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MEMORANDUM

File No. 0209759-000

TO: Greater Lafayette Region Water Stewardship Committee

FROM: Haley & Aldrich, Inc.
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SUBJECT: Third-Party Review
Wabash Aquifer Characterization
Indiana Economic Development Corporation
West Lafayette, Indiana

This memorandum details our third-party review of the Wabash Regional Water Supply Yield Analysis for the 70-acre parcel located on the south bank of the Wabash River (Site 1 and 2 or Parcel 1) and the 42-acre parcel (Site 3 or Parcel 2) also located on the south bank of the Wabash River downstream of West Lafayette, Indiana. Three aquifer pumping tests and groundwater flow modeling analyses were completed by INTERA, Incorporated (INTERA) to estimate the potential well yield and extent of drawdown associated with the proposed radial collector wells that are to be finished in the Wabash River alluvial aquifer. Haley & Aldrich's review considered the following reports and raw data associated with the three pumping tests.

- Riverbank Filtration Along the Wabash River in Tippecanoe County, Desktop Study, prepared for State of Indiana, prepared by INTERA, Incorporated, dated June 26, 2023.
- Riverbank Filtration Along the Wabash River in Tippecanoe County, Stream-Aquifer Characterization and Yield Estimates Test Well Sites 1 and 2, prepared for State of Indiana, prepared by INTERA, Incorporated, dated November 14, 2023.
- Riverbank Filtration Along the Wabash River in Tippecanoe County, Stream-Aquifer Characterization and Yield Estimates Test Well Site 3, prepared for State of Indiana, prepared by INTERA, Incorporated, dated February 23, 2024.
- Executive Summary, Riverbank Filtration Along the Wabash River in Tippecanoe County, Stream-Aquifer Characterization and Yield Estimates, prepared for State of Indiana, prepared by INTERA, Incorporated, dated March 20, 2024.

SUMMARY

Based on our review of these documents, Haley & Aldrich provides the following observations:

1. The analysis of aquifer properties is sound and supports an appropriately conservative estimate of sustainable yield in the proposed collector wells.

2. The analysis did not focus on potential effects of the proposed groundwater withdrawals on neighboring wells, which will need to consider well depth, water levels under operating conditions, pump setting and other details of well construction.

3. The proposed withdrawal of 30 million gallons per day (MGD) will reduce low flow in the Wabash River by approximately 7% (flow at 99% exceedance probability) to roughly 12% (lowest flow measured historically in the Wabash River). We understand that a higher withdrawal rate of 100 MGD was considered in the analysis. The increased effects on Wabash River would be proportional to the withdrawal rate; therefore, low flow in the Wabash River would be reduced by approximately 23% (99% exceedance probability) to 40% (lowest flow recorded).

4. Predicting sustainable basin yield and potential effects of the proposed groundwater withdrawals on basin yield were beyond the scope of the study. Analysis of potential effects of the LEAP withdrawals and future withdrawals would benefit from a detailed basin-wide analysis of groundwater recharge, collective withdrawals from the basin, and targeted minimum flows in the Wabash River.

AQUIFER TESTING

Aquifer testing was completed by INTERA by pumping from three (3) 12-in. diameter test wells (TW-1, TW-2, and TW-3) that were each constructed with 30 ft of stainless-steel well screen. Test wells TW-1 and TW-2 are located on Parcel 1 and test well TW-3 is located on Parcel 2. Stilling wells were constructed at each site to track Wabash River stage, and 2-in. monitoring wells were installed at each site to monitor drawdown (change in water level under pumping conditions) during the pumping tests. Initial step-rate pumping tests were conducted to estimate suitable flow rates for the respective constant-rate pumping tests, which were each approximately 72 hours in duration. Pumping rates, observed maximum drawdown, and specific capacity (Q/s, flow rate per ft of drawdown) were as follows:

Test well	Pumping rate, gpm	Drawdown, ft	Q/s (gpm/ft)
TW-1	1,420	37.7	37.6
TW-2	1,350	43.1	31.3
TW-3	1,100*	51.7	21.3

*Flow rate held for 880 gpm for 2.1 days, then increased to 1,100 gpm

Test results were analyzed by INTERA using the TTim computer software (Bakker, 2013; Bakker, 2023). The TTim software incorporated geometry of the monitoring well system, flow rates and drawdown encountered during the testing to estimate hydraulic properties of the aquifer. Haley & Aldrich independently reduced the raw data provided by INTERA to estimate aquifer properties for comparison to the values reported by INTERA. Haley & Aldrich analyzed the raw pumping test data associated with the three pumping tests using Aquifer Testing Software (Duffield, 2007). Hydraulic conductivity was estimated by curve matching distance drawdown plots using the Theis (Theis, 1935) Solution for Unconfined Aquifers.

The hydraulic conductivity values estimated by Haley & Aldrich are consistent with the values estimated by INTERA, as summarized in **Table 1:**

Table 1: Wabash Aquifer Characterization Aquifer Permeability Comparison

Pumping Test	Haley & Aldrich	INTERA
	Hydraulic Conductivity (ft/day)	Hydraulic Conductivity (ft/day)
Site 1: TW-1	520	425 – 500
Site 2: TW-2	480	450 – 550
Site 3: TW-3	490	450 - 500

GROUNDWATER FLOW MODELING

INTERA completed groundwater flow modeling using the two-dimensional, steady-state, analytic element groundwater modeling software GFLOW (Kelson and Haitjema, 1994), to estimate sustainable well yield at each site. The modeling process iteratively adjusts aquifer properties, including hydraulic conductivity of the aquifer, riverbed resistance (i.e., to infiltration induced by pumping), and well skin effects to estimate the range of sustainable well yields.

The modeling is appropriately conservative for estimating sustainable yield at the proposed well sites but should be reconfigured and recalibrated to predict effects of long-term groundwater withdrawals from the proposed wells on existing groundwater supply wells – both residential wells and high-capacity wells in the region. Specifically, the southern limits of the aquifer established in the model exclude several

high-capacity water supply wells without documenting geologic conditions that may hydraulically isolate these wells from the proposed wells. If these and other wells are screened at intervals that are hydraulically connected to the proposed wells, simulating a smaller area of aquifer is likely conservative for predicting long-term yields in the proposed wells and potential effects on water resources within the modeled aquifer limits, but precludes predicting hydrologic effects on resources that are outside of the modeled aquifer limits.

Haley & Aldrich understands that future modeling will be more tailored to predicting long-term effects on regional groundwater resources. Such efforts should be supported by a detailed inventory of water-supply wells that likely fall within the radius of influence of the proposed pumping wells. The inventory should document important installation details for evaluating potential implications of predicted drawdown, including well depth, well screen interval, and pump setting.

EFFECTS OF PUMPING ON WABASH RIVER UNDER LOW-FLOW CONDITIONS

Based on INTERA's model output, the Wabash River falls within the predicted radius of influence of the proposed wells. Wells affect river flow through 1.) induced infiltration, where water exfiltrates the river through its bed materials under the influence of pumping, and 2.) reduced baseflow to the river where the wells intercept groundwater that, absent the pumping stresses, would reach the river and contribute to its flow. Accordingly, the proposed pumping wells will reduce flow in the Wabash by up to 30 million gallons per day (MGD) through some combination of induced infiltration and reductions in baseflow.

Based on streamflow statistics reported by INTERA for the Wabash River (Desktop Study, June 2023), the proposed 30 MGD withdrawal would reduce flow in the Wabash by roughly 7% under low-flow conditions (428 MGD) of 1% recurrence probability (100-year low-flow condition). The 30 MGD rate is roughly 11.6% of the lowest flow, which was recorded during a drought in the 1940s – 258 MGD. Potential impacts of changes in streamflow depend on the interests of multiple stakeholders with respect to the river as habitat, reliance of other water-supplies, including stream-side wells, on river flow, and flow requirements for recreational uses.

We understand that a higher withdrawal rates of 100 MGD were considered in the analysis (INTERA, 2023). The increased effects on Wabash River would be proportional to the withdrawal rate; therefore, low flow in the Wabash River would be reduced by approximately 23% (99% exceedance probability) to 40% (lowest flow recorded) under a 100 MGD withdrawal rate.

REGIONAL SAFE YIELD

Prolific aquifers can serve as a renewable resource when managed effectively, but there are limits to which the aquifer can be exploited before exceeding the limits of the water supply – the drainage basin safe yield. Regional pumping from the aquifer must be balanced by recharge over the watershed, and streamflow depletion - only to a degree that is acceptable given the multiple stakeholders that rely on streamflow in the Wabash River. Work completed to date for the LEAP project is a sound and conservative analysis for predicting sustainable yields at the proposed wells. A basin-wide analysis is not reasonably within the scope of INTERA's analysis of the collector wells' capacity; however, evaluating regional safe yield will ultimately be needed to predict the effects of the proposed withdrawal of 30 MGD from the LEAP project on the regional safe yield available from the aquifer to all users within the basin.

Regional safe yield analyses quantify the water balance between water-supply withdrawals, groundwater recharge, and temporary depletion of storage in the aquifer, to prevent the basin's collective withdrawals from adversely affecting streamflow or "mining" the aquifer, wherein water levels decline progressively over time, depleting the resource.

References

1. Bakker, M. 2013. Semi-Analytic Modeling of Transient Multi-Layer Flow with TTim. Hydrogeology Journal, 21: 935Ð943

2. Bakker, M. 2023. https://github.com/mbakker7/ttim

3. Duffield, G.M., 2007. *AQTESOLV for Windows Version 4.5 User's Guide*, HydroSOLVE, Inc., Reston, VA.

4. Harbaugh, A.W., 2005. MODFLOW-2005, the US Geological Survey modular ground-water model: the ground-water flow process (pp. 6-A16). Reston, VA: US Department of the Interior, US Geological Survey.

5. INTERA, Incorporated, 2023. Riverbank Filtration Along the Wabash River in Tippecanoe County, Desktop Study, prepared for State of Indiana, dated June 26, 2023.

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9. Kelson, V. and Haitjema, H. 1994. GFLOW Reference Manual. Haitjema Software, LLC.

10. Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519- 524.