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June 19, 2017

Brent Huntsman
Terran Corporation
4080 Executive Drive
Beavercreek, Ohio 45430-1067

Dear Mr. Huntsman:

The Ohio Department of Natural Resources (ODNR) Division of Mineral Resources Management (Division) received your letter on May 15, 2017 concerning the report *Evaluation of Groundwater Impacts, Dewatering of Proposed Enon Quarry, Clark County, Ohio* prepared by Eagon & Associates, Inc. (Eagon). Eagon submitted the report on behalf of Enon Sand & Gravel as part of the request to modify application IMM-340-4 to add dewatering. After March 15, 2002, existing Industrial Minerals permit holders requesting to add dewatering to their mining plan were required to submit a groundwater modeling report or request ODNR to perform groundwater modeling to establish a cone of depression. Enon Sand and Gravel hired Eagon to perform groundwater modeling and submit a report for the Division to review. The Division and the ODNR, Division of Water Resources (DWR) reviewed the report per requirements in Ohio Revised Code 1514.13 and Ohio Administrative Code 1501:14-5-01. The Division approved the report after Eagon provided clarification and additional data for further review.

The purpose for establishing a cone of depression is to determine the regulatory 10-foot drawdown contour. The 10-foot drawdown contour shows where water levels, extending outward from the quarry site, could potentially be lowered 10 feet during mine dewatering. The permit holder is responsible for investigating complaints and remediating or replacing impacted water wells within the 10-foot drawdown contour. Complaints beyond the 10-foot drawdown can also be investigated by the permit holder or the Division. The scope of ORC 1514.13 and OAC 1501:14-5-01 is specific to using ground water modeling for this purpose.

The Division reviewed the letter submitted by Terran Corporation (Terran). Throughout the letter, Terran describes problems and issues they found with the Eagon model report. Many of these concerns are not required or are not within the scope of ORC 1514.13 and OAC 1501:14-5-01, or do not consider the entirety of the groundwater model report that the Division had during its review. The content from the Terran letter is shown in italics, and the response(s) from the Division follows.

A computer model was constructed attempting to estimate the effects of quarry dewatering on groundwater levels in the vicinity of the proposed quarry pits. Absent from this model exercise was a supportable estimation of effects of the quarry operation on ground-water quality and supply to existing wells. Also absent was assessment of quarry dewatering operations on surface water flow regimes, specifically streams, springs and wetlands (fens) or the effects of operational blasting on the regional groundwater system.

1. The ground water model report submitted by Eagon shows the cone of depression was established as required in ORC 1514.13 and OAC 1501:14-5-01. Surface water flow regimes, specifically streams in the model include the Mad River, the Little Miami River, tributaries of these rivers, and other streams within the model domain.
2. Neither ORC 1514.13 or OAC 1501:14-5-01 require an assessment of ground-water quality and supply to existing wells. If the water supply from ground water has a diminution, contamination, or interruption within the projected cone of depression, the permit holder must supply temporary water until the groundwater supply can be remediated or replaced according to ORC 1514.13.
3. The requirements for establishing a cone of depression do not include reviewing the proposed blasting plan or including blasting effects in the ground water model. Blasting requirements are specified in ORC 1514.12 and OAC 1501:14-3-04. Blasting plans are evaluated by the Division blasting specialist during the application review process.

Using a regional model to accurately simulate the effects of quarry operations on adjacent groundwater supplies in the area can be misleading if site-specific hydrogeologic data is not used.

4. A regional model is used to simulate a cone of depression including features that affect the ground water flow regime. The Mad River to the north and the Little Miami River to the south act as boundary conditions. When a model domain is too small, the boundary conditions can influence the area of interest, which is the cone of depression. Site-specific hydrogeologic data used in the Eagon model included: DWR water well logs, geological data reports, and other boring data such as the Jurgensen Aggregates Borings.

Sensitivity analyses are needed to quantify the uncertainty in the calibrated model caused by the vagueness in the estimated parameter values (Anderson & Woessner, 1992; Hill & Tiedeman, 2007) as well as characterize the model output reliability.

5. Ground water models are evaluated by comparing the head values simulated in the model with the heads measured in the field. In this model, the calculated head values in the model were compared with DWR water well log data for 865 calibration targets. Several methods are used to compare these values. Figure 13 from the Eagon report shows the comparison between these values on a scatter plot with accompanying statistics to indicate how well the values match. An R-square value of 0.99976 indicates how close the data are to the fitted regression line, or how well the simulated heads in the model match the observed heads data. The highest possible value is 1. Figure 14 is a histogram showing the distribution of the residuals, the difference between the observed (well log) and the modeled heads. The histogram shows a Normal Gaussian Distribution also known as a bell curve with values lacking a strong negative or positive bias. Plates 10 and 11 show the distribution of residual values throughout the model domain. Residual maps are reviewed to assess the spatial distribution of negative and positive residuals.

Excepting one test boring log, all quarry site-specific geologic and hydrogeologic information was redacted in the copy of the EAI (Eagon & Associates, Inc.) *report Terran reviewed.*

6. The only material redacted in the copy of the Eagon report sent to Terran was the Geological Data Reports. Geological Data Reports are required to be kept confidential per ORC

1514.02(A)(9). Site-specific data not removed from the report include the Jurgensen Aggregates Boring No. 14-C-1, 300 water well logs, cross sections, and numerous maps.

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."

7. The Division considers the entirety of a submittal including text, figures, tables, well logs, and maps when reviewing a ground water model report. The statement described as misleading does not specify *all* wells were finished in those deposits or that these wells were *only* completed in sand and gravel deposits, and is one of many sentences describing ground water in the report. Wells completed in the carbonate bedrock are described throughout the report text and are the majority of well logs included in the report.

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. 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.

8. This section of the Terran letter lacks a complete characterization of information considered in the Eagon report when the carbonate aquifer is evaluated. In addition to the single paragraph of the report described here, the following information was considered:
   a. ODNR, DWR Clark and Green County Groundwater Resources Maps, and County Groundwater reports
   b. Professional papers of research within the study area,
   c. Potentiometric Surface Map,
   d. Well log data,
   e. Drift thickness and Bedrock Geology maps in Plates 3 and 4, and
   f. Specific capacity mapped on Plate 9 and summarized in text.

Some general hydrogeologic characteristics of the Silurian carbonate aquifer within the study site that need to be understood and quantified for use in any groundwater flow model is the aquifer water transmissive capacity, both primary and secondary pathways, the aquifer's current production potential and sustain yield. The carbonate aquifer in Mad River Township has higher permeability at the top and bottom of the 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). Although it would require field verification, identified spring flows may be sustaining the recognized high-quality wetlands (fens) throughout the area in addition to ongoing shallow carbonate aquifer subsurface recharge/discharge.

9. Secondary porosity and permeability exist across the carbonates of western and southwestern Ohio. These localized features are often accounted for by changes in hydraulic conductivity during calibration. The carbonate aquifer has both fractured rock zones and unfractured zones. It is beyond the scope of establishing a cone of depression to attempt to determine localized flow features. Existing data are not available on the localized flow features in the model domain, and small flow features can be very difficult to quantify even over a detailed, long term study.
10. Aden and Martin (2012) examined springs and karst features in and around the City of Springfield. The study area partially overlaps with the model domain of the Eagon model. The karst features identified in Aden and Martin range in distance from the Enon Sand and Gravel permit approximately 0.8 to 7 miles with most features occurring along the Mad River from around I-70 and northwest into the City of Springfield.
11. Peterson (2017) is cited in the text and included in the references, but the citation lacks a publisher, journal, or company.
12. During the application review, the Division identifies areas of hydric soil in the proposed application area and sends a map showing the extent of the hydric soils to the U.S. Army Corps of Engineers. Hydric soils are one indicator of possible wetland areas. Delineation and regulatory authority of wetlands falls with the U.S. Army Corps of Engineers.

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."

13. The amount of casing in residential wells controls the water level measured. Many wells are cased into the bedrock with most of the borehole left open below the bedrock surface to access as much of the carbonate aquifer as possible. This prevents a clear distinction between the upper and lower carbonate aquifer.

The lower section of the carbonate aquifer in Mad River Township consists of the Laurel/Osgood/Dayton formations overtop a thicker section of the Brassfield formation. The Brassfield formation has been recognized as a significant aquifer for well over a century (Orton, 1874). According to Frost (1977), the Brassfield can be dense and possess relatively low intergranular porosity. However, near the base of the rock unit can be a two to six foot zone of coarse, very porous sucrosic dolomite, commonly called "Sugar Rock". In outcrop, this zone provides copious springs. In the more dense portions of the Brassfield, joints appear to contribute the bulk of the vertical permeability. Recharge reaching the Sugar Rock is probably dominated by the orientation and degree of weathering of joints and fracture. Joint patterns have been identified in the Brassfield throughout Clark and Greene Counties trending mainly north-north east and north-northwest, perpendicular to Mud Run and the two proposed quarry sites.

14. The Brassfield Formation contains the same variability as the rest of the carbonate aquifer with zones of less permeability where it is dense and greater permeability in the areas of "Sugar Rock". It is not known where these areas of greater and less productivity occur. Determining such would require a comprehensive study far beyond the scope of simulating a cone of depression. Instead, the model is tested with a variety of hydraulic conductivity values to test the goodness of fit of the final model calibration.

To determine the hydrologic cone of depression for the proposed quarry operations, OAC 1501:14-5-01 requires a detailed hydrogeologic description for the proposed permit and hydrologic study area. The EAI report provided a narrative of the regional hydrogeologic conditions that served as an introduction to the model development. This was augmented with plates, figures, tables and appendices that compiled and summarized information gathered from public sources, mainly the Ohio Department of Natural Resources, Division of Water Resources. Unfortunately, little analysis or interpretation of this compiled data was used in the modelling scenarios presented.

15. The model report submitted by Eagon includes the hydrogeologic description in sufficient detail to explain how the model was constructed, tested, and then used to simulate a cone of depression for two mining phases. The process of constructing a groundwater flow model requires the modeler to compile hydrogeological information, and interpret those data to determine what values to initially use in the model, and how to modify those data during the calibration process. One example of this included in the model report is the review of the DWR Groundwater Resources maps and county reports used to assign hydraulic conductivity zones and values.

Critical aquifer parameters needed (and required in OAC 1501:14-5-01 (B)) to calculate a realistic radius of influence (cone of depression) for the quarry dewatering activities include transmissivity, hydraulic conductivity, aquifer thickness, storativity and specific yield. Literature values for hydraulic conductivity in the outwash aquifers and streambed permeability for streams and rivers were used in the model construct. The hydraulic conductivity values for the various model layers of bedrock aquifers and aquitards was estimated during the model calibration process without regard to published literature data or calculable values from specific capacity measurements in local wells. Probably the most misrepresented aquifer coefficient used in the EAI model was a hydraulic conductivity of 1.0 ft/day for the carbonate aquifer.

Transmissivity values derived from aquifer tests for the Silurian age carbonates in the Mad River Valley range from 70 to 28,000 ft^2/day (Sheets and Yost, 1994; Joseph and Eberts, 1994). Sheets and Yost (1994) further references Casey (1992) using this range of transmissivities to derive calculated horizontal hydraulic conductivities of 10^{-1} to 5 x 10^2 ft/day for the carbonate aquifers. Furthermore, the blasting and extraction of the carbonate aquifer during quarrying operations will increase the natural hydraulic conductivity of the bedrock. The Ohio EPA required CEMEX to increase the assumed hydraulic conductivity of unmined Brassfield Formation from 0.5 ft/day to 100 ft/day for areas in which the formation was mined in evaluating the acceptability of a groundwater flow model (OEPA, 2006). A similar increase in hydraulic conductivity of the overlying carbonate aquifer above the Massie Formation should be anticipated due to the mining operations at the proposed quarry sites.

16. Aquifer parameters are adjusted during the calibration process in ground water modeling. The changes and justification of those changes are not required to be included in the report. It is not known if published or calculated hydraulic conductivity values were or were not tested. The values of hydraulic conductivity for the upper carbonate aquifer range from 7.5 to 20 gallons per day per square foot (1 to 2.68 feet per day) in the calibrated model according to Figure 10. These values fall within the range of hydraulic conductivity values in the literature and presented in the section above of 0.1 to 500 feet per day (ft/d). Throughout the Eagon report, reference is made to the DWR Groundwater Resources Maps in their consideration of aquifer characteristics. Plate 7 shows the potential yield from those maps. The maps also include descriptions of the hydrogeology of each zone. The area assigned 1 foot per day in the Eagon model corresponds to the lower yielding area of 5 to 15 gallons per minute versus the area to the west with yields up to 100 gallons per minute. Additional response from Eagon concerning the hydraulic conductivity value of 1.0 ft/d is included in Addendum 1 of this letter.

17. The 2006 Ohio EPA document examined solutions to determine remediation alternatives to prevent landfill leachate contaminants from reaching areas where people could be exposed. The report includes comments from CEMEX, the owner and operator of the landfill, as to why the chosen remediation action was not suitable. The comments from CEMEX include two hydraulic conductivities of 0.5 ft/d for unmined Brassfield and 100 ft/d for mined Brassfield to calculate flux. The comments do not address how a value of 100 ft/d was determined for the Brassfield or if this value occurred in the literature. Later comments from Ohio EPA indicate the hydraulic conductivity of 0.5 ft/d was determined by a pump test previously conducted by a consultant on behalf of the landfill.
18. The requirements for establishing a cone of depression do not include revising the ground water model after it is approved unless the permit holder proposes to add acreage and/or to lower the final mining depth.

The analysis of the well log data provided in the EAI model report did not include an assessment of spatial hydraulic conductivity variability throughout the carbonate aquifer beneath Mad River Township. If this assessment was to be completed, water-wells constructed in significant joint/fracture zones or in the Sugar Rock at bottom of the carbonate aquifer would be found very productive. These wells should have much higher specific capacity values. Two examples would be the former Mad River-Green Local School on Husted Rd, located approximately 2,500 feet east of the proposed Phase I quarry (Well # 271726). The second would be a well located on the Enon Sand and Gravel property on the border of the proposed Phase 1 quarry (Well # 902119). Using the same single-well calculation procedures discussed, the transmissivity for Well # 271726 was estimated at 29,623 ft^2/day and resulting hydraulic conductivity of 215 ft/day. At the time of installation, the well test results for Well # 902119 reported sustain pumping for one hour at 40 gpm with no drawdown. This is improbable, so a drawdown of 0.5 feet was assumed which provided a calculated transmissivity of 23,178 ft^2/day and a hydraulic conductivity of 203 ft/day.
If the EAI model was to utilize ranges of hydraulic conductivity that are calculated from well logs and distributed appropriately throughout the model report area, it would be readily apparent the previously assumed hydraulic conductivity value of 1.0 ft/day substantially underestimated both the volume of water to be pumped from each quarry site and the areal effects of quarry operations on groundwater levels in Mad River Township. Also, by using a single hydraulic conductivity value for all of the carbonate aquifer (an equivalent porous media approach) the resultant modelled cone of depression appears to be coarsely circular around each quarry pit. This is an unrealistic conceptualization of the Silurian fractured and karstic media, specifically the Brassfield formation, where anisotropic transmissivity predominates (Raab, 1990; Ritzi and Andolsek, 1992).

19. The assessment of spatial hydraulic conductivity variability throughout the carbonate aquifer in the model was based on the areas designated in the Clark and Green County Groundwater Resources maps. Plate 7 in the Eagon report shows the zones of varying yields considered when assigning hydraulic conductivity zones. Assessing the water well logs for spatial hydraulic conductivity variability is not a requirement. Determining the hydraulic conductivity for every well log and assigning spatial variability based on 865 wells could result in an overly complex, regional groundwater model that is difficult to run and calibrate if many zones are used. Ultimately, the spatial hydraulic conductivity variability based on the groundwater resources maps resulted in a model that was tested for 865 well logs with a suitable goodness of fit between modeled head values and water well log head values.
20. Attributing areas of greater hydraulic conductivity where fractured zones or Sugar Rock occur would require evidence of those features. The DWR water well logs provide important information such as water level, total depth of the well, general stratigraphy such as limestone, shale, sand, and gravel,

and well construction details. The logs generally lack identification of joints and fractures, of producing water zones, and of specific formations like the Brassfield that are needed to confirm if these correlate to areas of greater hydraulic conductivity. For example, two well logs, 271726 and 902119, are used in the Terran letter to calculate specific capacity and hydraulic conductivity with the assertion these wells should have higher conductivity values due to either being drilled in significant joint/fracture zones or being finished in the "Sugar Rock" at the bottom of the Brassfield Formation. Neither well log notes joints or fractures, or the Brassfield Formation or a zone of "coarse, very porous sucrosic dolomite" indicating Sugar Rock. Without such descriptions, it is not known if greater production is due to these or other factors. Both wells have large sections of open borehole with 138 feet in well 271726 and 121 feet in well 902119. Within those sections, other formations could be the result of the greater production. Testing if the greater productivity is due to the Brassfield Formation or to joints and fractures would require identifying if those are present in the open borehole, and then, performing a packer test to isolate that section to determine hydraulic conductivity.

21. The letter from Terran characterizes the cone of depression to be "coarsely circular". A cone of depression in a homogeneous aquifer would consist of perfectly circular drawdown contours centered around a pumping source. In a heterogenous aquifer, the drawdown contours show the gradient of the cone of depression with contours closer with a steeper gradient and further apart at shallower gradients. The influence of streams and water bodies can limit the extent of the cone with higher conductance increasing recharge from surface water features into the system. Lower conductance is shown by surface water features not being connected to the regional ground water system, and drawdown contours may occur below and beyond a stream or water body. The simulated cone of depression shown in Plate 12 shows the cone spreading further south and not north where Mud Run and the outwash aquifer with higher transmissivity are limiting the extent of the drawdown contours. The cone of depression in Plate 13 expands less west to east due to the same outwash aquifer. The contours bend where they intersect Mud Run to the east.

In the EAI model, the values for aquifer coefficients of the unconsolidated sand and gravel materials that fill the buried valleys of the Mad River, Mud Run and other tributaries were selected from published literature. So were stream infiltration values for modeling the stream-aquifer interface. These selected coefficient values appear low but reasonable as initial tenets to begin the modeling process, knowing adjustments must be made during the calibration process. Unfortunately, since the EAI model assumed a low hydraulic conductivity value for most of the carbonate aquifer, calculation of or adjustment to other hydraulic parameters in the model are suspect and unreliable.

22. During the calibration process, hydraulic parameters including hydraulic conductivity and recharge are adjusted to improve the fit of simulated heads to observed head values from water well logs. The letter from Terran acknowledges the aquifer coefficients of the unconsolidated sand and gravel materials and of the stream infiltration process were adjusted during the calibration process, but it fails to consider that the same process was done with the lower hydraulic conductivity values assigned to the carbonate aquifer. The Terran letter also indicates the EAI model assumed a low hydraulic conductivity for most of the carbonate aquifer. That assumption is not included in the model report, and the area assigned the lower hydraulic conductivity is less than half of the model domain as indicated on Figures 10 and 11. The carbonate aquifer is assigned a hydraulic conductivity of 7.5 gpd/ft^2 in the area designated to have lower yield in the water resources maps, and a higher hydraulic conductivity of 20 gpd/ft^2 in the area designated to have a higher yield. Also, the model calibration shows the simulated head values match those from the water well logs with a lower hydraulic conductivity value assigned to that area of the carbonate aquifer.

For example, areal groundwater recharge to the aquifer is one parameter calculated in the EAI model that appears implausible. From water budget calculations for the carbonate aquifers in the Mad River Valley, Sheets and Yost (1994) determined groundwater recharge through overlying ground moraine to range 4 to 6 in/yr. Essentially this same range of recharge was referenced in the EAI report; 4 to 7 in/yr. Recharge of this amount is evident in the upper portion of the carbonate aquifer through the formation of many perennial springs discharge areas. However, in the model simulations, the recharge was reduced to as little as 0.5 in/yr over large portions of the carbonate aquifer in an attempt to calibrate the water levels around the proposed quarry sites. This inaccurate depiction of areal groundwater recharge will significantly affect dewatering capture zone calculations required in the permit application.

23. The lower recharge rate of 0.5 inches per year was assigned in areas of thicker drift or steeper surface topography according to the Eagon report. Water will runoff steeper topography before it can infiltrate into the ground. Eagon provided additional response to the lower recharge rate in Addendum 1 of this letter.

Another aspect of recharge that was not discussed in the EAI model report relates to direct precipitation into the operating quarries. Average precipitation for the Mad River Valley is about 40 in/yr or approximately 3.3 feet/yr. If 3.3 feet of precipitation is applied to the anticipated 73 acre working area of the Phase I quarry, this would be about 240 acre/ft (78,200,000 gal/yr) of water that the dewatering system discharge would be pumping directly to Mud Run. The EAI model steady-state modeling simulation of the Phase I quarry dewatering estimated about 260,000 gpd (94,900,000 gal/yr) would need to be pumped to maintain desired water levels. If it is assumed the withdrawal of the 78.2 million gallons of direct precipitation into the quarry is annualized, about 330 gpm would need to be pumped from the quarry, not the hypothesized 180 gpm extraction rate from the model, to maintain water levels. This is a 55% increase in daily discharge to Mud Run. A greater increase in daily discharge from dewatering operations in Phase II would be predicted, due to the larger quarry footprint.

24. The direct recharge calculations fail to consider the effects of evaporation, the gradual increase in quarry area and depth with mining, and the stabilization of the cone of depression. Discharge permits are issued and monitored by the Ohio Environmental Protection Agency, Division of Surface Water.

Where buried valley aquifers have incised the Silurian carbonate formations, lateral inflow exchanges with the bedrock aquifers are significant (Sheets and Yost, 1994). Seyoum (2012) investigated the hydraulic relationships amid buried valley sediments and adjacent bedrock formations and found nearly 40% exchange of water between aquifers. Between the two proposed quarry sites, as depicted in the EAI report cross-section, a sand and gravel buried valley aquifer exists beneath Mud Run. Blasting may cause fracturing of quarry walls, increasing permeability and increasing drainage towards the quarry face (Langer, 2002). Inflow exchange between aquifers, either before or after quarry blasting increases permeable pathways, was not addressed in the EAI model. The effect of lateral inflow between aquifers or quarry pits on the calculated cone of depression or the proposed dewatering operations is unknown at this time.

25. Inflow exchange between model layers is addressed by changing hydraulic conductivity. The estimate of 40% exchange of water between aquifers provided in the letter was determined for the Pottsville Formation, Cuyahoga Shale, and Berea Sandstone aquifers in northeastern Ohio. These alternating layers of shale, sandstone, conglomerate, and siltstone interact very differently from the carbonate aquifer present in Clark and Greene Counties.

In response to submission requirements (OAC 1514:13) for this permit application, the EAI report outlines broadly how Enon Sand & Gravel plans to evaluate possible effects of Phase I quarry operations on groundwater levels and quality in all wells encompassed by the modeled 10-foot drawdown contour. Work would consist of a survey (not defined) to update and expand the pre-mining database of water levels and water quality (not defined) together with establishing a network of key wells (not defined) to annually monitor groundwater levels. It was further stated this monitoring approach would be expanded for Phase II operations if needed.

26. Groundwater monitoring is not required under ORC 1514.13 and OAC 1501:14-5-01 when quarry dewatering occurs. The inclusion of groundwater monitoring in the Eagon model report is voluntary. The Division cannot specify how the permit holder conducts ground water monitoring or require submittals of water quality, water levels, and other aquifer measurements.

Blasting and groundwater extractions, in all cases, serve to reactivate and enhance karst, leading to sinkhole development (Lolcama et al., 2002). Quarry blasting may result in the destruction or disruption of groundwater flow paths, changes in the pattern of groundwater movement and changes in the quantity of water flowing through the karst system (Ekmekci, 1993). There are documented occurrences of increases in turbidity of groundwater to wells and springs at limestone quarries that utilize blasting (Green et al., 2005). Any groundwater monitoring program designed for determining potential adverse effects of the proposed quarry operations in the carbonate aquifers beneath Mad River Township must pay special attention to the disturbs of blasting. How this will be assessed is completely missing in the current groundwater monitoring outline provided in the EAI report.

27. The Division reviewed the study performed by the Minnesota Department of Natural Resources and cited as Green et al., 2005 above. The Terran letter indicates the study documented an increase in turbidity of groundwater to wells. The study examined turbidity at three mine sites during blasting with turbidity sensors installed in monitoring wells at two of the sites and a handheld turbidity meter used in a spring at the third site. No significant changes in turbidity were observed in the monitoring wells. Turbidity of the spring was monitored during blasting and then, during precipitation events. Turbidity levels of the spring did increase after the blast, but the increase in turbidity due to precipitation was much larger.
28. As stated previously, groundwater monitoring is not required under ORC 1514.13 and OAC 1501:14-5-01 when quarry dewatering occurs. The permit holder is voluntarily added groundwater monitoring to the ground water model report. Blasting is addressed in ORC 1514.12 and OAC 1501:14-3-04.

Should quarry operations create any adverse effects to existing groundwater wells, the stated remedial action options offered by Enon Sand & Gravel would include lowering of pumps, deepening of existing wells, or installation of replacement wells. These remedial actions might be plausible for some wells distant from the quarry whose water levels have not been lowered near the top of the Elkhorn shale. These remedial measures would not be successful for wells close to the quarry where essentially the entire thickness of the carbonate aquifer has been drained. There are no aquifers in the Elkhorn shale to deepen or replace the affected homeowner well. The proposed remedial measures would not be successful for well owners if the lower portion of the carbonate aquifer has minimal saturated porosity or lacks permeability. Also, these remedial measures would not address the taking of groundwater from owners whose groundwater levels have been lowered sufficiently to dry up springs on their property.

29. Eagon provided additional response to their water replacement beyond what is included in their report. The additional response is included in Addendum 1 of this letter.

Please contact me with any questions at (614) 265-6502 or via email at Kelly.Barrett@dnr.state.oh.us.

Sincerely,

Kelly Barrett, Geologist
ODNR, Division of Mineral Resources Management

Enclosures

Cc: Kathy Estep, Vice President – Mad River Township Trustees
Dave Crow, Deputy Chief of Coal and Industrial Minerals – ODNR, DMRM
Tyson Lamielle, Field Supervisor – ODNR, DMRM
Mike Mitchell, Mineral Resources Inspector – ODNR, DMRM
IM-0340 Columbus file

Addendum 1

EAGON
& ASSOCIATES, INC.

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eagoninc.com

June 12, 2017

Ms. Kelly Barrett
Ohio Department of Natural Resources
Division of Mineral Resources Management
2045 Morse Road
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Columbus, Ohio 43229

Dear Ms. Barrett:

The following responses to your questions regarding the Enon Sand & Gravel Quarry model and residential well mitigation are provided on behalf of Enon Sand & Gravel.

Question 1. The report indicates recharge values for the carbonate aquifer ranged from four to seven inches per year in the ODNR Ground Water Pollution Potential of Clark County, Ohio report, and an initial uniform value of two inches per year was assigned to the model. The model recharge distribution map in Figure 9 shows the final calibrated value for the western portion of the carbonate aquifer is 0.5 inches per year. Please explain why the recharge value was reduced to 0.5 inches per year.

Response 1. The Ohio Department of Natural Resources Division of Water maps Ground-Water Resources of Clark County (Schmidt, 1982) and Ground Water Resources of Greene County (Schmidt, 1991) delineate different areas of groundwater production potential within the respective counties. These delineated areas were the basis for the boundaries used to define the different zones of hydraulic conductivity and recharge used in the groundwater flow model. Actual recharge and hydraulic conductivity values were determined during model calibration. The 0.5 inch per year zone of recharge shown on Figure 9 includes three areas from the groundwater resources maps that are indicated to have a groundwater production potential ranging from less than three to 20 gallons per minute (gpm). The generally eastern area of the model corresponds to areas of the groundwater resources map that are indicated to have a groundwater production potential of between 75 and 100 gpm and was modeled using higher values of recharge and hydraulic conductivity. Areas of lower modeled recharge are also areas of steeper topography, i.e., areas of higher runoff and less groundwater recharge.

Question 2. Figures 10 and 11 in the report show a final calibrated hydraulic conductivity value of 7.5 gpd/ft^2 assigned to the western portion of the carbonate aquifer. Please explain why this lower value was used.

Response 2. The areas on Figures 10 and 11 assigned a hydraulic conductivity of 7.5 gpd/ft^2 correspond to areas of lower groundwater production potential based on the *groundwater resources mapping referenced in the answer to Question 1. These areas also correspond to thinning of the carbonate aquifer which results in a lower aquifer transmissivity which is simulated in the model using the lower hydraulic conductivity. The hydraulic conductivity value of 7.5 gpd/ft^2 was determined during model calibration and resulted in the best comparison between observed and modeled heads.*

Question 3. Please describe in more detail what the alternative water supply for wells located close to the proposed mined area will be. The quarry floor elevation contours shown in Figure 2 appear to be at or near the top elevation of the Ordovician Elkhorn Formation when compared with the top elevation of the Elkhorn listed on the Site Test Boring Logs in Appendix B. The Elkhorn Formation is considered a poor aquifer. Will the entire carbonate sequence be mined at the quarry? Will some of the carbonate material not be mined? Please explain what formation will be used as a suitable replacement water supply.

Response 3. Mining is planned to extend to the base of the carbonate aquifer. Dewatering to that elevation will only occur within the quarry excavation. Groundwater levels outside of the quarry will be above the base of the carbonate aquifer. Dewatering of the quarry will not completely dewater the aquifer. Groundwater flow model results (Plates 12 and 13) show that the cone-of-depression from quarry dewatering is relatively steep around the quarry phases.

Enon Sand & Gravel understands that it has an obligation to mitigate residential well problems that are a result of quarry dewatering. Mitigation measures include lowering pumps and deepening or replacing wells. Water treatment equipment will be used to if necessary to address groundwater quality issues that could arise.

The amount of aquifer saturation that will remain in the carbonate aquifer at the full extent of quarry dewatering was evaluated using the groundwater flow model results. GIS mapping for Clark County was used to determine likely locations for replacement wells at residences closest to the quarry areas. Based on Ohio Department of Health regulations, a residential well can be installed no closer than 10 feet to a property boundary.

The closest residence to the Phase I quarry area is near the southwest corner of the quarry area along Garrison Road. At the full extent of quarry dewatering there would be approximately 51 feet of saturation in the aquifer at this location. Other locations along Garrison Road and Fairfield Pike were also examined and end-stage aquifer saturation at those locations ranged from about 32 to 37 feet.

Evaluation also was made of the remaining saturation to be expected at closest residences to the Phase II quarry area. On the west side of the Phase II area at the closest residences in the Echo Hills subdivision and along Hagan Road the remaining amount of saturation was between 21 and 26 feet. On the east side of

> *the Phase II area along Tecumseh Road the remaining amount of saturation at the closest residences was over 42 feet.*
>
> *The amount of saturation remaining in the aquifer will be greater at other locations as compared to those described above and will be adequate at all locations to support replacement or deepening of wells.*
>
> *The purpose of the groundwater monitoring network, described on page 12, is to provide actual data illustrating the amount and rate of groundwater level change. These data can be used by the quarry owner/operator to continually assess the vulnerability of wells and the potential cost of well mitigation. The quarry owner/operator always has the option of stopping mining at an elevation above the permitted floor elevation.*

If you require any additional information or have additional questions, please contact me or Mr. Cory Kiser.

Sincerely,

Stephen J. Champa, PG
Senior Hydrogeologist

SJC/kj
cc: Cory Kiser, Melvin Stone Company