PROTOCOL FOR CONTROLLING CONTAMINATED GROUNDWATER BY PHYTOSTABILIZATION

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Introduction

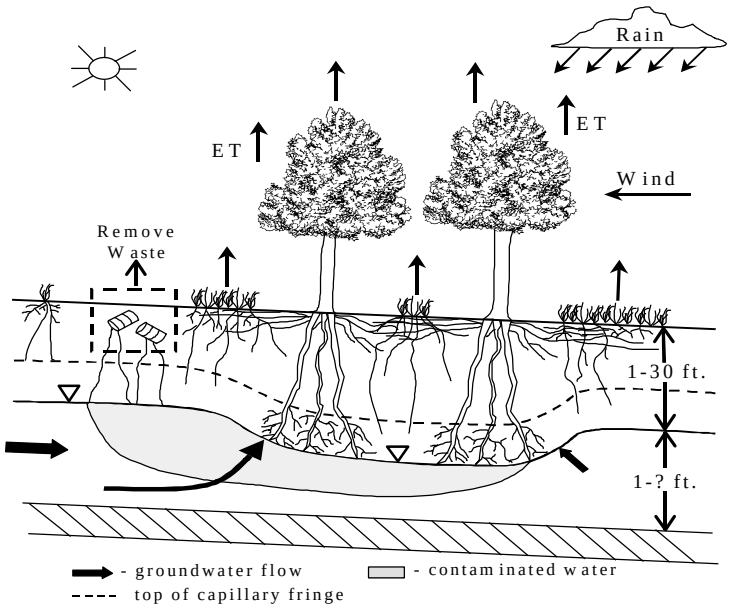
The purpose of this protocol is to guide Air Force Remedial Project Managers (RPMs) through the steps leading to design and implementation of phytostabilization to control groundwater movement at a site. Each step is discussed in the context of the information that RPMs will need in order to manage the project. The decisions required to determine whether phytostabilization is feasible are presented as a screening tool to aid in the decision-making process. The principal sections of this document address the following:

- An overview of phytoremediation in it various forms
- A description of phytostabilization
- The technologies and science behind phytostabilization
- Site selection and screening
- Design and implementation
- Operation, maintenance, and monitoring
- Technical appendixes to aid the RPM

This document is intended to provide informative and practical guidance on the design of phytostabilization for an Air Force site. In most cases, the RPM will be overseeing the work of one or more contractors who will perform the field investigation, design the needed facilities, install the remediation, and provide long-term maintenance and monitoring. References are provided for those wanting more detailed information about design and installation.

Phytostabilization

This protocol is intended to explain the principles that govern the use of phytostabilization to withdraw sufficient groundwater to control the lateral movement of contaminants in the shallow groundwater. Phytostabilization is the use of plants to immobilize contaminants in the soil or to control groundwater movement. The figure below shows the concept with a cross-section of a typical phytostabilization site. Mechanisms for phytostabilization include absorption and accumulation by roots, precipitation of chemicals within the root zone, and control of water movement in shallow groundwater by extraction with plants (use of plants in lieu of or in support of extraction wells or physical barriers). Phytostabilization may lower the water table sufficiently to reduce or control vertical movement of contaminants downward into deep aquifers. The intention is to control contaminant movement until natural attenuation or other processes can reduce contaminant concentrations to meet remediation requirements.



This document focuses on phytostabilization as it is used to remove groundwater from the capillary fringe at a rate sufficient to stabilize movement of near-surface groundwater. The goal of a phytostabilization effort is to stabilize a contaminated plume and to assist in complete remediation at the site. Cleanup goals for remediating a dissolved phase contaminant plume are not likely to be achieved, however, if the source of the contamination is not remediated or contained. As with other site remediation efforts, phytostabilization requires that the source of the contaminant be removed, controlled, or remediated so that no additional contaminant will be introduced into the environment. At sites with appropriate conditions, phytostabilization might completely replace traditional groundwater pumping as a method for controlling groundwater plume movement. At sites where complete year round containment of contaminant movement in the groundwater is not possible, it may be feasible to shut off the groundwater pumping during the growing season and consequently save considerable operating and maintenance costs. At other sites where the groundwater is too deep for plant roots to reach, it may still be economically attractive to pump groundwater to the root zone for irrigation and use the plants to remove the water rather than incur the expense of *ex situ* treatment and discharge of the groundwater.

Benefits, Cost-Effectiveness and Disadvantages

Phytostabilization may offer a number of advantages as part of the remediation effort at sites with shallow groundwater containing low to moderate contaminate concentrations. These may include some or all of the following:

- The technology relies on growing trees or other plants and thus is aesthetically pleasing
- It is a solar-energy driven, passive technique requiring little energy input
- It requires little operator attention or labor
- It requires minimal maintenance once established
- It is a “green technology” with public acceptance

Though relatively unproven in full-scale, tests suggest that phytostabilization may produce substantial cost savings. The plant roots will typically come in direct contact with a much greater volume of soil than is possible for pumping wells. In addition, depending upon the contaminant and the plant species utilized, other forms of

phytoremediation (e.g. phytodegradation or rhizodegradation) may occur as a by-product of plant growth, thus enhancing effectiveness.

The RPM must consider, however, that an application of phytostabilization might have the following limitations:

- Phytostabilization requires sunlight for the plants and thus adequate space over the contaminant plume is needed for planting
- Water removal is reduced during the winter which might allow contaminated water to migrate away from the capture zone
- Complete year round containment of groundwater and contaminant movement may not be possible in all regions of the country
- Groundwater removal is limited by the potential rooting depth of the vegetation, which may limit the number of applicable sites
- Plants, especially trees, may attract unwanted birds or animals to the site

General Requirements for Successful Phytostabilization

The general requirements for a successful implementation of phytostabilization includes the following:

- Plants must root deep enough to use large volumes of groundwater
- For complete year round containment of contaminant movement in groundwater, evapotranspiration must exceed precipitation and groundwater flowing into the containment zone.
- An adequate sized site must be available for planting
- Soil properties must support robust plant growth
- The hydrogeology of the site must be suitable
- Plant establishment must be carefully planned and executed
- Project goals should be carefully defined to permit verification of performance
- Project completion should be carefully defined

Implementation of a field-scale phytostabilization project, however, may reveal additional site-specific requirements or suggest modification of the requirements listed above.

Technology For Planning And Implementation

Knowledge from several areas of science and technology are required for successful application of phytostabilization to control groundwater movement at a contaminated site. This protocol examines the hydrology, climate, evapotranspiration, plant science, and soil requirements necessary to plan and implement a phytostabilization project and provides the basic requirements that form the foundation for successful application of phytostabilization at any site, including those with less favorable site or climatic conditions.

Successful phytostabilization requires robust growth of selected species to achieve the remediation goals. It is sometimes assumed that plants can modify soils, but this may not be possible. While plants are found in nature growing in very difficult environments, these conditions are not suitable for phytostabilization. For instance, trees sometimes appear to grow out of a rock, but they are usually stunted and to grow under these conditions they must have roots that reach soil. Grasses and other plants grow in abandoned roadways suggesting that the plants modified the undesirable features of the soil in the roadway. However, close examination of the site usually shows that the plants are weedy species capable of producing a small amount of biomass under unfavorable conditions.

Phytostabilization cannot be applied in all circumstances and just "planting a tree" cannot overcome all adverse site conditions. Good planning and active management are required to assure success of phytostabilization activities. Phytostabilization will be most effective and least costly if selected plants grow robustly and extend their roots into the capillary fringe of the water table. This can most effectively be accomplished if the site soils, plant nutrients, plant disease and insect control, and water supply are optimized for plant growth. Therefore, the active practice of agricultural engineering and the application of principles used in agricultural production apply to most aspects of phytostabilization and are included in this protocol.

Site Screening

Because remediation activities are expensive, it is desirable to evaluate a site to determine whether phytostabilization may be appropriate there. The goal of this protocol is to assist the Air Force RPM in making the correct choice quickly and at low cost, and to reduce the risk of decision-making error. A decision that phytostabilization is a viable technology should then be confirmed by a more complete investigation during the design phase.

The site screening may typically be undertaken with existing information. Most Air Force remediation sites have been evaluated, and substantial factual information is available. The protocol presents a list of the types of information needed for the feasibility screening. It will be rare that missing information will require new field investigations during screening evaluation of an Air Force site.

The protocol also describes a ten-step screening process to determine whether phytostabilization is suitable and feasible for this application.

References

See protocol.