Groundwater Flow Direction at the Industrial Excess Landfill (IEL) Superfund Site, Uniontown, Ohio

Date: 08/25/2022

What is Groundwater?

Groundwater is water that fills the void spaces between sediment and fractures within the subsurface. If the void spaces transmit water readily into wells and springs, it is called an aquifer (figure 1).

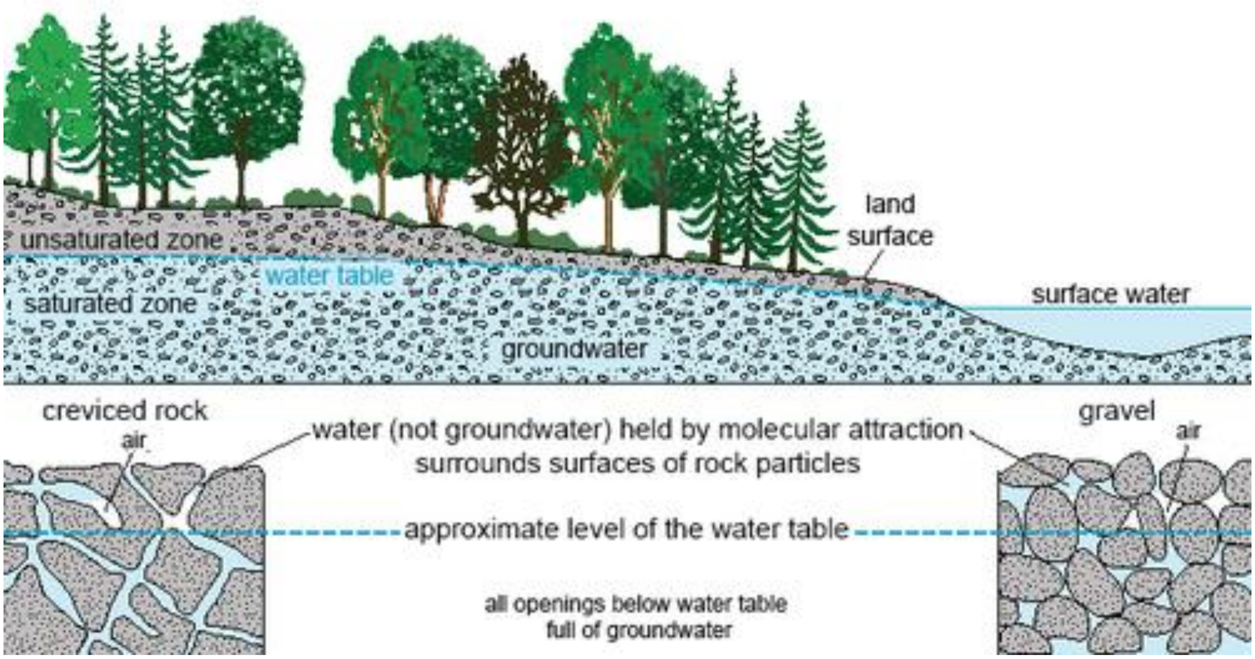

Figure 1. How groundwater works in sediment and rocks, Image from U.S. Geological Survey (2022a).

Movement of water through sediment and rock

Groundwater moves from high elevation to lower elevation taking the path of least resistance, through larger interconnected void spaces (Fetter, 1994). These void spaces are measured as porosity (Fetter, 1994).

Sands and gravels have larger pore spaces that are more interconnected which allow groundwater to flow readily under the influence of gravity or pressure. Silts and clays have smaller pore sizes with less interconnection and restricts or decreases the ability of groundwater to flow within these deposits. Hard rock like sandstone, limestone, and granite can have fractures within the rock that allow groundwater to flow where the fractures are interconnected. The rate at which water moves through these interconnected pore spaces is controlled by the hydraulic conductivity (Fetter, 1994).

Types of deposits at and surrounding IEL

Glaciers carved out bedrock and left behind sand, gravel, silts, and clays in various patterns. Glaciers build up moraines (higher elevation ridges) by slowly depositing everything carried within the frozen mass. As the glacier receded due to warming temperatures, the meltwaters carried and sorted material such as sand, gravel, cobbles, and sometimes boulders into the valleys, and lower elevation areas and filled them in.

The region of IEL consists largely of sand and sand and gravel deposited by glacial meltwater. A majority of the deposits are, rolling hills consisting of sands overlying the glacially eroded and carved out sandstone bedrock (per the 1988 Remedial Investigation Report and Ohio regional geologic maps). Kettle lakes and wetland areas are also common at the low-lying depressions caused by the glaciers. Additional information describing the Ohio geology and glacial history can be found within the Ohio Department of Natural Resources Division of Geological Survey (2022a) and Hansen (2020).

At IEL specifically, the geology consists of interbedded sand and gravel, but the uppermost part has been altered with excavations and fill of waste materials and liquids mixed with fly-ash deposits. The fly-ash reduces the ability of the material to transmit water. The waste is on top of a sand and gravel ridge that covers a bedrock high. The ridge is present from the northeast to southwest near the Site and is most prominent just north of the landfill (RI, USGS 1989, 1994). Some lower-lying depressions and the Metzger Creek also include low-permeable deposits such as silts and clays.

Factors that influence groundwater flow direction

Hydrogeologists focus on how groundwater might move within these various deposits. Because of the complex geology and different layers of sand, silt, and gravel, groundwater flow directions can be complicated and challenging to predict. The flow path that groundwater is driven partially by gravity (from high to low elevations) as well as porosity (the ease through which groundwater will flow through material), and the rate at which precipitation enters the groundwater. As mentioned previously, sand and gravel have greater amounts of pore spaces that are interconnected and water usually moves move rapidly through this type of material. If sand and gravel is present from the ground surface all the way to the top of the water table, precipitation will easily infiltrate the unsaturated zone and enter groundwater. A sand and gravel aquifer may be referred to as an unconfined aquifer (U.S. Geological Survey, 2022a; U.S. Geological Survey, 2022b) if sand and gravel extend through the unsaturated zone to the ground surface. If the unsaturated zone above the aquifer consists of low-permeable material such as silts and clays the rate water entering the aquifer is reduced. The combination of low-permeable material near ground surface and limited areas where water enters an aquifer can cause the aquifer to be under pressure, and this type of aquifer would be referred to as a confined or semi-confined aquifer. The uppermost aquifer at IEL is primarily unconfined (Remedial Investigation, 1988) meaning water can enter the aquifer rapidly and move quickly within the aquifer.

Surficial drainage patterns may cause water to flow towards low-lying depressions (ponds and Metzger Ditch) during rainfall events and may infiltrate into the aquifer. Groundwater flow directions in the shallow, intermediate, and deep parts of an aquifer is illustrated in figure 2. Flow directions of shallower groundwater at and near the water table can be influenced by surface topography, depending on the geology of the area (Haitjema and Mitchell-Bruker, 2005). Groundwater flow directions at increasing depths from the water table surface are not as affected by infiltration from the surface. Groundwater flow direction in deeper aquifers is usually equal to the regional flow direction.

Groundwater also moves vertically within an aquifer as shown in the figure below. Groundwater will move vertically downwards in areas with higher elevation as infiltrating rainfall recharges the aquifer. Groundwater will transport upwards and into lower elevation areas and drain into a surface water body such as streams, lakes, or wetlands. The vertical movement of groundwater can be measured from monitoring wells that are clustered together and are screened at different depths. Higher groundwater elevations in the shallow monitoring wells than in the deeper monitoring wells will generally indicate the area at and near the clustered monitoring wells is a recharge area. Lower groundwater levels in the shallow monitoring wells than in the deeper monitoring wells will generally indicate the area is a discharge area, where groundwater is moving towards and into a nearby surface-water body.

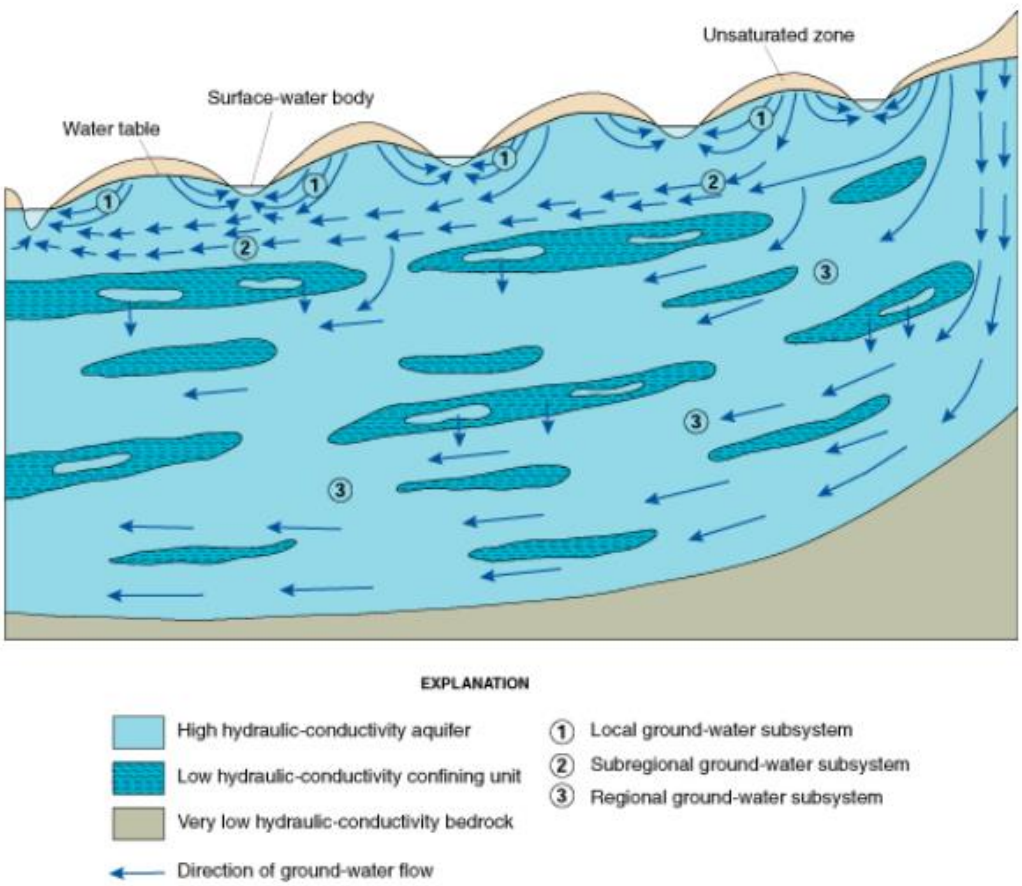

Figure 2. Image of groundwater flow in aquifers with low, high, and moderate hydraulic conductivity at local and regional scale; image from USGS, 2022b

A topographic relief map of Summit County shows higher elevation (white, red, and orange) north of the IEL site and on IEL (yellow) (Figure 3) (Topographic-Map.com, 2022). Lower elevations are present west of the IEL site. The groundwater flow direction in the uppermost part of the shallow aquifer is influenced by the surficial topography (Remedial Investigation, 1988; U.S. Geological Survey, 1989; U.S. Geological Survey, 1994).

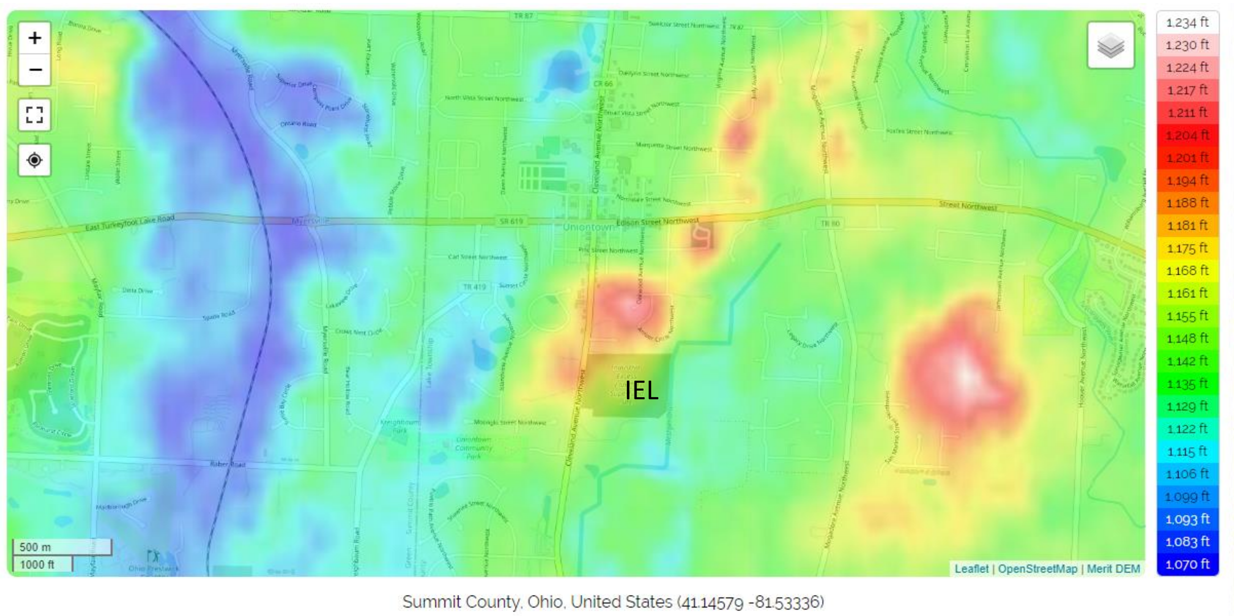

Figure 3. Surficial topography of Industrial Excess Landfill (IEL) and surrounding area, [Summit County topographic map, elevation, relief (topographic-map.com, 2022)]

Underlying the glacial sand and gravel is the sandstone bedrock aquifer (Pennsylvanian Pottsville Formation) (figure 4) (Topographic-Map.com, 2022). The bedrock near IEL has valleys west and northwest of the site.

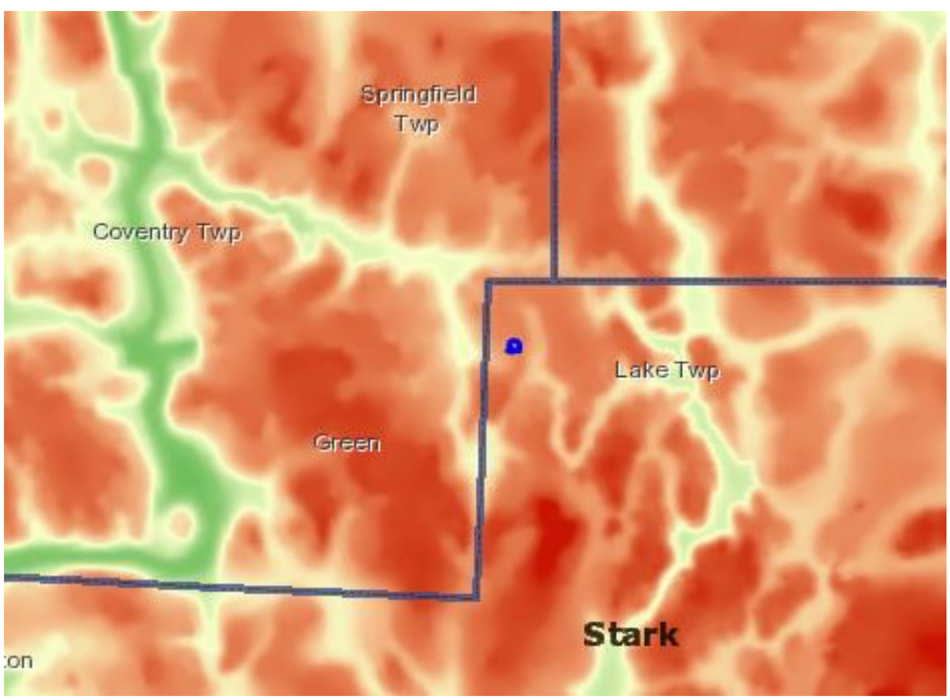

Figure 4. Bedrock topographic map near Industrial Excess Landfill (IEL) (Ohio Department of Natural Resources, 2022b).

Water level maps of the unconsolidated (sand and gravel aquifer) material and the consolidated bedrock aquifers are also available through the Ohio Department of Natural Resources interactive map (Ohio Department of Natural Resources, 2022). The figures 5 and 6 below is a snapshot of the interactive map for the IEL area of interest. The groundwater contours can be viewed in higher resolution by accessing the interactive map and selecting the Groundwater folder in the “legends and layers” options. The water level contour maps were created using regional water level data from supply wells or monitoring wells open to either the sand and gravel aquifer or the bedrock aquifer, according to the Ohio DNR. The groundwater contours depicted on the map for Stark and Summit counties appear similar to a topographic map, however, these maps are showing the water level elevation and are not land surface elevation. Groundwater flows perpendicular to the contour lines. From IEL, the groundwater in the sand and gravel aquifer flows from the 1125 ft contour west and northwest towards the 1100 ft contour, and ultimately towards the Tuscarawas River.

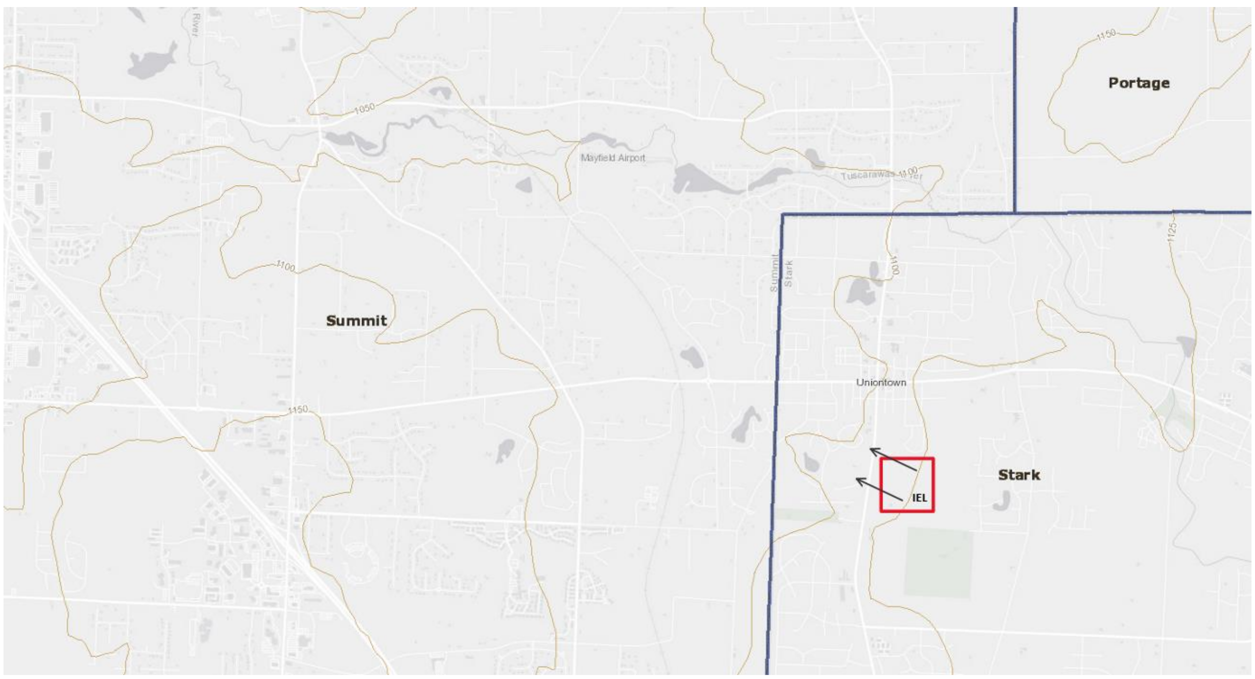

Figure 5. Potentiometric surface (unconsolidated) map available on Ohio Department of Natural Resources interactive map (https://gis.ohiodnr.gov/website/dgs/geologyviewer/).

The potentiometric surface for the consolidated aquifer (bedrock) shows black contour lines near IEL, groundwater flows from the 1100 ft contour northwest towards the 1050 ft contour at the Tuscarawas River (figure 6).

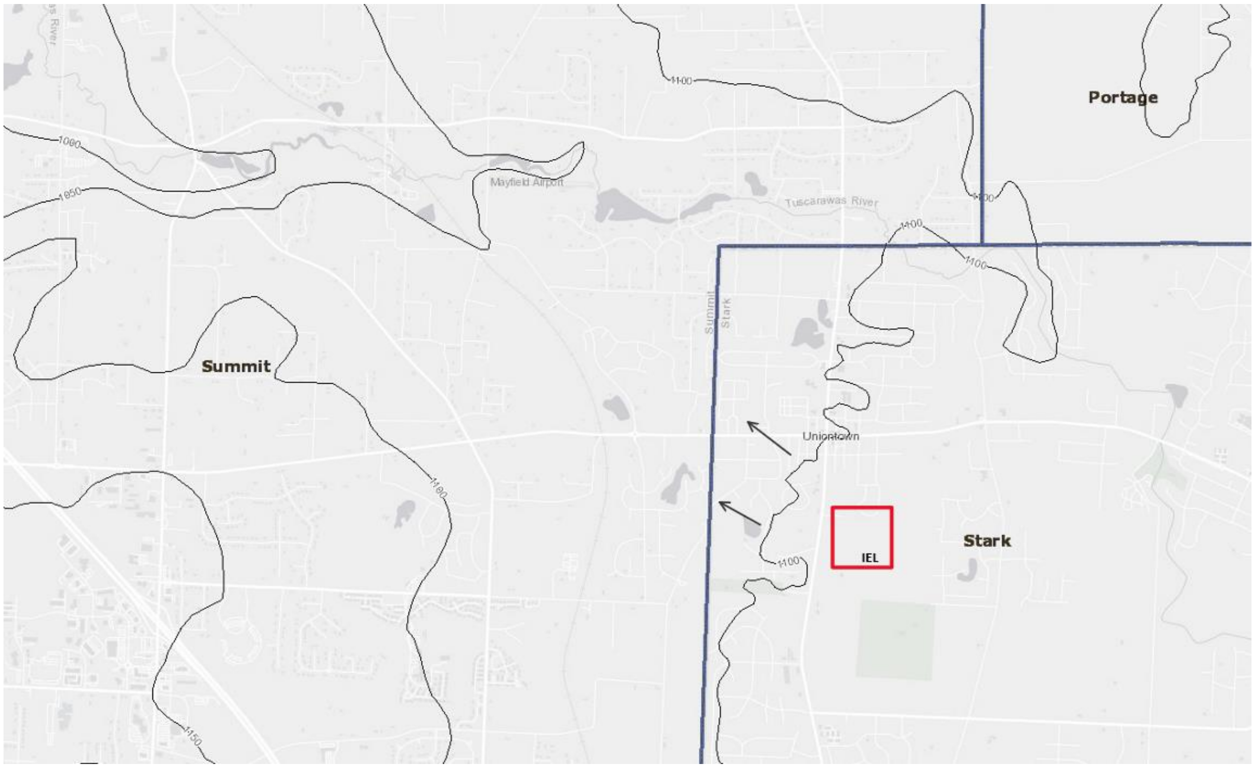

Figure 6. Potentiometric surface (consolidated) available on Ohio Department of Natural Resources interactive map (https://gis.ohiodnr.gov/website/dgs/geologyviewer/)

How Contaminants Help to Determine Groundwater Flow Direction

Contaminants can be used to map primary locations of disposal and estimate the groundwater flow path. Contaminants within the groundwater are used to identify an area of groundwater contamination known as a plume. The vertical and horizontal extent of the plume is affected by the contaminant interaction with the subsurface geology, organic carbon, microbial population, geochemistry, and groundwater flow velocity. The concentrations generally are highest near the source areas and decrease along a predominant flow path. Concentrations decrease along the flow path from a variety of processes including, but not limited to, dispersion, dilution, and degradation. Some contaminants do not degrade or reduce significantly and move in the same direction and rate as the groundwater. 1,4-dioxane and per- and polyfluoroalkyl substances (PFAS) are examples of these types of contaminants that may be used as evidence for the groundwater flow directions.

Previous IEL GW Flow Investigations

The Remedial Investigation (RI) (U.S. Environmental Protection Agency, 1988) described the local and regional hydrogeology and groundwater flow direction at IEL. Regional groundwater flow was estimated to be from east to west based on drillers logs and surface water elevations. Local groundwater flow at IEL was assessed with additional shallow, intermediate, and deep monitoring wells. The shallow wells monitor the top of the water-table and are most influenced by recharge. Water levels from the shallow wells often reflect the slope of the land surface (topography) and can influence the local groundwater flow direction. Intermediate wells at IEL are screened about 35 ft below the water table, and water levels in these wells are less influenced by topography and are more representative of the regional flow direction. The deep wells installed at IEL monitor the upper part of the sandstone bedrock and are representative of the regional groundwater flow direction. The RI also describes the IEL landfill location as situated on a recharge area where precipitation at land surface is able to reach the aquifer quickly through sandy permeable soils, carrying contamination to greater depths within the aquifer.

A U.S. Geological (USGS) report (Bair and Norris, 1989) report aimed to further understand the local and regional groundwater flow direction by compositing 279 water levels recorded on drillers logs. The compiled data from various dates indicated a northeast-southwest ridge (groundwater mound) along the northwestern corner of IEL from which groundwater flows in several directions away from this ridge, primarily northwest and southeast. At the highest point of the groundwater mound, the groundwater starts off by flowing radially in all directions from this high-point and then flows either northwest or southeast. The report also discussed the vertical component of the groundwater indicating a downward flow of shallow groundwater into deeper portions of the aquifer, consistent with most recharge areas.

Another report by the USGS (Dumouchelle and Bair, 1994) is a similar study to the previous report but was updated with a synoptic (same day) water-level study in the local and regional groundwater flow system. Dumouchelle and Bair, 1994 provided water-level contour maps from wells screened between the elevation 1,100 to 1,112 ft above mean sea level, which is within the shallow zone of the aquifer. The results of that study indicated elevated groundwater levels at IEL in the shallow monitoring wells, showing a groundwater mound consistent with the topography. Groundwater flow within this shallow zone moves from the groundwater mound out towards the northwest and southeast, recharges the intermediate zone, and resumes to regional flow patterns west and northwest away from IEL.

Conceptual Groundwater Flow Model at IEL

The groundwater flow at IEL has been described in the RI as having locally radial flow that connects to regional flow directions from east to west. This conclusion was further supported in subsequent regional and local groundwater elevation supplemental studies by the USGS (Bair and Norris, 1984; Dumouchelle and Bair, 1994). Vertical downward flow is evident in many of the nested shallow, intermediate, and deep wells along the northeast-southwest trending topographic ridge along the northwestern portion of IEL. The higher groundwater elevations in the shallow and intermediate portions of the aquifer indicate a recharge zone is present at the site.

The shallow water-bearing zones may drain towards wetlands and ponds as described historically, and possibly currently. The vertical downward gradient of the recharge areas likely pushes contaminants downward into the intermediate zone and deeper zones of the sand and gravel aquifer.

Historically, contaminants at IEL have primarily been detected along the western half of the IEL site and west from the site at several residential wells and monitoring wells during the RI. VOCs have largely attenuated naturally and did not extend substantially west of Cleveland Ave. 1,4-dioxane and PFAS are considered emerging contaminants, of which USEPA requested sampling for during the recent 2021 Five Year Review. The detections of 1,4-dioxane in IEL monitoring wells and in residential wells screened in the glacial sand and gravel aquifer indicates this contaminant is following the northwesterly groundwater flow component as described in the previous investigations (USEPA, 1988; USGS, 1989; USGS; 1989; and Sharp and Associates, Inc., 2003). The PFAS data is currently under review. Additional vertical aquifer sampling is needed for complete delineation of the 1,4-dioxane plume emanating from IEL.

The primary location of the 1,4-dioxane contaminant is detected in higher concentrations in the shallow and intermediate zones of the sand and gravel aquifer along the western half of IEL and downgradient areas. 1,4-dioxane concentrations south and southeast just outside of IEL property boundaries are relatively low, indicating the predominant deposition and or flow path of these contaminants are following along the west and northwesterly flow paths as influenced by the regional groundwater flow direction.

The USEPA continues to sample residential homes surrounding IEL and along the west and northwest flow paths to identify private wells that have been impacted. Homes with elevated 1,4-dioxane above the current health-based criteria are provided bottled water and are currently being hooked up to municipal water supplies. The selected residential homes north and south, and southwest have been tested and contaminants have not been detected in these directions. The depth range for these tested homes are between 25-100 feet according to the Ohio DNR Water Wells Database (Ohio Department of Natural Resources, 2022c). The Metzger Ditch is also recommended to be sampled to assess the groundwater to surface water hydrologic flow path and contaminant transport.

Contact: Amy Gahala, Gahala.amy@usepa.gov, USEPA phone number: 312-886-6678

References

Bair, E.S., and Norris, S.E., 1989, Groundwater levels and flow near the Industrial Excess Landfill, Uniontown, Ohio; U.S. Geological Survey Open-File Report 89-272, available at https://pubs.usgs.gov/of/1989/0272/report.pdf

Dumouchelle, D., H., and Bair, E.S., 1994, Groundwater levels and directions of flow near the Industrial Excess Landfill, Uniontown, Ohio, March 1994; U.S. Geological Survey Water Resources Investigations Report 94-4136 available at https://pubs.usgs.gov/wri/1994/4136/report.pdf

Fetter, C.W., 1994, Applied Hydrogeology, third edition, Prentice-Hall, Inc.

Haitjema, H.M. and Mitchell-Bruker, S., 2005, Are water tables a subdued replica of the topography?, Groundwater, November 2005, pages 781—786 accessed June 16, 2022 at https://ngwa.onlinelibrary.wiley.com/doi/full/10.1111/j.1745-6584.2005.00090.x

Hansen M.C., 2020, The Ice Age in Ohio, Educational Leaflet No. 7, Revised Edition 2020; Ohio Department of National Resources Division of Geological Survey, accessed June 21, 20222 at EL-7+The+Ice+Age+in+Ohio_WEB_rev+2020_Final.pdf (ohiodnr.gov)

Ohio Department of National Resources Division of Geological Survey, 2022a, "Evidence of Ohio's Glaciers", webpage, accessed June 21, 2022 at https://ohiodnr.gov/wps/wcm/connect/gov/ohio+content+english/odnr/discover-and-learn/safetyconservation/about-odnr/geologic-survey/glacial-geology/evidence-of-glaciers#:~:text=The majority of glacial landforms in Ohio are,landforms found at the surface of Ohio today.

Ohio Department of Natural Resources, 2022b, Ohio Geology Interactive Map, Groundwater, Potentiometric Surface, Division of Geological Survey, accessed June 27, 2022 at https://gis.ohiodnr.gov/website/dgs/geologyviewer/

Ohio Department of Natural Resources, 2022c, Water Wells Database, Ohio Interactive Map, Division of Geological Survey, accessed July 20, 2022 at https://waterwells.ohiodnr.gov/search/interactive-search

Sharp and Associates, Inc., 2003, Summary report on an Assessment of individual groundwater monitoring wells at the Industrial Excess Landfill Ste and the Regional Hydrogeologic Setting, Sharp and Associates, Inc Environmental Engineers and Scientists, Columbus, OH. EPA Region 5 Records Center 360030

Topographic-Map.com, 2022, Summit County, accessed June 16, 2022 at https://en-us.topographic-map.com/maps/vtsd/Summit-County/

U.S. Environmental Protection Agency, 1988, Remedial investigation Report for Industrial Excell Landfill, Uniontown, Ohio.

U.S. Geological Survey, 2022a, "What is the difference between a confined and an unconfined (water table) aquifer", webpage: Frequently Asked Questions: Water; accessed June 21, 2022 at https://www.usgs.gov/faqs/what-difference-between-confined-and-unconfined-water-table-aquifer

U.S. Geological Survey, 2022b, "General facts and concepts about ground water", U.S. Geological Survey webpage for Sustainability of Groundwater Resources—Circular 1186, available at https://pubs.usgs.gov/circ/circ1186/html/gen_facts.html

WSP, 2021, (unpublished) "figure 5B, 1,4-dioxane concentrations January 2022" 2021 Groundwater and Landfill Gas Monitoring Report Industrial Excess Landfill (IEL), Uniontown, Ohio (figure 5B).