Q. [By Mr. Yannacone: Doctor, is it possible to describe the regional transport systems in order to predict the transfer and distribution of a biologically active toxic material such as tritium? Yes or no.

A. [By Dr. Loucks] It's possible to make a description, yes.

Q. And without the development of an adequate systems model is it possible to predict the transfer and distribution of a biologically active toxic material such as tritium"!

A. No. You cannot possibly make a satisfactory prediction without a complete descriptive model of the transport [of] material through the systems.

Q. Doctor, at this time can you, with a reasonable degree of ecological certainty, based on the data contained in the technical discussions of over-the-site safely programs for underground nuclear detonation and in the exhibit Project Rulison Postshot Plans and Evaluations adequately predict the transfer and distribution of the material tritium throughout the Rulison regional transport system?

A. I do not think so.

Q. Doctor, would you elaborate on your answer as to why you cannot?

A. I would like to contrast the completeness of the systems description in these two documents with one in a paper entitled "**Systems** Analysis of a Coupled **Compartment** Model for Radionuclides Transfer in a Tropical Environment," by Stephen V. Kaye and Sidney J. Ball, both of Oak Ridge National Laboratory, ...

Q. Do you know either of those authors?

A. Yes, I know Dr. Kaye.

Q. Have you on prior occasions reviewed and considered his work in your work"?

A. Yes.

Q. Doctor let's lay a proper foundation for that paper.... Without quoting therefrom, would you indicate briefly the subject matter of that Kaye paper"?

A. This paper is concerned with the feasibility and safety, particularly the safety, of the proposed sea-level canal in Panama, and it offers a systems model that they use to answer some questions with respect to the redistribution of radionuclides that may be expected in the tropical environment if and when the blast for the sea-level canal is set off.

Q. And is that a systems model that was prepared by, though, or under the aegis of the Atomic Energy Commission"?

A. Yes, it is.

Q. Have you examined the model as purely a systems model?

A. Yes, I have.

Q. Is the substance of that paper fairly representative of the basic elements of compartmentalized systems models as now being developed under the aegis of the Atomic Energy Commission"?

A. Yes, it is.

Q. Would you indicate where, if anywhere, in the "Postshot Rulison Memorandum" *does* there appears any reference to systems modeling or systems considerations for the purpose of predicting the ecological effects?

A. In the "Preshot Memorandum" there is a Chapter 15, "Environmental Safety," by **R.** G. Fuller, ecologist for Bat-telle Memorial Institute. In Chapter 15 there is a system model, Figure 15.2, ""Generalized Materials Transfer Program," which has some similarity to a figure in the paper by. Kaye, Figure I, entitled "Preliminary Diagram of Environmental Pathways for Transfer of Radionuclides to Man in a Tropical Environment.""

MR. EARDLEY: Your Honor, I want to object to this line of questioning. If, as I gather, he is about to testify that there isn't a proper model-a proper model has not been prepared for this problem at Rulison-it seems to me that he can so state and tell us the reasons. I would ask no more when I compare what's wrong with a lawyer's brief, and say, "'Well, let me show you what a good brief looks like." I don't think we have to go to some other model. If he is an expert, as he purports to be, he can tell us, without comparing, what the defects are in our study.

THE COURT: Seems to me that the objection is well taken.

Q. Doctor, in the course of your regular professional activities have you had occasion to evaluate systems models with respect to water transport"?

A. Yes.

Q. Doctor, in the course of your regular professional activities have you had occasion to take and review the systems model set forth in the Pre-Shot Memorandum?

A. Yes, I have.

After consideration of the Atomic Energy Commission Systems Model, the direct examination of the witness turned to those elements of the systems study which did not represent adequate support for the Atomic Energy Commission safety evaluation.

Q. Doctor, can you with any reasonable degree of ecological certainty evaluate that model, first of all with respect to its capability as a fair and adequate descri1tion of the Rulison regional transport system, based Oil other data in the same documents?

A. This systems model represents a relatively advanced description of the system at Rulison, but it is deficient in several major respects. The information is simply not yet available to provide a fully satisfactory description of the regional transport system around Rulison; the model provided

here represents the state of the art as of two or three years ago....

Well, in certain laboratories across the United States and in Canada, there have been some major innovations in the description of terrestrial ecological systems as described here primarily in incorporating the atmospheric and water transport systems. If you examine the Pre-Shot model, you will see that it is primarily a model of the biological transport system and the redistribution of materials in that biological system to the environment. lt does not provide an adequate model of the uptake of materials in the environment into the biological materials.

As often happens during litigation involving complex technical issues, an experienced Trial Judge enters the dialectic process and seeks to clarify the position of the parties and occasionally recapitulates the evidence in the record to that point in the trial.

THE COURT: Aren't the dotted lines merely to show that part which results from the fallout and then it gets into the system, and then the solid line gives the pathway or transfer into the system? ls that correct?

DR. LOUCKS: The solid line represents the transfer between variables within the system.

THE COURT: Yes, but on the fallout, it has to start someplace. It falls out as shown by the dotted line, as I understand this. I'm not arguing about it. I'm just trying to understand it.

DR. LOUCKS: That's the way the AEC is presenting it, but I say that the fallout and uptake by the plant represents a series of processes such as infiltration, absorption, and uptake through the leaves, evaporation, both from the surface and vicinity of the plants, and then from the leaves themselves through transformation. These are all processes involved in that uptake, and the complete

system and the complete description of the transport system from the point source represented in the plans for the postshot evaluation ought to be incorporated in the model.

Q. Doctor, have you in the course of your regular professional activities had occasion to investigate the elements of the transport mechanisms that are so summarily represented by dotted lines in this figure entitled “Generalized Materials Transfer Program of the Prcshot Evaluation Report”?

A. Yes. ***

Q. [By Mr. Yannacone] What elements in your study do not appear in the [Generalized Materials Transfer Program]?

A. There are none of the elements of our study showing relationship to the various water variables and the water transfers in the AEC study.

The questioning continued to develop the ramifications of a safety evaluation that had been based in par! on an incompletely described system model. The central issue was whether the AEC studies did in fact represent the "state of the art" in environmental systems methods at the time they were dune, and if they did not, was the omission likely to result in underestimation of the potential health hazard to any of the people living in the vicinity of the proposed release. Objections by AEC defense counsel were frequent, but several major points were established. The first dealt with the feasibility of a more complete predictive model, and the second with the independence of system characteristics from the absolute quantities of tritium transported.

The Judge concluded with the following findings of fact:

Q. Do you have with yon any examples of the relationships that exist and are summarized by that dolled line?

A. Well, the best model of this relationship is in... the report by [Dr.] Donald G. Watts and myself. In a color chart at the back of the report, emitted "Water Variables and Water Transfer

Functions," we have described in a block diagram similar to the one in[the Pre-Shot Evaluation Report the exchanges that go on in the movement of water from the point at which it reaches the surface as precipitation to its subsequent redistribution by evaporation to the atmosphere or into root zone storage or stream flow into pools, lakes, or reservoirs.

Q. Would you elaborate for the Court and tell us what those elements that don't appear [in the AEC study] consist of?

A. Well, they consist of the transformation of precipitation to surface water and surface flow. The transformation by infiltration of precipitation of water at the surface to water in the root zone. These are separate compartments that are similar to the transfer of a radioactive material, for example, in [the "Generalized Materials Transfer Program"] from upper leaves to lower leaves, this is a transfer that is sufficiently important to have been included in this figure and the processes involved in infiltration and redistribution of water in the soil profile and to the plant roots are of equal consequence in simulating the system as a whole and predicting the tritium uptake by plants.

Q. Are you telling us, Doctor, that the ["Generalized Materials Transfer Program"] in Defendants" exhibit considers only stems and leaves in that subsystem and ignores the root stem and the ground infiltration to the roots?

A. As inputs. It does provide for materials in the soil and in the soil water as outputs from the biological systems.

Q. Doctor, unless you have fully identified all the inputs and outputs of a given regional transport system, can you adequately develop a model on which you may base predictions"?

A. No, you cannot make a model that will give you satisfactory predictions unless you have included all of the major variables and transfer systems through which the material must move to reach the biologically important materials.

Q. After these have all been identified, before you can use the model for predictive purposes, is it still necessary to perform field

observations and assemble field data with respect to the particular regional transport system involved"!

A. This is one or the most important points. It is strongly evident from both exhibits that these reports acknowledge that we do not now have the information to express quantitatively the transfers between these compartments. These models, incomplete as they are, show only the description, the kinds of transfers that will have to be taken into con- sideration to give you a predictive model. I haven't counted the total number of transfers that will have to be estimated here, but they are in the order of 30 or 40, each of which must have a transfer coefficient determined for it before a simulation of that system and a prediction of biological magnification or flow through the system can be achieved with any quantitative accuracy.

Q. All right Doctor, assuming that we know the actual amount of tritium released as tritiated water vapor plus l little bit of tritiated natural gas at the wellhead during the flaring process, on the basis of the information contained... in the ""Pre-Shot" and the "Post-Shot" evaluation reports, can you determine the distribution and transfer of tritium throughout the Rulison Regional Transport System?

A. No, you cannot.

Q. ... Doctor, what is the relationship of the atmospheric transport system which we haven't discussed in the detail and this type of water model?

A. The water model itself begins with the precipitation input, so that any characteristics of the topography in this region that will influence the precipitation will then influence the water transport system... determining flow, so there is this coupling of the atmospheric transport system to the characteristics of the drainage basin.

Q. Is it possible to determine the actual quantitative tritium input to the Rulison Regional Transport System with respect to its

water transport system unless it's atmospheric transport system from ground zero to the point where the inputs [are shown] in the water models has been accurately determined or described?

A. No, you would have to begin with a full description and analysis of the atmospheric transport system from the point source.

The discussion of biological aspects of a regional systems model was centered largely around the systems study offered by the AEC as part of their safety evaluation program. The criticisms were really ones of scale or precision, rather than error. With the examination of the AEC systems model complete, therefore, counsel began asking about the regional systems which control the biological system, carry waste materials such as radionuclides, and which had not been considered in the AEC safety evaluation model.

Q. Doctor, would you outline briefly for us what are the elements of an adequate description of the Rulison atmospheric trans- port system, and would you refer to the ["Pre-Shot Evaluation Report"] and indicate what if any differences there arc?

A. I would like to draw a diagram in support of this answer... [and]... discuss first of all the induction of precipitation by orographic effects over a plain that is followed downwind by some local elevation, perhaps 1000 feet. We may have horizontal flow of air carrying a volume of water, but as it moves over this topography the air naturally is forced upward. As it is forced upward it is cooled because of the adiabatic lapse rate of temperature, on the order of three degrees f Fahrenheit for 1000 feet.

This cooling by upward motion frequently results in the induction of cumulus clouds at some point near the top of the hill, and if the atmospheric system is unstable, with air at that point having a dew point near the ambient air on the plain, the cloud will build in sufficient size so that we get rain. Orographic rainfall of this type is what occurs all

summer long in the mountain systems and is what accounts for the differences in the forest composition that are described in Appendix B, "Ecological Considerations," of the "Pre-Shot Evaluation Memorandum". The differences, of course, in forest composition that I am talking about, are the presence of alpine fir and Englemann spruce, both species with relatively high demands for water. They occur on the upland in the White River National Forest, the so-called Battlement Mesa, south and east from the ground zero site, whereas at lower elevations in the Battlement Creek area you have species such as pinon pine that are tolerant to droughts and will survive with very little water.

So, if I may draw a specific cross section of the Battlement Creek and adjacent topography, we have the high topography in the White River National Forest at approximately 10,000 feet elevation, and we have the Battlement Creek Valley with a point at which flaring will be done somewhere in the vicinity of 6500 feet. Thus, we have a difference in elevation of 3500 feet, which under normal adiabatic lapse conditions would give a temperature difference of ten degrees magnitude, which clearly is sufficient to bring about considerable cooling and, therefore, considerable condensation of water vapor as air masses move from the west to east over the Battlement Mesa plateau. The differences in species composition which are recorded in Appendix B indicate a major difference in precipitation, and this difference is predictable as a function of the topography, the temperature differences, and the regional flow conditions.

Since this precipitation is induced locally, over a difference of approximately two and half miles, we can expect that tritiated water released into the atmosphere at the flare point will be precipitated in the immediate vicinity when showers occur.

As long as there is stability in the air mass, and there is no shower occurring, the tritiated water of course will be dispersed over a considerable distance, but the primary time for testing for contamination in this area must be when you are getting local precipitation induced as a result of the orographic effect.

I might point out that the report also shows that there will be a considerable release of heat from the flaring, and the heat itself will initiate updrafts that will reinforce the buildup of cumulus clouds and shower activity on this upland.,

Since the shower activity will not be initiated until close to the top of the mountain, the continuation of that shower into the next valley is really the site at which most of the contamination would be expected to occur. This is in the Plateau Creek Valley, and I would point out that although the post-shot plans and the evaluation documents show the location of residences in the Battlement Creek Valley system, it does not take into consideration the distribution of residences in the Plateau Creek area, the area where a system model of the regional atmosphere transport system predicts much or most of the contamination would take place.

The central issue at this point in the trial was whether the Atomic Energy Commission System Study for Project Rulison did in fact represent the "state-of-the-art" in environmental systems science at the time it was done and if it did not, were the inadequacies likely to have increased the potential hazard to the health of the people of the Colorado Regional Ecological System. In spite of frequent objections by the attorneys for the Atomic Energy Commission and the Austral Oil Company, several major points were established.

The first dealt with the feasibility of a more complete predictive model, and the second with the independence of systems characteristics when considered from an analytical and conceptual

point of view, from the absolute quantity of the environmental toxicant transported.

Q. Doctor, can you with a reasonable degree of scientific certainty indicate what, if any, studies will be needed before the actual transfer, transport, and distribution of tritium as released during the flaring process of Project Rulison can be accurately predicted in a quantitative sense?

A. It is my opinion from analysis of these two [AEC] documents, and my understanding of ecological systems, that we would require a major program of study relating specifically to tritium and its activity, and its differences from water in movement through the atmospheric, water, and biological transport systems.

The model I envisage would be approximately twice as complex as that presented by the AEC. This isn't impossible. There are groups at several locations across the country that are dealing with models that are this complex, but these are people that are primarily concerned with water and nutrient transport, and the Atomic Energy Commission probably has had access to those particular kinds of studies which allow us to examine the extent of infiltration of the water corning down on Battlement Mesa, its infiltration and subsequent reappearance in the stream water in the valley of Plateau Creek. and the potential contamination of those reservoir systems.

It seems to me that this is the kind of program which if carried out could give us the assurance that the proposed post-shot plans and evaluation could be carried out safely, and I am very much struck by how far short of an adequate program the materials in the Post-Shot Plans and Evaluation are.

Q. Doctor, can you state with a reasonable degree of scientific certainty that the actual qualitative system description that is derived from the studies you have performed is invariant with

respect to its systems relations subject only to modification of rate constants and transfer coefficient functions with respect to the chemical and physical properties of the toxic materials that are biologically active being transferred through the system?

A. Yes.

MR. SEARLS: I object for the further reason, Your Honor, that he has no knowledge of the amount and quantity of tritium which will be released in this particular reentry.

Q. Doctor, docs the actual amount of tritium to be released go the qualitative description of the system or only the ln1antitative 1nedictability of the system"?

A. No, the characteristics of the system and the characteristics of the material moving through the system will determine the essential properties of where that material will turn up at other points within the system and this is independent of the total load entering the system.

Q. In other words, then, Doctor, the water transport system, once it is described for the Rulison regional transport system, will still be the Rulison regional transport system for water, in spite of the fact that you might introduce tritium, Cesium-137, or 1-131 into the water system"!

A. Yes, and it will still be the same system if you double the quantity of material or change the levels in any way.

MR. YANNACONE: Your Honor, I must object on the grounds that Mr. Fuller, who testified here on the first trial as the ecological evaluator of this particular Rulison shot, testified to the sum and substance of all the data he had on the ecology of Project Rulison, and this witness testified that he was shown the transcript and examined that testimony.

THE COURT: Well, he could have said that. He could have said that in response to this answer. The objection is over-ruled.