NAU Compost Monitoring Program

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Northern Arizona University-CENE 486

Fall 2019

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SAS Engineering

Background

Purpose:

- To create a comprehensive management plan for Northern Arizona University's (NAU) composting system.
- To determine if NAU can perform lab analysis in-house.
- To compare external lab costs vs. in-house testing cost.

Client: Adam Bringhurst

Location: NAU Facilities

Figure 1: Finished compost; Photo by Abdul Almehmadi

Site Location

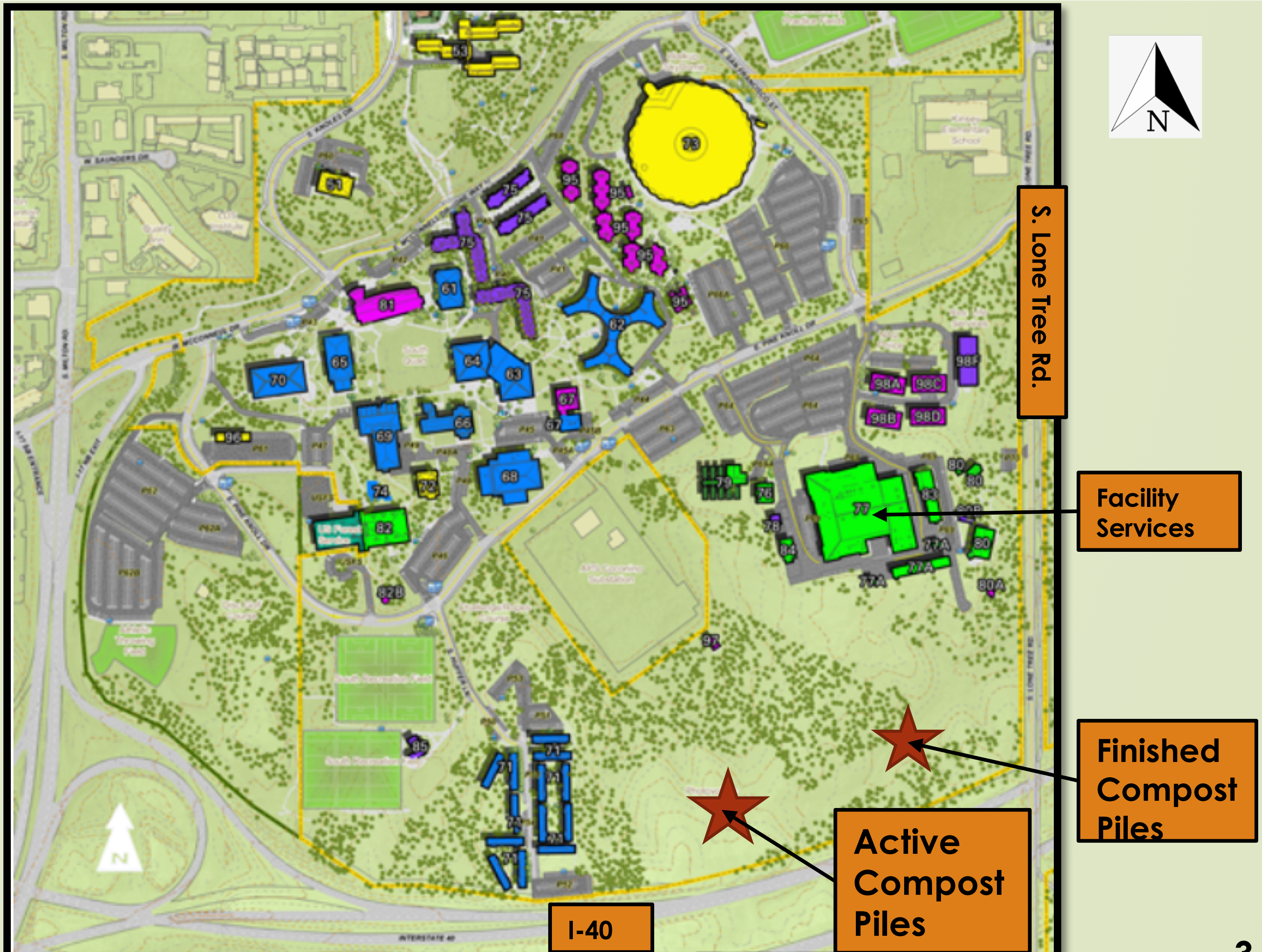


Figure 2: Project Site at Northern Arizona University; Photo Credits NAU Maps

Regulations

Table 1: Regulations [2] [8]

Parameters	Determination	Importance
pH	6-7.5	Too Basic causes damage to plants.
Ash Content	~50% ash weight	Higher shows mineralization (shows in older compost).
Heavy Metals	Varies	Toxic substances that can harm human health.
E. Coli	3 MPN/g dry weight compost	Toxic microbes that can harm human health.
Nitrate/Nitrite	Below 100 PPM	Not enough nitrates indicates insufficient amount of oxygen; causing gaseous loss of nitrogen.
Ammonia	100-550 PPM	Indicates why pH is high or low.
Salmonella	4MPN/4g dry weight compost	Toxic microbes that can harm human health.
C:N Ratio	Below 14 Ratio	Shows the rate of decomposition. Accurately depicts when compost reaches ripeness.

Figure 3: Finished Compost Pile 1; Photo by: Sara Page

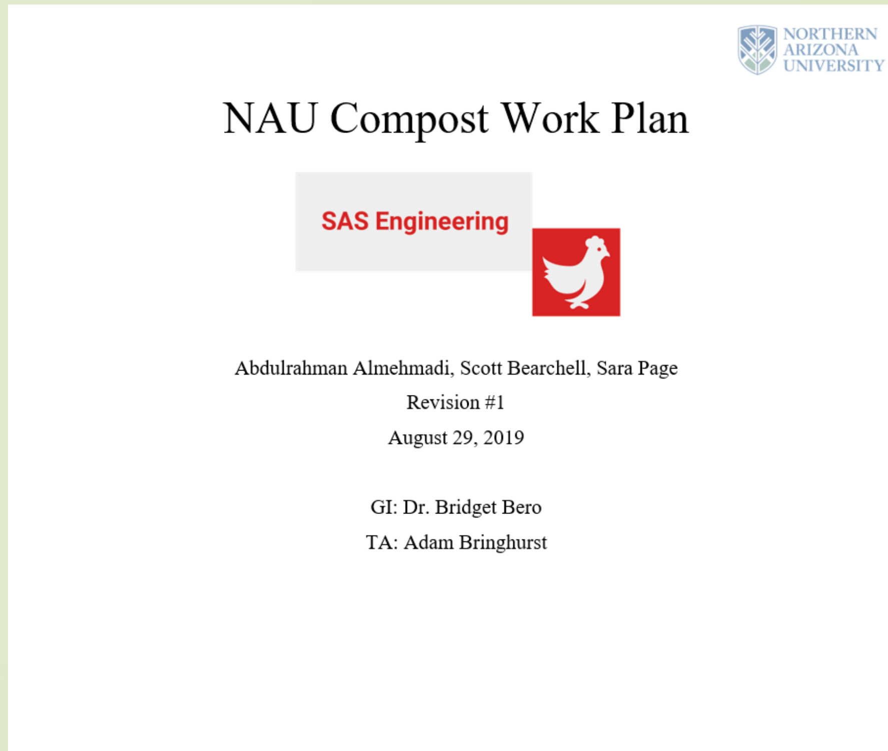
Work Plan

Sampling and Analysis Plan (SAP)

- Project Data Quality
- Field Methods and Procedures
- Disposal Methods

Health and Safety Plan (HASP)

- Hazardous Assessment
- Training Requirements
- Personal Protective Equipment
- Emergency Response Procedures



NORTHERN ARIZONA UNIVERSITY

NAU Compost Work Plan

SAS Engineering

Abdulrahman Almehmadi, Scott Bearchell, Sara Page

Revision #1

August 29, 2019

GI: Dr. Bridget Bero

TA: Adam Bringhurst

Figure 4: Work Plan: Workplan Title Page

Figure 5: Compost Pile Sampling 2; Photo by: Sara Page

Sampling

- Samples taken on 9/20/2019
- 4ft height sampling
- 3 piles = 3 samples
- 8 locations within a pile
- Gallon of sample per pile composited

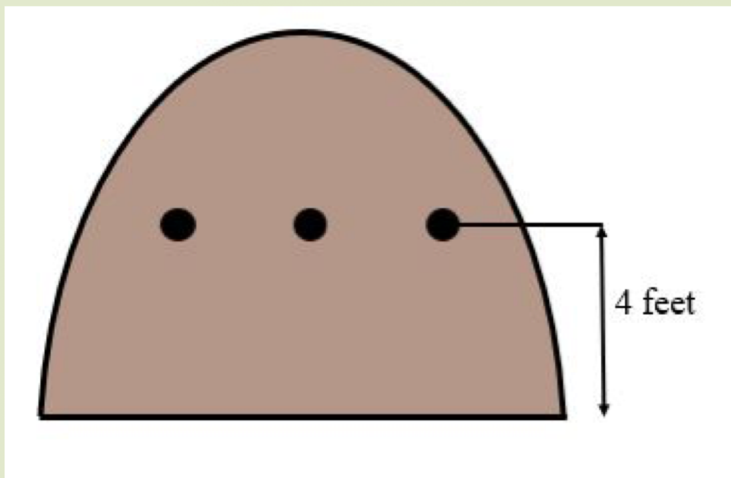


Figure 6: Compost Pile Side View; Created by: Sara Page

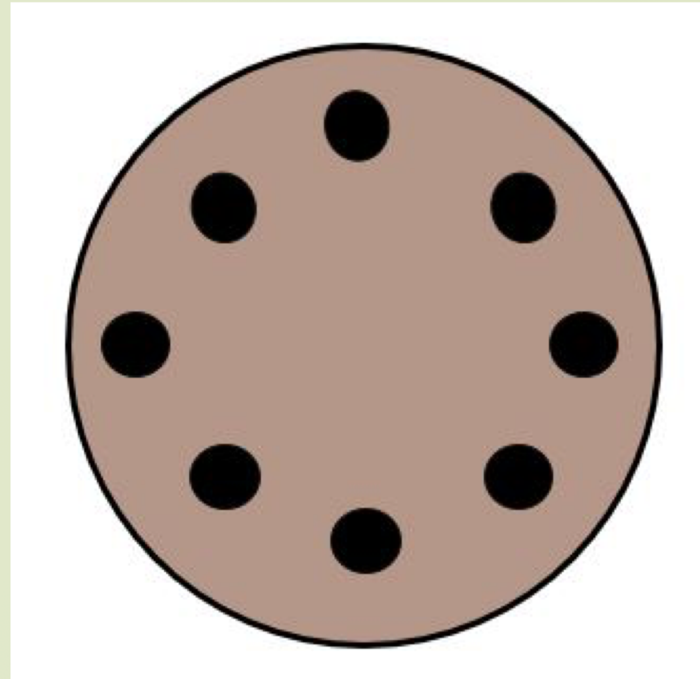


Figure 7: Compost Pile Top View; Created by: Sara Page

Temperature:

- Temperatures taken at different intervals
- Plateaus when temperature doesn't change even when mixed for a week.
- Temperatures plateaued.

Table 2: Temperature

Date:	10/14/2019	10/31/2019	11/24/2019	Temp. Avg.	Determination: <90° F [2]
Pile	Temperature ° F				
1.1	110	110	90	112 ± 9	High
1.2	128	112	106		
1.3	118	122	112		
1.4	113	106	114		
2.1	126	119	112	119 ± 8	High
2.2	126	120	117		
2.3	128	122	104		
2.4	127	122	108		
3.1	116	112	105	108 ± 8	High
3.2	116	108	98		
3.3	118	111	100		
3.4	113	110	90		

Analysis: pH

- Test Method for Examining Composting and Compost (TMECC) 4.11A

Table 3: pH Results

Sample	pH	Avg pH	Determination: between 6 -7.5 [2] [8]
1.1	6.89	6.79 ±0.09	Good
1.2	6.71		
1.3	6.77		
2.1	7.06	6.97 ±0.13	Good
2.2	7.02		
2.3	6.82		
3.1	7.27	7.23 ±0.04	Good
3.2	7.20		
3.3	7.22		

Figure 8: pH Samples on Shaker; Photo by: Abdul Almehmadi

Analysis: Ash Content

- Test Method Examination for Composting and Compost (TMECC) TMECC 3.02A

Table 4: Ash Results

Sample	Ash %	Ash % Avg	Determination: ~50% [8]
1.1	59%	54% ±7%	Good
1.2	45%		
1.3	56%		
2.1	50%	51% ±3%	Good
2.2	49%		
2.3	55%		
3.1	82%	83% ±1%	**High**
3.2	84%		
3.3	84%		

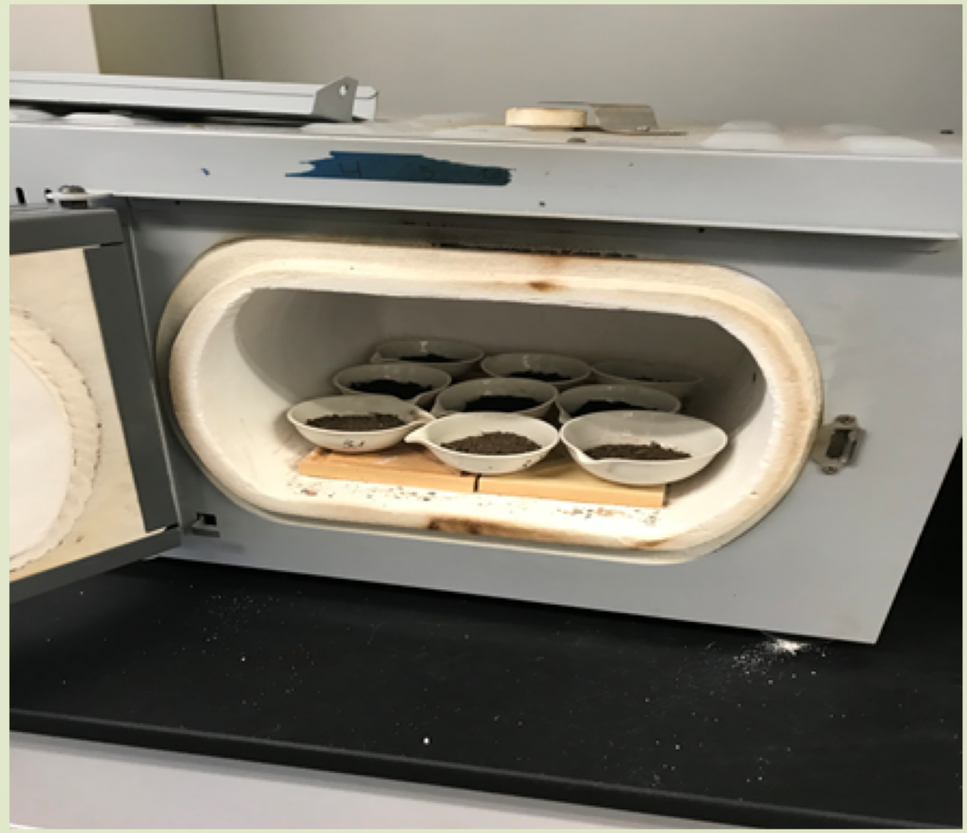


Figure 9: Ash sample in muffle furnace; photo by: Sara Page

Analysis: Heavy Metals

- Subcontracted out; Followed EPA 6200

Table 5: Heavy Metal Results

Metals	Pile Sample 1 Avg. (PPM)	Pile Sample 2 Avg. (PPM)	Pile Sample 3 Avg. (PPM)	Standard Deviation (PPM)	EPA Limit: [2] [8] (PPM)	Within Limit:
Arsenic	6.4	12.1	12.1	2.7	41	Good
Cadmium	< 10	< 10	< 10	7.2	39	Good
Copper	28.5	35.2	37.3	9.3	1500	Good
Chromium	<10	26.7	40.9	10.2	1200	Good
Lead	7.3	9.2	19.4	3.1	300	Good
Mercury	<5	<5	<5	5.9	17	Good
Nickel	<15	<15	32.3	16.0	420	Good
Zinc	120.1	116.4	120.7	8.0	2800	Good
Molybdenum	2.9	<1	< 1	2.9	75	Good
Selenium	<3	<3	<3	2.4	100	Good

Analysis: E. Coli

- HACH Method 8001 with modifications of adding 5 grams of compost and DI water into the vials

Table 6: E. Coli

Sample	E. Coli	Avg E. Coli	Determination: <3 MPN/g Compost
1.1	0	None Detected	Good
1.2	0		
1.3	0		
2.1	0	None Detected	Good
2.2	0		
2.3	0		
3.1	0	None Detected	Good
3.2	0		
3.3	0		

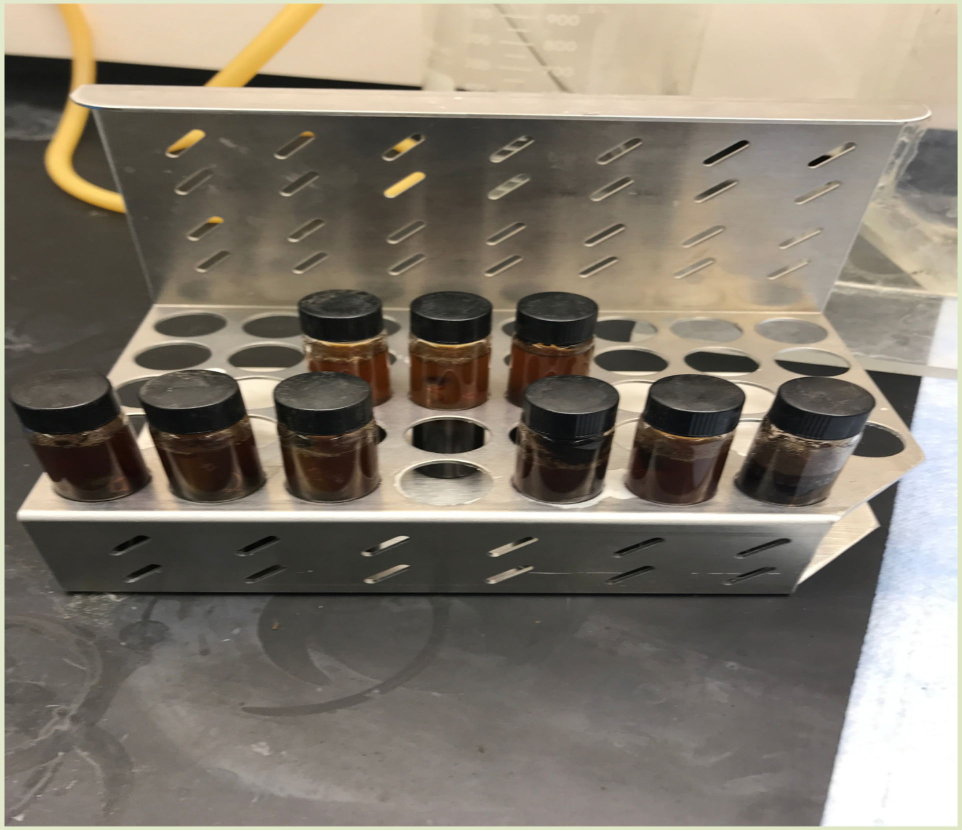


Figure 10: *E.Coli*; Photo by Sara Page

Analysis: Nitrate/Nitrite

- HACH Method 8039
- Had to be modified due to not having a Ion Chromatograph
- Slurry was created and utilized as liquid
- Slurry was filtered twice for sampling

Table 7: Nitrates

Sample	Nitrate (mg/L)	Nitrate Avg (mg/L)	Determination: >100 PPM [2] [8]
1.1	5.1	6.8 ±1.7	**Fail**
1.2	6.7		
1.3	8.5		
2.1	12.5	13.6 ±1.3	**Fail**
2.2	15		
2.3	13.4		
3.1	5.4	4.1 ±1.2	**Fail**
3.2	3.8		
3.3	3.1		

Figure 11: Nitrate; Photo by Abdul Almehmadi

Analysis: What Couldn't be Tested

Ammonia

- TMECC 4.02C
- EnE labs were not equipped with a working Ion-Selective Electrode.

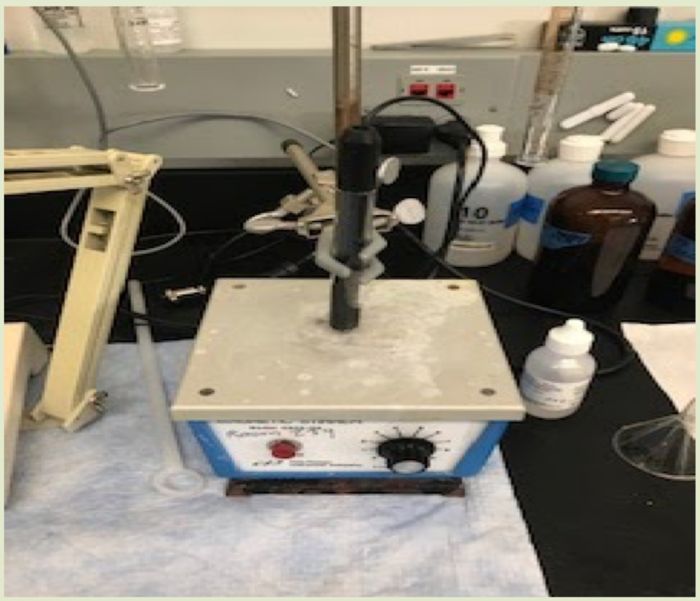


Figure 12: Ammonia; Photo by Abdul Almehmadi

Salmonella

- Test Method Examination for Composting And Compost TMECC 07.02A
- Could not test due to absence of a Stomacher.
- Stomacher is used in microbiology applications to extract and wash intact microbes into solution.

Figure 13: *Salmonella*; Stomacher 400 Circulator

C:N Ratio

- Test Method Examination for Composting And Compost TMECC 4.02-A and TMECC 4.02-C.
- Could not test due to absence of an Aluminum Heating Block for 500˚C and a Sulfur/Carbon Determinator.
- These devices are used to test carbon through combustion.

Figure 14: *C:N Ratio*; Sulfur/Carbon Determinator

External Lab Source Results:

Table 8: External Lab Source Compared

Parameter	Units	Pile 1 from SAS	Pile 1 from External Lab	% Error
Ash	%	54%	47.9%	11%
pH	N/A	6.8	7.77	14%
Nitrate	PPM	6.8	310	**4459%**
Arsenic	PPM	6.4	3.5	45%
Cadmium	PPM	< 1	<1	0%
Copper	PPM	28.47	36	26%
Chromium	PPM	< 10	20	**100%**
Lead	PPM	7.3	5.4	26%
Mercury	PPM	< 1	<1	0%
Nickel	PPM	< 10	15	50%
Zinc	PPM	120.10	100	17%
Molybdenum	PPM	2.915	1.7	42%
Selenium	PPM	< 1	<1	0%

Operations Analysis

Compost Components

Food

- Pre-consumer waste is gathered from The Hot Spot and The DüB Dining District, located on campus

Emulsifier and Dehydrator

- Post-consumer waste is processed using Somat products to produce an emulsified pulp that is then added to compost piles

Bulking Agents

- Tree trimmings and pine needles are donated from Arizona Public Service (APS) and local businesses.
- Horse manure is donated from local stables
- Dirt is collected from various NAU Facility projects.

Figure 15: *Somat, HYDRA-EXTRACTOR; Photo by Scott Bearchell*

Figure 16: *Emulsified post-consumer waste; Photo by Scott Bearchell*

Operations Analysis

Composting
- 1 Week of dining waste is collected.
- Six 2 month old piles are created with the last pile being 12 months old.

Testing
- 1 Sample every 2 months is sent to Soil Control Laboratory, in Watsonville, California for quality testing

Finish
- Compost is turned into an amended soil with 80% compost and 20% dirt.
- Product is sold

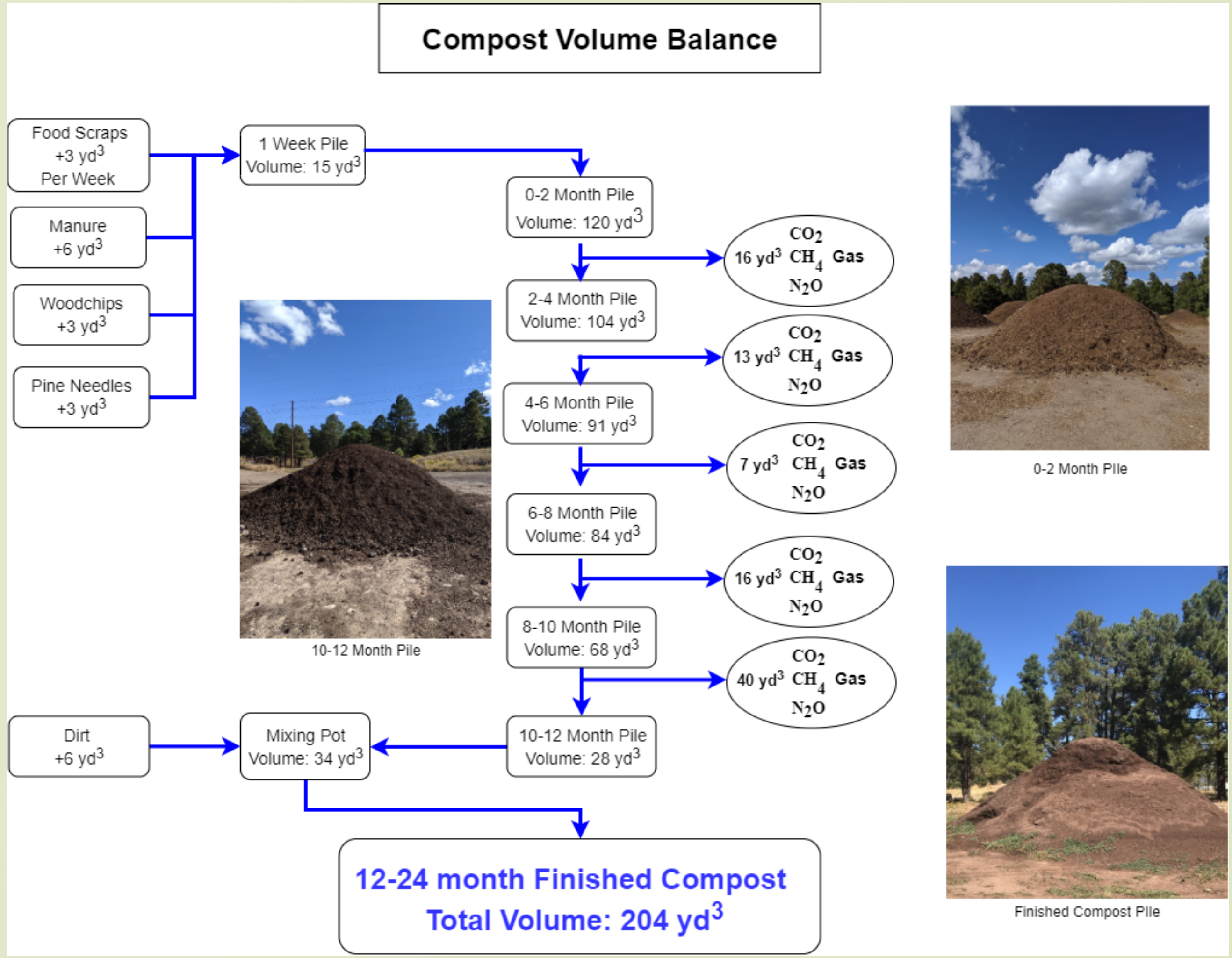


Figure 17: Volume Flow Balance; Created by Scott Bearchell

Economic Analysis: In-House Testing

Capital Cost at Year 0 for In-House:

- Calculates all cost of Bulk Materials and Equipment needed for each test.
- Total capital cost is ~$61K.

Table 9: Capital Cost At Year 0

Capital Cost at Year 0		
Method	**Materials**	**Cost for Item**
Organic Carbon TMECC	Aluminum Oxide, 25lbs	$63.04
	Sucrose, 500g	$16.60
	CaCo3, 500g	$10.75
Nitrogen TMECC	Kjeltabs Cu-3.5,Foss 1000pk	$251.00
	Salicylic Acid, 1 lbs	$9.67
	Sodium Thiosulfate, 4 lbs	$20.39
Salmonella TMECC	lactose broth, 1 kg	$29.22
	Brilliant Green Bile Broth 500 g	$79.00
	Idoine-Iodide solution 1L 5mg	$36.95
	Tetrathionate broth 500 g	$53.57
	Hektoen Enteric Agar, 500 g	$149.50
	Selenite F broth 500g	$74.30
	1-2 Test Kit, 48pk	$114.20
Ammonia TMECC	deionized, ammonia-free water, 3500 mL	$99.75
NItrate/Nitrite TMECC	deionized, ammonia-free water, 3500 mL	$99.75
E.Coli HACH	Lauryl Tryptose broth tubes, Qty 15	$32.75
	EC Medium with MUG, Qty 15	$33.20
Method	**Equipment**	**Cost $/ Equipment**
Organic Carbon TMECC	832 Series Sulfur/Carbon Determinator	$35,000.00
	Furnace	$1,169.00
Nitrogen TMECC	Microwave	$2,653.00
	Aluminum Heating Block. 500C	$445.40
Salmonella TMECC	Stomacher	$5,606.50
	Strainer bag, Qty 1	$12.49
pH TMECC	pH meter	$12.99
	Glass Electrode	$50.70
	Stirring Rod	$3.00
	Centrifuge Extraction Apparatus	$1,312.00
Ammonia TMECC	Ion -Selective electrode	$884.00
	Manetic Stirrer	$317.19
Ash TMECC	Balance	$148.00
	Evap dish 525mL, Qty 1	$136.00
	Dessicator Cabinets 24"x18"	$131.00
Total Solids & Moisture Content TMECC	Drying oven	$399.00
NItrate/Nitrite TMECC	Ion Chromatograph Dionex DX120	$9,600.00
	Colorimeter AQ4000 Thermo Scientific	$1,279.00
E.Coli HACH	Incubator	$299.00
	Alcohol burner	$7.99
	Incoulating loops	$101.00
	Pipet 10 mL	$197.00
	Pipete filler	$116.40
	Coliform tube rack	$115.00
Total Capital Cost for Year 0		
AT YEAR 0		**$61,170**

Economic Analysis: In-House Testing

Annual Cost for In-House:

- Calculates all cost of single use materials needed.
- Tests one sample of compost every other month; 6 times a year.
- Total annual In-House cost is ~$7.5K.

Table 10: Annual In-House Cost

Annual Cost- Supplies & Labor				
Method	**Materials**	**Pile 1- #Samples**	**Cost for Item**	**Cost/Test**
Organic Carbon TMECC	Aluminum Oxide, 25lbs	1	$63.04	$0.01
	Sucrose, 500g	1	$16.60	$3.32
	CaCo3, 500g	1	$10.75	$2.69
Nitrogen TMECC	Kjeltabs Cu-3.5,Foss 1000pk	1	$251.00	$0.25
	Salicylic Acid, 1 lbs	1	$9.67	$0.01
	Sodium Thiosulfate, 4 lbs	1	$20.39	$0.02
Salmonella TMECC	lactose broth, 1 kg	1	$29.22	$0.38
	Brilliant Green Bile Broth 500 g	1	$79.00	$6.58
	Idoine-Iodide solution 1L 5mg	1	$36.95	$0.37
	Tetrathionate broth 500 g	1	$53.57	$0.50
	Hektoen Enteric Agar, 500 g	1	$149.50	$12.46
	Selenite F broth 500g	1	$74.30	$6.19
	1-2 Test Kit, 48pk	1	$114.20	$2.38
Ammonia TMECC	deionized, ammonia-free water, 3500 mL	1	$99.75	$11.08
NItrate/Nitrite TMECC	deionized, ammonia-free water, 3500 mL	1	$99.75	$11.08
E.Coli HACH	Lauryl Tryptose broth tubes, Qty 15	1	$32.75	$3.64
	EC Medium with MUG, Qty 15	1	$33.20	$3.69
NAU Lab	$100/day for 6 days	1	$600.00	$600.00
NAU Lab Student Technicians	$12/hour for 48 hours	1	$576.00	$576.00
Total In-House Annual Cost				
Annual Cost				**$7,444**

Economic Analysis – In House

In-House Testing Over a 20 Year Period:

- Interest Rate i=4%
- Initial capital cost C= -$61,169
- Annual testing cost A1= -$3,988
- Annual labor cost A2= -$3,456
- Present Worth **Pw= -$162,345**

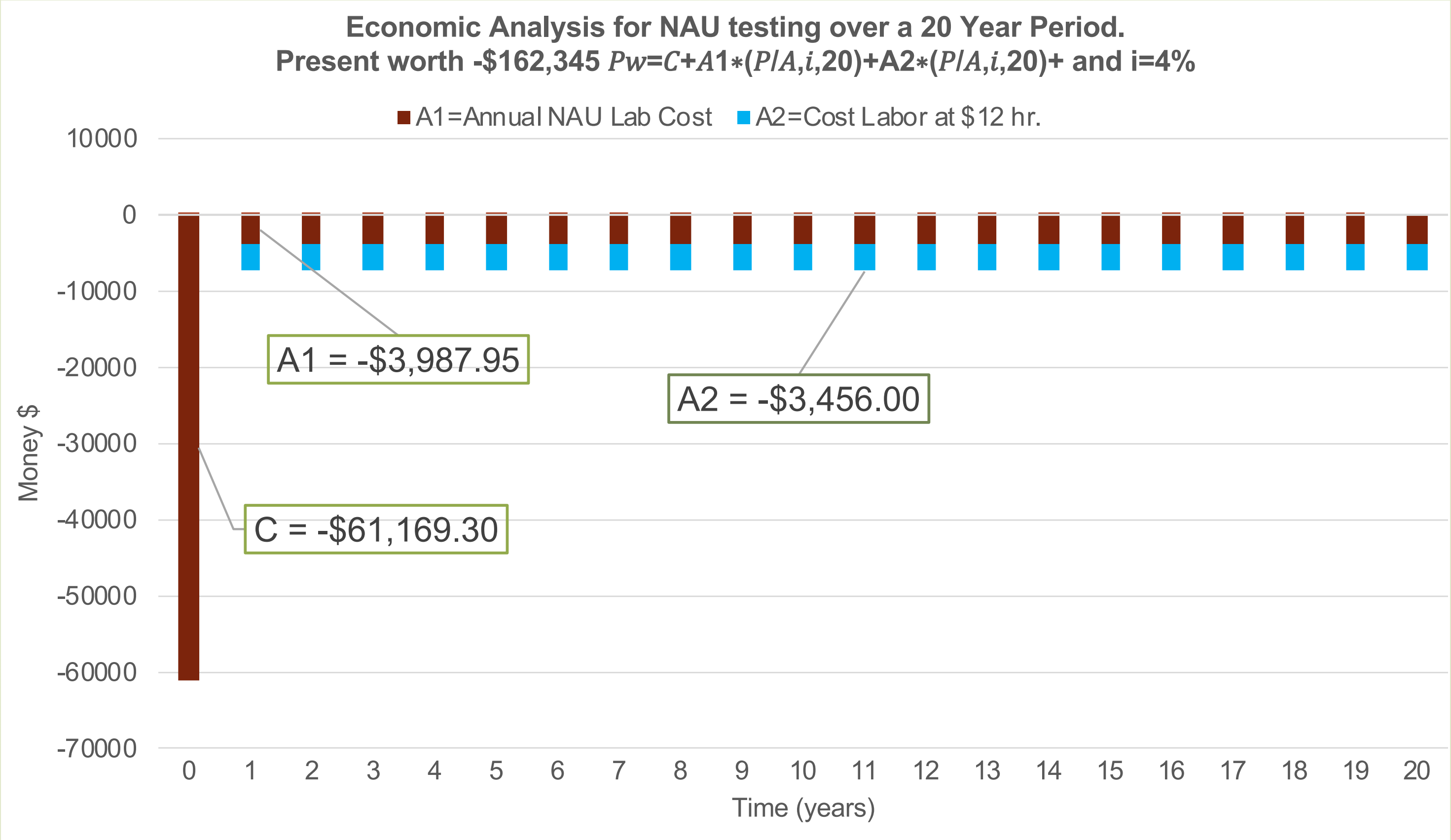


Figure 18: In-House Testing Over a 20 Year Period

Economic Analysis – External Lab

External Lab Testing Over a 20 Year Period:

- Interest Rate i=4%
- Annual testing cost A= -$2,094
- Present worth **Pw= -$28,458**

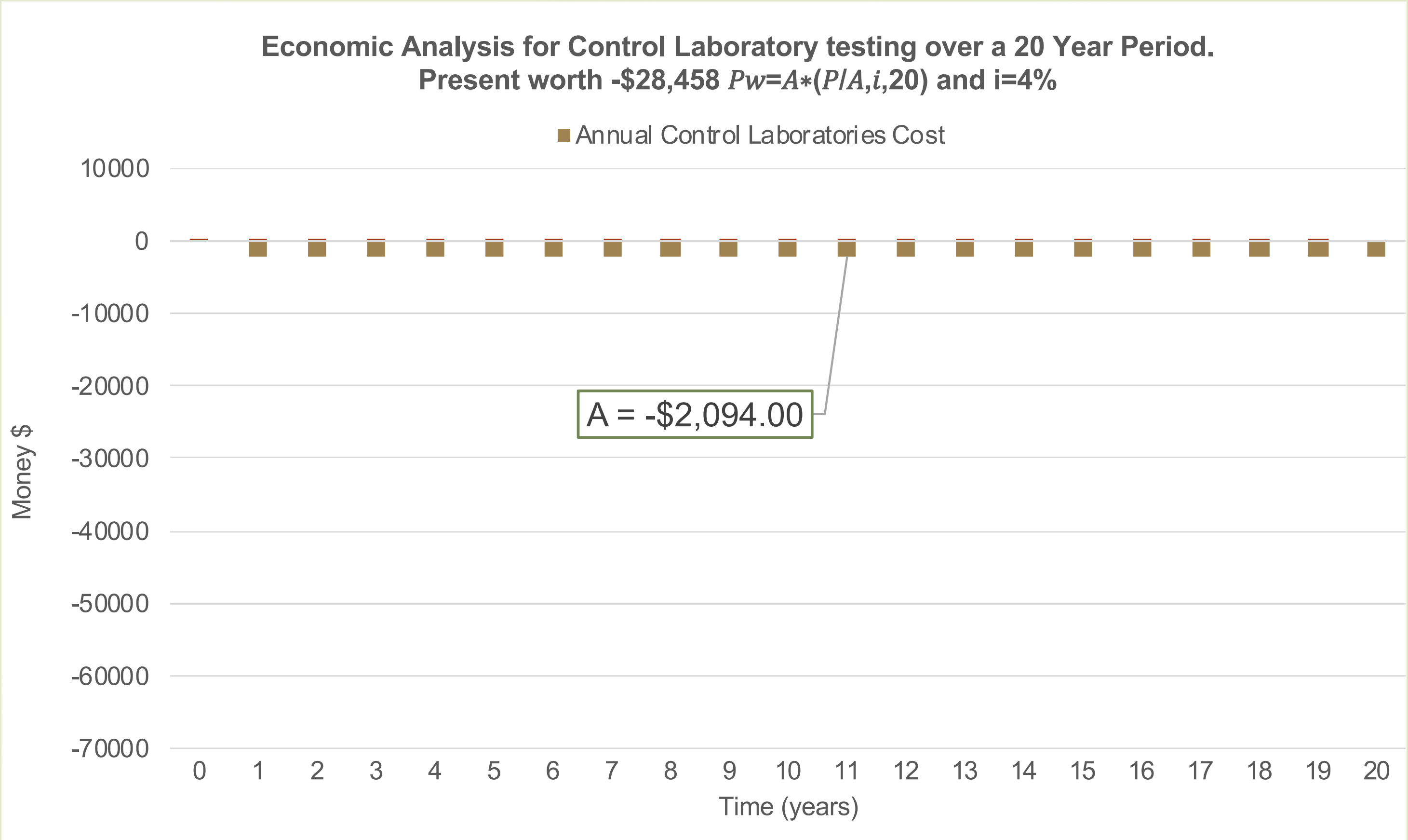


Figure 19: External Testing Over a 20 Year Period

Where A= $349 per test for 6 tests a year [12]

Impacts

Economic Impacts

- Selling compost provides funding for more projects in NAU facilities.
- Local companies and NAU avoid tipping fees from the landfill by bring waste to the compost site.

Social Impacts

- Alternative to throwing out waste.
- Purchase local gardening needs; greater sense of community within NAU and Flagstaff.

Environmental Impacts

- Saves landfill space.
- Eco-friendly safe product.
- Compost being utilized to help grow plants.

Figure 20: Food scraps after emulsifier process

Conclusion

Lab Analysis:

- Testing must follow TMECC for credibility and accuracy.
- For In-House Testing, NAU must follow TMECC.

Economic:

- Using the External Lab saves NAU ~$64K over 20 years and ~$5,400 a year.

Figure 21: Finished Compost Pile 3; Photo by: Sara Page

Project Management

Table 11: Proposed Staff Hours

Proposed Staffing Hours			
Task	**Senior Engineer**	**Engineer**	**Lab Tech**
Task 1.0 Research			
1.1 Regulations Research	2	4	8
1.2 Operations Research	3	7	3
Task 2.0 Work Plan	2	4	8
2.1 Sampling and Analysis Plan(SAP)	3	16	15
2.2 Health and Safety Plan (HASP)	3	22	22
Task 3.0 Sampling	16	22	20
Task 4.0 Testing and Analysis	24	40	65
Task 5.0 Operations Analysis	14	15	4
Task 6.0 Economics Analysis	22	35	0
Task 7.0 Impacts	3	15	12
Task 8.0 Project Management	2	4	3
8.1 Meetings	3	3	3
8.2 Team Management	8	9	5
8.3 Deliverables	7	15	4
8.3.1 Milestone	6	13	3
8.3.1.1 30% Report and Presentation	3	7	2
8.3.1.2 60% Report and Presentation	3	8	2
8.3.1.3 90% Report and Presentation	3	6	1
8.3.1.4 Final Presentation	1	1	1
8.3.1.4 Final Report	1	2	1
8.3.2 Meeting Memo Binder	0	8	8
8.3.3 Website	3	10	0
Total	**588**		

Table 12: Actual Staff Hours

Actual Staffing Hours			
Task	**Senior Engineer**	**Engineer**	**Lab Tech**
Task 1.0 Research			
1.1 Regulations Research	0	6	0
1.2 Operations Research	0	10	0
Task 2.0 Work Plan	2	14	3
2.1 Sampling and Analysis Plan(SAP)	5	9	0
2.2 Health and Safety Plan (HASP)	1	3	3
Task 3.0 Sampling	1	6	1
Task 4.0 Testing and Analysis	3	4	78
Task 5.0 Operations Analysis	1.5	8	0
Task 6.0 Economics Analysis	5	13	4.5
Task 7.0 Impacts	1	2	0
Task 8.0 Project Management	0	0	0
8.1 Meetings	8.5	28.5	25
8.2 Team Management	9	28	16.5
8.3 Deliverables	0	0	0
8.3.1 Milestone	0	0	0
8.3.1.1 30% Report and Presentation	4	7	0
8.3.1.2 60% Report and Presentation	7	17	2
8.3.1.3 90% Report and Presentation	10	20	8
8.3.1.4 Final Presentation	9	11	6
8.3.1.4 Final Report	10	12	5
8.3.2 Meeting Memo Binder	4	18	0
8.3.3 Website	0	12	0
Total	**461.5**		

Schedule – Proposed vs Actual

ID	Task Name
1	Project Start
2	**Task 1.0 Research**
3	1.1 Regulations Research
4	1.2 Operations Research
5	**Task 2.0 Work Plan**
6	2.1 Sampling and Analysis Plan (SAP)
7	2.2 Health and Safety Plan (HASP)
8	**Task 3.0 Sampling**
9	**Task 4.0 Testing and Analysis**
10	**Task 5.0 Operations Analysis**
11	**Task 6.0 Economic Analysis**
12	**Task 7.0 Impacts**
13	**Task 8.0 Project Management**
14	8.1 Meetings
15	8.2 Team Management
16	8.3 Deliverables
17	8.3.1 Milestones
18	8.3.1.1 30% Report and Presentation
19	8.3.1.2 60% Report and Presentation
20	8.3.1.3 90% Report and Presentation
21	8.3.1.4.1 Final Presentation
22	8.3.1.4.2 Final Report
23	8.3.2 Meeting Memo Binder
24	8.3.3 Website

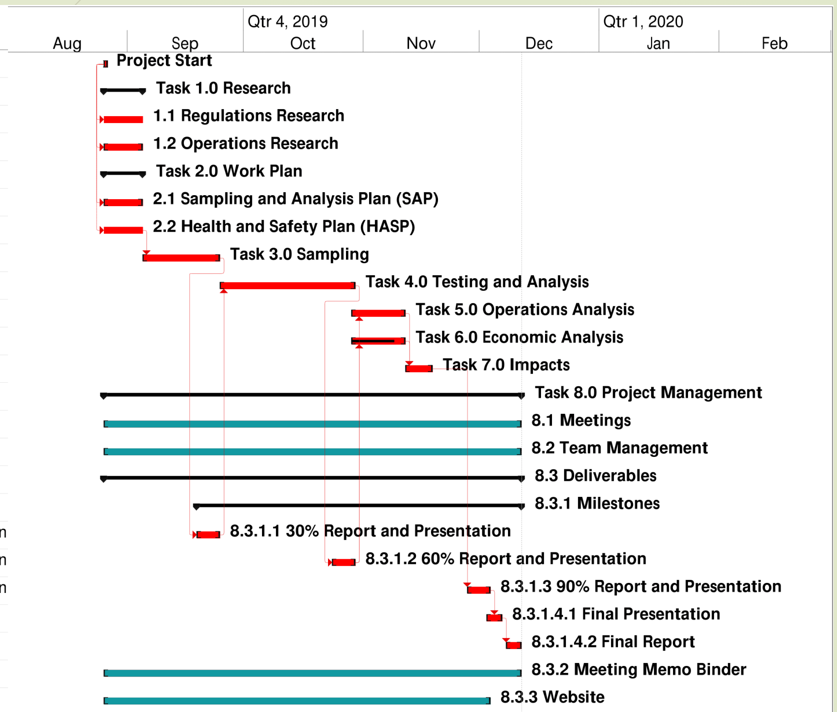


Figure 22: Proposed Schedule

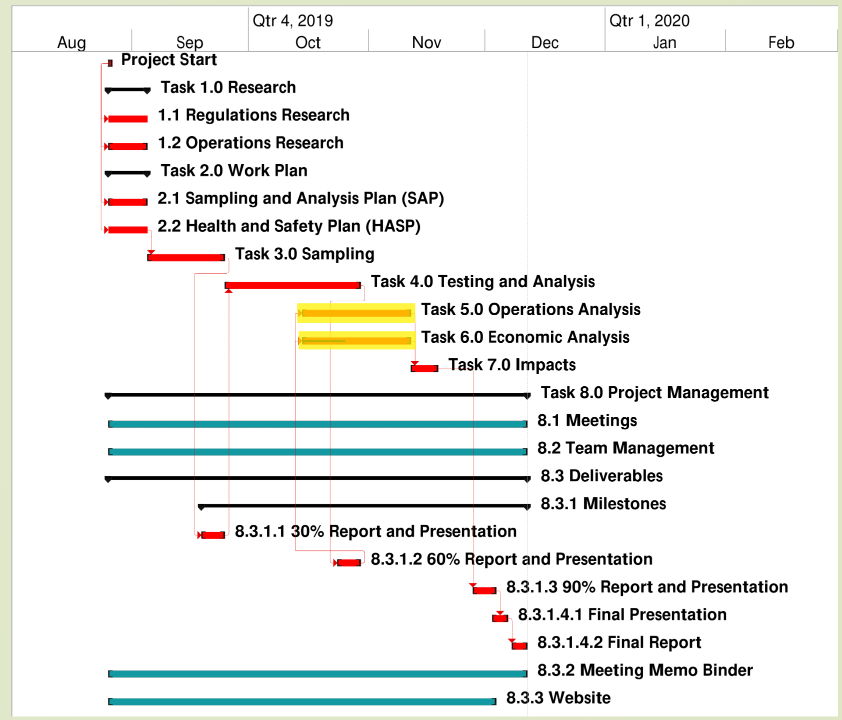


Figure 23: Actual Schedule

Budget – Proposed vs Actual

Table 13: Proposed Cost of Engineering Services

Proposed Cost of Engineering Services				
1.0 Personnel				
Classification	**Hours**	**Rate, $/hr**	**Cost $**	
SENG	123	200	24600	
ENG	241	74	17834	
LAB	224	63	14112	
Total Personnel	588	N/A	56546	
2.0 Supplies				
Item	**Cost/unit $**	**Unit**	**Quantity**	**Cost $**
NAU Lab Rental	100	120	1	12000
E.coli Broth Glass Ampules, pk/20	56	1	20	56
m-ColiBlue24 Broth, Plastic Ampules, PK/50	130	1	50	130
Total Organic Carbon (TOC) Reagent Set, HR	489	1	1	489
Nitrogen-Ammonia Standard Solution, 50 mg/L as NH3-N, pk/20 - 2 mL PourRite™ Ampules	54	1	20	54
NitriVer® 3 Nitrite Reagent Powder PIllows, 10 mL, pk/100	43	1	100	43
Nitrate TNTplus Vial Test, LR (0.2-13.5 mg/L NO3-N)	47	1	1	47
Phosphorus (Reactive and Total) TNTplus Vial Test, LR (0.15 to 4.50 mg/L PO4)	59	1	1	59
Potassium Reagent Set	210	1	1	210
Salmonella EPA Test Broth pk/15	108	1	15	108
Total Supplies	**$13,196**			
Total	**$69,742**			

Table 14: Actual Cost of Engineering Services

Actual Cost of Engineering Services				
1.0 Personnel				
Classification	**Hours**	**Rate, $/hr**	**Cost $**	
SENG	81	200	16200	
ENG	228.5	74	16909	
LAB	152	63	9576	
Total Personnel	461.5	N/A	42685	
2.0 Supplies				
Item	**Cost/unit $**	**Unit**	**Quantity**	**Cost $**
NAU Lab Rental	100	120	1	12000
Buffered Peptone Water	89.9	1	1	90
Lamp, Ultraviolet, Portable	78.69	1	1	79
EC/MUG without Durham Tubes, Package of 15	33.2	1	1	33
Lauryl Tryptose Brother MPN Tubes, Concentrated, pk/15	32.75	1	1	33
Ion Selective Electrode for Ammonia	884	1	1	884
Total Supplies	**$13,119**			
Total	**$55,804**			

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Questions?