Section	EPA Comment/Response	Response
1.0 - Site Characterization		
1.1	The characterization of geologic and hydrogeologic parameters should be based on site-specific data such as geologic cores, outcrop data, seismic surveys, and well logs. HCS should provide EPA with more site-specific data and updated geologic and hydrogeologic parameters that reflect that data.	To progress the geologic characterization and understanding of the site, HCS's geologists and engineers continue to evaluate the geologic model using newly acquired 3D seismic, additional core measurements as well as opinions from qualified geologists and engineers. The application will be updated if any significant information obtained deviates from the current application. Additionally, data from the Class VI well will be included in a pre-operational data submittal as required by 40 CFR 146.82(c) and 146.87.
2.0 – Plume Model		
2.1	The map on page 5 of the Introduction, Section 0 (Figure Intro-1) shows overlap occurring for well plumes 1 and 3 and contact occurring for plumes 1 and 2. Explain how this overlap and contact is not significant interaction since the figure does not depict plumes in different model layers. Provide EPA with a revised map that says what model layers these three plumes are in and the model times they represent.	HCS provided the three-well plume models as a complete view of a future expansion of the project. This application is for Well #1 only. As HCS refines the understanding of the reservoir as data is collected from this proposed Class VI well, the second and third wells will be fully modeled as part of their separate permit applications. These future applications will consider and model a strategy to assess interference and evaluate the impact of such interference from a saturation or pressure point of view. In the initial modeling scenario, for example, the maximum plume extents for each well will not interfere with each other as the maximum extents occur in different subintervals at different times, as shown in the attached Figure 2.1.A and Figure 2.1.B. Arrow 1 in Figure 2.1.A identifies the layer of Well No. 3 that reaches the furthest North-West and Arrow 2 identifies the layer of Well No. 1 that reaches the furthest South-East. While the aerial view of the plume extents show overlap, the plumes within individual layers do not actually overlap. In Figure 2.1.B, Arrow 3 identifies the layer of Well No. 2 that reaches the furthest North-East and Arrow 3 identifies the layer of the well that reaches the furthest South-West. Again, the plumes do not actually touch but appear to have contact from an aerial view of the max extent of the plumes.

Section	EPA Comment/Response	Response
		In Figure Intro-1 on page 5 of the Introduction, the outlines shown represent a composite of the maximum extent of all plumes from all layers from all time steps.
2.2	Explain when and where displacement of CO2 by the original wetting fluid/brine occurs, the rate of simulated displacement and how that will be checked and measured in the subsurface, and how far outward from the injection well imbibition is projected to occur after injection ceases.	Drainage/imbibition of the CO_2 plume from the surrounding aquifer occurs along the outer edges of the plume approximately two years after injection ceases after the plume reaches its maximum size. The plume then begins to contract which is a function of both hysteresis and dissolution of the CO_2 into the connate fluids of the reservoir. The proposed monitoring plan will aim at monitoring any change in fluid saturation along the outer edge of the plume to measure the rate of imbibition.
2.3	Besides the model properties provided in Section 2, HCS should further define the "other rock properties" mentioned above?	The word "other" will be removed upon the final submittal of all changes. The rock properties are the ones described in Section 2.
2.4	HCS should provide why the relationship of vertical permeability is 91% to horizontal permeability and why that is appropriate throughout the entire model. Since there is no site-specific core data, explain why using the relationship throughout the model is appropriate when sedimentation patterns and stratigraphic relationships resulting from deltaic	The values shown in Table 2-1 were a summary of the values used in the model shown in Figure 2-1. Table 2-1 is meant to give an idea of the porosity and permeability ranges seen and used. Available logs for nearby wells in the area will be used to evaluate the lateral variability of petrophysical properties, including the vertical to horizontal permeability ratio. Additionally, HCS's engineers and geologists are continuing to evaluate the data from the

Section	EPA Comment/Response	Response
	environments of deposition and marine sedimentation patterns are complex and change over short distances. In addition, if regional or local geologic studies were used for the 91% estimate, provide information from such studies that explicitly describes the depositional characteristics and patterns of the lower Miocene that support the estimate for the entire model. HCS should explain why the average values for permeability (Table 2-1) are used throughout the entire model instead of assigning permeability values for each layer (Figure 2-1).	stratigraphic test well and performing further measurements on the test core to confirm our understandings. These additional studies will include heterogeneous model scenarios. If the information indicates a significant deviation from the initial application, updates will be submitted. Ultimately, the data taken from the Class VI well will be used to update the models and included in a pre-operational data submittal as required by 40 CFR 146.82(c) and 146.87.

Section	EPA Comment/Response	Response
2.5	HCS should justify applying the relative permeability relationships found for the sand across the entire model. Since there is no site-specific core data, explain why using the relative permeability relationship throughout the model is appropriate when sediment particle sizes, sorting and packing, and sedimentation patterns and stratigraphic relationships from deltaic environments of deposition and marine sedimentation patterns are complex and change over short distances. In addition, provide any related information from regional or local geologic studies, if used for Section 2, that support the assumption of applying the relative permeability relationships found for the sand across the entire model.	Available logs for nearby wells in the area will be used to evaluate the variability of relative permeability and other petrophysical properties. Additionally, HCS's engineers and geologists are continuing to evaluate the data from the stratigraphic test well. The additional studies will include heterogeneous model scenarios. Ultimately, the data taken from the Class VI well will be used to update the models and included in a pre-operational data submittal as required by 40 CFR 146.82(c) and 146.87.
2.6	HCS should clarify which study is being referred to for determining the maximum residual gas saturation to [redacted]; (i.e., Suzanne et al., 2003, or from project core analysis). In addition, provide the complete reference for Suzanne et al., 2003.	[redacted] Additional ongoing testing and measurements on the core from the stratigraphic test well is expected to confirm the range of saturation values. Final residual gas saturation values will be determined from data collected from the Class VI well and will be used to update the models and included in a pre-operational data submittal as required by 40 CFR 146.82(c) and 146.87.

Section	EPA Comment/Response	Response
		Sources used are listed at the bottom of the document. These references will be added to the application upon the final submittal of all changes.

2.7	Explain why applying the capillary pressure result from a single sand sample and the capillary pressure result from a single shale sample is appropriate for all sand and shale layers in the model. Since there is no site-specific core data, provide a justification based on the known environments of deposition, sedimentation patterns, and stratigraphic relationships from regional and local geologic studies that explain why the same capillary pressure can be applied for the entire vertical distance. It does not appear reasonable to EPA to assume that 63' of core, from cores 3 and/or 4, which represents approximately 1.1% of the entire vertical injection interval, can represent all lower Miocene sand layers over an approximately 5607' vertical distance.	[redacted] HCS's geologists and engineers are continuing to evaluate and model nearby well information to confirm the described scenario. HCS intends to collect comprehensive data from the Class VI well following construction [redacted] to complete the crossplot correlation of geophysical properties. These correlations will provide petrophysical property measurement values that will be used to update the models, including heterogeneous scenarios, and included in a pre-operational data submittal as required by 40 CFR 146.82(c) and 146.87 as necessary. This extrapolation method is common practice in subsurface modeling and follows rules consistent with industry standards.

Section	EPA Comment/Response	Response
2.8	HCS should explain which well(s) this core came [redacted], the offset well, or other wells. Explain how many core samples were used and whether 92% water with less than 2% oil values was used as initial conditions for all model layers. If 92% water with less than 2% was used for all model layers, justify doing so and include supporting information based on any regional or local geologic studies since there is no site-specific core data.	[redacted]
2.9	Although CO2 and methane make up nearly all the injected composition at a given time, the percentage of the remaining components should be considered for modeling because the total volume of these components resulting from injection over time may be significant. Given the possible significant totals over time, HCS should explain why approximately 2% of contaminants should not be modeled besides concerns about computational demand. Further, clarify if the model can simulate the effects of components with relatively high densities (such as n-Nonane, n-Heptane, and n-Octane) filling pore spaces over time and any impact they may have on CO2 plume movement.	[redacted]

Section	EPA Comment/Response	Response
2.10	It is not clear from the provided information that the plume movement ceased after 120 years. Since 120 years has not been determined to be the fixed time period specified by the UIC Program Director, HCS' model must be revised to determine the area of review based on the requirements in 40 CFR 146.84(c)(1).	The model was run out to 120 years. [redacted]
2.11	HCS should discuss what model inputs will need to be changed if logging at the injection well sites finds that the sand unit/injection zone elevations are different from the current model's elevations.	[redacted]
2.12	Explain the difference between LA Storage SWD No. 003 (SN 975774) and API No. 023-02268 type well. Are these the same wells? If not, show on a map where API No. 023-02268 is located and provide core and lithologic information for this well.	[redacted]
2.13	HCS should clarify if there are 13 or 15 different perforation intervals.	[redacted]

Section	EPA Comment/Response	Response
2.14	Same comment as above. HCS should explain the difference between LA Storage SWD No. 003 (SN 975774) and API No. 023-02268 type well. Are these the same wells? If not, show on a map where API No. 023-02268 is located and provide core and lithologic information for this well.	[redacted]
2.15	HCS should provide the contour maps mentioned in the above statement.	Reference to maps provided in Appendix B.
2.16	Show an aerial view of the entire model domain, including active and inactive cells on the map provided on page 5 of the Project Overview (Figure Into-1) or similar maps. HCS should show the locations of the exterior model boundary conditions. Show locations of any boundary conditions inside the model domain. Explain any assumptions related to the presence of the salt dome and any influences it may have on model boundaries.	[redacted]

Section	EPA Comment/Response	Response
2.17	As stated on p. 2-16, the maximum extent of the plume is considered the point where the concentration of supercritical phase CO2 reaches below 3% saturation. Provide maps and cross-sections similar to figures 2-8, 2-11, and 2-12, showing the extent of plumes for the concentration of supercritical phase CO2 at 2%, 1%, and 0% saturation.	[redacted] **§146.84(c)(1)** defines the extent of the plume as: *Predict, using existing site characterization, monitoring and operational data, and computational modeling, the projected lateral and vertical migration of the carbon dioxide plume and formation fluids in the subsurface from the commencement of injection activities* *1) until the plume movement ceases,* **(no concentration specified)** *2) until pressure differentials sufficient to cause the movement of injected fluids or formation fluids into a USDW are no longer present,* ***or*** *3) until the end of a fixed time period as determined by the Director.* [redacted]

Section	EPA Comment/Response	Response
		[redacted]
2.18	Provide a more detailed explanation about what HCS refers to as an injection pattern (e.g., does this refer to the length of injection events, injection timing between wells 1, 2, and 3, or other simulations. Explain how optimizing was performed, including whether it was achieved using automated or manual techniques. Further, explain how the model sensitivity was evaluated with respect to optimization.	[redacted] [redacted]

Section	EPA Comment/Response	Response
2.19	EPA does not specify that the maximum extent of a plume is where the concentration of supercritical phase CO2 reaches below 3% saturation, and HCS does not explain why 3% was chosen. HCS must revise the model to determine the area of review based on the requirements in 40 CFR 146.84(c)(1).	**§146.84(c)(1)** defines the extent of the plume as: *Predict, using existing site characterization, monitoring and operational data, and computational modeling, the projected lateral and vertical migration of the carbon dioxide plume and formation fluids in the subsurface from the commencement of injection activities* 1) *until the plume movement ceases,* **(no concentration specified)** 2) *until pressure differentials sufficient to cause the movement of injected fluids or formation fluids into a USDW are no longer present,* ***or*** 3) *until the end of a fixed time period as determined by the Director.* [redacted] [redacted]

Section	EPA Comment/Response	Response
2.20	Explain how GEM simulates carbon dioxide becoming trapped from hysteresis and how GEM simulates CO2 dissolving in brine. Provide the model inputs required by GEM for these computations. Provide model output showing the effect of imbibition over time from the injection wells outward after injection is stopped.	[redacted]
3.0 – AOR		
3.1	The area of review is delineated using computational modeling that accounts for the physical and chemical properties of all phases of the injected carbon dioxide stream and displaced fluids and is based on available site characterization, monitoring, and operational data as outlined in § 146.84 The model must: Be based on detailed geologic data collected to characterize the injection zone(s), confining zone(s), and any additional zones; and anticipated operating data, including injection pressures, rates, and total volumes over the proposed life of the geologic sequestration project;	[redacted]

Section	EPA Comment/Response	Response
	Take into account any geologic heterogeneities, other discontinuities, data quality, and their possible impact on model predictions HCS should provide EPA with detailed geologic data such as cores, outcrop data, seismic surveys, and well logs that will be used for more detailed site characterization and AOR delineation.	

Figure 2.1.A 3D View of Plume Showing Separation of Well No.1 and Well No.3

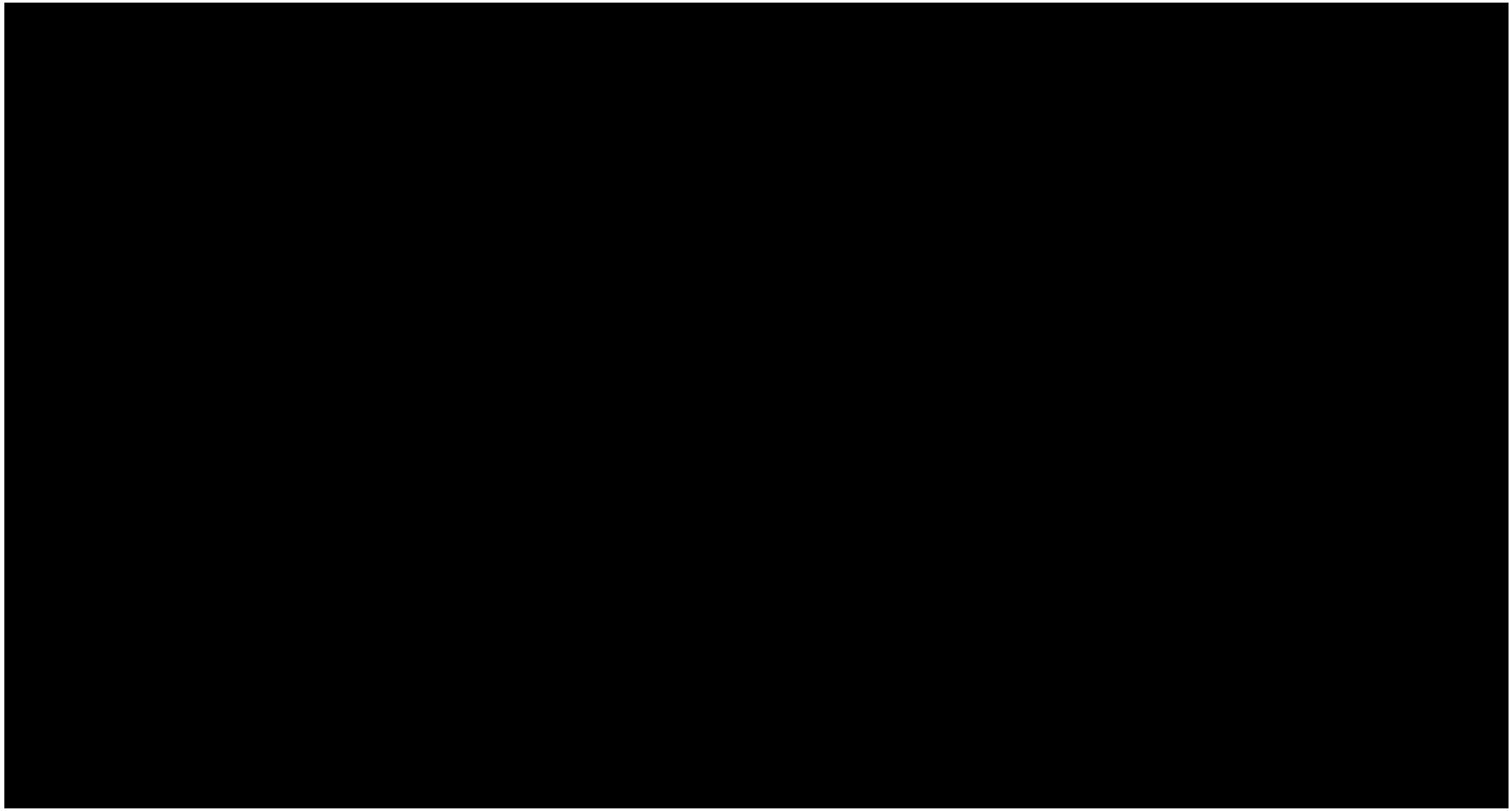


Figure 2.1.B 3D View of Plume Showing Separation of Well No.1 and Well No.2

2.6 [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

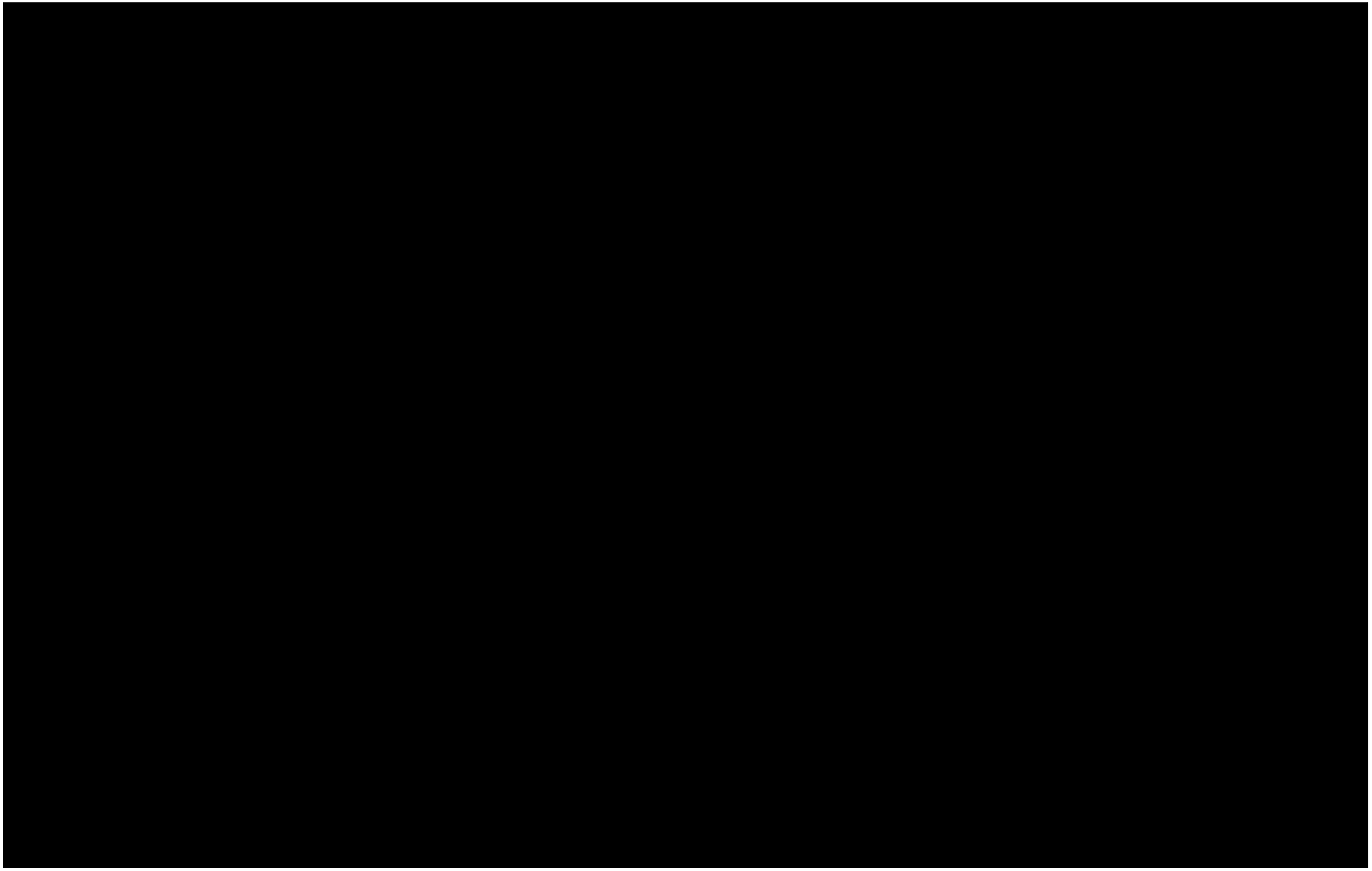
[redacted]

[redacted]

[redacted]

[redacted]

2.17a Plume extents and Cross-sections for the concentration of supercritical phase CO2 at 0% Saturation



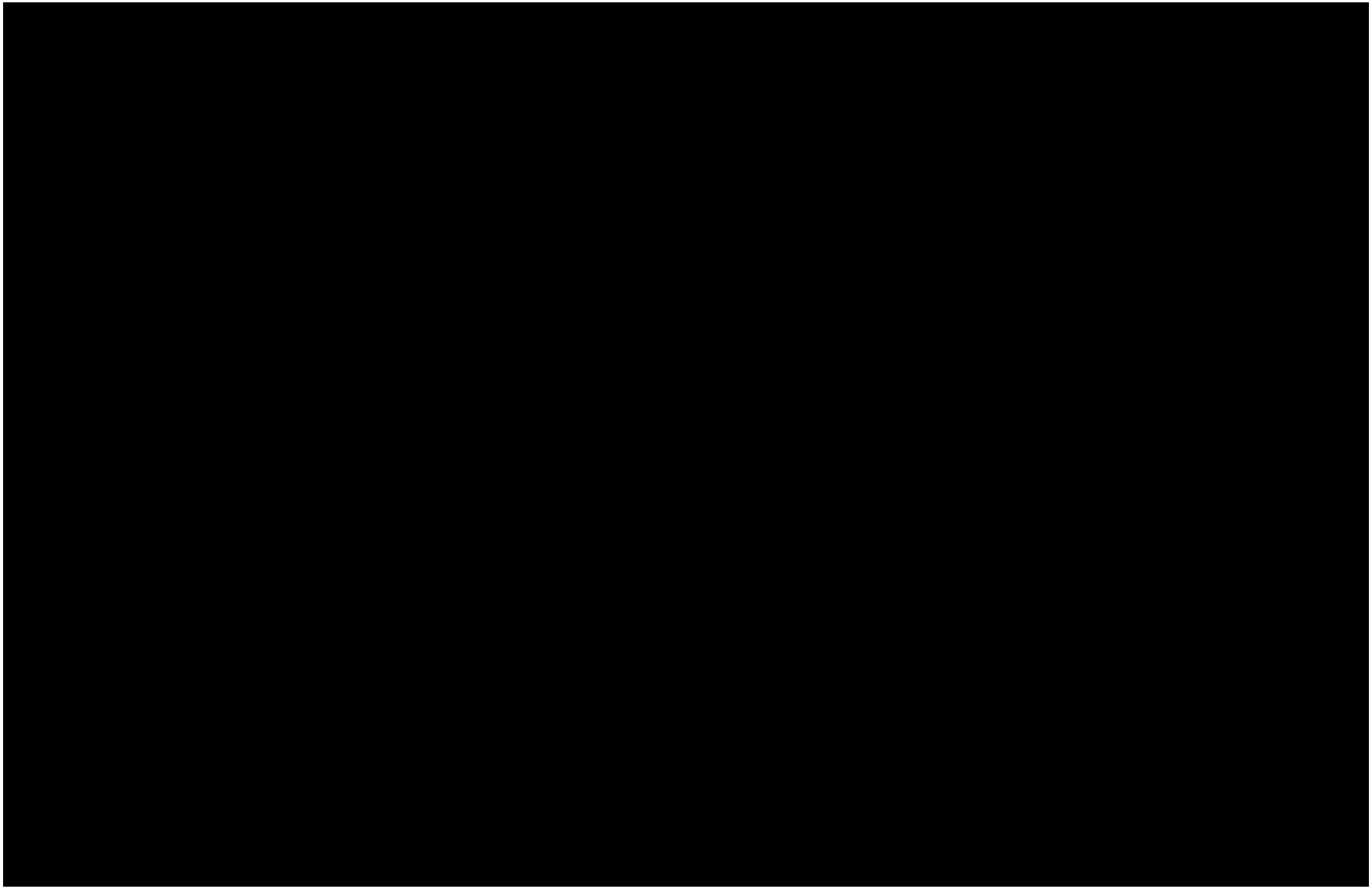
2.17b Plume extents and Cross-sections for the concentration of supercritical phase CO2 at 1% Saturation

2.17c Plume extents and Cross-sections for the concentration of supercritical phase CO2 at 2% Saturation

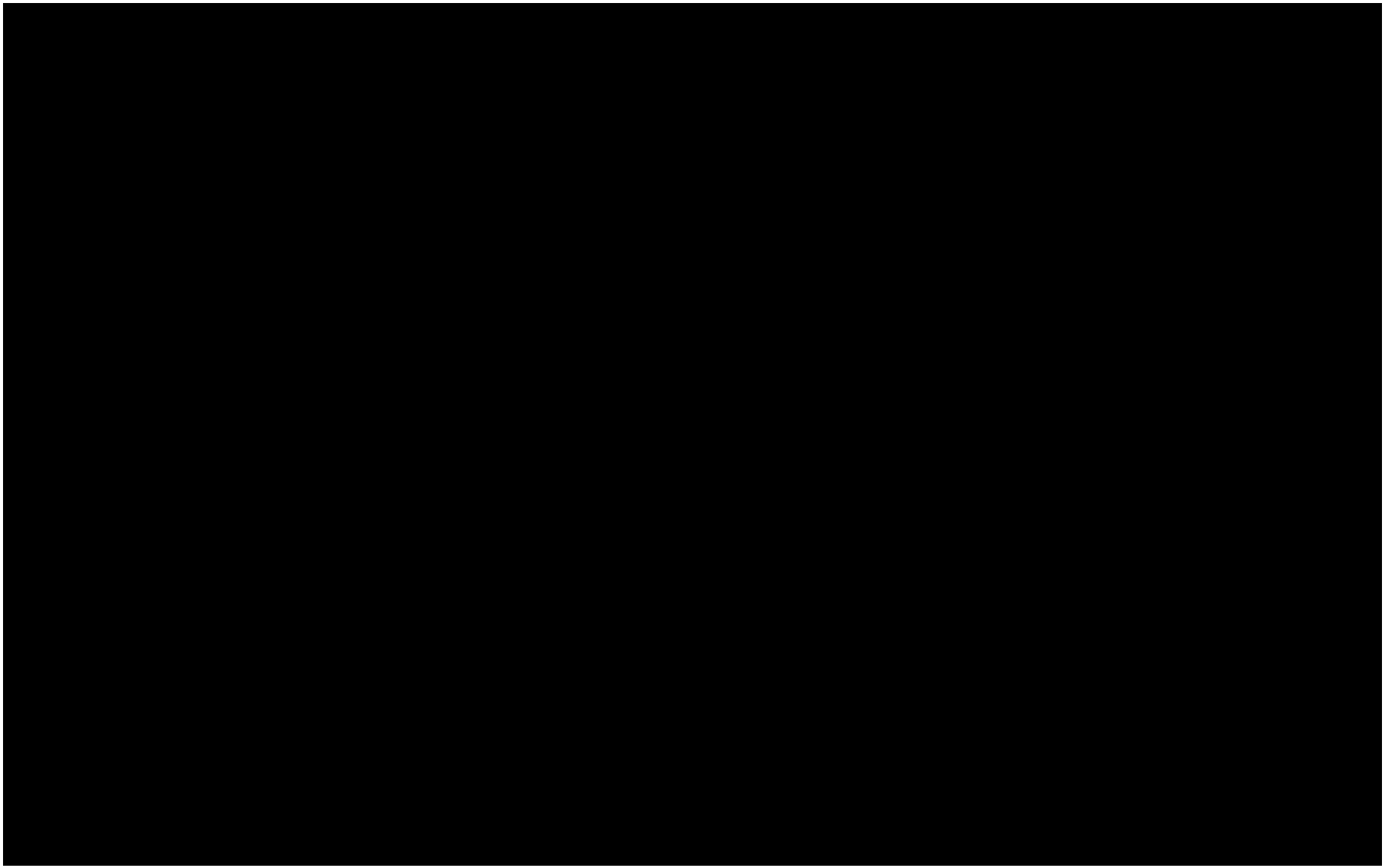
2.17d Plume extents and Cross-sections for the concentration of supercritical phase CO_2 at 3% Saturation

[redacted]

2.17e Plume Cross-sections, J plane, for the concentration of supercritical phase CO2 at 0% Saturation



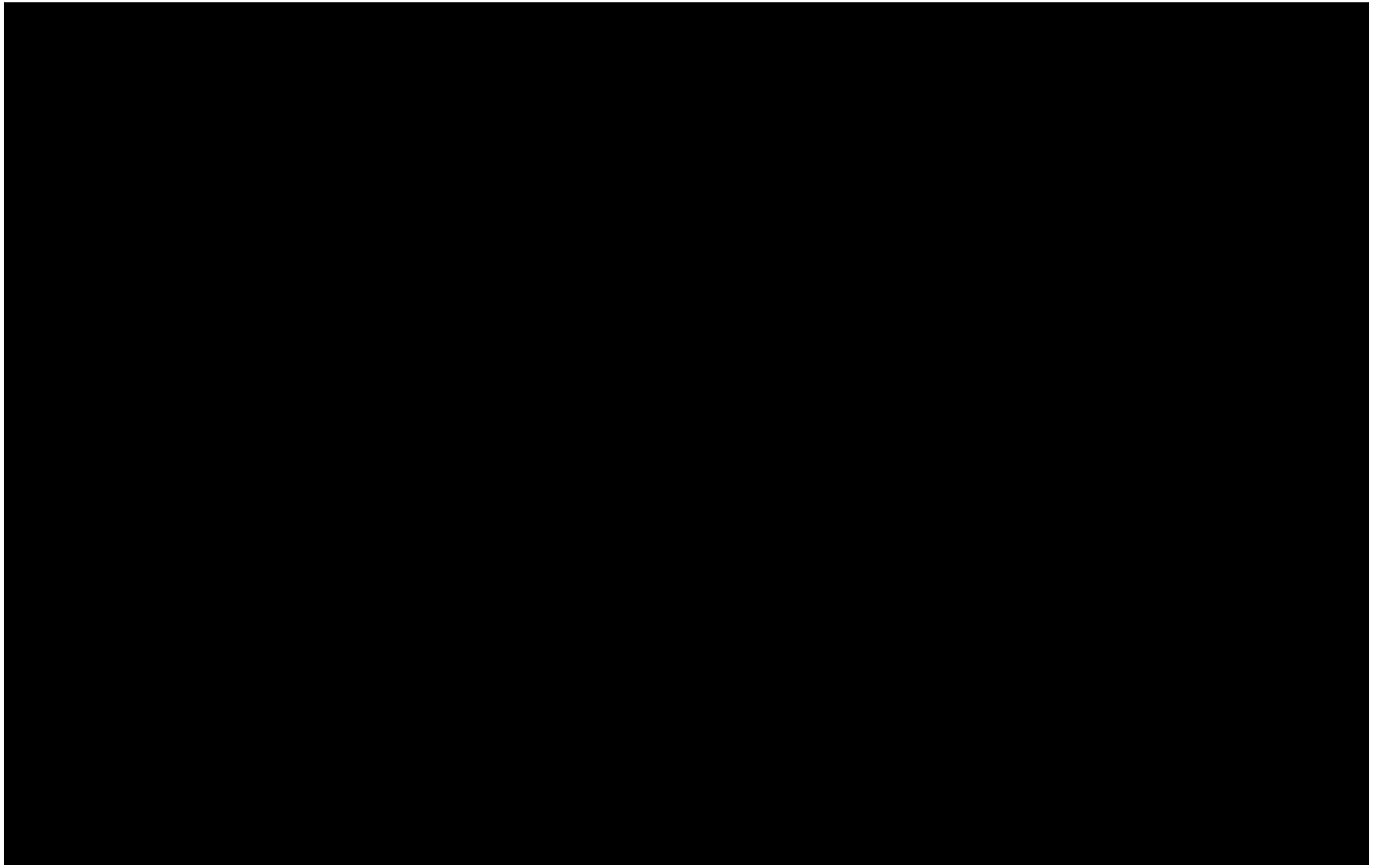
2.17f Plume Cross-sections, J plane, for the concentration of supercritical phase CO2 at 1% Saturation



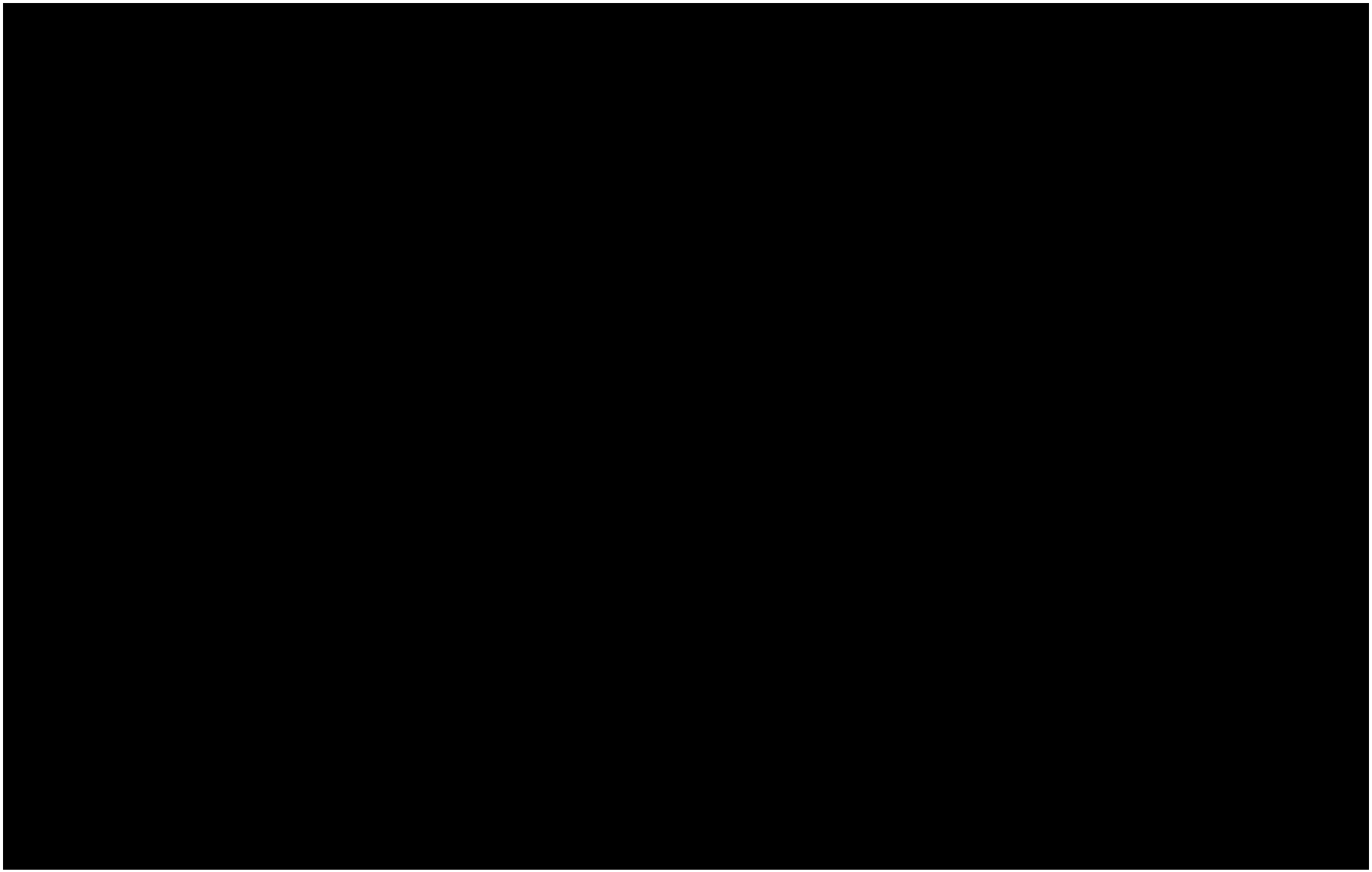
2.17g Plume Cross-sections, J plane, for the concentration of supercritical phase CO2 at 2% Saturation

2.17h Plume Cross-sections, J plane, for the concentration of supercritical phase CO2 at 3% Saturation

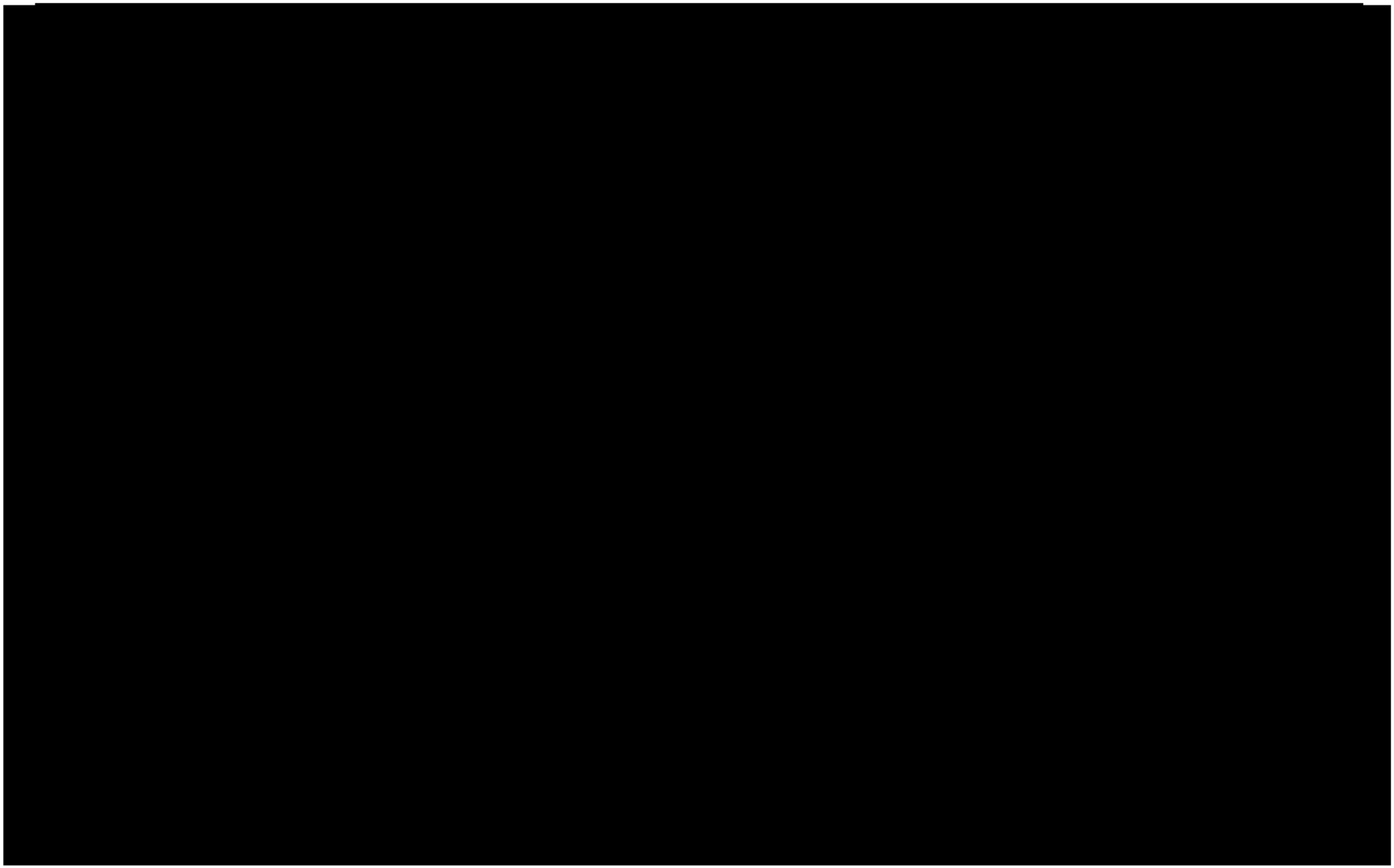
2.17i Plume Cross-sections, I plane, for the concentration of supercritical phase CO2 at 0% Saturation



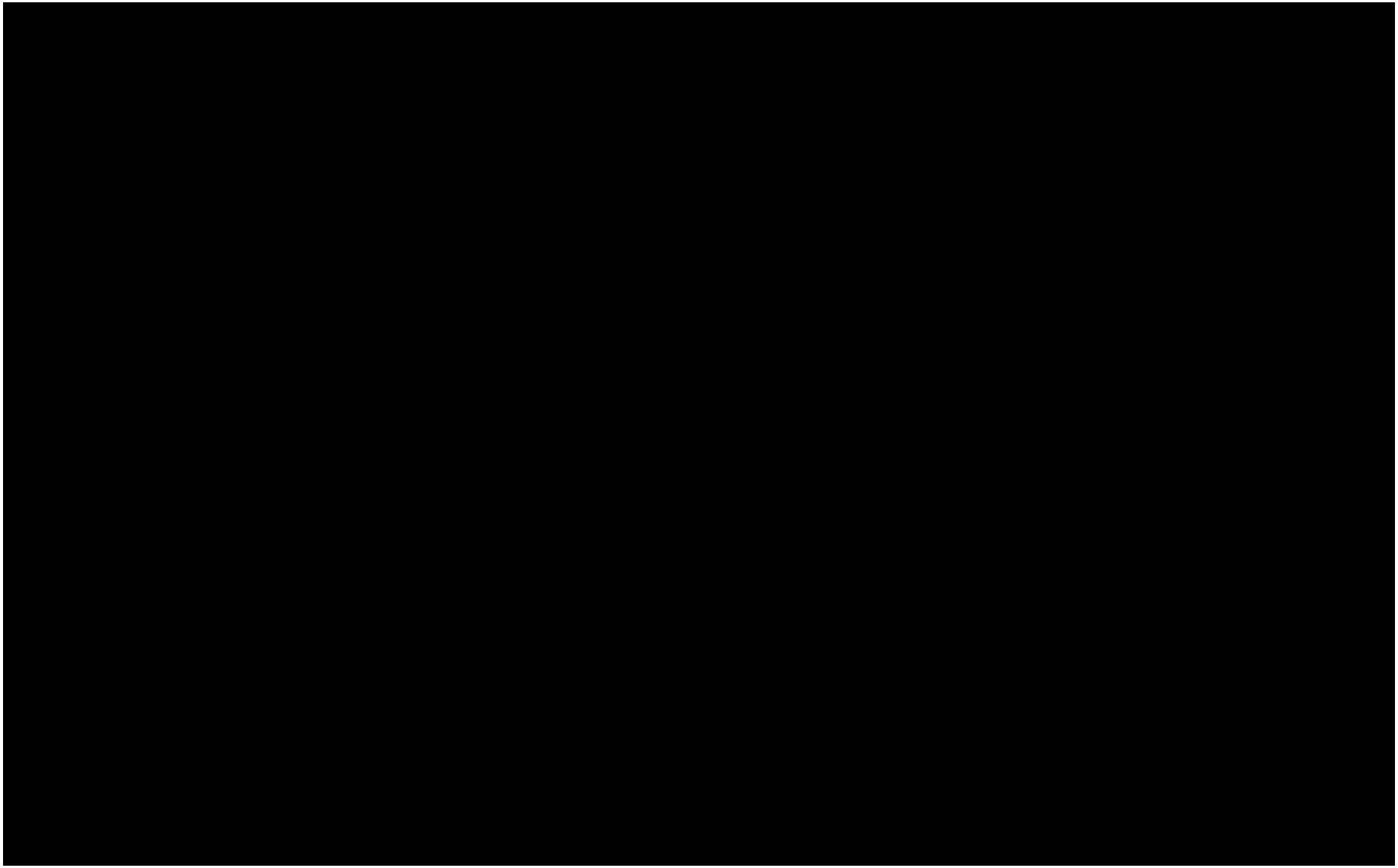
2.17j Plume Cross-sections, I plane, for the concentration of supercritical phase CO2 at 1% Saturation



2.17k Plume Cross-sections, I plane, for the concentration of supercritical phase CO_2 at 2% Saturation



2.17l Plume Cross-sections, I plane, for the concentration of supercritical phase CO2 at 3% Saturation



2.20 Gas Trapped Due to Hysteresis

[redacted]