FINAL REPORT - RIVERTON CITY PUBLIC WORKS

CHR Engineers - Luke Rowley, Seth Harris, Brian Clancy
Graduate Mentor: Russell Irion

Department of Civil & Environmental Engineering
Ira A. Fulton College of Engineering and Technology
Brigham Young University

Executive Summary

To meet the secondary water filtration needs of Riverton City, CHR Engineers designed a portable filtration system. This is a system that would be manufactured to fit on an 8’ x 10’ pull along trailer that would be towed by one of the city’s Trucks. The system includes hose hook up, a weir, multiple 100 and 50 micron filters, exit points for filtered water and a compartment where filters will be cleaned and sediment from the blow outs will be disposed.

If the proposed solution is implemented by Riverton City, it will affect the city and every citizen of Riverton who lives in the city’s 610 hundred cul-de-sacs. On a municipal level, implementation of this system will make the city’s practices in removing secondary water line particulates compliant with the EPA’s secondary water filtration regulations. On a citizen level, the system will provide a cleaner solution than the status quo blowout method. Various advantages and disadvantages to the proposed design are carefully discussed in the subsequent report.

Contents

List of Figures

List of Tables

1) Introduction

1.1 Background Information

The City of Riverton is a growing suburb of Salt Lake which needs to improve their secondary water filtration methods in order to meet EPA standards. Subdivisions have been constructed and the cul-de-sacs in these new subdivisions are supplied with open ended secondary water lines (lines for non-potable water). The inherent issue with the open-ended water system is clearing out sediment which gets trapped at the end of these lines. At the end of the open ended water lines, sediment builds up. Previously, to clean the line, Riverton has simply “blown out” thousands of gallons of sediment rich water and let it run into the storm drain. Social and ethical problems have arisen from this. Sediments left from the blow-outs release sediment into the streets and storm drains of the cul-de-sacs. Additionally, and more substantially, allowing sediment saturated water to run into the storm drains is now forbidden by the EPA. Riverton City has charged CHR Engineers with the task of designing a secondary water filtration system that will serve as a replacement to the current blow-out method.

1.2 Key Limitations and Constraints

The filtration system design must be one that achieves a level of usability and positive environmental impact that is better than the status quo. To achieve this level of efficient design, the following constraints and limitations were considered: time, convenience and socio-economic issues.

The City of Riverton must clean all of the open water lines semi-annually. With 610 open ended water lines, 1220 blowouts are conducted annually. Blow outs are run seven months out of the year, which means that the city workers need to run average of 175 blowouts per month. Riverton City currently has two city workers who run all of these blowouts together. It usually takes 15 minutes to run a blowout. To make the system efficient, it must also be able to clean out an open-ended water line in around 15 minutes.

Figure 1 A common Riverton Cul-de-sac with the open ended water line illustrated in blue.

The usability of the design was another consideration in the design process. Although according updated EPA standards the current blowout process is illegal, it is still a simple process. All one has to do is simply run the water into the storm drain until the water runs clear. Now that the water has to be filtered, the system has to be efficiently filtered without requiring an excessive amount of screen and sieve cleaning on part of the technician. By nature, running water through a filtration system and cleaning filters will require more technical expertise than running the blowouts; but the new filtration system must be user friendly if it is to be implemented by Riverton City.

Along with efficiency and usability, the design also had to consider socio-economic impact. The blowout system was economically inexpensive, but it sparked citizen complaints because of sediment left in the neighborhoods. The new system has to be cleaner and leave no footprint. Traffic obstruction from city vehicles being used to operate the filtration system is also a concern to citizens. In addition, the system needs to be quiet, economical, and needs to filter the water with such efficiency that it will be EPA compliant.

1.3 Governing Assumptions

A flow rate of 400 gallons per minute (gpm)was assumed for the flow of water out of the open-ended water line into the system. A conservative estimate of 0.5 cubic yards of sediment per blowout is assumed. With consideration to the sieve grade in the system, it was assumed that the sediment was previously filtered by a 200 micron sieve. Thus, sieve sizes greater than 200 microns were deemed unnecessary for filtration. All of these assumptions were made based from figures told us by Riverton City Public Works.

2) Report

2.1 Deciding on a Design

CHR Engineers held multiple collaboration meetings with Riverton Public Works. Design ideas were discussed for the proposed filtration system and three preliminary ideas were narrowed down, including a system using settling bags, a filter and settling basin system and a fabricated screen system

2.1.1 Settling Bags

The first of the design options included using settling bags for trapping the particles, with various other design aspects to account for other constraints. Part of this design included using a tiered, two to three bag system with the bags on top of one another in a truck, with an openable back to the truck for access in attaching hoses and cleaning out the bags. The blowout was to flow from the secondary water line through a hose that would split into three separate hoses, one for each settling bag. The velocity of the blowout was to be decreased by a combination of the hydraulic jump involved in getting the water up from the ground level to the top of the truck and the division of the flow into three separate hoses. It was considered possibly necessary to offset the three divisions of the hose so that the highest velocity can go into the first hose and to the settling bag on the top, which would create the largest hydraulic jump and compensate for the velocity that it would have from being the first of the three hoses. Once the water-particle mix got into the settling bags, the settling bags would fill with the particulates, and the water would flow out of these settling bags, so the surface that the bags rest on would need to have been a screen or mesh to allow the cleaned water to flow through the bottom of the truck, onto the ground, and then into the storm drain. At this point in designing, it was still to be determined what methods may have been necessary to clean out the settling bags for this idea to work efficiently. As this design was researched, it was determined that this would not be the most feasible idea due to the problem of cleaning out the settling bags in an efficient manner.

2.1.2 Filter & Settling Basin

In the initial meeting, a filter system was revealed which was designed by a former Riverton field technician. A diagram of the system can be seen in the appendix. Not long after this system was initially proposed, and reviewing the system carefully together had been done, it was concluded that this system was impractical due to the amount of effort it would take to clean the filters during the filtering process. A new system was brainstormed which would have made the filter system more efficient. Upon realizing that the on-site cleaning and the disposal of the material which was filtered out were both impractical, it was concluded that the filter system could be altered. In the beginning, the idea was that unfiltered water would enter into a filter and come out clean. This was a problem as the amount of material in the system would be as shown below in Figure 2, with more sludge in the system in the first few moments of the blow out.

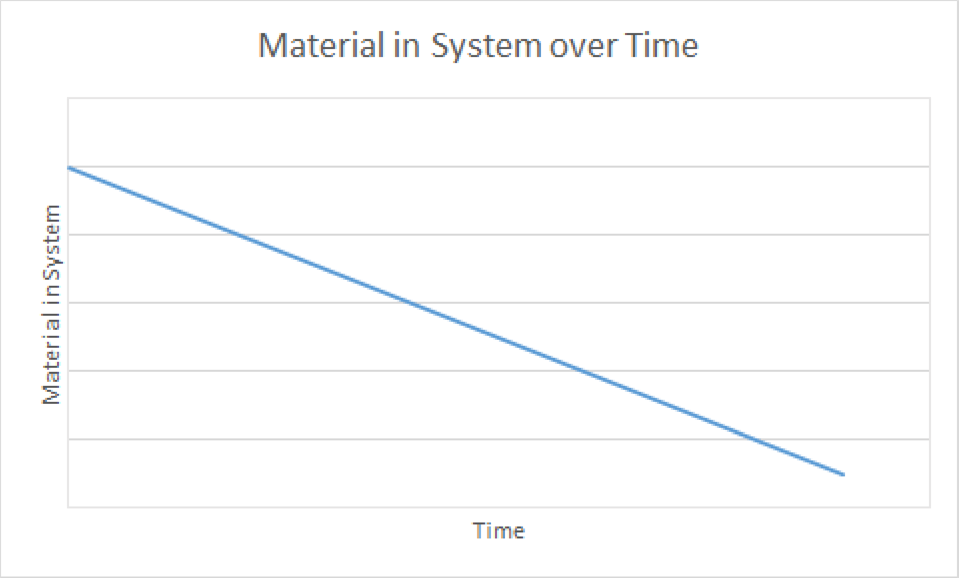


Figure 2 Amount of material in the secondary water system over time as water is cleansed

To deal with the issue of a large amount of sludge in the initial moments of cleaning, the system would have had a blow off that would push the initial minute of slow highly concentrated material in the water into a basin. After the amount of sludge in the system decreased, this would be closed and forced through a filter system located above the basin. However, material would still have built up in the filters and slow the flow of water.

During this process, as the buildup of material in the filters became too great, a temporary blow out would need to have been added to the filter itself. Just as this system was to clean the sediment and particulate material from the secondary line, this blow out would have guided the material in the filter into a catch basin. This process would have been quick. A stop of flow from the clean water and opening the blow out for the filter would have forced any material cleaned out by the filter to be washed out, leaving the filter much cleaner and allowing for the cleaning of water to continue without slowing down. The basin that the water and material would have been released into was to be a basin laden with screens allowing for the water to be cleaned even further. This process of cleaning was explained previously. As the basin became more laden with mud, the system would have needed to return to the shop to remove the material.

In the end, this design became impractical because of the inherent issues with cleaning in the field, as well as the larger problem of too many particulates per blowout than the system could handle.

2.1.3 Fabricated Screens

Another design idea involved the use of a fabricated screen system. The system would have been fabricated inside of a clean dumpster that could be loaded onto one of Riverton City's hook trucks. A six inch diameter hose connected to the secondary water system was to pump water and sediment into the dumpster. With the height drop that was to occur when the water fell from the top of the dumpster to the bottom, head loss would occur and make the flowing 400 gpm of water more manageable. The length of the dumpster was to contain eight removable screens of four different gradations. Two screens of each gradation were to be placed next to each other to act as a double screen system. The four double screen sieves were to be placed equidistant to each other in the system. The purpose of the double screens of each gradation was to allow for screen cleaning during the filtration process. While one screen was being cleaned, the other screen could be in place to continue with the filtration process. With a concept similar to a geotechnical sieve test, the gradation of the screens was to gradually get finer as the water went through the system. The last sieve that the water was to pass was a 50-

micron screen. After the water had flowed through the length of the dumpster, it would have exited out of a hose connection at the end of the dumpster. When the “blow out” for the cul-de-sac had finished, the dumpster truck and could have been transported to another facility for sediment removal and cleaning. Because the screens were removable, the technician would simply have to remove the screen and spray it off with a hose. The sediment in the dumpster could be dumped in a landfill. Possible issues with this plan were discussed, adjustments were made and the final design began to unfold.

2.1.4 Creation of the Final Design

At this point, with three design ideas ready to be further analyzed and tested, a plan needed to be made of specific goals and actions. To provide the necessary deliverables, CHR Engineers planned to use a design, analyze and testing process. As the work was divided and detailed, specific designs for each of these models were created. The designs included dimensions and effort expended to ensure a thorough design. After designs were created, they were each carefully reviewed and revised accordingly. Pros and cons to each design were be brainstormed, and one of the three design options was selected for final presentation. A flow chart with specific dates and goals throughout this process is included in the appendix.

As each of the three potential designs was being finished, multiple meetings were held to determine which would be the best design. Issues were discussed, and it was determined that the fabricated screens system was to be the best design. When this design was presented, however, several issues were made manifest, and adjustments had to be made, and an adjusted plan was created. With additional insight for possible issues with any design presented, the final design was repeatedly scrutinized mercilessly, with the goal of ensuring success. An adjusted version of the fabricated screens system was used, and is presented as follows.

2.2 Weir and Sieve System: The Final Design

Having already been through a handful of design ideas, the team's largest issue was finding a filtration system that would be realistic for the field technicians to use. Since the issue with the fabricated screens system was being able to remove the screens and clean them during the filtration process, Riverton City suggested rotating the fabricated screen system 90 degrees and having the screens placed horizontally in a vertical system. Instead of water flowing horizontally through a vertical screen system, the water would trickle vertically downwards through a series of horizontally placed screens. Please note that the words "sieve" and "screen" are used interchangeably. This system would be placed on the back of a tow-along trailer. For visual reference, refer to the following figures.

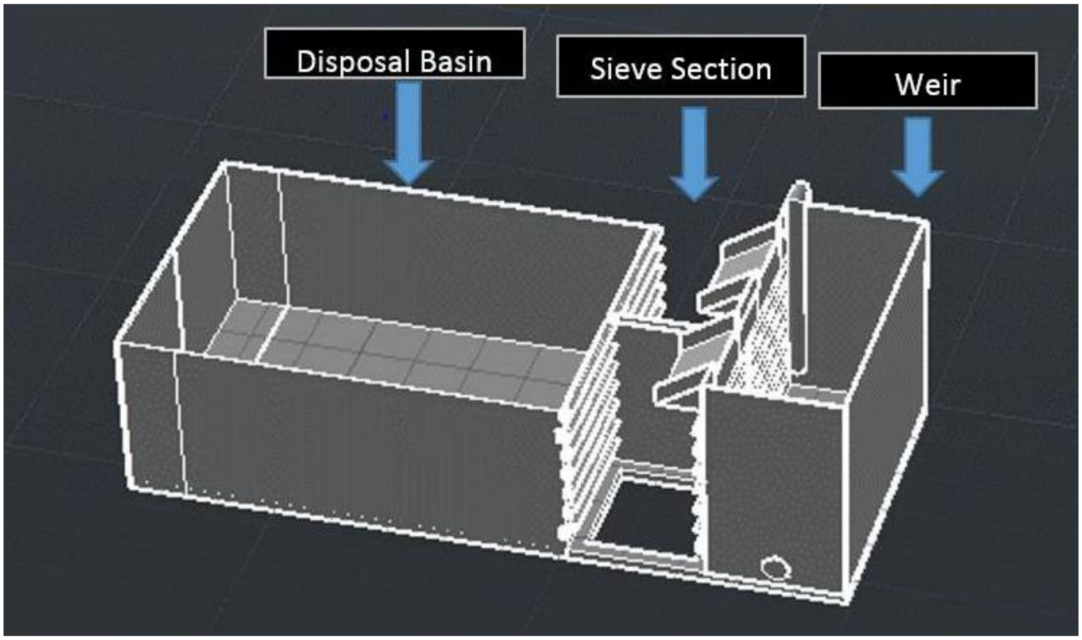


Figure 3 Profile view without the removable micron screens

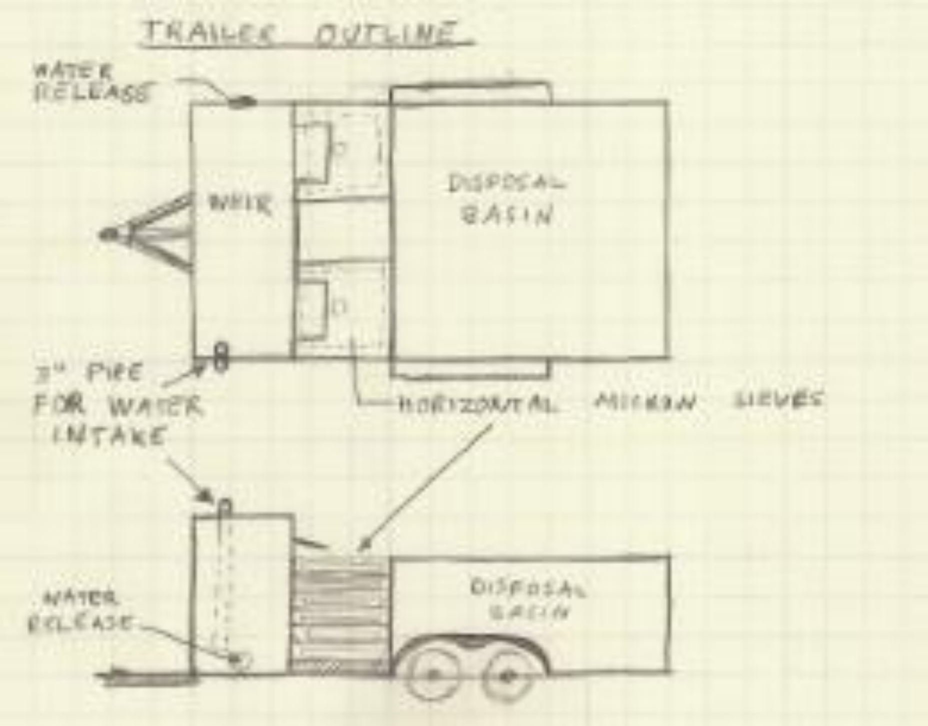


Figure 4 Plan and Side Views of the Weir and Sieve System respectively

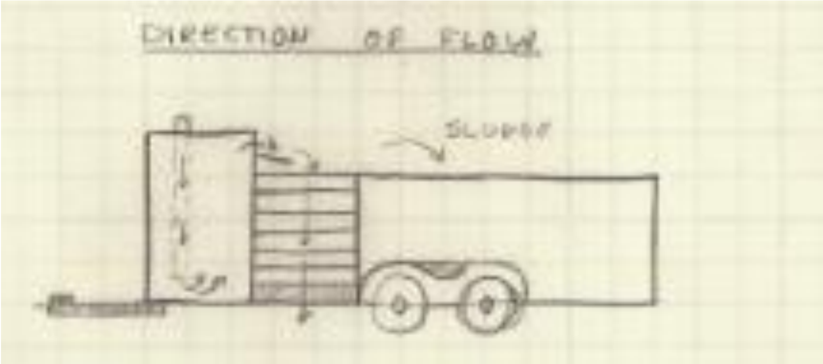


Figure 5 Direction of Flow through the System (indicated by Arrows)

Water from the open ended lines is drawn out by 3” diameter hose and the other end of the hose is attached to a 3” pipe at the top of an initial catching basin. Head loss occurs as the water travels from ground level to the top of the weir and through the bend in the pipe, helping decrease some of the velocity in the pipe. As water flows out of the hose, entrance of the water into the larger area initial basin substantially slows down the velocity of the water. The initial basin fills up**,** and the water eventually flows through one of two weirs at the top of the weir. Both weirs lead the flow through a series of screens. A side view of one of these two series of screens is shown in Figure 5. The first set of 3 screens is 80 microns while the second set of 3 screens is 40 microns (50 microns is the standard for filtration in secondary water systems). After the water has run through the sieves, it falls onto the street and runs clean into the storm drain.

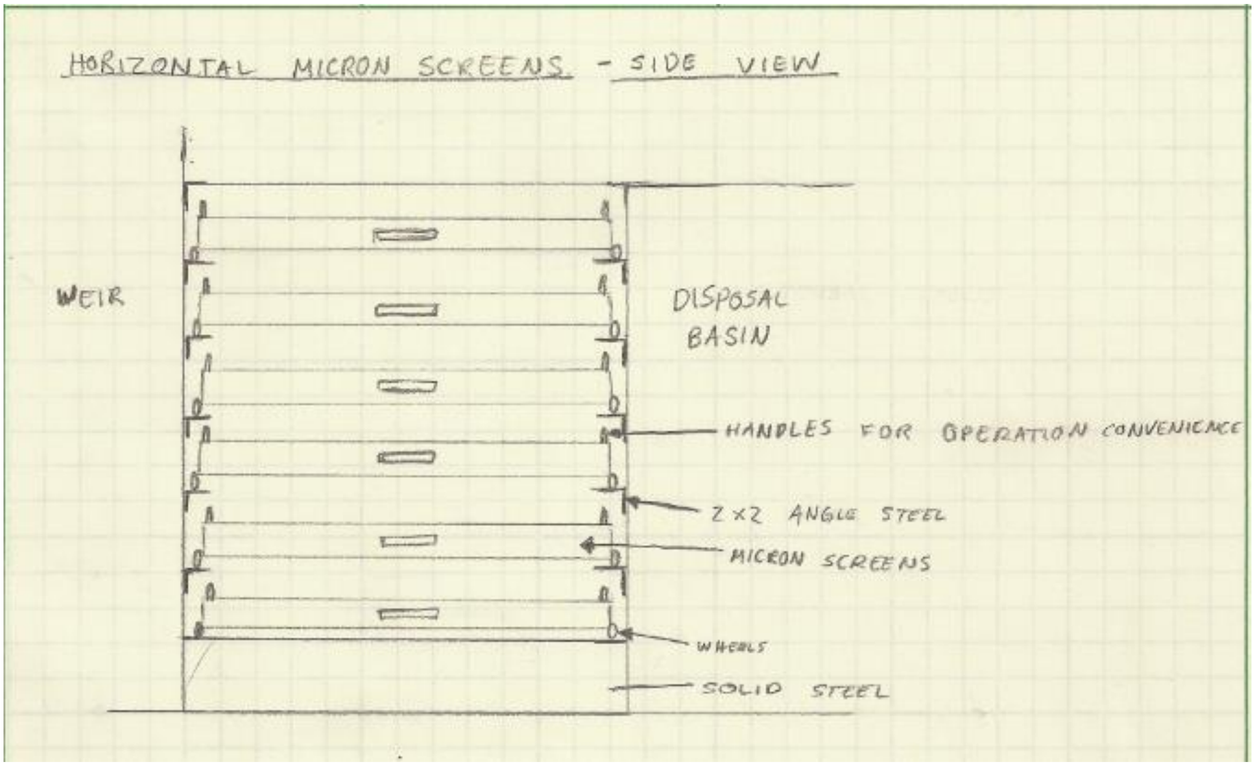


Figure 6 Horizontal Micron Screens (Side View)

To allow for ease in changing the screens while water is flowing, a series of removable micron screens was designed. Each of these screens is framed with a wooden box. The wooden box is mounted with 4 wheels and a handle. When a clogged screen needs to be cleaned out, the operator simply grabs the handle and pulls out the framed screen. 2x2 angle steel serves as a track for the wheels to roll on, providing relative ease for the operator in pulling out the framed screen. When the screen is removed, the operator dumps the sediment into the disposal basin, rinses the screen and places it back into its track in the system. When the open ended water line has been cleaned of sediment, the technician will close the door (See Figure 6) in order to secure the screens while the trailer is in motion. Water and sediment that are left in the initial catching basin after the filtration process is completed can be drained out by pulling the water release plug (see Figures 3 and 4). This plug operates in a similar manner to a plug or a drain in a shower or a bathtub. For sediment and water that settle below the level of the water release plug, the operator may need to scoop it out with a shovel and place it in the disposal basin.

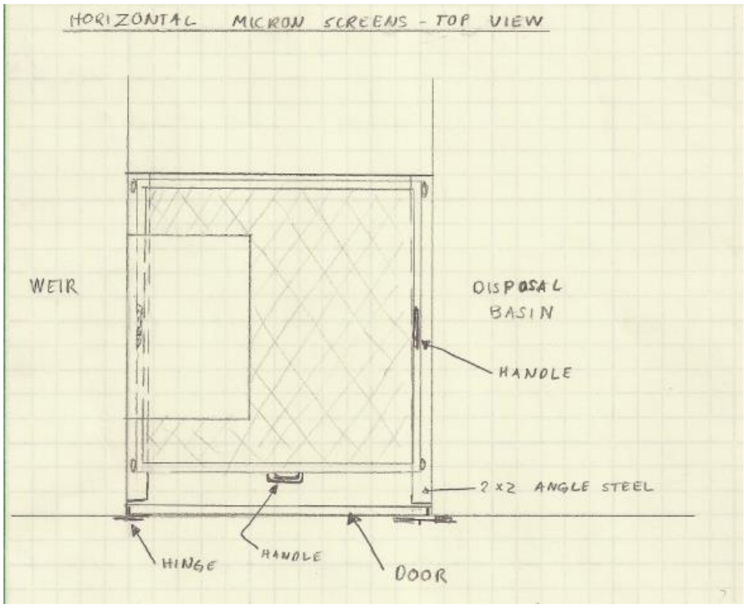


Figure 7 Horizontal Micron Screens (Top View)

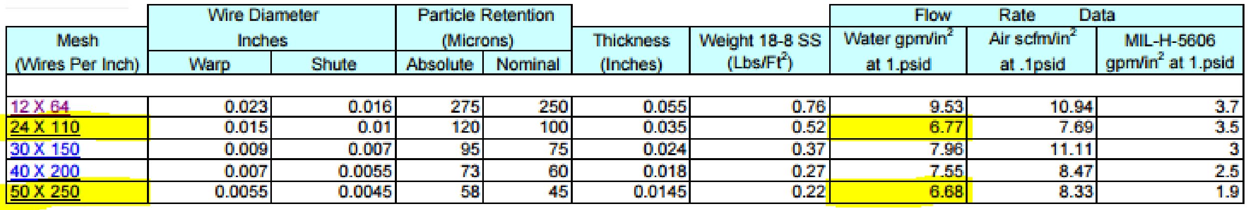
2.3 Analysis of the Weir and Sieve System

2.3.1 Flow of Water and Sediment through the Sieves

The flow of sediment and water will flow through a 26" x 24" (624 square inches) sieve. Before the water is sieved, the flow will be split into one of two weir channels which will carry the flow to the sieves. The system which has an initial flow rate of 400 gpm will now flow at 200 gpm through the sieves because of the 2 weir channels dividing the flow in half. The 80 micron mesh can handle a flow rate of 6.77 gpm/in2, and the 40 micron mesh can handle a flow rate of 6.68gpm/in^2 (refer to Table 1). With each sieve being 624 square inches, the 80 and 40 micron meshes can withstand maximum theoretical flows of 4224.48 and 4168.32 gpm respectively.

Since the system can easily withstand the flow of water, we assume that it can also withstand the flow of the sediment with water.

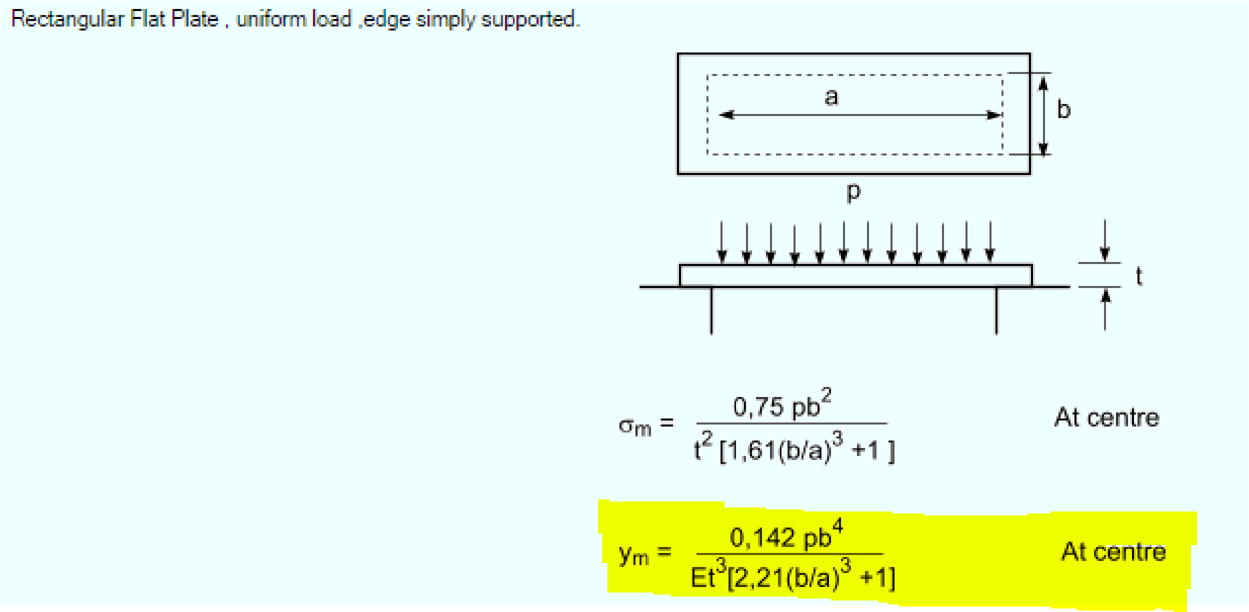
Table 1 Flow Data for Sieve Cloth (24 X 110 represents 80 Micron Mesh while 50 X 250 represents 40 Micron Mesh); Copyright TWP Inc. 2007



	Wire Diameter Inches		Particle Retention (Microns)				Flow Rate Data		
Mesh (Wires Per Inch)	Warp	Shute	Absolute	Nominal	Thickness (Inches)	Weight 18-8 SS (Lbs/Ft^2)	Water gpm/in^2 at 1.psid	Air scfm/in^2 at .1psid	MIL-H-5606 gpm/in^2 at 1.psid
12 X 64	0.023	0.016	275	250	0.055	0.76	9.53	10.94	3.7
24 X 110	0.015	0.01	120	100	0.035	0.52	6.77	7.69	3.5
30 X 150	0.009	0.007	95	75	0.024	0.37	7.96	11.11	3
40 X 200	0.007	0.0055	73	60	0.018	0.27	7.55	8.47	2.5
50 X 250	0.0055	0.0045	58	45	0.0145	0.22	6.68	8.33	1.9

2.3.2 Deflection of the Screens due to Sediment Weight

With the possibility of 1400+ lbs of sediment hitting the mesh screens during one blowout, deflection must be taken into account. The deflection calculations were based on three assumptions: 1) the stainless steel mesh has a poisson's ratio of 0.30, 2) the load on of sediment on the mesh is treated like a uniformly distributed load on rectangular flat plate (refer to Figure 7, and 4) the sediment load is spread evenly through all of the meshes. When the sieve boxes are 10% full of sediment, the 80 micron mesh undergoes a deflection of .059 meters at center while the 40 micron mesh undergoes a deflection of 0.258 meters. To ensure that the mesh doesn't deflect beyond breaking capacity, city workers will need to clear the sediment from one sieve box every 15 seconds in order to keep blowouts to the 15 min status quo. This is assuming that 0.5 cubic yards of sediment passes through the system in each blowout, which is a conservative estimate.


Rectangular Flat Plate , uniform load ,edge simply supported.

$$\sigma_m = \frac{0,75\, pb^2}{t^2\,[1,61(b/a)^3 + 1\,]}$$ At centre

$$y_m = \frac{0,142\, pb^4}{Et^3[2,21(b/a)^3 + 1]}$$ At centre

Figure 8 Deflection of a uniformly loaded plate
(http://www.roymech.co.uk/Useful_Tables/Mechanics/Plates.html)

2.3.3 Towing Capacity and Sediment Load on City Vehicles

The City of Riverton currently designates use of a 2005 Ford F-150 for blowouts. Assuming that the truck has automatic transmission and is in good condition, it can have a towing capacity ranging between 5000 and 9900 pounds (Refer to Table 2 in the Appendix). With a 900 pound filtration system, a 400 pound pull along trailer and an estimated 1485 pounds of sediment per half cubic yard; the truck would be able to tow about 2.5 blowouts worth of material before the city workers would have to clear the disposal basin and lighten the load of the truck for more blowouts. Again, this is assuming that every blow out yields exactly a half cubic yard of material.

2.3.4 Cost Analysis

Inherent in the weir and sieve system solution is manufacturing cost. The materials cost for building the system would cost around $5,000 (Refer to Table 3 in the Appendix). This includes an actual materials cost of $4603.69, tax, shipping and the cost of two items on the materials schedule that were not able to be found through research. Additional costs include the cost of a hook-up trailer and the cost of labor to build the system. In addition, costs can be adjusted by buying from other manufacturers, and adjusting the design and the materials of the system. The current system is designed in such a way that all stainless steel has to be custom cut by the manufacturers. If the system was adjusted to fit generic dimensions (e.g. 1' x1' or 14" x14"), then the steel would not have to be custom cut, and the price would decrease. In the event that Riverton alters the system design, they can enter the new materials and dimensions into a custom spreadsheet, which will be included with the deliverables. The spreadsheet can run new cost estimates, calculate the weight of the system, and figure out how many cul-de-sacs the system could clean before the disposal basin would need to be emptied. This designed solution would be much less expensive than the $30,000 fine that Riverton City would have to pay if they don't comply with the EPA's standard.

2.3.5 Socioeconomic Considerations

Riverton City already has a pick-up truck and will be able to tow the system. For safety reasons, there are also two people hired that work together to run all of the blowouts. As the system is designed to fit on a tow along trailer and designed to be operated by two people, the system will not incur any additional fixed costs. The main financial cost of the system is manufacturing.

The social benefits and potential for this design are worthy of note. Because the system is able to store all sediment and waste in a disposal basin, sediment won't be left on the street for street sweepers to clean up. Additionally, as the system has not mechanical or electrical components to it, it will not require energy to run. With the absence of any motors in the system, there will be no additional noise. Citizen complaints will thus be decreased. Since clearing sediment in these open ended water lines is an issue prevalent in many cities along the Wasatch Front, this solution, if proven socioeconomically desirable, could be replicated throughout Utah.

3) Conclusions

In meeting the requirements of removing suspended particulates from the cul-de-sac ends of the secondary water line for the City of Riverton, it is concluded that the aforementioned design is sufficient. The weir and sieve design decreases the velocity of the blowout mechanism in a way that actually uses the high flow rate advantageously; provides adequate means for catching, storing, and disposing of particulates down to the smallest required size; and allows for the cleaning of said screens while a blowout is being performed.

Further analysis may be required as this system is implemented. While the screens were designed based on an assumption of smallest particle size, a visual analysis after each blowout should be performed to ensure that a significant amount of particulates has been captured. Additionally, it will be necessary for those performing the blowouts to carefully monitor the screens to ensure that they can be removed and cleaned *before* the screens deflect to their breaking point. It is also recommended that the design be analyzed further in ways that can only be discovered through implementation of the design, to ensure overall effectiveness. Brigham Young University representatives have offered use of their research facilities for the testing of any prototype that Riverton City would like to test. Should changes need to made in the design, it will be made easier through the provided AutoCAD drawings and excel spreadsheet. It is left to the discretion of Riverton City Public Works to make these analyses and adjustments.

4) Appendix

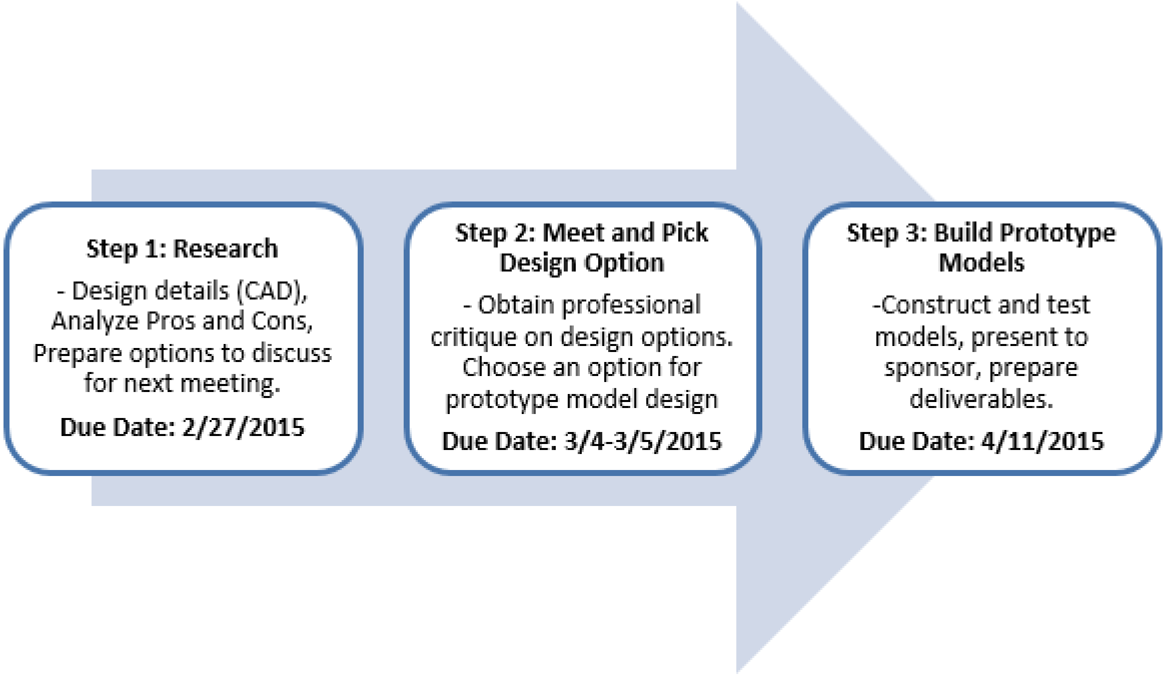
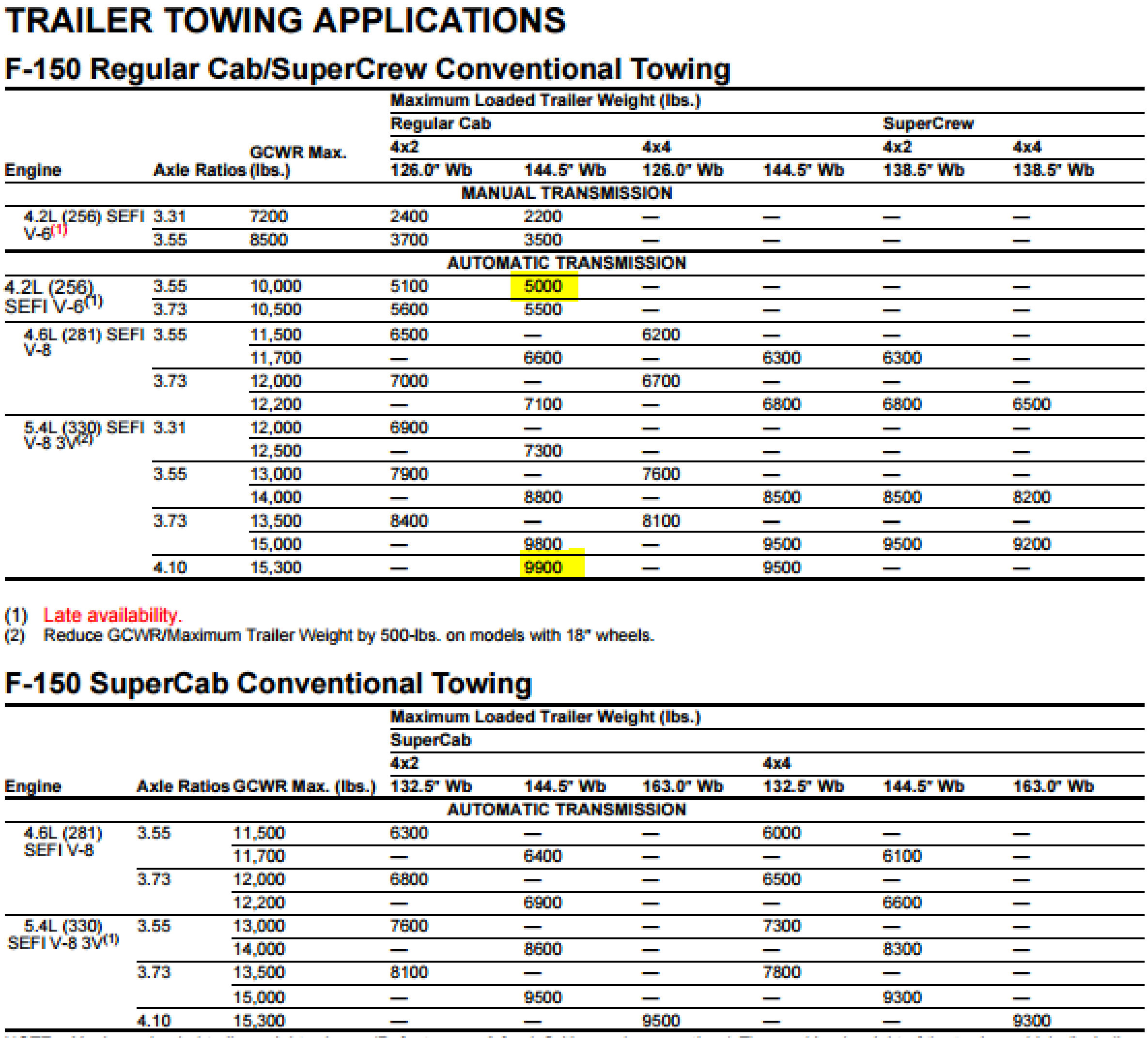


Figure 9 Proposed Flow Chart of Timeline of Events

Table 2 Conventional Towing Capacity of a 2005 Ford F-150 Pickup (Ford 2005 RV and Trailer Towing Safety Guide, 16)



TRAILER TOWING APPLICATIONS

F-150 Regular Cab/SuperCrew Conventional Towing

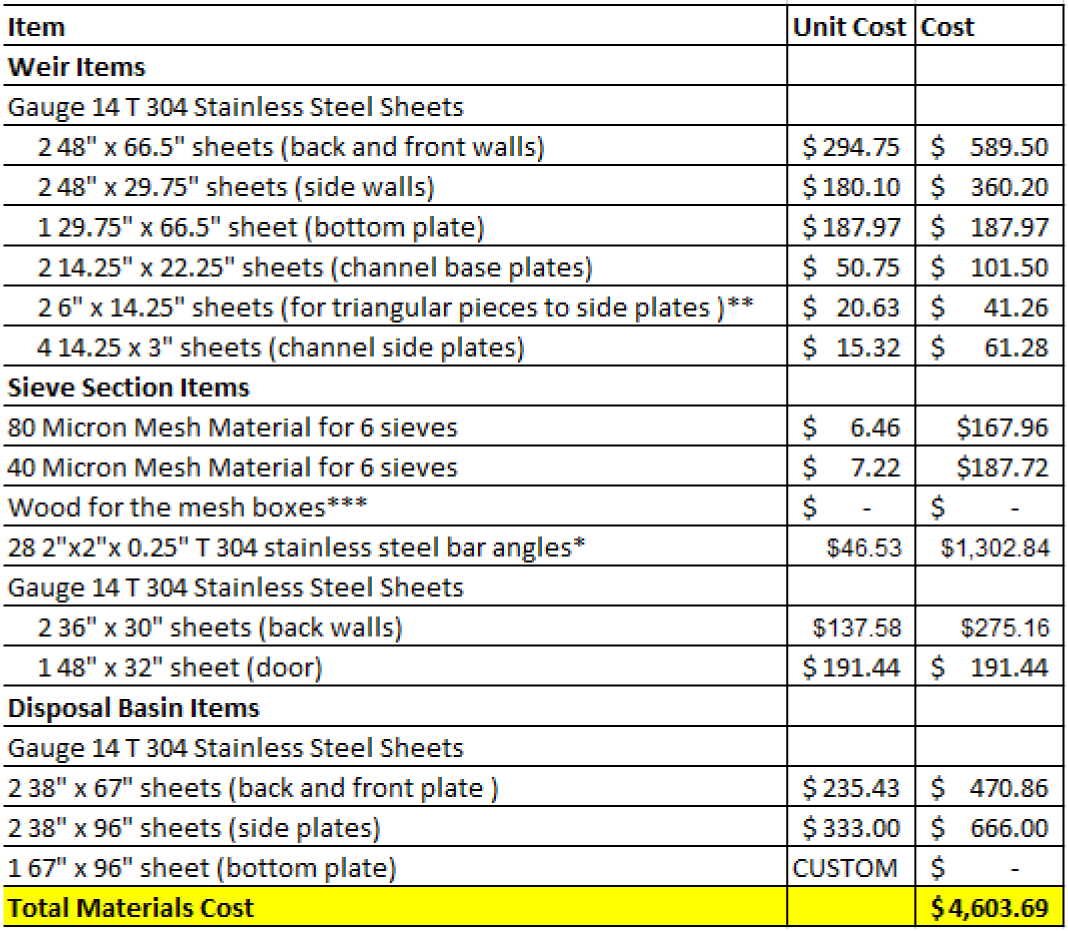
			Maximum Loaded Trailer Weight (lbs.)					
			Regular Cab				SuperCrew	
			4x2		4x4		4x2	4x4
Engine	Axle Ratios	GCWR Max. (lbs.)	126.0" Wb	144.5" Wb	126.0" Wb	144.5" Wb	138.5" Wb	138.5" Wb
			MANUAL TRANSMISSION					
4.2L (256) SEFI V-6[1]	3.31	7200	2400	2200	—	—	—	—
	3.55	8500	3700	3500	—	—	—	—
			AUTOMATIC TRANSMISSION					
4.2L (256) SEFI V-6[1]	3.55	10,000	5100	5000	—	—	—	—
	3.73	10,500	5600	5500	—	—	—	—
4.6L (281) SEFI V-8	3.55	11,500	6500	—	6200	—	—	—
		11,700	—	6600	—	6300	6300	—
	3.73	12,000	7000	—	6700	—	—	—
		12,200	—	7100	—	6800	6800	6500
5.4L (330) SEFI V-8 3V[2]	3.31	12,000	6900	—	—	—	—	—
		12,500	—	7300	—	—	—	—
	3.55	13,000	7900	—	7600	—	—	—
		14,000	—	8800	—	8500	8500	8200
	3.73	13,500	8400	—	8100	—	—	—
		15,000	—	9800	—	9500	9500	9200
	4.10	15,300	—	9900	—	9500	—	—

(1) Late availability.
(2) Reduce GCWR/Maximum Trailer Weight by 500-lbs. on models with 18" wheels.

F-150 SuperCab Conventional Towing

			Maximum Loaded Trailer Weight (lbs.)					
			SuperCab					
			4x2			4x4		
Engine	Axle Ratios	GCWR Max. (lbs.)	132.5" Wb	144.5" Wb	163.0" Wb	132.5" Wb	144.5" Wb	163.0" Wb
			AUTOMATIC TRANSMISSION					
4.6L (281) SEFI V-8	3.55	11,500	6300	—	—	6000	—	—
		11,700	—	6400	—	—	6100	—
	3.73	12,000	6800	—	—	6500	—	—
		12,200	—	6900	—	—	6600	—
5.4L (330) SEFI V-8 3V[1]	3.55	13,000	7600	—	—	7300	—	—
		14,000	—	8600	—	—	8300	—
	3.73	13,500	8100	—	—	7800	—	—
		15,000	—	9500	—	—	9300	—
	4.10	15,300	—	—	9500	—	—	9300

Table 3 Materials Cost for the System



Item	**Unit Cost**	**Cost**
Weir Items		
Gauge 14 T 304 Stainless Steel Sheets		
2 48" x 66.5" sheets (back and front walls)	$ 294.75	$ 589.50
2 48" x 29.75" sheets (side walls)	$ 180.10	$ 360.20
1 29.75" x 66.5" sheet (bottom plate)	$ 187.97	$ 187.97
2 14.25" x 22.25" sheets (channel base plates)	$ 50.75	$ 101.50
2 6" x 14.25" sheets (for triangular pieces to side plates)**	$ 20.63	$ 41.26
4 14.25 x 3" sheets (channel side plates)	$ 15.32	$ 61.28
Sieve Section Items		
80 Micron Mesh Material for 6 sieves	$ 6.46	$167.96
40 Micron Mesh Material for 6 sieves	$ 7.22	$187.72
Wood for the mesh boxes***	$ -	$ -
28 2"x2"x 0.25" T 304 stainless steel bar angles*	$46.53	$1,302.84
Gauge 14 T 304 Stainless Steel Sheets		
2 36" x 30" sheets (back walls)	$137.58	$275.16
1 48" x 32" sheet (door)	$ 191.44	$ 191.44
Disposal Basin Items		
Gauge 14 T 304 Stainless Steel Sheets		
2 38" x 67" sheets (back and front plate)	$ 235.43	$ 470.86
2 38" x 96" sheets (side plates)	$ 333.00	$ 666.00
1 67" x 96" sheet (bottom plate)	CUSTOM	$ -
Total Materials Cost		**$ 4,603.69**
Ted