U. S. Army Corps of Engineers Ground Water Extraction System Subsurface Performance Checklist

Installation Name	______________________
Site Name / I.D.	______________________
Evaluation Team	______________________
Site Visit Date	______________________

This checklist is meant to aid in evaluating the overall performance of ground water extraction systems designed and installed to achieve specific objectives of subsurface performance. This checklist is divided into the following sections:

1) Evaluation team
2) Typical treatment objectives
3) References and background information
4) Data collection requirements
5) Evaluation of system performance
6) Typical performance problems
7) Recommendations for system modifications and alternative technologies
8) Conclusions
9) Supplemental notes and data

This checklist provides a format for recording the recommended information. If additional space is required, the supplementary notes should be numbered to correspond with the checklist sections. This checklist is not a substitute for careful observation and evaluation of engineering data to determine whether reported performance matches design and operational parameters.

1) Evaluation Team

The evaluation of the subsurface performance of a ground water extraction system and the identification of the need for system optimization or modification should be done based on objective observation and testing. The following disciplines should be included in the evaluation team:

- Hydrogeologist (attend site visit, subsurface performance evaluation)
- Process Engineer (attend site visit, well installation evaluation)
- Chemist (chemical compatibility)
- Regulatory Specialist (regulatory requirements)
- Cost Engineer (cost of alternatives)

2) Typical Treatment Objectives

There are two typical objectives for ground water extraction systems: containment and contaminant removal (i.e., removal to achieve some concentration standard or removal of mass). Both objectives have historically been applied to sources and plumes. Ground water extraction usually cannot achieve source zone cleanup, and cannot achieve plume cleanup unless the source zone has been controlled or removed. This technology is most useful either for reducing contaminant concentrations in a dissolved plume once the source zone has been removed or controlled or for controlling movement of a contaminant plume. In some cases, ground water extraction is used to maintain hydraulic control over a source zone, but additional measures such as physical barriers are used to ensure source zone control. Operation and maintenance costs for these systems can be significant (e.g., 10 to 20 times the initial installation costs over a 30-year period). Regulations may require that these systems be operated for the foreseeable future. However, some effort should be made to implement other actions that would reduce the time needed to operate the ground water extraction system. Based on the results of this evaluation, it may be possible to negotiate alternative cleanup goals.

3) References and Background Information

Coordinate this checklist with the Extraction and Monitoring Wells Performance checklist and the Environmental Monitoring checklist. The following references may also be helpful:

ETL 1110-1-201 [1]:	Ground Water Extraction
EPA 540/R-93/080	Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration
EPA 542/B-98/006:	Site Remediation Technology InfoBase: A Guide to Federal Programs, Information Resources, and Publications on Contaminated Site Cleanup Technologies
EPA 600/R-94/123	Methods for Monitoring Pump and Treat Performance.
EPA Directive 9283.1-06	Considerations in Ground-Water Remediation at Superfund Sites and RCRA Facilities – update.

3.1) Site-specific Documents

Site-specific documents are a primary source of data for the evaluation. The following is a list of documents that are frequently useful. Record the title author and date of each document referenced.

- System monitoring plan–basis for evaluating system performance
- Long term monitoring plan–basis for evaluating remediation or plume control
- Historic performance data–provides data for assessment of system performance
- Historic chemical data–provides data for assessment of system performance
- Trouble reports–data for evaluating the adequacy of system maintenance
- Maintenance records–data for evaluating the adequacy of system maintenance
- Annual reports–comprehensive historical evaluations of system performance

4) Data Collection Requirements

4.1) Site Visit

A site visit may not be necessary if sufficient information is provided in the reference documents. A site visit may yield observations about operating deficiencies that could explain these anomalies. An evaluation of the performance of extraction wells may also be necessary (see Extraction and Monitoring Well Performance checklist).

4.2) Extraction System Objectives

The objectives for the extraction system should be clearly defined. The monitoring plan should be designed to measure how well the objectives are being met. Significant information that should be provided includes the following:

a) What are the objectives of the groundwater extraction system (e.g., source zone remediation, source zone containment, plume containment, plume remediation)? *(If the objective is source zone remediation, alternative technologies should be evaluated.)*

____

____

b) If the objective is source zone containment, are there complementary containment measures?

____

c) If the objective is plume remediation, is the source zone controlled or removed?

____

d) What is the estimated length of time to meet the objectives? What is the basis for this estimate?

____

4.3) Data Requirements for Evaluation of System Performance

Much of the data needed for this evaluation should be specified in a monitoring plan. Additional data should have been collected for the design of the system. Any anomalous conditions or adverse effects of pumping should have been reported.

a) Are monitoring points constructed appropriately? Are screened units in the migration pathways? Are screen lengths appropriate for aquifer unit heterogeneity?

____

____

b) Are monitoring points distributed adequately to determine containment or capture in three dimensions?

____

c) Is the number of monitoring points appropriate or are too many or too few monitoring points installed? *(Redundant wells should be eliminated.)*

____

____

d) Are water level and contaminant concentration measurements made with adequate frequency? *(Measurements should be made with adequate frequency to determine if there are significant natural or man-made effects on containment or remediation. The frequency should match seasonal variations in water levels. Long periods of extraction system shutdown may require monitoring to determine when capture is lost.)*

____

____

e) What are the hydraulic parameter values determined from pumping tests or slug tests?

____

____

f) If ground water modeling was performed, how well does the observed capture match predicted capture? Has optimization modeling been performed?

____

____

g) Is ground water withdrawal causing ground subsidence?

____

h) Are other contaminant plumes being entrained and captured by this extraction system? *(This could result in overloading of treatment systems or the introduction of contaminants for which the treatment systems were not designed.)*

____

5) Evaluation of System Performance

Every system is different and the evaluation of performance data must be made with the specific objectives of the system in mind. The following are general considerations that are common to most ground water extraction systems. Both hydraulic performance and chemical trend data must be evaluated. The data necessary to answer these questions (e.g., contour maps of ground water elevations, contaminant concentrations over time, treatment plant influent and effluent concentrations, estimates of volumes of water extracted and contaminant mass removed) should be included in reports required by the monitoring plan. At a minimum, these reports should be prepared for statutory reviews (e.g. Superfund 5-year review).

5.1) Hydraulic Performance

The hydraulic performance of the extraction system can be evaluated using piezometric surface maps. Maps should be prepared for each aquifer unit of concern. Groundwater models, if available, are particularly useful for this analysis.

a) Is the capture zone adequate (i.e., do all flow lines passing within the target treatment zone reach extraction wells or is a ground water divide established between the plume and water supply wells or other discharge points)?

____

b) Is there an inward (toward the extraction wells) gradient everywhere in the desired containment area?

____

c) Is the pumping properly distributed to capture the plume with minimum total volume of water for treatment? *(It may be appropriate to recommend an optimization study if there is some indication that the system is pumping more than necessary to achieve goals.)*

____

d) Has the system been operating with enough consistency to achieve its objective? *(The system may experience so much down time that although capture is achieved during operation, capture may be lost during extended periods of downtime.)*

____

5.2) Chemical Trends

Contaminant concentration trends should be evaluated using concentration versus time plots for all extraction wells and all contaminants of concern, treatment plant contaminant mass removal versus time plots, and mass removal versus total volume of water extracted plots. There must be some estimate of contaminant mass in place in order to evaluate system efficiency, percent mass removal, and time to reach cleanup goals.

a) Has the system reached its cleanup objectives?

____

b) If the extraction system is being used to remediate a plume, is the contaminant mass extraction rate adequate to achieve cleanup goals (assuming an asymptotic decline in rate with time)?

____

c) If the cleanup objectives have not yet been met, has there been sufficient mass removal to allow the extraction system to be turned off and monitored natural attenuation be used to achieve the cleanup objective while remaining protective of human health and the environment?

____

____

d) Has there been unexpected contamination found outside the capture zone or any other indication of an unknown source?

____
____

e) Have contaminant concentrations been increasing beyond the previously mapped lateral and vertical limits of the plume? *(Increasing concentrations around the previous limits of the plume would indicate a failure of containment or possible entrainment of contaminants from another source. This strongly suggests that the performance of the system be re-evaluated in detail.)*

____
____

f) Have contaminant concentrations been declining in most of the target zone? *(If the system is being used to remediate a plume, there should be a decline in contaminant concentrations. If concentrations are not declining, the source zone may not be adequately contained or removed.)*

____

g) Has the total mass extraction rate leveled off or have contaminant concentrations in the influent to the treatment plant or in water from individual extraction wells leveled off? *(This behavior is often an indicator that contaminant removal is diffusion rate-limited (inherent to organic contaminants present as nonaqueous phase liquids) and that alternate technologies must be used for remediation.)*

____
____

h) Have the contaminant concentrations in some areas been reduced to below action levels? *(If so, this may be an opportunity to reduce the extent of the extraction system.)*

____

i) Can additional wells be placed in the plume or can the extraction rates from existing wells be increased in a way that would economically speed remediation? (This issue should be carefully considered in light of the objectives. Simple analyses can be conducted using analytical capture models as part of the evaluation. **Detailed ground water modeling and extraction system optimization should be recommended as part of a separate study, if appropriate.** Such a study should only be recommended if the potential costs savings justify it.)

____
____

6) Typical Performance Problems

Some typical performance problems for ground water extraction systems are described below. Possible causes are described for each. Possible solutions can be site specific. The potential for these problems to exist should be considered when evaluating the system performance.

a) Have the total extraction rates declined over time? Causes may include well fouling, sedimentation in the extraction wells, or outside influences such as increased regional pumping or regional drought.

____
____

b) Have the total extraction rates ever reached those projected during design or those needed for efficient treatment plant operation? If not, the causes may include poor well development, improper well design, unexpected hydrogeologic conditions, improper operation of the well system, or improper pump placement or sizing.

____
____

c) Do contaminants appear to have escaped containment? Causes may include improper operation of the extraction system such that containment is lost, prolonged system shutdown, previously undetected preferred hydrogeologic pathways, outside influences on flow paths, or other sources of contaminants.

____

____

d) Have concentrations in the plume failed to decline in response to pumping? Causes may include inadequate flushing volume or stagnation zones in the aquifer, uncontrolled sources of contamination, or diffusion limitations (inherent to organic contaminants present as nonaqueous phase liquids).

____

____

e) Is treated water disposal difficult or expensive? *(Refer to Treated Water Disposal Checklist. It may be possible to discharge treated water to the surface or to a publicly owned treatment facility. Treated water can also be injected to improve system containment or flushing. However, injection wells and trenches often require constant maintenance to minimize the biofouling that results when warm, aerated water is introduced into the subsurface.)*

____

____

f) Is the capture zone of the extraction system inadequate? Causes may include improper well locations, improper operation, or outside influences such as pumping, regional water level rise, or climatic influences such as drought or flood.

____

____

7**) Recommendations for System Modifications and Alternative Technologies**

In some cases, other technologies may be able to accomplish the same objectives for lower cost or be able to accelerate clean up. The application of these alternative technologies should be economically justified based on present worth analysis compared to the cost of the current system. One source of information on available and emerging cleanup technologies is the *Site Remediation Technology InfoBase: A Guide to Federal Programs, Information Resources, and Publications on Contaminated Site Cleanup Technologies* (EPA, 1998). This document lists numerous online sources of information. The rapid development of cleanup technologies makes online sources of information the most efficient. Care must be taken to evaluate all emerging and innovative technologies for site-specific applicability. Case studies and well-monitored demonstrations should be consulted. A feasibility study or detailed cost-benefit analysis may be necessary to justify the use of an alternative technology.

Some of the most common and effective technologies that are being used or are proposed to replace ground water extraction for source control and removal and for plume control and remediation are listed below. Not all may be appropriate for the suite of contaminants, the concentrations of contaminants, or hydrogeologic conditions at a given site.

Source control and removal

- Excavation and disposal – This technology is limited only by the costs of excavation, dewatering or hydraulic control of the excavation, treatment of the extracted water, and disposal of extracted water and excavated soils. Sufficient site characterization to define hotspots is necessary.
- Soil vapor extraction (SVE) – This technology is extremely effective at removing vapor phase contaminants from the unsaturated zone. It requires no excavation of contaminated material. It performs best in relatively high permeability, homogeneous soils.
- Bioremediation and bioventing – This technology has been proven to be extremely effective for petroleum hydrocarbons and is often inexpensive and relatively rapid.
- Dual phase extraction – This technology combines vapor and liquid extraction, usually in a single wellbore. It has been proven to be very effective at removing petroleum hydrocarbons in the unsaturated zone, at the water table, and smeared below the water table by changes in water table elevation.
- Air sparging – Air sparging alone has been shown to have limitation, but may be able to remediate solvents in ground water, often in conjunction with SVE. It has been shown to increase partitioning of dissolved solvents from the aqueous phase and the smear zone to the vapor phase so that the efficiency of SVE is enhanced.

- Flushing with surfactants and cosolvents – This technology is not well proven. It is limited to aquifer units with high hydraulic conductivity and may result in the downward mobilization of dense, nonaqueous phase liquid contaminants (DNAPL). Some of the chemicals used are themselves toxic. Demonstrations of high removal efficiency are subject to debate, because the method used to estimate mass in place before and after flushing relies on tracers that move with ground water in the most porous and permeable units.
- Steam and thermal treatment – This technology is not well proven. It may result in the mobilization of vapors and DNAPL.
- In-situ Chemical Oxidation - Can be used to quickly reduce source area concentrations or hot spots. In some small plumes, if site conditions are appropriate, could treat much of the plume to remediation.
- Barriers – Sheet pile or slurry walls can be used to contain a source zone if there is an underlying aquitard or low permeability unit that has not been penetrated by the contaminant. Some pumping to maintain an inward hydraulic gradient to the enclosed source zone may be necessary.

Plume control and remediation

- Permeable reactive barriers – Zero valent iron is used to degrade dissolved chlorinated solvents to nontoxic end products (patented EnviroMetal process) in the ground. The advantages of this technology are that no contaminants are brought to the surface; there is very little surface infrastructure associated with the remediation; and regulatory action levels can be met. No problems with clogging, either by precipitates or biologic action, have been experienced to date. The primary limitation of this technology is installation – the current depth limit for conventional installation is 30 feet. Innovative installation methods are being demonstrated at various sites. Detailed site characterization is required for adequate barrier design. Refer to Air Force Design Guidelines for Application of Permeable Barriers to Remediate Dissolved Chlorinated Solvents, Feb 1997.
- Monitored natural attenuation – Once a source zone has been controlled or removed, it is possible that the dissolved plume will attenuate below regulatory action levels before it reaches a receptor. Careful characterization of the assimilative capacity of the aquifer must be done and historical evidence must be presented that the plume is stable or retreating.

Other technologies such as phytoremediation, recirculating wells, oxidation by addition of ozone, permanganate and other compounds, and bioremediation of chlorinated hydrocarbons that are innovative and unproven are actively being studied and may prove to be useful additions to the suite of remedial alternative to ground water extraction.

8) Conclusions

The observations, observations, and conclusions from this evaluations should be documented in detail. In documenting the conclusions from this evaluation, the following questions should be answered:

- Is the system meeting performance objectives?
- Are the performance objectives achievable with this technology or any technology?
- Are the performance objectives overly protective of human health and the environment?
- Are there alternate technologies that could meet or exceed the performance objectives faster or cheaper?
- Is there new information about the mass and distribution of the contaminant that should be used to evaluate appropriate alternative technologies?

Even if the system is meeting performance objectives, alternative approaches to remediation and containment should be evaluated. Regulatory factors, risk assessment data, cost data, and new information that fills previous data gaps in the conceptual site model should all be considered in the evaluation of cleanup goals and appropriate remedial technologies.

If the system is not meeting performance objectives, both the objectives and the extraction technology should be reevaluated.

9) Supplemental Notes and Data

There are _______ pages of supplemental notes and data attached to this checklist.

____

[1] ETL: USACE Engineering Technical Letter