

The Environmental Studies Lab: Expansion

East Coast, USA

Codi Shine

Construction Option

Advisor: Dr. Chimay Anumba



Analysis 1:

Alternative Delivery Method

Analysis 2:

Short Interval Production Schedule (SIPS)

Analysis 3:

Façade Study

Breadths:

Architectural & Mechanical

Analysis 4:

Building Information Modeling (BIM)
Implementation

The Environmental Studies Lab: Expansion

Project Background

Statistics

Size:

72,000 GSF

Stories:

2 plus a penthouse

Delivery Method:

Design-Bid-Build

Contract Value:

\$41 million

Construction Dates:

6/1/11-4/22/13

LEED:

Platinum

Project Team	
Architect/MEP Engineer	Ewing Cole
General Contractor	Hensel Phelps
Structural Engineer	Woods Peacock
Civil Engineer	Alpha Corporation



Schedule Summary	Start	End
Notice to Proceed	June 1, 2011	
Earthwork	November 3, 2011	November 1, 2012
Concrete	November 7, 2011	November 12, 2012
Structural Steel	February 22, 2012	April 23, 2012
HVAC	October 31, 2011	November 27, 2012
Electrical	December 19, 2011	November 30, 2012
Plumbing	December 21, 2011	October 24, 2012
Specialty Trades	December 21, 2011	February 22, 2013
Turnover		April 22, 2013

The Environmental Studies Lab: Expansion

Background

Analysis 1 – Alternative Delivery Method

Project Background

Analysis 1 – Alternative Delivery Method

Background

Research/Comparisons
Schedule reduction

Analysis 2 – SIPS

Sequence & crews
Different SIPS Options
Schedule Reduction

Analysis 3 – Façade Study

Background
Materials/Research
Architectural Breadth
Changes
Model
Mechanical Breadth
R-value & Condensation
Production & Cost

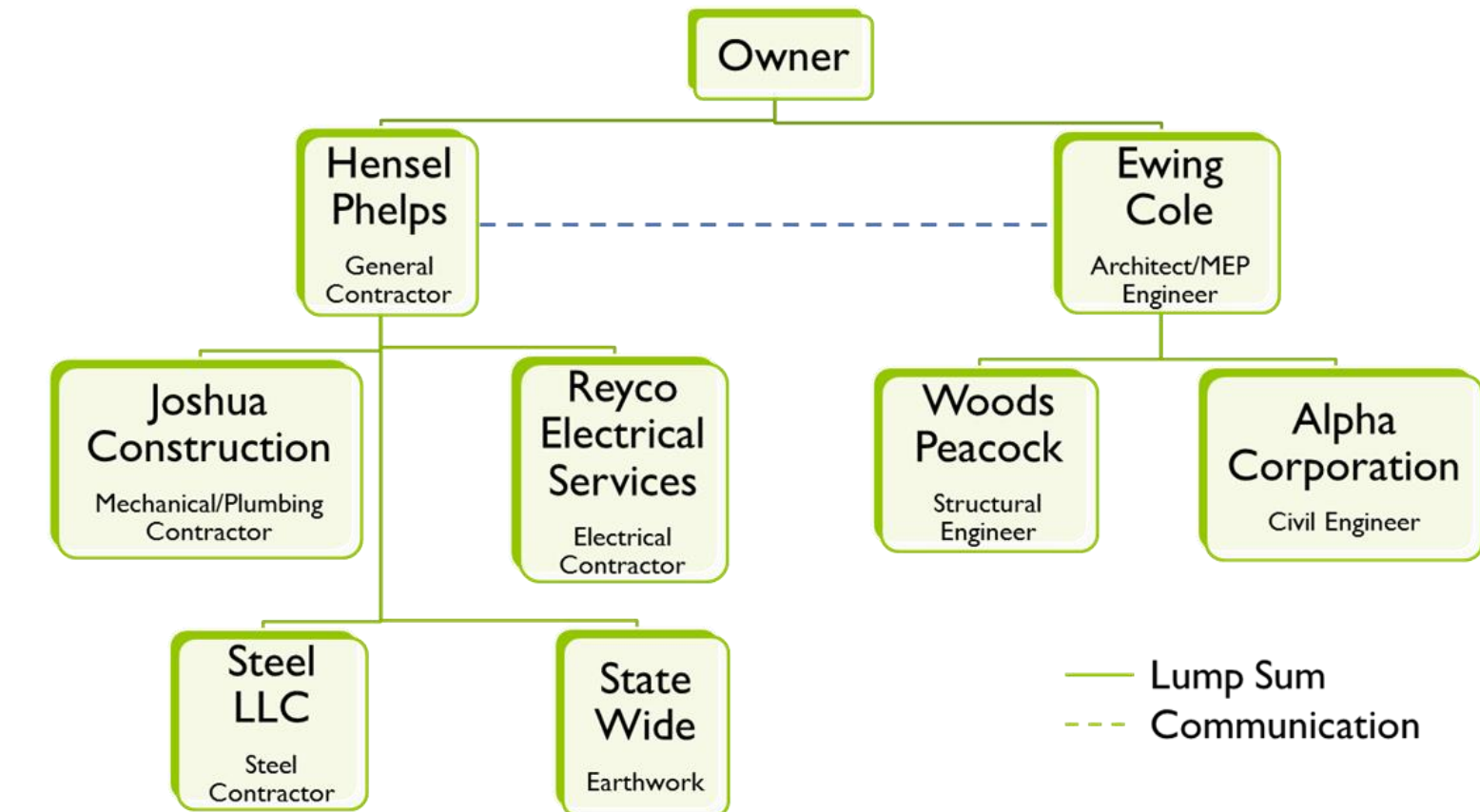
Recommendations

Acknowledgements

Analysis Goals

Reduce the schedule by getting the General Contractor in earlier

Current: Design-Bid-Build	Proposed: Design-Build
<ul style="list-style-type: none"> • Phases are Finish-Start relationship • Lacks chemistry • Owner acts as a mediator • Owner has to find all parties • Owner holds the liability • Multiple contracts 	<ul style="list-style-type: none"> • GC can be involved earlier • Subcontractors assist with design • GC and designer are in a joint venture • One point of contact • Cost effective • Shared risk • One contract



The Environmental Studies Lab: Expansion

Research & Comparisons

Analysis 1 – Alternative Delivery Method

Project Background

Analysis 1 – Alternative Delivery Method

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Research/Comparisons

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Different SIPS Options

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Building Name	Square Foot	Cost/Sq Ft	Intensity	Construction Speed	Delivery Duration
Environmental Studies	72,000	\$491	\$1,756,192	3576	3473
Technical Monitoring Hub	71,336	\$460	\$2,218,444	4820	--
Commercial Hanger	60,000	\$329	\$1,768,125	--	3947

Interviews

- **Design assist subcontractors**
- **Involved owner**
- **Owner let Hensel Phelps take control**
- **Start site work early**
- **Innovation**
- **Finalize long lead items early**

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Schedule Reduction

Analysis 1 – Alternative Delivery Method

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Analysis 1 – Alternative Delivery Method

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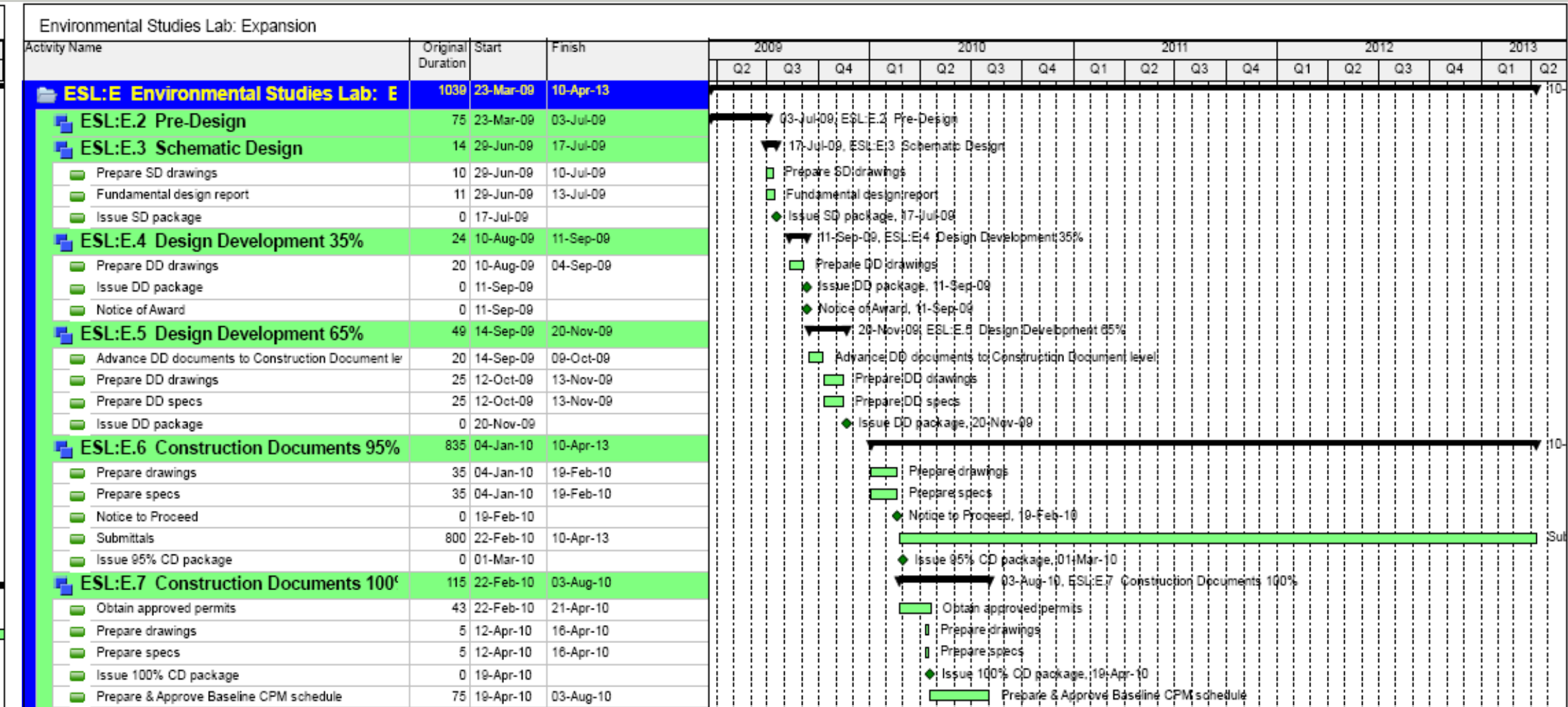
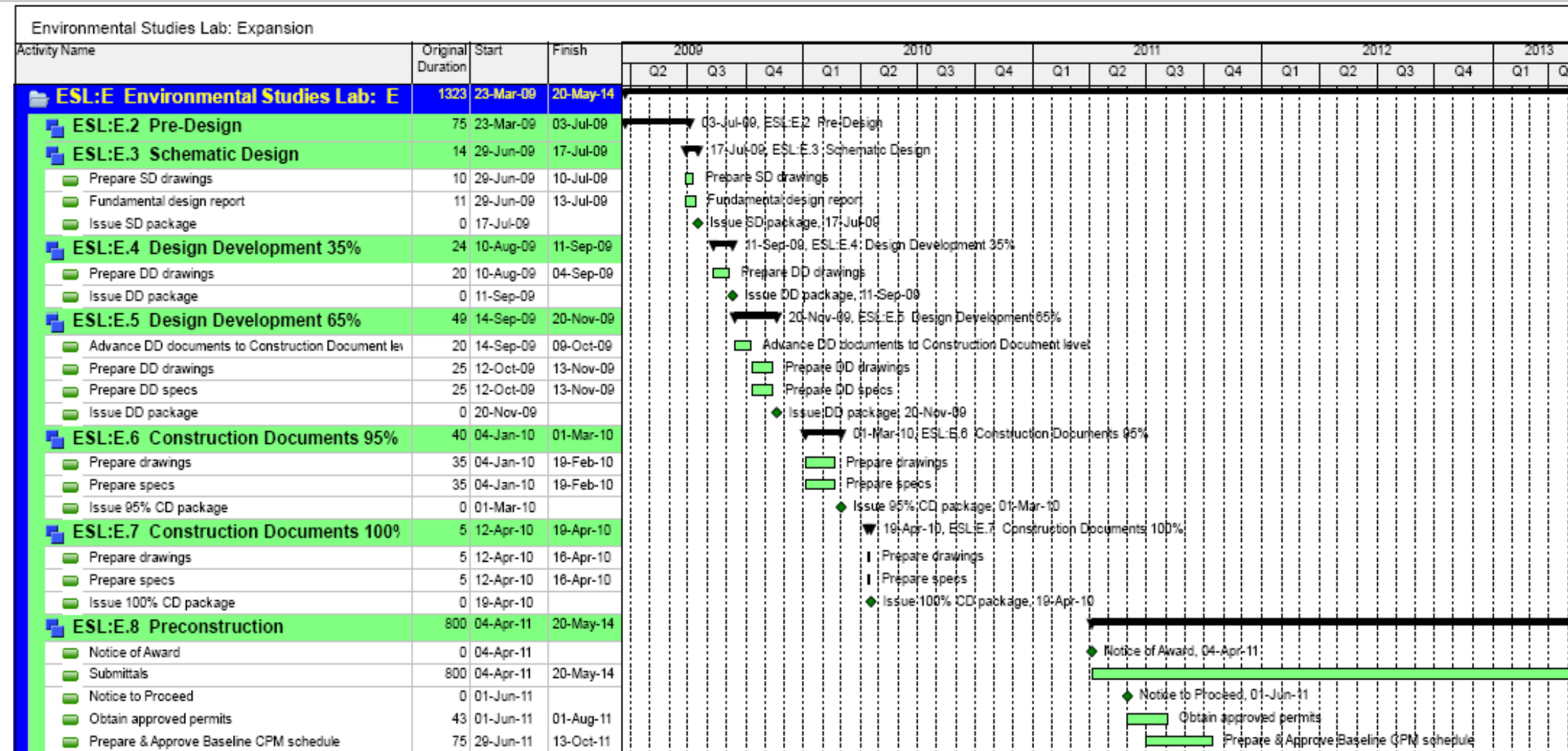
Mechanical Breadth

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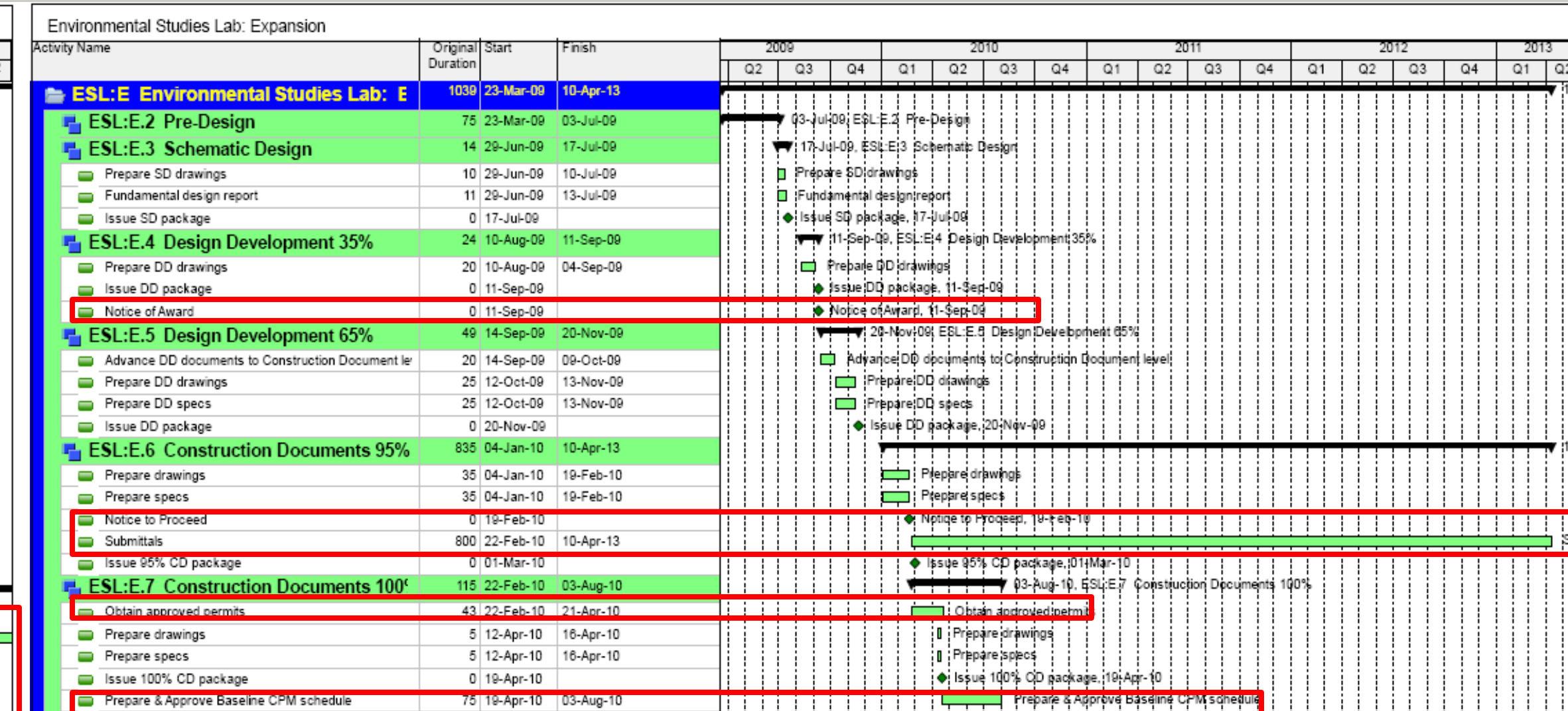
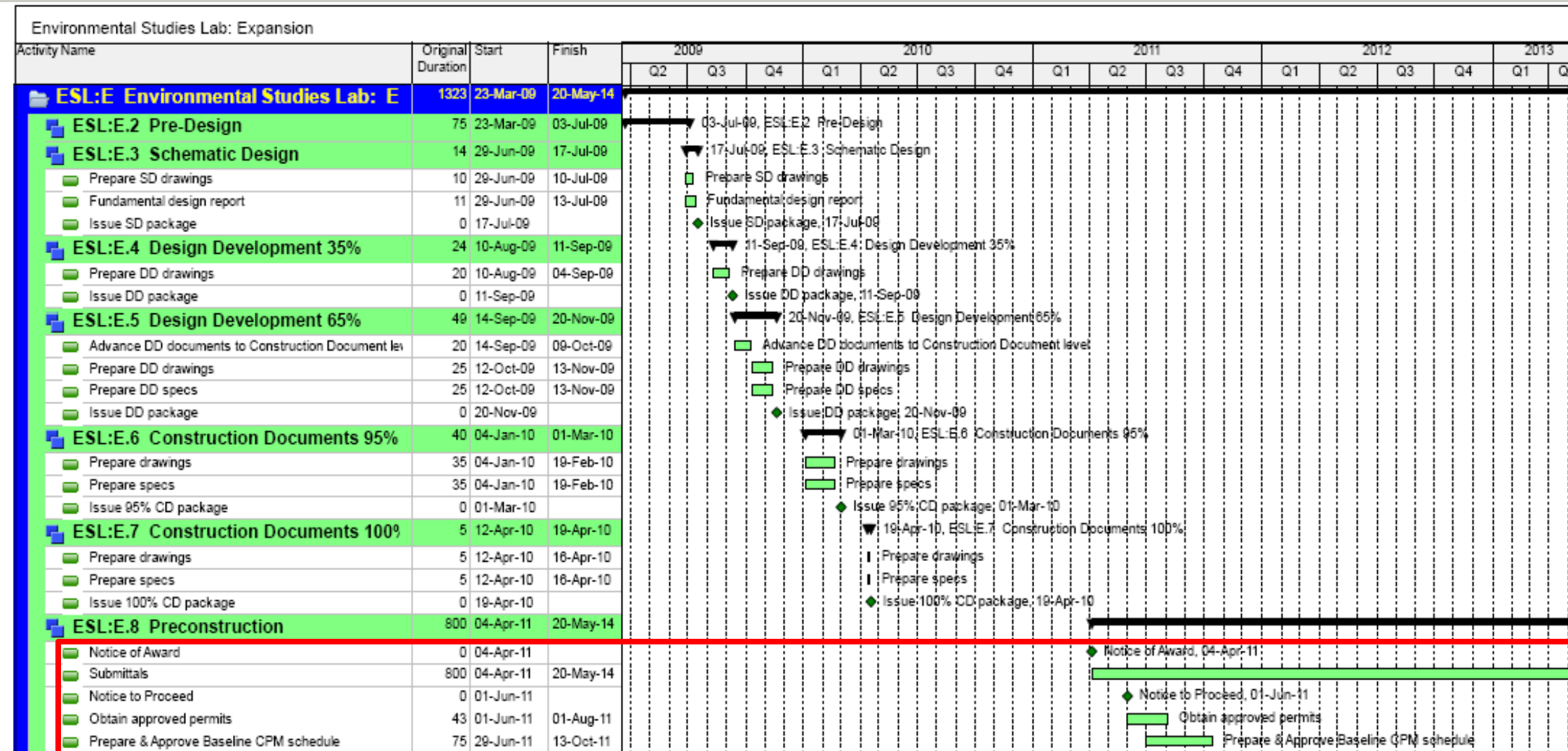
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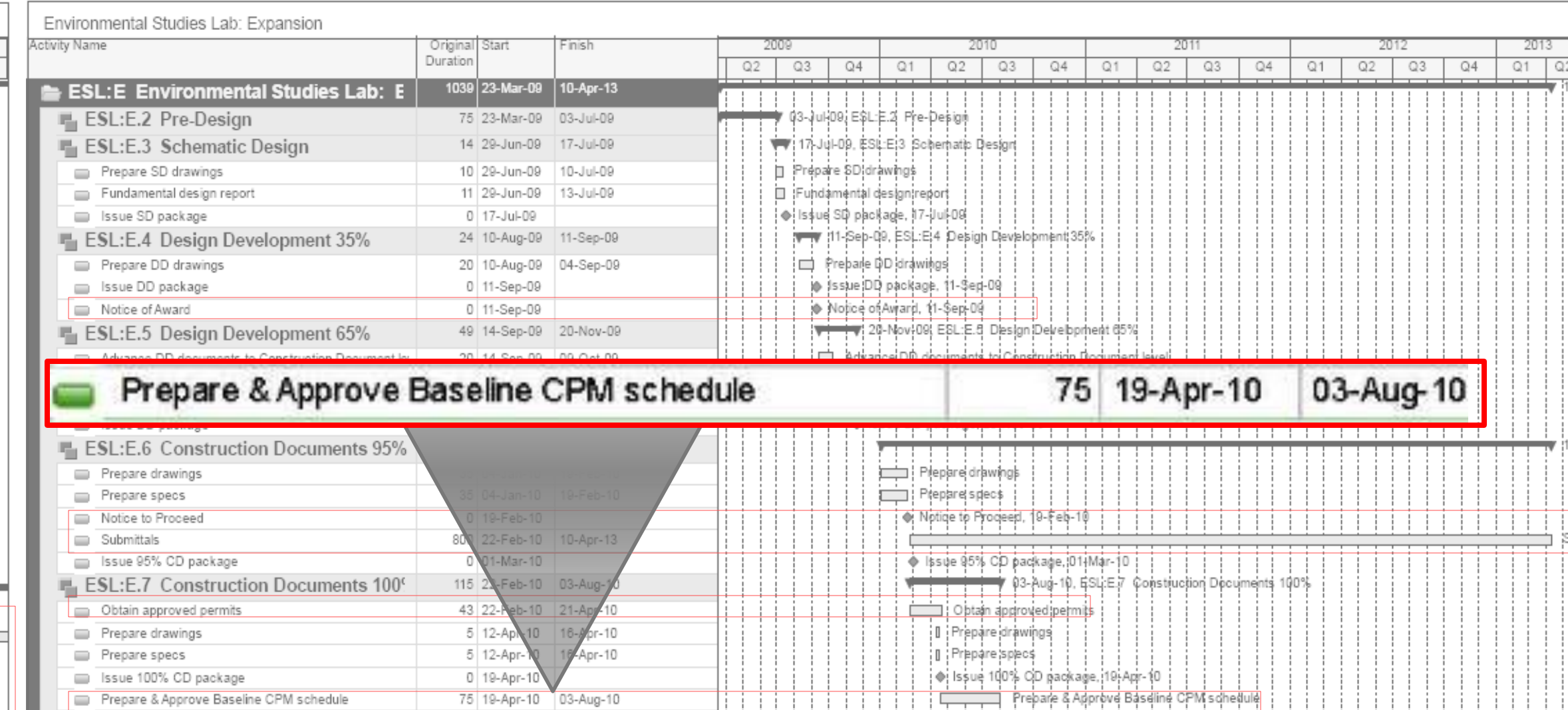
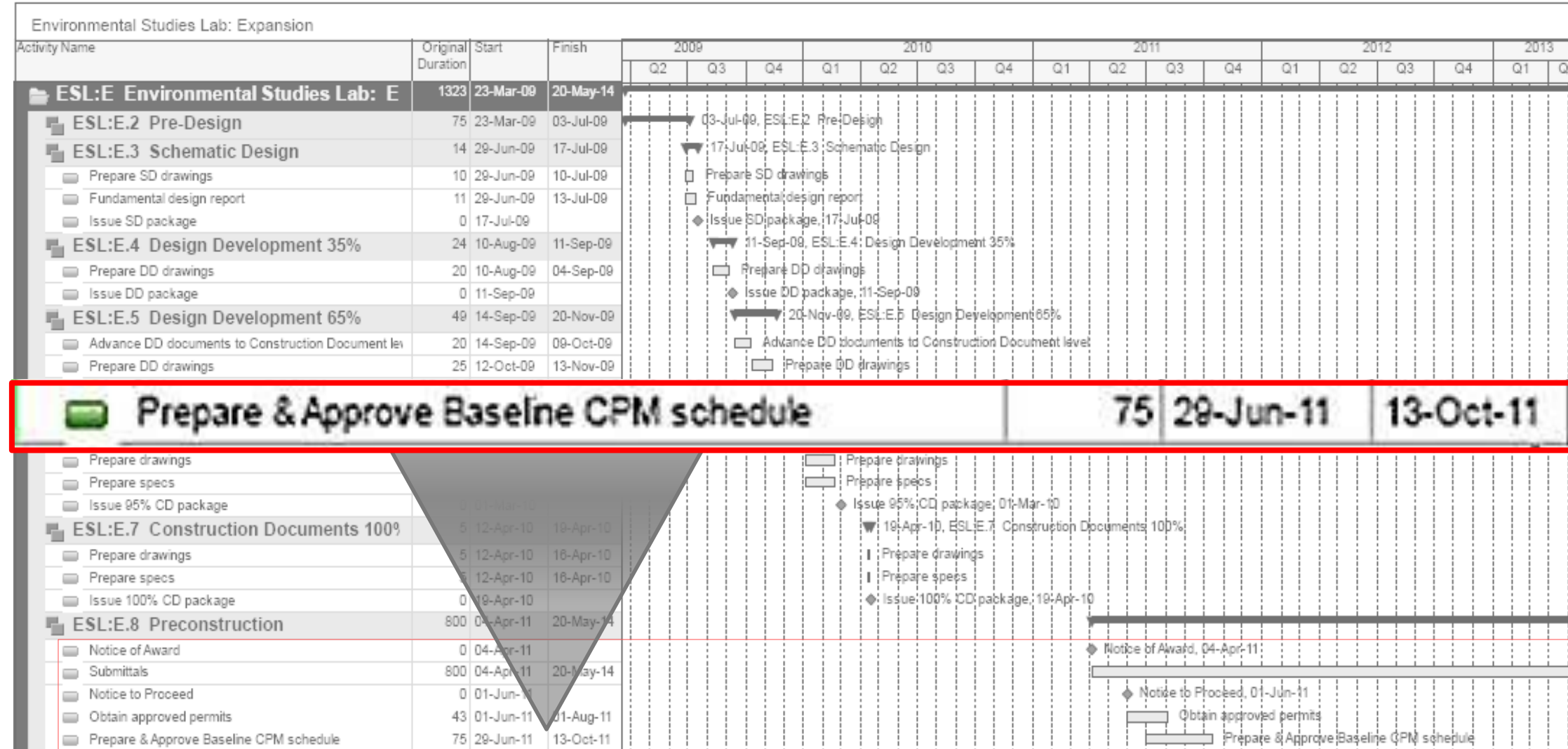
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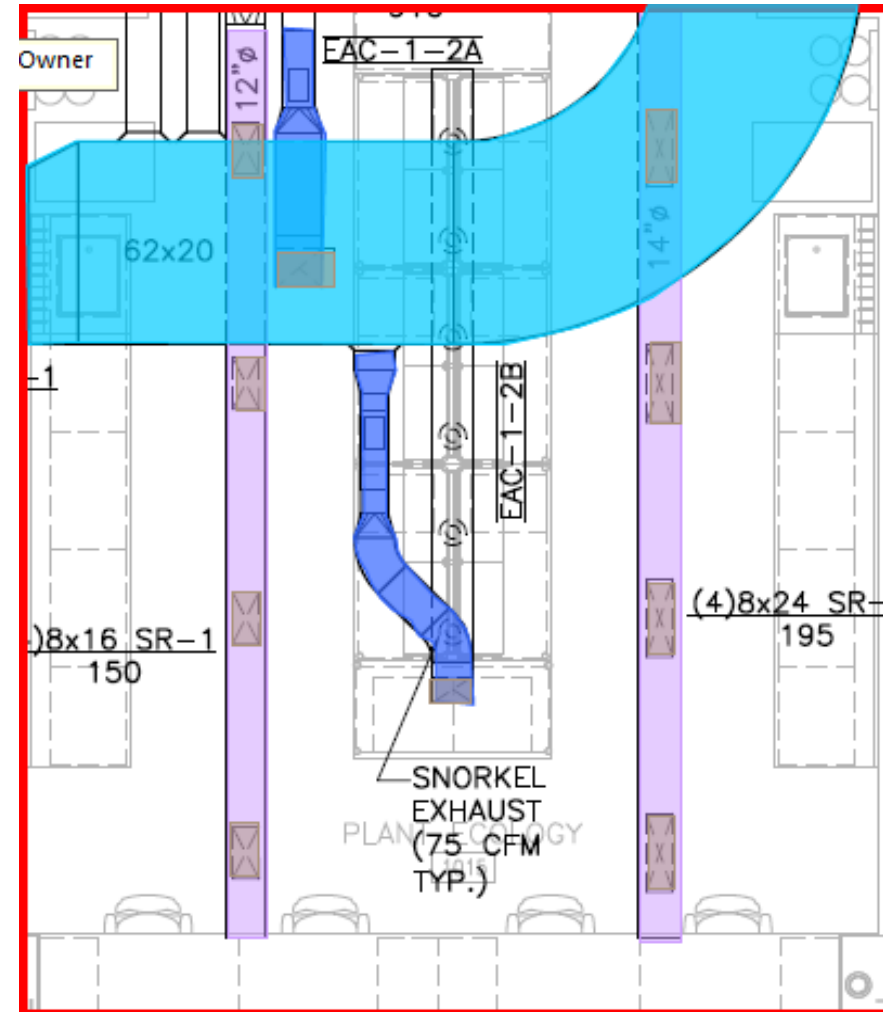
Sequencing & Crews

Analysis 2 – Short Interval Production Schedule (SIPS)

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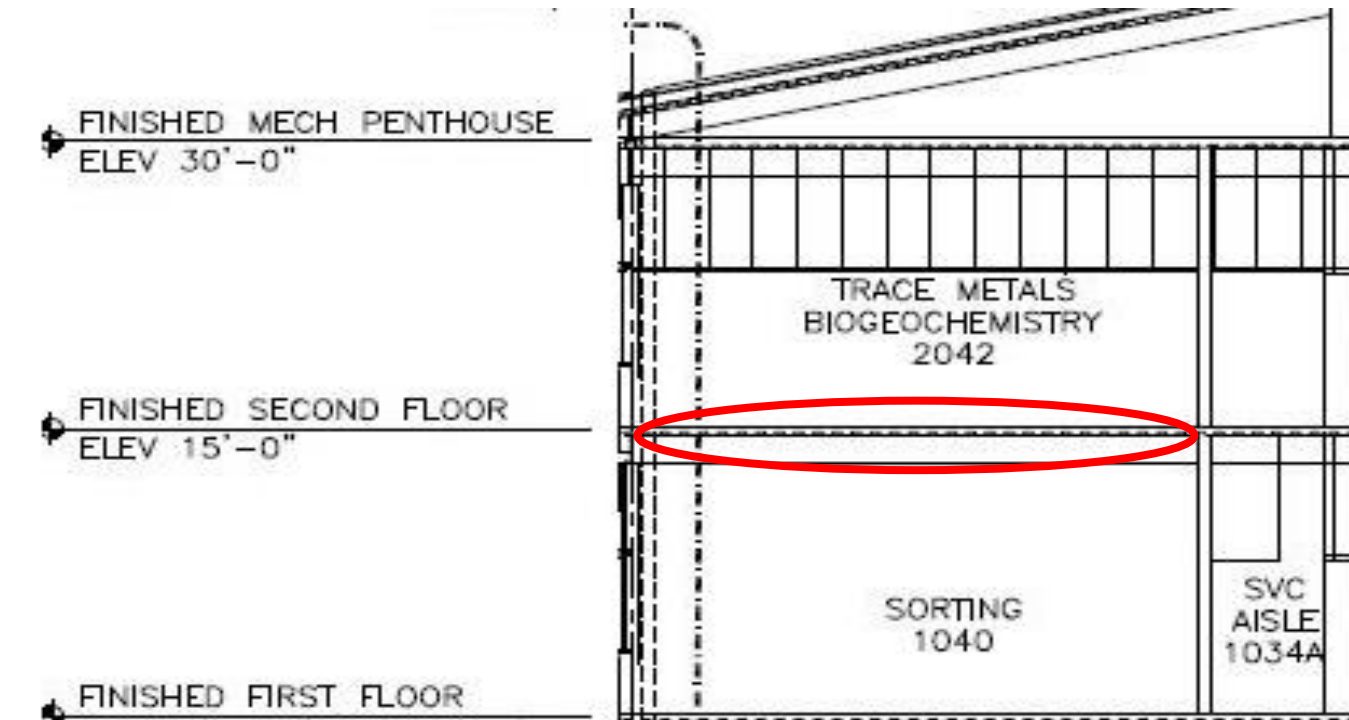
Analysis Goals

Reduce the schedule by creating a repetitive manner of construction that will also improve the quality of the work.



Activity	Crew
Layout	1 Sheet Metal Layout
Install sleeves	1 Sheet Metal Worker
Install Hangers/anchors	1 Sheet Metal Worker 1 Sheet Metal Apprentice
Layout/Rough-in	1 Sheet Metal Layout
Unload and distribute duct sections	2 Sheet Metal Workers
Hang trunk lines	2 Sheet Metal Workers 1 Sheet Metal Apprentice
Install medium pressure branch	2 Sheet Metal Workers 1 Sheet Metal Apprentice
Install SACs, EACs	1 Sheet Metal Worker 1 Sheet Metal Apprentice
Install Low Pressure Branch	2 Sheet Metal Workers 1 Sheet Metal Apprentice
Hard Duct Taps (Exhaust)	2 Sheet Metal Workers 1 Sheet Metal Apprentice
Install RGD	1 Sheet Metal Worker

- 8 hour work days
- Slightly different sequence on first and second floors



The Environmental Studies Lab: Expansion

Different SIPS Options SIPS 2

Analysis 2 – Short Interval Production Schedule (SIPS)

Project Background
Analysis 1 – Alternative Delivery Method

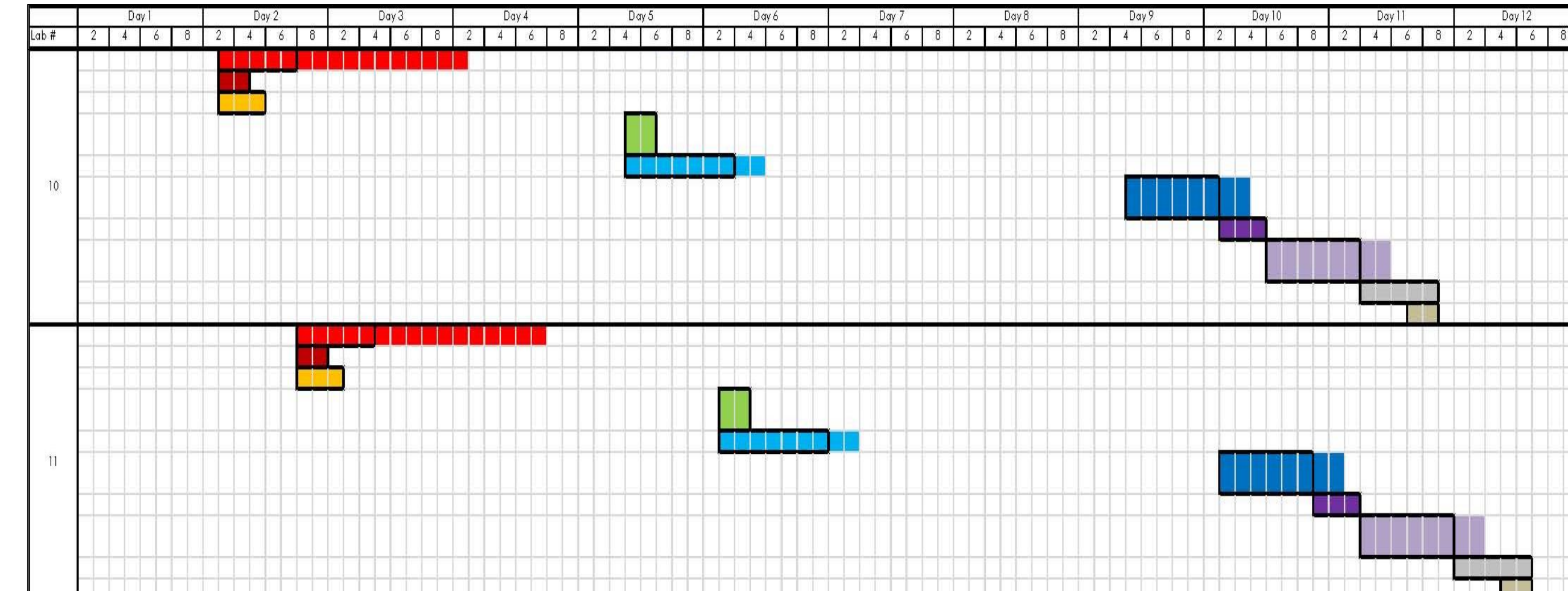
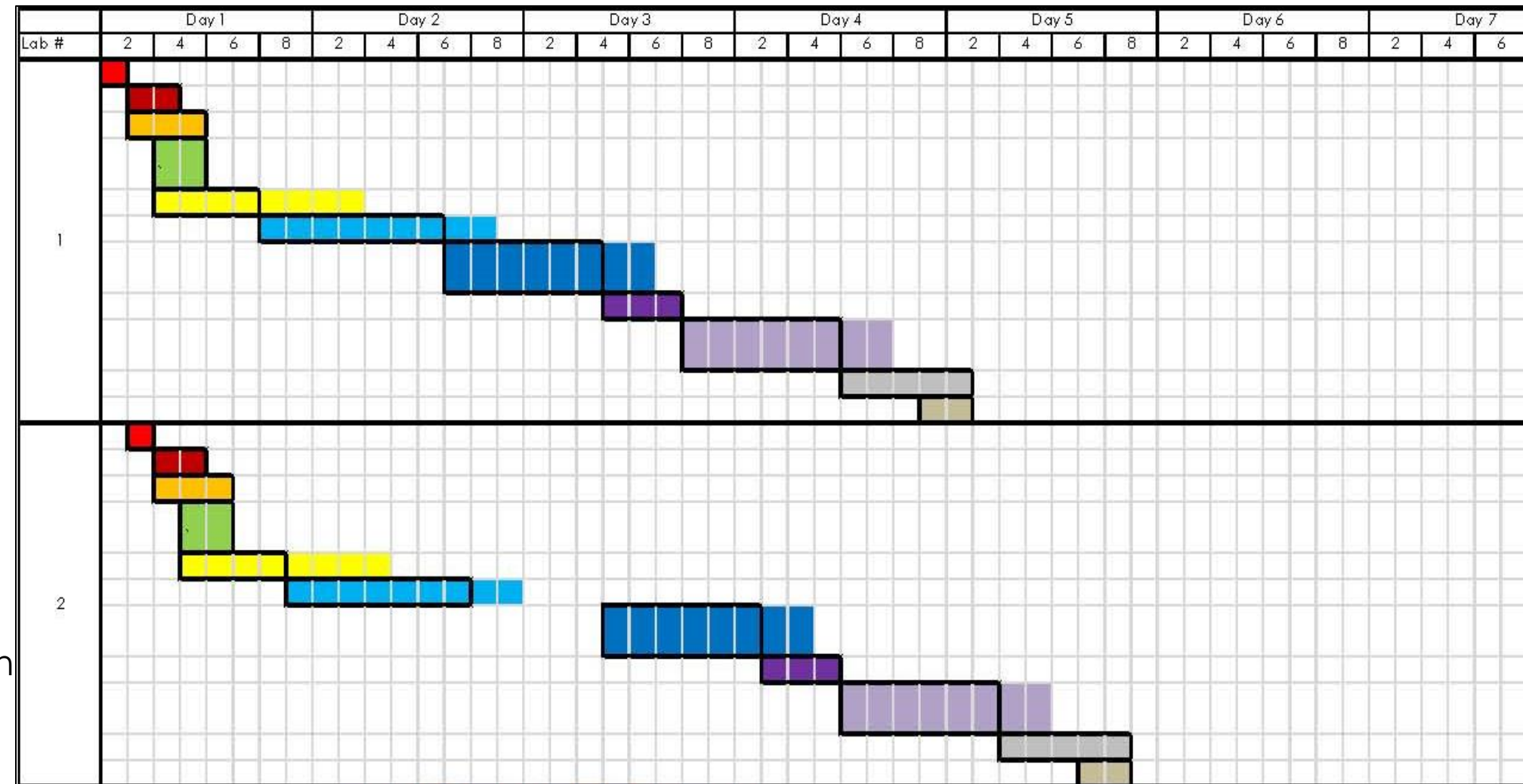
Multiple crews on the activities “Layout” and “Hang Trunk Lines”

Background
Research/Comparisons
Schedule reduction

Analysis 2 – SIPS
Sequence & crews
Different SIPS Options
SIPS 2

Schedule Reduction
Analysis 3 – Façade Study

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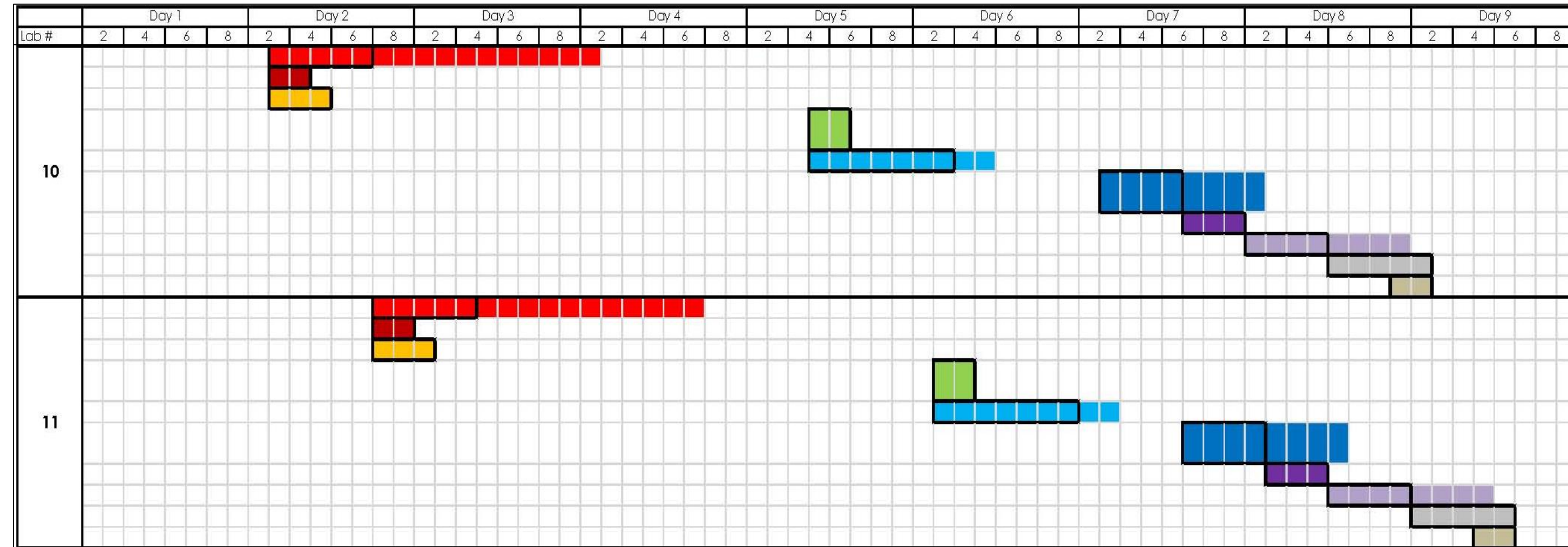
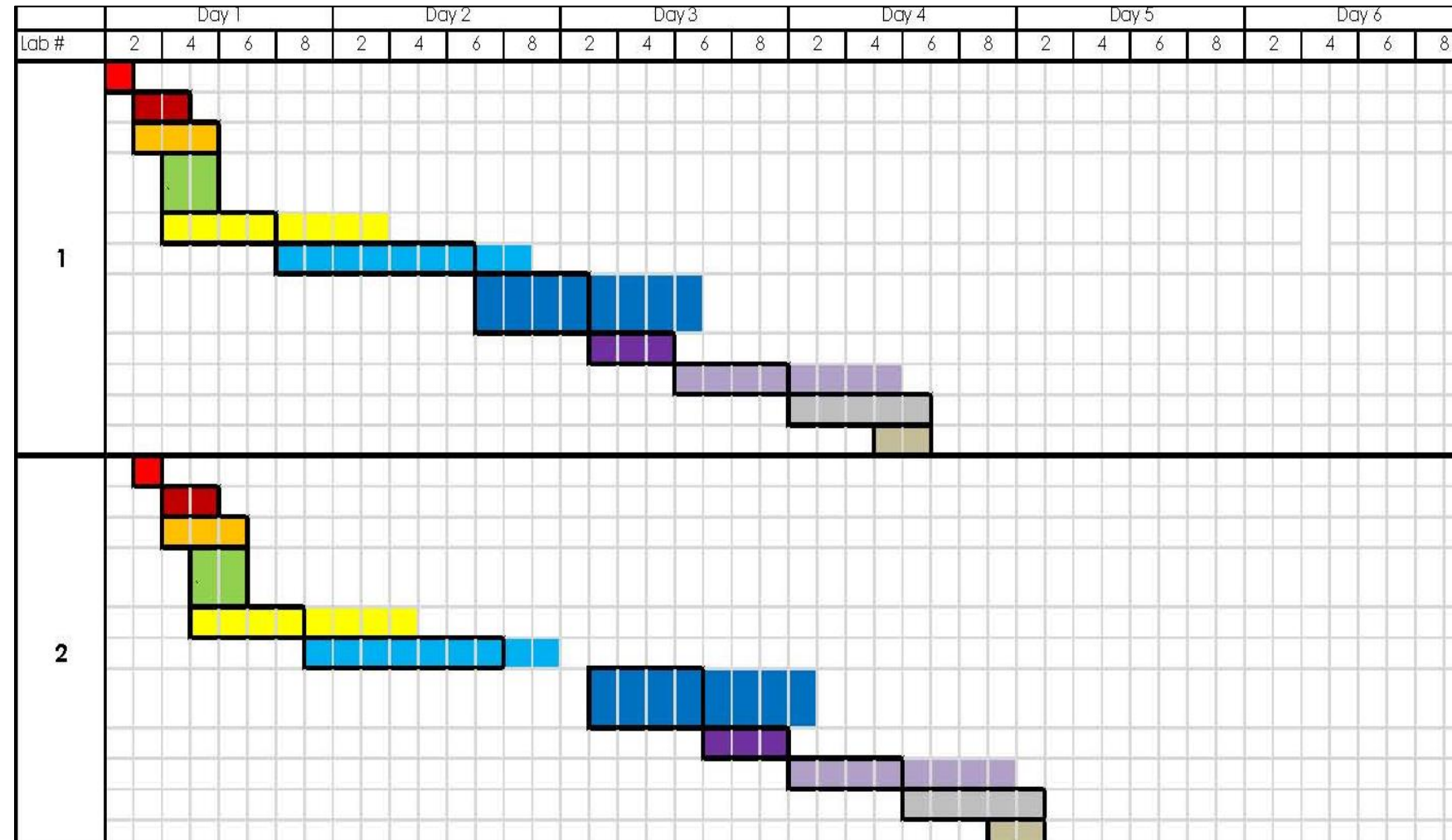
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Different SIPS Options SIPS 3

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Multiple crews on the activities “Layout” and “Hang Trunk Lines.” Add a crew member to “Install Medium Pressure Branch” and “Install Low Pressure Branch.”



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Schedule Reduction

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Schedule 1st	Crew/Lab	Hourly Rate	Hours/lab	Total Cost/lab	Total cost
Original	22	\$39.93	50.22	44,116	\$397,046
SIPS 1	48	\$39.93	40.00	76,666	\$689,990
SIPS 2	32	\$39.93	40.00	51,110	\$459,994
SIPS 3	34	\$39.93	37.60	51,047	\$459,419
Schedule 2nd	Crew/Lab	Hourly Rate	Hours/lab	Total Cost/lab	Total cost
Original	21	\$39.93	57.33	48,073	\$432,656
SIPS 1	44	\$39.93	40.44	71,050	\$639,449
SIPS 2	32	\$39.93	40.44	51,673	\$465,054
SIPS 3	32	\$39.93	38.04	48,612	\$437,505
TOTAL					Total cost
Original					\$829,703
SIPS 1					\$1,329,439
SIPS 2					\$925,047
SIPS 3					\$896,924

Schedule	Duration	Days Saved
Original	33	-
SIPS 1	12	21
SIPS 2	17	16
SIPS 3	13	20

The Environmental Studies Lab: Expansion

Schedule Reduction

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Schedule	Duration	Days Saved
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SIPS 1	12	21
SIPS 2	17	16
SIPS 3	13	20

SIPS 3 saves 20 days and only \$67,000 more for labor

The Environmental Studies Lab: Expansion

Background

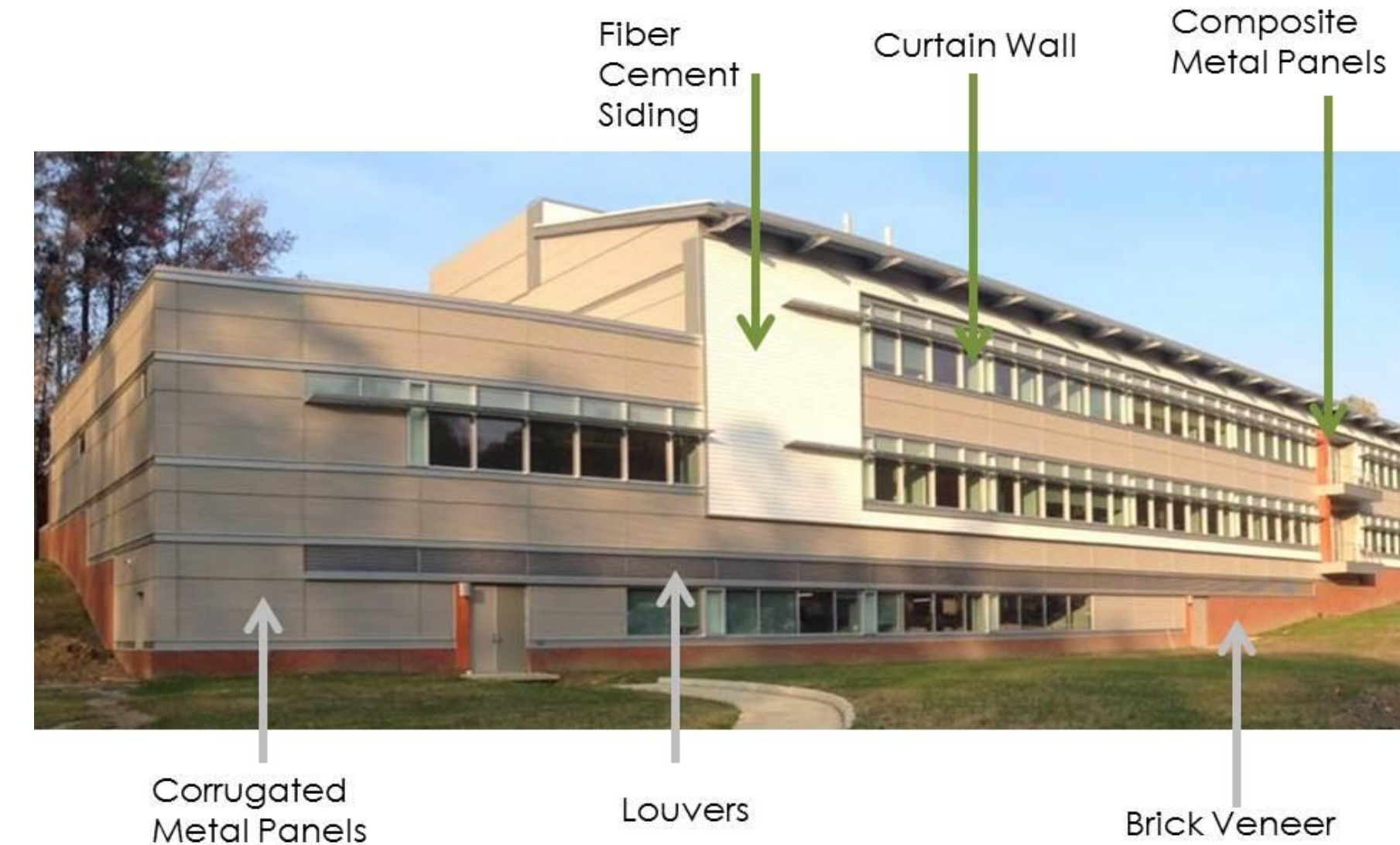
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Analysis Goals

Reduce the schedule by reducing the complexity of the façade materials.

Expansion						
Elevation	Corrugated	Composite (orange)	Fiber Cement Siding	Louvers	Brick Veneer	Total Square Footage
North	2,307	0	992	0	818	4,117
South	14,769	2,412	8,146	1,833	5,737	32,897
East	490	0	0	0	0	490
West	3,846	0	0	0	959	4,805
Total	19,105	2,412	9,138	1,833	7,514	40,002

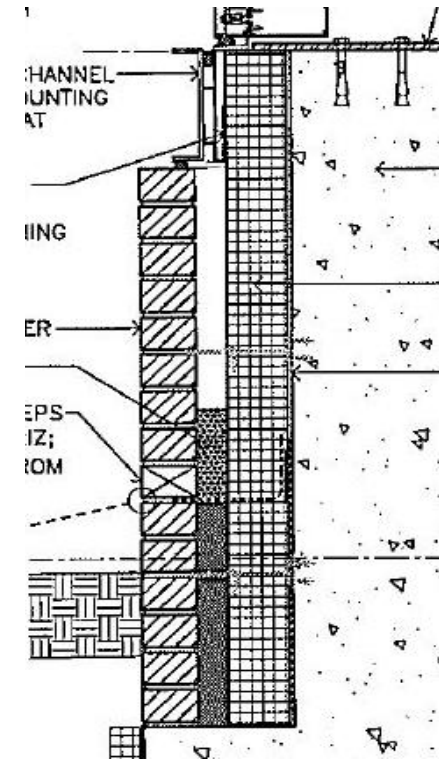


The Environmental Studies Lab: Expansion

Materials & Research

Analysis 3 – Façade Study

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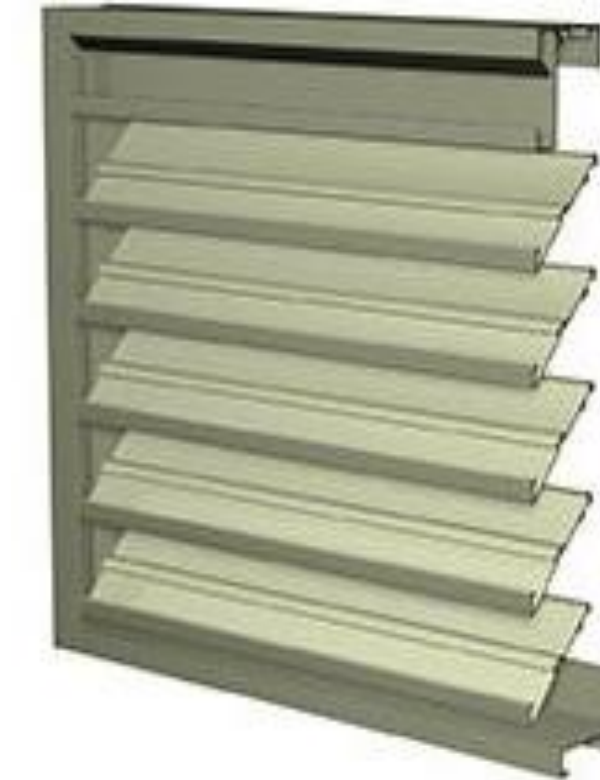
Brick Veneer



Composite Metal Panels



Corrugated Metal Panels



Louvers



Fiber Cement Siding

The Environmental Studies Lab: Expansion

Architectural Breadth

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Change 1: Composite Metal Panels to Fiber Cement Siding

- Difficult installation on metal Z-clips
- Same Manufacturer
- Vertical Panels are 4'x10'
- Not fabricated metal look



Change 2: Corrugated Metal Panels to Fiber Cement Siding

- Stainless-steel fasteners over hat channels
- Same Manufacturer
- 4" Minimum exposure
- Not fabricated metal look

The Environmental Studies Lab: Expansion

Architectural Breadth

Analysis 3 – Façade Study

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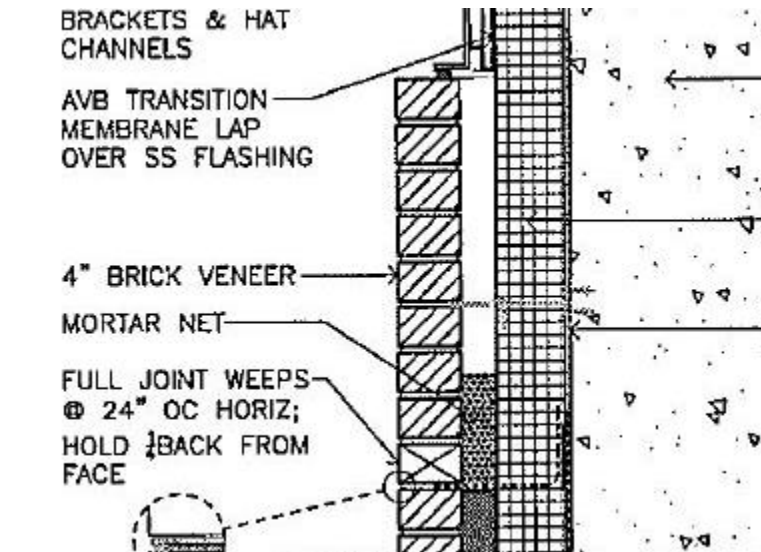
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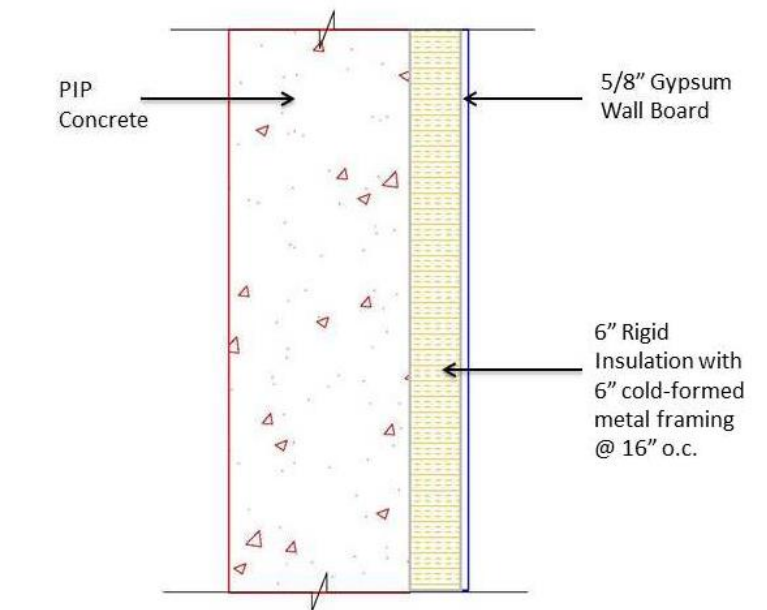
Change 3: Louvers to Fiber Cement Siding

- Stainless-steel screws
- Same exposure
- Consistent look



Change 4: Brick Veneer to Concrete

- Dovetail connection to concrete
- Ties into the site
- Hensel Phelps will self-perform
- Fewer wall materials

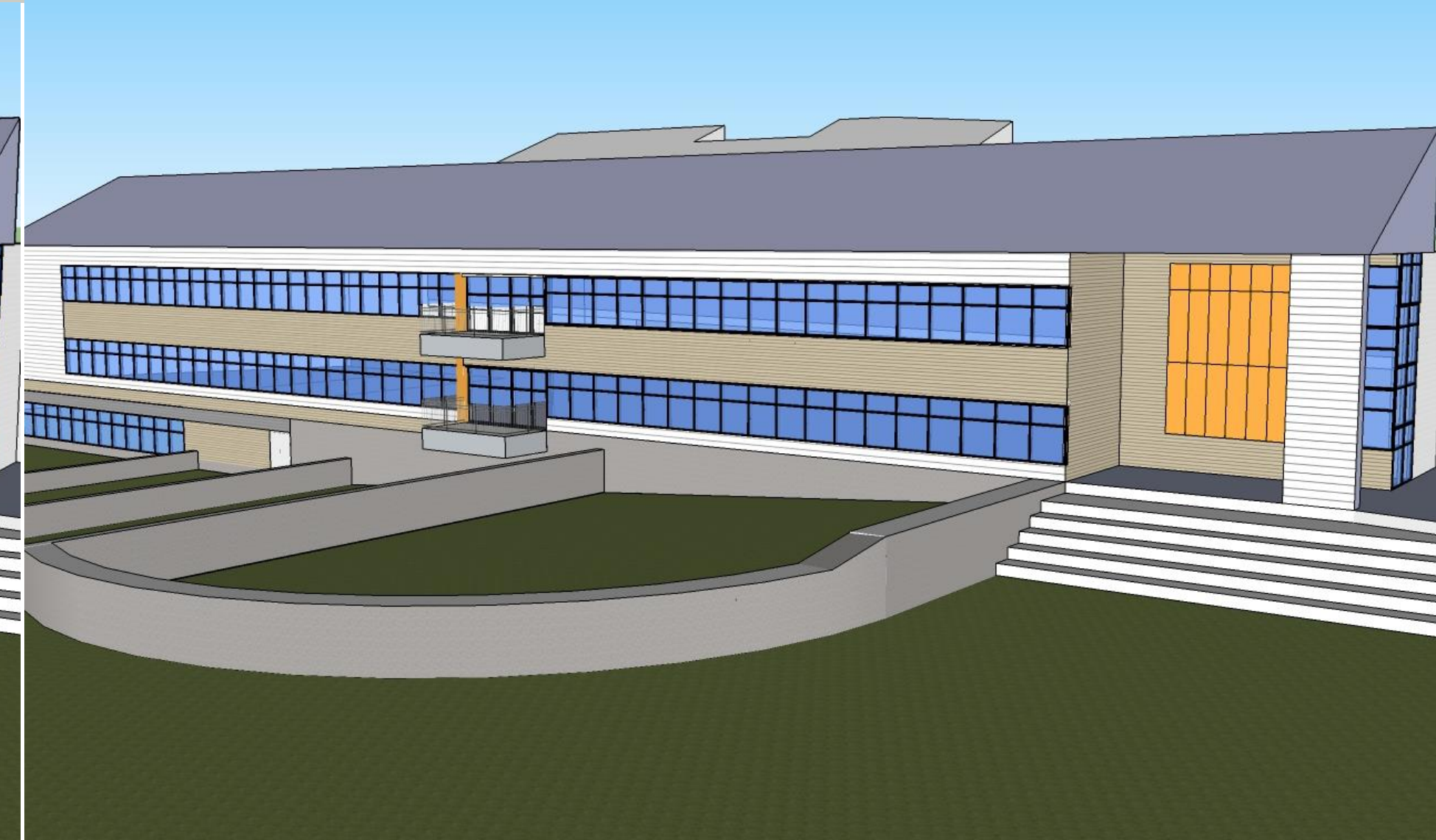
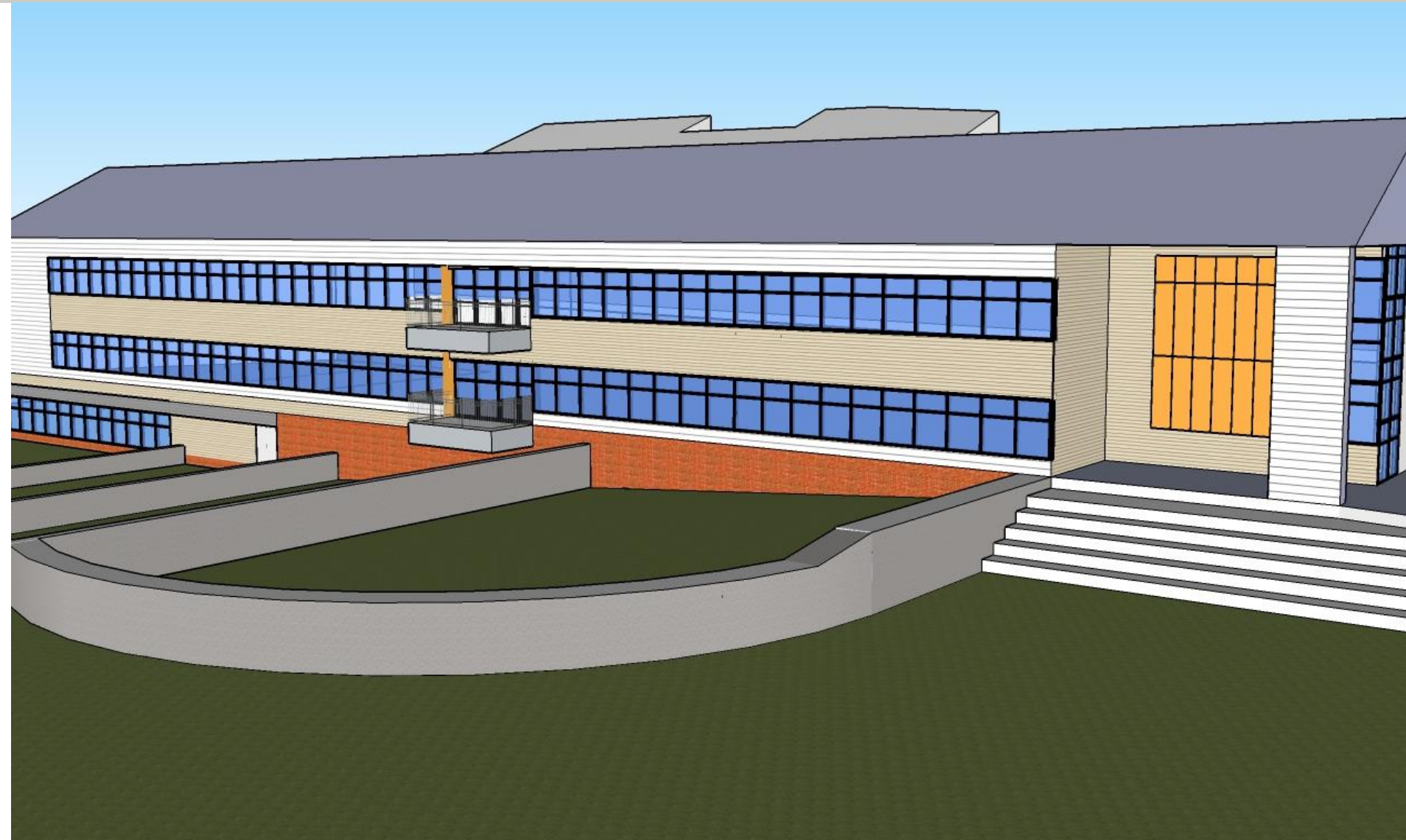


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Architectural Breadth

Analysis 3 – Façade Study



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Mechanical Breadth

Analysis 3 – Façade Study

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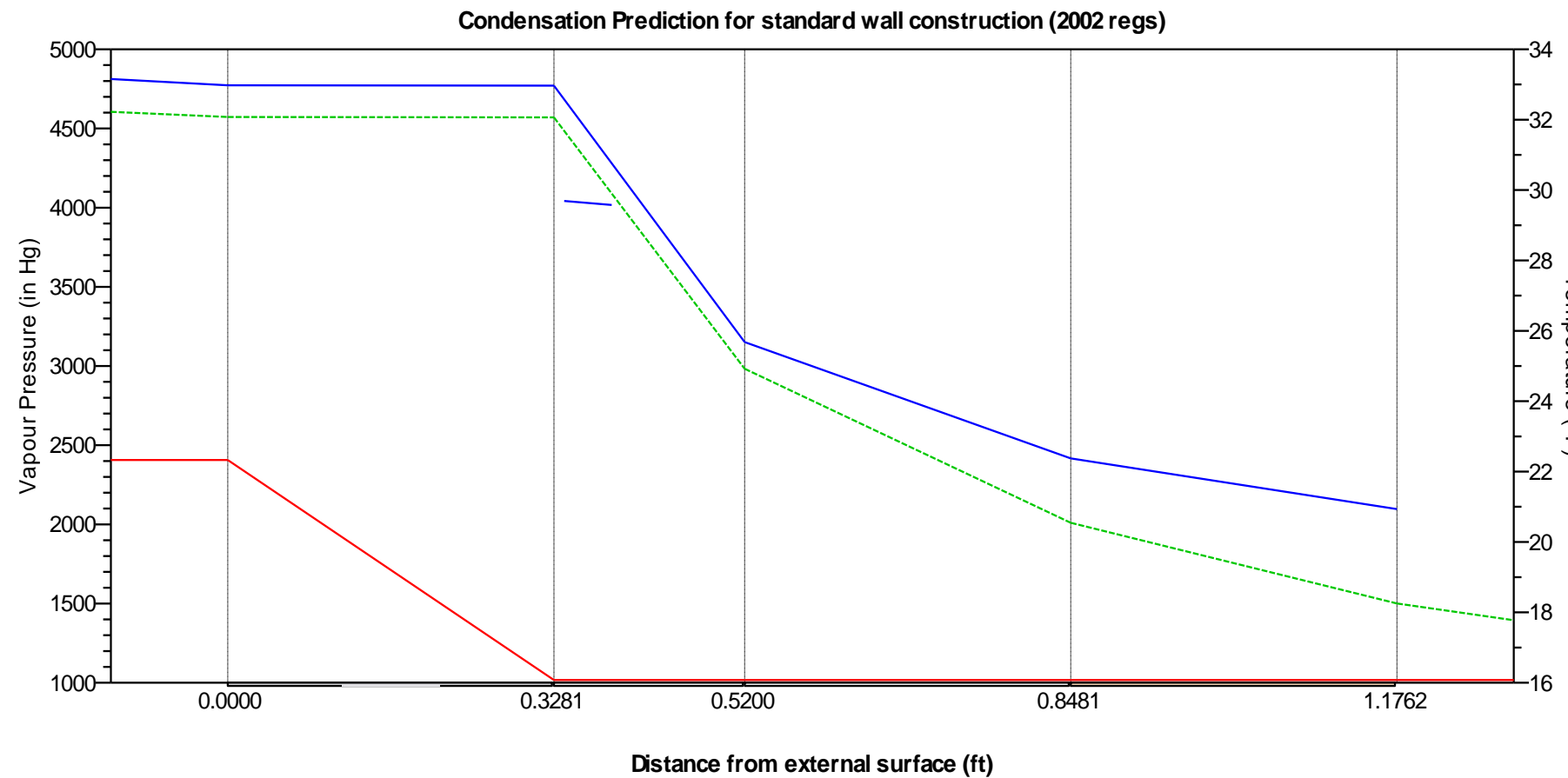
Mechanical Breadth

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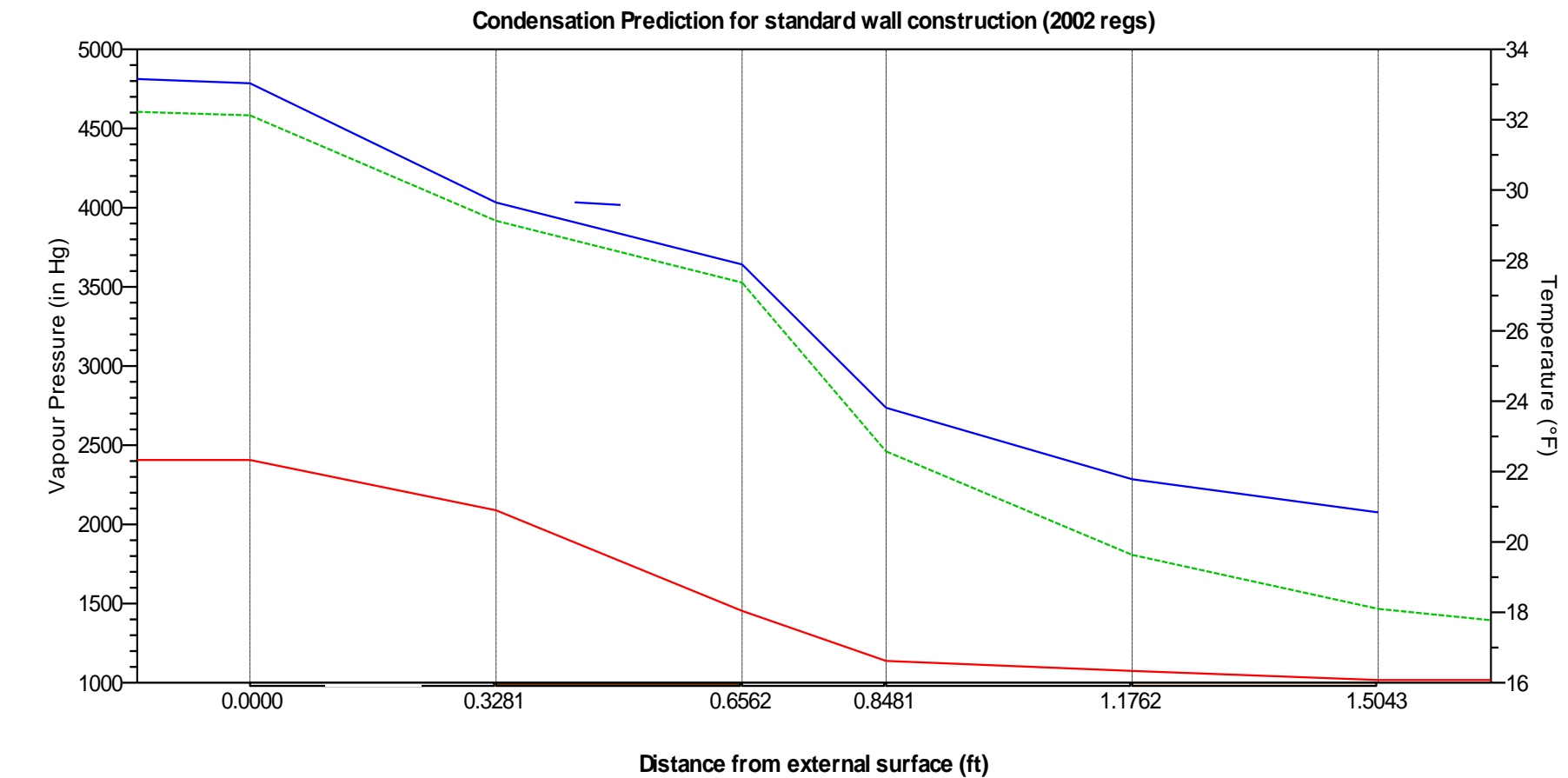
Production & Cost

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R-Value	
Original Summer	35.64
New Summer	43.33
Concrete Summer	31.68



Original Summer



New Summer

The Environmental Studies Lab: Expansion

Production & Cost

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Original Production and Cost						
Material	Square Footage	Duration (Days)	Production Rate (SF/Day)	Cost/Sqft	Cost/Day	Total Cost
Corrugated	19,105	21	940	\$15.00	\$14,100.00	\$296,100
Composite	2,412	15	161	\$40.00	\$6,440.00	\$96,600
Fiber Cement Siding	9,138	10	979	\$13.09	\$12,815.11	\$128,151
Louvers	1,833	5	367	\$41.50	\$15,230.50	\$76,153
Brick	7,514	19	395	\$23.00	\$9,095.89	\$172,822
Total	40,002	70	2,842		\$57,681.50	\$769,826

New Production and Cost							
Material	Quantity	Units	Duration (Days)	Production Rate (Unit/Day)	Cost/Unit	Cost/Day	Total Cost
Fiber Cement Siding	32,488	SF	33	979	\$13.09	\$12,815.11	\$425,268
Concrete	509	CY	14	37	\$100.00	\$3,700.00	\$50,928
Total			47	1,016		\$16,515.11	\$476,196

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Production & Cost

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Total			47	1,016		\$16,515.11	\$476,196

**Façade changes
saves 23 days and
\$293,630**

The Environmental Studies Lab: Expansion

Recommendations

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Analysis 1: Alternative Delivery Method
Saves 315 days with construction starting August 3, 2010

Recommend

Analysis 2: Short Interval Production Schedule (SIPS)
Saves 21 days with a slight labor cost increase

Recommend

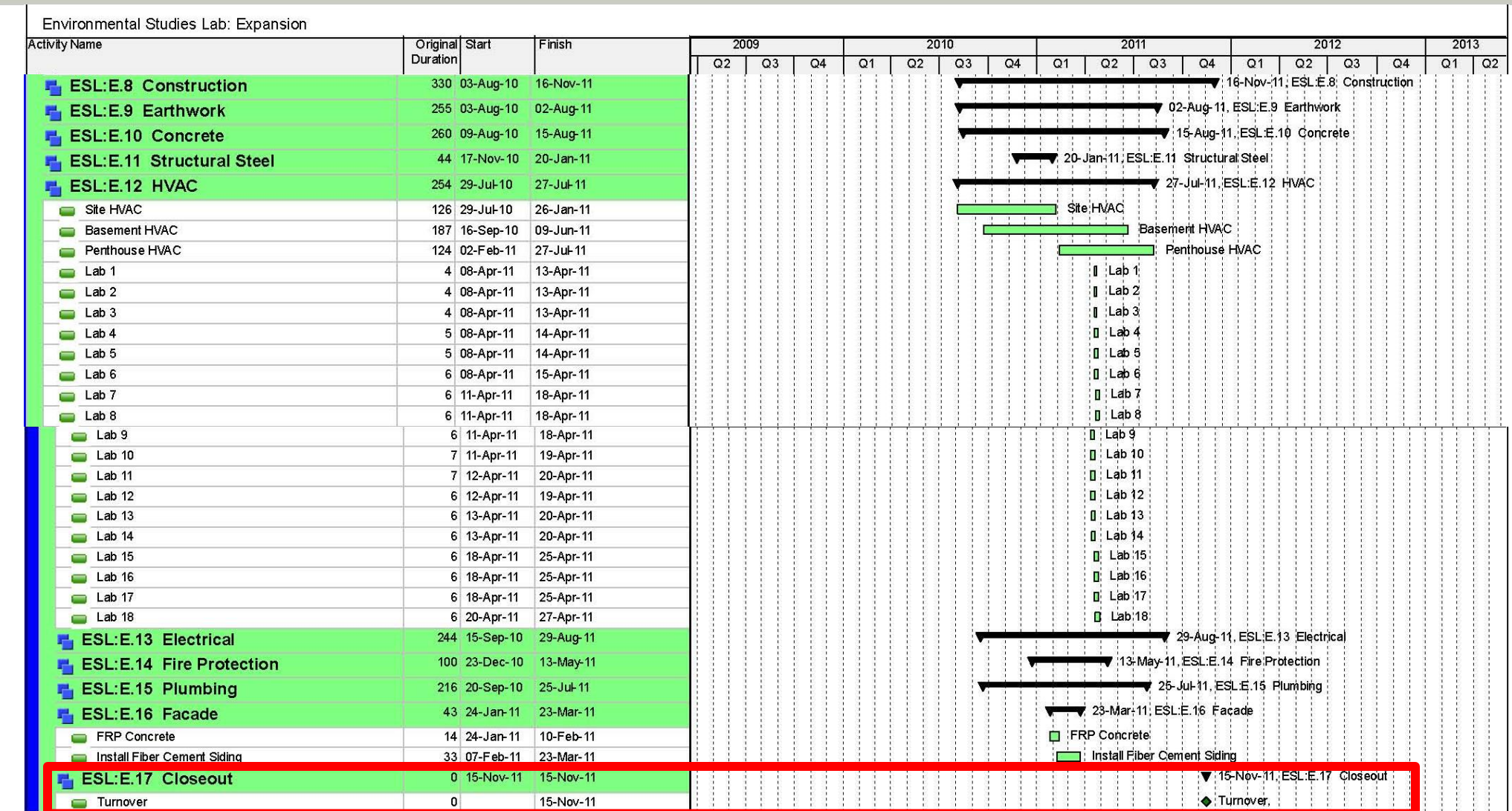
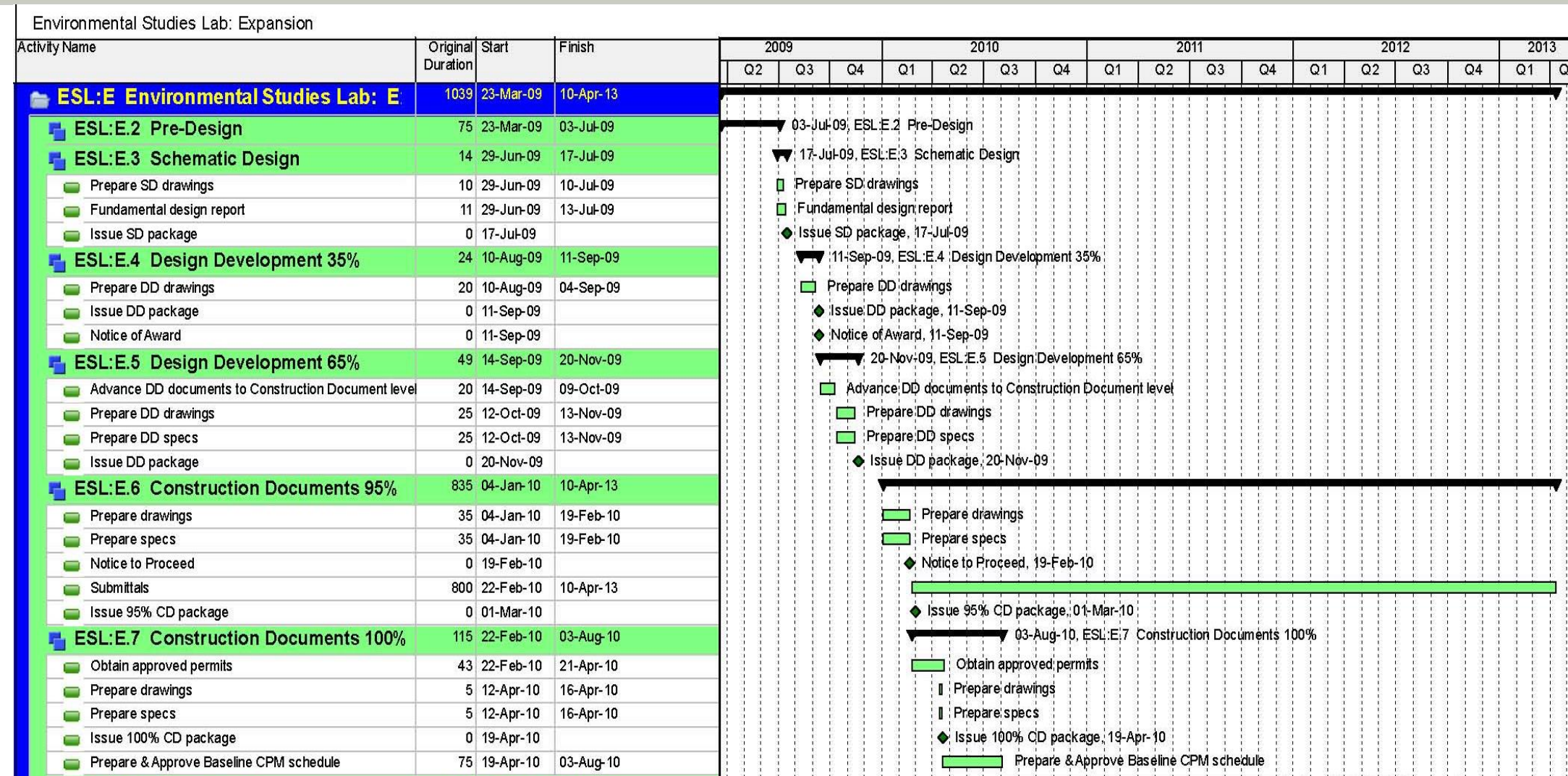
Analysis 3: Façade Study
Saves 23 days with about a \$300,000 cost savings

Recommend

The Environmental Studies Lab: Expansion

Recommendations

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Acknowledgments

Industry:

- Hensel Phelps
- Ewing Cole
- Centria

Academic:

- Dr. Chimay Anumba
- Dr. Robert Leicht
- Dr. Craig Dubler
- Dr. David Riley
- Professor Parfitt
- Dr. Cox
- Penn State Architectural
Engineering Facility

Special Thanks to:

- The Project team
- The Owner and Owner's Representative
- Pace Industry Members
- My Family and Friends
- Jessica Weber

The Environmental Studies Lab: Expansion



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Appendix

Project Outcome Metrics

Metric	Equation
Unit cost (\$/SF)	Actual project cost / Gross square-footage
Cost growth (%)	[(Actual project cost – Initial project cost) / Initial project cost] x 100
Intensity (\$/SF/Month)	Unit cost / (Actual project duration in days / 30)
Schedule growth (%)	[(Actual project duration in days – Initial project duration in days) / Initial project duration in days] x 100
Delivery speed (SF/Month)	Gross square-footage / (Actual project duration in days / 30)
Construction speed (SF/Month)	Gross square-footage / (Actual construction duration in days / 30)
Turnover quality (Sum ratings)	Start-up difficulty + Call back frequency + O&M costs
System quality (Sum ratings)	Structure & envelope expectations met + Interior expectations met + Environmental system expectations met
Design quality (Sum ratings)	Aesthetic expectations met + Functional expectations met
Sustainability	LEED certification level

Building Name	Building Type	Delivery Method	Square Foot	NTP	Project End	Project Duration	Start Actual Date	Finish Plan date	Finish Actual date	Construction Duration	Initial Construction Cost	Final Construction Cost	Cost/Sq Ft	Intensity	Construction Speed	Delivery Duration
Environmental Studies	Lab	DBB	72,000	06/01/11	10/17/13	622	6/15/11	04/22/13	10/07/13	604	33,981,000	35,358,000	\$491	\$1,756,192	3576	3473
	Naval Base	DB	99,460	04/30/09	05/12/11	531	10/22/09	05/15/11	05/12/11	406	53,787,000	54,518,970	\$548	\$4,028,495	7349	5619
	Health Care	IPD	4,350,100	04/14/08	09/12/12	1153	5/28/09	08/31/12	02/09/12	706	352,852,000	272,892,000	\$63	\$11,595,977	184848	113186
	Municipal building	DB	520,000	12/23/10	08/17/12	432	2/28/11	06/29/12	07/22/12	366	49,177,044	53,396,376	\$103	\$4,376,752	42623	36111
	Transportation	DB	71,336	06/02/11	04/22/13	493	8/10/11	08/01/13	04/22/13	444	25,900,000	32,832,966	\$460	\$2,218,444	4820	4341
	Office/Training/Warehouse	DB	41,155	03/14/12	04/24/13	291	5/21/12	05/31/13	04/24/13	243	8,256,000	10,309,714	\$251	\$1,272,804	5081	4243
	Transportation	DB	2,656,300	10/17/06	06/30/10	967	7/1/07	06/30/10	06/30/10	784	512,771,000	669,456,000	\$252	\$25,616,939	101644	82408
	Office	DB	250,000	08/01/07	08/01/09	525	8/1/07	06/01/09	06/01/09	479	92,860,000	92,727,765	\$371	\$5,807,584	15658	14286
		DB	449,000	06/03/11	On Schedule	NA	1/3/12	12/16/15	On Schedule	NA	141,231,044	TBD	NA	NA	NA	NA
	Museum	DB	47,000	12/07/09	11/10/12	766	8/7/10	08/23/11	11/09/12	591	11,400,000	12,562,509	\$267	\$637,691	2386	1841
	Hanger-Commercial	DB	60,000	11/03/11	08/01/13	456	3/13/12	06/24/13	06/24/13	335	19,498,000	19,744,063	\$329	\$1,768,125	5373	3947

The Environmental Studies Lab: Expansion

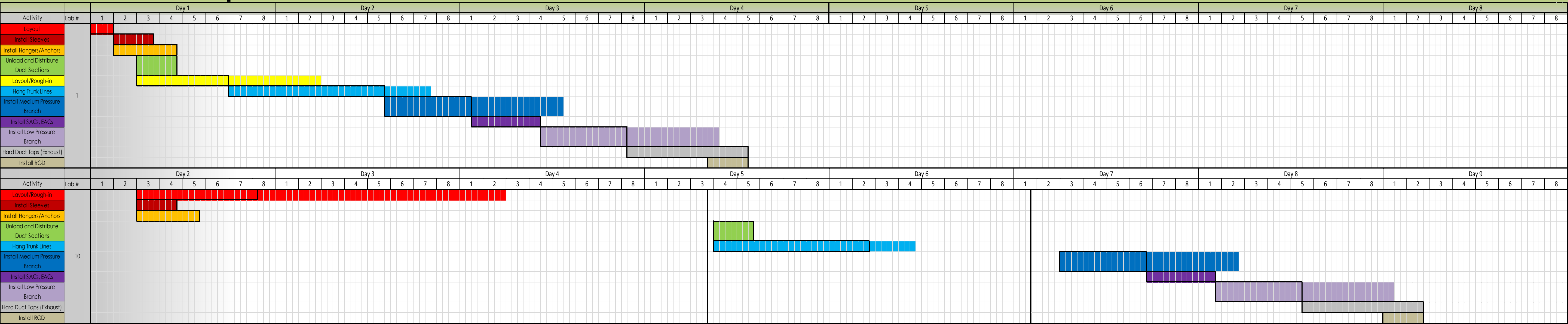
Appendix

First Floor									
Activity	Days/Floor	Crew Members	Hours/floor	Hours/lab	Hours/Worker	SIPS 1 & 2 Crew Members	Adjusted Hours/lab	SIPS 3Crew Members	Adjusted Hours/lab
Layout	1	1	8	0.89	0.89	1	0.89	1	0.89
Install Sleeves	2	1	16	1.78	1.78	1	1.78	1	1.78
Install Hangers/Anchors	3	2	24	2.67	1.33	2	2.67	2	2.67
Unload and Distribute Duct Sections	2	2	16	1.78	0.89	2	1.78	2	1.78
Layout/Rough-in	9	1	72	8.00	8.00	2	4.00	2	4.00
Hang Trunk Lines	10	3	80	8.89	2.96	4	6.67	4	6.67
Install Medium Pressure Branch	9	3	72	8.00	2.67	4	6.00	5	4.80
Install SACs, EACs	3.5	2	28	3.11	1.56	2	3.11	2	3.11
Install Low Pressure Branch	9	3	72	8.00	2.67	4	6.00	5	4.80
Hard Duct Taps (Exhaust)	6	3	48	5.33	1.78	3	5.33	3	5.33
Install RGD	2	1	16	1.78	1.78	1	1.78	1	1.78
Total		22.00	452	50.22		26	40.00	34	37.60

Second Floor									
Activity	Days/Floor	Crew Members	Hours/day	Hours/lab	Hours/Worker	SIPS 1 Crew Members	Adjusted Hours/lab	SIPS 3Crew Members	Adjusted Hours/lab
Layout/Rough-in	18	1	144	16.00	16.00	3	5.33	3	5.33
Install Sleeves	2	1	16	1.78	1.78	1	1.78	1	1.78
Install Hangers/Anchors	3	2	24	2.67	1.33	2	2.67	2	2.67
Unload and Distribute Duct Sections	2	2	16	1.78	0.89	2	1.78	2	1.78
Hang Trunk Lines	10	3	80	8.89	2.96	4	6.67	4	6.67
Install Medium Pressure Branch	9	3	72	8.00	2.67	4	6.00	5	4.80
Install SACs, EACs	3.5	2	28	3.11	1.56	2	3.11	2	3.11
Install Low Pressure Branch	9	3	72	8.00	2.67	4	6.00	5	4.80
Hard Duct Taps (Exhaust)	6	3	48	5.33	1.78	3	5.33	3	5.33
Install RGD	2	1	16	1.78	1.78	1	1.78	1	1.78
Total		21.00	516	57.33		26	40.44	32	38.04

The Environmental Studies Lab: Expansion

Appendix



The Environmental Studies Lab: Expansion

Appendix

Whole Building (Phase 1 & 2)						
Elevation	Corrugated	Composite (orange)	Fiber Cement Siding	Louvers	Brick Veneer	Total Square Footage
North	2,307	0	5,908	0	818	9,033
South	14,769	2,412	8,146	1,833	5,737	32,897
East	1,788	0	638	0	0	2,426
West	9,333	0	0	0	3,768	13,101
Total	28,197	2,412	14,692	1,833	10,323	57,457

Expansion						
Elevation	Corrugated	Composite (orange)	Fiber Cement Siding	Louvers	Brick Veneer	Total Square Footage
North	2,307	0	992	0	818	4,117
South	14,769	2,412	8,146	1,833	5,737	32,897
East	490	0	0	0	0	490
West	3,846	0	0	0	959	4,805
Total	19,105	2,412	9,138	1,833	7,514	40,002

Original Production and Cost						
Material	Square Footage	Duration (Days)	Production Rate (SF/Day)	Cost/Sqft	Cost/Day	Total Cost
Corrugated	19,105	21	940	\$15.00	\$14,100.00	\$296,100
Composite	2,412	15	161	\$40.00	\$6,440.00	\$96,600
Fiber Cement Siding	9,138	10	979	\$13.09	\$12,815.11	\$128,151
Louvers	1,833	5	367	\$41.50	\$15,230.50	\$76,153
Brick	7,514	19	395	\$23.00	\$9,095.89	\$172,822
Total	40,002	70	2,842		\$57,681.50	\$769,826

Fiber Cement Siding						
Material	Square Footage	Duration (Days)	Production Rate (SF/Day)	Cost/Sqft	Cost/Day	Total Cost
Composite	2,412	2	979	\$13.09	\$12,815.11	\$31,573
Corrugated	19,105	20	979	\$13.09	\$12,815.11	\$250,084
Louvers	1,833	2	979	\$13.09	\$12,815.11	\$23,994
Fiber Cement Siding	9,138	10	979	\$13.09	\$12,815.11	\$128,151
Total	32,488	34	3,916		\$51,260.44	\$433,803

New Production and Cost							
Material	Quantity	Units	Duration (Days)	Production Rate (Unit/Day)	Cost/Unit	Cost/Day	Total Cost
Siding	32,488	SF	33	979	\$13.09	\$12,815.11	\$425,268
Concrete	509	CY	14	37	\$100.00	\$3,700.00	\$50,928
Total			47	1,016		\$16,515.11	\$476,196