Guidance for Determining if a Cleanup Action uses Permanent Solutions to the Maximum Extent Practicable using Disproportionate Cost Analysis

Public Comment Draft

Toxics Cleanup Program

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Olympia, Washington

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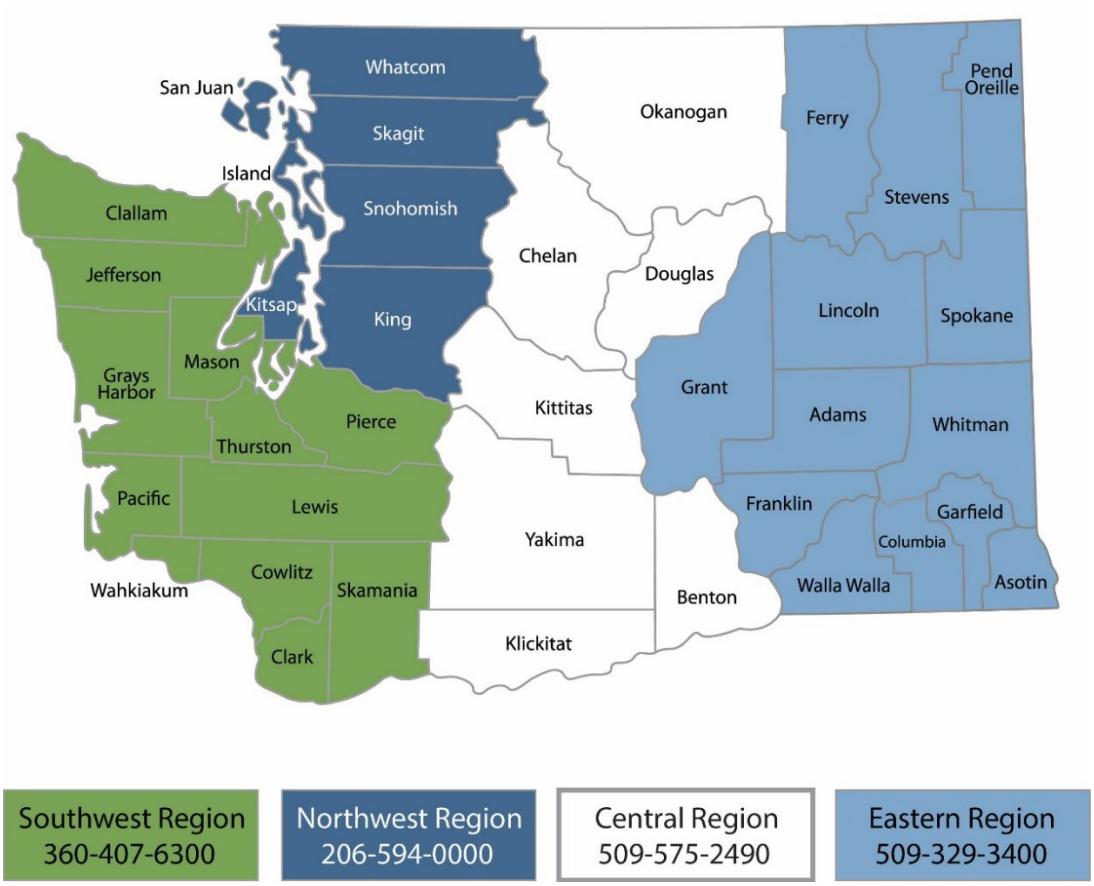

Region	Counties served	Mailing Address	Phone
Southwest	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Mason, Lewis, Pacific, Pierce, Skamania, Thurston, Wahkiakum	PO Box 47775 Olympia, WA 98504	360-407-6300
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Acronyms and Abbreviations

ALT or alternative	Cleanup action alternative
BPJ	Best professional judgment
CAP	Cleanup action plan
DCA	Disproportionate cost analysis. The DCA is Step 4 of a PMEP evaluation, which is summarized in Chapter 2. Instructions for conducting a DCA under each PMEP method are included in Sections 4.4 and 5.4.
Ecology	Washington State Department of Ecology
FS	Feasibility study
MTCA	Model Toxics Control Act, Chapter 70A.305 RCW
MTCA rule	Model Toxics Control Act Cleanup Regulations, Chapter 173-340 WAC
PMEP	Permanent to the maximum extent practicable
PMEP evaluation	MTCA rule evaluation to determine whether a cleanup action is permanent to the maximum extent practicable. The PMEP evaluation is specified in WAC 173-340-360(5) and summarized in Chapter 2.
PMEP methods	Methods for conducting a PMEP evaluation, including narrative and semi-quantitative. The methods are summarized in Chapter 3. Instructions for using each method are included in Chapters 4 and 5.
RCW	Revised Code of Washington
SMS rule	Sediment Management Standards, Chapter 173-204 WAC
WAC	Washington Administrative Code

Chapter 1: Introduction

1.1 Purpose

The Model Toxics Control Act (MTCA) requires Ecology to "give preference to permanent solutions to the maximum extent practicable" (RCW 70A.305.030(1)(b)). Reflecting this statutory mandate, the MTCA rule requires cleanup actions to "use permanent solutions to the maximum extent practicable" (WAC 173-340-360(3)(a)(x)). The MTCA rule also specifies procedures (steps) for how to evaluate cleanup action alternatives in a feasibility study (FS) to determine which alternative meets this requirement (WAC 173-340-360(5)).

This document provides Ecology staff and other persons cleaning up contaminated sites guidance on how to conduct such evaluations and make such determinations. To facilitate semi-quantitative evaluations, Ecology has also developed a companion Disproportionate Cost Analysis (DCA) Tool in Microsoft Excel, which is available separately on Ecology's website.[2] This guidance document describes and provides instructions on how to use the DCA Tool.

Throughout this document, the evaluation is referred to as the permanent to the maximum extent practicable (PMEP) evaluation. Step 4 of the PMEP evaluation is referred to as the DCA.

1.2 Applicability of PMEP evaluation

The MTCA rule requires a PMEP evaluation to select a cleanup action unless the cleanup action selected is either a permanent cleanup action or a model remedy (WAC 173-340-360(5)(b)).

The applicability of the PMEP evaluation does not depend on which administrative option in WAC 173-340-510 is used to conduct the cleanup action (independent, Ecology-supervised, or Ecology-conducted) or the media contaminated. For sediment contamination, the Sediment Management Standards (SMS) rule requires compliance with the PMEP requirement in the MTCA rule, except that a different hierarchy is used to guide the evaluation of the long-term effectiveness of cleanup action components (WAC 173-204-570(4)).

1.2.1 Permanent cleanup action

A PMEP evaluation is not required as part of a FS to select a "permanent cleanup action" (WAC 173-340-360(5)(b)). The MTCA rule defines such an action as one "in which cleanup standards … can be met without further action being required at the site being cleaned up or any other site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances" (WAC 173-340-200).

[2] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools

1.2.2 Model remedy

Ecology may establish a model remedy to streamline and accelerate the selection of a cleanup action for routine types of cleanup projects at sites with common features and lower risk to human health and the environment (WAC 173-340-390). Ecology has already established model remedies for several types of sites, which are available on our website.[3]

A feasibility study, including a PMEP evaluation, is not required to select a model remedy as the cleanup action or as a component of the cleanup action for a site. However, a FS, including a PMEP evaluation, is still required to select any remaining cleanup action components for the site (WAC 173-340-351(2)(a)(ii) and 173-340-360(5)(b)).

To qualify for this exemption or partial exemption, sufficient information must be collected and included in the remedial investigation report to demonstrate the site meets the conditions established by Ecology for using the model remedy (WAC 173-340-351(2)(a)(ii) and 173-340-390(4)(a)).

1.3 Feasibility study steps conducted before PMEP evaluation

The PMEP evaluation should be conducted at the end of the FS, only after screening out any alternative that:

- Based on a preliminary analysis in Step 3 of the FS, is either not technically possible or clearly impracticable (costs are clearly disproportionate to benefits).
- Based on a detailed analysis in Step 4 of the FS, either does not meet all other cleanup action requirements in WAC 173-340-360 or does not conform, as appropriate, with the cleanup action expectations in WAC 173-340-370.

When conducting these steps, the evaluator should use best professional judgment (BPJ) and document their evaluation and reasoning in the applicable report (FS report, cleanup action plan (CAP), or independent remedial action report).

The preceding steps of the FS, and their relevance to the subsequent PMEP evaluation, are summarized below.

1.3.1 Step 1 – Identify cleanup goals

Identify the goals for the cleanup action, in addition to compliance with the requirements in WAC 173-340-360. Include any planned future uses of the site and any habitat restoration or

[3] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/MTCA-model-remedies

resource recovery goals for the site (WAC 173-340-351(6)(a)). These goals could affect the requirements for the cleanup action and the alternatives that are developed and then evaluated.

1.3.2 Step 2 – Identify alternatives

Identify cleanup action alternatives for evaluation in the FS. The alternatives must achieve the goals identified in Step 1 of the study and comply with the requirements in WAC 173-340-360 (WAC 173-340-351(6)(b)). The range of alternatives considered could significantly influence the outcome of the PMEP evaluation.

Reasonable number and type of alternatives

Include a reasonable number and type of alternatives considering:

- The characteristics and complexity of the site, including current site conditions and physical constraints.
- The threats posed by the site to human health and the environment, including likely vulnerable populations and overburdened communities.

See WAC 173-340-351(6)(b)(i) and (5)(a).

At least one permanent alternative

Include at least one permanent alternative (WAC 173-340-351(6)(b)(ii)). In a PMEP evaluation, a permanent alternative is used as the initial baseline for conducting the iterative DCA unless all such alternatives are eliminated from further evaluation in Step 3 or 4 of the FS.

Points of compliance

For each environmental medium, include at least one alternative with a standard point of compliance (WAC 173-340-351(6)(b)(iii)). By definition, a permanent alternative includes a standard of compliance for all environmental media. However, if all permanent alternatives are screened out in Step 3 of the FS as either technically impossible or clearly impracticable, consider non-permanent alternatives with a standard point of compliance for one or more environmental media.

As appropriate, include alternatives with a conditional point of compliance for one or more environmental media (WAC 173-340-351(6)(b)(iv)).

Combinations of components

As appropriate, include alternatives relying on a combination of cleanup action components for an environmental medium (such as treatment of some soil contamination and containment of the remainder). The alternatives must specify remediation levels for each component (WAC 173-340-351(6)(b)(v)).

1.3.3 Step 3 – Screen alternatives and components

Based on a preliminary analysis, eliminate from further evaluation the following cleanup action alternatives or components identified in Step 2 of the FS:

- Alternatives or components that are not technically possible at the site.
- Alternatives that clearly do not meet the requirements for a cleanup action in WAC 173-340-360, including alternatives for which costs are clearly disproportionate to benefits under WAC 173-340-360(5) without performing a detailed PMEP evaluation.

Alternatives screened out in Step 3 should not be included in Step 4 of the FS, including in a detailed PMEP evaluation (WAC 173-340-351(6)(c)).

If all permanent alternatives are screened out, identify the most permanent alternative that is technically possible and not clearly impracticable for detailed evaluation in Step 4 of the FS. This may be an alternative other than the ones initially identified in Step 2 of the FS.

1.3.4 Step 4 – Evaluate remaining alternatives against other requirements

Conduct a detailed evaluation of the cleanup action alternatives remaining after Step 3 of the FS as follows:

- First, before conducting a detailed PMEP evaluation, determine whether each remaining alternative meets all other requirements in WAC 173-360-360 (other than the PMEP requirement) and conforms, as appropriate, to the expectations in WAC 173-340-370. Screen out any alternative that does not.
- Second, conduct a detailed PMEP evaluation of only the remaining alternatives, which were not screened out in Step 3 or the first part of Step 4 of the FS.

If necessary, conduct additional remedial investigations under WAC 173-340-350 to complete the detailed evaluations, including any investigations needed to complete a terrestrial ecological evaluation (WAC 173-340-351(6)(d)).

1.4 Supplemental feasibility study evaluations

For Ecology-conducted and Ecology-supervised remedial actions, Ecology may conduct additional FS evaluations of cleanup action alternatives, including PMEP evaluations, after issuing a FS report. This guidance also applies to those supplemental evaluations. Any such supplemental evaluations must either be reported in a revised FS report or in the CAP (WAC 173-340-351(6) and 173-340-380(5)).

Chapter 2:
Overview of PMEP Evaluation

The MTCA rule requires cleanup actions to "use permanent solutions to the maximum extent practicable" (WAC 173-340-360(3)(a)(x)). The MTCA rule also specifies procedures (steps) for how to evaluate cleanup action alternatives in a FS to determine which alternative meets this requirement (WAC 173-340-360(5)). The PMEP evaluation involves the following four steps, which are illustrated in Figure 2-1:

- **Step 1** – Determine the costs (construction and post-construction) and the following benefits of each cleanup action alternative using the factors specified in the rule:

    - Protectiveness.
    - Permanence.
    - Effectiveness over long term.
    - Management of implementation risks.
    - Technical and administrative implementability.

    The benefit criteria may be weighted, but any unequal weights need to be justified. See Section 4.1.4 and 5.1.4. of the document. For Ecology-conducted or supervised remedial actions, consider public concerns and tribal rights and interests when estimating or weighting the benefits.

    For guidance on how to evaluate the costs and benefits of an alternative, see Chapters 7 and 8 of this document.

- **Step 2** – Rank and list the cleanup action alternatives in order of decreasing permanence based on the evaluation of permanence in Step 1.

- **Step 3** – Identify the initial baseline alternative for use in the DCA in Step 4 based on the ranked list of alternatives identified in Step 2.

- **Step 4** – Conduct a DCA of the ranked list of cleanup action alternatives identified in Step 2 to determine which alternative is PMEP.

    - Starting with the initial baseline alternative identified in Step 3, compare the relative costs and benefits of successively less permanent pairs of cleanup action alternatives in the order listed in Step 2.

    - In each pairwise comparison, determine whether the more permanent (baseline) alternative is practicable compared to the next most permanent alternative in the ranked list (whether its incremental costs are not disproportionate to its incremental benefits). Use BPJ to consider uncertainty in cost and benefit estimates. Sensitivity analysis may be used to support BPJ. See Chapter 9 of this document for guidance.

- As appropriate, after each pairwise comparison, determine whether there is another more permanent alternative that may be practicable.
- Continue the successive pairwise comparisons until either:
  - The first comparison where the more permanent (baseline) alternative is determined to be practicable compared to the next most permanent alternative. In that case, the baseline alternative is PMEP, and all less permanent alternatives in the ranked list are eliminated from further evaluation; or
  - No alternatives remain in the ranked list for comparison. In that case, the last alternative, which is also the least permanent among all alternatives in the list, is PMEP. Other more permanent alternatives should be considered during the DCA before making this determination.

Chapter 3 of this document describes two methods for conducting a PMEP evaluation (narrative and semi-quantitative) and provides guidance on how to determine which method is best for your evaluation. For instructions on how to implement each step of the PMEP evaluation using the narrative and semi-quantitative PMEP methods, see Chapters 4 and 5 of this document. Chapter 6 of this document describes the DCA Tool for the semi-quantitative PMEP method.

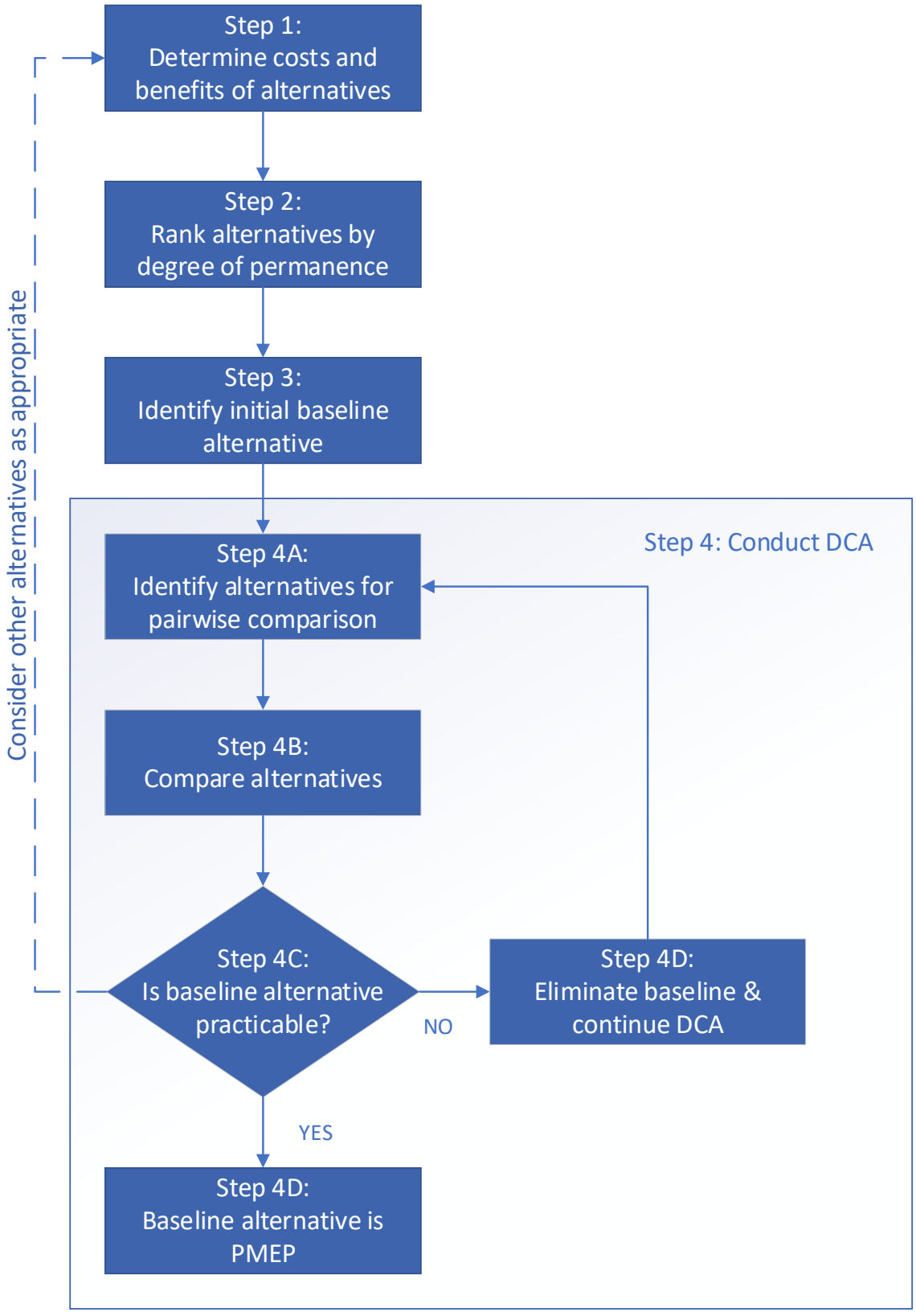

Figure 2-1: PMEP flow chart

Chapter 3:
Selection of PMEP Method

The PMEP evaluation involves comparisons of quantitative costs and five qualitative benefits. The need to combine and compare quantitative and qualitative values raises the following questions that need to be answered to conduct a PMEP evaluation:

- How do I evaluate and compare the benefits of one alternative with those of another?
- For each alternative, should I combine the evaluations of the five benefits into a single indicator of total benefit?
- How do I compare the costs and benefits of one alternative with those of another?

The narrative and semi-quantitative PMEP methods described in this chapter provide different approaches to answering these questions.

This chapter provides an overview of these two PMEP methods and guidance on how to determine which method is best for your site-specific PMEP evaluation. For instructions on how to conduct a PMEP evaluation using each of the methods, see Chapters 4 and 5 of this document.

3.1 Narrative PMEP method

The narrative PMEP method compares cleanup action alternatives based on their quantitative costs (ratio-type variable) and qualitative benefit rankings (ordinal-type variable).[4]

3.1.1 Assessment of benefits

Under the narrative method, the evaluator ranks the five benefits of an alternative relative to another alternative (such as, Alternative B is more protective than Alternative A). However, the evaluator cannot combine the five benefit rankings into a single overall benefit ranking for an alternative.

3.1.2 Assessment of costs

Under both narrative and semi-quantitative method, assessment of costs is quantitative. The evaluator calculates the incremental cost (change in total cost or proportional difference) of the baseline (more permanent) alternative over the next most permanent alternative.

[4] For a description of the types of quantitative and qualitative variables and their use in the PMEP evaluation, see Attachment A.

3.1.3 Comparison of alternatives

Under the narrative method, the comparison of alternatives is qualitative. The evaluator compares the more permanent baseline alternative with next most permanent alternative using documented logic and BPJ to determine whether the incremental cost of the more permanent baseline alternative is disproportionate to its incremental degree of benefits based on the differences in the five benefit rankings. The use of BPJ needs to be documented in writing in the applicable report (FS report, CAP, or independent remedial action report).

3.1.4 When to use

While both PMEP methods can be used at any site, deciding which PMEP method is best to use depends on the number, complexity, and the variety or variability of the benefits considered in the PMEP evaluation. The narrative PMEP method, which relies only on qualitative comparisons of alternatives, is best suited for simpler PMEP evaluations with all or most of the following characteristics:

- The site is simple. For example, the site impacts only one or two environmental media, such as soil or groundwater.
- The alternatives are simple. For example, the alternatives contain only one or two cleanup action components.
- The alternatives are easy to compare. For example:
    - The alternatives do not significantly differ in the degree of permanence.[5]
    - The alternatives significantly differ for only one or two benefit criteria so that it is easier to distinguish the total benefit of one alternative over another.

3.2 Semi-quantitative PMEP method

The semi-quantitative PMEP method compares cleanup action alternatives based on their quantitative costs (ratio-type variable) and qualitative benefit scores (interval-type variable).

3.2.1 Assessment of benefits

Under the semi-quantitative PMEP method, the evaluator quantifies their qualitative comparison of the alternatives using numerical scores for each of the five benefit criteria. As a default, the five benefit criteria are assigned equal weights; however, the evaluator can assign different

[5] If there is little or no difference in permanence among all the alternatives, the PMEP evaluation reduces logically to a simple comparison of alternatives based on their cost-effectiveness (i.e., total cost per total degree of benefit). For such evaluations (but also depending on the number and complexity of the alternatives), a narrative analysis may be sufficient.

weights on a site-specific basis with a documented rationale. The evaluator adds the weighted scores to create a single combined benefit score for each alternative.

3.2.2 Assessment of costs

Under both narrative and semi-quantitative method, assessment of costs is quantitative. The evaluator calculates the incremental cost (proportional difference) of the baseline (more permanent) alternative over the next most permanent alternative.

3.2.3 Comparison of alternatives

Under the semi-quantitative PMEP method, the evaluator compares the incremental cost and incremental combined benefit score of the baseline (more permanent) alternative over the next most permanent alternative to determine whether the baseline alternative's incremental cost is disproportionate to the incremental combined benefit score or not. The incremental costs and incremental combined benefit scores of the two alternatives are calculated as percentages or proportional differences to make the comparison unitless. This guidance uses cost-effectiveness ratios ($ cost in millions divided by combined benefit score) for comparison of alternatives. As demonstrated in Attachment A, comparing the cost-effectiveness of two alternatives is mathematically equivalent to comparing proportional differences in costs and benefits.

3.2.4 When to use

While both PMEP methods can be used at any site, deciding which PMEP method is best to use depends on the number, complexity, and the variety or variability of the benefits considered in the PMEP evaluation. The semi-quantitative method, which relies on a quantitative comparison of alternatives, is best suited for more complex PMEP evaluations with one or more of the following characteristics:

- The site is complex. For example, the site impacts multiple environmental media, including both upland and sediment.
- The alternatives are complex. For example, the alternatives contain more than two cleanup action components.
- The alternatives are difficult to compare. For example:
    - The alternatives have significant differences in the degree of permanence.[6]

[6] To compare alternatives with significant differences in the degree of permanence, the MTCA rule requires iterative, pairwise comparisons in order of decreasing permanence. This process may be more difficult to conduct and explain without using quantified benefit scores.

- The alternatives have significant differences for several benefit criteria[7], such that it is difficult to distinguish the total benefit of one alternative over another.

[7] To compare alternatives with significant differences for several benefit criteria, it is practically necessary to award relative benefit scores for each criterion, and then sum those scores to identify a total benefit score for each alternative.

Chapter 4:
Instructions for Narrative PMEP Method

This chapter provides detailed step-by-step instructions on how to implement the PMEP evaluation using the narrative PMEP method. Figure 2-1 in Chapter 2 of this document provides a flow chart of these steps. The method compares cleanup action alternatives based on their quantitative costs (ratio-type variable) and qualitative benefit rankings (ordinal-type variable). For guidance on which method to use for your PMEP evaluation, see Chapter 3 of this document.

4.1 Step 1 – Determine the costs and benefits of each alternative

In Step 1 of the PMEP evaluation, the evaluator needs to determine the benefits and costs of each cleanup action alternative using the criteria specified in WAC 173-340-360(5)(d). See WAC 173-340-360(5)(c)(i). To determine the costs and benefits of each alternative, do the following:

4.1.1 Step 1A – Document alternative

Document each alternative in sufficient detail to identify its components. Summarize the significant technical differences between the alternatives, including sources of uncertainty for subsequent benefits and cost estimates.

4.1.2 Step 1B – Evaluate costs

Estimate the total cost of each alternative, including both construction costs and the present value of post-construction costs. For each alternative, consider the uncertainty of the cost estimate using BPJ. For guidance on how to evaluate costs, see Chapter 7 of this document.

4.1.3 Step 1C – Evaluate benefits

For each of the five benefit criteria, qualitatively assess and rank the alternatives from high to low based on the degree to which the alternative provides that benefit. Use BPJ. For guidance on how to evaluate each of the five benefit criteria, see Chapter 8 of this document.

4.1.4 Step 1D – Weight benefit criteria

On a site-specific basis decide how to weight (favor or disfavor) the five benefit criteria.

- The default is that each criteria has equal weight. No justification is needed to assign equal weights.

- Document the site-specific basis for any uneven weightings and describe the effect on the PMEP evaluation. For example, you may favor protectiveness over long-term effectiveness because the site has an ongoing existing risk that needs to be reduced as soon as possible. Use BPJ and document your rationale in the applicable report (FS report, CAP, or independent remedial action report).

- For Ecology-conducted or supervised cleanups, consider public concerns (including those of any likely vulnerable population or overburdened community) and tribal rights and interests when assigning weights.

4.2 Step 2 – Rank alternatives by degree of permanence

In Step 2 of the PMEP evaluation, the evaluator needs to order cleanup action alternatives by degree of permanence from highest to lowest based on the permanence rankings assigned in Step 1C (WAC 173-340-360(5)(c)(ii)) and the following considerations.

4.2.1 Only one permanent alternative

By definition, a permanent alternative has the highest degree of permanence. If there is only one permanent alternative, rank that alternative as number one (1) in the ranked list of alternatives.

4.2.2 More than one permanent alternative

If there is more than one permanent alternative in the list of alternatives, do the following:

- Compare qualitatively the relative costs and degrees of benefits of the permanent alternatives based on the rankings and weightings assigned in Step 1. Use BPJ. Note that the ordinal rankings of the five benefit criteria cannot meaningfully be consolidated as an overall benefit ranking.

- Based on the qualitative comparison and BPJ, determine which permanent alternative is the most cost-effective (the one with the lowest cost per degree of benefit).

- Keep the most cost-effective permanent alternative in the list and rank it as number one (1) in the ranked list of alternatives.

- Eliminate from further PMEP evaluation the less cost-effective permanent alternatives.

4.2.3 No permanent alternative

If there are no permanent alternatives in the list, rank the most permanent alternative as number one (1) in the ranked list of alternatives.

For an explanation of why permanent alternatives might be screened out during a FS before conducting a PMEP evaluation, see Section 1.3 of this document.

4.2.4 Non-permanent alternatives with same permanence rank

If two or more non-permanent alternatives are assigned the same permanence rank, do the following:

- Compare qualitatively using BPJ the relative costs and degrees of benefits of those alternatives based on the rankings and weightings assigned in Step 1. Note that the ordinal rankings of the five benefit criteria cannot meaningfully be consolidated as an overall benefit ranking.

- Based on the qualitative comparison and BPJ, determine which of those alternatives is the most cost-effective (the one with the lowest cost per degree of benefit).[8]

- Keep the most cost-effective of those alternatives in the ranked list. Eliminate from further PMEP evaluation the less cost-effective of those alternatives.

4.3 Step 3 – Identify initial baseline alternative for DCA

In Step 3 of the PMEP evaluation, the evaluator needs to identify the initial baseline cleanup action alternative for use in the iterative DCA required in Step 4 (WAC 173-340-360(5)(c)(iii)). To do this, find the alternative that is ranked number one for permanence in the ranked list of cleanup action alternatives identified in Step 2. Use that alternative as the initial baseline alternative for the next step.

4.4 Step 4 – Conduct DCA of ranked list of alternatives

In Step 4 of the PMEP evaluation, the evaluator needs to conduct a DCA of the ranked list of cleanup action alternatives identified in Step 2 to determine which alternative uses permanent solutions to the maximum extent practicable (WAC 173-340-360(5)(c)(iv)).

The DCA involves an iterative, pairwise comparison of the relative costs and benefits of successively less permanent alternatives in the ranked list. To conduct a DCA using the narrative PMEP method, do the following.

4.4.1 Step 4A – Identify alternatives for pairwise comparison

[8] If the comparison of alternatives is difficult using the narrative PMEP method, consider switching to the semi-quantitative PMEP method.

Identify the baseline alternative and the next most permanent alternative for pairwise comparison.

Baseline alternative

Identify the baseline alternative as follows:

- In the **first iteration** of the DCA, use the alternative identified in Step 3 as the baseline.
- In any **subsequent iteration** of the DCA, as needed, use the alternative specified in Step 4D of the previous iteration.

Next most permanent alternative

Identify the next most permanent alternative from the ranked list of alternatives identified in Step 2.

4.4.2 Step 4B – Compare the two alternatives

Compare the baseline alternative with **only** the next most permanent alternative identified in Step 4A. For ease of reference, this alternative is referred to as ALT X below. **Do not** compare the baseline alternative with any other alternatives. To compare the two alternatives, do the following:

- Calculate the change in total cost from ALT X to the baseline alternative. The incremental cost can also be expressed as the proportional difference in cost from ALT X to the baseline alternative.
- Qualitatively assess the difference in the benefit rankings from ALT X to the baseline alternative. Note that the ordinal rankings of the five benefit criteria cannot meaningfully be consolidated as an overall benefit ranking. Use BPJ and describe your assessment.
- Qualitatively compare the change in total cost with the individual differences in the benefit rankings. Use BPJ and describe your assessment.

4.4.3 Step 4C – Determine whether baseline alternative is practicable

The baseline alternative is practicable if its incremental costs are not disproportionate to its incremental degree of benefits, compared to the next most permanent alternative (ALT X).[9]

Make determination after considering uncertainty

[9] A more qualitative way of considering disproportionality is to ask the question: "Is the increased cost of the more permanent (baseline) alternative justified by the greater benefits (such as protectiveness or long-term effectiveness) provided by that alternative?"

Based on the qualitative comparison of the baseline alternative and ALT X in Step 4B, determine whether the baseline alternative's incremental costs are disproportionate to its incremental degree of benefits. Due to uncertainties in the cost and benefit inputs identified in Step 1, BPJ is usually needed to make this determination. See Sections 9.1 and 9.2 of this document. Describe the logical basis for the determination in the applicable report (FS report, CAP, or independent remedial action report). Note that Ecology may use BPJ to make the final determination. See Section 9.4 of this document.

As appropriate, identify other alternatives based on determination

Based on the determination, identify as appropriate whether the following types of alternatives may exist:

- For only the first iteration of the DCA, if the baseline is practicable compared to ALT X but not a permanent solution, determine whether there is another alternative that is more permanent than the baseline that may be practicable compared to the baseline. If any such alternative is identified, go back to Step 1 instead of proceeding to Step 4D.

- For all iterations of the DCA, if the baseline is not practicable compared to ALT X, determine whether there is another alternative that is less permanent than the baseline, but more permanent than ALT X, that may be practicable compared to ALT X. If any such alternative is identified, go back to Step 1 instead of proceeding to Step 4D.

Other alternatives could include ones with a different combinations of existing cleanup action components (such as more or less disposal versus containment) or with different components (technologies). Ecology may use BPJ to identify other alternatives and then require or conduct further DCA to evaluate those alternatives. See Section 9.4 of this document.

4.4.4 Step 4D – Identify next steps

Based on whether the baseline alternative is practicable (as determined in Step 4C), do the following[10]:

If baseline alternative is practicable

If the baseline alternative is practicable compared to ALT X (i.e., incremental costs are not disproportionate to incremental degree of benefits), the baseline alternative is PMEP. Eliminate any remaining alternatives on the ranked list from further analysis. The DCA and PMEP evaluation are complete. See WAC 173-340-360(5)(c)(iv)(B)(I).

[10] The MTCA rule includes three decision criteria for determining what to do next based on the results of each pairwise comparison in the DCA. See WAC 173-340-360(5)(c)(iv)(B). The second criterion applies when there are equal benefits. Ecology has decided not to enforce that criterion because it either duplicates or conflicts with the other two criteria. For additional information, see Attachment A.4 of this document.

If baseline alternative is not practicable

If the baseline alternative is not practicable compared to ALT X (i.e., incremental costs are disproportionate to incremental degree of benefits), eliminate the baseline alternative from further analysis. Depending on whether ALT X is the last alternative on the ranked list, do one of the following:

- If ALT X is not the last alternative on the ranked list, return to Step 4A for another iteration of the DCA. Use ALT X as the new baseline alternative for the next iteration.
- If ALT X is the last alternative on the ranked list, ALT X is PMEP. The DCA and PMEP evaluation are complete.

See WAC 173-340-360(5)(c)(iv)(B)(III).

4.5 Hypothetical example of narrative PMEP evaluation including DCA

This section provides a hypothetical example of a narrative PMEP evaluation described in Sections 4.1 to 4.4 of this document. The example includes multiple iterations of a DCA.

4.5.1 Step 1 – Determine the costs and benefits of each alternative

The FS includes three cleanup action alternatives that meet all other cleanup action requirements: Alternatives A, B, and C.

Step 1A – Document alternatives

The evaluator would describe each of the alternatives. For this example, assume Alternative C is permanent, and Alternatives A and B are not permanent.

Step 1B – Evaluate costs

The evaluator would estimate the total cost of each alternative. The estimate is a ratio-type variable. Assume the cost estimates are as specified in Table 4-1.

Step 1C – Evaluate benefits

For each of the five benefit criteria, the evaluator would use BPJ to qualitatively assess and rank the alternatives from 1 (best) to 3 (worst) based on the degree to which the alternative provides that benefit. The rank is an ordinal-type variable. Assume the ranks are as specified in Table 4-1.

Step 1D – Weight benefit criteria

The evaluator would decide how to weight (favor or disfavor) the five benefit criteria. For this example, assume the weights are equal. As such, no justification for the weighting is necessary.

Table 4-1: Narrative method example – description of alternatives and summary of cost estimates and benefit rankings

DCA Criteria	Alternative A	Alternative B	Alternative C
Alternative Name	Site specific	Site specific	Site specific
Narrative Description	Site specific	Site specific	Site specific
Costs	Total cost in million dollars		
Total cost	$2.0 million	$1.5 million	$4.0 million
Benefits	Relative rank of 3 alternatives from 1 (best) to 3 (worst)		
Protectiveness	2	3	1
Permanence	2	3	1
Long-term effectiveness	2	3	1
Management of implementation risks	1	2	3
Implementability	2	1	3

4.5.2 Step 2 – Rank alternatives by degree of permanence

Based on the permanence ranks, Alternative C (permanent alternative) has the highest degree of permanence followed by Alternative A, and then Alternative B.

4.5.3 Step 3 – Identify initial baseline alternative for DCA

Alternative C is the initial baseline alternative because it has the highest degree of permanence.

4.5.4 Step 4 – Conduct DCA of ranked list of alternatives

First iteration

Step 4A – Identify alternatives for pairwise comparison

For the first iteration, the baseline is Alternative C, the alternative identified in Step 3. The baseline will be compared with Alternative A, the next most permanent alternative in the ranked list identified in Step 2.

Step 4B – Compare the two alternatives

Compare the baseline alternative, Alternative C, with the next most permanent alternative, Alternative A. Table 4-2 (below) summarizes the cost and benefit information for this analysis. The total cost of Alternative C is $2.0 million more than Alternative A (100 percent higher than Alternative A). For the benefits comparison, the protectiveness, permanence, and long-term effectiveness of Alternative C is better than Alternative A. On the other hand, management of implementation risks and implementability of Alternative C is worse than Alternative A.

Table 4-2: Narrative method example – first iteration of DCA

DCA Criteria	**Baseline alternative** (Alternative C)	**Next most permanent alternative** (Alternative A)	**Comparison**
Costs	$ in millions		
Total cost	$4.0 million	$2.0 million	100% increase
Benefits	Relative rank of the alternatives from Table 4-1		
Protectiveness	1	2	better
Permanence	1	2	better
Long-term effectiveness	1	2	better
Management of implementation risks	3	1	worse
Implementability	3	2	worse

Step 4C – Determine whether baseline alternative is practicable

The baseline alternative (Alternative C) is practicable if its incremental costs are not disproportionate to its incremental degree of benefits, compared to the next most permanent alternative (Alternative A).

For this method, the evaluator relies on a narrative account of the rankings and cost estimates shown in Table 4-2 above. The evaluator uses BPJ to assess whether Alternative C's 100 percent cost increase is proportionate to (justified by) its relative advantages (protectiveness, permanence, and long-term effectiveness), while considering its relative disadvantages (management of implementation risks and implementability). The evaluator should consider the rank order position of each benefit criterion in the analysis. For example, for management of implementation risks, Alternative C is the worst (rank 3) and Alternative A is the best (rank 1). Whereas, for protectiveness, Alternative C is the best (rank 1) and alternative A is worse (rank 2) but not the worst, which would be rank 3. The evaluator should also consider uncertainty in cost estimates and benefits rankings. In this hypothetical example, based on BPJ, the evaluator determines the baseline alternative (Alternative C) is not practicable because its incremental costs are disproportionate to its incremental degree of benefits.

Step 4D – Identify next steps

Since the baseline alternative (Alternative C) is not practicable compared to the next most permanent alternative (Alternative A), and Alternative A is not the last alternative on the ranked list, do the following:

- Eliminate the baseline alternative (Alternative C) from further analysis.
- Return to Step 4A for another iteration of the DCA. Use Alternative A as the baseline alternative for the next iteration.

Note that if the evaluator had instead determined that the baseline alternative was practicable, then it would be PMEP and the DCA would be complete.

Second iteration

Step 4A – Identify alternatives for pairwise comparison

For the second iteration of the DCA, the baseline is Alternative A, the alternative identified in Step 4D of the first iteration. The baseline will be compared with Alternative B, the next most permanent alternative in the ranked list identified in Step 2.

Step 4B – Compare the two alternatives

Compare the baseline alternative, Alternative A, with the next most permanent alternative, Alternative B. Table 4-3 (below) summarizes the cost and benefit information for this analysis. The total cost of Alternative A is $0.5 million more than Alternative B (i.e., 33 percent higher than Alternative B). For the benefits comparison, the protectiveness, permanence, long-term effectiveness, and implementation risk management of Alternative A is better than Alternative B. On the other hand, the implementability of Alternative A is worse than Alternative B.

Table 4-3: Narrative method example – second iteration of DCA

DCA Criteria	**Baseline alternative** (Alternative A)	**Next most permanent alternative** (Alternative B)	**Comparison**
Costs	$ in millions		
Total cost	$2.0 million	$1.5 million	33% increase
Benefits	Relative rank of the alternatives from Table 4-1		
Protectiveness	2	3	better
Permanence	2	3	better
Long-term effectiveness	2	3	better
Management of implementation risks	1	2	better
Implementability	2	1	worse

Step 4C – Determine whether baseline alternative is practicable

The baseline alternative (Alternative A) is practicable if its incremental costs are not disproportionate to its incremental degree of benefits, compared to the next most permanent alternative (Alternative B).

Like the first iteration, the evaluator relies on a narrative account of the rankings and cost estimates shown in Table 4-3 above. The evaluator uses BPJ to assess whether the Alternative A's 33 percent cost increase is proportionate to (justified by) its relative advantages (protectiveness, permanence, long-term effectiveness, and management of implementation risks), while considering its relative disadvantages (implementability). Based on BPJ, the evaluator determines that Alternative A's 33% increase in cost is not disproportionate to its incremental degree of benefits (i.e., Alternative A is practicable).

Step 4D – Identify next steps

In this pairwise comparison, the baseline alternative (Alternative A) is practicable. Therefore, Alternative A is PMEP. Eliminate any remaining alternatives on the ranked list from further analysis. The DCA and the PMEP evaluation are complete.

Chapter 5:
Instructions for Semi-quantitative PMEP Method

This chapter provides detailed step-by-step instructions on how to implement the PMEP evaluation using the semi-quantitative PMEP method. Figure 2-1 in Chapter 2 of this document provides a flow chart of these steps. This method compares cleanup action alternatives based on their quantitative costs (ratio-type variable) and qualitative benefit scores (interval-type variable).[11] For guidance on which method to use for your PMEP evaluation, see Chapter 3 of this document.

To facilitate semi-quantitative PMEP evaluations, Ecology has developed a companion DCA Tool in Microsoft Excel, which is available separately on Ecology's website.[12] This guidance document describes and provides instructions on how to use the DCA Tool in Chapter 6 of this document.

5.1 Step 1 – Determine the costs and benefits of each alternative

In Step 1 of the PMEP evaluation, the evaluator needs to determine the benefits and costs of each cleanup action alternative using the criteria specified in WAC 173-340-360(5)(d). See WAC 173-340-360(5)(c)(i). To determine the costs and benefits of each alternative, do the following:

5.1.1 Step 1A – Document alternative

Document each alternative in sufficient detail to identify its components. Summarize the significant technical differences between the alternatives, including sources of uncertainty for subsequent benefits and cost estimates.

5.1.2 Step 1B – Evaluate costs

Estimate the total cost of each alternative, including both construction costs and the present value of post-construction costs. For each alternative, specify a confidence interval for the cost estimate using BPJ. For guidance on how to evaluate costs, see Chapter 7 of this document.

5.1.3 Step 1C – Evaluate benefits

[11] For a description of the types of quantitative and qualitative variables and their use in the PMEP evaluation, see Attachment A.
[12] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools

Determine the relative degree of benefit of each alternative by qualitatively assessing and scoring each of the five benefit criteria as follows:

- Establish a linear numerical scale (for example, 1-10 or 1-100) for scoring the relative benefits of the alternatives, on which:
    - A higher score indicates a higher degree of benefit (such as a higher degree of protectiveness).
    - An equal difference in scores represents a roughly equal difference in degree of benefit.
    - The number of intervals on the scale is sufficient to make a meaningful distinction between alternatives.
- Assign scores for each of the five benefit criteria, using BPJ and the full range of the scale.

For guidance on how to evaluate each of the five benefit criteria, see Chapter 8 of this document.

5.1.4 Step 1D – Weight benefit criteria

On a site-specific basis, decide how to weight (favor or disfavor) the five benefit criteria using BPJ.

- The default is that each criteria has equal weight (0.2 or 20%). No justification is needed to assign equal weights.
- Document the site-specific basis for any uneven weightings and describe the effect on the PMEP evaluation. For example, protectiveness may be favored over long-term effectiveness because the site has an ongoing existing risk that needs to be reduced as soon as possible. Use BPJ and document your rationale in the applicable report (FS report, CAP, or independent remedial action report).
- For Ecology-conducted or supervised cleanups, consider public concerns (including those of any likely vulnerable population or overburdened community) and tribal rights and interests when assigning weights.

5.1.5 Step 1E – Calculate total (combined) benefit score

Calculate the total (combined) benefit score (weighted or unweighted) for each alternative by multiplying the score for each benefit criteria by its weight and then adding the weighted benefit scores.

5.2 Step 2 – Rank alternatives by degree of permanence

In Step 2 of the PMEP evaluation, the evaluator needs to order cleanup action alternatives by degree of permanence from highest to lowest based on the permanence scores assigned in Step 1C and the following considerations (WAC 173-340-360(5)(c)(ii) and (iii)).

5.2.1 Only one permanent alternative

By definition, a permanent alternative has the highest degree of permanence. If there is only one permanent alternative, rank that alternative as number one (1) in the ranked list of alternatives.

5.2.2 More than one permanent alternative

If there is more than one permanent alternative in the list of alternatives, do the following:

- Calculate the cost-effectiveness of each permanent alternative by dividing its total cost (Step 1B) by its total combined benefit score (Step 1E). As appropriate, conduct sensitivity analyses to consider uncertainties in cost estimates and benefit rankings (see Section 9.3 of this document).
- Based on the calculations and sensitivity analyses, determine which permanent alternative is the most cost-effective (the one with the lowest cost per degree of benefit).
- Keep the most cost-effective permanent alternative in the list and rank it as number one (1) in the ranked list of alternatives.
- Eliminate from further PMEP evaluation the less cost-effective permanent alternatives.

5.2.3 No permanent alternative

If there are no permanent alternatives in the list, rank the most permanent alternative (alternative with highest permanence score) as number one (1) in the ranked list of alternatives.

For an explanation of why permanent alternatives might be screened out during a FS before conducting a PMEP evaluation, see Section 1.3 of this document.

5.2.4 Non-permanent alternatives with same permanence score

If two or more non-permanent alternatives are assigned the same permanence score, do the following:

- Calculate the cost-effectiveness of each of those alternatives by dividing its total cost (Step 1B) by its total weighted benefit (Step 1E). As appropriate, conduct sensitivity analyses to consider uncertainties in cost estimates and benefit rankings (see Section 9.3 of this document).

- Based on the calculations and sensitivity analyses, determine which of those alternatives is the most cost-effective (the one with the lowest cost per degree of benefit).

- Keep the most cost-effective of those alternatives in the ranked list. Eliminate from further PMEP evaluation the less cost-effective of those alternatives.

5.3 Step 3 – Identify initial baseline alternative for DCA

In Step 3 of the PMEP evaluation, the evaluator needs to identify the initial baseline cleanup action alternative for use in the iterative DCA required in Step 4 (WAC 173-340-360(5)(c)(iii)). To do this, find the alternative that is ranked number one for permanence in the ranked list of cleanup action alternatives identified in Step 2. Use that alternative as the initial baseline alternative for the next step.

5.4 Step 4 – Conduct DCA of ranked list of alternatives

In Step 4 of the PMEP evaluation, the evaluator needs to conduct a DCA of the ranked list of cleanup action alternatives identified in Step 2 to determine which alternative uses permanent solutions to the maximum extent practicable (WAC 173-340-360(5)(c)(iv)).

The DCA involves an iterative, pairwise comparison of the relative costs and benefits of successively less permanent alternatives in the ranked list. To conduct a DCA using the semi-quantitative PMEP method, do the following.

5.4.1 Step 4A – Identify alternatives for pairwise comparison

Identify the baseline alternative and the next most permanent alternative for the pairwise comparison.

Baseline alternative

Identify the baseline alternative as follows:

- In the **first iteration** of the DCA, use the alternative identified in Step 3 as the baseline.

- In any **subsequent iteration** of the DCA, as needed, use the alternative specified in Step 4D of the previous iteration.

Next most permanent alternative

Identify the next most permanent alternative from the ranked list identified in Step 2.

5.4.2 Step 4B – Compare the two alternatives

Compare the baseline alternative with **only** the next most permanent alternative identified in Step 4A. For ease of reference, this alternative is referred to as ALT X below. **Do not** compare

the baseline alternative with any other alternatives. To compare the two alternatives, do the following:

- Calculate the cost-effectiveness of both alternatives (baseline and ALT X) by dividing its total cost (Step 1B) by its total (combined) benefit score (Step 1E).
- Compare the cost-effectiveness of the two alternatives (baseline and ALT X).

5.4.3 Step 4C – Determine whether baseline alternative is practicable

The baseline alternative is practicable if it is more cost-effective than the next most permanent alternative (ALT X). To determine whether the baseline is practicable, do the following:

Make determination after considering uncertainty

Based on the semi-quantitative comparison of the baseline alternative and ALT X in Step 4B, determine which alternative is more cost-effective. Due to uncertainties in the cost and benefit inputs identified in Step 1, BPJ is usually needed to determine which alternative in the pairwise comparison (the baseline or ALT X) is more cost-effective. To support the use of BPJ when considering these uncertainties, the evaluator may conduct sensitivity analyses to:

- Identify the most important and uncertain inputs (costs or benefit criteria) in the comparison.
- Test the effect of reasonable variations of such inputs on the outcome of the comparison.

The evaluator should briefly describe the results of any sensitivity analysis performed in the applicable report (FS report, CAP, independent remedial action report). See Sections 9.1 through 9.3 of this document for additional guidance on the use of BPJ and sensitivity analysis. Ecology may use BPJ to make the final determination. See Section 9.4 of this document.

As appropriate, identify other alternatives based on determination

Based on the determination, identify as appropriate whether the following types of alternatives may exist:

- For only the first iteration of the DCA, if the baseline is practicable compared to ALT X but not a permanent solution, determine whether there is another alternative that is more permanent than the baseline that may be practicable compared to the baseline. If any such alternative is identified, go back to Step 1 instead of proceeding to Step 4D.
- For all iterations of the DCA, if the baseline is not practicable compared to ALT X, determine whether there is another alternative that is less permanent than the baseline, but more permanent than ALT X, that may be practicable compared to ALT X. If any such alternative is identified, go back to Step 1 instead of proceeding to Step 4D.

Other alternatives could include ones with a different combinations of existing cleanup action components (such as more or less disposal versus containment) or with different components (technologies). The evaluator can use the results of any sensitivity analyses to help identify such alternatives. Ecology may use BPJ to identify other alternatives and then require or conduct further DCA to evaluate those alternatives. See Section 9.4 of this document.

Note regarding use of DCA Tool

Note that when using the DCA Tool to conduct the DCA, as discussed in Chapter 6, the evaluator can only consider uncertainties in cost and benefit estimates and other alternatives after the Tool completes all iterations of the DCA and identifies an apparent PMEP alternative. To do this uncertainty analysis, the evaluator needs to evaluate the outcome of each DCA iteration (pairwise comparison) one at a time, starting with the first iteration. Do not start with the last DCA iteration. See Sections 6.4 and 9.3 of this document.

5.4.4 Step 4D – Identify next steps

Based on whether the baseline alternative is practicable (as determined in Step 4C), do the following[13]:

If baseline alternative is practicable

If the baseline alternative is practicable compared to ALT X (i.e., more cost-effective than ALT X), the baseline alternative is PMEP. Eliminate any remaining alternatives on the ranked list from further analysis. The DCA and PMEP evaluation are complete. See WAC 173-340-360(5)(c)(iv)(B)(I).

If baseline alternative is not practicable

If the baseline alternative is not practicable compared to ALT X (i.e., less cost-effective than ALT X), eliminate the baseline alternative from further analysis. Depending on whether ALT X is the last alternative on the ranked list, do one of the following:

- If ALT X is not the last alternative on the ranked list, return to Step 4A for another iteration of the DCA. Use ALT X as the new baseline alternative for the next iteration.
- If ALT X is the last alternative on the ranked list, ALT X is PMEP. The DCA and PMEP evaluation are complete.

See WAC 173-340-360(5)(c)(iv)(B)(III).

[13] The MTCA rule includes three decision criteria for determining what to do next based on the results of each pairwise comparison in the DCA. See WAC 173-340-360(5)(c)(iv)(B). The second criterion applies when there are equal benefits. Ecology has decided not to enforce that criterion because it either duplicates or conflicts with the other two criteria. For additional information, see Attachment A.4 of this document.

5.5 Hypothetical example of a semi-quantitative PMEP evaluation including DCA

This section provides a hypothetical example of a semi-quantitative PMEP evaluation described in Sections 5.1 to 5.4 of this document. The example includes multiple iterations of a DCA.

5.5.1 Step 1 – Determine the costs and benefits of each alternative

The FS includes six cleanup action alternatives that meet all other cleanup action requirements: Alternatives A, B, C, D, E, and F.

Step 1A – Document alternatives

The evaluator would describe each of the alternatives. For this example, Assume Alternative F is the only permanent alternative, and the other five alternatives are not permanent alternatives.

Step 1B – Evaluate costs

The evaluator would estimate the total cost of each alternative . The estimate is a ratio-type variable. Assume the cost estimates are as specified in Table 5-1.

Step 1C – Evaluate benefits

For each of the five benefit criteria, the evaluator would use BPJ to qualitatively assess and score the alternatives from 1 (least) to 10 (most) based on the degree to which the alternative provides that benefit. The score is an interval-type variable. Assume the benefit scores are as specified in Table 5-1.

Step 1D – Weight benefit criteria

The evaluator would decide how to weight (favor or disfavor) the five benefit criteria. For this example, assume the weights are equal. As such, no justification for the weighting is necessary.

Table 5-1: Semi-quantitative example – description of alternatives and summary of cost estimates and benefit weights and scores

DCA Criteria		ALT. A	ALT. B	ALT. C	ALT. D	ALT. E	ALT. F
Alternative Name		Site specific	Site specific	Site specific	Site specific	Site specific	Site specific
Narrative Description		Site specific	Site specific	Site specific	Site specific	Site specific	Site specific
Costs		Total cost in million dollars					
Total cost		$10 M	$15 M	$25 M	$ 18 M	$28 M	$45 M

Benefits	Criteria weights	Relative benefit scores on a scale of 1 (least) to 10 (most)					
Protectiveness	0.20	1.0	5.0	6.0	4.0	10.0	8.0
Permanence	0.20	1.0	3.0	5.0	4.0	8.0	10.0
Long-term effectiveness	0.20	1.0	2.0	4.0	6.0	7.0	10.0
Management of implementation risks	0.20	10.0	8.0	6.0	9.0	5.0	1.0
Implementability	0.20	10.0	6.0	7.0	8.0	4.0	1.0

5.5.2 Step 2 – Rank alternatives by degree of permanence

Alternative F, being the only permanent solution, has the highest permanence score. Based on the permanence scores of the cleanup action alternatives, Alternative F has the highest degree of permanence followed by Alternative E, C, D, B, and A. The ranks are provided in Table 5-2.

Table 5-2: Semi-quantitative method example – ranking of alternatives by degree of permanence

Alternatives	**ALT. A**	**ALT. B**	**ALT. C**	**ALT. D**	**ALT. E**	**ALT. F**
Permanence Rank	6	5	3	4	2	1

5.5.3 Step 3 – Identify initial baseline alternative for DCA

Since Alternative F has the highest permanence rank (#1) in the list, Alternative F is the initial baseline alternative.

Note that if there were more than one permanent alternative, only the most cost-effective permanent alternative would be included in the ranked list and the less cost-effective permanent alternative would be eliminated from further PMEP evaluation (see Section 5.2.2 above for details).

5.5.4 Step 4 – Conduct DCA of ranked list of alternatives

First iteration

Step 4A – Identify alternatives for pairwise comparison

For first iteration, the baseline is Alternative F, the alternative identified in Step 3. The baseline will be compared with Alternative E, the next most permanent alternative in the ranked list identified in Step 2 (ranked #2 in Table 5-2 above).

Step 4B – Compare the two alternatives

Compare the baseline alternative, Alternative F, with the next most permanent alternative, Alternative E. For this method, the evaluator calculates the cost-effectiveness of each alternative, as the ratio of its total cost to its total weighted benefit. Note that, as shown in Attachment A.3.2, the cost-effectiveness of two alternatives is mathematically equivalent to comparing their proportional changes in incremental costs and benefits. Table 5-3 (below) summarizes the cost and benefit information and identifies the total weighted benefit and cost-effectiveness for both alternatives.

Table 5-3: Semi-quantitative method example – first iteration of DCA

DCA Criteria		**Baseline alternative** (Alternative F)	**Next most permanent alternative** (Alternative E)
Costs		$ in millions	
Total cost		$45 M	$28 M
Benefits	Criteria weights	Relative benefit scores on a scale of 1 (least) to 10 (most)	
Protectiveness	0.20	8.0	10.0
Permanence	0.20	10.0	8.0
Long-term effectiveness	0.20	10.0	7.0
Management of implementation risks	0.20	1.0	5.0
Implementability	0.20	1.0	4.0
Total weighted benefit score (B)		6.00	6.80
Cost effectiveness ($/B) - $ in millions		7.50	4.12

Step 4C – Determine whether baseline alternative is practicable

The baseline alternative (Alternative F) is practicable if it is more cost-effective than the next most permanent alternative (Alternative E). The cost-effectiveness ($/B) of Alternative F is 7.50, whereas the cost-effectiveness of Alternative E is 4.12. So, the baseline alternative (Alternative F) is not practicable because it is less cost-effective than the next most permanent alternative (Alternative E). In other words, the baseline alternative's incremental costs are disproportionate to its incremental degree of benefits.

Before making a determination, however, the evaluator needs to consider uncertainties in the cost and benefit inputs identified in Step 1. To support the use of BPJ when considering these uncertainties, the evaluator may conduct sensitivity analyses as specified in Section 9.3 of this document. In this hypothetical example, after considering uncertainties, assume the evaluator still determines the baseline alternative (Alternative F) is not practicable compared to Alternative E.

Step 4D – Identify next steps

Since the baseline alternative (Alternative F) is not practicable compared to the next most permanent alternative (Alternative E), and Alternative E is not the last alternative on the ranked list:

- Eliminate the baseline alternative (Alternative F) from further analysis.
- Return to Step 4A for another iteration of the DCA. Use Alternative E as the baseline alternative for the next iteration.

Note that if the evaluator had instead determined that the baseline alternative was practicable, then it would be PMEP and the DCA would be complete.

Second iteration

Step 4A – Identify alternatives for pairwise comparison

For the second iteration, the baseline is Alternative E, the alternative identified in Step 4D of the first iteration. The baseline will be compared with Alternative C, the next most permanent alternative in the ranked list identified in Step 2 (ranked #3 in Table 5-2 above).

Step 4B – Compare the two alternatives

Compare the baseline alternative (Alternative E) with the next most permanent alternative (Alternative C). Table 5-4 below summarizes the cost and benefit information and identifies the total weighted benefit and cost-effectiveness for both alternatives.

Table 5-4: Semi-quantitative method example – second iteration of DCA

DCA Criteria		**Baseline alternative** (Alternative E)	**Next most permanent alternative** (Alternative C)
Costs		$ in millions	
Total cost		$28 M	$25 M
Benefits	Criteria weights	Relative benefit scores on a scale of 1 (least) to 10 (most)	
Protectiveness	0.20	10.0	6.0
Permanence	0.20	8.0	5.0
Long-term effectiveness	0.20	7.0	4.0
Management of implementation risks	0.20	5.0	6.0
Implementability	0.20	4.0	7.0
Total weighted benefit score (B)		6.80	5.60

Cost effectiveness ($/B) ($ in millions)	4.12	4.46

Step 4C – Determine whether baseline alternative is practicable

The cost-effectiveness ($/B) of Alternative E is 4.12, whereas the cost-effectiveness of Alternative C is 4.46. So, the baseline alternative (Alternative E) is more cost-effective than the next most permanent alternative (Alternative C). In other words, the baseline alternative's incremental costs are not disproportionate to its incremental degree of benefits.

Before making a determination, however, the evaluator needs to consider uncertainties in the cost and benefit inputs identified in Step 1. To support the use of BPJ when considering these uncertainties, the evaluator may conduct sensitivity analyses as specified in Section 9.3 of this document. In this hypothetical example, after considering uncertainties, assume the evaluator still determines the baseline alternative (Alternative E) is practicable compared to Alternative C.

Step 4D – Identify next steps

Since the baseline alternative (Alternative E) is practicable compared to Alternative C, it is the PMEP alternative. Eliminate any remaining alternatives on the ranked list from further analysis. The DCA and PMEP evaluation are complete.

Note that if Alternative E were not practicable, the DCA would continue through at least another iteration.

5.6 Graphical analysis

When using the semi-quantitative method, the evaluator can also identify the apparent PMEP alternative by conducting a graphical analysis instead of performing an iterative DCA in Step 4 of the PMEP evaluation. The apparent PMEP alternative can be identified graphically by using a scatterplot of the cost-effectiveness ratio versus the permanence score of each alternative. The DCA Tool (discussed in Chapter 6) generates the necessary chart to identify the apparent PMEP alternative.

5.6.1 Instructions

This section provides detailed step-by-step instructions on how to implement the semi-quantitative PMEP method using graphical analysis.

Before conducting a graphical analysis, complete Steps 1 through 3 as specified in Sections 5.1 to 5.3 above. Instead of conducting an iterative DCA as specified in Step 4 in Section 5.4 above, do the following:

1. Calculate the cost-effectiveness ratio of each alternative in the ranked list identified in Step 2.

2. Graph (x, y) values for each alternative using a Cartesian coordinate system in which the x-axis represents the alternative's permanence score, and the y-axis represents the alternative's estimated cost per total degrees of benefit ($/B). Connect these points with straight line segments. See Figure 5-2 below for hypothetical example.

3. Identify the most permanent "local minimum" on the graph. This is the apparent PMEP alternative. On the plot of cost-effectiveness versus permanence, a "local minimum" is any point that is more cost-effective than its neighbors. The most permanent "local minimum" is the local minimum with the highest degree of permanence.

    a. If there is no local minimum, the alternative with the lowest permanence score is the apparent PMEP. This can happen when the cost-effectiveness ratio continues to decrease with decreasing permanence in the plot.

    b. If there is only one local minimum, it is the apparent PMEP alternative.

    c. If there are two or more local minimums, the most permanent local minimum is the apparent PMEP alternative. It is the local minimum furthest on the right-hand side of the graph. On the x-axis, permanence increases as you move right.

After identifying the apparent PMEP alternative, consider uncertainty and any additional alternatives in the PMEP evaluation as specified in Chapter 9 and select the final PMEP alternative.

5.6.2 Hypothetical example

Figure 5-2 below shows a graph of the six cleanup action alternatives that were discussed as a part of the hypothetical example in Section 5.5 above. In this example, ALT E is the apparent PMEP alternative because it is the most permanent local minimum on the graph.

- There are two local minimums on the graph, ALT E and ALT D.
- ALT E is a local minimum because it is more cost-effective than both ALT F (the most permanent alternative) and ALT C (the next most permanent alternative to ALT E).
- ALT D is a local minimum because it is more cost-effective than both of its neighbors, ALT B and ALT C.
- ALT E is the most permanent local minimum. It is further to the right on the x-axis than the other local minimum, ALT D. Note that the alternatives that are further to the right are more permanent because the permanence scores are plotted in the positive x-axis direction.
- ALT A is the most cost-effective (practicable) of the six alternatives, but it is not PMEP.

The uncertainty of the cost inputs to the DCA calculations are shown by error bars based on the evaluator's input cost-estimate confidence intervals (+30%, -30%). These error bars provide a

visual representation of uncertainties in cost estimate. The effects of uncertainty in the benefit scores can also be assessed through sensitivity analysis by varying the benefit score.

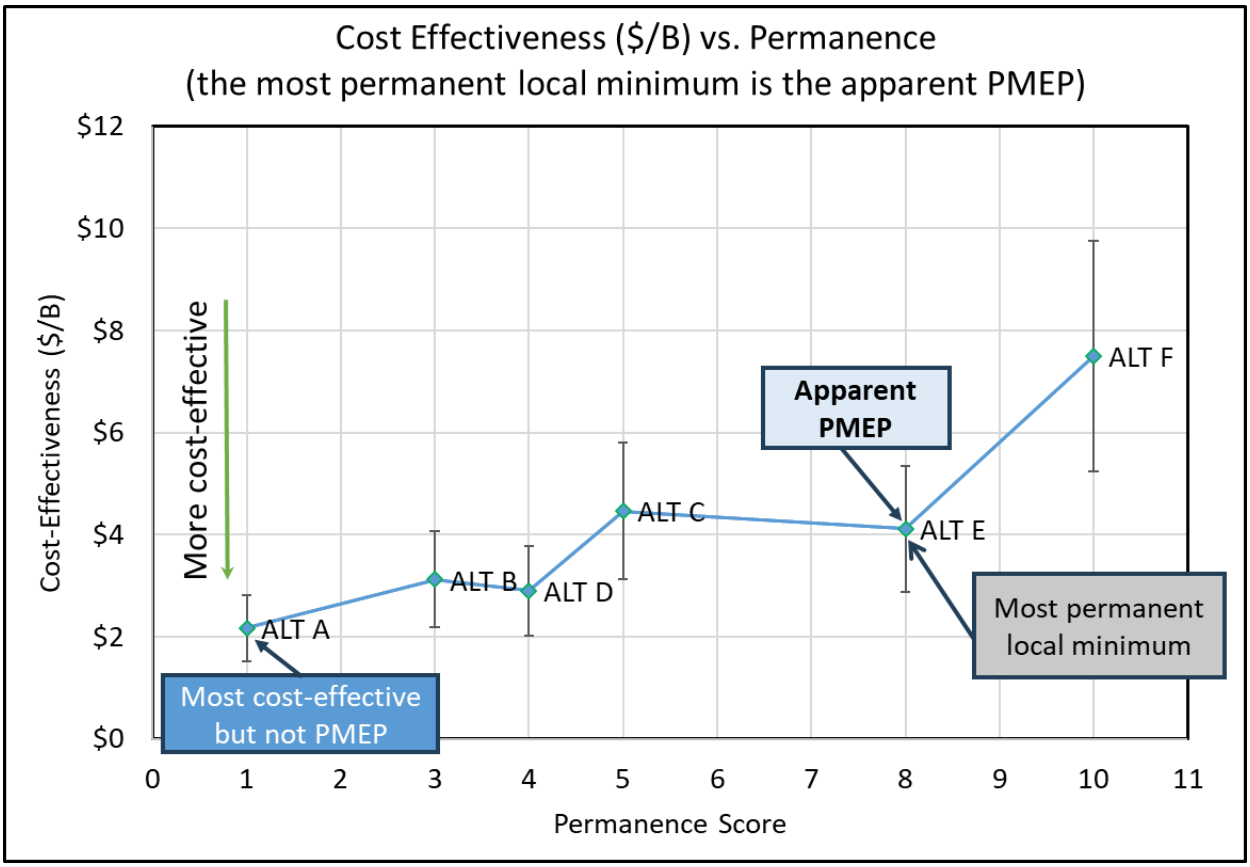

Figure 5-2: Semi-quantitative method example – graphical analysis

Chapter 6:
DCA Tool for Semi-quantitative PMEP Method

To facilitate semi-quantitative PMEP evaluations described in Chapter 5 of this document, Ecology has developed a DCA Tool in Microsoft Excel. The DCA Tool is available separately on Ecology's website.[14] This chapter provides instructions on how to use the DCA Tool.

6.1 Prerequisites

Before using the DCA Tool, do the following:

- Complete Step 1 of the PMEP evaluation. See Section 5.1 of this document for instructions, and Chapters 7 and 8 of this document for guidance on how to evaluate costs and benefits. The DCA Tool uses input values developed by the evaluator during Step 1.

- If two or more alternatives are permanent, follow the procedures under Step 2 of the PMEP evaluation to eliminate all but the most cost-effective permanent alternative. See Section 5.2.2 of this document.

- If two or more non-permanent alternatives are assigned the same permanence score, follow the procedures under Step 2 of the PMEP evaluation to eliminate all but the most cost-effective of those equally non-permanent alternatives. See Section 5.2.4 of this document.

6.2 Inputs and instructions

In the DCA Tool worksheet, all cells are locked and protected except the gold highlighted input cells in the Input Data table. To use the DCA Tool, enter the following into the Input Data table:

- The names of up to eight alternatives, from left to right, in the cells K3 through R3.
    - Alternatives may be entered in any order or permanence. They will be automatically re-ordered, analyzed in the DCA calculations table, and then graphed by degree of permanence based on permanence scores.[15]

[14] https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools

[15] Note that this feature of the DCA Tool supports sensitivity analysis by allowing the user to change the permanence scores of the alternatives without manually re-entering the alternatives.

  - For fewer than eight alternatives, leave the default text "not used" in row 3 for the unused alternatives. An empty cell in row 3 will cause errors in the DCA calculations. Leave all other input cells empty for the unused alternatives.

- The total present value of the cost estimates for each alternative, in millions of dollars, in cells K4 through R4.

- The upper and lower confidence ranges for the cost estimates, as percentages, in cells L5 and L6. This input is optional. Leave the cells empty if you don't want to input cost confidence information.

- The DCA Tool sets the default "DCA Benefit Criteria Weights" at 20%. If you change the weights, enter the revised weight for each of the five benefit criteria, in decimals or percentages, in cells J9 through J13. Make sure the total weight in cell J14 equals 100%.

- The scores for each of the five benefit criteria for each alternative in cells K9 through R13.

To see more detailed explanatory notes in the context of the DCA Tool worksheet, hover over cells with red triangles.

6.3 Analysis and outputs

The DCA Tool uses the inputs to do the following:

- Calculate the total (combined) weighted benefit score of each alternative. See Table 1 (Input Data and Cost-Effectiveness Calculation) in the DCA Tool.

- Calculate the cost-effectiveness ratio (cost per total weighted degrees of benefit) of each alternative. See Table 1 (Input Data and Cost-Effectiveness Calculation) in the DCA Tool.

- Generate a bar chart that graphically summarizes the total cost and total benefit of each alternative in order of decreasing permanence. See Chart 1 in the DCA Tool.

- Rank the alternatives in order of decreasing permanence. See Table 2 (DCA Calculations) in the DCA Tool.

- In order of decreasing permanence, compare the cost-effectiveness ratios of pairs of alternatives to determine which alternative is the most cost-effective. See Tables 1 and 2 in the DCA Tool.

- Identify the apparent PMEP alternative based on the decision criteria in Section 5.4 of this document. See Table 2 in the DCA Tool (yellow highlighted cell is the apparent PMEP alternative).

- Generate a chart of cost-effectiveness (million dollars per total weighted benefit) versus permanence score (relative degrees of permanence) for all alternatives. See Chart 2 in the DCA Tool. The most permanent local minimum on Chart 2 is the apparent PMEP alternative.

6.4 Considering uncertainty and additional alternatives

When conducting a PMEP evaluation using the DCA Tool, uncertainties in cost and benefit estimates and additional alternatives can only be considered near the end of the DCA process when an apparent PMEP alternative is identified by the DCA Tool (instead of at the end of each iteration of the DCA as specified in Step 4C in Section 5.4.3).

To consider uncertainty and additional alternatives when using the DCA Tool, evaluate the outcome of each DCA iteration (pairwise comparison) one at a time, starting with the first iteration. Do not start with the last DCA iteration, where an apparent PMEP alternative is identified by the DCA Tool. See Sections 5.4.3 and 9.3 for how to consider uncertainty and additional alternatives at each iteration.

Sensitivity analysis can support BPJ at sites where there is uncertainty about cost or benefit estimates and what alternatives should be considered. You can conduct sensitivity analyses using the DCA Tool in two ways:

- Test the effect of upper and lower bounds of costs and benefit estimates manually on the outcome of each DCA iteration (that is, determine whether the baseline is cost-effective during each pairwise comparison starting with the first iteration).

- Find out what percentage change of an input would change the outcome of any DCA iteration (pairwise comparison) and consequently the PMEP evaluation using Excel's Goal Seek tool. This tool is available for performing sensitivity analysis using the unprotected input cells. In the DCA Tool worksheet, use the Excel drop-down menu options: Data > What-If Analysis > Goal Seek.

See Section 9.3 of this document for instructions and examples on the use of sensitivity analysis. For more information on using Excel’s Goal Seek tool, consult Help in Excel.

Chapter 7:
Evaluation of Costs

In Step 1 of the PMEP evaluation, the evaluator needs to determine the costs and benefits of each cleanup action alternative using the criteria specified in WAC 173-340-360(5)(d).

This chapter provides guidance on how to assess the cost criterion specified in WAC 173-340-360(5)(d)(vi), including what costs are included and how to calculate those costs and what costs are excluded.

7.1 What costs are included?

The evaluator should include the costs of all remedial actions needed to implement a cleanup action alternative for as long as such actions are needed under MTCA, including:

- Construction costs.
- Present worth of post-construction costs.

A "remedial action" includes "any action or expenditure consistent with the purposes of Chapter 70A.305 RCW to identify, eliminate, or minimize any threat posed by hazardous substances to human health or the environment including any investigative and monitoring activities with respect to any release or threatened release of a hazardous substance and any health assessments or health effects studies conducted in order to determine the risk or potential risk to human health" (WAC 173-340-200).

7.1.1 Construction costs

The evaluator should include all costs of constructing the cleanup action alternative, including but not limited to the following:

- Preconstruction engineering design and permitting.
- Physical construction (including labor, equipment, materials, and contingencies).
- Waste management and disposal.
- Compliance monitoring during construction (including sampling and analysis).
- Construction management.
- Establishment of institutional controls.
- Regulatory oversight.
- Quality assurance and quality control.

See WAC 173-340-360(5)(d)(vi)(A). Do not discount construction costs using present worth analysis.

7.1.2 Present worth of post-construction costs

To determine the present worth of the post-construction costs of a cleanup action alternative, do the following:

- Step 1 – Identify post-construction remedial actions.

  Identify all post-construction remedial actions needed to implement the alternative, including but not limited to:

  - Operation and maintenance activities necessary to maintain the effectiveness of a constructed cleanup action component.
  - Waste management and disposal.
  - Replacement or repair of equipment (including labor, equipment, and materials).
  - Permit renewal.
  - Compliance monitoring (including sampling and analysis).
  - Maintaining institutional controls.
  - Financial assurances.
  - Periodic reviews.
  - Postconstruction management.
  - Regulatory oversight.

  See WAC 173-340-360(5)(d)(vi)(B).

- Step 2 – Identify period and frequency of post-construction remedial actions.

  Identify the period and frequency that each post-construction remedial action is needed to implement the alternative.

- Step 3 – Estimate cost of post-construction remedial actions.

  Estimate the future cost of conducting all post-construction remedial actions identified in Step 1 for the period specified in Step 2. Use constant-year dollars (WAC 173-340-360(5)(d)(vi)(B)(II)).

  To estimate the cost of replacing or repairing equipment, do the following:

  - Estimate the design life of each cleanup action component, including engineered controls.

  - If the period in which a component is needed exceeds the design life of the component, include the cost of replacing or repairing the component in the cost estimate.

  See WAC 173-340-360(5)(d)(vi)(B)(I).

- Step 4 – Discount cost of post-construction remedial actions.

  Discount the future post-construction costs using the current U.S. Treasury real interest rate for bonds of comparable maturity to the period of analysis. If project costs exceed

30 years, use the current U.S. Treasury 30-year real interest rate (WAC 173-340-360(5)(d)(vi)(B)(II)).

The U.S. Treasury real interest rates are updated annually in December for the next calendar year, and are available from the White House Office of Management and Budget in OMB Circular A-94, Appendix C.[16]

7.2 What costs are excluded?

The evaluator should exclude the costs of any actions that are not remedial actions needed to implement a cleanup action alternative under MTCA, including the following:

- The cost of any action to redevelop the site that is not a remedial action needed to implement the alternative under MTCA.
- The anticipated economic or other benefits from any post-cleanup site reuse or redevelopment.
- Any assessment of natural resource damages caused by the release of hazardous substances at the site.

[16] https://www.whitehouse.gov/omb/information-for-agencies/circulars/

Chapter 8:
Evaluation of Benefits

In Step 1 of the PMEP evaluation, the evaluator needs to determine the costs and benefits of each cleanup action alternative using the criteria specified in WAC 173-340-360(5)(d).

This chapter provides guidance on how to evaluate the benefits of an alternative, including:

- How to assess the each of the five benefit criteria (Section 8.1).
- How to consider vulnerable populations and overburdened communities when assessing the benefits of an alternative (Section 8.2).
- How to consider public concerns and tribal rights and interests for Ecology-conducted or supervised cleanups (Section 8.3).

8.1 Benefit criteria

This section provides guidance on how to assess each of the five benefit criteria specified in WAC 173-340-360(5)(d)(i) through (v).

8.1.1 Protectiveness

The evaluator must consider the degree to which the alternative protects human health and the environment, including likely vulnerable populations and overburdened communities (WAC 173-340-360(5)(d)(i)).

Factors for evaluating relative protectiveness

When assessing the relative protectiveness of an alternative, consider at least the following:

- The degree to which the alternative reduces existing risks.

  Determine the degree of risk reduction of an alternative by subtracting future risk from existing risk. Consider how risks will be reduced (whether by reducing or eliminating the contaminants or by reducing or eliminating exposure to those contaminants), the amount of contamination remaining at the site, where that contamination is located (vertically and horizontally), and the toxicity of that contamination (acute or chronic). In general, eliminating/reducing contaminants scores higher than eliminating/reducing exposure to containments. Compare all the alternatives in reducing existing risks on a scale.

- The time required for the alternative to reduce risks at the site and attain cleanup standards.

  An alternative must have a reasonable restoration time frame (WAC 173-340-360(3)(a)(x)). The rule specifies the factors the evaluator must consider when making

that determination (WAC 173-340-360(4)(c)). That evaluation needs to be documented in the FS. Only those alternatives with a reasonable restoration time frame should be included in the PMEP evaluation (see Section 1.3 of this document).

When evaluating and comparing the relative degree of benefit provided by each of the remaining alternative's restoration time frame in the PMEP evaluation, consider both the quantitative time frame for restoring each impaired land or other resource use and the qualitative benefit of restoring each of those uses. When conducting this evaluation, consider the factors used to evaluate the time frame's reasonableness in WAC 173-340-360(4)(c).

- The on-site and offsite risks remaining after implementing the alternative.

  Consider both the risks at the site being cleaned up and any other site involved with the cleanup action, such as an off-site treatment or disposal facility.

- Improvement of the overall environmental quality.

  Consider the cleanup action goals identified in Step 1 of the FS, including any planned future uses of the site and any planned habitat restoration or resource recovery goals for the site. Do not consider historical natural resource damages. Then consider the degree to which the alternative reduces risks to terrestrial and aquatic life to achieve those goals.

See WAC 173-340-360(5)(d)(i).

8.1.2 Permanence

The evaluator must consider the degree to which the alternative permanently reduces the toxicity, mobility, or mass of hazardous substances. (WAC 173-340-360(5)(d)(ii)). This includes, but is not limited to, in situ or ex situ treatment, in situ stabilization, and treatment/stabilization at an off-site treatment or disposal facility.

Definition of permanent solution

A "permanent solution" or "permanent cleanup action" is defined as one "in which cleanup standards … can be met without further action being required at the site being cleaned up or any other site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances" (WAC 173-340-200).

Factors for evaluating relative permanence

When assessing the relative permanence of an alternative, consider at least the following:

- The adequacy of the alternative in destroying the hazardous substances.

- The reduction or elimination of hazardous substance releases and sources of releases.

- The degree of irreversibility of waste treatment process.
- The characteristics and quantity of treatment residuals generated.

See WAC 173-340-360(5)(d)(ii).

8.1.3 Effectiveness over the long-term

The evaluator must consider the degree to which the alternative is likely to be effective over the long term, including for likely vulnerable populations and overburdened communities (WAC 173-340-360(5)(d)(iii)).

Factors for evaluating relative long-term effectiveness

When assessing the relative long-term effectiveness of an alternative, consider at least the following:

- The degree of certainty that the alternative will be successful.
- The reliability of the alternative during the period of time hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels.
- The resilience of the alternative to climate change impacts.

  The ability to resist and recover from climate change impacts should be considered explicitly and documented in the FS (WAC 173-340-360(5)(d)(iii)(A)(III) and 173-340-351(6)(f)(vii)). This includes likely climate-induced resistance to effective treatment or changes in sequestration effectiveness. This is particularly important for cleanups using contaminant mobility sequestration or capping technologies at sites affecting sediment. For additional guidance on how to assess the risks to an alternative associated with a changing climate and how to identify adaption measures that can increase the resilience of an alternative, see Sustainable Remediation: Climate Change Resilience and Green Remediation – A Guide for Cleanup Project Managers.[17]
- The magnitude of residual risk with the alternative in place.
- The effectiveness of controls required to manage treatment residues or remaining wastes.

See WAC 173-340-360(5)(d)(iii)(A).

Hierarchy of upland cleanup action components ranked by relative long-term effectiveness

[17] https://apps.ecology.wa.gov/publications/SummaryPages/1709052.html

For upland contamination, when assessing the relative degree of long-term effectiveness of cleanup action components, the following types of components may be used as a guide, in descending order:

- Reuse or recycling.
- Destruction or detoxification.
- Immobilization or solidification.
- On-site or offsite disposal in an engineered, lined and monitored facility.
- On-site isolation or containment with attendant engineering controls.
- Institutional controls and monitoring.

See WAC 173-340-350(5)(d)(iii)(B).

Hierarchy of sediment cleanup action components ranked by relative long-term effectiveness

For sediment contamination, when assessing the relative degree of long-term effectiveness of cleanup action components, the following types of components may be used as a guide, in descending order:

- Source controls in combination with other cleanup technologies.
- Beneficial reuse of the sediments.
- Treatment to immobilize, destroy, or detoxify contaminants.
- Dredging and disposal in an upland engineered facility that minimizes subsequent releases and exposures to contaminants.
- Dredging and disposal in a nearshore, in-water, confined aquatic disposal facility.
- Containment of contaminated sediments in-place with an engineered cap.
- Dredging and disposal at an open water disposal site approved by applicable state and federal agencies.
- Enhanced natural recovery.
- Monitored natural recovery.
- Institutional controls and monitoring.

See WAC 173-204-570(4)(b).

Both the upland and sediment hierarchies reflect current technologies that have a long implementation history, proven applicability, and appropriateness for upland and sediment contamination. Depending on site-specific circumstances, Ecology will consider new technologies as they become available and determine how they should be placed in the hierarchies.

These hierarchies are provided only as a guide and may be modified depending on site-specific circumstances. For example, for sediment contamination, shoreline configurations, seismic stability, or land use restrictions might make a site unsuitable for dredging and contained disposal (sediment components #4 and #5, above). In such a case, sediment components #6 through #10 would rank above others in the hierarchy.

Difference between permanence and long-term effectiveness

The permanence criterion focuses on the degree to which an alternative, if successfully implemented, would irreversibly reduce the toxicity, mobility, or mass of hazardous substances at the site being cleaned up or any other site involved with the cleanup action.

The long-term effectiveness criterion focuses on the degree to which the alternative reliably achieves and maintains cleanup standards, including the effectiveness of controls required to manage treatment residues or remaining wastes either at the site being cleaned up or any other site involved with the cleanup action.

For example, when ranking or scoring an alternative that uses long-term treatment or monitored natural attenuation to achieve cleanup standards:

- The permanence rank or score should reflect the degree to which the alternative uses irreversible mechanisms, such as thermal destruction (not volatilization) or biodegradation, to achieve cleanup standards.

- The long-term effectiveness rank or score should reflect the degree of certainty that the alternatives will be able to achieve cleanup standards (given environmental and other conditions and potential changes in those conditions[18]) and the degree of certainty that any needed engineered or institutional controls during or after the cleanup will remain effective based on current and potential land and resource uses.

8.1.4 Management of implementation risks

The evaluator must consider the risks to human health and the environment, including likely vulnerable populations and overburdened communities, associated with the alternative during construction and implementation, and the degree to which the alternative effectively manages such risks (WAC 173-340-360(5)(d)(iv)).

[18] For example, consider the resilience of the alternative to changes in geochemical parameters such as oxidation reduction potential associated with the treatment or natural attenuation process.

Factors for evaluating relative effectiveness of implementation risk management

When assessing the relative effectiveness of an alternative to manage implementation risks, consider at least the following:

- The risks to human health and the environment posed by the alternative during construction and implementation.
- The measures the alternative uses to manage the risks posed by the alternative.
- The degree to which those measures will effectively manage the risks posed by alternative.

Distinguishing implementation risks from other site risks

Implementation risks may include, for example:

- Potential suspension of air-born dust containing contaminants.
- Water quality degradation during dredging operations.
- Incidental exposure to contaminated water during pumping, dewatering, or other cleanup activities.
- Loading and transfer spillage of contaminated material during transport.
- Exposure to strong oxidant or reductant chemicals during in-situ injections.
- Exposure to steam during thermal conduction heating or steam enhanced extraction.
- Potential risk of electric shock or spatter during electric resistive heating.

Do not consider the following types of risks under this criterion:

- The ongoing risk from contamination at the site (not caused by the cleanup) until the site is cleaned up (restored). This factor is considered under the protectiveness criterion.
- The on-site and off-site risks remaining after the cleanup (restoration). This factor is considered under the protectiveness criterion.
- Uncertainty as to whether the alternative will achieve cleanup standards. This factor is considered under the long-term effectiveness criterion.
- Uncertainty as to whether the alternative will be able to effectively manage contamination during or after the cleanup. This factor is considered under the long-term effectiveness criterion.

8.1.5 Technical and administrative implementability

The evaluator must consider the degree to which the alternative is technically and administratively implementable (WAC 173-340-360(5)(d)(v)).

Factors for evaluating relative implementability

When assessing the relative technical and administrative implementability of an alternative, consider at least the following:

- The technical difficulty of designing, constructing, and otherwise implementing the alternative in a reliable and effective manner, regardless of cost. See discussion of engineering design below.
- The availability of necessary off-site facilities, services, and materials.
- Administrative and regulatory requirements.
- Scheduling, size, and complexity.
- Monitoring requirements.
- Access for construction operations and monitoring. This may require cooperation of property owners other than the person conducting the cleanup.
- Integration with existing facility operations and other current or potential remedial actions.

See WAC 173-340-360(5)(d)(v)(A) through (G).

Considering engineering design

When evaluating the technical difficulty of an alternative, engineering design is often an important consideration. For example, the complete removal of contaminated material next to a bulkhead or building may not be technically feasible due to the potential for collapse. In such cases, other alternatives may need to be considered in the FS. In the example, an alternative that includes partial removal of contaminated material with temporary tiebacks and partial cap might be evaluated instead.

Considering post-construction activities

The evaluator needs to consider not only the implementability of construction activities, but also post-construction activities, including:

- Operation and maintenance activities necessary to maintain the effectiveness of a constructed cleanup action component.
- Replacement or repair of equipment (including labor, equipment, and materials).
- Waste management and disposal.

- Permit renewal.
- Compliance monitoring (including sampling and analysis).
- Maintaining institutional controls.
- Financial assurances.
- Periodic reviews.
- Postconstruction management and regulatory oversight.

8.2 Considering vulnerable populations and overburdened communities

When evaluating the benefits of a cleanup action alternative in Step 1 of the PMEP evaluation, the evaluator needs to consider the impacts of the alternative on a likely vulnerable population or overburdened community based on their site uses and potential exposures. Specifically, as part of the evaluation, the evaluator needs to consider such impacts when evaluating the following three benefit criteria:

- **Protectiveness:** The degree to which the alternative protects the health and environment of a likely vulnerable population or overburdened community (WAC 173-340-360(5)(d)(i)).

- **Long-term effectiveness:** The degree to which the alternative is likely to be effective over the long term for a likely vulnerable population or overburdened community (WAC 173-340-360(5)(d)(iii)).

- **Implementation risk management:** The risk of implementing the alternative to the health or environment of a likely vulnerable population or overburdened community, and the effectiveness of the alternative to manage such risks (WAC 173-340-360(5)(d)(v)).

When evaluating each of these three criteria, keep in mind that an alternative may not provide the same degree of benefit to different population groups if their site uses or degrees of site use are different. For example, an alternative may restore a site faster for recreational fishing than for subsistence fishing.

When documenting the detailed evaluation of cleanup action alternatives in the applicable report (FS report, CAP, or independent remedial action report), the evaluator needs to briefly describe how they considered the impacts on a likely vulnerable population or overburdened community in the PMEP evaluation (WAC 173-340-351(6)(f)(vii) and 173-340-380(5)(c)). Specifically, as part of the report or plan, the evaluator needs to briefly:

- Identify any likely vulnerable population or overburdened community impacted by the cleanup action alternative.

- Describe how the cleanup action alternative may impact the likely vulnerable population or overburdened community.

- Explain how such impacts were considered when ranking, scoring, or weighting each of the three benefit criteria.

- Assess and explain how those considerations may have affected the outcome of the PMEP evaluation.

For additional guidance on how to identify a likely vulnerable population or overburdened community and consider the impact of the site and its cleanup on such populations when conducting a remedial investigation and FS, see the Toxics Cleanup Program's Implementation Memorandum No. 25[19] and Implementation Memorandum No. 26[20], respectively.

8.3 Considering public concerns and tribal rights and interests in Ecology-conducted or supervised remedial actions

For Ecology-conducted or Ecology-supervised remedial actions, when evaluating and weighting the benefits of cleanup action alternatives in Step 1 of the PMEP evaluation, the evaluator needs to consider the following:

- Public concerns identified through public participation during the cleanup process under WAC 173-340-600(13) and (14).

- Tribal rights and interests identified through meaningful engagement of interested Indian tribes during the cleanup process under WAC 173-340-620.

When documenting the detailed evaluation of cleanup action alternatives in the applicable report (FS report, CAP, or independent remedial action report), the evaluator needs to briefly describe how they considered public concerns and tribal rights and interests in the PMEP evaluation (WAC 173-340-351(6)(f)(vii) and 173-340-380(5)(d)). Specifically, as part of the report or plan, the evaluator needs to briefly:

- Identify how the public and affected Indian tribes were engaged.

- Describe the level of interest and any concerns identified by the public or Indian tribes. As applicable, distinguish the concerns of any vulnerable population or overburdened community (see Section 8.2 of this document).

- Explain how such concerns were considered when ranking, scoring, or weighting each of the three benefit criteria.

[19] https://apps.ecology.wa.gov/publications/SummaryPages/2409044.html
[20] [publication number and URL for IM26 pending]

- Assess and explain how those considerations may have affected the outcome of the PMEP evaluation.

Chapter 9: Use of Best Professional Judgment and Sensitivity Analysis

Ecology recognizes that PMEP evaluations involve a significant degree of uncertainty, and frequently require decisions using the best available data and BPJ (WAC 173-340-360(3)). The MTCA rule specifically recognizes that "the estimation and comparison of benefits and costs may be quantitative, but will often be qualitative and require the use of best professional judgment" (WAC 173-340-360(5)(c)(i)(A)).

BPJ is the best judgment by a professional (e.g., MTCA practitioner) who uses accumulated knowledge, experience, skills, and critical thinking to make an informed decision while maintaining technical and ethical standards. This chapter provides guidance on the use of BPJ and sensitivity analysis when estimating and comparing costs and benefits in PMEP evaluations, and determining which alternative is PMEP.

9.1 Sources of uncertainty

Principal sources of uncertainty in a PMEP evaluation include:

- The quality and quantity of physical site data.
- The completeness and accuracy of the conceptual site model.[21]
- The cost and effectiveness of the remedial technologies in achieving cleanup goals.[22]
- The cost and effectiveness of new or innovative methods or treatment technologies, or new application of a proven technology.[23]
- Whether an alternative can achieve cleanup goals within a reasonable restoration timeframe.[24]
- The number and type of cleanup action alternatives evaluated.
- The estimated costs and relative degrees of benefit of the alternatives.

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[21] For example, hydrogeological heterogeneities of a site could lead to higher uncertainties for a cleanup action.
[22] For example, uncertainties in contaminant removal rate from a soil vapor extraction system that could reach a low asymptotic level without reaching cleanup goals.
[23] For example, uncertainties in successful implementation of a new application of a proven in situ bioremediation technology.
[24] For example, uncertainties in monitored natural attenuation or an active treatment system to achieve cleanup goals within an estimated timeframe.

- The consideration of public concerns, including those of a likely vulnerable population or overburdened community, and Indian tribes' rights and interests.

9.2 Developing inputs

Given the sources of uncertainty, BPJ is usually needed to develop the following inputs to a PMEP evaluation:

- Descriptions and specifications of the cleanup action alternatives to be evaluated.
- Quantitative cost estimates, including upper and lower confidence ranges for the cost estimates.
- Qualitative benefit rankings or semi-quantitative benefit scores for each of the five benefit criteria.
- Site-specific benefit criteria weights.
- For Ecology-conducted or supervised remedial actions, consideration of public concerns and Indian tribes' rights and interests when evaluating or weighting benefits.
- Developing new alternatives for further PMEP evaluation, including alternatives with new cleanup action components or new combinations of existing components.

When documenting the detailed evaluation of cleanup action alternatives in the applicable report (FS report, CAP, independent remedial action report), the evaluator should briefly describe any significant sources of uncertainty.

9.3 Considering uncertainty and identifying additional alternatives using sensitivity analysis

Due to uncertainties in the cost and benefit inputs identified in Step 1, BPJ is usually needed in Step 4 to determine whether the baseline alternative in each DCA iteration is practicable (more cost effective) compared to the next most permanent alternative (ALT X).

To support the use of BPJ when considering these uncertainties, the evaluator may conduct sensitivity analyses to:

- Identify the most important and uncertain inputs (costs or benefit criteria) in the comparison.
- Test the effect of reasonable variations of such inputs on the outcome of the comparison. Use BPJ to determine what is reasonable within the bounds of uncertainty.

The evaluator may also conduct sensitivity analyses to identify additional alternatives that are less permanent than the baseline but more permanent than ALT X, that may be practicable

compared to ALT X. Such alternatives could include ones with different cleanup action components (technologies) or different combinations of existing components (such as more treatment and less containment).

When documenting the detailed evaluation of cleanup action alternatives in the applicable report (FS report, CAP, or independent remedial action report), the evaluator should briefly describe the results of any sensitivity analyses performed, as well as any other alternatives considered.

9.3.1 Reasonable variations

Costs

For total costs, a ± 30% uncertainty can be used as a default when conducting a PMEP evaluation in the absence of a more accurate cost-estimate.

Benefits

For each benefit criterion (such as protectiveness), the reasonable variation in the criterion score should be limited to those that do not change the ranking of alternatives by that criterion identified during Step 1 of the PMEP evaluation.

For example, assume that the protectiveness score of the apparent PMEP alternative is 80 (on a scale of 1 to 100), the score of the next more protective alternative is 90, and the score of the next less protective alternative is 70. In that case, a reasonable variation in the protectiveness score of the apparent PMEP alternative can be between 71 and 89. Any protectiveness scores beyond that range would not be considered reasonable because it will change the protectiveness rank of the apparent PMEP alternative.

9.3.2 Analysis methods

There are two different ways to test the effect of reasonable variations in input variables on the outcome of each DCA iteration (whether the baseline alternative is practicable compared to the next most permanent alternative, ALT X).

Manually change inputs

The first method is to manually change input variables (cost or benefit scores) to see if those changes affect the outcome of a DCA iteration (pairwise comparison) and consequently the PMEP evaluation.

For example, assume the baseline alternative in the first DCA iteration was not practicable compared to the next most permanent alternative (ALT X) based on the preliminary pairwise comparison in Step 4B. The evaluator can conduct sensitivity analyses on cost inputs as follows:

- Assume the uncertainty in the total cost of both alternatives is ±30%. (Note that, while ±30% is typical, the degree of cost uncertainty may be different based on site-specific factors.)

- Decrease the cost of the baseline alternative by 30% and see whether that changes the outcome (whether the baseline alternative becomes practicable).

- Similarly, increase the cost of ALT X by 30% to see if that changes the outcome (whether the baseline alternative becomes practicable).

- Generally, it is not necessary to increase the cost of the baseline alternative or decrease the cost of ALT X because, in these cases, the outcome will not change.

If the sensitivity analysis does not change the outcome, the evaluator can assert it is not affected by the reasonable variation of cost inputs. If the outcome changes, the evaluator should use BPJ to determine whether the change is justified.

When the preliminary pairwise comparison shows that the baseline alternative is practicable compared to ALT X, the evaluator can conduct similar sensitivity analyses on cost inputs (i.e., increase the cost of baseline alternative or decrease the cost of ALT X) to see if the outcome is changed.

Following the above procedure, the evaluator can do similar sensitivity analyses for benefit criteria scores. Follow the reasonable variation guidelines for benefit criteria scores in Section 9.3.1 above.

Find out what change in inputs changes outputs using software

The second method is use of software, such as Microsoft Excel's Goal Seek tool, to find out what percentage change of an input would change the outcome of any DCA iteration (pairwise comparison) and consequently the PMEP evaluation.

For example, assume the baseline alternative in the first DCA iteration is not practicable compared to the next most permanent alternative (ALT X) based on the preliminary pairwise comparison. To conduct a sensitivity analysis of that pairwise comparison using Excel's Goal Seek tool, first evaluate the sensitivity of variables in the baseline alternative as follows:

1. In the Excel DCA Tool spreadsheet, select the cell that contains the cost-effectiveness value of the baseline alternative in the pairwise comparison.

2. Use the Excel drop-down menu options: Data > What-If Analysis > Goal Seek. In the “Goal Seek” dialogue box, set the cell to a value slightly below the cost-effectiveness value of ALT X so that the baseline alternative would be practicable after the “Goal Seek” analysis.

3. For the “By changing cell”, select the cell for which the evaluator would like to see the sensitivity (i.e., cost or any benefit criteria for that alternative selected in step 1).

4. Close the dialogue box. If the "Goal Seek" tool found a solution, the values would be reflected in the selected cells (i.e., value set for the cost-effectiveness cell and corresponding cost/benefit criteria value that resulted in the change). Calculate the sensitivity (percent change) of that parameter that forced a different outcome to the pairwise comparison.

5. Use BPJ to determine whether the percent change is reasonable (within uncertainty limits) and whether such a variation is justified in this case. Note that for benefit criteria, a reasonable variation should not alter the original ranking of alternatives by that criterion, as determined in Step 1 of the process (see Section 9.3.1 above).

Second, evaluate the sensitivity of ALT X variables by selecting the cost-effectiveness value of the ALT X in step 1 above. However, in the "Goal Seek" dialogue box, set the cell to a value slightly above the cost-effectiveness value of baseline so that the baseline alternative would be practicable after the "Goal Seek" analysis. Follow the remaining steps to complete the analyses.

As another example, assume instead the baseline alternative in the first DCA iteration was practicable based on the preliminary pairwise comparison. In this case, select the cell that contains the cost-effectiveness value of the baseline alternative and set it to a value slightly above the cost-effectiveness value of the next most-permanent alternative (ALT X). Follow steps 3 through 5 above.

9.4 Ecology's decision

Ecology retains all authority to determine compliance with state cleanup law requirements, including:

- What cleanup action alternatives should be considered in a FS, including in a PMEP evaluation.

- Whether an alternative meets cleanup action requirements, including whether it is PMEP.

- Whether the plan or report documenting the FS, including the PMEP evaluation, meets applicable reporting requirements.

See WAC 173-340-130(9).

When conducting a PMEP evaluation, or reviewing the evaluation conducted by another person, Ecology may use best professional judgment to:

- Weight the benefit criteria.

- Estimate the costs and degrees of benefits of each alternative.

- Favor or disfavor qualitative benefit and cost estimates in the analysis.

- For each iteration of the DCA in Step 4 of the PMEP evaluation, determine whether the baseline alternative is practicable (more cost-effective) compared to the next most permanent alternative on the ranked list.

As discussed in Section 9.3 above, in cases where the baseline alternative is not clearly impracticable (less cost-effective) compared to the next most permanent alternative due to uncertainty and reasonable variations in the cost and benefit estimates, Ecology may use its BPJ to determine that the baseline alternative is practicable and therefore PMEP. See WAC 173-340-360(3) and (5)(c)(i).

Attachment A:
Technical Notes on PMEP Methods

The PMEP evaluation involves comparisons of quantitative costs and five qualitative benefits. The need to combine and compare quantitative and qualitative values raises the following questions that need to be answered to conduct a PMEP evaluation:

- How do I evaluate and compare the benefits of one alternative with those of another?
- For each alternative, should I combine the evaluations of the five benefits into a single indicator of total benefit?
- How do I compare the costs and benefits of one alternative with those of another?

The narrative and semi-quantitative methods summarized in Chapter 3 and detailed in Chapters 4 and 5 of this document provide different approaches to answering these questions. This attachment discusses several of these problems in greater detail.

A.1 Variables and level of measurement

Table A-1 applies a widely used classification of variable types, based on how the variables are measured,[25] to variables used in the PMEP evaluation. The MTCA rule considers estimated costs to be fully quantitative (ratio type) variables. But because the five DCA benefit criteria can't practically be quantified in monetary terms or otherwise measured quantitatively, the PMEP evaluation must consider the benefit criteria as either ordinal or interval-type variables as shown in the table.

The **narrative PMEP method** (summarized in Section 3.1 and detailed in Chapter 4 of this document) treats the benefit criteria as ordinal variables. As such, the alternatives can be ranked relative to one another but not added to create a single total benefit score.

The **semi-quantitative PMEP method** (summarized in Section 3.2 and detailed in Chapter 5 of this document) quantify the evaluator's qualitative assessments of each alternative's benefits as interval variables. Each alternative is scored numerically for each benefit criterion, in relative degrees of benefit, as compared to the other alternatives. This method uses a single linear scale defined by the evaluator to compare alternatives separately for each criterion. The benefit scores of each alternative are then added to create a total benefit score, with or without weightings that favor or disfavor one or more of the criteria.

[25] Williams, M. Levels of Measurement and Statistical Analyses. Meta-Psychology, 2021, vol 5, MP.2019.1916, https://doi.org/10.15626/MP.2019.1916 (accessed March 18, 2024).

Table A-1: Variable types and levels of measurement in the PMEP evaluation

Variable type	How is it defined or measured?	What comparison is allowed?	Example of comparison	Use in PMEP evaluation
Nominal	Membership in a subset or category related to the attribute.	Allows comparison only in terms of whether an alternative is a member of the category.	"ALT A is not permanent."	Distinguish whether an ALT is permanent.
Ordinal	Differences in an attribute that are only >, =, or < other alternatives.	Allows comparison in terms of ranked lists. Does not allow degrees of variation in the ranked list.	"ALT B is more protective than ALT A."	Narrative method: rank benefits
Interval	Degrees of difference in an attribute with respect to a relative scale defined for that attribute, in which the degrees of difference are consistent throughout the scale. Does not have an absolute zero.	Allows for addition and subtraction of degrees, and comparisons of ratios of intervals	"The difference in protectiveness between ALT A and C is twice the difference between ALT A and B." "The proportional increase in cost from the less permanent ALT to the more permanent ALT is twice the proportional increase in degrees of benefit".	Semi-quantitative method: score benefits
Ratio	Differences in an attribute with respect to an absolute (independent) unit of measurement. Ratio scale contains absolute zero (no negative numbers).	Allows for multiplication and division, and comparisons in terms of ratios	"In 2024 dollars, ALT A costs twice as much as ALT B".	All methods: calculate costs

A.2 Comparing incremental costs and benefits

For the purpose of a DCA in a PMEP evaluation, the MTCA rule defines "practicable" in terms of disproportionality as follows (emphasis added in italics):

> "Practicable" means capable of being designed, constructed, and implemented in a reliable and effective manner including consideration of cost. *An alternative is not practicable if its incremental costs are disproportionate to its incremental degree of benefits, compared to another alternative.* Whether a cleanup action uses permanent solutions to the maximum extent practicable is determined using the procedures in WAC 173-340-360(5).

See WAC 173-340-200.

The DCA compares pairs of cleanup action alternatives sequentially, in order of decreasing permanence, to identify the most permanent alternative with incremental costs that are not disproportionate to its incremental degrees of benefit (WAC 173-340-360(5)(c)(iv)).

However, the combination of qualitative and quantitative variables in the DCA complicates this comparison. Cost inputs to a DCA are estimated in present worth dollars (ratio type variable). In a semi-quantitative DCA, benefits are estimated in relative degrees of benefit based on a scoring system and weightings defined by the evaluator for each site (interval type variable). On this basis, for any two alternatives, the evaluator can calculate an incremental cost (the difference in total costs of each alternative, in dollars) and an incremental benefit (the difference in total benefit scores of each alternative, in relative degrees of benefit). Since the units are different, it is not possible to directly compare incremental cost with incremental degree of benefits.

However, since the relative degree of benefit has no absolute dollar value, the simple ratio of incremental cost to incremental degrees of benefit does not indicate whether one alternative is practicable compared to another. For instance, when comparing two alternatives in a DCA, who can say whether an increase of 1.3 degrees of relative benefit (incremental benefit) is worth a $25,000 increase in cost (incremental cost)?

Therefore, the logical indicator of practicability is the ratio of *proportional* (percentage) incremental cost to *proportional* incremental degrees of benefit.[26] Before considering uncertainties in estimated costs and degrees of benefit,[27] the baseline alternative is practicable if its proportional (percent) increase in cost is less than or equal to its proportional (percent) increase in degrees of benefit, as compared to the next most permanent alternative. Using the terms of the definition in the MTCA rule: the baseline alternative is practicable if its incremental costs are not disproportionate to its incremental degrees of benefit, compared to the next most permanent alternative.

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[26] Ratios of proportional (percentage) changes are common in economics, where they are called elasticities.

[27] Chapter 9 discusses the use of BPJ and sensitivity analyses in a PMEP evaluation.

A.3 Implementing DCA using cost-effectiveness ratios

The DCA Tool determines which cleanup action alternative is PMEP through sequential cost-effectiveness comparisons of pairs of alternatives, where the cost-effectiveness of an alternative is the ratio of its total cost to its total weighted benefit score. Comparing the cost-effectiveness of two alternatives is mathematically equivalent to comparing proportional differences in costs and benefits (i.e., incremental costs versus incremental degrees of benefits as specified in WAC 173-340-360(5)(c)(iv)). This section shows how this method meets the requirements of the rule.

A.3.1 DCA using incremental cost and benefit comparisons

First, note that the rule requirements for DCA are stated in terms of the incremental costs and benefits a baseline alternative and its next most permanent alternative. The rule can be operationalized directly by calculating and comparing proportional changes in costs to proportional changes in degrees of benefit, from the less permanent to the more permanent alternative in each pair, as follows:

- The more permanent cleanup action in each comparison is considered the baseline, denoted below by a subscript **b** for that comparison.
- The less permanent cleanup action in each comparison is considered the alternative, denoted below by a subscript **x** for that comparison.
- Proportional changes in costs (**C**) and relative degrees of benefit (**B**) from x to b are defined as follows:
    - Change in cost: $\Delta C = C_b - C_x$
    - Proportional change in cost: $\Delta C_{prop} = \frac{\Delta C}{C_x}$
    - Change in degrees of benefit: $\Delta B = B_b - B_x$
    - Proportional change in total degrees of benefit: $\Delta B_{prop} = \frac{\Delta B}{B_x}$

Using these definitions, the disproportionality test decision criteria of WAC 173-340-360(5)(c)(iv)(B) can be represented by the equations in Table A-2.

Table A-2: DCA Tool disproportionality test criteria

Criteria	DCA test conditions	Test criteria	Outcome
1	Both ΔC and ΔB are positive (i.e., ΔC > 0 and ΔB > 0)	If $\frac{\Delta C_{prop}}{\Delta B_{prop}} > 1$	Baseline is not practicable
		If $\frac{\Delta C_{prop}}{\Delta B_{prop}} \leq 1$	Baseline is practicable
2	Both ΔC and ΔB are negative (i.e., ΔC < 0 and ΔB < 0)	If $\frac{\Delta C_{prop}}{\Delta B_{prop}} \geq 1$	Baseline is practicable
		If $\frac{\Delta C_{prop}}{\Delta B_{prop}} < 1$	Baseline is not practicable
3	ΔB = 0	If ΔC > 0	Baseline is not practicable
		If ΔC ≤ 0	Baseline is practicable
4	Only ΔB is negative (i.e., ΔC ≥ 0 and ΔB < 0)	No further test needed	Baseline is not practicable
5	Only ΔC is negative (i.e., ΔB ≥ 0 and ΔC < 0)	No further test needed	Baseline is practicable

The DCA disproportionality test criteria in Table A-2 can be interpreted as follows:

- **Criterion 1** applies if both costs and benefits increase from **x** to **b**. In this case, **b** is practicable if the proportional increase in benefit from **x** to **b** equals or exceeds the proportional increase in cost from **x** to **b**.
- **Criterion 2** applies if both costs and benefits decrease from **x** to **b**. In this case, **b** is practicable if the proportional cost savings from **x** to **b** exceed the proportional loss of benefit.
- **Criterion 3** applies if there is no change in benefit from **x** to **b.** In this case, **b** is practicable if the cost decreases or remains the same from **x** to **b**.
- **Criterion 4** applies if the benefit decreases from **x** to **b** and cost increases or remains the same. In this case, **b** is not practicable.
- **Criterion 5** applies if the cost decreases from **x** to **b** and the benefit increases or remains the same. In this case, **b** is practicable.

A.3.2 DCA using cost-effectiveness comparisons

Comparing the cost-effectiveness of two alternatives is mathematically equivalent to comparing their proportional changes in incremental costs and benefits (described in Section A.3.1). The DCA Tool uses the cost-effectiveness method because it is more compact and intuitive than the incremental approach and lends itself to a simple graphical interpretation of the analysis.[28] See Section 5.6 of this document for details on that approach.

The cost-effectiveness of an alternative can be calculated by dividing its total cost by its total weighted relative degree of benefit. The proof below demonstrates that comparing the cost-effectiveness of two alternatives is mathematically equivalent to comparing their proportional changes in incremental costs and benefits using Criterion 1 in Table A-2: if the baseline alternative in a DCA comparison is practicable, then the baseline alternative's cost per degree of benefit (C_b/B_b) must be less than or equal to the cost per degree of benefit of the next most permanent alternative (C_x/B_x). Similar logic works for the other criteria in Table A-2.

Proof of Criterion 1

Under Criterion 1 (see Table A-2), both costs and benefits increase from **x** (less permanent alternative) to **b** (baseline or more permanent alternative). In this case, **b** is practicable if the proportional increase in cost from **x** to **b** is less than the proportional increase in benefit from **x** to **b**. Mathematically,

$$If\ \frac{\Delta C_{prop}}{\Delta B_{prop}} \leq 1, then\ baseline\ alternative\ is\ practicable$$

Or, $\Delta C_{prop} \leq \Delta B_{prop}$

Or, $\frac{C_b - C_x}{C_x} \leq \frac{B_b - B_x}{B_x}$ apply the definition of proportional change (see Section A.3.1)

Or, $\frac{C_b}{C_x} - 1 \leq \frac{B_b}{B_x} - 1$

Or, $\frac{C_b}{C_x} \leq \frac{B_b}{B_x}$ add (+1) on both sides of the inequality

Or, $\frac{C_b}{C_x} . \frac{C_x}{B_b} \leq \frac{B_b}{B_x} . \frac{C_x}{B_b}$ multiply both sides of the inequality by $\frac{C_x}{B_b}$

Or, $\frac{C_b}{B_b} \leq \frac{C_x}{B_x}$ after simplification

Since cost-effectiveness of the baseline alternative is less than cost-effectiveness of the less permanent alternative, the baseline alternative is practicable.

[28] Chart 2 of the DCA Tool worksheet summarizes the DCA as a scatterplot of the alternatives' cost-effectiveness ratios versus their permanence scores. The apparent PMEP alternative is the most permanent local minimum on the plot.

A.4 Resolving conflicting DCA decision criteria

The MTCA rule includes the following three decision criteria for determining what to do next based on the results of each pairwise comparison of the baseline alternative and next most permanent alternative (ALT X) in the DCA:

- If the baseline alternative is practicable (its incremental costs are not disproportionate to its incremental degree of benefits), then the baseline alternative is PMEP.
- If the benefits of the two alternatives are the same or similar, then the lower cost alternative is PMEP.
- If the baseline alternative is not practicable (its incremental costs are disproportionate to its incremental degree of benefits), then:
    - Unless ALT X is the least permanent (last) alternative on the ranked list, return to Step 4A for another iteration of the DCA. Use ALT X as the new baseline alternative for the next iteration.
    - If ALT X is the least permanent (last) alternative on the ranked list, ALT X is PMEP.

See WAC 173-340-360(5)(c)(iv)(B). After the rule amendments were adopted, Ecology discovered that the second and third decision criteria above conflict in the following narrow set of circumstances:

- The benefits of the two alternatives are the same or similar;
- The baseline alternative is not practicable compared to ALT X;
- ALT X is not the least permanent (last) alternative on the ranked list; and
- ALT X is not practicable compared to the next most permanent alternative on the ranked list.

The decision criteria conflict in that narrow set of circumstances because the criteria provide different outcomes:

- Under the second criterion, ALT X would be PMEP and the DCA would end.
- Under the third criterion, another iteration of the DCA would be required and ALT X would be the baseline for that iteration. And if ALT X were not practicable compared to the next most permanent alternative in the ranked list, ALT X would not be PMEP.

To resolve this conflict in the rule, Ecology has decided not to enforce the second decision criterion. Ecology made this decision for the following reasons:

- Except in the narrow set of circumstances where the conflict exists, the second criterion results in the same outcome as under the other two criteria and therefore is unnecessary.

- Keeping the second criterion would create confusion and unnecessarily increase the complexity of the DCA, making it more difficult for staff and the regulated community to implement and achieve compliance.