A HIGH PERFORMANCE SCHOOL CASE STUDY: NORTHERN GUILFORD MIDDLE SCHOOL

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ABSTRACT

Northern Guilford Middle School in Greensboro, North Carolina is an excellent example of the commitment to promoting sustainable design. The school features a comprehensive and well-integrated set of green strategies that include:

- A holistic water cycle approach (rainwater for toilet flushing to the Living Machine™ to underground irrigation to the aquifer) coupled with bio-swales and wetlands;
- A new daylighting design that has never been implemented in any facility;
- Indirect lighting with photocells and occupancy sensors;
- Energy-efficient building shell;
- Underfloor air distribution system;
- Solar water heating and photovoltaic systems;
- Recycled materials and use of local products;
- Indoor environmental quality management;
- 3-D experiential learning centers linking curriculum to sustainable design features;
- And the 70 million year old Nicklas Mosasaur Fossil.

This case study will introduce detailed information of each green strategy and how comprehensive strategies are well integrated into the project to stay within the budget.

1. INTRODUCTION

The Northern Guilford Middle School is designed as a 3-D textbook so the students, teachers and the community can learn about sustainable design strategies and how they reduce the impact that human development has upon our environment. The middle school has 140,000 square feet and includes classrooms for 950 students plus dining, gymnasium, auditorium, science, art, music, technology, media center and administration facilities. To minimize cost and maximize environmental benefit, the site work for both the adjacent high school and middle school were designed by Innovative Design. This work includes rainwater harvesting, extensive bio-swales and three constructed wetlands, wastewater treatment, and subsurface irrigation systems.

The Northern Guilford Middle School has been designed to consume less than half the energy of typical existing schools in the region. Northern Guilford Middle School has been '*Designed To Earn The Energy Star*', in accordance with building energy consumption standards as set by the United States Environmental Protection Agency (USEPA). Detailed, hourly DOE-2 building energy simulations for this project place it among the top 10% in energy efficiency in K-12 school category nationally.

2. SITE DESIGN

2.1 Orientation and Ecosystem Protection

The school has been oriented on an east-west axis to maximize the southern solar potential for daylighting, passive solar, solar domestic hot water, and photovoltaic applications. East and west glazing is minimized to reduce heat gains. Certain site features have been retained to later serve as 3-D teaching tools. 32% of the surrounding site has been left undisturbed to sustain a 'natural' landscape and most of disturbed site has been developed to permeable surface such as constructed wetlands, bioswales, athletic fields, berms, etc.

2.2 Water Cycle

The school features a holistic water cycle approach. No public stormwater sewer system is available near the site so all the stormwater is treated on site and released back to the aquifer. Rainwater is collected from two schools' roofs and sent to cistern, back to two buildings for flushing toilets, to the Living Machine, to the three athletic fields, and finally to the aquifer. Stormwater on the ground surface is diverted to bioswales and constructed wetlands and finally back to the aquifer.

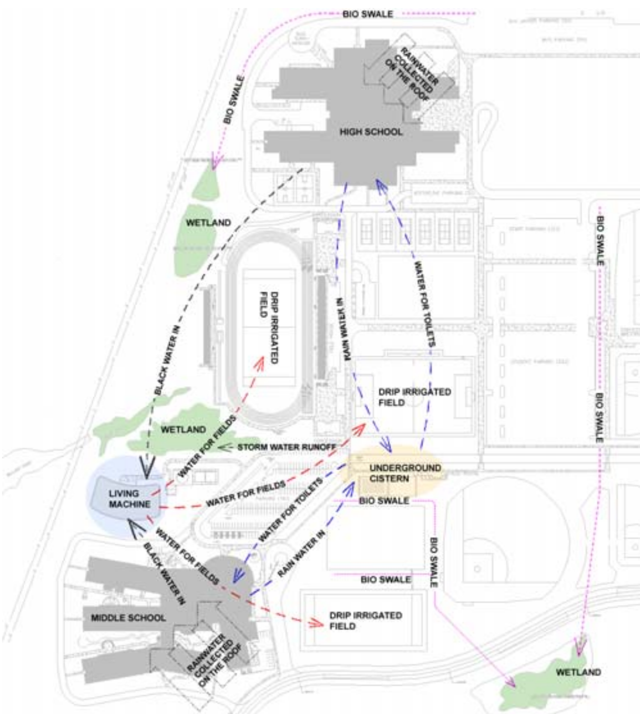

Fig. 1: Overall water cycle

2.2.1 Rainwater Catchment

The school's innovative, sustainable cycle of water usage is one of the most unique features and a lesson for the students in ecology. Rainwater is collected from the roof areas of the middle school and adjacent high school and is stored in a centrally located 360,000-gallon concrete cistern, the top of which also serves as a basketball court for the school. The top half of the reserved water is used primarily for toilet flushing and this part of the water cycle saves 4 million gallons of potable water annually. A bottom half reserve of the water is always maintained in the tank for fire fighting.

2.2.2 Living Machine™

The next component of this water cycle is the hybrid horizontal flow wetland (HFW) and tidal flow wetland (TFW) Living Machine system. It uses plant-based strategies to cleanse 30,500 gallons of wastewater per day from the middle and high school buildings and produces enough clean water to irrigate three athletic fields. The HFW is an outdoor surface treatment area and removes TSS (Total Suspended Solids), BOD (Biochemical Oxygen Demand) and denitrify the wastewater. The TFW is another outdoor partially underground structure that is consisted of three cells. The TFW cells have high nitrification rates resulting from fill and drain hydraulics and other design features including a special treatment media.

This environmentally-sound, on-site treatment strategy costs less than other pre-treatment strategies and helps to reduce the amount of nitrogen entering the watershed. It was incorporated because there are no central sewer lines within miles of the site. This part of the water-saving strategy saves an additional 5 million gallons of potable water per year by using the water twice. The cost of extending the city waste lines to the site would have been at least $4 million more expensive to the school system.

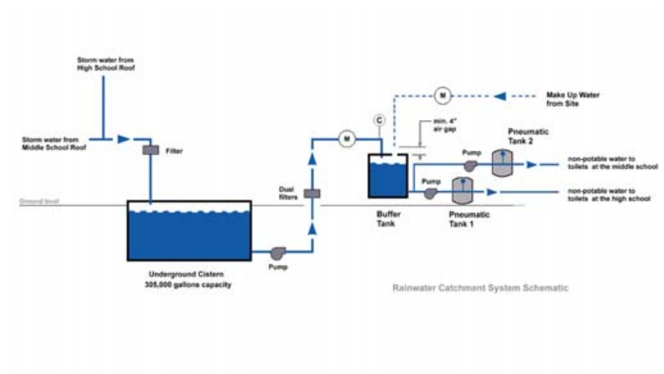

Fig. 2: Rainwater collection flow diagram

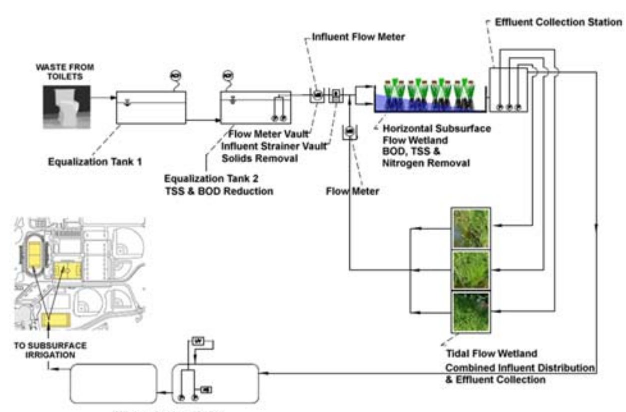

Fig. 3: Living Machine flow diagram

2.2.3. Subsurface Irrigation System

Additionally, a sub-surface piping system is utilized for irrigating total 6.1 acres of the three athletic fields. It uses 40% less water than conventional sprinkler irrigation due to reduced evaporation. The final significant benefit of this water strategy is that clean water is returned to the aquifer. When schools are not in session during summer break, wastewater treatment is minimal so rainwater is used for irrigation.

2.2.4 Constructed Wetlands and Bioswales

A series of bio-retention swales and three constructed wetlands capture all rainfall that does not fall on the roof areas, further minimizing nitrogen runoff before being discharged to the local streams and rivers. No storm water will be discharged directly to local storm sewers. Special soils and a variety of aquatic plants such as Pickerel Weed, Soft Rush, and Spike Rush are used to reduce pollutants from the storm water. One of the wetlands is also used as part of the school's science curriculum, offering the students a unique opportunity to study local eco-systems. Photovoltaic driven aerators are used in constructed wetlands.

3. DAYLIGHTING

Natural light is the primary source for all educational and administrative spaces during two-thirds of the daylight hours. Daylighting reduces the need for fluorescent lighting and also the school's air conditioning because the efficacy of the daylighting is about twice higher than the fluorescent lamps. The integrated design of daylighting, roof assembly, and underfloor air distribution system reduced the installed tonnage by 82 tons. DOE-2 analysis results that the daylighting reduced the 50% of lighting energy and 11% of the total building energy compared to the ASHRAE 90.1-2001 compliant base model.

3.1 Innovative Daylighting Design

The use of natural daylight is the primary energy saving strategy as well as a significant factor improving student performance. At Northern Guilford Middle, a new approach to daylighting is being incorporated for the first time anywhere. By facing south in both north and south classrooms coupled with optimized overhang design, maximum solar heat gain during the winter and minimal heat gain during the summer is achieved while the daylighting benefit is maximized. The significant breakthrough in daylighting design utilizes a unique curved, translucent interior lightshelf, which in combination with highly reflective ceiling tiles enables the light levels within the classroom spaces to be very uniform while requiring 40% less glass area than is normally used in other daylighting applications. Because of the 20% T_{vis} (Visible Light Transmittance) level translucent panel of the lightshelf and the design of the aperture, glare is minimized and soft light is distributed well.

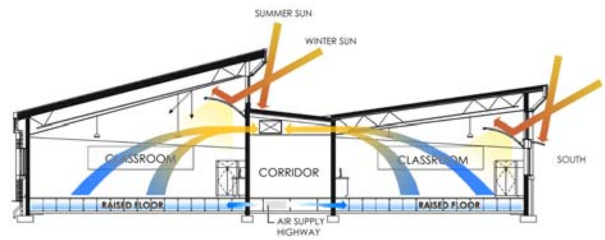

Fig. 4: Typical classroom section

Fig. 5 Interior view of daylit classroom

3.2 Daylight Monitors

Daylighting in the gymnasium and dining areas of the school is provided by south-facing roof monitors with translucent fabric baffles in the light wells. These features eliminate direct glare and effectively diffuse light throughout the spaces. Clear, double glazing is used to maximize visible light transmittance and minimize glass-to-floor ratio. Adequate overhangs over the monitor windows protect the spaces from direct light during peak cooling periods.

Fig. 6 Baffles in monitor well cutting off direct sunlight

3.3 Strategically Selected Glazing

The types of glazing are selected strategically. In daylight clerestory windows, clear double glazing is used to maximize T_{vis} resulting in minimizing glass area. Lower view windows facing south and north have clear low-e double glazing. Windows facing east and west have tinted low-e double glazing.

3.4 Interior Architectural Shading

Another innovative daylighting strategy used in the classrooms is a unique interior dropped soffit that slopes up towards the rear of the space. This architectural element is situated to intentionally shade the projection screen area and the TV monitors located at the corner (Fig.5 and 7) without blocking views, and without the need for manual/ automatic window shading devices.

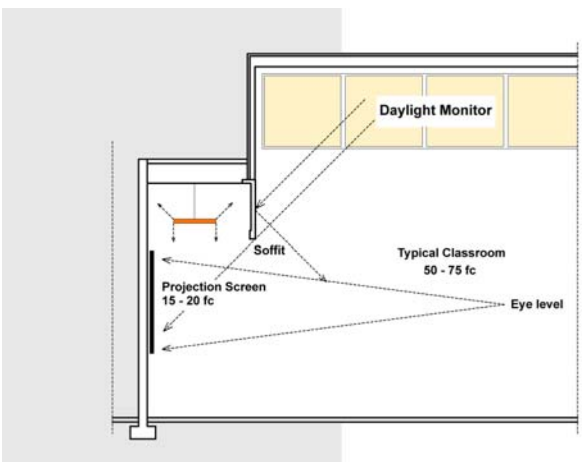

Fig. 7 Architectural shading strategy

3.5 Daylight-Responsive Electrical Lighting

Indirect fluorescent lighting is installed throughout the school building. The lighting is dimmable and controlled by an occupancy sensor and a photocell sensor that work in conjunction with the natural daylight to minimize artificial light usage.

Spaces to be used only during daytime such as classrooms where 60 foot candles is desired, 1/6 of light fixture cost was saved initially due to the fact that daylighting provides at least 10 foot candles even on a very cloudy day.

4. ENERGY EFFICIENT BUILDING SHELL

4.1 Thermal Mass Construction

Interior and exterior walls are constructed with concrete masonry units with an exception of interior walls at offices in the administration wing. The 8-inch thick CMU wall provides approximately 8 hours of thermal lag time so it stores the heat during the daytime and release overnight in winter. In summer, it stores cooler air overnight and release during the daytime.

4.2 Highly Reflective Roofs

Flat roof area is covered with white TPO (Thermoplastic Polyolefin) membrane material. Sloped roof area is covered with light tan color insulated steel panels. The initial and 3 year solar spectrum reflectance of the TPO membrane is 0.87 and 0.83. That of the insulated steel panel is 0.68 and 0.55. Both roof materials are qualified for Energy Star. Knowing more than 80% of heat gain is through the roof, these highly reflective roof materials reduce significant amount of cooling load.

4.3 High R-value Insulations

Exterior wall is consisted of 4-inch brick and CMU veneer, 4 inch of cavity and 8 inch CMU. The 4 inch cavity - actual dimension is 4 3/4 inches - is filled up with foam-in-place insulation which is consisted of an amino-plast resin and a catalyst foaming agent surfactant. 8-inch CMU wall has grouted solid in cells at every 48 inches on center and all the other cells are filled up with the foam-in-place insulation. The total R-value of this wall assembly reached to R-37. High ceiling spaces such as auditorium and gymnasium are stratified. Lower portion of these spaces are enclosed by other low-ceiling spaces and the high portions are exposed to the exterior. The exposed exterior walls have 1 inch of EIFS (Exterior Insulation Finish System) and foam-in-place insulation in empty CMU cells.

Roof assemblies - both membrane and metal roof areas - are consisted of minimum R-30 insulation.

5. UNDERFLOOR AIR DISTRIBUTION SYSTEM

An underfloor air distribution system has been incorporated in classrooms, the media center and administrative offices. The raised floor system greatly enhances comfort, air quality, flexibility, and energy-efficiency. This system also saves initial construction cost by reducing the need for expensive steel ductwork and ceiling plenum for ductwork. The saving can be maximized when underfloor air distribution system is integrated with daylighting strategy.

Fig. 8 Underfloor system construction

6. RENEWABLE ENERGY

6.1 Solar Domestic Hot Water

10 CPC (Compound Parabolic Collector) panels are installed on the south exterior wall outside the kitchen and boiler room. This drain-back solar thermal system provides approximately 75% of the hot water for the school, the majority of which is used for the cafeteria.

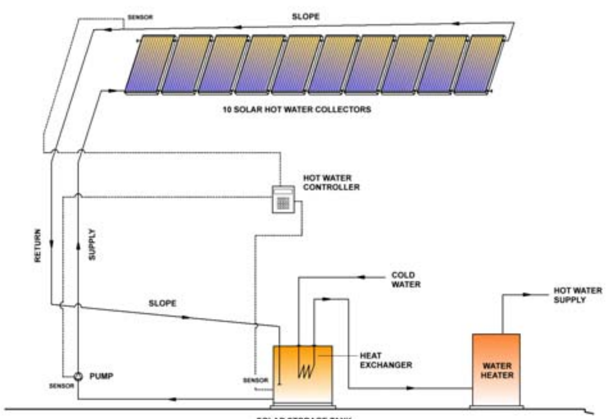

Fig. 9 Solar hot water schematic diagram

Fig. 10 Solar hot water system

6.2 Photovoltaic

Photovoltaic systems have been strategically incorporated into the 6th grade science courtyard as an educational tool and to provide electricity used by the 6th grade wing. A separate, remote photovoltaic system has been implemented to light the main school sign. The aerators in the wetland areas and the fountain at the sensory garden for disabled students are also powered by photovoltaic. All these systems are total 1.5kW. Initial cost saving was achieved by using PV system for these remote locations otherwise the conduit cost from the main building would have exceeded PV cost.

Fig. 11 Various PV systems

7. ENVIRONMENTALLY SENSITIVE MATERIALS

7.1 Recycled And Local Materials

Materials with recycled content include carpeting, metal roofing and acoustical ceiling tiles. A construction waste management plan was required by the G3-Guilford Green Guide during construction to minimize waste going to landfills. Almost 60% of the total construction waste has been diverted for recycling. Also, the school will implement a program for daily recyclable.

Locally manufactured masonry products are the predominant structural and finish materials. The specifications were developed to encourage local products and manufacturers, and preference was given to local manufacturers during the bidding process.

FSC (Forest Stewardship Council) certified wood floors are installed in gymnasium and auditorium stage and wood doors throughout the school.

7.2 Indoor Environmental Quality Management

A U.S. General Accounting Office investigation of the conditions of our country's 80,000 public schools concluded that over half the schools in the United States had poor indoor environmental conditions – factors that were directly affecting the health, safety and comfort of 42 million students. Northern Guilford Middle School is designed to address these issues by implementing the following measures in the building:

- No adhesives used for carpet tiling
- Low VOC paints and adhesives
- Urea-formaldehyde free casework
- High MERV filters used throughout
- Xeriscaping to minimize use of pesticides and irrigation
- Radon testing during construction of all spaces
- Indoor Air Quality Management Plan required during construction
- Air quality testing or 2 weeks of flush out required prior to occupancy
- Increased ventilation using outdoor air
- CO2 sensors to determine need for outside air
- Sound control using green acoustic products
- 100% daylighting in all educational spaces

8. ECO EDUCATION

8.1 3-D Experiential Learning Environment

Every aspect of Northern Middle is an opportunity to enhance experiential learning. Five educational courtyards are designed to provide students hands-on learning environments. A special sensory garden courtyard has been designed for challenged students to stresses their multiple sensory experiences. The main courtyard includes a sundial. Many of the sustainable features, including the Living Machine, constructed wetlands, solar hot water system, rainwater collection, PV systems, and weather station, are highly visible as well as interconnected through computer monitoring systems. These sustainable strategies, strongly linked to their science curriculum, give students unique opportunities to learn through first-hand experience.

When the school opened, the architect gave all the students and teachers a tour of the entire facility to educate them on the sustainable features. Also an educational handout has been provided to the school.

Interpretive signage is developed and installed at multiple locations throughout the campus to educate students, staff, community and visitors. Further, they can use their computer monitoring systems to compare the performance of their systems to other schools.

8.2 Sustainable Feature Monitoring System

Monitoring provides an interactive graphic interface to help educate visitors and students about the different sustainable systems being used at the school. Further, Internet (online) monitoring systems allow multiple interfaces to connect and be available to Internet users at schools, and other educational facilities. An LCD screen is installed in the main hall outside administration office to demonstrate sustainable features to visitors. The following systems are monitored real-time:

- Solar water heating
- Photovoltaic systems
- Daylighting
- Rainwater harvesting
- Living Machine
- Weather Station

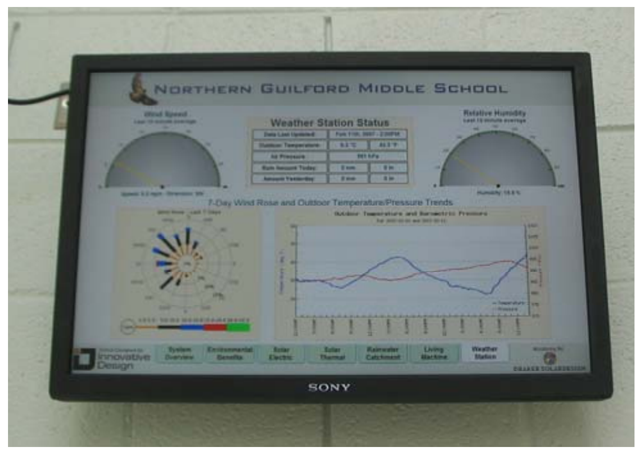

Fig. 12 Monitoring screen

8.3 Symbol of Sustainability

A 70-million-year-old mosasaur, an extinct marine reptile that lived in the sea that existed then in central North America, are donated to the school and displayed at the main hall. Found by Dr. Steven Nicklas near Chadron, Nebraska in July 2005, it is restored with 85% of original bones. The goal was to reinforce the overall objective of creating the school as a teaching tool. By incorporating the Mosasaur in the school, it is hoped that the students will make the connections between the extinction of past species and the issues of sustainability that we face today.

9. CONCLUSION

Green buildings are perceived to cost a lot more than conventional buildings. Studies found that green buildings can be built with very small percentage of additional cost if the sustainable strategies are implemented at the early stage of design and through whole-building design approach. Northern Guilford Middle School is an exceptional example. The integrated design of sustainable technologies is expected to achieve total 35% of energy reduction compared to the ASHRAE 90.1-2001 compliant building which is equivalent to less than a half of the average energy consumption of existing other schools in the region and 9 million gallons of potable water saving per year while the construction cost stayed just 7 cents per square foot above the school district's prototype non-green school that was out to bid around the same time.