NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

August 2005

NWMO BACKGROUND PAPERS
6. TECHNICAL METHODS

6-17 ADAPTIVE PHASED MANAGEMENT: VALIDATION OF COST ESTIMATING PROCESS FOR ADAPTIVE PHASED MANAGEMENT OF THE LONG TERM MANAGEMENT OF USED NUCLEAR FUEL

A.W. Hooker Associates Ltd.

NWMO Background Papers

NWMO has commissioned a series of background papers which present concepts and contextual information about the state of our knowledge on important topics related to the management of radioactive waste. The intent of these background papers is to provide input to defining possible approaches for the long-term management of used nuclear fuel and to contribute to an informed dialogue with the public and other stakeholders. The papers currently available are posted on NWMO's web site. Additional papers may be commissioned.

The topics of the background papers can be classified under the following broad headings:

1. **Guiding Concepts** – describe key concepts which can help guide an informed dialogue with the public and other stakeholders on the topic of radioactive waste management. They include perspectives on risk, security, the precautionary approach, adaptive management, traditional knowledge and sustainable development.

2. **Social and Ethical Dimensions** - provide perspectives on the social and ethical dimensions of radioactive waste management. They include background papers prepared for roundtable discussions.

3. **Health and Safety** – provide information on the status of relevant research, technologies, standards and procedures to reduce radiation and security risk associated with radioactive waste management.

4. **Science and Environment** – provide information on the current status of relevant research on ecosystem processes and environmental management issues. They include descriptions of the current efforts, as well as the status of research into our understanding of the biosphere and geosphere.

5. **Economic Factors** - provide insight into the economic factors and financial requirements for the long-term management of used nuclear fuel.

6. **Technical Methods** - provide general descriptions of the three methods for the longterm management of used nuclear fuel as defined in the NFWA, as well as other possible methods and related system requirements.

7. **Institutions and Governance** - outline the current relevant legal, administrative and institutional requirements that may be applicable to the long-term management of spent nuclear fuel in Canada, including legislation, regulations, guidelines, protocols, directives, policies and procedures of various jurisdictions.

8. **Workshop Reports** - provide information on the outputs and outcomes of some NWMO engagement activities including discussions and expert workshops.

9. **Assessments** - provides perspectives on the advantages and limitations of the management approaches under study.

Validation of Cost Estimating Process for Adaptive Phased Management, of the Long Term Management of Used Nuclear Fuel.

Prepared for:

Nuclear Waste Management Organization

Submitted By:

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GLOSSARY OF TERMS

AACE	Association for the Advancement of Cost Engineering
ADH	ADH Technologies Inc.
AECL	Atomic Energy of Canada Limited
APM	Adaptive Phase Management
AWHAL	A.W. Hooker Associates Ltd.
CES	Centralized Extended Storage
CIQS	Canadian Institute of Quantity Surveyors
CRA	Charles River Associates
DGR	Deep Geologic Repository
HQ	Hydro Quebec
JWO	Joint Waste Owners
LPSI	Ludlow Project Services Inc.
NBP	New Brunswick Power
NFWA	Nuclear Fuel Waste Act (the “Act”)
NWMO	Nuclear Waste Management Organization
OPG	Ontario Power Generation
PMI	Project Management Institute
RES	Reactor Extended Storage
UFT	Used Fuel Transport
WBS	Work Breakdown Structure
WEDS	Work Element Definition Sheet

1.0 Executive Summary

1.1 Background

The Nuclear Fuel Waste Act (NFWA) requires the NWMO to submit a report to the Government of Canada which includes comparison of costs, risks and benefits of at least three approaches for managing Canada's nuclear fuel wastes over the long-term.

In advance of the NWMO being established, Ontario Power Generation, Hydro-Québec, AECL and New Brunswick Power (the "Joint Waste Owners) -- anticipating their responsibilities under the NFWA to establish the NWMO and to ensure a comprehensive study is completed within the legislated timelines, commissioned work on the costing of the options in the then draft NFWA.

Specifically, prior to the establishment of the NWMO the Joint Waste Owners commissioned cost and design studies in 2001 and 2002 based on the anticipated requirements in the Act. These studies concerned the development of technical descriptions for the alternative approaches and associated cost estimates for three technical management methods. They developed conceptual designs for the technical methods in the Act, and the associated cost estimates.

It was intended that this costing work, once completed, would be made available to the NWMO for consideration as the NWMO conducts its assessment of the management approaches.

The Joint Waste Owners presented this body of work to the NWMO at the end of 2003, for use in the NWMO's study of management approaches. Subsequent to this work the NWMO developed a fourth management approach, titled "Adaptive Phased Management" (APM).

NWMO has issued a Draft Study Report, which includes a recommendation for an Adaptive Phased Management approach, with the following characteristics:

- Centralized containment and isolation of the used fuel in a deep geologic repository in suitable rock formations, such as the crystalline rock of the Canadian shield or Ordovician rock;
- Flexibility in the pace and manner of implementation through a phased decision-making process, supported by a program of continuous learning, research and development;
- Provision for an interim step in the implementation process in the form of shallow underground storage of used fuel at the central site, prior to final placement in a deep repository;
- Continuous monitoring of the used fuel to support data collection and confirmation of the safety and performance of the repository; and

- Potential for retrievability of the used fuel for an extended period, until such time as a future society makes a determination on the final closure, and the appropriate form and duration of postclosure monitoring.

The NWMO commissioned Golder Associates to develop an estimate for this scenario, which is based on the earlier JWO cost estimates. The present study provides a review and validation of the estimating process employed in developing the APM estimates.

1.2 The Cost Estimates

The Joint Waste Owners prepared Estimates for the following three mandated approaches to nuclear spent fuel management:

- Deep Geologic Repository approach (DGR)
- Reactor Extended Storage approach (RES)
- Centralized Extended Storage approach (CES)
- As well as Estimates for the Transportation of Spent Nuclear Fuel to the storage/repository site.

A key assumption is that the total amount of spent fuel to be managed will be approximately 3.7 million bundles.

The estimates for storage of used fuel at reactor sites have been calculated using waste volumes provided by respective owners and the application of OPG full unit interim storage costs to these volumes.

The estimate for transportation of the nuclear fuel waste, where applicable, to a final location, has been provided by Cogema Logistics. Cogema Logistics is a French company with extensive experience in transportation of nuclear fuel waste in Europe.

The estimated cost of siting, design, construction, operation, extended monitoring, closure and decommissioning of the waste management facilities was provided by CTECH. At the time the estimates were prepared, CTECH was a joint venture of CANATOM (SNC-Lavalin, AECON) and AEA Technologies (UK) (now RWE Nukem).

Based on these estimates the NWMO has developed the APM approach for management of used nuclear fuel that combines features of the management approaches previously developed by the Joint Waste Owners. NWMO has developed this option from a combination of both existing cost estimating information and additional professional estimates, adapted to the implementation requirements of the Adaptive Phased Management approach.

1.3 NWMO Commissions a Third-Party Review of the APM

The NWMO invited a third party review to validate the cost estimates for the APM approach as being appropriate for use in the NWMO's formal study of management options.

This review and validation by a qualified third party is seen as essential to provide the NWMO with the assurance of the integrity of this costing work. The NWMO felt it particularly important to ensure that the APM estimates have been prepared in an appropriate manner and were developed consistent with established estimating standards, so that those using the estimate information in comparison and assessment of the APM option can be confident that they are referring to reliable estimates.

Accordingly, in May 2005 the NWMO launched a third-party review to validate the cost estimating process used by Golder Associates in developing the APM option. The NWMO engaged A.W. Hooker Associates (the "Reviewers") for this purpose. A.W. Hooker Associates LTD. was assisted by Maurice Hunt, previously of Ludlow Project Services Inc. (LPSI). LPSI is now part of AW Hooker associates LTD.

The focus of this project was to verify and validate the estimating methodology rather than the underlying assumptions. In addition, the review was to comment on the flexibility to update the estimates as assumptions or circumstances change in the future.

The NWMO set out eight specific criteria for validation of the APM Cost Estimates as follows:

1. The Reviewers will advise on the adequacy of the estimating standards adopted for this estimation work.

2. The Reviewers will assess the cost estimate documentation and comment on the quality and completeness.

3. The Reviewers will map the document trail that supports the cost estimates.

4. The Reviewers will comment on whether or not the estimates are structured such that they can be revised in the future as may be required, as the forecast of the used fuel volume or key estimating assumptions change.

5. The Reviewers will document the extent to which the cost estimating process adhered to all steps in the estimating standard.

6. The Reviewers will make recommendations as to how the estimating process will “stand the test of time” and if it could be easily updated with respect to:

    - Standards
    - Document trail
    - Data trail
    - Presentation
    - Data management

7. The Reviewers will assess the degree to which each estimate can stand alone, without the need of the team who produced it to provide further explanation and/or justification.

8. The Reviewers will deliver a signed opinion on the process and standards that were followed in deriving the estimates.

1.4 Findings of the Third-Party Review

1.4.1 Summary

The Estimate of the Adaptive Phased Management approach comprises of a selection of waste management options from a set of previously validated waste handling, storage & disposal Estimates, subsequently adjusted to integrate them into a single waste management scenario.

There are two configurations for the APM approach, one with and one without the CES-CRC component. Both of these estimates use the same data, estimating methods and standards. By validating the APM approach with the CES-CRC component, the APM approach without the CES-CRC component is also validated.

The estimating process to be reviewed and validated comprises of three methods of estimating:

a) Major components of the cost estimate are derived from estimates that were previously validated.
b) New facilities have been added to the scope and estimated by assumption and judgment.
c) Schedule revisions and activity deletions were made to the previously validated components.

The estimating method employed throughout is largely made at the summary level of existing data with new scope estimated by allocating reasonable cost allowances to these items.

The Golder Estimate Memorandums of the March 7, 2005 contain a statement of "Major Costing Limitations" and the Memorandum of March 10, 2005 contains statements of "Assumptions and Limitations…Additional Limitations". These disclaimers identify and acknowledge the parameters of accuracy and reliability of the resulting estimate.

The vast majority of the APM Management approach facility cost estimates were done by means of interpretation and adjustment for similar estimated components within the JWO cost estimates, and therefore may include a minimally less accurate estimate than the previously validated costs.

1.4.2 Validation Criteria Comments

The scenario estimate was reviewed to determine the following criteria:

1. Adequacy of the Estimating Standards

   Comment:
   Standards used to adjust existing estimates and estimate new scope are not specifically outlined, but are predicated on the standards used and verified from the extensive work developed in the original JWO cost estimate. The validated cost estimates of the JWO were the primary data source from which Golder developed the cost estimate for APM.

   The estimating standards established for producing the APM estimate are those used for the JWO cost estimate and closely follows key estimating elements recommended by Professional Institutions.

2. Quality and Completeness of the Estimate documentation

   Comment:
   Extensive and detailed documentation exists in support of the vast majority of the APM estimate as it was drawn directly from previously validated JWO cost estimating work. Where professional judgment was used, it was informed by experience of similarly scaled projects and international analogues.

3. Map of the Document Trail that supports the Estimate

   Comment:
   The trail is available from the previously validated JWO cost estimates. New adjustments and additions to the cost estimate foe APM, which compromise less than 6% of the total costs of Golder's APM estimate of $24.4 billion, can be traced through the available back-up data. The document trail follows the documented estimating process and completion:

   Instructions to Estimators Document
   Work Definition Sheets Document
   Estimate Workbook Spreadsheets Documents
   Summary Work Sheet
   Unit Price Work Sheet
   Estimate Detail Work Sheet
   Data Transfer Work Sheets

   Cost Estimate Database Document
   Cost Estimate Summary Document

   The documents available to summarize, explain and display the content and calculations in the Cost Estimate are adequate for the purpose.

4. Can the Estimate be adjusted for changes in fuel volumes and key assumptions?

   Comment:
   The Estimate is structured and summarized in such a way that revisions to the fuel volume and key estimating assumptions could be undertaken, in line with the methods used to adjust these variables within the original and validated JWO cost estimates. New cost components developed by Golder do not have variable costs tied to changes in fuel volumes.

   A formula can be developed to show how any or all of the Cost Estimate would vary as the fuel volume varied as well as variations in key estimating assumptions.

   The vast majority of the estimates are described, scoped, complied and calculated within separate documents with dependent data copied from one document to the other as required to support the specific estimating tasks. However, the Estimate could not be automatically or globally revised at the detail level to drive an overall programme summary result.

5. Document how the estimating process adhered to the standards

   Comment:
   The estimating process in the Golder cost estimate builds directly on the validity of the extensive data and documentation developed for the JWO cost estimates. Golder used the independently validated cost estimates of the JWO, as they were shown to be well documented in their adherence to costing standards, as the data source for the vast majority of APM cost components.

   Where new cost components were developed, professional experience and judgment were used to provide an order of magnitude cost estimate. This represented less than 6% of the total cost of Golder's APM estimate of $24.4 billion.

6. Will the Estimate 'Stand-the-Test-of-Time' and can it easily be updated?

   Comment:
   To stand the test of time the estimate will need to be updated to the current cost of the programme in the dollars of the year. The assembly of estimates that form the APM cost estimate could be updated using the same methodologies required to update the JWO cost estimates.

   Updating the Standards would only be necessary should the NWMO decide to follow different standards to those listed in the original JWO cost estimating documents.

7. Does the Estimate Documentation 'stand-alone' and does not need someone to explain it?

   Comment:
   The Estimate Documentation is designed to work in conjunction with the supporting documentation of the JWO cost estimates. The summary information developed for the APM approach can stand alone in a manner similar to the summary documents developed for the JWO cost estimates. However, the APM estimate relies on the extensive and detailed data in the JWO source materials.

   An experienced estimator should have little difficulty following these estimates and understanding them.

8. Deliver a 'Signed Opinion' on the process and standards that were followed in deriving the Estimate

   Comment:
   Please refer to the Cover Letter containing our "Professional Opinion".

2.0 The Review Team

The Review Team has prepared this report in order to provide the NWMO with a stand-alone document for their use that addresses the requirements of the Request for Proposal and validates the estimating process used.

Team Members

The members of the estimate validating team require a range of experience in the process of estimating large engineering projects such as those under consideration by the NWMO. In particular, skills in estimating and cost control, project management, and economic analysis are important for fulfillment of the estimate validation exercise.

The key members of the team who performed the estimate validation are:

Mr. P. Burger, PQS – A.W. Hooker Associates Ltd. – Leader
Mr. M. Hunt, PQS. CCC – A.W. Hooker Associates Ltd. - Estimating Analyst

3.0 Methodology

There are established practices and standards used in industry in preparing estimates for large complex engineering projects such as those represented by the options contemplated by the NWMO.

The team is fully cognizant of these practices and has established a methodology for reviewing and assessing the validity of the estimating process. Although the amount of estimate data is complex and voluminous, standardized review and assessment techniques were applied.

Estimating Practice

In industry associated with large engineered projects such as long-term nuclear waste management systems, there are established estimating standards.

Organizations such as the Association for the Advancement of Cost Engineering (formerly American Association of Cost Engineers (AACE)), the Canadian Institute of Quantity Surveyors (CIQS) and the Project Management Institute (PMI), develop and maintain such standards.

A key feature of these standards is that they have a classification system for estimates of large engineering projects that set out accuracy guidelines for estimates.

Typically, the standards provide a classification system for estimates depending on how developed the underlying information is and the ultimate use of the resulting estimate.

For some estimates, it is sufficient to have a minimum of scope definition and supporting data so that an overview of the particular project is obtained. Users may find this sufficient for feasibility assessment and concept comparison.

At the other end of the spectrum of estimate classes there is a considerable amount of technical definition and supporting data, such as quantities of material available to the estimators. Such estimates are used for project implementation and detailed budgeting of the work.

One standard applicable to the NWMO spent fuel management options is the AACE Recommended Practice No. 17R-97 “Cost Estimate Classification System”. In performing the work, the CRA/ADH team referred to this standard as reference and guideline in assessing the validity of the estimating process used by Golder Associates Ltd, and Gartner Lee Ltd. This standard classifies estimates in five levels and recommends their use in accordance to level of engineering definition used in the estimates (see Table 1).

Table 1 – Estimate Classification System

Estimate Class	Level of Definition	End Usage	Methodology	Expected Accuracy Range
Class 5	0% to 2%	Concept Screening	Capacity Factored, Judgment, Analogy	-20% to-50% +30 to +100%
Class 4	1% to 15%	Study or Feasibility	Equipment factored or parametric models	-15% to -30% +20% to +50%
Class 3	10% to 40%	Budget Authorization or Control	Semi-detailed unit costs with Assembly level line items	-10% to -20% +10 to +30%
Class 2	30% to 70%	Control or Bid	Detailed unit cost with forced detailed take-off	-5% to -15% +5% to +20%
Class 1	50% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	-3% to -10% +3% to +15%

Source: AACE Recommended Practice No. 17R-97, Cost Estimate Classification System

The estimates provided by the NWMO and reviewed by the CRA/ADH team are in the range of Class 3 or 4 in Table 1.

4.0 Conclusion

The estimate of the Adaptive Phased Management (APM) approach is the estimate of a scenario made up of data extracted from the original estimates for the Long Term Management of Used Nuclear Fuel put together and validated in 2004 from which various scenarios could be assembled by adjusting the details of those estimates.

This APM estimate is one such scenario derived from those original estimates with additional items added and some of the original estimates adjusted to suit the APM scope and arrive at the resulting estimate. These additions and adjustments were made at a summary level based largely on 'professional judgement' and assumptions that the detail calculations remained valid.

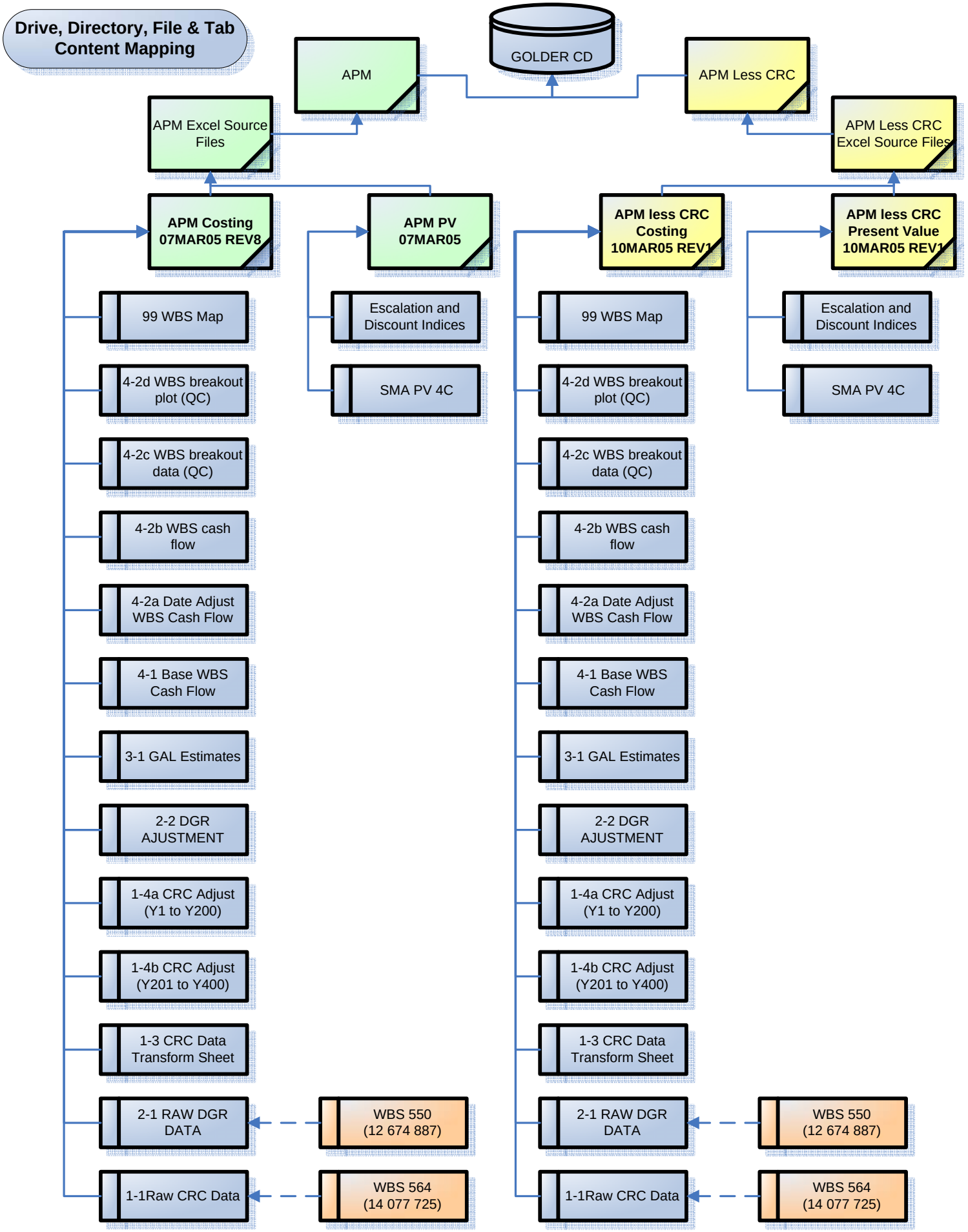
The resulting scenario estimate has been produced through a 'Top-Down' or 'Summary' process commonly used to assemble estimates to compare alternatives and is consistent with accepted industry standards and practices. The level of accuracy and reliability of this 'summary-level' method of estimating depends heavily on the knowledge and experience of those individuals doing the adding and adjusting and is generally less reliable than when adjustment are made at the detail level.

The overall accuracy of the APM Estimate could therefore be the same as the previous validation at plus and minus 33%. This falls between a Level 3 and 4 of the Cost Estimating Classification System of the AACEI Recommended Practices and Standards. These APM estimates are useful as an aid to directional planning.

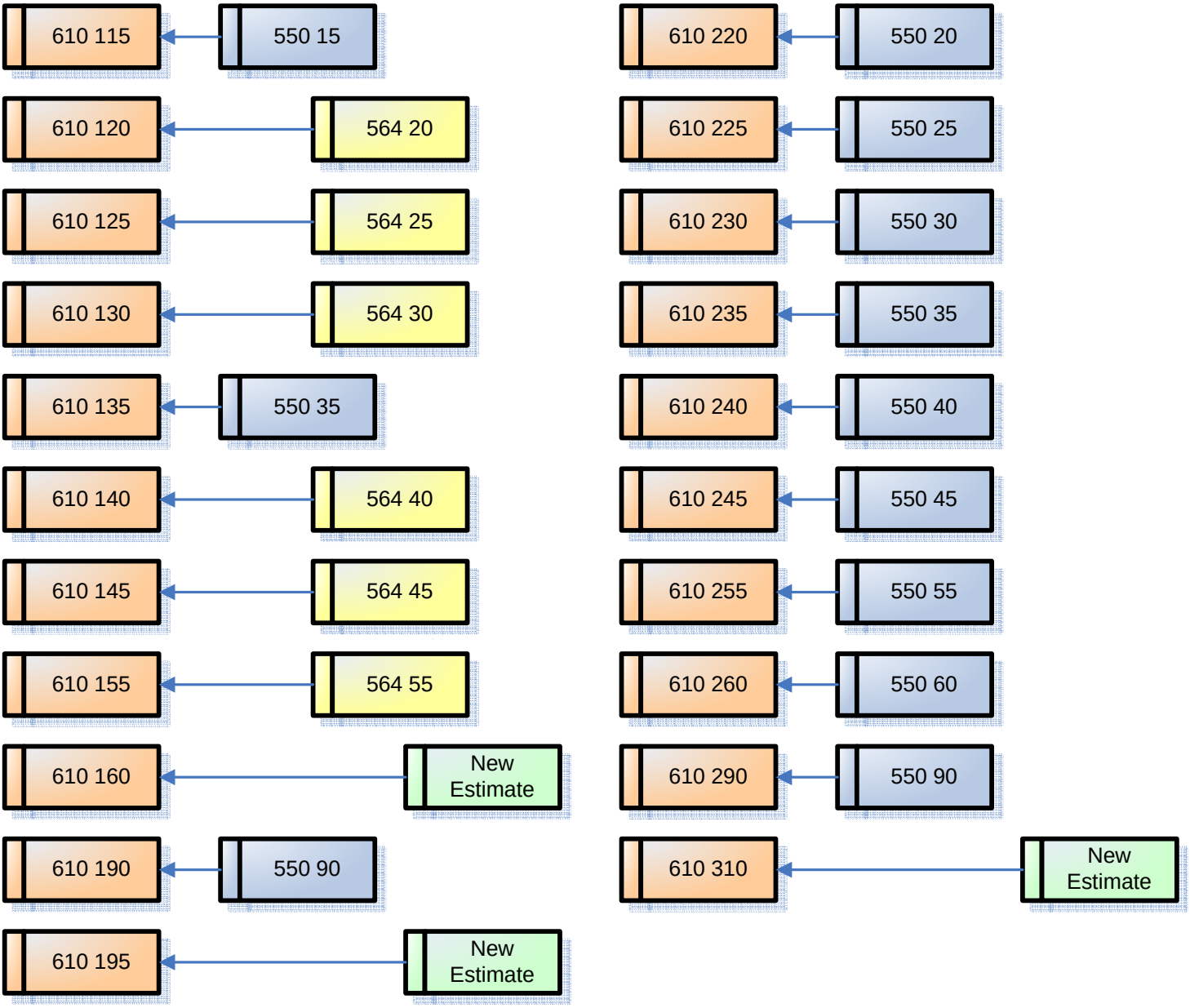
The cost estimates have been prepared with an appropriate estimating methodology. Hence they should be considered adequate for the NWMO's current options assessment process.

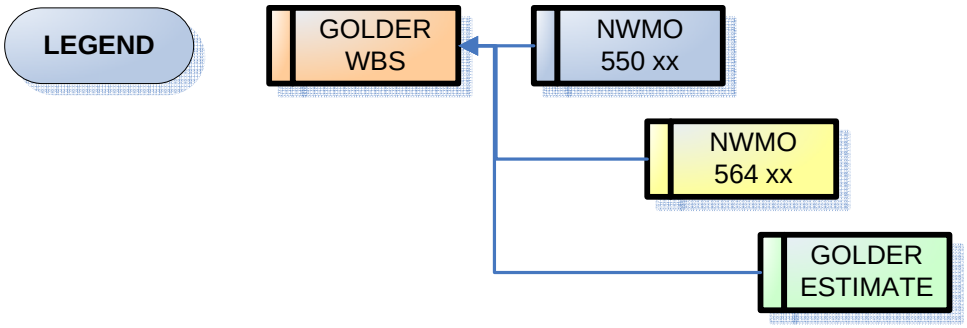
VISUAL SOURCE MAPPING

Drive, Directory, File & Tab Content Mapping



VISUAL WORK BREAKDOWN STRUCTURE MAPPING





WORK BREAKDOWN STRUCTURE
Estimate Comparison - Golder

Golder WBS		Activity	Estimate		
			Original (A)	New (B)	Diff (B-A)
610	115	Siting	396,844	396,844	0
610	120	System Development (Caverns)	89,338	89,338	0
610	125	Phase-I Safety Assessment	37,271	23,311	(13,960)
610	130	Phase-I Licensing & Approvals	205,824	80,945	(124,879)
610	135	Phase-I Public affairs (note-1)	106,945	106,945	0
610	140	Cavern Storage Design & Construct	536,468	530,544	(5,924)
610	145	Cavern Storage Operations	12,431,365	2,196,217	(10,235,148)
610	155	Cavern Storage EA & Monitoring	530,341	152,496	(377,845)
610	160	Cavern Plug & Flood	0	20,000	20,000
610	190	Cavern Programme Management (note-1)	285,044	285,044	0
610	195	URL Construct & Operate	0	1,380,000	1,380,000
610	220	Phase II System Development (isolation)	411,191	411,191	0
610	225	Phase II Safety Assessment	687,190	1,104,371	417,181
610	230	Phase II Licensing & Approvals	120,421	182,660	62,239
610	235	Phase II Public Affairs (note-2)	106,945	106,945	0
610	240	Isolation Design & Construct	2,381,931	2,381,931	0
610	245	Isolation operatiions	7,208,354	9,793,927	2,585,573
610	255	Isolation EA & Monitoring	236,142	457,904	221,762
610	260	Isolation Decommission & Closure	840,825	840,825	0
610	290	Isolation Programme Management (note-2)	285,044	285,044	0
610	310	Post Closure Monitoring	0	44,630	44,630
			26,897,483	20,871,112	(6,026,371)
These Activities describe the entire Scope of the Fourth Option The Adaptive Phased Management Approach without the Transportation costs			100% Raw Cost Data	78% Raw Cost Data Revised	-22% Added, Deducted & Adjusted
610	various	Used Fuel Transportation (mostly by Road)	927,546	927,546	0
		Total with Transportation	27,825,029	21,798,658	(6,026,371)

Note-1 Included in 610-145 after y29
Note-2 Included in 610-245 after y60
General Note - All costs in constant 2002 cadk$

Table Intent & Purpose

This Table shows the list of the Cost Estimates (original) used to support the Golder Estimate (new) of the APM approach 78% of the "original" estimates are carried over to "new" estimates with an overall reduction of 22% (2% deductions and 20% additions). The cavern storage operation is considerably less ($10.2 billion) in the "new" estimate than in the "original" estimate, accounting for most of the deductions. The additional costs of $4.7 billion are due to the addition the URL ($1.4 billion) and the "isolation operations" of the DGR ($2.6 billion). The "original" estimate of the transportation (road) has been the Golder estimate to show the complete cost of the APM approach.