Phase II Site Assessment

Sampling Station & Mobile Office

Design Report

for Experts-Conseils CEP

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Executive Summary

Experts-Conseils CEP inc. can improve upon their process of collecting soil samples for Phase II Site Assessment with the purchase of a mobile office and sampling station. This report outlines the specifications of these novel designs.

Electricity, sample refrigeration, ventilation, and equipment storage space is provided within a vehicle that is legal to operate with a Quebec Class 5 driver's license. The use of a mobile office optimizes worker time by reducing the amount of packing and unpacking vehicles for site assessment. Site Assessment can proceed regardless of weather conditions within the heated workspace.

The portable workstation provides a uniform work platform that could be easily transported and set up on site, allowing workers to quickly collect environmental samples and clean equipment.

After prototyping, testing, assessment of failure modes and safety, and optimizing features of the mobile office and sampling station, these designs were underwent economic analysis to justify Experts-Conseils CEP inc.'s investment.

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Introduction

Phase II Site Assessment

Phase II site assessment involves determining and documenting the extent of potential contamination. This process is used to determine human and environmental health risk due to pollutant concentrations. Site assessment is a necessary precursor to environmental remediation, aiding environmental engineers in deciding if a site must undergo remediation and determining which technology will be utilized and how it will implemented. Site conditions are inherently varied, with a wide range of potential contaminants to be sampled and vast differences in the scale of assessment between residential, commercial, and industrial properties.

Client

Alexandre Cournoyer is a junior engineer at Experts-Conseils CEP who often works on-site to undertake phase II site assessment. His occupational duties heavily involve fieldwork, and as a result he has noticed inefficiencies in the repetitive sample-gathering process. Specific issues he has cited with the process includes the setup of field equipment and the time required for the entire process. Saving time on site assessment is beneficial for both the company and its customers.

Needs Analysis

Field assessors load their personal cars with all the necessary material for site assessment and drive to the site. Not all sites are tested for every contaminant and the scale of the assessment varies from site to site. As a result, employees must thoughtfully pack their equipment and risk forgetting necessary materials. Noting the inefficiency that can arise from human error in loading a vehicle with necessary equipment, a design that can be used in small-scale residential sites or large-scale industrial sites, while incorporating all the equipment that could be used in testing for pollutants is preferred.

Once on site, employees unpack their cars mindfully laying out equipment necessary for analysis. Site assessment is generally completed in groups of at least two people but can be performed alone. Employees collect environmental samples, and clean their equipment after it has touched anything that could be potentially contaminated. They document their actions, then repack their equipment to bring it to the next sampling location in the field. This process may be repeated numerous times over the course of site assessment when employees are working at a large site with extensive potential for contamination, or few times for privately owned, residential property.

Field data logging is currently handwritten on paper. After site assessment, employees transfer this data to a digital platform, and the files are sent throughout the company while the hard copies are stored. Incorporating digital data logging in the field could, from a company standpoint, improve the efficiency of the entire process.

Experts-Conseils CEP could benefit from improved sample storage capabilities. Since microbial activity can skew pollutant concentration results, samples must be refrigerated until they are processed at the laboratory (EPA, 2009). Current procedure asks employees to pack coolers with ice before driving to the site. Employees estimate the space requirements for their samples and bring coolers accordingly.

Sampling equipment must be cleaned between samples to ensure there is no cross contamination. The current process uses acetone and hexane to wash hand shovels and other tools. These chemicals can be unsafe if not transported and used properly. Employees use squeeze bottles to spray their equipment and 19 L buckets to collect the chemicals.

Vehicle cleaning after site assessment is another time consuming process. Storing equipment in the employee's personal vehicle comes with the issue of dirt from the site depositing in the employee's car. Employees must clean their vehicles after site assessment. Due to these considerations, the company is open to the idea of purchasing a vehicle specifically for site assessment.

Alexandre Cournoyer also noted his company's interest in an all-weather solution, since site assessment can be a lengthy process and must be completed even in unfavorable conditions. As some sites require vast amounts of samples, the ability to work after sundown will save the company time on transportation to the site. Similarly, employees must decide whether or not to pause site assessment when rain occurs.

Design Objective

To develop a system which will improve employee comfort and decrease time spent on sample preparations during Phase II site assessment, while maintaining sample integrity.

Considerations and Constraints

The budget and efficiency of a proposed site assessment vehicle must justify the company's investment. The proposed designs must improve the working condition of employee performing phase II site assessment, so considerations for worker comfort, including ease of mobility within the vehicle, are paramount to the design process.

An all-weather solution is required, since environmental sampling in Quebec may be carried out in uncomfortably warm or cold weather, and in rain or shine. Electricity should be provided to extend sampling time after the sun sets, and could aid in other aspects of the design, such as the ability for sample refrigeration, and air conditioning.

The company can save time by investing in a fully stocked mobile assessment vehicle. A truck containing all potentially necessary equipment will save time, instead of having to thoughtfully pack and unpack their vehicles daily and potentially deal with equipment shortages. Employees will still be responsible for processing environmental samples, reloading cleaning chemicals and materials, disposing of waste, and on the occasion that equipment is damaged, replacing said equipment. The vehicle, however must not require an upgraded license, as the company views this as an inconvenience.

Once on site, the improvement in sample collecting, employee comfort, and simplified setup are the main considerations in designing and optimizing a portable sampling station. Workers must be able to carry the system, therefore weight is a limiting factor. One or two workers should be able to work on-site, so the entire system must be able to be utilized by two people. The station must be able to accommodate a soil core that is 0.1016 m in diameter and 1.2192 m in length. Chemicals that are used to clean the work surface and other site tools cannot be dumped on-site and must be collected and disposed of responsibly.

Mobile Office

Analysis and Specifications

To address the needs of Experts-Conseils CEP a mobile office was designed, prototyped, tested, and optimized.

Vehicle Choice

For the vehicle to be able to be driven with a standard Quebec Class 5 license, the total weight of the vehicle must be under 4500 kg (Société de l'assurance automobile du Québec, 2016). To achieve this weight limit, the smallest vehicle with maximum storage space was chosen. The vehicle chosen is the 2016 GMC Savana 3500 cut-away with a 3.53m (139") wheelbase (wb). This vehicle has a maximum weight limit of 4490kg, resulting in a maximum allowable body and payload weight of 3314 kg (Light commercial vehicle body application guide, n.d.). The maximum body length that can be fitted onto this vehicle is 3.66m (12 ft) (Light commercial vehicle body application guide, n.d.).

Figure 1: 2015 GMC Savana cut-away 3.53m wb with 3.66m body (Paramount trucks, n.d.)

Body Dimensions and Materials

As the largest allowable body length for the chosen vehicle is 3.66m (12ft), it is our designed body length for the mobile office. Although the most common body length for similar vehicle type is 3.048m (10 ft), a body length of 3.66m was chosen as it has a larger storage capacity. The width and height of the body are the standard sizes of 2.44m (96”) and 2.13m (84”) respectively.

The main considerations for the body materials are the durability, ability to withstand pressure washing, and resiliency to weather. The body material must be resistant to acetone and hexane as they will be and used inside the vehicle during sampling, and may also be spilled or splashed inside the vehicle. The client has specified that their cleaning method of choice is pressure washing, and has requested that the vehicle be compatible with pressure washing.

There are a few available choices for the material of the body to be considered. The more common materials for similar vehicles are aluminum and plywood, and fiberglass reinforced plywood is used occasionally. Fiberglass reinforced plywood is the body material of choice as it is the most shock absorbent material, is corrosion resistant, waterproof, and has good insulation properties (Dry freight: FRP, n.d.). It is a common material used for boats as well as laboratory wall panels, making it suitable for a mobile office application (Fiberglass reinforced plastics, n.d.). The panels are 0.019m (¾ in.) thick with a seamless finish, allowing for a larger interior capacity compared to its aluminium and plywood counterparts (Dry freight: FRP, n.d.). The calculated total internal capacity of the designed vehicle body is 19.25m^3.

Figure 2: Fiberglass reinforced plywood panel for truck bodies (Dry freight: FRP, n.d.)

The total volume of equipment to be transported on site is 1.5126 m^3. A complete list of the equipment volumes is included in Appendix II. The mobile office's 19.25 m^3 body will be able to carry all potentially useful equipment to the field.

Electric Load

The calculated maximum electrical load of the mobile office in the field is calculated to be 472 W. This calculation includes the maximum power requirement of all the electrical appliances within the vehicle, as well as 2 floodlights that may be used to provide visibility of the area. To meet this requirement, the mobile office utilizes a PowerBright 1500W inverter, which provides power so long as the vehicle is in operation. A backup Champion 1500W Gas Generator is recommended as it exceeds the total electrical load. The recommended inverter and generator yields a safety factor of 3 for the mobile office operating at maximum capacity.

Table 1: Table of Electrical Appliances for Electrical Load Calculations		
Equipment	Product Name	Electrical Load (W)
Power Source		
Inverter	PowerBright 1500W Inverter	1500
Generator	Champion 1500W Gas Generator	1500
Electrical Appliances		
2 Flood Light	Lithonia D-Series Size 1 Flood	74

2 LED ceiling lights	Maxxima LED Dome Light (AX434)	18
Refrigerator	Evakool 210L Platinum Upright Fridge*Freezer	60
Computer	Macbook Pro 3.7GHz (late 2013)	205
Heating Fan	Webasto AirTop EVO 3900 Heater	55
Ventilation Fan	MaxxFan Standard 4500K	60
	Total Electrical Load	472 W

Ventilation

The ventilation calculations were performed to assure that the selected fan met the design specifications to prevent the buildup of chemical volatilization. An air change per hour unit (ACH) of 2.0 was selected to provide a comfortable breathing atmosphere within the office (Lefsrud, 2016). The selected fan provided an airflow of 1.53 x10^7 L / h, satisfying the requirement. To meet this requirement, the MaxxFan Standard 4500K was selected due to its ideal power loading, dimensions, ability to provide airflow in both directions, and variable speed settings (MaxxFan Standard 4500K).

Table 2: Ventilation requirement calculations

Volume of Truck	Desired ACH	Required Airflow	Provided Airflow	Maximum Provided ACH
192500 L	2.0	1.53 x10^6 L / h	1.53 x10^7 L / h	10

Refrigerator

The selected refrigerator for the mobile office is the Evakool 210L Platinum Upright Fridge*Freeze. It has a storage capacity of 210L, which surpasses the designed capacity of 200 storage samples, and has a relatively low power consumption of 60W. There is an unobstructed path to the refrigerator as it will be heavily utilized to store and transfer samples taken during site analysis.

Internal Workstation

A workstation that can house the designed sampling station is included in the mobile office. The workstation will provide the mobile office with a flat work surface and storage space. The workstation has a height of 0.9017m and a work surface of 0.765m x 1.50m and is designed to be constructed of spruce and oak plywood, for ease of construction and installation. It is positioned at the back, driver's-left corner of the vehicle to allow for a field worker to use the workstation without blocking the path to other equipment.

Chemical Disposal Station

The chemical disposal station is a 0.96m x 0.65m x 0.95m (LxWxH) cube with two 0.30m diameter cutouts on the surface for two chemical disposal containers to be placed inside. There is a shelf 0.30m from the top of the surface for the containers to rest on, and to create additional storage space below. One chemical disposable container is used for washing with acetone and hexane, and the other is used for disposing water. The chemical disposal containers are assumed to be standard 19L containers that are used by the client. The chemical disposal station is positioned between the workstation and the entrance of the vehicle to improve access and for ventilation and safety considerations. The containers used for chemical disposal are recommended to be color-coded in order to reduce the risk of disposal into the wrong container.

Laptop Table

A folding laptop table will be attached to the storage cabinet within the vehicle. The laptop table will have an area of 0.45m x 0.40m, positioned with a surface height of 0.75m. The folding table will allow for additional space when the table is not in use. The laptop table is placed in the middle of the body against the left wall. This is to allow for a seated worker utilizing the laptop table while having sufficient space for a second worker to move around comfortably.

Storage Cabinet

The L-shaped storage cabinets are designed to maximize storage capacity within the vehicle. It is placed at the front left corner next to the refrigerator to help balance the weight of the vehicle.

The storage cabinet is designed to be made from spruce and oak plywood as it can be easily machined to the right dimensions to maximize the storage space of the vehicle.

Chemical Safety Cabinet

An Uline Flammable Storage Cabinet H-2569M is chosen as the chemical safety cabinet for the storage of acetone and hexane within the mobile office. It has a storage capacity of 15 L, which is the maximum volume that will be carried out to the field. This is a safety consideration that was taken in order to prevent the overcapacity of chemicals within the vehicle. Thus when the vehicle is properly packed, a full cabinet will mean that the maximum chemical load of the vehicle has been reached.

Lighting

The light source chosen for the inside of the vehicle is the Maxxima LED Dome Light (AX434), of which two will be used. These lights have an illumination of 900 lumens each, providing an average illumination of 231 lux (1800 lumens / 7.76m^2). While this value is approximately half of the recommended value for laboratories (The Engineering Toolbox, n.d.), the small volume of the mobile office as well as the white FRP walls would increase the amount of light reflected, causing the illumination from the lights to be under-estimated.

Heating

Part of the client specifications for the vehicle is to have it operational regardless of the environmental conditions. A heating source is required in order to have the vehicle operational at an environmental temperature of -30℃ To meet this requirement, the Webasto AirTop EVO 3900 Heater was chosen as it provided a heating fan to circulate the heat, and raise the environmental temperature to above freezing. Thus it allows for the vehicle to be operational in the historically harsh weather conditions.

Codes and Bylaws

Workers of CEP must have a Class 5 license, as they must drive a personal vehicle to sample a given site. The mobile office must remain within the Class 5 vehicle license in order to prevent the requirement of a special permit or having to obtain another license. As stated by the SAAQ

(Société de l'Assurance Automobile du Québec), a Class 5 license is defined for “an automobile, that is, a vehicle having 2 axles and a net weight of less than 4,500 kg” (SAAQ, 2016). As such, the vehicle must weigh less than 4,500 kg to keep the vehicle under a Class 5 classification. The calculated weight load of the vehicle and its fully-stocked equipment is calculated to be 3,282 kg. An itemized list of the vehicle, office body, and equipment is included in Appendix I. CEP’s mobile office would not require workers to upgrade their driver’s license in order to operate the vehicle.

Since a generator is to be provided inside the vehicle, gasoline external to the main tank must be transported. In Canada, the maximum amount of gasoline that is able to be transported by a noncommercial vehicle is 150 L (Transport Canada, 2016). However the total weight of the container and gasoline may not exceed 30 kg (Transport Canada, 2016). In this case, a jerry can with 25 L of gasoline will weigh less than 30 kg (Transport Canada, 2016). This allows for 6 jerry cans of 25 L to be transported and without exceeding the 150 L limit (Transport Canada, 2016).

Both acetone and hexane are used by the workers to clean the equipment before and after each sample. Both chemicals are classified as a Class 3 flammable liquid, and in the packing group 2 (Transport Canada, 2015). Chemicals of this packing group are classified as extremely flammable liquids with a flash point less than 23^{o}C (Transport Canada, 2015). The maximum quantity per container for both is 1L (Transport Canada, 2015), with an overall maximum total amount of 5L (Transport Canada, 2015).

Bill of Materials

The bill of materials (Table 3) for the mobile office results in a total cost of $65,465.87. It is an estimation of the total cost of the mobile office, including the cost of purchasing a vehicle, the box for the office, and the fixtures within the vehicle. An additional 15% is factored into the total cost to account for engineering and design errors, assembly cost, and price fluctuations.

Table 3: Bill of Materials for Mobile Office					
No	Equipment	Description	Unit Cost	Units	Total Cost
1	Vehicle	GMC Savana 3500 139"wb	$29,400.00	1	$29,400.00
2	Body	Transit FRP Cube 12'x96"x84"	$10,000.00	1	$10,000.00
3	Inverter	PowerBright 1500W Inverter	$199.99	1	$199.99
4	Generator	Champion 1500W Gas Generator	$399.99	1	$399.99
5	Floodlight	Lithonia D-Series Size 1 Flood	$530.00	2	$1,060.00
6	Interior lighting	Maxxima LED Dome Light (AX434)	$133.90	2	$267.80
7	Fridge	Evakool 210L Platinum Upright Fridge*Freezer	$2,199.00	1	$2,199.00
8	Heater	Webasto AirTop EVO 3900 Heater	$3,330.00	1	$3,330.00
9	Vent	MaxxFan Standard 4500K	$367.00	1	$367.00
10	Laptop Table	RiversEdge FS1714 Folding Workstation	$75.67	1	$75.67
11	Interior Workstation	Tabco CB-SS-244M 24"x48" Work Table	$1,686.15	1	$1,686.15
12	Chemical Safety Cabinet	Uline Flammable Storage Cabinet H-2569M	$516.00	1	$516.00
13	Cleaning Station	Reno Standard Spruce Plywood 4'x8'x1/2"	$22.25	1	$22.25
14		Reno Oak Plywood: 4'x8'x3/4"	$69.99	2	$139.98
15	Storage Cabinet	Reno Standard Spruce Plywood 4'x8'x1/2"	$22.25	6	$133.50
16		Reno Oak Plywood: 4'x8'x3/4"	$69.99	7	$489.93
17	Cabinet Knobs	Richelieu Cabinet Knobs: Model #DP3295195	$17.99	1	$17.99
				Subtotal	$49,501.60
				Tax	$7,425.24
				Total	$56,926.84
				Total + 15%	$65,465.87

Prototyping and Testing

The prototype for the truck body was created using AutoCAD. The locations and layout of the equipment were positioned accounting for a list of priorities. The priority list is as follows:

1. Frequency of use: equipment that are utilized frequently are positioned at easily accessible locations and close to the entrance. This is done to improve the efficiency of the worker.
2. Safety considerations: preventive measures are taken by properly positioning high-risk items in suitable locations to reduce the risk of incidents.
3. Ergonomics: ensure comfortable and functional design layout of the mobile office. An ergonomic layout will improve worker well-being and morale.
4. Weight considerations: equipment arranged to optimize weight distribution of vehicle when stationary and during transportation.

Door type and location

The options for the location and type of door for the body allowed for a more optimized vehicle layout. The location of the door either at the back or side of the body would change the entry point into the workspace. The options for the type of door between a single door, double door, roll-up door, or sliding door. The vehicle layouts for the side and backdoor design were prototyped using AutoCAD to compare the differences between them.

The back-door layout utilizes one side wall and the front wall of the body. This creates a rectangle workspace of approximately 4.00 m^2. The rectangular workspace creates a suitable workspace for one operator with the equipment laid out in an ergonomic and systematic format. However, workspace may not be ideal for multiple personnel as the same path must be used to access the cabinets and equipment, and may cause interruptions.

← Back of vehicle Front of vehicle→

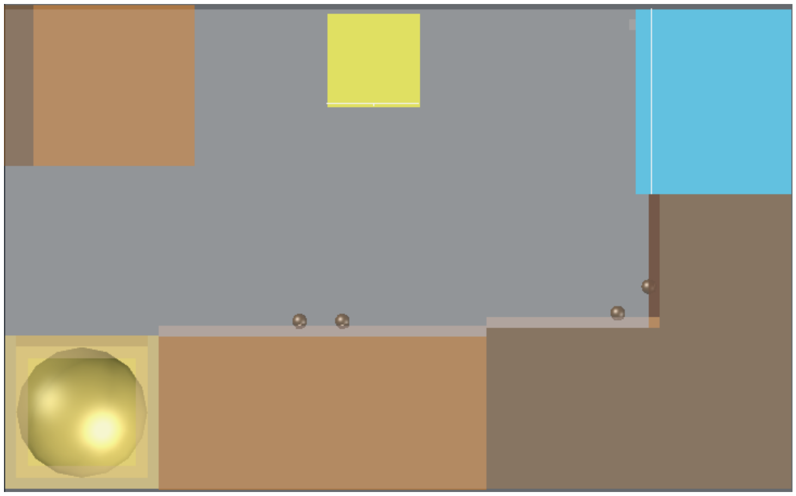

Figure 3: Top view of back-door layout mobile office CAD

The side-door layout utilizes both side wall and the front wall of the body. This creates an L-shaped workspace of approximately 4.64 m^2. The side door is positioned in the middle of the body on the driver's right side of the vehicle. This was done to improve accessibility in entering and exiting the body. This design creates an ergonomic and systematic layout optimized for multiple workers. One worker can be utilizing the workstation and washing station located at the back of the vehicle without blocking the entrance and pathways to the other equipment and storage areas of the mobile office. This allows for two workers to be working efficiently without interrupting one another.

← Back of vehicle Front of vehicle→

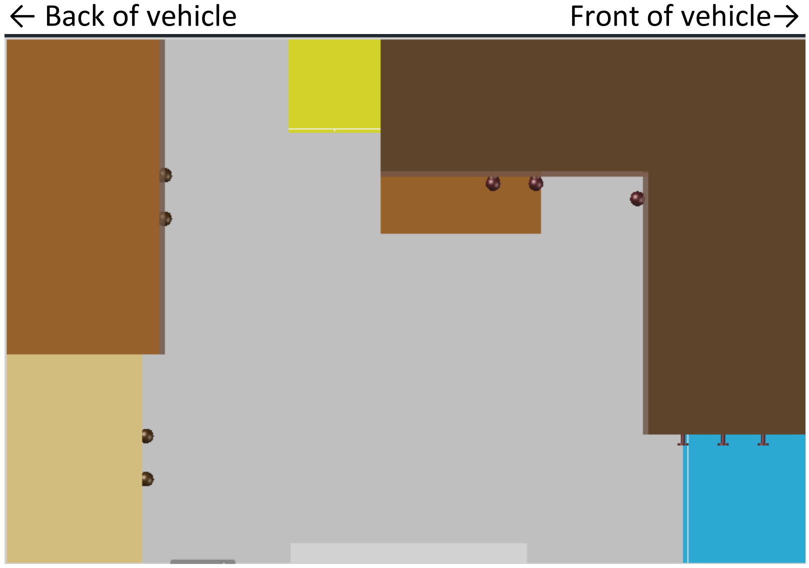

Figure 4: Top view of side-door layout mobile office CAD

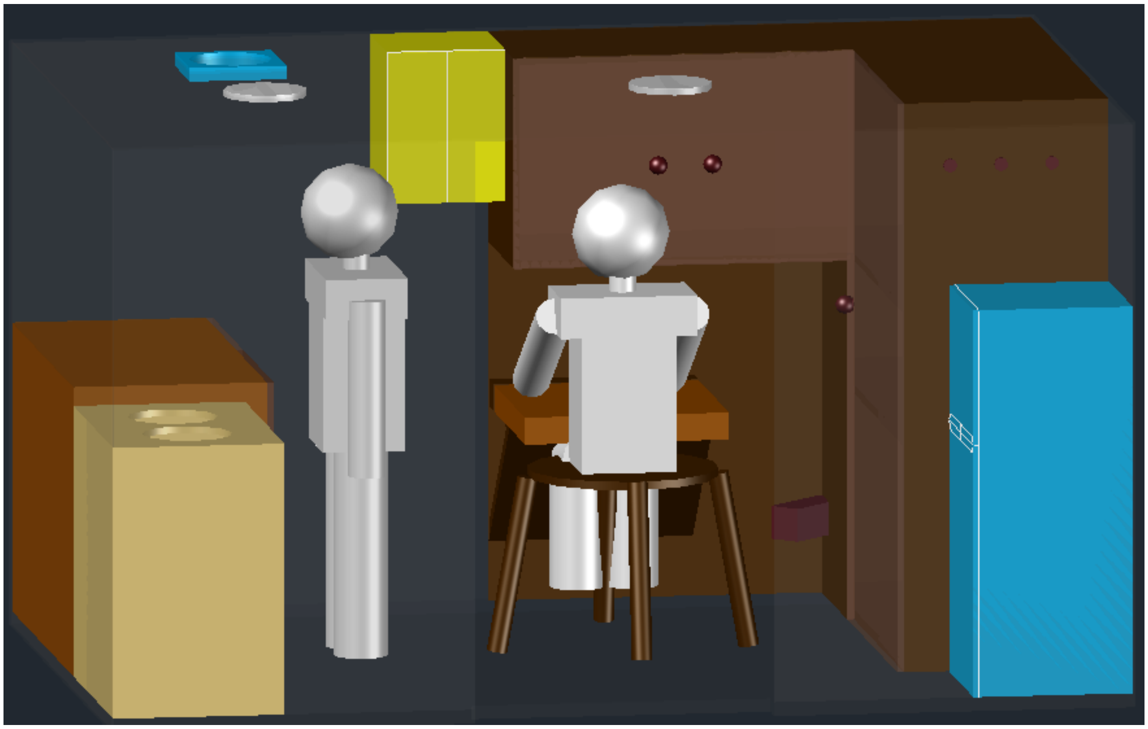

Figure 5: Prototyped CAD of the internal layout of the mobile office

Optimization

Refrigerator

The capacity of the chosen refrigerator is still large when compared to the maximum number of samples that a worker may examine. As such, a refrigerator of smaller volume would still provide enough capacity for samples, while allowing for expansion of the equipment cabinet.

Internal Workstation

The internal workstation is currently designed to be constructed of wood. An alternative would be to use a food-grade stainless steel table, such as the Advance Tabco CB-SS-244M 24" x 48" 14 Gauge Work Table, which would provide better resistance from cleaning and from chemical use. This will provide a longer lasting workstation that does not need to be replaced as often as a wooden table. However, the stainless steel table would be more costly.

Laptop Table

An alternative to the wooden folding laptop table would be purchasing a folding stainless steel table. It would be more durable. The table can be cleaned much more easily and the potential for damage and replacement is much lower. The RiversEdge model FS1714 wall-mounted stainless steel folding laptop workstation is recommended.

Heating

Currently, a small heat generator is included inside the vehicle and is located at the bottom corner of the L-shaped cabinet. Although sufficient, the process is rather slow and as such, additional heating fans within the vehicle may be preferred in order to provide additional heat generation. However, when taking into account the environment outside of the vehicle, no form of external heating is available to the workers. Due to large external environment, a convective heater is ineffective at providing heat for the workers, thus a portable radiant heater, such as the EnerG+ HEA-215119CVR Free Standing Infrared Heater, is required.

Ventilation

For ventilation, one fan exists as both the intake and exhaust, and is located at ceiling level. During warmer periods, the current setup is ideal seeing as heat rises and the exhaust would be venting out the hot air as it intakes cool air. This however poses an issue during colder periods where heat must be generated in order to work. In this case, hot air that is generated inside the vehicle would be exhausted.

The cleaning station is also affected by ventilation, as fumes are produced from the chemicals and should be exhausted as quickly as possible. The optimization for ventilation would consists of having a small fume hood above the cleaning station, or by placing an exhaust fan above it on either wall. This would reduce the amount of heat exhausted, thus increasing the overall efficiency of the system, while also exhausting the fumes produced by the chemicals.

Sampling Station

Analysis and Specification

It was determined that a workstation with ample writing surfaces designed for ergonomic cleaning would provide the client with an easy to use and cost effective means for collecting environmental samples during phase II site assessment given the design constraints. This design is seen in Figure 6 located below.

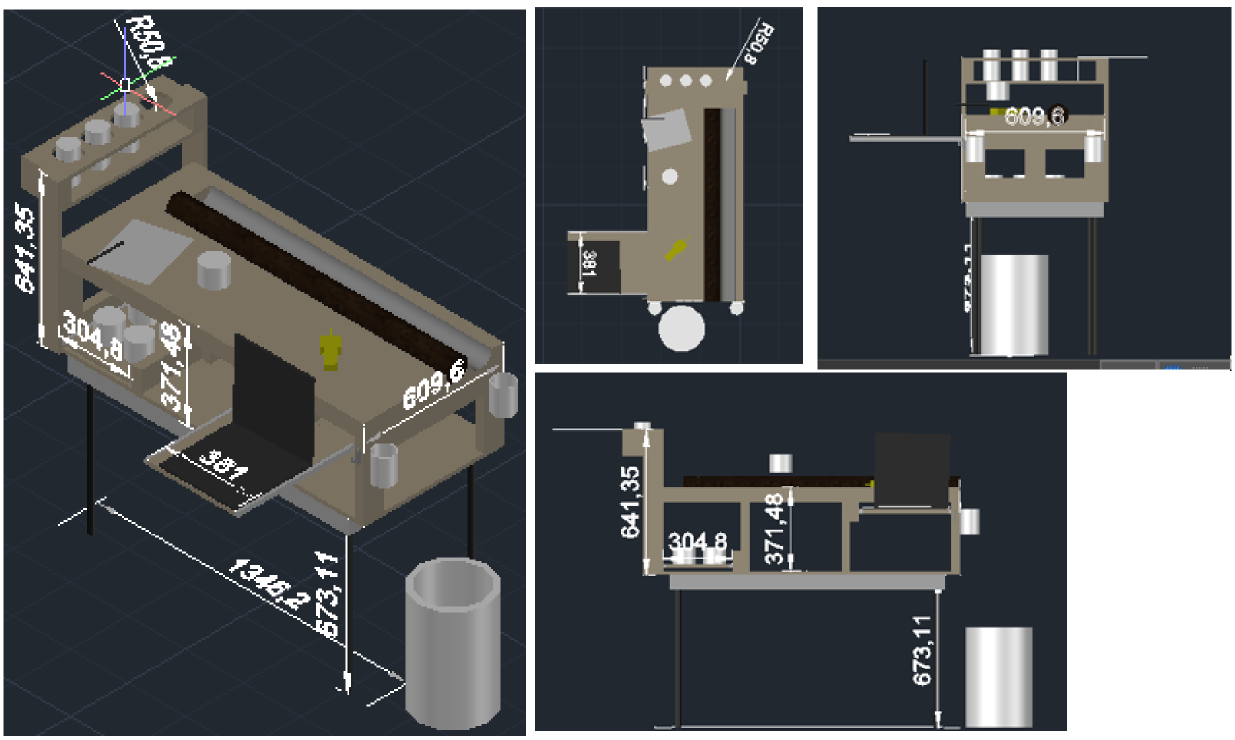

Figure 6. Sampling Station, dimensions are in mm

The height of the sample station is designed for ideal worker comfort. Full soil cores can weigh over 12 kg, so workstation height should allow a worker to undergo lifting without unnecessary strain. Average male elbow height is 1.078 m off the ground when standing (Ergotron Ergonomics Data 2014). The top of the sampling station is 0.1143 m lower than the average elbow height, 0.9652 m off the ground for comfortable working conditions.

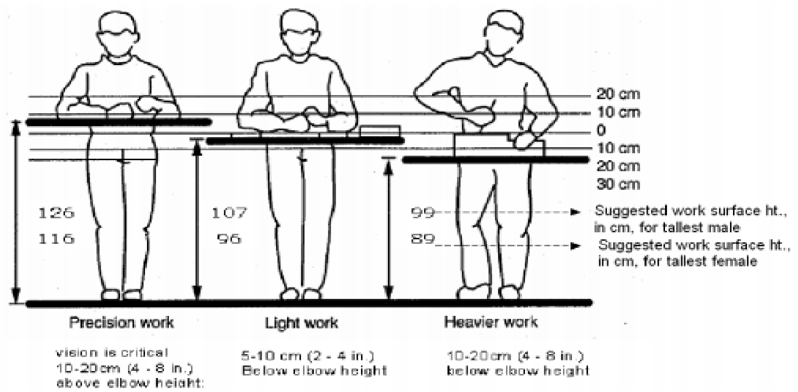

Figure 7: Optimal standing workstation heights for employee comfort (Ergonomic Systems Associates, 2009)

The Sampling Stations' 0.6096m width was designed to accommodate comfortable working space. The troughs running along the length of the table are used to hold soil cores while the environmental samples are collected. It was determined that optimal placement of the troughs were within arm's reach of the site assessor, with a flat surface between the assessor and the troughs to allow for sample containers, hand shovels, and sensors to be placed down while working. Two troughs were installed to allow for storage of both halves of the core casing. The troughs are large enough to contain the 0.1016 m diameter, 1.2192 m long soil cores.

Since site documentation is handwritten, ample writing surfaces are an essential component of the sampling table. Along the length of the table, a flat surface allows the assessor to use this area near the soil cores for any writing necessary on site, including official documentation of sensor data, site maps to verify sampling location, or site notes. There is also pull-out writing surfaces for additional workspace.

Additionally, although paper documentation is legal proof of site data, computer notes are often used within the company, so any information written on site should be copied to digital information, to be used by employees back in the office. Cournoyer suggested the company would eventually make a switch to using iPads or laptops in the field to log data in addition to paper, in order to make collaborative working more convenient. The 0.381 m wide pull-out surface, located to the right of the intended employee position, provides the flexibility to make digital notes while working in the field.

The sampling station allows for storage underneath the top working surface. Sampling containers are used to collect representative soil samples for laboratory analysis. The containers are stored under the table, in the box they are packed in. Employees reach into the box, write down the drill location and depth of the sample container, fill the container with soil from the core, and close the container. Our workstation has drawer space for the completed samples to allow workers to quickly move on to cleaning their equipment in preparation of another soil core. Glove boxes and garbage are also located side by side in the storage space under the table, allowing quick turnaround from one sample to another. There is also room in the workstation to house the VOC sensor's case. A hook is attached at the right-hand end of the workstation to hang a cleaning brush used to wipe excess soil out of the cores.

Cleaning fluids are placed above the end of the work station on the left hand side within arm's reach of the site assessor. The height of the shelf was designed to be shoulder height for an average male, a comfortable height to reach and pour fluid as seen in Figure 8. Liquid waste is caught in receptacles at the right hand end of the workstation. These receptacles are designed to contain the volume of fluid in the cleaning liquid's wash bottle, so the site assessor can transfer the waste to its proper container in the mobile office and at the same time, bring out more bottles of cleaning liquid.

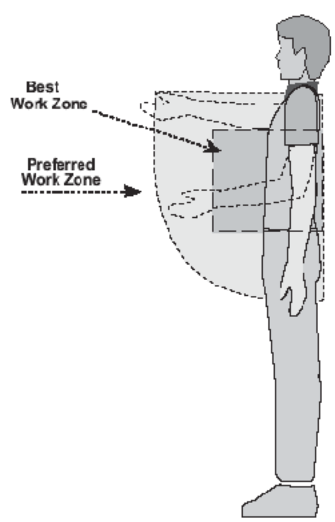

Figure 8: Standing Reach Zones (OSHA 2004)

The workstation is designed to be constructed out of polypropylene, a physically resilient plastic that does not degrade under contact from acetone, hexane, or acids (Polypropylene Chemical Resistance Guide, 2012).

Bill of Materials

A bill of materials for the sampling station is included in Table 4. The total cost of manufacturing the sampling station is $773.94, including the cost of fabrication. Manufacturing costs can be conservatively estimated at 10 times the cost of the material (King, 2014). Polypropylene pieces can be welded together without compromising the structural integrity of the piece (Wegener Welding, 2009). The sampling station's fabrication cost uses the median wage of a welder in Laval, Quebec, the company's headquarters (Job Bank, 2016).

Table 4. Sampling Station Bill of Materials

No.	Item	Dimensions	Description	Price per Unit	Amount	Line Price ($)
1	Polypropylene (PP)	0.079577 m^3	900 kg/m^3	1.23/kg	1	41.75
2	Manufacturing Polypropylene Pieces		10x Material Cost			417.47
3	Folding Table	2"x4"	Base Table	65.99	1	65.99
4	Reinforced Drawer Slides	20"	Pull out Writing Surface and Sample Storage	24.73	2	49.46
5	Waste Receptacles	2.5	Soap & Water and Hazardous Waste	8.99	2	17.98
6	Fabrication		Welder Wages	20.16	4	80.64
				Subtotal		673.29
				Tax		100.66
				Safety Factor (15%)		100.99
				Total		$773.94

Prototyping

The workstation went through various design compromises between the original CAD and what materials were on hand. One of the first major deviations was the addition of a folding table to act as the base platform for our workstation. The workstation can be lifted and housed in the mobile office workstation, while the folding table is stored separately. As well, this was seen as a much easier design to build and test, since it removed an element containing moving parts from the overall machining process.

The second major difference the prototype underwent was the inclusion of guides on the work surface in place of troughs. While the original design called for elevated troughs that were attached to the workstation with hinges to facilitate cleaning, the prototype was built with wooden guides to hold core sample cases instead.

There were other changes that the workstation underwent based on recommendations from the client for an optimal prototype. The cleaning station was changed to hold the different chemicals and cleaning fluids in an upright position, completely eliminating a previously designed the hose cleaning system. This was done in response to the uncertainty of the convenience of loading enough chemicals to make a gravity fed hose cleaning system worthwhile for smaller sampling sites. As well as this, the attached waste receptacle at the end of the table was completely removed. Since the sample core cases could be freely manipulated, there was no need to build a waste receptacle specifically to catch waste at the end of the troughs. Finally, wood was chosen as the working material for the prototype since it was durable, easy to machine, and cheap. However, since it weighs more than plastic, the overall dimensions of the table were reduced to keep the prototype light enough to be carried by one person.

Figure 9. Prototype construction

Testing

To test the sampling station, a simulated phase II site assessment using the prototype was completed by, Alexandre Cournoyer indoors at McGill's Technical Services Building in Sainte Anne de Bellevue Quebec.

The sampling station was lifted, moved, and set up in a way that imitated the process of setting up the apparatus at the sampling location. The process of gathering samples from a soil core was replicated, with Alexandre Cournoyer mimicking changing gloves, opening the core casings, using a hand shovel to insert portions of the core into sample containers, labeling the sample container, taking VOC sensor measurements, writing field notes, disposing of unused soil, washing he casings and hand shovel with soap and water, cleaning the casings and hand shovel with acetone and hexane, properly disposing of waste liquid, and changing gloves again.

The weight of the workstation is cumbersome, but can be transported by one employee. An improvement on the mobility of this apparatus would be construction with a lighter material.

The workstation proved to be sturdy, easily holding weight. Leaning on the apparatus between samples, the tabletop remained structurally stable.

Figure 9 shows a model of a simplified polypropylene workstation loaded with 2500N of force, well above the expected load. The displacement caused by the load does not warrant plastic failure in the propylene with a Young's Modulus of 0.896 GPa (Materials Data Book 2003).

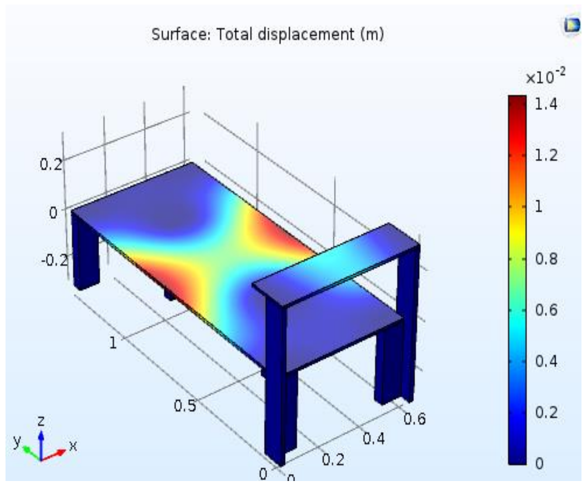

Figure 9: Displacement of Simplified Plastic Workstation with 2500 N Total Load

Simulated trough location showed although raised troughs seems to minimize soil spills onto the counter of the table, the lip was awkward for our client. Hand shovels and sample containers had to be lifted above the trough and lowered into the trough. Preference was given to a trough sunken into the level of the working surface.

To clean the troughs, employees use three separate receptacles, one for the earth that was previously contained in soil cores, one for soap and water, and the last for acetone and hexane. The two waste collection receptacles attached to the end of the sample station could be useful for the liquid waste, although Cournoyer did not prefer using a soil waste container that was attached to the workstation.

The prototype's drawer slides are a point of potential failure. The 0.508 m sliders have relatively low overhang, and risk falling out during transportation. They can be re-slid into their grooves, but if their fall results in them denting, this option might be unavailable.

Optimization

Although wood proved to be an effective media for machining during prototyping, polypropylene is an overall better choice for the workstation material. This compound is highly weather-proof and does not need epoxy coating to prevent rot like the OSB and birch prototype. Its relative low cost of $1.23/kg (Plasticker, 2016) and chemical resistance to acetone, hexane, and weak acids (Polypropylene Chemical Resistance Guide, 2012) make this plastic a suitable workstation material.

The cleaning shelf is detachable from the workstation in the optimized design. Grooves for simple male-female connection allow the site assessor to carry the cleaning shelf separately, and guide the male cleaning shelf supports into the workstation's female grooves, in the field. Spent liquid is recovered in receptacles on platforms at the right hand side of the workstation. This minimizes the time workers must bend to pour material from troughs into containers on the ground, improving the ergonomics of the set up.

Sunken troughs optimize ease of sample collection, since workers will be able to access the soil core vertically and horizontally with their hand shovel. To improve on the stability and lifetime of the drawers, reinforced drawers with a load capacity of 45 kg are incorporated into the workstation for the sample container storage and the pull-out writing surface.

Failure and Safety Modes

The failure risk analysis of the mobile office in Figure 10 showed that the main issues would arise from an electrical issue. From this analysis, the specifications of the electrical loads are looked into with more detail. As the inverter that generates the electricity has a safety factor of 3, the inverter and power generation should be sufficient to mitigate electrical issues. Furthermore, the inverter has a peak load power rate of < 3000 W (PowerBright 1500W inverter, n.d.), thus providing more cushion for electrical surges.

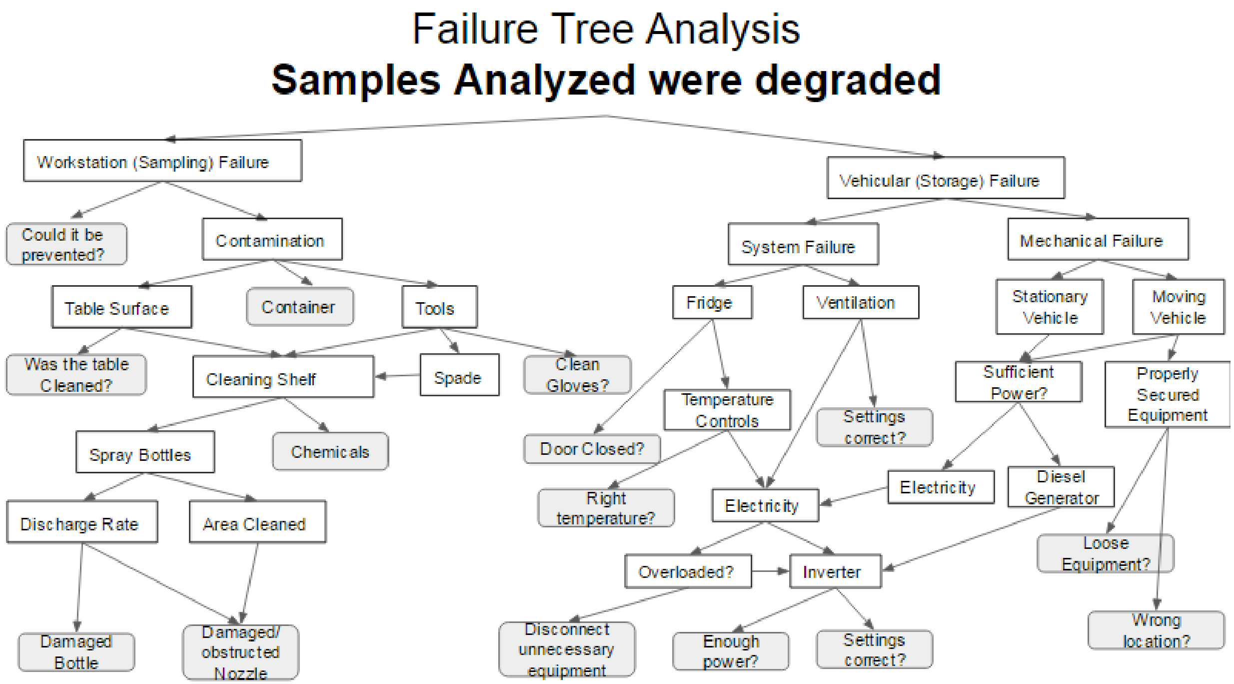

Figure 10: Failure tree analysis for mobile office if samples were degraded

As a safety precaution, there should be a fire-extinguisher located next to the door of the mobile office. This is to ensure that the fire-extinguisher is located at a central area, and can be easily utilized when necessary.

After examining the workstation prototype, the optimized AutoCAD drawing, and the COMSOL models for the table, several potential failure points were identified. Firstly, the drawers in the prototype were identified as problematic, since the quality of the railings are low quality. It has been recommended that workers handle the draws with care on the field, as well as making sure not to overload them with too much weight. The optimized sampling station uses reinforced drawers with an advertised maximum load capacity of 45 kg (Home Depot, 2016).

Secondly, in both the optimized CAD and prototype of the table, the cleaning station stands as an appendage to the table. While all care has been made to secure it to table, damages could occur during transportation and storage of table. While the optimized table has a removable cleaning station, care must also be taken to make sure that it is stored properly and not neglected, lest damages occur and it becomes unusable. Finally, the last area of concern is the wear and tear on the working surface of the table. Through use and cleaning, it may become rough and uneven, making it unpractical for using as a writing surface. Care should be taken to constantly clean the surface of the table to prevent dirt from accumulating on the table, as well as drying the surface after is has been cleaned.

Economic Analysis

During testing with CEP employee, Alexandre Cournoyer, it was estimated that by using the designed workstation, site assessors could save 30 seconds to one minute per sample, compared to CEP's current setup. Taking into consideration the median wage of an environmental engineer in Laval, Quebec ($32.69/hr) a payback period for the sampling station was calculated (Job Bank, 2013). In a month of sampling, CEP could assess up to 10 sites, so an average month is represented as one with five small sites and three large ones. The sampling station's cost is $773.94 (Table 5). The calculated payback period for this apparatus is 8.12 months.

Table 5. Monthly Avoided Expenses with Sampling Station

Site Type	Samples	Sites Sampled Per Month	Time Saved (min/month)	Cost Savings
Small	10	5	25	$13.62
Large	100	3	150	$81.725
			Monthly Avoided Expenditure	$95.35

Design Competition

This design will be submitted for the Canadian Geotechnical Society's 2016 Undergraduate Design Competition. It will be submitted by Dr. Meguid of the Department of Civil Engineering at McGill University on our behalves.

Conclusion

In conclusion, the proposed mobile office and sampling station improve CEP Experts Conseils' process of gathering environmental samples for phase II site assessment. Throughout the development, and optimization of the design, the mobile office and sampling station have been designed to mitigating time spent on gathering samples, improve the ergonomics of job duties, and create a weather resistant workspace, while minimizing costs.

References

APGO. 2011. APGO.: Guidance for Environmental Site Assessment under Ontario Regulation. Available at: https://www.apgo.net/files/. Accessed on 8 November 2015.

Advance Tabco CB-SS-244M 24" x 48" 14 Gauge Work Table with cabinet base and mid shelf. Webstaurant Store. Available at: http://www.webstaurantstore.com/advance-tabco-cb-ss-244m-24-x-48-14-gauge-work-table-with-cabinet-base-and-mid-shelf/109CBSS244M.html. Accessed 14 April 2016.

Champion 1500W Gas Generator. Generators. Canadian tire. Available at: http://www.canadiantire.ca/en/pdp/champion-1500w-gas-generator-0550314p.html#.Vwwd5fkrLIU. Accessed 14 April 2016.

Classes of driver’s license. Driver’s license. 2016. Société de l'assurance automobile du Québec. Gouvernement du Québec, 2016. Available at: https://saaq.gouv.qc.ca/en/drivers-licences/drivers-licence-classes/. Accessed 14 April 2016.

D-Series size 1 LED flood luminaire. 2014. Lithonia lighting. Acuity brands lighting, inc. Available at: http://www.acuitybrandslighting.com/library/ll/documents/specsheets/dsxf1.pdf. Accessed on: 14 April 2016.

DC210 platinum upright fridge*freezer. Evakool. Available at: http://www.evakool.com/210-litre-platinum-upright-caravan-fridge-freezer. Accessed 13 April 2016.

Doors for box truck. Transit. Les Fourgons Transit. Available at: http://www.transit.ca/en/accessories/doors. Accessed 13 April 2016.

Dry Freight: FRP. Morgan Corporation. Morgan Corporation. Available at: http://www.morgancorp.com/dry-freight/frp/features.php. Accessed 11 April 2016.

EnerG+ HEA-215119CVR Free Standing Infrared Heater. Patio Heaters. Lowe’s. Available at: https://www.lowes.ca/patio-heaters/energ-hea-215110cvr-free-standing-infrared-heater_g2504483.html. Accessed 14 April 2016.

Environment Quality Act. 2015. Éditeur officiel du Québec. 1 October 2015. Available at: www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=/Q_2/Q2_A.htm. Accessed 10 November 2015.

EPA. 2009. Industrial Waste Resource Guidelines. EPA Victoria.: Sampling and Analysis of Waters, Wastewaters, Soils and Wastes. Available at: http://www.epa.vic.gov.au. Accessed 6

November 2015.

Ergotron Ergonomics Data. 2014. Ergonomics Data & Mounting Heights. Available at: https://www.ergotron.com/Portals/0/literature/whitePapers/english/ergonomics_arms_data.pdf Accessed 13 April 2016.

Fiberglass Reinforced Plastic. Architects and Design Community. Royal Plywood Company. Available at: http://www.royalplywood.com/Architects/AR-Fiberglass-reinforced-plastic.html. Accessed: 14 April 2016.

Guidelines for the design of Standing Workstation. 2009. Ergonomic Systems Associates. Available at: http://www.ergosystems.ca Accessed 28 Jan 2016.
Home Depot. 2016. Richelieu Full Extension Slide 20 In. Zinc. Available at: https://www.homedepot.ca/en/home/p.full-extension-slide-20-in-zinc.1000424835.html. Accessed on: 14 April 2016.

Illuminance - recommended light levels. The engineering toolbox. Available at: http://www.engineeringtoolbox.com/light-level-rooms-d_708.html. Accessed 14 April 2016.

Inventory. Paramount Trucks. D.B.Z. Holdings Ltd. Available at: https://www.paramounttrucks.com/inventory/product_info.asp?Inventory_ID=4259. Accessed 11 April 2016.

Job Bank. 2013. Government of Canada. Environmental Engineers. Available at: http://www.jobbank.gc.ca/report-eng.do?area=2359&lang=eng&noc=2131&action=final&s=1&source=8. Accessed 14 April 2016.

Job Bank. 2016. Government of Canada. Welder and Related Machine Operators. Available at: http://www.jobbank.gc.ca/LMI_report_bynoc.do?lang=eng&noc=7265&reportOption=wage. Accessed 14 April 2016.

King, J. 2014. The True Cost of Running a Desktop 3D Printer. 3D Print Headquarters. Available at: http://3dprinthq.com/cost-running-desktop-3d-printer/. Accessed on 14 April 2016.

LED Cargo Lights. Truck Lighting. Aw Direct. Ariens Specialty Brands LLC. Available at: http://www.awdirect.com/icatalog/p.asp?page=83. Accessed 14 April 2016.

Lefsrud, Mark. “Ventilation.” BREE-314: Agri-food Buildings. McGill MacDonald Campus. St-Anne de Bellville. 24 March 2016. Lecture

Light commercial vehicle body application guide. GM Fleet & Commercial. Available at:

http://www.gmc.com/content/dam/GMC/global/master/nscwebsite/en/home/Vehicles/Commercial/2016_Savana_Cutaway/01_images/2016-bag-gmfleet-final.pdf. Accessed: 14 April 2016.

Materials Data Book. 2003. Cambridge University Engineering Department. Available at: http://www-mdp.eng.cam.ac.uk/web/library/enginfo/cueddatabooks/materials.pdf Acessed on: 15 April 2016.

MaxxFan Standard 4500K. Fans. Camping World. CWI inc. Available at: http://www.campingworld.ca/shopping/item/maxxfan-standard-4500k/55477. Accessed 14 April 2016.

OSHA. 2004 Ergonomics for the Prevention of Musculoskeletal Disorders. OSHA 3192-06N. Available at: https://www.osha.gov/ergonomics/guidelines/retailgrocery/retailgrocery.html#introduction Accessed on: 14 April 2016.

Plasticker. 2016. Real Time Price List. Available at: http://plasticker.de/preise/pms_en.php?show=ok&make=ok&aog=A&kat=Mahlgut. Accessed 14 April 2016.

Polypropylene Chemical Resistance Guide. 2012. HMC Polymers. Available at: http://www.hmcpolymers.com/uploads/files/resources/hmc-pp-chemical-resistance.PDF Accessed on 13 April 2016.

PowerBright 1500W inverter. Power Inverters. Costco Wholesale. Available at: http://www.costco.ca/PowerBright-1500-W-Inverter.product.10353207.html. Accessed 14 April 2016.

Reference Manual for the Consumer Chemicals and Containers Regulations. 2007. Health Canada. 28 September 2009. Available at: http://www.hc-sc.gc.ca/cps-spc/pubs/indust/cccr-2001-rpccc/ref_man/index-eng.php. Accessed 26 November 2015.

Regulation respecting safety standards for road vehicles. 2015. Éditeur officiel du Québec. 1 December 2015. Available at: http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=%2F%2FC_24_2%2FC24_2R32_A.htm. Accessed 21 November 2015.

Société de l'assurance automobile du Québec. 201. Classes of Driver’s Licence. Available at: https://saaq.gouv.qc.ca/en/drivers-licences/drivers-licence-classes/. Accessed on 14 April 2016.

Transportation of Dangerous Goods. 2015. Transport Canada. 3 December 2015. Available at: http://www.tc.gc.ca/eng/tdg/safety-menu.htm. Accessed 19 November 2015.

Wegener Welding. 2009. Guidelines for Welding Thermoplastic Materials. Available at: http://www.wegenerwelding.com/pdf/09_Guidelines.pdf. Accessed 14 April 2016.

Workstation, stainless, wall-mount folding, 17”x14”, laptop. Riversedge. Available at: http://rivers-edge-products.com/shop/workstation-stainless-wall-mount-folding-17-x-14-laptop-kitchen/. Accessed 14 April 2016.

Appendix

Appendix I: Total Weight Calculation of Fully Loaded Mobile Office					
No.	Equipment	Description	Unit Weight (kg)	Units	Total Weight (kg)
1	Vehicle	GMC Savana 3500 139"wb	1,176.16	1	1,176.16
2	Cube	Transit FRP Cube 12'x96"x84"	868.18	1	868.18
3	Inverter	PowerBright 1500W Inverter	3.6	1	3.60
4	Generator	Champion 1500W Gas Generator	26.00	1	26.00
5	Floodlight	Lithonia D-Series Size 1 Flood	3.30	2	6.60
6	Interior Lighting	Maxxima LED Dome Light (AX434)	0.45	2	0.91
7	Fridge	Evakool 210L Platinum Upright Fridge*Freezer	54.00	1	54.00
8	Heater	Webasto AirTop EVO 3900 Heater	5.90	1	5.90
9	Vent	MaxxFan Standard 4500K	6.62	1	6.62
10	Laptop Table	RiversEdge FS1714 Folding Workstation	2.06	1	2.06
11	Interior Workstation	Tabco CB-SS-244M 24"x48" Work Table	3.17	1	3.17
12	Chemical Safety Cabinet	Uline Flammable Storage Cabinet H-2569M	27.22	1	27.22
13	Cleaning Station	Reno Standard Spruce Plywood 4'x8'x1/2"	16.93	1	16.93
14	Cleaning Station	Reno Treated Plywood: 4'x8'x3/4"	42.18	2	84.37
15	Storage Cabinet	Reno Standard Spruce Plywood 4'x8'x1/2"	16.93	6	101.58
16	Storage Cabinet	Reno Treated Plywood: 4'x8'x3/4"	42.18	7	295.26
17	VOC Sensor	Minirae 3000	0.7	1	0.70
18	Hardcase	Nanuk 925	0.6	1	0.60
19	1L container of fluid	Acetone, Hexane, Water and Acid	4	1	4.00
20	Soap	950 mL Dawn	0.9785	1	0.98
21	Glove box	100 Latex Gloves	0.85	2	1.70
22	2L containers	Waste Receptacles	0.2	2	0.40
23	Brush		0.2	1	0.20
24	Computer	MacBook Pro	2.06	1	2.06
25	iPad	iPad Pro 12.9 inch model	1.05	1	1.05

26	Phone	iPhone 6	0.172	1	0.17
27	Paper Towels		0.25	2	0.50
28	Clipboard		0.311845	1	0.31
29	Pens		0.005	5	0.03
30	Wash Bottle		0.2	4	0.80
31	Hand Shovel		0.3	1	0.30
32	Hammer		0.675	1	0.68
33	Sampling Jar		0.2	200	40.00
34	Buckets		0.885	3	2.66
35	Acetone	1L containers	0.791	4	3.16
36	Hexane	1L containers	0.655	4	2.62
37	Water	1L containers	1	19	19.00
38	Gasoline	Jerry Can	0.9	5	3.60
39	Acid	1L containers	1.07	4	4.28
40	Disposable Gloves		0.85	10	8.50
41	Measuring Tape		0.45	1	0.45
42	Paper		1	1	1.00
43	Flash light		4.5	1	4.5
44	Coolers		4	1	4
45	Ground Flags		0.05	20	1
46	Shovel		2.5	1	2.5
47	Pump		5	1	5
48	Funnel		0.1	1	0.1
49	Hose	120ft	8	1	8
50	GPS		0.7	1	0.7
51	Sampling Station		44	1	44
52	Coveralls		1.8	2	3.6
53	Measuring wheel		2.1	1	2.1
				Subtotal	2,853.80
				Safety Factor (15%)	428.07
				Total	3,281.87

Appendix II: Volume of Equipment Calculation of Mobile Office			
No.	Equipment	Quantity	Volume est. (m^3)
1	Hardcase	1	0.0363
2	Soap	950 mL	0.0010
3	2L containers	2	0.0020
4	Brush	1	0.0020
5	Computer	1	0.0018
6	iPad	1	0.0006
7	Paper Towels	2	0.0292
8	Clipboard	1	0.0002
9	Pens	5	0.0000
10	Hand Shovel	1	0.0020
11	Hammer	1	0.0030
12	Inverter	1	0.0068
13	Generator	1	0.0624
14	Floodlights	2	0.0109
15	Folding Table	1	0.0378
16	Sampling Jar	240	0.0600
17	Buckets	3	0.0200
18	Acetone	5L	0.0050
19	Hexane	5L	0.0050
20	Water	19L	0.0190
21	Gasoline	5L	0.0050
22	Acid	5L	0.0050
23	Glove Boxes	10	0.0264
24	Measuring Tape	1	0.0003
25	Paper and Maps	1	0.0001
26	Flash light	1	0.0100
27	Coolers	1	0.0865
28	Ground Flags	20	0.0001
29	Shovel	1	0.1520
30	Pump	1	0.3000
31	Funnel	1	0.0010
32	Hose	120 ft	0.0200
33	GPS	1	0.0020

34	Sampling Station	1	0.2761
35	Coveralls	2	0.0260
36	Measuring wheel	1	0.1000
		Subtotal	1.3153
		Safety Factor (15%)	0.1973
		Total	1.5126