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Plume Intensity and Extent

The general topics of plume detection, estimation, and interpolation are related to plume intensity and extent. A reliable estimation of the groundwater plume geometry or the extent of soil contamination provides both a snapshot of site conditions at a point in time, as well as a means to estimate contaminant mass. Geospatial methods can help achieve optimization objectives by providing useful information to understand the plume. Objectives include:

- determining whether various detected concentrations represent a plume or isolated impacted areas during the release detection stage
- contouring the extent and magnitude of contamination in soil or groundwater

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All categories of geospatial methods (simple, more complex, advanced) can be used to generate contaminant contour maps or other types of maps to assess the presence of a plume or characterize site conditions. In general, contour maps are generated from data that are associated with cells on a grid. One of the geospatial interpolation methods is used to convert discrete data points into values representing the entire area of each grid cell. Depending on the software, users may need to select the density of the grid. A finer grid produces more details in the final map, but may be computationally expensive depending on the interpolation method used. In addition to square or rectangular gridding, the map can be produced by interpolating onto a set of contiguous triangles or polygons.

When contouring groundwater concentrations and potentiometric surfaces, consider the stratigraphic layer, or aquifer, corresponding to each data point. It may be necessary to contour concentrations within different layers independently based on the CSM. Document decisions regarding handling of duplicate results and nondetect results and consider various alternatives. Evaluate how these decisions affect contouring results. Further information is provided in GSMC-1, Section 5.7.

The primary goal of geospatial methods used for site characterization and plume assessment is to interpolate the available data in a way that produces a model that is consistent with the CSM. For example, if the CSM includes a geologic fault that is a barrier to groundwater flow, then the method should incorporate this feature into the interpolation. Otherwise, the resulting interpolated map will display incorrect concentrations across the fault and be inconsistent with the CSM. Simple geospatial methods are generally useful for optimization when there is either a very high density of data (such that most interpolation algorithms yield similar results), or a small amount of data that precludes application of the more complex methods. Simple methods generally cannot directly incorporate features such as barriers to flow into the interpolation. Separate interpolations, however, could be performed on each side of the barrier and then combined for the final map. In some cases, it may be necessary to add dummy data points to the actual measured data in order to ensure that the interpolation method incorporates important features from the CSM.

In addition to site features such as barriers, it is useful to incorporate other explanatory variables into the interpolation to supplement the primary sample results so that interpolation is more accurate and consistent with the CSM. Explanatory variables are correlated with the quantity of interest and are most useful when they are densely sampled throughout the area of interest. There are many publically available data sets that can be used as explanatory variables. For example, when interpolating a groundwater elevation map it may be useful to include a digital elevation model (DEM) as an additional explanatory variable because groundwater levels are often correlated with ground surface elevation. Another type of explanatory variable is created by the user. For example, when interpolating soil concentrations near a river, a useful explanatory variable may be distance to the river if the soil contamination resulted from flooding. A grid would be created throughout the area of interest in which each grid cell contains the distance to the river from that location. An example of the use of explanatory variables is shown in the Methods section. Explanatory variables can be identified during the EDA process.

Simple methods do not typically include a way of incorporating features such as barriers or explanatory variables, so more complex or advanced methods should be used in these cases. However, if the area of interest is densely sampled, then all of the interpolation methods (including simple methods) give similar results and the effects of any features such as barriers are shown in the results of the interpolation. More complex (regression) methods provide the simpler approach to incorporating supplemental data as additional explanatory variables. Most software that performs regression is flexible enough to incorporate both categorical (for example, soil type) and continuous variables (for example, ground elevation). Regression diagnostic statistics such as the p-value on the regression coefficients can be used to determine if each explanatory variable is contributing to the prediction.

If there are no useful additional explanatory variables that can be identified, then advanced methods should be considered so that the spatial correlation in the sample data can be used most effectively. To use advanced methods, a model of spatial correlation such as a variogram is first estimated from the data. Depending on the results of EDA, a model for the spatial trend is selected, with constant, linear trend, or quadratic trend being the most typical choices. Based on the variogram and trend models, kriging is used to interpolate the data onto a grid that can be mapped.

Contour maps with connected isoconcentration lines with higher values around a suspected source and lower values extending in an elliptical shape in the direction of groundwater flow likely indicate the presence of a plume. Detached, closed contour lines with breaks in between indicate that a connected plume may not be present, and concentrations are associated with localized effects. Alternatively, this situation may represent insufficient data to characterize the plume in question, or a limitation of the chosen simple method that does not account for spatial correlation and anisotropy of the plume.

Different data presentation techniques can be used to visualize plume intensity and extent, such as filled, color-shaded contours and manually specified contour intervals with a value corresponding to the detection limit or cleanup level. Cross-validation of the interpolation provides a general indication of the accuracy of the results, and areas of high uncertainty could be indicated with dashed isopleths. Overall, the knowledge gained from interpolation of the data can be used to inform and optimize future sampling efforts to detect a plume, characterize concentrations across a site, or demonstrate that closure criteria have been met. The estimates may be recalculated as additional sampling events provide updated concentration information.

Only more complex and advanced methods provide an estimate of uncertainty in the interpolated values. The estimate of uncertainty can be used to select additional samples in areas with the highest uncertainty. Although simple methods provide no way of assessing the uncertainty in the interpolated quantity, they may be the most practical methods to use with large numbers of samples due to their computational efficiency.