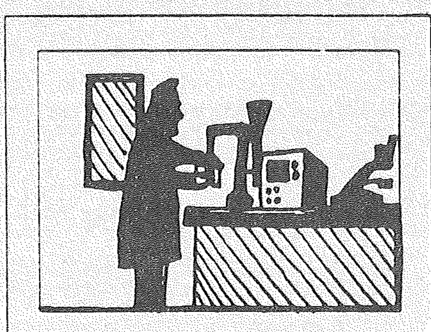
June 1990

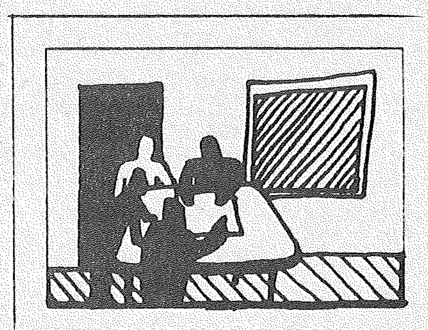
WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

The Effects-Based Design Process

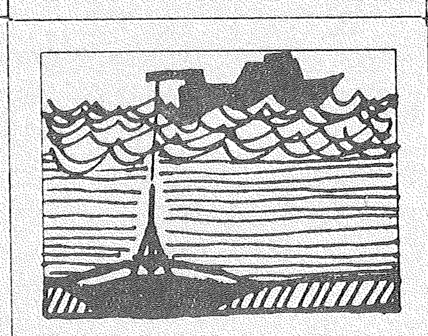
Confined Disposal of Contaminated Sediments



Testing



Site Design



Monitoring

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1. INTRODUCTION

1.1 FUNCTIONAL AND EFFECTS-BASED DESIGNS

The Washington Department of Ecology (Ecology) is developing standards for the confined disposal of contaminated sediments. The standards address sediment testing; site design; dredging, material transport, and disposal; and site monitoring for confined disposal in three environments (upland, nearshore, and aquatic). The draft standards are presented in a report *Standards for Confined Disposal of Contaminated Sediments, Development Documentation* (Parametrix 1990).

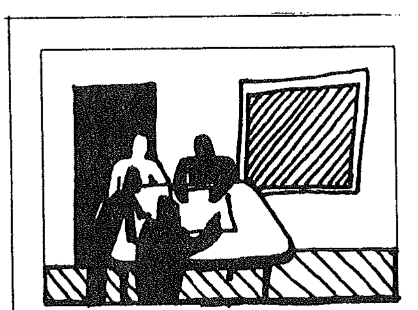
Confined disposal of contaminated sediments is a complex issue that includes several contaminant transport pathways, and transverses different environments (i.e. removing material from an aquatic environment and placing it in an upland environment). Ecology's goal is developing standards that are technically valid and also economically feasible. For the sake of users, a predictable course of events is provided as one option, and the choice for custom designing remains a second option. Thus, two types of designs were developed. The two types are referred to as "functional designs" (FD) and "effects-based designs" (EBD).

The FD is a straightforward approach that defines sediment testing requirements; site design features; dredging, transport and disposal methods; and site monitoring. It is limited to sediments within the range of contamination from exceeding PSDDA's definition of clean in water to one-tenth dangerous waste. A detailed description of how the functional designs were developed is presented in the draft standards report (Parametrix 1990).

A flexible approach is needed because different sediments and disposal sites will have unique characteristics. The EBD approach offers the flexibility to deal with varying sediment and site characteristics. The choice between these options is built into Ecology's confined disposal decision-making process. One step of the decision process deals with the disposal environments (Figure 1). Within the disposal environment step, a proponent can select between functional and effects-based designs (Figure 2).

The EBD approach will define a customized design that provides the requisite environmental protection. The approach will likely be used in the following circumstances:

- A proponent wants to modify one or more components of a functional design to better match the proposed development.
- A proponent wants to use a specific site that is more protective than the functional design criteria.



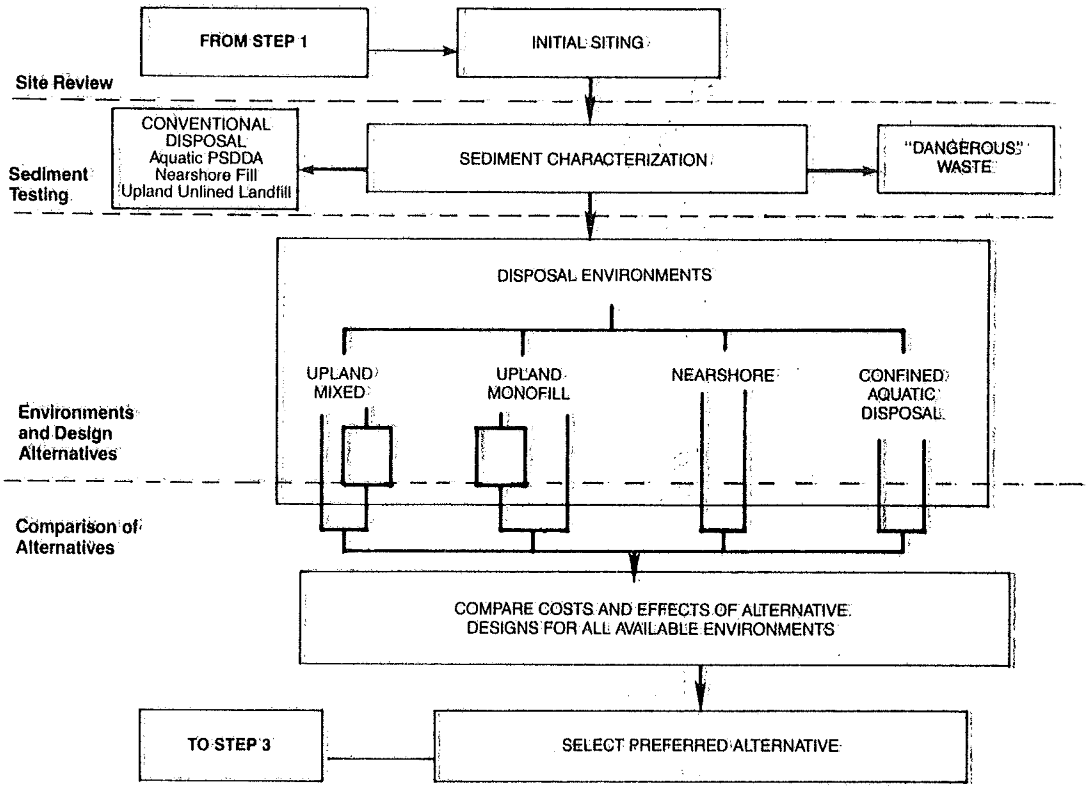


Figure 1. Overview of the Decision Model used in the confined disposal selection process.

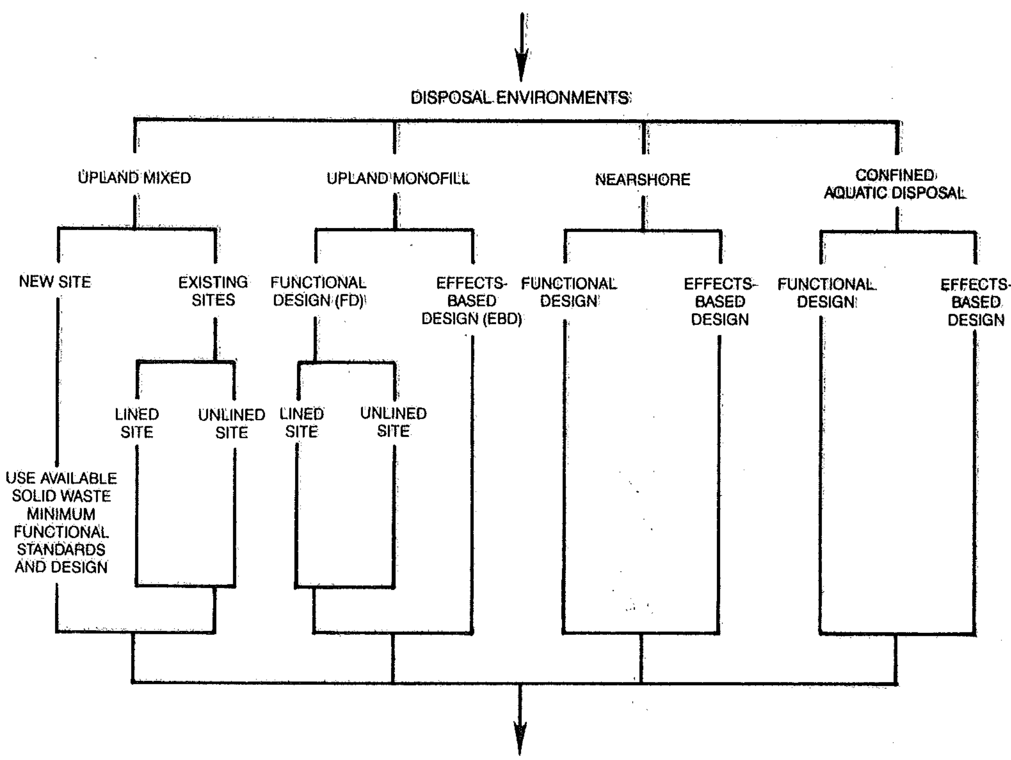


Figure 2. Overview of the disposal environments and site design step in the Decision Model.

- A proponent wants to use a specific site that is less protective than the functional design criteria.

- A proponent wants to use an EBD because their dredged material is relatively uncontaminated or has physical characteristics that reduce the likelihood of contaminant migration.

- A proponent needs to create an effects-based design because their material is more contaminated than the functional design allows.

These scenarios are wide-ranging; they indicate considerable variability in when an effects-based design is needed. Each design will be customized to its own particular situation. For this reason, we cannot identify specific dredging, transport, disposal, design, or monitoring elements of an effects-based design as part of these standards. The standards must therefore identify a process for determining an EBD. This report defines that process.

1.2 REPORT OVERVIEW

The following chapters show how the four steps summarized above should be accomplished.

Chapter 2 describes a checklist process for identifying pathways of concern and issues associated with dredging and disposal technologies.

Chapter 3 describes the elements that should be included in a project workplan. This chapter reviews the tests and models that are available for examining contaminant transport pathways. It also provides examples of workplans for hypothetical EBDs in aquatic, nearshore, and upland environments.

Chapter 4 describes how the results of the workplan can be interpreted and evaluated to determine if the EBD will provide adequate environmental protection.

1.3 EFFECTS-BASED DESIGN PROCESS

The technical issues need to define how a proponent determines if an EBD provides the necessary environmental protection. The regulatory policy issues need to define the review and approval process so that proponents know how to get an EBD accepted. For each design, technical and regulatory issues need to be addressed through a standardized process.

We have separated the EBD process into four basic steps:

1. Define contaminant transport pathways of concern for the EBD

2. Identifying how to demonstrate that the pathways are adequately blocked (i.e. further testing, modeling, and/or design features). Prepare a workplan.

3. Implement the workplan

4. Interpret the results, use the Confined Aquatic Assessment Procedure (CAAP), and make a decision regarding the EBD's effectiveness.

Regulatory review meetings will be needed periodically as these steps unfold. Opportunities should be provided for review by interested parties other than regulatory agencies, as well. These meetings are essential to prevent having to prolong a project through additional testing that was overlooked initially. The effects-based design process as it is described in this report is summarized schematically in Figure 3.

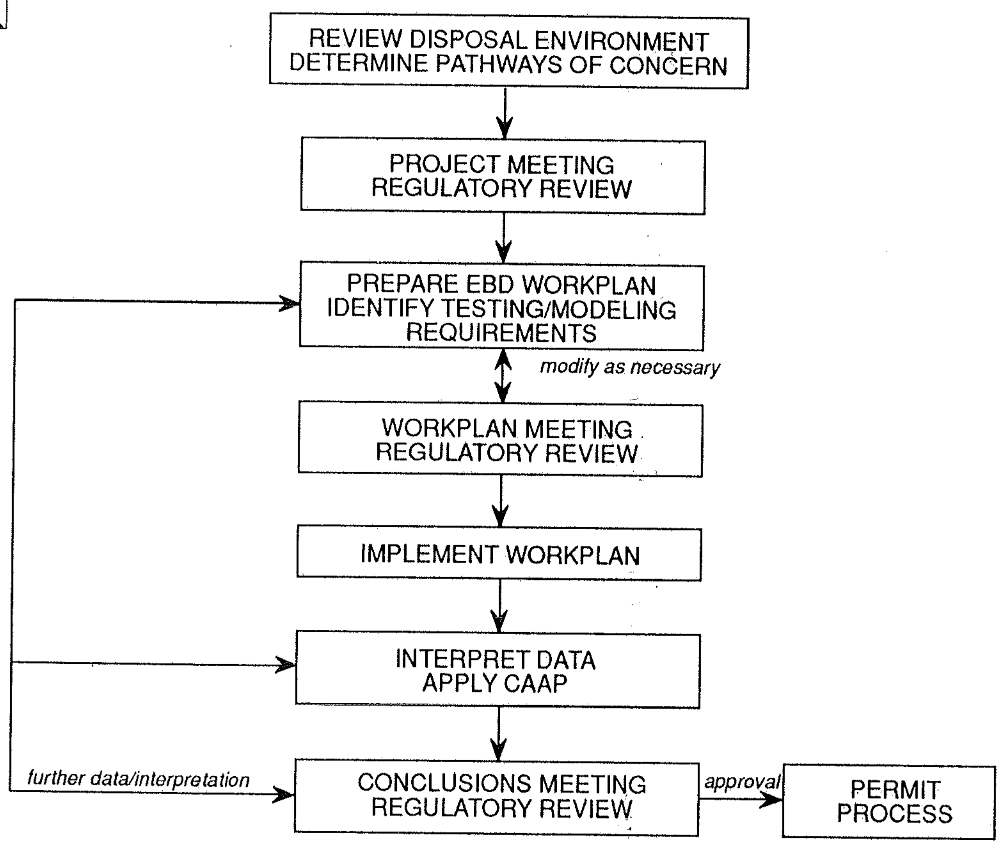


Figure 3. Effects-based Design Process

2. PATHWAYS OF CONCERN CHECKLIST

The functional designs that were developed were intended to block potential contaminant transport pathways. For each disposal environment and dredging method, the transport pathways vary. The main pathways of concern are illustrated in Figures 4, 5, 6, and 7. Each of the technologies identified in the functional designs were targeted at blocking contaminant transport along certain pathways. In some cases a certain technology may only block one pathway, while in other cases a technology may serve to block several pathways. Collectively, these technologies comprised a functional design that provided an adequate level of environmental protection.

Both EBD and FD must meet a requisite level of environmental protection (Figure 8). The issue of assessing adequate protection is discussed further in Chapter 4. The basic thrust of EBDs is that they must also block the pathways that the FD blocks. Therefore, the logical place to begin evaluating effects-based designs is to determine what the pathways of concern are for a particular design. Certain technologies are associated with particular pathways of concern. Use of the checklist will call attention to pathways of concern in an EBD.

2.1 PURPOSE OF THE CHECKLIST

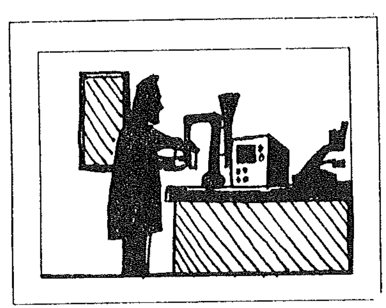
EBDs will have different technologies (site designs and dredging/disposal methods) than the function designs. The checklists will define what pathways of concern are associated with these different technologies. Applicant analysis and regulator attention should focus on the pathway of concern and corresponding technology/site condition during Effects-Based Design assessment.

The checklist can be used by the proponent/applicant to:

- Understand pathways of concern that are applicable to the proposed disposal environment
- Identify pathways to be assessed by testing for EBD approval
- Identify potential engineering options, site conditions, and/or sediment characteristics that will protect pathways that are identified.

The checklist can be used by regulatory or review agency to:

- Identify disposal site elements that must be analyzed by engineering design professionals



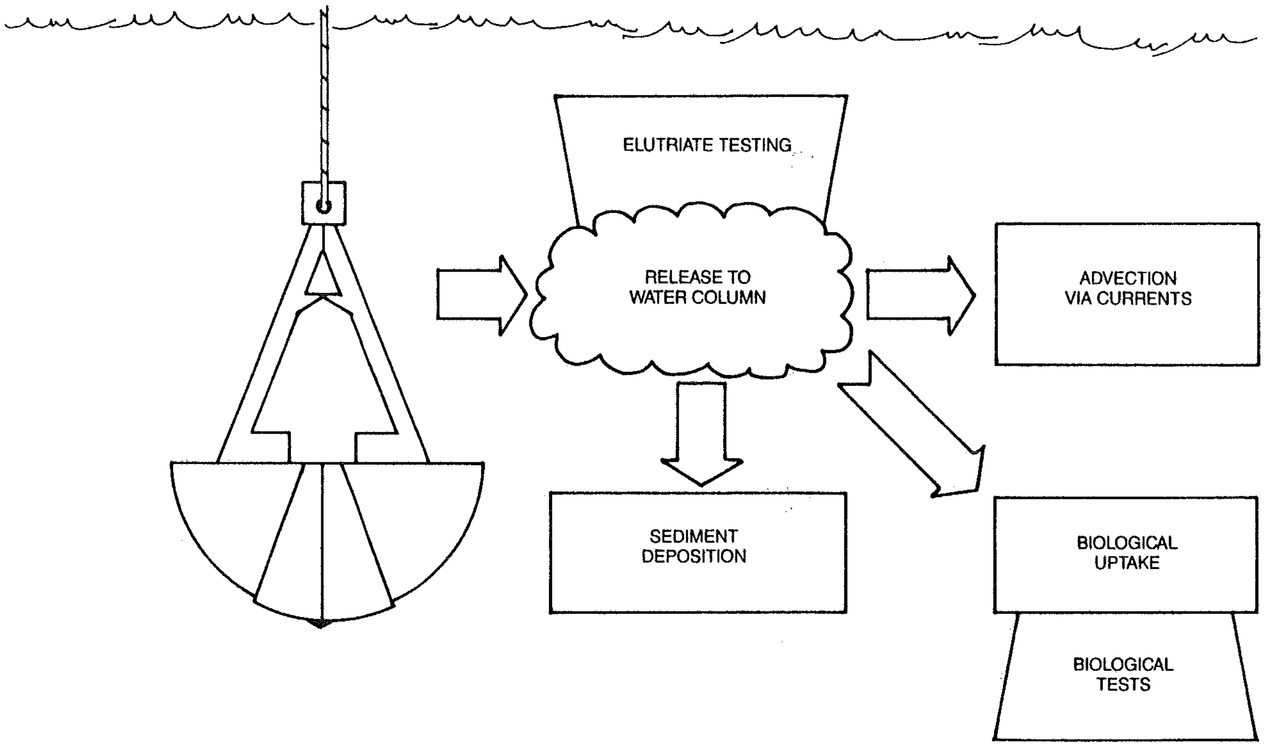


Figure 4. Exposure pathways associated with dredging and transport of contaminated sediments.

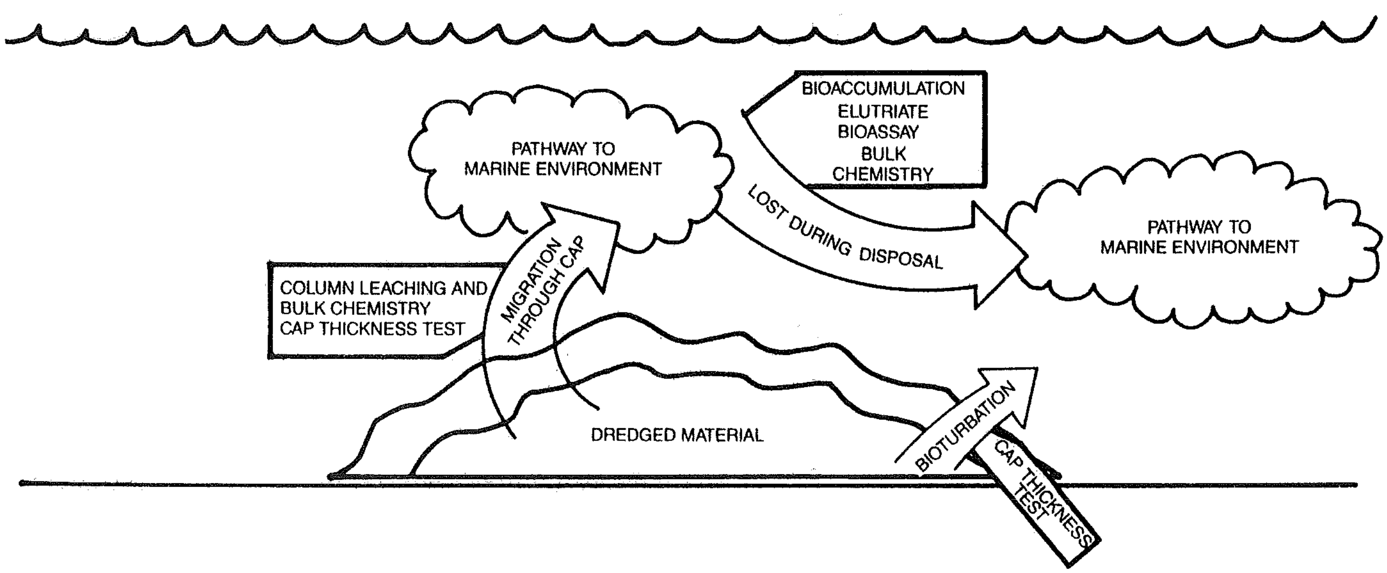


Figure 5. Exposure pathways associated with capped aquatic disposal.

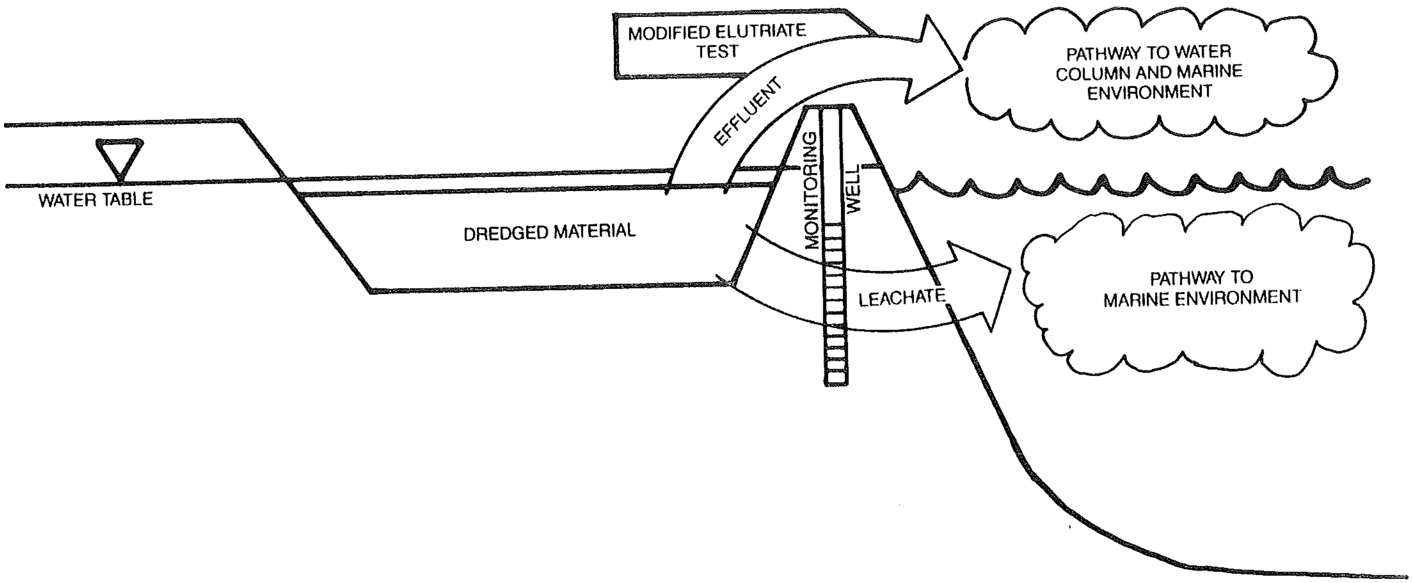


Figure 6. Exposure pathways associated with nearshore disposal.

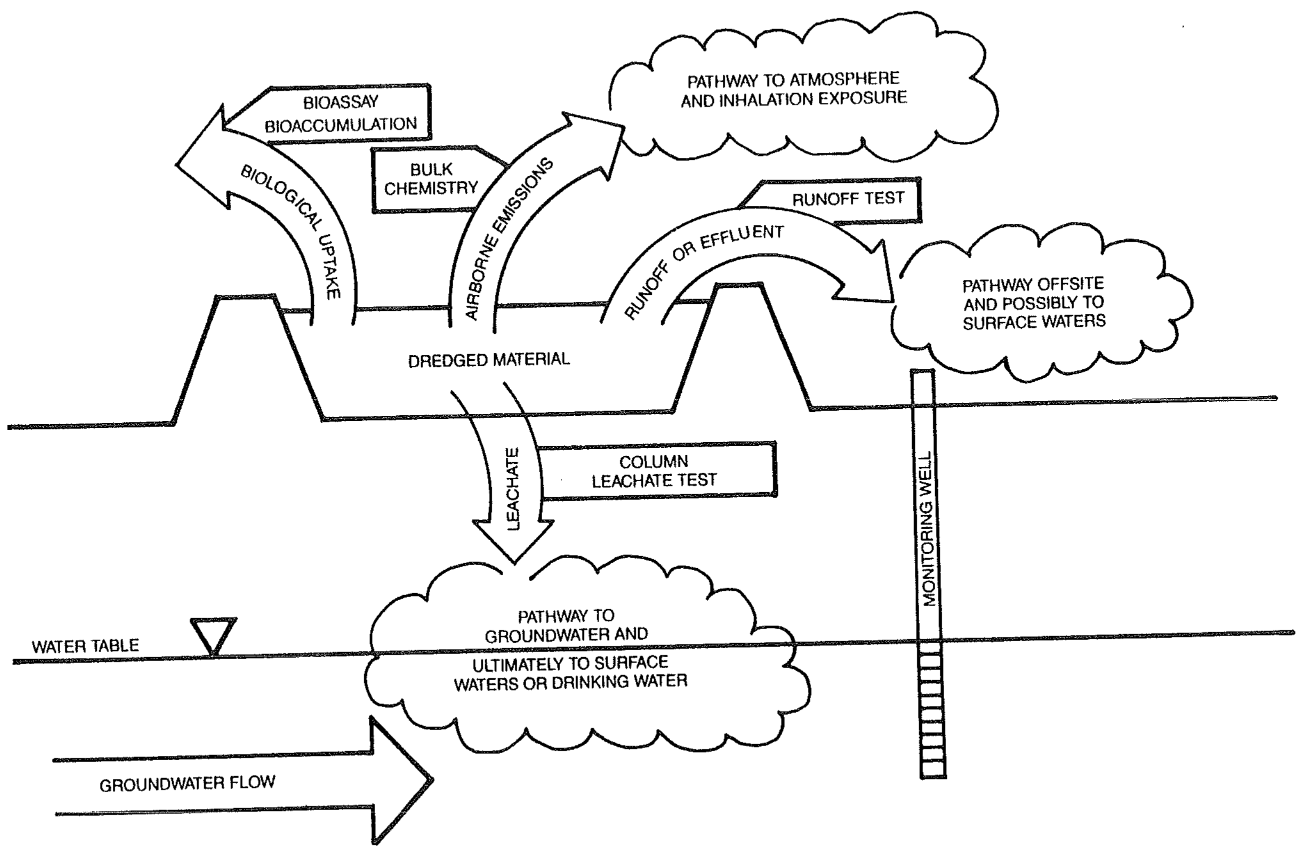


Figure 7. Exposure pathways associated with upland disposal.

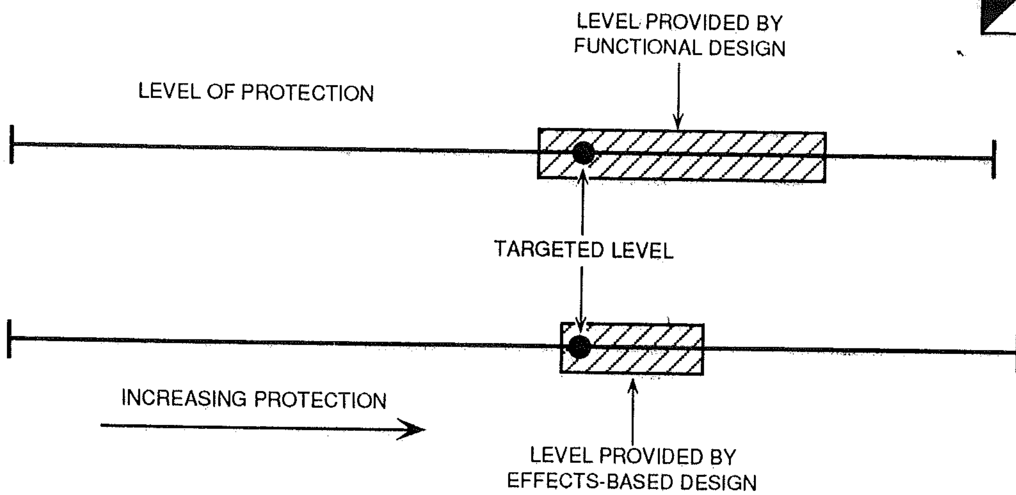


Figure 8. Conceptual representation of the level of protection provided by the FD and EBD.

- Establish acceptability of proposed testing workplan to satisfy EBD
- Provide a basis for application review and continued dialogue with applicant.

2.2 HOW TO USE THE CHECKLISTS

In using these checklists, a proponent should compare the technologies they are considering for their effects-based design against those listed in the checklist. Where the effects based design suggests an alternative technology(s), a proponent should note what pathway(s) is of concern. The key to a successful effects-based design is to be able to demonstrate that the pathway(s) which was noted can be adequately protected by the alternative technology(s).

The checklists are formatted with potential contaminant transport pathways being the focal point. There is a checklist for each of the following disposal environments:

- Confined Aquatic
- Nearshore
- Upland Monofill

Each checklist is separated into the following disposal operation components:

- Dredging
- Material Transport
- Material Placement
- Site Design
- Monitoring

The checklists (Tables 2.1 through 2.3) are structured in a matrix fashion. Across the top of the matrix are potential pathways of concern. Down the side of the matrix are technologies (characterization tests, site design features, and dredging and disposal methods) for each of the disposal operation components.

An "X" is placed in the cell of a matrix where a technology adequately protects a pathway of concern. If a cell is left blank, this indicates the pathway is not of concern because it is not a potential route of contaminant transport. The technologies presented in these checklists are the same as those in the functional design. The technologies are presented to help identify pathways. They are in no way intended to be technologies that drive effects-based designs.

The technologies identified for functional designs are required because they address certain issues associated with contaminant transport along pathways. Understanding these issues is important to determine if an alternative technology (effects-based design) provides adequate protection. The issues associated with each technology are also summarized on Tables 2.1 through 2.3. These issues provide two functions:

- better define why a certain technology was required for the functional design,
- identify what the alternative technology needs to focus on in demonstrating that it provides adequate protection

Once the pathway(s) has been identified, the next step of the EBD process is to demonstrate that an alternative technology can provide adequate protection. A workplan approach has been developed that is a systematic way to determine if an EBD provides adequate protection. The workplan approach is described in detail in the next chapter.

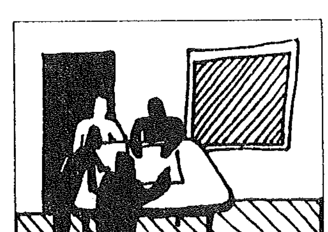
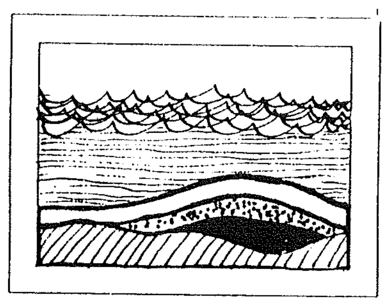


Table 2.1. **CONFINED AQUATIC DISPOSAL PATHWAYS OF CONCERN CHECKLIST**

WC = water column; BU = biological uptake; SW = surface water; GW = groundwater; RO = runoff; AE = airborne emissions; X = identifies pathways that are protected by corresponding technology

	Pathway of Concern						
	WC	BU	SW	GW	RO	AE	Issues
SEDIMENT CHARACTERIZATION							
Screening Test							
Bulk Chemistry							
• Contaminants are less than 0.1 Dangerous Waste (<0.1 DW)							Bulk chemistry is a general indicator of potential contaminant migration. Limiting chemistry for FD puts limits on possible environmental exposure.
Functional/Conventional Design Tests							
Biological Test							
• Results less than Site Condition III	X	X					Potential negative impact to aquatic organisms if biological tests exceed these standards and if the capping is not successful.
CAD SITE DESIGN							
Water Depth							
• Site location in depths between 80 and 200 ft.	X	X					Difficulty in accurately placing material and remediating a disturbed site in deep water. Potential disturbance of CAD from currents and/or mechanical forces such as ship anchors and prop wash in shallow water (less than 80 ft).
Bed Slope							
• Slope of bed is flatter than 3%.	X	X					The slope stability of the CAD site decreases with increasing slopes.
• Bed is loose, unconsolidated sediments thicker than 10 ft.	X	X					Energy dissipation of dump on sea bed. A hard bottom could result in greater areal distribution of the dump.
Bed Stability							
• Engineering Assessment completed using most relevant information indicating bed is stable for CAD design.	X	X					An unstable bed could result in loss of contaminated sediment.
Berms							
• No berms - bed slope, site stability and biological conditions satisfied.	X	X					Underwater berms can be difficult to construct. An improperly constructed berm could result in loss of contaminants. The FD is for sites which do not require berms.



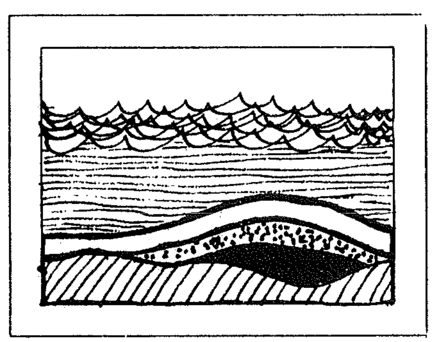
Aquatic

	WC	BU	SW	GW	RO	AE	Issues
	Pathway of Concern						
Water Column Velocities							
• Current velocities identified by available records or onsite measurement of near-bed, mid-depth and near-surface velocities.	X	X					Current velocities are needed to address the loss to the water column during dumping, as well as the erosional potential on the sea bed.
• Water currents less than 1 ft/sec or below 0.5 ft/sec near-bed.	X	X					Greater velocities could result in unanticipated loss of contaminants during dumping or due to bed erosion.
Design Volume							
• One time disposal greater than 10,000 yd^3.	X	X					Small project limitations.
• One time disposal less than 10,000 yd^3.	X	X					Yes (small projects)
Cap Design							
Cap Sediment Type							
• Cap materials placed by hydraulic slurry.	X	X					Other methods such as bottom dump barge could greatly displace the contaminated sediments.
• Cap materials a non-cemented sand matrix sediment.	X	X					The short-term strength of the cap could be compromised by use of other than sandy soils.
Cap Sediment Quality							
• Sediments chemically meet screen level PSDDA requirements.	X	X					Cap material should not violate PSDDA.
Cap Thickness							
• Technical design demonstrates primary cap thickness greater than 3 ft after placement and consolidation.		X					Caps of lesser thickness may not provide the desired long-term isolation of the contaminated sediment.
CAD DREDGING STANDARDS							
Dredge Type							
• Contaminated sediments dredged by mechanical clamshell dredge	X	X					Mechanically dredged sediments retain significantly more strength than hydraulically dredged sediments. This helps limit the loss during disposal.
• Contaminated sediments dredged by mechanical dredge with clamshell bucket size of 5 yd^3 or larger	X	X					Use of smaller buckets would result in proportionally more remolding of the soil and associated loss of strength. This could result in greater loss during disposal.
• Dredging depths limited to 200 ft or less	X						Depths greater than 200 ft are outside of the "normal" depths of dredging. There is an increased risk of loss to the water column during dredging.

	WC	BU	SW	GW	RO	AE	Issues
	Pathway of Concern						
• Contaminated dredge plan includes 1 ft or more overdepth beyond contaminated and clean sediment interface.	X	X					Overdredging by 1 ft is intended to accommodate variations between explorations.
CONTAMINATED TRANSPORT							
Transport Type							
• Contaminated materials will be transported from dredge to disposal by bottom-dump haul barge.	X	X					Contaminated sediment needs to be transported to the disposal site in an intact state following mechanical dredging (not hydraulic slurry) to avoid significant strength loss, and greater loss during disposal.
MATERIAL PLACEMENT							
Contaminated Placement							
• Contaminated sediments will be rapidly released below water surface.	X	X					Rapid placement is required to reduce segregation of the mass, and thereby reduce loss during disposal.
• Release position will be established by electronic system with plus or minus 3-meter accuracy.	X	X					Accurate placement of contaminated sediment is required to accurately cap sediment.
• Target area for release will be within a 500-foot radius.	X	X					Control the size of the CAD.
Capping Placement							
• Capping materials will be released as a hydraulic slurry over the contaminated sediments.	X	X					Hydraulic slurry has a significantly less disturbing impact on the contaminated sediments, and results in less resuspension or displacement of contaminated sediments.
• One week minimum will elapse between contaminated placement and capping placement.	X	X					The time period allows for initial consolidation and strength gain of the contaminated sediments, and results in less disturbance during capping.
• Technical analysis will demonstrate gradual and uniform cap placement to avoid contaminated displacement.	X	X					Gradual and uniform cap placement will reduce potential for displacement of contaminated sediment.
• Single cap lift will not be greater than 4 ft thick.	X	X					As above.
• Each cap lift will be complete over the contaminated sediments before the next lift commences.	X	X					As above.
• Cap slurry discharge position will be by electronic system with plus or minus 3-meter accuracy.	X	X					To provide necessary control for gradual and uniform cap placement.

	Pathway of Concern						Issues
	WC	BU	SW	GW	RO	AE	
MONITORING							
Dredging Site							
Bathymetry							
• Surveys will be accomplished at least one time per week.	X	X					Surveying to assure that the contaminated sediments are being removed as planned.
• Acoustical depth sensing techniques will be employed.							Provides a more consistent and rapid result than manual techniques.
• Cross-section spacing no greater than 25 ft will be employed.							As above.
Dredge/Survey Positioning							
• Dredged position updated at each dredging relocation during clamshell dredging.							To assure that the contaminated sediments are being removed as planned.
• Positioning of dredging by method capable of plus or minus 3-meter accuracy.							As above.
Disposal Site, Short Term							
Positioning							
• Positioning of disposal by electronic positioning capable of plus or minus 3-meter accuracy.	X	X					Accurate placement of contaminated sediment is required to accurately cap the sediment.
Bathymetric Surveys							
• Bathymetric surveys done before disposal, monthly intervals during disposal and two weeks after contaminated sediment disposal.		X					Bathymetric surveys give an indication of the nature and extent of the CAD.
• Bathymetric surveys after each lift of cap placement and one month after site is capped.							As above.
• Bathymetry will be obtained by acoustic depth sounder with real time and data logging of x-y-z.							Provides a more consistent and rapid result than manual techniques.
Sidescan Surveys							
• Sidescan surveys before and within two weeks after contaminated disposal.							Sidescan surveys indicate the nature and extent of contaminated sediment which aids in refinement of the capping plan and in establishing the baseline condition of CAD prior to capping.
• Sidescan survey within one month after site is capped.							To indicate the nature and extent of the cap, and as a baseline to refine, if necessary, the long-term monitoring plan.

	Pathway of Concern						
	WC	BU	SW	GW	RO	AE	Issues
Sediment Profile Sampling							
• Sediment profile camera survey within two weeks after completion of contaminated disposal.		X					Identifies the extent of contaminated sediment, particularly in the outer flanks. The results are used to establish if the contaminated sediments will be covered by the planned cap.
• Sediment profile camera survey within one month after site is capped.		X					Used to verify that the contaminated sediments were capped.
Shallow Borings							
• Shallow borings obtained before contaminant disposal and after cap placement.		X					The pre-disposal borings establish the nature of the native sediments, such as grain size and density/consistency, which is needed for design. The post cap borings verify the cap thickness.
<u>Disposal Site, Long Term - First Year</u>							
Bathymetry		X					
• Bathymetric surveys conducted at three and six months.		X					Indicates large-scale changes in CAD shape.
Sediment Profile Samples		X					
• Sediment profile camera surveys conducted at three and six months.		X					As above, but on a finer scale.
<u>Disposal Site, Long Term - Subsequent Years</u>							
Shallow Borings							
• Borings obtained during years two, four, seven, and ten after capping.		X					Indicates if the cap is changing.
Benthic Resources Evaluation							
• BRAT surveys will be conducted during years two, four, and seven after capping.		X					



Aquatic

Table 2.2. **NEARSHORE CONFINED DISPOSAL PATHWAYS OF CONCERN CHECKLIST**

	Pathway of Concern						
	WC	BU	SW	GW	RO	AE	Issues
SEDIMENT CHARACTERIZATION							
Screening Test							
Bulk Chemistry							
• Contaminants are less than 0.1 Dangerous Waste (<0.1DW)	X	X	X	X	X	X	Bulk chemistry is a general indicator of potential contamination migration. Limiting chemistry for FD puts limits on possible environmental exposure.
Functional/Conventional Design Tests							
Water Quality Test							
• Effluent tests pass applicable Water Quality Criteria with or without attenuation/dilution factor.			X	X			Protection of surface water and groundwater from degradation by contaminant migration.
NEARSHORE SITE DESIGN							
Groundwater/Tidal Elevations							
• Long-term consolidated elevation of contaminated material will be below the lowest groundwater/tidal elevation.				X			Keep the sediments saturated so they remain anaerobic, and the contamination stays bound to the sediment.
Bed Materials							
• Investigation of bed materials completed for geotechnical design of dike structure and site consolidation.	X	X	X	X	X	X	Facility should be designed to be stable with respect to actual subsurface conditions. Otherwise, release of contaminated sediments could occur.
Equipment Access							
• Transport equipment access to site identified and available.							Constructability.
Distance from Dredging							
• Distance within a pumping distance requiring less than two booster pumps.							Constructability, and to limit the possiblity of material loss due to pipe failure.
Confinement Dikes							
• Dikes designed using accepted geotechnical and earthwork engineering methods.							See bed materials.

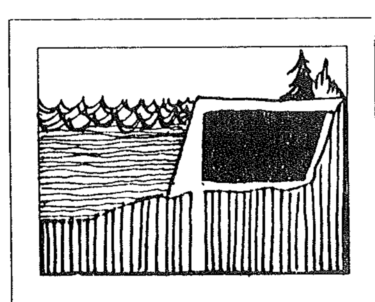


Table 2.2. **NEARSHORE CONFINED DISPOSAL PATHWAYS OF CONCERN CHECKLIST**

	Pathway of Concern						
	WC	BU	SW	GW	RO	AE	Issues
• Adequate retention is available based on effluent quality release of less than 100 mg/L.			X				Improper retention basins and outlet could result in loss of contaminated sediment at the overflow.
Effluent Control							
• Drop inlet sluice style outlet is designed for dredge size, with overflow depths of 2-4 inches.							As above.
Cap Design							
• Cap over contaminated sediments includes a primary and final cap.		X	X		X	X	The primary cap provides short-term isolation of the contaminated sediments, until the site is ready to receive the final cap.
• Final cap is an engineered design appropriate for future use and contaminant isolation.		X	X		X	X	The final cap is designed to accommodate the site usage, while not exposing the contaminated sediments to the air, or to biological disturbance.
NEARSHORE DREDGING STANDARDS							
Dredge Type							
• Contaminated sediments are dredged by hydraulic pipeline dredge.	X						Hydraulic dredging does not require rehandling of the material, and results in less contaminant loss.
• Depth of cut during any one swing advance of dredge limited to a value less than 1.5 diamter of cutter head.	X						These dredging techniques result in greater control of dredging, and less chance for resuspension and loss of contaminants.
• Removal of contaminated layer includes a minimum 1 ft of clean sediments below contaminated and clean sediment interface.	X	X					Overdredging by 1 ft is intended to accommodate variations between explorations.
CONTAMINATED TRANSPORT							
Transport Type							
• Contaminated materials will be transported from dredge to disposal by hydraulic discharge pipeline.	X	X	X	X	X	X	To accommodate hydraulic dredging and reduce potential for loss during transport.
• Discharge pipeline route and type of discharge line is identified, and is acceptable.							Availability of easements for overland or in water pipeline routes may limit disposal site selection.
• Submerged pipeline required in navigation areas.							As above.
• Limit booster pumps in line to two or less.							Constructability.

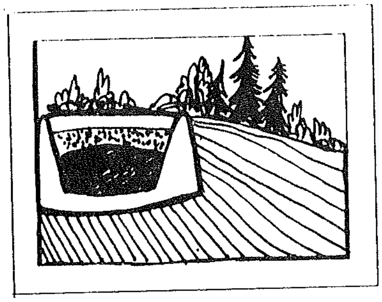
Table 2.2. **NEARSHORE CONFINED DISPOSAL PATHWAYS OF CONCERN CHECKLIST**

	Pathway of Concern						Issues
	WC	BU	SW	GW	RO	AE	
MATERIAL PLACEMENT							
Contaminated Placement							
• Contaminated sediments placed in site so as to remain saturated.			X	X			To limit the loss of contaminants through oxidation.
• Site controlled to prevent access during disposal.		X					To limit exposure to the uncapped contaminated sediment.
Cap Placement							
• Primary cap will be placed over contaminated sediments before surface drying occurs.		X	X	X	X	X	To keep the sediments saturated and limit exposure.
• Primary cap placed in lift thickness which is engineered to prevent displacement of contaminated materials.							Displacement of the contaminated sediments could result in contaminant loss.
• Final (secondary) capping will occur after initial phase consolidation and settlement of dredged materials.		X	X	X	X	X	Capping prior to initial phase consolidation could result in displacement of the contaminated sediments.
MONITORING							
Dredging Site							
Bathymetry							
• Surveys will be accomplished at least one time per week.	X	X					Surveying to assure that the contaminated sediments are being removed as planned.
• Acoustical depth sensing techniques will be employed.							Provides a more consistent and rapid result than manual techniques.
• Cross-section spacing equal or less than 25 ft will be employed.							As above.
Dredge/Survey Positioning							
• Dredged position shall be updated at 1-hour intervals and at each dredging relocation.							To assure that the contaminated sediments are being removed as planned.
• Positioning of dredging by method capable of plus or minus 3-meter accuracy.							As above.
Disposal Site, Short-Term Monitoring							
Effluent Overflow							
• Water samples will be obtained from slurry effluent immediately downstream of overflow weirs.			X				For analysis of suspended sediments and targeted contaminants.

Table 2.2. **NEARSHORE CONFINED DISPOSAL PATHWAYS OF CONCERN CHECKLIST**

	Pathway of Concern						
	WC	BU	SW	GW	RO	AE	Issues
Water Quality							
• Water quality monitoring for DO and turbidity at dilution zone boundaries from effluent point of return will be completed.			X				Maintain necessary water quality compliance.
Groundwater Monitoring							
• Six sampling wells will be installed or already available for groundwater monitoring.				X			Monitor the impacts to groundwater.
• A minimum of one sample round will be obtained after five days of disposal or before end of disposal, whichever occurs first, and anlyzed.				X			As above.
Periphery Water Chemistry							
• Waterways adjacent to confinement structure will be sampled weekly.			X				Monitor the impacts to adjacent water bodies.
• Samples will be collected 2 ft below water surface during last three hours of ebb tide and analyzed.							As above.
Disposal Site, Long-Term Monitoring							
• Waterways adjacent to nearshore confinement structures will be sampled annually.			X				To monitor the impacts to adjacent water bodies.
• Samples will be collected 2 ft below water surface during last three hours of ebb tide conditions.							As above.
• Samples will be analyzed for chemicals of concern.							As above.
Groundwater Monitoring							
• Six wells sampled five times during first year.				X			To monitor the impacts to the groundwater.
• Six wells sampled twice a year for a specific period of time.							As above.
• Samples will be analyzed for chemicals of concern.							As above.
Cap Borings							
• A minimum of four borings through cap sediments is identified in monitoring plan for review and approval.		X		X			To establish actual thickness of the cap and to identify any contaminant migration through the cap.

Table 2.3 **UPLAND MONOFILL CONFINED DISPOSAL PATHWAYS OF CONCERN CHECKLIST**



	Pathway of Concern						
	WC	BU	SW	GW	RO	AE	
SEDIMENT CHARACTERIZATION							
Screening Test							
Bulk Chemistry							
Monofill Lined							
• Contaminants are less than Dangerous Waste (<DW).	X	X	X	X	X	X	As required by WAC 173-304.
Monofill Unlined							
• Contaminants are less than 0.1 Dangerous Waste (<0.1 DW).	X	X	X	X	X	X	Bulk chemistry is a general indicator of potential contaminant migration. Limiting chemistry for FD limits possible environmental exposure.
Functional/Conventional Design Tests							
Monofill Unlined							
• Effluent tests pass applicable water quality criteria with or without attenuation/dilution factors.			X	X			Protection of surface water and groundwater from degradation by contaminant migration.
SITE DESIGN - MONOFILL LINED							
• Bottom liner is either 30 mil liner above 2 ft of material with hydraulic conductivity of 10^{-6} cm/sec OR Bottom liner is 4 ft material with hydraulic conductivity 10^{-6} cm/sec without geomembrane liner.				X			Provide a barrier to block migration of leachate from the fill to the surrounding subsurface.
• Leachate collection system maintains no more than 2 ft of head above the liner				X			Provide a leachate collection system which is properly sized to handle the possible flows from the fill.
• Leachate disposal system designed to handle 1.25 times calculated volume entering it.				X			As above.
• Onsite leachate must pass NPDES discharge standards.			X				To protect the receiving waters from degradation.
• Offsite leachate meets pretreatment standards.			X				As above.
• All natural materials used at upland monofill site are chemically compatible with brackish water.				X			Some materials, such as clay liners, may degrade when contacted by brackish water.

• Access to disposal site and leachate collection system is prevented.							Limit exposure to contamination.
• Dredged sediments placed in controlled, measured quantities.	X	X	X	X	X	X	Proper construction to limit the possibility of an uncontrolled release.

SITE DESIGN - MONOFILL UNLINED

• Surface water management system able to handle runoff from 2-year and 50-year storm.				X			Control of runoff is required to limit infiltration of water into the monofill.
• Surface water management system able to handle run-on from 50-year storm.				X			As above.
• Final cover is either 30-mil thick liner above 1 ft material with hydraulic conductivity of 10^{-6} cm/sec. OR Final cover is 2 ft of low permeable material without liner.				X			As above.
• Drainage layer keeps head over line no more than 1 ft.				X			As above.
• Unlined monofill is located over brackish aquifers.							Water which leaches from a marine sediment will be brackish. The receiving groundwater may be degraded unless it is also brackish.
• Access to site is prevented.							Limit exposure to the contaminated sediments.
• Dredged sediments placed in controlled, measured quantities.	X	X	X	X	X	X	Proper construction to limit the possibility of an uncontrolled release.

UPLAND MONO DREDGING STANDARDS

<u>Dredge Type</u>

• Contaminated sediments are dredged by mechanical clamshell dredge.	X	X	X	X	X	X	Mechanical dredging limits the amount of entrained water, and reduces the potential for contaminant loss during rehandling.
• Dredging depths limited to 200 ft or less.							Constructability and loss during dredging.
• Contaminant dredge plan includes 1 ft or more overdepth beyond contaminated and clean sediment interface.	X	X					The overdredging by 1 ft is intended to accommodate variations between explorations.

CONTAMINATED TRANSPORT

<u>Transport Type</u>

• Contaminated materials will be transported from dredge to rehandling site by haul barge.							To avoid entraining additional water, as would happen with hydraulic transport.
• No overflow of sediment will be allowed from haul barge during dredging or transport.							To reduce the resuspension of contaminated sediments in the water column.

• Flat deck barges will be watertight along side board and deck interface.							As above.
• Shallow hull barges will have hydraulic system checking.							As above.
<u>Rehandling</u>							
• Offloading of contaminated sediments from haul barge only at approved rehandling site.	X	X	X	X	X	X	To reduce potential for uncontrolled release of sediments.
• No stockpiling of contaminated sediments will occur during rehandling.							As above.
• Rehandling site will be contained to control incidental contaminated sediments misplaced during offloading.							As above.
<u>Upland Haul</u>							
• Contaminated sediments transported from rehandling site to disposal site using lined, watertight and covered haul equipment.							
<u>Action Plan</u>							
• Action plan to control and avoid sediment loss during rehandling, dewatering, and haul to final disposal is completed.	X	X	X	X	X	X	To limit the possibility of an uncontrolled release of contaminants.
• Action plan identifies location of rehandling and dewatering.							As above.
• Action plan identifies dewatering method and clean up.							As above.
MONITORING							
<u>Dredging Site</u>							
Bathymetry							
• Surveys will be accomplished at least one time per week.	X	X					Surveying to assure that the contaminated sediments are being removed as planned.
• Acoustical depth sensing techniques will be employed.							Provides a more consistent and rapid result than manual techniques.
• Cross-section spacing greater than 25 ft will be employed.							As above.
Dredge/Survey Positioning							
• Dredged position updated at each dredging relocation for clamshell.							As above.
• Positioning of dredging by method capable of plus or minus 3-meter accuracy.							As above.

Disposal Site - Monofill Lined

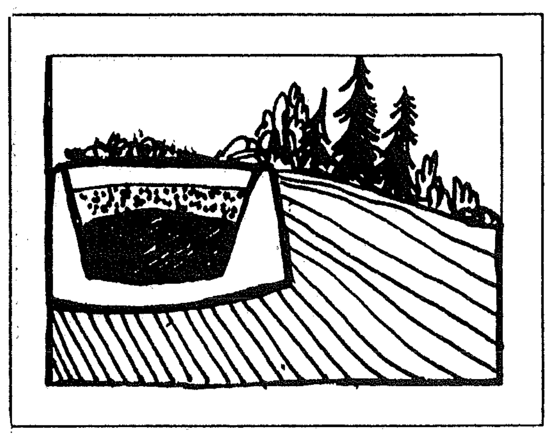
Groundwater

• Four wells will be sampled.		Monitor the impacts to groundwater.
• First year sampling will be each well five times.		As above.
• Second and subsequent year sampling will be each well two times per year.		As above.
• Priority pollutants tested in all post disposal samples.		As above.
• Project is a dredging project ranging from 10,000 to 500,000 yd^3.		Small projects are given special consideration. Large projects will be EBD.

Disposal Site - Monofill Unlined

Groundwater

• Five wells will be sampled.	X	Monitor the impacts to groundwater.
• First year sampling will be each well, six times.		As above.
• Second and subsequent year sampling will be each well two times per year.		As above.
• Priority pollutants tested in all post disposal samples.		As above.
• Project is a dredging project ranging from 10,000 to 500,000 yd^3.		Small projects are given special consideration. Large projects will be EBD.



Upland

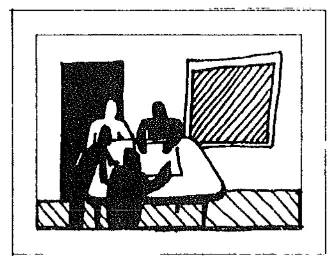
3. WORKPLAN

The first step in proposing an EBD is development of a work plan. This chapter presents discussion of the workplan process, and provides three examples.

3.1 CONTENTS OF WORKPLAN

The workplan identifies the issues of concern of a proposed sediment disposal project, identifies possible solutions, presents a scope for testing/modeling/analysis, and establishes the interpretation criteria for the work. In identifying solutions (site features, technologies, etc. that block the pathways of concern), the workplan must identify alternative EBDs. These alternatives should target at providing adequate environmental protection. The presence of alternatives will streamline the regulatory review process because there will be more than one solution to evaluate. At a minimum, each work plan should contain the following items:

- overview
- variations
- mitigating features
- tests/models
- alternative designs.



3.1.1 Project Overview

The project overview describes the general location and nature of the project. It includes site maps, sediment data, dredging alternatives, and disposal alternatives.

Existing sediment data is useful in understanding the impact of a proposed project:

- Soil and water chemistry
- Physical soil properties
- Bioassay results
- Volume to be dredged.

The proposed dredging plan (with map) should identify the general dredging and transport methodologies. The proposed disposal plan should identify the disposal site location and size (with map), and the general disposal technology.

3.1.2 Pathways of Concern

The checklist presented in Chapter 2 highlights the issues of concern and identifies the environmental pathways that could contribute to contaminant loss. The workplan should summarize the project components (design features, site features, dredging methods, etc.)

that trigger pathways of concern.

3.1.3 Mitigating Design Features

The project sponsor should include in the workplan the proposed solution (mitigating feature) for providing adequate environmental protection. This is the portion of the workplan where a proponent should present alternative EBDs. For example, a CAD project might be proposed for less than 80 ft of water, with the proposed solution incorporating the armoring of the CAD. The alternatives presented may include different armoring materials and/or differences in armoring thickness.

3.1.4 Proposed Testing/Modeling/Analysis

Chemical, biological, and/or water quality tests can be used to demonstrate acceptably low levels of contaminant migration potential and establish the performance of the EBD. Solute transport modeling can be used to demonstrate the favorable attenuation or dilution of contaminants before they reach a receiving water. For example, engineering analyses can be completed to demonstrate that an asphalt concrete pavement over an upland fill is a suitable substitute for the functional design cover.

The workplan shall spell out details of the work intended to substantiate proposed EBD alternatives. It shall identify the type and quantity of testing/modeling/analysis and the specific conditions to which they will be applied.

3.1.5 Incorporation of CAAP Evaluation

Chapter 4 (Page 41) describes the CAAP evaluation procedure. The process relates to the pathways of concern checklist presented in Chapter 2 and establishes a method for scoring the results of testing/modeling/analysis. Each EBD alternative should be evaluated using the CAAP procedure. The results of the CAAP evaluation will be used in the final evaluation of the EBD alternatives. How the CAAP scores can best be used, especially in the early development of the procedure, is explained in detail in Chapter 4. The workplan should address how the results of the proposed testing/modeling/analysis will be incorporated into the CAAP evaluation process.

3.2 TESTING/MODELING ANALYSIS CONSIDERATIONS

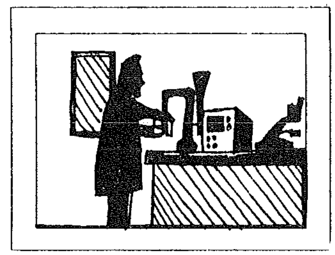
3.2.1 Testing and Modeling

The approach and methodologies for assessing contaminant release from dredged material are currently evolving. The tests and models currently recommended in the *Documentation of Standards Development Report* are seen as transitional, pending development of new technologies. As new tests and models become available and are validated, their inclusion in the effects-based process will be appropriate.

The *Documentation Report* presents considerable discussion regarding testing and modeling. Specifically, Section 9.1 presents a phased methodology for sediment characterization. The four phases are:

- Phase 1 - Existing Data Review
- Phase 2 - Screening Tests
- Phase 3 - Functional/Conventional Design Tests
- Phase 4 - Sediment Characterization for Effects-Based Design.

This process is summarized in Figure 9.



Testing

Phase 1: Existing Data

EXISTING DATA

Phase 2: Screening Tests

SCREENING TEST
- Work Plan
- Bulk Chemistry
- Soil Index Prop

Phase 3: Functional/Conventional Design Tests

AQUATIC: OPEN WATER
- Bioassay (PSDDA)

AQUATIC: CAPPED
- Bioassay (PSDDA)

NEARSHORE: UNLINED
- Modified Elutriate
- Leaching (Column)
- Column Settling

UPLAND: MONO UNLINED
- Leaching (Column with Aging)

UPLAND: MONO LINED
- None Required

UPLAND: MIXED LINED
- None Required

Phase 4: Effects Based Design Tests/Models

AQUATIC: CAPPED
- Modified Elutriate
- Leaching (Column)
- Cap Thickness
- Dump Model
- Discharge Model
- Solute Transport Model

NEARSHORE: UNLINED
- Cap Thickness
- Plant Intake
- Runoff
- Solute Transport Model

UPLAND: MONO UNLINED
- Cap Thickness
- Plant Uptake
- Runoff
- Solute Transport Model
- Mod. Elutriate

UPLAND: MONO LINED
- Cap Thickness
- Plant Uptake
- Runoff

UPLAND: MIXED LINED
- Cap Thickness
- Plant Uptake
- Runoff

Figure 9. Phased approach to sediment characterization

In general, the tests required for screening (Phase 2) and functional/conventional design (Phase 3) will be required for effects-based design. In addition, tests that address cap effectiveness, solute transport, surface runoff, biological uptake, and other pathways of concern may be required to address specific characteristics of each project. The seven primary pathways and the control methods to provide adequate environmental protection along these pathways are summarized in Table 3.1.

Table 3.1. Functional design pathway controls.

Pathways	Control Methods
Water Column	Limiting modified elutriate test concentrations to applicable water quality criteria.
Surface Water	Limiting chemical concentrations and runoff.
Groundwater	A landfill liner (upland-lined) or limiting leachate concentrations to applicable water quality criteria.
Runoff	Cap, limiting chemical concentrations, and construction controls.
Airborne Emissions	Cap, limiting chemical concentrations, and construction controls.
Fugitive Dust	Cap, limiting chemical concentrations, and construction controls.
Biological Uptake	Cap and limiting chemical concentrations.

A variety of tests are available to assess how well site design technologies, or dredging/disposal methods provide environmental protection. These tests are summarized in Tables 3.2, 3.3, 3.4, and 3.5; and are presented in Chapters 4, 9 and 10 of the *Documentation Report*. A proponent should use these tables to help select the appropriate tests/models to evaluate their EBD alternatives.

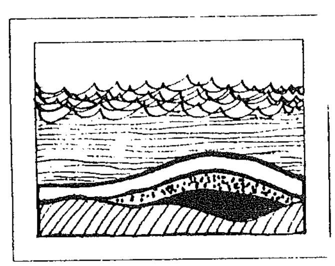
3.2.2 Risk Assessment

When dealing with upland disposal environments, there is an overlap between land-based regulations and dredging/disposal regulations. Two pathways of concern have been identified for contaminant release in the upland environment. One of these is release to the groundwater, and the other is release to the air and "above-ground" environment (i.e., plants, wildlife, and human exposure). Release to the groundwater is controlled through liners. The need for liners can be evaluated through leachate tests and hydrogeologic modelling that are identified in Tables 3.2 through 3.5. This section of the document deals with evaluating acceptable levels of contaminants that are not controlled through a cap.

The functional design standards we have identified for upland and nearshore disposal require that sites be capped. The cap serves two purposes. It minimizes infiltration of surface water through the contaminated material and reduces the potential for contaminated

Table 3.2. Capped aquatic disposal effects-based design testing/modeling.

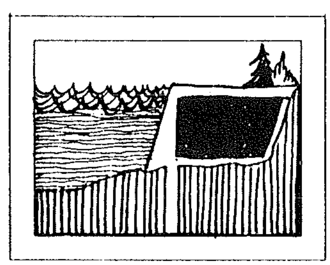
Test	Pathway	Results	Use/Interpretation
Chemical			
Bulk chemistry	All pathways	Numerical concentrations	Design accordingly
Standard elutriate	Surface water	Numerical concentrations	Design for appropriate dilution based on whether appropriate WQC are exceeded
Modified column leaching	Groundwater transport	Numerical concentrations	Design for attenuation/ dilution
Solute transport modeling (groundwater discharge zone)	Groundwater transport	Numerical concentrations	Design for attenuation/ dilution
Cap thickness	Diffusion to surface water Bioturbation	Thickness of cap	Design cap according to results
Biological			
PSDDA Biological Testing	Diffusion to surface water	Toxicity to marine organism	Modify cap or other design features according to results
Physical			
Dump Model	Surface water	Sediment loss	Sizing of disposal site
Discharge Model	Surface water	Sediment loss	Sizing of disposal site



Aquatic

Table 3.3. Nearshore disposal effects-based design testing/modeling.

Test	Pathway	Results	Use/Interpretation
Chemical			
Modified elutriate	Surface water	Numerical concentrations (model of effluent)	Design for appropriate dilution based on whether appropriate WQC are exceeded (treatment for effluent)
Column leaching	Groundwater transport	Numerical concentrations	Design for attenuation/ dilution based on whether appropriate WQC are exceeded
Runoff	Surface water transport	Numerical concentrations	Design for cover as needed
Solute transport modeling (groundwater discharge zone)	Groundwater transport	Numerical concentrations	Design for attenuation/ dilution based on whether appropriate WQC are exceeded
Biological			
PSDDA Biological Testing	Diffusion to surface water	Toxicity to marine organisms	Modify cover/berm or other design features according to results
Terrestrial/wetlands plant uptake	Terrestrial uptake of contaminants	Uptake by plants	Modify cover/berm or other design features according to results
Physical			
Column Settling Test (EM 110-2-5027)	Surface water	Solids loading/removal curves	Design retention basin size to control effluent loss



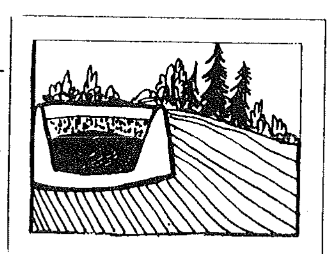
Nearshore

Table 3.4. Upland unlined disposal effects-based design testing/modeling.

Test	Pathway	Results	Use/Interpretation
Chemical			
Modified elutriate	Surface water	Numerical concentrations	Design for appropriate attenuation/dilution based on whether appropriate WQC are exceeded
Column leaching	Groundwater transport	Numerical concentrations	Design for attenuation/ dilution appropriate WQC are exceeded
Solute transport modeling	Groundwater transport	Numerical concentrations	Design for attenuation/ dilution appropriate WQC are exceeded
Runoff test	Surface water transport	Numerical concentrations	Determine appropriateness of cover
Biological			
Cyperus uptake bioassay	Biological uptake	Numerical concentrations	Determine appropriateness of cover based on evidence of biological waste

Table 3.5. Upland lined disposal effects-based design testing/modeling.

Test	Pathway	Results	Use/Interpretation
Chemical			
Runoff test	Surface water transport	Numerical concentrations	Determine appropriateness of cover
Biological			
Cyperus uptake bioassay	Biological uptake	Numerical concentrations	Determine appropriateness of cover based on evidence of biological uptake



Upland

leachate. It also isolates the contaminated material from plant, animal, and human exposure thus minimizing human health risks.

In some circumstances, a project proponent may want to dispose of their material upland, but not cap it. This circumstance may arise if a proponent believes their material is clean enough to serve as clean uncontrolled fill or daily cover at an existing landfill. In this type of circumstance, the issue that effects-based design testing needs to address is, what level of contamination is acceptable. A number of options are available. Some of the options include pre-determined contaminant limits, while others are more of a modelling approach to determine acceptable levels. In either case, all of them are founded on risk assessment approaches. The options are summarized below.

Model Toxics Control Act Cleanup Regulations. Initiative 97, the Model Toxics Control Act, requires the Department of Ecology to develop cleanup standards that are protective of human health and the environment. Ecology has developed draft standards (March 1990) to implement this law. Appendix A-4 of the draft standards lists soil cleanup standards for a variety of hazardous substances including heavy metals, PCBs, select pesticides, certain petroleum products, and a number of common organic constituents. The levels identified in this list were determined based on health risk evaluations. One option for a project proponent would be to compare the levels of contamination in their sediment against the proposed cleanup standards, if their levels were lower, than use of their material as uncontrolled fill would likely be acceptable.

Given the wide range of constituents present in dredge material, it is conceivable that not all of the constituents in the sediments will be on the list of proposed cleanup levels. In that situation the proposed regulations identify an equation for calculating the acceptable level. The equation is a risk assessment approach that defines the exposure period, the average weight of the individual being exposed, and the ingestion/absorption rates. The equation basically sets most of the parameters that are normally evaluated and set through a risk assessment process.

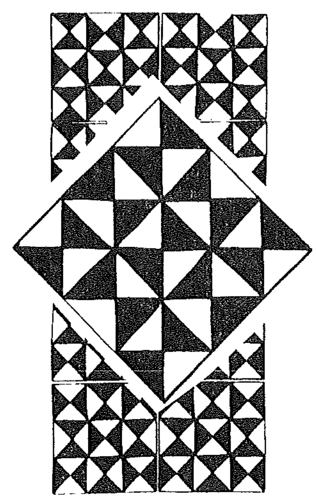
Risk Assessments. Risk assessments are commonly the driving force in establishing cleanup levels at hazardous waste sites. The US Environmental Protection Agency has established approaches for health risk evaluations at superfund sites (US EPA 1986). Risk assessments tend to evaluate the following parameters:

- Exposed population
- Ingestion rates
- Inhalation rates
- Absorption rates of chemicals
- Length of exposure
- Weight of individuals exposed
- Acceptable levels of risk.

Once each of these parameters is set, the risk assessment then establishes the level of contaminant that does not pose an unacceptable level of risk to human health. Acceptable levels of risk typically range between 10^{-4} to 10^{-7} for carcinogenic effects. For noncarcinogenic effects, concentration limits tend to be set at levels that do not result in a dose that exceeds the relevant allowable level of exposure (EPA acceptable intake for chronic exposure or EPA reference dose).

The main difference between traditional risk assessments and the equation in the draft Ecology regulations is that the equation in the draft regulations has already established all of the parameters. For example, the level of risk for carcinogen compounds is set at 10^{-6}.

Other Approaches. Health districts at a number of counties around Puget Sound have had to deal with the issue of determining what materials qualify as clean uncontrolled fill. In the past there have not been any models or standardized approaches used to determine material acceptance. For the most part, projects have been evaluated on a case by case basis. Health-based standards have historically been used since districts in the past have been more concerned with direct exposure pathways (i.e., inhalation and ingestion) as opposed to leachate to groundwater. An example of one standard that has been used in the past is the Toxic Substance Registry. Now that draft state standards have been published, some health districts have been using those criteria to determine what materials qualify for clean uncontrolled fill.



3.2.3 Site Specific Characteristics

Each disposal site will have unique physical and biological characteristics. These characteristics may be important for assessing an EBD. For example, a proponent may want to establish an EBD for a CAD site in less than 80 ft water. Navigation dredging, and cap disruption due to anchor dragging, are not issues due to site location. However, cap erosion due to wave force and natural currents are of concern. A physical oceanography study of the disposal site will clarify these concerns. This is just one example of how a site specific study could be used to validate an EBD. Table 3.6 lists common site specific studies that may be used to evaluate EBDs.

Table 3.6. Potential disposal site specific tests/investigations for verifying EBDs.

Test Type	Purpose
CAD Environment	
• Sieve size analysis of surface sediments	Assess whether the disposal site is an accretion or erosion zone.
• Settling cones	Same
• Near bed water samples	Same
• Currents	Same
• Side scan sonar	Uniformity of bed material over entire site
• Biological studies - trawls - benthos - REMOTS	Determine habitat importance, and species/life stage utilization
• Linear wave theory analysis	Determine erosional forces of waves at the site
Nearshore Environment	
• Groundwater elevation studies	Identify elevation corresponding to the anaerobic zone
• Groundwater chemistry	Determine what is coming on to the site, and history of the site
• Permeability studies	Determine permeability of berm, site, cap, and contaminated materials for input to modeling

• Biological studies - trawls - seines - benthos - epibenthos - REMOTS	Determine habitat importance, and species/life stage utilization. (Also will be used for determining appropriate mitigation.)
Upland Environment	
• Subsurface soil explorations	Determine presence of natural aquitards

3.2.4 Analysis

Technical analysis can be used to validate an effects-based design. Analyses could include:

- Engineering analysis for design of the dredging and disposal sites
- Regulatory analysis of the project for compliance with the appropriate laws and regulations
- Risk assessment to evaluate the potential impact to human health.

The technical analysis may incorporate the results of testing and modeling, or may be independent of such work.

3.3 EXAMPLE WORKPLANS

Three example projects are presented, each having a variation from the functional design. The purpose of these simplified cases will be to show how the basic workplan is put together:

- Confined aquatic disposal in shallow water
- Nearshore disposal with chemical screening results exceeding one-tenth Dangerous Waste
- "Conventional" upland disposal.

Each workplan will be based on the outline presented in Table 3.7. (The workplans will become the basis for discussion at pre-application meetings.)

Table 3.7. Workplan outline.

A.	Project Overview
B.	Variations from Functional Design
C.	Mitigating Design Features
D.	Proposed Testing/Modeling/Analysis
E.	Incorporation of CAAP Evaluation

NOTE:
The example workplans refer to figures and appendices that do not exist. Instead, these references are used to show how additional information could be incorporated into an actual workplan.

3.3.1 Example 1: Confined Aquatic Disposal in Shallow Water

A. Project Overview

ABC, Inc. intends to develop a 700-boat marina at the Puget Sound location shown on Figure ___. To establish the minimum draft of 10 ft at MLLW, the project will require dredging approximately 55,000 yd^3 of sediment.

Sediment Conditions. Sediment conditions at the site are generally understood, based on limited past sampling. These conditions are anticipated to be as follows:

Chemistry. The upper 3 ft of dredged sediment (21,000 yd^3) will likely fail two PSDDA criteria, but will be well below the 0.1 Dangerous Waste criteria. The balance of the sediment (34,000 yd^3) will likely meet the PSDDA criteria for open-water disposal.

Physical Soil Properties. All of the sediment to be dredged appears to be loose to medium dense, silty sand to slightly silty sand.

Biological Properties. No bioassay tests have been completed on the sediments.

Dredging Plan. The proposed dredging plan (Figure ___) involves clamshell removal and barge transport of the contaminated sediment, in accordance with CAD functional design.

Disposal Plan. The proposed disposal site is within the boundary of the marina development, and consists of a natural depression in about 25 ft of water (MLLW). The intended disposal plan calls for dredging of contaminated sediment first using clamshell/haul barge techniques to place the sediment in the depression, followed by hydraulic dredging of the cleaner sediments for use as cap.

The contaminated sediment zone of the CAD will average 3 to 4 ft in thickness, extending over about a 3-acre area. The cap will average 4 to 5 ft in thickness. Following disposal, the water depth at the disposal site will be approximately 16 to 18 ft (MLLW).

B. Pathways of Concern

The issue of concern, because of the site's shallow water depth, is disturbance of the cap. The functional design requires a water depth of between 80 and 200 ft while this project provides a water depth between 18 and 25 ft. Natural forces, such as currents or waves, could potentially erode the cap. Mechanical action from anchor drag or prop wash could also result in cap erosion.

The environmental pathways of concern relate to exposure of the contaminated sediments to the marine environment. The potential for biological uptake, and/or resuspension into the water column are the main pathways of concern.

C. Mitigating Design Features

Natural Currents/Waves. The marina is not adjacent to any river, and is located at the head of a waterway where significant sustained currents from river discharge are not possible. Tidal currents must be identified. The site is exposed to a 2-mile fetch and wind-generated waves do occur. To protect the marina from this exposure, a breakwater structure around the perimeter of the development is planned (Figure ___). The breakwater also eliminates waves that could erode the sediment cap.

Mechanical Forces. The marina area will be limited to small boats by the design draft of 10 ft at MLLW. The small size of the boats in the marina will in turn limit the magnitude of prop wash. Anchor drag is not considered to be a major concern within the protected harbor. The penetration depth of an anchor from the largest anticipated vessel is less than 3 ft.

Alternative 1. This alternative provides for doubling the thickness of the cap (3 ft) to a total of 6 ft. The extra thick cap is intended to prevent anchor penetration from disrupting cap material to the point of resuspending contaminated material. It is also intended to insure that erosional forces (wave, current, and prop wash) do not disrupt the integrity of the cap.

Alternative 2. This alternative provides for increasing the physical size of the cap material to prevent erosion. The functional design standard of 3 ft of matching grain size material will be used to isolate the contaminated material from biota and the environment. On top of this 3 ft cap will be placed a 1 ft thick layer of 6-inch minus rock (quarry spalls) to serve as cap armoring. The armoring material is intended to be sufficiently large so that erosional forces can not move it and anchors can not penetrate it.

Alternative 3. This alternative is a combination of the first two. It includes a 5 ft cap of matching grain size, plus a one-foot armored layer consisting of 6-inch minus rock. The total cap thickness is 6 ft. The purpose of including both a thicker cap and an armored layer is to account for any erosion/settling that may occur prior to the site stabilizing.

D. Proposed Testing/Modeling/Analysis

Basic Program. All work required for functional design will be completed as part of this workplan.

Natural Currents/Waves. Water column velocities will be measured at 3 stations (Figure ___) concurrently at nearbed, mid-depth, and near surface. The measurements will be collected during the first quarter of 1990, and will include a -2 MLLW and +10 MLLW tide.

Linear wave theory analysis will be completed to predict the nature of waves impacting the breakwater, as well as passing through or around the breakwater. See Appendix ___ for a detailed description of the current measurement and wave modeling techniques.

Mechanical Forces. A detailed analysis will be completed to estimate the maximum penetration of anchors in the seabed. Techniques developed for design of seabed burial of communication cables specifically address the influence of soil type, anchor type, and ship pull on anchor penetration. See Appendix ___ for the technical details. Prop wash potential will be evaluated through application of prop design principals and prototype studies (Appendix ___), and verification of the cap armoring based on predicted prop-related water velocities near the seabed.

3.3.2 Example 2: Nearshore Disposal, Sediment Chemistry >0.1 DW

A. Project Overview

A Puget Sound Port intends to deepen a waterway to provide access for large container vessels. The project will require dredging approximately 300,000 yd^3 of sediment to a depth of -50 MLLW.

Sediment Conditions. The sediment conditions are understood based on past projects in the waterway. The conditions are as follows:

Chemistry. The upper 2 to 4 ft of sediment (approximately 80,000 yd^3) tends to exceed at least two of the PSDDA criteria. Approximately 25,000 yd^3 of that volume has chemistry anticipated to exceed 0.1 Dangerous Waste criteria. The balance of the sediment (220,000 yd^3) will likely meet the PSDDA open-water disposal criteria.

Physical Soil Properties. Both of the contaminated and non-contaminated sediments tend to be sandy silty to silty sand.

Biological Properties. Bioassay testing in the area indicates that the upper 2 to 4 ft of sediments exceed PSDDA criteria for open-water disposal.

Dredging Plan. The proposed dredging plan (Figure ___) would be completed in accordance with the functional design requirements for nearshore disposal. All sediment would be removed by hydraulic dredging and transported to the disposal site by hydraulic pipeline.

Disposal Plan. The disposal site (Figure ___) will be designed in accordance with the functional design standards. The contaminated sediments will be pumped into the diked-off waterway. All of the contaminated sediment will be placed at or below +3 (MLLW) which is about 4 ft below the lowest anticipated groundwater level in the final nearshore fill. The contaminated sediments will be covered with approximately 12 to 15 ft of noncontaminated sediments from the dredging site. The final cap will consist of 3 to 5 ft of granular fill covered by asphalt-concrete paving to provide a working surface for a container storage area.

B. Pathways of Concern

The proposed nearshore disposal is consistent with functional design parameters, except the sediment bulk chemistry is slightly higher than the 0.1 Dangerous Waste criteria. Functional designs are intended for sediments with chemistry levels less than 0.1 Dangerous Waste, but past testing indicates that some constituents are near 0.15 Dangerous Waste.

The issue of concern with bulk chemistry being higher than the standard is the increased potential for contaminant release and migration. The question to be answered is what will be the actual contaminant release, and what will be the impacts of this release.

The environmental pathways of concern are the water column during dredging, surface water during disposal, and leaching from the site to the adjacent marine environment in the long term.

C. Mitigating Design Features

Since the levels of contaminants exceed the 0.1 dangerous waste level, the mitigating design features should be directed to:

- controlling effluent runoff quality during disposal
- controlling groundwater quality discharging from the site to the marine environment.

The alternative designs described below address these two issues with varying levels of certainty. The proposed testing/modeling should serve to identify which of the alternatives provides adequate protection.

Alternative 1. Under this alternative, the most contaminated material will be placed in the site first. This will give it the maximum retention time available for the site. The longer retention time will limit the concentration of suspended solids in the effluent, and decrease the amount of contaminants returned to the receiving waters.

Disposal site size will be based on providing adequate sediment retention. Sediment retention is a function of disposal site area, volume capacity and dredge discharge. Procedures developed by the Waterways Experiment Station, U.S. Corps of Engineers (Averett, et al. 1988) will be used to determine adequate disposal site size.

The confinement dikes surrounding the site also serve as a buffer zone between the contaminated sediments and the receiving waters. Assuming that the contaminated is less permeable than the dike material, the contaminant material will act as the throttle on leachate rate from the site. In this scenario the dikes can be standard material and dimensions. Hydraulic conductivity testing will be necessary to verify which materials are controlling leachate release.

Alternative 2. This alternative also requires that the most contaminated material be placed in the site first. The retention basin volume will be the same as Alternative 1, but operational controls will be imposed to control suspended solids concentrations in the effluent. The controls will most likely be imposed during the latter half of dredging, and will consist of periodic discharge (i.e., 10 hr/day) into the site to increase retention time full-time over (24 hr/day) discharge operations. Dike structures will be the same as alternative, against assuming the contaminated material is the throttle on release rates.

Alternative 3. This alternative is the same as #2 in terms of using operational controls to maximize retention time and improve effluent quality. In addition, a flocculating agent will be added to enhance settling of solids and improve effluent quality.

Should the hydraulic conductivity testing indicate the contaminated material is more permeable than the dike materials, further controls will be necessary to regulate discharge from the disposal site. The dike design will consider placing an impervious core in the sediment fill to decrease leaching across the dike.

D. Proposed Testing/Modeling/Analysis

Basic Program. All work required for functional design will be completed as part of this workplan.

Surface Water During Disposal. The modified elutriate and column settling testing will establish the water quality parameters for design. If the oversized retention basin does not solve the effluent concerns, additional tests will be completed to examine the effectiveness of injecting flocculating agents added upstream of the discharge (as discussed in Appendix ___).

Long-Term Groundwater Conditions. The column leaching tests will indicate the quality of leachate within the contaminated sediments. A solute transport model will be applied to site conditions to determine chemical concentrations in the leachate as it exists in the dike (as discussed in Appendix ___). Those results will be compared to appropriate water quality criteria.

3.3.3 Example 3: "Conventional" Upland Disposal

A. Project Overview

An industrial waterfront facility in northern Puget Sound requires maintenance dredging along a 1,200-foot-long wharf. The project will require dredging of approximately 25,000 yd^3 of sediment to re-establish the desired depth at -40 MLLW. The dredging program would not differentiate between contaminated and non-contaminated sediment, removing all sediment as one unit.

Initial screening of the sediment was completed in 1985 (Appendix ___). The conditions are as follows:

Chemistry. Portions of the upper 1 to 2 ft of sediment fails PSDDA criteria as metals. The balance of the volume to be dredged is suitable for open-water disposal. The contaminated sediment is not continuous across the site, tending to be consistent at the eastern end of the wharf, and spotty at the western end. The in-situ volume of contaminated sediments is estimated to be 8,000 to 12,000 yd^3.

Physical Soil Properties. All of the sediment to be dredged is loose-to-medium dense sand to slightly silty sand.

Dredging Plan. The proposed dredging plan (Figure ___) would be completed in accordance with the Functional Design requirements of upland monofill.

Disposal Plan. The proposed 4-acre disposal site is shown on Figure ___. It is approximately 500 ft behind the pier. Due to the presence of a brackish water aquifer beneath the site, an unlined disposal design is being proposed. The dredged sediments would be used to raise site grades approximately 4 ft. The monofill would be surfaced with 6 to 8 inches of crushed rock and the site utilized for open storage of industrial equipment. Transport and disposal of dredged materials would be in accordance with Functional Design.

B. Pathways of Concern

The proposed project is consistent with all but one component of the upland monofill functional design: the cover. The Functional Design requires a multiple layer cover consisting of a barrier, top layer, drainage layer, and topsoil. Because of future site uses, and the low levels of contamination, this project proposes a less extensive cover.

The issues of concern are increased groundwater flow through the dredged fill and increased potential of surface pathway exposure due to the absence of the surface barrier.

The pathways of concern are:

- Groundwater
- Runoff
- Airborne emissions
- Biological uptake.

C. Mitigating Design Features

The primary mitigative design feature is that the sediment is not significantly contaminated. This fact decreases the risk to groundwater and runoff contamination, and decreases human health risks associated with exposure to the contaminated material. In addition to the low sediment contamination, the following alternatives are being considered.

Alternative 1. Under this alternative, the consolidated dredged material would be covered with 6 to 8 inches of crushed rock. No controls for groundwater or surface water runoff are proposed. It is anticipated they will not be necessary because of the low leachate potential from the contaminated material. Further testing will be necessary (described below) to verify this assumption.

Alternative 2. A drainage layer will be placed prior to the crushed rock. This layer will divert the majority of the runoff to a perimeter ditch, and will decrease the amount of surface water that infiltrates to the underlying aquifer. The crushed rock surface will be 6-8 inches thick.

Alternative 3. This alternative will have a drainage layer underlaid by an impermeable clay. This will further reduce infiltration into the underlying aquifer. The crushed rock surface will be 12-15 inches thick to minimize the potential for human health exposure.

D. Proposed Testing/Modeling/Analysis

Basic Program. All of the work required for functional design will be completed as part of this work plan. The leaching tests will address the concerns for groundwater and runoff pathways.

Risk Assessment. A risk assessment will be completed to verify that no acute or chronic effects on human health are anticipated due to direct contact with the contaminated sediment. The analysis will be based on the standard exposure assumptions and procedures specified in WAC 173-340-740(3) Alternate Cleanup Levels.

4. CAAP

CAAP, an acronym for Confinement Alternative Assessment Procedure, is used to evaluate alternative proposals for Effects Based Designs (EBDs). A CAAP evaluation is required for two reasons. First, the evaluation will identify flaws in a proposed EBD that are due to a design's failure to adequately consider contaminant transport, pertinent laws and regulations, safety, or public concern factors. Second, the assessment will permit an evaluation of the level of environmental protection, expressed in terms of reduced risk of contaminant movement from dredged material, afforded by the EBD.

4.1 CAAP's ROLE IN THE EFFECTS BASED DESIGN PROCESS

The FD concept introduced in Chapter 1 of the *Standards Documentation Final Report* was established on the basis that dredging, dredged material transport and placement, and disposal site design technologies are sufficiently developed so that realistic and protective technology-based designs can be selected and documented. When an EBD is proposed, it becomes the applicant's responsibility to clearly describe and evaluate how the proposed design will effect contaminant movement along relevant pathways. The description is done through the workplan, the evaluation is done using CAAP.

The use of the CAAP in the EBD process is intended to provide a structured path along which the applicant must examine the important environmental and non-environmental consequences of his proposal. It also provides an applicant the opportunity to take site-specific considerations into account when evaluating their EBD. The numerical outcome of applying CAAP will not be used as the only reason to accept or reject an EBD proposal. The workplan together with the CAAP evaluation will be the basis for discussions between the applicant and the regulator(s) and a decision concerning the EBD proposal will be made at the conclusion of discussions.

The numerical outcome from applying CAAP should not be used to solely accept or reject an EBD for several reasons. CAAP, as an assessment procedure, is still too developmental to be relied on as the ultimate pass/fail decision-making tool. It does provide a useful indication of how protective a potential EBD is, and therefore can be used as a good starting point in discussions/negotiations with permitting agencies.

NOTE:
CAAP has not been proven and refined over years of evaluating EBDs. Also, although quantitative, it has a limited range of scores for technical effectiveness (1-3), and therefore has a limited amount of rigor. Because it is not an intensely quantitative evaluation, it should be used early in the decision-making process, when different EBDs are first being considered.

4.2 APPLICATION OF CAAP

CAAP's application during the evaluation of EBDs is to compare the level of protection provided by the EBD with an adequate level of protection. The functional designs for the confinement of dredged material provide examples of adequate protection. Level of protection refers specifically to the ability of a confinement design to limit the transfer of contamination along the various pathways associated with each disposal environment.

The basic CAAP procedure, and that used in assessing dredging, dredged material transport and disposal standards, consists of six steps:

Step 1. Presume Contaminant Pathways associated with Dredging, Transport and Disposal Technologies. The transport pathways considered are listed below:

- water column
- surface water
- groundwater
- atmospheric
- direct contact

Step 2. Develop dredging, dredged material transport and dredged material disposal alternatives. Alternatives associated with CAD, Nearshore and Upland Disposal EBDs need to be developed. The alternatives are the same as those required in the workplan.

Step 3. Alternative Evaluation and Ranking. This is a multi-step process that scores or otherwise considers each pathway individually and then combines the results of individual pathway analysis to produce a composite score.

CAAP employs five different evaluation factors in assessing an alternative. They are the following:

- Technical Effectiveness
- Regulatory Requirements
- Safety
- Public Acceptance
- Cost

For each factor, the relative numeric rankings and their definitions are shown in Table 4.1. During CAAP implementation, the evaluation factor scoring for different alternative standards should be based on the best professional judgement and experience in conjunction with the guidelines and considerations described below.

Table 4.1. Evaluate factor scoring.

Weight			
3	Technical Effectiveness	1	low probability that standards will be met
		2	moderate probability that standards will be met
		3	high probability that standards will be met
2	Regulatory Requirements	1	probably meets requirements
		2	fully compliant with applicable laws, ordinances, and regulations on the implementation of proposed control/treatment alternatives
1	Safety	1	no apparent safety risks
1	Public Acceptance	1	some public concern is probable
		2	no public concern is anticipated
None	Costs	Capital Costs O&M Costs	

Technical effectiveness. The technical effectiveness/efficiency factor addresses the ability of an alternative to meet control/treatment requirements and provide an adequate level of protection. The ability of an EBD alternative to provide an adequate level of protection is assessed by comparing the allowable contaminant release at a specific site with the estimated contaminant release after implementation of the control/treatment option. The evaluation process should be conducted by estimating the contaminant containment efficiency (for all pathways) of each EBD alternative.

Regulatory Requirements. The regulatory requirements evaluation factor addresses the impact of compliance with applicable laws, ordinances, and regulations on the implementation of the proposed control/treatment alternative. Regulatory requirements are extremely important in that they may determine the overall acceptability of an alternative, and at the very least, impact the cost and time required for implementation. Because it is assumed that all EBD alternatives must comply with appropriate regulations, it may be argued that these requirements would have an equal impact on all alternatives. However, not all regulations will apply equally, if at all, to all alternatives. For example, only those alternatives resulting in discharges to surface waters would have to comply with state water quality standards under Section 404 of the Clean Water Act.

Safety. The safety evaluation factor addresses the issue of whether the proposed control/treatment alternative can be safely implemented. The safety of both on-site personnel and the general public should be addressed. Whereas the technical effectiveness/efficiency evaluation factor addresses the consequences of the migration of contaminants from the dredged material, the safety evaluation factor considers those direct hazards associated with implementation of the control/treatment alternatives. Examples of concerns addressed by this evaluation factor include:

a. Can the proposed control/treatment alternative be safely constructed or operated?
b. Will special personnel protection be required during the construction process?
c. Will transportation of material endanger the general public during active project performance?

Public Acceptance. The public acceptance evaluation factor addresses the concerns of the public about implementation of control/treatment alternatives, including all of those factors perceived by the public as being important. Addressing public concerns has proven to be a vital consideration in a number of cases, particularly those involving siting. A major difficulty in dealing with public concerns is that they are often problems of perception, not based solely on technical considerations; nonetheless, they cannot be dismissed solely on a technical basis.

Cost. The cost factor addresses the overall cost of implementing a control/treatment alternative. Overall cost (including capital and operation and maintenance costs) should be quantified as the present worth or equivalent annual cost of the alternative. Alternative EBD designs will not be selected solely on cost since other important factors must be considered. Cost effectiveness is the main criteria by which the cost factor should be measured.

Step 3.1. Estimate Costs using experience and Best Professional Judgment.

Step 3.2. Determine Technical Effectiveness of the Control/Treatment Technology for affecting contaminant transport along individual pathways (performed concurrently with step 3.1). Score according to Table 4.1.

Step 3.3. Evaluate for Regulatory Requirements, Safety and Public Acceptance. Score according to Table 4.1.

Step 4. Calculate composite scores for the specific alternative/pathway combination. Using the CAAP scoring form shown in Table 4.2, determine the composite score for each alternative/pathway combination. Note that weighting factors have been added to technical effectiveness (3X) and the regulatory requirement (2X) evaluation factors.

Step 4.1. Calculate weighted scores for each pathway.

Step 4.2. Apply weighted scores to calculate composite pathway scores relating to the formula

$$T_w * R_w * (S + P) = P_1$$

where T_w = weighted score for Technical Effectiveness
R_w = weighted score for Regulatory Requirements
S = Safety
P = Public Acceptance
P_1 = Pathway

Step 5. Calculate composite scores for the entire alternative according to the formula

$$P_1 + P_2 + P_3 + P_n$$

where P_1 through P_n represent the composite scores for each pathway associated with a particular alternative, and

Step 6. Select the alternative considering the Cost and the Composite score.

Table 4.2. [redacted] assessment procedure scoring form. [redacted]

DISPOSAL ACTION: CAD, Nearshore, Upland Mixed, Upland Mono Lined, Upland Mono Unlined (Circle One)

COMPONENT: Dredging, Transport, Site Design (Circle One)

ALTERNATIVE: 1, 2, 3, Other (Circle One)

PATHWAY: Water Column, Surface Water, Groundwater, Atmospheric, Direct Contact (Circle One)

Control/ Treatment Technology	Effectiveness Test or Procedure	Level of Protection	Technical Effectiveness (Score 1-3)	Mult. Factor (3)	Tech. Effect. Total	Regulatory Requirements (Score 1-2)	Mult. Factor (2)	Regulat. Require. Total	Safety (Score 1-1)	Public Acceptance (Score 1-2)	TOTAL SCORE

CAAP Factors That Influence Level of Protection

Among the five factors (described above) used by CAAP to assess a design alternative, only the technical effectiveness factor is used for the level of protection determination. This is not to say that the other four CAAP factors of cost, compliance with regulatory requirements, public safety and public acceptance are irrelevant during an EBD assessment; these four other factors are simply irrelevant to the level of protection determination.

Level of Protection Standards

CAAP technical effectiveness scores achieved by the preferred functional designs offer an indication of adequate protection. These scores offer a yardstick for comparing EBD proposals to determine if they provide adequate protection. The following brief analysis of the CAAP reveals how the Technical Effectiveness scores of functional design alternatives were calculated. More importantly, for the purposes of this discussion, the analysis identifies the minimum and maximum technical effectiveness scores that are possible and the actual scores achieved by the candidate and preferred functional designs. In the following analysis, we have used confined aquatic disposal design (CAD) as an example. A similar logic would apply if we had chosen to use nearshore or upland designs. The references for this discussion are in Chapter 8 and Appendix F of the Standards for Confined Disposal of Contaminated Sediments, Development Documentation Report (Parametrix 1990).

CAD Dredging

The application of CAAP to the dredging component of alternative CAD functional designs identified the water column as the single predominant pathway for potential contaminant transport. The possible range of technical effectiveness scores for dredging control/treatment technologies is one to three. As Technical Effectiveness is the only CAAP factor being evaluated, there is no rationale for weighting the score to make this factor relatively more or less important than other factors such as regulatory compliance. The minimum score, therefore, is one point, and the maximum is three points.

CAD Dredged Material Transport

Water column contamination was also the predominant pathway for potential environmental contamination during the transport of dredged material to a confined aquatic disposal site. The range in possible scores is, for the same reasons described by the dredging discussion, one to three points.

CAD Site Design

Surface water, direct contact, atmospheric conditions and groundwater were identified as potential contaminant transport pathways to be considered by the design of a confined aquatic disposal site. The Technical Effectiveness of a design when evaluated for each pathway leads to point scores from one to three for each pathway and a possible range in total score values between four and twelve points.

Technical Effectiveness Scores for the Alternative Functional Designs and the Preferred Alternative

Functional Design Element	Possible Range	Alternatives 1	2	3	Preferred
Dredging	1-3	2.0	1.2	2.5/2.0	2.0
Transport	1-3	2.5	2.5	2.0	2.3
Site Design	4-12	10.9	10.2	10.1	10.6

The conclusion of this exercise is that the preferred CAD functional design alternative offers Technical Effectiveness levels of protection scores for dredging, dredged material transport, and site design of 2.0, 2.3, and 10.6 points respectively.

Use of an Intuitively More Easily Interpreted Scoring System

While the technical logic upon which the CAAP is founded is sound, and the procedure is quite straight forward, it is intuitively difficult to interpret the relevance of numerical values such as 2.0, 2.3 and 10.6. One solution that is proposed to remedy this shortcoming is the use of a simple percentage transformation that considers these values relative to the maximum possible values and converts them to values that range between ten and 100 percent. The formula is simply:

$$\frac{\text{calculated level of protection score}}{\text{maximum possible score}} \times 100$$

When this formula is applied to the preferred CAD Functional Design Standard, the resulting scores are:

Dredging	66.6
Dredged Material Transport	76.6
Site Design	88.3

These values then become an indication of an adequate level of protection against which the levels of protection afforded by proposed EBDs can be compared.

Scoring Effects Based Design Level of Protection

The following four step process is used for determining the level of protection afforded by a proposed EBD:

Step 1 - Use the checklist (Chapter 2) to focus the level of protection assessment only on those EBD features that are modified from the Functional Design Standards.

Step 2 - Tabulate technical effectiveness scores for the EBD using the CAAP scoring forms to insure that all of the appropriate control/treatment technologies and pathways of potential contaminant transport are considered.

Step 3 - Determine the effects of the EBD's proposed mitigating design features on the technical effectiveness values and adjust the values based on that determination.

Step 4 - Calculate the total unweighted technical effectiveness score, which we will call the raw level of protection score, carry out the percentage transformation of the score. The transformed value can then be used to assess the level of protection provided by each EBD alternative. The values can also be used as a starting point for negotiations/discussions with permitting agencies.

4.3 CAAP SCORE RANGES AND THEIR INTERPRETATION

In assessing how CAAP scores could be interpreted, we completed a dynamic ranging exercise. The ranges we examined were:

- Minimum possible score
- Maximum possible score
- Three functional design alternatives
- Recommended functional designs.

The CAAP scores, using the percentage transformation, for each of the above categories is listed in Table 4.3. The purpose of this exercise was twofold:

- Put into perspective what range of scores is possible, and

- Begin the process of targeting in on what scores provide an adequate level of environmental protection.

Table 4.3. Ranges of potential CAAP scores.

	Component	Pathway	Minimum	Maximum	Functional Design Alternative 1	2	3	Rec. Functional Design
CAD	Dredging	Water Column	33.3	100.0	66.7	66.7/40.0	83.3/66.7	66.7
	Transport	Water Column	33.3	100.0	83.3	83.3	66.7	76.7
	Site Design	All	33.3	100.0	90.8	85.0	84.2	88.3
Nearshore	Dredging	Water Column	33.3	100.0	83.3/66.7	83.3	66.7	66.7
	Transport	Water Column	33.3	100.0	93.3	76.7	70.0	76.7
	Site Design	All	33.3	100.0	89.2	80.0	60.8	80.0
Upland Mixed	Dredging	Water Column	33.3	100.0	66.7	66.7	83.3	66.7
	Transport	Water Column	33.3	100.0	66.7	66.7	83.3	66.7
	Site Design				Not scored (MFS required)			
Upland Mono	Dredging	Water Column	33.3	100.0	66.7	66.7	83.3	66.7
	Transport	All	33.3	100.0	91.7	91.7	80.8	91.7
	Site Design (Lined)	All	33.3	100.0	97.5	95.8	86.7	95.8
	Site Design (Unlined)	All	33.3	100.0	97.5	88.3	73.3	88.3

As stated earlier, CAAP is still in the developmental stages, and it is not currently possible to assign hard and fast scoring criteria for EBD acceptance or failure. The CAAP can, however, provide an indication of the protectiveness of a proposed EBD. In assessing the Functional Design CAAP scores presented in Table 4.3, and in evaluating the three case studies using CAAP (see Section 4.4), we were able to make a preliminary breakdown of CAAP scores into two ranges:

- Those that generally provide an adequate level of protection, and
- Those that require further investigation/study before a decision on EBD acceptance can be made.

This breakdown is very preliminary and is only based on a limited amount of practical application. It will need to be refined and updated as CAAP is put into practice. The preliminary breakdowns are summarized in Table 4.4.

4.4 CAAP EVALUATION OF CASE STUDIES

For each of the case studies, we completed a CAAP evaluation of the site design. That evaluation is summarized below.

Confined Aquatic Disposal in Shallow Water

In this example, the dredging and dredged material transport components of the proposed EBD are the same as the CAD functional design. An examination of the proposed dredged material disposal and disposal site design features, and a comparison between the proposed EBD and the checklist, leads to the conclusion that the project varies from the functional design in the following areas:

- The disposal site is too shallow so that there is a potential for disturbance of the cap by currents or wave energies or mechanical forces such as ship anchors and prop wash.

- The magnitude of the physical forces due to current velocities and waves on the shallow water cap is not known.

The technical effectiveness evaluation for CAD site design, based upon the CAAP scoring form, includes six different control/ treatment technology categories and considers four potential contaminant transport pathways. Table 4.5 presents the completed scoring form for the proposed basic EBD. The basic design incorporates mitigating design features that would shield the proposed site from current and wave-induced physical energies and that reduce the potential for cap disturbance due to prop wash or anchor drag.

EBD alternatives 1 through 3 (Tables 4.6-4.8) increase cap thickness, add armoring to protect the cap from mechanical disturbance or thicken and armor the cap. An interesting conclusion from the level of protection analysis is that increasing the cap from the 4-5 foot thickness specified by the basic EBD to the 6 foot thickness specified by EBD alternative 1 did not improve the level of protection score. Armoring the cap did improve the score. The results of the EBD alternatives scoring are presented in Tables 4.6 through 4.8. The EBD alternatives had transformed scores of about 78%. There was little variation between the scores generated by the three alternatives. This indicates that each offers about the same level of protection. In comparison with the ranges presented earlier, 78% indicates the design is likely protective enough, but the proponent will have to do some verification testing/modelling and will have to conduct relatively intense monitoring.

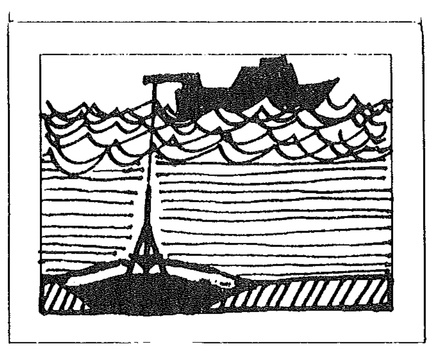


Table 4.4 Breakdown of CAAP scores into ranges of generally adequate LOP or requiring further study.

	Component	Pathway	Generally Adequate Level of Protection	Requires Further Testing
CAD	Dredging	Water Column	60 - 100	33 - 60
	Transport	Water Column	70 - 100	33 - 70
	Site Design	All	70 - 100	33 - 70
Nearshore	Dredging	Water Column	60 - 100	33 - 60
	Transport	Water Column	70 - 100	33 - 70
	Site Design	All	75 - 100	33 - 75
Upland Mixed	Dredging	Water Column	60 - 100	33 - 60
	Transport	All	70 - 100	33 - 70
	Site Design		Not Scored (MFS Required)	
Upland Mono	Dredging	Water Column	60 - 100	33 - 60
	Transport	All	70 - 100	33 - 70
	Site Design (Lined)	All	90 - 100	33 - 90
	Site Design (Unlined)	All	65 - 100	33 - 65

Nearshore Disposal, Sediment Chemistry > 0.1 DW

According to this examples, dredging, dredged material disposal, and site designation features are generally in accordance with functional design. But approximately 25,000 cubic yards of the nearly 300,000 cubic yards of material to be dredged has chemistry values which exceed 0.1 Dangerous Waste criteria.

The technical effectiveness evaluation to determine the level of protection afforded by operational controls during and following dredged material disposal, fits best into the site design scoring form. Included in this CAAP scoring form is a retention dike design feature intended to control the ability of a nearshore site to achieve specific effluent quality standards. The three alternatives differ according to the measures that they incorporate for increasing the retention time of the hydraulic slurry or for otherwise reducing the concentration of suspended solids at the effluent discharge point of the disposal site. The preferred functional design possesses a level of protection score of 80 percent. The effects of EBD alternative 1, 2, and 3 are detailed in Tables 4.9 through 4.11 and indicate level of protection scores for these alternatives of 80, 88.6 and 88.6 percent respectively.

"Conventional" Upland Disposal

The preferred functional design alternative for an upland mono fill unlined dredged material disposal site is one that employs cover design features to capture or divert surface water runoff and to prevent infiltration of the dredged material fill by water that could lead to groundwater contamination. The proposed EBD alternatives do not incorporate the preferred cover design and vary in the degree to which surface water and the potential for leachate into groundwater would be controlled. Environmental concerns about groundwater contamination are mitigated to some extent by the presence of a brackish water aquifer beneath the site and the fact that the levels of sediment contamination are believed to be low.

Both surface water and groundwater pathways are affected by changes in what the CAAP scoring form refers to as surface water management and final cover control and treatment technologies (Tables 4.12 - 4.14). The level of protection afforded by the preferred functional design alternative is calculated to be 88 percent. In comparison, EBD alternatives 1 and 2, which incorporate modest runoff and permeability control features, yield scores of 66 and 69 percent. Alternative 3 is not totally consistent in its cover design with the functional design standard. But because of its performance characteristics in diverting surface runoff and preventing infiltration, and the low level of sediment contamination, it suggests, with a score of 73. While this score is quite a bit lower than the level of protection associated with the preferred functional design, it is within the range of values initially defined as generally adequate level of protection. Its occurrence at the lower end of that range would logically influence the need for thoughtful discussion, additional monitoring, and the formulation of a remediation plan.

4.5 SITE SPECIFIC CONSIDERATIONS

The examples presented in Chapter 2 make it evident that site specific characteristics can significantly affect EBDs by permitting variations from Functional Design standards without reducing the probable level of protection afforded by the design. In Example 1: Confined Aquatic Disposal in Shallow Water, the location of the CAD site in a protected area, together with restrictions at the marina (which would limit the marina's use to small boats with shallow drafts and relatively small anchors), combine to reduce the serious risk of loss of cap integrity. Chapter 3, Section 3.4 of the *Standards Documentation Final Report* describes factors that influence site suitability for contaminated sediment disposal. These can be used by the applicant to guide EBD agreements regarding departure from the Functional Design standards.

Table 4.5. Effects based design assessment, CAD basic EBD, Technical Effectiveness Score.

Control/Treatment Technologies for Site Design	Surface Water			Direct Contact			Atmospheric		
	Score		Mitigation	Score		Mitigation	Score		Mitigation
1. Depth	1*3		1	1*2		1	3*3		N/A
2. Currents	1*2		1	1*1		1	N/A		N/A
3. Seabed Slope	3*2		N/A	2*1		N/A	N/A		N/A
4. Bed stability	2*2		N/A	N/A		N/A	N/A		N/A
5. Cap physical quality and thickness	1*3		1	1*3		1	N/A		N/A
6. Cap chemical quality	N/A		N/A	3*3		N/A	N/A		N/A
	18	+	3	12	+	3	9	+	0
		12			10			3	
Average Scores	=	1.75			11.5			3.0	
Total Score (raw level of protection score)	=	9.25							
Transformed Score (level of protection value)	=	77.08							

CAD
Basic EBD

Table 4.6. Effects based design assessment, CAD Alt. 1, EBD, Technical Effectiveness Score.

Control/Treatment Technologies for Site Design	Surface Water		Direct Contact		Atmospheric		Groundwater	
	Score	Mitigation	Score	Mitigation	Score	Mitigation	Score	Mitigation
1. Depth	1*3	1	1*2	1	3*3	N/A	3*3	N/A
2. Currents	1*2	1	1*1	1	N/A	N/A	N/A	N/A
3. Seabed Slope	3*2	N/A	2*1	N/A	N/A	N/A	N/A	N/A
4. Bed stability	2*2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5. Cap physical quality and thickness	1*3	1	1*3	1	N/A	N/A	N/A	N/A
6. Cap chemical quality	N/A	N/A	3*3	N/A	N/A	N/A	N/A	N/A
	18 +	3	12 +	3	9 +	0	9 +	0
	12		10		3		3	
Average Scores	= 1.75		1.5		3.0		3.0	
Total Score (raw level of protection score)	= 9.25							
Transformed Score (level of protection value)	= 77.08							

CAD Alternative 1

Table 4.7. Effects based design assessment, CAD Alt. 2, EBD, Technical Effectiveness Score.

Control/Treatment Technologies for Site Design	Surface Water		Direct Contact		Atmospheric		Groundwater	
	Score	Mitigation	Score	Mitigation	Score	Mitigation	Score	Mitigation
1. Depth	1*3	1	1*2	1	3*3	N/A	3*3	N/A
2. Currents	1*2	1	1*1	1	N/A	N/A	N/A	N/A
3. Seabed Slope	3*2	N/A	2*1	N/A	N/A	N/A	N/A	N/A
4. Bed stability	2*2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5. Cap physical quality and thickness	1*3	2	1*3	2	N/A	N/A	N/A	N/A
6. Cap chemical quality	N/A	N/A	3*3	N/A	N/A	N/A	N/A	N/A
	18 +	4	12 +	4	9 +	0	9 +	0
	12		10		3		3	
Average Scores	= 1.83		1.6		3.0		3.0	
Total Score (raw level of protection score)	= 9.43							
Transformed Score (level of protection value)	= 78.58							

CAD Alternative 2

Table 4.8. Effects based design assessment, CAD Alt. 3, EBD, Technical Effectiveness Score.

Control/Treatment Technologies for Site Design		Surface Water		Direct Contact		Atmospheric		Groundwater	
		Score	Mitigation	Score	Mitigation	Score	Mitigation	Score	Mitigation
1. Depth		1*3	1	1*2	1	3*3	N/A	3*3	N/A
2. Currents		1*2	1	1*1	1	N/A	N/A	N/A	N/A
3. Seabed Slope		3*2	N/A	2*1	N/A	N/A	N/A	N/A	N/A
4. Bed stability		2*2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5. Cap physical quality and thickness		1*3	2	1*3	2	N/A	N/A	N/A	N/A
6. Cap chemical quality		N/A	N/A	3*3	N/A	N/A	N/A	N/A	N/A
		18 +	4	12 +	4	9 +	0	9 +	0
		12		10		3		3	
Average Scores	=	1.83		1.6		3.0		3.0	
Total Score (raw level of protection score)	=	9.43							
Transformed Score (level of protection value)	=	78.58							

CAD
Alternative 3

Table 4.9. Effects based design assessment, nearshore Alt. 1, EBD, Technical Effecitveness Score.

Control/Treatment Technologies for Site Design	Surface Water			Direct Contact			Atmospheric			Groundwater		
	Score		Mitigation	Score		Mitigation	Score		Mitigation	Score		Mitigation
1. Dikes - Structural	3*2		N/A	3*2		N/A	N/A		N/A	N/A		N/A
2. Dikes - Retention	2*3		N/A	N/A		N/A	N/A		N/A	2*3		N/A
3. Primary Cap	3*3		N/A	3*3		N/A	3*2		N/A	N/A		N/A
4. Final Cap	2*2		N/A	2*3		N/A	2*2		N/A	N/A		N/A
	25	+	0	21	+	0	10	+	0	6	+	0
		10			8			4			3	
Average Scores	=	2.5			2.63			2.5			2.0	
Total Score (raw level of protection score)	=	9.63										
Transformed Score (level of protection value)	=	80										

Nearshore Alternative 1

Table 4.10. Effects based design assessment, nearshore Alt. 2, EBD, Technical Effectiveness Scores.

Control/Treatment Technologies for Site Design	Surface Water			Direct Contact			Atmospheric			Groundwater		
	Score		Mitigation	Score		Mitigation	Score		Mitigation	Score		Mitigation
1. Dikes - Structural	3*2		N/A	3*2		N/A	N/A		N/A	N/A		N/A
2. Dikes - Retention	2*3		1	N/A		N/A	N/A		N/A	2*3		N/A
3. Primary Cap	3*3		N/A	3*3		N/A	3*2		N/A	N/A		N/A
4. Final Cap	2*2		N/A	2*3		N/A	2*2		N/A	N/A		N/A
	25	+	1	21	+	0	10	+	0	6	+	0
		10			8			4			3	
Average Scores	=	2.6			2.63			2.5			2.0	
Total Score (raw level of protection score)	=	9.73										
Transformed Score (level of protection value)	=	81.08										

Nearshore
Alternative 2

Table 4.11. Effects based design assessment, nearshore Alt. 3, EBD, Technical Effectiveness Score.

Control/Treatment Technologies	Surface Water		Direct Contact		Atmospheric		Groundwater	
for Site Design	Score	Mitigation	Score	Mitigation	Score	Mitigation	Score	Mitigation
1. Dikes – Structural	3*2	N/A	3*2	N/A	N/A	N/A	N/A	N/A
2. Dikes – Retention	2*3	1	N/A	N/A	N/A	N/A	2*3	N/A
3. Primary Cap	3*3	N/A	3*3	N/A	3*2	N/A	N/A	N/A
4. Final Cap	2*2	N/A	2*3	N/A	2*2	N/A	N/A	N/A
	25 +	1	21 +	0	10 +	0	6 +	0
	10		8		4		3	
Average Scores	= 2.6		2.63		2.5		2.0	
Total Score (raw level of protection score)	= 9.63							
Transformed Score (level of protection value)	= 81.08							

Nearshore Alternative 3

Table 4.12. Effects based design assessment, "conventional" upland Alt. 1, EBD, Technical Effectiveness Score.

Control/Treatment Technologies for Design of Upland Mono Unlined Sites	Surface Water Score	Surface Water Mitigation	Groundwater Score	Groundwater Mitigation	Atmospheric Score	Atmospheric Mitigation	Direct Contact Score	Direct Contact Mitigation
1. Surface Water Management	2*3	N/A	1*2	N/A				
2. Final Cover	1*3	N/A	1*3	N/A	2*3	N/A	3*3	N/A
3. Berms	3*2	N/A					2*3	N/A
4. Dewatering	2*2	N/A	2*3	N/A				
5. Gas Management					2*3	N/A		
6. Vector Control							3*3	N/A
	19 +	0	11 +	0	12 +	0	24 +	0
	10		8		6		9	
Average Scores	= 1.9		1.38		2.0		2.67	
Total Score (raw level of protection score)	= 7.95							
Transformed Score (level of protection value)	= 66.25							

Conventional Upland Alternative 1

Table 4.13. Effects based design assessment, "conventional" upland Alt. 2, EBD, Technical Effectiveness Score.

Control/Treatment Technologies for Design of Upland Mono Unlined Sites	Surface Water		Groundwater		Atmospheric		Direct Contact	
	Score	Mitigation	Score	Mitigation	Score	Mitigation	Score	Mitigation
1. Surface Water Management	2*3	N/A	1*2	1				
2. Final Cover	1*3	1	1*3	1	2*3	N/A	3*3	N/A
3. Berms	3*2	N/A					2*3	N/A
4. Dewatering	2*2	N/A	2*3	N/A				
5. Gas Management					2*3	N/A		
6. Vector Control							3*3	N/A
	19 +	1	11 +	2	12 +	0	24 +	0
	10		8		6		9	
Average Scores	= 2.0		1.63		2.0		2.67	
Total Score (raw level of protection score)	= 8.3							
Transformed Score (level of protection value)	= 69.16							

Conventional Upland Alternative 2

Table 4.14. Effects based design assessment, "conventional" upland Alt. 3, EBD, Technical Effectiveness Score.

Control/Treatment Technologies		Surface Water			Groundwater			Atmospheric			Direct Contact		
for Design of Upland Mono Unlined Sites		Score		Mitigation	Score		Mitigation	Score		Mitigation	Score		Mitigation
1. Surface Water Management		2*3		N/A	1*2		2						
2. Final Cover		1*3		2	1*3		2	2*3		1	3*3		N/A
3. Berms		3*2		N/A							2*3		N/A
4. Dewatering		2*2		N/A	2*3		N/A						
5. Gas Management								2*3		N/A			
6. Vector Control											3*3		N/A
		19	+	2	11	+	4	12	+	1	24	+	0
			10			8			6			9	
Average Scores	=		2.10			1.88			2.17			2.67	
Total Score (raw level of protection score)	=		8.82										
Transformed Score (level of protection value)	=		73.5										

Conventional
Upland
Alternative 3

4.6 MANAGEMENT OF RISK AND UNCERTAINTY IN EFFECTS BASED DESIGNS

Effects-based designs, strictly interpreted, imply that design decisions are the product of predictive modeling calculations using site-specific conditions or are based on the results of a prototype. It is not possible to base decisions concerning level of protection afforded by a proposed EBD from the results of monitoring because that site has not been constructed (unless an identical design is in place and has been monitored). Instead, the CAAP evaluation must rely upon laboratory tests, results of computational and numerical simulation methods, and applicable prototype data from similar projects to achieve estimates of contaminant movement. The CAAP evaluation does need to account for the fact that many methods available to predict contaminant movement have limited prototype verification because of limited application or because they are new research and development tools for use in a regulatory program. An approach within the CAAP methodology to address this condition is to flag conclusions that are the products of new R&D tools or limited prototype verification. When a flag is raised, the options for the applicant and the regulator are:

- Abandon the proposed EBD as too risky due to the uncertainty of estimates for contaminant transport or

- Condition the approval of the proposed EBD upon a monitoring program that would be capable of field testing the conclusions of the preliminary lab testing and upon a remediation plan that would be implemented if unacceptable adverse contaminant transport conditions were observed.

The option selected would be the subject of negotiations between the applicant and the regulator. These would ideally occur during a pre-application meeting or after the applicant has developed a preliminary EBD proposal based on site specific considerations and a preliminary estimate of the level of protection afforded by the proposed design. Flaws in the proposed design may be obvious, so that discussion about the viability of the design at this point in the process would save the applicant time and money (see Section 4.2).

The decision about which of the two options to pursue will be based on cost considerations and other factors. Cost considerations aside, the decision will pertain to views about the role of science in environmental management. Choosing the first option, to abandon the proposed EBD as too risky because of the uncertainty of contaminant movement estimates is an environmentally conservative management position. Maintaining only this position within the purview of the proposed standards would tend to promote use of Functional Designs. Although choosing this option also places the regulatory program on a static, environmentally conservative course, the opportunity to implement continuing technological advances, as well as improvement in quality of future management decisions, would be lost.

A decision to permit option 2 is consistent with the concepts of adaptive management of natural resources. The following views are largely extracted from Walters (1986). While that book focuses on the management of renewable fisheries resources, the complexity and uncertainty associated with the geochemistry and management of contaminated sediments makes it relevant to this discussion about regulating the EBD:

> Frustration with the linkage between science and management has led to the concept that management should be viewed as an adaptive process, in which regulatory and enhancement actions are treated as deliberate experiments with uncertain outcomes. This concept goes far beyond the traditional notion that uncertainties imply risks that should be accounted for through cautious decision making; risky choices are also seen in adaptive management as opportunities to learn more about system potentials, and hence to have positive value in reducing the legacy of uncertainty that will be faced by future decision makers. Basic research is seen not as taking a lead in developing the understanding needed for making predictions, but rather as a means to better understand the response patterns revealed by management (in hindsight) and as an exploratory investment that might uncover new policy instruments and options.

It is possible to design a blind process of trial-and-error management that would be adaptive in the evolutionary sense that major mistakes would tend not to be repeated. But such a process would be unnecessarily wasteful: the approach provided through the Effects-Based Design provides analysis of historical experience in relation to ecological theory and constraints, and makes it possible to design much more intelligent, directed searches for contaminated sediment policies.

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It is possible to design a blind process of trial-and-error management that would be adaptive in the evolutionary sense that major mistakes would tend not to be repeated. But such a process would be unnecessarily wasteful: the approach provided through the Effects-Based Design provides analysis of historical experience in relation to ecological theory and constraints, and makes it possible to design much more intelligent, directed searches for contaminated sediment policies.

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