The Value of Value Engineering – Functionality without Breaking the Bank on a Raw Water Transmission Project in Texas

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ABSTRACT

The Tarrant Regional Water District (TRWD) with the City of Dallas Water Utilities (DWU), are currently engaged in the planning, design and implementation of a 350 MGD raw water transmission system, which will run across north central Texas from Lake Palestine to Lake Benbrook, with connections to Cedar Creek Reservoir, Richland Chambers Reservoir and a Dallas delivery point. Collectively, the system consists of approximately 145 miles of 84-inch to 108-inch pipeline, a 5-mile 120-inch diameter tunnel, three 150 to 275 MGD lake intake pump stations, three 200 to 350 MGD pump stations two of which include 80 MG suction reservoirs, one 450 MG balancing reservoir and ancillary facilities. The program developed by TRWD and DWU to accomplish these improvements is called the Integrated Pipeline Project (IPL).

At the onset of the IPL, the project teams were given the mission to deliver this complex program in a sustainable manner by balancing the triple bottom line of “people, planet and profit” or “social, environmental and economic”. As part of the efforts to optimize design functionality against the “profit” component a series of value engineering studies were conducted at key milestones along the project delivery schedule.

Formal value engineering workshops were held at the end of the program’s conceptual study to help guide further definition of project components and design scopes. The project was considered in three major areas: pipeline, booster pump stations and balancing reservoir facilities, and lake intake pump station facilities. Value engineering workshops for each of the components of design were conducted at preliminary design and progress design stages. Informal value engineering for each sub-project was collaboratively conducted through component concept reviews and milestone design reviews.

The paper discusses the use and results of Value Engineering for a cross country water transmission line project with particular attention to the balancing reservoir sub-components of this system which through “VE” realized a range of savings of 30% to 50% of project budget on a delivered unit basis.

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1. IPL Program Management Team | AECOM, Fort Worth, TX
2. Freese and Nichols, Inc., Fort Worth, TX
3. Nathan D. Maier, Inc., Dallas, TX
4. Tarrant Regional Water District, Fort Worth, TX
INTRODUCTION

The Tarrant Regional Water District (TRWD) with the City of Dallas Water Utilities (DWU), are currently engaged in the construction of the beginning phase of a 350 MGD raw water transmission system, which will run across north central Texas from Lake Palestine in east Texas to Lake Benbrook near the DFW metroplex, with connections to Cedar Creek Reservoir, Richland Chambers Reservoir, and a Dallas delivery point. Collectively, the system consists of approximately 145 miles of 84” to 108” diameter pipeline, a 5-mile 120-inch diameter tunnel, six 100–350 MGD pump stations two of which include 80-MG suction reservoirs, one 450 MG balancing reservoir, and ancillary facilities. The program developed by TRWD and DWU to accomplish these improvements is called the Integrated Pipeline Project (IPL). See Figure 1 for project location.
double in the next 50 years. The IPL project is developed to provide an additional 350 MGD supply to meet these growing needs.

The IPL Project is being developed in five distinct phases. Phase 1, scheduled for completion in 2018, is currently in construction and includes 70 miles of 84 inch to 108 inch pipeline, a 350 MGD booster pump station including an 80 MG suction reservoir, three facilities interconnecting the new IPL with existing TRWD pipelines, a 450-MG terminal storage balancing reservoir, and ancillary facilities. Phase 2, scheduled for completion in 2020, includes 11.5 miles of 108 inch pipeline, a ½ mile long approximately 14-ft dia. river tunnel, and a 275 MGD lake intake pump station at Cedar Creek Reservoir. Phase 3, scheduled for completion in 2025, includes 12 miles of 96-inch pipeline and an expansion of the TRWD existing Richland Chambers lake pump station to an additional 250 MGD capacity. Phases 4 and 5, scheduled for completion thru 2035, includes the remaining components of the IPL – 50 miles of 84-inch pipeline, 5 miles of 120-inch pipeline in tunnel, two booster pump stations at 200-350 MGD, an 80 MG suction reservoir, and a 150 MGD lake intake pump station at Lake Palestine.

Leadership of TRWD and DWU set out from the beginning to deliver the IPL as a truly sustainable project. Project goals include decision making to balance the “triple-bottom-line” function of “people” (social), “planet” (environmental) and “profit” (economics). Life cycle costing was used to compare various alternates where sustainable payback may be years out from capital outlay. Goals in the planning and design were to provide a reliable system with a 100-year service life. Development of all IPL facilities took into consideration the potential for future expansions and operational scenarios.

For such a large, complex, multi-phase, multi-decade project, the application of Value Engineering was undertaken to provide additional review and evaluation to consider opportunities for economies of scale, to avoid obsolescence in design, to balance flexibility with interconnections to the existing system, to reduce projects risks and to balance concepts of design for the future with current capital costs.

TRWD and DWU selected Robinson Stafford & Rude, Inc. (RSRI) of Gulfport, FL as the Value Management Consultant to conduct a series of Value Engineering Workshops at various design stages. RSRI was responsible for assembly of a team of national experts with various pertinent disciplines. The RSRI team along with various Owner and IPL team members constituted the VE Team. Workshops were held over a period of three years considering: the Concept Design, the 30% design of the joint booster pump stations and suction reservoirs, the 30% design of the lake intake pump stations, the 60% design of the JB3 Booster Pump Station, JB3 suction reservoir and Midlothian Balancing Reservoir (MBR), the 60% design of the Joint Cedar Creek (JCC1) Lake Intake Pump Station, and the 60% design of the various section pipelines. Further, IPL program management team provided informal VE with design reviews on each deliverable and worked collaboratively with Designers to achieve greater value in the projects. The efforts of formal VE and informal VE resulted in an estimated opportunity of savings ranging from 1% of reviewed cost to almost 50% of individual component project costs.
VALUE ENGINEERING PROCESS

SAVE International™ notes that Value Engineering is “a systematic process used by a multidisciplinary team to improve the value of a project through the analysis of its functions.” Noting that value of a given component can be defined as the ratio of function to cost, it becomes apparent that the value of a project’s design can be improved in three basic ways:

1. Maintaining the result of a design function at a lower cost,
2. Improving the result of a design function at the same or similar cost, or
3. Improving the result of a design function at a reasonable / acceptable increase in cost.

Formal Value Engineering for the IPL Project utilized a consistent process including Pre-workshop activities, multi-day workshop, and post workshop decision making. Pre-workshop activities generally included review of project information (studies, reports, design drawings, specifications, and schedules) and developing cost models. The workshop followed the six phase “Job Plan” as outlined by SAVE International™:

1. Information Phase – Owner and Designer present to VE Team project background, establish VE study constraints, determine economic data for life cycle cost, and define functional requirements.
2. Functional Analysis Phase – Confirm project objectives, determine key items / elements of project.
3. Creative Phase – Generation of large quantity of ideas which could add value to project regardless of idea feasibility (brainstorming session).
4. Evaluation Phase – Select from ideas generated in Creative Phase those with the most merit for further development as recommendations or as a design suggestion.

Mid Workshop Review – Owner and Designer review ideas selected in Evaluation Phase to determine fatal flaw of ideas that were infeasible OR encourage further development of ideas from Creative Phase that did not make it to the Evaluation Phase selection. Refinement of Evaluation Phase idea list based on Mid Workshop Review.

5. Development Phase – Each idea from refined Evaluation Phase is developed into a narrative description, life cycle cost analysis and comparison of advantages / disadvantages.
6. Presentation Phase – Final day of VE Workshop, VE Team presentation to Owner and Designer
The Post Workshop activities included VE Team preparing preliminary report of findings from the workshop. Designer response to each idea presented from Workshop Development Phase and a decision making meeting with the VM Consultant, Owner/IPL Program staff and Designers.

Utilizing the above noted process resulted in successful workshops. Besides the potential cost savings to be realized from the suggested revisions, certain ideas were presented noting other benefits including:

a. Improved operations / maintainability
b. Improved coordination / constructability
c. Improved consistency of quality control
d. Longer life project elements
e. Reduction in carbon footprint
f. Improved safety

In the section below on IPL Reservoirs design, specifics on some idea development from the formal VE will be presented in more detail. Summary outcomes of the six formal value engineering workshops are summarized in Table 1 below:

<table>
<thead>
<tr>
<th>Workshop Topic/Stage</th>
<th>Number of Ideas for Evaluation</th>
<th>Est. VE Savings</th>
<th>Date of VE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Design</td>
<td>Creative Phase: 183 Evaluation Phase: 49 Accepted / Further Study: 44</td>
<td>8%</td>
<td>Sept. 2010</td>
</tr>
<tr>
<td>30% Booster Pump Stations (JB2, JB3, JB4)</td>
<td>288 Creative Phase: 53 Evaluation Phase: 53 Accepted / Further Study: 46</td>
<td>38%</td>
<td>May 2012</td>
</tr>
<tr>
<td>30% Lake Pump Stations (LP1, JCC1, JRC1)</td>
<td>285 Creative Phase: 47 Evaluation Phase: 47 Accepted / Further Study: 24</td>
<td>16%</td>
<td>Oct. 2012</td>
</tr>
<tr>
<td>60% JB3 and MBR</td>
<td>317 Creative Phase: 56 Evaluation Phase: 56 Accepted / Further Study: 30</td>
<td>5%</td>
<td>Sept. 2013</td>
</tr>
<tr>
<td>60% JCC1</td>
<td>272 Creative Phase: 59 Evaluation Phase: 59 Accepted / Further Study: 18</td>
<td>~1%</td>
<td>Oct. 2013</td>
</tr>
<tr>
<td>60% Pipelines</td>
<td>209 Creative Phase: 44 Evaluation Phase: 44 Accepted / Further Study: 30</td>
<td>4%</td>
<td>Oct. 2013</td>
</tr>
</tbody>
</table>

**INFORMAL VE MEASURES**

Along with the formal VE, a considerable effort was made in constant refinement of project design criteria and design reviews. This informal VE process was truly a collaborative effort with idea initiation and vetting from amongst staff from Owner, IPL program team, Designer, and program wide service consultants. While not conducted using the six phase process as described above, the savings can be considered a value to project as it reduces cost without compromising the functionality of design. Table 2 lists a handful of the value increase ideas.
Table 2 – IPL Informal Value Engineering Summary

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Est. VE Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing Permits</td>
<td>Design of several road and creek crossings were revised from tunnel crossings to open cut crossings</td>
<td>Five crossings saving approximately 2400 feet of tunneling work and 10 shafts</td>
</tr>
<tr>
<td>Tunnel Design</td>
<td>Design of several tunnels revised to standard pipe wall and cover depths based on site specific conditions</td>
<td>Reduced shaft excavation by 60,000 cy; reduced pipe materials by 7,500 tons</td>
</tr>
<tr>
<td>Vertical pump can</td>
<td>Design revised to allow use of partial can in lake intake pump station</td>
<td>Significant savings in material and installation costs</td>
</tr>
<tr>
<td>Steel Coils for Pipe</td>
<td>Purchasing decision allows for early payment for steel coil – assumed savings based on reduced interest costs</td>
<td>Cash flow cost savings</td>
</tr>
<tr>
<td>Pipe Wall</td>
<td>Pipe wall design based on pressure class with sidewall support developed by improved embedment materials. Allowing use of 46ksi yield steel for pressure class design.</td>
<td>Approximately 15,000 tons of pipe material</td>
</tr>
<tr>
<td>MBR Yard Pipe</td>
<td>Design reconfiguration of MBR site reduced quantity of valves and large diameter pipe</td>
<td>Approximately 500 tons of pipe materials, 2 large dia control valves and vaults</td>
</tr>
<tr>
<td>Granular Embedment</td>
<td>Design revision to allow use of local source sand and gravel embedment</td>
<td>Approximate 700,000 tons of embedment material – eliminates 1,000 miles hauling</td>
</tr>
<tr>
<td>Reservoir</td>
<td>See below discussion</td>
<td>See below</td>
</tr>
<tr>
<td>TOTAL</td>
<td>Informal VE lead to a savings of approximately 4% of project budget</td>
<td></td>
</tr>
</tbody>
</table>

IPL RESERVOIRS

One of the major components of the IPL system is a group of earthen embankment suction and balancing reservoirs located along the pipeline route. The Reservoir Design Engineer Team, consisting of prime consultant Freese and Nichols, Inc. of Fort Worth Texas and subconsultant Nathan D. Maier, Inc. of Dallas, TX, are responsible for the planning, design and construction of three reservoirs for the IPL. Two of the reservoirs, JB2R and JB3R, are suction reservoirs at the system booster pump stations – design of these reservoirs consists of two 40-MG cells with space for future expansion to an ultimate buildout of four 40-MG cells. The initial buildout of JB3R is scheduled for completion in summer 2015 – JB2R is scheduled for Phase 4 of the IPL Project. The other reservoir, MBR, is a balancing storage reservoir at the system high point – sitting at
interface of the 108-inch dia. Pipelines for Sections 13 and 14. MBR is currently under construction and is configured for three approximately 150-MG cells (See Figure 2).

The balancing and suction reservoirs located along the proposed pipeline route serve several purposes. At the booster pump stations, they allow for sufficient water to be stored such that the net positive suction head requirements of the pumps are met. They also provide a level of surge control along the pipeline so that, if a valve is closed unintentionally, the surge wave will not travel the entire length of the pipeline, but will likely be contained in a reservoir. The balancing reservoirs will also potentially allow for time-of-day pumping - which is a situation where water is pumped from the supply reservoirs into the balancing reservoirs at a time of day when the cost of pumping is lower. Water can then be gravity fed to downstream distribution points during periods when pumping costs are significantly higher.

Design of IPL reservoirs are also configured with consideration for future expansion and regular operation maintenance. The reservoirs are designed for multiple cells – this allows for
some redundancy and maintainability. Each cell at the booster pump station sites contains sufficient volume to backfill the system following a line break / emergency dewatering. The cells are designed to remain serviceable when one cell is down for maintenance and the other is at maximum water height. Similarly, at the MBR, the third cell allows for greater flexibility in operation and maintenance.

Design elements

The basic design of the reservoirs include a). earthen embankments either full clay or with a zoned clay core embankment, b). an interior liner system consisting of a 60-mil HDPE liner over composite geonet and covered with a 9” layer of soil cement, c). exterior slope protection with locally common Bermuda grasses, d). an underdrain system, e). inlet and outlet pipes and structures, and f). an overflow structure. (Figure 3)

![Figure 3 – Typical Design Section](image)

Reservoir Lining - Liners are needed to provide protection from erosion from wave action as well as some additional protection from seepage. In addition a liner provides a means to allow sediment removal from the reservoir. The use of a thin soil cement lining system provides a durable surface which is also economical. Placing the soil cement over the HDPE liner provides a durable relatively impervious surface. (See Figure 4 below)
Inlet and Outlet: The inlet and outlet of the reservoir is designed for a maximum capacity of the pipeline. The inlet transitions from the pipeline through a control valve. The pipeline section which goes under or through the embankment includes a concrete encasement around the pipe. The entrance into the reservoir is through a concrete headwall structure at the bottom of the reservoir cell. The outlet pipe is constructed in a similar fashion with a headwall and concrete encasement around the pipe. The outlet has a trash rack installed to prevent introducing any foreign materials into the pipeline and/or pump station suction header. The inlet and outlet are located on opposite sides of the reservoir to create as much turnover of the water as possible. For JB2R and JB3R – the outlet pipe is sized at 114-inch while the inlet is 108-inch diameter. For the MBR, both inlet and outlet pipe are sized at 120-inch diameter. (See Figure 5 below)
Figure 5 - Construction of Encasement on 108-inch Steel Inlet Pipe at JB3R

Overflow Weir - The reservoir needs an overflow weir to prevent potential overtopping of the embankment. It provides an uncontrolled outlet in case of operator error or lost communication to a pump station or outlet structure. It also provides a discharge capability in the during a significant storm event. The overflow design for all IPL reservoirs includes a broadcrested weir located on the side of the reservoir which will allow flow to move down a protected section away from the toe of the embankment.

VALUE ENGINEERING ELEMENTS

As discussed above, an extensive Value Engineering (VE) review was conducted by multiple consultants on behalf of the IPL Team. The VE approach evaluated several project recommendations in an effort to reduce the cost of the project, as initially proposed, or to provide concepts that added value to the overall project. The VE evaluation looked at all recommendations
of the overall IPL Project, which included the booster pump stations and suction reservoirs. Many VE recommendations were considered and discarded, and other recommendations were selected for additional review and consideration. Through a series of meetings, the VE recommendations were further evaluated and selected recommendations were identified to carry into the preliminary design phase and for modification to the draft Preliminary Design Report.

Formal VE recommendations included one major revision coordinating design assumptions at the booster pump station which allowed for reduced operating levels conducive to site earthwork balance. Recommendations also included revisions to steepen interior slopes in the reservoirs and to provide reduced size of clay core at the MBR zoned embankment section.

Informal VE process also led to several revisions which added value to the project. The MBR site was re-designed from four cells at 100 MG each to a three cell at 150 MG each configuration. This allowed greater capacity in individual cells, provided full build out rather than expansion in the future, allows additional capacity for system operations and reduced the overall volume of earthen embankments. Another informal revision included removal of chemical feed from within reservoir outlet structure – which was determined as non-essential following a physical modeling study conducted for the JB3 pump station / reservoir system. As part of TRWD innovative approach to developing technology in design, manufacturing and construction, the JB3R 114-inch diameter outlet pipes were allowed on a trial basis to be cement mortar lined in the plant; which turned out to be a successful technique and provides value to the future projects in the system utilizing this size pipe.

Table 3 provides a summary of the “value” of the VE Process with respect to the reservoir design. The “value” as defined above, i.e. ration of functional unit to cost, for the reservoir is gallons storage per dollar capital construction (gal / $).
Table 3 – Progression of Value Add to IPL Reservoir Projects

<table>
<thead>
<tr>
<th>Milestone</th>
<th>JB2 Reservoir</th>
<th>JB3 Reservoir</th>
<th>MBR</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Design&lt;sup&gt;1&lt;/sup&gt; Jul. 2010</td>
<td>40 MG - $11,046,000</td>
<td>40 MG - $11,046,000</td>
<td>NIC</td>
<td>3.62 gal / $ budget ($276,000 / MG)</td>
</tr>
<tr>
<td>IPL Baseline&lt;sup&gt;2&lt;/sup&gt; Apr. 2011</td>
<td>40 MG - $11,247,000</td>
<td>40 MG - $11,247,000</td>
<td>200 MG - $48,300,000</td>
<td>3.96 gal / $ budget ($252,000 / MG)</td>
</tr>
<tr>
<td>Program Update&lt;sup&gt;3&lt;/sup&gt; Mar. 2012</td>
<td>120 MG - $41,650,000</td>
<td>120 MG - $57,746,000</td>
<td>300 MG - $52,003,000</td>
<td>3.57 gal / $ budget ($280,000 / MG)</td>
</tr>
<tr>
<td>30% VE Study&lt;sup&gt;4&lt;/sup&gt; Dec. 2012</td>
<td>80 MG - $16,454,000</td>
<td>80 MG - $16,580,000</td>
<td>400 MG - $56,952,000</td>
<td>6.22 gal / $ budget ($161,000 / MG)</td>
</tr>
<tr>
<td>MBR Reconfiguration&lt;sup&gt;5&lt;/sup&gt; Mar. 2013</td>
<td>80 MG - $16,454,000</td>
<td>80 MG - $16,580,000</td>
<td>450 MG - $49,423,000</td>
<td>7.40 gal / $ budget ($135,000 / MG)</td>
</tr>
<tr>
<td>60% VE Study&lt;sup&gt;6&lt;/sup&gt; Nov. 2013</td>
<td>80 MG - $13,898,000</td>
<td>80 MG - $12,625,000</td>
<td>450 MG - $44,601,000</td>
<td>8.58 gal / $ budget ($117,000 / MG)</td>
</tr>
<tr>
<td>Reservoir Phase 1 Bid&lt;sup&gt;7&lt;/sup&gt; Aug. 2014</td>
<td>80 MG - $13,898,000</td>
<td>80 MG - $11,387,000</td>
<td>450 MG - $44,223,000</td>
<td>8.78 gal / $ budget ($114,000 / MG)</td>
</tr>
</tbody>
</table>

1. Baseline system from Concept Design. Did not include MBR in Concept Project.
2. System configuration established with MBR included. Minimum sizes of reservoirs for IPL established.
3. System pumping requirements set at much high elevations than anticipated; additional capacity requested requires build out of three cells per reservoir.
4. VE recommendation accepted resulting in lower NPSH elevation and a balanced earthwork site; additional capacity requested at MBR
5. Informal VE results in reconfiguration of MBR from 4 cells to 3 cells
6. Formal VE results in steeper interior slopes; informal VE results in removal of 24” outlet and chemical feed revision
7. Actual bid results from JB3R and MBR – MBR combined project with adjacent pipeline; JB3R bid in advance of JB3 Pump Station for coordination ease.

As can be seen, the IPL Value Engineering process both formal and informal provide great value to the project and for the reservoir component resulted in more than doubling the value during the life of the design process.