CCN 132589

Hanford Tank Waste Treatment and Immobilization Plant

May 2006 Estimate at Completion

May 31, 2006

Bechtel National, Inc.

Washington Group International
Integrated Engineering, Construction, and Management Solutions

Aerial Photo of WTP

The Waste Treatment Plant Construction Site, May 2006. Clockwise from top right, Low-Activity Waste Facility, High-Level Waste Facility, Pretreatment Facility, Analytical Laboratory.

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ACRONYMS AND ABBREVIATIONS

BOF	balance of facilities
BNI	Bechtel National, Inc.
DOE	U.S. Department of Energy
DOE-ORP	U.S. Department of Energy, Office of River Protection
DWPF	Defense Waste Processing Plant
EAC	estimate at completion
EPC	engineering, procurement, and construction
EPCC	engineering, procurement, construction, and commissioning
EFRT	External Flowsheet Review Team
ERT	External Review Team
EVMS	earned value management system
FAC	forecast at completion
FPR	forward pricing rates
FY	fiscal year
HLW	high-level waste (facility)
ITS	important to safety
Lab	analytical laboratory
LAW	low-activity waste (facility)
M	million
NDE	non-destructive examination
NLD	non-radioactive liquid waste disposal system
PT	pretreatment (facility)
ROM	rough order of magnitude
TPA	Tri-Party Agreement
TPRA	technical and programmatic risk assessment
USACE	U.S. Army Corps of Engineers
WBS	work breakdown structure
WGI	Washington Group International
WTP	Hanford Tank Waste Treatment and Immobilization Plant

1. Overview

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is a first-of-a-kind project designed to solve one of our nation's most difficult nuclear waste problems—immobilizing 54 million gallons of dangerous chemical and highly radioactive waste. In 2000, the U.S. Department of Energy, Office of River Protection (DOE-ORP), awarded a contract to Bechtel National, Inc. (BNI) and subcontractor, Washington Group International (WGI), to complete the WTP engineering, procurement, construction, and commissioning (EPCC).

In December, the forecast at completion (FAC), which is the estimated contract cost for the project, was $8,777 million. This included an estimate at completion (EAC) of $7,736 million for the work scope plus project contingency of $1,041 million to address uncertainties within that scope (Figure 1). Based on a technical and programmatic risk assessment (TPRA) of the project, BNI also recommended that DOE-ORP maintain an additional allowance of $1,760 million for risks outside the current scope of the contract. Total project cost without fee, but with TPRA, was estimated at $10,537 million at that time.

Subsequent to the *December 2005 EAC*, the project commissioned two external "best-and-brightest" review teams, the External Flowsheet Review Team (EFRT) and the External Review Team (ERT). Both teams were composed of experts from industry and academia. The EFRT conducted a comprehensive review and analysis of the WTP design and throughput capacity to identify risks associated with meeting project requirements. The ERT reviewed the project cost and schedule. The results of the reviews, which are discussed in Section 3.2, are currently being addressed and the estimated costs are included in this EAC.

Two recommendations from the ERT have had significant impact on this EAC. Based on industry experience with first-of-a-kind projects of prolonged duration, the team recommended the addition of $1 billion to account for the "unknown unknowns" that could be encountered and are outside of the contract scope. Examples of unknown unknowns include regulatory changes and uncertainties in the economy, such as the steep rise in construction material pricing that occurred prior to the *December 2005 EAC*.

No nuclear facility of similar size or complexity has been built in the United States in nearly three decades. Among the challenges:

- ***Rebuilding an atrophied U.S. nuclear supply chain***
- ***Designing and constructing a first-of-a-kind nuclear facility at the frontier of science and engineering***
- ***Addressing change, including a significant increase in plant size and revised ground motion criteria***

Summary EAC Reconciliation ($ millions)

	EAC	Project Contingency	TPRA	Total
***December 2005 EAC* (without fee)**	**$7,736**	**$1,041**	**$1,760**	**$10,537**
Allowance for unknown unknowns ("best-and-brightest" recommendations)		300	700	1,000
All other changes (net)	1,050	310	(1,344)	16
***May 2006 EAC* (without fee)**	**$8,786**	**$1,651***	**$1,116**	**$11,553**

**Note: This figure represents $1,351 million project contingency plus $300 million DOE contingency for scope options.*

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Figure 1.

The WTP is currently estimated to cost $10,437 million plus contractor fee.

Based on the results of the technical and programmatic risk assessment (TPRA), the project team recommends that DOE maintain an additional allowance of $1,116 million to address risks outside the contract scope, bringing total project cost to $11,553 million.

The ERT also recommended that a number of the risks identified in the TPRA allowance be transferred into the scope of the project and included in the EAC. The net impact of these transfers and all other changes to the project was $16 million, as shown in Figure 1 and further described in Section 3.8.

As shown in Figure 2, the May 2006 FAC is $10,437 million. This includes $8,786 million for the work scope, $1,351 million for project contingency, and an additional $300 million for DOE contingency for scope options. Based on an updated TPRA analysis, we also recommend that DOE-ORP maintain an allowance of $1,116 million for risks outside the current scope of the contract, including $700 million for unknown unknowns (which, when coupled with the $300 million DOE contingency for scope options, accounts for the $1 billion recommended

May 2006 Cost and Schedule Summary ($ millions)

	Cost to Date	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Estimate at Completion	2,738	552	611	622	606	545	554	614	549	472	385	336	235	(33)	-	$8,786
Project Contingency		20	71	42	54	124	101	42	101	165	172	169	123	84	84	$1,351
DOE Contingency for Scope Options													100	100	100	$300
Forecast at Completion*	**2,738**	**572**	**682**	**663**	**660**	**669**	**655**	**656**	**650**	**637**	**557**	**505**	**458**	**151**	**184**	**$10,437**
TPRA Allowance																$1,116
Total Project Cost (w/o fee)																$11,553

**Note: Annual costs total less than $690 million to reserve funding for contractor fee. The EAC also includes a credit ($84 million) for operations spares and salvage values for construction equipment per Contract Section B.*

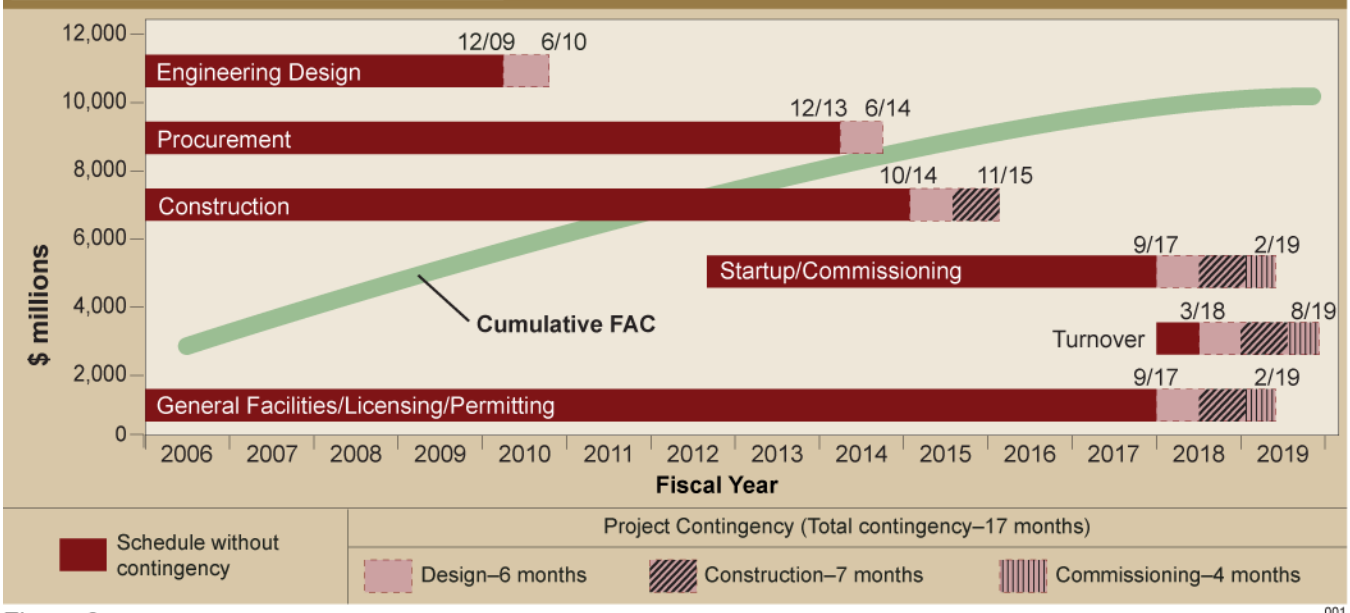

Figure 2.

by the ERT). Total project cost without fee, but with TPRA, is now estimated at $11,553 million.

The detailed estimate (approximately 2,400 pages) is based on the existing detailed engineering design, which is more than 65% complete. The estimate includes site productivity factors, labor wage rates, escalation, and other elements that influence project costs.

Figure 3 provides a comparison of the estimated costs by facility for the contract baseline in March 2003, the *December 2005 EAC*, and the *May 2006 EAC*. The figure also shows the project contingency and TPRA allowance that were included in each of these estimates.

WTP Cost Progression ($ millions) All figures are escalated

Facility	Mar 2003 Contract Baseline	*Dec 2005 EAC*	*May 2006 EAC*
Pretreatment	1,619	3,169	3,463
Low-Activity Waste	988	1,192	1,331
High-Level Waste	1,389	2,076	2,243
Balance of Facilities	508	682	918
Analytical Laboratory	352	421	494
Late Adjustments	0	196	337
Total Estimate at Completion	**$4,856**	**$7,736**	**$8,786**
Project Contingency	550	1,041	1,351
DOE Contingency for Scope Options	–	–	300
Total Forecast at Completion	**$5,406**	**$8,777**	**$10,437**
TPRA Allowance	100	1,760	1,116
Total Project Cost (w/o fee)	**$5,506**	**$10,537**	**$11,553**

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Figure 3.

Figure 4 provides a schedule comparison of hot commissioning and contract completion for the March 2003 contract baseline, the *December 2005 EAC*, and the *May 2006 EAC*.

Schedule Comparisons—Hot Commissioning and Contract Completion

	Start of Hot Commissioning	Completion of Hot Commissioning	Contract Completion
March 2003 Contract Baseline	June 2010	January 2011	July 2011
December 2005 EAC	March 2016	November 2016	May 2017
May 2006 EAC	June 2018	February 2019	August 2019

Note: All dates include schedule contingency.

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Figure 4.

2. Project Background

The WTP project scope is to design, build, and commission a plant to immobilize 54 million gallons of dangerous chemical and highly radioactive waste stored in 177 aging underground tanks at the DOE's Hanford Site near Richland, Washington. The waste was accumulated between 1944 and 1989, when the Hanford Site produced plutonium and other nuclear materials for nuclear defense, and represents one of the nation's most serious cleanup problems. Sixty-seven of the tanks have leaked more than a million gallons of waste into the ground. The new plant will use a vitrification process to transform the waste into a chemically immobile glass that is environmentally safe and stable.

As shown in Figure 5, the WTP includes three primary processing facilities: the pretreatment (PT) facility, which separates the waste into its low-activity waste and high-level waste components; the high-level waste (HLW) facility, which immobilizes (vitrifies) the high-level waste

WTP Site Plan

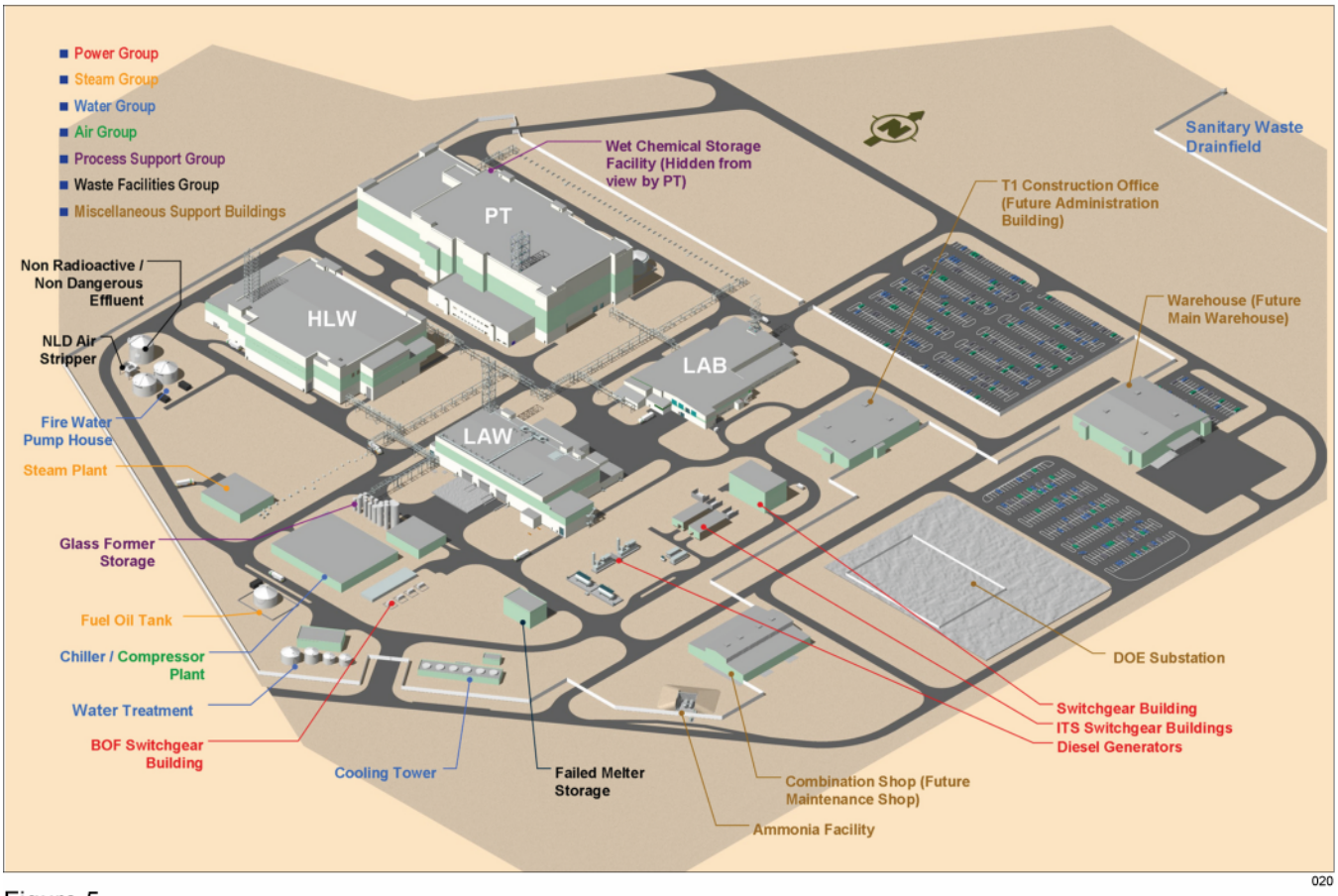


Figure 5.

for offsite (proposed Yucca Mountain) disposal; and the low-activity waste (LAW) facility, which vitrifies the low-activity waste for onsite (Hanford) disposal. The WTP also includes the large analytical laboratory (Lab) and supporting facilities, referred to as the balance of facilities (BOF).

The WTP is a massive undertaking, comparable in scope to simultaneous construction of two nuclear power plants. No nuclear facility of similar size has been built in the United States in nearly three decades—DOE and Bechtel have had to rebuild a significantly atrophied nuclear industry supply chain and train a new generation of employees to work to nuclear standards.

The WTP is sometimes compared with the Defense Waste Processing Plant (DWPF), a radioactive waste vitrification plant built in the 1980s and 1990s at the DOE Savannah River Site. However, the WTP is larger than the DWPF, with more throughput capability, and is subject to broader and more stringent regulatory requirements.

The WTP is technically demanding as well. In addition to the significant challenges of handling and vitrifying high-level radioactive waste, the WTP uses a caustic chemical process rather than the acidic process used in DWPF, making the WTP chemical process a first-of-a-kind design.

The Hanford radioactive waste is not only toxic and radioactive—it is also chemically and physically heterogeneous. The characteristics of this feed material require the integration of research and development of new technology into the plant design processes.

EAC History. This *May 2006 EAC* is the fourth in a series of EACs developed for the WTP. Figure 6 summarizes the evolution of the WTP project cost from December 2000 through May 2006. In 2000, the project was based on a schedule-driven approach designed to meet regulatory deadlines. Detailed design was just starting and the project plan included a second plant (that was not yet estimated or included in the project cost) in order to complete the mission.

The project approach underwent a fundamental change between the 2000 and 2003 EACs. The capacity of the WTP was increased both in pretreatment and in high-level waste, eliminating the need for the second plant and saving billions of dollars in life-cycle costs. Throughput of the

WTP EAC Evolution

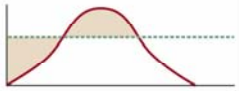
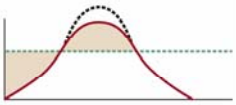
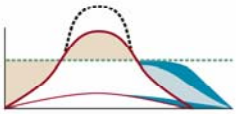
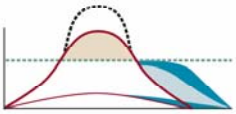
	December 2000	March 2003	December 2005	May 2006
% Design	<5%	<40%	>60%	**>65%**
% Procurement	0%	<10%	>40%	**>40%**
% Construction	0%	<15%	>25%	**>25%**
Major Events	▪ Multi-Billion $ WTP Phase II Planned (cost not included in project)	▪ HLW Throughput Increased 4X ▪ PT Increased 40% ▪ WTP Phase II Eliminated	▪ Seismic ▪ Fire Protection ▪ Pulse Jet Mixer ▪ Pricing and Productivity ▪ Material Quantities ▪ Contingency Increased 2X	▪ TPRA transfer to FAC – EFRT recommendations – ERT recommendations – $490M FY06 funding – New regulations ▪ Unknown unknowns, $1B allowance – $300M in FAC – $700M in TPRA
Execution Driver (Also see Figure 13)	 ***Schedule***	 ***Schedule***	 ***Funding Constrained***	 ***Funding Constrained***
Contract FAC (Contractor contingency and DOE contingency for scope options in parens)	$4.0B ($0.5B)	$5.4B ($0.55B)	$8.777B ($1.04B)	$10.437B ($1.651B)
Gov't Technical/Program Contingency (TPRA)	$0.2B (Tech Only)	$0.1B (Tech Only)	$1.760B	$0.416B
Gov't Risk of Unknown unknowns (TPRA)	$0.0B	$0.0B	$0.0B	$0.700B
Total (without fee)	**$4.2B**	**$5.5B**	**$10.537B**	**$11.553B**
Start of Hot Commissioning (including contingency)	**December 2007 (0 months)**	**June 2010 (6 months)**	**January 2016 (12 months)**	**June 2018 (17 months)**

Figure 6.

Aerial Photos of WTP Progress

August 2001

May 2006

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high-level waste glass-making process was quadrupled and the capacity of the pretreatment processes was increased by 40%. By 2003, detailed design had commenced and fieldwork at the site was underway.

By the time the *December 2005 EAC* was prepared, project progress had been substantial and significant lessons learned were incorporated into the estimate. Four major aspects of the project evolved from 2003 to 2005. First, substantial regulatory changes, including changes to criteria for seismic design, affected the project. Second, the design of the plant advanced sufficiently to identify solutions to known technical challenges on this first-of-a-kind plant. Third, procurement and construction advanced sufficiently to identify and begin to solve the nuclear supply chain issues that resulted from the atrophy of large-scale, domestic nuclear construction projects. And fourth, BNI and the Government came to recognize that the significant technical and programmatic risks outside the scope of the BNI contract should be allowed for in the estimate (via the TPRA). The period between 2003 and 2005 also saw unprecedented increases in certain construction material costs (e.g., steel, lumber) on world markets.

The *December 2005 EAC* also included a change in approach from a schedule-driven to a funding-constrained baseline. The result was a substantial increase in the project cost due to escalation and extension of the project schedule (Section 3.8, Figure 14).

The *May 2006 EAC* incorporates the recommendations from the two external "best-and-brightest" review teams, including the addition of $1 billion in DOE contingency to address potential unknown unknowns. It also reflects the impacts of reduced fiscal year 2006 funding and new regulations, including DOE Order 226.1 on DOE oversight and 10 CFR 851 on worker safety and health.

Detailed design is more than 65% complete and construction is more than 25% complete, providing confidence in the current cost and schedule.

3. Cost and Schedule Summary

The following sections describe the methodology for determining the WTP cost and schedule estimates, provide details regarding those estimates, and discuss events that have impacted the project and caused changes in the cost and schedule. The *May 2006 EAC* reflects a project for which design is more than 65% complete and construction is more

than 25% complete. The level of detailed design available at this point in the project provides confidence in the estimate.

3.1 Estimate Methodology and Basis

The *May 2006 EAC* is a bottom-up cost estimate based on the quantities of construction commodities (such as cubic yards of concrete and tons of steel) derived from the detailed design and on the labor and non-labor resources required to complete design, construction, and commissioning. As shown in Figure 7, the estimate is based on the major work elements (facilities) and the processes used to design, build, and commission them. The detailed design specified the quantity of material (concrete, steel, pipe, etc.) and equipment (pumps, vessels, instruments, etc.) required. These quantities then provided the basis for estimating craft, supervision, and management jobhours, total costs for materials and equipment, and required subcontracts.

Both the cost estimate and the schedule are built up from the individual activities and resources required for completion of the WTP.

Once the commodities and labor and non-labor resources were defined, the activities required to design, procure, install, and commission these components were scheduled. The schedule is logic-driven and recognizes

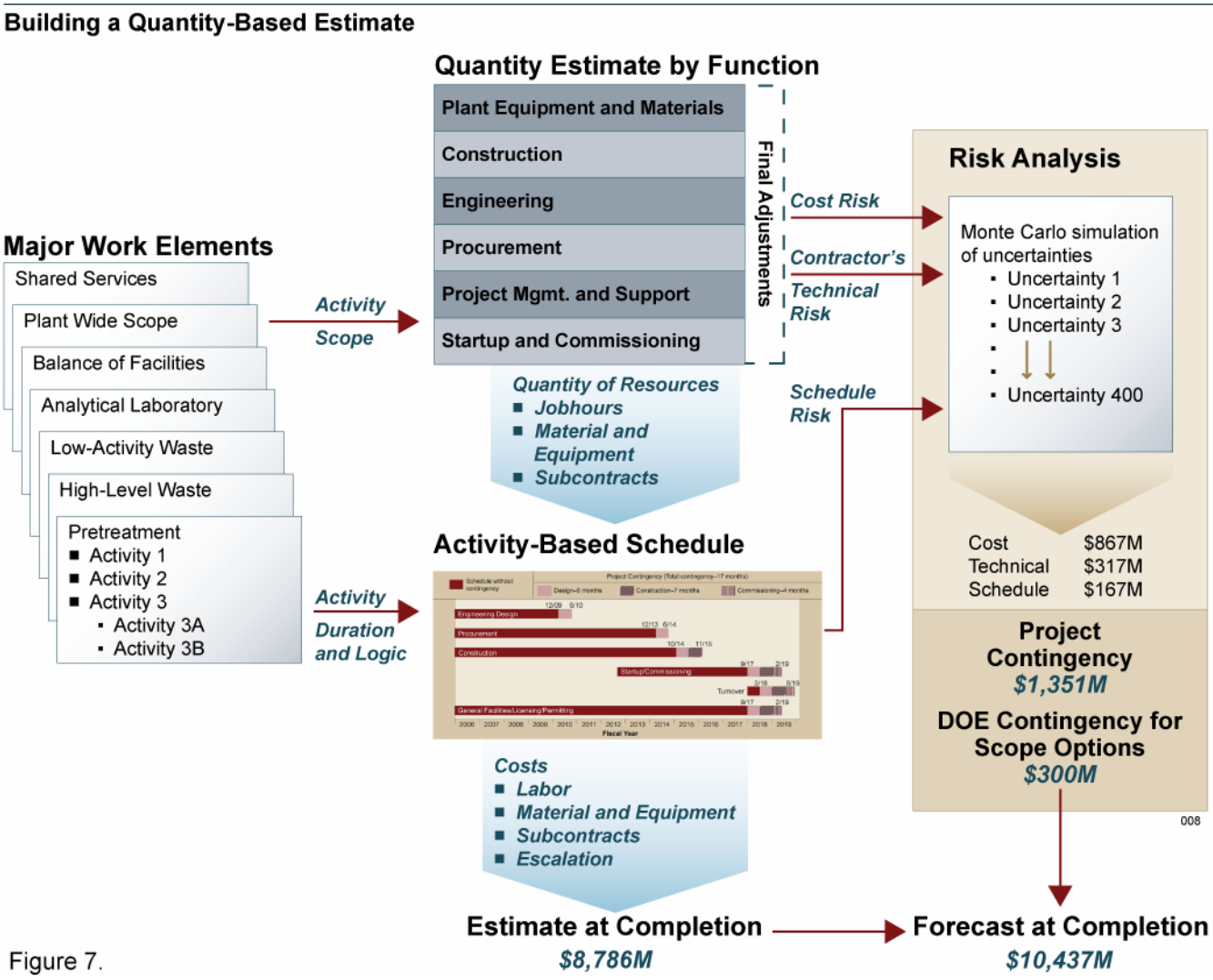

Figure 7.

The time between engineering and construction was increased to minimize the possibility of construction rework

predecessor and successor relationships, i.e., if one task has to be complete before the next task can begin, that logic is built into the schedule. The time between engineering and construction was increased for activities to minimize the possibility of construction rework. The schedule also incorporates constraints to recognize the availability of funds or personnel. The status of design, procurement, and construction was factored into the schedule and includes experience to date with productivity rates and procurement lead times.

Once the base estimate was established, the contingency for the project was calculated. Project contingency is defined as the additional funds and schedule duration that are added to an estimate to account for uncertainties in estimate detail, quantity, pricing, and productivity. For the WTP, the project contingency was developed at an 80% confidence level, which means there is an 80% probability that the project scope can be completed at or below the estimated cost. To arrive at this confidence level, the project analyzed more than 400 separate cost and schedule uncertainties to quantify the funds and time necessary to address the uncertainties. Through this detailed analysis, which is further explained in Section 4.1, it was determined that a project contingency of $1,351 million was required to achieve an 80% confidence level. Based on DOE direction, $300 million was added to the project contingency as DOE contingency for scope options.

WTP tank cooling towers, January 2006.

The project team also performed a TPRA analysis of remaining risks outside the current scope of the project. Based on this assessment, the project recommends that DOE-ORP maintain an additional allowance of $416 million (also calculated at an 80% confidence level), which, when added to the $700 million in TPRA for unknown unknowns, results in a total updated TPRA of $1,116 million. A schedule sensitivity analysis was conducted to determine the schedule contingency required; schedule contingency was also calculated to provide an 80% confidence level.

3.2 EAC Review and Validation

Two best-and-brightest review teams were commissioned to validate the technical approach and to ensure a robust, high-confidence estimate.

Industry experts have provided support throughout the estimating process, bringing additional knowledge and capabilities to the project team. Two "best and brightest" review teams from outside the WTP project were tasked with validating the technical approach and ensuring a robust, high-confidence estimate. The recommendations of these two teams—the EFRT and the ERT—are discussed in the following sections. These recommendations have been incorporated into the project and are reflected in this EAC. The USACE also performed an extensive review of the *December 2005 EAC*, and is currently reviewing the *May 2006 EAC* for validation. Figure 8 presents a status of the activities that were identified in the *December 2005 EAC*.

External Flowsheet Review Team. In October 2005, the EFRT was assembled to challenge the technical design of the WTP. The team was made up of the foremost experts from the chemical processing industry,

WTP EAC Plan for Fiscal Year 2006

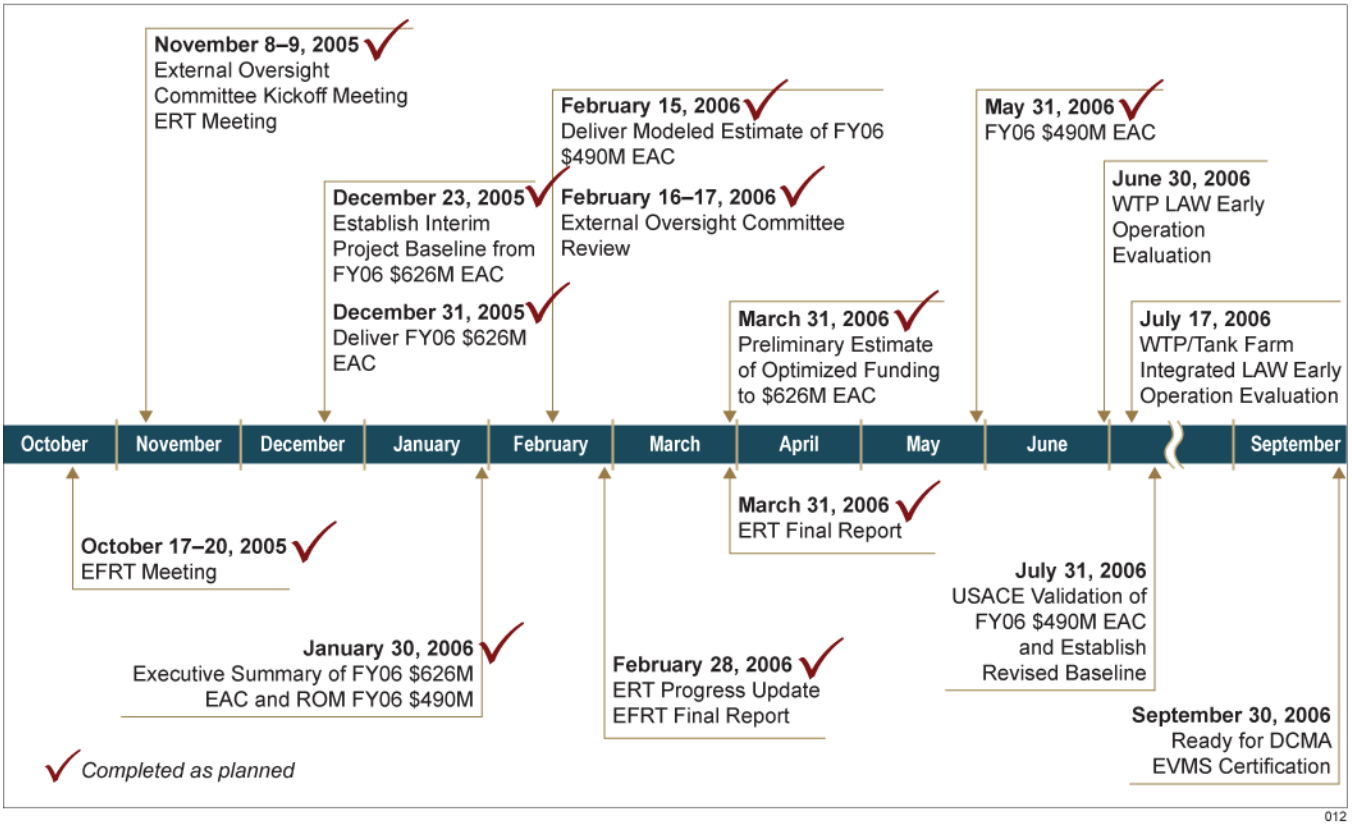

Figure 8.

the glass industry, the nuclear waste industry, national laboratories, and universities. The EFRT, which included representatives from most major DOE suppliers and competitors of BNI and WGI, consisted of 31 main reviewers, 22 of whom have doctorate degrees in their area of specialization. Collectively, the team has over 1,000 years of experience in their fields. Another 20 consultants provided support.

In March 2006, the team documented their findings in a final report, "Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput." After reviewing hundreds of technical questions, the team identified 17 major issues that needed to be resolved to ensure the WTP would meet design throughput requirements. The team also identified 11 potential issues that, when resolved, would provide additional assurance of meeting design throughput. The EFRT concluded that all of the issues had solutions and would not require development of new technologies. They noted that resolution efforts for some of the issues identified were already underway by the project team.

Immediate action was taken to develop a project response plan to address all issues in a thorough, timely, and prudent manner.

External Review Team. In November 2005, the ERT was assembled, bringing together experts from the engineering and construction industry and academia with demonstrated expertise in the design, construction,

operation, project management, and cost estimating of nuclear and chemical processing plants. The 16-member team was comprised of individuals from outside BNI including most major DOE suppliers and competitors as well as retired BNI engineers who are experts in their field. The talent brought together for this type of cost and schedule review is unprecedented in the DOE complex.

Construction of the WTP chiller-compressor building, April 2006.

The ERT's charter was to challenge the *December 2005 EAC* cost and schedule estimate. The ERT assessed the scope of the project, the contract requirements, the management execution plan, the project schedule, and the cost estimate, including contractor contingency. They also performed an analysis of risks outside the current scope of work.

The ERT concluded that the execution plan for the contract scope of work, the estimating methodology, and the estimate itself were generally valid and achieved an 80% confidence level as measured by standard industry criteria. However, the ERT also concluded that the TPRA did not address the unknown unknowns associated with "pioneer process plants." Based on a Rand study of comparable pioneer process plants, the team recommended that DOE increase the TPRA allowance by $1.0 billion to address the unknown unknowns and that a more proactive risk management program be initiated to identify and manage these risks, which are outside of the contract scope.

The ERT also recommended that some risks outside the scope of work (but identified and captured in the TPRA allowance) be transferred into the project scope and included in the EAC. Examples include the impacts associated with the reduction in fiscal year 2006 funding from $626 million to $490 million, operational enhancements recommended by the EFRT, and new regulations recently included in the WTP contract. To provide a higher confidence estimate, the ERT recommended increasing allowances to cover the possibility of future economic inflation, to mitigate the potential lack of a skilled workforce to operate the WTP, and to address other uncertainties in the remaining work scope. The resulting changes to the TPRA allowance are more thoroughly discussed in Section 3.8.

Bolting structural steel for installation at the WTP LAW facility, April 2006.

3.3 Estimated Cost at Project Completion

The *May 2006 EAC* includes a detailed estimate of $8,449 million for direct costs for engineering, procurement, construction, and commissioning of the WTP. In addition, the estimate includes $337 million of late adjustments, resulting in an EAC of $8,786 million. Examples of these late adjustments include:

- ERT recommendation that the contract scope for commissioning be increased to provide a fully trained WTP operating and maintenance staff at the end of hot commissioning
- Requirements of the new federal law for worker health and safety (10 CFR 851) and DOE Orders

- Additional construction subcontractor overheads due to schedule extension

Figure 9 shows the current cost estimate for the major facilities at WTP. This figure also shows: project contingency of $1,351 million derived from the WTP risk assessments of estimate, schedule, and other EPCC risks; the $300 million DOE contingency for scope options; and the recommended TPRA allowance of $1,116 to address potential risks outside the scope of the current contract, including additional unknown unknowns.

May 2006 Estimate at Completion by Facility ($ millions) All figures are escalated

Facility	May 2006 EAC
Pretreatment	3,463
Low-Activity Waste	1,331
High-Level Waste	2,243
Balance of Facilities	918
Analytical Laboratory	494
Late Adjustments	337
Total Estimate at Completion	**$8,786**
Project Contingency	1,351
DOE Contingency for Scope Options	300
Total Forecast at Completion	**$10,437**
TPRA Allowance	1,116
Total Project Cost (w/o fee)	**$11,553**

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Figure 9.

3.4 Estimated Schedule

Figure 10 summarizes the WTP schedule by phase. Major schedule milestone dates, with contingency included, are:

- June 2010—completion of design
- November 2015—completion of facility construction
- February 2019—completion of hot commissioning
- August 2019—completion of facility turnover

The overall schedule in this EAC is 27 months longer than that reflected in the *December 2005 EAC*. This increase is a result of 1) the transfer of scope from TPRA into the project schedule; 2) funding constraints and the reduction of funding in 2006; and 3) an increase in schedule contingency (6 months) to account for the DOE contingency for scope options.

A schedule sensitivity analysis determined that 7 months of schedule contingency was required for construction and 4 months for commissioning, resulting in a total of 11 months of schedule

WTP Summary Schedule

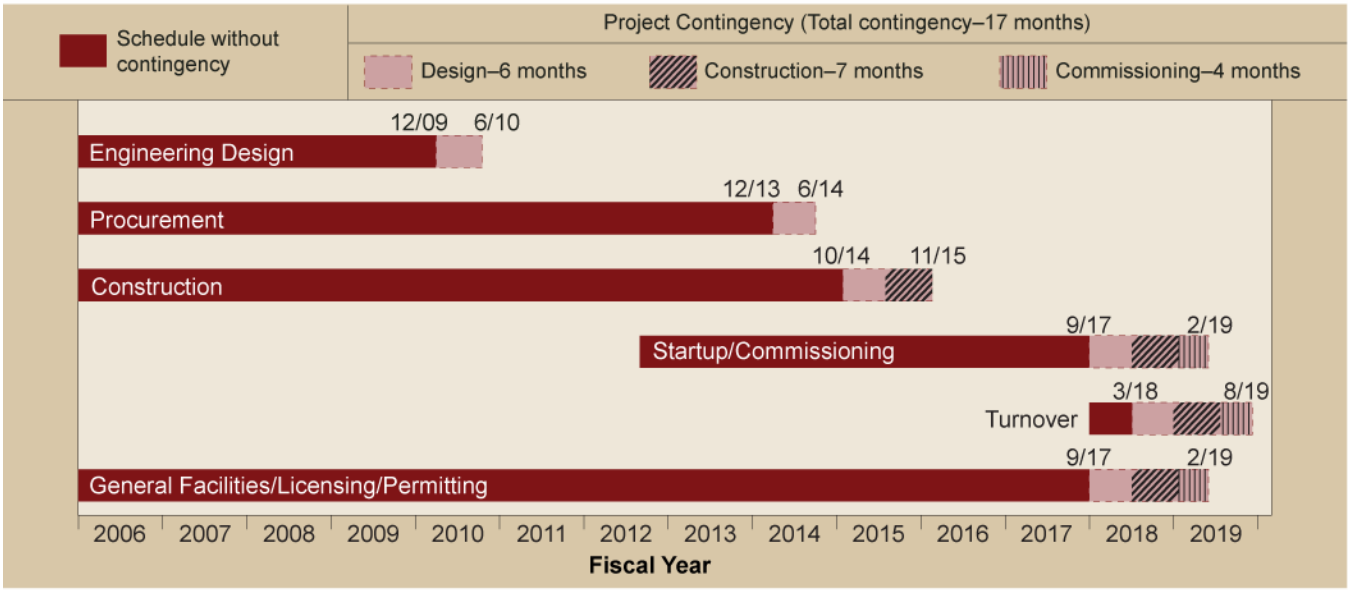

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Figure 10.

contingency, plus the 6 months of DOE contingency for scope options not included in the *December 2005 EAC*. Adding this contingency and the time required for facility turnover results in an expected project completion date of August 2019.

3.5 EAC Assumptions

Construction of the WTP analytical laboratory hot cell, April 2006.

The *May 2006 EAC* is based on assumptions regarding the program and the contract, including:

- ***Authorization of Work.*** The EAC and project contingency represent contractor costs, while the TPRA is a Government reserve. Many of the transfers from TPRA to the EAC and project contingency resulting from the EFRT/ERT recommendations will require formal revisions to the contract.
- ***Funding.*** The *May 2006 EAC* is based on $490 million funding in fiscal year 2006, and $690 million annual funding thereafter. In addition, execution plans and schedules are based on a project-developed facility-specific funding profile in accordance with the new five funding streams (PT, LAW, HLW, BOF, and Lab). Should the project receive funding that varies either in total amount or in distribution among the five facilities, changes to the EAC will be required.
- ***Execution Strategy.*** The *May 2006 EAC* is based on an execution strategy that increases the time between engineering and construction for activities to minimize the possibility of construction rework.

3.6 Optimized Funding Scenario

At DOE's request, BNI also developed a rough order of magnitude (ROM) estimate at completion based on optimized project funding. The objective was to establish order of magnitude benefits in both cost and schedule that reasonable increases in funding could provide. The optimized ROM estimate is based on $490 million funding in fiscal year 2006, $690 million in fiscal year 2007 (based on the fiscal year 2007 President's budget), and unconstrained funding in the remaining years.

HEPA filters in the WTP LAW facility, March 2006.

Craft density, i.e., the number of craft workers on the site at the same time, was the limiting factor for accelerating the project schedule. While more craft workers on site can accomplish the work faster, increased craft density has the potential to deteriorate performance due to lack of available resources and increased congestion. Determining optimum craft density also must factor in safety and quality, which cannot be compromised. Based on demonstrated experience on this and other large projects, the peak construction staffing level of 2,400 craft was established as the basis for the optimized ROM. The ROM also assumed acceleration of specific procurements to support the accelerated schedule. The annual funding required to support this scenario peaks at $850 million, and ranges from approximately $850 million to $800 million in fiscal years 2008, 2009, and 2010.

The optimized funding model showed that increased funding could result in a cost reduction of approximately $165 million to $210 million over the life of the project and a schedule improvement of approximately 16 to 19 months. It is worthwhile to note that, at this phase in the project, only construction can be substantially accelerated; therefore, the current optimized model is based on significant construction acceleration and limited engineering and procurement acceleration.

Although the optimized ROM was developed using the *December 2005 EAC*, which was issued prior to the EFRT/ERT recommendations, the project has concluded that the cost and schedule improvements are also applicable to the *May 2006 EAC*.

3.7 Current Project Status

The project status for three main elements of the project—engineering, procurement, and construction—is summarized in the following sections. Progress is calculated based on the revised jobhours and funding identified in the *May 2006 EAC*.

Status of Engineering

In addition to specific design deliverables, Engineering is responsible for studies, procurement/construction support, interface with regulators, and mitigation of technical issues. The first-of-a-kind nature of this project causes the engineering effort, including conceptual design and technology research and development, to be far greater than that of a design/build project with known technology, scope, and systems.

Figure 11 provides the engineering percent complete based on total engineering hours by facility and total project. Overall, the engineering design for the WTP was 68% complete as of February 12, 2006.

Engineering Status
Based on EAC Data through February 12, 2006

Facility	% Complete
Pretreatment	66.4%
Low-Activity Waste	87.7%
High-Level Waste	74.9%
Balance of Facilities	83.0%
Analytical Laboratory	84.6%
Total Engineering	**68.3%**

Figure 11. 018

Status of Procurement

Procurement awards and administers purchase orders for equipment and materials, and subcontracts for specialty services. Figure 12 shows that procurement was 42% complete as of April 2006. This status is based on committed value (the cumulative value of funding apportioned to awarded orders) as a percentage of the total budgeted value for equipment, materials, and services.

Procurement of bulk materials and equipment poses a significant challenge in this project. The WTP requires an amount of nuclear-grade material and equipment comparable to two nuclear power plants. To meet procurement needs, the project team had to essentially rebuild the nuclear manufacturing industry supply base. In many instances, BNI personnel have been deployed to suppliers' facilities to help them rebuild their nuclear quality programs, assist them with their design work, and train them in how to inspect their own work. This has occurred even with long-time nuclear suppliers whose nuclear programs had atrophied. BNI

Procurement Status
Based on EAC Data through April 2006

Category	% Complete
Direct Capital Equipment/ Material	40%
Other Material	19%
Subcontracts	61%
Total Procurement	**42%**

Figure 12. 017

has qualified more than 150 suppliers to the Qualitiy Assurance Program Requirements for Nuclear Facilities (NQA-1).

Status of Construction

The construction status summary (Figure 13) shows the summary of construction percent complete based on total craft hours by facility and total project. Based on this evaluation, project construction was 29% complete as of February 12, 2006.

Construction Status
Based on EAC Data through February 12, 2006

Facility	% Complete
Pretreatment	24.6%
Low-Activity Waste	38.8%
High-Level Waste	20.6%
Balance of Facilities	48.1%
Analytical Laboratory	29.8%
Total Construction	**29.2%**

016

Figure 13.

The key construction challenge is to achieve the estimated productivity for installation of bulk materials and equipment. To help meet this challenge, the project is developing a 3D model with expanded capabilities that tie the model to the live construction schedule. By allowing the team to visualize how the HLW and PT facilities will be built over time, the team can select a construction sequence for simultaneous work, expediting construction of these critical-path facilities. This state-of-the-art use of 3D modeling will help the project achieve the estimated installation rates.

3.8 Reconciliation to the March 2003 Contract Baseline and the December 2005 EAC

Changes to the WTP project from the March 2003 contract baseline to the *December 2005 EAC* totaled $2,880 million ($7,736 minus $4,856). The most significant impacts to the EAC resulted from the following:

- Revised seismic design criteria
- Design changes to accomplish mixing of non-Newtonian fluids
- Issues surrounding hydrogen generation in piping and vessels
- Annual funding cap of $690 million
- Fiscal year 2006 funding reduction from $690 million to $626 million

Deferred work can cost two to three times as much to perform in the future.

The EACs developed prior to December 2005 were developed to be compliant with the Tri-Party Agreement (TPA) schedule milestones and were not constrained by funding limits—it was assumed that funds needed for optimum project execution would be available through management of carryover funds from prior years and from as-needed funding requests. The December 2005 EAC, however, was developed with adherence to a funding cap of $690 million per year, and a further reduction to $626 million in Fiscal year 2006, resulting in deferred work.

As illustrated in Figure 14, deferred work (due either to a funding cut or a scope increase) can cost two to three times as much to perform in the future on a project that extends for several years, such as the WTP. This is caused by inflation (called escalation in the estimate), disruption and inefficiency, and carrying costs for the project (e.g., cost of project management, facilities, regulatory activities, and utilities) in the additional months of the project.

Cost and Funding Impacts

The funding requirements for a typical engineering, procurement, construction (EPC) project follow a bell-shaped curve as project efforts ramp up, peak, then ramp back down. To optimize resources on a funding-constrained project, where level funding is anticipated, the excess funds available early in the project are carried over to later years when the funding required exceeds the expected funding limits.

If new project scope is identified during the course of the project, activities must be deferred until funds can be made available. Similarly, if project funding is reduced, the activities that were planned for that funding must be deferred to a point in time where funds are available. For WTP, this represents approximately 6 years. Funding cuts also create costly disruption such as layoffs and suspension of procurements.

By deferring scope, the project schedule is extended, creating additional time-dependant costs due to escalation and the requirement to continue maintaining facilities and project office staff. For WTP, under the current funding and schedule profile, a notional $100 million funding cut creates an estimated $120 million net increase in the EAC from time-dependent costs, escalation, and disruption.

015

Figure 14.

The total project cost for the WTP increased by an additional $1,016 million between the *December 2005 EAC* and the *May 2006 EAC*. As previously discussed, this increase was primarily due to the addition of $1 billion to account for the unknown unknowns that could be encountered in this first-of-a-kind project. The net impact of all other changes to the EAC was $16 million (Figure 16).

The reconciliation against the March 2003 contract baseline and the *December 2005 EAC* is summarized in Figure 15. The reconciliation is rolled up into one of six cost change categories defined as follows:

- Time-dependent/funding costs result from schedule extensions and consist of costs such as escalation, extension of facilities, and the cost of the project office, as explained in Figure 14. This category does not include direct costs associated with scope increases but does include the impact of scope increases due to funding constraints and time-related costs.
- Project event costs are direct costs resulting from new or substantially changed scope, typically caused by new technical information.
- Design evolution costs result from the maturing of the plant design. These costs generally reflect changes in design and construction, and the associated changes in construction quantities.
- Project efficiency and disruption costs result from changes in unit rates and performance factors. Disruption specifically refers to the costs associated with previously unforeseen changes in project direction. The result of these changes may be unplanned ramp-up or ramp-down of work, unplanned reductions in force, inefficient skill mixes of onsite personnel, or redirection of work that is already underway—all of which tend to reduce productivity from its expected steady-state rates. Also included are execution strategy changes and total installed cost initiatives.

Reconciliation by Causal Category ($ millions)

Cost Change Category	Mar 2003 Contract Baseline to *December 2005 EAC*	*December 2005 EAC to May 2006 EAC*	Total Change
	Mar 2003 Contract Baseline $4,856	Dec 2005 EAC $7,736	
Time-Dependent/Funding	869	443	1,312
Project Events	417	252	669
Design Evolution	717	28	745
Project Efficiency and Disruption	298	53	351
Pricing	403	139	542
Other Changes	(20)	(6)	(26)
Incorporation of Late Adjustments		(196)	(196)
New Late Adjustments	196	337	533
	Dec 2005 EAC $7,736	May 2006 EAC $8,786	$3,930

025

Figure 15.

- Pricing costs result from changes in pricing of labor, materials, and equipment. This EAC is also escalated from a different base (2006 dollars) than the *December 2005 EAC* (2005 dollars), leading to further pricing variances.
- Other cost changes are a result of either a transfer of costs between facilities or minor changes that are not otherwise categorized.
- Late adjustments, as shown in Figures 9 and 15, represent items added to the EAC that, due to time restrictions or availability of information, were not incorporated into the EAC details.

These cost change categories are interrelated; and portions of a single project event may appear in different categories. For example, the EFRT/ERT recommendations impacted multiple categories.

Figure 16 presents the approximate total impact of event-based changes from December 2005 to May 2006, separated into the base EAC cost, the project contingency, and the Government's TPRA. Many of the changes are items that were accounted for in the December 2005 TPRA, as shown by the negative numbers in that column. For example, the *December 2005 EAC* had a $298 million cost in TPRA for the fiscal year 2006 funding cut, which is valued at approximately $320 million in this

Approximate Total Impact of Event-Based Changes From December 2005 EAC ($ millions)

	EAC	Project Contingency	TPRA	Total
***December 2005 EAC* (without fee)**	**$7,736**	**$1,041**	**$1,760**	**$10,537**
Reduction in FY06 funding from $626M to $490M and 5 fund sources	320		(298)	22
Incorporation of EFRT technical items (e.g., ultrafilters)	110	101	(274)	(63)
Operator availability, training, and efficiency (ERT recommendation)	130		(465)	(335)
Project contingency adjustments (ERT recommendation)	35	117		152
Rates (base wage, escalation, and FPR) and pricing updates	105			105
Additional TPRA items moved to EPCC		17	(17)	-
TPRA items closed			(190)	(190)
Incorporation of new DOE Orders such as 226.1 and 10CFR851	66		(100)	(34)
Procurement claims for material and equipment caused by construction slow-down	60			60
Miscellaneous evolution items (e.g., startup attrition calculations, 100% NDE)	54			54
Miscellaneous late adjustments	30			30
Re-sequence of facilities (allowance for LBL-first operation)		75		75
Funding impact from above items (beyond $490M FY06 funding)	140			140
Net impact of above changes	**$1,050**	**$310**	**($1,344)**	**$16**
Allowance for the unknown unknowns per Rand study (ERT recommendation)		300	700	1,000
***May 2006 EAC* (without fee)**	**$8,786**	**$1,651***	**$1,116**	**$11,553**

**Note: This figure represents $1,351 million project contingency plus $300 million DOE contingency for scope options.*

005

Figure 16.

estimate. The operator availability, training, and efficiency event is an example of risk mitigation. The DOE's strategy for transition from plant commissioning to full post-contract operations was identified in December as a substantial risk, potentially representing nearly a half-billion-dollar cost to the Government. The ERT recommended, and DOE agreed, that Bechtel should build the full operations organization during commissioning, which has a direct cost of about $130 million, but avoids a greater risk.

4. Cost and Schedule Uncertainties

The *May 2006 EAC* is an estimate and, as with all estimates, includes uncertainties. There are two categories of uncertainties—those within the current scope of the contract and those outside the scope of the contract. Project contingency accounts for uncertainties in the estimate that are associated with in-contract scope. The TPRA allowance, discussed previously and further described in Section 4.2, is recommended for uncertainties outside the scope of the contract.

4.1 Project Contingency

Experience consistently demonstrates that defined or assumed conditions seldom occur precisely as predicted for complex projects. Project contingency accounts for this uncertainty and includes components of both cost and schedule uncertainty in the estimate, as well as other EPCC risks accounted for as in-scope risk.

Total Project Contingency ($ millions)

	May 2006 EAC
Cost Contingency	867
Contingency for Schedule Risk	167
Contingency for Other EPCC Risk (Technical)	317
Project Contingency	**$1,351**
DOE Contingency for Scope Options	300
Total Project Contingency	**$1,651**

021

Figure 17.

As shown in Figure 17, The sum of the cost risk ($867 million), schedule risk ($167 million), and other EPCC risks ($317 million) is the recommended $1,351 million project contingency for the WTP project. An additional $300 million DOE contingency for scope options was added. A discussion of the three components of project contingency follows.

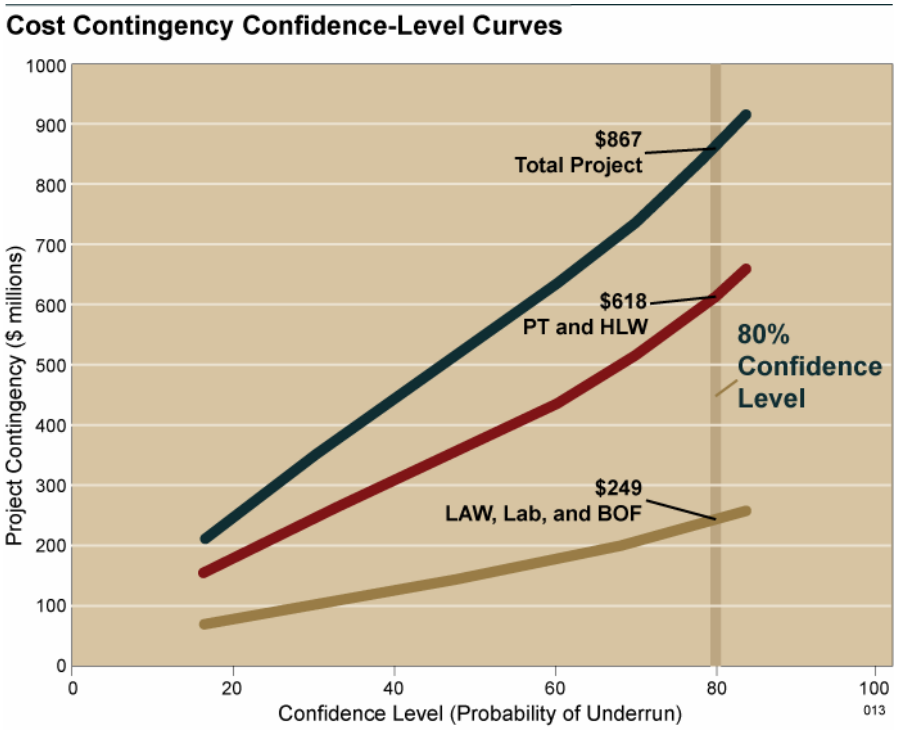
Contingency for Cost Uncertainty. Cost uncertainty is due primarily to variances such as:

- Commodity and equipment quantities—the total amount of commodities (such as concrete and steel) and equipment that need to be designed and constructed
- Craft productivity—the number of manual craft hours needed to install a unit of a commodity, such as a cubic yard of concrete
- Nonmanual hours—the number of hours needed for all nonmanual operations, including engineering, construction supervision, project management, and quality assurance
- Labor pricing—the wages assumed for all employees
- Material and equipment pricing—the price of material such as concrete, rebar, and wire; and the price of equipment required to support installation

The project uses a sophisticated Monte Carlo simulation of cost uncertainties to analyze project contingency. This is a well-established practice within the engineering and construction industry for analyzing and quantifying risk. Each functional group (Engineering, Procurement, Construction, etc.) developed a model consisting of terms for material and equipment, labor, and subcontracts for its work. “Terms” refers to work elements in the project cost estimate that are vulnerable to uncertainties, such as the precise quantity of instrumentation equipment required and the amount of labor required to install that equipment. The WTP project is modeled by approximately 400 terms. The variables that quantify the risk associated with quantity, pricing, and productivity are then applied to each term. These variables are based on a standard set of probability distributions to ensure consistency in the input by the various functions.

Running the Monte Carlo model approximately 5,000 times with randomized variables generated a statistically significant forecast of project contingency. This forecast is in the form of a confidence curve that shows project contingency versus probability of under-running that project contingency. Figure 18 illustrates the WTP project confidence curve. The EAC includes the 80% confidence level value of $867 million in the project contingency for cost uncertainty. It is reasonable to further divide the project contingency for cost uncertainty between the high-level waste handling facilities (PT/HLW) and the lower-activity and support facilities (LAW/Lab/BOF), as shown in the figure. This division is logical because both PT and HLW are Category 1 nuclear facilities, use largely the same suppliers, are on parallel completion schedules, and are at comparable points in engineering completion (approximately 70%). On the other hand, LAW, Lab, and BOF are largely not Category 1, have few technical challenges remaining, have few constraints other than funding, and are at a higher level of engineering completion (approximately 85%).

While the Monte Carlo analysis models the probabilities within a defined problem, it is dependent on the terms and variables assigned. Confidence in the individual terms is primarily a function of the state of plant design. Because conceptual design is now essentially complete



Note: Represents cost contingency only; does not include project contingency for schedule risk, other EPCC risk, or DOE contingency for scope options.

Figure 18.

and detailed design is well advanced, there is high confidence in the terms. Confidence in the variables is also a function of the state of the design (for quantities) as well as project-specific experience (for productivity). Again, the advanced design and substantial completed field work result in high confidence in the assigned variables.

Contingency for Schedule Uncertainty. Schedule uncertainty and the required project contingency are estimated using Monte Carlo techniques similar to cost uncertainty. For schedule uncertainty, the terms are the scheduled activities on or near the critical path; and the variables are the potential range of durations for specific activities. The Monte Carlo analysis focused on five key milestones—completion of each of the four major facilities and completion of hot commissioning.

Construction of the export bay at the WTP LAW facility, January 2006.

The result shows that completion of HLW and completion of hot commissioning are the main drivers of schedule risk, with a recommended schedule risk allowance of 7 months for construction and 4 months for commissioning, resulting in a total of 11 months of schedule contingency, plus 6 months of DOE contingency for scope options not included in the *December 2005 EAC*. The cost attributable to this schedule contingency, comprised of escalation and time-dependent project costs, is $167 million.

Contingency for Other EPCC Risks. The project contingency also includes a component for specific technical risks and other EPCC risks that are within the scope of the project, including:

- Uncertainties associated with late adjustments since they have been incorporated in the EAC using ROM estimates
- Potential technical issues with the melters
- Potential problems during startup and commissioning
- Possibility of re-sequencing facilities, i.e., startup of the LAW facility years ahead of the PT and HLW facilities
- Additional potential impacts from EFRT recommendations

Once again, the analysis of these EPCC risks uses Monte Carlo analysis of many different terms and variables (risks) to derive an 80% confidence risk allowance. The total project contingency for these other EPCC risks is $317 million.

The TPRA allowance accounts for uncertainty in the program that is outside of the project scope.

4.2 Technical and Programmatic Risk Assessment

The TPRA allowance accounts for uncertainties in the program, and is generally the responsibility of the owner (DOE). To determine the recommended TPRA allowance, the project conducted an assessment of known technical and programmatic risks. The assessment identified 15 technical risks and 20 programmatic risks. During this assessment, 13 technical and programmatic risks that were included in the *December 2005 EAC* TPRA allowance were either fully or partially transferred into project scope and out of the TPRA allowance.

Based on the ERT recommendations, several project risks that had previously been included in the TPRA allowance were moved and included in the project EAC. These risks included operational enhancements recommended by the EFRT, new regulations that have been incorporated into the WTP contract, and the reduction in fiscal year 2006 funding to $490 million.

BNI performed a Monte Carlo analysis on the range of best, most likely, and worst-case values ranging from $0 to $1,596 million. The recommended TPRA allowance of $416 million provides an 80% confidence level. An additional $700 million in TPRA for unknown unknowns was added based on ERT recommendations, resulting in a total updated TPRA of $1,116 million.

5. Path Forward

To improve management and communication, the project has developed ways to better align and integrate project management control and risk management tools with DOE's reporting tools. Design has been pushed more than a year ahead of construction to resolve all remaining technical challenges and ensure smooth construction and startup.

To improve the nuclear supply chain capability, project employees have been deployed to our key suppliers to ensure they manufacture to the current nuclear quality standards. This investment will not only improve the WTP project, but every future nuclear project built in the United States.

The project is now implementing the recommendations from the two external expert review teams to ensure construction of a robust plant to a higher confidence cost estimate.

Opportunities for Improvement. The project will continue to seek opportunities to reduce cost and shorten schedule, and has several initiatives currently being undertaken that include:

- Maintaining 1 year of backlog between engineering and construction
- Implementing a certified earned value management system (EVMS) to support project tracking and control
- Implementing the Nuclear Safety and Quality Imperative to enhance the nuclear safety and quality culture
- Implementing Human Performance Improvement
- Employing engineering initiatives to improve engineering quality and production and to address technical issues
- Developing a long-range plan to ensure high construction productivity and to minimize workarounds
- Enhancing the baseline change control program to emphasize early warning and timely resolution of project controls issues
- Enhancing the risk management program

Once approved and validated, this EAC will provide a strong foundation for successfully managing completion of the WTP project.

EAC Approval and Validation. This EAC is an accurate reflection of the project and includes project contingency and TPRA allowances for potential project impacts and unknown unknowns.

Upon DOE approval and validation by the USACE, the intent is for this EAC to become the project baseline. BNI will then pursue EVMS certification against this baseline. The realistic, validated baseline will provide a strong foundation for successfully managing completion of the WTP project.