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Toward a Balanced Strategy to Address Contaminated Groundwater Plumes at the Massachusetts Military Reservation

Final Report
of the
Technical Review & Evaluation Team

May 1996

TABLE OF CONTENTS

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1. EXECUTIVE SUMMARY

This document contains the findings and recommendations of the Technical Review and Evaluation Team (TRET) for the plume containment project at the Massachusetts Military Reservation (MMR). The findings and recommendations are in response to the 60 Percent Plume Containment Design, submitted by Operational Technologies (OpTech) in January 1996. In short, the TRET recommends the MMR depart substantially from the strategy of simultaneous, 100 percent containment and treatment that was assigned to OpTech for design in accordance with the Record of Decision (ROD) for Interim Action. This strategy guided the course of the plume containment project over the past two years.

In 1994, the Senior Management Board, the Plume Containment Team, and representatives from the regulatory agencies arrived at a consensus. They agreed that a system to contain and treat 100 percent of the volatile organic compounds (VOCs) found in seven plumes at MMR should be designed. Inorganics that posed unacceptable risks would also be addressed as appropriate. OpTech began work in March 1995, and submitted its 60 Percent Design for this containment system in January 1996. This submittal met the design criteria of 100 percent containment.

However, during public review the 60 Percent Design was considered unacceptable by all parties because of adverse impacts on Cape Cod's sensitive ecosystems and sole-source aquifer. The TRET, composed of a hydrological group and an ecological group drawn from a number of agencies and contractors, was assembled in March 1996 to technically evaluate the 60 Percent Design. The primary finding of the TRET's evaluation is that concurrent achievement of the ROD for Interim Action goal of simultaneous, 100 percent capture of all the plumes at their leading edges is not possible without significant negative environmental impacts. After reaching consensus that a new approach was needed, the TRET began work to develop a new set of design criteria and containment strategies.

To avoid adverse ecosystem impacts associated with simultaneous, full containment of all plumes and to deal with significant knowledge gaps, the TRET decided to develop and follow a design process that examines each plume individually. The TRET selected the following criteria to balance the design process:

- Avoid unacceptable toxicological risk from plume contaminants to human health and biological organisms;
- Avoid unacceptable impacts from the proposed containment strategy to the natural resources and;
- Avoid undesirable impacts on regional groundwater flow and the paths and spreading of other plumes.

These criteria foster the comprehensive, iterative design approach which the TRET identified as essential. Because tradeoffs can be identified allowing decision makers to balance sometimes conflicting objectives.

Using these criteria, the TRET formulated their recommendations. In some cases, the TRET recommends phased installation of a P&T system or a pilot test that can be implemented in the near-term. In other cases, additional data and/or assessments are necessary to develop a plume response strategy (*i.e.*, understanding needs to be improved concerning the degree to which plumes enter ponds and the acceptable lifetime loading of specific contaminants to ponds). The TRET's specific recommendations for actions at each plume it was asked to consider follow:

- **Fuel Spill-12 (FS-12):** Design and install a P&T system to capture the FS-12 plume.
- **Chemical Spill (CS-10) - Source Area:** MMR officials are proceeding with the design and installation of a reactive wall pilot test close to the source of CS-10. If successful, design and installation of this technology is expected to take place.
- **CS-10 (Eastern Lobe):** Evaluate applicability of recirculating well technology by conducting a pilot test in an area of high contamination. Expand pilot test to include more recirculating wells as appropriate. Use the pilot test to demonstrate the suitability of recirculating well technology to treat other plumes. Compare effectiveness with conventional P&T technology.
- **CS-10 (Western Lobe):** Through an iterative process, develop a plume response strategy which reduces toxicological risks while minimizing ecological impacts of response actions.
- **Storm Drain-5 (SD-5) (North):** Design and install a P&T system. The containment fence will be located north of Ashumet Pond.
- **SD-5 (South):** Through an iterative process, develop a plume response strategy which reduces toxicological risks while minimizing ecological impacts of response actions.
- **Landfill-1 (LF-1):** Through an iterative process, develop a plume response strategy which reduces toxicological risks while minimizing ecological impacts of response actions.
- **Ashumet Valley:** Complete analysis of phosphorus loading to Ashumet Pond. Through an iterative process, develop a plume response strategy which reduces toxicological risks while minimizing ecological impacts of response actions.
- **Eastern Briarwood:** Continue monitoring the plume to ensure that no unacceptable toxicological risk develops.
- **Western Aquafarm:** Continue monitoring the plume to ensure that no unacceptable toxicological risk develops.

The following plumes were not included in the 60 Percent Design, yet would be part of a comprehensive plume response process. A brief summary of each is included here for completeness:

- **CS-4:** Monitoring activities are planned by the MMR to determine whether plume capture is being achieved by the existing containment system. If it is not being captured, the current P&T system may be modified to ensure plume capture at the existing fence without affecting adjacent plumes or compromising future efforts to remediate the entire plume. Use performance information from this system to aid in design and evaluation of other P&T efforts on MMR. This system does not include treatment of ethylene dibromide (EDB).

- **CS-4 (EDB Portion):** Requires completion of a Remedial Investigation/Feasibility Study (RI/FS) to define plume. Subsequently, a response strategy should be developed that reduces toxicological risks while minimizing ecological impacts. MMR and local officials are proceeding with the immediate installation of well-head treatment at the Coonamessett Pond public supply well. This action will guarantee the quality of water from this well in the event it is needed.

- **Petroleum Fuels Storage Area (PFSA):** Continued monitoring of the plume will help ensure that no unacceptable toxicological risk has developed.

- **FS-1, FS-13,** ***etc.*****:** RIs are being completed by the MMR for these plumes. Subsequently, the plume response strategy should be developed which minimizes toxicological risks while minimizing ecological impacts.

Development of response strategies for each plume must include consideration of these human health and ecological risk recommendations:

- Determine inorganic (*i.e.*, metals) concentrations and evaluate their mobility to surface water bodies.
- Refine estimates of contaminant dilution within ponds and rivers.
- Monitor for plume contaminants of concern using tiered sampling approach (sediments, pore water, and surface water).
- Perform biological tissue sampling to determine actual exposures and contaminant uptake through the food chain.
- Refine food chain models to reduce uncertainties associated with the ecological risk assessment in those cases where remedial action is recommended solely on the basis of the food chain model results.

The TRET recommends that monitoring of regional groundwater levels, pond levels, streamflows, sensitive resources, and plume locations in the MMR area begin as soon as possible. This detailed, three-phase monitoring of hydraulic heads and contaminant concentrations as well as other water quality parameters will be needed at each pumping site to confirm plume capture and contaminant-mass removal, and to ensure that nearby ecologically sensitive areas are not adversely impacted. This is a long-term activity which will need to be evaluated and modified as additional information becomes available.

The TRET also recommends that the geologic, hydrologic, chemical, biological and ecological data be organized in one or more data bases that are well documented and readily accessible so that maximum use of the information is possible. A summary of recent work and findings should also be distributed regularly to facilitate communication and interaction among all groups working at the MMR.

2. BACKGROUND

Over fifty years of military activities at the MMR, beginning in the 1930s, led to the development of numerous plumes of contaminated groundwater emanating from the reservation. Remedial Investigations and modeling by various consultants and the U.S. Geological Survey (USGS) as of January 1995 identified sources of contamination for seven plumes. This work also provided initial characterization of each plume's extent and explained the direction of movement of the plumes. Based on these studies, the public, the military, and regulatory agencies agreed that an interim plan should be developed to contain the plumes in order to:

- Protect and restore drinking water for the communities around the MMR;
- Abate potential public-health and ecological risks resulting from current and future discharges of these plumes to sensitive surface water bodies, and;
- Promote and facilitate the final long-term cleanup of the aquifer..

The concept of containment for the seven plumes, as an interim action, was originally put forth in the Plume Response Plan (PRP) (Plume Management PAT, 1994). The P&T concept developed therein was formalized in the ROD for Interim Action (Stone and Webster Environmental Technology and Services, 1995). The P&T concept included "extraction of contaminated groundwater at the seven plumes, treatment of extracted groundwater, and discharge of the treated water to groundwater and/or beneficial use."

The selected remedy was directed at intercepting the seven plumes and preventing further migration of contaminants at levels above the Safe Drinking Water Act Maximum Contaminant Levels (MCLs) and non-zero Maximum Contaminant Level Goals (MCLGs). Extraction and treatment would continue until the final groundwater remedy for the site was chosen and implemented.

Selection of a final groundwater remedy would depend on the results of comprehensive RI/FSs. For cost estimating purposes, it was assumed "the interim containment remedy would operate for 20 years." (ROD for Interim Action, pg. 10-2). Thus, both the PRP and the ROD for Interim Action specified placement of the extraction well fences for containment at the leading edge of each plume. The remedial response objectives specifically outlined in the ROD include:

- Reduce risks to human health associated with the potential future consumption and direct contact with groundwater and surface waters;
- Protect uncontaminated groundwater and surface water for future use by minimizing the migration of contaminants;
- Reduce potential ecological risks to surface waters and sensitive coastal waters through implementation of the containment systems; and
- Reduce the time required for aquifer restoration.

Six of these plumes (Ashumet Valley, CS-10, Eastern Briarwood, FS-12, LF-1, and SD-5) were selected for interim containment action following the completion of the data gap field work. A map showing these six plumes, and three additional plumes, is included in Appendix A. The Western Aquafarm plume was excluded from requiring interim containment action, and is therefore not shown on the map. The northern portion of the CS-4 plume is shown on the map, but was not included in the overall design because a plume containment system is already operating at this location. The southern (EDB) portion of the CS-4 plume is not shown on the map since it is still being investigated. The PFSA plume is shown on the map yet was not included in the design since it is undergoing significant natural attenuation. Two other plumes, FS-1 and FS-13, are not shown on the map nor were they included in the overall design as they are still being characterized. The J. Braden Thompson plume, which is located near FS-12, but originated from a site unrelated to the MMR is also not shown on the map.

During previous investigations, three groundwater models were developed. A regional model was developed by the USGS and covers the entire upper Cape area. A subregional model was developed by ABB-Environmental Services (ABB-ES) for evaluating plume transport in the Southeast Regional Groundwater Operable Unit (SERGOU) area (encompassing Eastern Briarwood, PFSA, SD-5, and the Western Aquafarm plumes). The SERGOU model was later expanded by ABB-ES to include the Ashumet Valley Groundwater Operable Unit.

The National Guard Bureau (NGB) contracted OpTech to perform the design for the plume containment system in March 1995. This involved several components including:

- Field investigative work to fill data gaps between the information in the RIs and data requirements for containment system design,
- Development of a groundwater model of suitable extent and discretization for design of extraction well networks to capture each of the plumes,
- Evaluation of technologies and approaches for the extraction, treatment, and injection portions of the system, and
- Preparation of design drawings and specifications for plume containment and treatment systems. A new groundwater model was developed by an OpTech subcontractor, Environmental Consulting Engineers, Inc. (ECE), for this effort.

All of the above activities were performed in accordance with the strategy outlined in the PRP and the ROD for Interim Action. As directed, OpTech's modeling and design activities concentrated on placing the proposed extraction well fences at the leading edge of each plume. The design process for each plume involved:

- Identification of locations (areal and vertical) of extraction well screens,
- Selection of well or gallery locations for recharging treated water to the aquifer,
- Evaluation of well spacing and extraction rates needed to satisfy PRP and ROD for Interim Action requirements, and
- Evaluation of treatment process requirements and locations

In March 1996, the NGB, U.S. Environmental Protection Agency (USEPA), and Massachusetts Department of Environmental Protection (MA DEP) established a new organizational structure (Figure 1). Its purpose was to provide a mechanism to rapidly and thoroughly review the 60

Percent Design, investigate other alternatives, identify criteria with which to evaluate the design, and assess impacts to the environment. The primary goal of this structure was to achieve consensus on a viable plume containment project.

One of the key components of this organizational structure has been the TRET. It is composed of a hydrological group and an ecological group with members drawn from a number of agencies and contractors. A list of the TRET members and their agency affiliation is in Appendix B. Since March 1996, the TRET has frequently reported its findings and presented its recommendations to the various teams and organizations depicted in Figure 1.

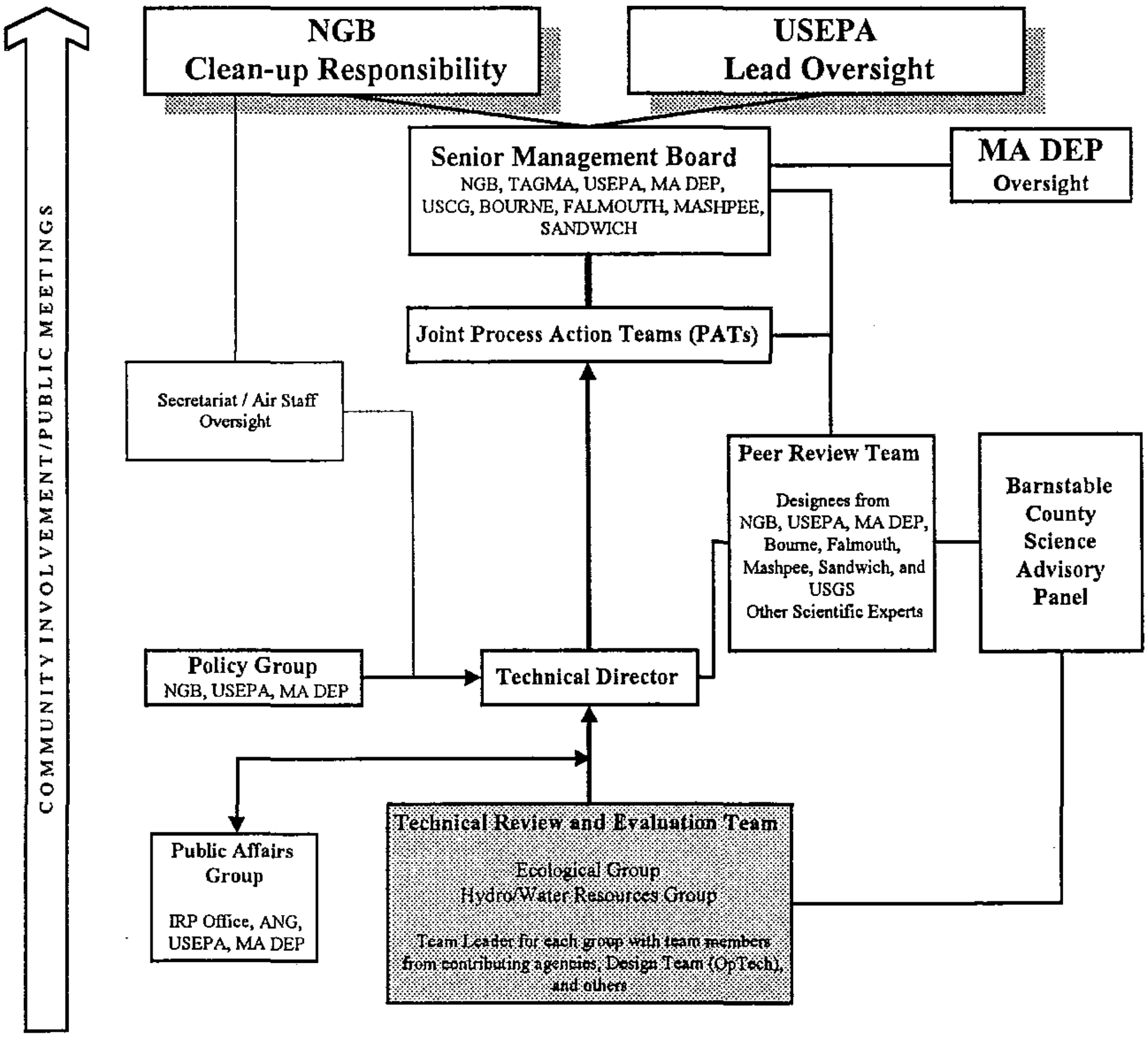

Figure 1. MMR Organizational - Flow Diagram

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3. EVALUATION OF THE 60 PERCENT DESIGN

The 60 Percent Design for the plume containment system was delivered to the NGB in January 1996 (OpTech, 1996). This design was based on the use of extraction well fences at the leading edges of the plumes. The newly developed groundwater model was used to estimate pumping requirements for 100 percent capture of constituents exceeding drinking water maximum contaminant levels (MCL). For 100 percent containment, the model indicated a total pumping rate about twice the rate that had been projected using simple analytical methods and plume delineations available at that time (1994). A portion of this increase is attributable to the revised plume extent as determined in the data gap field effort. A portion may also be attributable to uncertainty associated with modeling parameters

The USGS groundwater model predicted that the proposed pumping to achieve 100 percent plume containment would cause significant changes in groundwater levels, surface water levels, and streamflows. In order to achieve full containment, the ECE model predicted that full containment necessitated extraction of 27 million gallons per day of uncontaminated groundwater along with contaminated water. All extracted groundwater would be treated and then returned to the aquifer or to the ponds. The ECE model assumed that all pond levels would be maintained at present levels by direct discharge of treated water to the ponds; in some cases, thousands of gallons per minute. After carefully considering the model results, the following observations were made:

- Projected aquifer withdrawal and discharge volumes could shift or deflect existing plume trajectories. For example, containment systems near the CS-4 plume could change its direction and deflect portions away from the extraction well system already placed to contain it. Even under undisturbed conditions, it is difficult to accurately predict the leading edge path of a plume over a period of time. And added complication is that some plumes overlap others, for instance CS-4 and CS-10.

- The leading edges of at least four plumes have reached or are close to their discharge point so that 100 percent containment would not be possible without major disruption of the receiving surface water systems and significant ecological impacts. These include LF-1 at the salt/freshwater interface at Red Brook Harbor, SD-5 at Johns Pond, CS-10 at Ashumet Pond, and Eastern Briarwood at the Quashnet River.

- Water table drawdown caused by plume containment could harm critical surface resources. Six types of ecosystems would be potentially impacted to varying degrees. These ecosystems include ponds, natural freshwater wetlands, cranberry bogs, vernal pools, streams, and estuaries. The aquatic ecological resources potentially involved include at least: 850 acres of freshwater ponds (11 ponds), 72 acres of natural freshwater wetlands, 126 acres of cranberry bogs, 15 certified vernal pools that are likely to be groundwater fed, 7 streams, and 5 estuaries. Many of these natural resources are critical elements of unique ecosystems. Drying out some of these ecosystems would damage or destroy them. Conversely, rising water levels in recharge areas could flood septic-system leaching fields and potentially alter terrestrial and aquatic ecosystems.

- The treatment process will alter some of the physiochemical parameters of the extracted groundwater (*e.g.*, total and dissolved organic carbon, and dissolved oxygen). Direct discharge of the treated water to ponds or indirect discharge through wells near the shorelines could cause adverse impacts to the habitats and organisms. These impacts include disrupting temperature patterns, significantly increasing flushing rate of ponds, and reversing groundwater flux across pond basins.

- Concentrations of VOCs in portions of the plumes are currently sufficiently elevated to be of concern if groundwater were to be used for drinking water. However, these compounds are readily diluted during mixing with surface water, and concentrations are reduced further by evaporation, ultraviolet light, and biodegradation at marine and freshwater discharge points. The concentrations of metals and semi-volatile compounds in the plumes may be a potential concern in aquatic ecosystems, but a review of existing data suggests many of the metals values are overestimated due to the problems during purging and sampling and do not reflect concentrations actually moving in the aquifer. Some of the semi-volatile values may also be overestimated.

- Records of occurrence or verified suitable habitat exist within the potential impact zone for 39 species of federal and state rare or endangered plant and animal species. Present ecological concerns and regulatory constraints to potential engineering actions. Types of critical habitats include coastal-plain pondshore communities, wetlands, anadromous fish runs, vernal pools, and coastal salt ponds.

The NGB, its contractors, the regulatory agencies, and local citizens and organizations expressed concern regarding potentially detrimental impacts and ramifications of the pumping strategy put forth in the 60 Percent Design. A graphic representation (Figure 2) indicates well placement under this approach results in unacceptable impacts to nearby surface water bodies.

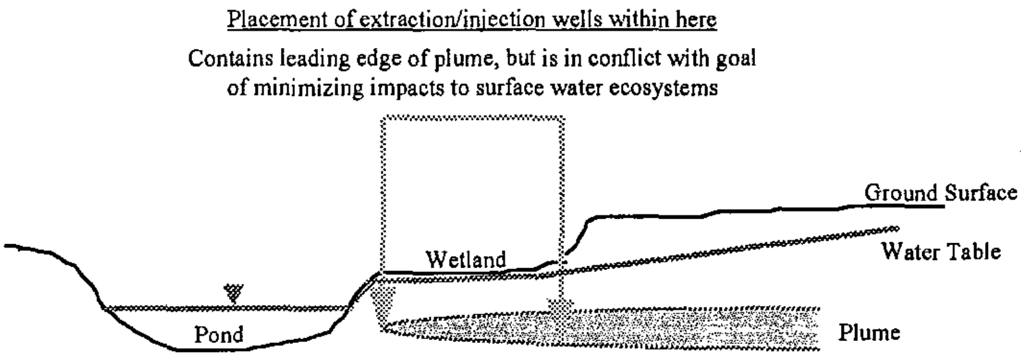

Figure 2. The 60 Percent Design Approach

The primary finding of the TRET's evaluation of the 60 Percent Design is that achievement of the ROD for Interim Action goal of 100 percent capture of all the plumes at their leading edges is not possible without significant negative environmental impacts. Tradeoffs will have to be made to reduce toxicological risks while minimizing ecological impacts and advancing toward the goal of aquifer clean-up.

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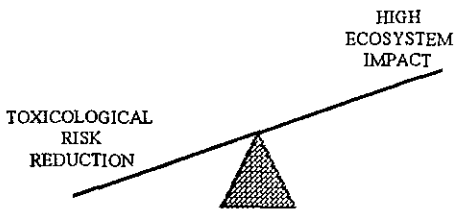
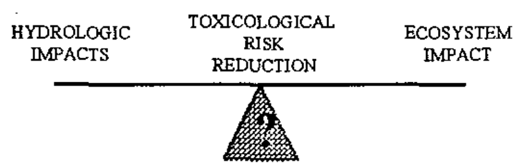
4. A DIFFERENT APPROACH TO THE DESIGN

Based on concerns for adverse impacts from the predicted aquifer response actions, the NGB requested that the TRET quantify potential ecological impacts and propose and evaluate alternative pumping strategies. The TRET determined that alternative pumping strategies could not be agreed upon until the tradeoffs associated with full plume capture as stated in the ROD for Interim Action, were determined. That is, the potential toxicological risks (human health and ecological) of not containing, or only partially containing, plumes must be balanced against the impacts of containment on local ecosystems and regional groundwater flow (Figure 3a). Once these criteria were set the TRET could evaluate pumping strategies that balance impacts and consequences (Figure 3b). Detailed design of these pumping strategies is the responsibility of the design contractors. Selection of strategies on which to move forward will be accomplished by a process including the RPM, SMB, TRET, and the public.



(a) The 60% Design emphasizes one more than another



(b) Decision makers need to carefully weigh tradeoffs

Figure 3. Can a Better Balance be Achieved?

The overall strategy must be to design systems that maximize risk reduction and aquifer protection while having minimal impacts on ecosystems and the regional groundwater flow system. A graphic representation (Figure 4) indicates the zone where well placement would have to occur in order to achieve balance. It is essential to note that plumes cannot be managed individually without regard to the interconnectedness of the aquifer system.

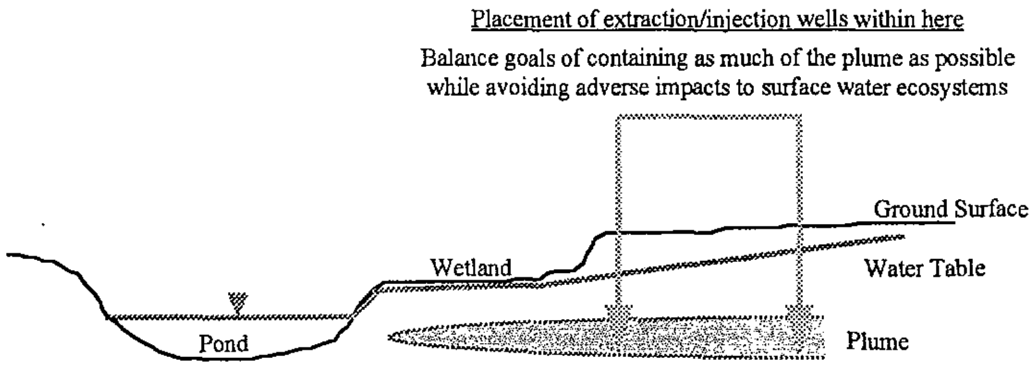


Figure 4. Toward a Balanced Approach

The approach to what is termed "plume response design" is outlined in Figure 5 which reflects the iterative, evolutionary nature of that process. Note that an incremental approach to systems installation, pilot scale test when appropriate, and further model verification are important parts of the process. The flowchart also reflects the important interaction of risk assessments, ecological impact assessments, and monitoring in the design process. Another key aspect of the plume response design process is the three-phased monitoring program being developed by the TRET, that will provide: baseline data collection (Phase 1), detailed monitoring during construction and start-up of operations (Phase 2), and monitoring during full operation of the system (Phase 3).

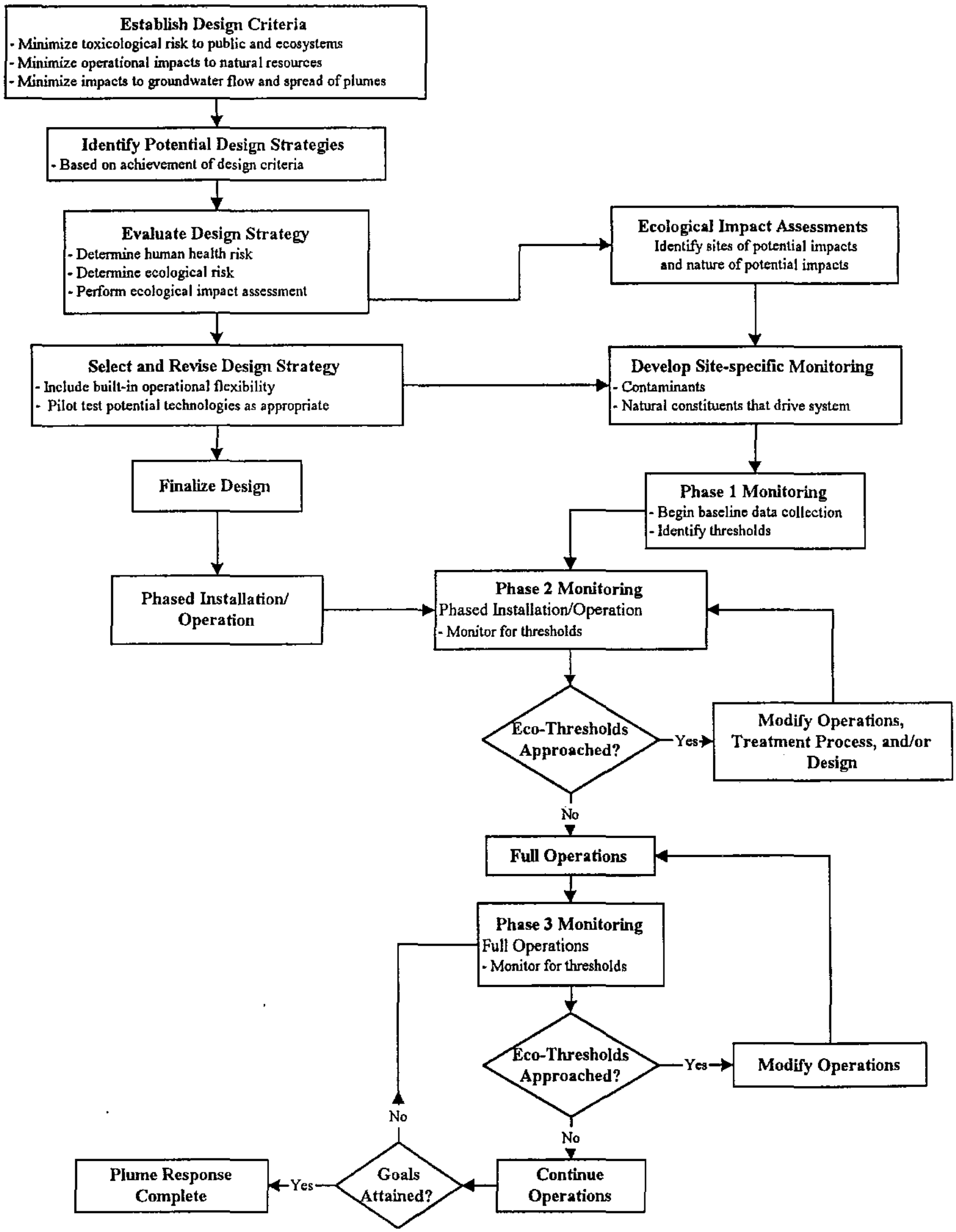


Figure 5. Plume Response Design

To start toward a balanced approach, an ecological group evaluates each plume for the potential risks from plume contaminants to humans, and aquatic and semi-aquatic organisms. Examples of the types of assessment tools used to evaluate the potential ecological and hydrological impacts to surface water resources are available for review in Appendix C. The potential risks are determined by assuming direct exposure to contaminated groundwater, or exposure to surface water that receives or is projected to receive groundwater discharge from a plume. After combining data from previously completed Remedial Investigations (RIs) with new data from OpTech's on-going Data Gap Technical Memorandum, risks are calculated for a scenario whereby each plume is hypothetically allowed to flow naturally to its point of discharge without containment or treatment.

Plumes that pose a risk if allowed to flow naturally to their discharge points are studied by a hydrological group for development of a containment and treatment strategy. The design team contracted for the plume containment project as a whole completes the actual design and modeling work for the containment and treatment system. The hydrological group evaluates and comments on proposed designs as they are developed. When considering containment or treatment, the ecosystem impacts of those actions are simultaneously assessed. The predicted hydrological changes resulting from plume response strategies are then appropriately weighed during the design process.

Once a specific plume response strategy is determined and the ecological impacts are considered acceptable, a risk assessment is repeated. This subsequent assessment evaluates strategy and design alternatives that might recommend allowing a portion of the plume to flow naturally to its point of discharge. The process is an iterative one until a design is achieved balancing risk reduction and ecosystem health.

Since the TRET's establishment, the iterative plume containment process has been highly interactive. It is hoped that the TRET report will help the MMR Remedial Program Manager (RPM), in concert with the community, to approach the challenging and complex decision of how best to begin dealing with each plume. This generic process (Figure 6) should be applied until a plume response strategy is developed for each of the plumes.

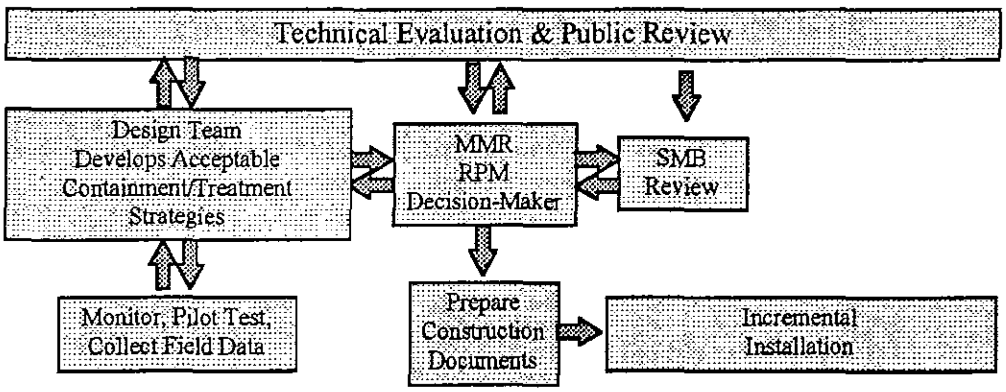


Figure 6. Iterative and Interactive Plume Response Process

The heart of the process is represented by the technical and public review phase, which begins when the design process starts, and continues through incremental installation. The technical team and public interact with the design team who develop the containment/treatment strategies in an on-going, iterative review. The design team collects the required field data to carry the strategies forward. The RPM, with input from the technical team, the public, the design team, and the SMB as required, decides on the selected strategy. This strategy is then prepared in construction document format. Incremental installation begins as soon as the contract award is made.

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5. PLUME RESPONSE RECOMMENDATIONS

General recommendations of the TRET fall into two categories. Some recommendations address concepts related to the longer term plume response process, while a second set of recommendations identifies specific tasks to execute on a plume-by-plume basis. A summary of actions is given in Table 1 below:

TABLE 1. SUMMARY OF TRET RECOMMENDED ACTIONS

PLUMES	NEAR-TERM ACTIONS	PILOT TESTING	FUTURE ACTIONS
FS-12	Phased extraction/injection system		
CS-10 (Source) *		Reactive Wall	
CS-10 (Eastern Lobe)		Recirculating Well	Evaluate effectiveness compared to pump and treat; proceed as appropriate
CS-10 (Western Lobe)	Decision makers weigh tradeoffs after all plumes in area are delineated		Design containment or other appropriate action
SD-5 (North)	Phased extraction/injection system		
SD-5 (South)	Decision makers weigh tradeoffs		Select strategy and/or proceed with investigations as appropriate
LF-1	Decision makers weigh tradeoffs after inorganics data are evaluated		Select strategy and/or proceed with investigations as appropriate
Ashumet Valley	Evaluate phosphorus loading to Ashumet Pond Decision makers weigh tradeoffs		Select strategy and/or proceed with investigations as appropriate
Eastern Briarwood	Continued monitoring of plume		
Western Aquafarm *	Continued monitoring of plume		
CS-4 *	Capture efficiency to be verified; existing P&T system to be modified as necessary		
CS-4 (EDB) *	Well-head treatment at Coonamessett well RI/FS for EDB plume		Remediation is planned as appropriate
PFSA *	Continue monitoring of plume		
FS-1 *	RI being completed		
FS-13 *	RI being completed		

* Denotes plumes not evaluated by TRET, but actions planned or underway by MMR are shown for completeness

FS-12

- **Recommendation: Design and incrementally install a plume containment system.**

The FS-12 plume is located near the regional groundwater high. If left uncontained, the plume would contaminate a significant portion of the aquifer before reaching a discharge point. The

FS-12 plume contains elevated concentrations of EDB that pose significant potential human health risk. EDB is a significant risk driver for potential ingestion of groundwater.

The design containment strategy for the FS-12 plume must focus on minimizing the impacts to Snake Pond and maximizing plume capture. Also, the P&T system should not make another plume larger or eliminate options for the containment design of another plume. Therefore, the strategy must minimize disturbance of the J. Braden Thompson plume. Fortunately, the FS-12 plume is relatively isolated spatially and hydraulically from other known contaminant plumes on MMR. A containment system can be designed and implemented for the FS-12 plume without constraining or precluding designs for the remediation of other MMR plumes.

The recommended containment approach for FS-12 will probably include a combination of strategies previously considered by the TRET, including various arrangements of extraction and injection wells in and adjacent to the downgradient portion of the plume east of Snake Pond. The extraction and injection fence system should be installed and evaluated in a phased approach. The initial step would include installation of some of the extraction and injection wells. Operation of these wells for a testing period would allow evaluation of the aquifer hydraulic response to specified extraction and injection rates and evaluation of the effectiveness of plume capture. These data would be compared to modeled results and used to calibrate the groundwater model. The refined model would be used to predict the effectiveness of the full system and any impacts on groundwater flux to Snake Pond. The final system design could be modified based on these results. Following this evaluation, additional wells would be installed and the evaluation repeated until the full system has been installed. The entire process should require one and one-half to two years.

A site-specific monitoring plan for the ecological resources at Snake and Weeks Ponds is being developed. Certain time-sensitive biotic surveys are beginning in May 1996.

<u>CS-10 (Source Area)</u>

- **Note: The MMR Installation Restoration Program (IRP) Office is proceeding with a pilot test demonstration of the University of Waterloo reactive wall technology at the CS-10 source area.**

The original intent was to test the feasibility of the University of Waterloo's funnel-and-gate type system at a shallow depth in the vicinity of Fire Training Area-1 (FTA-1). Due to site constraints and the in-progress remediation of the FTA-1 source area, this test could not be pursued. After an extensive site selection process, the CS-10 source area was chosen for the reactive wall demonstration. This site will accommodate the pilot test in an area with a higher contaminant concentration - 150 parts per billion (ppb) of trichloroethylene (TCE) - than concentrations at FTA-1 (approximately 20-50 ppb).

The reactive wall demonstration involves the installation of iron reactive media at a depth of approximately 80-120 feet below ground surface. Although testing at this depth has not been done before, using a funnel-and-gate system would be difficult and costly at this depth. Among the different emplacement systems for the iron media being presently evaluated include:

- Slurry Walls
- Driven Mandrel (Hollow Section Technologies)
- Deep Soil Mixing (Augers)
- Overlapping Caissons
- Jetting (Jet Grouting)
- Hydro-Fracturing (Vertical)

Selection of the emplacement system will be based on cost, ease of installation, and the methods to be used in testing and ensuring performance. This decision is planned to be made by the project management team during the first week of June 1996. The actual testing, planned for a minimum 50-foot long section of reactive wall, is to be conducted during late summer 1996.

CS-10 (Eastern Lobe)

- **Recommendation: Pilot test and evaluate the use of an innovative in-situ treatment technology (recirculating wells) at the area of high contaminant concentration, particularly TCE, in the southeastern CS-10 plume (portion of plume moving towards Ashumet Pond).**

The groundwater models presently cannot predict with certainty whether the eastern lobe of the CS-10 plume discharges into Ashumet Pond or underflows the pond. The immediate benefit of installing a recirculating well will be contaminant mass removal in a highly contaminated area without a significant drawdown of the water table or nearby ponds. Potential toxicological risk posed by high levels of contamination will thereby be reduced. An additional benefit, if the system operates successfully, is the possible further use of recirculating wells at this and other locations for contaminant mass removal and/or plume capture. The recirculating well technology has been recognized by the Department of Energy's Deputy Assistant Secretary for Environmental Management as a promising technology for groundwater plume remediation (*Weapons Complex Monitor*, February 13, 1996).

One type of recirculating well technology consists of a standard well having two screens, the first positioned at the bottom and the second positioned at the top of the plume, respectively. Groundwater is drawn into the bottom screen by bubbling air into the well. This process is referred to as airlift pumping. Both the air and water rise vertically inside the well up to the water table. The mixing of air and water together results in air stripping that transfers VOCs from the groundwater to the air due to their volatility.

At the water table, the air and water in the well column are separated by a packer. The air is drawn up through the remainder of the well by an above-ground vacuum pump. Here the VOC-laden air is then treated by a standard technology, such as vapor phase carbon treatment. After air stripping, groundwater exits the well through the upper screen. This arrangement creates a groundwater recirculation zone in the aquifer between the upper and lower screens which effectively reduces spreading of contamination in the aquifer.

Because groundwater is extracted and reinjected into the aquifer at the same areal location, there is little drawdown of the water table at the well location. This technology may be a suitable approach for avoiding hydrologic impacts on nearby surface water bodies. Because the contaminant removal process is air stripping, the recirculation well technology removes VOCs, and in certain circumstances, metals. Recirculating wells can be constructed with off-the-shelf materials using standard well installation techniques; therefore, no special problems are anticipated.

Recirculating wells are being used at several locations in the United States. Because the technology is experimental, the TRET recommends that a pilot test be conducted at the CS-10 location to obtain field performance data relevant to the MMR situation. The CS-10 plume has a vertical thickness of approximately 100 feet at this location. Recirculation wells addressing this vertical extent and with in-well groundwater flowrates of approximately 200 gpm have been used at other locations worldwide. Hydraulic and chemical monitoring of the system will be required. These data will provide information on the three-dimensional extent of the recirculation zone, the number of times groundwater recirculates through the system before passing farther downgradient, verification of groundwater models for prediction of recirculating well hydraulics, the efficacy of VOC removal from groundwater (confirm removal to MCL or non-detect levels), and any potential problems with implementation at MMR. With this information, decisions regarding additional design and application of recirculating wells for VOC groundwater treatment at the CS-10 or other plumes can be made.

This evaluation should include:

- An additional risk analysis to determine the toxicological consequences if allowing some of the contaminant mass is not captured;
- Assessment of the suitability of this technology for application at the site and its potential to achieve clean-up goals;
- Groundwater flow simulation to predict hydrologic impacts and the extent of the capture zones; and
- If recirculation appears favorable, an evaluation of expanding the pilot test to determine the capability of multiple recirculating wells to act as a containment system.

Recirculating wells may be able to extract contamination closer to Ashumet Pond than fences of conventional extraction and injection wells. Private land ownership in small lots and hilly terrain make it difficult to install extraction and injection wells near Ashumet Pond.

Depending on the results of the pilot test, additional wells of this type may be installed to capture larger portions of the plume. Alternatively, conventional extraction/injection well fences could be installed some distance upgradient of the pond. Placement farther upgradient would be necessary because conventional extraction well fences would cause more hydrologic disturbance and construction impacts than recirculating wells. The additional human health and ecological risk analyses would be used to determine how far upgradient the fence can be moved and still provide acceptable risk protection. Due to the uncertainty associated with the potential for ecological risks, recommendations for fence adjustments are likely to be driven by the concentrations of VOCs and subsequent human health risk analysis.

CS-10 (Western Lobe)

- **Recommendation: Through an iterative process, develop a plume response strategy which reduces toxicological risks while minimizing ecological impacts.**

The western lobe of the CS-10 plume, the leading edge of which is presently north of the base boundary, could potentially spread to the south and southwest as it migrates toward surface-water bodies in Falmouth. The plume includes several contaminated zones and is near several other plumes: the LF-1 plume is to the west, the Ashumet Valley plume is to the southeast, and the CS-4 and FS-13 plumes are in the same area, although possibly at a slightly higher elevation. The only nearby surface-water bodies are Edmunds and Osbourne Ponds, and they are not predicted to receive discharge from the plumes.

The CS-10 plume containment system in the 60 Percent Design predicted large changes in groundwater levels and groundwater-flow directions, including an eastward "smearing" of the CS-4 plume. Preliminary analysis (by TRET) suggested that it may be possible to combine a system to address the eastern lobe of the CS-10 plume (see above) with a second system targeting the western lobe and adjacent plumes. This system was to include parallel fences of extraction and injection wells in an arc across the LF-1, CS-10, CS-4, and FS-13 plumes aligned with existing water-table contours.

The on-going delineation of plumes in this area should be completed so that vertical locations of the plumes and hydrogeologic conditions in the area are better known. A system should then be designed to address this section of the CS-10 plume while either capturing its neighboring plumes or not shifting their paths if they are not captured. Such a system could be similar to one evaluated in the preliminary analysis, consisting of parallel lines of extraction and injection wells with screens set at elevations opposite the contaminated zones and located near the leading edge of the western lobe and cutting in an arc, parallel to the water-table contours, across the plume. The pumping rates should be as low as possible so that the plumes are captured without changing water levels in the ponds or shifting regional directions of flow.

Plume paths should be evaluated using groundwater model for the entire period of system operation to ensure that the plumes are not smeared upgradient of the fences compromising future efforts to remediate them. Because of complicated spatial relationships among the plumes and the possibly large containment system width, a comprehensive sensitivity analysis of expected flow directions and capture effectiveness should be performed before a final design is prepared. The system should be installed in phases to ensure that the predicted aquifer response is correct.

A site-specific monitoring plan for ecological resources just north of and including Ashumet Pond is being developed. Certain time-sensitive biotic surveys are beginning in May 1996.

SD-5

- **Recommendation: Install a P&T containment fence for the northern part of the SD-5 plume approximately 2500 feet north of Ashumet Pond. Through an iterative process, develop a plume response strategy which reduces toxicological risks while minimizing ecological impacts. The hydrogeologic complexity between Ashumet and Johns Ponds may make a containment or remediation of the southern part of the SD-5 plume problematic.**

The TRET recommends that a P&T fence system be installed at the MMR boundary to capture the northern part of the SD-5 plume. Placement of the fence at this location would minimize hydrologic impacts to Ashumet and Johns Ponds. Determination of extraction and injection rates to achieve complete capture should be possible because the plume is shallow, the groundwater flow directions are almost horizontal, and the hydrogeology is not complex. The containment system should be designed to capture the full thickness and width of the plume at the MMR boundary (at a minimum, the portion above MCL concentrations) and must not adversely affect the PFSA and Western Aquafarm plumes.

The extraction and injection fences (or recharge basins) should be positioned along South Outer Road where the SD-5 plume crosses the MMR boundary. The extraction fence should extend approximately 400 feet along South Outer Road. An injection fence (or series of recharge basins) should be installed downgradient and parallel to the extraction fence line. With this configuration, the balance between extraction and injection will limit water level changes which could have adverse impacts to a small portion of the aquifer.

The proposed P&T strategy would not contain or capture the southern part of the SD-5 plume. The proximity of Ashumet and Johns Ponds to the plume, the extreme hydrogeologic variability between the ponds, and uncertainties concerning the plume's path in this hydrogeologically complex area, make design of a containment system problematic. Uncertainties concerning the effectiveness of a pumping and injection system near the ponds would be very large.

A risk assessment has been completed for the southern part of the SD-5 plume that would not be intercepted by the northern fence. If the southern half of the SD-5 plume discharges to Johns Pond, human health risks would not exceed the USEPA target risk range, meaning that no known unacceptable human health risks result from allowing of this portion of the plume to remain uncaptured.

Discharge of the SD-5 plume to Johns Pond may pose a potential risk to aquatic and semi-aquatic organisms through exposure to inorganics that may reach the surface waters. However, the inorganics concentrations appear to be artificially elevated, and a reevaluation of the inorganic concentrations in the groundwater is needed to help refine the ecological risk estimates. More importantly, surface water and sediment sampling in Johns Pond should be conducted to verify whether contaminants are reaching the ponds and, if so, whether they exist in concentrations that would present a potential ecological risk.

The TRET recommends that the results of a new risk assessment for the southern part of the plume be presented to the public and the decision makers. The latter will help identify the tradeoffs to be made in selecting a final strategy. An in-depth analysis of the hydrologic uncertainties associated with pumping strategies between Ashumet and Johns Ponds should be part of the presentation.

LF-1

- **Recommendation: Through an iterative process, develop a plume response strategy which reduces toxicological risks while minimizing ecological impacts.**

Based on estimates that large pumping rates will be needed for full containment of the LF-1 plume, the TRET believes that implementation of the modified 60 Percent Design will cause unacceptable impacts to wetland, pond, and salt-marsh resources located near the extraction and injection systems. Mounding resulting from water reinjection may also flood on-lot subsurface disposal systems located near the injection fence. Public-water supply service should be extended to all water users in the projected plume path. No unacceptable risks are predicted for swimmers in the harbors; therefore the TRET recommends that the MMR delay installation of a containment system for the LF-1 plume until the following tasks are completed and additional data are available for review and consideration:

- Complete evaluation of the quality of the available inorganic data and resample is needed to reduce uncertainties associated with the reported elevated values and the resulting potential ecological risks from LF-1 discharge to the harbors.
- Identify which constituents in the plume drive ecological risks.
- Delineate horizontal and vertical extent of those portions of the LF-1 plume which pose unacceptable risks.
- Based on results of the above, identify potential extraction fence locations which may prevent unacceptable risks while minimizing adverse impacts on sensitive ecological organisms.
- Determine the points of discharge for the plume into the harbors and sample, in a tiered fashion, the sediments, pore water, surface water, and shellfish in this area. This would most effectively determine if adverse human or ecological health effects could result from exposure to these media or consumption of shellfish.

It is unclear whether or not additional plume characterization efforts are needed to finalize or refine potential approaches to control the plume at this time. This determination should not be made until a more thorough review of available data is conducted. For metals, all available geochemical data should be evaluated to assess their transport characteristics and probable fate.

Ashumet Valley

- **Recommendation 1: Complete the analysis of phosphorus loading to Ashumet Pond from the Ashumet Valley plume.**

Proposed engineering actions recommended in this report should not cause significant changes in the interaction between the Ashumet Valley plume and Ashumet Pond. Several studies (LeBlanc, 1984; K-V Associates, 1991; Walter and others, 1995) show that a portion of the plume contains phosphorus derived from past disposal of treated sewage at MMR. This portion discharges in part to the Fishermans Cove area of the pond. There is concern that phosphorus entering the pond from the plume could affect the trophic state (ecological health) of the pond.

On-going work, supported by the 102nd Fighter Wing Environmental Management Office at Otis Air National Guard Base, should continue to determine if the phosphorus loading has a detrimental effect on the water quality of Ashumet Pond. Action to limit that loading should be taken if necessary. VOCs from the fire training area, found deep in the plume upgradient of the pond, should be monitored to ensure that predictions which show they will not enter the pond are correct (ABB-ES, 1995).

- **Recommendation 2: Through an iterative process, develop a plume response strategy which reduces toxicological risks while minimizing ecological impacts.**

The part of the Ashumet Valley plume that is south of Ashumet Pond contains VOCs, nitrates, and other contaminants. The leading edge of the VOC plume is located just south of Carriage Shop Road, while other sewage-related contaminants may have traveled as far south as groundwater-discharge locations along the coast. The leading edge of the plume south of Hayway Road underlies wetlands, cranberry bogs, and streams where the water table is at land surface. Reasons for the apparent splitting of the plumes into two lobes at Carriage Shop Road are unknown, but could be related to hydrogeologic factors or past variations in the sources of the plume.

An analysis of the potential impacts on water resources of the Ashumet Valley plume must be completed and consensus reached on the goals and constraints of a containment or treatment system. A system that meets these goals within the constraints would then be designed. This system could include parallel fences of extraction and injection wells, although the shallow depths to water as far north as Hayway Road will limit the magnitude of groundwater level changes that are acceptable. The design should include installation of the system in phases so that the hydrogeologic factors, which may be the cause of the two lobes and could control the magnitude of drawdown at the water table, are identified and considered in the final design. Consideration of the chemical quality of groundwater that discharges to the Backus River will be necessary, particularly if the system results in a significant volume (relative to the river's total discharge) of treated water entering the river.

Eastern Briarwood

- **Recommendation: Continue monitoring the plume to ensure that no unacceptable toxicological risk develops from discharge to the Quashnet River.**

Within several years the plume is expected to flush itself from the aquifer if no continuing source of contamination exists. The human health risk assessment concludes that only arsenic contributes risk above the USEPA target risk range. However, this conclusion is suspect because a bias in the sampling methodology may have caused artificially elevated concentrations of inorganics. Potential ecological risks are also driven by inorganics.

A site-specific monitoring plan for ecological resources is being developed for the wetlands surrounding, and to the north of, the upper reaches of the Quashnet River. If the evaluation of inorganics results in a conclusion that risk to ecological organisms is probable, or if monitoring results in the detection of ecological impacts or greater concentrations of compounds than previously measured, an extraction system could be considered to contain or limit growth, or reduce concentrations with no ecological impacts.

The maximum VOC concentration reported in the data gap report is 10.5 ppb TCE - the MCL is 5 ppb. This occurs just upstream of the Quashnet River, about 20 feet below the water table. At that location the water table is about one foot below the ground surface. The next highest concentration is 7.3 ppb approximately 1400 feet upstream of the river and about 5 feet below the water table.

If monitoring suggests the need for remediation, one should evaluate its suitability for the site. An alternative technology that has minimal impacts on water levels is preferred to conventional extraction and injection wells because the water table is so close to the ground surface and mounding at an injection well could be problematic.

CS-4

- **Recommendation: Modify, as necessary, the CS-4 plume containment system to achieve capture of the full plume thickness at the location of the existing well fence.**

A plume-containment system was installed in November 1993 to capture the CS-4 plume in the Crane Wildlife Area before it crossed Route 151 and approached the area north of Coonamessett Pond. An Air Force Center for Environmental Excellence (AFCEE) Peer Review Team recently concluded that the existing P&T well fence in the CS-4 plume is probably capturing most, and maybe all, of the CS-4 plume at a point about 1,200 feet upgradient (north) of Route 151 in the Crane Wildlife Area. Capture is probably being achieved despite evidence that the plume moved downward as it approached the well fence relative to the trajectory that had been predicted prior to installation of the fence. The review team suggested that additional chemical data be collected to determine if full capture has been achieved.

The CS-4 well fence system will meet the present design goals if it is fully effective. Therefore, a rigorous evaluation of the system's effectiveness should be completed, and the characteristics and operation of the fence should be modified, if necessary, to ensure complete capture of the CS-4 plume at this location. If pumping rates need to be increased, the effect on directions of regional groundwater flow should be evaluated by computer modeling and field observations of water levels to ensure that the paths of other plumes, especially the Ashumet Valley plume, do not shift. The location of after-treatment recharge to the aquifer should be changed, if necessary, to prevent undesirable shifts in plume paths. This system should be used to gain information (for example, estimated recharge rates from precipitation) that can be transferred to other P&T efforts on MMR.

CS-4 (EDB Portion)

- **Recommendation: Complete the RI/FS to define the plume and subsequently develop a plume response strategy by reducing toxicological risks while minimizing ecological impacts. Ensure that the recommended strategy does not jeopardize the other containment efforts.**

Work should continue to define the EDB plume that extends south of the present CS-4 containment fence into the area west of Coonamessett Pond. The work should be expanded to include the effort required for a RI/FS. Evaluate plans to contain or remediate this plume with the regional groundwater flow models being used to design the overall containment system. Evaluation should address the effectiveness of proposed systems and concerns that the system does not adversely impact containment of other plumes. MMR and local officials are proceeding with the immediate installation of well-head treatment at the Coonamessett Pond public-supply well. This action will guarantee the quality of water from this well in the event it is needed.

6. HUMAN HEALTH/ECOLOGICAL RISK CONCLUSIONS

The ecological group has completed ecological and human health risk assessments for the FS-12, CS-10, SD-5, LF-1, Ashumet Valley, and Eastern Briarwood plumes. These assessments are based on the following scenarios:

- Human health and ecological risks calculated and summarized for each of the plumes from their respective RIs
- Human health and ecological risks calculated from the new Data Gap Technical Memorandum
- Human health and ecological risks calculated whereby the plumes naturally attenuate
- Human health and ecological risks calculated for potential failures of treatment options (*e.g.*, pipeline leakage)

To obtain a copy of a specific risk assessment, please write to MMR IRP Office; 322 East Inner Road, Box 412; Otis ANG Base, MA 02542.

A summary of the risk assessments for the natural attenuation scenario (where the plumes are allowed to flow naturally to their points of discharge without containment or treatment) is provided below. The basis of these assessments consisted a list of surface water bodies; the plumes that would potentially discharge to each; the estimated total flux of groundwater into the surface water body; and the percentage of the flux contributed by plumes into each. A dilution factor was applied to the groundwater concentration to determine a concentration in surface water. If more than one plume discharges into a single surface water body, the maximum concentration of each contaminant from all discharging plumes was used in the risk assessment with a dilution factor applied.

Risks to the resident from domestic use (*i.e.*, drinking) of groundwater under a natural attenuation scenario were evaluated in the RI. The assessment conclusions provided here apply primarily to the discharge of groundwater to surface water bodies and the associated risks to surface water organisms. For human health risks, the surface water organism considered is the recreational swimmer. For ecological risks, the organisms include aquatic organisms and a semi-aquatic organism, the osprey. The osprey is the most sensitive semi-aquatic organism chosen for the MMR due to the bioaccumulation in the food chain.

FS-12 Conclusion

The FS-12 plume is predicted to discharge to Mashpee pond, Snake Pond, and Mashpee River. The recreational swimmer was evaluated for human health risk. Of the discharging contaminants, EDB and Benzene result in risks above the USEPA target risk range or above the target hazard index for all of the surface water bodies.

For ecological risk assessment, the aquatic and osprey organism in all three discharging surface water bodies result in a HI above the target level. The primary risk drivers for the aquatic organism are xylene and aluminum for Mashpee Pond; benzene, xylene, aluminum, cadmium, chromium, iron, lead, and manganese for Snake Pond; Aluminum for Mashpee River. The primary risk drivers for the osprey are manganese for Mashpee Pond; benzene, naphthalene, aluminum, cadmium, lead, manganese, vanadium, and zinc for Snake Pond. No single contaminant exceeded a hazard quotient of 1, however the hazard index for Mashpee River was above the target hazard level.

CS-10 Conclusion

The CS-10 plume is predicted to discharge to Coonamessett Pond, Fresh Pond, Great Pond, Ashumet Pond, Green Pond, Bourne Pond, and the Coonamessett River. The recreational swimmer was evaluated for human health risk. The discharging contaminants do not result in risks above the USEPA target risk range or above the target risk hazard for any of the surface water bodies.

For ecological risk assessment, each of the ponds/rivers had a hazard index above 1 for both aquatic and semi-aquatic organisms. In each case, the ecological risks are due primarily to the presence of inorganics, including manganese, aluminum, copper, iron, zinc, mercury, and thallium.

(Correction for SD-5 Conclusion, dated 15 May 96)

SD-5 Conclusion

The SD-5 plume is predicted to discharge to Johns and Ashumet ponds. The recreational swimmer was evaluated for human health risk. The discharging contaminants do not result in risks above the USEPA target risk range or above the target risk hazard for Johns Pond. However, the hazard index for Ashumet Pond is 1.02 which slightly exceeds the target hazard index of 1. The Hazard Quotient (HQ) is driven by TCE.

For ecological risk assessment, aquatic organisms were evaluated, as well as a semi-aquatic organism, the osprey. In John's Pond, only aluminum results in a hazard quotient above 1 for aquatic receptors. For the osprey, copper, manganese, and selenium result in a HQ above 1. For Ashumet Pond, numerous inorganics are predicted to exceed a hazard quotient of 1 for both aquatic organisms and the osprey. They include cadmium, copper, manganese, zinc, and thallium.

LF-1 Conclusion

The LF-1 is predicted to discharge to Megansett Harbor, Red Brook Harbor, and Squeteague Harbor. The recreational swimmer was evaluated for human health risk. The discharging contaminants do not result in risks above the USEPA target risk range or above the target risk hazard for any of the harbors.

For ecological risk assessment, lead and zinc result in HIs of 1.3 and 5.2, respectively, for aquatic organisms. Zinc is the only contaminant resulting in a hazard index above 1 for the osprey in Squeteague Harbor.

APPENDIX A

Ashumet Valley Conclusion

The Ashumet Valley plume is predicted to discharge to the Backus River, Coonamessett River, Ashumet Pond, Green Pond, and Bourne Pond. The recreational swimmer was evaluated for human health risk. The discharging contaminants do not result in risks above the USEPA target risk range or above the target hazard for any of the surface water bodies.

For ecological risk assessment, each of the ponds/rivers had a hazard index above 1 for both aquatic and semi-aquatic organisms. In each case, the ecological risks are due primarily to the presence of inorganics, including manganese, aluminum, copper, iron, zinc, mercury, silver, thallium, lead, and cadmium.

Eastern Briarwood Conclusion

The Eastern Briarwood plume is predicted to discharge to the Quashnet River. Risks were calculated to the recreational swimmer, and did not exceed the USEPA target risk range or target hazard index.

Ecological risks were calculated for aquatic organisms and a semi-aquatic organism, the osprey. Only xylene exceeded a hazard quotient of 1 for aquatic organisms. Copper, manganese, mercury, and selenium all exceed a hazard quotient of 1 for the osprey.

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7. HUMAN HEALTH/ECOLOGICAL RISK RECOMMENDATIONS

In addition, the ecological group has identified critical issues that should be resolved in order to reduce uncertainties associated with risk estimations. They have also recommended work that should be completed in the near future.

- **Recommendation 1: Determine Inorganic Concentrations and Evaluate the Potential Mobility of Inorganics to Downgradient Surface Water Bodies**

Mean and maximum total unfiltered inorganic concentrations were incorporated into the human health and ecological risk assessments. However, there are several orders of magnitude difference between filtered and unfiltered inorganic concentrations in groundwater sampled during the RIs and data gap effort. In addition, studies conducted by the USGS have shown that chromium, copper, cadmium, and zinc are not very mobile in the Ashumet Valley sewage plume. A review by USEPA and USGS geochemists of the analytical data and field parameters indicates that inorganic concentrations in unfiltered samples may be artificially elevated because of entrainment of suspended particulates during sampling. Therefore, the risk characterization probably overestimates the potential for risk from exposure to these inorganics.

A subset of all monitoring wells showing high inorganic concentrations in the RI and data gap sampling should be resampled using low flow sampling techniques. Once new data are obtained, mean and maximum values for total inorganics should be recalculated and human health and ecological risks analyses should be reanalyzed. The expected lower inorganic concentrations probably will lead to more realistic estimates of potential toxicological impacts to ecological organisms.

During this resampling effort, certain field geochemical parameters, such as dissolved oxygen, pH and oxidation/reduction potential should be measured to aid in understanding plume geochemistry. A geochemical analysis of the data will provide better estimates of the ability of these inorganics to migrate at high concentrations and discharge to downgradient surface waters. Resampling is very important since the current screening level ecological risk assessments rely on unrealistically high concentrations and predict an unrealistic potential for ecological risk to aquatic and semi-aquatic organisms.

- **Recommendation 2: Refine Estimates of Dilution within Ponds and Rivers**

To assist in evaluating the risks of a natural attenuation scenario (whereby the plumes flow naturally to their points of discharge without containment or treatment), the hydrological group provided the ecological group with a list of surface water bodies and the plumes that would potentially discharge to each surface water body (Table 2). Also provided were the total flux of groundwater into each of the surface water bodies (cubic feet per day) and the percentage of the flux that could potentially be contributed by each plume to those surface water bodies when the plumes reach the water bodies.

TABLE 2. SUMMARY OF POTENTIAL INTERACTION OF PLUMES AND SURFACE WATER BODIES

Surface Water Body	Potentially Discharging Plumes
Ashumet Pond	CS-10, SD-5, Ashumet Valley
Bourne Pond	CS-10, Ashumet Valley
Coonamessett Pond	CS-10
Fresh Pond	CS-10
Great Pond	CS-10
Green Pond	CS-10, Ashumet Valley
Johns Pond	SD-5
Mashpee Pond	FS-12
Snake Pond	FS-12
Megansett Harbor	LF-1
Red Brook Harbor	LF-1
Squeteague Harbor	LF-1
Backhus River	Ashumet Valley
Coonamessett River	CS-10, Ashumet Valley
Mashpee River	FS-12
Quashnet River	Eastern Briarwood

Assuming instantaneous mixing of all entering groundwater, a dilution factor was computed. The maximum groundwater concentration identified by the RI or data gap sampling was diluted accordingly. If more than one plume discharges into a single surface water body (*e.g.*, Ashumet Pond), the maximum concentration of each contaminant from all discharging plumes was used in those risk assessments with a dilution factor applied.

It is recognized that this is a screening level approach. A refinement of this methodology is highly recommended that would allow for the incorporation of a mixing zone calculation for the streams if plumes were to continue discharging into them. A mixing zone would be established at the discretion of Commonwealth of Massachusetts officials and should be consistent with guidance set forth in the Clean Water Act. Guidance for defining mixing zones can be located in the *Water Quality Standards Handbook: Second Edition* (EPA-823-B-94-005a) and *Technical Support Document for Water-Quality-Based Toxics Control* (EPA/505/2-90-001).

For the ponds, a mass loading calculation could be performed by applying the maximum concentration of contaminants to the volume of the plume; however, there is a great amount of uncertainty associated with this calculation since the plumes were characterized and defined only by the concentrations of VOCs. There is also the uncertainty associated with the mobility of the inorganics as discussed in the first recommendation.

Maximum concentrations could be run through an equilibrium partitioning equation to better assess the concentration of contaminants that may reach the surface water. The equilibrium partitioning approach is only relevant to non-polar organics and not the inorganics. Finally, these calculations and predictions can be confirmed through site specific surface water, pore water, and sediment sampling in surface water bodies where contaminated groundwater is located or is expected to discharge.

- **Recommendation 3: Monitor for Contaminants of Concern in Environmental Media**

Samples should be collected and analyzed in a tiered fashion (sediments, pore water, and surface water) for plume contaminants from potential groundwater discharge locations. This sampling should take place very soon so as to establish a point of comparison for future sampling and analysis. Any surface water sampling should also include measuring dissolved oxygen, specific conductance, pH, and temperature at the time of sampling, and hardness should be calculated during chemical analysis. Sediment samples should be analyzed for total organic carbon and grain size, and oxidation-reduction potential, since these factors help predict oxidation states/phases of metals and are integrated in the determination of whether non-ionic hydrophobic constituents are bioavailable. Toxicity testing should follow if contaminant concentrations indicate a potential for adverse impacts to biological organisms. The sampling program should consist of a sufficient number of samples to support complete statistical analyses, and locations should be sampled and analyzed seasonally to account for any variation. An ecological risk assessment should be developed following the sampling and analysis.

More specifically, the sampling needs of the eco-risk analysts should be integrated into the long-term environmental monitoring program. These needs include regular measurements of contaminants in surface waters, pore waters and sediments in both Johns Pond and Ashumet Pond. Specific water quality parameters (*e.g.*, dissolved oxygen, pH and water transparency) should be integrated into the program along with measures of phosphorus since there is a potential for an increase in eutrophication from the Ashumet Valley plume. The long term flux of phosphorus into Ashumet Pond could be responsible for a greater ecological impact than any toxicological risk.

A limited number of surface water and sediment samples were collected and analyzed for contaminants of concern from Ashumet Pond, Johns Pond, the Quashnet River, and the cranberry bog north of Ashumet Pond during 1993 and these sampling locations were not intended to be representative of spatial or temporal concerns.

- **Recommendation 4: Complete Tissue Sampling for Biological Organisms**

As outlined in the *Risk Assessment Handbook*, the Preliminary Risk Assessment performed during the Remedial Investigation identifies a Tier IV component that includes biological investigations such as rapid bioassessment protocols for macroinvertebrates, toxicity testing and tissue analysis. Tier IV analysis is pursued only if baseline ecological risk assessments indicate a potential risk based on the cumulative Hazard Indices representing the mean and maximum contaminant concentrations. The handbook states, *"if Hazard Index > 1.0, then Tier IV will be implemented."* These biological investigations have not been implemented for any of the ecological risk assessments. However, there was a determination of the percent contribution of each contaminant so as to identify the contaminants potentially responsible for the greatest contribution to the risk. In order to evaluate those site specific risks, in comparison to background risks, those same determinations need to be made since the potential ecological risk to aquatic organisms is primarily being driven by the inorganics, which may be naturally occurring.

There has been minimal site specific biological sampling and analysis conducted in surface water bodies that are potentially impacted by contaminated groundwater discharge since a majority of the plumes were not known to be discharging into surface water bodies when the RIs were done. A limited number of mussel and fish samples were collected and analyzed for contaminant concentrations from Johns and Ashumet Pond during the spring and fall of 1994. Fish species collected included brown bullhead, trout, largemouth bass and yellow perch.

Sample size between species and ponds was inconsistent. Whether or not a reference pond was sampled for comparison was not always included as part of the study design. In general, mussel and fish tissue concentrations were composed of low level organic and inorganic contaminant concentrations. There were slightly elevated concentrations of the pesticides, DDD, DDE, and dieldrin in yellow perch whole bodies collected from Ashumet Pond during the Spring of 1994. Certain contaminants were only detected in the reference ponds, not in Ashumet and Johns Ponds.

Drawing definitive conclusions from various measures collected from the Ashumet and Johns Ponds Study is difficult due to the fact that the study design did not focus on relating biological effects to exposure to plume contaminants.

This study did reveal an incidence of oral/body surface papillomas in brown bullheads collected from Johns Pond and Ashumet Pond. During the May 1994 sampling event, there was a 33 percent (10/29) prevalence of papillomas in Ashumet Pond and a 50 percent prevalence (5/10) in Johns Pond. In Long Pond, the reference pond, there was a 27 percent (4/15) prevalence of papillomas. In September 1994, all ponds were sampled again and another reference pond was sampled. Ashumet Pond had a 17 percent (2/12) and Johns Pond had a 50 percent (1/2) incidence of oral papillomas restricted to brown bullheads but both reference ponds had no detects of papillomas out of approximately 30 fish. The elevated prevalence of oral/body papillomas, higher Health Assessment Index scores for yellow perch and the evidence of fish liver damage in Ashumet and Johns Ponds requires further investigation.

Since the cause for these papillomas could be genetic, viral, or related to the exposure to contaminants in sediments, it is imperative to phase any additional studies. The primary focus of any proposed sampling design must address whether the contaminants discharging from the plumes are responsible for the increased occurrence of oral/body surface papillomas in brown bullheads. The first phase may consist of a non-destructive brown bullhead population survey to be conducted by the Massachusetts Department of Fisheries and Wildlife or the United States Fish and Wildlife Service. This survey should consist of field observations as to whether the higher prevalence of these papillomas is restricted to these ponds or is a regional phenomena.

Evaluation of these data should include a well-replicated statistical analysis including analysis of variance with multiple comparison tests and/or linear regression with calculation of confidence limits. This investigation will be defined in the ecological monitoring plan for the pond ecosystem.

- **Recommendation 5: Review and Refine Semi-Aquatic Food Chain Model**

Based on the results of the first recommendation regarding the addition and confirmation of inorganic concentrations, it may be necessary to review and refine the semi-aquatic food chain models. This recommendation would become very important should the potential ecological risk to aquatic or semi-aquatic organisms be used to drive a remedial action.

In the *Risk Assessment Handbook*, food chain models were developed for a number of semi-aquatic organisms, such as the osprey, black-crowned night heron, American black duck, mallard, and muskrat. The factors incorporated into this methodology were designed to be extremely conservative (worse case) screening values. They were intended to be used to definitively state which sites were not a problem. However, they were not designed to determine clean-up levels, or to determine actual site-specific exposures.

The team's review of the factors that are incorporated into these food chains and the derivation of Hazard Quotients, a representation of the comparison between predicted dose to an organism and a reference toxicity value, appear to be elevated and may be unrealistic when determining the magnitude of potential effects. This situation is particularly true in the case of inorganics, which were discussed in the first recommendation. Thus, the Hazard Quotients may a lead a reviewer to make the judgment that there is a significant or elevated risk to a particular organism that may be directly or indirectly related to exposure to plume contaminants.

However, there is a high degree of uncertainty attached to these conclusions, and the ability to discern the magnitude of that risk is unknown. These constraints, combined with the uncertainties associated with the inorganics data, result in the inability to address the question of whether the potential for any ecological risk is significant and clean-up standards based on ecological risks cannot be determined.

If it was decided that a potential for ecological risk were to drive the need to implement a remedial action for any of the plumes or if it was important to refine those screening level Hazard Quotients to make a more realistic attempt at assessing the magnitude of the risk, the following revisions should be made:

- **Recommendation 5.1 Review and revise the bioaccumulation factor for fish**

Fish bioaccumulation factors should be revised by multiplying the bioconcentration factor for the contaminant, ratio of contaminant concentration in food to concentration in water by the appropriate food chain multiplier (Opresko *et al,* 1995). For example, the handbook cites 350,000 as the bioaccumulation factor for manganese and this number appears to be quite high and unrealistic.

- **Recommendation 5.2 Review and revise the reference toxicity values and application of uncertainty factors**

The reference toxicity value is the denominator of the Hazard Quotient and alone can be responsible for contributing to the conclusion that there is a potential for risk. It is very important that reference toxicity values are selected using laboratory studies that identify the species of compound, test species, study duration, endpoint, exposure route, and dosage so final no-observed-acute-effect levels can be calculated. The *MMR Risk Assessment Handbook* was finalized in August 1994. Research and information in the literature database continues to be refined and changed.

There may be a number of values that were considered the most appropriate and up-to-date at the time of the publishing of the handbook, but more current research and literature may supersede these values. Within the last year, Opresko *et al.*, prepared by Lockheed Martin Energy Systems, Inc. (1995), has provided additional information on benchmark values for many of the species used in these ecological risk assessments adjusting for body weight, food and water intake. Caution and best professional judgment should be employed in the application of uncertainty factors added to species- specific reference toxicity values.

If it is determined that a particular analyte is driving clean-up based on ecological risk assessment, the literature should be reviewed to determine if the toxicity values applied to the risk assessment are based on the most current understanding of the toxicity of that compound to ecological organisms at MMR.

- **Recommendation 5.3 Refine the home range factor**

Better risk estimates for semi-aquatic organisms could be calculated by applying a more realistic home range factor; much of this information can be extracted from EPA's Wildlife Exposure Factors Handbook (EPA/600/R-93/187 a&b). Ecological risk assessments conducted for six plumes on the MMR assumed the home range to be equal to the area of concern or the particular pond to which groundwater was predicted to discharge.

- **Recommendation 6: Develop Environmental Monitoring Plans**

Ecological impact includes ecological risks due to contaminants as well as individual and population impacts due to physical and chemical alteration. Therefore, changes in water levels, water chemistry, temperature, and the potential presence of contaminants of concern are all evaluated in and are key parts of comprehensive ecological monitoring (Appendix D contains a draft ecological monitoring plan).

Comprehensive ecological monitoring plans are currently being developed to:

- Understand the existing ecosystems and gather baseline conditions,
- Develop ecosystem thresholds to the potential impacts,
- Allow "real-time" mitigation of impacts through operation and/or design changes, and
- Provide real time insurance of contaminant status. Site specific monitoring plans are being developed initially for Snake Pond, Ashumet Pond, a vernal pool to the north of Ashumet Pond, Johns Pond, and the uppermost reach of the Quashnet River based on the recommendations for strategies presented.

The plan for this monitoring should contain and address the following recommendations applied to all plumes and treatment options:

- Measure baseline conditions of the ecological resources of concern prior to constructing and operating the containment systems to the maximum extent possible.
- Identify and monitor for thresholds, that if exceeded could result in serious impact to the ecological resources.
- Build flexibility into monitoring that will allow changes in response to: new or changing treatment approaches; findings from baseline characterizations; and early operational findings.
- Limit monitoring to parameters likely to be clearly attributable to impacts of the action.
- Develop monitoring plans that answer the following questions:
- What is the water source?
- What are the water fluctuations?
- What are the unique physical and biological characteristics that result in the presence of this ecosystem?
- What functions and values of an ecological resource are being damaged by the action?
- What are the direction and magnitude of changes?
- Based on possible but less likely changes, what other measurements need to be taken, when, and what thresholds will decide?
- Identify appropriate reference sites as points of comparison to the maximum extent possible.
- Develop field tasks descriptions and schedules immediately for the survey of rare and endangered, sensitive, or indicator species so that this ecological study season will not be missed.

In order to help ensure that the monitoring effort meets quality assurance and programmatic objectives, a systematic and well-defined data collection and management system must be in place. This system would include (by not necessarily be limited to) the following:

- A sampling design that is statistically valid
- Reference ecosystems that represent the potentially affected ecosystems to the maximum extent possible
- Methodologies for sampling that are tailored for the ecosystem characteristics and for the questions being answered
- Quality assurance procedures defined for collection of each type of data
- Software defined for data management
- Statistical methods defined for data analysis
- Protocol set for data distribution
- Repository identified for specimen collections
- Oversight well-defined for data collecting, coordination, data control, and analysis
- Data evaluation team established with well-defined milestones
- Public involvement defined for data presentation

8. OTHER HYDROLOGIC AND OPERATIONAL RECOMMENDATIONS

- **Recommendation 1: MMR Groundwater Modeling**

Groundwater models are essential to obtain an overall understanding of the hydrologic system and its response to pumping and recharge. The models integrate the complex interactions among hydraulic parameters and stresses, such as pumping, so that the behavior of the system can be explained and predicted. However, the models are only approximate representations of the real system and inherently contain some uncertainty.

Two groundwater flow models independently developed by ECE and the USGS are being used to design groundwater extraction systems for containment and capture of contaminant plumes on the MMR. The modeling analyses are being used to determine extraction and injection locations and rates, as well as to aid evaluation of the hydrologic changes that are likely to occur as a result of operating the containment/capture system. At present, there are some fundamental differences in the construction of the two models, and there are differences in the model calculations. Some of these differences exist because the models were initially developed for differing purposes.

At the request of the TRET, and with the concurrence of AFCEE and the NGB, a preliminary review of the two models was initiated. The purpose of the review is to evaluate the differences in the construction of the two models and identify whether those differences may affect the interpretation of the hydrologic effects of proposed extraction/injection scenarios. The review is expected to focus on the following:

- Model grid discretization in the horizontal and vertical directions;
- Spatial distribution of hydraulic properties within the model grid;
- Model boundary conditions; and
- Model calibration

The results of the review will be contained in a separate letter report that addresses these issues and, to the extent possible, makes recommendations regarding coordination of modeling efforts to assist the remedial design process. The report is to be submitted to AFCEE and the NGB by May 17, 1996.

The TRET recommends that the changes made to the steady-state calibrated ECE model since submittal of the 60 Percent Design be documented in a summary report. This report should address the four bullets above and how these items affect the model's usefulness for predicting the effects of extractions and injections. A report describing the USGS's steady-state calibrated model is already available (*Masterson et al., USGS Open-File Report 96-214)*.

The TRET also recommends that the hydrologic and geologic interpretations on which the models are based be refined as new data are collected from the ongoing RIs, data-gap work, pilot tests, and phased installation of containment/remediation systems. The regional and site-specific groundwater models used at the MMR should be updated and tested accordingly.

The TRET recommends that sensitivity analysis be used to test the proposed extraction/injection scenarios. In sensitivity analysis, the predicted hydrologic response and capture efficiency is modeled repeatedly while aquifer properties and other hydrologic parameters are varied over a realistic range of values. The analysis shows how sensitive the outcomes are to the uncertainty of knowledge about the system and allows evaluation of the robustness of the design.

In the future, solute-transport simulation may be needed to address specific questions, such as the time it will take to completely flush contaminants from a part of the aquifer. In addition, formal optimization modeling could be helpful. Formal optimization can be used to help select optimal designs for pumping and recharge to meet specific goals while meeting pre-selected hydrologic, ecological and economic constraints.

- **Recommendation 2: Hydrologic-System Considerations**

Several aspects of the hydrologic system that are not well understood make interpretations of the field data difficult and limit confidence in groundwater model predictions. These include the following:

- Patterns of groundwater flow at ponds. The degree to which plumes, such as the CS-10 and SD-5 plumes, intersect ponds is unknown. The fate of the contaminants if they pass through the pond-bottom sediments and enter the surface waters also is unknown.
- Rate of natural recharge on western Cape Cod. The rate of natural recharge used in groundwater models of the MMR area varies from model to model by almost 50 percent. The rate directly affects the downward trajectory of plumes and the amount of water that must be pumped for containment.
- Spatial trends and variations of horizontal and vertical hydraulic conductivity. The shape of capture zones and the paths of plumes are sensitive to the structure of the hydraulic-conductivity field, yet little is known about hydraulic conductivities in the moraines and in the deeper, fine-grained sediments beneath the outwash plains.

Additional analysis of these issues with models and field studies is needed and should be undertaken concurrently with the design and implementation of the plume response effort.

- **Recommendation 3: Zones of High Concentration with Plumes**

The mapping of the plumes on the MMR to date has focused on delineating plume boundaries. Considerably less information is available concerning the distributions of concentrations inside the plumes and near the sources. In several plumes, zones of high concentration have been detected, although the zones are often defined by only a few wells so little is known about the areal extent of the zones. It is possible that the appearance and disappearance of these zones (for example, the "hot spots" once shown in the western lobe of the CS-10 plume) may reflect small-scale spatial variations in concentrations that occasionally pass by the observation wells. The main zone of highest concentration within a plume is not considered one of these isolated zones.

The TRET recommends that isolated zones of high concentration not be contained or pumped for mass removal as part of the interim containment effort because (1) the extent and nature of the zones is uncertain and requires study on a case-by-case basis, (2) these zones will be captured by the containment systems, and (3) additional pumping and recharge inside the plumes may cause undesirable changes in flow directions that could compromise containment and delay the eventual flushing of all contamination, not just high concentrations, from the aquifer. It may be advantageous to treat zones of high concentration as part of future efforts to clean up the bodies of the plumes. However, these actions should be part of a comprehensive plan to remediate the plumes that includes steps to remove the sources in order to prevent creation of more zones of high concentrations.

- **Recommendation 4: Pilot Tests versus Phased Installation**

The design and implementation of a plume containment system will require a significant amount of field testing. Two types of field testing of the system are recommended for use at the MMR: (1) pilot testing of specific methodologies and (2) phased installation for containment of specific plumes.

Pilot tests should be used to test the application of specific methods at the MMR. An example is the pilot test of recirculating wells that has been proposed in the eastern lobe of the CS-10 plume. The purpose of a pilot test should be the evaluation of the method and, therefore, the test should be designed as an experiment, not as the first phase of a larger installation. The test should include detailed monitoring and independent evaluation of the system's effectiveness. Several "runs" of the test may be needed before the method can be used operationally in various plumes. The TRET recommends that pilot tests generally be applied at one site initially, rather than simultaneously at many sites. A simultaneous approach is likely to reduce the scrutiny applied to the method and may waste significant resources that could have been saved on the basis of the initial test.

A phased installation should be used during implementation of remedies at specific plumes, where these remedies are known from past experience or pilot tests to be appropriate methods for the site. The purpose of the phased approach is to allow incremental refinement of the design during installation to account for the site-specific characteristics that were difficult to predict during the initial design. A field-scale test, with stresses similar to those in the final system, can provide the final information on the likely performance of the system. The data from these field-scale tests should be used to refine the site-specific and regional computer models to enhance their predictive capability.

- **Recommendation 5: Hydrologic Monitoring**

The containment and remediation of the plumes on the MMR might involve the pumping and injection of substantial quantities of groundwater. Because the MMR is on top of a single aquifer, these hydrologic stresses have the potential to cause regional changes in water levels, groundwater-flow directions, and groundwater discharges to surface waters. Pumping for water supplies and climatic variations can cause similar changes that may be difficult to distinguish from changes caused by containment and remediation. Indeed, these independent changes could affect the clean-up. Temporal data are needed to calibrate groundwater models to the transient response of the aquifer to pumping and natural climatic variations. Therefore, the TRET recommends that monitoring of regional water levels, streamflow, and plume locations be an integral part of the planned actions.

Detailed monitoring of hydraulic heads and chemical concentrations will also be required in the vicinity of the pumped wells to verify that the systems are capturing the plumes or reducing concentrations as intended without causing detrimental impacts on nearby water resources.

Regional water levels and streamflow: A network of observation wells should be established to monitor regional groundwater levels and flow directions. This network should be distributed evenly over the MMR area (approximately the area included in the USGS's regional groundwater flow model.) The network should complement the existing networks operated by the USGS, the Cape Cod Commission, and the MMR, and should include wells in areas, such as wetlands, that have been identified as critical environmental concerns. New wells will be needed in areas where no wells presently exist. The observation wells should be located away from pumping and injection wells and infiltration galleries so that regional, rather than local, changes in levels can be monitored. Water levels should be measured monthly. The data should be examined regularly through preparation of water-table maps, hydrographs, and calculation of flow directions, as the USGS does now in the Ashumet Valley.

Pond water levels also should be measured monthly in selected ponds in the MMR area. The ponds should complement the existing network operated by the Association for the Preservation of Cape Cod with assistance from the USGS.

Streamflow discharges of all the major streams in the MMR area should be monitored regularly. This effort should include the continued operation of the USGS's continuously recording gage on the Quashnet River. Additional stations should be established on those streams most likely to be affected by the recommended actions. Because changes in flow can occur along specific reaches of streams, more than one measurement site should be established on the longer streams. Most of these stations could consist of staff gages that are measured weekly and where flows are measured manually to develop stage-discharge relations.

Regional hydrologic monitoring should begin as soon as possible to obtain as much information as possible on hydrologic conditions prior to the start of large-scale pumping and recharge. The USGS's long-term records of water levels and streamflow at several sites can be used to compare the current state of the system to its historical condition during wet and dry years, including the drought of the mid-1960s.

Plume locations: The locations of the plumes in the MMR area should continue to be monitored by regular collection and analysis of groundwater samples from a network of wells that define the three-dimensional boundaries of each plume. Refinement of the MMR's existing quarterly and semi-annual sampling program will be sufficient. Chemical analysis can be limited to a few "indicator" constituents and sampling protocols should be as simple as possible. Graphs of concentrations versus time and maps and vertical sections of the plume should be updated regularly.

Hydrologic response, plume capture, and mass removal: The operation of the extraction and recharge systems will be based initially on predictions made with groundwater models and observations made during phasing in of the systems. Measurements of hydraulic head and chemical concentrations during operation of the systems are needed to check and refine the predictions. The spatial and temporal detail of the measurements will be greater than the detail needed for plume delineation.

Detailed monitoring of hydraulic heads in three dimensions will be needed to determine if flow directions indicate hydraulic capture and mass removal from targeted zones. The detailed measurements are particularly important while the systems are being installed, tested and evaluated. The spatial density and frequency of the observations will depend on the specific objective and design of each system and the hydraulic responses predicted by the groundwater-flow models.

Detailed monitoring of chemical concentrations will also be needed to verify capture and mass removal. The spatial density and frequency of the observations will depend on the specific objective and design of each system. The spatial distributions of chemicals must be known in detail and coupled with the flow analysis in order to assess the success of containment or mass removal where the extraction systems located within the plumes create areas of low velocity (stagnation zones).

Additional measurements of groundwater and pond levels and streamflows will be needed in ecologically sensitive areas near the extraction and recharge systems to supplement regional monitoring. Monitoring should be most frequent at the start of operation when the changes will be most rapid.

Recommendation 6: Evaluate Leak Detection for Each Containment Strategy

A methodology to complete such an evaluation is in Appendix E. Combined with this methodology are summaries of risk assessments based on piping system failures, These were completed for the OpTech 60 Percent Containment Strategy Design.

Recommendation 7: Data Bases and Communication of Results

A significant roadblock to integrated analysis and technical review of work on the MMR is the widely dispersed nature of the data. An additional roadblock is the difficulty of communication among the many consultants and technical agencies involved at the MMR. The TRET recommends that the geologic, hydraulic, chemical, biological and ecological data be organized in one or more data bases that are well documented and readily accessible. This will facilitate the maximum sharing and use of information.

The TRET also recommends that a summary of recent technical work and findings be distributed regularly to facilitate communication and interaction among all the groups working at the MMR. The summary would be distinct from the fact sheets and updates prepared for the public in that it would be intended for a technical audience familiar with the MMR.

Recommendation 8: Complete a Containment System Operation Plan

An draft outline of a Containment System Operation Plan is in Appendix F.

9. EPILOGUE

The evaluation of proposals is critical to meeting community expectations and achieving a technically defensible approach to plume remediation. This process was started during this technical review, and it is recommended that the interaction continue. It is recommended that pumping strategy goals, criteria of acceptability, modeling assumptions, and situations for which capture should be achieved are clarified and specified in writing prior to pumping strategy development.

The RPM and major interested parties (*e.g.*, SMB, PATs, TRET, Barnstable County Science Advisory Panel, and regulators) should all be involved in this process. It is also recommended that, as the contractor develops remediation strategy proposals, the ecological and hydrological groups review and evaluate the strategy with regard to potential ecological impacts and risk reduction. This evaluation process is outlined in Figure 5.

The TRET focused on the critical concerns about toxicological risks and hydrological and ecological impacts associated with implementation of the containment program. It recognizes that many factors not addressed in this report will have to be considered during the development of the longer term plume response strategy. These factors either could not be addressed in the time available or were outside the scope of the technical review.

The following issues and questions remain to be considered:

- **Reducing exposure duration:** The level of risk reduction that may be achieved should be evaluated, along with the level of contaminant mass reduction that may be achieved. In certain cases, if the maximum concentration cannot be captured, but only a small mass of contamination is involved, capture of contaminant mass becomes more important than risk reduction. The calculation of risks to humans is based on the assumption that exposure occurs over a period of thirty years. Reducing contaminant mass means that exposure may not occur for the assumed exposure duration, thus reducing actual risks, while not necessarily capturing the maximum detected concentration. Both considerations are essential when weighing toxicological risks and ecosystem impacts.

- **Other areas of contamination:** It is possible that new plumes will be discovered. The plume response strategy should be flexible so that any newly discovered contamination can be addressed. Minimal disturbance of regional flow should be a design criterion so that other contamination is not spread inadvertently during the restoration process.

- **Effects of actions on the speed of complete aquifer restoration:** The TRET selected actions for its recommendations that would minimize the further spreading of contamination. However, it did not address how quickly the plumes will be flushed from the aquifer under the various scenarios and what actions could speed that process.

- **Effects of water supply development on the plume response actions:** Development of new water supplies and operation of existing wells affect flow directions and could potentially change the paths of the plumes. The plume response strategy must be based on an understanding of the areas contributing water to public and private supply wells and may need to include a management strategy for the use of these wells.

- **Practicality of injection wells for return of the treated water to the aquifer:** Although the use of injection wells allows precise recharge of the return flow from treatment units to minimize ecological and hydrological impacts, long-term operation of these wells may prove problematic and may require a greater reliance on infiltration galleries.

- **Requirement for metals treatment:** Treatment is planned for iron and manganese; however, other metals have been identified in various plumes which are present at levels below MCLs, yet pose a possible ecological risk. The question of mobility of these metals must be resolved, as well as definition of appropriate treatment standards applicable to sub-surface discharge of the treated water.

- **Placement of extraction fences:** The AFCEE review of the CS-4 containment system recommended that extraction fences be placed within the plumes rather than ahead of the leading edge to prevent misplacement of the fences. A detailed analysis of the transport and dilution of parts of plumes that are not captured because of fence placement upgradient of the leading edges would be needed if this recommendation is followed.

- **Nutrient loading analyses:** The Ashumet Valley plume contains both phosphorus and nitrates. Nitrate loading to Green Pond, but also potentially to Great and Bourne Ponds, needs critical scientific evaluation.

- **Impacts on the communities because of construction and operation of the plume response systems**

- **Practical limits on the ability to construct the remedial systems**

APPENDIX B

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TECHNICAL REVIEW AND EVALUATION TEAM STAFFING

Hydrological/Water Resources Group

Name	Expertise	Affiliation
Richard Peralta (Lead)	Groundwater Modeling	AFCEE & Utah St.
Denis LeBlanc	Hydrogeologist	USGS
Matt Alexander	Chemical Engineer	OpTech
Marcel Boelitz	Geologist	MA DEP
Dave Hill	Geologist	OpTech
Ernest Waterman	Geologist	USEPA
Dave Schafer	Hydrogeologist	TRC (USEPA)
Steve Garabedian	Hydrogeologist	USGS
Lorie Baker-Wallace	Hydrogeologist	OpTech
Dave Delorenzo	Hydrogeologist	MA DEP
Paul Blain	Hydrogeologist	MA DEP
Marty Aker	Hydrogeologist	Otis IRP Office
Dick Willey	Hydrologist	USEPA

Ecological Group

Name	Expertise	Affiliation
Joyce Dickerman (Lead)	Eco Impacts Assessment/Monitoring	HAZWRAP/ORNL
Steve Hurley	Eco Impacts Assessment/Monitoring	MA Fish & Wildlife
Clay Runck	Eco Impacts Assessment/Monitoring	HAZWRAP/ORNL
Liz Kouloheras	Eco Impacts Assessment/Monitoring	MA DEP - Wetlands
Walter Hill	Eco Impacts Assessment/Monitoring	HAZWRAP/ORNL
Michael Hutcheson	Eco Impacts Assessment/Monitoring	MA DEP - Research & Stnds
Jeff Duncan	Eco Impacts Assessment/Monitoring	HAZWRAP/ORNL
Joe Costa	Eco Impacts Assessment	MA Coastal Zone Mgt
Jim Fair	Eco Impacts Assessment	MA Div of Marine Fisheries
Patti Tyler (Lead)	Eco Risk	USEPA
Ron Porter	Eco Risk	Armstrong Labs
Mike Simini	Eco Risk	US Army ERDEC
Gary Gonyea	Eco Risk	MA DEP
Stanley Hewins	Eco Risk	AFCEE
Susan Stines (Lead)	Human Risk	HAZWRAP/ORNL
Angie Obrey	Human Risk	HAZWRAP/ORNL
Joe Prince	Human Risk	OpTech
Tess Rottero	Human Risk	HAZWRAP/ORNL
Donald Schall	Monitoring	Fugro
Mario DeGregario	Monitoring	Sabatia
Matt Schliesburg	Monitoring	USEPA
Richard McLean	Monitoring	PTRL Env Services
Karen Wilson	Monitoring	Army Env Center

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APPENDIX C

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Endangered, Threatened, and Species of Special Concern That Occur in the Area of Potential Impact From the 60% Design Plume Containment Plan

Common Name	Genus	Species	Federal Status[1]	State Status[1]	Habitat Association[2]
Invertebrates					
Barrens Bluet	Enallagma	recurvatum	SC	T	FW
Coastal Barrens Buckmoth	Hemileuca	maia maia		T	U
Comet Darner	Anax	longipes		SC	FW
Eastern Pondmussel	Ligumia	nasuta		SC	FW
Gerhard's Underwing Moth	Catocala	herodias gerhardi		T	U
New England Bluet	Enallagma	laterale	SC	SC	FW
Spiny Oakworm	Anisota	stigma		SC	U[3]
Tidewater Mucket	Leptodea	ochracea		SC	FW
Tule Bluet	Enallagma	carunculatum		SC	FW
Water-willow Stem Borer	Papaipema	sulphurata	SC	T	FW
	Zanclognatha	theralis		T	
Vertebrates					
American Brook Lamprey	Lampetra	appendix		T	FW
Bald Eagle	Haliaeetus	leucocephalus	T	E	U/FW
Barn Owl	Tyto	alba		SC	U
Common Tern	Sterno	hirundo	SC	SC	C
Cooper's Hawk	Accipiter	cooperii		SC	U
Diamondback Terrapin	Malaclemys	terrapin		T	S
Eastern Box Turtle	Terrapene	carolina		SC	U
Eastern Spadefoot	Scaphiopus	holbrookii		T	U
Four-toed Salamander	Hemidactylium	scutatum		SC	U/FW
Grasshopper Sparrow	Ammodramus	savannarum		T	U
Least Tern	Sterna	antillarum		SC	C
Northern Parula	Parula	americana		T	U
Piping Plover	Charadrius	melodus	SC	T	C
Roseate Tern	Sterna	dougallii	T	E	C
Spotted Turtle	Clemmys	guttata		SC	FW
Upland Sandpiper	Bartramia	longicauda		E	U
Vascular Plants					
Adder's-tongue Fern	Ophioglossum	pusillum		T	U/FW
Arethusa	Arethusa	bulbosa		T	FW
Bristly Foxtail	Setaria	geniculata		SC	S
Broad Tinker's Weed	Triosteum	perfoliatum		E	U
Bushy Rockrose	Helianthemum	dumosum	SC	SC	U
Climbing Fern	Lygodium	palmatum		SC	U/FW

Creeping St. John's Wort	Hypericum	adpressum	SC	T	FW
Fibrous Bladderwort	Utricularia	fibrosa		T	FW
Grass-leaved Ladies'-tresses	Spiranthes	vernalis		SC	U
Long-beaked Bald-sedge	Rhynchospora	scirpoides		SC	FW
Maryland Meadow Beauty	Rhexia	mariana		E	FW
Mattamuskeet Panic-grass	Dichanthelium	mattamuskeetense		E	U/FW
Midland Sedge	Carex	mesochorea		E	U
New England Blazing Star	Liatris	scariosa	SC	SC	U
New England Boneset	Eupatorium	leucolepis	SC	E	FW
Plymouth Gentian	Sabatia	kennedyana		SC	FW
Pondshore Knotweed	Polygonum	puritanorum		SC	FW
Redroot	Lachnanthes	caroliana		SC	FW
Rigid Flax	Linum	medium		T	U
Rough Panic-grass	Dichanthelium	scabriusculum		T	FW/U
Salt Reedgrass	Spartina	cynosuroides		SC	S
Saltpond Grass	Leptochloa	fascicularis		T	S
Saltpond Pennywort	Hydrocotyle	verticillata		SC	FW
Sandplain Flax	Linum	intercursum		SC	U/C
Sandplain Gerardia	Agalinis	acuta	E	E	U
Short-beaked Bald-sedge	Rhynchospora	nitens		T	FW
Swamp Oats	Sphenopholis	pensylvanica		T	FW
Terete Arrowhead	Saggitaria	teres		SC	FW
Torrey's Beak-sedge	Rhynchospora	torreyana		E	FW
Wright's Panic-grass	Dichanthelium	wrightianum		SC	FW

[1] E = Endangered, T = Threatened, SC = Species of Special Concern

[2] FW = Associated with one or more freshwater habitats or habitat margins, including ponds, marshes, swamps, sphagnum bogs, and streams.

U = Associated with upland habitats, including scrub oak/pitch pine forest, moist forest, open fields, and disturbed areas.

S = Associated with salt or brackish habitats, including salt marshes and salt ponds.

C = Associated with coastal areas, primarily feeding offshore or on shoreline.

[3] Likely habitat, confirmation unavailable prior to distribution of this report.

Summary:	FW	U	S	C
Invertebrates	7	3	0	0
Vertebrates	4	9	1	4
Vascular Plants	19	12	3	1
Totals*	30	24	4	5

* Some species counted in more than one habitat association.

VERNAL POOLS
NATURAL HERITAGE AND
ENDANGERED SPECIES PROGRAM AND CONSERVATION COMMISSION DATA

LIST OF VERNAL POOLS ASSOCIATED WITH SHALLOW GROUNDWATER[1]		
VERNAL POOLS	COMMUNITY	STATUS
1.) North of Rt. 151	FALMOUTH	Certified
2.) South of Coonamessett Rd.	FALMOUTH	Certified
3.) West of Crooked Pond - West of Rt. 28	FALMOUTH	Certified
4.) SW of Coonamesset Pond (borders open water and Cranberry Bogs)	FALMOUTH	Certified
5.) Waquoit Village	FALMOUTH	Pending Certification
6.) SW of Coonamessett Pond (borders cranberry bog)	FALMOUTH	Investigated
7.) West of Falmouth Airport (3 vernal pools-borders cranberry bog)	FALMOUTH	Investigated
8.) NE of Flax Pond	BOURNE	Certified
9.) NW of Rt. 28-151 Int.	BOURNE	Certified
10.) North of Pine Tree Corner & Rt. 28 Intersection (borders cranberry bog)	MASHPEE	Certified
11.) NE of Jehu Pond	MASHPEE	Certified
12.) North of Jehu Pond	MASHPEE	Certified
13.) Bwt. Peter's & Wakeby Ponds	SANDWICH	Certified
14.)Raccoon Swamp	MMR	Investigated
15.)North of Rod & Gun Club	MMR	Investigated

1. Estimated depth to groundwater less than or equal to 7.5 feet.

Pre- and Post-Containment Simulated Streamflows
(USGS/MMR Flow Model: ECE Run 35)

River	Pre-Containment (ft^3/s)	Post-Containment (ft^3/s)	Difference (ft^3/s)
Coonamessett R.	0.2	0.0	0.2
	5.0	3.7	1.3
	8.3	6.2	2.1
	13.0	10.9	2.1
Backus R.	1.9	2.4	-0.5
Bourne R.	1.1	1.6	-0.5
Childs R.	1.0	1.4	-0.4
	5.0	6.2	-1.2
Quashnet R.	0.8	0.5	0.3
	13.5	12.7	0.3
Mashpee R.	12.3	11.6	0.7
Santuit R.	5.4	5.3	0.1

Pre- and Post-Containment Simulated Pond and Ground-Water Level Altitudes (USGS/MMR Flow Model: ECE Run 35)

Pond or Well	Pre-Containment	Post-Containment	Difference
	(feet)	(feet)	(feet)
Ashumet P.	44.0	41.1	-2.9
Johns P.	39.6	38.2	-1.4
Coonamessett P.	36.6	34.4	-2.2
Snake P.	66.4	63.5	-2.9
Mashpee P.	58.0	56.2	-1.8
(1) BHW 215-83	43.9	43.1	-0.8
(2) FSW 167-55	41.6	38.2	-3.4
(3) FSW 375-15	23.5	22.4	-1.1
(4) MW-12B	63.3	58.7	-4.6
(5) SDW 253	60.0	59.6	-0.4
(6) WT-2	67.7	66.3	-1.4

(1) Bourne Landfill
(2) Near Route 151 and Sandwich Road
(3) Carriage Shop Road (Ashumet Valley)
(4) Near MMR Landfill
(5) South of Triangle Pond, Sandwich
(6) North of Snake Pond, Sandwich

HISTORICAL POND LEVEL FLUCTUATIONS

POND	AVERAGE CHANGE[1] DURING A YEAR (FEET)	MAXIMUM[2] CHANGE	RECORD PERIOD	SOURCE
Ashumet	1.46 range 0.5-2.5	5.15	1/74-12/82	Letty 1984
Johns	1.5	2.35	5/93-1/94	SERGOU RI 1994
Snake	1.1 range 0.5-1.7	6.99	1/74-12/82	Letty 1984
Crocker	0.93 range 0.4-1.6	2.95	1/74-12/82	Letty 1884
Spectacle	1.12 range 0.5-1.9	6.32	1/74-12/82	Letty 1984

1. Difference between minimum and maximum pond level elevations (feet above sea level) within a year, averaged over the period. Range = range of those differences over the period of record.

2. Difference between minimum and maximum pond level elevations over the period of record. NOTE: Minimum and maximum elevations do not necessarily occur within the same year.

SOURCE MATERIAL:

LETTY 1984
U.S. GEOLOGICAL SURVEY
OPEN FILE REPORT 84-719

SERGOU 1994
SOUTHEAST REGION GROUNDWATER OPERABLE UNIT REMEDIAL REPORT
(INCLUDING REGION III)
VOLUME I TEXT
AUGUST 1994

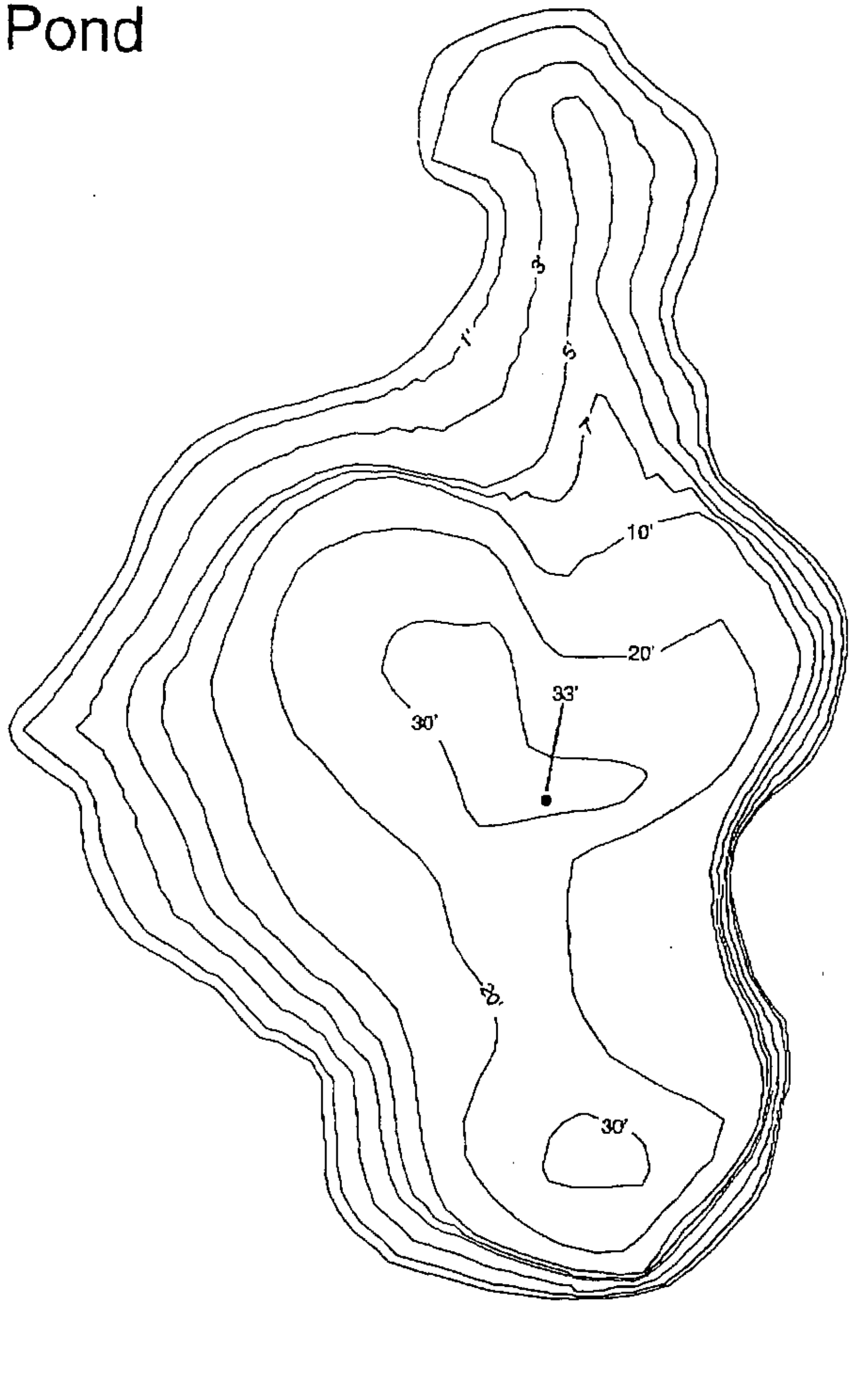
SENSITIVE AND CRITICAL HABITATS

Location Information			Sensitive and Critical Habitat Categories			
Surface Water Resources	COMMUNITY	MMR PLUME (WHOSE COTAINMENT MIGHT POTENTIALLY IMPACT THESE SURFACE WATER RESOURCES)	Rare and Endangered Species[3]	Coastal Plain Pond Shores[4]	Anadromous Fish Runs[4]	Coastal Salt Ponds[4]
SNAKE POND	SANDWICH	FS-12	6 VASCULAR PLANTS [3]	YES		
WEEKS POND	SANDWICH	FS-12	1 VERTEBRATE [3] 1 INVERTEBRATE [3] 10 VASCULAR PLANTS [3]	YES		
MASHPEE POND	MASHPEE	FS-12		YES	MASHPEE R. INTO MASHPEE P.	
WAKEBY POND	MASHPEE	FS-12		YES	LARGE ALEWIVES RUN [1]	
MASHPEE RIVER	MASHPEE	FS-12			MASHPEE R.INTO MASHPEE P.	
JOHNS POND	MASHPEE	CS-10/AVP SD-5,EASTERN		YES	ALEWIVES SPAWNING [1] UP QUASHNET R. AND CHILDS R.	
QUASHNET RIVER	MASHPEE	CS-10/AVP			MIGRATORY [2]	
ASHUMET POND	MASHPEE/ FALMOUTH	CS-10/AVP	1 INVERTEBRATES [3] 3 VASCULAR PLANTS [3]	YES		
GREAT POND	FALMOUTH	CS-10/AVP		NO		YES
BACHUS RIVER	FALMOUTH	CS-10/AVP				
GREEN POND	FALMOUTH	CS-10/AVP		NO	GREEN POND INTO MILL POND	YES
B[illegible]RNE'S POND	FALMOUTH	CS-10/AVP		NO	INTO BOURNE POND	YES
[illegible]S RIVER	FALMOUTH.	CS-10/AVP			MIGRATORY [1] ,INTO JOHNS POND	
GRASSY POND	FALMOUTH	CS-10/AVP	1 VERTEBRATE [3] 1 INVERTEBRATE [3] 2 VASCULAR PLANTS[3]	YES		
COONAMESSETT R.	FALMOUTH	CS-10/AVP			MIGRATORY [1]	
COONAMESSETT P.	FALMOUTH	CS-10/AVP		NO	COONAMESSETT R. INTO POND	
FLAX POND (PICTURE LAKE)	BOURNE	LF-1	4 INVERTEBRATES [3] 3 VASCULAR PLANTS [3]	YES		
LILY POND	BOURNE	LF-1		YES		
RED BROOK POND	BOURNE	LF-1		NO	INTO RED BROOK POND	
RED BROOK HARBOR	BOURNE	LF-1				
POCASSETT RIVER	BOURNE	LF-1				
MEGANSETT HARBOR	BOURNE	LF-1				
LONG POND(ELEV. 27)	BOURNE	LF-1		NO		
CUFFS POND	BOURNE	LF-1		NO		
OSBORNE POND	BOURNE	LF-1		NO		
EDMUNDS POND	BOURNE	LF-1		NO		

FOOTNOTES

1. Mike Hutcheson. Personal Communication with J.Fair. Massachusetts Division of Marine Fishiers.
2. Hurley, S. 1992. Fisheries Sampling Report. Quashnet River, Falmouth-Mashpee, October 26, 1991. Massachusetts Division of Fish and Wildlife.
3. Massachusetts Natural Heritage & Endangered Species Program, Division of Fisheries & Wildlife, Rt. 135, Westborough, MA 01581. March 25, 1996.
4. Vanluven, David. August 1990. Cape Cod Critical Habitats Atlas. Association for the Preservation of Cape Cod.

Snake Pond

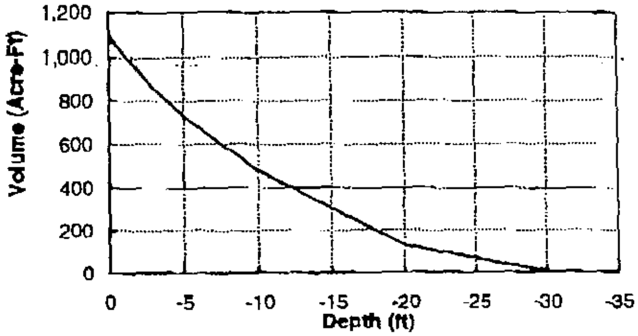


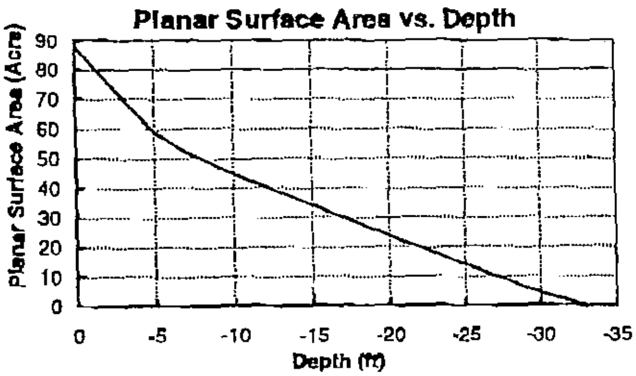
Snake Pond

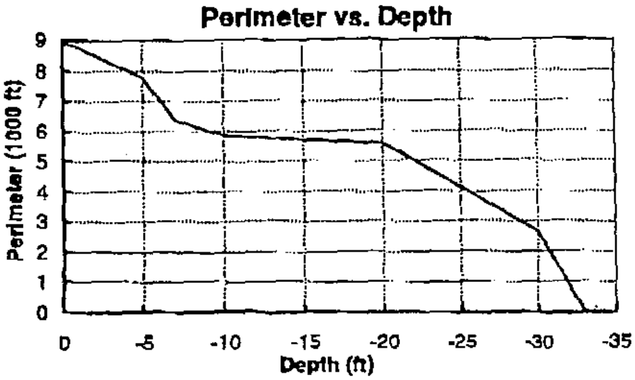
Drop in Pool Elevation	Volume Change	Planar Surface Area Change	Surface Area Exposed Change	Perimeter Change
ft	Acre-ft	Acre	Acre	ft
1	85.0	6.2	6.2	168.9
3	236.9	18.0	18.0	660.0
5	366.0	29.2	29.2	1135.5
7	474.3	35.8	35.8	2552.8
10	619.2	43.3	43.3	3100.8

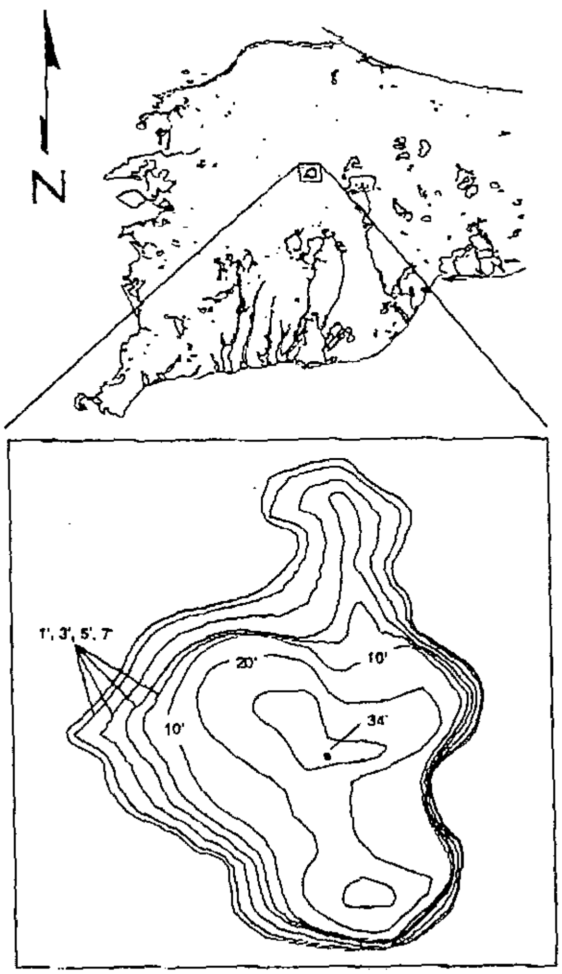
Pool Elevation	Volume	Planar Surface Area	Perimeter
ft	Acre-ft	Acre	ft
68.09	1,097	88.1	8,915
67.09	1,012	81.9	8,746
65.09	860	70.1	8,255
63.09	731	58.9	7,780
61.09	622	52.3	6,362
58.09	478	44.8	5,814
48.09	132	23.8	5,563
38.09	7	4.4	2,653
35.09	0	0.0	0

Maximum Depth = 33 ft

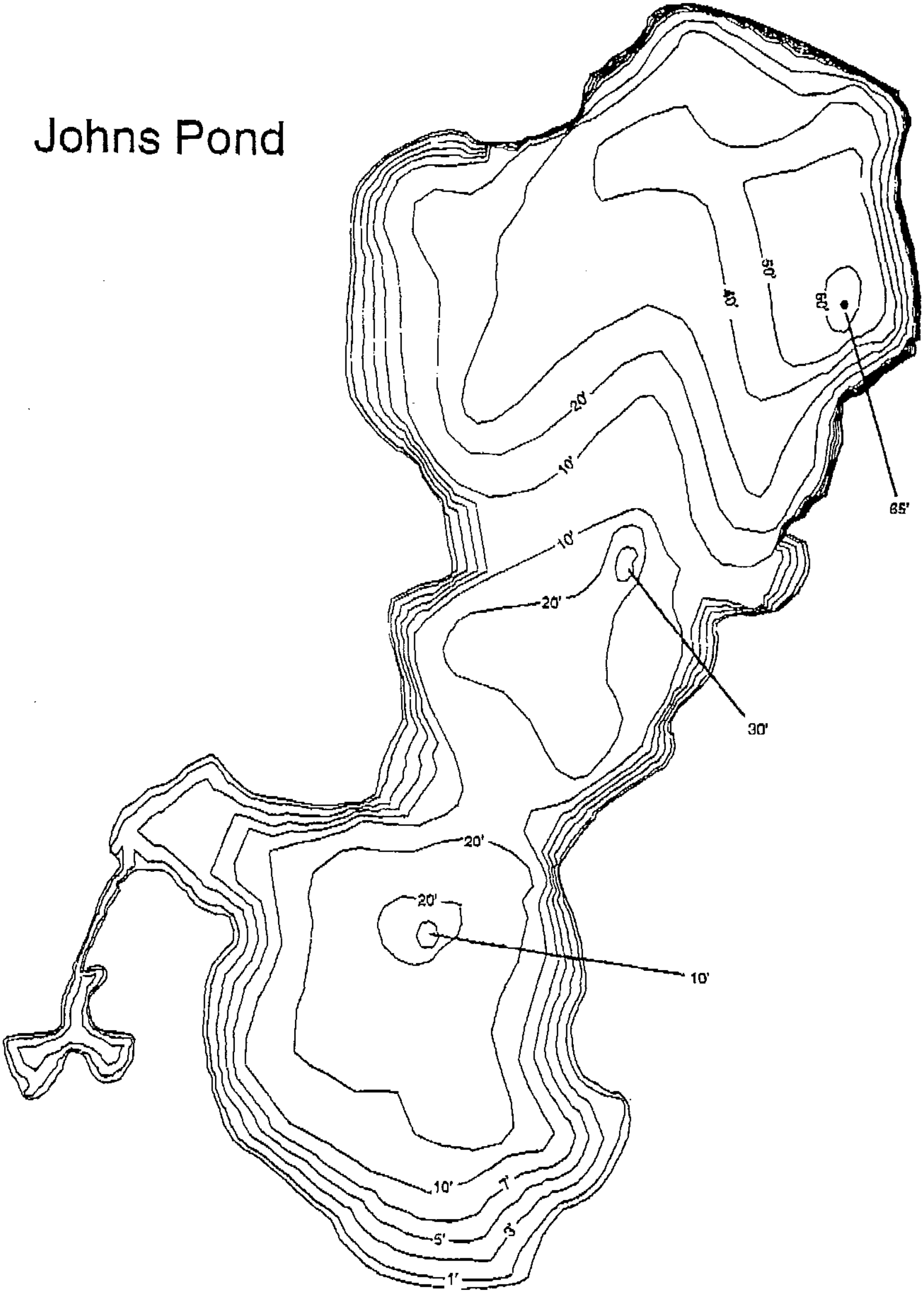








Johns Pond

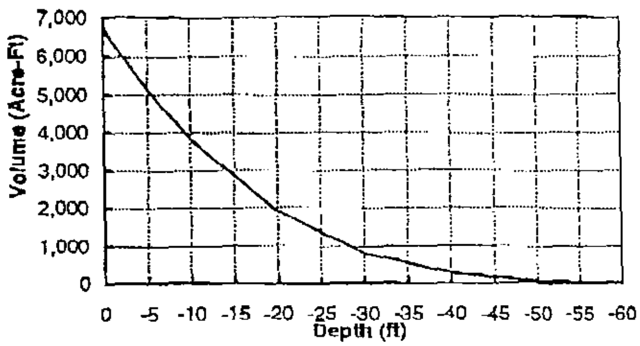


John Pond

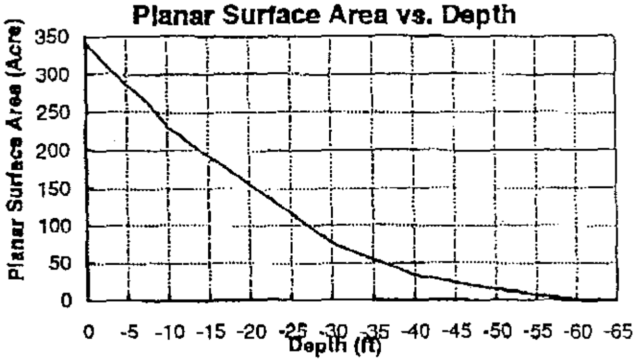
Drop in Pool Elevation	Volume Change	Planar Surface Area Change	Surface Area Exposed Change	Perimeter Change
ft	Acre-ft	Acre	Acre	ft
1	335.4	11.8	11.8	-85.0
3	971.2	34.1	34.2	2599.0
5	1,566.0	55.5	55.6	5675.5
7	2,121.1	71.9	72.0	6119.6
10	2,891.1	110.7	110.9	3887.2

Pool Elevation	Volume	Planar Surface Area	Perimeter
ft MSL	Acre-ft	Acre	ft
37.92	6,718	341.3	25,186
36.92	6,383	329.5	25,271
34.92	5,747	307.2	22,587
32.92	5,152	285.8	19,511
30.92	4,597	269.4	19,066
27.92	3,827	230.6	21,299
17.92	1,897	155.7	19,060
7.92	794	76.4	9,282
-2.08	279	32.6	5,794
-12.08	60	14.2	3,200
-22.08	3	1.3	908
-27.08	0	0.0	0

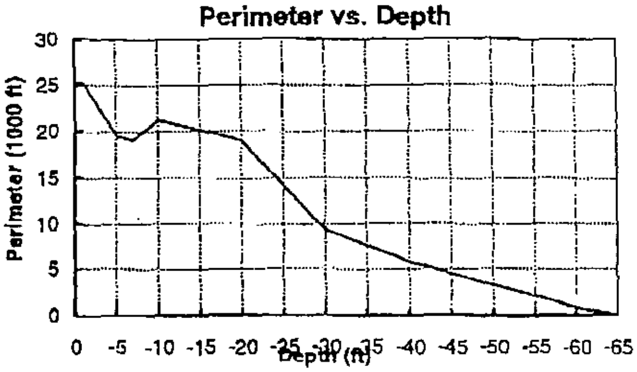
Volume vs. Depth Storage Curve



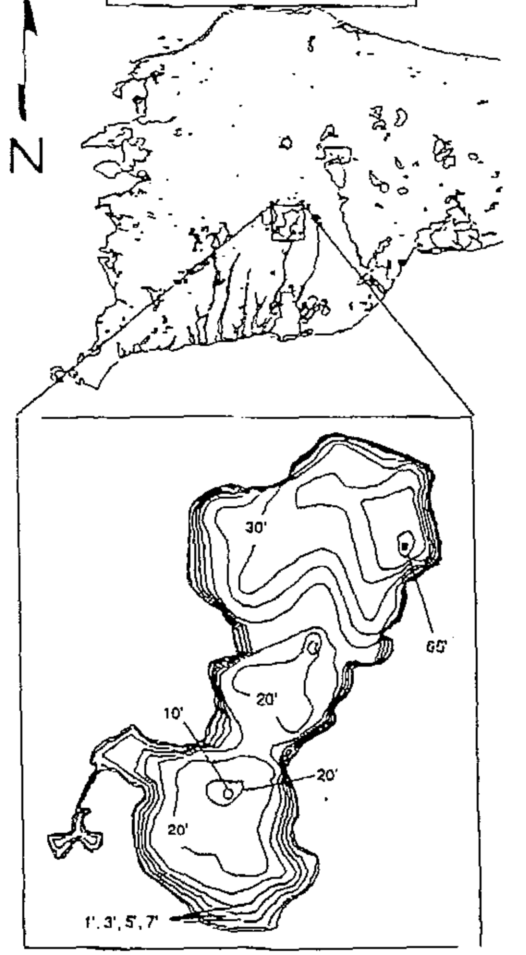
Planar Surface Area vs. Depth



Perimeter vs. Depth

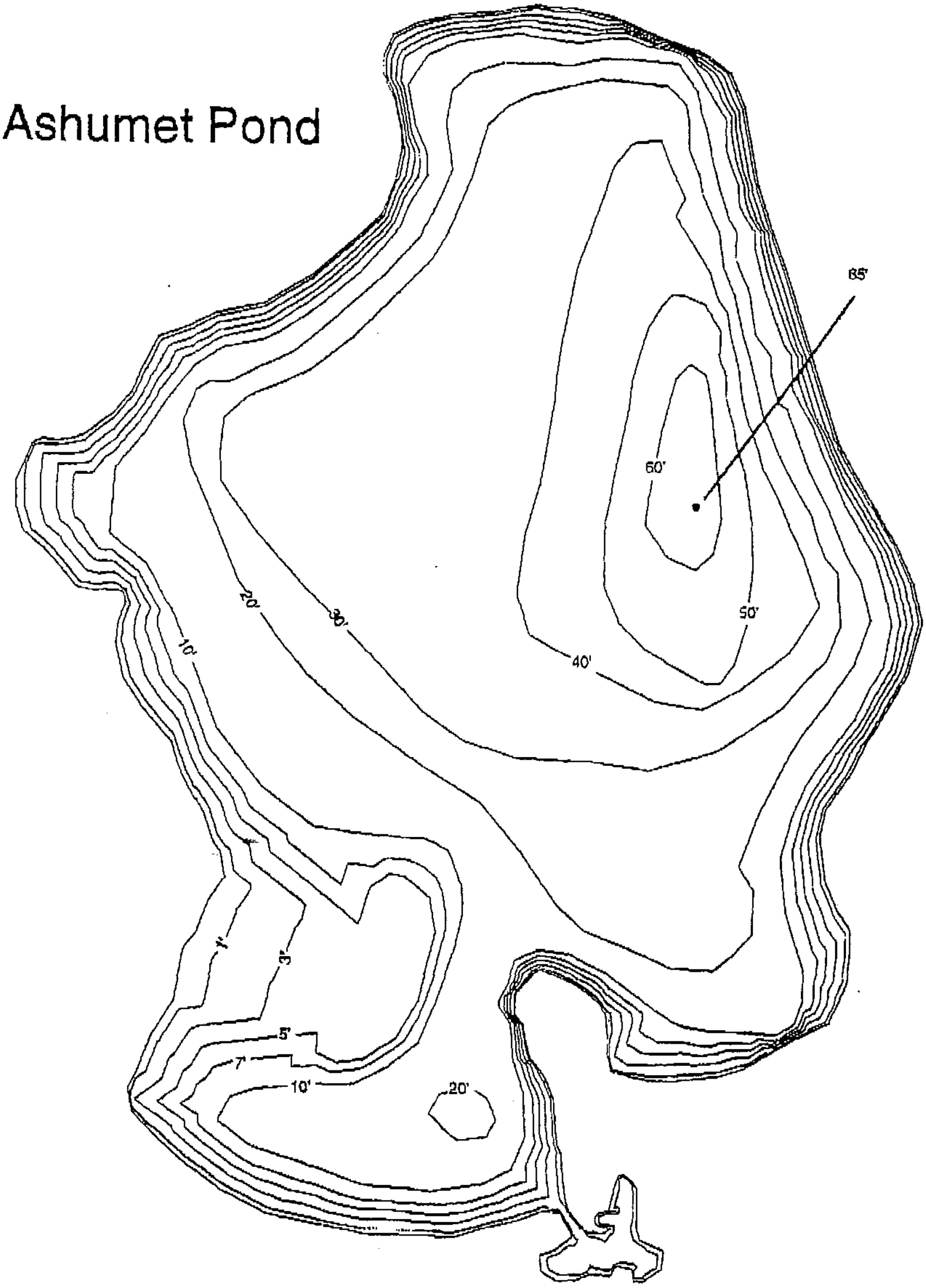


Maximum Depth = 65 ft



Full Pool Elevation = 37.92 ft MSL

Ashumet Pond

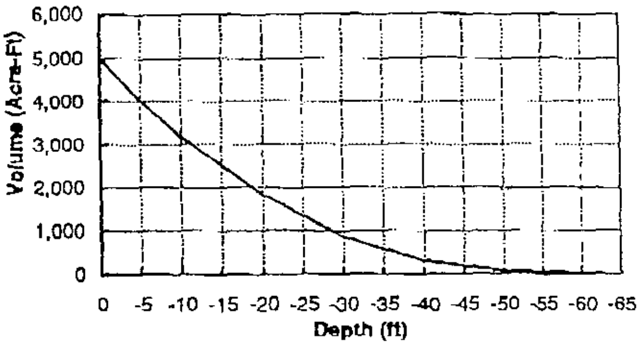


Ashumet Pond

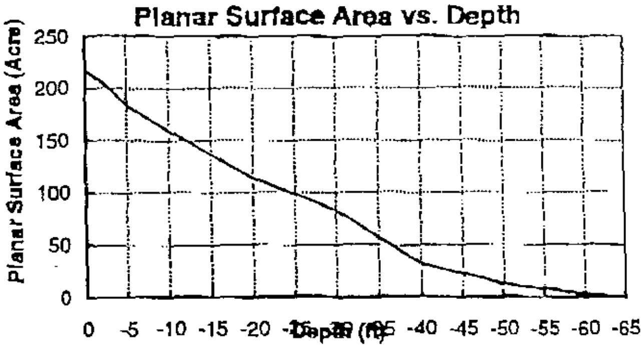
Drop in Pool Elevation	Volume Change	Planar Surface Area Change	Surface Area Exposed Change	Perimeter Change
ft	Acre-ft	Acre	Acre	ft
1	215.2	6.2	6.1	-86.8
3	626.9	18.9	19.0	1775.3
5	1,014.2	34.6	34.6	1011.2
7	1,371.0	45.0	45.1	1551.5
10	1,869.3	59.3	59.4	2423.3

Pool Elevation	Volume	Planar Surface Area	Perimeter
ft MSL	Acre-ft	Acre	ft
43.1	5,034	218.3	16,003
42.1	4,818	212.1	16,090
40.1	4,407	199.4	14,228
38.1	4,019	183.7	14,992
36.1	3,663	173.3	14,452
33.1	3,164	159.0	13,580
23.1	1,823	113.8	9,834
13.1	845	82.3	7,427
3.1	292	31.4	5,075
-6.9	81	12.9	3,274
-16.9	8	3.3	1,711
-21.9	0	0.0	0

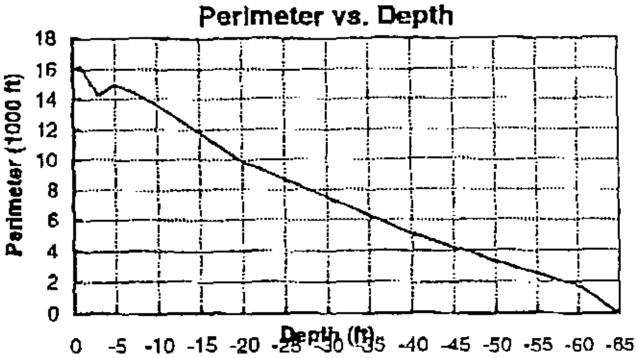
Volume vs. Depth Storage Curve



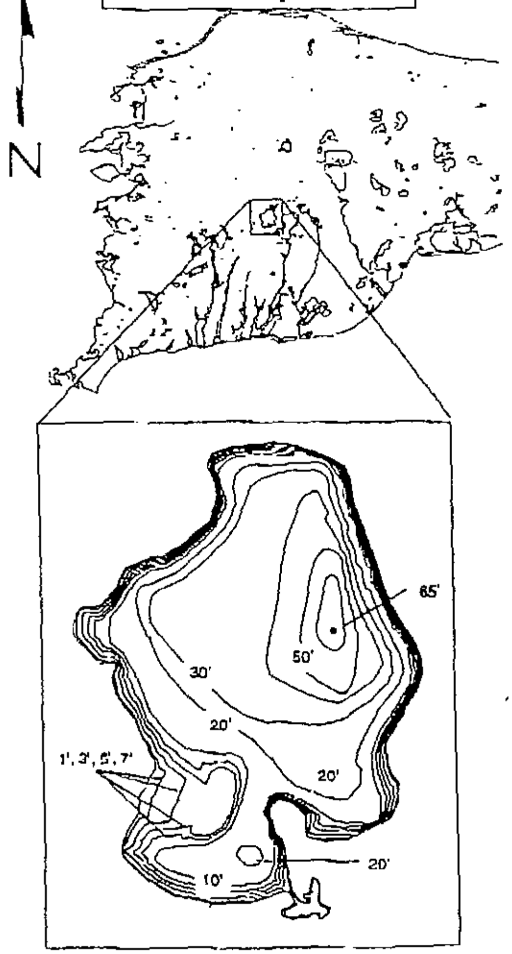
Planar Surface Area vs. Depth



Perimeter vs. Depth



Maximum Depth = 65 ft



Full Pool Elevation = 43.10 ft MSL

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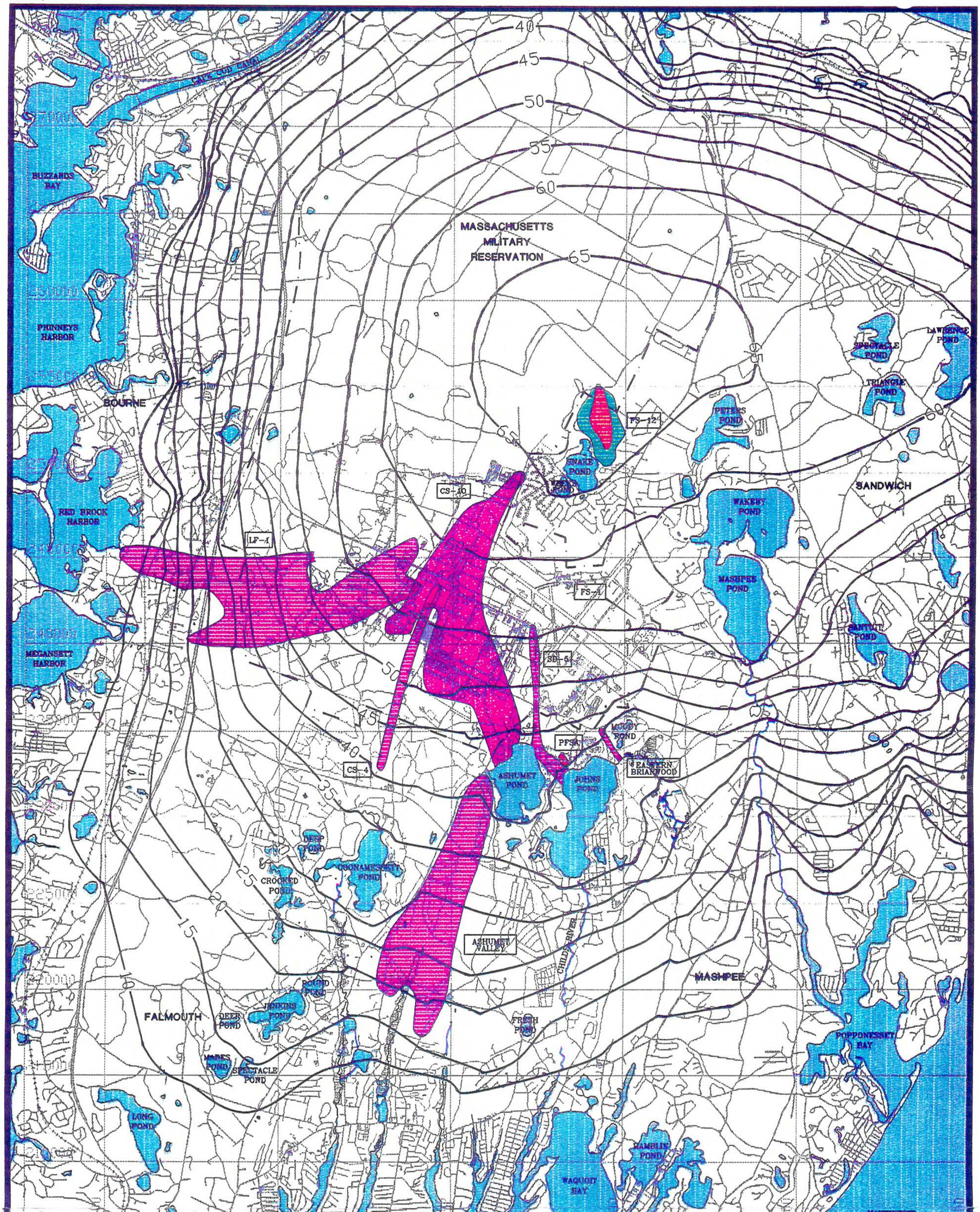

LEGEND

BASE BOUNDARY

RIVER/POND/STREAM

5 — LINE OF EQUAL GROUNDWATER ELEVATION (FEET MSL)

COMPOSITE MCL EXCEEDANCE SOLVENT GROUNDWATER CONTAMINATION

COMPOSITE MCL EXCEEDANCE FUEL GROUNDWATER CONTAMINATION

COMPOSITE MCL EXCEEDANCE EDB CONTAMINATION

WATER

SOURCE: HAZWRAP, MODIFIED BY OPTECH 1996.

NOTES:

1. GROUNDWATER ELEVATION INFORMATION IS BASED ON DATA COLLECTED IN NOVEMBER 1995 AND USGS WATER TABLE MAPS
2. PLUME PRESENTATIONS BASED ON COMBINATION OF DATA GAP AND REMEDIAL INVESTIGATION REPORTS
3. LOW LEVEL SPORADIC DETECTIONS OF EDB AT LOCATIONS OTHER THAN FS-12 ARE NOT SHOWN
4. PFSA PLUME DETERMINATION IS BASED ONLY ON RI DATA
5. CS-4 PLUME IS REPRESENTED AS A SUM OF THE VOCs PRESENT BASED ON 1989 DATA

N

0 5700

SCALE IN FEET

DRAFT

PLUME AREA MAP

Massachusetts Military Reservation

Cape Cod, Massachusetts

OPTECH

OPERATIONAL TECHNOLOGIES CORPORATION

MARCH 1996

OTIS\WTR-HYD

APPENDIX D

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CONTAINMENT SYSTEM OPERATION PLAN

I. Introduction
   A. Overview of System Operation

II. Extraction Well Fence Components
   A. Pump Operation
      - Controls
      - Safety Features
      - Monitoring

   B. Pump Installation and Removal
   C. Pump Maintenance and Replacement
   D. Extraction Well Maintenance

III. Well Fence Monitoring and Observation System
   A. Aquifer Potentiometic Measurements from Multi-Level Samplers
   B. Groundwater Sampling from Multi-Level Samplers
      - Sampling Procedure
      - Analytical Sampling Methods
      - Data Validation and Quality Control
      - Monitoring Schedule
   C. Multi-Level Sampler Maintenance
   D. Groundwater Recovery Adjustment
      - Data Imput in GIS
      - Evaluation of Potentiometric Head Data
      - Evaluation of Water Quality Data
      - Incorporation of Hydraulic Data into Groundwater Model for Analysis and Prediction of System Performance
      - Extraction System Adjustments Based on Monitoring System Data

IV. Extracted Groundwater Transfer Pipeline
   A. Leak Detection Monitoring
   B. Pipeline Maintenance

V. Extracted Groundwater Transfer Pipeline
   A. Treatment System Operation Monitoring
      - Flowrate and Pressure Monitoring
      - Water Quality Monitoring
         - Points of Measurement
         - Sampling Analyses and Monitoring Schedule
         - Process Adjustments Based on Monitoring Results
   B. Maintenance During Treatment Operation
      - Pressure Filter Backwashing
      - Greensand Filter Permanganate Addition

- Preparation of Chemical Feeds
- Ultraviolet/Oxidation
- Granular Activated Carbon Media Replacement

C. Sludge Filtration and Handling

D. Periodic Process Units Maintenance Requirement

- Pumps
- Pressure Filters
- Granular Activated Carbon Units
- Ultraviolet/oxidation Units
- Filter Presses
- Summary Maintenance Schedule

IV. Discharge System

A. Reinjection Wells (RC)

- Performance Monitoring
- Reinjection Well Maintenance

VII. Summary of Monitoring/Control from Central Control Facility

VIII. System Operating During Unit Failures or Reduced Flow

A. Operable Conditions/Shutdown Conditions

B. Operation/Control of Components Under Such Conditions

- Extraction Wells
- Pumps in Treatment Unit
- Process Units in Treatment Train
- Recharge Elements

IX. Ecological Monitoring Plan

APPENDIX F

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LEAK DETECTION MODEL/RISK ASSESSMENTS

Introduction

The Joint PAT used a specialized decision modeling system to develop consensus regarding the utilization of either single wall or double wall pipe for the transmission piping from the well heads to the treatment facilities. The idea was to generate one model that could be used to make this determination on a plume by plume basis. The model could then be used to make this determination for the following plumes: FS-12, CS-10, SD-5, LF-1, Ashumet Valley, and Eastern Briarwood

The model development process began with the FS-12 plume. This plume was selected because a proposed plume response strategy has been substantially developed for FS-12 which provided the level of technical detail required to run the model. Model development was accomplished by a representative form Montgomery-Watson and individuals from the community. An initial model was presented to the Joint PAT and in subsequent meetings, was refined until an acceptable model was developed.

The data for the criteria (*e.g.*, cost, schedule, existing plume impacts, community perception, ecological risk, human risk, risk of action) and subcriteria (e.g., installation cost, operations and maintenance cost) were then inputted into the model. Cost data were provided in thousands of dollars. Schedule data were provided in the number of days to construct. Existing plume impacts were provided in percent capture. Community perception was provided as a subjective rating on a scale of 1 to 10. Ecological risk was provided as a hazard quotient. Human risk was provided as life days saved per person, a conversion from the normal data presented as cancer risk in a population and risk of action was provided as life hours lost per construction worker.

The weightings (relative importance of the criteria and subcriteria) of each criteria were provided by the community members in a Joint PAT meeting. It should be noted that the weightings were heavily biased towards the use of double wall pipe. For example, the weightings for cost, risk of action , and schedule are rated very low; whereas, the weightings for ecological risk, human risk, community perception, and impact on existing plumes are rated very high.

FS-12

The inputted data (i.e., 11,000 feet of 12-inch pipe; 40,000 gpd leakage rate; installation costs; installation rate; effect on capture of the existing plume; 9E-03 human cancer risk; no ecological risk; risk to construction workers based on extended schedule) provided the following results for each of the criteria for FS-12:

Criteria	SW-PVC	SW-HDPE	DW-HDPE
Installation cost	$429,000	$627,000	$1,166,000
O&M cost (annual)	$750	$600	$8,625
Installation schedule	55 days	69 days	92 days
Existing plume impact	none	none	none
Human risk	0 life days saved	37.5 life days saved	50 life days saved
Ecological risk	none	none	none
Risk of action	42 life days lost	62 life days lost	116 life days lost
Community perception	50%	67%	100%

The decision that was produced by the model indicated that double wall pipe should be utilized. Again, this decision is configured in large part to the weighting provided by the Joint PATs. Since a human cancer risk was calculated for ethylene dibromide (EDB) in the FS-12 plume, and human risk was given the maximum rating of 100, it provided a significant portion of the contribution of the decision to utilize double-wall pipe.

SD-5

The inputted data (i.e., 3,600 feet of 6-inch pipe; 14,000 gpd leakage rate; installation costs; installation rate; effect on capture of the existing plume; no human risk; no ecological risk; risk to construction workers based on extended schedule) provided the following results for each of the criteria for SD-5:

Parameter	SW-PVC	SW-HDPE	DW-HDPE
Installation cost	$104,000	$159,000	$245,000
O&M cost (annual)	$750	$600	$8,625
Installation schedule	18 days	23 days	30 days
Existing plume impact	none	none	none
Human risk	0 life days saved	0 life days saved	0 life days saved
Ecological risk	none	none	none
Risk of action	10 life days lost	16 life days lost	22 life days lost
Community perception	50%	67%	100%

The decision that was produced by the model indicated that double wall pipe should be utilized. In this case, there is no risk to humans or the environment, but the criteria that swayed the decision towards double wall pipe was public perception because it was weighted so heavily. So even though there is no risk, the model produced a decision in favor of double wall pipe almost entirely based on the public perception.

Detailed technical data was not available for the other plume treatment facilities, therefore decisions were not made for the other plumes. However, based on the results of SD-5, it is clear that if the weighting values provided by the Joint PATs are utilized, they will yield similar results for the other piping systems. As discussed above, community perception, by itself, weighted the decision to double wall pipe even with no ecological or human risk. More detailed information, provided on a plume-by-plume basis, for ecological and human risk assessments associated with pipeline leakage is summarized below.

Risk assessments for pipeline leakage were based on the maximum undetectable flow rate and the pretreatment concentrations in the influent pipeline for each groundwater plume presented in the 60% Design (OpTech, 1996). Assessments were performed using the assumptions that if a leak occurred, a private well would be in the immediate vicinity for human health risk assessment, and a surface water body would be in the immediate vicinity for ecological risk assessment.

Influent pipeline concentrations were assumed to be the 95% UCL for the plume or the ((% UCL for the plume. The maximum was not used because due to the fact that extraction wells pump out a combination of both plume and no plume groundwater, the influent pipeline concentration well be less than the maximum.

Because the leakage scenarios are based on the 60% design, these risk estimates are provided as a point of reference for future proposed influent concentrations into pipelines and potential leakage from those pipelines.

FS-12 Conclusions

Based on the maximum undetected flow rate and pretreatment concentration in the influent pipeline for FS-12, risk assessments were performed for leakage scenario. Assuming that if a leak occurred a private well would be in the immediate vicinity, human health risk assessments were performed for an adult resident and an adult swimmer. EDB and benzene result in potential risk to the resident above the USEPA target risk range and hazard level. The potential leaking contaminants to a nearby surface water body do not result in cancer risks to the swimmer above USEPA target risk range or hazard level.

For ecological risk assessment, it was assumed a surface water body would be in the immediate vicinity. Aquatic receptor were evaluated as well as a semi-aquatic receptor, the osprey. The potential leaking contaminants to not result in hazards above the USEPA target hazard level to the either of the receptors.

CS-10 Conclusions

For human health risk assessment, it was assumed that if a leak were to occur, it could immediately be taken up by a private well and used for residential purposes. None of the leakage scenarios for CS-10 resulted in human health risks or hazard indexes above the USEPA target range or level.

For the ecological risk scenario, the total hazard index for aquatic receptors does not exceed the target hazard index of 1. For the semi-aquatic receptor, the osprey, no single contaminant exceeds the target hazard quotient of 1, but the total hazard index is 2 when using the 99% UCL for determining exposure.

SD-5 Conclusions

Based on the maximum undetectable flow rate and the pretreatment concentration in the influent pipeline for SD-5, risk assessment were performed for a leakage scenario. Assuming that if a leak occurred a private well would be in the immediate vicinity, human health risk assessment were performed for an adult resident and an adult swimmer. The potential leaking contaminants do not result in a cancer risks above the USEPA target risk range or target hazard index for the resident or the swimmer.

For ecological risk assessment, it was assumed a surface water body would be in the immediate vicinity. Aquatic receptors were evaluated, as well as, a semi-aquatic receptor, the osprey. The potential leaking contaminants do not result in hazard quotients above one for either receptor.

The maximum and mean calculated human health and ecological risks for the new data gap data do not result the maximum and mean calculated risk in the Remedial Investigations.

LF-1 Conclusions

For human health risk assessment, it was assumed that if a leak were to occur, it could immediately be taken up by a private well and used for residential purposes. In this case for LF-1, the use of the 99% UCL as the exposure concentration results in a risk of 2E-04 and a hazard quotient of 2. No single contaminant has a hazard quotient above 1, and the only compound with a risk above the USEPA target risk range is arsenic.

For the ecological risk scenario, the total hazard index for aquatic receptors does not exceed the target hazard index of 1. For the semi-aquatic receptor, the osprey, only manganese exceeds the target hazard quotient of 1, with a HQ of 4 and 5 for the 95% UCL and the 99% UCL, respectively

Ashumet Valley Conclusions

For human health risk assessment, it was assumed that if a leak were to occur, it could immediately be taken up by a private well and used for residential purposes. None of the leakage scenarios for Ashumet Valley resulted in human health risks or hazard indexes above the USEPA target range or level.

For the ecological risk scenario, the total hazard indexes for aquatic receptors and semi-aquatic receptors do not exceed the target hazard index of 1.

EASTERN BRIARWOOD

None of the leakage scenarios for human use of groundwater or swimming in affected surface water result in risks or hazard indices above USEPA target criteria. For ecological receptors exposed to potentially affected surface water, only manganese ingested in the food chain by the osprey results in a hazard quotient above 1 (HQ=2).

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