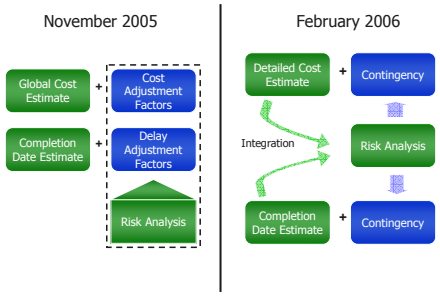
Support of

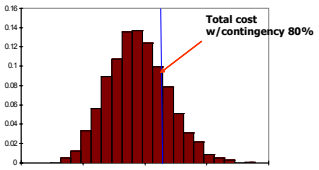
Project Risk Management

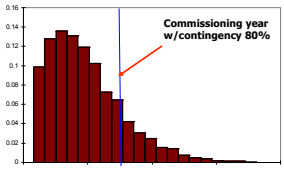
Development of Risk Based Contingency Values for a Baseline Project Budget Estimate

Panama Canal 3rd Lane Locks

Atlantic and Pacific Locks, Pacific Access Channel, and Navigation Channel







Prepared for the

Autoridad del Canal de Panamá

by the

Expert Technical Committee

1 March 2006

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1.0 INTRODUCTION

In September and October of 2005, the academic Expert Technical Committee (ETC) performed an independent review for the Autoridad del Canal de Panamá (ACP) of the methods used to prepare the cost and schedule updates for the concept level design of the Panama Canal 3rd Lane Locks Project. In preparation for the development of a baseline cost estimate, the ETC recommended that the ACP prepare a risk-based contingency for cost and schedule estimates, and ultimately develop this analysis into a formal risk management plan. Members of the ETC have supported this risk management plan from mid-October 2005 to March 1, 2006. This report summarizes the ETC's accomplishments, observations and findings during the time of this support.

1.1 Scope of Support and Guidance

Autoridad del Canal de Panamá specifically requested that the ETC provide support and guidance for:

1. Developing a risk based contingency value for a baseline project budget estimate;
2. Conforming the risk model to allow connectivity of the project budget estimate and the risk model;
3. Refining the risk model to allow for the analysis and management of risk mitigation strategies; and
4. Establishing a process that supports the ongoing management of risks.

The ETC has specifically provided support and guidance in the following areas:

1. **Risk Assessment and Input**
   Support the design and coordination of a risk management workshop so that ACP may obtain a subset of major risks for the risk model, obtain initial assessments of those risks, and identify key sources that can provide further detailed assessments of the risks.

2. **Model Structure**
   Provide guidance on data gathering and model structure to ACP modelers to develop an initial contingency model that provides contingency amounts to offset the owner's risk which should be added to the construction baseline estimate.

3. **Model Refinement**
   Assist in model refinement so that a final model can support risk mitigation and contingency tracking by reviewing model functionality, logic, assumptions and methodology.

4. **Risk Management Planning**
   Aid ACP to further integrate the risk model into the risk management plan by providing advice in the development of risk mitigation analysis and management plans.

1.2 Expert Technical Committee Members

The members of the ETC are:

- Dr. Luis F. Alarcón (Pontificia Universidad Católica de Chile – (Professor, Construction Engineering and Management Program, Department of Civil Engineering, Universidad Católica de Chile; Director, Centro de Excelencia en Gestión de Producción)
- Dr. David B. Ashley (Executive Vice Chancellor and Provost, Shaffer-George Chair in Engineering, University of California, Merced; formerly Dean, College of Engineering, Ohio State University)
- Dr. Keith R. Molenaar (Assistant Professor, Construction Engineering and Management Program, Department of Civil, Environmental, and Architectural Engineering, University of Colorado at Boulder; past Chairman of American Society of Civil Engineer's Construction Research Council)

1.3 Value of Risk Management

Risk management is the art and science of anticipating and planning for future uncertain events. It is concerned with identifying and analyzing a range of possible outcomes, then control and mitigate their negative impacts. The objective is to understand, and mitigate or control risks. Understanding the risks inherent with each potential project alternative is important to controlling cost and developing estimates that reflect the cost of accepted risks. The Panama Canal 3rd Lane Locks Expansion is a project that inherently contains risk and uncertainty. It is the ACP's responsibility to apply best practices in risk management on this project to serve its customers and the citizens of Panama.

In the context of cost estimating, risk management and an understanding of project uncertainty will assist the ACP in setting an appropriate contingency for the project. It will also assist project management in understanding and controlling contingency as the project progresses through its development. The development of a risk-based contingency value for a baseline project budget estimate is the outcome of a rigorous quantitative risk analysis process. In the broader context of project risk management as shown in Figure 1, risk analysis is the second step in a comprehensive and continuous risk management process that includes:

- Risk Identification;
- Risk Analysis (qualitative and/or quantitative);
- Risk Mitigation Planning;
- Risk Monitoring; and
- Risk Control.

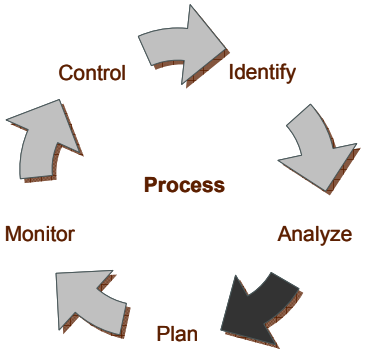


Figure 1: Risk Management Process

Risk identification is the process of identifying potential project risks and documenting their characteristics. Risk identification is best done in a group setting with representation from all project disciplines. Analysis of risk and uncertainty

involves the quantification of identified risks. Risks are typically first analyzed in a qualitative procedure to produce a filtered set of risks to be analyzed quantitatively. In a comprehensive risk management process, risk analysis is used to prioritize the identified risks for mitigation, monitoring, and control purposes. Risk mitigation involves the process of avoiding, transferring, mitigating or accepting the risk. Risk monitoring and control involves the tracking of the identified risks and the analysis of new risks. It also ensures the execution of risk response plans and evaluates their effectiveness. In the context of cost estimating, risk analysis can be extremely helpful for understanding project uncertainty and setting appropriate contingencies.

Even with the best design and engineering, capital construction is a complex task that is fraught with risk and uncertainty. Traditional methods of cost estimating and project management often overlook risk and uncertainty or deal with it in an *ad hoc* manner. Using a formal risk management process that is integrated into the cost estimating and project management process will have many advantages. Some of the most often cited advantages include:

- A better understanding of the project delivery process, including schedule, contact packaging, procedural requirements, and potential obstacles;
- More realistic and transparent estimates of individual project components, which lead to more realistic expectations of total project cost and duration;
- A better understanding of the project contingency requirements and a basis for tracking contingency resolution;
- More accurate information to support other project activities, such as value management and strategic planning; and
- The potential to improve the project budget and scheduling processes.

Risk management should be a dynamic and continuous process throughout project development. At the earliest stages of project development, it will be helpful in developing an understanding of project uncertainty and in developing an appropriate project contingency. As the project progresses, the monitoring and control processes assist in managing cost escalation resulting from scope growth or the realization of uncertain events.

1.4 Limitations of Support and Guidance

The scope of this work is to provide guidance and support the development of an appropriate contingency and of the continuing risk management effort. The ETC is providing review, advice and quality assurance for the process. The risk model was constructed by the ACP with participation from the Engineering and Projects Department, the Finance Department and the Office of Program Development. The ETC did not create a new risk model nor review every detail of the cost or itemized amounts that resulted from the cost estimating process. Similarly the ETC did not review the detail of individual items, which compose the project schedule.

Within the scope of this review, the ETC is confident that the ACP team has created an excellent construction risk model. The risk model is fully operational and able to produce meaningful results. The sensitivity analyses demonstrate the validity of the basic model structure and variable relationships. The contingency value produced by the model seems to be well supported by the details and structure of the model. The regular participation of project team members from all disciplines in the model development is especially noteworthy. The modelers have an increasingly thorough understanding of the estimating processes and the engineers' considerations. The estimators are becoming quite comfortable with the assumptions and structure of the model, including making valuable contributions to the model design. The team is a very solid foundation for the continued activities toward risk mitigation and management.

2.0 RISK ASSESSMENT AND INPUT

The first ETC task involved support for the design and coordination of a risk management workshop so that ACP could obtain a subset of major risks for the risk model, obtain initial assessments of those risks, and identify key sources that can provide further detailed assessments of the risks. This was a fundamental activity in order to obtain a model that produced reliable results. The ETC provided early remote support for this activity from the US during October 2005. The US members of the ETC (Ashley and Molenaar) interacted with the ACP team between 17 October and 29 October 2005 to help obtain initial assessments and inputs for the model. The ETC trip reports from these visits are provided in Appendix A – ETC Trip Reports.

While the short timeframe between the development of the ETC task order and the initial workshop did not allow the ETC team to provide significant advice on the design of the workshop, the ETC was able to support the refinement of the workshop results and their input into the model during the remainder of the task order. Specifically, the ETC had the opportunity to perform several activities to support the assessment and input process in its first three visits to the ACP during the period 29 October 2005, through 5 January 2006. All ETC members traveled to the ACP from 29 October through 2 November 2005 and again on 3-5 January 2006. Additionally, David Ashley traveled to ACP on 12-13 December 2006; this trip was in addition to those specifically set out in the consulting agreement. Some of the activities accomplished by the ETC to support risk assessment and input include:

1. A review of the assessment and process against industry standards; and
2. Advise on structuring, refinement, and obtaining expert probability judgments of risk input.

2.1 Review of Process against Industry Standards

The initial assessment and input process was supported by providing examples and reviews of risk management practices used in the industry for projects in similar stages. The ACP team developed a successful risk workshop that started moving ACP personnel towards a culture of project risk management. The workshop followed industry standards for risk assessment and input, filtered and grouped risks, made *qualitative* assessments of

risks, and developed the foundation for a project risk register. The following list of external documents was used by the ETC for reference and benchmarking purposes in this review.

Caltrans (2003). Project Risk Management Handbook. *California Department of Transportation (Caltrans)*, Office of Project Management Process Improvement. Sacramento, CA.

Curran, Michael W. (1998). *Professional Practice Guide #2: Risk. Association for the Advancement of Cost Engineering International,* Morgantown, WV.

Federal Highway Administration (2004). Major Project Program Cost Estimating Guidance, *Federal Highway Administration*, Washington, D.C.

Federal Transit Authority (2004). Risk Assessment Methodologies and Procedures. *Federal Transit Administration*, Project Management Oversight under Contract No. DTFT60-98-D-41013, Washington, D.C.

Highways Agency (2001). Highways Agency Framework for Business Risk Management, *Report of the Highways Agency*, London, England. <Viewed on August 1, 2005, http://www.highways.gov.uk/roads/projects/misc/risk_man/>

Procedures for Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction, Draft Final Report (2006). *National Cooperative Highway Research Program,* Project 8-49, Washington, D.C.

Project Cost Estimating a Synthesis of Highway Practice (2003). *National Cooperative Highway Research Program*, Project 20-07/Task 152 Final Report, Washington, D.C.

Project Management Body of Knowledge (PMBOK), Third Ed. (2004). *Project Management Institute*.

"Project Risk Management" (2000). A Guide to the Project Management Body of Knowledge, *Project Management Institute*, Chapter 11, pp. 127-146.

U.S. Department of Energy (2003). Risk Management. Office of Management, Budget and Evaluation, *Initiated by: Office of Engineering and Construction Management.*

Washington State Department of Transportation – Cost Estimating Validation Process (CEVP) through the following references:

- http://www.wsdot.wa.gov/projects/cevp/
- Cost Estimating Validation Process (CEVP) Initiation Report (2002). *Washington State Department of Transportation*, Olympia, Washington.
- "Programmatic Cost Risk Analysis for Highway Mega-Projects" (2005). *ASCE Journal of Construction Engineering and Management*, 131(3), 11 pp., March.

Wideman, R.M. (1992). Project and Program Risk Management: A Guide to Managing Project Risks. Newton Square, Pennsylvania.

The ACP used a number of practices described in the reference list above in the development of the risk workshop. For example, the method used for qualitatively measuring frequency and impact of various risks is described similarly in no less than five of the documents above. Overall the ETC believes that the ACP conducted a

workshop that meets or exceeds industry standard and it can be considered a great advancement in the risk culture at ACP.

2.2 Structuring, Refinement, and Elicitation of Risk Input

The progressive ranking, selection and refinement of the initial risks obtained in the workshop was followed closely and reviewed during each of the ETC visits to Panama. The ETC also provided support to structure the final list of risks for the initial model by sorting risks in terms of cost and time significance. The structuring of risks also reduced redundancy of risks and looked at risks at the margin.

The ACP team developed a number of specific activities that were reviewed and discussed with the ETC. The initial list of risks collected in the workshop was sorted in terms of both time and cost significance in order to rank them and capture the most significant ones. The most significant risks were further analyzed to reduce redundancy for modeling purposes. Some risks that were not included in the initial model were assessed to identify mitigation strategies. Figure 2 depicts the sequential process that was carried out to identify, sort, group and select the significant risks that were included in the model. The figure identifies several activities and participants that were involved in each one.

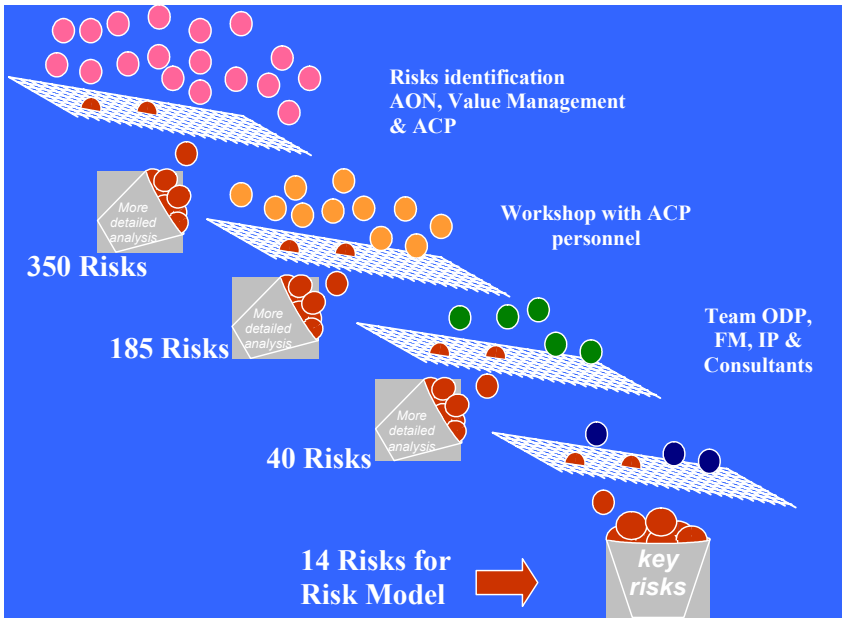


Figure 2: Process of Identification, Evaluation and Selection of Risks to be Modeled

A multidisciplinary ACP team that included risk modelers and estimators developed more detailed assessments for risks that were included in the model. This task consisted of refinement and reassessment of qualitative workshop measurements for risks with significant schedule and cost impacts. The ACP and ETC teams developed a process to update assessments as needed and as appropriate for future model refinements. The whole team had the opportunity to learn how the assessments interact with the model.

The result of this process was a set of risks that include items not previously identified such as:

- Organizational risks
- Productivity risks
- Change orders and claims
- Effects of duration
- Others

Figure 3 describes the 14 significant risks that were finally included in the model. Additionally, some of the risks that were not significant enough to be modeled were kept in a risk register for future tracking and mitigation.

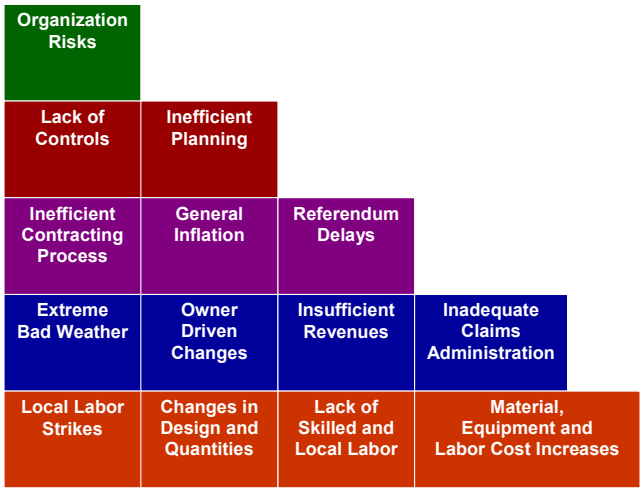


Figure 3: Major Risks Included in the Model

The ETC supported the structuring and performance of the risk elicitation process to achieve accurate quantifications and better integrate the risks into the cost and schedule model. The initial elicitation process was performed under the guidance of the ETC and included the selection of metrics for measuring the risk and a comparison of risks present in the schedule and construction estimate. Support and advice was given both verbally during the meeting and through the ETC trip reports (see trip reports dated 7 November 2005 and 30 December 2005).

3.0 Model Structure

The second ETC task involved providing guidance on data gathering and model structure for the ACP modelers in the development of an initial contingency model. As previously stated, the model is intended to provide contingency amounts to offset the owner's risk which should be added to the construction baseline estimate. This work was primarily done through the ETC's first three visits to the ACP during the period 29 October 2005

through 5 January 2006. The ETC members met with key ACP project individuals to assess model progress and verify model performance. Specifically, the ETC accomplished the following tasks relating to the support of the model structure:

1. Addressed modifications and additions to input assessments;
2. Reviewed and provided feedback of model/assessment documentation;
3. Reviewed and provided feedback of 21 November 2005 *Contingency Presentation*;
4. Reviewed the 4 January 2006 *Risk Model Presentation*;
5. Developed strategies for model refinements to support contingency tracking;
6. Reviewed strategies for model validation process.

Items 1-4 listed above are described in the ETC Trip Reports in Appendix A dated 30 December 2005 and 10 January 2006. Items 5 and 6 are summarized below and covered in detail in Appendix A.

3.1 Strategies for Model Refinements to Support Contingency Tracking

The ACP team has completely changed the cost-risk model structure in the four months between November 2005 and February 2006 as shown in Figure 4. The initial cost risk model was a "top-down" structure that modeled cost and schedule variation by applying delay and cost overrun event outcomes. Variation of these outcomes was generated simply through cost and delay adjustment factors. The primary shortcoming of the model was that the factors were generated at a global level with little basis in the understanding of the organizational, engineering, production or risk events that will drive the variation. The ETC did not have confidence that the original model provided an accurate reflection of the cost and schedule uncertainty and risk due to these factors.

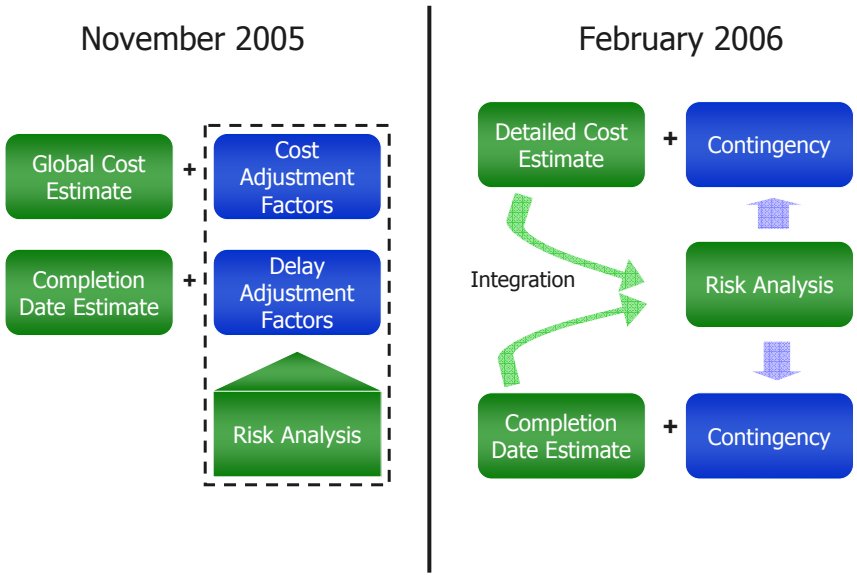


Figure 4: Evolution of Cost-Risk Model

Through a multidisciplinary team effort by the ACP project team involving the Engineering and Projects Department, the Finance Department and the Office of Program Development and external consultants, the team constructed a cost-risk model that more appropriately reflects the cost and schedule uncertainty and risk involved in the project. The revised approach builds the risk model from the cost estimate to allow for appropriate modeling of labor, equipment and material variations. It also integrates a critical path schedule to model more global project delays stemming from items such as organizational risks, labor strikes, and inefficient contracting. The new model structure incorporated the 14 risks, discussed in the previous section, and modeled them in three distinctly different structures in the model through an analysis of 1) the impact of reduced revenues, 2) the impact of delays and 3) the impact of cost overruns to the expansion project. This structure provided a more accurate model of cost and schedule risk while still providing the output required for the overall financial model. Figure 5 depicts how the 14 major risks relate to the model structure.

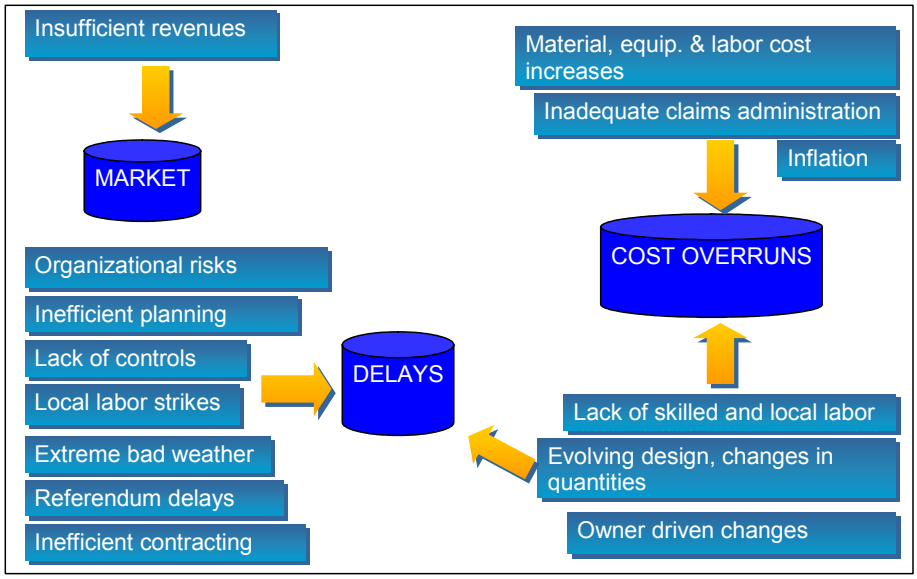


Figure 5: Model Structure and Areas of Critical Risk

A principal product of the ETC task was to suggest refinements to the model structure to support a risk-based contingency. The ETC made four primary recommendations that merit a discussion in this report: 1) replace simple construction timeline with more accurate detailed timeline; 2) link productivity and quantity changes to activity durations; 3) refine dynamic cash flow, which was later replaced with Primavera data to better model the cash flow at the beginning of the project; and, 4) add events with low probability but high impact to the construction timeline. These four recommendations were addressed in the ETC Trip Reports dated 30 December 2005 and 10 January 2006. The ETC is confident that the ACP team has addressed these recommendations in the current model at the time of this report.

3.2 Review of Model Validation Process

The ETC spent a substantial amount of time validating the model in each of its visits. More correctly stated, the ACP team performed the model validation and the ETC performed an audit of the validation process. The validation process consisted of multiple measures.

The team continually verified the assumptions in the model through open dialogue and debate among the members from the Engineering and Projects Department, the Finance Department, the Office of Program Development and the external consultants. Team members continually varied model parameters and questioned model output to ensure that the model was producing consistent results in multiple scenarios. The ETC spent considerable time testing the model with the team members as well. Some of this testing was done using the sensitivity analysis tools available in the modeling software (see section 4.0 Model Refinement) and other testing was done by manually manipulating parameter values to ensure that the output was behaving properly.

In addition to the revision of parameters in the model, the methodology was presented to and discussed with other key ACP employees. Extensive debate took place during discussions resulting in thorough revision and modification of parameters previously assigned to the variables.

Finally, the ACP team developed a documentation system to archive the model construction and the pertinent assumptions. In its January 2006 visit, the ETC helped to produce an annotated outline of the report to consolidate this documentation. The entire ETC reviewed the report titled "Documentation - Risk Model and Contingency Estimation (Revised: Jan 10, 2006)." The ETC is pleased with both the level of detail in the documentation and the fact that all important assumptions and model constructs are adequately addressed in the documentation.

The ETC believes that the model has been properly validated and that the structure is robust. Multiple design scenarios are being modeled and the team has verified the reasonableness of the output. The model has the capability to vary productivity rates and the variance is being modeled in an appropriate level of detail. The commodity variance is being modeled in an appropriate level of detail and is providing reasonable output. Overall, changes in model variables are making reasonable changes in model output and this output is providing useful information for the project development team.

4.0 MODEL REFINEMENT

The third ETC task involved providing guidance on model refinement so that a final model can support risk mitigation and contingency. This work was primarily done during the second and third visits to the ACP during the periods of 12-13 December 2005 and 3-5 January 2006. The ETC members met with key ACP project individuals to assess model progress, verify model performance and make model refinements. Specifically, the ETC accomplished the following tasks relating to the support of the model refinements:

1. Reviewed and provided final advice on model functionality, logic, assumptions and methodology; and
2. Developed strategies for final model refinements to support risk management; and
3. Discussed appropriate percentile level for establishing contingency.

The model refinements described in the previous section provided for a much more accurate assessment and output of contingency to support a baseline estimate. However, the model should also be able to support the risk management process. In creating a model to support the contingency analysis within the short timeline required, some of the model's applicability to support risk management was lost. As the project progresses through development, more will be known about the project; uncertainty will diminish and the amount of contingency in the budget should be reduced. For example, the risk model currently simulates quantity variations to represent four possible designs for the locks. As these designs become known, this contingency should be reduced. The ETC provided support for refining the model to better support risk management. Specifically, the ETC assisted with model refinements to: 1) support contingency categories and 2) risk management.

4.1 Model Refinements to Contingency Categories

Two options for creating contingency categories were discussed. The first involved separating the contingencies into program and project categories, and the second involved the separation into contingencies for design, owner and construction categories. The ACP team produced a good basis for these contingency categories. The team is encouraged to continue development of these contingency categories, but only to a level that is required for decision making and reasonably supported by the model structure, assumptions and assessments. The ETC advice in this area is discussed at length in the ETC Trip Report dated 30 December 2005 and 10 January 06 in Appendix A.

4.2 Model Refinements to Support Risk Management

The strength in producing a risk-based contingency from the model described in Section 3.1 is derived from its integration with the detailed cost estimate and resource-loaded construction timeline. Where similar risk models in the industry are often built from the top down – assessing variation in the high-level risks (similar to the fourteen risks in this model) – this model utilizes a bottom-up approach by applying these fourteen risks across the detailed estimate and construction timeline. The sacrifice of this approach is that the correspondence of these initial fourteen risks and the current model parameters is not readily observable in the same detail for each of them. The comparative advantage of this approach is the strong fidelity to the cost estimate and estimate structure.

The ETC provided advice on how to quantify the 14 risks that were discussed earlier in this report. Risks such as referendum delays, extreme weather, and labor strikes are directly obtained from the model, and other risks such as changes in material prices and some project changes can be obtained from the simulation results. To determine the contribution of other primary risks to the overall results may require a series of sensitivity

analyses especially designed to isolate the contributions of each of these primary risk factors and in some cases may require significant additional modeling efforts. It would be most desirable to have a rank order of these primary risks including, if possible, a measure of the impact similar to that produced by a Tornado diagram. However, the ETC would caution the modeling team in attempting to make a direct estimate of cost impacts for the fourteen primary risks from the model. Recall that the model was constructed to develop a risk-based contingency and not specifically to isolate the value of the fourteen primary risks. Changing the model to isolate these risks would likely result in a diminished ability of the model to produce an appropriate contingency value.

Sensitivity analysis is a primary modeling tool that can be used to assist in valuing the fourteen risks and also in general risk management support. Figure 6 provides an example of the sensitivity output available from the model in the form of a "Tornado diagram." The modeling software ("@Risk" in this case) has several built-in analysis tools for such model testing. Perhaps the most useful is the "Tornado diagram" that shows a correlation between variations in model inputs and the distribution of the outcomes; in other words, it highlights the greatest contributors to the overall risk. While this is an important tool for explaining the final model results, it is equally valuable in verifying internal variable relationships and validating input parameters. The modeling team is continually running these Tornado analyses and collaborating with the estimators on refinements to their assessments

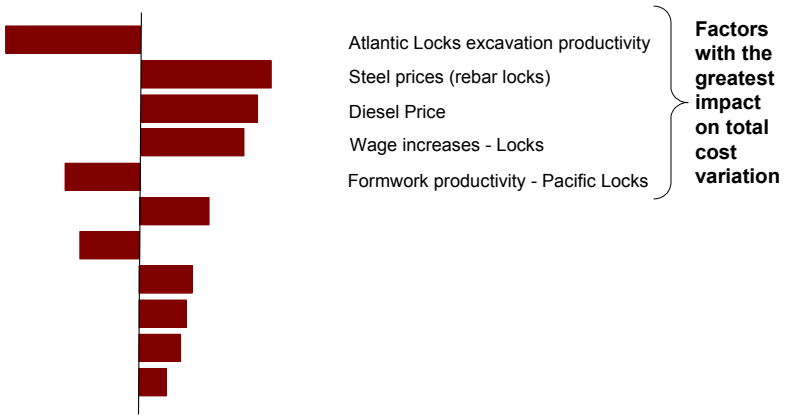


Figure 6: Example Sensitivity Output

Sensitivity analysis was discussed in-depth in the meetings in December in the context of model verification. The sensitivity analysis being generated from the model was extremely helpful in determining which risks should be mitigated and gave possible insights to the value of the mitigation. During the mid-December visit one such Tornado analysis was reviewed with the team, including the estimators, indicated that this ranking generally conformed to expectations. The team continued to conduct multiple sensitivity analyses and adjusted the model accordingly if the results were not reasonable. The team is further probing the other risk factors and will continue to do so with each major run of the model.

4.3 Appropriate Percentile Level for Establishing Contingency

The risk model produces a range of possible cost and schedule outcomes. The ETC and ACP had extensive discussions about what amount of contingency to use in the baseline cost estimate. Figure 7 depicts possible cost and schedule ranges shown with the contingency generated from the 80% level of confidence in the model. An 80% value implies that one in five times a project such as this would exceed this 80% value; four out of five times the final cost would be below this number. The appropriate contingency amount is a decision which the ACP must determine.

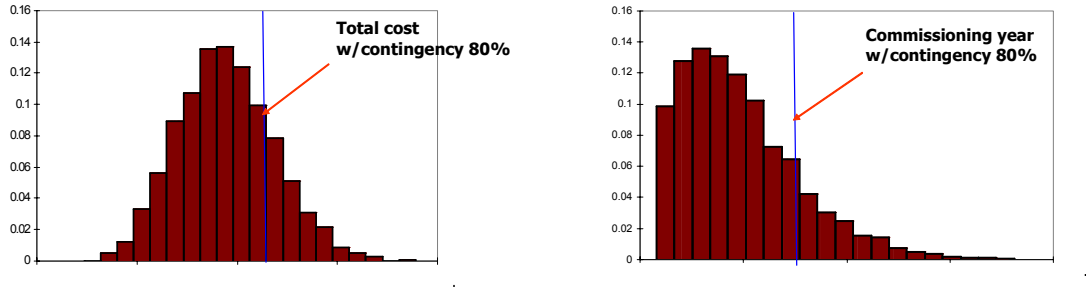


Figure 7: Commissioning Date and Project Cost Results

The percentile level used in establishing contingency is directly related to the level of risk aversion of the decision maker (or firm); the more risk adverse, the higher the percentile. The 50% value of the outcome total cost distribution is the median, and would in most instances be approximately equal to the mean. Using this value would imply a risk-neutral, or expected value, decision maker – this would be highly unusual for an investment of this very large scale. One standard deviation above the mean would be at approximately the 85% level, and is sometimes used as a basis for setting the project contingency. The more typical value used in the industry for projects of this magnitude is 80%, but some agencies, such as the Washington State Department of Transportation, use 90%.[1] In summary, 80% is a reasonable criterion for projects of this magnitude and has a straightforward interpretation.

Overall, the ETC believes that the risk model structure is sound and well serves its intended purpose. The cost contingency (in real dollars) seems well supported by the data and model used in developing it. It will serve as a firm foundation for implementing an extensive risk management/mitigation strategy.

[1] Federal Transit Authority (2004). Risk Assessment Methodologies and Procedures. *Federal Transit Administration*, Project Management Oversight under Contract No. DTFT60-98-D-41013, Washington, D.C.

Procedures for Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction, Draft Final Report (2006). National Cooperative Highway Research Program, Project 8-49, Washington, D.C.

Washington State Department of Transportation (2006). Cost Estimating Validation Process (CEVP) <http://www.wsdot.wa.gov/projects/cevp/>

5.0 RISK MANAGEMENT PLANNING

The fourth and final ETC task involved providing guidance to further integrate the risk model into the risk management plan by providing advice in the development of risk mitigation analysis and management plans. This work was primarily done in the final two visits on 3-5 January and 6-9 February 2006. The ETC members met with key ACP project individuals to develop strategies to incorporate risk management into the project approach and more generally into the ACP capital project development culture. Due to the necessity of having the ETC present the risk modeling efforts to the ACP Board of Directors and various other project stakeholders, the team did not accomplish as much in the area of risk management planning as it could have, but the team has an excellent start in providing a long-term risk management plan. Specifically, the ETC accomplished the following tasks related to the support of risk management planning:

1. Developed the framework for a risk register;
2. Developed initial risk resolution milestones; and
3. Suggested future risk management events and tools.

The overall goal of the risk management advise is to aid in the development of risk mitigation analysis and management plans. During the final visits, the ETC was able to assist the team in completing some essential first steps. The ACP team developed Figure 8 to depict the summary steps involved in risk management and the progress made by the team at the date of this report.

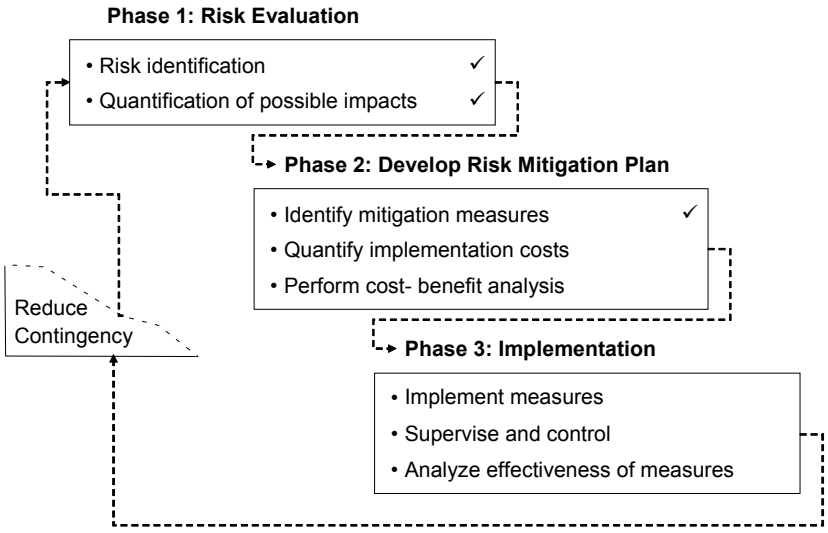


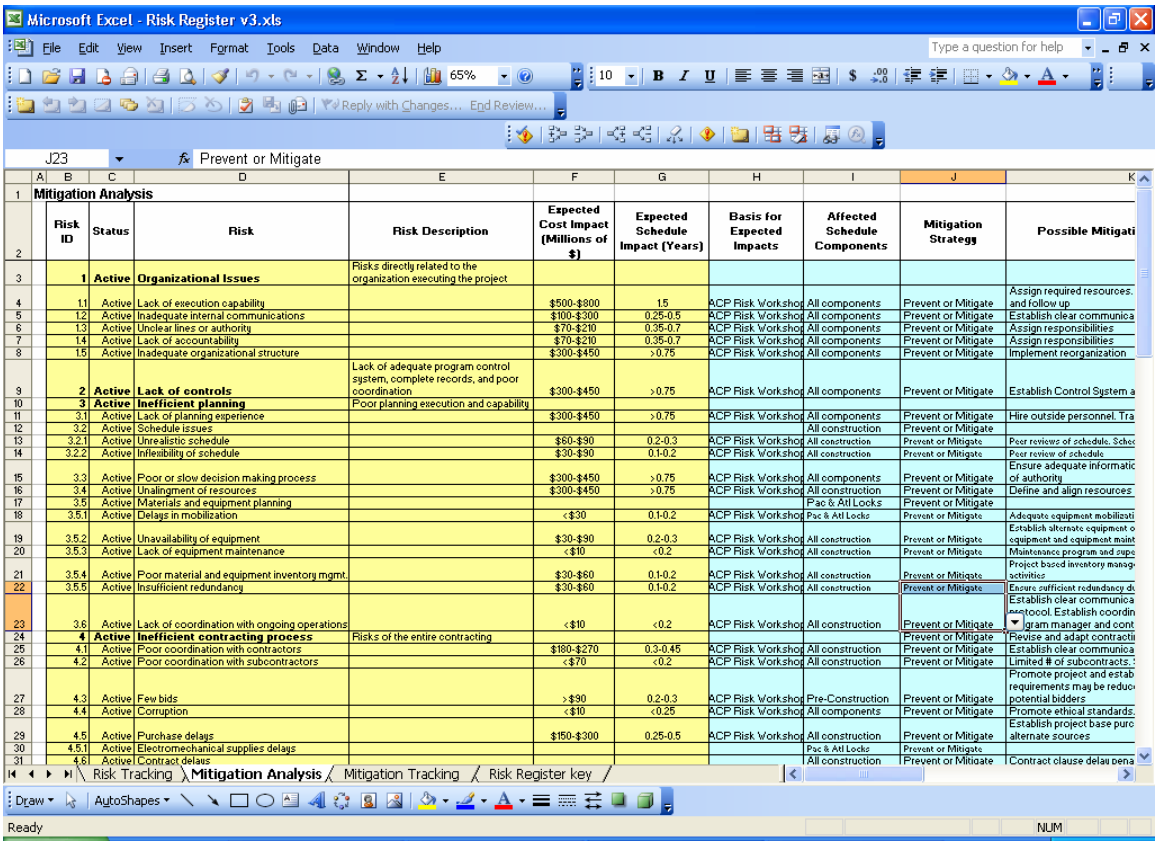
Figure 8: Phases of the Risk Management Process

Figure 8 depicts a process that is continuous throughout the life of the project. It also depicts a reduction in project contingency throughout the life of the project. Also as depicted in Figure 8, the risk management process can be subdivided into three primary phases: 1) Risk evaluation; 2) Development of Mitigation Plan; and 3) Implementation.

At the time of this report, the ACP team had completed phase one and was well on the way to completing phase two. The risk model, which is now complete, will assist in quantifying of the implementation costs (when a qualitative order of magnitude assessment will not suffice). The risk model will also assist in performing cost-benefit analyses of mitigation alternatives. The implementation phase will be ongoing throughout the project. To facilitate implementation and tracking, a risk register and set of associated contingency resolution milestones have been developed by the ACP team with support from the ECT. These items are discussed in the next two sections of this report.

5.1 Development of Risk Register Framework

A *risk register* is a tracking tool for risk mitigation and management. The preliminary risk register was developed in a Microsoft Excel format, but the ACP team may choose to develop a database version or purchase commercial software intended for this purpose. A screen clip of the preliminary register is shown in Figure 9.



Mitigation Analysis

Risk ID	Status	Risk	Risk Description	Expected Cost Impact (Millions of $)	Expected Schedule Impact (Years)	Basis for Expected Impacts	Affected Schedule Components	Mitigation Strategy	Possible Mitigati
1	Active	**Organizational Issues**	Risks directly related to the organization executing the project						
1.1	Active	Lack of execution capability		$500-$800	1.5	ACP Risk Workshop	All components	Prevent or Mitigate	Assign required resources. and follow up
1.2	Active	Inadequate internal communications		$100-$300	0.25-0.5	ACP Risk Workshop	All components	Prevent or Mitigate	Establish clear communica
1.3	Active	Unclear lines or authority		$70-$210	0.35-0.7	ACP Risk Workshop	All components	Prevent or Mitigate	Assign responsibilities
1.4	Active	Lack of accountability		$70-$210	0.35-0.7	ACP Risk Workshop	All components	Prevent or Mitigate	Assign responsibilities
1.5	Active	Inadequate organizational structure		$300-$450	>0.75	ACP Risk Workshop	All components	Prevent or Mitigate	Implement reorganization
2	Active	**Lack of controls**	Lack of adequate program control system, complete records, and poor coordination	$300-$450	>0.75	ACP Risk Workshop	All components	Prevent or Mitigate	Establish Control System a
3	Active	**Inefficient planning**	Poor planning execution and capability						
3.1	Active	Lack of planning experience		$300-$450	>0.75	ACP Risk Workshop	All components	Prevent or Mitigate	Hire outside personnel. Tra
3.2	Active	Schedule issues					All construction	Prevent or Mitigate	
3.2.1	Active	Unrealistic schedule		$60-$90	0.2-0.3	ACP Risk Workshop	All construction	Prevent or Mitigate	Peer reviews of schedule. Schec
3.2.2	Active	Inflexibility of schedule		$30-$90	0.1-0.2	ACP Risk Workshop	All construction	Prevent or Mitigate	Peer review of schedule
3.3	Active	Poor or slow decision making process		$300-$450	>0.75	ACP Risk Workshop	All components	Prevent or Mitigate	Ensure adequate informatic of authority
3.4	Active	Unalingment of resources		$300-$450	>0.75	ACP Risk Workshop	All construction	Prevent or Mitigate	Define and align resources
3.5	Active	Materials and equipment planning					Pac & Atl Locks	Prevent or Mitigate	
3.5.1	Active	Delays in mobilization		<$30	0.1-0.2	ACP Risk Workshop	Pac & Atl Locks	Prevent or Mitigate	Adequate equipment mobilizati
3.5.2	Active	Unavailability of equipment		$30-$90	0.2-0.3	ACP Risk Workshop	All construction	Prevent or Mitigate	Establish alternate equipment o equipment and equipment maint
3.5.3	Active	Lack of equipment maintenance		<$10	<0.2	ACP Risk Workshop	All construction	Prevent or Mitigate	Maintenance program and supp
3.5.4	Active	Poor material and equipment inventory mgmt.		$30-$60	0.1-0.2	ACP Risk Workshop	All construction	Prevent or Mitigate	Project based inventory manag activities
3.5.5	Active	Insufficient redundancy		$30-$60	0.1-0.2	ACP Risk Workshop	All construction	Prevent or Mitigate	Ensure sufficient redundancy d
3.6	Active	Lack of coordination with ongoing operations		<$10	<0.2	ACP Risk Workshop	All construction	Prevent or Mitigate	Establish clear communica estocol. Establish coordin gram manager and cont
4	Active	**Inefficient contracting process**	Risks of the entire contracting					Prevent or Mitigate	Revise and adapt contracti
4.1	Active	Poor coordination with contractors		$180-$270	0.3-0.45	ACP Risk Workshop	All construction	Prevent or Mitigate	Establish clear communica
4.2	Active	Poor coordination with subcontractors		<$70	<0.2	ACP Risk Workshop	All construction	Prevent or Mitigate	Limited # of subcontracts.
4.3	Active	Few bids		>$90	0.2-0.3	ACP Risk Workshop	Pre-Construction	Prevent or Mitigate	Promote project and estab requirements may be reduc potential bidders
4.4	Active	Corruption		<$10	<0.25	ACP Risk Workshop	All components	Prevent or Mitigate	Promote ethical standards.
4.5	Active	Purchase delays		$150-$300	0.25-0.5	ACP Risk Workshop	All construction	Prevent or Mitigate	Establish project base purc alternate sources
4.5.1	Active	Electromechanical supplies delays					Pac & Atl Locks	Prevent or Mitigate	
4.6	Active	Contract delays					All construction	Prevent or Mitigate	Contract clause delay pena

Figure 9: Preliminary Risk Register

The register is developed through the risks identified in the risk assessment process. The comprehensive risk assessment conducted on this project provided a list of fourteen primary risks for this project, but it would be prudent to track more than these fourteen risks. These fourteen risks were derived by combining a longer list of similar risks from the October Risk Assessment Workshop results. This longer list contains approximately

50 risks that should be tracked, mitigated or managed over the life of the project. The team decided to organize the longer list of risks as sub-risks to the fourteen primary risks in the risk register. This organization will allow for tracking of all the critical risks identified to date without being overly cumbersome to manage. The risk register will allow for these risks to be retired when they are resolved and also invite new risks as they arise on the project. The preliminary risk register includes sheets for risk tracking, mitigation analysis and mitigation tracking. Table 1 is a summary of the items that could be tracked in the risk register.

Table 1: Risk Register Framework

Risk Tracking	Mitigation Analysis	Mitigation Tracking
Risk ID	Risk ID	Risk ID
Status	Status	Status
Risk Description	Risk	Risk
Risk Category	Risk Description	Risk Description
Potential ACP Assignment	Expected Cost Impact (Amount or Rating)	Assignment
Expected Cost Impact (Amount or Rating)	Expected Schedule Impact (Months or Rating)	Current Allocation
Expected Schedule Impact (Months or Rating)	Affected Schedule Components	Mitigation Strategy
Mitigation Strategy	Mitigation Strategy	Proposed Mitigation (Description)
Mitigation Status	Possible Mitigation Alternatives	Proposed Mitigation Status
Monitoring & Control	Expected Cost of Implementation	Monitoring and Control Status
Resolution Schedule	Basis of Expected Cost of Implementation	Estimate Basis for Mitigation Cost Benefit
	Estimate Basis for Mitigation Cost Benefit	Estimated Value of Mitigation Benefit ($)
	Value of Mitigation Benefit ($)	Estimate Basis for Mitigation Schedule Benefit
	Value of Schedule Benefit (months)	Estimated Value of Schedule Benefit (months)
	Allocation	Expected Value of Implementation
	Proposed Mitigation (Description)	Actual Cost of Mitigation Implementation
		Actual Value of Mitigation Benefit ($)
		Actual Value of Schedule Benefit (months)
		Project Risk Metrics
		Risk Mitigation Audits
		Source of Information Risk Model Location
		Resolution Schedule

Much of the discussion about the risk register focused on valuing the risks and providing a risk resolution schedule. The 10 January 2006 ETC trip report in Appendix A discusses qualitative versus quantitative assessment of risks and mitigation at length. The risk modeling team should take caution in attempting to value all of the risks on the register in detail. An approximate value should be used in the risk register to provide a relative ranking and a more precise value can be derived when necessary for management decisions.

5.2 Development Risk Resolution Milestones

A preliminary schedule for risk resolution was developed during the ETC visits. The schedule will support risk management in three primary ways. First, the schedule will provide milestones to update the risk-based contingency model with new information. Second, it will provide a timeline for risk mitigation planning. Third, it will help to establish critical risk communication points in the project. The team drafted the following preliminary risk resolution schedule for future consideration:

- Project Delivery Decision
- ACP Reorganization
- Program Management Decision
- Project Controls System Decision
- Referendum
- Final Funding Decision
- Contract Award (multiple)
- Begin mass concrete (each project)
- Excavation complete (each project)
- Concrete complete (each project)
- 70% Construction complete (each project)
- Commissioning

5.3 Future Risk Management Events and Tools

In addition to the risk resolution schedule, the team discussed a number of other risk management events and tools. It is important to share the risk-based contingency model and risk management advancements with the October Risk Assessment Workshop participants. Additionally, risk management training should be implemented in the form of workshops and events, and individual or departmental training. Lastly, other communication techniques such as email updates or circulation of periodic readings on risk will help to facilitate a culture of risk management within the ACP. Section 6.4 Path Forward expands on the need for future risk events and tools.

6.0 CONCLUSIONS AND PATH FORWARD

Prior discussion within this report emphasized the ETC role in supporting the ACP team in developing a risk management capability. This final section shifts the emphasis to the

accomplishments of the ACP team, the overall value of the risk work performed by the team, and suggestions for a path forward.

6.1 Summary of ACP Team Accomplishments

During the execution period of Task Order 25, October 2005 – March 2006, ACP has significantly advanced both the *risk model* and *risk management planning* for the 3rd Lane Locks and Access Channel Expansion Program. More specifically, ACP has:

- Initiated, developed, and refined an integrated risk model that provides program and project contingencies and supports decision making.
- Addressed important issues including the choice of contingency level, how to use and communicate contingency values, and what is the standard practice for risk modeling for similar large-scale projects.
- Initiated a formal risk mitigation and management program by building on a series of risk and value management workshops. The evolving risk register serves to both document these workshops and track the identified risks. The risk register is built on a standard framework of categorization, mitigation strategies, costs, and benefits. The enhancements already added include linking to the risk model, aligning with risk planning milestones and providing a framework for periodic risk register updating.
- The combined modeling and risk planning activities are firmly establishing a culture of active risk planning for the Expansion Program.

6.2 Assessment of Model Progress and Performance

In line with ETC Trip Reports in Appendix A, the ETC is impressed with ACP's progress and is very comfortable with the risk model's functionality, logic, assumptions, and methodology in regard to cost risk and schedule predictions. The ACP team has developed an excellent construction cost-risk model. The ETC is also comfortable with the model's logic and functionality in terms of schedule analysis and predictions of commissioning date.

The regular participation of the estimating group in the model development is especially noteworthy. Model refinements and improved data assessments are a collaborative effort of the modelers and estimators. The modelers have an increasingly thorough understanding of the estimating processes and the engineers' considerations. The estimators are becoming quite comfortable with the assumptions and structure of the model, including making valuable contributions to the model design. The team is a very solid foundation for the continued activities toward risk mitigation and management.

The risk model is fully operational and able to produce meaningful results. The sensitivity analyses demonstrate the validity of the basic model structure and variable relationships. The last model viewed by the ETC was producing an overall cost contingency on the order of $1.0 billion. This contingency value seems to be well supported by the details and structure of the model.

The determination of the commissioning year (or total project duration) appears to be reasonable as well, but certainly not overly conservative. The last schedule model viewed by the ETC was producing a schedule contingency (at the 80% confidence level) on the order of 6 months above the model mean. The contingency commissioning date was 12 months beyond the base schedule (not using the simulation).

Overall, this is an outstanding risk model and well serves its intended purpose. The cost contingency (in real dollars) seems well supported by the data and model used in developing it. We believe the model will continue to evolve and mature over the life of the program. Regular model and data updating will yield the desired tracking of major project risks over time. It will serve as a firm foundation for implementing an extensive risk management/mitigation strategy for the 3rd Lane Locks and Access Channel Expansion Program.

6.3 Value of Work Performed to Date

The original ETC engagement on the 3rd Lane Locks and Access Channel Expansion Program was a verification of the cost estimating and scheduling processes. The primary conclusions of this review were: 1) the estimating and scheduling processes are rigorous and supportive of the planning needs for the program; 2) ACP should develop a baseline program estimate and schedule; and 3) a systematic contingency analysis should be prepared as part of the baseline estimate. The ETC further recommended that the contingency analysis should be based on the risk modeling efforts already well advanced in the financial analysis area. It is this third point that is specifically and successfully addressed in this current assignment and final report.

The risk model now provides the necessary basis for the contingencies incorporated in the baseline estimate and schedule. The risks included and the corresponding assessments are clearly identified. There is now greater clarity into what is included in the base costs, allowances, and contingencies. The model is structured so that sensitivity analyses can be used to differentiate various risk impacts and comparative contributions of risks. Additionally, the model allows the team to consider alternate contracting or project implementation strategies by changing assessments or linkages. Thus, the contingencies now used in the formal program estimates and external communications have a robust, rigorous, and defensible basis.

The contingency values produced by the modeling efforts are especially important at this point in the program development. The ACP Board of Directors and Administrator have specific contingency values to use in their decision making. Greater confidence in these values and what they represent will allow them to move forward with assurance that the major risks have been identified and are being actively managed.

6.4 Path Forward

The ETC has emphasized from the time of its original engagement that developing a culture of risk management would greatly enhance the ability of ACP to manage its 3rd Lane Locks and Access Channel Expansion Program. The risk modeling and

contingency assessment documented in this report are primary, initial components. Equally important are the risk communications, risk and contingency updating, and risk mitigation activities.

The ETC recommends the following future steps concentrating on risk communications:

- Use additional workshops or similar interactive sessions to communicate the risk modeling, contingency, and risk register results to prior workshop participants.
- Engage in additional risk management training and broad-ACP education utilizing
    - Mailings of periodic readings
    - Workshops and events
    - Individual team training
- Develop a control and reporting process that includes
    - Periodic reporting to senior management for significant risks
    - Reassessment of new risks
    - Reassessment of contingency values at milestones and periodic intervals
    - Performance measures for the risk management program

Risk Management as a formal project management discipline has the greatest value when it is continuously applied throughout the life of a project or program. The basic steps of risk identification, analysis, mitigation, and control are applied iteratively at key project milestones. This allows refinement of the contingency estimates, as well as tracking of key risks and mitigation strategies. For the Expansion Program this would include regular updating of the risk model and reassessment of probability distributions. The Risk Register is also revised and updated on a similar interval. As previously mentioned, the ETC worked with the ACP team to define the following candidate project milestones for model and register updating:

- Project Delivery Decision
- ACP Reorganization
- Program Management Decision
- Project Controls System Decision
- Referendum
- Final Funding Decision
- Contract Award (multiple)
- Begin mass concrete (each project)
- Excavation complete (each project)
- Concrete complete (each project)
- 70% Construction complete (each project)
- Commissioning

Due to the extraordinary importance of the Expansion Program and its multi-year duration, ACP may also elect to undertake one or two audits of the risk management program. These would include, but would not be limited to, the following areas: 1) the then current version of the risk model, 2) probability assessments of important risk variables, and 3) key elements of the risk register including mitigation strategies. These

audits would be designed to assure management that the risk management program is being actively and aggressively pursued, as well as the data underlying the program is being refreshed as appropriate.

The risk management program has several additional areas of potential focus including: 1) a formal organizational structure, 2) risk/contingency resolution management, and 3) specific analysis of several significant decisions affecting the program risk allocation.

The formal decision to proceed with the 3rd Lane Locks and Access Channel Expansion Program will likely lead to establishing a major program office to directly manage the effort. ETC recommends that ACP consider placing the Expansion risk management program and associated personnel in this office and have it report directly to the program director. Regular reporting on risk mitigation activities and updated estimates of primary risks is most valuable for effective management of the overall program.

The ETC also recommends that the risk management program include a risk/contingency-resolution framework for tracking and managing the contingency funds. In its simplest form, the estimated contingency reserve is allocated over time to match the exposure to the underlying risks. For example, the contingency derived from uncertainty in the excavation costs would be allocated prior to start of excavation and continue until excavation is complete; once the excavation is complete, any of the remaining contingency for that item would be removed to avoid the temptation of spending it elsewhere in the project. Major projects that have employed this approach often successfully limit the total contingency expended.

A final area of consideration in the path forward is the use of the risk model to analyze specific decisions significantly impacting risk. Candidates include several immediate decisions related to project execution strategies:

- Project delivery decision
- Procurement decisions
- Contracting mechanisms
- Acceleration analysis

Each of these decisions has significant risk allocation implications and would benefit from a more analytical review. The current risk model serves as a good basis for these analyses and would likely require only modest refinements or risk variable additions. Due to the importance of commissioning time on the overall program economics, it may be particularly beneficial to start with an examination of construction and design acceleration strategies.

APPENDIX A – ETC TRIP REPORTS

Overview of Risk Modeling Accomplishments – October 29 - November 2, 2005
Summary of ACP Visit – December 12-13, 2005
Summary of ACP Visit – January 3-5, 2006

To: Angelique Sucre de Hanily
Oficina de Desarrollo de Programas
Autoridad del Canal de Panamá

From: Expert Technical Committee
- Luis F. Alarcón, Ph.D.
- David B Ashley, Ph.D.
- Keith R. Molenaar, Ph.D.

Date: 7 November 2005

Re: Overview of Risk Modeling Accomplishments

We are pleased to submit the following as a summary status report on the development and implementation of a risk model to support the Panama Canal's 3rd Lane Locks and Access Channel Expansion Program. It documents progress to date and especially emphasizes the Expert Technical Committee's (ETC) participation in activities during the period October 29, 2005, through November 2, 2005. ACP's immediate goal in this effort is to develop a risk-based contingency value to be incorporated into the program's baseline estimate. The longer-term objective is to create a robust risk model that both links to the ACP Financial Model and serves as a basis for risk planning and management for the expansion program.

Purpose of Visit
Support and guidance in developing a risk-based contingency value for a baseline project budget estimate
- The risk model now appropriately reflects construction risk and owner contingency
- Risk model now more fully represents the risks identified by the expanded project team
- Model has much greater value for decision-making around engineering and contracting questions
- Contingency values are not ready, but can be solid in approximately 2 weeks
- Foundation for sound mitigation planning is set

Scope of ETC Visit
Provide guidance on data gathering and model structure to ACP modelers to develop an initial contingency model that provides contingency amounts to offset the owner's risk which should be added to the construction baseline estimate.

Specifically, support and guidance in:
- Risk assessment and input to the model
- Risk analysis and model structure
- Model validation process

Accomplishments of ACP team
Support and guidance in developing a risk-based contingency value for a baseline project budget estimate

Risk Identification and Assessment

- Key output – appropriate risks for developing contingency and beginning mitigation planning
- Team conducted a successful risk workshop
    - Followed industry standards for risk assessment and input
    - Filtered and grouped risk
    - Made *qualitative* assessments of risks
    - Foundation for risk register and better risk management
    - Advancement of risk culture at ACP
- Team developed a final list of risks for initial model
    - Sorting risks in terms of both time and cost significance
    - Reduce redundancy of risks for modeling purposes
    - Assessment of those risks not modeled but important to mitigate
- Risk and estimating teams have developed more detailed assessments (measurements)
    - Refined qualitative workshop measurements for risks with significant schedule and cost impacts
    - Developed process to update assessments as needed and as appropriate
    - Team is learning how the assessments interact with the model
- Outcome is current set of risks that include items not previously identified
    - Organizational risks
    - Productivity risks
    - Change orders and claims
    - Effects of duration
    - Others

Risk Analysis

- Key output – team has developed an appropriate structure for capital cost risk assessment without loosing structure for financial model
- Model structure directly links cost estimate output to risk model
    - Allows for variation in material prices
    - Allows for variation in wage rates
    - Allows for initial variation in productivity
    - Ties the estimate output to model
    - Utilizes schedule baseline matching project schedule
    - More appropriately models delays
- Initial assessments are included, but must be refined in parallel with model validation

Model Validation

- Model validation process is in place and has begun
    - Initial model results viewed on Wednesday
    - Team is verifying assumptions in model
    - Team is verifying that the model is producing consistent results with multiple scenarios
    - Team is developing documentation system of assumptions

Observations and Next Steps

- Successful risk identification
- Basis of model structure is sound
- Continuing refinement of assessments is necessary
- Validation has begun, but thorough validation will take time
- Contingency estimate for baseline is not yet ready
- Upon completion of contingency estimate, mitigation and "opportunity" modeling is next step to manage and reduce contingency

To: Angelique Sucre de Hanily
Oficina de Desarrollo de Programas
Autoridad del Canal de Panamá

From: Expert Technical Committee (ETC)

- Luis F. Alarcón, Ph.D.
- David B Ashley, Ph.D.
- Keith R. Molenaar, Ph.D.

Date: 30 December 2005

Re: Summary of ACP Visit – December 12-13, 2005 *(Revised)*

We are pleased to submit the following as a summary trip report related to the development and implementation of a risk model to support the Panama Canal's 3rd Lane Locks and Access Channel Expansion Program. It documents continued progress during the period November 2, 2005, through December 13, 2005. David Ashley was the single participant in this visit and his primary role was to meet with key ACP project individuals to assess model progress and verify model performance; this trip was in addition to those specifically set out in the consulting agreement.

ACP's immediate goal in this effort is to develop a risk-based contingency value to be incorporated into the program's baseline estimate. The longer-term objective is to create a robust risk model that both links to the ACP Financial Model and serves as a basis for risk planning and management for the expansion program. Both short- and longer-term goals seem readily achievable within the time frame desired. This trip report summarizes model development progress by commenting on structural changes, sensitivity analyses, possible additional model modifications and additions, and an overall model status assessment. It also provides a possible agenda for next steps, especially those involving the ETC team during its subsequent visits.

Review of model structure and assessments

The two-day meeting with the ACP team concentrated on reviewing and assessing overall model structure and input data assessments. The following specific reviews were undertaken:

1. Review and feedback on November 21st *Contingency Presentation*
2. Review of model/assessment documentation prepared by ACP team
3. Discussion of changes to model structure since October
4. Summary of additional or revised input assessments
5. Overall review of model with estimating team

Changes in the model structure are consistent with feedback from the ETC's October/November feedback and recommendations. The significant revision of several probability assessments is an indication of a good working dialogue between the modelers and the estimators; the changes are a result of operating the model and both groups jointly verifying that the relationships and result variations are consistent with the estimators' expectations. This interaction provided the estimators with a better understanding of how allowances and contingencies will be represented and differentiated in the total program cost estimate. From the ETC's viewpoint, it appears that the estimators and modelers are working quite well as an integrated risk analysis team.

Modifications

After a detailed review of prior model changes, it was determined that two additional modifications should be made to the structure during this visit. The first was the method of including *weather* and *labor strike* risks as events. The previous modeling approach was to divide the activity duration (of an activity impacted by the risk event) by the frequency of occurrence of each event (in terms of mean number of years between such risk events occurring; for example, an activity with a five-year duration designated as being potentially impacted by a severe weather event and a probability of severe weather occurring once every five years would have yielded a probability of 1.0 of the risk occurring. This would have over-represented the risk incidence and not provided the appropriate variation associated with weather influence. The model was modified to consider both weather and labor strikes as *renewal processes* and then model the possibility of occurrence on an annual basis. This approach is more consistent with the theoretical basis for such event modeling and will lead to more reasonable variations in the outputs. It should be noted, however, that the delay effects of either type of event are comparatively small and these modifications will have only minor or negligible effects on the results.

The second model modification undertaken during the visit will likely have more significant impact on overall results. The focus of this second modification was on the possibility of only one bidder on either of the lock structures. Such a prospect had not previously been included. The assumption had been that a one-bidder situation would not be allowed and was thus not modeled. After further discussion, there was consensus that the probability of receiving only one bid on either of the lock projects was non-negligible and that it should be included. Two approaches were considered, either: 1) including the possibility of a delay for re-packaging and re-bidding or 2) allowing a broader range in the contractor mark-up percentages. The opinion remained that as a matter of public policy ACP would not wish to award a contract with only one bidder, so the option of modeling a delay for re-bidding was selected. Since the delay could be multiple months and incur additional costs, this modification should be further developed and tested with the estimators.

Sensitivity Analyses

An important step in model verification is the exercising of the model and performing various sensitivity analyses. **@Risk** has several built-in analysis tools for such model testing. Perhaps the most useful is the "Tornado diagram" that shows a correlation between variations in model inputs and the distribution of the outcomes; in other words, it highlights the greatest contributors to the overall risk. While this is an important tool for explaining the final model results, it is equally valuable in verifying internal variable relationships and validating input parameters. The modeling team is continually running these Tornado analyses and collaborating with the estimators on refinements to their assessments. During the mid-December visit one such Tornado analysis produced the following rank order of "program risks":

Tornado diagram for base case

a. Diesel cost
b. Gates cost
c. Delay – Chamber concrete
d. Wages -- Locks
e. Delay – Contract locks award
f. Probability Delay – referendum
g. Delay – referendum
h. Cement
i. Deepening Gaillard & Gamboa & Chag. Cr.
j. Formwork
k. Delay -- Chamber excavation (L65)
l. Mark-up (J77)
m. Altantic Lock – Aggregate transportation from Pacific Access
n. Electro-mechanical (J82)
o. Formwork (Y20)
p. Weather (M72)

Discussions with the team, including the estimators, indicate that this ranking generally conforms to expectations. The higher placement of *diesel* and *gates costs* is symptomatic of the uncertainty the team places on material costs such diesel fuel and steel. The team is further probing the other risk factors and will continue to do so with each major run of the model.

Another area of sensitivity analysis key to the team is the variation in lock design -- this variation is seen as additional to the allowance included in the estimate for completion of the proposed base design. The team has developed four variants of a base-design scenario that differ primarily in quantities for both concrete and excavation for four major lock components (approach walls, lock heads, chambers, and water saving basins). During the visit, a design sensitivity analysis was conducted by setting each alternate scenario to a probability of 1.0 and then comparing cost results to the base case (Option 3). As examples, Option 1 and Option 5 increased total costs by approximately $27 million and $150 million, respectively. While these values are notable, they do not appear to be as large as one might initially anticipate. The explanation appears to center on the relative conservatism of the quantities included in the base case; namely, the team

appears convinced that the quantities utilized in the base case are greater than they expect to see when the engineering design is further advanced. An example often repeated was the conservative excavation slope currently used in the preliminary design. As design progresses, the team should revisit both the base-case quantity assumptions and the possible design scenario variations.

A typical class of sensitivity analyses for a construction project risk model is the factor inputs. These include productivity rates for labor and equipment, material costs and delays. The model as currently structured allows relatively easy testing of these input factors at a high- or aggregate-level. The estimators especially value the ability to broadly vary such items as diesel fuel or cement unit costs, as well as aggregate labor productivity by major cost component. The model does not yet fully break down the productivity by specific labor type; it currently uses general or aggregate labor categories and assigns these to cost components. This aggregate approach appears quite reasonable and appropriate for this stage of project development, but it does add an element of complexity for the estimators in preparing their productivity assessments. As currently modeled, what is not reflected well is the relationship between productivity changes and construction activity durations; this will be the basis for a recommendation on future model enhancement. Additionally, the sensitivity analyses have uncovered the need to reassess the delay distributions associated with construction activities. The initial probability assessments contained significant optimism and are now being reassessed as asymmetric distributions where the possibility of delay is greater than early completion; this has been carefully considered and discussed extensively with the estimators.

Possible additions

A principal product of this visit is a list of potential model enhancements -- these additions are seen as refinements and extensions of the basic model:

- Replace current construction timeline
  - Replacement should be based on the integrated "Heavy-Bid" – Primavera®/resource-loaded model currently being developed by the estimators.
  - The schedule should be at a more aggregate level than currently being developed in the integrated/resource-loaded model. The team should aggregate activities into subnets by area of work and/or critical path.
  - Once the new timeline is incorporated, the team needs to reassess duration uncertainties for each of these activities. These assessments should follow a similar approach to the previous assessments where multiple risk factors are assigned to each activity and the duration assessment considers them in combination.
- Link productivity changes to activity durations (as mentioned above)
  - Since cost components are typically categorized differently than construction activities, the team may need to utilize an approximate/proportional approach to creating this linkage. This

approximation is facilitated by the work currently underway in creating the integrated Primavera®/"Heavy-Bid" model.

    - The organization of Heavy-Bid creates resource units combining different types of labor and equipment. It may be necessary to calculate relative percentages by labor and equipment type to allow greater granularity/detail on the productivity changes.

- Add cash flow from Primavera®
    - The model currently uses a very basic and static allocation of construction/investment cash flow to support the financial portions of the overall model. This may be too simplistic for the true needs of ACP financial planning. Utilizing the resource-loaded model to develop the construction timeline should allow the team to build an appropriately dynamic characterization of investment cash flow to better support the financial modeling.

- Separate contingencies into categories:
    - Option A: Project and Program. Program would be the overall contingency and would include Project as a subcategory. It could further define subcategories below the Project level such as Atlantic Locks or even lower-level such as Water Saving Basin - Atlantic. This approach would allow a hierarchical assignment of increasing level of expenditure control over contingency from the lowest level upward.
    - Option B: Design, Owner and Construction. The intent of this division would be to anticipate what levels of contingency might be included in the contractor bids. It would also allow tracking of design evolution and how contingencies for both design and construction change with greater design detail. The actual contingency amounts in each category strongly depend on the selected method for project procurement (e.g., Design-Bid-Build, Design-Build).
    - Option C: Other. Other breakdowns could be considered.
    - It should be noted that when the categories are defined as mutually exclusive such as Option B, the sum of the category contingencies does not equal the total contingency; so care should be taken in interpreting any such category results.
    - The model is not currently organized or defined to readily produce such contingency categorization. It may require significant additional effort to produce such a breakdown.

- Evaluate the fourteen primary risks from the risk workshops
    - The risk workshops created an extensive list of risks that went through multiple levels of consolidation to produce the fourteen primary risks used in creating the construction portion of this risk model. These risks, in turn, were used to support such probability assessments as the construction

activity durations and were mainly used for conditioning these assessments.

- The correspondence of these initial fourteen risks and the current model parameters is not readily observable. It would be very useful to determine the contribution of each of these primary risks to the overall results. This may require a series of sensitivity analyses especially designed to isolate the contributions of each of these primary risk factors.
- It would be most desirable to have a rank order of these primary risks including, if possible, a measure of the impact similar to that produced by a Tornado diagram.

o Set up risk categories to better support risk management options/mitigation strategies.

Some of these proposed changes allow incorporation of greater detail, and thus improve model transparency or data assessment. A few improve linkages such as the impact of productivity change on activity durations. Some anticipate follow-on uses of the model such as ACP financial planning or development of the Expansion risk management program. And finally, some of these enhancements provide greater clarity in understanding the model and its results.

Current status/assessment of model

The ACP team has made excellent progress in developing the construction risk model. The regular participation of the estimating group in the model development is especially noteworthy. Model refinements and improved data assessments are a collaborative effort of the modelers and estimators. The modelers have an increasingly thorough understanding of the estimating processes and the engineers' considerations. The estimators are becoming quite comfortable with the assumptions and structure of the model, including making valuable contributions to the model design. The team is a very solid foundation for the continued activities toward risk mitigation and management.

The risk model is fully operational and able to produce meaningful results. The sensitivity analyses demonstrate the validity of the basic model structure and variable relationships. The model is currently producing an overall cost contingency on the order of $1.2 billion. This contingency value seems to be well supported by the details and structure of the model. Proposed model enhancements may have a minor impact on the cost contingency, but will not likely produce a significantly different outcome. The determination of the commissioning year (or total project duration), on the other hand, appears to lead to an overly narrow distribution and still requires further model development. Several of the proposed model enhancements should address this schedule concern, but it will also require careful attention to activity duration assessments to ensure the reasonableness of these values.

Since the model uses a *real-dollar* approach, it shows only minimal impact when the schedule is extended. One simple sensitivity analysis performed by the ACP team

including only modest inflation values showed a substantial increase in total cost and contingency. The ETC continues to be concerned with the potential effects of inflation and cost escalation should the Expansion program duration increase, and therefore recommends that more study should be devoted to how best to include these factors.

Overall, this is an outstanding risk model and well serves its intended purpose. The cost contingency (in real dollars) seems well supported by the data and model used in developing it. We believe the model will continue to evolve and mature over the life of the program. Regular model and data updating will yield the desired tracking of major project risks over time. It will serve as a firm foundation for implementing an extensive risk management/mitigation strategy for the 3rd Lane Locks and Access Channel Expansion Program.

Possible activities on next visit

The next visit is scheduled for January 3-5, 2006, and will include all three members of the ETC. We will continue to work with the ACP team on model development and validation. The following list includes possible additional activities for this next meeting:

- Meet with ACP Board of Directors and/or Administrator to summarize the status and quality of the risk model.
- Use the risk model to test one or more risk management strategies.
- Start development of risk charter activities.
- Align prior risk workshop results with both the risk model and risk charter. This could provide the basic structure for definition and implementation of the Expansion Program's risk management program.
- Work with the ACP team to set up the process for risk tracking and updating.

To: Angelique Sucre de Hanily
Oficina de Desarrollo de Programas
Autoridad del Canal de Panamá

From: Expert Technical Committee (ETC)

- Luis F. Alarcón, Ph.D.
- David B. Ashley, Ph.D.
- Keith R. Molenaar, Ph.D.

Date: 10 January 2006

Re: Summary of ACP Visit – January 3-5, 2006

We are pleased to submit the following as a summary trip report related to the development and implementation of a risk model to support the Panama Canal's 3rd Lane Locks and Access Channel Expansion Program. It documents continued progress during the period December 13, 2005, through January 5, 2006. Expert Technical Committee (ETC) members Luis F. Alarcón, David B. Ashley and Keith R. Molenaar participated in this visit January 3-5, 2006. The ETC originally planned to have only one member visit at this time in the current consulting agreement (Task Order 25), but all three members participated to add value to the review and because the ACP is making such rapid advances in the risk model. The additional participation was accomplished within the task order budget. The ETC is planning a final visit for this task during the week of February 6, 2006.

The primary objectives of this visit were to: a) assess model progress and verify model performance; b) assist in model refinement so that the final model can support risk mitigation and contingency tracking; and c) aid Autoridad del Canal de Panamá (ACP) with the integration of the risk model into the risk management plan by providing advice in the development of risk mitigation analysis and risk management plans.

The three-day visit included reviews and working meetings with ACP members from the Engineering and Projects Department, the Finance Department and the Office of Program Development. Specifically ETC and ACP members:

1. Reviewed the January 4, 2006 *Risk Model* presentation;
2. Reviewed risk model/assessment documentation prepared by the ACP team;
3. Developed strategies for final model refinements to support contingency tracking;
4. Developed strategies for model refinements to support risk management;
5. Developed an annotated outline for risk model documentation;
6. Discussed risk mitigation analysis and risk management planning; and
7. Confirmed the schedule and tasks for the final ETC visit under the current agreement.

This trip report provides an overall assessment on the progress to date and summarizes these accomplishments. The report discusses the assessment of model progress and performance, documents final refinements to support the risk-based contingency and risk management, discusses an annotated outline developed for risk model documentation, touches on risk mitigation analysis and risk management planning accomplished during the visit, and outlines the final steps to complete the current task order agreement.

Assessment of model progress and performance

In-line with the December 12-13 ETC visit made by David Ashley, the additional team member are impressed with ACP's progress and are very comfortable with the risk model's functionality, logic, assumptions and methodology in regard to cost risk variability. Changes in the model structure are consistent with feedback from the ETC's October/November feedback and recommendations, and work is continuing on the feedback from the December visit. While the ETC is not yet as comfortable with the model's logic and functionality in terms of schedule analysis and predictions of commissioning date, the model refinements discussed with the ACP and outlined in this report should provide this comfort and seem to be achievable in the timeframe before the final visit. The following comments restate and expand on those from the ETC's December visit.

The ACP team has made excellent progress in developing the construction risk model. The regular participation of the estimating group in the model development is especially noteworthy. Model refinements and improved data assessments are a collaborative effort of the modelers and estimators. The modelers have an increasingly thorough understanding of the estimating processes and the engineers' considerations. The estimators are becoming quite comfortable with the assumptions and structure of the model, including making valuable contributions to the model design. The team is a very solid foundation for the continued activities toward risk mitigation and management.

The risk model is fully operational and able to produce meaningful results. The sensitivity analyses demonstrate the validity of the basic model structure and variable relationships. The model is currently producing an overall cost contingency on the order of $1.2 billion. This contingency value seems to be well supported by the details and structure of the model. Proposed model enhancements may have a minor impact on the cost contingency, but will not likely produce a significantly different outcome.

The determination of the commissioning year (or total project duration), on the other hand, appears to lead to an overly narrow distribution and still requires further model development. The ETC noticed that the current schedule model considers the initial year to be 2005; the next update of this model should consider updating the initial schedule date to avoid potential confusion in the interpretation of the results. The model is currently producing a schedule contingency (at the 80% confidence level) on the order of 6 months above the model mean. The contingency commissioning date of 2014.5 is actually 13 months beyond the base schedule (not using the simulation) of 2013.3. The ETC also noted that the risk model produces few outliers for catastrophic events that can occur on a project of this size and duration. Several of the proposed model enhancements

suggested during this visit should address this schedule concern, but it will also require careful attention to activity duration assessments to ensure the reasonableness of these values.

Overall, this is an outstanding risk model and well serves its intended purpose. The cost contingency (in real dollars) seems well supported by the data and model used in developing it. We believe the model will continue to evolve and mature over the life of the program. Regular model and data updating will yield the desired tracking of major project risks over time. It will serve as a firm foundation for implementing an extensive risk management/mitigation strategy for the 3rd Lane Locks and Access Channel Expansion Program.

Final model refinements to support risk-based contingency

A principal product of this visit is suggestions for final model refinements to support a risk-based contingency. As previously stated, the model is producing meaningful results, particularly in terms of project cost. There are four primary recommendations that will yield more meaningful results in regard to commissioning date: 1) revise or replace current construction timeline; 2) link productivity and quantity changes to activity durations; 3) refine dynamic cash flow; and, 4) add events with low probability but high impact to the construction timeline.

1) Replace/revise current construction timeline

To improve the overall schedule output and analysis capabilities for risk management, the team determined that the current construction timeline would need to be replaced with a more accurate schedule. The ACP team was working on replacing the current construction timeline with a new schedule based on the integrated "Heavy-Bid" – Primavera®/resource-loaded model recently developed by the estimators. The construction timeline in the model should be at a more aggregate level than currently being developed in the Primavera®/resource-loaded schedule. At the time of this visit, the estimators had developed a resource-loaded schedule and aggregated it to just over 150 activities. The team was beginning to further aggregate the schedule into subnets based on critical and near-critical path activities. This approach was tested on the Pacific Locks activities during the visit and appears to be a good methodology for modeling the entire project.

Once the new timeline is incorporated, the team needs to reassess duration uncertainties for each of these activities. In some cases, when activity durations are closely related to changes in productivity and quantities, the scenarios used in the cost model could be directly applied for computing changes in durations without the need of obtaining new assessments. In other cases, when these linkages are not directly available, assessments should follow a similar approach to the previous assessments where multiple risk factors are assigned to each activity and the duration assessment considers them in combination. The team should be careful to remove the optimistic bias that may exist in previous estimates. Effort should be made to include all the potential variability existing in extreme case scenarios that reflect the full extent of the uncertainties in this early stage of program development.

2) Link productivity and quantity changes to activity durations
Linking productivity and quantity changes in the estimate to activity durations in the construction timeline will produce more meaningful results and give the estimators more confidence in the schedule output from the model. In some cases, the cost model scenarios can be directly used to compute changes in durations in the schedule model. However, in other cases the link is not readily available and the team should seek a concise (or simplified) method for creating this link as an elaborate approach will not likely produce significantly more accurate results. Since cost components are typically categorized differently than construction activities, the team may need to utilize an approximate/proportional approach to creating this linkage. This approximation is facilitated by the work currently underway in creating the integrated Primavera®/"Heavy-Bid" model.

The organization of Heavy-Bid creates resource units combining different types of labor and equipment. It may be necessary to calculate relative percentages by labor and equipment type to allow greater granularity/detail on the productivity changes.

3) Refine dynamic cash flow
The model constructed during the November/December timeframe contained a very basic and static allocation of construction/investment cash flow to support the financial portions of the overall risk model. This may be too simplistic for the true needs of ACP financial planning. At the time of this visit, the estimators had completed the initial resource-loaded Primavera® schedule, which provides a much more accurate prediction of the project cash flow than has been available to date. It is the team's intent to utilize this to new information to develop an appropriately dynamic characterization of investment cash flow to better support the financial modeling.

Two distinct approaches were discussed for constructing this dynamic cash flow during the visit. The most accurate, but also the most model-intensive approach is to provide a separate cash flow for each of the activities in the revised construction timeline. The data is available for this effort and the approach seems achievable with a significant risk modeling effort. The second approach is to model the shape of the base schedule cash flow and then mirror this shape in the risk model simulations. This second approach would be significantly less model intensive and should yield a reasonable characterization of the expected investment cash flow. The team should consider using the second approach initially and attempting the more model-intensive approach if additional accuracy is required to support the financial modeling.

4) Add events with low probability but high impact to construction timeline
During the review of the construction timeline and commissioning date output from the model, the team spent time discussing reasons why there might be a lack of variability in the commissioning date. It became apparent that the model was not reflecting events with a low probability of occurrence but a high impact on delay. During the risk filtering process for modeling, these high impact/low probability events were excluded from the initial modeling process and noted for later consideration. For example, a landslide in the canal requiring the use of dredging equipment scheduled for the expansion, a single bidder responding to a request for proposal, and a catastrophic event in the gate

production/transportation were not modeled. Similar examples of actual delays can be cited on many large infrastructure projects around the world and these should not be neglected.

The current model structure will allow for the addition of these events quite easily. They can likely be modeled accurately using only the construction timeline components of the risk model. Numerous high impact/low probability events were identified early in the risk assessment process through the Aon modeling process, the Value Management Workshop and the October Risk Assessment Workshop. The model is currently capturing two events that span across multiple activities in the construction schedule – labor strikes and extreme weather – and this structure can be used to model the additional risks in a similar manner. During this visit, the team reviewed the previously identified risks with low probability and high impact that are not currently included in the model. It appears that there are five to ten additional risks that should be added to the model. The ACP team should assess the probability and impact of these risks again and add them into the current model to see how they affect the predicted commissioning date and related elements.

Model refinements to support contingency resolution and risk management
Upon completion of the model refinements to support a risk-based contingency, the risk modeling team will focus its attention on a few more refinements to better support contingency resolution (or contingency tracking). As the project progresses through development, more will be known about the project; uncertainty will diminish and the amount of contingency in the budget should be reduced. For example, the risk model currently simulates quantity variations to represent four possible designs for the locks. As these designs become known, this contingency should be reduced. The model can be revisited at critical risk management milestones with more information to produce a new contingency value. Refining the model to support risk management decisions that need to be made in regard to the contingency will be helpful. This section discusses 1) refinements to support contingency categories, 2) refinements to support risk management, and 3) sensitivity analysis.

1) Refinements to support contingency categories
Two options for model refinements were discussed during David Ashley's visit in December and the team examined these in more detail during this visit. The first involves separating the contingencies or *program* and *project* categories, and the second involves the separation into contingencies for *design*, *owner* and *construction* categories. The ACP team thought that it was feasible to include these refinements and the ETC concurred.

In separating the contingency into program and project categories, the program would be the overall contingency and project would be considered as a subcategory. It could further define subcategories below the project level such as Atlantic Locks or even lower-level such as Water Saving Basin - Atlantic. This approach would allow a hierarchical assignment of increasing level of expenditure control over contingency from the lowest level upward. The ACP team is well on its way to producing these contingency categories. The team is encouraged to continue development of these contingency

categories, but only to a level that is required for decision making and reasonably supported by the model structure, assumptions and assessments.

The intent of dividing the contingency into design, owner and contractor categories is to anticipate what levels of contingency might be included in the contractor bids. It would also allow tracking of design evolution and how contingencies for both design and construction change with greater design detail. The actual contingency amounts in each category strongly depend on the selected method for project procurement (e.g., Design-Bid-Build, Design-Build, etc.). Again, the team is encouraged to continue to develop these contingencies to a level that is helpful for decision making and reasonably supported by the model structure and input.

2) Refinements to support risk management

The current model was developed to support a risk-based contingency estimate, and is both reasonably detailed and well designed for that purpose. It is, in fact, one of the best models that the ETC has seen in its experience for this purpose. The model was constructed from an exhaustive risk assessment that included ACP members from a wide variety of disciplines and experts who are familiar with both risk management and large infrastructure project construction. The exhaustive list of risks was condensed into fourteen significant risks and the model was integrated into a detailed construction cost estimate. The strength in producing a risk-based contingency from this model is derived from its integration with the detailed cost estimate and resource-loaded construction timeline. Where similar risk models are often built from the top down – assessing variation in the high-level risks (similar to the fourteen risks in this model) – this model utilizes a bottom-up approach by applying these fourteen risks across the detailed estimate and construction timeline. The sacrifice of this approach is that the correspondence of these initial fourteen risks and the current model parameters is not readily observable in the same detail for each of them. The comparative advantage of this approach is the strong fidelity to the cost estimate and estimate structure.

Risks such as referendum delays, extreme weather, and labor strikes are directly obtained from the model, and other risks such as changes in material prices and some project changes can be obtained from the simulation results. To determine the contribution of other primary risks to the overall results may require a series of sensitivity analyses especially designed to isolate the contributions of each of these primary risk factors and in some cases may require significant additional modeling efforts. It would be most desirable to have a rank order of these primary risks including, if possible, a measure of the impact similar to that produced by a Tornado diagram. *However, the ETC would caution the modeling team in attempting to make a direct estimate of cost impacts for the fourteen primary risks from the model.* Recall that the model was constructed to develop a risk-based contingency and not specifically to isolate the value of the fourteen primary risks. Changing the model to isolate these risk would likely result in a diminished ability of the model to capture an appropriate contingency value.

Sensitivity analysis is a primary modeling tool that can be used to assist in valuing the fourteen risks and also in general risk management support. Sensitivity analysis was discussed in-depth in the meetings in December in the context of model verification. It is

appropriate to revisit this discussion in the context of risk management. The sensitivity analysis being generated from the model will be extremely helpful in determining which risks should be mitigated and possibly give insights to the value of the mitigation. The following discussion is from the December 12-13 trip report as it is appropriate for this discussion.

3) Sensitivity analyses
@Risk has several built-in analysis tools for such model testing. Perhaps the most useful is the "Tornado diagram" that shows a correlation between variations in model inputs and the distribution of the outcomes; in other words, it highlights the greatest contributors to the overall risk. While this is an important tool for explaining the final model results, it is equally valuable in verifying internal variable relationships and validating input parameters. The modeling team is continually running these Tornado analyses and collaborating with the estimators on refinements to their assessments. During the mid-December visit one such Tornado analysis produced the following rank order of "program risks":

Tornado diagram for base case

q. Diesel cost
r. Gates cost
s. Delay – Chamber concrete
t. Wages -- Locks
u. Delay – Contract locks award
v. Probability Delay – referendum
w. Delay – referendum
x. Cement
y. Deepening Gaillard & Gamboa & Chag. Cr.
z. Formwork
aa. Delay -- Chamber excavation (L65)
bb. Mark-up (J77)
cc. Altantic Lock – Aggregate transportation from Pacific Access
dd. Electro-mechanical (J82)
ee. Formwork (Y20)
ff. Weather (M72)

Discussions with the team, including the estimators, indicate that this ranking generally conforms to expectations. The higher placement of *diesel* and *gates costs* is symptomatic of the uncertainty the team places on material costs such diesel fuel and steel. The team is further probing the other risk factors and will continue to do so with each major run of the model.

Another area of sensitivity analysis key to the team is the variation in lock design -- this variation is seen as additional to the allowance included in the estimate for completion of the proposed base design. The team has developed four variants of a base-design scenario that differ primarily in quantities for both concrete and excavation for four major lock components (approach walls, lock heads, chambers, and water saving basins). During the visit, a design sensitivity analysis was conducted by setting each alternate

scenario to a probability of 1.0 and then comparing cost results to the base case (Option 3). As examples, Option 1 and Option 5 increased total costs by approximately $27 million and $150 million, respectively. While these values are notable, they do not appear to be as large as one might initially anticipate. The explanation appears to center on the relative conservatism of the quantities included in the base case; namely, the team appears convinced that the quantities utilized in the base case are greater than they expect to see when the engineering design is further advanced. An example often repeated was the conservative excavation slope currently used in the preliminary design. As design progresses, the team should revisit both the base-case quantity assumptions and the possible design scenario variations.

A typical class of sensitivity analyses for a construction project risk model is the factor inputs. These include productivity rates for labor and equipment, material costs and delays. The model as currently structured allows relatively easy testing of these input factors at a high- or aggregate-level. The estimators especially value the ability to broadly vary such items as diesel fuel or cement unit costs, as well as aggregate labor productivity by major cost component. The model does not yet fully break down the productivity by specific labor type; it currently uses general or aggregate labor categories and assigns these to cost components. This aggregate approach appears quite reasonable and appropriate for this stage of project development, but it does add an element of complexity for the estimators in preparing their productivity assessments. As currently modeled, what is not reflected well is the relationship between productivity changes and construction activity durations; this is the basis for the recommended model enhancement included in this report. Additionally, the sensitivity analyses have uncovered the need to reassess the delay distributions associated with construction activities. The initial probability assessments contained significant optimism and are now being reassessed as asymmetric distributions where the possibility of delay is greater than early completion; this has been carefully considered and discussed extensively with the estimators.

Annotated outline for risk model documentation

The modeling refinement and verification for supporting a risk-based contingency is quickly nearing an end. Again, the ETC believes that the ACP team has made excellent progress in developing the construction risk model in such a short time. The risk model's functionality, logic, assumptions and methodology in regard to cost is robust and the ETC believes that the schedule model issues will be resolved with the current refinements planned to be completed before the February visit.

During the visit, the risk-modeling team was charged with the task of preparing a comprehensive risk model report to support model quality assurance and communicate the model with the various project stakeholders. The ACP team has been documenting the modeling processes throughout its development. The team discussed the December 7, 2005 *Risk Model and Contingency Estimation* document and also reviewed the January 4, 2006 *Risk Model* presentation to the ACP Board of Directors. The risk-modeling team will be using these documents as a basis for model documentation.

The ETC provided the risk-modeling team with additional guidance on the model documentation. To ensure that the ACP is meeting industry standards, the ETC provided

examples of risk model documentation from the Project Management Institute, the U.S. Department of Energy, the California Department of Transportation, the Highways Agency of England, and the Washington State Department of Transportation.

The result of this discussion was an annotated outline for a risk model documentation report. The outline incorporates the framework from *Risk Model and Contingency Estimation* document with the important figures from the *Risk Model* presentation. Important concepts from the industry standard documents are being used to ensure that the final report framework adequately documents the risk model, supports model quality assurance and communicates the results effectively to the various project stakeholders. The annotated outline will support a comprehensive risk modeling report and provide adequate information to support any number of summary documents that will be required to communicate the results to the Board of Directors, the various ACP departments, the general public or other stakeholders.

Risk mitigation analysis and management plan

Because the risk model is making such rapid advances and the ETC was able to make an additional visit under the terms of the agreement, the ETC began the advising originally planned for February on this trip. The overall goal of the risk management advising is to aid in the development of risk mitigation analysis and management plans. During the visit, the team was able to complete some essential steps. A preliminary *risk register* was developed to help track risk mitigation and contingency resolution and a preliminary set of risk management milestones was developed for overall risk management.

A *risk register* is a tracking tool for risk mitigation and management. The register is developed through the risks identified in the risk assessment process. The comprehensive risk assessment conducted on this project provided a list of fourteen primary risks for this project, but it would be prudent to track more than these fourteen risks. These fourteen risks were derived by combining a longer list of similar risks from the October Risk Assessment Workshop results. This longer list contains approximately 50 risks that should be tracked, mitigated or managed over the life of the project. The team decided to organize the longer list of risks as sub-risks to the fourteen primary risks in the risk register. This organization will allow for tracking of all the critical risks identified to date without being overly cumbersome to manage. The risk register will allow for these risks to be retired when they are resolved and also invite new risks as they arise on the project. The draft risk register summary sheet includes the following items:

- Risk ID
- Status
- Risk Description
- Assignment
- Expected Cost Impact
  (Amount or Rating)
- Expected Schedule Impact
  (Months or Rating)
- Mitigation Strategy
- Proposed Mitigation Description

- Monitoring and Control Status
- Risk Resolution Schedule

Much of the discussion about the risk register focused on valuing the risks and providing a risk resolution schedule. Some of the risks can be valued in terms of cost and time directly from the model output and others can be inferred from the model. Many risks can only be valued through a qualitative assessment such as those done in the Value Management Workshop. Valuing the risks will be helpful for management decision concerning staffing or contracting priorities. Valuing the risks will also be helpful for determining a cost/benefit analysis of mitigation alternatives. In either case, a direct estimate of the cost or schedule impacts may not be readily available. However, an approximation may likely be adequate to make the decision at hand. The risk modeling team should take caution in attempting to value all of the risks on the register in detail. An approximate value should be used in the risk register to provide a relative ranking and a more precise value can be derived when necessary for management decisions.

A preliminary schedule for risk resolution was developed during the visit. The schedule will support risk management in three primary ways. First, the schedule will provide milestones to update the risk-based contingency model with new information. Second, it will provide a timeline for risk mitigation planning. Third, it will help to establish critical risk communication points in the project. The team drafted the following preliminary risk resolution schedule for future consideration:

- Referendum
- Project Strategy Decision
    - Project Delivery Decision
    - ACP Reorganization
    - Program Management Decision
    - Final Funding Decision
    - Project Controls System
- PPC Design Deliverables
    - Hydraulic Modeling
    - Geotechnical analysis
    - 70% Design
- Contract Award
- Commissioning
- Periodic as required between above

In addition to the risk resolution schedule, the team discussed a number of other risk management milestones. It is important to share the risk-based contingency model and risk management advancements with the October Risk Assessment Workshop participants. Additionally, risk management training should be implemented in the form of workshops and events, and individual or departmental training. Lastly, other communication techniques such as email updates or circulation of periodic readings on risk will help to facilitate a culture of risk management within the ACP. These items will be explored in more depth during the February ETC visit.

Questions raised during visits
During this and the preceding visits several questions were raised regarding the interpretation of the risk model results and the typical use of such models. The two most prominent questions can be summarized as follows:

1) Why do we use 80% for setting contingency instead of 50%?
2) Is this model and approach "standard"?

Each of these will be answered more fully in the ETC final report. For the purpose of this trip report, however, it is worthwhile to offer an initial response.

The percentile level used in establishing contingency is directly related to the level of risk aversion of the decision maker (or firm); the more risk adverse, the higher the percentile. The 50% value of the outcome total cost distribution is the median, and would in most instances be approximately equal to the mean. Using this value would imply a risk-neutral, or expected value, decision maker – this would be highly unusual for an investment of this very large scale. One standard deviation above the mean would be at approximately the 85% level, and is sometimes used as a basis for setting the project contingency. The more typical value used in the industry for projects of this magnitude is 80%; it implies that one in five times a project such as this would exceed this 80% value, four out of five times the final cost would be below this number. While 80% is a reasonable criterion and has a straightforward interpretation, ACP may want to consider a more rigorous assessment of the level it should use to capture the authority's willingness to accept risk.

It is becoming more and more standard for larger, longer-duration and complex projects to use a simulation model to estimate the cost or time variability. Several state highway authorities in the US have adopted or are considering adoption of simulation models to forecast risk on projects ranging from millions to billions of dollars. Washington State Department of Transportation is among the most advanced in using this approach, and applies it on all its major projects. The U.S. Department of Energy has developed and regularly employs a risk estimating and modeling approach for its significant projects. The ACP risk model created for the Expansion Program is thus quite similar in purpose and use to those analyses being utilized for many major projects in the U.S. and elsewhere. It should be noted that the ACP risk model incorporates both cost and schedule risk, and links directly to the ACP financial model; this makes the risk model even more valuable for decision making support. It is also better aligned with the establishment of a risk management and mitigation program for the project. These questions will be further discussed in the ETC's final report.

Schedule and tasks for final ETC visit under the current agreement
The team confirmed a time for the final visit under the current agreement. Luis F. Alarcón, David B. Ashley and Keith R. Molenaar will travel to Panama during the week of February 6. A final report format was reviewed and agreed upon. The ETC will deliver the final report by the end of February. The primary task remaining is advising on risk mitigation and management plans, but the ETC believes that it is ahead of the

originally proposed schedule. The remaining discussions will focus on how to best integrate the model with the risk management plan, what risks and decisions can be supported from the model, how to track the risk resolution and contingency management process, and how to communication the risk management results to the various stakeholders.