UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

KAIROS POWER LLC – HERMES CONSTRUCTION PERMIT PRELIMINARY SAFETY ANALYSIS REPORT SITE CHARACTERISTICS (CHAPTER 2) AUDIT PLAN (CAC/EPID NO. 000955/05007513/L-2021-NEW-0011)

APPLICANT INFORMATION

Applicant: Kairos Power LLC

Applicant Address: 707 W. Tower Ave., Alameda, CA 94501

Plant Name(s) and Unit(s): Kairos – Hermes Test Reactor

Docket No(s).: 50-7513

Background:

By letter dated September 29, 2021, Kairos Power LLC submitted the Hermes Part 50 construction permit application and corresponding preliminary safety analysis report (PSAR) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21272A375). PSAR Chapter 2, "Site Characteristics," describes the site location, including a discussion of the population in the vicinity, the distribution of infrastructure and natural features, as well as the basis for selection of the Hermes reactor site.

Purpose:

The purpose of this audit is for the U.S. Nuclear Regulatory Commission (NRC) staff to gain a better understanding of Kairos's PSAR Chapter 2. The audit achieves a more effective and efficient review by allowing the staff to review and discuss supporting material with the objective of improving communication and eliminating unnecessary requests for additional information. Reviewing underlying documentation and engaging in audit discussions about site characteristics will facilitate the staff's understanding of the Hermes application. If the NRC staff identifies information that is needed to support a finding, Kairos will need to submit that information on the application docket.

Regulatory Audit Basis:

The bases for the audit are the regulations of Title 10 of the *Code of Federal Regulations*, 50.34(a)(1)(i) and 50.34(a)(4).

Regulatory Audit Scope

This audit will focus on information provided by Kairos on the online reference portal and during virtual meetings.

Information and Other Material Necessary for the Regulatory Audit

Kairos should be prepared to provide documents, drawings, reports, calculations, and other material, as applicable, supporting the analyses documented in the PSAR. The NRC staff may request that Kairos make these additional materials available in the online reference portal. Preliminary questions on site characteristics were previously transmitted by e-mail on January 10, 2022, ADAMS Accession No. ML22024A492. Kairos responded to the preliminary questions on February 3, 8, and 9, 2022 (ML22041A337, ML22040A142, ML22040A338). Any additional information needed related to the preliminary questions is requested below. The NRC staff initially requests material that will address the questions below.

Questions on Nearby Facilities

2.2-1	In Section 2.2.1.3, the last sentence of the middle paragraph reads "… the annual average daily vehicle count at TN 58 north of the intersection with TN 58 was 12,641 in 2018." Should the first reference to TN 58 in this portion of the sentence refer to TN 327?
2.2-2	The last paragraph of Section 2.2.2.3 states, "The average flight distance of 37 miles is selected based on the generic flight length provided in Table B-43 of DOE-STD-3014-2006." However, the DOE Standard value of 37 miles is provided as an example; it is not generic. Please clarify the justification for the average flight distance of 37 miles, or revise PSAR Section 2.2.2.3 and Tables 2.2-8 and 2.2-9 as appropriate.
2.2-3	Section 2.2.3.1 does not identify specific stored chemical explosion risks for nearby facilities. Please provide a basis for not considering these explosions or provide assessments of the potential explosion hazards for the chemicals identified in Tables 2.2-3 and 2.2-4.
2.2-4	PSAR Section 2.2.3.1 states that the proposed Oak Ridge Airport will include two 10,000 gallon above-ground tanks for aviation fuels. The PSAR discusses potential explosive hazard from jet fuel tanks but does not appear to consider potential BLEVE. Would potential BLEVE of two jet fuel tanks at the proposed Oak Ridge Airport be a credible hazard to the proposed facility? If not, please explain. If so, please provide an analysis of this hazard in the PSAR
2.2-5	In PSAR Table 2.2-8, based on footnote (b), it appears Kairos based the “x distance” and “y distance” values on an assumption that all flights either taking off or landing use the same runway end (i.e., all flights take off or touch down at the same point at the same end of the runway). However, the NRC staff notes that it is not clear whether this assumption is correct. Please explain the coordinate system used in assessing “x distance” and “y distance” of the proposed facility from the proposed runway and discuss and justify whether Kairos used an assumption that all flights use the same runway end.

Questions on Hydrology

2.4-4	In PSAR Section 2.4, the applicant used different vertical datum, mean sea level (msl), NGVD29 and NAVD88, to indicate flood elevations and the Hermes site grade, respectively. Please provide the elevations using a consistent vertical datum or justify why the provided data are adequate.
2.4-5	With respect to consideration of potential floods, PSAR Section 2.4 states, "River blockage on the Clinch River arm of the Watts Bar Reservoir, and flow diversion on Poplar Creek and the Clinch River are also considered. Additional information will be provided with the application for the Operating License." PSAR Tables 2.4-2 and 2.4-3 show the flood elevations for various flood events resulting from river hydraulic computations. Please clarify whether the river blockage and flow diversion as indicated in the quoted statement from Section 2.4 were included in the computations to support the flood elevations shown in the Tables 2.4-2 and 2.4-3. If the Tables are not the result of considering the blockage and diversion, please clarify where the computational result of considering the blockage and diversion may be found in the PSAR. Also, according to PSAR Figure 2.4-1, there are three bridges crossing Poplar Creek. Are blockages on the stream due to potential failures of these bridges included in the river flood computations in Tables 2.4-2 and 2.4-3 or elsewhere in the PSAR?
2.4-6	PSAR Section 2.4.1 states, "The November 28, 1973, and April 4, 1977, [East Fork Poplar Creek] floods were about equal in magnitude. These floods reached an elevation of 770.2 feet NGVD with a recurrence interval of approximately 30 years at 3.3 miles upstream of the confluence with Poplar Creek. Only minor damage occurred as a result of these floods (Reference 5)." The staff notes that the distance from the confluence to the Hermes site is approximately 2 miles. Based on the 2 miles of distance, it appears that floods at the recorded flood elevation of 770.2 feet (based on NGVD29) in the East Fork Poplar Creek may have an impact at the Hermes site, with a grade elevation at 765 feet (based on NAVD88). Please discuss what the potential inundation at the Hermes site could be, if the recorded 1973 and 1977 flood events extended to the Poplar Creek flow near the Hermes site.
2.4-7	PSAR Section 2.4.3 indicates a "site-specific PMF analysis will be discussed with the application for an Operating License." However, the details and basis of this "site-specific PMF" are not clear. Please clarify whether the "site-specific PMF" is a flood event resulting from a local intense precipitation (LIP) event as PSAR Section 2.4.3.3 appears to indicate, which the staff notes is different from the PMP used to estimate the PMF in Section 2.4.2.1. Are the meanings of the "local PMP event" and "local intense precipitation [LIP] event" interchangeable as used in Section 2.4.3.3?

2.4-8	PSAR Section 3.3.2, "External Flooding Events," states, "The meteorological characterization from Section 2.3 provides a probable maximum precipitation accumulation of water." As stated in PSAR Section 2.3.2.6, "Precipitation," "For the site area, using a 100-year return period, the PMP for 6, 12, 24, and 48 hours is 5.0, 6.0, 6.8, and 8.0 inches, respectively (see Table 2.3-20)." Comparing these two quoted statements from Sections 3.3.2 and 2.3.2.6, the staff notes that, given how a PMP is otherwise described in Section 3.3.2, the statement in Section 3.3.2 appears to be inconsistent with the meteorological information from Section 2.3 because Section 2.3 describes a PMP that is based on a storm with a 100-year return period. Please clarify the quoted statement in Section 3.3.2 to confirm that the storm with a 100-year return period is different from the PMP event used in Sections 2.4 and 3.3.2 for evaluation of external floods. In addition, please clarify that the storm with a 100-year return period discussed in Section 2.3 is not applicable to Section 3.3.2, in which Kairos assumed the PMP is an event causing a PMF event with equal probability (see the assumption in Section 2.4.2.1).

Questions on Geology, Seismology, Geotech

2.5-1	PSAR Section 2.5.2 discusses borings and observation trenches used to explore subsurface conditions at the Hermes site, but some details of results of the borings and trenches do not appear to be provided in the PSAR. Please provide details of observations from the borings, including standard penetration test (SPT) N-values, as well as the trenches. In addition, please discuss how the information has been used in the design of the Hermes facility.
2.5-2	PSAR Section 2.5.2 discusses soil types encountered at the Hermes site, but some details of the soils are not clear from the PSAR. Please provide soil classification, different index properties, measured strengths, and stiffness properties (modulus and Poisson's ratio) for each soil type.
2.5-3	PSAR Figure 2.5-1 shows the boring plan for the Hermes site. Given that Figures 2.5-2 and 2.5-3 state that "[i]nformation between borings is assumed and actual conditions may vary" and given that the precise footprint of the reactor building is not determined and there are no boreholes in the close vicinity of the anticipated location, NRC staff needs additional information to assure that the site is appropriately characterized. Will the foundation of the safety related portion of the reactor building (basemat) be different than the foundation for the non-safety related portions of the building? Please explain the differences, if any.
2.5-4	PSAR Figures 2.5-2 and 2.5-3 provide subsurface profiles for the Hermes site, but do not appear to indicate the location of the reactor building. Describe the location of the reactor foundation in Figures 2.5-2 and 2.5-3.
2.5-5	Section 2.5.5.2.1 states that the underlying rock has adequate bearing capacity. To allow staff to confirm the bearing capacity of the rock, please provide rock fracture network characteristics, such as, number of joint sets and their orientations (dip and dip direction), open or filled joints, degree of weathering of the joints, and spacing of the joint sets. Also provide intact rock strength and

	stiffness properties (modulus and Poisson's ratio) and the rock mass strength and modulus estimation for each rock type along with the method used.
2.5-6	Based on the information in Figures in 2.5-2 and 2.5-3, the staff notes the high water table. The water table is not discussed in the text of the PSAR. Provide a discussion on what actions would be taken to address the high water table. Also discuss the seasonal variation of the water table and how the water table at the proposed site location would affect the bearing capacity and settlement of the reactor foundation.
2.5-7	PSAR Section 2.5.2.3.2 states that the north portion of the Hermes site is underlain by the Mascot Formation, which is "medium to thickly bedded." Please clarify what is meant by "medium to thickly bedded."
2.5-8	PSAR Section 2.5.2.3.2 states that the midsection of the Hermes site is underlain by the Pond Springs formation, which is "medium bedded" and "medium jointed." Please clarify what is meant by "medium bedded" and "medium jointed."
2.5-9	PSAR Section 2.5.2.3.2 states that the south end of the Hermes site is underlain by the Murfreesboro dolomitic limestone, which "is light gray, medium, close jointed…". Please clarify what is meant by this description.
2.5-10	PSAR Table 2.5-1 includes a description of Bedrock Murfreesboro that states it is "60 [degree]," and has "clay filled fracture at 30.5 [feet]." Please clarify what is meant by this description, including what type of clay the description is referring to.
2.5-11	PSAR Section 2.5.2.1 states that the geotechnical investigation at the Hermes site encountered indications of karstic activity. PSAR Section 2.5.4.3 states that the "geotechnical subsurface investigation encountered limited evidence of voids or karstic dissolution at or near the reactor building location." PSAR Section 2.5.4.3 discusses borings on the Hermes site, but it is not clear how the investigations confirmed that there are no unacceptable karst features at the site. However, it is not clear how Kairos plans to thoroughly evaluate the site for karst features. The staff notes that boring may not comprehensively identify karst features, and moreover, there are no boreholes within the reactor footprint that might identify small-scale karst features. How does Kairos propose to evaluate the subsurface rock mass for karst features? Does Kairos propose to use ground-penetrating radar (GPR), or perform other geophysical measurements?
2.5-12	PSAR Section 2.5.4.2 states that the Hermes safety-related reactor foundation basemat would be placed on bedrock, and surrounding structures would be placed either on bedrock or engineered soil. However, Kairos' response dated February 9, 2022 (ML22040A336), to Question 2.5-2 which the staff sent to Kairos by email dated January 10, 2022 (ML22024A492), states that the Hermes foundation will be placed "over an engineered crushed stone or lean concrete fill placed directly over sound rock." Please clarify the apparent discrepancy, especially with respect to the foundation of the safety-related portions of the reactor building.

	In addition, to allow the staff to confirm the adequacy of engineered soils/backfill, please provide characteristics of engineered soils, crushed stone, and lean concrete proposed to be placed between the foundations of the reactor and surrounding structures and the bedrock. Also, please identify the source(s) of these soils and crushed stones and show that both of these materials are available in adequate quantities; clarify whether the lean concrete would be consistent with any standard; and justify why the engineered backfill would not be susceptible to liquefaction.
2.5-13	Based on the location of the weathered limestone in PSAR Figure 2.5-2 and given that PSAR Section 2.5.4.2 states that the reactor building foundation basemat is deployed at bedrock, the staff notes that the reactor foundation would be below an elevation of 745 feet (below the weathered zone of limestone). Kairos notes in response to NRC question 2.5-2 (ADAMS No. ML22040A338) that "[t]he excavation is planned to reach the approximately 30 ft depth, exposing the surface of the foundation rock." The scale on the left of PSAR Figure 2.5-22 shows that the reactor building foundation would be at an elevation of 760 feet. Figure 2.5-22 also shows an excavation depth of about 20 ft below the existing surface. Please clarify the excavation depth for the proposed site, the depth to sound rock, and the correct elevation of the reactor building.
2.5-14	Regarding Section 2.5.5.2.1, provide an analysis of the estimated bearing capacity (static and dynamic) and foundation settlement. Describe the method(s) used along with the assumptions. Provide the estimated bearing capacity and elastic settlement including the factor of safety against bearing failure. Describe why long-term consolidation settlement is not a concern. Justify why any potential sliding along the interface between Murfreesboro limestone and Pond Springs Formation (Figure 2.5-2) due to the load imposed by construction of the reactor would not affect the stability of the proposed reactor site.
2.5-15	Regarding Figure 2.5-22, it appears that there is backfill to the side of the safety related portion of the reactor building. Please discuss how the lateral pressure from the backfill placed at side of the reactor building would be assessed.
2.5-16	Liquefaction potential is discussed in Section 2.5.4.2. Section 2.5.2.3 discusses standard penetration tests (SPT) of the soils of different boreholes at the site. The staff notes that the SPT N-values are not corrected, for example, in accordance with Youd, et. al., 2001 for each hole with depth. It is not clear how the liquefaction potential can be assessed with uncorrected values. The reference is Youd, T.L, et al. (2001), "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils," American Society of Civil Engineers Journal of Geotechnical and Geoenvironmental Engineering, October 2001, pp. 817-833.

2.5-17	The staff reviewed revised PSAR Figure 2.5-3 as well as the geologic profile provided in the Environmental Report (ER Figure 3.3-3), which appears to follow a similar trendline across the site as the profile shown in revised PSAR Figure 2.5-3. The staff observed that ER Figure 3.3-3 shows slightly different subsurface thicknesses of several units over the similar cross-section to revised PSAR Figure 2.5-3. Specifically, revised PSAR Figure 2.5-3 shows approximately 20 ft of clay fill underlain by a thin lens of alluvial clay that thickens towards the center of the profile and a thick layer of residuum clay to the northwest (B) section of the profile that thins towards the center. Bedrock is encountered below the residuum clay at elevation 710 ft and as high as elevation 740 ft at the base of the alluvial clay. In contrast, ER Figure 3.3-3 shows a thin layer of fill underlain by a layer of clay that thickens from the northwest (A) towards the center of the profile before encountering bedrock between about elevation 745 and 730 ft. The staff is requesting the applicant to clarify the spatial relationship between the profile shown in ER Figure 3.3-3 and that shown in revised PSAR Figure 2.5-3 and confirm the subsurface units between the two profiles, including the types of clay and the approximate thicknesses of these units.

Team Assignments

Ben Beasley	Project Manager, responsible for audit logistics and audit report
Ed Helvenston	Project Manager
Amitava Ghosh	Geotechnical Engineer, Audit Technical Lead
Yuan Cheng	Hydrologist
Jenise Thompson	Geologist
David Heeszel	Geophysicist
Jason White	Meteorologist

Additional audit team members may be added as needed.

Logistics

Entrance Meeting	June 2022, precise date and time are to be determined
Exit Meeting	August 2022, precise date and time are to be determined

Audit meetings will take place in a virtual format, using Microsoft Teams or another similar platform. Audit meetings will be scheduled on an as-needed basis after the entrance meeting and once the NRC staff has had the opportunity to review any documents placed in the online reference portal. The audit duration is anticipated to be approximately 10 weeks with activities occurring intermittently during that period.

Special Requests

None.

Deliverables

At the completion of the audit, the audit team will issue an audit summary within 90 days after the exit meeting but will strive for a shorter duration. The audit summary will be declared and entered as an official agency record in ADAMS and be made available for public viewing through the publicly available records component of ADAMS.

References

Title 10 of the *Code of Federal Regulations*

If necessary, any issues related to the conduct of the audit should be communicated to Ben Beasley (NRC) at 301-415-2062 or by e-mail at Benjamin.Beasley@nrc.gov.

Date: May 27, 2022

Signed by Kennedy, William on 05/31/22

William B. Kennedy, Acting Chief
Advanced Reactor Licensing Branch
Division of Advanced Reactors and Non-Power Production and Utilization Facilities
Office of Nuclear Reactor Regulation

SUBJECT: KAIROS POWER LLC – HERMES CONSTRUCTION PERMIT PRELIMINARY SAFETY ANALYSIS REPORT SITE CHARACTERISTICS (CHAPTER 2) AUDIT PLAN (CAC/EPID NO. 000955/05007513/L-2021-NEW-0011)
DATED MAY 27, 2022

DISTRIBUTION:
PUBLIC
UARL R/F
RidsNrrDanu Resource
RidsNrrDanuUarl Resource
RidsNrrDexEseb Resource
RidsNrrDexExhb Resource
RidsOgcMailCenter Resource
RidsACRS_MailCTR Resource

ADAMS Accession No.: ML22143B016 Audit Plan

OFFICE	NRR/DANU/UARL/PM	NRR/DEX/EXHB	NRR/DEX/ESEB
NAME	BBeasley	YCheng	AGhosh
DATE	05/24/2022	05/24/2022	05/25/2022
OFFICE	NRR/DEX/EXHB/BC	NRR/DEX/ESEB/BC	NRR/DANU/UARL/BC
NAME	KQuinlan	JColaccino	WKennedy
DATE	05/26/2022	05/26/2022	05/27/ 2022

OFFICIAL RECORD COPY