University of Toronto

MTO Parking Lot Proposal

CIV420 Estimation/Management Project

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CIV420 - Construction Engineering

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Project Team Management

Table 1 summarizes the roles of each member on the team, the tasks that they were responsible for and the amount of time each member dedicated to the project.

Table 1. Team Task Distribution

Team Member	Tasks	Time (hours)
Joel Algra	Cut and fill analysis, earthworks procedure and formation, earthworks timeline, earthwork equipment	50
Mahzabin Karim	Quantity takeoff, traffic management, site mobilization, subcontractor activities (drainage, lighting, markings, top soil), asphalt paving, safety management	45
Adneen Mir	Quantity takeoff, equipment production rates, concrete paving, stakeholder analysis, sustainability analysis, granular placement	45

Executive Summary

JAM construction, has taken another venture into the heavy civil construction industry by taking on a job for MTO that consists of the entire production of 2 parking lots equipped with GO bus loops for local commuters. The project began with the completion of cut and fill calculations in Civil 3D.The assumptions were made that the cross sections, which were taken to be homogeneous throughout, were taken to be at station 10+100 for the North - South section, and along the QSR Carpool E-W line for the East - West section. With the cut fill estimations found the group concluded that large cost and emissions savings could be made by introducing on site soil screeners instead of hauling the rocky soil off site. The most apparent risk of the construction was found to be the high amounts of machine traffic that was introduced on site to be able to make good timing. The high traffic introduced chances for collisions and setbacks to the job. These risks were analysed and addressed by having a coherent site traffic plan that will be briefed to workers daily. After all the calculations were done, risk concern were addressed, site plans made and workflows agreed upon, the overall length of the job was found to be 2.5 months of working days, coming to $4.95 M for all of the machine, labour, materials and overhead costs with a markup of 20% for overhead and profit, the price quoted to MTO comes to $5.94 M[1]. This means that JAM construction will be able to profit $594 000, assuming that 10% of the markup goes to project overhead, along with the $80 000 bonus for finishing 16 days early coming to a grand total profit of $674 000.

Work Schedule

The construction of both the carpool lots will occur simultaneously and it is projected to take roughly 2.5months (77 days) to complete. Given the project is complete 16 days prior to the deadline, JAM will be applicable for the $5000 bonus per day leading up to January 31st.

Table 2. Overall Timeline of Construction

From	To	Activity Lot 1	Activity Lot 2
11/1/23	11/3/23	Site Mobilization	Site Mobilization
11/6/23	11/10/23	Begin cut and complete fill	
11/13/23	12/04/23	Complete cutting and Screening	Begin/Complete Cut and Fill
12/5/23		Complete Grading	
12/6/23	12/13/23	Subcontractors place drainage and trucks begin coming in to deliver granular B	
12/14/23		Granular B Spreading, Compaction and Grading	Complete Grading
12/15/23	12/20/23		Subcontractors place drainage. Granular B delivery, spreading, compacting and grading
12/21/23	12/22/23	Granular A Delivery, Spreading, Compacting and Grading	Granular A Delivery, Spreading, Compacting and Grading
12/25/23		*Christmas Day-Off*	
12/26/23	12/28/23	Granular A Delivery, Spreading, Compacting and Grading	Granular A Delivery, Spreading, Compacting and Grading
12/29/23	01/01/24	*New-Years Break*	
1/2/24	1/4/24	Asphalt Paving	Asphalt Paving
1/5/24		Concrete Pour for Bus Loop	Subcontractor Work for all asphalt areas
1/8/24		Place Formwork for Sidewalk	
1/9/24		Pour Sidewalk	
1/10/24		Subcontractor Finish Up	Concrete Pour for Bus Loop
1/11/24			Place Formwork for Sidewalk
1/12/24			Pour Sidewalk
1/15/24		Demobilize	Complete Subcontractor work
1/16/24			Demobilize

Introduction

JAM was tasked to address material, labor, and equipment estimates, job scheduling, productivity, traffic management, and site layout while staying within time constraints and minimizing cost. JAM made assumptions, established workflows, and started with the initial task of quantity estimation in the estimating process. To facilitate accurate quantity estimations for two MTO parking lots, it was assumed that the design would be limited to the parking lot entrance edges and that boundary lines would be interpolated to accommodate the necessary slope for water runoff.

A key issue identified is the high rock content in the native soil which prevents the use of the cut for backfill. After analysis, the team decided to filter the native soil through a screener to reduce the rock content enabling use for backfill. A major assumption is that the screened soil will be of approved grading for backfill usage. It is assumed that the owner will accept this as an appropriate backfill as the graded soil produced by the screener can be adjusted to align with the grading requirements of the backfill. Additional assumptions and considerations can be found in Appendix A.

Site Layout and Logistics

Phase 1: Site Mobilization (3 days)

Site mobilization will encompass the procurement of related materials, equipment and skilled workforce, establishing a site boundary with fencing and installing temporary facilities for worker accommodations. This will all be done in compliance to documentation relating to permit acquisition, health and safety documents and daily activity recordings to ensure compliance.

Pre-Construction:

The construction area will be clear of site facilities, to maximize the space available for working and equipment parking. Equipment will be parked where it is last used. JAM will install 10 portable toilets, five at each carpool lot to ensure accommodation of all workers.

Carpool Lot 1:

NW of the proposed site, an existing service road with well graded road shoulders leading to a water tower for the nearby city of Queensville exists (Figure 1). JAM will have a 800m2 parking lot and main site office of 70m2, located right off this access road. Site office will be equipped with a half bathroom and kitchen. Only 150m away from carpool lot 1, workers are able to walk to the site in under 2 minutes. Given the public works nature of the project, obtaining necessary permits is expected to face minimal resistance. Main site office will be for any engineers, large briefings, and for the workers working in Carpool Lot 1 to have lunch.

Carpool Lot 2:

Considering the main site office is 400m away from Carpool Lot 2, a trailer of 40m2 equipped with a bathroom and lunchroom will be installed, this can be found nearing the perimeter of the construction boundary to ensure it is as far from the working zone. A 400m2 parking lot near the site will be of main use for workers.

Construction Zone Boundary:

JAM will keep the construction zone enclosed with fences during the period of the construction. Fences will consist of chain links and will be minimum 1.8m height as per the Proposed Construction Fence By-Law. Chain links provide full visibility of the work being done within the perimeters and the traffic coming in and out [2].

Figure 1 - Site Mobilization Layout

<u>Safety of Environment and Workers</u>

To ensure the continuous safety of daily activities and efficient progress, the following actions are necessary.

1. Every individual coming in and out of the construction zone will need to fill in the visitor sign in sheet located in the main site office, and a JAM representative shall complete the safety check for the contractor work and work area and have it signed off by a contractor representative.
2. All workers on site will be required to complete all the necessary safety training prior to entering the site.
3. Create clear transportation routes with signs and cones and implement entry protocols for trucks and equipment to avoid possible collision with site workers and traffic.

<u>Traffic Management</u>

Construction equipment will enter and exit the site from Queensville Sideroad, hence signage and warning will be required to alert drivers of the construction zone ahead (Figure 2). The focal point of traffic congestion occurring is at the entrance and exit of the carpool lots since equipment will require more space and time to turn in and out into traffic.

At times of heavy traffic at the entrance, there will be designated labourers at the entrance with signs and cones directing the trucks to where they need to be. Cones will also be placed around parked equipment to alert workers of potential hazards and to limit any traffic into that area.

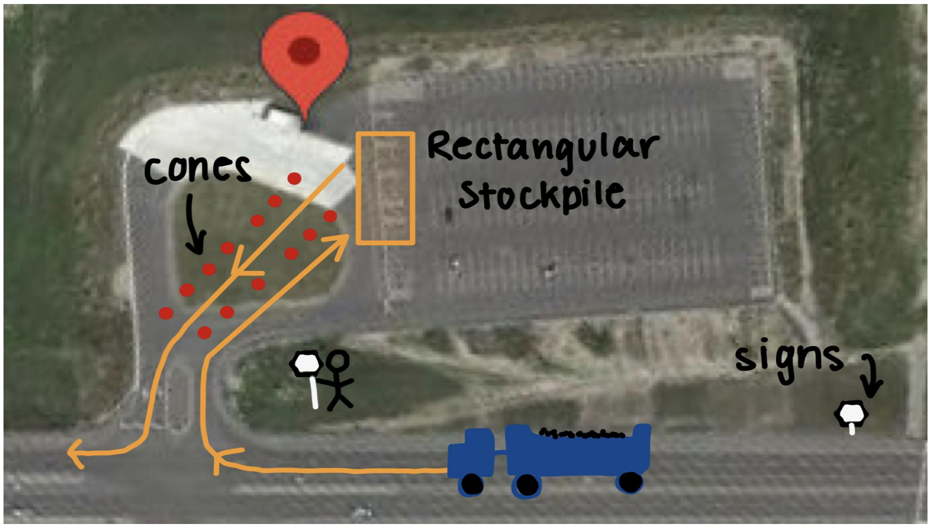

Figure 2 - Path of trucks hauling material into site, and placement of granular stockpile is central to the site. Rectangular pile maximizes the spread along the width of the site.

Earthworks

Phase 2 : Cut/Fill (1.5 Month)

Having completed the cut and fill calculations using Civil 3D [Appendix B], JAM looked into the cost and time associated with hauling and recycling the soil due to its rocky nature. A decision was made to screen the soil on site and use the screened soil for backfill in place of hauling the cut off site and having to buy fill to replace it. The soil present in the site, being sandy loam, was found to have good characterization to be properly compacted when used as fill [3]. There were also calculations carried out that concluded that introducing two Keestrack K4 Screeners, there would be significant savings to cost as well as emissions as far less trucks would be required to haul soil off site [Appendix C]. These screeners will be the centre of construction, being put at the meeting of cut and fill areas so they can be left in the same location throughout the construction process in order to be able to work non-stop [4].

Part 1: 5 Days

With the screeners' location chosen, the group began to build a cohesive construction plan in order to meet the deadlines set by the owner. Part 1 of this planning phase focuses on the first site (west of highway), beginning on the cut of the site using excavators, having loaders transferring the cut soil directly into the screener hoppers, and then a team of 2 dozers, a compactor and a surveyor taking the screened soil, moving it to the fill area of site 1 and then compacting it after 20 cm lifts for proper compaction. In order to finish the fill on time, and to avoid the cost of an extra dozer, the dozer team will have to work through the weekend at double time, this will save upwards of $500,000. Equipment decisions were made based on calculated production quantities to closely match the production of the screener [Appendix D]. This way the time equipment is used efficiently and idling is prevented. This process is visualized through a plan view as seen in [Appendix E.1] and will take 5 days to complete the total fill for site 1.

Part 2: 16 Days

Once the fill for the first site has been completed, the crew will be majorly expanded and the construction process will move onto step 2. During this step, production begins on both sites simultaneously, the cut and screening of soil on site 1 will continue while the screened soil will be transferred to site 2 (east of highway). The team of dozers along with the compactor will be moved to site 2 joined by a loader. A fleet of trucks will be introduced to begin the hauling of soil and stone being produced by the screeners off site as well as the cut being produced at site 2. Three types of trucks were considered for hauling, and JAM will try to maximize the use of C type trucks based on its higher production rate and cost effectiveness [Appendix F]. Half of the trucks will be tasked with delivering the screened soil to site 2. To avoid the need for another machine being added to an already crowded site, there will be a screener operator present with the task of staring and stopping the screeners while trucks are moving from under the outfeeder. This way the screen soil can be fed directly into the back of the trucks as shown by the construction plan in [Appendix E.3]. With the trucks being loaded with cut and screened soil will then haul that soil to the site where the compactor will be waiting. To remove the need for a grader or dozer to spread the lifts of soil, the hauling trucks will lift their bed as they drive into site, this way they dump while moving and spread the lifts of soil themselves. The compactor will then have the chance to follow behind the trucks for each lift to properly compact the soil as seen in [Appendix E.4]. Whilst site 2 is being filled, the dozers on site will be working on the cut section of the same site, while simultaneously ensuring that the incoming trucks have properly graded paths to keep safety and efficiency up to standard. This cutting process is also shown in [Appendix E.4]. This part of the phase will be where the bulk of the work happens and is estimated to last 16 days. This is when the most amount of risk is present on site as there will be a lot of traffic and consistent overlapping of machine paths on site. There will have to be caution taken by machines crossing over another machines' path that is laid out in [Appendix E.3/E.4.]

Part 3: 6 Days

Once the process of part 2 is finished the jobs left to do are final grading of both sites and the rest of the cut and fill process of site 2. Grading will be a short process as the site has been roughly graded throughout all parts. To finish the grading of site 1 it will take a grading crew a single day to perfect the grade and haul the leftover soil away.

With the assumption of there being 15% of rock present in the soil, the produced 85% of usable fill from site 1 ends up being just shy of producing the fill needed for both sites. Instead of hauling a screener over to the next site, it was easier for JAM to purchase the remaining fill and haul it in, this will take 1 day. Along with this, the rest of the cut from site 2 will be finished. In order to keep up with production of the 3 loaders and pair of excavators doing the cut, while hauling soil much further away then a neighbouring site, a large fleet of trucks will have to be introduced to adhere to the deadline given. The added premium cost of the trucks in this fleet will not be taken on for a significant period of time as this part of the phase will only take 7 days including the first day of soil import and fill finish of site. To see the proposed process for this part refer to [Appendix E.6].

Part 4: 1 Day

With everything else being finished, the only job left for this part is to fine tune the grading on site 2. This will be tackled by the same grading crew that did site 1 and similarly, will only take 1 day to complete. An overall phase timeline can be viewed in [Appendix E.9].

Drainage (1 day)

Upon completion of cut and fill, the subdrains will be installed by the subcontracted company. This includes the culvert on the west. They are responsible for performing the required cut and fill for the job. Geotextiles will be included in the quote to ensure long-term effectiveness and reduce risks that will impede water drainage (clogs) [5]. The total cost including material and installation is about $3500. Refer to Appendix K for the quantity and cost breakdown.

Phase 3: Subbase and Road base Placement (2 weeks)

Granular A and B will be placed after the entire site has been graded to subgrade. The parking lot granular B and A will begin being placed while the subcontractors are working on the subdrains on the GO bus loop. The steps to complete the placement of aggregates will be as follows:

1. Granular B and A aggregates will be delivered to site and purchased at a rate of \$19.5/tonne and \$20.65/tonne, respectively, including delivery [Dufferin Concrete PEY Experience]. The aggregate delivery path and stockpile location is shown in Figure 2. This will be the critical step as other stages are dependent on the timely delivery of the aggregates. Assuming trucks come at about 5 minute intervals, including dumping at stockpile, it will take about 5 days per type of granular [Appendix G]
2. A front end loader will be used to spread the aggregates through the parking lot and bus loop area. The loader will be spreading at a rate much after than the aggregate delivery time, so all aggregates will be done being spread by the time aggregate delivery is complete [Appendix G].
3. Once the aggregates are roughly placed along the parking lot, a grader will be used to level the aggregates to the desired thickness. This will only take a couple of hours for each aggregate type [Appendix G].
4. Aggregates will be watered using a water tanker to ensure a 5% water content [6].
5. A compactor will be used to roll over the watered aggregates until a 95-98% is reached [6]. This will take about 6 passes over the entire area [6]. The compaction should be done in about 5 hours [Appendix G]. Including watering time, compaction for each type of granular should take one day.

Phase 4: Asphalt Paving (3 days)

After comparing plant 1 and 2 for asphalt supply, JAM will be purchasing all asphalt from plant 2. The demand for asphalt on both sites combined is 2920 m3 [Appendix I]. Plant 2 fulfills all capacity requirements and is less susceptible to traffic due to the toll route, which allows for better projection of time and minimizes the risk of idling equipment and labourers.

There are a total of three lifts of asphalt, 60mm, 50mm and 40mm from bottom to surface. A dump truck will come in with the asphalt mix and will be poured directly into a paver. The paver will pour the asphalt onto the roadbed in lifts. Each lift will then be compacted with a compactor. The details of each stage are outlined below:

1. Once manufactured at the asphalt plant, the hot-mix asphalt is conveyed to the construction site via dump trucks. Trucks will arrive every 10 minutes to remain aligned with the paver cycle [Appendix I]. Two pavers will be rented at \$3000 each per day to

pave both sites at the same time (Table 2) [7]. See Figure 3 for the process of transporting material from truck into the paver.

2. The dump truck reverses towards the paver and releases its load into the hopper of the paver. It would take about 3 days to pave all the lifts [Appendix I]. With a day for each lift to give sufficient curing time. The vibrating screed in the paver performs the initial compaction on the asphalt mat, achieving roughly 85% of the final required density. It also ensures that the mat attains the correct width and thickness.

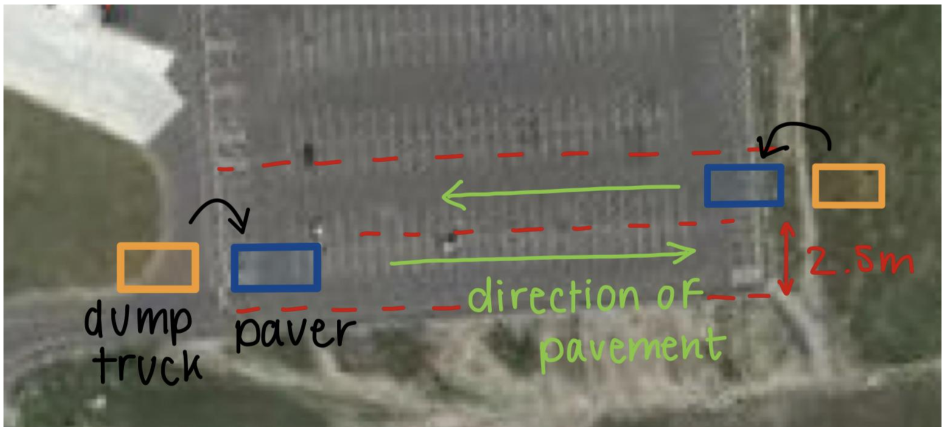

Figure 3 - Dump truck pouring asphalt into paver. One dump truck fulfills a run.

3. Directly following the paver is the vibrating compactor, which will take about two runs, over each lift, to compact the asphalt to approximately 95%. This will take about 5 hours split evenly across the lifts [Appendix I]. It will occur in conjunction with the paver and follow the paver (Figure 3), so there will be no additional time.

The grader and compactor will be shared amongst both the sites.

Potential Risks: It is assumed that 1 dump truck carrying hot-mix asphalt will supply the paver with enough material to complete one run across the site (85m). Currently asphalt trucks are expected to come in 10 minute intervals, so when running into this risk, trucks will be expected to come at shorter intervals increasing risk of accidents. Increased traffic at a faster rate will result in more traffic management protocols.

Phase 5: Concrete Paving (3 days)

All concrete required will be supplied from plant 2. The higher unit price of concrete for plant 1 is greater than the toll paid per trip to plant 2. Using a toll route also leads to a shorter cycle time that is less susceptible to traffic, making it the more reliable option. Full analysis can be found in Appendix [J].

GO Bus Loop (1 day)

The concrete for the GO bus loop will be placed level to the asphalt that has been paved around the loop. The concrete pour and finishing for the loop will be completed in one day to prevent cold joints. This will be a 10-12 hour work day with more labourers than usual. About 20 trucks of concrete will be required arriving at 30 minute intervals which should be enough to complete testing and pouring of a truck [8]. This will account for time to test the concrete and complete the pour from each truck. Figure 4 shows the pour boundaries and the truck entry.

Concrete Walkway (2 days)

The formwork for the concrete walkway will be placed the following day along the boundary between the walkway and bus loop, about 150mm high. The concrete pour for the walkway will be completed a day after, with a brushed finish for the pattern [Appendix J]. Trucks will arrive at 30 minute intervals following the same route that was taken to pour the bus loop.

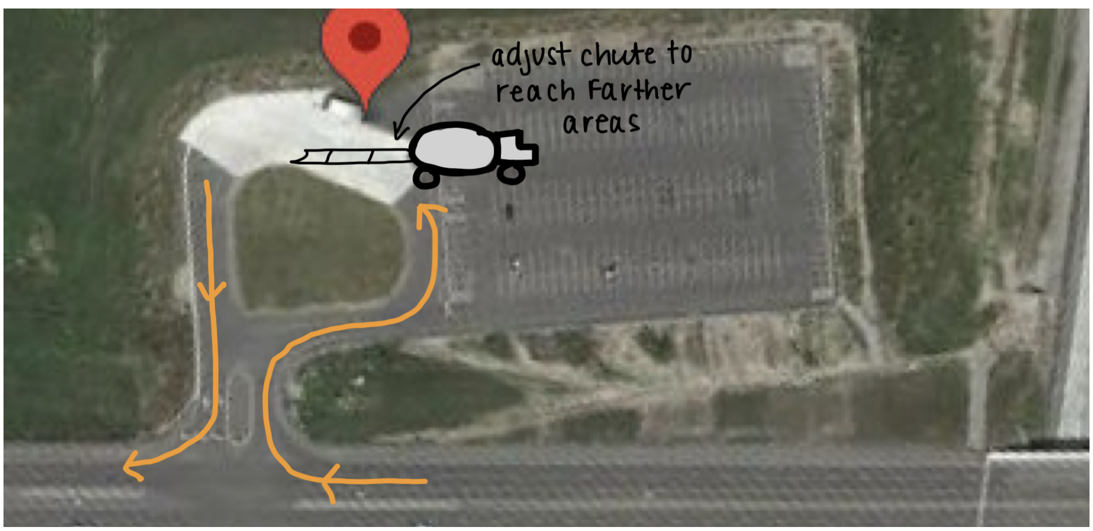

Figure 4 - Travel path concrete truck takes to later pour into the area bounded by formwork.

Phase 6: Seed and Sod, Curbs, Pavement Markings, Fencing, Lighting (3 days)
The following will be subcontracted to a company:

1. Topsoil and sod within the site
2. Concrete curb around the topsoil area and Go Bus Loop
3. Precast concrete parking lot bumper curbs
4. Markings for parking lot stall lines
5. Steel beam guide rails
6. Lighting poles around the parking lot and Go Bus loop

The first day will be allotted to completing the topsoil and sod, installing the precast concrete parking lot curbs, and the install of the steel beam guide rails. The second day will be for placing the concrete curb around the topsoil area and Go Bus loop, alongside marking the parking lot stall lines. The third day is to only install the lighting poles around the site. The total cost including material and installation is about $200,000. Refer to Appendix K and N for the quantity and cost breakdown for each item.

Project Cost Breakdown

Table 3 summarizes the costs incurred during the project. This includes the equipment, the labour and the material costs. A breakdown of all calculations can be found in Appendix L. A typical site mobilization cost was taken [27]. Material quantities can be found in Appendix [N].

Table 3. Cost Breakdown for Project

<table>
<tr><th>Phase</th><th>Material</th><th>Equipment</th><th>Labour</th><th>Total</th></tr>
<tr><td>Site Mobilization</td><td colspan="3">$25,000</td><td>$25,000</td></tr>
<tr><td>Earthworks</td><td></td><td>$3,484,854</td><td rowspan="4">$324,000</td><td>$3,484,854</td></tr>
<tr><td>Granulars</td><td>$207,017</td><td>$24,707</td><td>$231,724</td></tr>
<tr><td>Asphalt</td><td>$408,022</td><td>$24,370</td><td>$432,392</td></tr>
<tr><td>Concrete</td><td>$65,200</td><td>N/A</td><td>$65,200</td></tr>
<tr><td>Subcontracted Items</td><td colspan="3">Calculated in Appendix K</td><td>$412,078</td></tr>
<tr><td colspan="4">Total Project Cost</td><td>$4,975,248</td></tr>
<tr><td colspan="4">Total 10% Overhead, 10% Profit</td><td>$5,970,298</td></tr>
</table>

Sustainability and Environmental Evaluation

JAM will maintain sustainable practices on site by reducing waste and reducing energy consumption. By using a screener to separate the rock in the native soil on site, JAM will be able to eliminate the need for hauling in any backfill and significantly reduce the cut required to be hauled away. Assuming about 15% of rock content in the native soil, the filtered cut soil volume from both the lots will be enough to fulfill the demand of all the fill areas. By screening the cut soil and using it for fill, about 48000 cubic meters of soil hauling is saved [Appendix C].

Not only does using a screener maximize the amount of soil that can be reused, it also significantly reduces the number of trips that need to be taken to and from Y&T Works. About 2400 round trips would be required using the largest truck available to haul around 48000 cubic meters of earth. This would lead to about 664 metric tonnes of carbon dioxide emissions [Appendix M]. That is equivalent to what almost 350 cars would emit in one year [9]. The screener would be consuming fuel as well, but this can be assumed to be offset by the amount of fuel that Y&T Works would require to recycle the excess soil that will now be reused on site.

Community and Stakeholder Analysis

Potential impacts on the community during the duration of construction of the parking lots was considered. This includes the impacts during transportation of materials as well as the impact on traffic adjacent to the site during construction.

All concrete and asphalt quantities will be transported using the toll route from plant 2. This will reduce the amount of traffic incurred on local roads and limit the noise pollution as truck traffic will be kept away from residential roads. The trucks that will be hauling soil however, will be utilizing path C which passes through residential roads. This will lead to noise pollution and added traffic on residential roads. It may also reduce the safety of these roads that are not accustomed to heavy vehicle traffic. Since JAM has reduced the amount of soil needed to be hauled by reusing a lot of the soil on site, the number of trips on this path has been reduced by more than half [Appendix M]. In addition, the trucks will be spaced out in time such that there is no truck build up on these roads. Prior to beginning construction, all the houses that will be passed on path C will be provided with a notice alerting them of the heavy vehicle traffic they can expect over the following weeks. This will give the residents a warning and reduce the risk of accidents. They will also be provided with a number to contact us should they have any complaints. This may lead to a setback in timeline plans and require the use of path D if the complaints are not manageable. This is a risk that JAM is taking.

In terms of mitigating impacts surrounding the site, the key issue will be dust. There are not many residential homes that will be impacted due to the site being isolated from homes. The primary concern would be dust emitting onto the adjacent road. This will be mitigated over the course of the project's phases by using company water tanks to spray the site every couple hours [22].

Handling Uncertainty and Process

The team had to make many assumptions while planning out the execution of the two parking lots. JAM focused on the larger tasks at hand, which was the grading of the lot and placed emphasis on figuring out how to most efficiently execute this task, which was the bulk of the project. Keeping sustainability and time in mind, JAM proposed the idea to reuse as much of the soil cut as possible. This reduced the cost of the project significantly. It also resulted in less waste, impact on environment and time.

Equipment was chosen effectively to reduce the number of equipment idling on site at a time. The equipment or task that was critical or had the lower productivity (bottleneck) was identified for each stage of construction. The rest of the equipment for that task was placed such that it could match the productivity of the bottleneck task. This way equipment idling was limited. The equipment use was also determined by considering the availability and cost of each equipment. The productivity to cost ratio was analyzed for each equipment [Appendix D and F], and the use of equipment with higher productivity per unit cost was maximized when available.

JAM also considered uncertainty and delays in its scheduling by rounding up times to account for any delivery delay, weather or unexpected site conditions. The team used engineering judgement to determine the unknown quantities on the project. This included determining the cut and fill surface by projecting the existing and design sections throughout the lengths of the lots using Civil 3D. These were just some of the considerations made by the team throughout the planning stages.

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Appendices

Appendix A - Assumptions

Grading Assumptions

- Assume all building permits have been received (for the temporary facilities mentioned within the site mobilization)
- Assume a crew of 10 workers perform 8hrs/day, 5days/week
- Assume all equipment have been inspected for sufficient operation
- Boundary assumed in drawings
- N/S Cross Section is @ STN 10+100
- E/W Cross Section is @ QSR Carpool Line
- West side of existing elevations for first parking lot is 3%, then when lot starts just connected to known elevation

- Go Bus Loop is all sloped at 2% toward the south as to avoid water pooling
- Sidewalk (2%) and grass area near sidewalk is sloped away from Go Bus Loop to minimize water on driveway
- 150mm of topsoil cut from design grade everywhere
- Found a soil map that says the area that construction happens is mainly sandy loam
- About 15% of the native soil is rock
- Filtering the soil using a separator results in soil that is usable for fill
- Assume cost of hauling away rock from the soil is the same as hauling the soil

Appendix B - Cut and Fill Calculations and Procedure

The cut and fill calculations for the two parking lots were done by plotting the cross sections on Civil 3D. Figures B-1 and B-3 show the plan cut and fill regions for site 1 and 2 respectively. Figures B-2 and B-4 summarize the cut and fill quantities on each site.

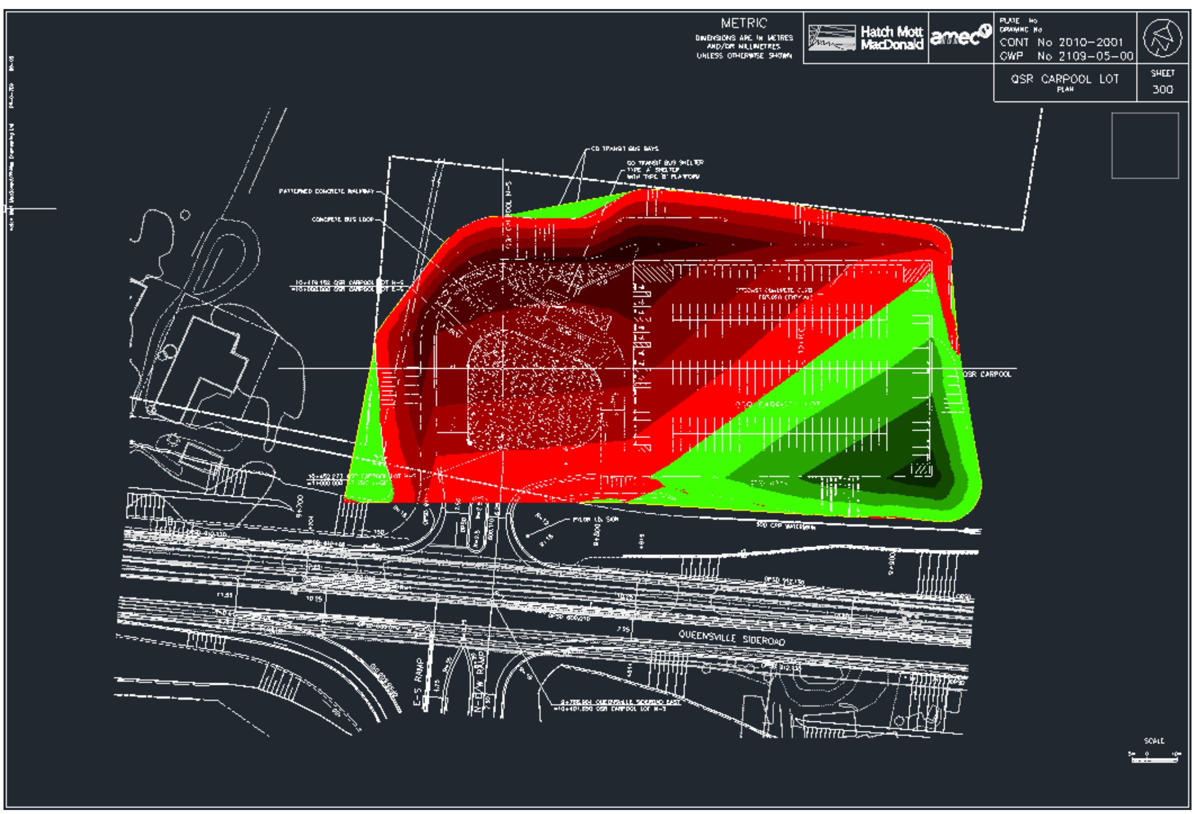


Figure B-1. Cut and fill regions for lot 1: red regions are cut and green are fill

Volume	
Base Surface	Existing Elevations
Comparison Surface	Design Elevations
Cut Factor	1.000
Fill Factor	1.000
Cut volume (adjusted)	54797.47 CU. M.
Fill volume (adjusted)	11581.41 CU. M.
Net volume (adjusted)	43216.06 CU. M. <Cut>
Cut volume (unadjusted)	54797.47 CU. M.
Fill volume (unadjusted)	11581.41 CU. M.
Net volume (unadjusted)	43216.06 CU. M. <Cut>

Figure B-2 Cut and fill quantities for lot 1

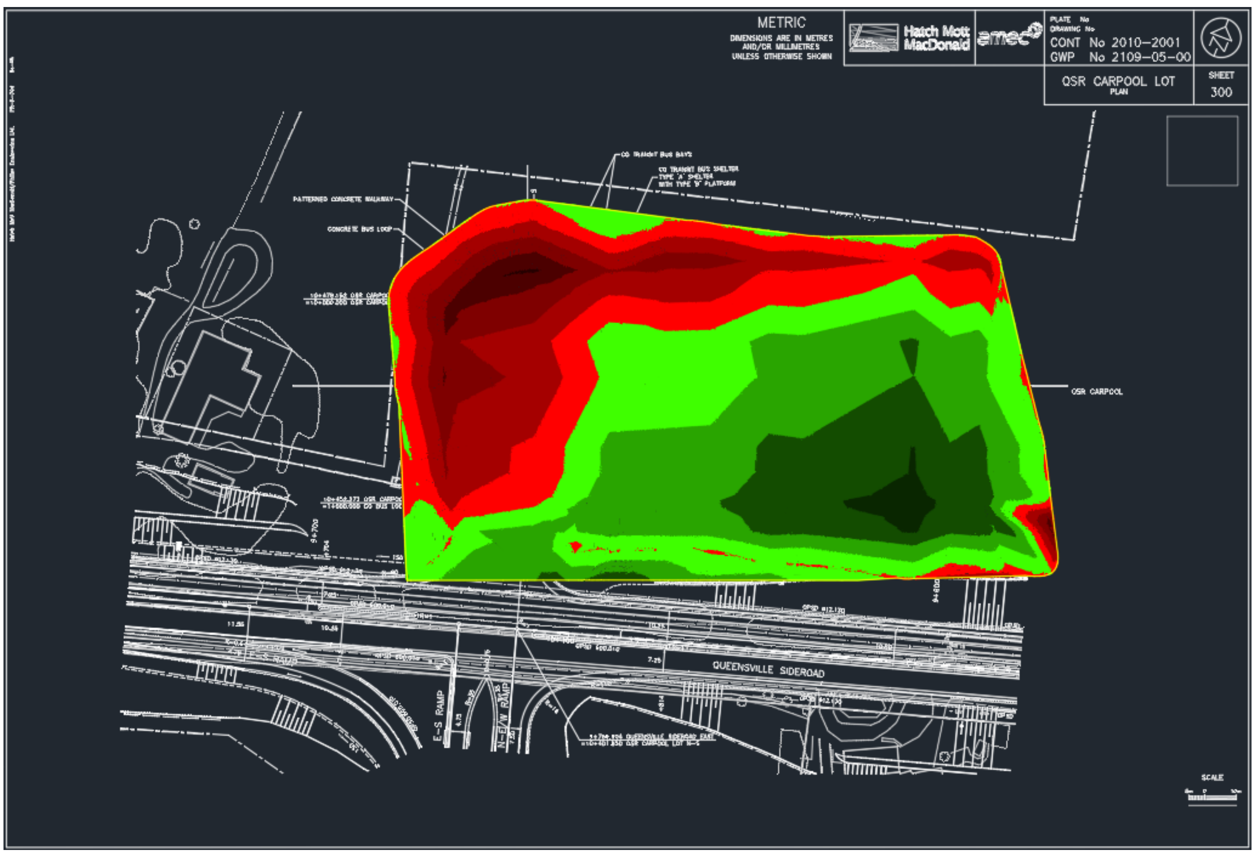


Figure B-3 Cut and fill regions for lot 2: red regions are cut and green regions are fill

Volume	
Base Surface	Existing Elevations
Comparison Surface	Design Elevations
Cut Factor	1.000
Fill Factor	1.000
Cut volume (adjusted)	28880.59 CU. M.
Fill volume (adjusted)	35743.72 CU. M.
Net volume (adjusted)	6863.13 CU. M. <Fill>
Cut volume (unadjusted)	28880.59 CU. M.
Fill volume (unadjusted)	35743.72 CU. M.
Net volume (unadjusted)	6863.13 CU. M. <Fill>

Figure B-4 Cut and fill quantities for lot 2

Appendix C - Soil Hauling vs Separator Comparison

Based on the cut and fill analysis, the total fill on both lots is 47326 cubic meters and the total cut is about 83678 cubic meters. With 50% of the native soil being unusable due to rock content, 23663 cubic meters of fill would need to be purchased. About 60000 cubic meters of cut would need to be hauled away if only 23663 is usable for fill. Table 4 summarizes these numbers.

Table 4. Cut Haul Volume and Backfill Purchase

	Total Requirement on Both Sites	**Haul Away/In Volume (assume 50% of fill is from cut) (m3)**
Backfill	47326	23663
Cut	83678	60015

The cost of recycling the cut volume and purchasing the required fill is summarized in Table 5. The recycling cost of one ton of soil is $30. On average, one cubic meter of soil is about 1.5 tons [9]. Therefore the rough cost of recycling one cubic meter of soil is about $45.

Table 5. Recycling Soil and Backfill Purchase Costs

	Volume	**Recycling/Purchase Cost**	**Total Cost**
Cut Recycle	60015	$45/m3	$2,700,675
Backfill Purchase	23663	$10/m3 [10]	$236,630
		Total Cost	**$2,937,305**

Table 6 shows the total costs if we were to use a screener and get 100% of the fill from the cut.

Table 6. Costs with a Screener

	Volume	Recycling/Purchase Cost	Total Cost
Cut Recycle	36352 m3	$45/m3	1,635,840
Backfill Purchase	0	$10/m3 [10]	0
Screener	2 units	26000/screener [3]	52,000
		Total Cost	**$1,687,840**

About 1.25 million is saved in just material costs alone. This is ignoring all the hauling costs that will be incurred with an additional 47326 cubic meters of soil that would need to either be hauled away or hauled in for backfill. There would also be costs associated with the time that it would take to haul away all this soil. This shows that the screener is a viable option.

Appendix D - Productivity of Grading Equipments

<u>Loader Production Rate</u>

Bucket capacity = 2.5m3

Speed = 25km/hr

Max distance = 0.15km

Bucket fill time loose = 7s

Bucket fill time bank = 14s

Turnaround = 5s

Dump time = 10s

Cycle time loose = (0.15km / 25km/hr * 3600s/hr) + 7s + 5s + (0.15km / 25km/hr * 3600s/hr) + 10s + 5s = 70.2s

Cycle time bank = (0.15km / 25km/hr * 3600s/hr) + 13s + 5s + (0.15km / 25km/hr * 3600s/hr) + 10s + 5s = 77.2s

Production loose (LCM) = 2.5m3/c * ((3600s/hr) / 70.2s/c) * 50min/60min = 106.8m3/hr

Production loose (for 4 loaders) = 106.8m3/hr * 4 loaders = 427.2m3/hr or 623.7T/hr

Production bank (LCM) = 2.5m3/c * 1.25 * ((3600s/hr) / 77.2s) * 40min/60min = 97.1m3/hr or 141.8T/hr

**Note: the 40min/60min in above calculation is to account for extra downtime due to the loader being used more aggressively.

Production bank (for 4 loaders) = 97.1m3/hr * 4 loaders = **3884m3/hr** or 567.06T/hr

Production loose (stockpile transfer) = 2.5m3/c * ((3600s/hr) / (7s + 5s + 5s + 5s + 13s)) * (50min/60min) = **250m3/hr**

Truck Production Rate:

15m3 / (350T/hr * 1m3/1.46T *0.85%soil) = 0.0736hr or 4.4 min to fill

10m3 / (350T/hr * 1m3/1.46T * 0.85%soil) = 0.0491hr or 2.9 min to fill

RR on site = 100kg/T /10 = 10%

RR on road = 20kg/T /10 = 2%

Turnaround empty = 0.3min

Turnaround full = 0.5min

Return = 0.8min

Haul = 3min

Total Cycle Time = 4.6 min

Production B = 60min/h / (4.6min +4.4min)/c * 15m3/c = **100LCM/hr**

Production A = 60min/h / (2.9min +4.4min)/c * 10m3/c = **82.2 LCM/hr**

3 (truck B) + 2 (truck A) = **464.4 LCM/hr**

Compactor Production Rate:

19.23m * (1km/1000m) / 7km/hr = 0.00275h or 9.89s

Since trucks will be coming in every 4.4+4.6/2 = 6.7min, 1 grader will easily keep up to production.

Excavator Production Rate:

Bucket size = 2.2yd3 or 1.7m3

1.7m3/c * 170c/hr * 0.83 * 1.25 LCM/BCM *50min/60min * 1 = **249.86 LCM/hr**

Screener Production Rate:

350T/hr / 1.46T/m3 = 239.73m3/hr

239.73m3/hr * 15%stone = **35.96 m3/hr of stone**

239.73m3/hr * 85%soil = **203.77m3/hr of soil**

Dozer Production Rate:

Speed = 4km/hr

Average haul distance = 50m

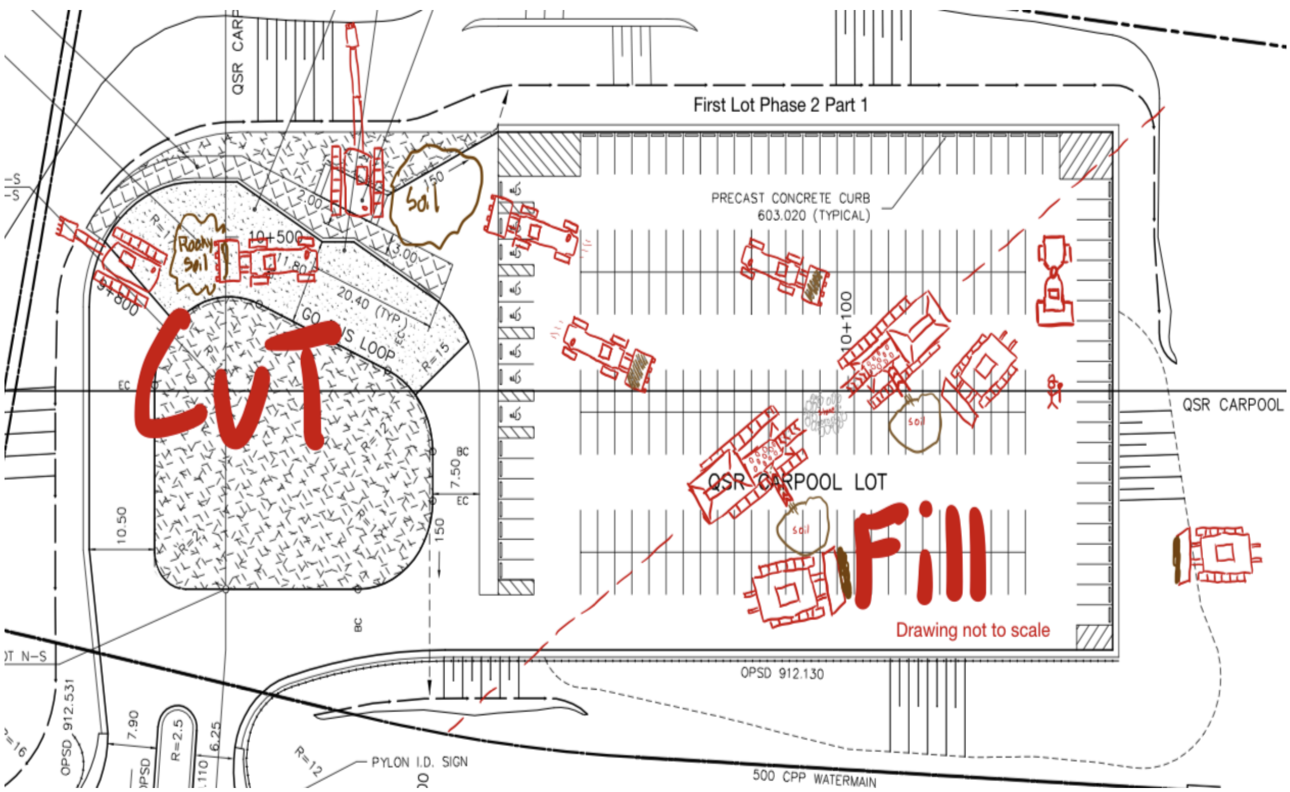
Production (for site 2) = 3.1 yd3 * (1yd3/1.3m3) / (50m * (1km/1000m) / 4km/hr) * 1BCM/1.25LCM * 30min/60min = **76.31m3/hr**

**Note: For above calculation, it takes 15min/hr to rough grate for.

Production (for site 1) = 3.1yd3 * 91yd3/1.3m3) / (35m * (1km/1000m) / 4km/hr) * 1BCM/1.25LCM * 45min/60min = **163.52 m3/hr**

Appendix E - Earthworks Plans & Respective Timeline Calculations

1) Plan of site layout for Phase 2, Part 1, Site 1



2) Part 1 Time (until fill is complete):

4 loaders = 427.2m3/hr

2 excavators = 499.72m3/hr

2 screeners = 479.46m3/hr, 71.92m3/hr stone and 407.54m3/hr soil

3 dozers = 490.56m3/hr

1 compactor

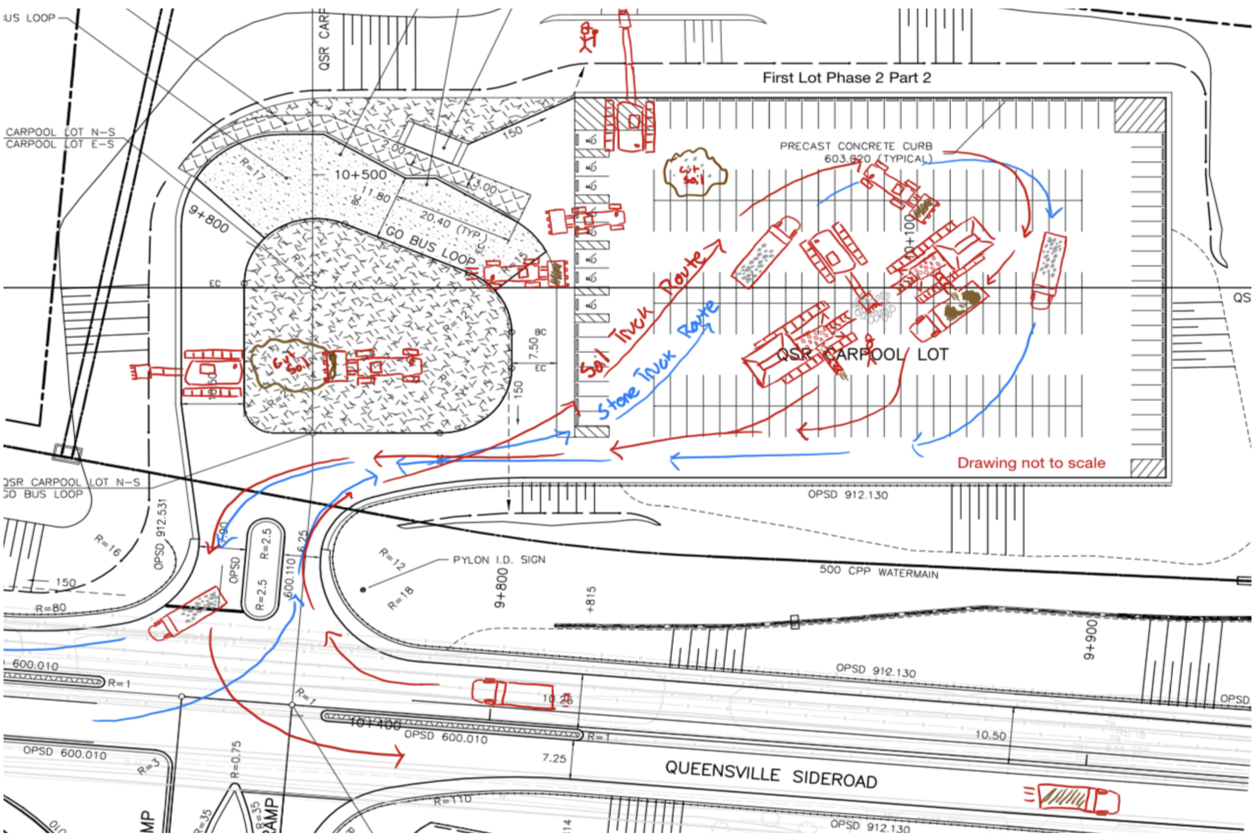
1 surveyor

Soil production is the limiting factor.

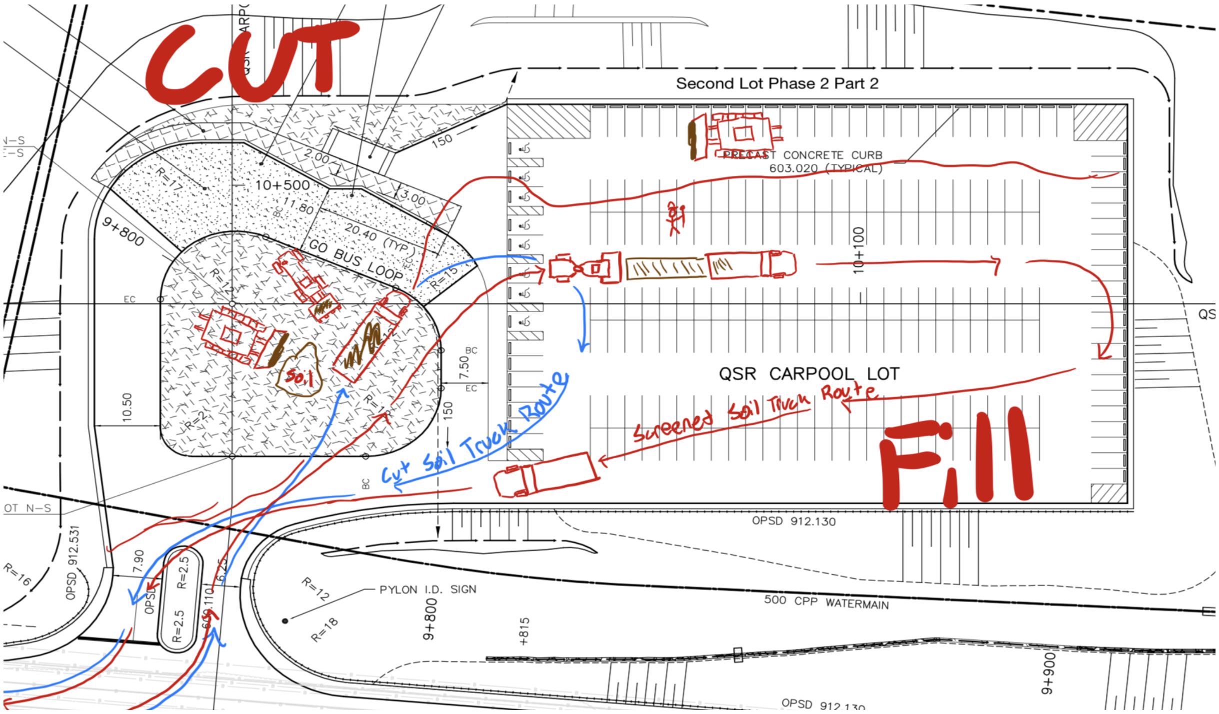
11582BCM * (1.25BCM/1BCM) / 407.54LCM/hr = 35.52hr or **4.44 days**

Round to **5 days** for clean up and finalization.

3) Plan of site layout for Phase 2, Part 2, Site 1



4) Plan of site layout for Phase 2, Part 2, Site 2



5) Part 2 Time (until cut #1 is complete):

Site 1

Will have cut 11582 BCM / 0.85 = 13626BCM, leaving 41171 BCM.

41171BCM * (1.25LCM/1BCM) / 427.2LCM/hr = 120.47hrs or **15.06 days**

Using loader production as it is the limiting factor

Round to **16 days** to also include one day of finalization.

Site 2

Dozer cut production = 76.31LCM/hr * 16 days * 8hrs * 2 dozers = 19535LCM or 15628BCM

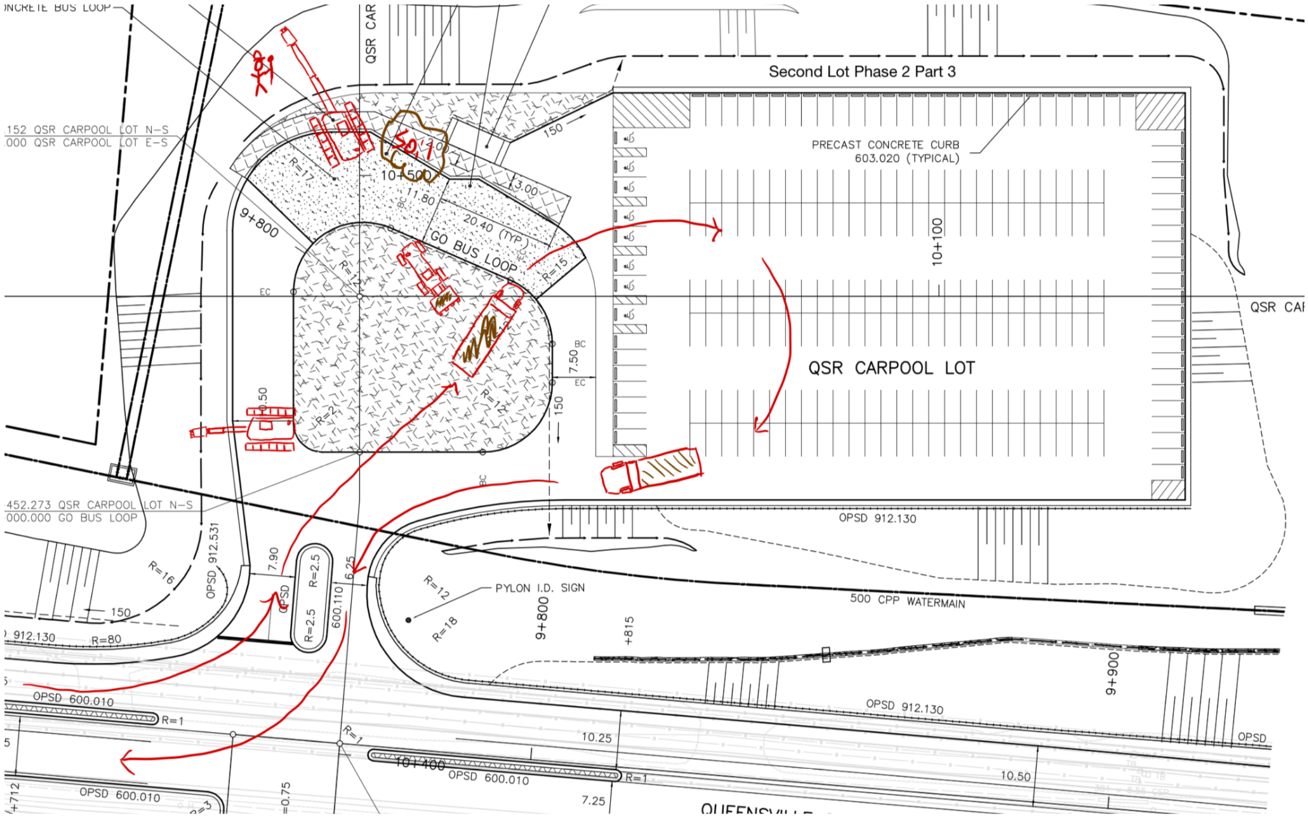
Production of 1 Loader = 250 LCM/hr > 152.62 LCM/hr = 2 dozers * 76.31 LCM/hr

Production of 4 type C trucks = 20.83 LCM/hr * 8 = 166.64 LCM/hr > 152.62 LCM/hr

∴ Dozer production governs

Leaves 13252 BCM to cut or 16565LCM

6) Plan of site layout for Phase 2, Part 3, Site 2



7) Part 3 Time (until cut site #2 complete):

Site 2

1 day to finish rest fo fill as it is only roughly 800BCM

Time for cut = (16565LCM) / (2 excavators * 249.86LCM/hr) = 33.15 hrs or **4.14 Days**

Going to need 16 565 LCM / (20.83 LCM/hr * 33.15 hrs) = 23.98 ∴ **24 trucks (C)**

Round to 5 days for fine tuning. Total of 6 days

8) Time for grading in Part 3 and 4

Time for grading:

Grading speed = 7km/hr

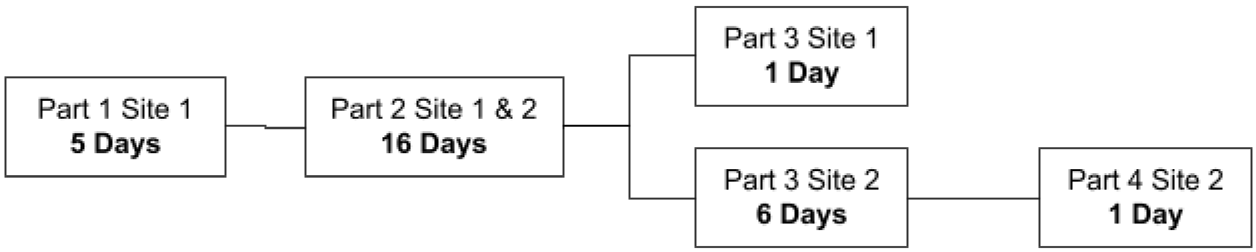
Blade width = 2.75m

Grader production = 7km/hr * 1000m/1km * 2.75 = 19250m2/hr

Parking is less than 19250m2/hr. Assume 1 hour/pass of a lot.

Therefore, **1 day** is plenty of time for the grader to properly grade the surface on one lot.

9) Overall Timeline of all parts in Phase 2



10) Crew composition at each stage

<u>Part 1 Site 1:</u>
4 Loaders, 2 Dozers, 2 Screeners, 1 Compactor, 1 Surveyor and 2 Excavators

<u>Part 2 Site 1:</u>
4 Loaders, 2 Screeners, 2 Excavators, 1 Surveyor, 1 Screener Operator, 3 Truck type C, 1 Truck type A (Shared with Site 2) 2 Truck type A and 3 Truck type B

<u>Part 2 Site 2:</u>
1 Compactors, 1 Surveyor, 2 Dozers, (Shared with Site 1) 2 Truck type A and 3 Truck type B

<u>Part 3 Site 1:</u>
1 Grader, 1 Surveyor, 1 Excavator, 1 Truck B

<u>Part 3 Site 2:</u>
3 Loaders, 2 Excavators, 1 Surveyor and 24 Truck type C

<u>Part 4 Site 2:</u>
1 Grader, 1 Surveyor, 1 Excavator, 1 Truck B]

Appendix F - Truck Comparison

The productivity and cost including gas, rent and operator costs were factored in when deciding on which truck to use. Truck C has the best productivity and cost ratio compared to the other trucks as can be seen in Figures C, D and E. Path C is assumed to be at a speed of 40 km/hr as it is residential and Path D is assumed to be 50 km/hr which is the Ontario standard. Path C is not only the cheapest, but it also leads to a shorter cycle time (more trips/hr), which leads to higher productivity. This is why path C will be used.

Truck	C						
			Path C (residential)		Path D		
Truck Efficiency	0.8333333		Distance	16	Distance	25	km
Operator Cost	55	$/hr	Speed	40	Speed	50	
Energy	3.8	L/km					
Capacity	20	m3					
Rent/day	620	$/day					
Gas Price / L	1.59	$/L					
PATH C			**PATH D**				
Trip time (hr)	0.8		Trip time (hr)	1		*ignoring loading and unloading time	
trips per hour	1.25		trips per hour	1			
soil hauled/trip	20	m3	soil hauled/trip	20	m3		
soil hauled/hour	25	m3	soil hauled/hour	20	m3		
Productivity	20.833333	m3/hr	Productivity	16.6667	m3/hr	*times efficency	
Day Production	**166.67**	**M3/day**	**Day Production**	**133.33**	**M3/day**	*assume 8 hour work day	
Costs			Costs				
Gas per trip	121.6	L	Gas per trip	190	L		
Gas Cost/trip	193.344	$	Gas Cost/trip	302.1	$		
trips/hr	1.25		trips/hr	1			
cost per hour	296.68	$	cost per hour	357.1	$		
Day Cost (assume 8 hou	2993.44		Day Cost (assume 8 hours	3476.8			
Cost/Unit Produced	**17.96064**	**$/m3 eve**	**Cost/Unit Produced**	**26.076**	**$/m3 every day**		

Figure C - Truck C Production, Cost and Time Calculations

Truck	B						
			Path C (residential)		Path D		
Truck Efficiency	0.8333333		Distance	16	Distance	25	
Operator Cost	65	$/hr	Speed	40	Speed	50	
Energy	2.9	L/km					
Capacity	15	m3					
Rent/day	550	$/day					
Gas Price / L	1.59	$/L					
PATH C			**PATH D**				
Trip time (hr)	0.8		Trip time (hr)	1		*add loading and unloading time	
trips per hour	1.25		trips per hour	1			
soil hauled/trip	15	m3	soil hauled/trip	15	m3		
soil hauled/hour	18.75	m3	soil hauled/hour	15	m3		
Productivity	15.625	m3/hr	Productivity	12.5	m3/hr	*times efficency	
Day Production	**125**	**M3/day**	**Day Production**	**100**	**M3/day**		
Costs			Costs				
Gas per trip	92.8	L	Gas per trip	145	L		
Gas Cost/trip	147.552	$	Gas Cost/trip	230.55	$		
trips/hr	1.25		trips/hr	1			
cost per hour	249.44	$	cost per hour	295.55	$		
Day Cost (assume 8 hou	2545.52		Day Cost (assume 8 hours	2914.4			
Cost/Unit Produced	**20.36416**	**$/m3 eve**	**Cost/Unit Produced**	**29.144**	**$/m3 every day**		

Figure D - Truck B Production, Cost and Time Calculations

Truck	**A**					
			Path C (residential)		**Path D**	
Truck Efficiency	0.8333333		Distance	16	Distance	25
Operator Cost	60	$/hr	Speed	40	Speed	50
Energy	2.5	L/km				
Capacity	10	m3				
Rent/day	390	$/day				
Gas Price / L	1.59	$/L				

PATH C			**PATH D**			
Trip time (hr)	0.8		Trip time (hr)	1		*add loading and unloading time
trips per hour	1.25		trips per hour	1		
soil hauled/trip	10	m3	soil hauled/trip	10	m3	
soil hauled/hour	12.5	m3	soil hauled/hour	10	m3	
Productivity	10.416667	m3/hr	Productivity	8.33333	m3/hr	*times efficency
Day Production	**83.333333**	**M3/day**	**Day Production**	**66.6667**	**M3/day**	
Costs			Costs			
Gas per trip	80	L	Gas per trip	125	L	
Gas Cost/trip	127.2	$	Gas Cost/trip	198.75	$	
trips/hr	1.25		trips/hr	1		
cost per hour	219	$	cost per hour	258.75	$	
Day Cost (assume 8 hou	2142		Day Cost (assume 8 hours	2460		
Cost/Unit Produced	**25.704**	**$/m3 eve**	**Cost/Unit Produced**	**36.9**	**$/m3 every day**	

Figure E - Truck A Production, Cost and Time Calculations

Appendix G - Granular B and A Placement Time Calculations

Granular B and A Transport Time:

Capacity per truck load delivered: 7 m3 [11]

Trucks of Gran B required = 3600 m3 / 7 = 515 truck loads

Trucks of Granular A required = 1613 m3 / 7 = 231 truck loads

*Assuming delivery from Y&T: 16 km away using residential path C at 40km/hr

With a loader spreading productivity of about 244 m3/hr, the truck delivering the granular is what will hold up the production. We can handle 35 trucks per hour with this loader production, but it is more likely to have trucks arriving at 10 minute intervals.

Front End Loader Spreading:

Average speed of Loader = 9.5km/hr

Average distance to and from stockpile = 85*2 = 170

Time per trip = 170/9500 = 0.0178 hr

Capacity per trip = 3.3 cubic yards = 2.52 m3

Productivity = 2.52m3 / 0.0178hr * efficiency = 117 m3/hr

Total Time Spreading Granular B = 3600m3 / 117m3/hr = 30.76 hr (about 4 work days)

Total Time Spreading Granular A = 1613 m3 / 117m3/hr = 13.78 hr (about two days)

<u>Grading Time for Granulars:</u>

Productivity = Volume/hr

Effective blade width (m) * average depth of cut (m) * grader speed (m/hr)* efficiency

= 2.75*0.1*7000*(50/60)

= 1604 m3/hr

Time for Granular B = 3600 m3 / 1604 m3/hr = 2.24 hours

Time for Granular A = 1613 m3 / 1604 m3/hr = 1 hour

<u>Compactor Productivity and Compaction Time</u>

Speed = 7000m/hr

Blade = 2.75 m

Efficiency = 45/60 = 0.75

Area covered/hour/pass = 7000*2.75*0.75 = 14437.5 m2/hr

Total Area of Granular Paving Required: 10,503.9 m2

Assuming six passes we get a total compaction area of: 10503.9*6 = 63023.4 m2

Time for each layer of Granular = 63023.4/14437.5 = 4.36 hr

Appendix H - Concrete and Asphalt Plant Comparison

Table 7 shows the time comparison of transporting concrete and asphalt from each plant. Assume the grade differences can be ignored on paved roadways. The speed on a highway that is tolled is assumed to be 110 km/hr and 50 km/hr on local routes.

Table 7. Time to get to the site from each plant

	Plant 1	Plant 2
Distance (km)	20	35
Speed (km/hr)	50	110
Time (hr)	**0.4**	**0.32**

Plant two is the faster plant despite being farther away since it utilizes the toll highway. It will also be less susceptible to traffic which will allow for more accurate scheduling projections.

A cost comparison is done between the two plants and can be found in Table 8. The unit price for materials is higher for plant 1, but the transportation cost is 0. We will be ignoring fuel costs in these calculations assuming them to be about the same for both paths. This is a valid assumption since travelling on a highway requires fewer stops/slowdowns. Accelerating speed leads to greater fuel consumption, and being on a highway especially with a toll will significantly reduce the speed fluctuation. This is assumed to equate to the extra fuel required to travel the greater distance between plant 2 and the site compared to plant 1.

Cost calculations in Table 8 are done for one trip to compare the two methods. **Assuming one trip transports about 9 cubic meters of asphalt/concrete.**

Table 8. Cost comparison of each plant

	Plant 1	**Plant 2**
Cost of Concrete	9*55 = 495	9*50 = 450
Cost of Asphalt	9*60 = 540	9*55 = 495
Cost of Travel	0	30
Total per Trip	**495/concrete, 540/asphalt**	**480/concrete, 525/asphalt**

Plant two is also the cheaper option as the higher unit price for plant one offsets the additional cost of using the toll route for plant 2. Even with the toll (one-way, assume regular roads used on return), plant 2 is cheaper. It is also faster based on Table 7 calculations. Therefore, all the concrete and asphalt on the job will be transported from plant 2.

Appendix I - Asphalt Paving Time Calculations

Trucks of Asphalt Required / Site

Total Asphalt Demand / site = 1460m3

Each truck = 9m3

Trucks required = 1460/9 = 163 truck loads

The trucks will be spaced at 10 min intervals for arrival.

Paver Time/site:

Average paver speed: 15m/minute*0.6 efficiency (includes loading time) = 9m/minute[12]

Average Paver distance from entrance = 85m

Time per run = 85/9 = 9.44 minutes = 0.16 hr

Paver Width of Pour = 2.5m

Total Paving Area covered per run = 85*2.5 = 212.5 m2/run

Total Area of Paving required = 9734/lift/site = 9734*3 = 29202m2

Total runs = 29202/212.5 = 137.42

Time for paving = 0.16hr/run * 137.42 = 22 hr (3 working days)

Time for Compaction:

Speed = 7000m/hr

Blade = 2.75 m

Efficiency = 45/60 = 0.75

Area covered/hour/pass = 7000*2.75*0.75 = 14437.5 m2/hr

Total Area of Asphalt Paving Required (all lifts): 29202m2

Assuming two passes we get a total compaction area of: 29202*2 = 58404 m2

Time for Asphalt Compaction (all lifts) = 58404/14437.5 = 4.045 hr

Appendix J - Concrete Paving Time

All times are calculated per lot (for one site only)

Bus Loop

Concrete: 183 m3 / site

Trucks required = 183 m3 / 9m3/truck = 21 trucks

Arrival every 30 minutes = around 11 hours of extended work and extra 1-2 hours for prep and cleanup. This will be an extended day for both sites with all labours on one task.

Concrete Pathway

Formwork is estimated to be placed in one day along the boundary. The pour will occur the following day and should not take the entire day. Crew can complete other tasks while this is being completed.

Concrete: 34 m3 / site

Trucks required = 34 m3 / 9m3/truck = 4 trucks

Arriving at 30 minute intervals and including brushed finish, the placement should not take more than half a day.

Appendix K - Subcontracting Costs: Seed and Sod, Curbs, Pavement Markings, Fencing, Lighting, Subdrains

All costs and times are calculated per lot (for one site only)

Topsoil and Sod:

Topsoil and Sod Unit Cost = 5.00/m2 [13]

Total Area = 1748m2

Total Cost = 1748m2 * $5/m2 = $8740

Concrete Curb (along the topsoil ground and Go Bus loop):

Concrete curb and gutter unit price = $75/m [14]

Total Curb Length = 104m

Total Cost = 104m * $75 = $7800

Precast Concrete Parking lot Bumper Curb:

Precast Parking lot Bumper Curb Unit Price = $77.53 /curb [15]

Total # of Curbs = 65

Total Cost = 65 curbs * $77.53/curb = $5039

Markings for Parking:

Parking Stall Line = $0.25/ft [16]

Total Length of Parking Stall Lines = 7024ft

Total Cost = 7024ft * $0.25/ft = $1756

Steel Beam Guide Rail:

Steel Beam Guide Rail Unit Price = $80/m [17]

Total Length of Guide Rail = 193m

Total Cost = 193m * $80/m = $15440

Lighting:

Spacing between poles = 6m [18]

Length of Parking Lot = 165m

# of Poles Required in Parking Lot:

In length direction: 165m / 6m = 27.5 poles

Assume 4 rows of lighting: 3 * 27.5 poles = 82 poles

Parking Lot Light Pole unit Price = $2000/pole [19]

Total Cost = 82 poles * $2000/pole = $164000

Subdrains:

150mm Subdrain Including Geotextile Unit Price = $27.50/m [20]

Total Length of Subdrains = 118.7m

Total Cost = 118.7m * $27.50/m = $3264.25

Appendix L - Construction Production Cost Calculations

Earthworks Costs

Part 1 Site 1:

2 Loaders * $350 000/Unit + ($95/h * 8h/day * 5 days) =	$703 800
1 Loader * $350 000/Unit * $1.3_{(Premium)}$+ ($95/h * 8h/day * 5 days) =	$485 800
1 Loader$_{(Owned)}$ * ($95/h * 8h/day * 5 days) =	+ $3 800
	$1 166 400

<u>THESE CALCULATIONS ARE FOR ALL PARTS A SCREENER IS USED</u>

2 Screeners * ($20 000/month x 1 month) + $6 000/setup =	$46 000
2 Screeners * 12L/h * 8h/day * 5 days/week * 4 weeks * $1.8/L =	+ $6 912
	$52 912
1 Excavator * $460 000 + ($85/h * 8h/day * 5 days) =	$463 400
1 Excavator(Owned) * ($85/h * 8h/day * 5 days) =	+ $3 400
	$466 800
1 Dozer * $530 000 + ($105/h * 8h/day * 5 days) =	$534 200
1 Dozer(Owned) * ($105/h * 8h/day * 5 days) =	$4 200
2 Dozer(Overtime) * ($210/h * 8h/day * 2 days) =	+ $6 720
	$545 120
1 Compactor * ($55/h * 8h/day * 5 days) =	$2 200
1 Compactor(Overtime) * ($110/h * 8h/day * 2 days) =	+ $1 760
	$3 960
1 Surveyor * ($40/h * 8h/day * 5 days) =	$1 600
1 Surveyor(Overtime) * ($80/h * 8h/day * 2 days) =	+ $1 280
	$2 880
Total for Part 1=	$2 238 072

Part 2 Site 1:

4 Loaders *95/h * 8h/day * 16 days =	$48 640
2 Excavator * $85/h * 8h/day * 16 days =	$21 760
2 General Labourers * $40/h * 8h/day * 16 days =	$10 240
3 Truck type C * $2993.44/day * 16 days =	$143 685
1 Truck type A * $2142/day * 16 days =	+ $34 256
	$258 581

Part 2 Shared:

2 Truck type A * (189 km/truck * 2.5 L/km * $1.8/L	
+ $390/day * 16 days + $60/h * 8h/day * 16 days) =	$29 541
3 Truck type C * (189 km/truck * 3.8 L/km * $1.8/L	
+ $620/day * 16 days + $55/h * 8h/day * 16 days) =	+ $54 758
	$84 299

Part 2 Site 2:

1 Compactor * $55/h * 8h/day * 16 days =	$7 040
1 Surveyor * $40/h * 8h/day * 16 days =	$5 120
2 Dozers * $105/h * 8h/day * 16 days =	+ $26 880
	$39 040
Total for Part 2=	$383 840

Part 3 Site 1:

1 Grader * ($290 000 + $80/h * 8h + 18L/h * 8h * $1.8/L)	$290 899
1 Surveyor * $40/h * 8h =	$320
1 Excavator * $85/h * 8h =	$680
1 Truck type B * ($550 + $65/hr * 8h + 2.9 L/km * 31 km * $1.8/L =	+ $1237
	$293 136

Part 3 Site 2:

3 Loaders *95/h * 8h/day * 6 days =	$13 680
2 Excavator * $85/h * 8h/day * 6 days =	$8 160
1 Surveyor * $40/h * 8h * 6 days =	$1 920
3 Truck type C * $2993.44/day * 6 days =	$52 881
3 Truck type C * $2993.44/day * $1.3_{(Premium)}$ * 6 days =	+ $490 319
	$566 960
Total for Part 3=	$860 096

Part 4 Site 1:

1 Grader * $80/h * 8h + 18L/h * 8h * $1.8/L	$899
1 Surveyor * $40/h * 8h =	$320
1 Excavator * $85/h * 8h =	$680
1 Truck type B * ($550 + $65/hr * 8h + 2.9 L/km * 31 km * $1.8/L =	+ $1237

$2 846

Total for Earthworks Phase=$3 484 854

Granular B and A Costs

Equipment Use

Site 1:

1 Compactor $_{(owned)}$ $55/h * 8h/day * 10 days = $3,080

1 Front End Loader$_{(owned)}$ $95/h * 8h/day * 10 days = $5,320

1 Grader (*$80/h + $1.8/L * 18L/h)* 8h/day * 10 days = $8,992

Site 2:

1 Front End Loader ($80/h + 12L/h [28 * $1.8/L) * 8h/day * 9 days = $7,315

(Share grader and compactor with site 1)

Total Granular Equipment Cost = **$24,707**

Material Purchase Cost

The cost to purchase all granular material including delivery is summarized in table 8.

Table_8. Costs for Purchasing Granular (Lot 1 and 2)

	Total Purchased (m3)	**Unit Price ($)**	**Total Cost ($)**
Granular A	3226	20.65	66,617
Granular B	7200	19.5	140,400
		Total	**207,017**

Asphalt Paving Costs

Equipment Use

Site 1:

1 Compactor $_{(owned)}$ $55/h * 8h/day * 3 days = $1,320

1 Paver$_{(rented)}$ ($3000/day [25] + ($1.8/L*14L/h + $80/h) * 8h/day) * 3 days = $11,524.8

Site 2:

1 Paver$_{\text{(rented)}}$ ($3000/day + ($1.8/L*14L/h [29] + $80/h) * 8h/day) * 3 days = $11,524.8

Share compactor with site 1 due to faster production

Total Paving Equipment Cost = **<u>$24,369.6</u>**

<u>Material Cost</u>

The total cost of purchasing asphalt from plant 2 and transporting it to the sites is summarized in Table 9. Each truck is assumed to carry 9 cubic meters of asphalt. 1 cubic meter is about 2.48 tons of asphalt [].

Table 9. Cost of Purchasing and Transporting all Asphalt from Plant 2

Asphalt Cost/ton	55
Asphalt Cost/m3	136.4
Plant Capacity	
unlimited	
unlimited	
Distance (km)	35
Speed (km/hr)	110
Time (hr)	0.32
Trips/hr	3.142857143
Cost ($/trip)	30
Trips required	324.4444444
Asphalt Transport cost	9733.333333
Asphalt Material Cost	398288
Total Cost of Asphalt	408021.3

Concrete Costs

Concrete costs are all including material and delivery. No special equipment is used for pour, so the bulk of the cost is the cost of ordering the concrete trucks. All concrete is purchased from plant 2 and uses the toll highway. The cost is summarized in Table 10. Assuming 9 cubic meters per truck and 1 cubic meter is 2.65 tons of concrete.

Table 10. Concrete Purchase and Transport Costs

Concrete cost/ton	50
Concrete cost/m3	132.5
Distance (km)	35
Speed (km/hr)	110
Time (hr)	0.32
Trips/hr	3.142857143
Cost ($/trip)	30
Trips required	53.33333333
Concrete Transport Cost	1600
Concrete Material Cost	63600
Total Concrete Cost	**65200**

Labour Costs

Assume that the labour crew of 10 will be working everyday for 8 hours. The total scheduled working days are 53 (excluding holidays). Labourer wage is taken as $75/hr [site experience PEY]. There will be overtime working on the two concrete pour days for the Bus Loop. We will pay all ten labourers 4 hours of overtime each day.

Total Labour Costs = 10 labours * 8h/day * $75/h/labour * 53 days = $318,000

Total Overtime Pay = 10 labours *(4*2)h * $75/h/labour = $6,000

Total Labour Costs = **$324,000**

Appendix M - Carbon Emissions Savings by Using Screener

Total Fill (both lots) = 47326 m3

Total Cut (both lots) = 83678 m3

Table 11. Haul Volume Savings

Hauling Type	Haul Volume with no Screener (assume 50% of fill is from cut) (m3)	Haul Volume with Screener (assume 100% of fill is from cut) (m3)	Reduction of Haul Volume by Integrating Screener (m3)
Backfill	23663	0	23663
Cut	60015	36252	23663

The number of truck trips saved by using a screener assuming we use the most efficient truck (truck C) to be conservative, can be seen in Table 12. Every trip hauls 20 m3 and will take Path C, the shortest path to Y&T which is a 32 km round trip.

Table 12. Total Trips Saved.

Hauling Type	Number of Trips to/from Y&T without Screener	Number of Trips to/from Y&T with Screener	Number of Trips Saved
Backfill	1184	0	1184
Cut	3000	1813	1187
Total Trips Reduced: 2371			

To determine the emissions saved, the total fuel saved is used. Truck C uses 3.8 L of gas per kilometer. Each round trip is 32 km. The volume of gas saved is as follows:

Liters of Fuel Saved = 2371 trips * (3.8L/km * 32km)/trip = **288313.6 L**

About 2.3 kg of carbon dioxide is emitted per litre of gasoline consumed [21]. Diesel would be even more.

Carbon Dioxide Reduced = Total Gasoline Saved * Carbon Dioxide Emitted per Litre of Gas

Carbon Dioxide Reduced = 288313.6L*2.3kg/L = **663121.28 kg or 664 metric tonnes**

Appendix N - Takeoff Quantities

Item	No.	L	W	H	Sub Total	Total	2nd Parking Lot	Total (2 Parking lots)	Unit
Concrete Barrier Curb OPSD 600.110		42.97			42.97	42.97	42.97	**86**	m
Curb in front of patterned concrete walkway		61.34			61.34	61	61	**122**	m
Concrete Go Bus Loop									
Concrete JPCP 240 mm		762.35		0.24	183	183	183	**366**	m3
Granular A 200mm		763.35		0.2	153	153	153	**306**	m3
Granular B 250mm		764.35		0.25	191	191	191	**382**	m3
Patterned Concrete Walkway		225.97		0.15	33.89	34	34	**68**	m3

Go Transit Bus Shelter Type A Shelter with Type B Platform									
Concrete Base		50		0.46	23	23	23	**46**	m3
Topsoil Area (seed/sod)									
Grass 1		1492.62			1492.62	1493	1493	**2986**	m2
Grass 2		255.23			255.23	255	255	**510**	m2
Carpool Lot Area									
Asphalt Lift 1 40		7653.44		0.04	306	306	306	**612**	m3
Asphalt Lift 2 50		7654.44		0.05	383	383	383	**766**	m3
Asphalt Lift 3 60		7655.44		0.06	459	459	459	**918**	m3
Granular A		7656.44		0.15	1148	1148	1148	**2296**	m3
Granular B		7657.44		0.35	2680	2680	2680	**5360**	m3
Asphalt around Go Bus loop									
Granular A		2080.11		0.15	312	312	312	**624**	m3
Granular B		2080.11		0.35	728	728	728	**1456**	m3
Precast Concrete Curb OPSD 603.020	65				65	65	65	**130**	EA
Steel Beam Guide Rail		193.01			193.01	193	193	**386**	m
Subdrain 150mm									
Bus Shelter		35.94			35.94	36	36	**72**	m
Concrete Bus Loop		82.76			82.76	83	83	**166**	m
Pavement Markings									
White Parking Lines	219	5.76			1476.15	1476	1476	**2952**	m
White markings around perimeter		664.99			664.99	665	665	**1330**	m