Cost Estimation for Process Plant Utility Systems

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Abstract

The current dynamic climate of the Australian resource sector has lead to an increased number of new projects being constructed throughout the country. United Group Limited Resources has identified the need to screen a large volume of these projects reliably and efficiently to ascertain their feasibility. During the project screening process, the cost estimation of process plant utility systems are often overlooked, even through they may contribute up to 40% of the final construction costs. This paper discusses the development of an approach to cost estimating process plant utility systems, in particular firewater systems, as well as the creation of an interactive cost estimating tool for the benefit of United Group Limited Resources. The project focussed on an investigation into cost estimating techniques and commercial cost rates as well as the engineering design of firewater systems. Upon implementation, the outcomes identified in the study are expected to lead to a significant reduction in the resources required to cost estimate process plant utility systems at a project screening phase.

1. Introduction

The current demand for natural resources from sources worldwide has led to a rapid expansion of the mining sector in Australia and in particular Western Australia. This expansion has led to an increase in the need for the construction of new major projects throughout the state. This dynamic climate of change has meant construction contractors such as United Group Limited Resources have had an increased interest in their services to engineer and construct process plant facilities, in order to satisfy the demand for natural resources. However, this has also led to an increase in pressure on the contractor to deliver the process plant on time and on budget.

The design and cost of a process plant utility system is often overlooked until the completion of the engineering phase, specifically after the process design. This is seen as a risk as the design and construction of these process plants can account for 40% of the total cost (Percival C., 2007). Ignoring these systems until a later stage into the project can cause the project to run over time and over budget.

This thesis was conducted as a result of a collaborative project with United Group Limited Resources, UWA and CEED. The project was a study into the cost estimating of process plant utility systems with a focus on firewater systems. It was an investigation into the possibility of creating a cost estimating tool that could produce a final cost of a firewater

system to a certain accuracy based upon some basic information that would be provided by a client.

The level of consumption information issued by the client will affect the accuracy of the cost estimate produced. This project was intended to produce a cost estimating tool that could be used in the early stages of a project when minimal information is available. The system was to be a high level factored cost estimating approach for utility systems that would give an estimate by assessing basic key utility consumption and configuration information. Many of the utility system types exhibit common elements regardless of the plant process type. By focusing on one utility system type, a cost estimating approach could be produced and applied to other process plant utility systems.

1.1 Project Objectives

- Investigate cost estimating techniques and identify the project phase where cost estimating tool can be implemented.
- Understand and identify the key technical parameters of a Firewater System.
- Develop engineering design equations and assumptions to be incorporated into a cost estimating tool.
- Obtain a set of commercial cost rates to apply to engineering design equations developed.
- Create and develop an interactive cost estimating tool for Firewater Systems.
- Test and review system against real data from UGL Resources in the form of a case study to verify accuracy of cost estimating tool.
- Produce recommendations and outline of future development for the client.

2. Background

2.1 Cost Estimating Techniques

Cost estimation is defined as the "evaluation of all the costs of the elements of a project or effort as defined by an agreed-upon scope" (AACE, 1990). UGL Resources required an approach to cost estimating process plant utility systems for project screening purposes. It was important to define what type of cost estimate was required for this phase of the project, as it specifies the accuracy, cost and resources required as well as the level of consumption information that would be available from the prospective client. Three types of cost estimates (De Garmo et al, 1997) were investigated to ascertain the most appropriate. These were:

- Order-of-Magnitude Estimate (Preliminary Estimate)
- Budget Estimate (Semi-Detailed Estimate)
- Definitive Estimate (Detailed Estimate)

Order-of-magnitude estimates can be based upon cost-capacity relationships, ratios or physical dimensions. However, their precision can vary as much as ±30-50% (Park et al, 1984), but this sacrifice in precision is justified by the ability to screen a large number of alternative projects in a short period of time. This definition satisfied the requirements of UGL Resources, and thus it was decided an order-of-magnitude approach would be utilised throughout the cost estimation procedure.

2.2 Firewater Systems

The fundamental purpose of a process plant facility is to refine raw material that is mined to produce a final product that can be sold on to a consumer. This main process requires support systems to help produce the final product and for the process plant facility to operate. These systems are known as utility systems. Although there are multiple utility systems present in a process plant facility it was decided to produce a cost estimating tool for a Firewater System as:

- They are required in any process plant facility irrespective of the process. *"Fires and explosions in mines have been identified as one of eight key causes of over 85% of fatalities in the Australian Mining Industry over the past 15 years"* (MISHCSI, 2005).
- Can often be the most expensive utility system to construct due to the specialised mechanical items required. E.g. pump arrangement and fire fighting equipment.
- Firewater systems contain many aspects that are identifiable in other utility systems. Taking this system as the most complex, the methodology can be applied to other utility systems.

A simplified firewater system was considered throughout the investigation which consisted of a firewater storage method, pump arrangement, piping distribution system and fire fighting equipment (See Figure 1). The firewater system design was dependent on a set of consumable information including the area to be protected, length of protection time in hours as well as the hazard level of the process plant.

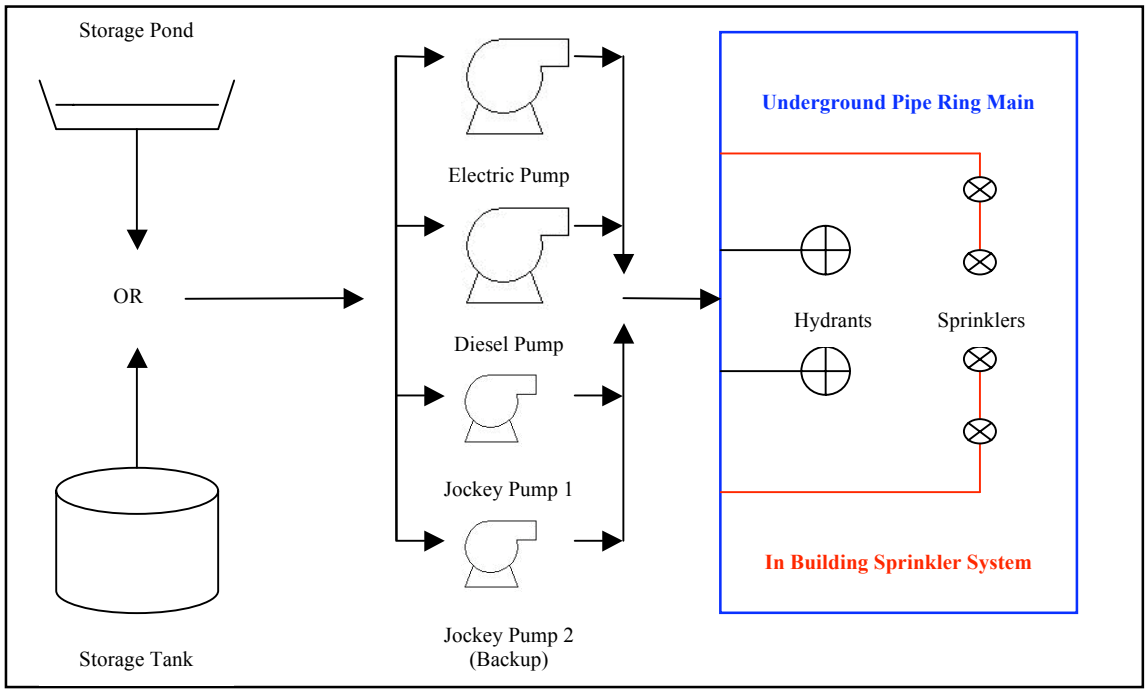

Figure 1 General Arrangement for Firewater System that was considered for cost estimation

2.3 Key Assumptions

Amongst other assumptions required to design the firewater system, three key ideals were kept in mind whilst completing the cost estimating procedure.

- Cost estimates considered were for greenfield projects only, that is, there was no existing process plant in place that must be taken into account. This equates to no constraints or costs for remodelling or reworking existing firewater systems.
- Mobilisation and demobilisation costs would be accounted for in the scope of work for the process plant facility as a whole, rather than individual systems to be constructed.
- Costs produced are for procurement and construction only, not utility design.

3. Methodology

UGL Resources requested that the cost estimating approach would be developed for not only firewater systems but all utility systems that may be present in a process plant facility, and as such the methodology derived was required to be robust enough to be applied across a range of utilities. The methodology developed incorporated the requirements of an order-of-magnitude estimate, breaking the system into components and then costing, yet was simple enough to be programmed into a cost estimating tool. Figure 2 provides a visual representation of the methodology used.

4. Discussion

4.1 Technical Analysis

As stated, the level of information available from a client at the project screening stage is limited and as such the firewater system considered was designed from three key parameters.

- The area to be protected,
- The number of hours of protection and,
- The hazard level of the process plant being considered.

From this information and by breaking down the major technical components of the firewater system into basic components, it was possible to derive a set of design equations that would calculate the quantities of materials and labour required to construct a firewater system for that process plant. The major technical components considered included:

- Storage Tank with Full Slab Foundation
- Storage Tank with Ring Beam Foundation
- Storage Pond with High Density Polyethylene (HDPE) Lining
- Pump Arrangement of an Electric, Diesel Back-Up, and Jockey Pumps
- Piping Ring Main (HDPE)
- Piping Deluge System (Carbon Steel)
- Fire Fighting Equipment

Each of these major technical components were broken down further into individual tasks that could be costed and would be required to complete construction of the Firewater System (See Table 1).

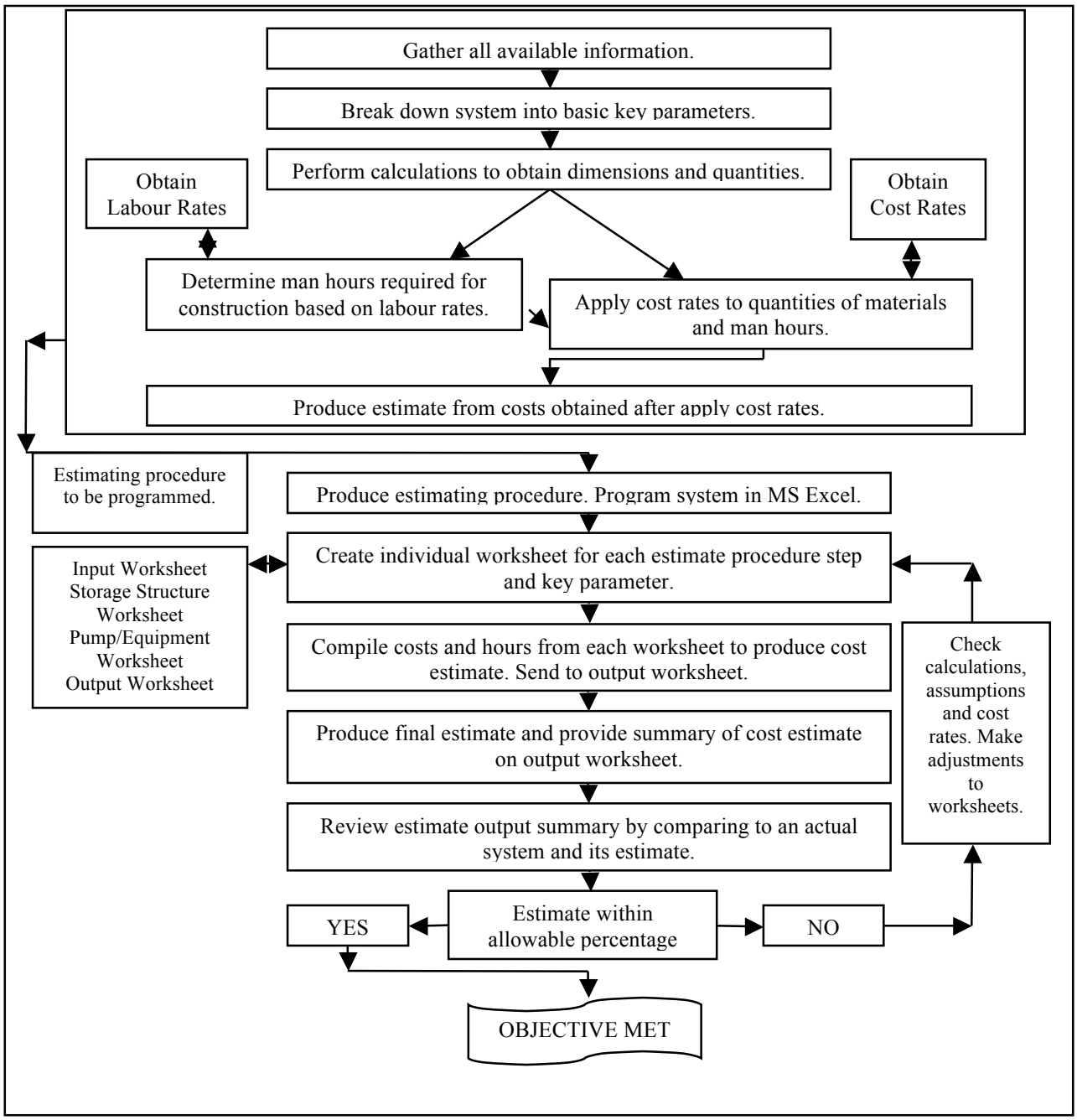

Figure 2 Methodology and procedure developed to create a cost estimation tool for process plant utility systems.

4.2 Costing

In order to produce a cost estimate a set of commercial cost rates were required to be obtained. These were sought from the estimating department at UGL Resources and material suppliers. The labour rates for construction, for example 1 man hour per meter of pipe laid, were obtained from construction handbooks such as, *"Estimator's Piping Man-hour Manual"* by J.S Page. The rates for labour and materials were applied to each design equation to compile a final cost for construction. To improve the accuracy of the estimate an allowance for a profit margin, overheads, design error, project location, contingency, escalation and growth were applied as percentage factors to the final cost.

Storage Tank Full Slab	Storage Tank Ring Beam	Storage Pond	Pumps	Piping HDPE	Pipe C Steel	Equipment
Steel	Steel	HDPE Lining	Electric	Pipe Material	Pipe Material	Monitor
Fabrication	Fabrication	HDPE Install	Diesel	Fusion Welding	Welding	Hydrant
Surface Treatment	Surface Treatment	Clear , Grub & Mulch	Jockey	Stub Flanges/ Backing Rings	Slip on Flanges	Sprinklers
Concrete Footing	Concrete Footing	Remove Top Soil	Concrete Plinths	Bolts	Bolts	Control Panel
Reinforcing	Reinforcing	Cut & Fill Clay Moisture	Reinforcing	Gaskets	Gaskets	Alarm Horn
	Bedding Sand	Compact & Condition	Diesel Tank	Excavation	Pipe Supports	Hose Cabinets
				Installation	Installation	Extinguishers
				Hydro-testing	NDT	

Table1 Individual components that were designed and costed for the Firewater System.

Two 'a-side' investigations were completed to assist in the decision making process for project screening at UGL Resources. These included a cost comparison between storage tanks and storage ponds so that the optimal firewater storage method was chosen, as well as a cost comparison between full slab and ring beam tank foundations.

4.3 Cost Estimating Tool

To achieve one of the major objectives of the investigation it was required to automate the cost estimating process, such that the process may be repeated for multiple projects now and into the future. To do this, the cost estimating methodology developed was programmed into Microsoft Excel to:

- Allow the tool to be used on any UGL Resources' computer.
- Provide an easy interface for users of any computer literacy level.

The layout of the system requires a user to enter the key information required to design the system from which the cost estimate is calculated. This cost is then sent to a set of output worksheets that the user can interpret and use for project screening. There are a range of worksheets behind the system that consume the information entered and perform the design equations derived in the Technical Analysis. The cost estimate can be viewed as a summary of costs and materials and as a range of system curves that show the breakdown of labour and costs for each discipline. A user handbook was developed to assist the user in using the cost estimating tool.

4.4 Cost Estimating Tool Verification

To verify the accuracy of the cost estimating tool that was developed, a case study was conducted. Project Aurora is the construction of an Ammonium Nitrate Complex in Moranbah, QLD. It is classed as a major hazard and covers roughly 162,000m^2 of process

area (UGLR, 2008). The client had requested that four hours of firewater protection should be provided. These details were entered into the cost estimating tool and a cost estimate was produced. The individual costs and material quantities generated were then compared to those provided by UGL Resources for Project Aurora to ascertain the accuracy of the cost estimating tool.

After producing a cost estimate for Project Aurora, a cost and material quantity comparison was conducted to verify if the estimate produced was within the objective range of ±30-50%. In reviewing the cost and material quantities it was found that the outputs from the cost estimating tool were well within this range. The total cost from the Project Aurora estimate and from the Cost Estimating Tool estimate had to be adjusted to ensure that they were both costing the same components, for example the Cost Estimating Tool estimate included excavation costs for the HDPE piping, where as the Project Aurora estimate did not. An accuracy of +0.64% was found whilst comparing the total adjusted cost for this case study. The material quantities were also found to be similar with Project Aurora requiring 3650m of HDPE pipe with the tool estimating 3536m, a 3% difference. A summary of the cost comparison can be seen in Table 2.

		Project Aurora		*Cost Estimating Tool*		**Cost Diff. (%)**
Item	**Description**	**Dimension**	**Cost**	**Dimension**	**Cost**	
Storage Pond	Capacity	2000 m^3	$333,622	2422m^3	$403,511	17.3%
HDPE Piping	Length	3650 m	$1,831,522	3536 m	$1,919,531	4.6%
Mechanical	-	-	$794,502	-	$939,800	15.5%
Pre-Adjusted Cost	-	-	$3,813,683		$4,487,084	15.0%
Adjusted Cost	-	-	$3,741,821		$3,765,821	0.64%
Man Hours	-	-	17,156 hrs		14,834 hrs	-15.6%

Table 2 Cost comparison between output generated by cost estimating tool and Project Aurora estimate

After reviewing the findings of this study, United Group Limited Resources have agreed that the approach to cost estimating and the associated cost estimating tool developed during this study will dramatically reduce the resources required to reliably produce a cost estimate for firewater systems at a project screening phase (Percival et al, 2008).

5. Conclusions

The cost estimating tool will reduce the resources required and provide UGL Resources with a market edge as they now have the ability to produce cost estimates almost instantaneously and reliably to assist in the project screening phase.

Due to the nature of the cost estimating process developed, it was found that the cost estimating tool could not only be used for estimating purposes, but also for firewater system layout and engineering design. When reviewing the potential that this tool can provide UGL Resources, it was evident that key engineering details could be extracted from the cost estimates produced.

Although the firewater system was the only process plant utility system that was investigated, sufficient work has been completed to provide a strong foundation to produce cost estimating tools for all utility systems. It has been recommended to UGL Resources to produce a

package of these cost estimating tools to form a suite of cost estimators that would provide the benefits this tool has demonstrated for all utility systems. The methodology that has been produced will allow UGL Resources to continue with the formulation of subsequent cost estimating tools. Furthermore, they have been provided with a cost estimating tool that will significantly reduce the amount of work required to produce a cost estimate and basic design details for what has been identified as a key process plant utility system.

6. Acknowledgements

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