Proposed Solar Panel Vegetation Impacts

Stafford Landfill Solar Installation: Structure and Shading Impacts

Prepared by Joseph Arsenault

July 2010

Study Purpose: Walters Homes, Inc. (hereafter referred to as "Walters") proposes installing a solar panel array to collect sun-generated power on the level space created by the closure of the Stafford Township municipal landfill. This will potentially conflict with newly planted warm season grasses. To assess the possible impacts the solar panels pose to the grass cover, Joseph Arsenault was retained by Walters to provide the field data collection and to produce a report documenting the possible impacts. This report would provide an assessment for the suspected conditions associated with solar panel installation.

Solar Array Impacts: The vegetation impact from solar panels includes the reduction in space for the existing vegetation created by the presence of the panels and their anchors. Anchors will be constructed of concrete. One will be located under each panel. Shading will occur under the panel, and a reduction of sunlight will be anticipated. The impact from each concrete support is a direct measurement of the area occupied by an individual anchor multiplied by the number of panels requiring an anchor. Shading occurs when shadows are created during daytime hours. Its impact would have some effect on the existing grasses.

Analysis Goal: The goal of this analysis is to determine the direct loss of vegetation by solar panel supports as well as provide an estimate of impacts created by the shade cast between each row. This information would be available to estimate changes to the grass cover present on the landfill cap.

Current Knowledge on Solar Panel Shading Effect

"The shade effects of solar photovoltaic on plants are still uncertain." (www.renewablepowernews.com / archives/1049). The literature appears void of any directly applicable citations that would attribute vegetation success to the size and shape of the solar panels or the shade cast by such photovoltaic (PV) structures. The majority of the knowledge associated with open field solar collection for electricity is less than 50 years old. Most literature associated with this type of energy production is descriptive and found with roof mounted systems. The use of solar farm technology is described best by researchers studying locations in the southwest United States and other solar rich areas of the globe. These studies, however, are silent on the impacts associated with grasses or wildlife. Ongoing research provided by the National Renewable Energy Laboratory (NREL, 2010) have begun to gather data on the effects of PV panels on vegetation, specifically in the arid west, but the results have yet to be published (Beatty, NREL, 2010). Therefore, there are few direct citations that can be relative to the Stafford Township landfill application.

On the contrary, shading effects on turf grasses have been well studied and provide some basis for the effects one would attribute to solar PV panels. Most research has discovered shade has physical and physiological impacts on plants (Stamps et al, 1994; Lin, 1999; Trenholm, 2000; Tegg and Lane, 2004; Caminos, 2006; Watts, 2008). It has been a well known physical phenomenon that light is one of the major limiting factors affecting plant growth (Daubenmire, 1974). Stier (2006) indicates shade is one of the three primary non-edaphic environmental stresses on turf grasses. Light is responsible for photosynthesis of sugars, required for plant growth and longevity. In a simplistic description, lower the light levels produce lower production of sugar via the photosynthetic process. Watts (2008) found shade grown grass had lower sugar levels, providing a selective pressure for herbivores that selected grasses with higher sugar first. Turf grasses and their related warm season bunch grasses are not adapted to shaded conditions (Stier, 2006). Naumburg et al (2001) found western bunch grasses grew better under un-shaded conditions yet such species did survive under shaded conditions, resulting in a normal suite of plant responses from leaf biomass accumulation to flowering. Trenholm (2000) found southern turf grasses, such as St. Augustine-grass, zoysia-grass and centipede-grass have a wide tolerance to shade. Moderate sun species require a minimum of 5 to 6 hours of direct light whereas species requiring full sun required as much as eight hours to grow successfully.

Light intensity has been measured in a variety of ways. Most studies use a percentage of full light as a division between light levels (Houx et al, 2009). Others use radiation levels that measured various wavelengths such as the red to far infrared ratios (Naumburg et al, (2001). None of the literature reviewed for this paper has found a consistent method to describe the light levels available for plant development and photosynthesis. Shade cloth provides a direct method to limit light to levels between 100 percent and 20 percent. The actual radiation recorded for these levels, however, is not described.

Methods


Typical Light Meter ground orientation for light collection

A series of light recordings were collected to estimate the survival and final disposition of the current landfill grasses. The readings were collected in various grass dominated conditions, existing solar panel arrays as well as under a simple shade test assembly.

Light measurements were made using an Amprobe® LM-120 digital light meter. Readings were recorded in Lux[1] (lx). The light recording aperture was placed flat on the ground to simulate the blades of grass.

Light measurements were collected from various conditions reflecting the range of grass habitats. Reference measurements were made at a well known switch grass field, located in the historic Batsto

[1] Lux (lx) is equivalent to 10.764 foot candles; lx is the measurement of 1 lumen per square meter.

village, Burlington County. This reference site provides measurements within an existing old field dominated by a suite mature warm season grasses including species common to the species planted on the landfill.

Reference data was also collected from a suite of other conditions to provide a range of light readings in situations where warm season grasses now exist. Readings were collected from:

- an open hay field mowed twice a season
- a field edge with significant shading supporting warm and cool season grasses
- a forest gap with little blue stem and Indian grasses
- a forest floor under a deciduous canopy with few herbaceous components

Data were also collected from an existing solar photovoltaic panel array installed at the Ocean County facilities located at the northern edge of the Stafford Landfill.

Records collected for reference and comparison were made during a full sun exposure during a cloud free sky, between the hours 10AM and 2PM.

The shading effect cast by the solar panel was estimated by creating a mock panel. This simulation was used to create shadowing and provide a means to directly measure sun strength under the proposed panel. A plywood sheet was used in place of a true panel. It was elevated 4.25' from the ground surface to provide a situation similar to the proposed installation. This was used to measure light and the effects of shading. The information will be used to assist the shade impact prediction.

The data collected from these diverse conditions would provide a basis to make an informative opinion on the impacts anticipated from the installation of the landfill's proposed solar panel array.

Results

Planned Development: The proposed solar array will occupy a portion of the reclaimed landfill. The arrays will be constructed from 1,026 individual panels (16 feet by 27 feet), attached in rows that will span the landfill. The panel rows will be spaced 20.5 feet apart to allow vehicular access for repair and maintenance. The panels will orient perpendicular to the available sun, elevated above the landfill surface by widely spaced concrete ballasts. Maintenance would include yearly non-growing season mowing to eliminate woody plants from interfering with the power production.

Solar Reflectance Measurements

Measurements made on the various landscapes indicates canopy and surrounding vegetation directly influences the light readings. Under an unobstructed sky, readings ranged between 1,250 lx at the landfill and 418 lx under a deciduous forest canopy. This range of 832 lx is the ambient conditions under which grasses apparently naturally grow.

Landfill Light Readings: The landfill's short, sparse vegetation produces a mosaic of cover, resulting in reflectance with high values where cover is less than 50%. This lower cover provides a high albedo with significant side scatter. The short newly establishing vegetation has few leaves and those that are present are small. The smaller leaves provide little or no reduction to side scatter and allow sunlight to reflect off the sandy substrates. Light readings made on this environment produced some of the highest values recorded during this study. The measurements recorded light values above 1,240 Lx on the top of the landfill and higher values were noted on the side slopes. The readings above 1,200 lx are attributed to the open sky, great distance to other vegetation, sandy soils and the reflectance created by this open condition. Table 1 presents the readings made on the landfill and similar grassland areas.

Table 1: Light Readings in bright sun between 10AM and 2PM 7/20; 7/21/2010.

Light Readings (*Lx*)	Landfill Terraces	Batsto Switch Grass Field mid-culm	Orchard Grass Field	Field edge West View with grasses	Oak Forest Gap with grasses	Oak Forest Floor few Gaps/Grass	Closed Canopy, no gaps/grasses
Minimum	1244	859	1199	679	981	418	225
Maximum	1274	914	1226	738	999	467	250

Reference Vegetation Light Readings: Light measurements were made at various existing grass dominated areas to illustrate the wide range of light conditions that native grasses grow.

- The Batsto site is completely vegetated supporting greater than 100% coverage, providing little opportunity for back scatter, thus reducing the ambient lx available to the meter. The switch grass site recorded light readings between 859 and 914 lx. This is a 336 lx difference between the landfill condition and this well established old field.
- The hay field measurements had values above 1,000 lx but lower than the landfill. This is also attributed to a reduced back scattered muted by a dense groundcover created by last year's leaves.
- Field edges dominated by grasses had values in the high 600 lx to approximately 750 lx. The lower values are attributed to the indirect light reaching the area before 2PM yet a presence of a back scatter from adjacent sun filled areas.
- Open canopy forest with a defined gap has measurements in the range similar to the Batsto reference population. This type of site has a weak back scatter but ample direct light for short durations.
- Closed canopy forest has low light readings less than 225 to 250 lx. Few herbs requiring full sun are found in this environment.

Native grasses, primarily little bluestem and broom grass, are found in light levels between 600 and 1,000 Lx. Generally, the measurements made in the various light regimes indicate native grasses grow best when light values exceed 600 Lx.

Mock Panel Findings: Measurements made under the simulated panel found values in excess of 600 Lx (> 819) where sunlight was visible without shadow. This bright light condition will occur from the edge of shadow cast by an adjacent row to a point approximately 4 feet under the front of each panel. There is a shadow zone that did not receive direct sun and this area will receive less than 600 Lx. The shadow area will receive reflected light scattered from the open area between each panel row. Measurements in the shade cast by the mock structure in late afternoon sun recorded values between 514 and 525 Lx. This is similar to the stippled lighting of an open canopy forest were grasses are widely scattered. It is brighter than the closed canopy conditions were scattered warm season grasses persist. This mock panel assembly was sufficient to add validity to the shade measurements when reviewed in conjunction with the shade evaluation made at the County solar array.


Solar panel array setup on County facility

Existing Solar Panel Array: The Ocean County Southern Resource facility is located at the terminus of Haywood Road, on the northern edge of the landfill. This facility supports numerous buildings that are occupied by a number of public departments, including roads, recycling and public works. The County installed an array of solar photovoltaic collection panels on a vacant part of this property. 24 stand alone panels surround a storm water retention basin near the facilities northern work limits. These panels are relatively new and the resulting landscape is still recovering from the basin and panel installation procedure.


Poles and caisson separation

The panels are composed of an aggregate of ten connected panes that measure 62 inches by 32 inches (nominal). The panes are tied together in a larger panel that is 11 feet by 13.3 feet. Each panel is supported by a single galvanized 8 inch pole. This pole attaches to the steel pane framework at the center of the structure. The pole provides the entire support for the stand-alone system. The support pole is anchored in a 38 inch wide circular concrete caisson. The panels are angled toward the sun with the lowest edge elevated 52 inches and the highest edge 128 inches above the ground. This set up closely matches a segment of the system proposed by Walters for the landfill. The individual panels are separated by 180 inches as measured between support poles.


Single panel array composed of 10 panes

The panel panes are attached in a surface that is closely spaced but not solid. A narrow (~1 inch) space exists between each pane, providing a narrow gap capable of allowing a sliver of sunlight to be transmitted to the underlying shaded area. Each panel is separated horizontally from the adjacent panel by a narrow distance. The gap as measured between the top of one system and the bottom of the next panel is 24 inches.


Planted red fescue cover beyond panel influences

Light readings collected beyond the influences of the solar panel resulted in a full sun measurement between 920 and 1,123 lx (~11AM 8/10/2010). Light measurements made in the center of the shaded area cast by the panel resulted is widely divergent light measurements. The meter recorded the range between 200 to nearly 1,500 lx. The lowest values were recorded during bright sunlight when the shadow was darkest, best defined without a cloud scatter. The higher values were recorded during an intermittent cloud cover. The cloud cover appears to provide significant light scatter between the single panel array and thus the substantially higher readings. Its record is higher than full sun is an anomaly that is not answered by this simple measurement.

The light under reach panel appears to be sufficient to support light grass cover. The vegetation surrounding the panels is planted with a mixture of soil erosion grasses naturally supplemented with a few opportunistic invasive species. The plant species recorded for the area surrounding and under the panels includes:

- *Agriositis stolonifera*
- *Festuca rubra*[2]
- *Conzia canadensis*
- *Anthemis cotula*
- *Kummerowia sriata*
- *Eupatorium serotinum*
- *Panicum virgatum*
- Winter Rye
- *Lolium multiflorium*

Vegetation did not appear significantly different in species composition or overall coverage between the full sun and panel shaded areas. What was noticeable was the grass in the shade appeared slightly taller and more lush, possibly a function of the slightly more moist soils created by the variable shade. The grasses found beyond the influences of the panels appeared more stressed from the intense sunlight and the dryer conditions created by the open conditions on the manmade substrates that were used to created the retention basin and its slopes.

Solar Panel Impacts

Vegetation Displacement

Concrete Anchor: The proposed concrete anchor that will hold each panel will exert a permanent impact of 28 square feet per anchor. Based on the need for two anchors per array, there will be 1.32 acres of permanent cover created by the concrete anchors. An equal area of warm season grasses would be permanently eliminated by the anchors. Calculations provided by the site engineer states an additional 0.23 acres would be occupied by inverters, poles and transformers. The total loss would be 1.55 acres used by panels, ballasts and associated equipment.

[2] The dominant species observed in the vicinity of the existing panels.

Reduction in Grass Cover and Grass Density

Shading: The proposed solar panel array will cast a variable sun shadow that could reduce the plant cover and plant density under each panel. The panel will reduce direct sunlight under each panel in direct proportion to its total collection area. Based on the proposed solar panel array layout, there will be a maximum 20.5 foot shadow behind each panel. Within this area there will be a reduced light intensity. Recordings made in a similar shadow reduced the sunlight to less than 600 Lx. This is reduced to a degree that should allow the grasses to persist but not bright enough to create the conditions associated with full open environments or as measured under the individual separated County panels. There will be a 282.5 square foot shadow produced by each panel. Figure 1 illustrates the proposed shadow conditions produced by each solar panel.

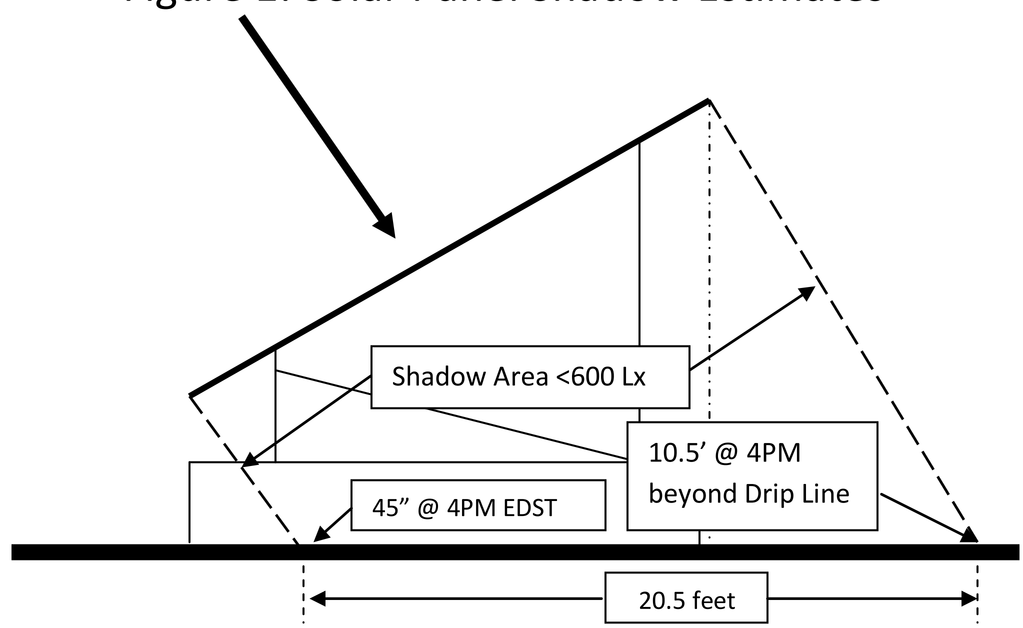

Figure 1: Solar Panel Shadow Estimates

Conclusions

The presence of solar panels on the Stafford landfill will impact the planted warm season grasses. The impacts can be separated into two types: Permanent vegetation loss created by the panel supports as well as grass vegetation reduction caused by the reduced sun directly on the planted grasses. Direct loss will occur through the use of concrete anchors used to hold the panels against the wind. This will eliminate 1.32 acres of grasses by displacement. Total loss would include associated infrastructure resulting in an additional 0.23 acres, for a final tally of 1.55 acres on permanent cover.

The second impact will be a reduction in the grass cover under each panel. This reduction will occur from the reduced light thus reducing the cover and grass clump density. This will reduce the grasses to a thinner cover commonly visible on Pine Barren forest sand roads. Data collected from the existing

County panels indicate the grasses may actually benefit from some shading providing a slightly moister substrate that could be utilized by the grasses. The grass cover found outside the influences of the solar panels and their anchors would not be impacted by the panels but will be manipulated seasonally by mowing and other maintenance activities. These areas would continue to receive ample sun light suitable for growth and seed production. The yearly mowing will maintain a grass cover removing the unwanted woody species. This activity would provide a season check on the anticipated succession toward a woody plant cover.

Based on this data there will be limited impacts to the planted landfill grass vegetation. The impacts are minor at worst and, based on observations of the county solar system, should have no negative impact. No modifications would be anticipated to the grass maintenance schedule and no additional seeding is anticipated to augment the plantings now maturing on the landfill.

References

Caminos, T.S. and S.J. Estevez. 2006. Effects of shade on the persistence of cool-season grasses to form turf grass. Agricultura Técnica (Chile) 67(4):372-383.

Houx, J.H. III; R.L. McGraw; F.B. Fritschi; N.E. Navarrete-Tindall. 2009. Effects of shade on growth and nodulation on three legumes with potential use in agroforestry. Native Plants Journal Vol. 10, 3: 232-238.

Lin, C.H.; R.L. McGraw; M.F. George and H.E. Garrett. 1999. Shade effects on forage crops with potential in temperate agroforestry practices. Agroforestry Systems Volume 44, Numbers 2-3, 109-119.

Naumburg, E.; L.E. DeWald; and T.E. Kolb. 2001. Shade responses of five grasses native to southwestern U.S. *Pinus ponderosa* forests. Can. J. Bot. 79 (9): 1001-1009.

Stamps, R.H; F.P. Beall; B.W. Beall; J,P, Carris; M.R. Jackson; S.M. Motley; P.S. Smith and N.L. Freeman. 1994. Effects of shade level and radiation freezes on the survival and growth of groundcover plants. Proc. Fla. State Hort. Soc. 107: 423-426.

Stier, J.C. 2006. Understanding and managing environmental stresses of turfgrass. ISHS Acta Horticultrae 762: XXVII International Horticultural Congress-IHC 2006: International Symposium on Horticultural Plants in Urban and Peri-urban Life, Chillan, Chile.

Tegg, R.S. and P.A. Lane. 2004. A comparison of performance and growth of a range of turfgrass species under shade. Aust. J. Agric. Res. 44: 353-358.

Trenholm, L.E. 2000. Growing turfgrass in the shade. University of Florida IFAS Extension, ENH151.

Watts, K. 2008. Grass in Shade is lower in Sugar. Rocky Mountain Research and Consulting. Funded by the Animal Health Foundation, pp. 1-5.