.0 | comfort | 12:46 | 21.5 | 80.0 | comfort | 9:31 | 35.0 | 76.6 | comfort |
| Sun Terrace | 14 | 5:24 | 22.7 | 79.2 | comfort | 12:47 | 19.7 | 80.6 | hot & dry | 9:32 | 32.0 | 81.0 | hot |
| Sun Terrace | 15 | 5:25 | 22.7 | 81.4 | hot | 12:48 | 17.8 | 77.9 | dry | 9:34 | 29.8 | 76.8 | comfort |
| Sun Terrace | 16 | 5:26 | 21.1 | 79.1 | comfort | 12:49 | 21.4 | 79.6 | comfort | 9:36 | 34.4 | 75.3 | comfort |
| Sun Terrace | 17 | 5:28 | 23.1 | 76.7 | comfort | 12:50 | 20.6 | 77.9 | comfort | 9:39 | 35.7 | 71.9 | comfort |
| Sun Terrace | 18 | 5:29 | 24.7 | 76.8 | comfort | 12:51 | 23.0 | 78.1 | comfort | 9:43 | 35.0 | 75.8 | comfort |
| South Lawn | 19 | 5:30 | 21.2 | 76.6 | comfort | 12:52 | 18.3 | 78.1 | dry | 9:45 | 39.5 | 78.5 | comfort |
| South Lawn | 20 | 5:31 | 21.6 | 77.0 | comfort | 12:52 | 21.4 | 76.1 | comfort | 9:49 | 34.3 | 79.2 | comfort |
| South Lawn | 21 | 5:32 | 22.5 | 76.9 | comfort | 12:55 | 19.0 | 78.6 | dry | 9:51 | 37.4 | 79.1 | comfort |
| South Lawn | 22 | 5:33 | 25.0 | 77.6 | comfort | 12:56 | 19.3 | 71.1 | dry | 9:52 | 41.0 | 77.5 | comfort |
| South Lawn | 23 | 5:34 | 23.1 | 75.2 | comfort | 12:57 | 20.7 | 80.8 | hot | 9:53 | 38.3 | 80.6 | hot |
| South Lawn | 24 | 5:36 | 22.9 | 77.8 | comfort | 12:59 | 20.1 | 77.5 | comfort | 9:55 | 38.8 | 72.9 | comfort |
| Swimming Lap Pool | 25 | 5:38 | 21.6 | 82.2 | hot | 1:02 | 19.1 | 79.1 | dry | 9:57 | 38.0 | 77.9 | comfort |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Swimming Lap Pool | 26 | 5:43 | 20.1 | 93.3 | hot | 1:03 | 17.8 | 82.8 | hot & dry | 9:58 | 38.4 | 77.9 | comfort |
| Swimming Lap Pool | 27 | 5:51 | 22.4 | 83.5 | hot | 1:05 | 20.4 | 77.1 | comfort | 9:59 | 31.5 | 80.1 | hot |
| Swimming Lap Pool | 28 | 5:52 | 23.0 | 78.2 | comfort | 1:07 | 16.8 | 78.1 | dry | 10:01 | 33.8 | 76.6 | comfort |
| Swimming Lap Pool | 29 | 5:53 | 20.9 | 79.1 | comfort | 1:08 | 23.0 | 79.2 | comfort | 10:02 | 35.2 | 74.8 | comfort |
| Swimming Lap Pool | 30 | 5:55 | 21.7 | 76.7 | comfort | 1:10 | 18.6 | 83.9 | hot & dry | 10:03 | 41.3 | 69.1 | comfort |
| Sun Terrace | 31 | 5:56 | 23.3 | 75.8 | comfort | 1:12 | 21.1 | 78.9 | comfort | 10:05 | 34.6 | 77.9 | comfort |
| Sun Terrace | 32 | 5:57 | 21.4 | 77.8 | comfort | 1:14 | 20.2 | 76.6 | comfort | 10:06 | 31.3 | 76.5 | comfort |
| Swimming Lap Pool | 33 | 5:58 | 19.7 | 77.0 | dry | 1:18 | 19.4 | 74.2 | dry | 10:07 | 35.9 | 69.7 | comfort |
| Swimming Lap Pool | 34 | 6:00 | 18.7 | 78.7 | dry | 1:19 | 22.8 | 74.9 | comfort | 10:08 | 35.7 | 74.3 | comfort |
| Swimming Lap Pool | 35 | 6:02 | 20.6 | 82.5 | hot | 1:20 | 22.8 | 75.7 | comfort | 10:09 | 38.2 | 76.0 | comfort |
| Swimming Lap Pool | 36 | 6:03 | 18.1 | 82.6 | hot & dry | 1:21 | 21.6 | 74.3 | comfort | 10:09 | 33.0 | 74.6 | comfort |
| Swimming Lap Pool | 37 | 6:04 | 20.5 | 82.5 | hot | 1:23 | 21.5 | 77.9 | comfort | 10:10 | 33.4 | 76.2 | comfort |
| Solar Panel Array | 38 | 6:06 | 17.6 | 88.5 | hot & dry | 1:24 | 21.9 | 81.9 | hot | 10:12 | 37.3 | 75.6 | comfort |
| Solar Panel Array | 39 | 6:08 | 19.4 | 83.9 | hot & dry | 1:25 | 20.1 | 80.8 | hot | 10:13 | 35.0 | 76.4 | comfort |
| Solar Panel Array | 40 | 6:09 | 25.4 | 78.5 | comfort | 1:27 | 18.4 | 74.1 | dry | 10:14 | 36.5 | 79.0 | comfort |
| Solar Panel Array | 41 | 6:10 | 22.5 | 77.6 | comfort | 1:33 | 21.5 | 77.9 | comfort | 10:15 | 36.5 | 78.8 | comfort |
| Outdoor Living Room | 42 | 6:12 | 25.1 | 79.6 | comfort | 1:34 | 26.2 | 80.2 | hot | 10:16 | 41.6 | 81.0 | hot |
| Outdoor Living Room | 43 | 6:13 | 22.0 | 79.8 | comfort | 1:36 | 18.8 | 82.2 | hot & dry | 10:17 | 33.7 | 80.2 | hot |
| Outdoor Living Room | 44 | 6:14 | 21.3 | 78.6 | comfort | 1:38 | 18.5 | 77.8 | dry | 10:18 | 33.5 | 81.8 | hot |
| Outdoor Living Room | 45 | 6:15 | 19.2 | 79.6 | dry | 1:40 | 21.3 | 84.9 | hot | 10:20 | 35.2 | 78.9 | comfort |
| Outdoor Living Room | 46 | 6:16 | 18.1 | 80.0 | dry | 1:42 | 19.5 | 81.7 | hot & dry | 10:20 | 35.2 | 79.4 | comfort |
| Outdoor Living Room | 47 | 6:17 | 19.4 | 79.6 | dry | 1:43 | 16.4 | 81.8 | hot & dry | 10:21 | 33.3 | 76.8 | comfort |
| Raised Vegetable Garden | 48 | 6:18 | 19.7 | 78.1 | dry | 1:44 | 15.0 | 80.5 | hot & dry | 10:22 | 32.5 | 75.5 | comfort |
| Raised Vegetable Garden | 49 | 6:20 | 18.3 | 79.6 | dry | 1:45 | 16.5 | 81.7 | hot & dry | 10:24 | 40.4 | 75.9 | comfort |
| Raised Vegetable Garden | 50 | 6:22 | 17.1 | 82.5 | hot & dry | 1:46 | 19.7 | 82.7 | hot & dry | 10:25 | 37.5 | 82.3 | hot |
| Raised Vegetable Garden | 51 | 6:23 | 20.3 | 80.7 | hot | 1:47 | 16.5 | 82.2 | hot & dry | 10:27 | 34.8 | 85.5 | hot |
| North Trees and Berm | 52 | 6:24 | 21.3 | 77.8 | comfort | 1:50 | 15.8 | 88.5 | hot & dry | 10:28 | 35.4 | 84.6 | hot |
| North Trees and Berm | 53 | 6:25 | 24.2 | 75.8 | comfort | 1:52 | 16.3 | 85.8 | hot & dry | 10:29 | 30.1 | 82.1 | hot |
| North Trees and Berm | 54 | 6:26 | 21.6 | 77.0 | comfort | 1:54 | 15.8 | 82.1 | hot & dry | 10:30 | 29.7 | 81.0 | hot |
| North Trees and Berm | 55 | 6:28 | 21.4 | 75.9 | comfort | 1:56 | 17.1 | 82.5 | hot & dry | 10:31 | 28.3 | 86.0 | hot |
| North Trees and Berm | 56 | 6:29 | 20.5 | 76.3 | comfort | 1:58 | 18.2 | 84.1 | hot & dry | 10:32 | 32.2 | 81.6 | hot |
| North Trees and Berm | 57 | 6:29 | 20.8 | 75.6 | comfort | 2:00 | 21.3 | 84.2 | hot | 10:33 | 35.1 | 79.6 | comfort |
| North Trees and Berm | 58 | 6:30 | 21.6 | 74.8 | comfort | 2:02 | 19.6 | 83.1 | hot & dry | 10:34 | 39.4 | 75.4 | comfort |
| Gravel Entry Drive | 59 | 6:31 | 20.3 | 75.3 | comfort | 2:03 | 21.1 | 83.5 | hot | 10:35 | 38.6 | 74.9 | comfort |
| Gravel Entry Drive | 60 | 6:33 | 18.9 | 75.8 | dry | 2:05 | 15.9 | 86.6 | hot & dry | 10:36 | 39.6 | 82.3 | hot |
| Arrival Court | 61 | 6:34 | 19.1 | 75.7 | dry | 2:06 | 15.7 | 84.5 | hot & dry | 10:38 | 31.5 | 80.8 | hot |
| Arrival Court | 62 | 6:35 | 19.7 | 75.1 | dry | 2:07 | 16.4 | 82.8 | hot & dry | 10:39 | 32.2 | 84.5 | hot |
| Arrival Court | 63 | 6:36 | 21.2 | 75.5 | comfort | 2:09 | 15.6 | 88.0 | hot & dry | 10:41 | 29.4 | 85.5 | hot |
| Arrival Court | 64 | 6:36 | 21.4 | 74.5 | comfort | 2:10 | 17.9 | 87.5 | hot & dry | 10:42 | 29.9 | 88.2 | hot |
| Arrival Court | 65 | 6:37 | 18.7 | 75.4 | dry | 2:12 | 16.9 | 83.3 | hot & dry | 10:44 | 27.6 | 86.2 | hot |
| Arrival Court | 66 | 6:39 | 17.0 | 77.7 | dry | 2:13 | 16.7 | 84.6 | hot & dry | 10:46 | 28.7 | 83.5 | hot |

**Figure 2.** Temperature and relative humidity data gathered at sampling locations in morning, afternoon, and evening.

The data were interpolated using the Kriging method in ArcMap10.1, the results of which are shown in Figures 3a-3i below. These images show general climatic trends across the site for wind velocity, relative humidity, and temperature for morning, afternoon, and evening on June 18, 2013.

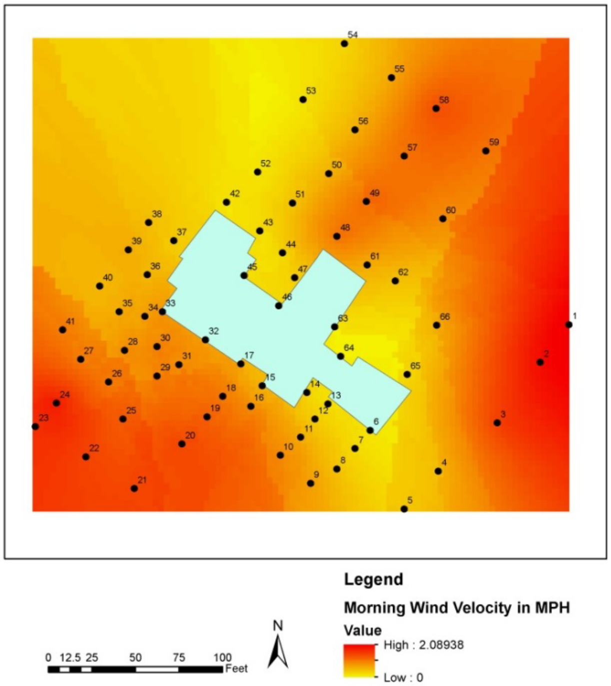



**Figure 3a.** Morning wind velocity

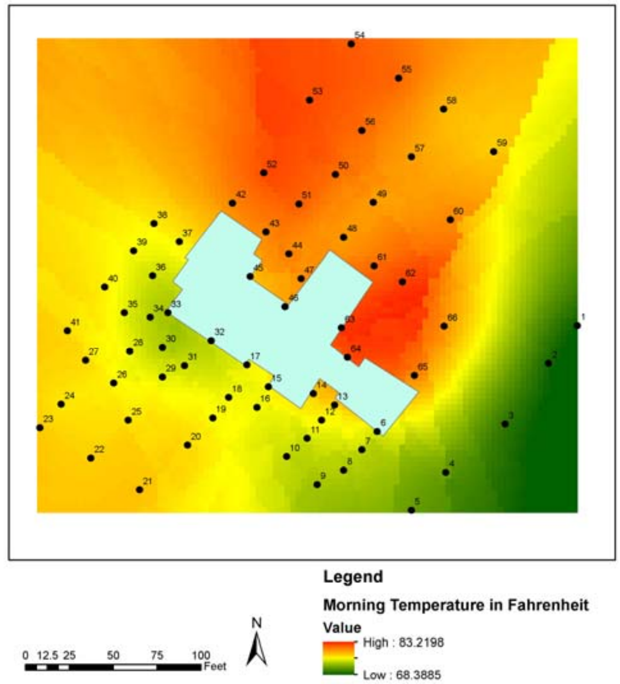



**Figure 3b.** Morning temperature

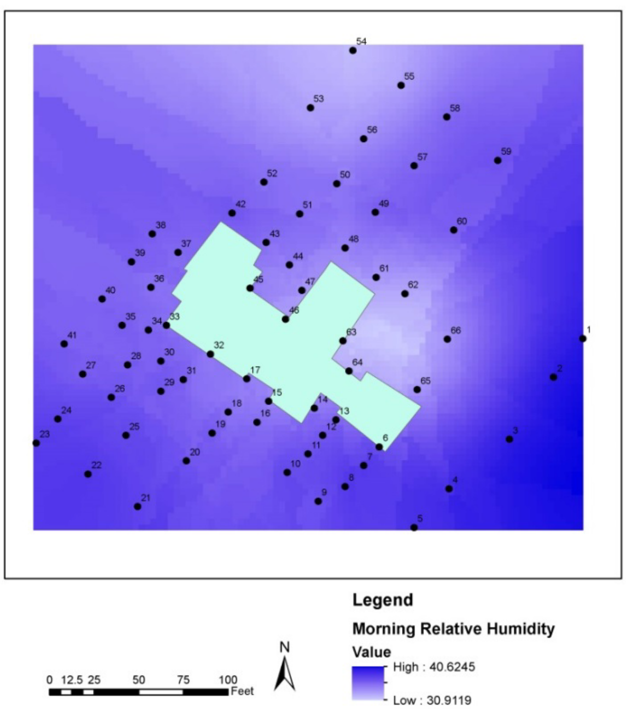



**Figure 3c.** Morning relative humidity

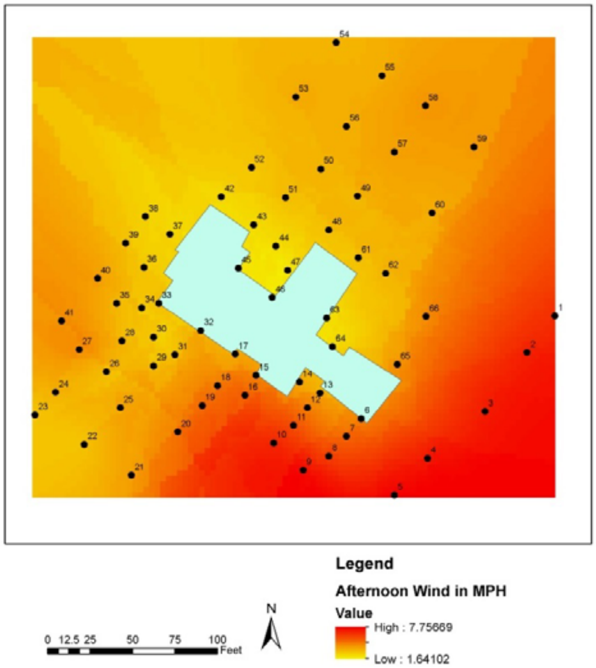



**Figure 3d.** Afternoon wind velocity

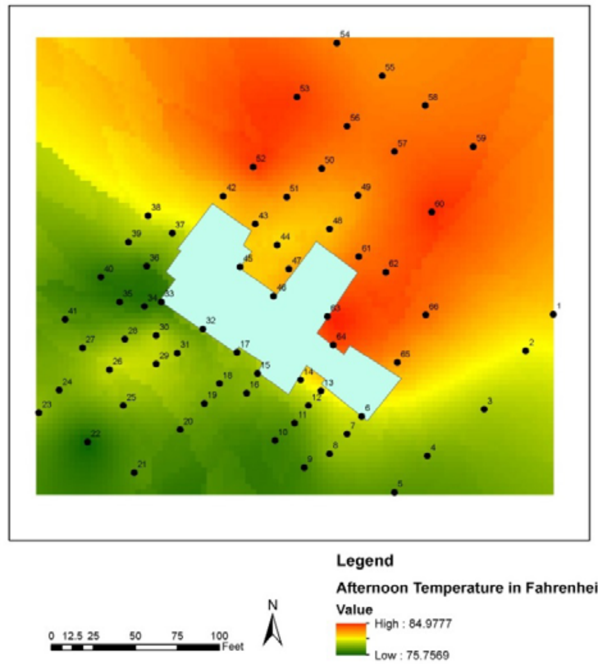



**Figure 3e.** Afternoon temperature

Afternoon Relative Humidity

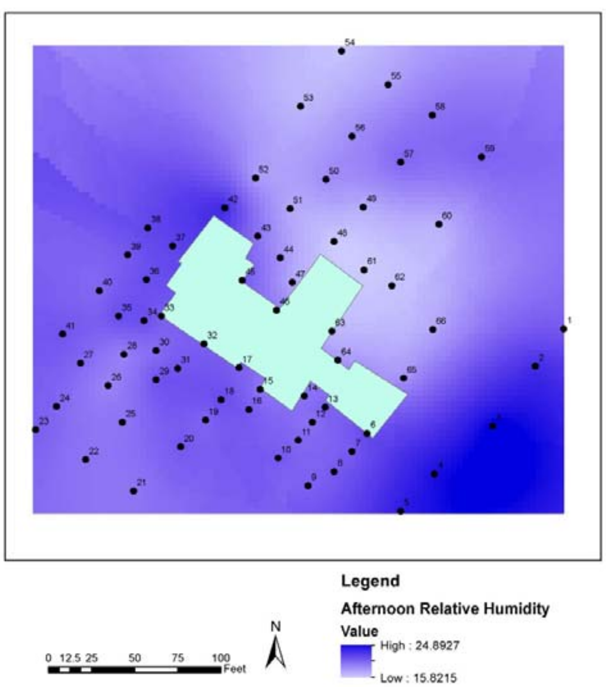



**Figure 3f.** Afternoon relative humidity

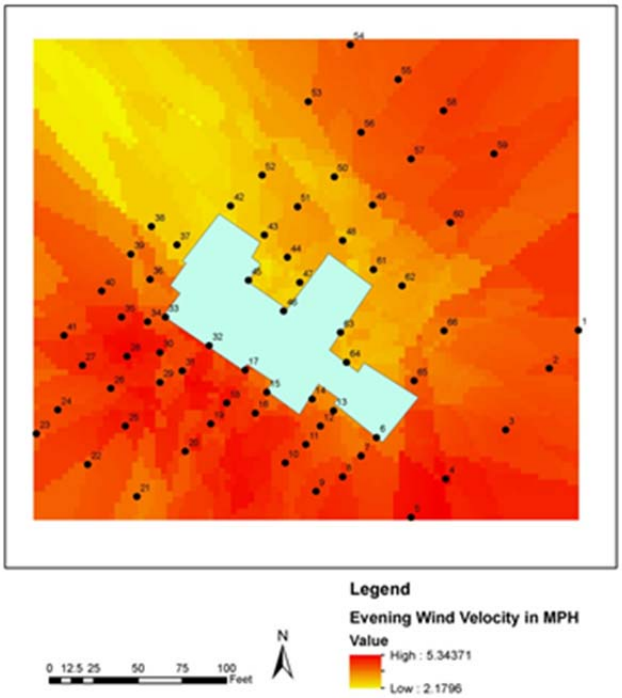



**Figure 3g.** Evening wind velocity

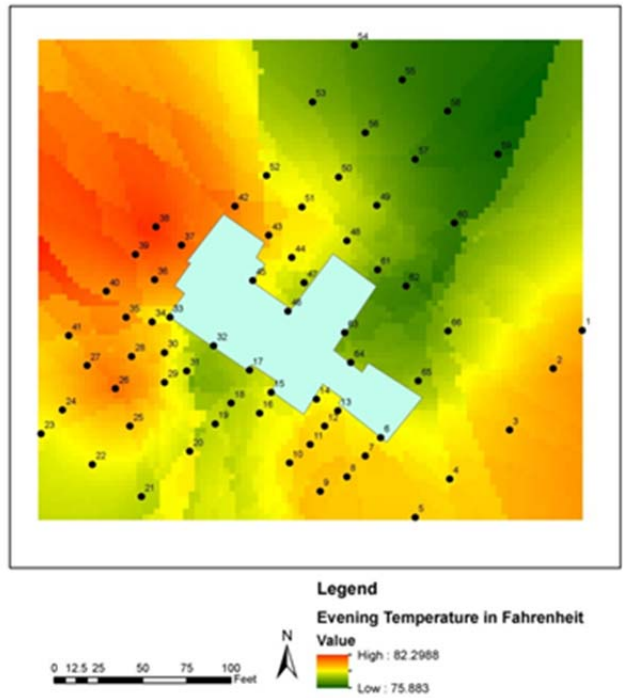



**Figure 3h.** Evening temperature

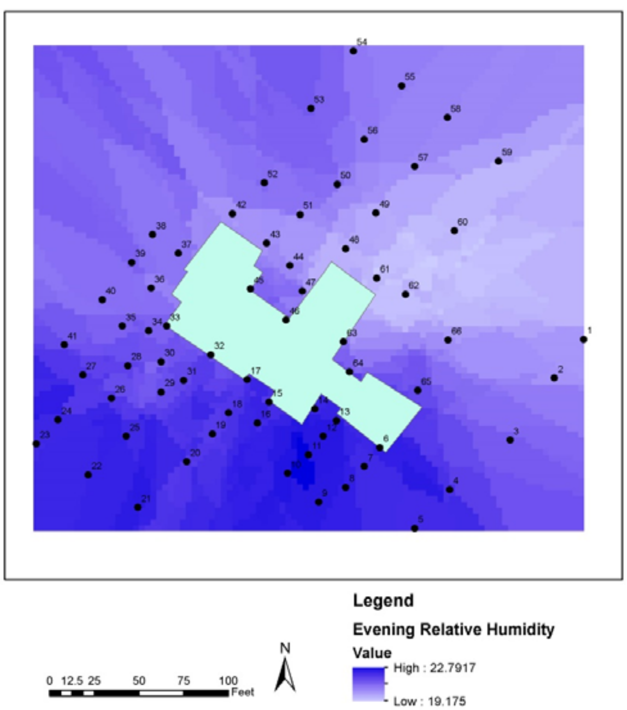



**Figure 3i.** Evening relative humidity

Temperatures and corresponding relative humidity data were entered into a human comfort chart (Figures 4a-4c). This chart uses a relationship between relative humidity and temperature to set guidelines for human comfort. The blue points are the data with temperature on the Y axis and relative humidity on the X axis. The solid red line delineates the area considered to be comfortable. Points inside this red box indicate that climatic conditions at the time the data was gathered at that location were within the human comfort zone.

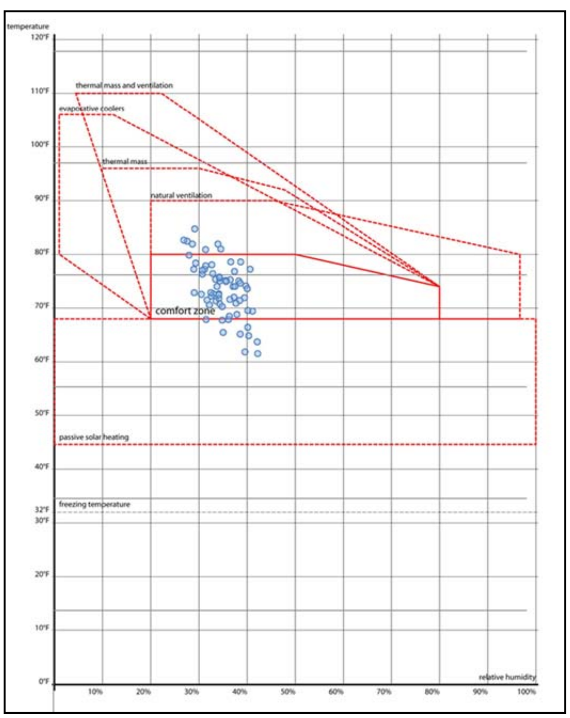



**Figure 4a.** Morning comfort chart

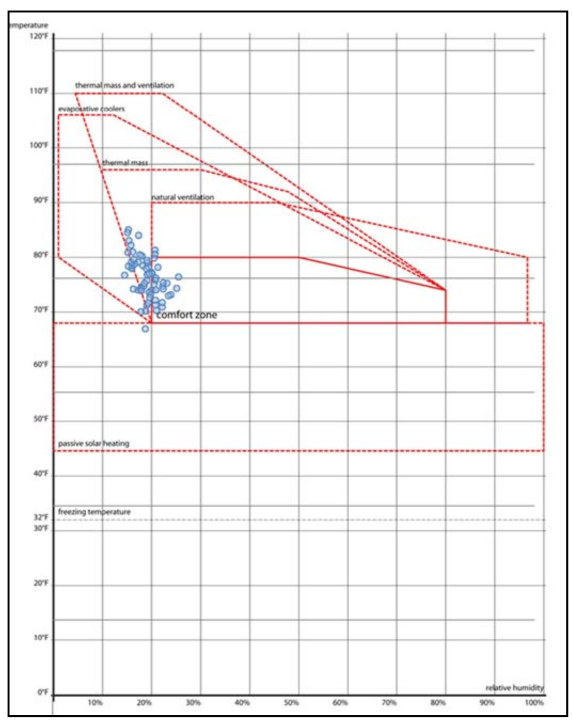



**Figure 4b.** Afternoon comfort chart

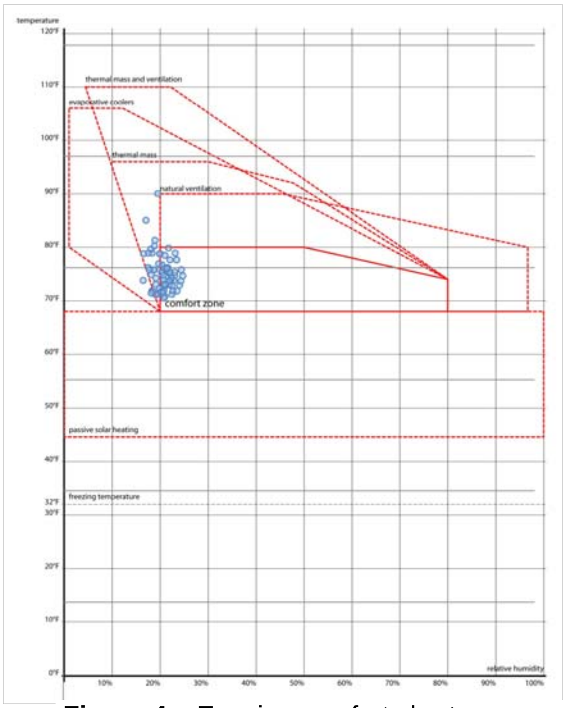



**Figure 4c.** Evening comfort chart

Of all the sampling locations, the outdoor "spaces" (e.g., Sun Terrace, Swimming Lap Pool, Outdoor Living Room, and Raised Vegetable Garden) were factored into the percentage. Of the 31 data points gathered in these spaces, 24 are considered to be in the comfort zone in the morning, 13 in the afternoon, and 15 in the evening.

Percent of outdoor spaces that fall into human comfort zone:

| | |
|---|---|
| Morning: | 24 / 31 = 77% |
| Afternoon: | 13 / 31 = 42% |
| Evening: | 15 / 31 = 48% |

*Limitations:*

1) Because points were not sampled simultaneously, temperatures changed dramatically by the time data were gathered over the entire site.
2) Because some locations took much longer to have the temperature stabilize than others, the maximum wind velocity represents varying lengths of time.

- ***Reduces visibility of the house from the nearby ranch road by nearly 100%, reducing visual impact on the pastoral setting for nearby homeowners and other road traffic.***

Panoramic photographs of the site were taken from the end of the public road leading to the house (Figure 3). This location was chosen because it is the closest vantage point to the home available to the public. Below procedure followed the methodology developed by Clay and Marsh (1997) and Chen *et al.* (2009).

**Figure 3.** Panoramic photograph showing the view of the property from the end of the public road

Photographs of the home were taken from the same angle and combined with on-site observations to create a silhouette of the home (Figure 4) as it appears from the same vantage point as the panoramic photo above.

**Figure 4 .**Silhouette of the home as viewed from the same angle as the panorama

The panoramic photograph and silhouette were imported into Adobe Photoshop 6.0 (Figure 5). The silhouette image was resized to match the scale of the panorama. The histogram feature in Photoshop was used to measure the number of pixels present in the silhouette layer. This is the number of pixels that would be visible if no buffer were present.

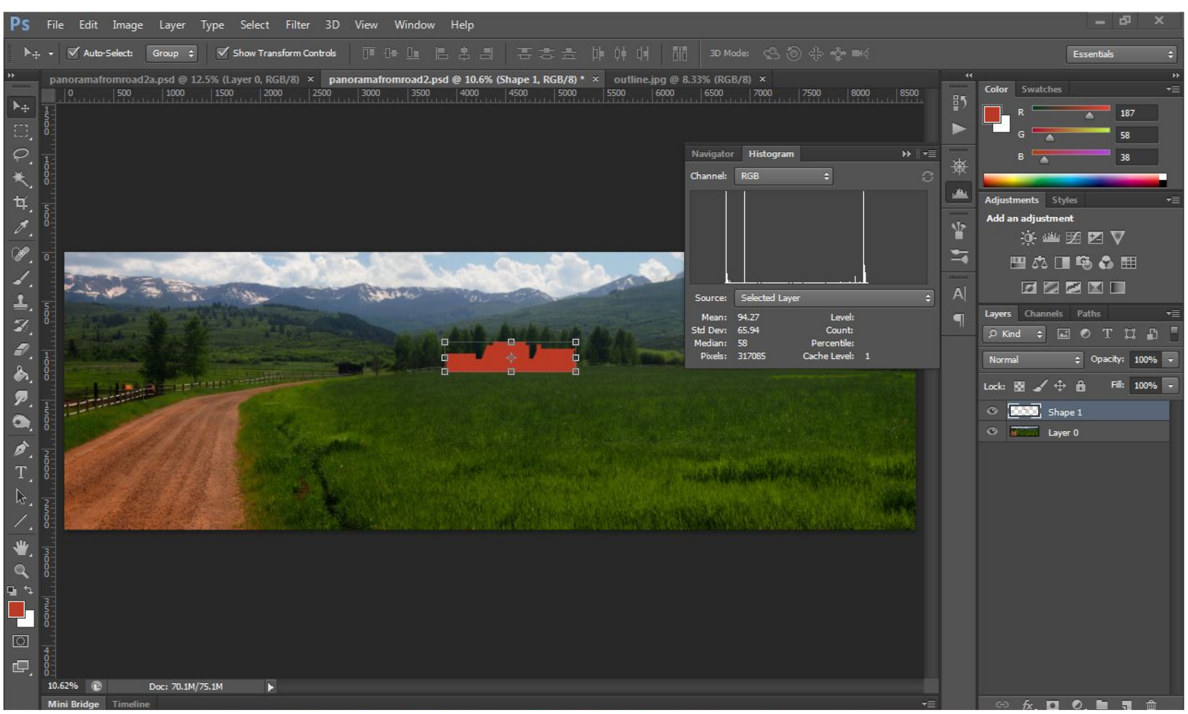


**Figure 5.** Pixel count for the selected layer (building silhouette)

There are a total of 317,085 pixels in the silhouette. Note that the Cache Level on the Histogram has been set to 1 to ensure that the entire layer is being evaluated, not a random selection (to save time, Photoshop will often survey a random selection of pixels to create the histogram, thus limiting the count to ¼ or ½ the actual number present).

The silhouette layer was moved underneath the panorama layer and the wand tool, set on a very low tolerance, was used to erase those parts of the panorama image that lie on the far side of the planted berm and tree buffer. This revealed the silhouette in just those areas that are not covered by berms, plantings, or trees in front of the home (Figure 6).

**Figure 6.** Removing the background revealed the visible parts of the building silhouette

Finally, the layers were merged and the visible parts of the building silhouette were selected. The histogram function was used again to determine how many visible pixels from the silhouette remained (Figure 7).

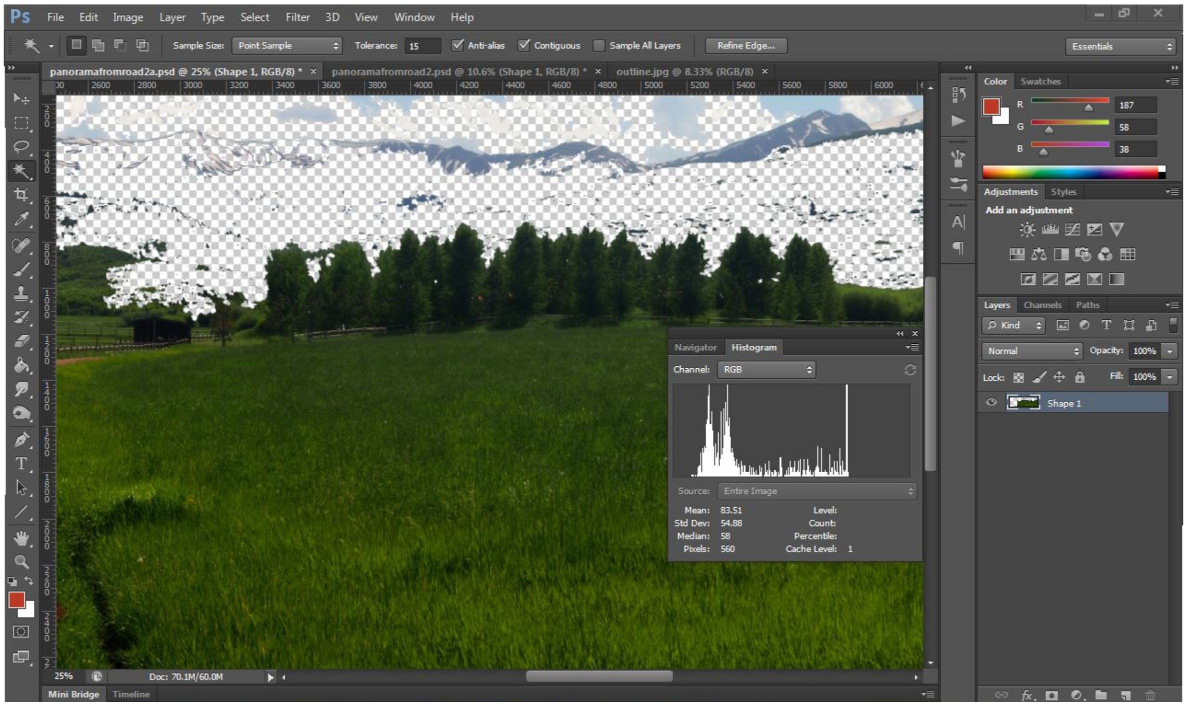



**Figure 7.** The histogram reveals how many pixels of the silhouette are visible

A total of 560 pixels are visible.
560 / 317,085 = 0.00177 or approximately 0.18%.
100% - 0.18% = 99.82% of the view of the home is blocked from the vantage point.

*Limitation*

1) The creation of the silhouette of the building was based on photographs and a visit to the site, but due to the visually impenetrable nature of the buffer we were unable to take photographs that would have allowed the creation of a precise silhouette. This could have been done easily when the house was first constructed and the trees were either not yet planted or much younger and smaller.

## Methodology for Cost Comparison

• ***By installing solar panels into the landscape to heat the outdoor pool the homeowners saved $58,494.62 in current Pitkin County Renewable Energy Mitigation Program fees. Purchase, installation and maintenance of the units totaled over $24,000.***

Pool = 400 sf (summer use only)

Use the REMP calculation sheet found here: http://www.aspenpitkin.com/Departments/Community-Development-Pitkin-County/Building/Building-Energy-Codes/.

The cost of one Gobi 3366 photovoltaic unit is listed as about $630 (http://www.thesolar.biz/solar_hot_water_heating.htm).

According to a paper by Dr. Fariborz Mahjouri and Albert Nunez, CEM that examines the relative cost of solar panel installation, only about 33% of the total cost can be credited to the unit itself. The other costs include logistical, installation, and overhead costs.

$630 / 0.33 = $1909 per unit X 8 units = $15,273 total cost for the photovoltaic cells.

Estimated maintenance costs were given from a solar contractor in Pitkin County for typical solar hot water heater systems as:

Annual maintenance is $200/year for life of the system.

Replacement of the pump and fluid every 10 years at $300-$500 each per replacement.

For this analysis, 30 years was used as an estimated life span given by the contractor.

Annual maintenance: $200 x 30 years= $6000

Replacement of pump: $500 x 3 = $1500 (worst case scenario)

Replacement of fluid: $500 x 3 = $1500 (worst case scenario) (Tierney, 2013)

Total life maintenance: $9000

Total costs: $9000 + $15,273 = $24,273

*Limitations*

1) The calculations are based on current Pitkin County Renewable Energy Mitigation Program (REMP) calculations. The calculations for the date of installation were not available, and though comparable, would likely have been less.
2) The exact amount paid for the purchase, maintenance and installation of the cells was not available, and the method used to determine approximate purchase and installation prices was based on commercial projects.

## References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Clay, G.R. and Marsh, S.E. (1997) Spectral analysis for articulating scenic color changes in a coniferous landscape. Photogrammatic Engineering and Remote Sensing 63(12): 1353–1362.

Mahjouri, F., & Nunez, A. (n.d.). The relative cost of solar thermal collector installations. Retrieved from http://www.thermotechs.com/Downloads/Relative%20Cost%20Paper.pdf.

Tierney, M. (2013, September 20). Solar contractor. (P. Blackmore, Personal interview)

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