

Optimizing Survey Unit Design to Mitigate the Potential Impacts of Wastewater on Remedial Costs and Final Status Survey Unit Integrity – 10153

Scott A. Walnicki*, Michael S. Winters**, David C. Hays***
FUSRAP Maywood Superfund Site, Maywood, New Jersey 07607
*Safety and Ecology Corporation
**Shaw Environmental and Infrastructure, Inc.
***United States Army Corps of Engineers

ABSTRACT

Management and disposition of impacted wastewater from remedial excavations can have a dramatic effect on overall clean-up costs. The goals of this paper are to introduce readers to the sources of potentially impacted wastewater at the FUSRAP Maywood Site; discuss the associated costs and challenges for the Maywood Team associated with the removal, management, and disposition of wastewater; discuss the primary methods, both physical and administrative, that the Maywood Team utilizes to control wastewater accumulations and associated costs while maintaining excavation productivity and decommissioning survey data quality; and discuss the input parameters and test case outcomes from a site-specific model developed to determine the most cost effective final status survey unit size when wastewater accumulation is present in a remedial excavation.

INTRODUCTION

The Formerly Utilized Sites Remedial Action Program (FUSRAP) Maywood, New Jersey, Superfund Site (FMSS) is listed on the National Priorities List (NPL) and is currently undergoing remediation for radioactive waste. The FMSS was contaminated with radionuclides-of-concern (ROCs) from rare earth and thorium processing operations during the first half of the twentieth century. Processing operations created wastes containing primarily thorium and lesser amounts of radium and uranium (i.e., the ROCs). These process waste materials were generally stored in open piles and retention ponds on the original processing site. Contamination was believed to have been spread to nearby properties primarily through use of the waste material as mulch or fill and via soil/sediment transport along the Lodi Brook. After the processing operations ceased, a large quantity of material was moved into three (3) NRC-licensed burial pits for storage.

The current (Phase II) remedial action at the FMSS is being performed by the U.S. Army Corps of Engineers (USACE) in accordance with the *Record of Decision for Soils and Buildings at the FUSRAP Maywood Superfund Site* [1]. The selected alternative in the Record of Decision (ROD) is excavation and off-site disposal of all material containing ROCs which exceed the established cleanup criteria.

A prevailing reality of remediation on the FMSS is the ubiquitous accumulation of wastewater within open excavations; a situation which has its roots in the intrinsic site characteristics of the FMSS. Those characteristics which are pertinent to this paper are summarized below:

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- The average depth of contamination is on the order of two (2) meters (m) below ground surface (bgs).
- The maximum depth of contamination is known to be at least 5.5 m bgs.
- Wetlands are common throughout the properties that comprise the FMSS.
- The generally shallow water table ranges from surface water to approximately three (3) m bgs.
- The estimated average water table depth is 1.5 m bgs with a seasonal variability of around 0.6 m.
- Average annual rainfall is 1.3 m.

Throughout the remedial history of the FMSS, excavation below the water table level has been the predominate reality and there have also been several instances where significant rain events (greater than 13 cm) have completely flooded out open excavations. These are the facts which are the impetus for this paper as it explores the selected methods for controlling wastewater at the FMSS and their associated cost and productivity impacts. To set the basis for further discussion, the remedial process at the FMSS will be introduced to presents some of the main cost factors which are impacted by wastewater accumulation. These cost factors will come into play later as we explore alternative methods for controlling wastewater's impact on remedial cost.

REMEDIAL PROGRESSION AND DESIGN

The remedial action on the FMSS follows a basic progression of excavating contaminated soils, performing final status survey (FSS), and backfilling excavations. Excavation is performed with the goal of preparing remediated land areas (Class 1 survey units) for FSS. FSS is performed to verify that the remedial action has successfully reduced contamination levels below the cleanup criteria established in the ROD [1].

Survey units were initially designed and classified for the FMSS in accordance with Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) guidance [4]. Class 1 survey units, representing areas subject to remediation, were generally designed to be as close to the MARSSIM-recommended maximum size of 2,000 m². FSS at the FMSS includes performing a gamma walkover survey over 100% of the survey unit, as well as collecting random samples along a systematic triangular grid and collecting biased samples from areas of elevated residual radiation levels for analysis via gamma spectrometry. Reports are generated following completion of data collection for each survey unit and serve as a means for documenting FSS results while providing an evaluation mechanism used to support backfill decisions.

Backfill is authorized after a review of FSS data demonstrates with statistical confidence that the survey unit is free of contamination in excess of cleanup criteria. Backfilling is performed by placing 30-cm (one-foot) lifts which are then compacted and subjected to in-field density testing; the process is repeated until the land area is returned to original grade.

WASTEWATER

Water that accumulates within open excavations from groundwater infiltration or surface water run-on is considered potentially contaminated and is treated as “wastewater.” Wastewater at the FMSS is pumped out of excavations and transported to an on-site water treatment facility for processing prior to being discharged to a sanitary sewer system in accordance with applicable permits and regulations. Water samples are taken and analyzed at a frequency prescribed by the discharge permit. It has been estimated that it costs \$0.083 per litre to process wastewater on the FMSS.

The amount of wastewater removed from temporary work site excavations on the FMSS has been tracked and recorded throughout the project’s Phase II remedial history. Data from 17 completely remediated vicinity properties, consisting of 121 Class 1 survey units, yielded the statistics shown in Table I.

Table I. Wastewater Statistics from Seventeen Remediated Properties.

Statistical Parameter	Result (average litres per day)
Maximum	58,643
Minimum	0
Mean	21,319
Standard Deviation of the Mean	20,835
Median	18,185

The average daily wastewater generation calculated from the 17 individual work site averages was 21,319 litres per day. A high degree of variability is present between temporary work sites as indicated by the large relative uncertainty around the mean. This was expected based on the historical dispersion of radioactivity on the FMSS which varies in depth from near-surface cross-contamination from historic site activities (<30 cm bgs) to burial pit / retention pond storage (>5.5 m bgs).

COSTS

The preceding discussion highlights some of the more prevalent work activities that contribute to the overall remedial costs of a survey unit. In summary, those factors include: excavation, FSS, backfill, and wastewater processing. In order to compare the relative costs of these factors, excavation, FSS, and backfill were standardized to an estimated cost of performing each task for a ten-hour work day. The direct cost of wastewater processing was estimated by applying the historical FMSS-specific average volume of wastewater generated from an open excavation of 21,319 litres per day (see **Table I**) to the estimated cost per litre (\$0.083 per litre). The relative *estimated* cost for each activity is illustrated on **Figure 1**.

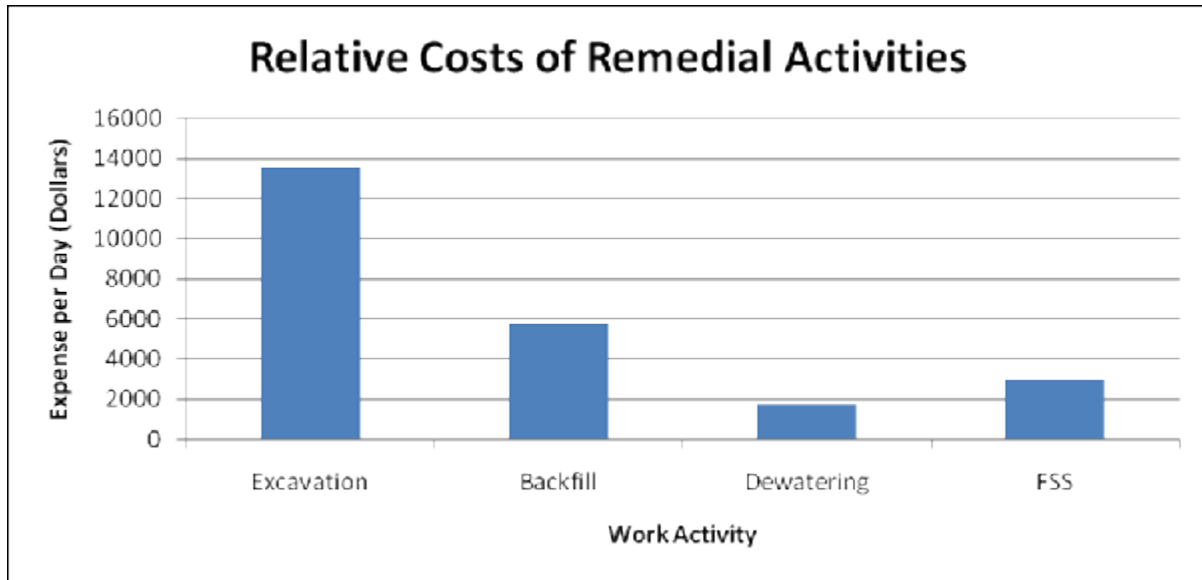


Fig. 1. Chart illustrating the relative cost per day of remedial work activities (estimated).

THE POTENTIAL IMPACT OF WASTEWATER ON REMEDIAL COSTS

As illustrated in **Figure 1**, the “direct” cost of dewatering an excavation is the least expensive work activity per day based on an average volume of wastewater accumulation. However, wastewater has “indirect” costs associated with it that are not captured in **Figure 1**. The Occupational Safety and Health Administration (OSHA) Regulation 29 CFR 1926 prevents workers from entering an excavation in which water has accumulated [5]. The safety issues that constrain personnel from entering water-filled excavations affect backfill and FSS activities as well. These compounded delays (i.e., indirect costs) can be significant.

To illustrate the impact that wastewater can have on remedial costs, a simple model was created based on a single, hypothetical, 2,000 m² survey unit. This model, which will be visited later in more detail, was used to calculate the cost of remediation based on increasing depths of wastewater requiring daily dewatering. **Figure 1** (above) presented the relative costs of the different remedial activities per day of activity. Since dewatering effectively delays the start of the other remedial work activities, there is an accretion of lost time per day which ultimately may result in an increase in the total number of days spent performing specific activities; thereby proportionally increasing the costs of remediation. **Figure 2** illustrates the impact that wastewater can have on remedial costs.

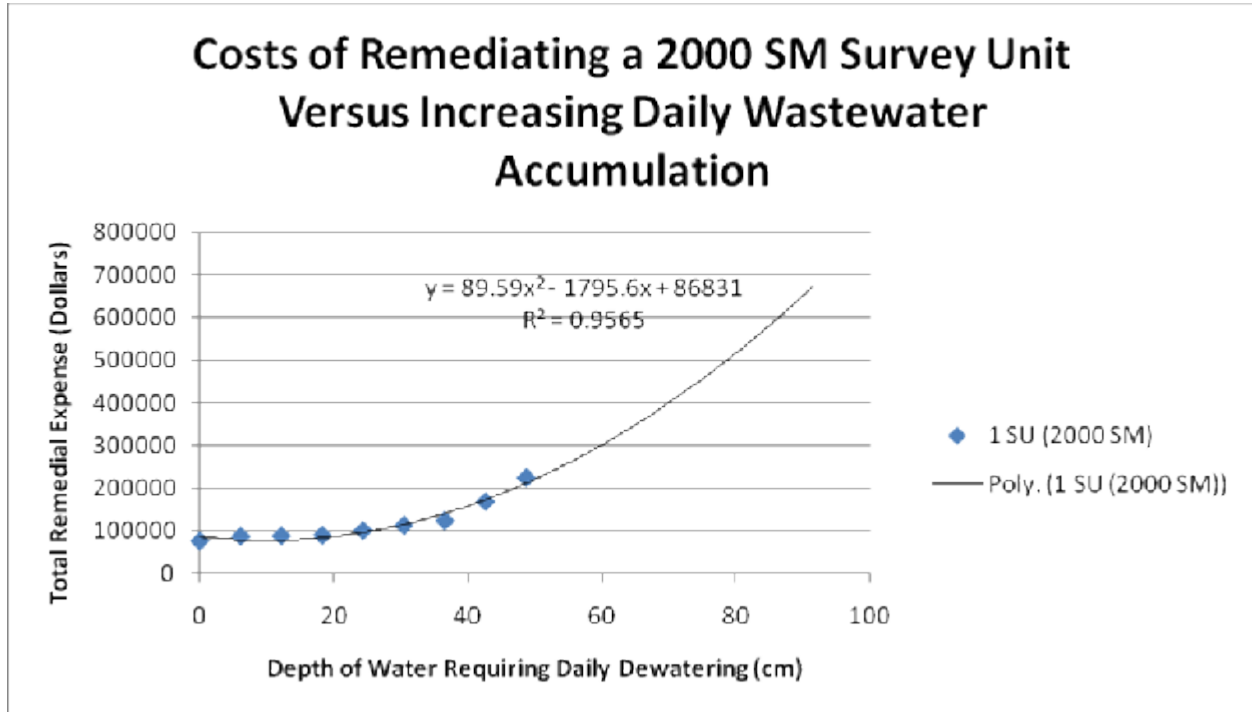


Fig. 2. Graph showing the impact that increasing depths of wastewater requiring daily removal from an excavation has on overall remedial costs.

Increasing depths of wastewater requiring daily removal results in escalating remedial costs for several reasons; one being that an increase in the amount of wastewater increases the *direct* cost of wastewater processing. However, as previously alluded to, this direct cost is minimal when compared to the *indirect* cost that daily dewatering incurs, namely delays imposed upon the other remedial activities (e.g., excavation, FSS, and Backfill). At greater depths of water, the primary result is an overall increase in the number of days required for excavation, and to a lesser extent, an increase the total number days required for performing FSS and backfill. In reference to the results of the model shown in **Figure 2**, the cost for remediating the hypothetical land area doubles with 20 cm of water requiring daily dewatering. **Figure 2** also shows that with a small amount of water, overall costs are not appreciably affected. This can be attributed to minimal daily delays which do not result in an overall increase in the total numbers of days required for remediation (i.e., the increase in cost is primarily restricted to the direct cost of wastewater processing).

PHYSICAL METHODS FOR CONTROLLING WASTEWATER IN EXCAVATIONS

There are two source of wastewater on the FMSS: surface water and groundwater. Surface water includes storm water, wetland flow, and open channel streams. Groundwater, through infiltration, constitutes the main source of wastewater and is the most difficult to control.

There are two main methods employed at the FMSS for controlling wastewater: prevention and dewatering. Prevention methods involve diversion (surface water), and displacement (groundwater). Dewatering an excavation is required when prevention techniques are either ineffective or not implemented.

Surface Water Diversion

Surface water entering an excavation has been successfully mitigated by constructing berms to control surface run-on, and by installing bypass systems to redirect water around excavations. By-pass systems are a virtual requirement when remediating within stream channels, but otherwise are not germane to our discussion of wastewater control.

Dewatering

Dewatering, typically by surface pumping from within an excavation, is the primary method used on the FMSS to remove accumulated wastewater. Wastewater is either pumped directly into vacuum trucks for transport to the on-site water treatment plant, or pumped into holding tanks for primary settling and then transported to the wastewater treatment plant at a later time. Using temporary holding tanks allows for higher dewatering rates/volumes than with standard commercial vacuum trucks. However, use of holding tanks may be limited by available space at satellite work sites. Both direct-loading to vacuum trucks and on-site holding tank storage have been used on the FMSS with success, especially when combinations of the two are implemented to combat changing conditions.

Groundwater Displacement

Groundwater infiltration constitutes the main source of wastewater on the FMSS and as such poses the greatest potential impact to remedial costs. One proven method for preventing groundwater from infiltrating an active excavation is the installation of an extraction well system to draw down the water table. The expense for installing and operating this type of extraction system is significant and is only cost effective in the most extenuating circumstances when daily dewatering causes significant delays. This type of extraction well system has been installed on the FMSS for the remediation of a burial pit where the size of area ($> 5,000 \text{ m}^2$), known depth of contamination ($\sim 5.5 \text{ m bgs}$), and the shallow water table ($\sim 2 \text{ m bgs}$) would have made remediation with daily dewatering expensive, impractical, and essentially impossible. This type of system also requires the installation of a dedicated water treatment plant to handle the continuous flow of water generated. On the FMSS this type of system cost upwards of \$350,000 to install and included a network of drawdown wells, piezometric wells, and sampling wells along with an on-location water treatment plant. The initial price is high, but the overall costs of daily dewatering (assuming it would have been feasible) very well may have been exponentially higher. However, for most "normal" remedial excavations on the FMSS, this system would be neither feasible nor cost effective; it is upon those "normal" excavations that the remainder of the paper will focus.

ADMINISTRATIVE METHODS FOR CONTROLLING WASTEWATER COSTS

Since preventing groundwater infiltration is cost preventative in most scenarios, removing the water after it enters the excavation becomes necessary. As with surface water, groundwater is pumped out of an excavation on a daily basis. This is to say that wastewater accumulation can also be controlled administratively *per se*. An administrative control of wastewater is really an

exercise in mitigating the impacts of wastewater by reducing the need to control it, thereby reducing overall costs. Two methods used with success at the FMSS are excavation sequencing and survey unit size reduction.

Excavation Sequencing

As previously mentioned, some contamination on the FMSS was dispersed as alluvial deposits along open channel streams. The majority of these streams have been channelized into subsurface culverts and the original stream beds were filled in resulting in several situations where contamination was found at depths below the water table in the areas corresponding to the historical stream bed, flanked by increasingly shallow depths of contamination. The administrative solution for reducing the volume of wastewater was to remediate on either side of the streambed to a depth just above the water table. This allowed remediation to progress with little or no wastewater to control. Once the shallow contamination was removed, the streambed itself was remediated. Had the entire area been remediated at one time, wastewater could have potentially caused daily delays to other remedial activities, thereby prolonging the remedial effort, and increasing the overall cost of remediation. As it were, the majority of the remedial effort was completed with little or no impact from groundwater infiltration.

Survey Unit Size Reduction

As was mentioned in the introduction, survey units on the FMSS were typically designed to be as close to the MARSSIM-recommended size of 2,000 m². However, in a situation where the depth of excavation is below the water table and groundwater infiltration is resulting in costly delays, it may be possible to control costs by performing the remediation in a series of smaller survey units (i.e., smaller and more manageable excavations). The theory being that with a smaller area open to wastewater accumulation, there will be less volume requiring daily dewatering, and therefore shorter delays to the other remedial activities as a result of wastewater accumulation. However, there are conflicted cost factors at play when considering survey unit size reduction. For example, multiple smaller survey units will increase the overall number of FSS samples because MARSSIM recommends a minimum number of samples be collected *per* survey unit (i.e., the survey unit's size does not affect the number of samples, only the spacing between them). It should be noted that this model was created specifically for the FMSS and the example listed above does not impact costs significantly because the FMSS has a fully staffed on-site laboratory which is essentially a fixed operating expense for the project. In other words, for the FMSS, doubling the number of samples does not double the total analysis costs.

POTENTIAL IMPACT OF SURVEY UNIT SIZE REDUCTION

In order to evaluate the effectiveness that reducing survey unit size may have on remedial costs, a simple model was created to capture as many of the conflicting cost factors thereby providing insight to the feasibility of the survey unit size reduction method. This model was based on remediating a hypothetical land area under various scenarios including remediating the 2,000 m² area as one (1) survey unit; remediating the area as two (2) – 1,000 m² survey units; and remediating the area as four (4) – 500 m² survey units.

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Using several input parameters based on simple assumptions, a plot was generated showing remedial costs versus increasing depths of wastewater requiring daily dewatering. The input parameters and assumptions are listed and explained below.

- Workday Length: The hours of a standard workday form the basis for calculating absolute excavation quantities in a given day, and determining how many days are required for excavation, FSS, and backfill. The length of the workday used in this model was set to ten (10) hours.
- Depth of Excavation: Depth of excavation plays an important part in the model because it is used in conjunction with the excavation rate to determine how many square meters of land area are remediated in a given day. The depth of excavation was set at one (1) m.
- Dewatering Rate: Dewatering rate is one of the more critical variables in the model as it has a big influence on remedial costs. This is because time spent dewatering effectively reduces time spent performing excavation, FSS, and backfill. The dewatering rate for this model was set at 11,350 litres per hour which represents the capacity of one vacuum truck and the time it takes that truck to complete an entire dewatering cycle.
- Excavation rate: The cubic meters (m^3) of soil removed per hour - set at 42 m^3 per hour based on a typical rate experienced at the FMSS.
- Cost per day of excavation: Set at a default rate of \$10,000 per day (estimate).
- Cost per day of backfilling: Set at a default rate of \$5,000 per day (estimate).
- Cost of performing FSS per survey unit: There is a direct relationship between the survey unit size and cost of completing FSS; however, there is an indirect relationship between survey unit size and cost of completing a given land area. In other words, a default cost of FSS for a 2,000 m^2 survey unit was set at \$6,500; whereas it costs \$4,000 to FSS a 1,000 m^2 survey unit, and \$2,750 to FSS a 500 m^2 survey unit. But to FSS a given land area of 2,000 m^2 , it would cost \$6,500 to FSS as one survey unit; \$8,000 to FSS as two (2) 1,000 m^2 survey units; and \$11,000 to FSS as four (4) 500 m^2 survey units. This is primarily because increased pre- and post- QC checks, increased bias sampling rates, increased reporting costs, and increased laboratory costs (not applicable to FMSS).
- Total days spent backfilling: Experience has shown that it takes about the same number of days to backfill a 2,000 m^2 survey unit as it does to backfill a 1,000 m^2 survey unit. The reasons for this lie in the logistics of backfilling at the FMSS. Backfill is placed in 30-cm (one-foot) lifts which are then compacted and subjected to in-place density testing. For larger survey units, backfill can continue on one side of the survey unit while compaction and testing are being performed on the other side. This is not as always possible in smaller survey units due to space constraints and the logistics of placing the fill.
- Dewatering costs: although minor compared to the delays associated with dewatering, the costs of removing and processing wastewater must be accounted for. For the model the cost of dewatering was set at \$0.083 per litre.
- Depth of water: This was the main variable used to evaluate the cost of remediating that land area using a different numbers and sizes of survey units.

The model used the above parameters to calculate the total number of days spent excavating based on the influence of wastewater. Wastewater volumes were calculated based on the area of

excavation open each day. The volume of wastewater was translated into time lost by applying the dewatering rate. Time lost translated into a reduction in the amount of land area remediated each day. As the depth of wastewater increased, so did the total number of days spent excavating due to the inherent delays associated with daily dewatering. The increase in the number of days spent excavating was the main influence in driving up the costs of remediation.

The total cost of excavation was then added to the other cost variables including the direct cost of processing wastewater, and the costs of performing FSS and backfill (delays to these activities were also impacted by wastewater delays in a manner similar to explained above).

Three scenarios were considered for remediating a 2,000 m² land area: one (1) 2,000 m² survey unit; two (2) 1,000 m² survey units; and four (4) 500 m². Each of these three scenarios was then run with variable depth of wastewater requiring daily removal from the excavation. Costs were then plotted against depth of wastewater with the following results as depicted in **Figure 3**.

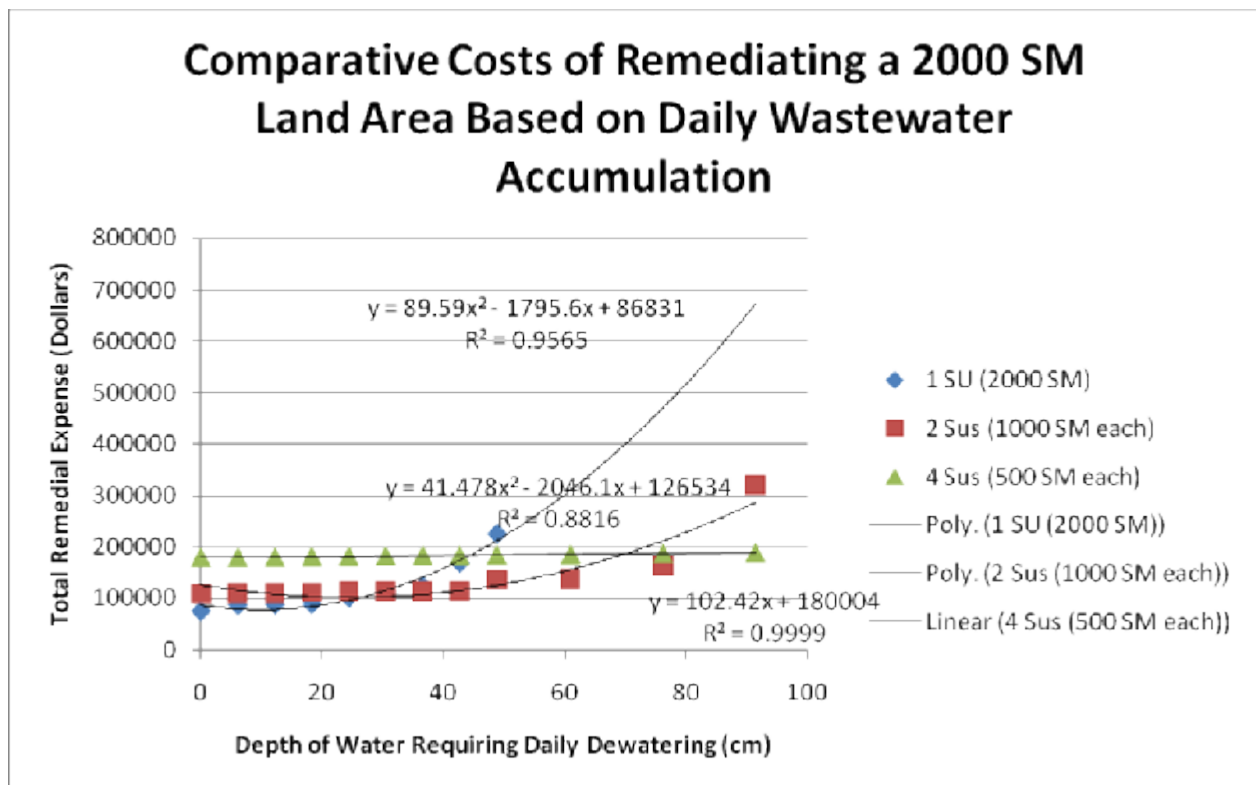


Fig. 3. Chart comparing cost of remediating a 2,000 SM land area using different SU size and showing the potential impact of wastewater on remedial costs.

Figure 3 illustrates that with no wastewater accumulation, maximizing survey unit size (2,000 m²) is the most cost effective remedial approach. Based on the “zero wastewater” scenario modeled in **Figure 3**, the costs increase by 46% when remediating the same land area as two, 1,000 m² survey units. When four, 500 m² survey units are remediated, the costs increase by 107%.

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As the depth of wastewater requiring daily dewatering increases, the cost curve for remediating the land area as one 2,000 m² survey unit increases exponentially. Interestingly, small amounts of wastewater (less than 15 cm) are absorbed with very little impact to remedial costs, but at depths greater than 30 cm the costs begin to increase significantly with additional depths of water. This can be attributed to the compounding effect that daily excavation delays have on the total number of days required to complete the survey unit excavation (recall that daily costs of excavation are the bulk of expenses).

The **Figure 3** curve for 2 survey units (1,000 m²) illustrates that remedial costs are mitigated to some extent by decreasing survey unit size in consideration of increasing wastewater depths. Whereas the “1-survey unit” curve remains relatively flat for only the first 15 cm of water, the “2-survey unit” curve remains relatively flat to almost 0.5 m of daily water accumulation. When the “2-survey unit” curve does begin to increase, it does so at a lower rate than the 1-survey unit curve. By limiting the survey units to 1,000 m² as wastewater depth increases, the daily excavation delays associated with dewatering are reduced and costs are easier to control.

The **Figure 3** curve for the 4 survey units (500 m²) is relatively flat, further demonstrating that reducing survey unit size is effective at controlling wastewater’s impact to remedial costs. Note however that the “4-survey unit” option does not become the preferred choice from a cost standpoint until the depth of water is greater than 70 cm.

SUMMARY AND CONCLUSIONS

Table II recaps the FMSS-specific results of the model.

Table II. Summary of model output for determining most cost effective survey unit size as depth of excavation below water table increases.

Depth of Excavation Below Water Table (cm)	Most Cost Effective Remediation Scenario
0 - 25	Maximize Survey Unit Size (2,000 m ²)
25 - 70	Reduce Survey Unit Size to 1,000 m ²
> 70	Reduce Survey Unit Size to 500 m ²
Significantly greater than 70 (i.e., > 150)	Seek alternative water control (i.e., extraction well)

The lesson learned from this evaluation model as it applies to the FMSS is that given a typical excavation, if contamination is expected to be no more than 25 cm below the water table then the most cost effective survey unit design is to maximizing survey unit size. If contamination is expected to be greater than 25 cm below the water table but less than 70 cm below the water table then reducing the survey unit size to 1,000 m² provides the most cost benefit. If contamination is expected to extend more than 70 cm below the water table then a further survey unit size reduction to 500 m² become the most cost effective design. At extreme depths of contamination (say greater than 150 cm below the water table) then a project should consider alternative approaches to controlling the water, such as lowering the water table through extraction well draw-down.

The evaluation and model presented in this paper were performed specifically for the FMSS which has fixed costs associated with sample analysis in its on-site state-certified radiochemistry laboratory. This evaluation and associated model can be used as a starting point for other

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remediation sites where buildup of potentially contaminated wastewater in excavations is expected. Serious consideration of potential wastewater impacts, especially in the design phase of a remedial project, will prove beneficial in terms of both cost minimization and schedule execution. Remedial designers should evaluate area-specific groundwater elevations when planning excavations (i.e., survey units) to minimize the controllable costs associated with the management of wastewater.

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