Glen Burnie High School

Glen Burnie, MD

Wade Myers

Mechanical Option

Glen Burnie High School

Glen Burnie, MD

School Background

- 6 building; campus style high school
- Located in Glen Burnie, MD
- Construction of first building started in 1934
- Junior High School absorbed by campus in 1955
- Latest building added in 1976

Wade Myers

Mechanical Option

Glen Burnie High School Crest

Glen Burnie High School

Glen Burnie, MD

Building Breakdown

- Building A: Media Building
- Building B: Industrial Arts Building
- Building C: Administration Building
- Building D: Old Main
- Building F: Business Building/ Secondary Gymnasium

Wade Myers

Mechanical Option

Glen Burnie High School Campus

Building A

Glen Burnie High School

Glen Burnie, MD

Building Breakdown

- Building A: Media Building
- Building B: Industrial Arts Building
- Building C: Administration Building
- Building D: Old Main
- Building F: Business Building/ Secondary Gymnasium

Wade Myers

Mechanical Option

Glen Burnie High School Campus

Building B

Glen Burnie High School

Glen Burnie, MD

Building Breakdown

- Building A: Media Building
- Building B: Industrial Arts Building
- Building C: Administration Building
- Building D: Old Main
- Building F: Business Building/ Secondary Gymnasium

Wade Myers

Mechanical Option

Glen Burnie High School Campus

Building C

Glen Burnie High School

Glen Burnie, MD

Building Breakdown

- Building A: Media Building
- Building B: Industrial Arts Building
- Building C: Administration Building
- Building D: Old Main
- Building F: Business Building/ Secondary Gymnasium

Wade Myers

Mechanical Option

Glen Burnie High School Campus

Building D

Glen Burnie High School

Glen Burnie, MD

Building Breakdown

- Building A: Media Building
- Building B: Industrial Arts Building
- Building C: Administration Building
- Building D: Old Main
- Building F: Business Building/ Secondary Gymnasium

Wade Myers

Mechanical Option

Glen Burnie High School Campus

Building F

Glen Burnie High School

Glen Burnie, MD

Building Breakdown

- Building A: Media Building
- Building B: Industrial Arts Building
- Building C: Administration Building
- Building D: Old Main
- Building F: Business Building/ Secondary Gymnasium

Wade Myers

Mechanical Option

Glen Burnie High School Campus

Glen Burnie High School

Glen Burnie, MD

Building Specifications

- Building E is the Physical Education Building
- Houses the primary gymnasium, locker rooms, team rooms, wrestling room, weight room & gymnastics area
- Approximately 26,500 S.F.

Wade Myers

Mechanical Option

Building E

Glen Burnie High School Campus

Glen Burnie High School

Glen Burnie, MD

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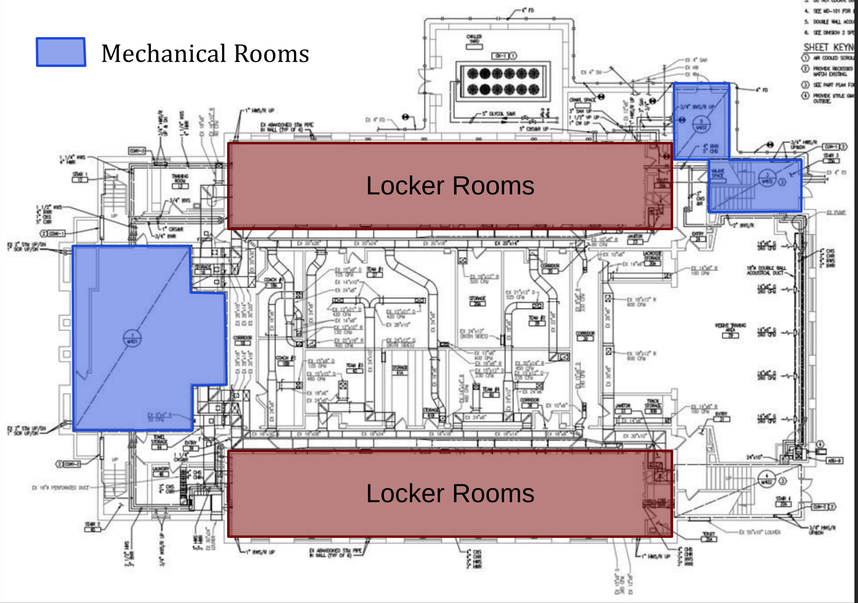
Wade Myers

Mechanical Option

Building E



Building E Ground Floor

Building E

Glen Burnie High School

Glen Burnie, MD

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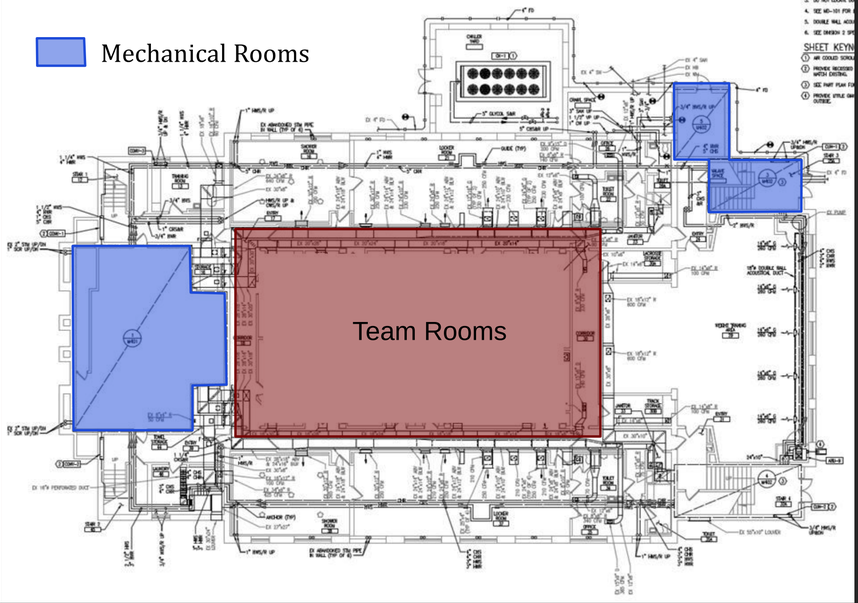
Wade Myers

Mechanical Option



Building E Ground Floor

Building E

Glen Burnie High School

Glen Burnie, MD

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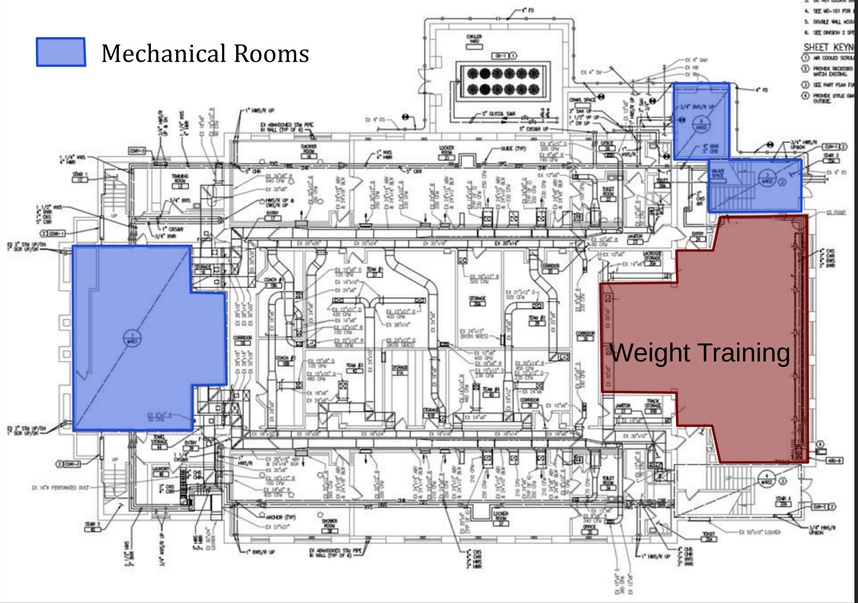
Mechanical Option



Building E Ground Floor

Building E

Glen Burnie High School

Glen Burnie, MD

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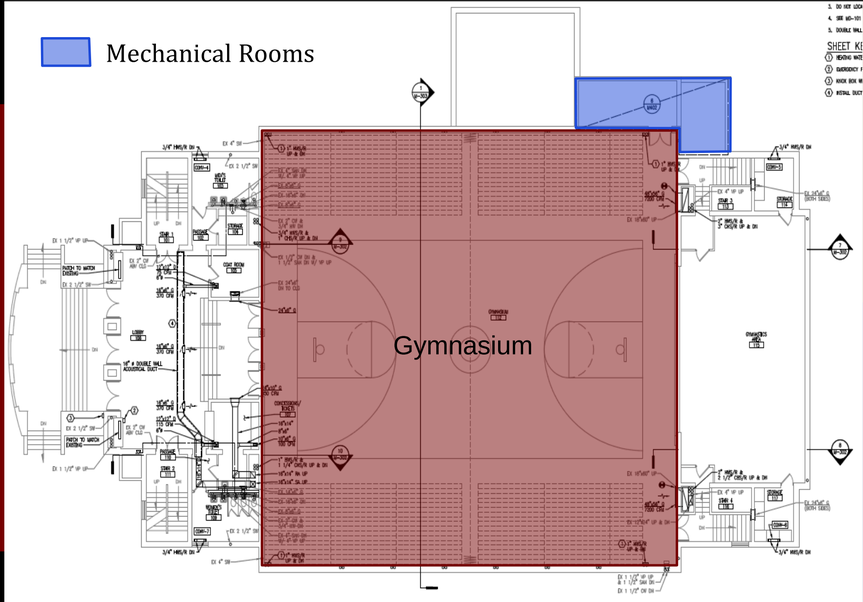
Wade Myers

Mechanical Option



Building E First Floor

Glen Burnie High School

Glen Burnie, MD

Building Specifications

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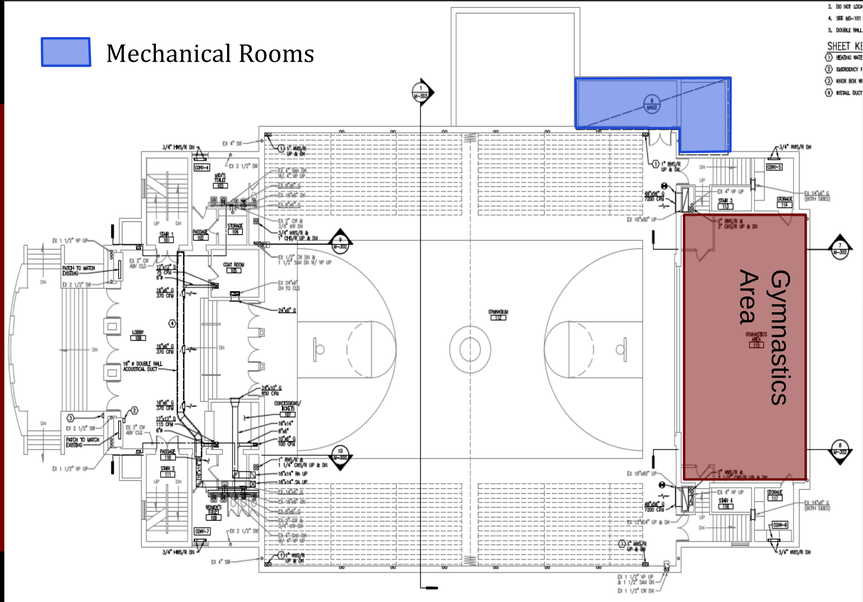
- Houses the primary gymnasium, locker rooms, team rooms, wrestling room, weight room & gymnastics area
- Approximately 26,500 S.F.

Wade Myers

Mechanical Option

Building E



Building E First Floor

Building E

Glen Burnie High School

Glen Burnie, MD

Building Specifications

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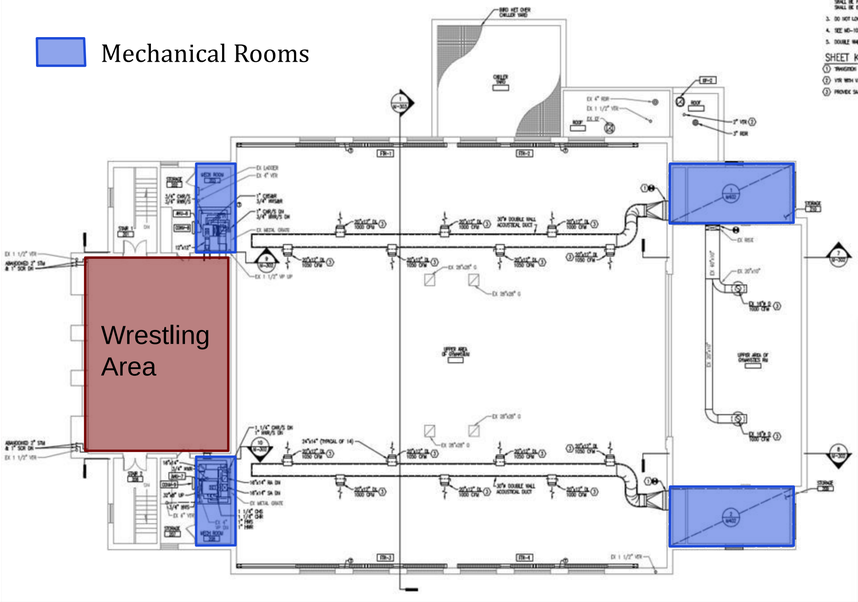
Wade Myers

Mechanical Option



Building E Second Floor

Building E

Glen Burnie High School

Glen Burnie, MD

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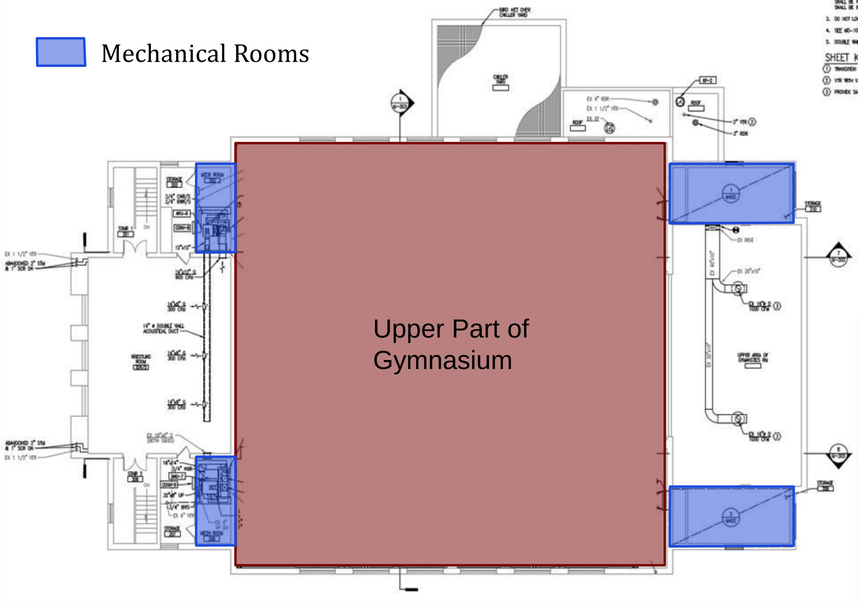
Wade Myers

Mechanical Option



Building E Second Floor

Building E

Glen Burnie High School

Glen Burnie, MD

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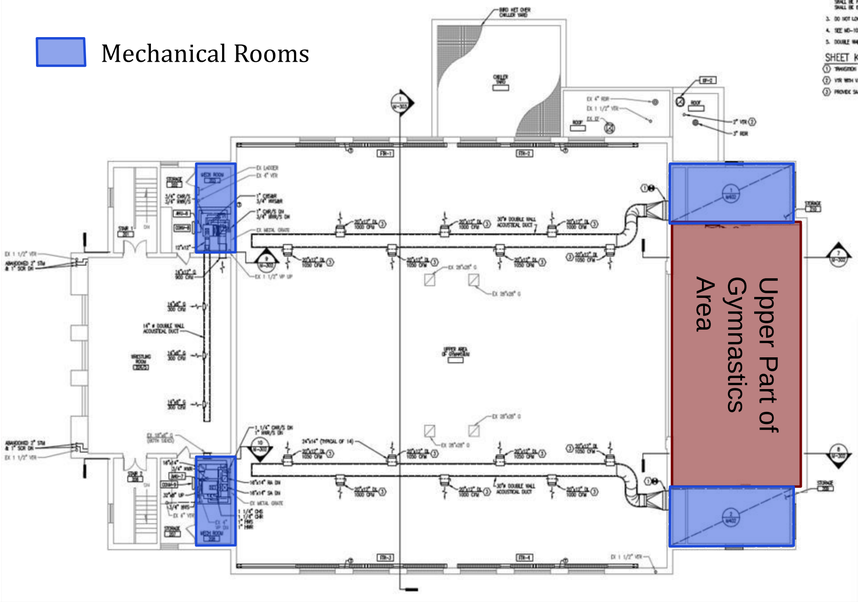
Wade Myers

Mechanical Option



Building E Second Floor

Glen Burnie High School

Glen Burnie, MD

Project Specifications	
Building Occupant	Anne Arundel County Public Schools
Occupancy Type	Education—High School
Size	110,000 Square Feet
Number of Stories	3
Project Team	Owner: Anne Arundel County Public Schools
	Architect: JRS Architects
	Mechanical & Electrical Engineer: JMT
	Civil & Structural Engineer: Carroll Engineering
	General Contractor: RWC Contracting
	Mechanical Contractor: Chilmar
Construction Dates	May 2010—August 2011
Renovation Costs	$6,000,000
Project Delivery	Design-Bid-Build

Wade Myers

Mechanical Option

Building E Front

Glen Burnie High School

Glen Burnie, MD

Existing Mechanical System

- Constant air volume system
- 9 Steam AHUs serve the building – No Cooling
- Gymnastics area served by own steam unit ventilator
- Extra heating in gymnasium by finned tube radiation
- Auxiliary heating supplied by convectors & CUHs
- Steam supplied by boilers in Building F

Wade Myers

Mechanical Option

Building E Airflow Rates

System	Service	Design Airflow (CFM)	Outdoor Air (CFM)	% OA
AHU-1	Men's Lockers	2000	2000	100
AHU-2	Team Rooms	2800	2800	100
AHU-3	Women's Lockers	2000	2000	100
AHU-4&5	Gymnasium	14400	6000	42
AHU-6	Laundry Room	2500	2500	100
AHU-7	Lobby	1300	350	26.9
AHU-8	Wrestling Room	900	100	11.1
AHU-9	Weight Room	1300	1300	100
UV-1	Gymnastics Area	2000	550	27.5
TOTAL		**29200**	**17600**	**60.3**

Building E Airflow Rates

Building E Load Summary			
System	**Service**	**Cooling (Ton)**	**Heating (MBH)**
AHU-1	Men's Lockers	5.7	101
AHU-2	Team Rooms	16.7	203.1
AHU-3	Women's Lockers	7.9	91.6
AHU-4&5	Gymnasium	84.4	696.8
AHU-6	Laundry Room	5	14.2
AHU-7	Lobby	4.2	80.4
AHU-8	Wrestling Room	3.5	72.9
AHU-9	Weight Room	7	93.1
UV-1	Gymnastics Area	6.4	164
TOTAL		**140.8**	**1517.1**

Building E Load Summary

Glen Burnie High School

Glen Burnie, MD

Existing Mechanical System - Renovation

- Chiller and enclosure added to serve Building E only
- Replace AHU's, unit ventilator, CUHs & convectors
- Energy recovery ventilating units added to 3 AHUs
- Install new chilled and heating water pipes
- Water/Glycol and Steam/Water Heat exchangers added
- Pumps added/replaced

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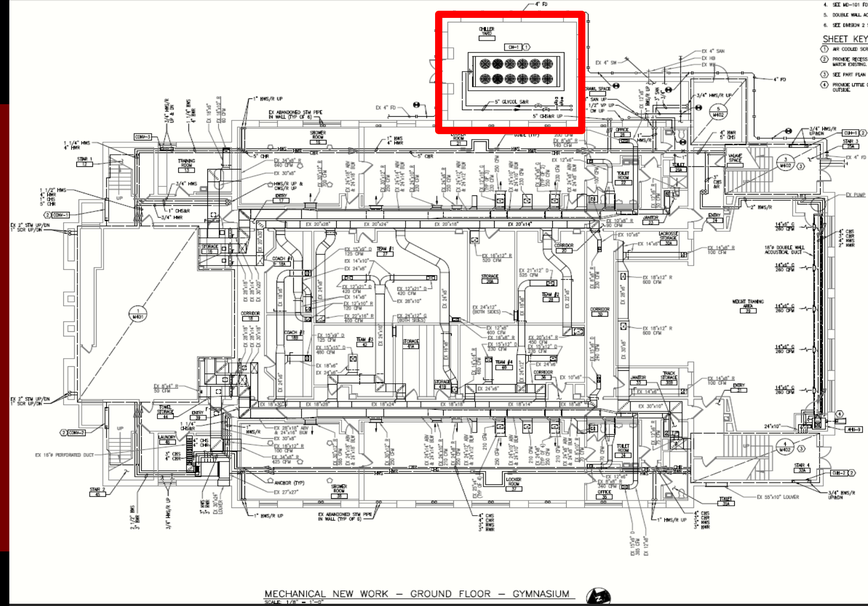
Mechanical Option



Ground Floor Mechanical Drawing

I. Introduction

II. Existing Mechanical System

III. Proposed System Alterations

IV. CM Breadth

V. Conclusion

VI. Acknowledgements

Glen Burnie High School

Glen Burnie, MD

Ground Source Heat Pump System

- Increasingly popular institutional option
- Abundance of usable ground on site
- Minimize or eliminate mechanical equipment
- Reduce energy use of the building
- Monetary savings

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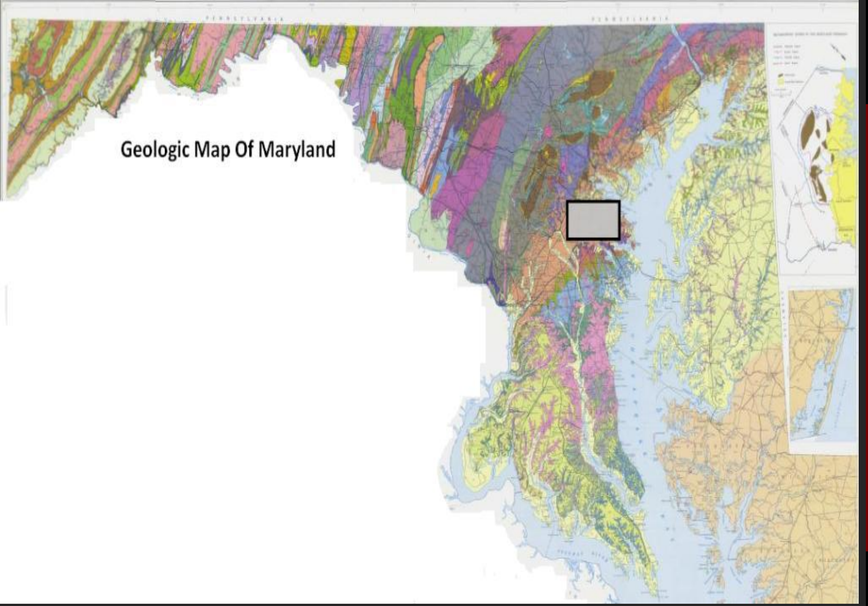
Mechanical Option

Typical Vertical Ground Source Heat Pump System



Geologic Map of Maryland

Glen Burnie High School

Glen Burnie, MD

Site Ground Analysis

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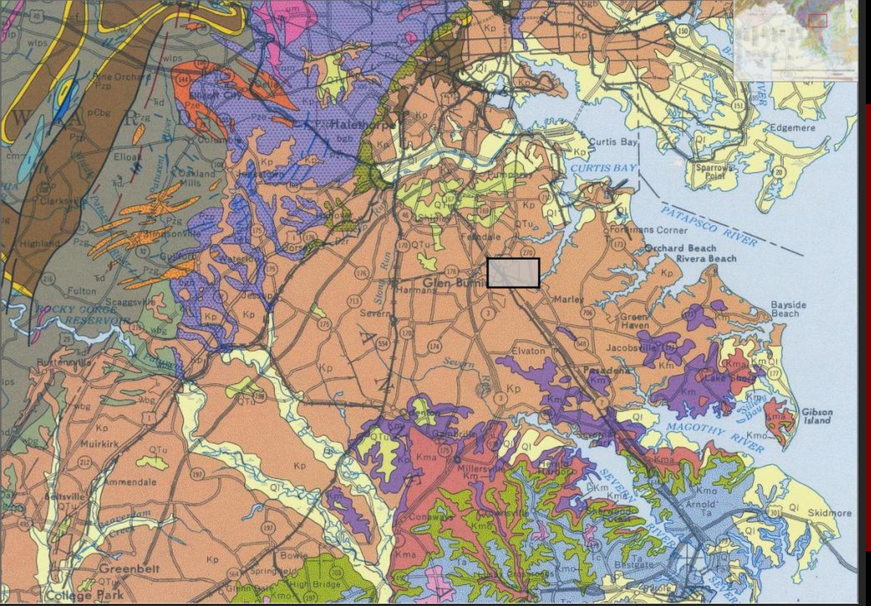
Mechanical Option



Geologic Map of Glen Burnie, MD

Glen Burnie High School

Glen Burnie, MD

Site Ground Analysis

- 7’ of Patapsco-Fort-Mott-Urban Land Complex soil above quartz sandstone
- ASHRAE values for Heavy Sand, 5% Water and Sandstone used
- Ground Temperature of 57°F

Wade Myers

Mechanical Option

GSHP System Ground Properties

Type	Material	Density (lb/CF)	Conductivity (BTU/h-ft-°F)	Diffusivity (SF/Day)
Soil	Heavy Sand, 5% Water	120	1.2 – 1.9	1.0 – 1.5
Rock	Sandstone	--	1.2 – 2.0	0.7 – 1.2
Grout	15% Bennonite/85% SiO_2 Sand	--	1.0 – 1.1	--

GSHP System Ground Properties

Glen Burnie High School Site Plan

Glen Burnie High School

Glen Burnie, MD

Ground Source Heat Pump System

- Athletic fields used for bores
- 23.6 acres = 1,023,016 SF available
- Bores placed close to building – Reduce extra piping

Wade Myers

Mechanical Option

$$L_c = \frac{(q_{lc} \times R_p) + (PLF_m \times F_{sc} \times q_a \times R_{ga}) + (PLF_d \times F_{sc} \times q_a \times R_{gd}) + (PLF_h \times F_{sc} \times q_a \times R_{gm}) + t_g - t_p}{t_g - \frac{t_{wi} + t_{wo}}{2} + \frac{W_c}{2}}$$

Where:

F_{sc}= *short circuit heat loss factor*

L_c= *required bore length for cooling, ft*

PLF_m= *part load factor during design month*

q_a= *net annual average heat transfer to ground, Btu/h*

q_{lc}= *building design cooling block load, Btu/h*

R_{ga}= *effective thermal resistance of ground (annual pulse), h-ft-°F/Btu*

R_{gd}= *effective thermal resistance of ground (daily pulse) , h-ft-°F/Btu*

R_{gm}= *effective thermal resistance of ground (monthly pulse) , h-ft-°F/Btu*

R_p= *thermal resistance of pipe and borehole, h-ft-°F/Btu*

t_g= *undistributed ground temperature, °F*

t_p= *temperature penalty for interference of adjacent bores, °F*

t_{wi}= *liquid temperature at heat pump inlet, °F*

t_{wo}= *liquid temperature at heat pump at outlet, °F*

W_c= *power input at design cooling load, Btu/h*

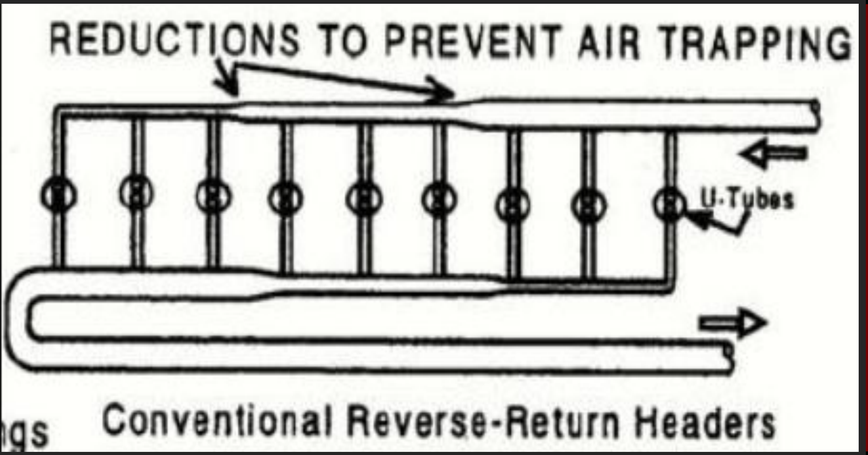
Required Cooling Bore Length Equation

Glen Burnie High School

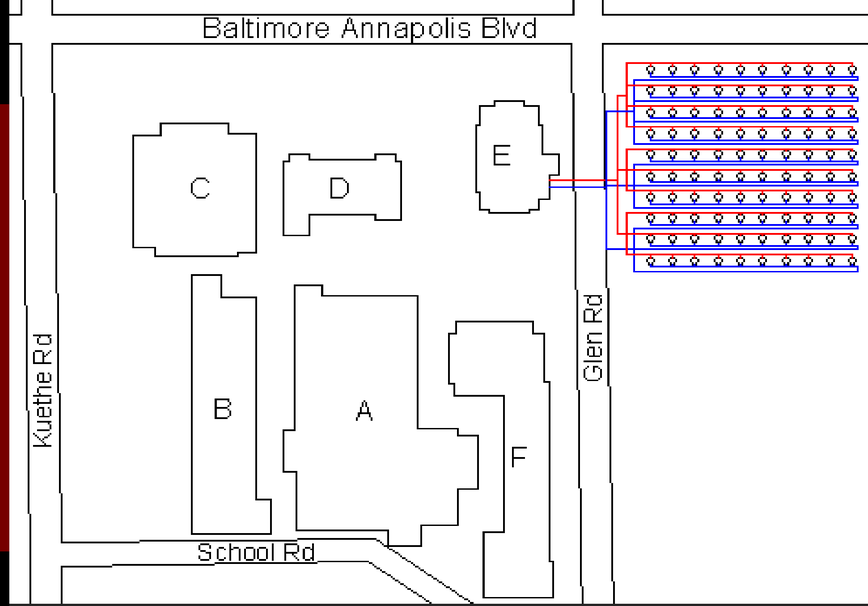
Glen Burnie, MD

Ground Source Heat Pump System

- 27,246 feet of bores
- 100 bores at 275 feet deep
- 10 x 10 grid layout; 20 foot spacing
- Reverse return piping



Typical Reverse-Return Piping



GSHP Piping & Bore Layout

Wade Myers

Mechanical Option

Building E NEW Load Summary			
System	**Service**	**Cooling (Ton)**	**Heating (MBH)**
AHU-1	Men's Lockers	3.7	61.8
AHU-2	Team Rooms	13.7	160.1
AHU-3	Women's Lockers	4.5	56
AHU-4&5	Gymnasium	80.1	394.9
AHU-6	Laundry Room	3.2	12.8
AHU-7	Lobby	1.7	28.3
AHU-8	Wrestling Room	2.7	32.8
AHU-9	Weight Room	3.3	57.3
UV-1	Gymnastics Area	7.5	95.1
TOTAL		**120.4**	**899.7**

Building E NEW Load Summary

Glen Burnie High School

Glen Burnie, MD

Ground Source Heat Pump System

- System sized for 105 tons
- Grid divided into 3 sections, each with own pump
- Pumps feature full redundancy
- Main header branches into sub-headers for each section
- Heat exchanger to cool chilled water

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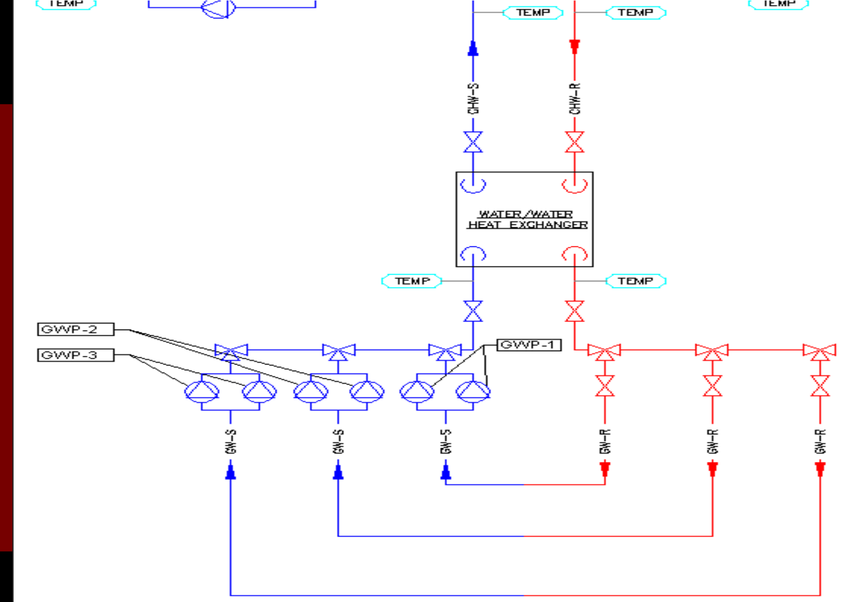
Mechanical Option



GSHP Pumping & Piping Schematic

Building E Energy Reduction			
Cooling (kBTU/yr)		Heating (kBTU/yr)	
Before	After	Before	After
174,210	47,163	1,056,069	644,483

Building E Energy Reduction

Glen Burnie High School

Glen Burnie, MD

Ground Source Heat Pump System

- Chiller reduced from 155 tons to 20 tons
- Chilled water pumps replaced
- Cost savings of $71,470
- Heat exchanger added to system for ground loop
- 8 new pumps added to the system; full redundancy

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Mechanical Option

GSHP System Pump Schedule				
Designation	Model	Flow Rate (GPM)	Total Head (FT H_2O)	RPM
GWP-1	Bell & Gossett Series 1531	126	80	1750
GWP-2	Bell & Gossett Series 1531	94.5	70	1750
GWP-3	Bell & Gossett Series 1531	94.5	75	1750
CHWP-1	Bell & Gossett Series 1531	360	65	1750

GSHP System New Chiller							
Desig.	Model	Capacity (Tons)	EER	Ambient Temp.	EWT	ELT	Elec.
CH-1	Trane CGAM 20	18.9	9.9	95°F	50°F	40°F	460/3

New Pump & Chiller Schedules

Glen Burnie High School

Glen Burnie, MD

CM Breadth

- Analyze schedule changes associated with alterations
- Determine potential monetary savings or added costs
- Calculate system payback periods

Wade Myers

Mechanical Option

GSHP System Schedule Variables			
Component	**Time**	**Amount**	**Total**
Bores	1,000 L.F./Day	27,246 L.F.	28 Days
Piping	1,000 L.F./Day	27,246 L.F.	28 Days
Grout	1,000 L.F./Day	27,246 L.F.	28 Days
Pumps	1.5 Units/Day	8 Units	6 Days
Heat Exchanger	1 Unit/Day	1 Unit	1 Day

Window Renovation Schedule Variables			
Component	**Time**	**Amount**	**Total**
Demo Existing Windows	200 S.F./Day	2,200 S.F.	12 Days
Install New Windows	90 S.F./Day	2,572.5 S.F.	29 Days

System Alteration Schedule Variables

Glen Burnie High School

Glen Burnie, MD

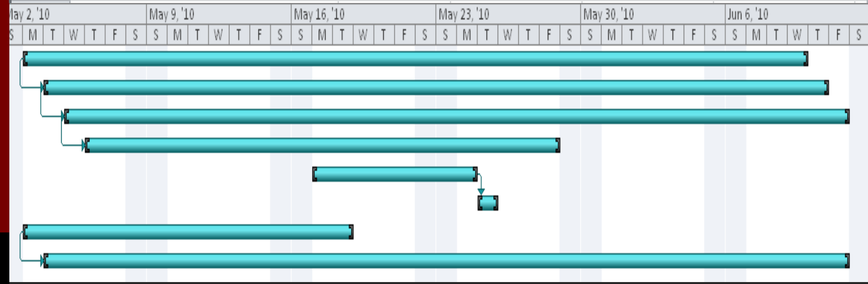
Schedule

- Changes to the schedule duration are minimal
- No interference by GSHP earthwork
- Window renovation long, but has no foreseen effects
- Chiller installation takes place of previous chiller
- Large time window for mechanical room installations

Wade Myers

Mechanical Option

	Task Name	Duration	Start	Finish	Predecessors
1	Drill Ground Bores	28 days	Mon 5/3/10	Wed 6/9/10	
2	Install Ground Loop Piping	28 days	Tue 5/4/10	Thu 6/10/10	1SS+1 day
3	Grout Boreholes	28 days	Wed 5/5/10	Fri 6/11/10	2SS+1 day
4	Install Headers	17 days	Thu 5/6/10	Fri 5/28/10	3SS+1 day
5	Install Pumps	6 days	Mon 5/17/10	Mon 5/24/10	
6	Install Heat Exchanger	1 day	Tue 5/25/10	Tue 5/25/10	5
7	Demo Existing Windows	12 days	Mon 5/3/10	Tue 5/18/10	
8	Install New Windows	29 days	Tue 5/4/10	Fri 6/11/10	7SS+1 day



Building E Renovation Schedule

GSHP System Cost	
Component	**Cost ($)**
Bores	47,408
Piping	37,950
Grout	5,995
Pumps	38,390
Heat Exchanger	3,000
Removed Equipment Cost Savings	-71,470
TOTAL	**51,273**

Window Renovation Cost	
Component	**Cost ($)**
Demo Existing Windows	2,354
Install New Windows	48,492
TOTAL	**50,846**

System Alteration Cost Schedules

Glen Burnie High School

Glen Burnie, MD

Cost

- Original renovation cost of $6,000,000
- GSHP cost of $51,273
- Removed equipment savings included in GSHP
- Window renovation cost of $50,846
- New Total Cost = $6,102,119

Wade Myers

Mechanical Option

GSHP System Cost	
Component	**Cost ($)**
Bores	47,408
Piping	37,950
Grout	5,995
Pumps	38,390
Heat Exchanger	3,000
Removed Equipment Cost Savings	-71,470
TOTAL	**51,273**

Window Renovation Cost	
Component	**Cost ($)**
Demo Existing Windows	2,354
Install New Windows	48,492
TOTAL	**50,846**

System Alteration Cost Schedules

Glen Burnie High School

Glen Burnie, MD

Simple Payback Analysis - GSHP

- Total Cost = $51,273
- Savings = $3,012.36
- Simple Payback = 17.1 Years

Wade Myers

Mechanical Option

GSHP System Cost	
Component	**Cost ($)**
Bores	47,408
Piping	37,950
Grout	5,995
Pumps	38,390
Heat Exchanger	3,000
Removed Equipment Cost Savings	-71,470
TOTAL	**51,273**

Window Renovation Cost	
Component	**Cost ($)**
Demo Existing Windows	2,354
Install New Windows	48,492
TOTAL	**50,846**

System Alteration Cost Schedules

Glen Burnie High School

Glen Burnie, MD

Simple Payback Analysis – Windows

- Total Cost = $50,846
- Savings = $5,261.35
- Simple Payback = 9.7 Years

Wade Myers

Mechanical Option

GSHP System Cost	
Component	**Cost ($)**
Bores	47,408
Piping	37,950
Grout	5,995
Pumps	38,390
Heat Exchanger	3,000
Removed Equipment Cost Savings	-71,470
TOTAL	**51,273**

Window Renovation Cost	
Component	**Cost ($)**
Demo Existing Windows	2,354
Install New Windows	48,492
TOTAL	**50,846**

System Alteration Cost Schedules

Glen Burnie High School

Glen Burnie, MD

Simple Payback Analysis - Combined

- Total Cost = $102,119
- Savings = $8,273.71
- Simple Payback = 12.3 Years

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Mechanical Option

Glen Burnie High School

Glen Burnie, MD

Conclusion

- GSHP system and window renovation have roughly the same first costs at $51,273 & $50,846, respectively.
- GSHP system's energy savings leads to a payback period of 17.1 years.
- Window renovation's energy savings leads to a payback period of 9.7 years.
- Recommend combining both alterations to maximize savings and average the payback period.

Wade Myers

Mechanical Option

Building E Front

Glen Burnie High School

Glen Burnie, MD

Acknowledgements

- Sam Kulceski, and the rest of the design team at JMT who worked on Glen Burnie High School.
- AACPS for their permission to use their buildings.
- My thesis advisor, Dr. Bahnfleth.
- The Penn State AE faculty for all of their help and support throughout my education.
- My fellow 5th year classmates.

Wade Myers

Mechanical Option

Building E Front

Glen Burnie High School

Glen Burnie, MD

Questions

?

Wade Myers

Mechanical Option

Glen Burnie High School

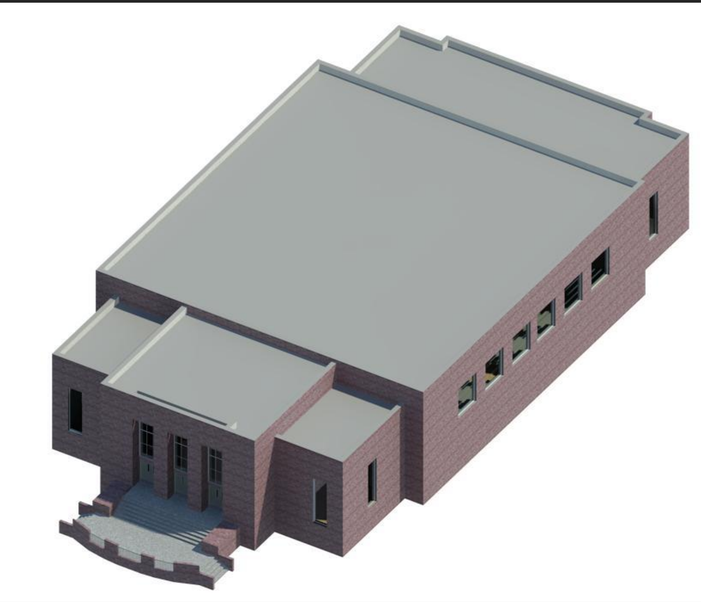
Glen Burnie, MD

Architectural Breadth

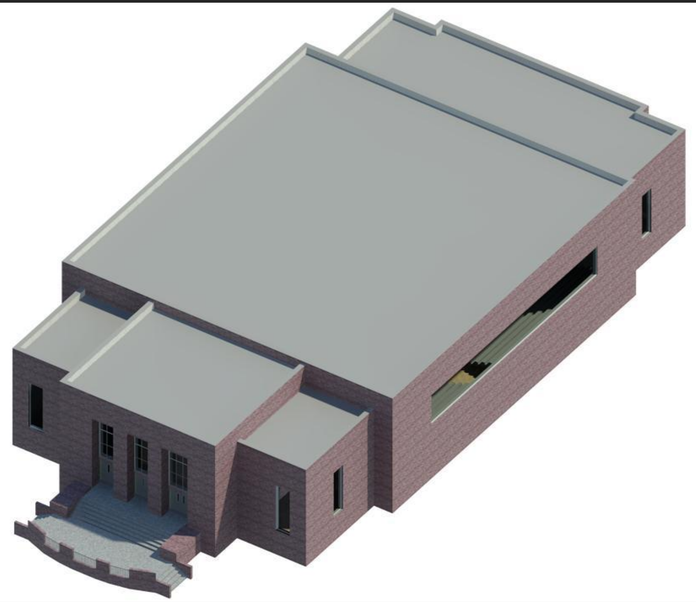
- Original windows replaced with better performing units
- New windows added to façade
- Modern architecture
- Match existing

Window Replacement Load Changes

Area	Load Before (tons)	Load After (tons)
Building E	140.8	120.4



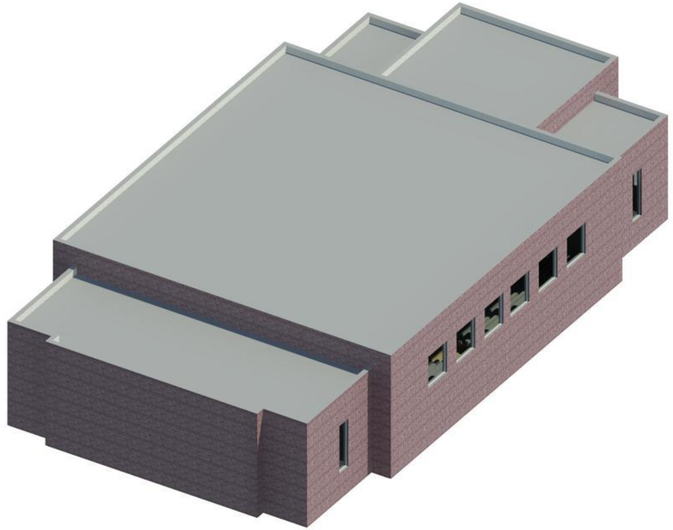
Building E Front Before



Building E Front After

Wade Myers

Mechanical Option



Building E Rear Before

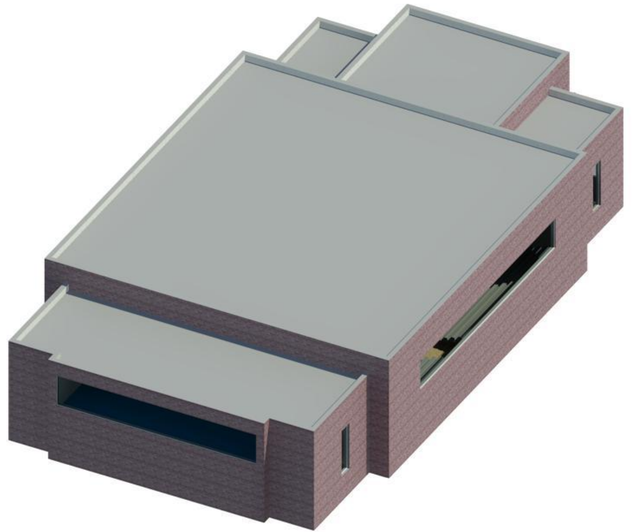
Glen Burnie High School

Glen Burnie, MD

Architectural Breadth

Wade Myers

Mechanical Option



Building E Rear After

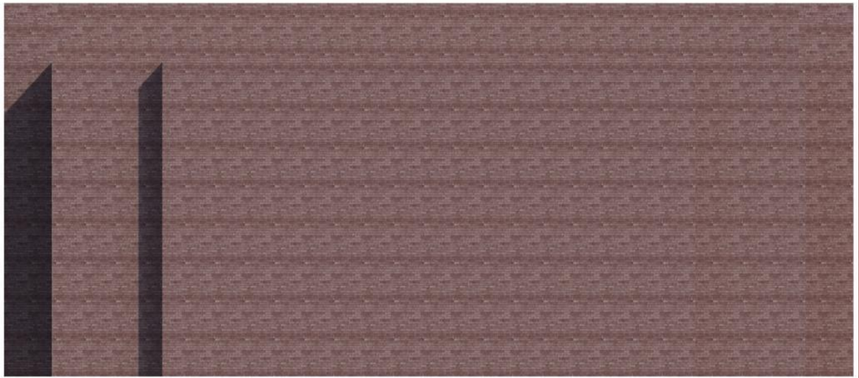
Glen Burnie High School

Glen Burnie, MD

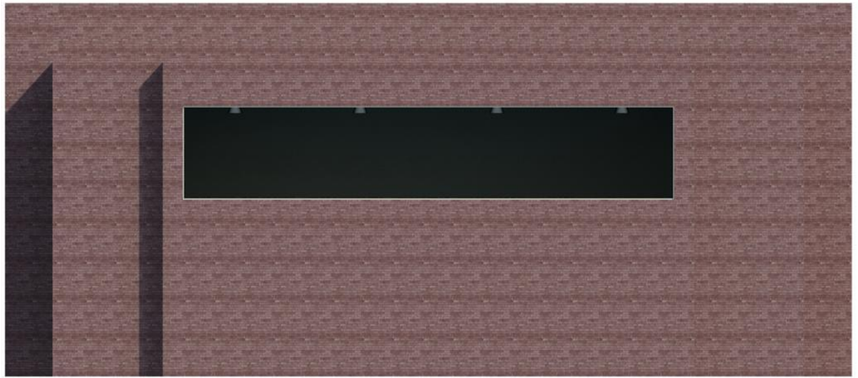
Architectural Breadth

- Glazing added to southern wall
- Ambient light to gymnastics area
- Increases thermal load on area

Window Replacement Load Changes		
Area	**Load Before (tons)**	**Load After (tons)**
Gymnastics Area	6.4	7.5



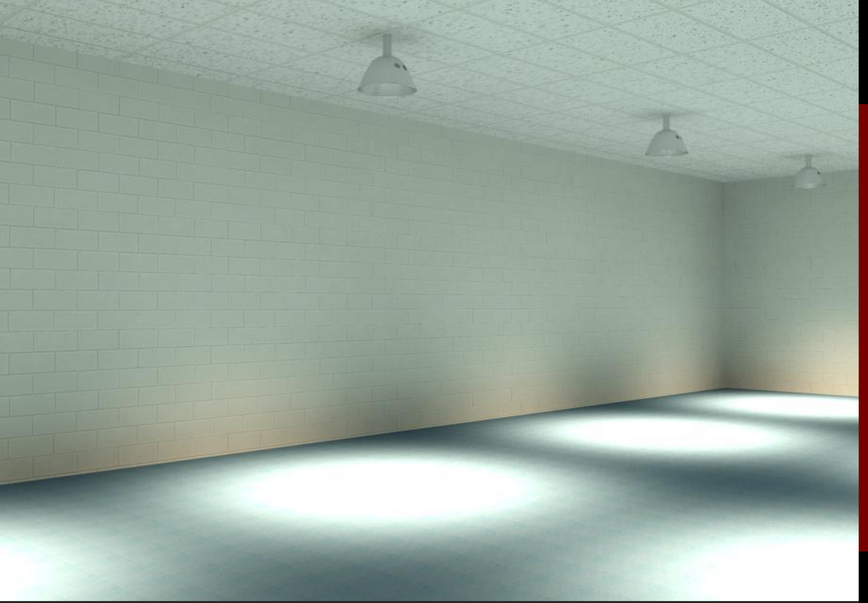
Building E South Façade Before



Building E South Façade After

Wade Myers

Mechanical Option



Building E Gymnastics Area Before

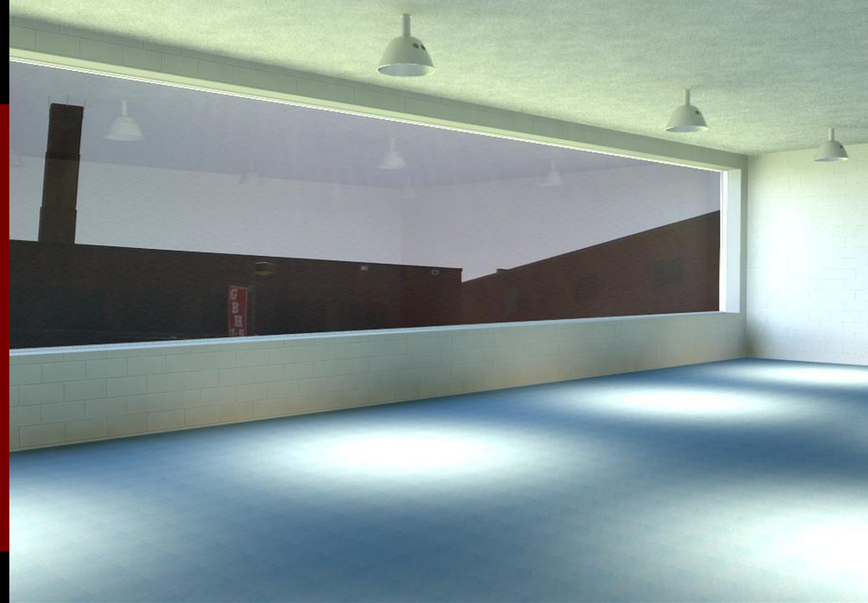
Glen Burnie High School

Glen Burnie, MD

Architectural Breadth

Wade Myers

Mechanical Option



Building E Gymnastics Area After

Glen Burnie High School

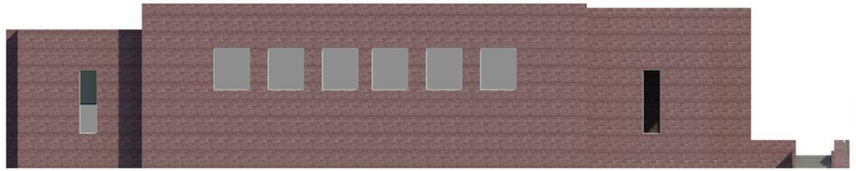
Glen Burnie, MD

Architectural Breadth

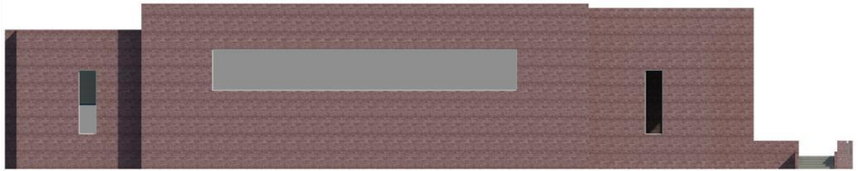
- Original windows replaced with single unit
- Increases ambient light to space
- Upgrades façade
- Decreases thermal load on area

Window Replacement Load Changes

Area	Load Before (tons)	Load After (tons)
Gymnasium	84.4	80.1

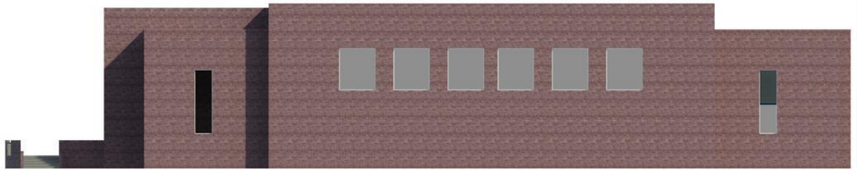


Building E East Façade Before

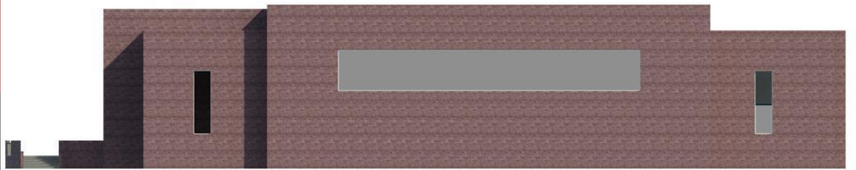


Building E East Façade After

Building E West Façade Before



Building E West Façade After



Wade Myers

Mechanical Option

Building E Gymnasium West Before

Glen Burnie High School

Glen Burnie, MD

Architectural Breadth

Wade Myers

Mechanical Option

Building E Gymnasium West After

Building E Gymnasium East Before

Glen Burnie High School

Glen Burnie, MD

Architectural Breadth

Wade Myers

Mechanical Option

Building E Gymnasium East After