Terran Corporation

Environmental Services

February 1, 2018

Mr. James Yskamp, Esq.
Fair Shake Environmental Legal Services
159 South Main Street, Suite 1030
Akron, Ohio 44308

RE: Technical Report Review: *"Evaluation of Groundwater Impacts, Dewatering of Proposed Enon Quarry, Clark County, Ohio"*

Dear Mr. Yskamp,

I, Brent E. Huntsman, CPG, President and Principal Hydrogeologist of Terran Corporation (Terran) was retained by Fair Shake Environmental Legal Services to review and comment upon the hydrogeologic characterization and predicted dewatering effects to the water resources of Mad River Township, Clark County, OH as described in a groundwater model report prepared for a mining permit modification. This report review was to include an evaluation of the aquifer response and hydraulic performance predicted by the model simulations of the groundwater system; the magnitude and extent of a cone of depression resulting from dewatering various limestone quarry pits. The purpose of my review is to provide a letter report summarizing my expert opinions regarding the adequacy of the groundwater model to appropriately simulate dewatering effects upon the local groundwater regime. All opinions in this report are based upon my review of existing information (developed through the litigation process in this case or in the public record) together with my 43-years of experience in applied hydrogeology, specifically aquifer characterization and water resources development. My current curriculum vita is included with this letter report as Attachment 2. These opinions are expressed to a reasonable degree of scientific and professional certainty. I reserve the right to supplement this report and opinions as additional material becomes available through the litigation process or continued review of public literature. Documents used in formulating and expressing these technical opinions will be referenced at the end of this letter report.

As you are aware, I previously prepared an initial review of the 2016 groundwater modeling report prepared by Eagon & Associates, Inc. (EAI) referenced above. This was completed at the request of the Mad River Township Trustees and the Village of Enon. The initial review, prepared as a letter report, was submitted to Mr. Lanny E. Erdos, Division Chief of Mineral Resources Management (DMRM) at the Ohio Department of Natural Resources (ODNR) on May 15, 2017. The primary purpose of the initial review was to determine if the model credibly represented the existing groundwater resources in proximity of the proposed mining operations and was capable of correctly simulating the effects of long-term quarry dewatering on existing groundwater users.

On June 19, 2017, Ms. Kelly Barrett, Geologist with DMRM, provided responses to my May 15 review comments for the Division. In her reply, Ms. Barrett acknowledged some of the problems and issues I identified in the EAI model report, but dismissed these concerns as not being required or not within the scope of ORC 1514.13 and OAC 1501:14-5-01. She further stated my concerns did not consider the entirety of the groundwater model report that the Division had during its review.

According to Ms. Barrett, the DMRM and the ODNR, Division of Water Resources (DWR) reviewed the EAI report per requirements in the Ohio Revised Code 1514:13 and Ohio Administrative Code 1501:14-5-01 and approved the EAI report after the applicant provided clarification and additional data for further review. Using the clarifications and technical responses provided by Ms. Barrett in the June DMRM reply together with additional information recently provided by ODNR through the discovery process, I have revised, amended and expanded my initial review of the EAI model report. This updated review will retain much of the initial review report material and will be presented in the same letter report format. At the end of the review comments for each major section of the EAI model and model report, I will summarize the potential impact of identified deficiencies or misrepresentations in correctly assessing the long-term effects of mine dewatering.

Model Purpose and Requirements

ORC 1514.13 (A) states that the chief of DMRM shall use the compilation of data for groundwater modeling submitted under section 1514:02 of the Revised Code to establish a projected cone of depression for any surface mining operation that may result in dewatering. The chief shall consult with the chief of the division of water resources when projecting a cone of depression. An applicant for a surface mining permit for such an operation may submit groundwater modeling that shows a projected cone of depression for that operation to the chief, provided that the modeling complies with rules adopted by the chief regarding groundwater modeling. However, the chief shall establish the projected cone of depression for the purposes of this section. Subsection (A) 1 of this code expresses groundwater modeling used for projecting the cone of depression shall be generally accepted in the scientific community. Subsection (A) 2 indicates groundwater modeling will be used in the replacement of water supplies. ORC 1514.01 (K) defines a cone of depression as meaning a depression or low point in the water table or potentiometric surface of a body of groundwater that develops around a location from which water is being withdrawn.

As clarified by Ms. Barrett in her June 19, 2017 letter, a groundwater model is currently an ODNR requirement of any Industrial Minerals permit holder requesting modifications to their existing mining plans incorporating dewatering in the mining process. The permit holder may prepare the requisite model or request ODNR to prepare a model. The primary purpose of the groundwater modeling simulations is to establish a cone of depression created by the mining operations. Regardless of who prepares the model, the ultimate goal is to establish a preliminary regulatory ten-foot cone of depression contour map based upon guidelines established by the DMRM chief who will then use this preliminary demarcation to establish the final cone of depression (OAC 1501:14-5-01 (E)). It is noted that the chief of DMRM may designate a different regulatory contour line based upon water resources availability, seasonal variations, other water users in the hydrologic study area as well as other groundwater data available (OAC 15:14-5-03).

OAC 1501:14-05-01 (C) describes the groundwater model submitted by the applicant used to define the projected cone of depression will be a three-dimensional groundwater flow model utilizing finite difference modeling software such as MODFLOW. The model must accurately reflect the groundwater flow conditions associated with the hydrologic study area and be consistent with ASTM international standards. OAC 1501:14-5-01 (A) and (B) sets forth the types of hydrogeologic data necessary to use in the construction, calibration and model simulations of the dewatering cone of depression.

Failure to Follow ASTM Guidance: Impact to Model Predictions

Based on the references cited in the EAI report and the cursory discussion of any apparent conceptual model of the subsurface in Mad River Township, it does not appear applicable ASTM standards were considered for this modeling project. ASTM defines a conceptual model as an interpretation or working description of the characteristics and dynamics of the physical system. The purpose of the conceptual model is to consolidate site and regional hydrogeologic and hydrogeologic data into a set of assumptions and concepts that can be evaluated quantitatively. Compiling, reviewing and evaluating available hydrogeologic information into a realistic conceptual model provide the technical foundation and much of the preliminary data needed to consider numerical modeling. This is lacking in the EAI modeling efforts. If the guidance provided in the *Standard Guide for Conceptualization and Characterization of Ground-Water Systems* (ASTM D5979-96 (2008)) was considered prior to EAI initial modeling attempt, a different model construct and simulation of a more extensive preliminary cone of depression would have undoubtedly occurred.

The primary October 2016 report submission by EAI was a hydrology information data package used in constructing and applying a regional groundwater flow model. The model was coded using modified MODFLOW 2000 software. The EAI model is a regional groundwater flow model since its design incorporates approximately 90 square miles of area within the model boundaries. The two proposed quarry sites within Enon Sand & Gravel 450-acre Mad River Township property will affect about 200 acres. This is less than one third of a square mile. Using a regional model to accurately simulate the effects of quarry operations on adjacent groundwater supplies in the area can be misleading if appropriate site-specific hydrogeologic data is not used.

Guidance provided in the *Standard Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem* (ASTM D5447-94 (2010)) details the benefits of both quantitatively and qualitatively evaluating groundwater flow model simulations with site-specific information. It is obvious EAI had not considered these guidelines before constructing the submitted MODFLOW model. Had EAI incorporated elements of this guidance document, such as code selection, boundary conditions or model calibration and sensitivity analysis, a much better understanding of why the model results provided are not complete and produced unrealistic simulations of the quarry dewatering impacts.

Controlled lowering of the water table near open pit mines depend mainly on the hydraulic characteristics of the aquifer close to the mine, regional aquifer properties and the amount and distribution of natural recharge and discharge (Dudgeon, 1998). Specifically, use of model parameter values to represent aquifer hydraulic performance (e.g. transmissivity, recharge, storativity, etc.) that are too high or too low will lead to erroneous determinations of the cone of depression shape and size, poor prediction of aquifer water level drawdown, and underestimating the volume of water to be pumped by the proposed dewatering activities.

Absent from this modeling exercise was a supportable estimation of effects of the quarry operation on groundwater supply to existing wells. Also absent was assessment of quarry dewatering operations on local surface water – groundwater flow interconnections. Specifically, recharge seized from streams, springs and wetlands (fens) (i.e. the Verbillion homestead) in this fracture and karstic flow regime will affect the amount of groundwater captured by the quarry sumps and the size of the cone of depression. These concerns need to be addressed in any model used for estimating the effects of dewatering.

A further complication initiated through improper and/or incomplete characterization of aquifer properties or local boundary conditions is nonuniqueness of model output or solutions. This rather complex problem and how to minimize adverse effects and improper results acquired during modeling simulations is discussed in some detail in the *Standard Guide for Calibrating a Ground-Water Flow Model Application* (ASTM D5981-96 (2008)). Simply stated, a good match of hydraulic heads and/or hydraulic conductivities does not prove the model validity since nonuniqueness can provide a good comparison with an inadequate or erroneous model (Castro & Goblet, 2003; Konikow & Bredehoeft, 1992). It is not apparent from the EAI report that the ASTM D5981-96 model guidance procedures were considered as part of the reported calibration of the EAI model. This will be discussed further in this review when the model results are considered. The underlying impact to the model predictions caused by neglecting model nonuniqueness will be in establishing the cone of depression.

Hydrogeologic Setting

ORC 1514.13 (A) states that the chief of DMRM shall use the compilation of data for groundwater modeling submitted under section 1514:02 of the Revised Code to establish a projected cone of depression for any surface mining operation that may result in dewatering. OAC 1501:14-5-01 expands the amount and type of data required to develop a hydrogeologic description in sufficient detail to determine the hydrologic cone of depression for the proposed dewatering operations. The EAI report addressed these requirements under the report heading "HYDROGEOLOGIC SETTING".

Site Geology

Excepting one test boring log, all quarry site-specific geologic and hydrogeologic information was redacted in the copy of the EAI report Terran reviewed. This limits what conclusions can be made as to the thickness, extent and continuity of the identified geologic units at the proposed mining sites.

The one available test boring, Jurgensen Aggregates Boring No. 14-C-1, was completed near the intersection of Garrison Road and Fairfield Pike. The subsurface geology at this location was described as 14.5 feet of silty clay overburden atop of 30.5 feet of (Lockport) dolomite belonging to the Cedarville/Springfield/ Euphemia Formations. In the EAI model, this rock unit was assigned to model layer 1. Below model layer 1, 6.2 feet of shale of the Massie Formation (model layer 2) was encountered. Model layer 3 consisted of 24.3 feet of shale and dolomitic limestone assigned to the Laurel/Osgood/Dayton Formations together with 46.5 foot thick unit of Brassfield Formation limestone. The Brassfield Limestone aquifer rests upon Ordovician shale identified as the Elkhorn Formation. Shale is designated to be in layer 4 of the EAI model. It should be noted the bedrock surface elevation of the Elkhorn shale will be approximately the bottom of the quarry dewatering operations, ranging between 846 to 853 feet msl in Phase 1 quarry operations and between 834 to 846 feet msl in Phase II mining. Proposed bottom elevation of the dewatering sump for Phase 1 will be about 836 ft msl and 826 ft msl for Phase II. This implies the entire aquifer of Silurian carbonate rock within and adjacent to the quarries is intended to be dewatered during the duration of mining at the permitted site.

When describing the occurrence and use of groundwater in the vicinity of the proposed quarry sites, the EAI report correctly identified the primary aquifer as Silurian age carbonate bedrock. Perhaps to downplay the importance of the carbonate bedrock aquifer in Mad River Township, the EAI report openly follows this declaration with an accurate but misleading statement "*Residential and municipal water supply wells are completed in unconsolidated sand and gravel deposits in the buried bedrock valleys.*" When considering the residential land potentially affected by the proposed quarry operations, the vast majority of the groundwater pumped by land owners in the EAI report study area is obtained from water wells completed in the bedrock. This was acknowledged in the EAI report with the admission that nearly 2,000 water well-logs within the report study area are on file at ODNR. In addition to residential wells, it should be noted that both public and commercial water wells are also completed in the carbonate bedrock aquifer near the proposed quarry sites. Greenon High School, Young's Jersey Dairy and Taylor's Tavern are examples (OEPA, 2017). The carbonate aquifer also provides water for agriculture use at such locations as the Verbillion homestead and Mud Run Farms, LLC.

As required by ODNR for preparation of the numerical model, EAI assembled and tabulated a variety of publically available lithologic and hydrogeologic literature data for the Mad River Township area. It should be recognized that much of the data cited in the EAI report was of a general nature developed to represent a regional trend in the parameter under consideration. Overall accuracy of this type of general or regional data should be determined and incorporated into any model development efforts. For example, the drift thickness map (Plate 3 of the EAI report) contour interval varies and is projected on the map with a change in color. The accuracy of the drift thickness interpreted at anyone specific area on that map will be quite variable. This lack of accuracy for drift thickness in Mad River Township was identified by researchers carrying out the Clark County Karst Investigation (OEPA, 2007). Stated in the report was field inspections and review of local well logs indicated some areas mapped by ODNR as having 25-100 feet of glacial till are inaccurate. Field inspections further identified a location mapped as having drift greater than 25 feet depth to bedrock as actually being exposed bedrock. The same sort of error should be expected and taken into consideration for other general or regional data sources (potentiometric surface maps, groundwater resources maps, bedrock contour maps, etc.) used for the EAI model development.

Little discussed in the EAI report was the lithology of the carbonate aquifer and how it affects the occurrence and supply of groundwater. Brief mention was made that wells completed in the carbonate bedrock *"are sometimes completed in the upper part of the bedrock above the shale and sometimes penetrate the entire thickness of the carbonate bedrock."* Comments were made that well yields from the carbonate aquifer generally correlate with aquifer thickness, well yields from bedrock are higher in the eastern portion of the model study area and that underlying Ordovician bedrock is a poor producer of groundwater. Absent from the EAI report was any recognition or quantification the epikarst aquifer beneath the shallow unconsolidated overburden and how it recharges the underlying fractured and fissured formations. For use in numerical modeling, this cursory hydraulic conceptualization of the carbonate aquifer throughout the potentially affected areas of Clark and Greene Counties is insufficient and negligent.

Failure to Correctly Characterize Site Geology: Impact to Model Predictions

The proposed quarry study site is located in a unique region of the Lockport – Sub Lockport formations known as the Dissected Niagara Escarpment. Unlike other Lockport quarry sites in the state, hydrogeologic characteristics of the upper Silurian carbonate aquifer within the Escarpment need to be better understood and quantified for use in any groundwater flow model. The carbonate aquifers in Mad River Township are known to have higher permeability at the top and potentially the bottom of the Silurian bedrock formations. At the bedrock top in the Cedarville/ Springfield/Euphemia Formations, due to karstification processes, increased groundwater flow and storage occurs. Aden and Martin (2012) have identified over 112 karst features including 32 springs just north of the proposed quarry site in the Springfield area. Peterson (2017) has continued a field reconnaissance from the southern-most extent of ODNR's Springfield karst review to south of the proposed quarry sites. To-date, more than 35 additional karst features, including sinkholes, disappearing rivulets and springs, have been located (see Attachment 1). The Ohio EPA (2007) while completing a hydraulic study of karst features in northern Mad River Township, identifying two caves, seven major sinkholes, two disappearing streams, thirteen spring and numerous smaller sinkholes. Flow in the epikarst sustains the recognized high-quality wetlands and fens (minerotrophic groundwater fed wetlands) throughout the area in addition to ongoing recharge/discharge of the carbonate aquifer(s).

Dissolution-enhanced joints and fractures within these formations are extremely important pathways for recharge or discharge for the aquifer, and as potential pathways for groundwater contamination (Bates and Evans, 1996). Karst areas in Mad River Township and other regions of Ohio are known to be sensitive due to bedrock dissolution along fractures that increases ground water flow rates. Enlarged fractures increase the potential for rapid infiltration of surface water while reducing natural filtration processes. The recharge pathways are both vertical and horizontal on the south side of the Mad River, with vertical recharge more dominate in the shallower carbonate formations and horizontal deeper recharge to the lower carbonate aquifer (OEPA, 2008). In Clark County, water wells that tap the fractured and weathered portions of these formations can yield up to 30-50 gallons per minute (Bendula and Moore, 1999). Review of Table 1 in the EAI report lists some limestone wells capable of pumping up to 350 gallons per minute.

For conceptualization of the hydrogeologic setting in the vicinity of the quarry, the EAI report contends the upper and lower portions of the carbonate aquifer are separated by what is locally known as the Massie Shale. According to the EAI report, because drillers and drilling techniques for most residential wells in the area could not identify this unit, the lateral extent and thickness of the Massie Shale in the report study area could not be determined. Based on one cross-section in the EAI report, the Massie Shale thickness appears to thin from 30 feet outside the Enon Sand & Gravel property to about five feet within the area to be mined. The shale unit is completely absent in the Mud Run buried valley where it has been eroded. This lack of detail as to the shale's occurrence throughout the Mad River Township limits its suggested use as a competent aquitard unit in any groundwater flow model.

This was further realized in the EAI report when a representative potentiometric surface map was attempted for the model study area; *"No clear distinction could be made between water levels from wells completed only in the upper bedrock versus those completed through the entire thickness of the carbonate strata."* This same difficulty was encountered by Bowser-Morner (2009) when attempting to construct a MODFLOW model of the former Demmy quarry adjacent to the proposed Phase I Enon Sand and Gravel quarry. Since most water well casings only extend through the unconsolidated overburden to the top of rock, formation(s) heterogeneity with respect to transmissivity and storage would be the major influence on local water levels.

To summarize, the EAI report geologic characterization does not correctly interpret the important role natural fracturing and karst forming processes of rock units (various limestones, dolomites, shales, etc.) has in creating the permeable pathways and amount of water storage of the aquifers affected by the mine dewatering. Data that supports this mischaracterization was used to construct the MODFLOW model. This model was then used to calculate a cone of depression that does not accurately represent the effects of the proposed dewatering activities. Its accuracy is indefinable. However, there are better approaches to geologic characterization for use in groundwater flow system model conceptualizations this type of carbonate aquifer that EAI should have considered.
Not referenced in the literature cited for the development of EAI model were detailed investigations characterizing and modeling the same Silurian Lockport and Sub Lockport formations considered in this permit application. Research by Ritzi & Andolsek (1992), Smith & Ritzi (1993) and Podgorney & Ritzi (1997) has provided demonstrable understanding of the fractured carbonate aquifer groundwater flow system of the Dayton